zygo®

Mx Reference Guide

OMP-0550E

AMETEK®
ULTRA PRECISION TECHNOLOGIES

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Mx Version 8.0...

ZYGO Software License Agreement

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Introduction 1

ZYGO Mx™ software offers the latest generation of powerful metrology tools.

- Based on XML (Extensible Markup Language) file structure.
- Superb data acquisition control.
- Intuitive interface with unmatched power and flexibility.
- Interactive data processing tools.
- Rich data presentation and visualization.
- Dynamic data reporting.

Mx Version 8.0…

1.1 Contacting ZYGO

We are interested in hearing from you about our instruments and software. Please visit our website, send us an email, or phone. Before contacting us, please have the instrument model and software version.

Zygo Corporation
Laurel Brook Road
Middlefield, CT 06455
United States

phone: 860-347-8506
website: www.zygo.com
email: info@zygo.com

Customer Support

phone: 800-994-6669
email: support@zygo.com

1.2 Warnings and Notes

WARNING!
Denotes a hazard that could cause injury to personnel, and can also cause damage to the equipment.

Note
Provides helpful information or tips.

Hint
Provides additional user hints for a particular function.

1.3 Laser Interferometer or Optical Profiler?

These are the general terms and icons used for ZYGO instruments herein.

Laser Interferometer

Verifire™
Dynafiz™
AccuFlat™

Optical Profiler

APM650™
Compass™
NewView™
Nexview™
Nomad™
ZeGage™

Typically, the generic terms are used instead of specific instrument names.

1.4 Using Help

The help system is designed to be used along with the software. It is cross-linked so that you can find relevant information to any subject from any location.

As far as possible the help provides procedures and background information. Refer to the "how-to" instructions when you are in a hurry and want to get your work done.

Getting Help

The quickest way to display the help is to press F1. If context-sensitive help is available it will be displayed automatically. For the help system use the built-in Contents, Index, and Search functions to find specific information.

When looking for a particular item in the software, use the Index tab and type the name of the item for best results.

Tooltip

Tips appear automatically when you move the pointer over a tool or control.

Navigating Help

1. Select the desired topic on the contents.
2. Expand the topic tree to find the information you are looking for. To view a topic, click the link in the topic tree.
3. Most topics provide a list of links to related topics at the bottom. Follow these links to learn more.
4. Use the Next Page and Prev Page buttons. These navigate either forward or backward through the topics.
5. To go to the major topic under consideration use the Topic Navigator button.

As an alternative to browsing the information this way, use the search function. Type a query into the Search field and click List Topics.

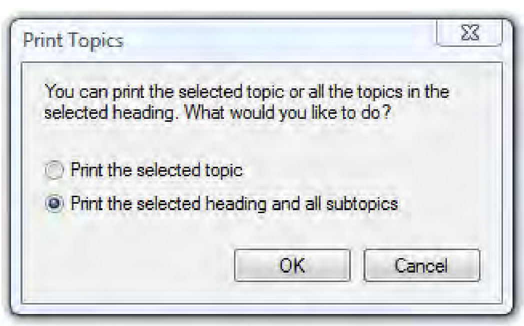
Printing Help Topics

Printing the Current Topic

1. Select the topic you want to print by clicking on it in the Contents.
2. Point to the topic screen and click the right mouse button and select Print...
3. Select your printer and other settings in the Print dialog box, then select OK to print.

Printing Multiple Topics

1. Select the "master" topic you want to print by clicking on in the Contents.
2. Click the Print button in the help window or right-click on contents heading.
3. In the Print Topics dialog box, select Print the selected heading and all subtopics and click OK.



4. Select your printer and other settings in the Print dialog box, then select OK to print.

1.5 Fingerprint Utility

The Fingerprint Utility is available under the Help menu and the Windows Start menu. ZYGO support personnel may request that a user generate a fingerprint of the system using this tool when giving hardware or software support.

Getting Started 2

To use the software you will need to:

- License the software.
- Understand the basics of the user interface.
- Know how to interact using the keyboard and mouse.
- Become familiar with basic terminology and software flow.
- Save and load files.
- Be familiar with the operation of your ZYGO instrument.

2.1 System Requirements

- Microsoft® Windows 10 Enterprise LTSB, Windows 10 Pro, or Windows 7 Professional x64 English.

  If you have an instrument running Mx on Windows 7 and want to update to Windows 10 or later, contact your ZYGO representative. Mx will not run properly with the standard commercial version.

- Multi-core processor (quad-core processor minimum).
- 16 GB RAM or greater.
- Dedicated graphics card that supports OpenGL 1.5 (or later) with 256 MB RAM (recommended).
- Color monitor capable of displaying true color (32-bit).

2.2 Compatibility

Mx is the latest generation metrology software from ZYGO. It is uniquely different than MetroPro. It uses an XML (Extensible Markup Language) based file structure for applications, data, settings, etc. Measurement data is based on the HDF5 standard. Mx can read MetroPro data files. However, Mx is not compatible with the older MetroPro application, mask, fiducial, settings, pattern, report, and script files.

Mx is designed to be used with ZYGO's latest instruments and computers with a multi-core processor. If you have questions about upgrading or instrument compatibility please contact ZYGO.

Display Compatibility Issues

If you are running Mx on Windows 10 computers that are NOT provided by ZYGO such as a laptop or notebook, there may be display issues due to differing screen resolutions. If so, try the following options:

1. Right click on the Mx shortcut and select Properties.
2. In the MX Properties box select the Compatibility tab.
3. Select the "Override high DPI scaling behavior. Scaling performed by:" check box and choose System.
4. Click the OK button.

If your monitor is ultra-high-definition (UHD), you may need to do the following:

1. Change the display resolution to 1920 x 1080.
2. Change the display scaling to 100%.
3. Reboot the computer and restart Mx.

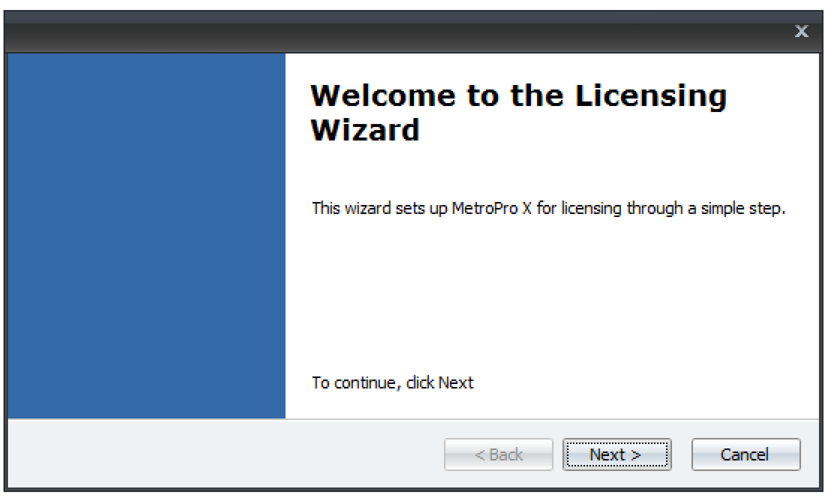
Note that an UHD display will not operate at maximum resolution while in this setting.

2.3 Licensing

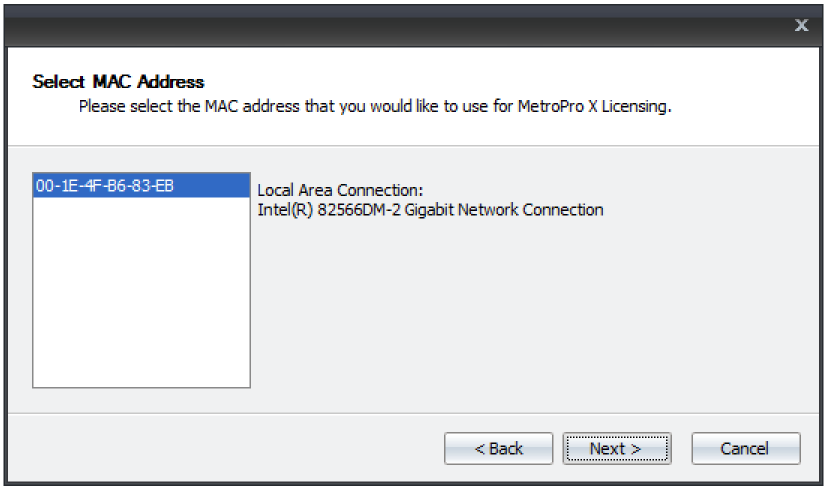
The software must be licensed or activated to be functional. Software licenses are tied to the Hardware ID of the computer.

A Sentinel dongle is also supported for generating a hardware ID. The dongle must be plugged into the computer before running the Licensing Wizard. Switching between the current licensing hardware (Ethernet) and the Sentinel will invalidate any entered licenses.

1. Double click the Mx icon to open the program.
2. On the Help menu, click Licensing. The Licensing Wizard opens the first time Licensing is selected. Click Next.

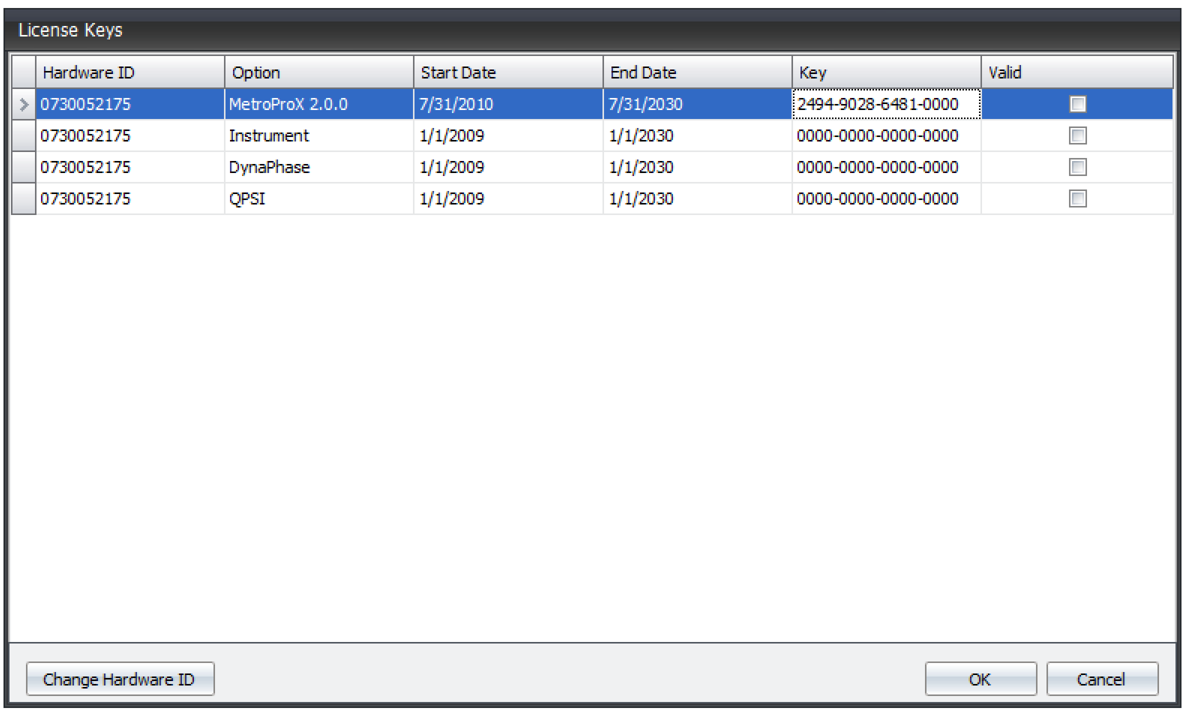


3. Select the MAC Address and click Next.



The MAC address is used as the Hardware ID. The MAC (Media Access Control) address is a unique identifier assigned to the network adapters by the computer manufacturer for identification.

4. Enter the Start Date, End Date, and Key into the appropriate fields.



If you do not have license codes, copy the Hardware ID and contact ZYGO.
You can use the clipboard to copy and paste codes into the applicable fields.

5. After the values are entered they are verified. A check in the Valid check box indicates the dates and key codes are valid.

2.4 Software Flow

In its simplest form, the software acquires multiple images of the test part and processes it into raw data, transforms the raw data, and then analyzes the data into meaningful results. Understanding the data flow can assist you in learning and using the software.

Acquisition	Controlling the instrument to obtain multiple images of the part under test and signal processing to provide raw measurement data.
Data Processing	Modifying or transforming raw data by such methods as fit remove, trimming, and filtering.
Data Analysis	Analyzing processed data in a particular manner and displaying the results in applicable graphic and numerical forms.
Output	Outputting analyzed data in various forms, including: printing results, making reports, and exporting results and graphics.

2.5 Quick Start

1. **Start Program**
   Double click the Mx icon to open the program.
2. **Load Application**
   On the File menu select Load Application, or on the toolbar click Load Application. In the Open dialog box select a file and click Open.
3. **Measure Part**
   Set up the instrument as described in the operating manual and measure a part. To make a measurement, do one of the following:
   - On the Actions menu select Measure.
   - On the toolbar click Measure.
   - Press F12.
4. **Save Data**
   On the File menu select Save Data, or on the toolbar click Save Data. In the Save dialog box enter a File name and click Save.

Closing Mx

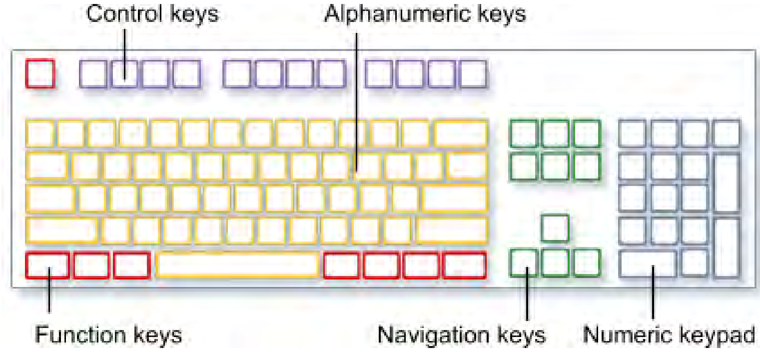
1. On the File menu select Exit or press Ctrl+Q.
2. To turn off the computer, use the Windows Start menu and click Shut down.
3. (Optional) Turn off all hardware components.

Sleep Mode

- Automatically happens after 30 minutes of software inactivity.
- Extends the life of the hardware.
- Click Resume to wake up the instrument.

2.6 Using the Keyboard

The keyboard is used for text entry, when using controls, when saving and loading files, and to substitute for mouse clicks.



Entering Text and Numbers

Text and numbers are entered with the keyboard. You must enter text when you select an item that needs information to carry out the command. For example, text is entered when renaming an item, saving a file, inputting a limit, and entering a numeric value. At the start of an entry, the entire field is highlighted. If you start typing text, the previous entry is completely replaced by the new entry. To edit or modify the current text, click on any point in the text.

Text Editing

Move through entry	Left and right arrow, Home, and End.
Edit entry	Insert, Delete, and Backspace.
End text entry	Press [Enter] or click left mouse button.
Cancel text entry	Press [Esc] or the click right mouse button.

Shortcut Keys

General Keys

Esc	Aborts processing, cancels text entry, alternate for NO in a Dialog box.
Enter	Completes text entry, alternate for YES or OK in a dialog box.
Backspace	Delete characters left of cursor one at a time.
Insert	Toggles insert mode; when on, characters are added at cursor.
Delete	Removes characters right of cursor one at a time.
Alt	Show/hide the Menu Bar.
←	Moves cursor left one space, move active item left.
→	Moves cursor right one space, move active item right.
↑ ↓	Moves active item up or down. For a numeric list, it increments the number in a positive or negative direction.

Function Keys (F Keys)

F1	Access online help.
F5	Find Part (optical profiler).
F6	Open Mask Editor.
F7	Open Lateral Calibrator.
F8	Focus Aid (optical profiler).
F9	Auto light level (optical profiler).
F11	Analyze.
F12	Measure.

Key Combinations

Ctrl+C	Cancel current operation.
Ctrl+O	Load (or open) data.
Ctrl+S	Save data.
Ctrl+P	Print.
Ctrl+Q	Quit or exit.
Ctrl+M	Measure.
Ctrl+N	Analyze.
Ctrl+U	Open Master Units and Precision.
Ctrl+F	Open Fiducial Editor.
Ctrl+R	Open Report Designer.
Ctrl+A	Select all shapes in the Mask Editor.
Ctrl+Shift+O	Load (or open) application.
Ctrl+Shift+S	Save application.
Ctrl+Shift+C	Close application.
Ctrl+Shift+L	Open the Switch User Level.
Alt+ F4	Close the active window.
Ctrl+Alt+O	Load (or open) settings.
Ctrl+Alt+S	Save settings.
Ctrl+Alt+Delete	Quit the program and all processing, return to Login screen.

Mask Editor, Fiducial Editor, and Lateral Calibrator Keys

Shift ←	Move active item left in larger increment.
Shift →	Move active item right in larger increment.
Shift ↑	Move active item up in larger increment.
Shift ↓	Move active item down in larger increment.

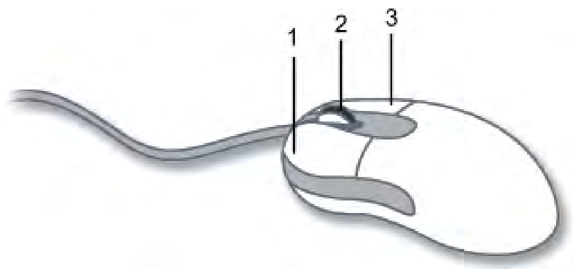
Light Level Keys (Optical Profiler)

Ctrl *	Coarse up.
Ctrl /	Coarse down.
Ctrl +	Fine up.
Ctrl -	Fine down.
Ctrl 1, etc	Adjust level in 10% increments: 1 = 10%, 2 = 20%, etc.
Ctrl tab	Toggle between last 2 light settings.

2.7 Using the Mouse

The mouse is the main tool you use to interact with the software.

Mouse Parts



1 Left button or primary button; the most commonly used button.

2 Scroll wheel, used to scroll through large clipped screens and for zoom and pan functions.

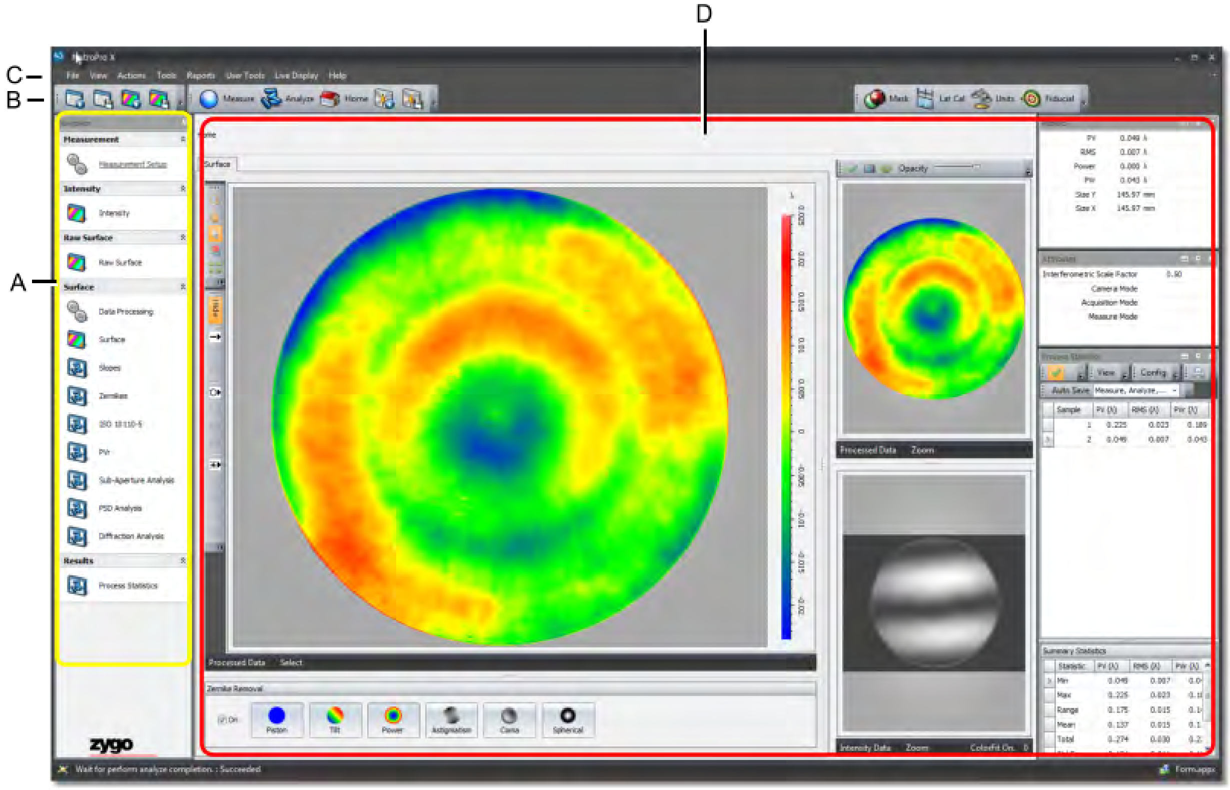
3 Right button or secondary button, typically used to access context sensitive menus.

Pointing, Clicking, and Dragging

Point	Means moving your mouse so the pointer appears to be touching the item.
Click	To click an item, point to the item on the screen, and then press and release the left button.
Double Click	Point to the item on the screen and then click the left button twice quickly.
Right-Click	Point to the item on the screen, and then press and release the right button.
Dragging	You can move items around your screen by dragging them. To drag an object, point to the object on the screen, press and hold the left button, move the object to a new location, and then release the left button.

2.8 User Interface

The screens will appear differently based on the selected skin.

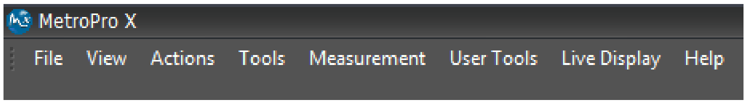


A. Navigator. **B.** Toolbar. **C.** Menu Bar. **D.** Workspace.

Item	Description
Navigator	The panel used to select, view, and interact with the data analysis stream.
Toolbar	The row of controls or icons, usually displayed across the top of the screen, that represent tasks you can do. The toolbar buttons provide shortcuts to common tasks frequently accessed from the menus.
Menu Bar	The region at the top of the application window where menus are accessed. Provides access to such functions as opening files and analysis tools.
Workspace	The largest window region used to view and interact with measurement results.

Menu Bar

The menu bar is the region of the interface where drop down menus are displayed.



The actual menus vary based on the loaded application.

Menu	Access to...
File	Commands relating to the handling of files, such as open, save, and print. It also has the Exit command for quitting the program. It may also contain a list of recently used files.
View	Commands used to view particular features of the program.
Actions	Commands dealing with the control of the instrument, such as measure, analyze, and settings.
Tools	Commands to access global tools (others are accessed through the Navigator). These include: Mask Editor, Fiducial Editor, Lateral Calibrator, Master Units, Auto Sequence, Tolerances, Custom Results.
Grid	Commands to add various Grid types to the application.
Reports	Provides access to the reporting function.
Measurement	Determines what is displayed in the Measurement portion of the Navigator and within the Measurement Type control.
User Tools	Commands for specific user functions, such as Data Generate.
Live Display	Command to open a Live Display window, which shows a "live" image from the instrument.
Help	Commands for licensing the program and modules, and getting online help.

Show/Hide Menu Bar

Press the Alt key to hide or show the Menu Bar.

Context Menus

A context menu (also called contextual or pop-up menu) is a menu that appears with a right mouse click on some program features. A context menu offers a limited set of choices that are available in the current state, or context, of where the pointer is. These are primarily used to select options for graphic displays, process statistics, numeric results, and toolbars.

Tabs

Tabs organize the user interface into functional task related screens. If present, these appear under the Menu Bar. Left-click on a tab to select.

The actual tabs vary based on the loaded application.

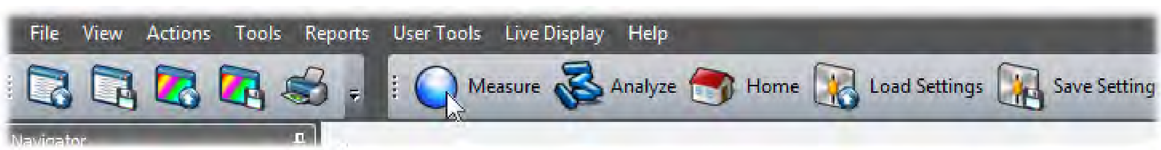
CALIBRATION	Used for pre-measurement instrument setup. It includes tools to calibrate objectives, the light source, and motorized stages.
MEASUREMENT	Choose instrument settings for capturing test part data.
ANALYSIS	Full range of tools to examine and process acquired data in great detail.
AUTOMATION	Setup and run the instrument to make multiple measurements at numerous sites.

Within each "tab", the Navigator provides access to various screens depicting the instrument work-flow from top down.

Toolbars

A toolbar is the panel on which onscreen buttons and icons, or other input or output elements are placed. The main program toolbar is actually made up of many smaller toolbars.

To identify an object on the toolbar, point to the item to see the ToolTip.



Other items also have toolbars, such as plots, Process Statistics, Mask Editor, Fiducial Editor, and Lateral Calibration.

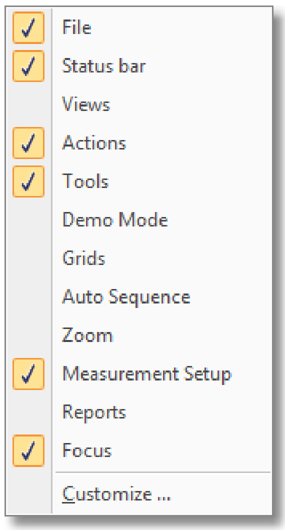
Basic Toolbar Features

- The specific toolbars available vary based on where they are accessed.
- Toolbars can be hidden or displayed.
- Toolbars can be moved or relocated.
- Allow user customization.

Changes made to the main program toolbar are automatically saved. Changes made to minor toolbars are not automatically saved.

Hide or Show a Toolbar

1. Position the cursor over the toolbar area.
2. Right-click and to select what toolbars to display. Checked items are displayed.



Moving a Toolbar

1. Point to the dots on the toolbar segment. The cursor changes to ✥ .
2. Press and drag the toolbar to new location and release the mouse button.

If the toolbar is moved outside of the toolbar area it becomes a standalone toolbar control. It can be moved back into the toolbar, or hidden by clicking close (x).

See Also

Zoom Toolbar

Plot Toolbars

Changing a Toolbar

Customization

Navigator

- Provides quick access to tools and analyses.
- Click an icon or name to access an item.
- Varies based on the loaded application.
- Shows the approximate sequential analysis flow from top down.

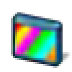
Navigator Icons

Tools open in a separate window. Data views and analyses open inside the workspace.

Tools and controls, typically used for data acquisition and for data processing.

Measurement type, represents a particular use and measurement setup of the instrument.

Sensor signal, this is the output of a signal acquisition action and at a minimum consists of a set of camera frames.



Measurement data; this is the sensor signal processed to create the basic surface or wavefront map. It may be before data processing (referred to as raw) or after data processing.

View or analysis; a unique arrangement of controls, graphics, and results that provide measurement results.

Statistics, numerical results over multiple measurements.

Accessing Sections

Click down arrows ⌄ to expand (show) an analysis.

Click up arrows ⌃ to collapse (hide) an analysis.

Minimizing the Navigator

See Pinning.

Ordered Data Flow

The Navigator shows the analysis stream, for example:

Measurement
(instrument control)

↓

Intensity
(data captured by the instrument)

↓

Raw Surface
(data no post processing)

↓

Surface
(data with post processing)

↓

Results
(statistics over multiple measurements)

Status Bar

The status bar is the bar containing information at the bottom of the application window and/or plot display.

Application Status Bar

A. License status... and state of current action. **B.** Connect... Laser... Application file name |Result Tolerances

Application Status Bar Icons

License Status	green, valid license yellow, license expires within 30 days red, expired license When red or yellow, click icon to display corresponding licenses
Connection	Instrument connected Not connected/no instrument
Laser *	laser locked laser not locked
Tolerances	not set within set limits outside set limits

* Only applicable to laser interferometer equipped with stabilized laser.

Plot Status Bar

The actual displayed status information varies based on the plot type and current conditions.

A. Analysis stage|cursor location in plot: x-axis, y-axis, z-axis (height) | plot mode. **B.** Palette scaling mode / Form Remove setting.

Showing or Hiding the Status Bar

For application	Right-click on the menu bar area of the screen and select Status bar.
For plot display	Right-click on the plot panel and select Tool Bars ▸ Status.

2.9 Basic Operations

This section covers basic software features.

General Interaction	Entering, specifying, and choosing settings.
Windows	Working with windows and screens.
Panels	Adjusting and pinning panels.
Grids	A specialized panels for controls, results, attributes, or process statistics.
Tables	Working with data or controls that are in a table form.

General Interaction

Check box

Select (or click the check box) item to turn the function on.

Clear (or click the check box) to turn the function off.

Drop-down list

Point and click the ▾ triangle.

Point and click on your choice.

Numeric selection

To enter a value directly, click the box and type the desired value.

or

To increment upward, click the box to activate the item, then click the up ▴ triangle (or press the up ↑ key).

or

To increment downward, click the box to activate the item, then click the down ▾ triangle (or press the down ↓ key).

Typed entry

To enter text (or a file name), click the box and type.

Pressing the Enter key is not required.

See Also

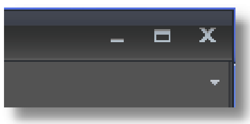
Using the Keyboard

Working With Windows

Controlling Windows

Standard window buttons are located in the top right corner of the window.

Minimize, Maximize, Close



Click a button to perform the action.

Resizing Windows

Both horizontal and vertical window size can be changed at the same time by pointing to the corner of a window. The resize function is disabled when the window is maximized.

1. Point to the edge of the window. The cursor changes to a double arrow ↔.
2. Press and drag the left mouse button to resize the window.
3. Release the mouse button when done.

Scrollbars

When content is too large to fit in the given space, scrollbars are provided.

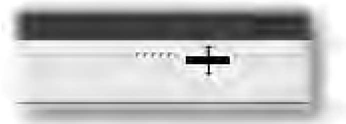
Scroll One Line	Click an arrow button at either end of the scrollbar.
Scroll One Screen	Point near an arrow button and click the left mouse button.
Quick Scroll	Click and drag the slider, release the mouse button when done.

Working With Panels

Resizing Panels (and Grids)

The panels that are found within a view or tool can be sized horizontally and vertically.

1. Point to the border between panels. The resize function is active when the cursor changes to a double sided arrow (see below).
2. Press and drag the left mouse button to resize the panel.
3. Release the mouse button when done.



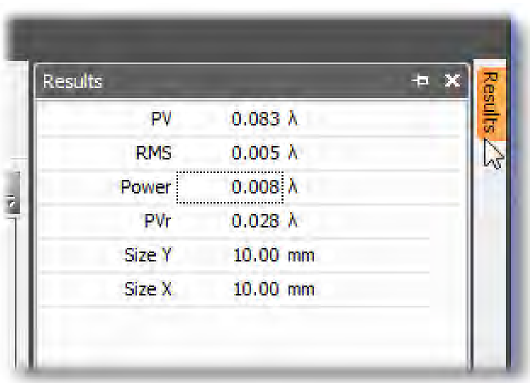
Pinning

Clicking on the "pin" tool on the title bar of some items, such as the Navigator and Results, "pins" the item to the border of the window. When the cursor is moved away, the item collapses into the margin, showing only its title in a tab. Use this feature to create a larger workspace.

1. To minimize an item click the vertical pin .

The item hides once the cursor is moved off it.

2. To temporarily show a pinned item point to the tab label. To hide the item again move the cursor away from the tab.



3. To continuously view the item click the horizontal pin .

Controls, Results, Attributes, Annotations

These are basic Mx components.

Control Selects how a task is performed or if a feature is used. Controls can take the form of a: check box ☒, radio button ⊙, drop-down list ▾, or numeric entry.

Result Provides an output, usually numeric, about the part being tested. Results appear in plots, in Results grid, and in Statistics. See Working With Results.

Attribute Provides characteristics or conditions about the measurement. Attributes appear in an Attributes grid and include such Measurement Setup panel entries as Part Number, Part Serial Number, and Comments. See Attributes.

Annotation An annotation is user entered text. It is typically used like a notebook to capture specifics about the application, part, or conditions. Annotations are available in a Annotations grid. See Working With Grids and Adding an Annotation.

Renaming Objects

1. Place the cursor over the name.
2. Right click and select Rename or Rename Item.
3. In the Name field enter the new name.
4. Click OK.

Identifying Objects

1. Place the cursor over the name.
2. Right click and select Identify or Identify Item.
3. Click OK.

Working With Grids

Grids are specialized panels used to contain objects, such as results, controls, images or annotations. Items can be added to and removed from these panels to customize the display.

Creating a Grid

1. Go to the analysis or screen where you want to add a grid. Grid panels are always created in the currently displayed screen.
2. Click the applicable button in the Grid toolbar or select the the Item from the Grid menu.

It may be necessary to first show the Grids toolbar. See Hide or Show a Toolbar.

Add Result Grid	Creates an empty Result panel.
Add Attribute Grid	Creates an empty Attributes panel.
Add Control Grid	Creates an empty Control panel.
Add Annotation Grid	Creates an empty panel for adding textual notations. This allows you to add any number of textual notes.
Add Image Grid	Creates an empty panel for inserting images. This provides the ability to add existing images, such as a logo or part drawing.
Add Plot Grid	Creates an empty panel for displaying plots.
Add Process Statistics	Creates a Process Statistics window. Items are added to Process Statistics in the same way they are added to grids. See Process Statistics for more information.
Add Control Chart	Creates an empty control chart. See Control Chart for more information.
Add View Grid	Creates an empty panel for displaying combinations of tools from multiple analyses.

Hiding a Grid

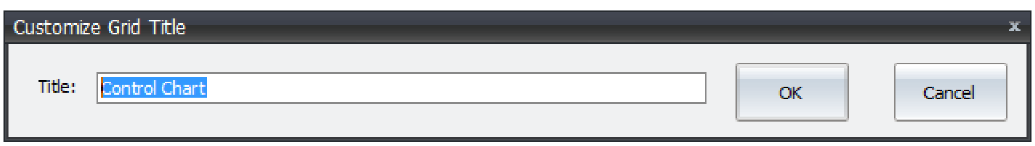
1. To save display space grids can be pinned.

Deleting a Grid

1. Click the X in the upper right corner of the grid.

Renaming a Grid

1. Right-click inside the panel to access the context menu.
2. Select Rename Grid.
3. Enter a name for the grid panel and press OK.

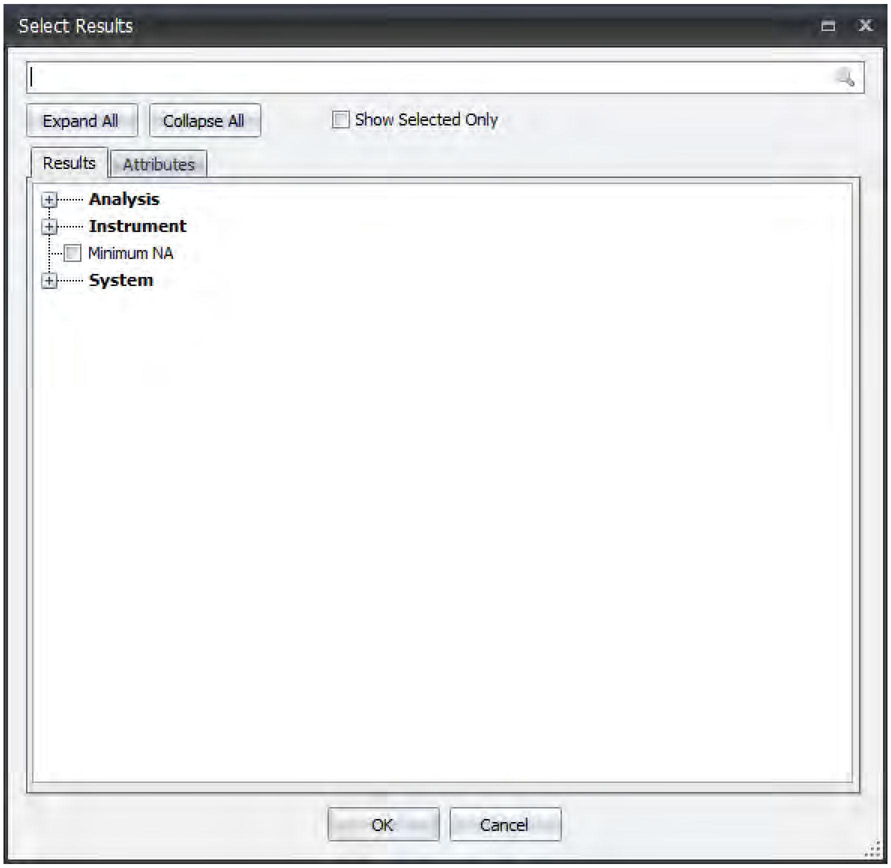


Adding or Removing Items

This applies not only to adding or removing items to grids but also includes Process Statistics, Control Charts, and 2D plots.

1. Right-click inside the panel and choose Select Items or Select Results.
2. In the Select dialog, select the check box of the items you want to appear in the panel.

You will lose any work done to the grid if you click the close button in the upper right corner of the panel. To preserve your work, save the application.



- To quickly find an item, enter text in the Search field.
- Note that Results and Attributes are under separate tabs within the same dialog.
- Click + (plus) to expand (show) a category.
- Click - (minus) to collapse (hide) a category.
- When the dialog is populated, use the scroll bar to access other items.
- Click Expand All to expand or open all listings.
- Click Collapse All to collapse or close all trees; only the major categories are shown.

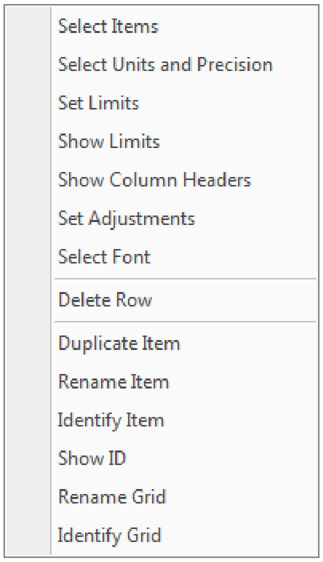
3. Click OK.

Adding an Annotation

1. Create an Annotations grid. See Creating a Grid.
2. Right on the Annotations grid and select Add Annotation.
3. In the Add Annotation dialog box, enter a Name for your custom note, and in the Value field enter the desired information.

Changing a Grid

1. Add items to the grid. See Adding or Removing Items.
2. Right-click inside the panel to access the context menu. Select the desired option.



This is the context menu for a result grid.

The context menus for attribute and control grids have fewer selections.

Select Items	Opens the Select dialog so items can be added or removed. See Adding or Removing Items.
Select Units and Precision	Change measurement units associated with the selected item. See Set Unit and Precision.
Set Limits	Opens a dialog to specify limit values for the selected result (Results only). See Entering Result Limits Directly.
Show Limits	Add Low Limit and High Limit cells to the grid. (Results only)
Show Column Headers	Display a descriptive row (Name/Value/Units) at the top of the grid.
Set Adjustments	Scale and Offset adjustments for results. See Adjustments.
Select Font	Change the style and size of the displayed text. See Select Font.
Delete Row	Removes the selected item from the grid.
Duplicate Item	Adds a copy of the selected row to the bottom of the grid.
Rename Item	Used to change the name of the item in the selected row. See Renaming Items.
Identify Item	Identifies the item in the selected row. This is useful when an item has been renamed.
Show ID	Opens a Current ID dialog so the item location can be copied to the clipboard for use elsewhere.
Rename Grid	Opens a dialog to change the title bar on the corresponding grid. See Renaming a Grid.
Identify Grid	Identifies the grid type. This is useful when the grid has been renamed.

Comment Behavior

The Comment control behaves differently than other items in a Control grid. In a newly added Comment, as text is typed into the field, it disappears and scrolls to the left. Press the enter key to resize the box so all text appears.

To always see the entire Comment entry, right-click on the grid and select Show Column Headers; then enlarge the width of the Value column. However, this may impact the look of other controls in the same grid. If this is unwanted, display the Comment control in a separate Control grid.

Working With Tables

Tables are used where appropriate to represent information. Two examples of tables are the Fit Remove tool Polynomial Table and Process Statistics (when viewed as Table).

Changing Units

If the column has units, right-click the column label and choose Select Units and Precision. See Setting Individual Units.

Changing the Column Order

Click and drag the column label to a new position and release the mouse button.

Adjusting Column Width

Point to the border between column headers, when the cursor changes to a double arrow ↔, click and drag the left mouse button to enlarge or reduce the width.

Hiding Columns

1. Point to the column headings, right-click and select Column Chooser.
2. To remove a column, click and drag it into the Customization panel.
3. Close the Customization panel.

Displaying Hidden Columns

1. Point to the column headings, right-click and select Column Chooser.
2. To add a previously removed column, click and drag it from the Customization panel back to the column header.
3. Close the Customization panel.

Selecting Table Data

Selecting Cells

Some tables do not allow selection of single cell.

One cell Point and click on cell.

Many cells Point to cell, press and drag the cursor over additional cells and release the mouse button.

Or click one cell, move the pointer to another cell, then press the Shift key and click a mouse button.

Selecting Rows

One row Point to the extreme left column before the row and click.

Many rows Click on one row, move the pointer to another row, then press the Shift key and click a mouse button.

To select (add) or deselect (remove) one row, press Ctrl and click the row.

Entire table Point to the left top corner of the table and click.

Selected cells are highlighted. The screen below shows Sample 2 selected.

	Sample	PV (λ)	RMS (λ)	PVr (λ)	NPoints	Peak (λ)	Size X (mm)	Size Y (mm)	Valley (λ)
	1	0.030	0.007	0.030	76800	0.011	5.85	4.39	-0.019
>	2	1.961	0.051	0.367	307200	0.438	2.82	2.12	-1.522
	3	0.497	0.075	0.497	76776	0.276	0.36	0.27	-0.221

Sorting Table Data

Changing the Sorting Order

Once sorting options are set, sorting takes place in real time as samples are added.

1. Click on the column label to change the sorting order based on that column. A small triangle indicates the sort order.

   ▲ Ascending order- sort table from low to high based on selected column.

   ▼ Descending order- sort table from high to low based on selected column.

or

2. Select rows in the table. Selected rows are highlighted.

   To select or deselect one row, press Ctrl and click the row. To select multiple rows or a range of rows, click on one row, move the pointer to another row, then press the Shift key and click a mouse button.

3. Point to the column header, right-click and select Sort Descending or Sort Ascending.

Multiple Column Sorting

1. Point to the first column label and click the left mouse button. Click the label to select ascending or descending sort.
2. Point to the second column label and Shift-click with the left mouse button. Hold down the Shift key and click on the column labels to change the sort preference.

Depending on the samples, multiple sorting may not be apparent. Only values that are identical in the first sort will be sorting with the secondary sort.

Turning Off Sorting

1. Right-click the column label and select Clear Sorting. This clears sorting for the only the selected column.
2. To remove sorting for all columns, repeat step 1 for each column label that has a small triangle displayed.

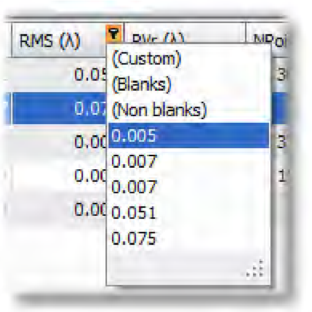
Filtering Table Data

Filtering lets you selectively hide values from the table database. It doesn't delete samples but hides them. Hidden samples are not used to calculate summary statistics.

- Use to hide questionable samples and quickly see the impact.
- Use to select a series of values and calculate the summary statistics.

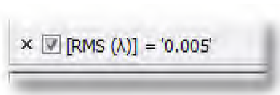
Using Filtering

1. Point to the column header and click the funnel icon.
2. Choose an option from the context menu.



Custom	Opens a Custom AutoFilter dialog.
Blanks	Displays samples with no data in that result.
Non blanks	Displays samples that have data in that result.
Numbers	Choose a number to display samples have that specific value.

A row appears at the bottom of the process panel denoting that a filter is active.

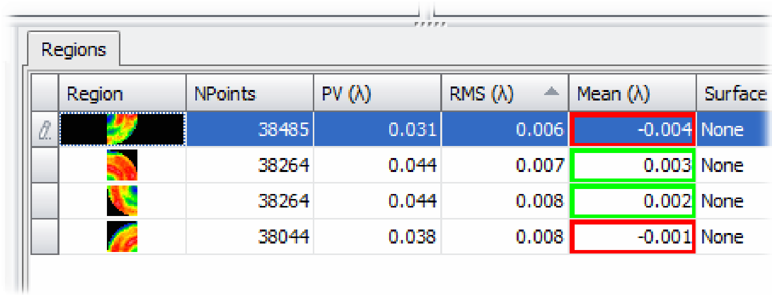


To remove a filter, clear the check box.

Using Limits on Table Data

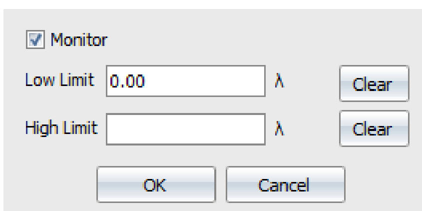
Limits are used to indicate whether individual results meet or fail user-entered tolerances.

- This feature is available in the Sub-Aperture Regions table.
- Low Limit specifies the smallest acceptable result value.
- High Limit specifies the largest acceptable result value.
- Passing results are outlined in green. Failed results are outlined in red.



Using Result Limits

1. Point and right-click on a result column header.
2. Select Set Limits from the menu.



3. Enter values for the Low Limit and/or High Limit.
4. Select the Monitor check box to display green (pass) or red (fail) outlines around the result fields.
5. Click OK.

Removing Result Limits

1. Point and right-click on a result column header.
2. Select Set Limits from the menu.
3. Click Clear to remove the corresponding limit.
4. Clear the Monitor check box.

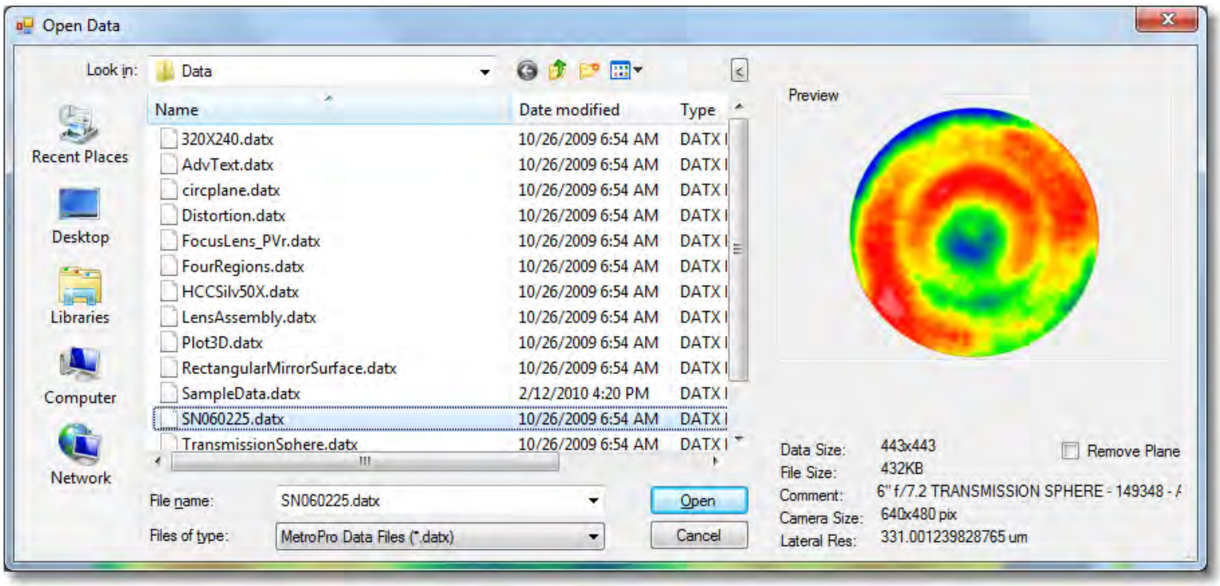
2.10 Working With Files

Loading Data Files	Explains how to load data files.
Saving Data Files	Explains how to save data files.
Native File Types	Describes the files types used directly by the software.
Using Settings	Shows how settings files can make things easier.
Compatible File Types	Lists other non-native file types supported by the software.

Loading Data Files

This is an example of loading or opening data.

1. On the File menu select Load Data, or on the toolbar click Load Data.
2. Choose the types of files to display with the Files of type drop-down box.
3. Click Open.



Opening Multiple Data Files

There are some cases when opening many data files at once is useful, such as when using Process Statistics or Control Charts and you want to examine existing data. To abort loading multiple data files press the Esc key.

1. To select multiple files one by one, hold down the Ctrl key and click on each file.
2. To select a range of files, click the first file, press the shift key, and then click on the last file; all files between the two choices are selected.

Files are loaded in the order in which they are selected.

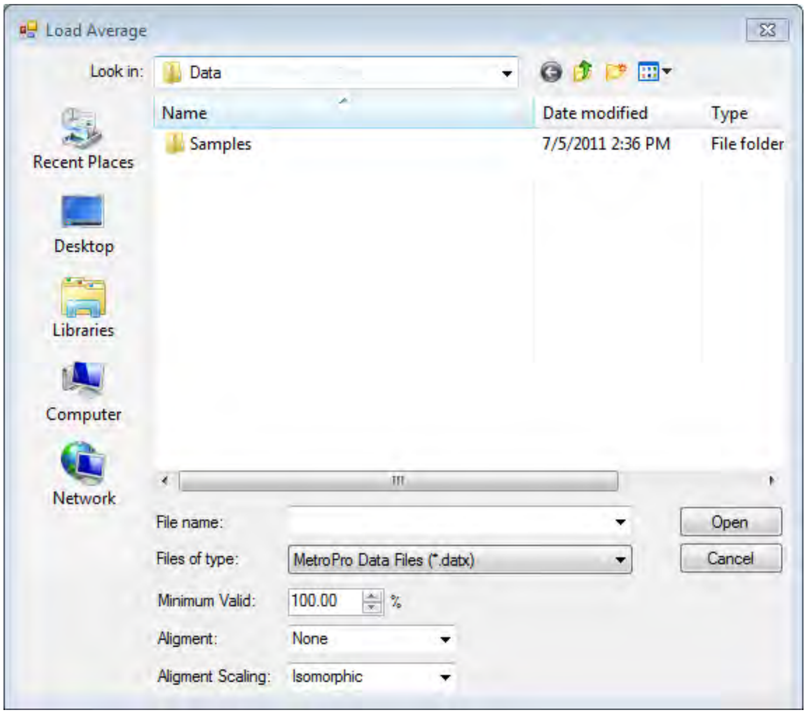
See Also

Importing Data

Load And Average Data

This function opens and averages multiple data sets.

1. On the File menu select Load And Average Data.
2. Choose the types of files to display with the Files of type drop-down box.
3. Select multiple files to open. See [Opening Multiple Data Files](#).
4. Click Open.



Load Average Options

If fiducials have been previously defined for all the data sets, they can be aligned to each other.

Minimum Valid Specifies the percentage for each pixel location in multiple data sets where corresponding data is required to be considered valid.

For example: a value of 100 means all averaged data sets must have valid data in corresponding pixel locations; a value of 50 means half of the averaged data sets must have valid data in corresponding pixel locations.

Alignment Selects if multiple data sets are aligned to each other. The choices are None (no alignment performed), or Fiducials (alignment performed based on fiducials).

To use Fiducials alignment, all loaded data files must have a similar set of fiducials previously defined. Isomorphic scaling needs at least 2 fiducials, while Anamorphic needs 3 fiducials. See [Fiducials](#).

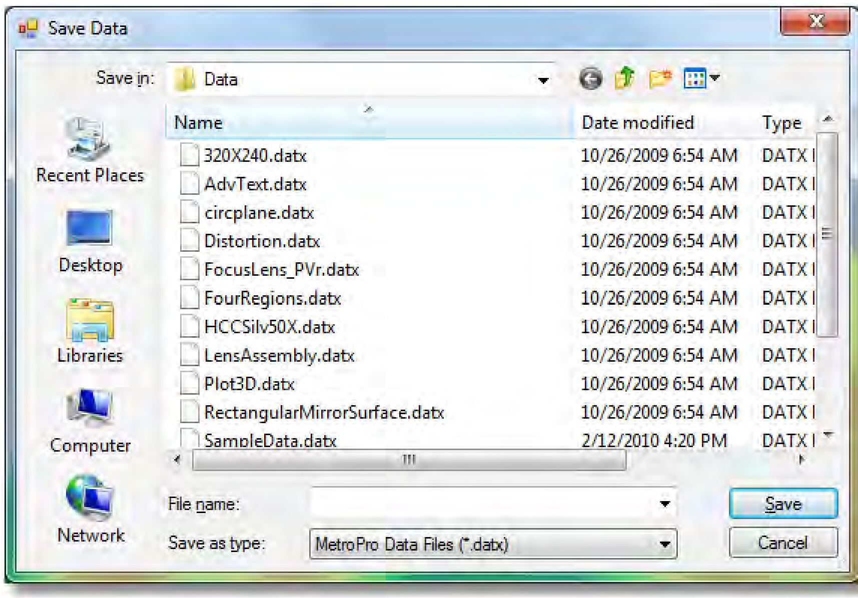
Alignment Scaling Selects how multiple data sets are scaled in x and y when using Fiducials alignment. Isomorphic scales both axes equally. Anamorphic scales to the best fit.

Saving Data Files

This is an example of saving data.

The Save Data command from the File menu saves unprocessed data. A plot context menu Save Data command saves processed data.

1. On the File menu select Save Data, or on the toolbar click Save Data.
2. Choose the file type with the Save as type drop-down box.
3. Type a name for the file after File name.
4. Click Save.



See Also

[Exporting Data]

Native File Types

There are several file types used by the software. Each is saved and loaded independently of the other.

File Type	Extension	Description
Application	appx	The look and placement of items, plus settings.
Configuration	sfgx	The configuration of the Process Statistics view.
Data	datx	Measurement data; it can be either unprocessed data (after signal acquisition and signal processing but before data processing) or processed data (data modified with data processing functions such as filtering, fit remove, edge trim, spike clip, etc.). The Save Data command from the File menu saves unprocessed data. A plot context menu Save Data command saves processed data.
Signal Data	ftpsix	Raw signal data file specific to a wavelength-shifting interferometer.
Signal Data	psix	Raw signal data file specific to a phase-shifting interferometer.
Signal Data	swlx	Raw signal data file specific to the optical profiler.
Movie & Raw	drmx	DynaPhase raw data.
Fiducials	fidx	Fiducial or part reference information used for alignment.
Mask	masx	Defines what to include or exclude in a measurement or analysis.
Native	prnx	Native XML printer format (or preview document format).
Pattern	patx	Defines all the parameters for a pattern.
Recipe	rcpx	Defines a sequence of automated actions.
Report	repx	Preserves the configuration options of a report.
Settings	setx	Tool and control selections including alphanumeric entries.
Sequence	seqx	A sequence of data analysis operations.
Stitch	stix	Defines all the parameters for a stitched measurement.

Using Settings

User settings of controls and tools are saved and loaded as .setx files. A settings file contains the setting of software controls, including both selections and alphanumeric entries.

To save settings, on the Actions menu select Save Settings, or on the toolbar click Save Settings.

To load settings, on the Action menu select Load Settings, or on the toolbar click Load Settings.

Uses For Settings Files

- Use unique control settings for particular parts.
- Use as user default settings to globally reset all controls to a known setting.
- Makes it easy to use one common application layout but measure different part types.

Compatible File Types

These additional file types are supported.

File Type	Extension	Description
MetroPro Data	dat	A file containing measurement data from MetroPro. A legacy data file contains multiple numerical arrays representing the part under test, plus measurement parameters. See dat Format.
Interferogram	int	An interferometer output data file. Also known as a CODE V data file. The INT file type is used in the Fit Remove tool and the Data Generate tool. See int Format.
Surface Data File	sdf	A text based surface data file comprised of general file descriptors and a data array. See sdf Format.
Stereolithography File	stl	A stereolithography CAD file format that describes a raw unstructured triangulated surface using a three-dimensional Cartesian coordinate system. This file type can be exported from plots and non-phase microscopes.
Digital Surf File	sur	A file containing surface measurement data compatible with Digital Surf.
Column/Row/ Height Data	xyz	A text file containing a header and measurement data. For details on this legacy format see xyz Format.
ASCII	asc	A text file containing a header, an intensity data matrix, and a phase data matrix. For details on this legacy format see asc (ASCII) Format.
ZeMaps Data	zmp	A file containing measurement data from ZeMaps.
Script	py	A script written in Python, an interpreted object-oriented programming language.

File Type	To load (or import)...	To save (or export)...
dat	File ▸ Load Data	File ▸ Save Data
int	File ▸ Import Data	File ▸ Export Data
sdf	File ▸ Import Data	File ▸ Export Data
stl	not supported	File ▸ Export Data
sur	File ▸ Import Data	File ▸ Export Data
xyz	File ▸ Load Data	File ▸ Save Data
asc	File ▸ Load Data	File ▸ Save Data
zmp	File ▸ Import Data	not supported

Basic loading and saving of files is described at Working With Data Files.

Data file formats and basic importing and exporting of files are described under Exchanging Data.

2.11 User Levels

This feature allows you to set limitations on what software components are available and assign them to user levels with passwords.

User levels are hierarchical, with the Operator having limited features available and the Admin having full control. To use this feature, on the File menu select Switch User Level.

Operator	The most restricted level; designed for the instrument operator to limit access to key components. Only the Operator level has predefined restrictions. In this level, tool bars are locked, option dialogs are not accessible, and the View and Options menus are not accessible.
Engineer	Recommended to be used by the person responsible for the instrument setup. No predefined restrictions.
AppsEngineer	Recommended to be used by the person designing the higher level application features, such as the processing flow. No predefined restrictions.
Admin	Reserved for the person with the highest level of control. No predefined restrictions.

Starting with a Specific User Level

1. On the Tools menu select Options.
2. In the Start with user level field, select a level from the drop-down list.
3. Click OK.
4. Quit and restart Mx.

Timeout Feature

If there is a period of inactivity, the application reverts to Operator level. To return to another level, on the File menu select Switch User Level, select the appropriate user level, and enter the password.

Defining User Levels

User levels can be associated with tabs, groupings, and screens. Any component that does not have a user level associated with it is assigned Operator by default.

As supplied by Zygo, no restrictions are set on Engineer and higher levels.

Example

This procedure hides the Calibrate Tab entirely from the Operator user level. Perform similar actions to limit user level access to components.

1. On the View menu select App Builder.
2. Under Tabs, double click the applicable tab name. In this example it is CALIBRATION.
3. In the component details panel, set the "Visible for UserLevel and above" field to the desired level. In this example set it to Engineer.
4. Close App Builder by going to the View menu and selecting App Builder.
5. Save the application.

The default applications cannot be saved; if this is the first time trying to save a default application use the Save Application As... command.

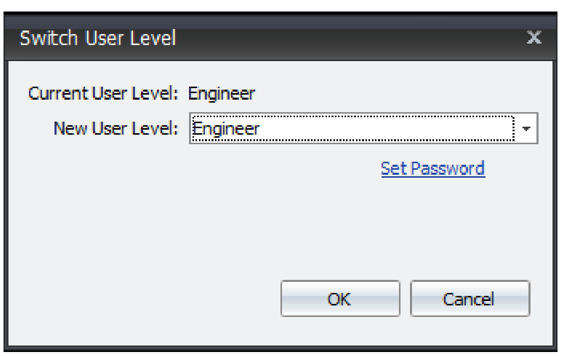
Using Passwords

Passwords can be assigned to each user level. As supplied no passwords are set. Passwords are stored with the application.

Assigning a Password to a User Level

This assigns an entered password to the selected user level. Each user level can be assigned a unique password.

1. On the File menu select Switch User Level (or press Ctrl+Shift+C).
2. In the New User Level field, select a level from the drop-down list. Set Password should appear in the dialog.



3. Click Set Password.
4. In the Set Password dialog, enter the password in both places and click OK.
5. On the File menu select Save Application As..., enter a name for the application and click Save.
6. Quit and restart Mx.

Changing a Password

1. On the File menu select Switch User Level (or press Ctrl+Shift+C).
2. In the New User Level field, select the applicable user level from the drop-down list. Reset Password should appear in the dialog.
3. Click Reset Password.
4. In the Reset Password dialog, enter the existing Old Password and then enter the new password in two places and click OK.
5. On the File menu select Save Application.
6. Quit and restart Mx.

Resetting a Password

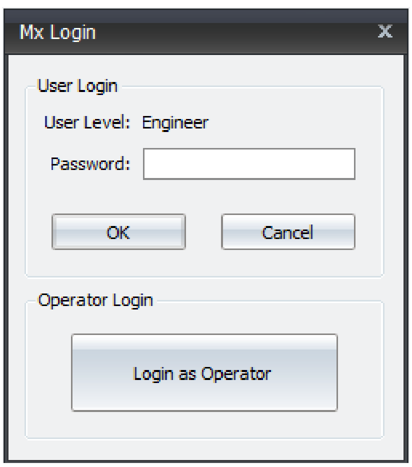
Follow steps above under Changing a Password. But at step 4 enter the Old Password, and leave New Password and Confirm Password blank.

Password Help

Contact Zygo for password assistance.

2.12 Mx Login

If passwords have been set and the starting user level has an assigned password, a login dialog appears when opening the application.



For information on passwords see Using Passwords.

For information on starting Mx at a particular user level see User Levels.

2.13 Local Languages

Some local languages other than English are supported. However, only basic items are available in the selected language, such as the main Tool Bar, Navigator, Measurement Setup, and Process Statistics. Some of the interface still appears in English.

Changing Language

1. On the File menu, click Change Default Language.
2. In the language dialog, select a language from the drop-down list.
3. Click OK.
4. Quit and restart Mx.

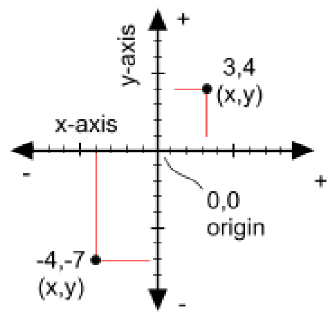
2.14 Coordinate Systems

Where applicable, different types of coordinate systems are used to identify and refer to instrument axes or results.

Cartesian Coordinates

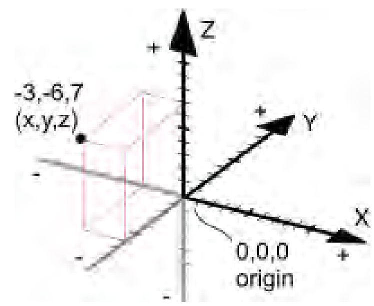
Two-dimensional

The two-dimensional Cartesian coordinate system locates each point on a plane by two numbers; one on the x-coordinate and the second on the y-coordinate.



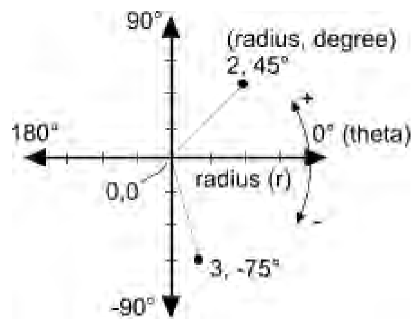
Three-dimensional

The three-dimensional Cartesian coordinate system provides three physical dimensions of space- length, width, and height.



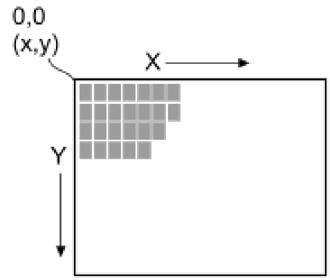
Polar Coordinates

The polar coordinate system is a two-dimensional coordinate system in which each point on a plane is determined by an angle and a distance.



Camera Coordinates

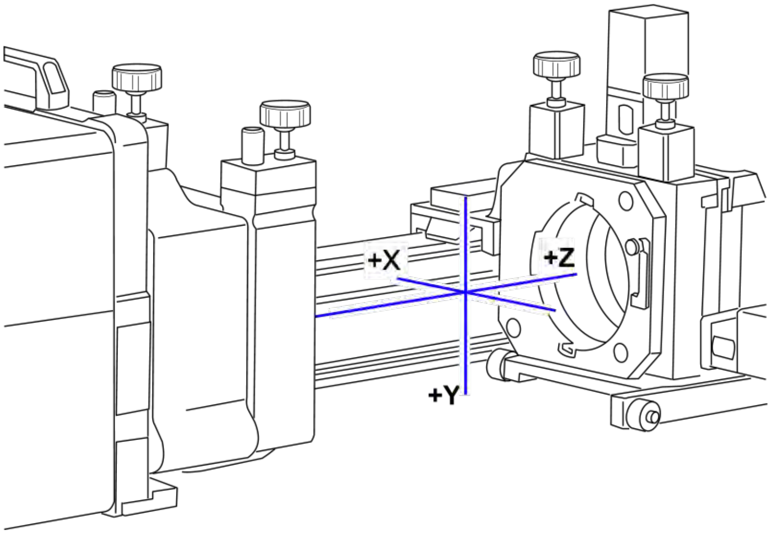
Camera coordinates relate to the instrument's camera and are in pixels.



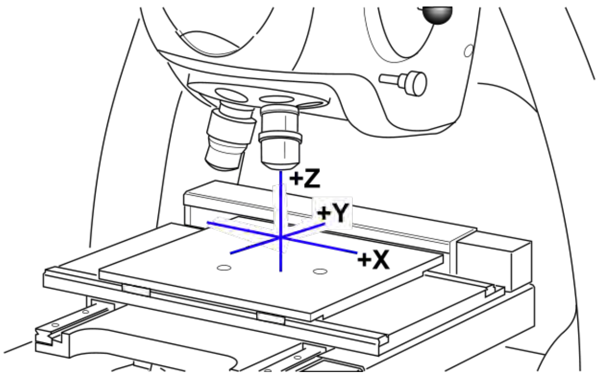
Instrument Axes

Axes as viewed from the user's point of view.

Laser Interferometer Axes



Optical Profiler Axes



Laser Interferometer Applications 3

An application is an arrangement of instrument specific components and software features designed to acquire and analyze measurement data. Application files have .appx as a file extension.

Applications typically have a unique navigator, menus, and toolbars. Data processing functions are structured for the specific need.

Application	Filename	Description	Features
Form	Form.appx	General purpose default application for laser interferometers	Specialized optical analyses: Angles, Corner Cube, Grazing Incidence, Polished Homogeneity, Radius Scale, Ritchey-Common, Three Flat, Two Sphere, Tool Offset
MST	MST.appx	Multiple Surface Testing application for MST laser interferometers	Measures two-surface, three-surface and four-surface cavities. Provides front surface map, optical thickness variation, and the back surface approximation.
AccuFlat	AccuFlat.appx	Designed to measure transparent, thin plane-parallel parts; it is specific to the AccuFlat interferometer	Focus Display

Default applications cannot be saved. To create your own custom version, on the File menu select Save Application As.

To specify an application to load when the program is opened see Starting With a Specific Application.

To save or load an application see Working With Files.

3.1 Form Application

- The Form application (Form.appx) is the general purpose application for ZYGO laser interferometers.
- Supports PSI, QPSI, and DynaPhase data acquisition. See Data Acquisition Details.
- Provides the following analyses: Diffraction, Intensity, ISO 10110-5, Legendre, PSD, PVr, Slopes, Sub-Aperture, Surface, and Zernike. See Analyses.
- Supports many measurement types including: Angles, Corner Cube, Form, Grazing Incidence, Polished Homogeneity, Radius Scale, Three Flat, and Two Sphere.
- For the general layout see Surface.

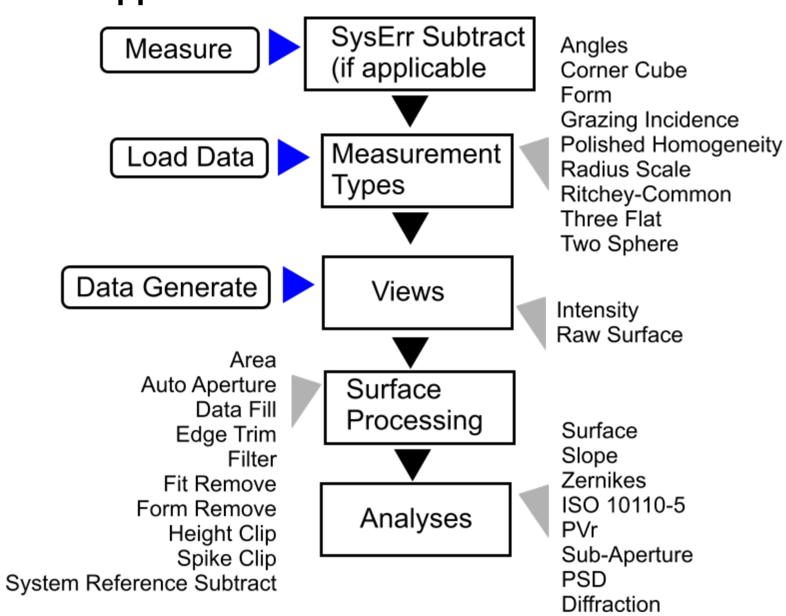
Form Application Overview

The two main user *actions* are selected with the large tabs and progress from left to right.

MEASUREMENT **ANALYSIS**

See Tabs for more information.

Form Application Data Flow



Measurement Type

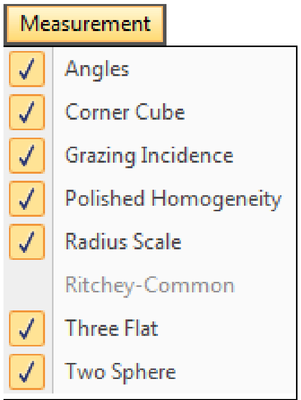
For the Form and MST applications a "Measurement Type" is a workspace configuration of graphics, results, and tools for a particular function. Each measurement type is activated with the Measurement Type control.

- Is part of an application (.appx) file. Some applications may not use measurement types.
- Used to obtain data of an appropriate test part in a specific measurement setup.
- For further processing options, use Surface Processing tools.
- Instrument specific; available types may vary.

See also MST Measurement Type.

Measurement Menu

For a Measurement Type to appear in the control pull-down list or in the Navigator, they must be selected in the Measurement menu.



Surface

ANALYSIS tab, Navigator : Measurement : Surface

Surface is the home or basic view for laser interferometers. It serves as a starting view when learning the software and when measuring a new or unknown part.

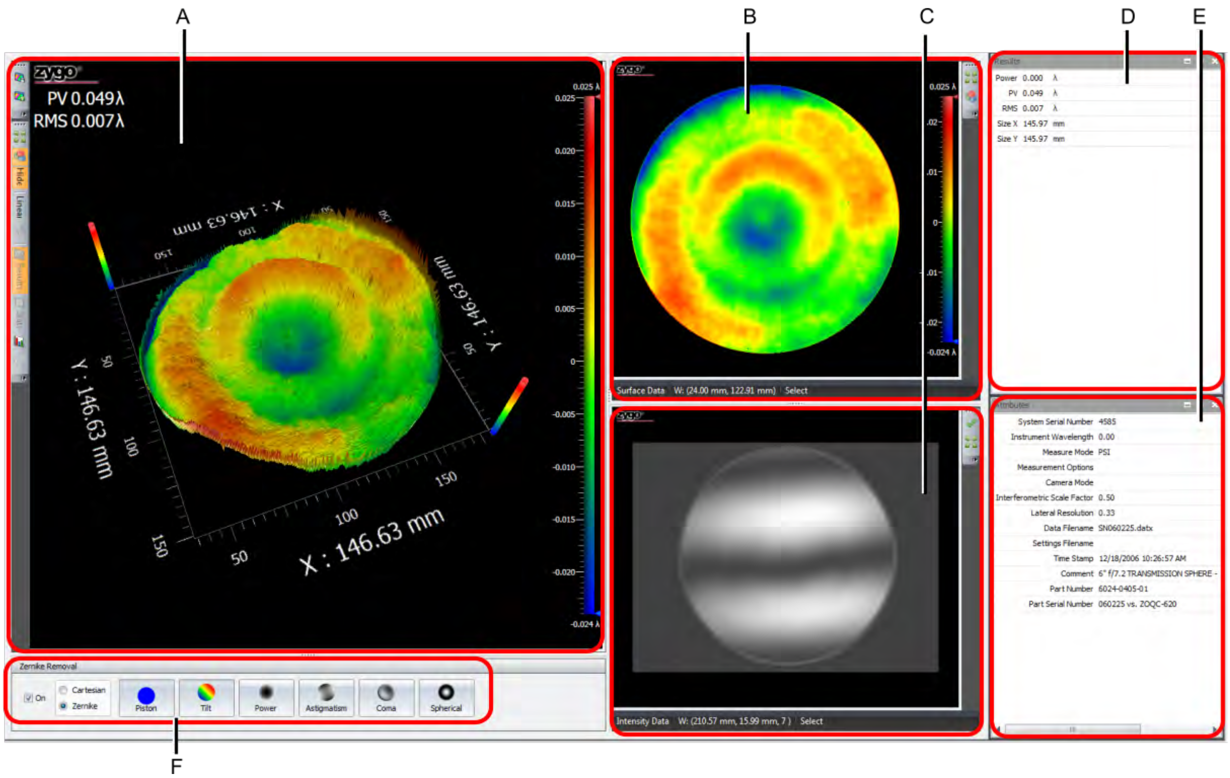
To activate, select Form in Measurement Type in the Measurement Setup tool or toolbar.

Use Conditions

- Applies to laser interferometers; part of Form.appx.

The Surface Screen

Resize and adjust screen elements to suit your need. Shown below is the ANALYSIS tab.



A. 3D Plot of data (see 2D/3D Plot Overview). **B.** 2D Plot of data. **C.** 2D plot of intensity data. **D.** Result grid. **E.** Attribute grid. **F.** Zernike or Cartesian Removal control (see Fit Remove- Basic).

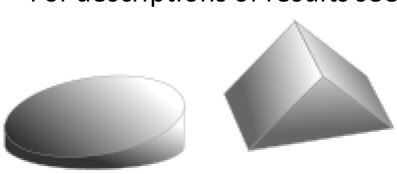
Angles

Navigator : Measurement : Angles

To activate, select Angles in Measurement Type in the Measurement Setup tool or toolbar.

Measurement Features

- Use to measure the mechanical wedge of an optical element having nonparallel surfaces, and the angle error of prisms.
- Measure the wedge orientation, direction, and magnitude of wedge optics.
- Wedge orientation and the thickest portion of the optic is indicated by an arrow on the test data plot.
- Measure the angle error of right-angle prisms.
- For descriptions of results see Standard Optic Results.

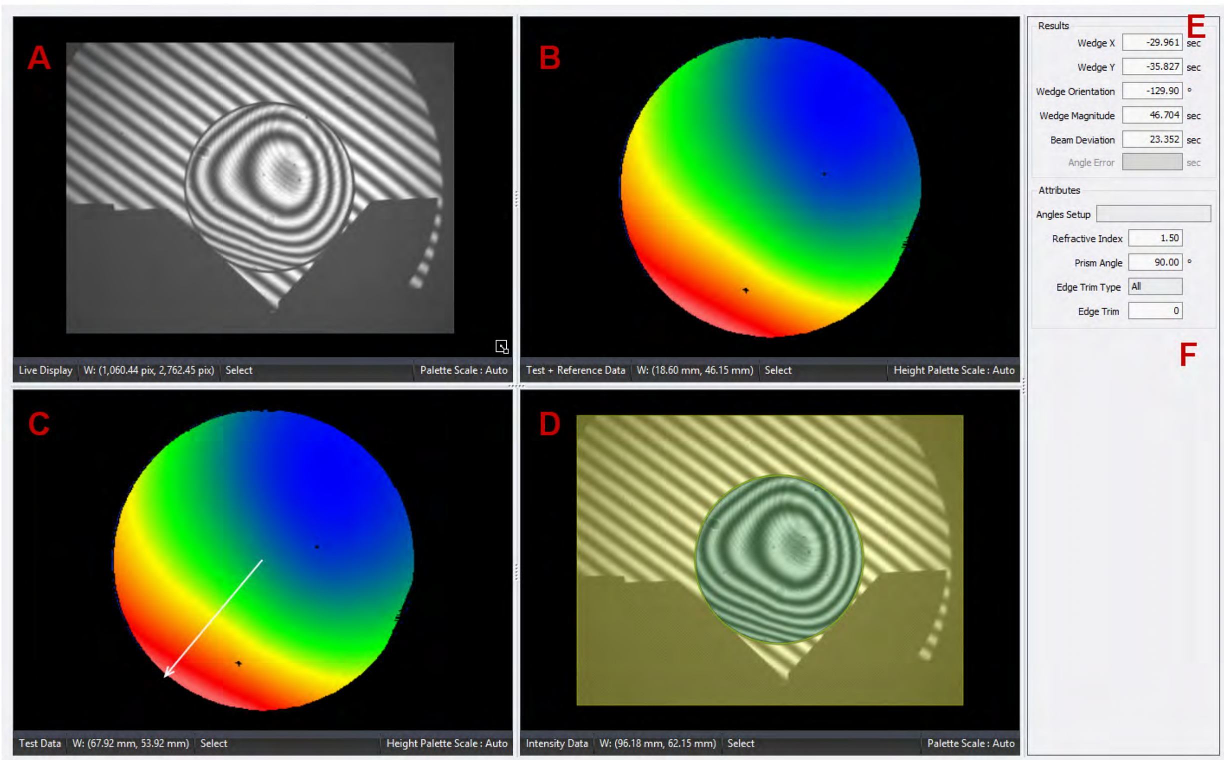


Use Conditions

- Applies to laser interferometers; included in Form.appx.
- Select the Angles Setup that matches the actual equipment setup.
- Some setups require a Refractive Index entry.
- Some setups require masks.
- Lateral calibration is required for Wedge and Tilt results other than orientation.
- When testing right-angle prisms, the vertex must be oriented vertically.

The Angles Screen

Shown below is the MEASUREMENT tab. For the ANALYSIS tab see Surface.



A. Live Display **B.** Test + Reference Data plot (shows result of comparing the test area to the reference). **C.** Test Data plot (arrow shows orientation and points to thinnest portion). **D.** Intensity Data (note reference and test areas are clearly visible). **E.** Angle results. **F.** Attributes (show setting of corresponding control).

See Also

Standard Optic Results

Attributes

Angles Controls

Angles Setup	Selects the angles measurement setup. For wedge setups see Measuring Wedge. For prism setups see Measuring Angle Error. The Angles Setup selection affects the use of masks, other control entries, and which results are calculated. See below for more details.
Mask	Shortcut to Mask controls. When this button is red, required masks for Test or Reference are missing.
Refractive Index	Specifies the refractive index of the part being measured. It defaults to 1.500 for Wedge Transmissive and Prism Internal setups. An appropriate index value for the actual material should be entered.
Prism Angle	Specifies the desired angle of the prism when the Angles Setup is Prism External.
Edge Trim Type	Edge trim type and size remove pixel layers from data edges to minimize edge effects. See Edge Trim Type.
Edge Trim Size	See Edge Trim Size.
More →	Expands view to reveal advanced controls. See Advanced Angles Controls.

Mask Requirements

Angles Setup	Acquisition Mask	Angles Test Mask	Angles Reference Mask
Prism External	no	yes	yes
Prism Internal Single Pass	no	yes	yes
Prism Internal Double Pass	no	no	no
Wedge Reflective	no	yes	yes
Wedge Transmissive	no	yes	yes
Custom	no	yes	yes

Control Interaction

Active controls and their default values depend on the Angles Setup control selection. To override the default value for the Interferometric Scale Factor (see Advanced Angles Controls), set Angles Setup to Custom.

Angles Setup	Refractive Index	Prism Angle è $_{prism}$	Interf Scale Factor	PZT Scale Factor
Prism External	Not Used	90° (enter actual)	$\frac{1}{4cos\left(\frac{\theta_{prism}}{2}\right)}$	1.00
Prism Internal Single Pass	1.50 (enter actual)	Not Used	1.00	1.00
Prism Internal Double Pass	1.50 (enter actual)	Not Used	0.50	0.50
Wedge Reflective	Not Used	Not Used	0.50	1.00
Wedge Transmissive	1.50 (enter actual)	Not Used	0.50	1.00
Custom	Not Used	Not Used	0.50 (enter actual)	1.00

See Also

Advanced Angles Controls

Advanced Angles Controls

These controls are displayed when the angles controls are fully expanded.

Output Data Selects what data is passed onto the analysis flow. This determines what is viewed as input data in Data Processing as well as other analyses.

The choices are: Acquired Data, Test (default), Reference, or Test+Reference.

Plane Fit Sigma Clip Excludes outliers from the plane fits used for angle calculations, as a multiple of the standard deviation of the fit residual. See Spike Clip.

Interf Scale Factor Specifies a scale factor for the actual optical path traveled by the recombining wavefronts. For most Angles Setup options this is determined automatically. For special applications requiring adjustments from the default, set the Angles Setup control to Custom.

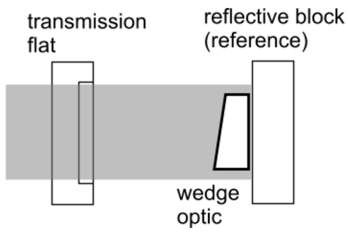
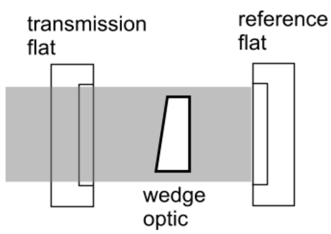
PZT Scale Factor Specifies the scale of PZT (piezoelectric transducer) movement. It is used in special applications to scale the PZT movement up or down to achieve the required one fringe of modulation.

Allowable settings: 0.125 to 2.000, the default is 1.000.

Measuring Wedge

1. Select the actual physical setup of the instrument in Angles Setup. Enter the Refractive Index if required.
2. Create the required masks.
3. Perform lateral calibration.
4. On the toolbar click Measure.

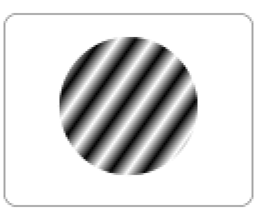
Wedge Setup Examples

Angles Setup	Example	Refractive Index entry
Wedge Reflective		no
Wedge Transmissive		Required, enter the refractive index of the wedge optic material

Wedge Mask Examples

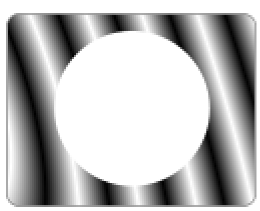
Masks are required so the test area is compared relative to the reference area. Use the Mask Editor to define masks.

Before making masks it is recommended to adjust the laser interferometer zoom until the area occupied by the wedge optic is approximately equal to the area *not* occupied by the wedge optic.



Angles Test Mask

Create test mask to include the wedge optic.



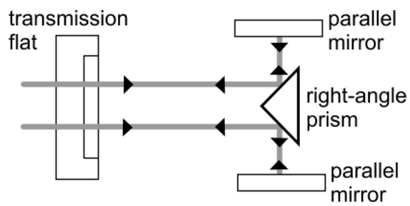
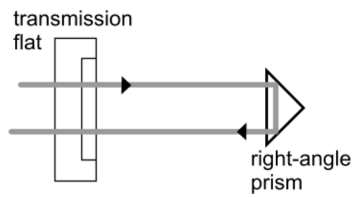
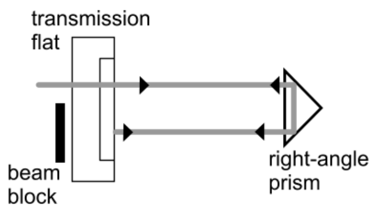
Angles Reference Mask

Create reference mask to include the reflective area behind the wedge optic; and to exclude the area taken up by the wedge optic.

Measuring Angle Error

1. Select the actual physical setup of the instrument in Angles Setup. Enter the Refractive Index if required.
2. Create masks if necessary.
3. Perform lateral calibration.
4. On the toolbar click Measure.

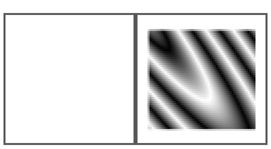
Prism Setup Examples

Angles Setup	Example	Refractive Index entry
Prism External		no
Prism Internal Single Pass		Required, enter the refractive index of the prism material
Prism Internal Double Pass		Required, enter the refractive index of the prism material

Prism (External) Mask Examples

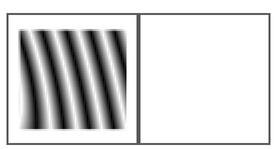
If the setup is Prism External, masks are required so the test area is compared relative to the reference area. Use the Mask Editor to define masks.

The sign convention of the Angle Error result is dependent upon how the masks are setup. If the sign convention is not as expected, flip-flop the test and reference masks.



Angles Test Mask

Define one face of the prism as the test.



Angles Reference Mask

Define the other face of the prism as the reference.

Angles Results

For details on result definitions see Standard Optic Results. The results provided vary based on the Angles Setup selection in Angles Controls.

Result Calculations

Angles Setup	Wedge Orientation, X, Y, Magnitude*	Angle Error	Beam Deviation	Tilt Orientation X, Y, Magnitude*
Prism External	no	yes	no	no
Prism Internal Single Pass	no	yes	no	no
Prism Internal Double Pass	no	yes	no	no
Wedge Reflective	yes	no	no	no
Wedge Transmissive	yes	no	yes	no
Custom	no	no	no	yes

*Lateral calibration required for X, Y and Magnitude.

Corner Cube

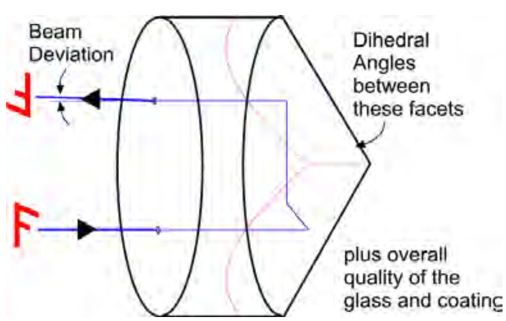
Navigator : Measurement : Corner Cube

To activate, select Corner Cube in Measurement Type in the Measurement Setup tool or toolbar.

Measurement Features

- A cube corner has three internally reflecting facets forming 90 degree angles with each other.
- Use to measure cube corner prisms (also known as retroreflectors).
- Evaluate any type of cube corner regardless of whether it is constructed of a single piece of glass or three individual mirrored surfaces.
- Supports both single pass and double pass test setups.
- Provides three categories of results: dihedral angle error, beam deviation, and transmitted wavefront quality.
- Automatically selects individual sectors for isolated results, no masking is required.

The corner cube is a cube with one corner cut off so there are three mutually perpendicular surfaces. It is designed to reflect all light rays toward their source.

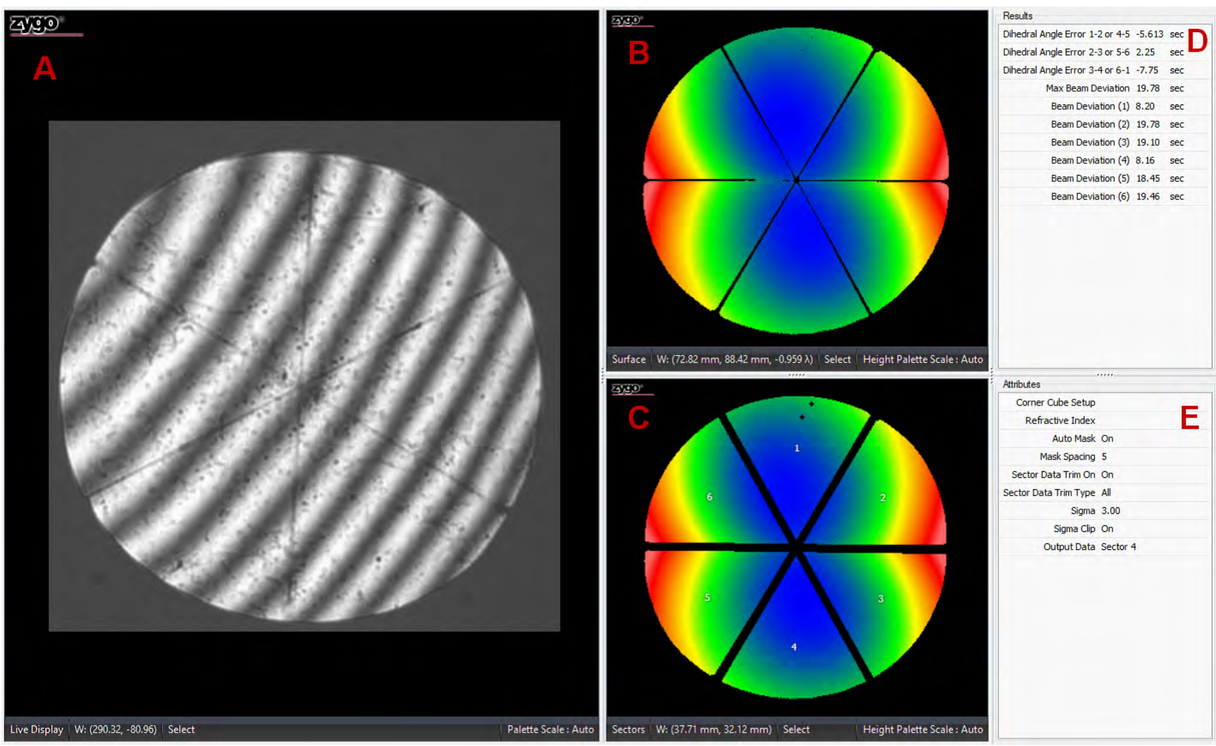


Use Conditions

- Applies to laser interferometers; included in Form.appx.
- Requires specific hardware- transmission flat (for single pass testing a Dynaflect flat or an attenuator filter is required), a user-provided aperture half-block (required for double pass testing), and a 2-axis mount with self centering element holder (optional).
- The cube should be oriented so that one of the facet intersections is vertical. Single pass testing is tolerant of facet rotation as the sectors are automatically numbered (and shown in the Sector plot). Double pass testing requires data on the right and the measurement fails if there is too much rotation.
- Note that it is normal for the Double Setup to display only half of the corner cube, though the entire cube is tested because the measurement beam travels through all facets.
- Lateral calibration is required for beam deviation and dihedral angle error results.
- The use of an Acquisition mask that includes the cube and excludes the background is optional.

The Corner Cube Screen

Shown below is the MEASUREMENT tab. For the ANALYSIS tab see Surface.



A. Live Display. **B.** Surface data. **C.** Sector data (corner cube facets are numbered). **D.** Corner Cube results. **E.** Attributes (show setting of corresponding control).

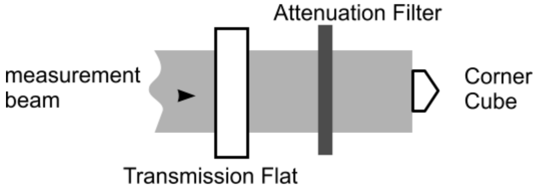
See Also

Corner Cube Results

Attributes

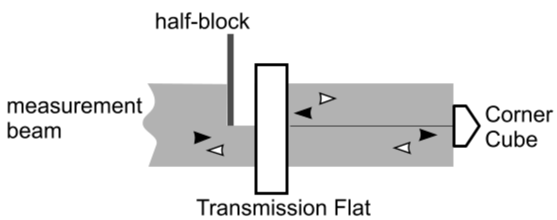
Corner Cube Test Setups

Single Pass



- Use when measuring very small or irregularly shaped prisms.
- Requires a Dynaflect flat or an attenuation filter.
- Can be useful in overcoming low fringe contrast polarization effects, which appear as data loss in the double pass setup.
- Doubles any asymmetrical wavefront errors introduced by the interferometer.

Double Pass

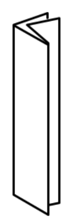


First Pass (black arrow)- half the measurement beam is retroreflected back to the transmission flat.

Second Pass (white arrow)- measurement beam is reflected by transmission flat back through the corner cube into the interferometer.

- Recommended over single pass.
- The measurement beam is blocked and the remaining half is retroreflected by the corner cube twice.
- Cancels out any asymmetrical wavefront errors introduced by the interferometer.
- Requires a user-provided beam block.

A beam half-block can be made from letter size paper folded as shown here. The beam block is inserted between the accessory receptacle and the PMR.



Corner Cube Controls

Corner Cube Setup	Selects the test setup you are using. Options are Double Pass or Single Pass. See Corner Cube Test Setups.
Refractive Index	Specifies the refractive index of the corner cube material, if the corner cube is a solid piece of glass. If the cube is constructed from three mirrored planes, enter the refractive index of air. For example, the Refractive Index for BK-7 is 1.51633; the refractive index of air at STP (standard conditions for temperature and pressure) is 1.0002714.
Edge Trim On/Off	When selected data is trimmed from each corner cube sector. When the check box is cleared edge trimming is not performed.
Edge Trim Type	Selects how data is trimmed. *All* trims pixel layers at the edges of all data, including outside edges and edges around internal holes. *Outside* trims pixel layers at the outside edge only. This is useful for removing edge effects such as diffraction.
Edge Trim Size	Specifies the number of pixel layers to remove based on the setting of Type.
Auto Mask	When selected, a mask is automatically created that surrounds each corner cube sector. It is used to isolate the sectors for results on each individual sector. When the check box is cleared, individual sector results are not calculated.
Rotate Auto Mask	When selected, the mask is automatically rotated to align with the corner cube sectors data. When the check box is cleared the mask is not rotated.
Mask Spacing	The width in camera pixels of space between the adjacent mask figures created by the Auto Mask function. The spaces between masks are necessary to eliminate facet intersections and their reflections from the analysis.
More →	Expands view to reveal advanced controls. See Advanced Corner Cube Controls.

See Also

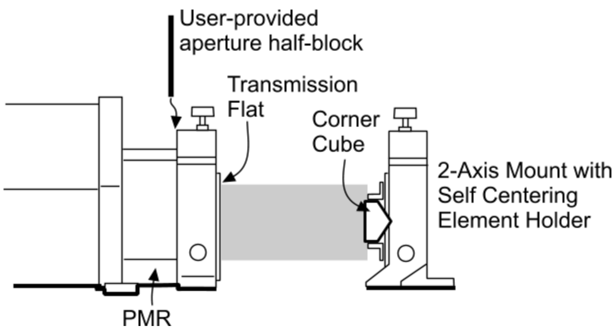
Angles Advanced Controls

Advanced Corner Cube Controls

These controls display when the corner cube controls are fully expanded.

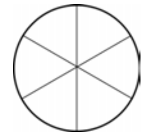
Output Data	Selects what data is passed onto the analysis flow. This determines what is viewed as input data in Data Processing as well as other analyses. The choices are: Acquired Data, Masked (default), Sector 1, Sector 2, Sector 3, Sector 4, Sector 5, or Sector 6.
Plane Fit Sigma Clip	Excludes outliers from the plane fits used for angle calculations, as a multiple of the standard deviation of the fit residual. See Spike Clip.
Interf Scale Factor	Specifies a scale factor for the actual optical path traveled by the recombining wavefronts. In most cases the default value should be used, but for special applications this can be adjusted.
PZT Scale Factor	Specifies the scale of PZT (piezoelectric transducer) movement. It is used in special applications to scale the PZT movement up or down to achieve the required one fringe of modulation. Allowable settings: 0.125 to 2.000, the default is 1.000.

Measuring Corner Cubes

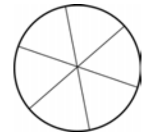


1. Select the setup with the Corner Cube Setup control.
2. If the corner cube is a solid piece of glass, enter the refractive index of the material in the Refractive Index control. If the cube is constructed from three mirrored planes, enter the refractive index of air.
3. Install the Transmission Flat in the interferometer accessory receptacle and align the flat. When in the interferometer Align mode, adjust the accessory receptacle Tip/Tilt knobs until the brightest spot is superimposed on the alignment crosshairs.
4. Mount the corner cube, such that its face is parallel to the face of the Transmission Flat. Then position the corner cube in the measurement beam.
5. Single Pass only- Place an attenuation filter between the transmission flat and the corner cube. If you are using a Dynaflect flat, ignore this step.

6. Set the interferometer zoom setting so the test part fills as much as possible of the Live Display.
7. Adjust the orientation of the corner cube in its mount such that one of the facet intersections and its reflection are vertical.

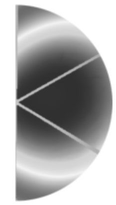


Good



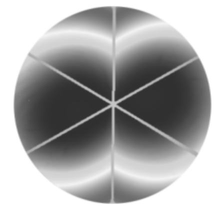
Bad

8. Double Pass only- Insert the half-block between the accessory receptacle and the PMR. Adjust the lateral position of the block so that only one half of the corner cube is observed.



Sample Double Pass Fringe Pattern

9. Single Pass only- Fine-tune the transmission flat Tip/Tilt to obtain the best possible nulled interference pattern. It may not be possible to completely null the pattern; however, you should come as close to it as you can, making the fringes as broad as possible.



Sample Single Pass Fringe Pattern

10. Focus the interferometer so that the edges of the corner cube are as sharp as possible and the ends of the fringes exhibit a minimum of bending.
11. Perform Lateral Calibration. This is required to calculate Dihedral Angle Error and Beam Deviation results.
12. On the toolbar click Measure.

Grazing Incidence

Navigator : Measurement : Grazing Incidence

To activate, select Grazing Incidence in Measurement Type in the Measurement Setup tool or toolbar.

Measurement Features

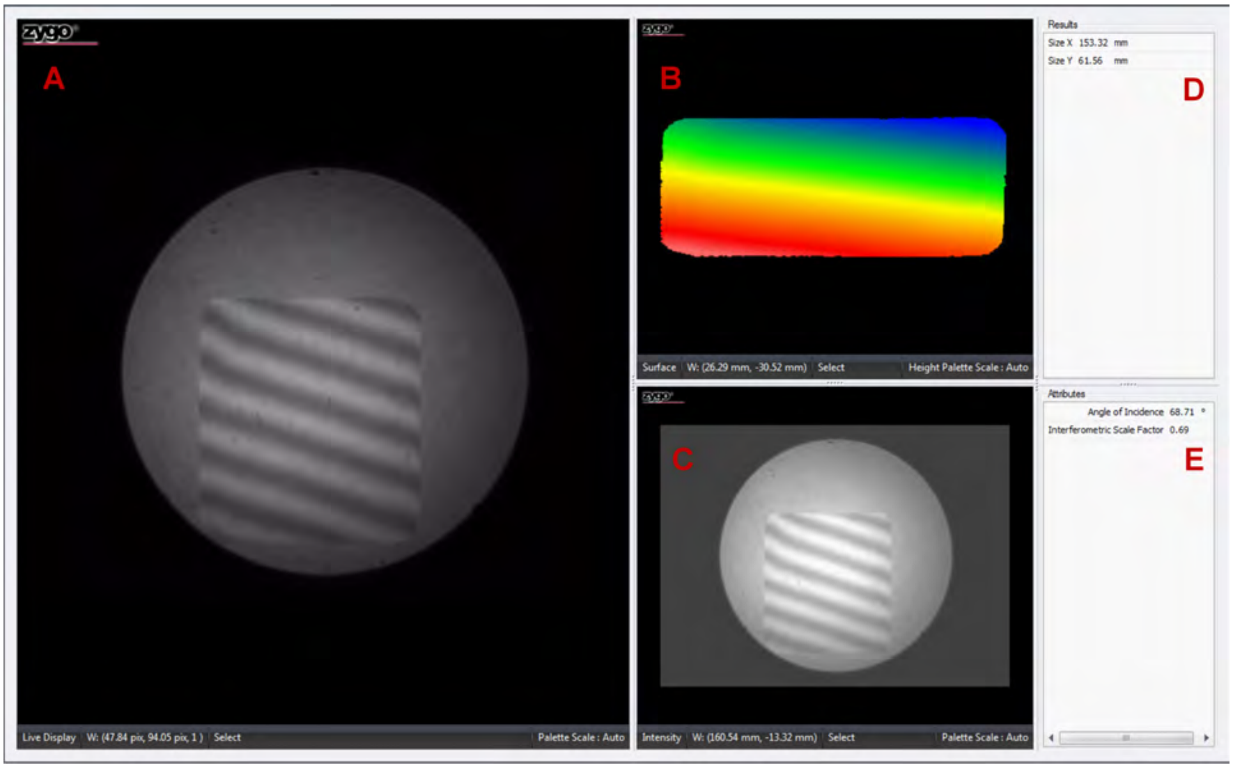
- Use to measure a test part that is larger than the interferometer aperture.
- Use to measure rough or non-specular plano surface, such as unfinished metal or ceramic.
- Automatically adjusts the Interf Scale Factor setting and reconstructs the Surface plot.

Use Conditions

- Applies to laser interferometers; included in Form.appx.
- Requires specific hardware: transmission flat, reference flat (90% reflectivity recommended), 2-axis adjustable mount (for reference flat), mount for test part.
- Requires lateral calibration in both horizontal and vertical directions. See Lateral Calibration, Grazing Incidence.
- Available when Measurement Mode is set to PSI.

The Grazing Incidence Screen

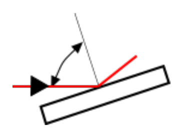
Shown below is the MEASUREMENT tab. For the ANALYSIS tab see Surface.



A. Live Display. **B.** Surface Plot (reconstructed using lateral Calibrator inputs). **C.** Intensity Plot shows a representative fringe pattern. **D.** Results grid. **E.** Attributes grid.

Grazing Incidence Attributes

Angle of Incidence Displays the angle that the measurement beam strikes the test part.



Interf Scale Factor Displays the actual Interf Scale Factor used. See Interf Scale Factor for a discussion of this factor.

See Also

Measuring Grazing Incidence

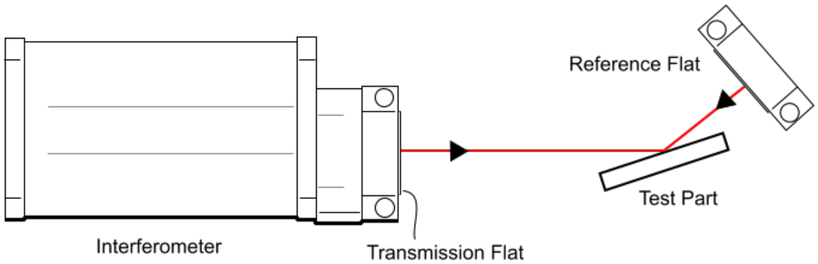
Lateral Calibration

Standard Optic Results

Measuring Grazing Incidence

The test part is placed at an oblique angle to the wavefront. A highly reflective reference flat is positioned to reflect the beam back into the test part. The positioning of the test part and the second reference surface reduce the effects of the absorption/scattering condition commonly observed in normal incidence setups.

The best possible angle for the grazing incidence setup is having the test part as close to normal incidence as possible. This minimizes foreshortening of the final image, uses more the camera pixels, and means the interferometric scale factor is less sensitive. The optimal angle for the test part for best metrology depends on how rough and how large the part surface is.



For details on using your laser interferometer see the applicable operating manual.

1. Mount the transmission flat in the interferometer accessory receptacle.
2. Mount the reference flat in the 2-Axis adjustable mount.
3. Make sure that both the transmission flat and the reference flat are aligned squarely to the optical axis of the interferometer.
4. Place the test part into the wavefront at a relatively high angle of incidence.
5. Put the interferometer in ALIGN mode. This provides the most energy making the beam on the test part easier to see. To help locate the test part, temporarily place a piece of white paper in front of the test part to see where the beam from the interferometer strikes the part. Move the part so the beam (though foreshortened) is centralized on the part.
6. Move the piece of paper to a position to find the reflected beam. Position the reference flat in place of the paper. The reference flat will reflect light back to the test surface and then the interferometer.
7. Continue to pivot the reference flat until a single, more faint, reflection appears on the Live Display.
8. Switch to VIEW mode and slowly move the reference flat until a fringe pattern is displayed.
9. Access the Grazing Incidence Lateral Calibrator. Draw a vertical line across the part image, click Set Vertical and enter the vertical physical dimension of the test part. Draw a horizontal line across the part image, click Set Horizontal and enter the horizontal physical dimension of the test part. Close the Lateral Calibrator.
10. Click Measure. The Interferometric Scale Factor setting is automatically established based on the calibration. The resultant surface map is also automatically reshaped accordingly.
11. Go to the Surface or Home screen to perform additional data processing.

Polished Homogeneity

Navigator : Measurement : Polished Homogeneity

To activate, select Polished Homogeneity in Measurement Type in the Measurement Setup tool or toolbar.

Measurement Features

- Homogeneity is a measure of the variation in the refractive index within a material.
- Measures the homogeneity of polished glass wedge optics.
- Removes errors in the test cavity as well as errors from the front and rear surfaces of the sample.
- Provides information about the internal quality of the glass by identifying optical imperfections.
- Frequently used to qualify raw material before it undergoes additional manufacturing steps.
- Each of the four requisite measurement files can be saved and loaded independently.
- You can measure repeatedly to establish the uncertainty of the individual measurements before committing to make the final calculation, thereby improving confidence in the result.

Use Conditions

- Applies to laser interferometers; included in Form.appx.
- The measured part must meet the nominal test part specifications below.
- Requires specific hardware- transmission element, reference element, two 2-Axis mounts, and a self centering element holder (or similar to hold the test part).
- To minimize air turbulence, the test cavity should be as short as possible; enclosing the cavity with a sheet of plastic or other material may be helpful.
- Use an Acquisition mask to include the part but exclude the edges.
- Requires a Refractive Index and Part Thickness entry.
- Lateral calibration is required for lateral results other than pixels.

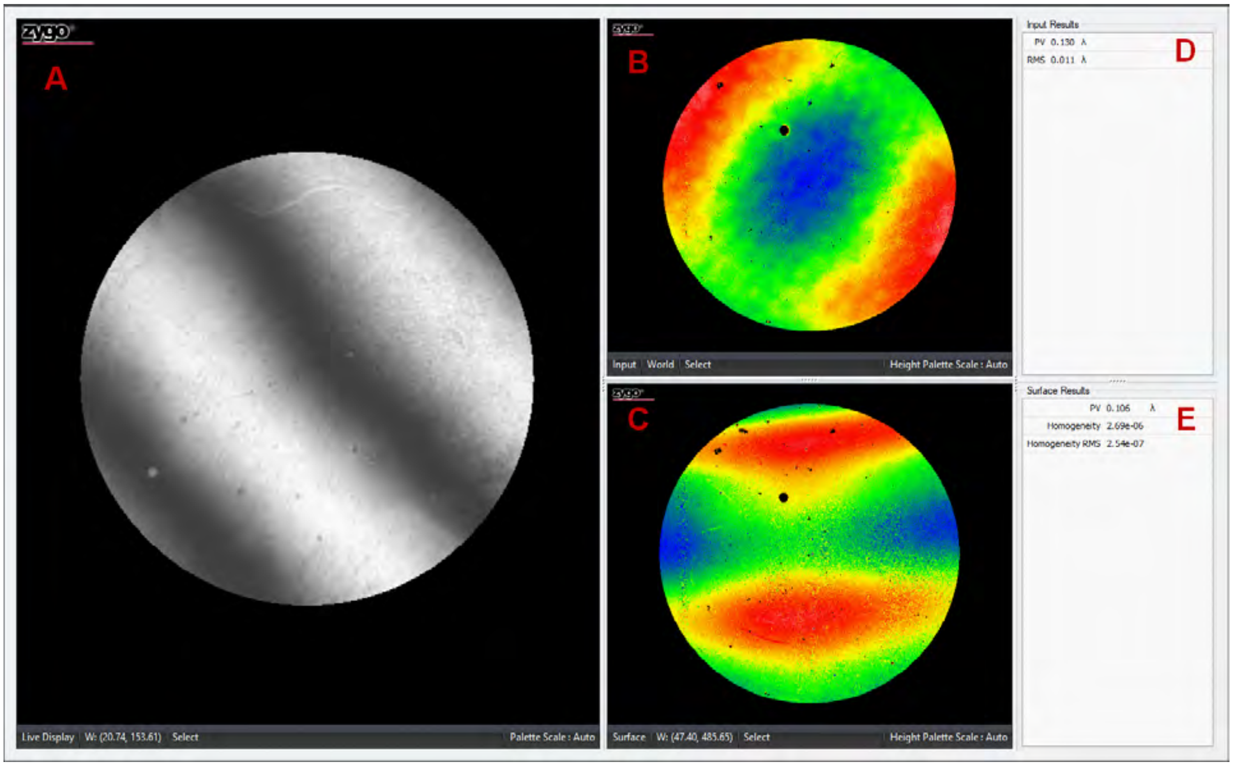
Nominal Test Part Specifications

Quality	**Specification**
Surface Finish	Polished, 1/2 λ PV
Aspect Ratio (thickness to diameter ratio)	Less than or equal to 6:1
Wedge	4 in. part: 5 to 25 arc minutes 6 in. part: 3.5 to 35 arc minutes 12 in. part: 2 to 66 arc minutes 18 in. part: 1 to 85 arc minutes

The Polished Homogeneity Screen

Shown below is the MEASUREMENT tab. For the ANALYSIS tab see Surface.

The Surface plot and results are blank until all measurements are saved and/or loaded and Calculate is clicked.



A. Live Display. **B.** Input plot (displays data as measurements are made or data is loaded). **C.** Surface plot (blank until all 4 measurements are saved and/or loaded and Calculate is clicked). **D.** Input Results. **E.** Surface Results.

See Also

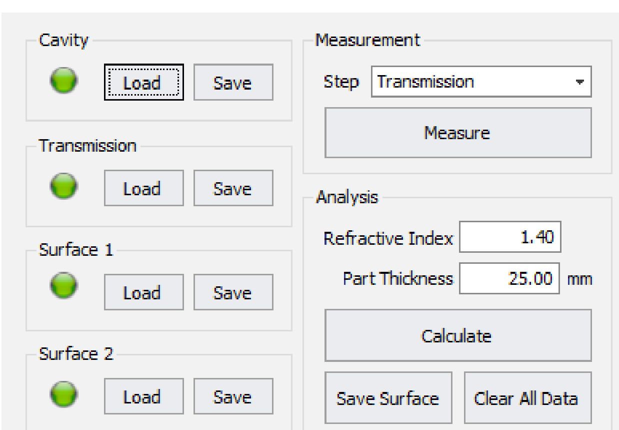
[Polished Homogeneity Controls]

[Measuring Polished Homogeneity]

[Changing Displayed Results]

[Standard Optic Results]

Polished Homogeneity Controls



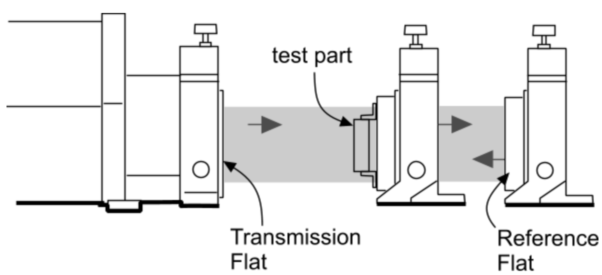
Red/Green State Indicator	Red indicates the corresponding measurement step data is missing. Green indicates the corresponding measurement step data is present.
Load **Save**	Each Load and Save pair corresponds to a particular measurement step. Click Load to load existing data that matches the corresponding step. Click Save to save the current data as a particular step.
Step	Selects the active measurement step. Choices are Transmission, Surface 1, Surface 2, and Cavity.
Measure	Acquire data for the currently selected measurement step.
Refractive Index	Specifies the refractive index of the material being measured. An entry is required so a scale factor for measuring Surface 2 can be determined.
Part Thickness	Specifies the thickness of the optic being measured. An entry is required to calculate Homogeneity.
Calculate	Click to calculate the Surface plot and results based on the loaded or saved measurement step data.
Save Surface	Click to save the combined results of multiple measurements.
Clear All Data	Click to clear all saved or loaded data sets within the tool.

Measuring Polished Homogeneity

1

Measure part in transmission

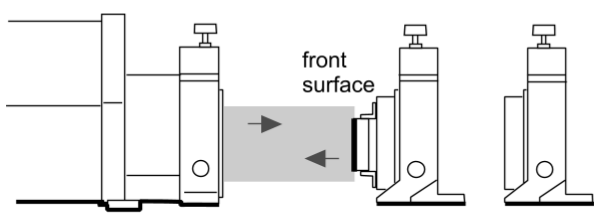
Transmission



2

Measure part front surface

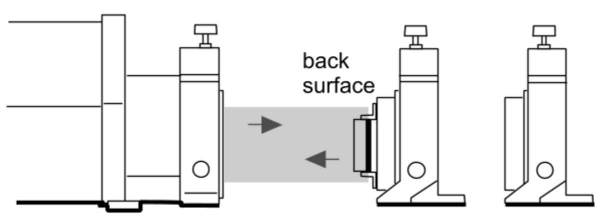
Surface 1



3

Measure part back surface

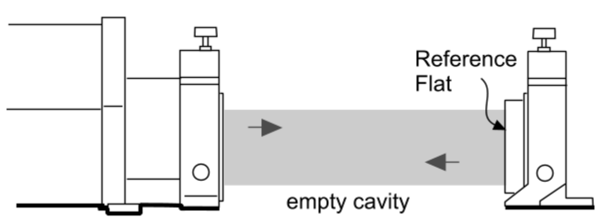
Surface 2



4

Measure empty cavity

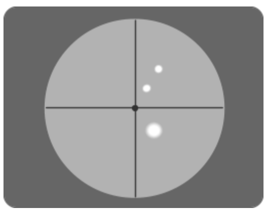
Cavity



For details on using your laser interferometer see the applicable operating manual.

Measurements can be performed in any order and repeated until the best possible data is obtained. To monitor a given measurement setup, add a Control Chart and select the PV result. Repeat a given test setup measurement until the PV result is stable and minimized.

1. Mount the test part and the reference flat. Keep the measurement cavity as short as possible.
2. Set the interferometer zoom setting so the test part fills the Live Display. Remove the test part from the cavity.
3. Align the reference flat to the transmission flat.
4. Return the test part to the cavity. Visually center the part to the output beam of the transmission flat. In the Align mode, adjust the reference flat so there is interference through the test part material. Make sure that the reflections from surface 1 or surface 2 are not aligned either to each other or to the transmission flat. The apertures should be coincident and not vignetted.



Live Display- Align Mode

The brightest dot is from the reference flat. The two smaller dots are reflections from the front and back surfaces of the test part; do not align these 2 smaller dots to the transmission flat.

5. Using the Mask Editor define a circular Acquisition mask to include the part but exclude the edges.
6. (Optional) Use the Lateral Calibrator to establish the lateral resolution of each camera pixel.
7. Enter values for Part Thickness and the Refractive Index of the test part material.
8. Select Transmission in the Step control. Click Measure. Click the corresponding Save button to save the Transmission data.
9. Misalign the reference flat (turn the Tip/Tilt knobs until there are no fringes).
10. Align the front surface of the test part to the transmission flat. Select Surface 1 in the Step control. Click Measure. Click the corresponding Save button to save the Surface 1 data.
11. Align the back surface of the test part to the transmission flat using the Tip/Tilt knobs on the mount. Select Surface 2 in the Step control. Click Measure. Click the corresponding Save button to save the Surface 2 data.
12. Remove the test part from the cavity. Realign the reference flat. Select Cavity in the Step control. Click Measure. Click the corresponding Save button to save the Cavity data.
13. Click Calculate. To save the combined results click Save Surface.

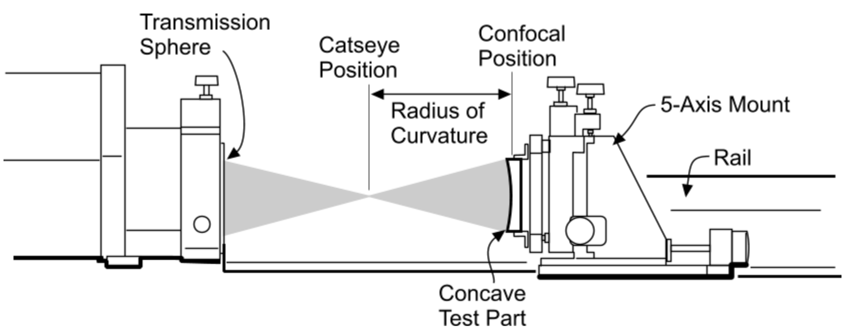
Radius Scale

Navigator : Measurement : Radius Scale

To activate, select Radius Scale in Measurement Type in the Measurement Setup tool or toolbar.

Measurement Features

- Radius of curvature is defined as the distance from the surface (or the best-fit spherical equivalent) to the center of curvature.
- Measure the radius of curvature of concave or convex spherical surfaces.
- Two phase measurements are made, one at catseye where the interferometer beam converges at a point, and the second at confocal where the center of curvature is coincident with the convergence point of the interferometer beam.
- The part radius is determined using the confocal and catseye measurements and the z-axis distance traveled between them.
- Null and focus errors are removed from the results using the data acquired with the catseye and confocal measurements.



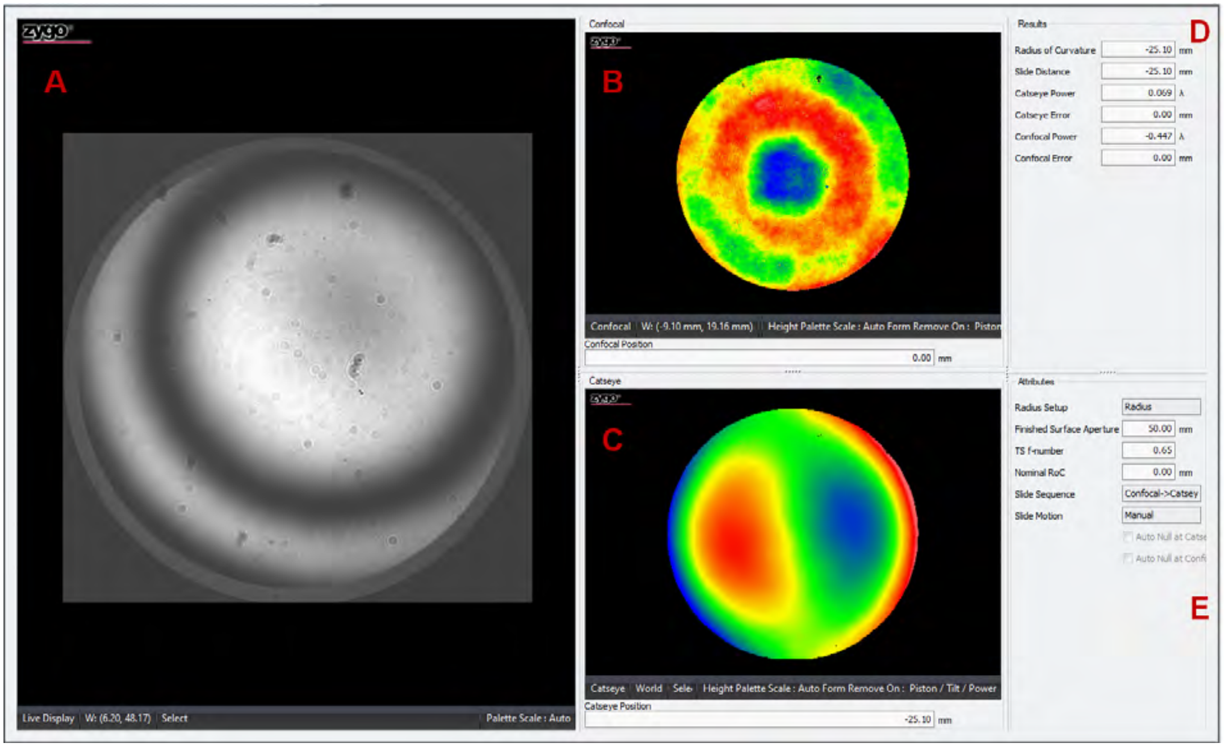
Use Conditions

- Applies to laser interferometers; included in Form.appx.
- Requires specific hardware- transmission sphere, encoded or interferometric 5-axis mount and rail (or short radius kit), and a self centering element holder (optional).
- Ensure that the transmission sphere has proper coverage of the test optic.
- Requires a Part Diameter and TS f-number entry, these are used to calculate and overwrite the lateral calibration.
- Use an Acquisition mask to include the part but exclude the edges.
- Lateral calibration is required for lateral results other than pixels.

The Radius Scale Screen

Shown below is the MEASUREMENT tab. For the ANALYSIS tab see Surface.

The loading of existing data for radius scale is not applicable, as a live instrument is required to obtain the z-axis position feedback.



A. Live Display **B.** Confocal plot (displays data when confocal measurement is made). **C.** Catseye plot (displays data when catseye measurement is made). **D**. Attributes show the setting of the controls when the measurement was made. **E.** Radius scale results (displayed after both measurements are made).

See Also

Measuring Radius

Minimizing Radius Error

Standard Optic Results

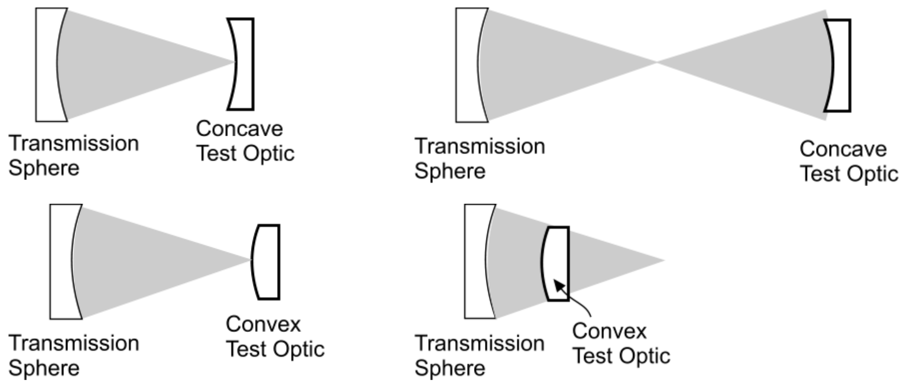
Radius Scale Setup

This shows the typical setup when measuring radius of curvature for convex and concave test parts. Convex radius of curvature results are positive. Concave radius of curvature results are negative.

Test Part **Catseye Position** **Confocal Position**

Concave (-)

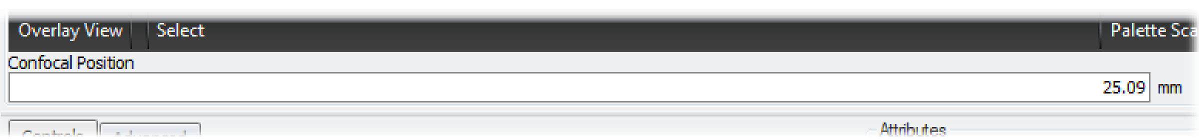
Convex (+)



To check for proper sign convention, the feedback is positive as the part is moved away from the transmission sphere, and negative when the part is moved toward the transmission sphere.

Radius Scale Position Feedback

Confocal Position and Catseye Position

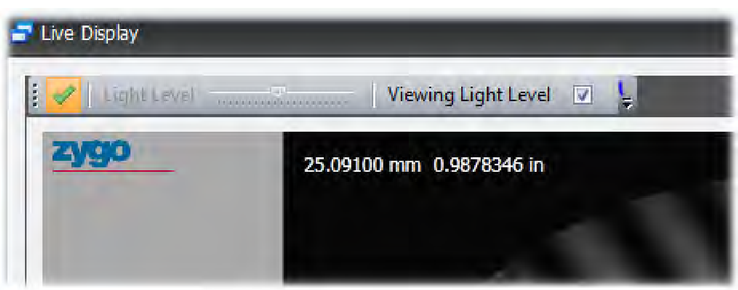


These fields display a numeric value for the corresponding location or are blank. Whenever a measurement is performed, one or both of these position fields are automatically updated with the respective z-axis positions (which are relative to the z-home position).

Confocal Position Displays the position read from the z-axis feedback device when the confocal data was acquired.

Catseye Position Displays the position read from the z-axis feedback device when the catseye data was acquired.

Live Display Readout



The Live Display shows the z-axis distance traveled from the first measurement to the second measurement.

Radius Scale Controls

Radius Setup
Selects what you want to measure. Choices are Catseye, Confocal, or Radius (which is both confocal and catseye).

Distance Readout
Click to toggle on/off a position tracking feature. When the readout is on, the distance traveled in millimeters and inches is displayed in the Live Display and in a Slide Distance readout in the Radius Scale window. See Radius Scale Position Feedback.

Test Diameter
Specifies the diameter of the part when measured at the confocal position. If an Acquisition mask is used, enter the diameter of the mask. A required entry.

Radius of Curvature
Specifies the nominal radius of curvature (RoC) of the part being measured. Enter concave radii starting with a – (minus) sign; enter convex radii starting with a + (plus) sign.

Transmission Sphere f-number
Specifies the f-number of the transmission sphere used in the radius measurement. A required entry. This entry is critical for obtaining precise radius measurements.
The correct f-number entry is defined by the Radius of Curvature ÷ Beam Diameter at the reference surface of the transmission sphere. TS f-number, as defined here, is printed on the ZYGO transmission sphere cell.

Slide Sequence
Selects the desired measurement order for both manual and automated radius of curvature measurements. Choices are Confocal->Catseye or Catseye->Confocal.

Slide Motion
Selects how the motorized z-axis mount is controlled when moving from catseye to confocal position. Choices are Auto, Manual, or Semi-Auto.

When Auto, the software drives to the initial position (as selected with the Slide Sequence control) and automatically drives the mount to the second position based on the value entered in the Nominal RoC. It also automatically selects the setting of the Slide Sequence control.

When Manual, the operator drives or moves the mount from catseye to confocal when prompted by the software.

When Semi-Auto, the software automatically drives to the initial position (as selected with the Slide Sequence control); the operator must fine-tune the z-axis position; it also automatically drives to the second position when prompted.

Auto Null At Catseye
When selected, the part is automatically nulled at the catseye position based on the settings of the Auto Null controls (in Measurement Setup) using the catseye calibration factors. Note that the tilt component of the Auto Null Mode control is ignored.

When cleared, the auto null function is not performed at the catseye position.

Auto Null At Confocal When selected, the part is automatically nulled at the confocal position based on the settings of the Auto Null controls (in Measurement Setup) using the standard calibration factors.

When cleared, the auto null function is not performed at the confocal position.

More → Expands view to reveal advanced controls. See Advanced Radius Scale Controls.

Advanced Radius Scale Controls

These controls display when the radius scale controls are fully expanded.

Output Data Selects what data is passed onto the analysis flow. This determines what is viewed as input data in Data Processing as well as other analyses. Choices are: None, Confocal, or Catseye.

Catseye Position Displays a numeric value for the catseye location or is blank.

Whenever a measurement is performed, one or both of these controls (Catseye Position and Confocal Position) are automatically updated with the current DMI position.

When performing a measurement with Slide Motion set to Auto, if both controls contain numeric values, they are compared with the current Z position in order to select the optimal slide sequence. The closest location is used for the starting position.

If either control is blank, then a dialog is displayed. The dialog prompts the operator to adjust the z-axis to a starting position and to choose the slide sequence.

Whenever Nominal RoC is changed or the DMI is reset, both Confocal Position and Catseye Position are reset to blank.

See Radius Scale Position Feedback.

Confocal Position Displays a numeric value for the confocal location or is blank. See Catseye Position for more details.

Move to Catseye Click to move the z-axis mount and part to the location indicated in Catseye Position.

Move to Confocal Click to move the z-axis mount and part to the location indicated in Confocal Position.

Measuring Radius

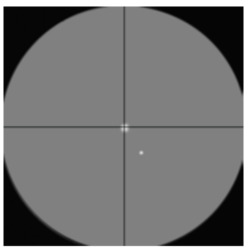
These are the basic steps for making radius of curvature measurements. Depending upon the option you are using, there might be different hardware or software instructions. For example, auto null controls are used only with systems equipped with motorized x, y, and z-axes.

For details on using your laser interferometer see the applicable operating manual.

For interferometric feedback, be careful not to break the measurement beam of the feedback device. If you do, an error message will be displayed and you will have to start over.

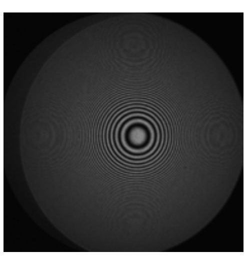
When measuring radius of curvature it is necessary to align the part and transmission sphere so that during measurement no adjustment other than motion in the z axis is required to null the fringe pattern at both the catseye and confocal positions.

1. Select a transmission sphere that fills as much of the test part as possible. Mount the transmission sphere in the interferometer's accessory receptacle.
2. Align the Transmission Sphere to the interferometer. Switch interferometer to Align mode and adjust the accessory receptacle Tip/Tilt to bring the brightest dot into the center of the cross hairs.

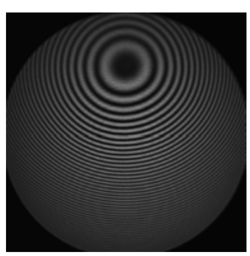


Brightest spot centered

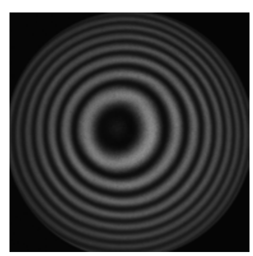
3. Enter the TS f–number and Part Diameter parameters.
4. Select the Radius Setup and Sequence parameters.
5. Mount the test part and switch interferometer to View mode.
6. To adjust the catseye position:
   a. Position the part at the catseye position. Adjust the part in z to fill the aperture as much as possible.
   b. Adjust the part Tip/Tilt to eliminate any vignetting.
   c. Make a one–time Tip/Tilt adjustment of the transmission sphere to center the circular fringe pattern.
   d. Finely adjust the part in z to reduce the number of fringes as much as possible.
   e. Make final part and transmission sphere Tip/Tilt fine-adjustments to null the cavity to the characteristic catseye "Yin/Yang" fringe pattern.



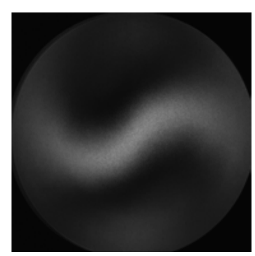
Fringes vignetted



Fringes off-center

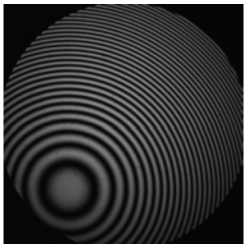


Fringes centered

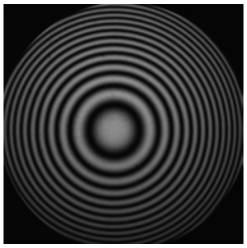


Fringes nulled

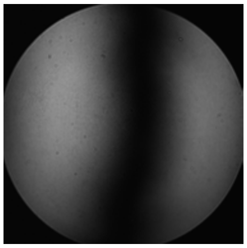
7. To adjust the confocal position:
   a. Move the part to the confocal position.
   b. Adjust the part in x and y to center the circular fringe pattern.
   c. Finely adjust the part in z to null the fringes.



Fringes off-center



Fringes centered



Fringes nulled

For systems with manual part stages and an encoded digital readout, see "Minimizing Radius Error".

8. When still at the confocal position, place a piece of paper in the field of view close to the surface of the test part. Adjust the interferometer focus so the edges of the paper, as viewed in the Live Display, are as sharp as possible. Remove the paper.
9. If necessary, adjust the interferometer zoom until the entire round aperture is visible in the Live Display.
10. Move the part back to the catseye position. Finely adjust the part in z to null the cavity to the characteristic catseye "Yin/Yang" fringe pattern.
11. Repeat steps 6 and 7 as necessary to ensure that no adjustment other than motion in the z axis is required to null the fringe pattern at both the catseye and confocal positions.
12. Click Measure. The software prompts you to position the part at the starting position (confocal or catseye, depending on the Slide Sequence setting).
13. Null the fringe pattern at the first location. Click OK or press Enter to continue. A measurement is made and displayed.
14. After the first measurement is finished, the software prompts you to move the part to the second location (either catseye or confocal depending upon the setting of the Slide Sequence control) and null the fringe pattern.
15. After nulling the fringe pattern, click OK or press Enter for the second measurement.

Minimizing Radius Error

The best radius of curvature results are achieved when power is minimized. For most users, nulling fringes at the catseye and confocal positions is sufficient. Some systems provide automatic correction, while other systems require operator fine-tuning to minimize error.

Minimizing Error for Systems with Manual Part Stage

Applies to systems with manual part stages and encoded feedback. For example- the short radius kit, or a horizontal rail with a manual 5-axis rail mount and either a digital display or interferometric feedback.

- Null the catseye fringe pattern as usual.
- Instead of nulling the confocal fringe pattern, display approximately 3-10 tilt fringes and adjust the part in z until the fringes are as straight as possible. The z adjustment determines straightness, while the x and y adjustments affect the number and direction of the fringes. For radii smaller than 5 millimeters it is recommended to set the z position (i.e. power) with at most 3-5 fringes.

Minimizing Error for Systems with Motorized Part Stage

Applies to systems with motorized programmable x, y, and z axes. For example- a horizontal rail with a motorized 5-axis rail mount and interferometric feedback.

- Correction occurs automatically; based on the measured power at catseye and confocal positions.
- Depends on accurate user-entered TS f-number and lateral calibration.

Using Auto Null

This is a basic procedure for setting up and using the auto null function for a radius of curvature measurement. Requires a mount with motorized x, y, and z axes.

1. Perform standard interferometer setup.

   Install TS in accessory receptacle (AR) and align.
   Install part into mount.

2. Click Home All Axes (Radius Scale - DMI tab).

   This is useful if stages are in an unknown state or if the dmi beam was inadvertently blocked or broken.

3. Enter part information and other options (Radius Scale - Controls tab).

   Part Diameter
   TS f-number
   Nominal RoC
   Slide Sequence: (select to match setup)
   Slide Motion: Auto

4. Open Measurement Setup. Go to Acquisition Options – Advanced tab.
5. Iterations should be set to 10.

   Selecting the Auto Null check box is only needed if you want to auto null as part of a non-radius measurement. Radius measurements auto select the check box based on which position is being measured and if the Auto Null At Catseye and Auto Null At Confocal check boxes are selected.

6. Enter values for X, Y, and Z under the Step tab. These are the distances moved between auto null iterations for each axis.

   The goal is to use values that allow the auto null routine to find null within a couple seconds. If values are too small the routine takes longer; if values are too large the routine may fail. Recommended starting step value for Z = 8 x λ x $(TS\ f/n)^2$

7. Move to confocal and null part using mount.
8. Move to catseye and null cavity using accessory receptacle.
9. Click Catseye Calibrate.
10. In the Auto Null Catseye Calibrate dialog select the desired parameters to calibrate and click Ok.

    When the catseye calibrate sequence is complete values are automatically entered into the Catseye Focus and Catseye Power controls (Factors tab).

11. Move back to confocal and re-null cavity using mount.
12. Click Calibrate to determine factors for Tilt X, Tilt Y, Focus, and Power. A "factor" represents how much stage movement causes one wave of change.

13. In the Auto Null Calibrate dialog select the desired axes to calibrate and click Ok.

    Note that it may be easier to calibrate axes one or two at time. When the calibrate sequence is complete values are automatically entered into the Tilt X, Tilt Y, Focus, and Power controls (Factors tab).

14. Select the Auto Null At Catseye and/or Auto Null At Confocal check boxes (Radius Scale – Controls tab) to do auto null as part of a radius measurement.

    Select the Auto Null check box (Measurement Setup – Acquisition Options) to do auto null as part of a non-radius measurement. If measuring at the catseye position, also select the Use Catseye Calibration check box.

15. Click Measure.

Ritchey-Common

Navigator : Measurement : Ritchey-Common

To activate, select Ritchey-Common in Measurement Type in the Measurement Setup tool or toolbar.

Measurement Features

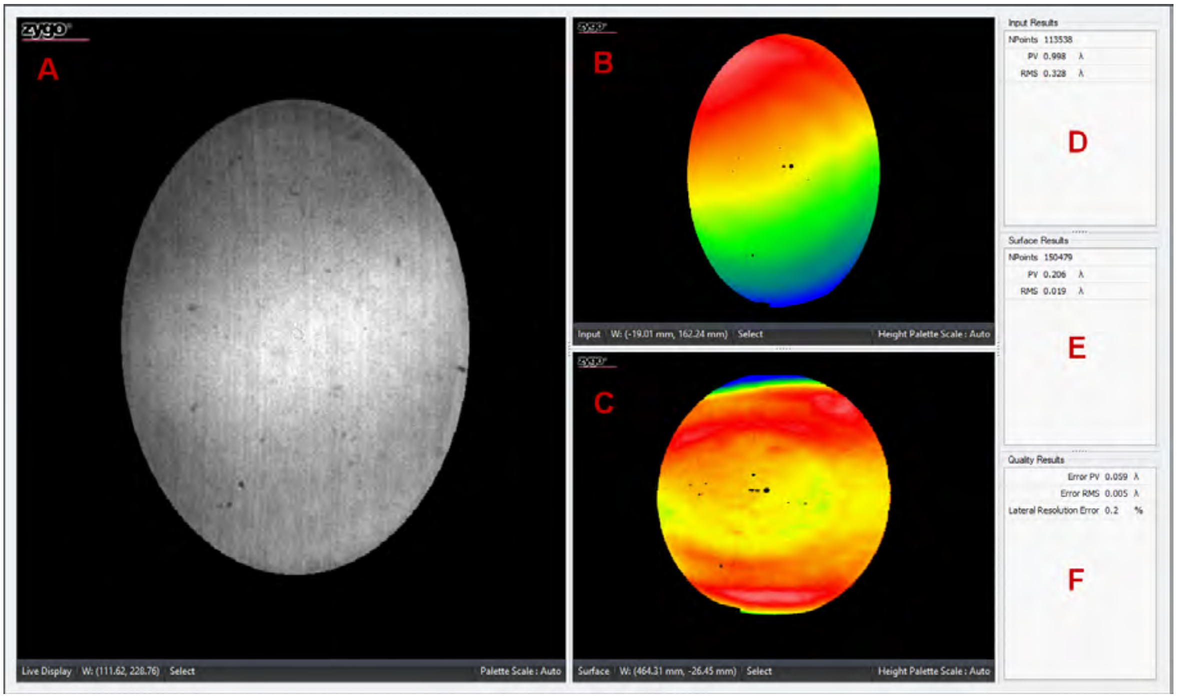
- Use to measure the surface quality of large flat optics.
- Does not require a large aperture interferometer or large transmission flat, and it provides an absolute measurement of the flat under test.
- The flat under test is used as a mirror between a transmission sphere and a large reference sphere.
- Uses three measurements: Ritchey Sphere, Ritchey Angle 1, and Ritchey Angle 2.
- The transmission sphere should be measured beforehand using the Two Sphere measurement; this is used as the system reference file. If a ZYGO UltraSphere is used, it includes the necessary calibration file and Two Sphere test can be skipped.

Use Conditions

- Ritchey-Common requires licensing to function. Refer to Licensing.
- Applies to laser interferometers; included in Form.appx.
- Use of fiducials is recommended. Refer to Fiducial Editor.
- Requires user-supplied custom fixturing. See Ritchey-Common Guidelines.

The Ritchey-Common Screen

Shown below is the MEASUREMENT tab. For the ANALYSIS tab see Surface.



A. Live Display. **B.** Current measurement surface plot. **C.** Combined measurement surface plot. **D.** Input Results. **E.** Surface Results. **F.** Quality Results.

See Also

Ritchey-Common Measurements

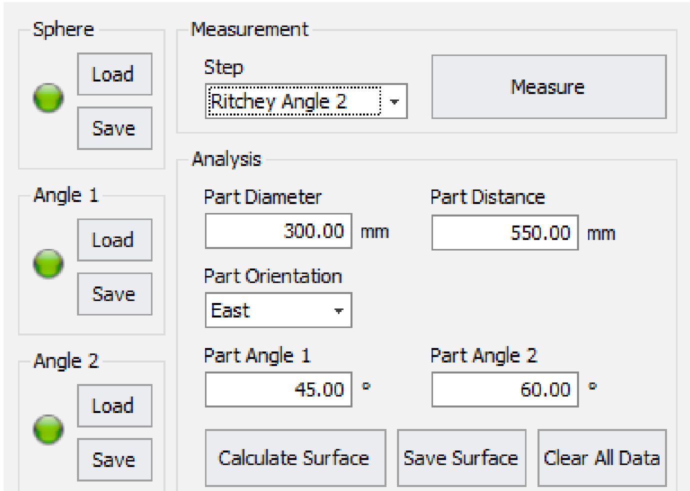
Measuring with Ritchey-Common

Standard Optic Results

Ritchey-Common Results

Changing Displayed Results

Ritchey-Common Controls



Key: Sphere, Angle 1, and Angle 2 refer to the three measurements.

State Indicator Red indicates the corresponding measurement step data is missing.

Green indicates the corresponding measurement step data is present.

Load Each Load and Save pair corresponds to a particular measurement step.

Save Click Load to load existing data that matches the corresponding step. Click Save to save the current data as a particular step.

Step Selects the active measurement step. Choices are Ritchey Sphere, Ritchey Angle 1, or Ritchey Angle 2.

Make sure the test part and the Ritchey Sphere are positioned in the matching physical setup before you measure.

Part Diameter Specifies the diameter of the flat under test.

Part Distance Specifies the distance between the transmission sphere focus and the center point 'C' on the test flat.

Part Angle 1 Specifies the angle that the part makes with the optical axis of the reference sphere for the Ritchey Angle 1 measurement.

52 degrees (Part Angle 1) and 38 degrees (Part Angle 2) are recommended, but any pair of angles can be used.

Part Angle 2 Specifies the angle that the part makes with the optical axis of the reference sphere for the Ritchey Angle 2 measurement.

Part Orientation Selects the orientation of the edge of the test flat that is located farthest away from the interferometer. Select this position exactly as it appears on the Live Display.

North- the part edge appears on top.
South- the part edge appears on bottom.
East- the part edge appears on right side.
West- the part edge appears on left side.

Calculate Surface Click to calculate the Surface plot and results based on the loaded or saved measurement step data.

Save Surface	Click to save the combined results as a single surface.
Clear All Data	Click to clear all saved or loaded data sets within the tool.

Ritchey-Common Guidelines

- *Measurement Sequence* - A Two Sphere test is first performed on the Transmission Sphere. The Ritchey-Common test requires three separate measurements. Measurements can be completed in any sequence, although it is recommended to perform them in this order: Ritchey Sphere, Ritchey Angle 1, and Ritchey Angle 2. This order will catch any setup or transmission sphere choice errors early.
- *Two Sphere Test Hardware Requirements* - The following items are required: For the Two Sphere Test, one Transmission Sphere (f/3.3 or higher recommended), a 5-Axis Mount, and a Self Centering Element Holder.
- *Two Sphere Test Constraints* - choose a second sphere, which is under filled by the interferometer beam in the confocal position. This will ensure complete measurement of the transmission sphere.
- *Richey-Common Hardware Requirements* - A Ritchey Sphere, and adequate fixturing to achieve the following test requirements (refer to Ritchey-Common Measurements):

  The center point “C” of the test part must be accurately positioned on the optical axis of the interferometer.

  The “C” coordinate of test part must remain in the same position between Angle 1 and Angle 2 rotations. A special user-supplied fixture to guarantee the rotation about this point is highly recommended.

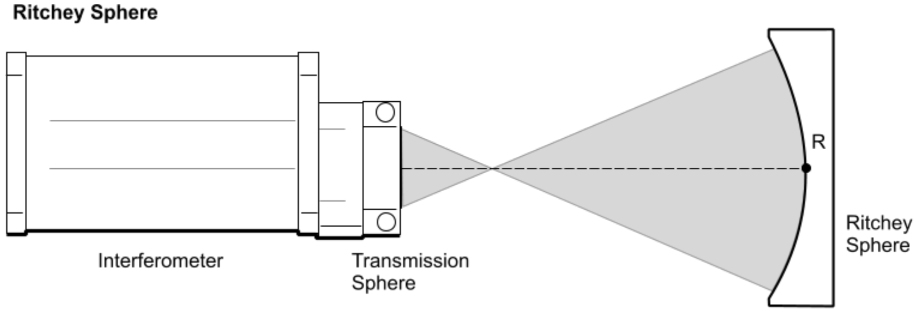
  The ray along the optical axis of the interferometer must hit the same point “R” on the Ritchey Common Sphere for all three Ritchey-Common setups. Special user-supplied fixturing is highly recommended.
- *Ritchey-Common Constraints* - the test flat must be fully filled by the interferometer beam, and the Ritchey Sphere should be under filled. The edges of the test flat must be visible in the camera image.
- *Interferometer Zoom Setting* - Do not adjust zoom from that used in the Two Sphere test.
- *Use a Fiducial* - The application requires the use of one fiducial.

Ritchey-Common Measurements

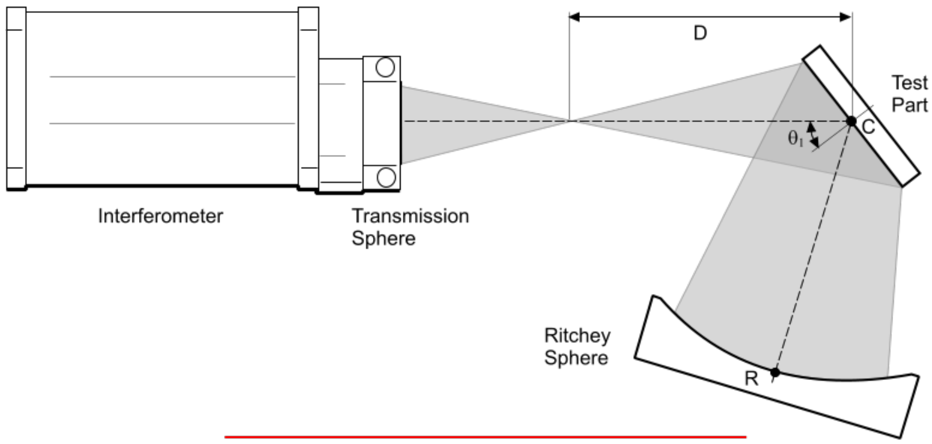
A transmission sphere is used to focus and then expand the interferometer beam until it hits the flat under test, tilted at a predetermined angle. After reflecting off of the flat under test, the beam continues to expand until hitting a reference sphere to form the interferometric cavity.

Three measurements are performed: Ritchey Sphere, Ritchey Angle 1, and Ritchey Angle 2 as shown below. These results are combined with a Two Sphere test of the transmission sphere to provide final flat data. Using this method, flat optics larger than the output aperture can be measured with absolute accuracies better than $\lambda/50$.

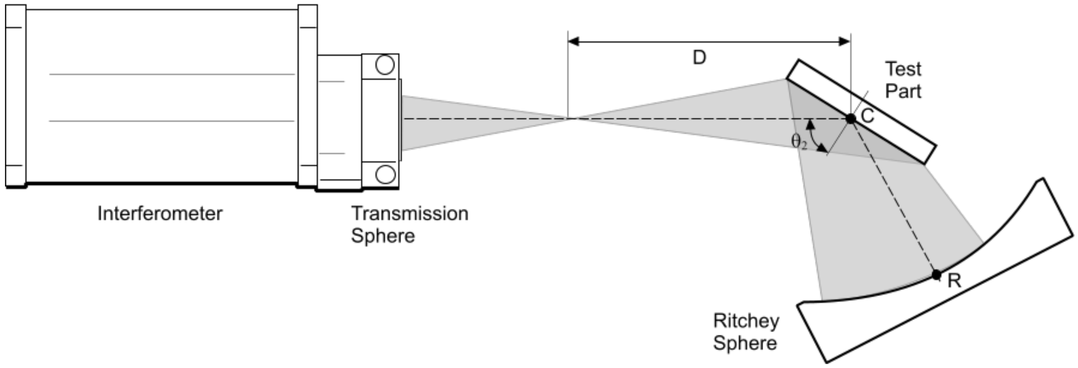
Ritchey Sphere



Ritchey Angle 1



Ritchey Angle 2



Key:
R = Ritchey-Common reference point (fiducial)
C = Center of test flat
D = Part distance from Transmission Sphere focus
θ_1 = Ritchey Angle 1
θ_2 = Ritchey Angle 2

Measuring with Ritchey-Common

For details on using your laser interferometer see the applicable operating manual.

Part 1 - Measure the Transmission Sphere (Two Sphere Test)

If a ZYGO UltraSphere is used, it includes a calibration file and eliminates this need for this measurement.

1. Select Measurement Type: Two Sphere.
2. Install the transmission sphere into the interferometer accessory receptacle and align the sphere.
3. Align a second sphere as a return sphere in the confocal position. This does not have to be the Ritchey Sphere. The only requirement is that the R/# of the return sphere is less than the f/# of the Transmission Sphere used.

   The f-number (f/#) of the transmission sphere is marked on the front ring of every TS. Matching the above criteria will ensure that the full aperture of the Transmission Sphere is being measured.
4. Set Surface control to TS. Perform an absolute measurement of the transmission sphere using the two sphere test. See Two Sphere for more details.
5. Save the Transmission Sphere surface data as a recognizable name, such as “RitcheySysRef.datx”.

Part 2 - Perform the Ritchey-Common Measurements

Do not change these settings from the Two Sphere Test (part 1): interferometer zoom and alignment of the transmission sphere.

Any individual measurement can be repeated as many times as needed and test flat results recalculated by clicking Calculate. Previously stored data sets can also be loaded in place of a measurement.

Measurements can be performed in any order and repeated until the best possible data is obtained. To monitor a given measurement setup, add a Control Chart and select the PV result. Repeat a given test setup measurement until the PV result is stable and minimized.

1. Select Measurement Type: Ritchey-Common.
2. Mount and align the Transmission (Ritchey) Sphere to the interferometer. Switch to Align mode and adjust the accessory receptacle Tip/Tilt to bring the brightest dot into the center of the crosshairs. Switch to View mode.
3. Open Data Processing tools. Select the Subtract On check box. Enter the file name after System Reference File. This must be the same file created from the Two Sphere test (or the calibration file provided with the sphere).
4. Select Ritchey Sphere with the Step control. Click Measure. If the measurement is successful, the Sphere state indicator turns green. (Optional) Click Save to save the corresponding results as a data set.
5. Mount the test flat at the desired value of Ritchey Angle 1.

6. Place three markers (or small stickers) along the edge of the test part; these will serve as an alignment aid when using fiducials. A recommended placement is 12, 3, and 8 o'clock.
7. Using the Fiducial Editor, define a set of fiducials over the three markers.
8. Enter control values. After Part Angle 1, enter the value of Angle 1. After Part Distance, enter the distance from TS focus to center point ‘C’. After Part Diameter, enter the diameter of the test flat.
9. Position the Ritchey Sphere at its new confocal position. Adjust the Ritchey Sphere to null the fringes.
10. Determine the orientation of the test flat by locating the edge of the flat that is farthest from the interferometer. Insert a small object in front of this edge and note which side of the Live Display image it appears. If it appears on the right side of the image, the orientation is East; if it appears on the top edge of the monitor image, the orientation is North, etc.
11. Set the Part Orientation control to match the orientation of the setup determined in the previous step.
12. Select Ritchey Angle 1 with the Step control. Click Measure. If the measurement is successful, the Angle 1 state indicator turns green. (Optional) Click Save to save the corresponding results as a data set.
13. Rotate the test flat about center point ‘C’ to the desired value of Ritchey Angle 2.
14. After Part Angle 2, enter the value of Angle 2. This is the only control that should be changed between angle measurements.
15. Position the Ritchey Sphere at its new confocal position. Adjust the Ritchey Sphere to null the fringes.
16. Select Ritchey Angle 2 with the Step control. Click Measure. If the measurement is successful, the Angle 2 state indicator turns green. (Optional) Click Save to save the corresponding results as a data set.
17. Click Calculate. To save the results click Save Surface.
18. Go to the Surface or Home screen to perform additional data processing.

Three Flat

Navigator : Measurement : Three Flat

To activate, select Three Flat in Measurement Type in the Measurement Setup tool or toolbar.

Measurement Features

- Measure the absolute departure of flat plano optics with uncertainty less than 1/100 of a wavelength.
- Results are provided along two diameters on any one or all three of the flats used for the test.
- Three series of measurements provide absolute test results over a vertical diameter; four measurements provide absolute test results also over the horizontal diameter.
- Each of the four requisite measurement files can be saved and loaded independently.
- You can measure repeatedly to establish the uncertainty of the individual measurements before committing to make the final calculation, thereby improving confidence in the result.

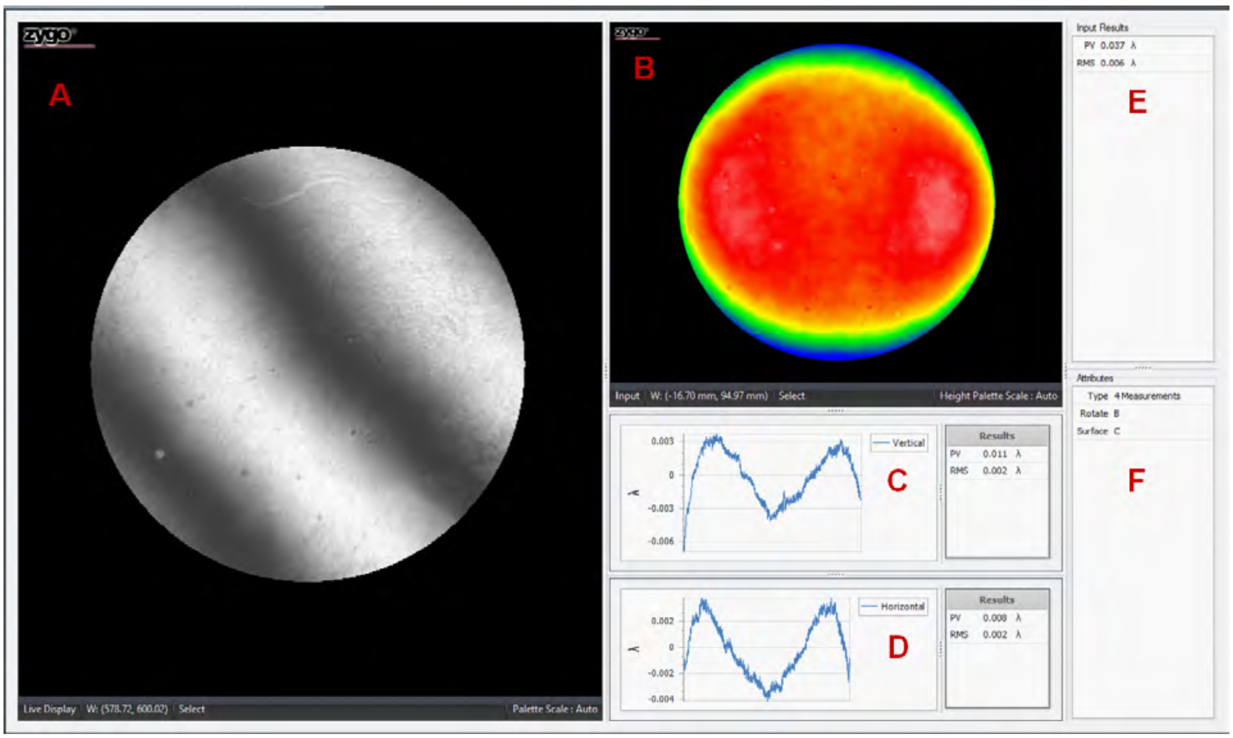
Use Conditions

- Applies to laser interferometers; included in Form.appx.
- Requires specific hardware- two transmission flats, 2-axis mount, and a self centering element holder (optional).
- For large aperture systems, 12 inches and above, only vertical data is obtainable because the large flat mount does not allow rotation.
- Use of fiducials is required.
- Use an Acquisition mask to include the part but exclude the edges.
- Lateral calibration is required for lateral results other than pixels.

The Three Flat Screen

Shown below is the MEASUREMENT tab. For the ANALYSIS tab see Surface.

The vertical and horizontal plots and results are blank until all measurements are saved and/or loaded and Calculate is clicked.



A. Live Display. **B.** Input plot (displays the current measurement). **C.** Vertical plot and results (coincident data over a vertical diameter). **D.** Horizontal plot and results (coincident data over a horizontal diameter). **E.** Input Results. **F.** Attributes.

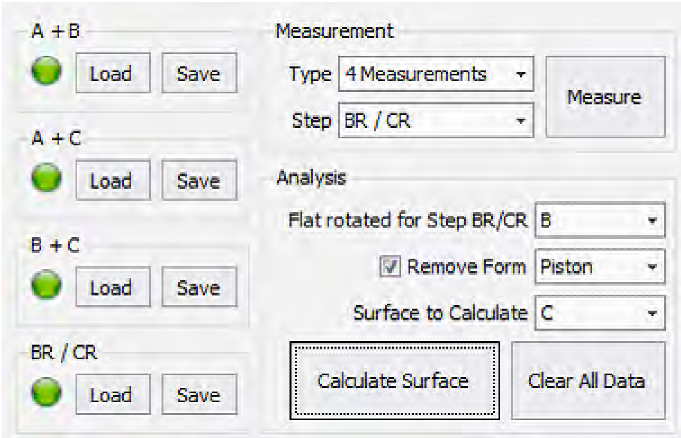
See Also

Measuring Three Flats

Changing Displayed Results

Standard Optic Results

Three Flat Controls



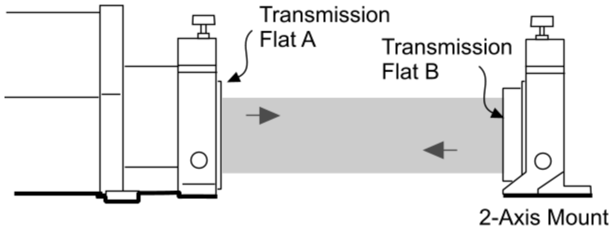
Key: flats A and B are standard transmission flats, flat C is the plano test part.

State Indicator	Red indicates the corresponding measurement step data is missing. Green indicates the corresponding measurement step data is present.
Load	Each Load and Save pair corresponds to a particular measurement step.
Save	Click Load to load existing data that matches the corresponding step. Click Save to save the current data as a particular step.
Type	Selects the measurement type. Options are 3 Measurements (skips the BR / CR measurement) or 4 Measurements. Three measurements provide a vertical profile; a fourth measurement also provides a horizontal profile.
Step	Selects the active measurement step. Choices are A + B, A + C, B + C, and BR / CR (flat B or test flat C rotated).
Measure	Acquire data for the currently selected measurement step.
Flat rotated for Step BR/CR	Selects the flat you plan to rotate 180 degrees for the BR / CR measurement. Options are B or C; these refer to the flats used in the test. You must physically rotate the flat. A bayonet mounted transmission flat (B) is easily rotated; to rotate a test flat (C), an indexing device is needed.
Surface to Calculate	Selects what flat results to calculate and display in the 1D plots. Options are A, B, or C. After a measurement series is complete, the setting can be changed and results for a different surface displayed by clicking the Calculate button.
Calculate Surface	Click to calculate the Surface plot and results based on the loaded or saved measurement step data.
Clear All Data	Click to clear all saved or loaded data sets within the tool.

Measuring Three Flats

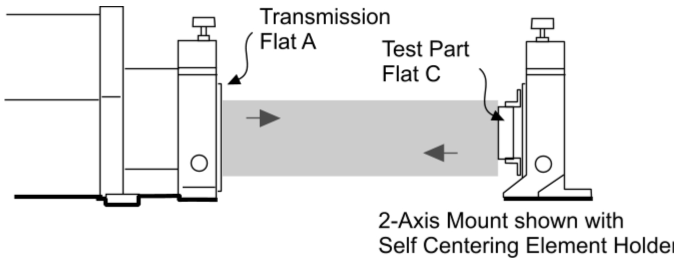
1

Measure with flats **A + B**



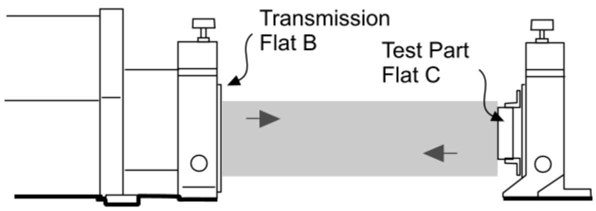
2

Measure with flats **A + C**



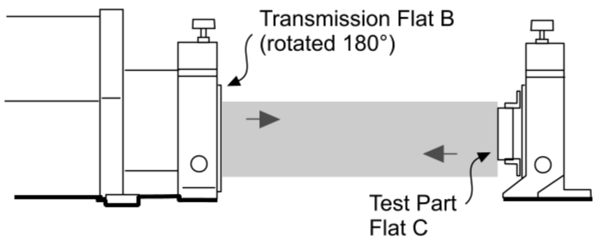
3

Measure with flats **B + C**



4

Measure with flats **BR / CR**
(flat B or C rotated)

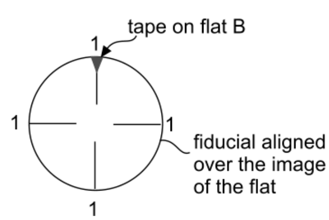


For details on using your laser interferometer see the applicable operating manual.

Label flats A and B so they are not confused with each other and so the rotation of flat B can be easily noted.

Measurements can be performed in any order and repeated until the best possible data is obtained. To monitor a given measurement setup, add a Control Chart and select the PV result. Repeat a given test setup measurement until the PV result is stable and minimized.

1. Install and align the transmission flat B to the interferometer.
2. Set the interferometer zoom setting so the test part fills the Live Display.
3. Using the Mask Editor define a circular Acquisition mask to include the part but exclude the edges.
4. Define a fiducial over the flat as an alignment aid. The fiducial should be centered within one pixel of the image.
5. Place a small triangular piece of tape on Flat (B) aligned with the fiducial mark. Use the image shown on the Live Display as your guide.
6. Use the Lateral Calibrator to establish the lateral resolution of each camera pixel.



7. Install transmission flat (A) into the interferometer accessory receptacle and align the flat. Adjust the Tip/Tilt knobs on the accessory receptacle until the brightest spot is superimposed on the alignment crosshairs.
8. Place transmission flat (B) into the 2-axis mount. Position the mount a short distance from the instrument. Align the flat by adjusting the Tip/Tilt knobs on the 2-axis mount until the brightest spot is superimposed on the alignment crosshairs.
9. Switch the interferometer to View mode. The triangular tape on flat (B) should be aligned with the fiducial marks. Alignment is complete when you have a full aperture image and the flat (B) tape aligns to the fiducial.
10. It is important to keep registration. It is recommended that you attach some type of registration blocks to the vibration isolation table after the system is aligned. A block against the 2-axis mount provides a hard stop to assist with positioning the mount after flats are switched.
11. Select A + B in the Step control. Remove the tape from Flat B. Click Measure. Click the corresponding Save button to save the data.
12. Remove flat (B) from the 2-axis mount and install test flat (C). Align and null flat (C). Select A + C in the Step control. Click Measure. Click the corresponding Save button to save the data.
13. Remove flat (A) and install flat (B) in the interferometer accessory receptacle. Align flat (B) and align and null flat (C). Select B + C in the Step control. Click Measure. Click the corresponding Save button to save the data.
14. Remove flat (B) from the interferometer, rotate it 180 degrees, and reinstall it. Align flat (B) and align and null flat (C). Select BR / CR in the Step control. Click Measure. Click the corresponding Save button to save the data.
15. Click Calculate.

Vertical and Horizontal Plots

- The Surface setting determines which flat is displayed.
- These profiles are the locations on the test part for which systematic errors in the reference surfaces have been compensated.
- The Vertical plot shows absolute test results over a vertical diameter.
- The Horizontal plot shows absolute test results over a horizontal diameter.
- The following equations are used to derive the absolute surface data along the diameters:

  Flat A = [(A+B) + (A+C) - (B+C)] /2

  Flat B = [(A+B) + (B+C) - (A+C)] /2

  Flat C = [(A+C) + (B+C) - (A+B)] /2

Two Sphere

Navigator : Measurement : Two Sphere

To activate, select Two Sphere in Measurement Type in the Measurement Setup tool or toolbar.

Measurement Features

- Evaluate the surface quality of concave or convex test optics and/or the interferometer's transmission sphere.
- Measure spherical optics with absolute accuracies better than 1/40 of a wavelength.
- Typically used to create a system reference subtract file for the transmission sphere.
- Each of the five requisite measurement files can be saved and loaded independently.
- You can measure repeatedly to establish the uncertainty of the individual measurements before committing to make the final calculation, thereby improving confidence in the result.

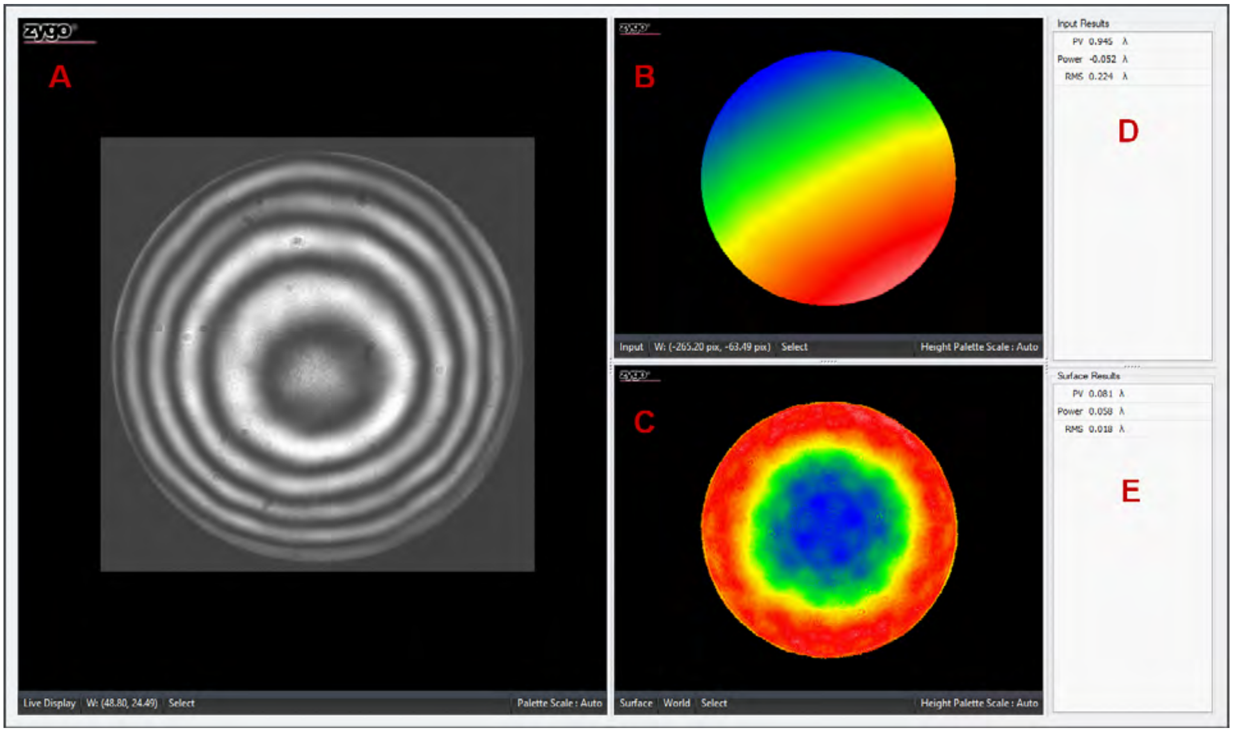
Use Conditions

- Applies to laser interferometers; included in Form.appx.
- This is an advanced metrology function; it requires an understanding of absolute testing, a user-supplied rotary part stage, and the use of fiducials.
- Requires specific hardware- transmission sphere, a 5-axis mount (with X/Y/Z and Tip/Tilt adjustability) with an indexed rotary stage that has a mechanism to hold the test part (or reference surface) and rotate in precise 90 degree increments.
- A #1 fiducial in the center of the data must be defined before clicking Calculate.
- The use of fiducials is suggested to ensure that the multiple data files properly align and scale when the rotary stage is rotated. To use fiducials, it is necessary to temporarily mark the test part (or reference surface) with stick-on labels.
- When measuring a spherical part, the transmission sphere must have sufficient coverage of the part.
- When measuring a transmission sphere, the reference surface must have sufficient coverage of the transmission sphere.
- Use an Acquisition mask to include the part but exclude the edges.
- Lateral calibration is required for lateral results other than pixels.

The Two Sphere Screen

Shown below is the MEASUREMENT tab. For the ANALYSIS tab see Surface.

The surface plot and results are blank until all measurements are saved and/or loaded and Calculate is clicked.



A. Live Display. **B.** Input plot (displays the current measurement). **C.** Surface plot (displays the results of the five measurements). **D.** Input Results **E.** Surface Results.

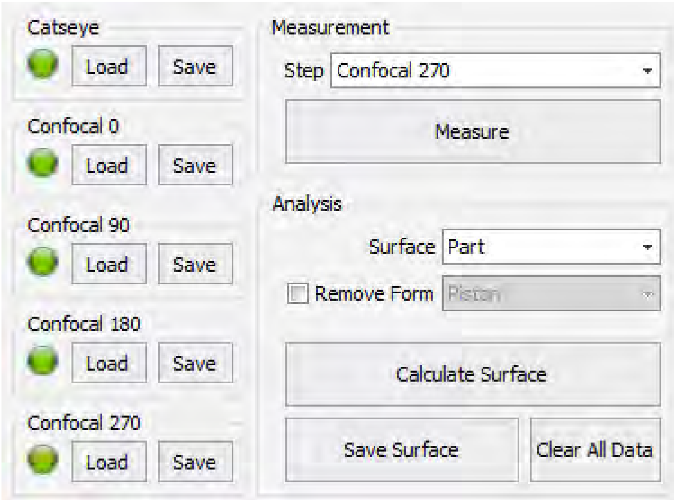
See Also

Measuring Two Spheres

Changing Displayed Results

Standard Optic Results

Two Sphere Controls

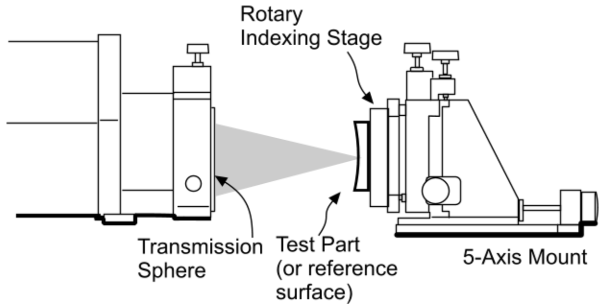


State Indicator	Red indicates the corresponding measurement step data is missing. Green indicates the corresponding measurement step data is present.
Load	Each Load and Save pair corresponds to a particular measurement step.
Save	Click Load to load existing data that matches the corresponding step. Click Save to save the current data as a particular step.
Step	Selects the active measurement step. Choices are Catseye, Confocal 0, Confocal 90, Confocal 180, and Confocal 270.
Measure	Acquire data for the currently selected measurement step.
Surface	Selects what sphere results to calculate and display in the Surface window. Options are Part or TS (transmission sphere). After a measurement series is complete, the setting can be changed and results for a different surface displayed by clicking the Calculate button.
Remove Form	When checked, removes the selected best-fit form from the calculated surface.
Calculate Surface	Click to calculate the Surface plot and results based on the loaded or saved measurement step data.
Save Surface	Click to save the combined results of multiple measurements.
Clear All Data	Click to clear all saved or loaded data sets within the tool.

Measuring Two Spheres

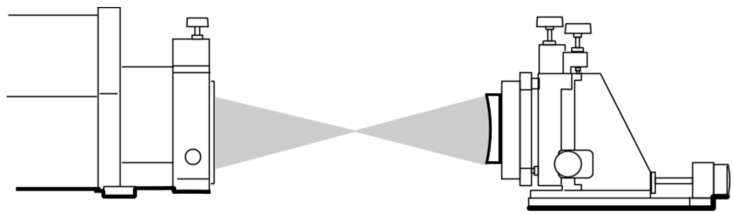
1

Measure **Catseye**



2

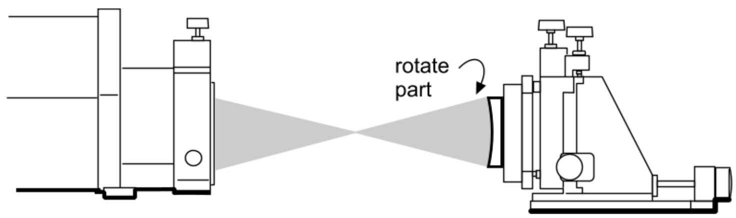
Measure **Confocal 0**



3
Measure **Confocal 90**

4
Measure **Confocal 180**

5
Measure **Confocal 270**

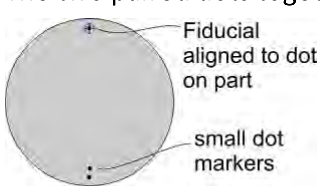


For details on using your laser interferometer see the applicable operating manual.

Measurements can be performed in any order and repeated until the best possible data is obtained. To monitor a given measurement setup, add a Control Chart and select the PV result. Repeat a given test setup measurement until the PV result is stable and minimized.

This procedure describes one technique used to obtain two sphere results; other user-specific techniques may be used.

1. Install and align the transmission sphere to the interferometer.
2. Place two uniquely distinguishable markers on the test part (or reference surface) 90 or 180 degrees apart near the edge of part. Shown here are three small adhesive dots on the test part. The two paired dots together form the second marker.



3. Mount the test sphere. Center and square the mount in front of the interferometer.
4. Set the interferometer zoom setting so the test part fills the Live Display.
5. For a concave surface, place an alignment flag in front of the beam. Locate Catseye position, where the cone comes to a point. Position the small hole in the alignment flag at this point. The beam passes through and then diverges.
6. Move the test part to Confocal position. A reflected beam back from the test part should appear on the other side of the flag. Adjust the X and Y axes on the mount to bring the reflected beam back through the hole in the flag. Remove the flag when done.

7. Clock the test part (or reference surface) through a 360 degree rotation, adjusting as required to minimize excursion of the image to assure the part is rotating on its optical axis. Use of fiducials as mentioned in step 2 will compensate for minor part excursion when the part is rotated.
8. Translate the part back and forth between confocal and catseye positions; the fringes should completely fill the aperture at both positions without vignetting. If necessary, adjust the alignment of the rotary stage until this is the case.
9. Null the fringes at both locations. Adjust the confocal null with the X/Y knobs on the mount; adjust the catseye null with the Tip/Tilt knobs on the interferometer accessory receptacle.
10. Move the test part to the confocal position. Using the Mask Editor define a circular Acquisition mask to include the part but exclude the edges.
11. (Optional) Use the Lateral Calibrator to establish the lateral resolution of each camera pixel.
12. Use the Fiducial Editor to create #1 fiducial in the center of the data. This is a required step. If defining other fiducials, the one in the middle of the data must be number 1.
13. Use the Fiducial Editor and create two additional fiducials each aligned over a marker on the test part. In all cases #1 fiducial must be in the data center.
    a. Save these fiducials as 0 degree fiducials.
    b. Rotate the two fiducials over the markers together 90 degrees and save them as 90 degree fiducials.
    c. Rotate the two fiducials together another 90 degrees and save them as 180 degree fiducials.
    d. Rotate the two fiducials together another 90 degrees and save them as 270 degree fiducials.
14. Position the test sphere (or reference surface) at catseye, then focus and null the image. Select Catseye in the Step control. Click Measure. Click the corresponding Save button to save the data.
15. Position the test sphere (or reference surface) at confocal 0. Load 0 degree fiducials. Adjust the mount X/Y knobs to spread the fringes; then null the fringes with the Z-axis knob. The position of markers on the part should align with the fiducials. Select Confocal 0 in the Step control. Click Measure. Click the corresponding Save button to save the data.
16. Rotate the test sphere (or reference surface) to 90 degrees. Load 90 degree fiducials. Adjust the sphere position as described in step 15. Select Confocal 90 in the Step control. Click Measure. Click the corresponding Save button to save the data.
17. Rotate the test sphere (or reference surface) to 180 degrees. Load 180 degree fiducials. Adjust the sphere position as described in step 13. Select Confocal 180 in the Step control. Click Measure. Click the corresponding Save button to save the data.
18. Rotate the test sphere (or reference surface) to 270 degrees. Load 270 degree fiducials. Adjust the sphere position as described in step 15. Select Confocal 270 in the Step control. Click Measure. Click the corresponding Save button to save the data.
19. Click Calculate Surface. To save the results click Save Surface.

Tool Offset

Measurement Features

- Measures the tool decentration or offset of turned spherical parts.
- For diamond-turned optical components, Tool Offset establishes the extent that the center of the circular tool arc lies on the axis of rotation.
- Useful for evaluating opthalmic contact lenses or molds.

Displaying and Using Tool Offset

To use this feature, the Tool Offset result and controls must be added to the workspace. It is not a Measurement Type.

1. Add Tool Offset result to a Result Grid. (Optional) Add RadCrv, RadCrv X, and RadCrv Y results.

   For details on using grids see Working With Grids.

2. If necessary, add a Control Grid to the workspace.
3. Add Tool Offset controls to the Control Grid: Tool Offset On, Tool Offset Radius, and Tool Offset Sign.
4. Enter Tool Offset control settings.
5. Perform Lateral Calibration.
6. Click Measure.

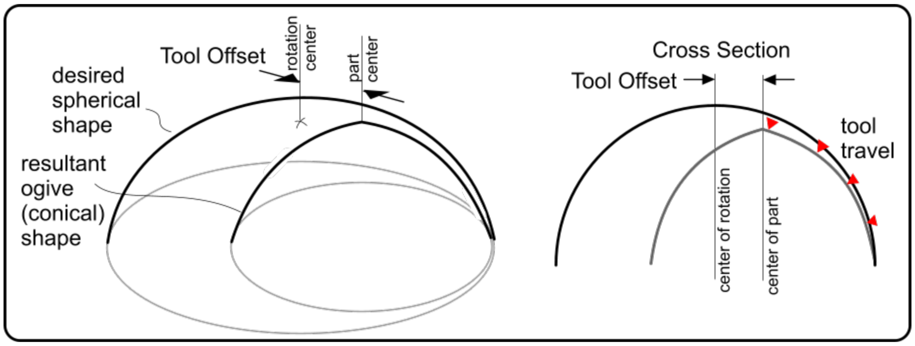
Tool Offset Controls

Tool Offset On	Selects whether to calculate Tool Offset. Options are Off or On.
Tool Offset Radius	Specifies the radius of the part being measured. This value is the nominal or planned radius of curvature of the spherical part. Use a negative sign for concave surfaces; convex surfaces are positive.
Tool Offset Sign	Selects the sign of the Tool Offset result to accommodate different test setups or lathe polarity. Options are Unchanged or Changed.

Tool Offset Result

Tool Offset is the lateral distance from the physical center of the part to the center of the curve of the arc of the cutting tool, along the horizontal axis of the part. Also known as “ogive”.

Tool Offset is the horizontal decentration, which will actually alter the overall figure of the part. When there is vertical decentration, the tool is denied access to the central region of the spherical part; it does not affect the surface figure significantly. Tool Offset is concerned only with horizontal decentration.

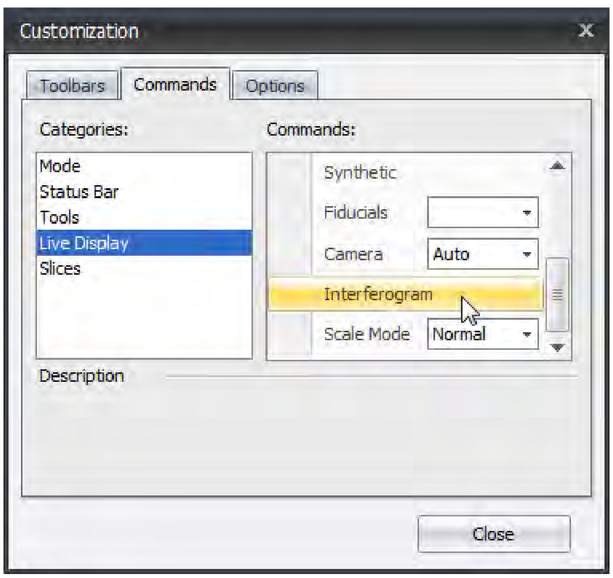


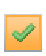
Interferogram

- A synthetic interferogram (virtual fringes) is created from phase data (valid data must be present).
- The number of fringes, the orientation, and the density are selectable.
- Can serve as an aid in viewing surface detail of a smooth part by increasing the scale.
- Can serve as a visual representation of the cavity when the intensity frame is well nulled.

Adding an Interferogram View

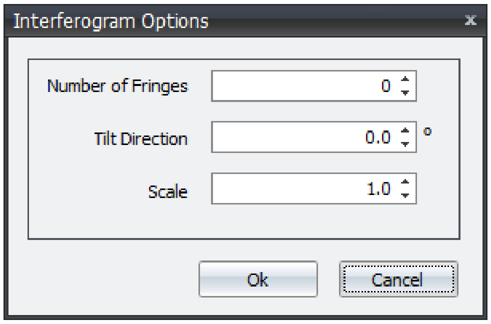
1. Right-click on the plot toolbar and choose Customize.
2. In the Customization dialog, select the Commands tab.
3. Under Categories select Live Display.
4. Under Commands, click and drag Interferogram to the plot toolbar.



5. Click Close.
6. If added to a Live Display, press the  button to view.

Interferogram Options

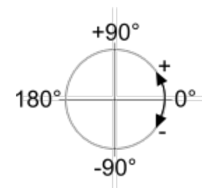
1. To display synthetic fringes, click Interferogram on the plot toolbar and select Show Interferogram.
2. To select options, click Interferogram on the plot toolbar and select Interferogram Options.



3. Enter options and click Ok.

Number of Fringes Adds the number of fringes to the cavity.

Tilt Direction Specifies the orientation of the tilt fringes. Numeric entry in degrees.



Scale Multiples or divides the number of fringes per wave. Less than 1 divides; greater than 1 multiples.

3.2 MST Application

- The MST application (MST.appx) is specifically for ZYGO MST laser interferometers.
- Provides FTPSI technology.
- Provides multiple surface testing capabilities.
- Shares many features with the general purpose Form application.
- Supports many measurement types including: Form, Parallel Window Bare, Parallel Window Simple, Parallel Window Transmission, Parallel Window Homogeneity, and Multiple Surface Investigation.

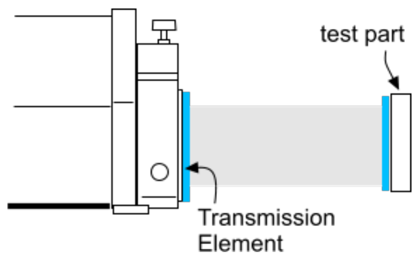
Key Features

- Simultaneously measures two-surface, three- and even four-surface cavities.
- Measures front surface map, optical thickness variation, and back surface simultaneously.
- Simplifies homogeneity metrology.

MST Measurement Type

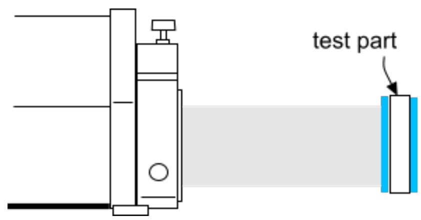
Except for the Form type setup, measurements for this system are designed for *parallel window* parts. This type of part has flat, polished front and back surfaces with minimal wedge. In addition to parallel windows parts, two measurement types can measure concentric or nearly concentric spherical parts. In the following illustrations each blue highlighted surface is an active surface; that is, it contributes to the fringe patterns viewed. The Measurement Mode control must be set to FTPSI. See also Measurement Type.

Form (MST)



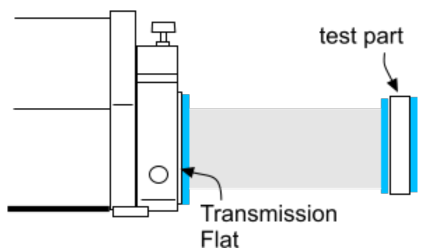
- 2 Surface
- One fringe pattern
- Measure flats or spheres
- 2 active surfaces
- WS-PSI and WS-QPSI measurement modes also available

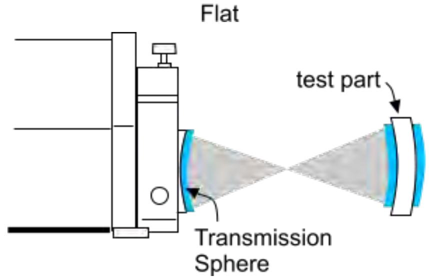
Parallel Window Bare



- 2 Surface without Transmission Flat
- Parallel surfaces
- Shows internal Fizeau
- 2 active surfaces

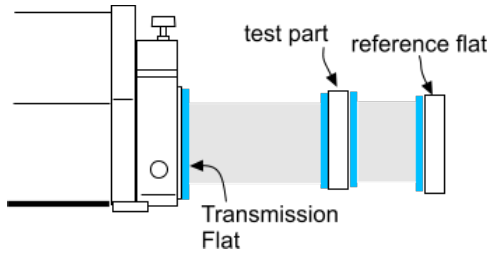
Parallel Window Simple





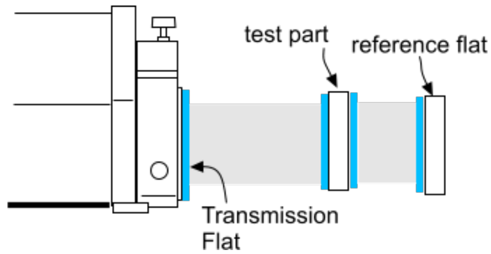
- 3 Surface
- Parallel surfaces
- 3 active surfaces
- Supports concentric or nearly concentric spherical parts

Parallel Window Transmission



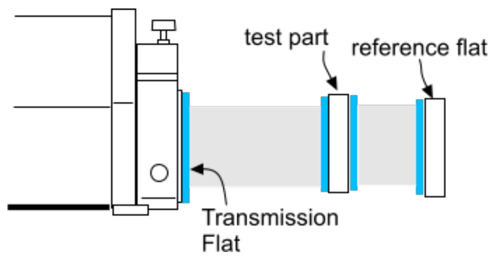
- 4 Surface
- Parallel surfaces
- 4 active surfaces

Parallel Window Homogeneity



- 4 Surface Homogeneity
- Parallel surfaces
- 4 active surfaces
- 2 measurements required

Multiple Surface Investigation



- Custom Surface Investigation
- Parallel surfaces
- Can have 2+ active surfaces
- Measure the optical path difference between any two surfaces
- Supports concentric or nearly concentric spherical parts

About FTPSI

FTPSI measures multiple surfaces simultaneously by assuming that each pair of surfaces is at a different optical length. By having each pair of surfaces at a different optical length, the fringe pattern from each pair of surfaces modulates (fringe movement) at a different frequency. The Fourier Transform based analysis then isolates and analyzes the frequency(s) of interest. See FTPSI for more details.

MST Guidelines

Keys to Using the MST

- Know your part parameters (part thickness and refractive index).
- Determine the type of measurement (two, three, or four surface).
- Establish the proper cavity geometry.

General MST Measurement Guidelines

- Use calibration markers(s) specified with the Cal Marker Editor. All setups require one T (test) marker, except homogeneity which requires an additional R (reference) marker.
- Minimize Environmental Effects. The best results are achieved when care is taken to minimize environmental effects. A vibration isolation system is recommended. To minimize air turbulence, the test cavity should be kept short whenever possible. To further reduce air turbulence, the cavity may be enclosed with a plastic screen or other material.
- For lateral results (Size X, Size Y, etc.) to display, Lateral Calibration must be performed.
- Adhere to the listed measurement Constraints (these appear after Calculate Geometry is clicked). Three and four-surface setups require specific part positioning (distance between surfaces). The distances used depend on the type of measurement performed, the optical thickness of the part, and the desired level of frequency suppression.

Cavity Length Limits

These limits are for the latest generation of MST interferometers. For previous generations of MST interferometers check the specifications or contact ZYGO.

	633 nm MST	**1550 nm MST**
Minimum Optical Length	1 mm	1.5 mm
Maximum Optical Length	5 m	2.8 m

Nominal Test Part Specifications

These specifications apply to three surface, four surface, and homogeneity setups. The part specifications are for the latest generation of MST interferometers. For previous generations of MST interferometers check the specifications or contact ZYGO.

	633 nm MST	**1550 nm MST**
Parallelism	Visible fringes from both front and back surfaces[1]	Visible fringes from both front and back surfaces[1]
Minimum Optical Thickness	1 mm	1.5 mm
Minimum Physical Thickness	1 mm/part index of refraction	1.5 mm/part index of refraction

1. Best results are achieved when the interference fringes are minimized.

MST Plot Details

The plots displayed for each MST Measurement Type are shown in the table below. Details for each plot are described below the table.

	Intensity Data	Optical Thickness Variation Data	Front Data	Back Data	Empty Data	Homo-geneity Data	(Single) Surface Data	OPD Spectrum
Bare	X	X						
Simple	X	X	X	X				
Transmission	X	X	X	X				
Homogeneity	X	X	X	X	X	X		
Investigation	X						X	X

Intensity Data Shows one frame of fringe data.

Optical Thickness Variation Data Shows a measure of the variation in optical thickness between the front and back surfaces of the test part. This includes effects from both physical thickness variation and glass homogeneity. An optically thicker area appears higher on the map.

Front Data Shows the front surface of the test part using the transmission flat as a reference surface.

Back Data Shows the back surface of the test part.

In a three surface setup, this represents the flatness of the rear surface plus any index inhomogeneity in the material.

In a four surface setup, this is a measurement of the back surface of the parallel plate using the reference flat as a reference surface; it does not include the effects of homogeneity.

In a homogeneity setup, this is a measurement of the back surface of the parallel plate using the transmission flat as a reference surface; it does not include the effects of homogeneity.

Empty Data Shows the empty cavity; includes the transmission flat and reference flat.

Homogeneity Data Shows the optical path difference due to the variation in index of refraction of the test part. An area with a lower index appears higher on the map.

Surface Data Shows a measure of the variation in optical thickness between the two selected surfaces in the test part cavity.

OPD Spectrum Shows a plot of the camera intensity history using the FTPSI algorithm. Each cavity (pairs of parallel surfaces) appears as a peak. See OPD Spectrum Plot.

Raw MST Data

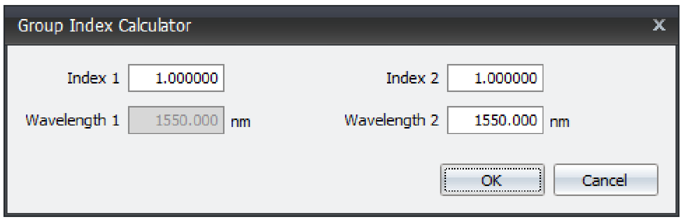
MEASUREMENT tab, Navigator : Raw Data : Raw MST Data

This view shows unprocessed OPD spectrum data and applies only to an MST laser interferometer using FTPSI.

It is used as a diagnostic tool to check FTPSI functionality when results don't match expectations; it shows all signal peaks found during a measurement.

Group Index Calculator

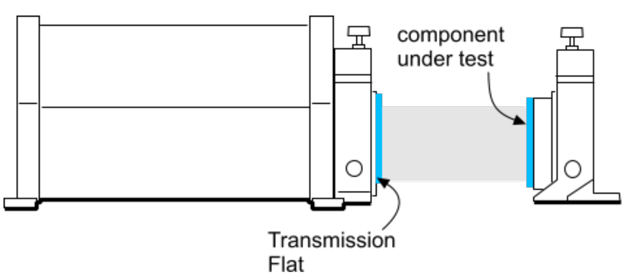
- Used to account for the changing of the wavelength (and index of refraction) during a measurement.



1. Click Calculate Group Index button in the corresponding Measure screen. This opens the calculator.
2. Enter the refractive index of the test part material (at the wavelength listed in Wavelength 1) in the Index 1 control.
3. Enter a slightly different wavelength in the Wavelength 2 control. In this example, 1556.000 would suffice.
4. Enter the refractive index of the test part material (at the wavelength listed in Wavelength 2) in the Index 2 control.
5. Click OK to close the calculator and automatically fill the Group Index value.

MST Form

- Measures 2 surfaces.
- Provides basic form results.



The MST Form Screen

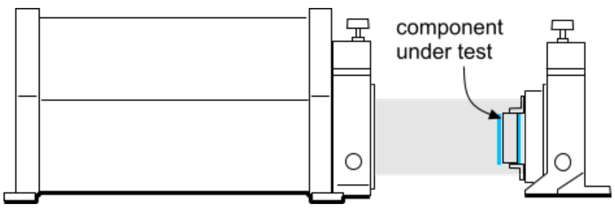
See the general Form application Surface screen.

Making an MST Form Measurement

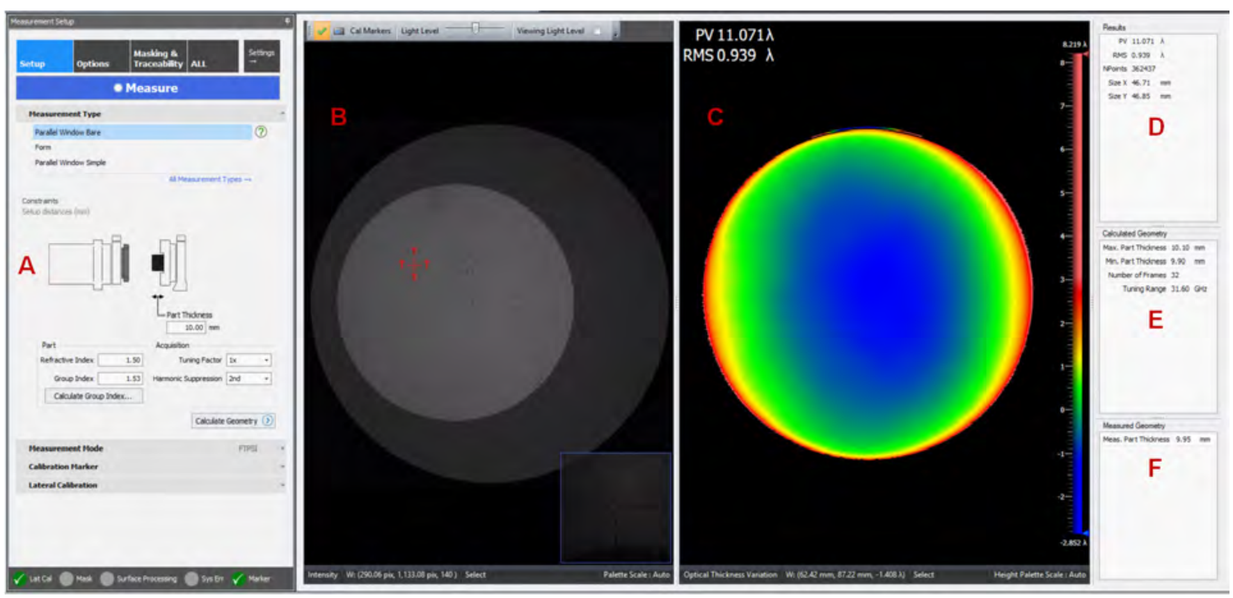
1. Select Measurement Type- Form and Measurement Mode- FTPSI. WS-PSI and WS-QPSI also available as measurement types.
2. Open the Cal Marker Editor. Select the T marker and click on the display to set the calibration test marker somewhere on the part under test.
3. Access the Measurement Setup panel and select the FTPSI tab.
4. Enter a reasonable guess at the Total Optical Cavity Length. The optical cavity length is the sum of the lengths of each sub-cavity times the index of the material which comprises the sub-cavity.
5. Select a Tuning Factor.
6. Click Measure.
7. Further data examination is done under the ANALYSIS tab.

Parallel Window Bare

- Measures 2 parallel surfaces of the test part.
- Measures without the use of transmission flat.



The Parallel Window Bare Screen



A. Setup controls. **B.** Live Display. **C.** Optical Thickness Variation Data plot. (For all plot details see MST Plot Details.) **D.** MST Results. **E.** Calculated Geometry. **F.** Measured Geometry.

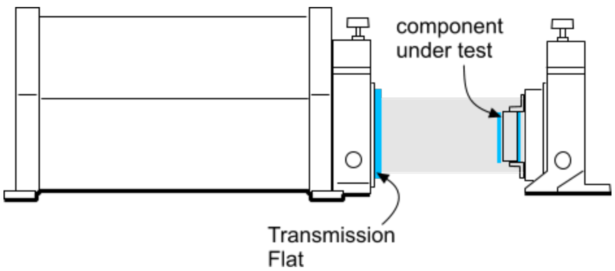
Making a Parallel Window Bare Measurement

1. Select Measurement Type- Parallel Window Bare and Measurement Mode- FTPSI.
2. Open the Cal Marker Editor. Select the T marker and click on the display to set the calibration test marker somewhere on the part under test.

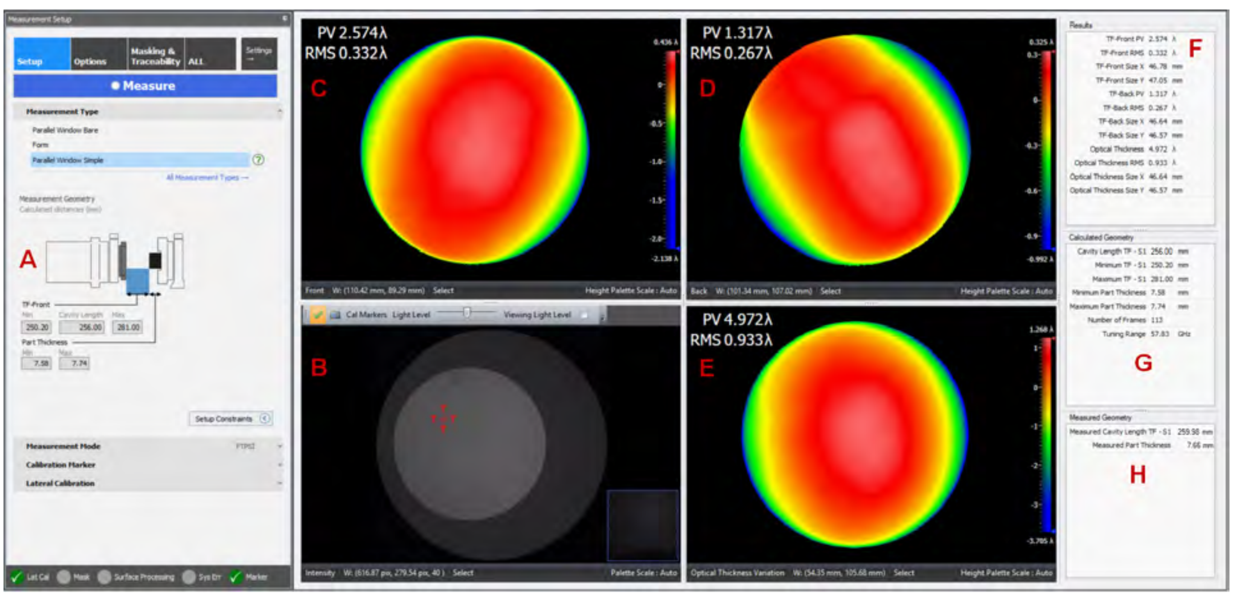
3. Enter Part Thickness and Part Refractive Index values.
4. To enter a Group Index, click Calculate Group Index and enter values in the Group Index Calculator.
5. Select a Tuning Factor; for best results select Max.
6. Click the Calculate Geometry button.
7. Review the Calculated Geometry panel. If the results meet your measurement criteria continue, if not adjust the above mentioned controls and repeat.
8. Click Measure.
9. Further data examination is done under the ANALYSIS tab.

Parallel Window Simple

- Measures 3 parallel surfaces.
- Measures the front surface and optical thickness variation of a sample.



The Parallel Window Simple Screen



A. Setup controls. **B.** Live Display. **C.** Front Data plot. (For all plot details see MST Plot Details.) **D.** Back Data plot. **E.** Optical Thickness Variation Data plot. **F.** MST Results. **G.** Measured Geometry. **H.** Calculated Geometry.

Making a Parallel Window Simple Measurement

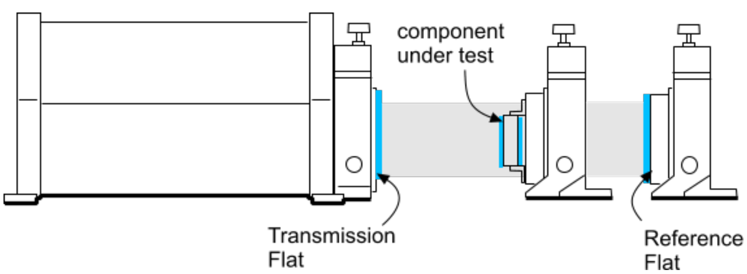
1. Select Measurement Type- Parallel Window Simple and Measurement Mode- FTPSI.
2. Open the Cal Marker Editor. Select the T marker and click on the display to set the calibration test marker somewhere on the part under test.
3. Enter Part Thickness and Part Refractive Index values.

4. To enter a Group Index, click Calculate Group Index and enter values in the Group Index Calculator.
5. Enter Constraints: Min Distance TF-Front and Max Distance TF-Front.
6. Select a Tuning Factor and Harmonic Suppression.
7. Click the Calculate Geometry button.
8. Review the Calculated Geometry panel. If the results meet your measurement criteria continue; if not adjust the above mentioned controls and repeat. Adjust cavity to meet geometry requirements.
9. Click Measure. If the measured cavity length and the measured part thickness are both highlighted in green, then your measurement setup is optimal. If either is highlighted in red, verify all parameters and try again.
10. Further data examination is done under the ANALYSIS tab.

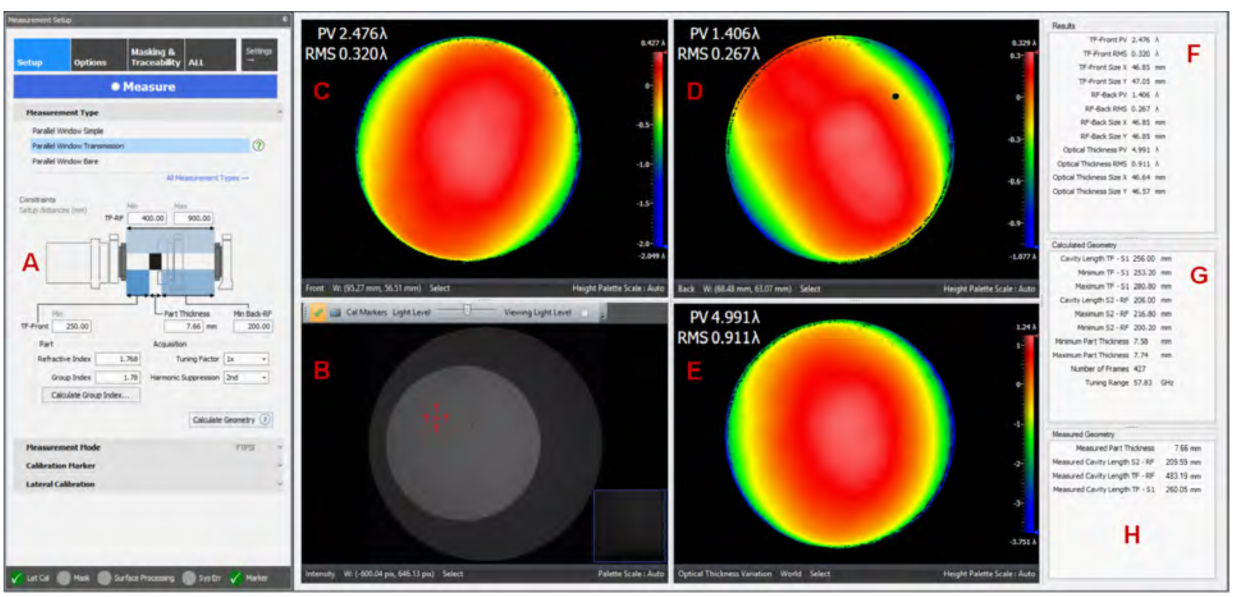
See also Subtracting System Error for Multiple Cavity Setups.

Parallel Window Transmission

- Measures 4 parallel surfaces.
- Measures the front surface, back surface, and optical thickness variation of a sample.



The Parallel Window Transmission Screen



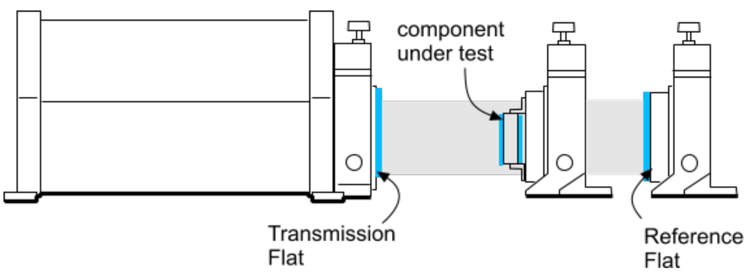
A. Setup controls. **B.** Live Display. **C.** Front Data plot. (For all plot details see MST Plot Details.) **D.** Back Data plot. **E.** Optical Thickness Variation Data plot. **F.** MST Results. **G.** Calculated Geometry. **H.** Measured Geometry.

Making a Parallel Window Transmission Measurement

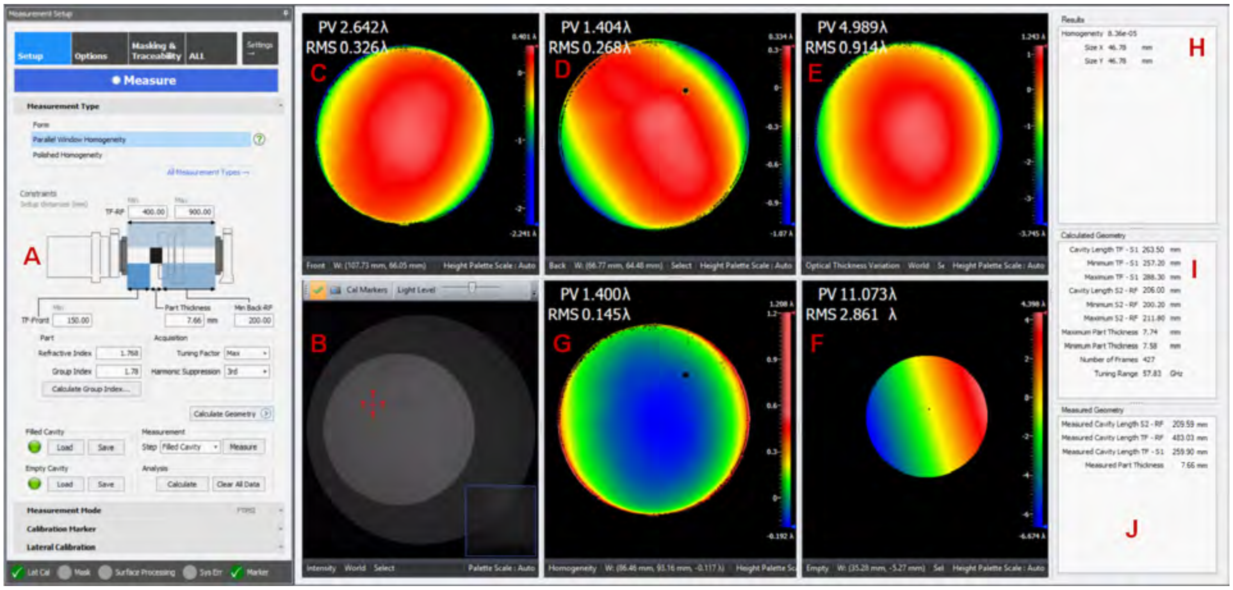
1. Select Measurement Type- Parallel Window Transmission and Measurement Mode- FTPSI.
2. Open the Cal Marker Editor. Select the T marker and click on the display to set the calibration test marker somewhere on the part under test.
3. Enter Part Thickness and Part Refractive Index values.
4. To enter a Group Index, click Calculate Group Index and enter values in the Group Index Calculator.
5. Enter Constraints: Min Distance TF-Front, Min Distance Back-TF, Min Distance TR-RF, and Max Distance TF-RF.
6. Select a Tuning Factor and Harmonic Suppression.
7. Click the Calculate Geometry button.
8. Review the Calculated Geometry panel. If the results meet your measurement criteria continue, if not adjust the above mentioned controls and repeat. Adjust cavities to meet geometry requirements.
9. Click Measure. If the measured cavity lengths and the measured part thickness are highlighted in green, then your measurement setup is optimal. If either is highlighted in red, verify all parameters and try again.
10. Further data examination is done under the ANALYSIS tab.

Parallel Window Homogeneity

- Measures 4 parallel surfaces.
- Measures the front surface, back surface, and optical thickness variation of a sample.
- Requires an empty cavity data acquisition to obtain homogeneity and physical thickness variation results.



The Parallel Window Homogeneity Screen



A. [Setup controls](). **B.** Live Display. **C.** Front Data plot. (For all plot details see [MST Plot Details]().) **D.** Back Data plot. **E.** Optical Thickness Variation Data plot. **F.** Empty Data plot. **G.** Homogeneity Data plot. **H.** [MST Results](). **I.** [Calculated Geometry](). **J.** [Measured Geometry]().

Making a Parallel Window Homogeneity Measurement

1. Select Measurement Type- Parallel Window Homogeneity and Measurement Mode- FTPSI.
2. Place the component under test in the optical cavity. Adjust the interferometer as instructed in the operating manual.
3. Open the [Cal Marker Editor](). Select the T marker and click on the display to set the calibration test marker somewhere on the part under test. Select the R marker and click on the display where there is no overlap with the test part cavity to set the calibration reference marker.

Use of the R marker is not required if the test part fills the display and the cavity cannot be seen.

4. Enter Part Thickness and Part Refractive Index values.
5. To enter a Group Index, click Calculate Group Index and enter values in the [Group Index Calculator]().
6. Enter Constraints: Min Distance TF-Front, Min Distance Back-RF, Min Distance TF-RF, and Max Distance TF-RF.
7. Select a [Tuning Factor]() and [Harmonic Suppression]().
8. Click the Calculate Geometry button.
9. Review the Calculated Geometry panel. If the results meet your measurement criteria continue, if not adjust the above mentioned controls and repeat. Adjust cavities to meet geometry requirements.
10. With the Step control select Filled Cavity. Click Measure. If the measured cavity lengths and the measured part thickness are highlighted in green, then your measurement setup is optimal. If either is highlighted in red, verify all parameters and try again.
11. If you want to keep the Filled Cavity data click the corresponding Save button and specify a directory location.
12. Remove the test part from the optical cavity.

13. With the Step control select Empty Cavity. Click Measure.

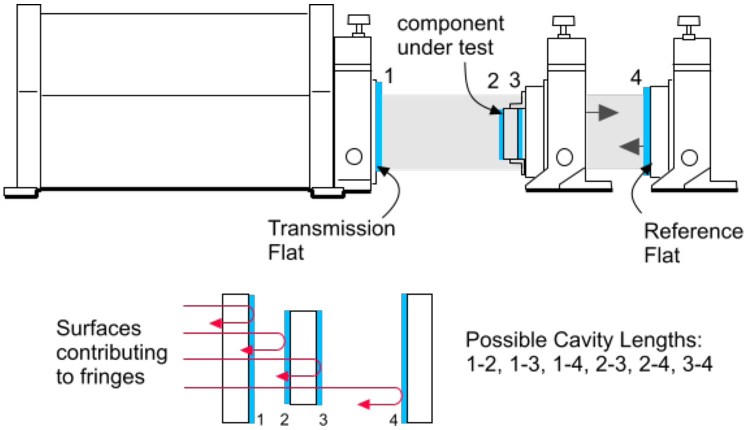
Empty cavity data is automatically saved as part of the Homogeneity measurement. Empty Cavity data can also be saved by clicking the corresponding Save button and specifying a directory location.

14. Click the Calculate button.
15. Further data examination is done under the ANALYSIS tab.

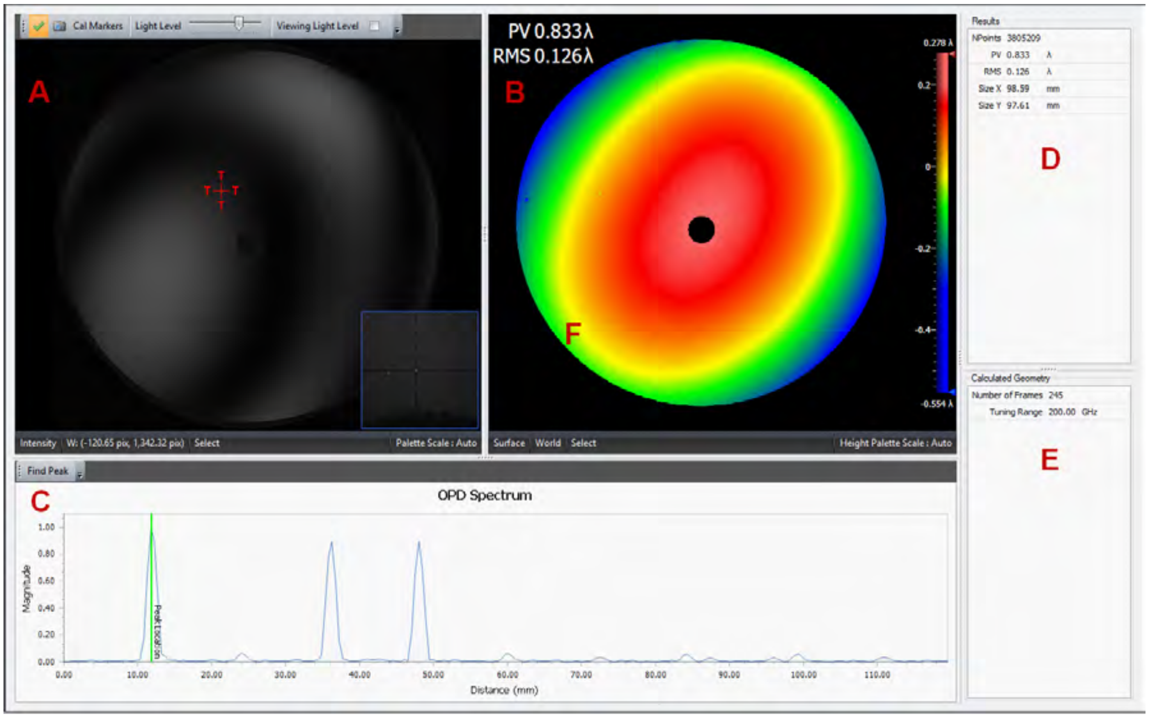
See also Subtracting System Error for Multiple Cavity Setups.

Multiple Surface Investigation

- Measures 2, 3, 4, or more nominally parallel surfaces.
- The user can choose to measure the variation in optical path difference between any two surfaces.
- This setup can have a range of active surfaces.

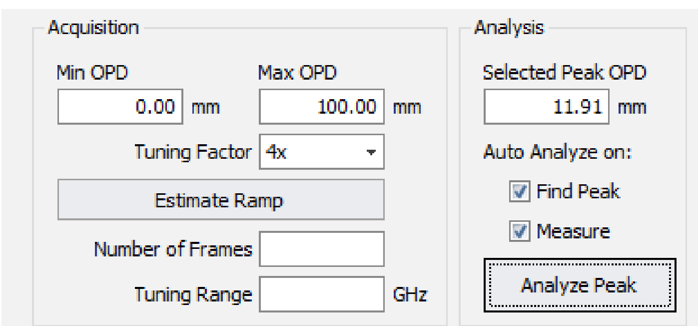


The Multiple Surface Investigation Screen



A. Live Display. **B.** Surface Data plot. (For all plot details see MST Plot Details.) **C.** OPD Spectrum plot. **D.** MST Results. **E.** Calculated Geometry.

Making a Multiple Surface Investigation Measurement



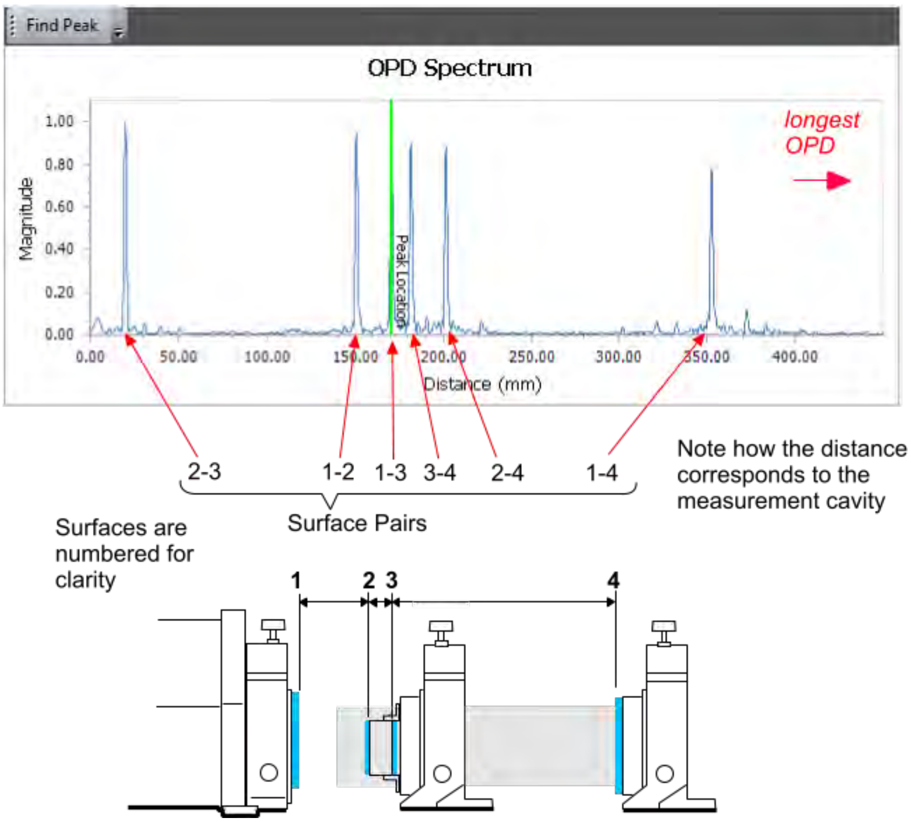
1. Select Measurement Type- Multiple Surface Investigation and Measurement Mode- FTPSI.
2. In the Measurement Setup panel access Calibration Marker. Select the T marker and click on the Live Display to set the calibration test marker somewhere on the part under test.
3. Enter the Max OPD (longest cavity) and Min OPD (shortest cavity).
4. Select a Tuning Factor.
5. Click Estimate Ramp button. The Number of Frames and Tuning Range are automatically calculated.
6. Click Measure.
7. Click the Find Peak button on the OPD Spectrum plot window.
8. Drag the mouse to position the magenta peak locator line over a peak and click the left mouse button. Select the peak at the distance which is closest to the estimated optical path length for the cavity of interest.
9. Click Analyze Peak. The Surface Data plot should be generated. If the Auto Analyze check box is selected Surface Data plot will generate automatically.

10. Further data examination is done under the ANALYSIS tab.
11. To analyze other cavities repeat steps 8-10 for other peaks.

See also Subtracting System Error for Multiple Cavity Setups.

OPD Spectrum Plot

- Appears on the Multi Surface Investigation measurement type screen and on Raw MST Data screens.
- Plots the camera intensity history using the FTPSI algorithm.
- It is similar to an FFT with frequency converted to optical path distance.
- Shows the individual optical cavities that are present within the calibration pixel data.
- Each cavity appears as an individual peak. The individual cavities correspond to each pair of parallel surfaces within the test cavity. Each peak can be matched to a corresponding optical path length between each surface pair.



Keep in mind the following equation:

Optical Path Length = (Index of Refraction) x (Physical Distance) = nT

Multiple reflection harmonics are sometimes visible within the OPD Spectrum plot. It is sometimes useful to change the plot's Y-axis scale to identify 2nd and higher order harmonics.

3.3 AccuFlat Application

The AccuFlat application is designed to measure transparent, thin plane-parallel parts, such as disc media. It features a Focus Display, used to provide user feedback for proper focus and part tilt.

Use Conditions

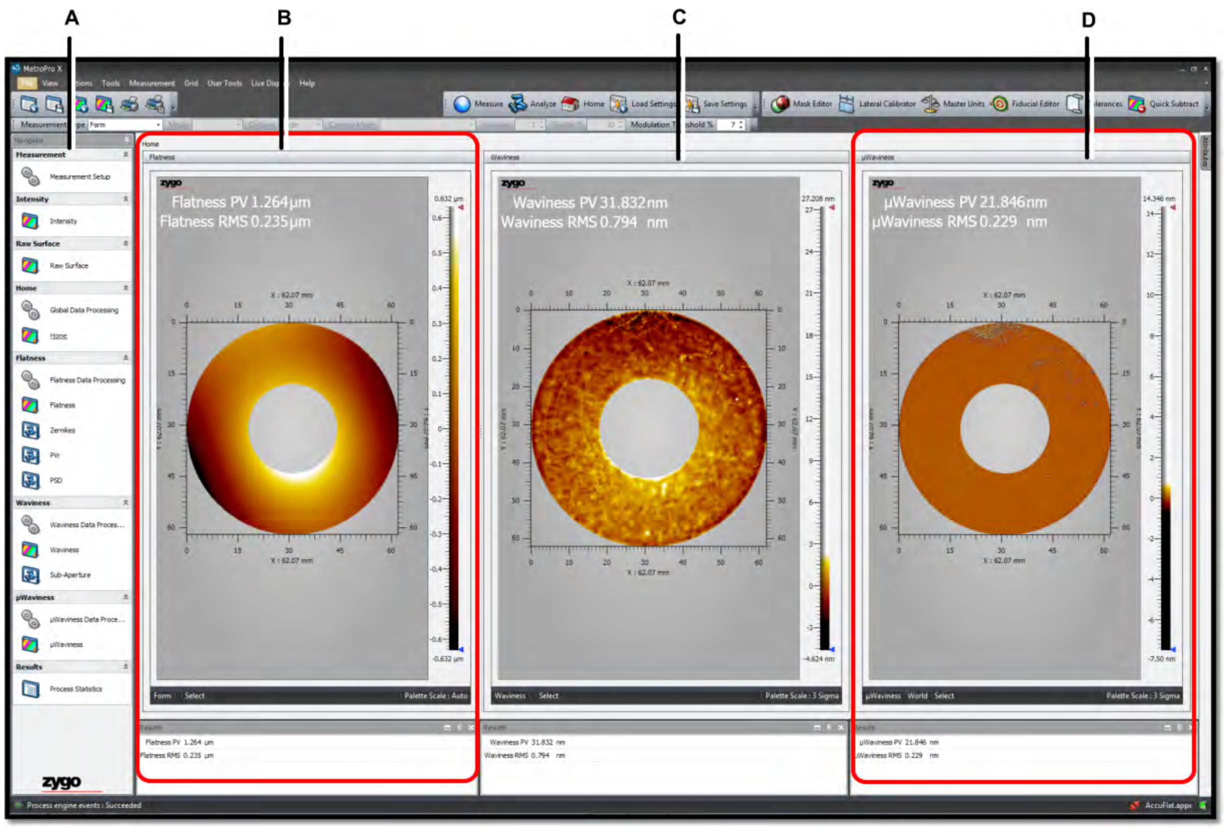
- Applies to the AccuFlat interferometer only; lateral calibration is automatic.
- Incoming data flows through three preconfigured versions of the Data Processing tool.
- Using filter settings outside of the preset ranges for each data section may result in erroneous results.
- Perform Focus Calibration as required.

AccuFlat Use Cases

- Characterizes the flatness, waviness, and µwaviness of the part surface.

The AccuFlat Screen

The screen features three data sections with similar features. The data displayed within each section is determined by filter settings in the corresponding Data Processing tool.



A. Navigator. **B.** Flatness plots and results. **C.** Waviness plots and results. **D.** µWaviness plots and results.

See Also

Focus Display

Flatness Results

Waviness Results

µWaviness Results

Focus Calibration

AccuFlat Data Flow

Incoming data is passed into the Global Data Processing functions and then flows simultaneously into three data processing functions and data sections (Flatness, Waviness, and µWaviness). The data displayed within each section is determined by filter settings in the corresponding Data Processing tool.

The surface parameters are derived by FFT filtering of the data into the underlying spatial frequencies. For flatness all frequencies are included. For waviness spatial frequencies from 0.2 to 2.0 cycles per millimeter (0.5 – 5 mm periods) are analyzed. The µwaviness setting covers a spatial frequency range from 2.0 to 10.0 cycles per millimeter (0.1 – 0.5 mm periods).

The default filtering settings can be changed to meet specific customer metrology requirements.

For more information on using these features see Data Processing and Data Manipulate.

See Also

Filter

Measuring Disk Media

1. Place test part onto holder and close the cover.

   Use the turbulence cover to prevent air turbulence from degrading the measurement.

2. Coarse align the test part by adjusting the Tilt X and Tilt Y knobs on the part stage to move the brightest dots into the center of the align screen crosshairs.
3. Turn the Part Stage Z-axis knob to adjust focus so the focus aid is in the green zone.
4. Fine-tune Tilt X, Tilt Y, and Z-axis knobs to null fringes and simultaneously maintain focus.
5. Click Measure or press F12.

   The Focus display provides feedback so you know when the front surface is in focus and aligned. If the display is ignored it is actually possible to incorrectly align and focus on the back surface.

Focus Calibration

Use Conditions

- Applies to the AccuFlat only; included in AccuFlat.appx.

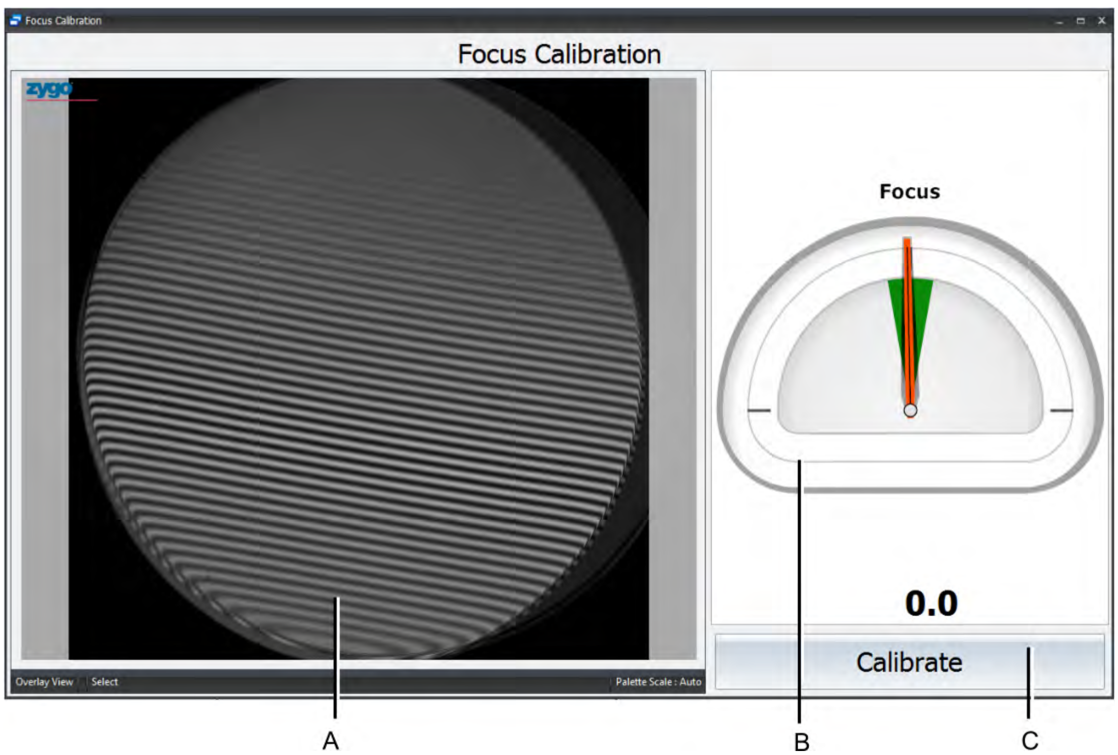
Function Overview

- Adjusts an internal focus sensor for optimal performance, resulting in best fringe contrast, best image focus, and minimal systemic optical error.
- Resets the Z-axis position where the Focus aid reads 0.
- Checks the instrument settings and provides feedback for proper setup.

When to Calibrate

- Every time the system is moved to a new location.
- If the operating temperature changes more than 5°C.
- At least every 3-6 months.

Focus Calibration Screen



A. Live part image. **B.** Focus aid. **C.** Calibrate button.

Performing Focus Calibration

1. Load a typical part onto the part stage.
2. On the User Tools menu, click Focus Calibration.
3. Click the Calibrate button and follow the dialog box prompts.
4. Adjust the part tilt and Z positions as instructed.
5. Adjust the part Z position as instructed.

Laser Interferometer Control 4

This section covers instrument control and topics specific to laser interferometers.

For the live image display refer to Live Display.

4.1 Laser Interferometer Toolbars

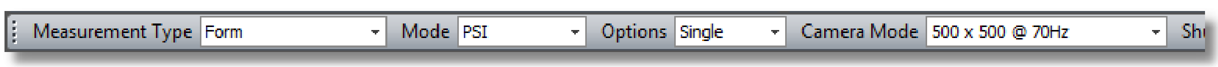
These toolbars provide laser interferometer control.

To change what is displayed in a toolbar see Changing a Toolbar.

To display, move, or hide toolbars see Toolbars.

Measurement Setup Toolbar

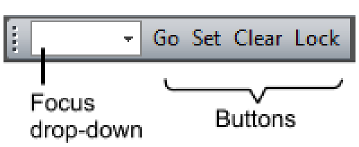
- Used to select frequently used instrument settings.
- It contains a subset of the controls available in the Measurement Setup panel.



For the controls in the toolbar refer to Laser Interferometer Measurement Setup.

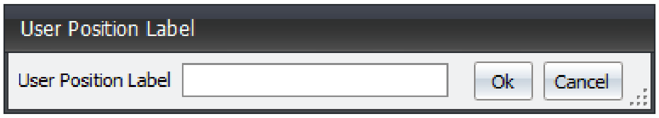
Focus Toolbar

- Used to set and go to defined focus positions.
- Applies to laser interferometers equipped with an encoded focus option.
- The toolbar is not available unless connected to an instrument.



Setting a Focus Position

1. Adjust the focus using the interferometer's remote.
2. Click Set, enter a label for the position and click OK. This adds a setting to the Focus drop-down list.



3. Repeat steps 1 and 2 for additional focus positions.

Using a Defined Focus Position

1. Select a defined position in the Focus drop-down list.
2. Click Go.

Removing a Defined Focus Position

1. Select a defined position in the Focus drop-down list.
2. Click Clear.

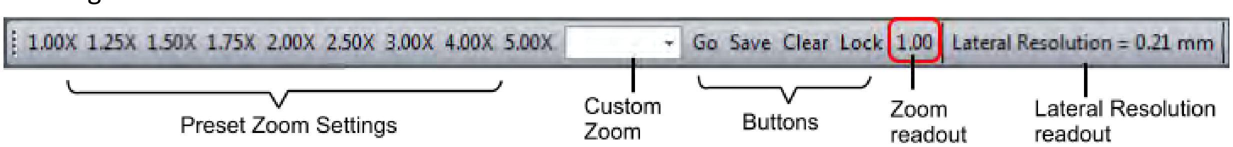
Locking the Focus Toolbar

This prevents the focus toolbar from being changed.

1. Click Lock.
2. To unlock the toolbar click Lock again.

Zoom Toolbar

- Used to select the zoom setting for a laser interferometer.
- Applies to laser interferometers.
- The toolbar is not available unless connected to an instrument.
- The Zoom and Lateral Resolution readouts actively update as interferometer zoom setting is changed.



Using a Preset Zoom Setting

1. Point to one of the preset zoom settings (1.00X, 1.25X, etc.) and click.

Saving a Custom Zoom Setting

1. Adjust the zoom using the interferometer's remote.

   The Zoom readout updates as the zoom is adjusted.

2. Click the Custom Zoom box and enter an appropriate numeric value (typically from 1.00 to 5.00).
3. Click Save to add the setting to the Custom Zoom drop-down list.

Using a Custom Zoom Setting

1. Click the Custom Zoom drop-down box and select a saved zoom setting.
2. Or Click Custom Zoom and enter a numeric value (typically from 1.00 to 5.00).
3. Click Go.

Removing Custom Zoom Settings

This removes *all* zoom settings and clears the drop-down list. Individual settings can not be deleted.

1. Click Clear.

Locking the Zoom Setting

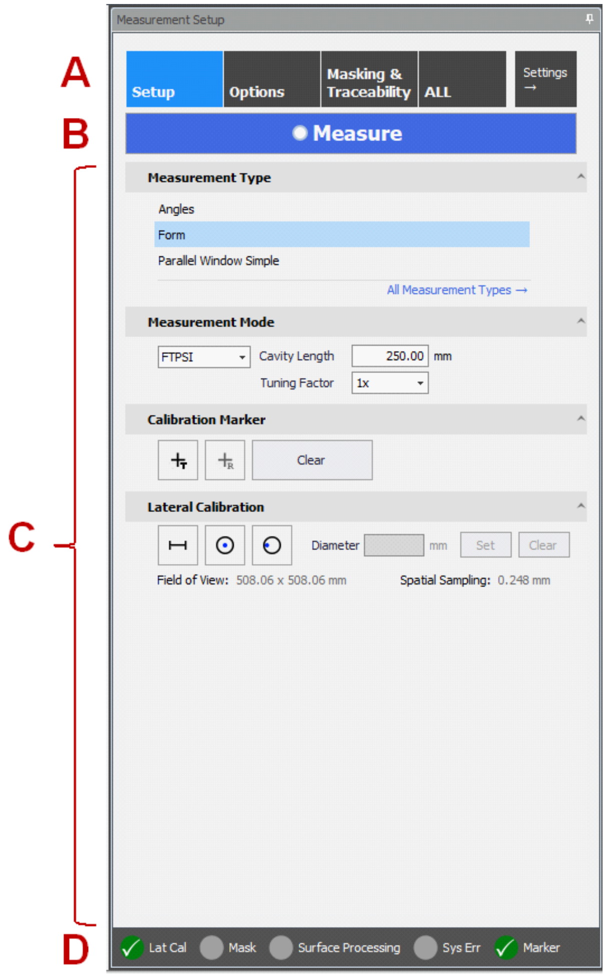
This prevents the zoom setting from being changed and also locks out the interferometer's remote.

1. Click Lock.
2. To unlock the zoom setting click Lock again.

4.2 Laser Interferometer Measurement Setup

Navigator : Measurement : Measurement Setup

- Commonly referred to as the Measurement Setup panel.
- The actual controls available are instrument specific.
- If there is no active instrument, some controls are grayed out and not available. However, some controls are available for setting even when running the software without an active instrument. This is so control settings can be specified, saved, and later loaded onto a system running an instrument.
- Control settings can be saved and loaded. See Using Settings.

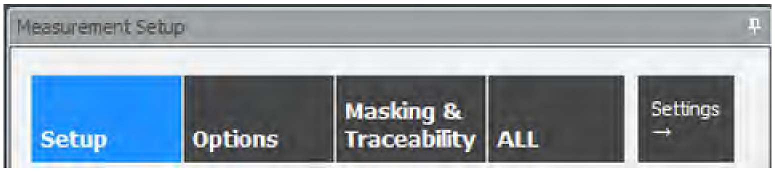


A. Navigation buttons used to display desired control group. B. Measure button. C. Control group for currently selected Navigation button. D. Setup Status bar.

Frequently Used Setup Controls

Measurement Type	Selects the type of measurement you want to perform. It may require specialized hardware.
Measurement Mode	Selects the technique for acquiring data. The selected choice activates controls related to the selection, or hides those not applicable.
Camera Mode	Selects the size of the camera and the speed at which data is acquired.
Modulation Threshold	Specifies the percent of modulation necessary for a valid data point.
Number	Specifies how many measurements of the same part to make and average together to improve the instrument repeatability.

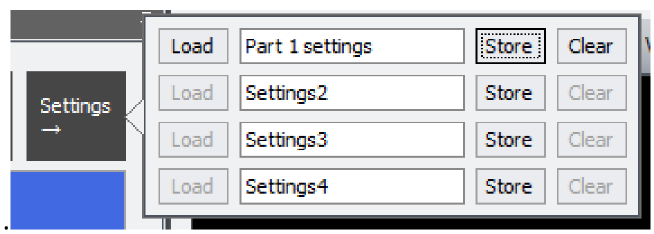
Measurement Setup Navigation



The Navigation buttons organizes controls in the following groups:

Setup	Control the overall measurement setup, including Measurement Type, Measurement Mode, Calibration Marker (when applicable), and Lateral Calibration.
Options	Measurement options such as Illumination & Camera controls, System Error Subtract, Averaging, Auto Null options, Signal Processing Options, and User Options.
Masking & Traceability	Provides tools for Masking, Fiducials, and optional user inputs to provide more information about the measurement (see Traceability).
ALL	Shows all available controls.
Settings →	Provides up to four shortcuts for saving and loading frequently used settings.

Settings

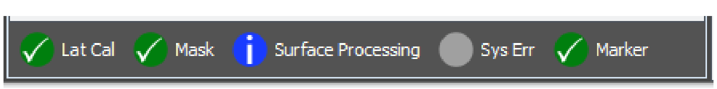


Each row corresponds to a different settings shortcut, which can be named as desired. The buttons perform the following actions:

Load	Loads the settings stored to the shortcut.
Store	Stores the current settings to the shortcut. This is option is hidden for the Operator user level.
Clear	Clears the current settings associated with the shortcut. This is option is hidden for the Operator user level.

Measurement Setup Status Bar

The status bar located at the bottom of Measurement Setup panel provides at-a-glance indicators for key setup elements. Mousing over an indicator displays more details, along with shortcuts to associated controls.



Status Icons

Icons change depending on state and can be interpreted as shown below.

Default state (not in use, not required)

Informational state: in use but not strictly required.

Required and in a good state.

Warning state. Possible issue to be resolved, but measurement can proceed if desired.

Error state. Condition that must be resolved before a measurement can occur.

Setup Elements

The status bar provides information for the following setup elements.

Lat Cal Indicates status of lateral calibration. Click this indicator to display Lateral Calibration controls.

lateral calibration done

lateral calibration not done and is required

lateral calibration is not done and is not strictly required.

Mask Indicates status of masks. Click this indicator to display Masking controls.

mask are required and defined.

masks are required but not defined.

masks are defined but not required.

masks neither defined nor required.

Surface Processing Indicates surface processing state. Click this indicator to open the Surface Processing Tool.

indicates the processing sequence has been changed from its last loaded/saved state.

indicates the processing sequence is the same as its last state.

Sys Err Indicates the status of system error subtract. Click this indicator to display System Error Subtract Controls.

a valid system error file is selected

an invalid system error file is selected.

no system error file is selected.

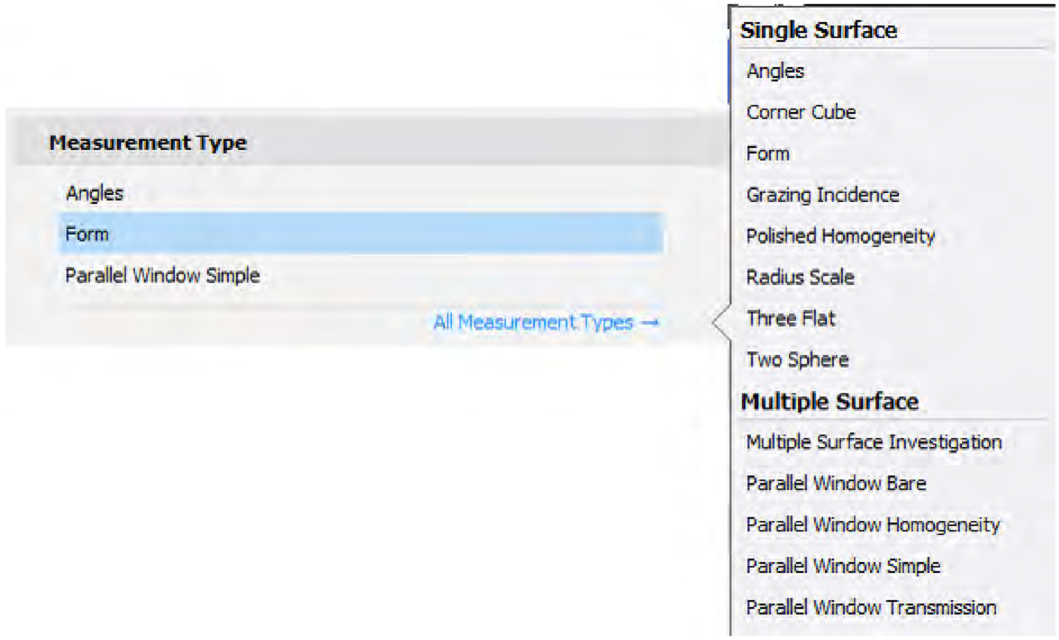
Marker Indicates Calibration Marker status only when it is required. Click this indicator to display Calibration Marker controls.

Calibration Marker(s) is required and placed.

Calibration Marker is required and missing.

Measurement Type

Selects the type of measurement you want to perform. The choices vary based on the instrument, the loaded application, and licensing options.



The three most recent selections are shown in the quick list. Clicking All Measurement Types→ shows all available options.

For some options, additional controls are displayed as appropriate. Click the links below for more details.

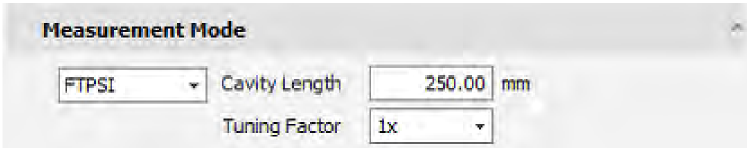
Single Surface

Angles	Measure mechanical wedge of an optical element having nonparallel surfaces, and the 90 degree angle error of right-angle prisms.
Corner Cube	Measure corner cube prisms or retroreflectors. A corner cube has three internal reflecting facets forming 90 degree angles with other.
Form	Measure the form or shape of surfaces or wavefronts. This is the general default measurement type for ZYGO laser interferometers and corresponds to the Home view.
Grazing Incidence	Measure a test part that is larger than the interferometer aperture by positioning the part at a high angle of incidence to the measurement beam.
Polished Homogeneity	Measure the homogeneity of polished glass. Homogeneity is a measure of the variation in the refractive index within a material.
Radius Scale	Measure the radius of curvature of convex or concave surfaces.
Ritchey-Common	Measure the absolute flatness of a plano part using two transmission spheres and specialized fixturing.
Three Flat	Measure the absolute departure of an optical flat with respect to an ideal flat.
Two Sphere	Measure the surface quality or wavefront of spherical optics.

Multiple Surface (in MST application)

Multiple Surface investigation	Measures 2, 3, 4, or more nominally parallel surfaces. The user can choose to measure the variation in optical path difference between any two surfaces.
Parallel Window Bare	Measures 2 parallel surfaces of the test part.
Parallel Window Homogeneity	Measures the front surface, back surface, and optical thickness variation of a sample. Requires an empty cavity data acquisition to obtain homogeneity and physical thickness variation results.
Parallel Window Simple	Measures the front surface and optical thickness variation of a sample.
Parallel Window Transmission	Measures the front surface, back surface, and optical thickness variation of a sample.

Measurement Mode



Measurement Mode controls select the way data is acquired by the laser interferometer. The choices vary based on the loaded application, with additional controls displayed as appropriate to the selection. Click the links below for more details. They are located in the Measurement Setup panel.

PSI	Phase-shifting Interferometry converts multiple frames of intensity data into phase data and then the phase data into surface height data.
QPSI	Uses proprietary phase-shifting techniques to measure optics in the presence of vibration.
FTPSI	Fourier Transform Phase-shifting Interferometry provides multiple surface testing with an MST interferometer. The interferometer must be equipped with wavelength shifting technology.
QFTPSI	Uses proprietary algorithms to improve the performance of FTPSI measurements in the presence of environmental instability.
WS-PSI	Wavelength Shifting PSI. This setting is advantageous for shorter cavities, and it is faster than FTPSI acquisition. For 2 surface measurements only. The interferometer must be equipped with wavelength shifting technology. Also see Wavelength Shifting Controls.
WS-QPSI	Wavelength Shifting QPSI. For vibration prone environments. For 2 surface measurements only. The interferometer must be equipped with wavelength shifting technology. Also see Wavelength Shifting Controls.
DynaPhase	Uses the intensity acquisition process to capture a single frame of data. Carrier fringe analysis converts the single intensity frame to surface height data.
Intensity	Analyzes one frame of intensity data but does not produce any surface height data.

Measurement Mode Options

Depending on the selected Measurement Mode and available hardware, a subset of the following controls may also appear:

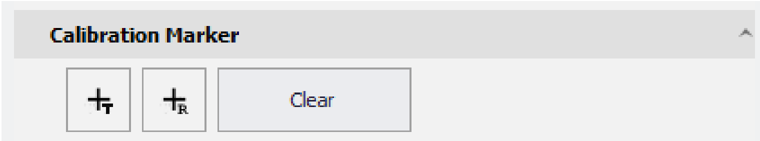
Cavity Length	Specify the approximate cavity length. Used for FTPSI and Wavelength-Shifting measurement modes. See also FTPSI Controls and Wavelength Shifting Controls.
Tuning Factor	Used with FTPSI to control the length of the acquisition. See FTPSI Controls for details.
Adjust	Used with Wavelength-Shifting measurement modes to automatically adjust the Cavity Length value.
Aperture	For dual aperture systems, selects the aperture that is in use. Select Small for a 4-inch or 6-inch aperture (the smaller channel of a dual aperture system), or Large for a 12-inch or 18-inch aperture that is equipped with a PMR (Phase Measuring Receptacle).
Calibration Threshold	Used with DynaPhase to specify the acceptable amount of residual astigmatism. See DynaPhase Controls for details.
(DynaPhase) Options	Selects the desired DynaPhase measurement option. See DynaPhase Controls for details.
(DynaPhase) Alignment	Selects which axis is adjusted in DynaPhase rough align and fine align steps. See DynaPhase Controls for details.

Advanced PSI Controls

These controls are applicable when Measurement Mode is PSI. These controls are available to add to a Control grid.
PZT stands for piezoelectric transducers, which are mechanical devices on the instrument used during phase-shifting interferometry.

PZT Calibration	When selected, the PZT's are automatically adjusted during data acquisition to obtain the correct phase relationships among numerous readings of light level data. The starting point for PZT calibration is the entered Gain value; it is adjusted if necessary to produce the correct phase differences. PZT calibration is most accurate when there are from 4 to 5 fringes across the measured area. When the Calibration check box is cleared, the Gain value is used but not adjusted.
PZT Gain	Gain specifies the modulation amplitude value used during data acquisition. The higher the value, the greater the PZT movement. Settings are from 0 to 4095, with a factory set default about 1600. Under normal circumstances it is not necessary to change this value. There are certain interferometer setups that require one-half the normal PZT motion; this can be set by dividing the Gain by two.

Calibration Marker

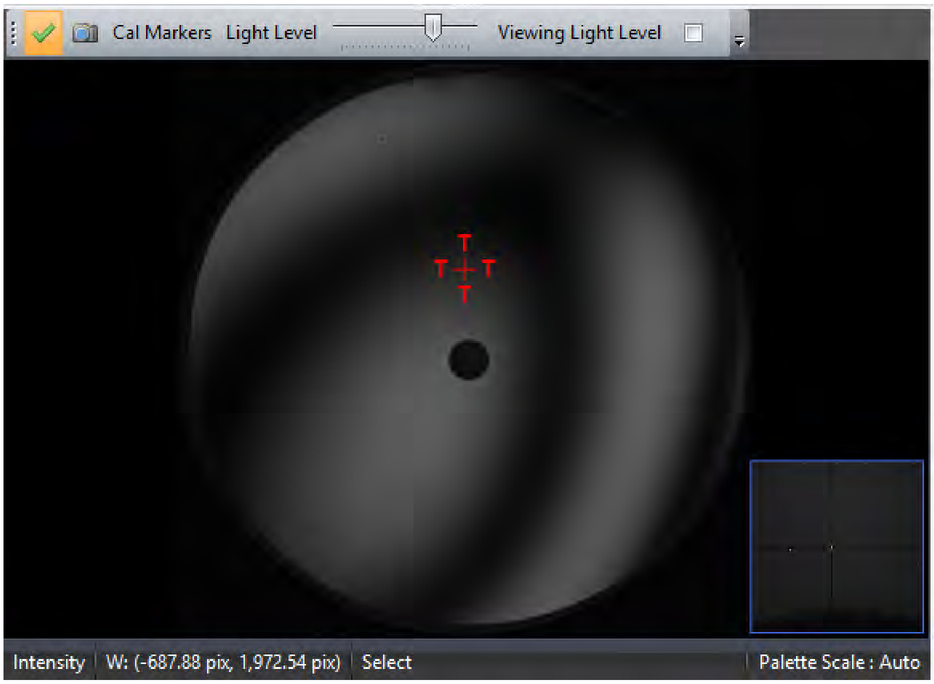


- Available in MST.appx.
- Used to define and apply calibration markers for wavelength shifting interferometry.
- A calibration marker is a single camera pixel used by FTPSI analysis to determine the lengths of the optical cavities to be analyzed.
- Defined calibration markers are saved along with the data.

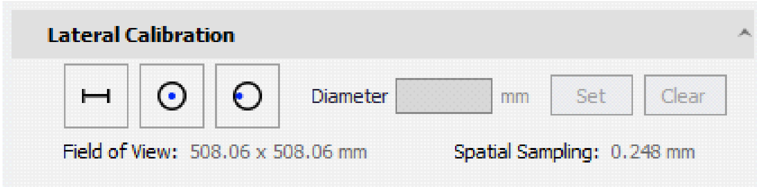
Defining a Calibration Marker

1. Setup your instrument with a part so you have an image.
2. Access the Calibration Marker shape tools In the Measurement Setup panel.
3. Click on the appropriate Draw Shape tool. $+_T$ (test) is used for all FTPSI measurements. $+_R$ (reference) is used for only homogeneity when the empty cavity is larger than the part under test. Place the “R” marker where there is no overlap with the test part cavity.
4. Position the mouse cursor over the Live Display and left click to place the marker.

The marker should be on a modulating area of the test part and not centrally located.



Lateral Calibration



Lateral Calibration controls are easily accessed using the built-in controls in the laser interferometer Measurement Setup panel. The Lateral Calibration (Legacy) screen is available as a standalone tool.

Lateral Calibration Details

- Calibration establishes the spatial sampling from one pixel to the next. (Spatial sampling is sometimes loosely called lateral resolution, but this is not technically correct.)
- Calibration is required to use lateral dimensions other than pixels.
- Calibration is required when the instrument zoom or focus are changed.

Lateral Calibration Conditions

- Calibration can only be performed if an instrument is connected and working.
- Calibration must be made before making measurements.
- Units for calibration are user selectable.
- You cannot recalibrate existing data.

Performing Lateral Calibration

1. Setup your instrument with a part so you have an image in the Live Display.
2. Click on the desired calibration shape tools (Ruler or Circle). draws a straight linear ruler. draws a circle from the center. draws a circle from edge to edge.
3. Position the mouse cursor over the Live Display and left click to draw the selected shape over a feature of known size. The shape can be moved or resized as desired.
4. Enter the known length or diameter.
5. Click the ‘Set’ button.

Following lateral calibration, the resulting Field of View and Spatial Sampling are displayed. To clear an existing lateral calibration, click the Clear button.

Editing Lateral Calibration Shapes

Shapes can be moved and resized as desired before setting lateral calibration.

Resizing a shape	Click on resizing handle and drag to the desired size, then release the mouse button.
Moving a shape	Click anywhere on the shape (except for on a resizing handle) and drag as desired. To move one pixel at a time, use the arrow keys. To move 10 pixels at a time, hold down the Shift key while using the arrow keys.
Deleting a shape	Hit the Delete key, or start drawing a new one.

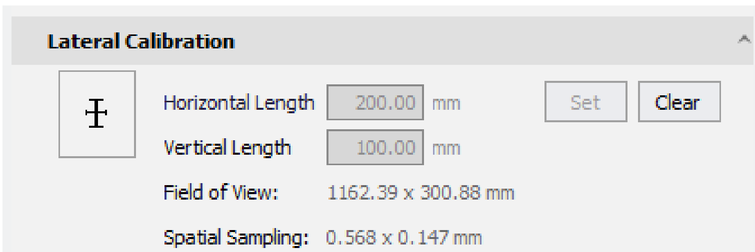
For Grazing Incidence measurements, a special form of Lateral Calibration is needed. See Lateral Calibration- Grazing Incidence.

Lateral Calibration Hint

When using a transmission flat, a simple way to calibrate is to place an object of known size in the field of view. In the live view screen, draw the definition line across the shadow of the object and enter its dimension in the Calibration dialog. This method works at any zoom setting, as long as the edges of the object are visible in the image area.

Lateral Calibration- Grazing Incidence

For Grazing Incidence measurements, spatial sampling is different along horizontal and vertical dimensions. For this case, a special form of lateral calibration is used.

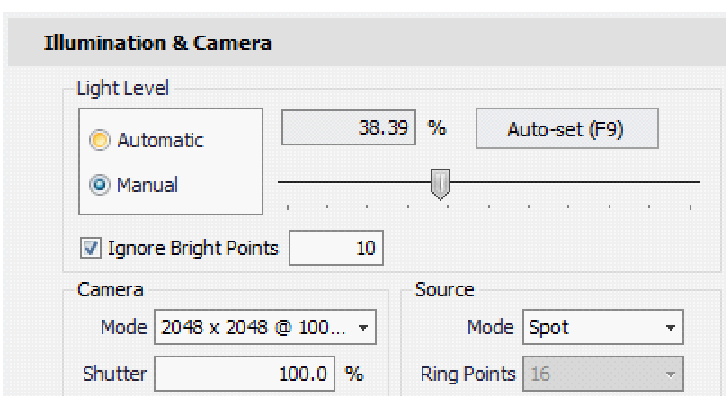


Performing Lateral Calibration for Grazing Incidence

1. Setup your instrument with a part so you have an image in the Live Display.
2. Click the Shape button.
3. Position the mouse cursor over the Live Display and left click to draw a rectangular crosshair in the Live Display over a feature of known horizontal and vertical size.
4. Enter the known Horizontal and Vertical Lengths.
5. Click the Set button.

When lateral calibration is complete, the displayed Spatial Sampling will comprise two values: the first is the pixel sampling in the horizontal direction, the second in the vertical dimension. To clear an existing lateral calibration, click the Clear button.

Illumination & Camera



Light Level Controls

The correct light level is important when viewing to see part detail, and when making measurements to ensure that as much data as possible is acquired. Manual and automatic control is provided.

Automatic **Manual**	Automatic optimizes light level continuously, even during measurements. Manual relies on user input for light level.
Light Level %	The slider or the control sets the instrument's illuminator light level in percent. Zero (0) is off and 100 is maximum light output.
Auto-set (F9)	When in Manual mode, click this button (or press F9) to optimize light level for the current scene in the Live Display. The adjusted light level is shown in the Light Level % control.
Viewing Light Level	Select the check box to adjust for the optimum light level when viewing the part. The light level used for viewing is displayed in the Light Level % control. When the check box is cleared, the viewing light level is based on the value in the Light Level % control.
Ignore Bright Points	Select to ignore bright pixels during the automatic adjustment of the measurement light level. Clear the check box to turn the function off. When checked, enter the number of brightest pixels to ignore.

Camera Controls

Mode	Selects the effective camera size for acquiring test data; it defines the measurement resolution in pixels. The selections vary based on the actual camera installed in the instrument. The greater the number of pixels, the finer the resolution, but the longer it takes to process data.
Shutter	Selects the camera shutter in % of frame rate. This is used to reduce exposure time to freeze environmental effects such as vibration and air turbulence. Applicable when Measurement Mode is DynaPhase or QPSI. For DynaPhase, Shutter speed is set to 5% of the camera frame rate by default. At full camera resolution (1200 x 1200) this equates to frame exposures of < 1 msec, which should be sufficient for most applications. With extreme vibration, typically of higher frequency, or setups that include regular manual interaction or adjustment (such as LivePhase alignment) it may be desirable to decrease the shutter speed further to prevent transient washing out of fringes and loss of data. The visual cue that Shutter should be decreased is isolated patches within a frame, or transient frames, that show loss of data (no fringes) in the synthetic null view. It is recommended to adjust shutter speed within the DynaPhase wizard where real-time feedback on the effect may be observed. For highest signal-to-noise, it is best to operate shutter speed at a setting that can still saturate the camera.

The Shutter speed attribute in ms (milliseconds) can be displayed in the Measurement Setup toolbar.

Source Controls

Mode	Selects the laser source mode for the laser interferometer. Choices are Spot or Ring. The Source Mode control is linked to Measurement Mode. All laser interferometers are equipped with a spot laser source. Some models are equipped with both a ring and spot laser source options. The Ring mode provides artifact reduction.
Ring Points	Selects the number of sequentially acquired and averaged points around one trace of the source ring when Ring Mode is Fixed. As more points are used the acquisition time increases with the benefit of higher precision. The number of points selected also defines the number of data averages. The default setting is 16.

System Error Subtract

- System errors can be minimized by subtracting a data file made from a measurement of a known high quality part or transmission element.
- Subtracting system errors improves measurement accuracy by subtracting instrument aberrations during the *acquire* cycle. Saved raw data will include the system error subtraction.
- This function is different than Subtract, which subtracts a specified file during the analysis phase.
- Once the subtract occurs, any subsequent Save Data operations will be saved with the data subtracted. There is no way to return to the original data. If that is required, then the Subtract tool should be used; it is available in Surface Processing.

Use Conditions

- The system error file is a standard data file (.datx) made by measuring a reference or high quality part with the instrument set to match the conditions of the test part measurement.
- The system error subtract function expects the camera size and lateral resolution of both data sets to match.
- The system error file must either already exist or be created for the specific instrument setup in use, before activating this function.
- Subtract System Error is not functional when Measurement Mode is Intensity or DynaPhase.

When To Make a New System Error File

- When the transmission element is removed and installed.
- When the Camera Mode is changed.
- When environmental conditions change.

Using Subtract System Error

1. Select the Subtract System Error On check box.
2. Click the directory button  to select the preexisting system error (.datx) file.

All future measurements subtract data directly from the measured map before any analysis is done. The raw surface map also has the system error subtracted.

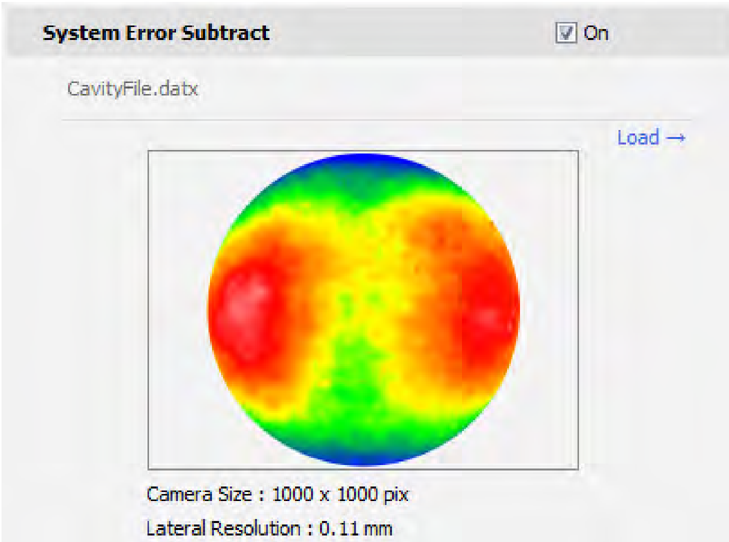
See Also

Subtracting System Error for Multiple Cavity Setups

Subtracting Reference Error for Specialized Single Cavity Setups

System Error Subtract Controls

System Error Subtract controls are in the Measurement Setup panel.



On	Select this check box in the header to enable System Error Subtract.
Load→	Click to load a file containing the System Error data. A thumbnail image of the selected data is display, along with the associated camera size and lateral resolution.

UltraSphere & UltraFlat Correction

ZYGO UltraSphere and UltraFlat transmission elements are high quality transmission elements that include element specific data files on a USB flash drive. Included with each calibrated transmission element are the following files:

- Acceptance Test Data: 1K x 1K (nominal): *.dat
  The data in this file is supplied as a full resolution record of the absolute calibration performed for specification acceptance. This file is for reference only and should not be used as a system error file.
- 37 Term Zernike Fit to acceptance test data: *.zfr and *.int
  These files represent the absolute calibration of the reference surface and are used to generate a usable system error reference file.

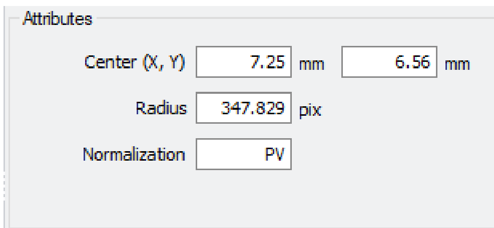
The following procedure is used to increase measurement accuracy by removing low-order Zernike error from the reference surface. The steps from 6 on should be performed each time an UltraSphere or UltraFlat is removed and re-installed.

Determine Aperture Parameters

This is an instrument specific, one-time procedure to determine the center and size of the valid field-of-view of your interferometer. After completing this section, save the generated values for future use.

1. Open Mx software and load the Form.appx application.
2. Make an overfilled measurement using the transmission element.
   a. If measuring with a transmission sphere (TS), the test part should be faster than the TS (i.e. f-number smaller than TS).
   b. If measuring with a transmission flat (TF), the test part should be larger than the TF.
3. Under the Analysis tab, click on the Zernike icon in the navigator. This opens the Zernike analysis.
4. The Zernike analysis includes Attributes. Make note of the values for Center X, Center Y and Radius.

   The values should be recorded in pixels. To change units, on the Tools menu click Master Units and select pixels for lateral units.



5. Multiply the Radius value times the factory calibrated clear aperture value.
   For 4/6 inch UltraFlat use 98.4% as the clear aperture value.
   For UltraSphere the clear aperture value is based on the f/number: f/0.75 is 98.2%, f/1.5 is 99.2%, and f/3.3 is 99.5%.
   For example, if using a 4-inch, f/3.3 transmission sphere, multiply the Radius value by 0.995 (99.5%).

   If measuring when using optical zoom, the Radius value should be multiplied by the zoom value. For example, if measuring at 1.7x zoom, multiply the Radius value by 1.7 and then by the clear aperture value.

Convert Zernikes to Phase Map

This part of the procedure generates a phase map from the provided Zernike file, which will be specific to the transmission element and interferometer combination.

6. From the User Tools menu in the menu bar, select Data Generate.
7. Set the Order control to 12. Click the Check All button and then deselect ZFR 0, 1, and 2 (piston and tilt) under the Generate column.
8. Clear the Auto Size check box.
   Set Width and Height to be equal to the size of your instrument camera.
   Set Center X, Center Y, and Radius per the values from step 4.
   OPTIONAL: Set a lateral resolution on the Advanced tab to give your system reference file a lateral calibration.
9. Open the included .int file using the Import button, and then click the Generate button. This will replace the active data displayed in Mx.
10. Close the Data Generate window.
11. From the File menu select Save Data, and save the .datx file with an appropriate name.

Subtract Reference Map from Measurements

12. To use the newly saved reference file, determine whether to subtract during data acquisition or during data analysis. Either choice is valid depending upon your preference.
    a. Acquisition: Select the System Error Subtract On check box in the Measurement Setup panel and load the reference file. When a measurement is performed, the reference error will be removed automatically. When data is saved, it will have the reference error removed from it. This is a more permanent method of error removal.
    b. Analysis: Under the Analysis tab click on Surface Processing in the Navigator and choose the Subtract step. Select the generated system reference file after Data File. When measurement data is saved, the reference error will not be removed as *only* raw data is saved.

Subtracting Error for Specialized Single Cavity Setups

When performing measurements with a more complex beam path, the application of the system reference file may not be appropriate or straightforward.

Transmitted Wavefront Error

In this double-pass test setup, a test part is measured in transmission using both a transmission element and a reflecting element.

In the case of two flat elements, a measurement of the empty cavity should be subtracted from the transmitted wavefront error. Simply align the reference flat to the interferometer, take a measurement, and subtract the resulting data from future measurements.

In the case of a spherical element used in conjunction with a flat element, removing error from the reflecting element can be challenging. In most cases, simply remove the system reference file for the transmission element and use a suitable high-quality reflecting element. If available, a reference file for the reflecting element can be used, but it must be flipped about the y-axis and properly scaled or masked depending upon the aperture being used.

For two spherical elements, great care must be taken if a reference file for the reflecting element is to be used. As the beam travels through the optical system under test, the final magnification will vary, and thus the aperture of the reflecting element being tested. As before, the reference file for a reflecting element should be flipped about the y-axis.

Polished Homogeneity

The multiple measurements of the Polished Homogeneity test account for any reference error. No system reference subtraction is required or recommended.

Angles

For Wedge Transmissive: See In the case of two flat elements (above under Transmitted Wavefront Error).

For Wedge Reflective: Subtract only the system reference file.

For Prism External: Subtract the system reference file. An additional source of error is the prism fixture.

For Prism Internal (Single Pass): Subtract the system reference file. For the highest precision prism measurement, use the double pass test setup.

For Prism Internal (Double Pass): Subtract the system reference file. An additional source of error is the front of the transmission flat used for the double pass reflection but subtracting this error can be prohibitively difficult.

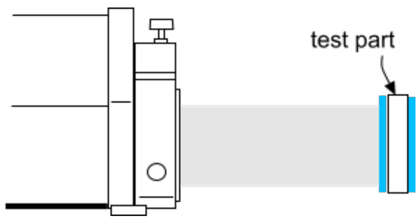
Corner Cube

Subtract the system error file, for single or double pass testing. Double pass is recommended for the highest precision measurement. An additional source of error is the front of the transmission flat used for the double pass reflection but subtracting this error can be prohibitively difficult.

Subtracting System Error for Multiple Cavity Setups

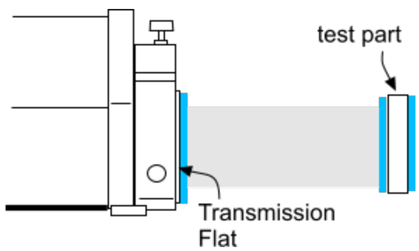
For multiple cavity setups, the availability and behavior of System Error subtraction depends on the measurement type.

Parallel Window Bare



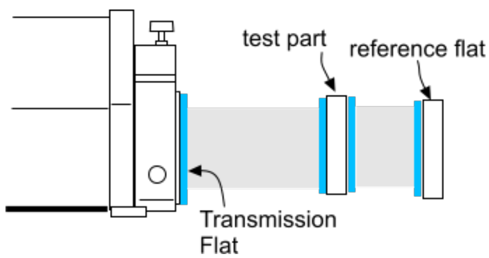
- This setup produces only optical thickness variation data.
- System Error correction is not needed for this measurement.

Parallel Window Simple



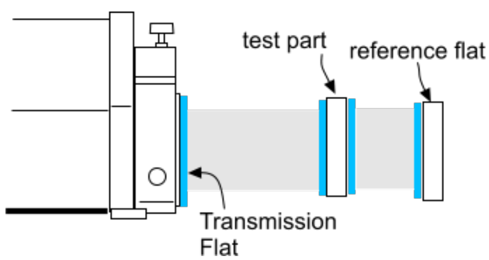
- When enabled, System Error correction is applied to both Front Surface and Back Surface data.

Parallel Window Transmission



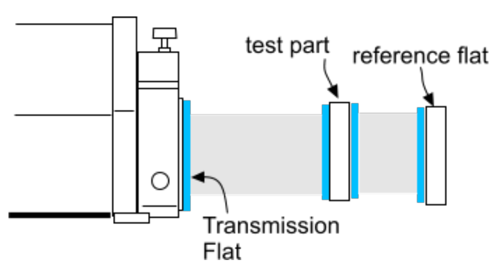
- System Error subtraction is not available for this measurement type.
- If System Error subtraction is desired, use the Parallel Window Homogeneity measurement type.

Parallel Window Homogeneity



- This requires measurements of both a Filled Cavity and an Empty Cavity.
- System Error correction is applied to the Front Surface as soon as the Filled Cavity measurement is performed.
- System Error correction is applied to the Back Surface only after both measurements are performed.
- Before the Empty Cavity is measured or loaded, and display Back Surface map will be uncorrected.

Multiple Surface Investigation



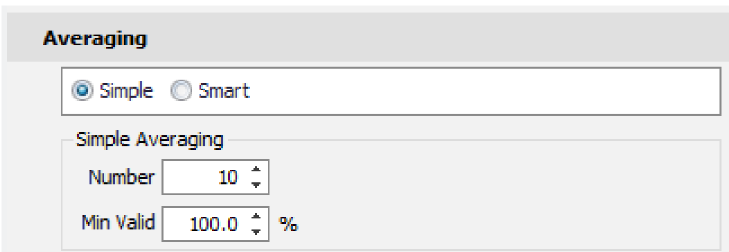
- Measures the optical path difference between any two surfaces in a setup.
- When enabled, System Error subtraction is applied to the raw measurement.

Averaging

Averaging refers to making multiple measurements of the same part and averaging the results. This improves the instrument measurement repeatability by increasing the signal-to-noise ratio of the data acquisition system. Averaging controls are in the Measurement Setup panel.

Simple Averaging

Simple averaging combines results from a fixed number of acquisitions.



Number Specifies the number of averages performed during a measurement cycle. Averaging increases the time required to analyze data. The time is dependent on the computer speed, the complexity of the data, and the number of data points.

If issues are encountered during a particular acquisition cycle, the software will keep trying until the specified number of averages are obtained.

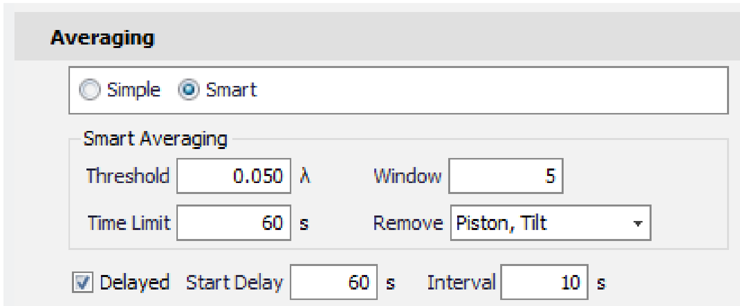
Min Valid Percent Specifies the percentage of the contributing height maps wherein a point must be valid in order to produce an averaged point. This control is used to reject dropouts in some of the contributing height maps so the final averaged height map is not missing data.

This control determines what to do with a dropped pixel in one of a series of acquisitions when averaging is used. A setting of 100 means that pixels must be present in all acquisitions or they are dropped in the final data map. A lower value means that all acquisitions do not have to be complete in order to be passed to the final data map.

When Measurement Mode is DynaPhase the recommended setting is 75.

Smart Averaging

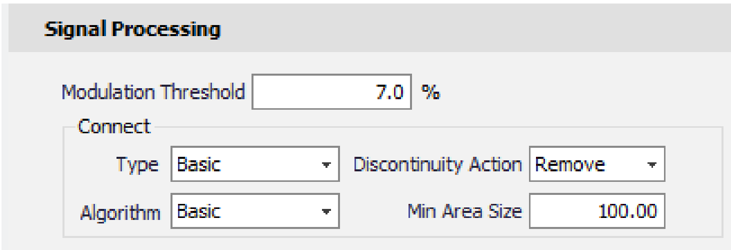
Smart Averaging (also known as SmartAveraging) performs repeated acquisitions until the specified convergence criteria are met.



Threshold	Specifies an RMS value that triggers an end to data acquisition. This control works in tandem with the Threshold Window control.
Time Limit	Specifies the length of time to acquire data.
Window	Specifies the number of continuous acquire/average sequences that the RMS value of the Spatial Deviation map must fall below the user-specified RMS Threshold before ending data acquisition. This ensures that the RMS value has stabilized. Default is 5.
Remove	Specify low-order form to be removed from individual acquisition results before computing the average result. Use to reduce the effects of rigid-body motion.
Delayed	When selected, adds a specified time interval between each averaged acquisition. This feature is only supported for DynaPhase measurements. Delayed averaging is useful when measuring in an environment with cavity disturbances (such as air turbulence) that are slowly moving (with respect to the camera frame rate). By introducing an appropriate Interval the local cavity variances are better dispersed over the number of averaged frames producing faster convergence to a measurement representing the undisturbed cavity. Properly setting the Interval control requires observing the cavity to determine the rate at which the disturbance moves through the imaged cavity interferogram.
Start Delay	Specifies a time delay in seconds *before* performing the averaging sequence
Interval	Specifies a time delay in seconds between each averaged acquisition.

Signal Processing

These controls determine the technique and algorithms used to capture the raw signal from the instrument. They are located in the Measurement Setup panel.



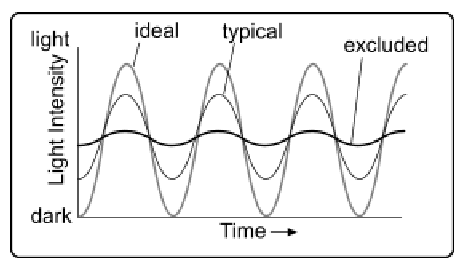
Modulation Threshold

Specifies the percent of modulation necessary for a valid data point. The term modulation refers to the change from light to dark as the phase of the interference pattern is shifted. A low value (under 15%) will include areas with lower fringe contrast, but decreases the signal-to-noise ratio. Rough surfaces, surfaces with high slopes, or surfaces producing low fringe contrast fringes, will have points that do not modulate as well; thus a lower percentage allows more points to pass as valid data points. A high value (above 15%) will exclude areas that don't modulate enough. In previous versions of software this control was called Min Mod (%).

Full modulation is represented internally in the instrument as an intensity range, which is based on the instrument hardware. When modulation occurs over less than a minimum portion (or percent) of this range, the data is considered invalid. During a measurement, the light intensity at any given camera pixel varies (or modulates) from light to dark as the phase of the interference pattern is shifted. Modulation Threshold sets the acceptable intensity range or minimum modulation necessary for data.

Modulation relates to the signal-to-noise ratio and repeatability. The greater the modulation of each data point, the higher the signal-to-noise ratio and the better the repeatability. As the modulation decreases, the lower the signal-to-noise ratio and the worse the repeatability. When modulation is low it is hard to obtain usable data from the test part.

The drawing represents the modulation of three data points over time. Each sine wave is the signal from a given camera pixel when the PZT's are ramping. Ideal modulation is when the light intensity of each data point varies from zero to maximum. Typically, the light intensity from each data point does not have ideal contrast. When the modulation is insufficient, the data point is excluded.



Connect Controls

Connect is the process of converting raw phase data to a map representing the test part.

Type	Selects the technique used to connect isolated data regions. Choices are Basic (default) or Spider. *Basic*- Uses all data when determining how areas are interrelated. *Spider*- Looks at isolated regions and the underlying form to connection regions. This is for surfaces divided by radial legs, such as that caused by a part fixture in the field of view. Surface form at the edge of disjointed regions is assumed to represent the form between the regions. As separation of regions increases, so does the likelihood that the form error in one region becomes uncorrelated to the form error in the adjacent region. Large edge effects may interfere with the estimation of the underlying form of each region.
Algorithm	Selects which algorithm is used to connect data. Options are Basic (default) or Noise Tolerant. Noise Tolerant is a slower, but more forgiving algorithm, when the acquired data has spikes, jumps, or a general roughness that may result with measurement conditions resulting in a low signal-to-noise ratio. In these conditions using this noise tolerant connect algorithm may result in fewer data discontinuities or dropouts. This setting generally provides more reproducible data sets for noisy surface profiles.
Discontinuity Action	Selects how discontinuities or ambiguous data is handled, when Measurement Mode is PSI. A discontinuity occurs when very steep pixel-to-pixel slopes or steps greater than half the wavelength of the light source are found in the data. Missing data in plots may indicate discontinuities. *Remove*- Areas or regions that have discontinuity are removed. This setting is useful when the test part has hundreds of separate discontinuous areas of data, in which some of these areas may have discontinuities. In this case, areas with discontinuities are removed and the analysis continues. However, with a typical test part comprised of one area of data with a few discontinuities, the entire area is eliminated and the connect process fails. *Ignore*- Data is checked for discontinuities, but they are not removed.
Min Area Size	Specifies the smallest area in pixels to include when connecting data. Areas smaller than this size are deleted from the dataset.

Interf Scale Factor

The Interf Scale Factor control is available in the Angles and Corner Cube measurements. This section provides additional details.

Interferometers function by dividing a wavefront into two or more parts, principally a reference wavefront and a test wavefront, which travel different paths and then combine to form an interference fringe pattern. The geometrical properties of the interference fringe pattern are determined by the difference in optical path traveled by the recombining wavefronts.

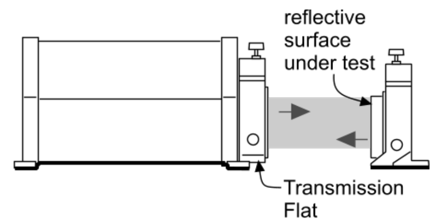
The interferometer receives as input information from the test wavefront. It cannot tell whether this wavefront has traveled through a window, reflected from a surface, what angle it has reflected from a surface, etc. The Interf (Interferometric) Scale Factor specifies how this input wavefront error (read directly from the fringe pattern as one wavelength per fringe) is scaled to properly represent the output parameters which the user wants to display in the results. The default setting is 0.5.

Why a default Interf Scale Factor of 0.5?

Consider the specific example of a wavefront reflecting off of a surface. This is exactly what happens in the setup of normal incidence, double pass testing of a flat surface.

For this setup, users often want to see results of the surface errors, not the reflected wavefront error that is being directly measured via the fringe pattern. They are different by a factor of 0.5.

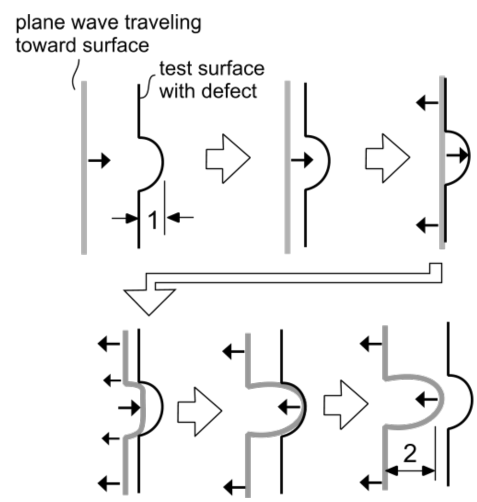
Measuring Surface Form Error



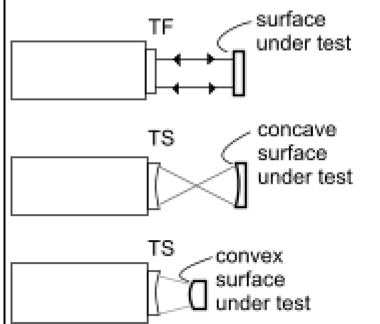
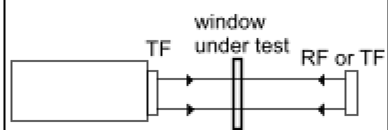
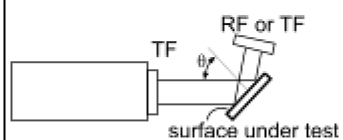
Let's examine what happens when a perfect plane wave is incident on a test surface, which has a defect 1 unit deep.

The wavefront hits the flat portion of the surface first; while part of the wavefront continues to travel into the defect the rest of the wave has already reflected off of the "good" portion of the surface and is traveling back toward the interferometer. By the time the center of the wave has reached the deepest part of the defect, the majority of the wave has traveled 1 unit away from the flat portion of the surface. As a result the returning wavefront has a defect that is 2 units deep, even though the surface defect is only 1 unit deep.

Plane Wavefront Incident on Test Surface



The following table shows some common Fizeau test setups and the appropriate Interf Scale Factor as based on the desired results. In the diagrams and text, TF refers to transmission flat, TS to transmission sphere, RF to reference flat, and normal incidence is when the laser beam is perpendicular to the surface under test.

Description	Example Test Diagrams	What shows in results	Interf Scale Factor
Fizeau double-pass, normal incidence, one reflection from test surface		surface form error reflected wavefront error	0.5 1.0
Fizeau double-pass, transmission through window		double-pass transmitted wavefront error single-pass transmitted wavefront error	1.0 0.5
Fizeau double-pass, incident angle è on test surface, two reflections from test surface		reflected wavefront error at angle theta (è) surface form error at angle theta (è)	1/2 cos è 1/4 cos è

Auto Null/Tilt

Auto Null and Auto Tilt controls are located in the Measurement Setup panel.

Auto Null

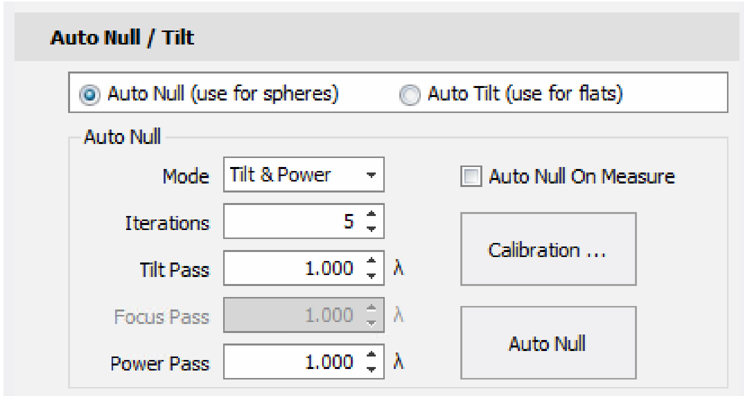
- Instruments equipped with motorized x, y, and z axes can Auto Null the fringes when measuring a spherical part (radius scale).
- A quick, non-displayed base measurement is made to determine the existing focus, power, and tilt before making any adjustments.
- Applies to laser interferometers.
- Requires motorized x, y, and z stages.

Using Auto Null

Auto null requires an instrument equipped with motorized programmable x, y, and z stages. Auto null is used when measuring the radius of curvature. In summary, auto null uses the calibration factors to minimize the amount of tilt, power, or focus so they are less than or equal to the pass limits. The z-axis is moved to minimize the amount of focus or power as selected by the Mode control; the x and y axes are moved to minimize the amount of tilt.

The auto null function works best when:

- Measuring many similar spherical parts.
- Using a secure and repeatable part fixture.



Mode

Selects how the auto null routine is performed. Options are: Tilt, Focus, Power, Tilt & Focus, or Tilt & Power. Note that when at catseye, the tilt component of the Mode control is ignored so there are two effective options: Focus and Power.

Tilt nulls the part based on TiltMag (Z).

Focus nulls the part based on FocMag (Z).

Power nulls the part based on Power.

Tilt & Focus nulls the part based on both TiltMag (Z) and FocMag (Z).

Tilt & Power nulls the part based on both TiltMag (Z) and Power.

For definitions of the (Z) parameters see Seidels.

Iterations

Specifies the number of tries the auto null function should attempt when correcting the part's position for null. 10 is the default setting.

Tilt Pass

Specifies the minimum TiltMag (Z) value that auto null should achieve before considering the part nulled. Required entry for auto null.

Focus Pass

Specifies the minimum FocMag (Z) value that auto null should achieve before considering the part nulled. Required entry for auto null.

Power Pass

Specifies the minimum Power values that auto null should achieve before considering the part nulled. Required entry for auto null.

Auto Null On Measure

Select to perform auto null as part of the measurement. Clear to disable Auto Null.

Calibration ...

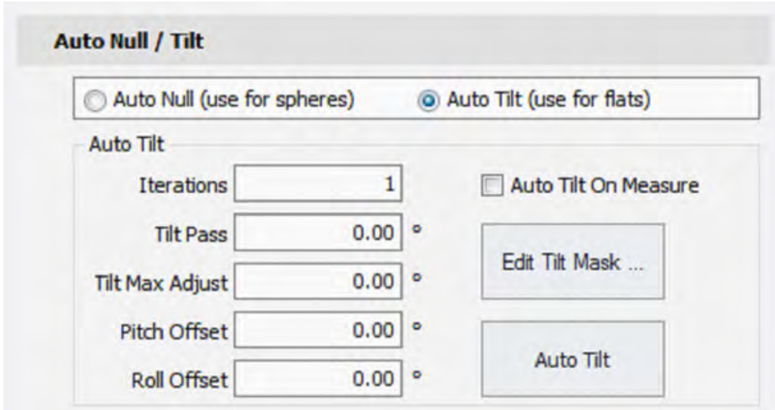
Click to open the Auto Null Options dialog with options for calibration.

Auto Null

Click to perform an auto null adjustment based on the current settings of the auto null controls.

Auto Tilt

Auto tilt requires an instrument equipped with motorized programmable pitch and roll stages. Auto null is used when measuring flat parts. The pitch and roll axes are moved to minimize the amount of tilt.

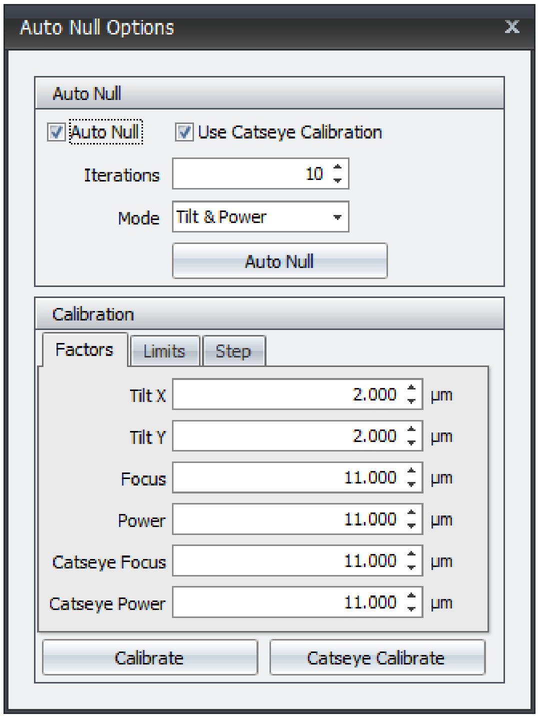


Iterations	Specifies the number of tries the auto tilt function should attempt when correcting the part's position for null. 10 is the default setting.
Tilt Pass	Specifies the minimum TiltMag (Z) value that auto null should achieve before considering the part nulled. Required entry for auto null.
Tilt Max Adjust	Limits the maximum tilt adjustment that is allowed.
Pitch Offset	Use to specify a target pitch for the test part. Enter zero for null.
Roll Offset	Use to specify a target roll for the test part. Enter zero for null.
Auto Tilt On Measure	Select to perform auto tilt as part of the measurement. Clear to disable Auto Tilt.
Edit Tilt Mask …	Click to define a region of the test part over which auto tilt will be performed. Opens a Mask Editor.
Calibration …	Click to open the Auto Null Options dialog with options for calibration.
Auto Tilt	Click to perform an auto null adjustment based on the current settings of the auto null controls.

Auto Null Options

To access advanced auto null settings:

1. Open the Measurement Setup panel.
2. Go to the Auto Null/Tilt controls.
3. Click Calibrate...



Some of these controls are the same as those found the in basic auto null controls.

Auto Null Options- Auto Null

Auto Null	Select to use the auto null function. This is the same as On/Off in the basic auto null panel.
Use Catseye Calibration	When selected, it uses the catseye focus and power calibration factors to adjust Z. When cleared, the standard focus and power calibration factors are used.
Iterations	See Iterations.
Mode	See auto null Mode.
Auto Null (button)	See Auto Null (button).

Auto Null Options- Calibration (common)

Calibrate (button)	Click to initiate the auto null calibration routine and establish tilt x, tilt y, focus, and power calibration factors. This function establishes the lateral measurement resolution of each camera pixel in the instrument for the x, y, and z axes. This should be performed before using the auto null function.
Catseye Calibrate (button)	Click to initiate the auto null catseye calibration routine and establish catseye focus and power calibration factors. This function establishes the lateral measurement resolution of each camera pixel in the instrument for the z axis. This should be performed before using the auto null function.

Auto Null Options- Calibration Factors

These controls set the amount of stage movement needed to effect one wave of tilt, focus, or power in the measurement. Factors can be specified by the user or automatically entered.

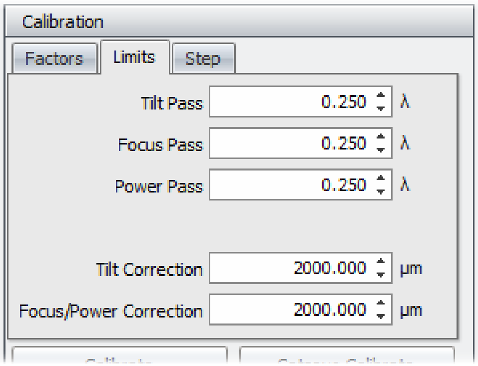
Tilt X, Tilt Y, Focus, and Power are automatically entered when Calibrate is clicked and the corresponding factor is selected.

Catseye Focus and Catseye Power are automatically entered when Catseye Calibrate is clicked and the corresponding factor is selected.

Tilt X	Specifies a calibration factor that the auto null function uses when nulling the part along the x-axis.
Tilt Y	Specifies a calibration factor that the auto null function uses when nulling the part along the y-axis.
Focus	Specifies a calibration factor that the auto null function uses when nulling the part along the z-axis based on FocMag (Z).
Power	Specifies a calibration factor that the auto null function uses when nulling the part along the z-axis based on Power.
Catseye Focus	Specifies a calibration factor, based on FocMag (Z), that the auto null function uses when nulling the part along the z-axis during a radius of curvature catseye measurement.
Catseye Power	Specifies a calibration factor, based on Power, that the auto null function uses when nulling the part along the z-axis during a radius of curvature catseye measurement.

Auto Null Options- Calibration Limits

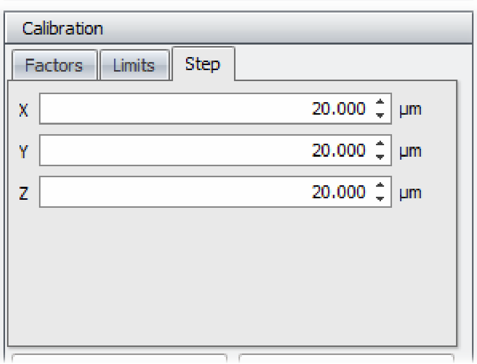
These controls specify the points or levels beyond which the auto null function cannot extend or pass. Pass controls specify passing values for tilt, power, and focus. Correction controls specify the maximum amount that tilt, focus, and power can be adjusted in single move.



Tilt Pass	See Tilt Pass.
Focus Pass	See Focus Pass.
Power Pass	See Power Pass.
Tilt Correction	Specifies the maximum lateral (x and y axes) move allowable during a single auto null iteration.
Focus/Power Correction	Specifies the maximum z-axis move allowable during a single auto null iteration.

Auto Null Options- Calibration Step

These controls determine the distance moved in each axis between auto null iterations.



X	Specifies the distance to move along the x-axis between measurements when calibrating the system for auto null.
Y	Specifies the distance to move along the y-axis between measurements when calibrating the system for auto null.
Z	Specifies the distance to move along the z-axis between measurements when calibrating the system for auto null.

User Options

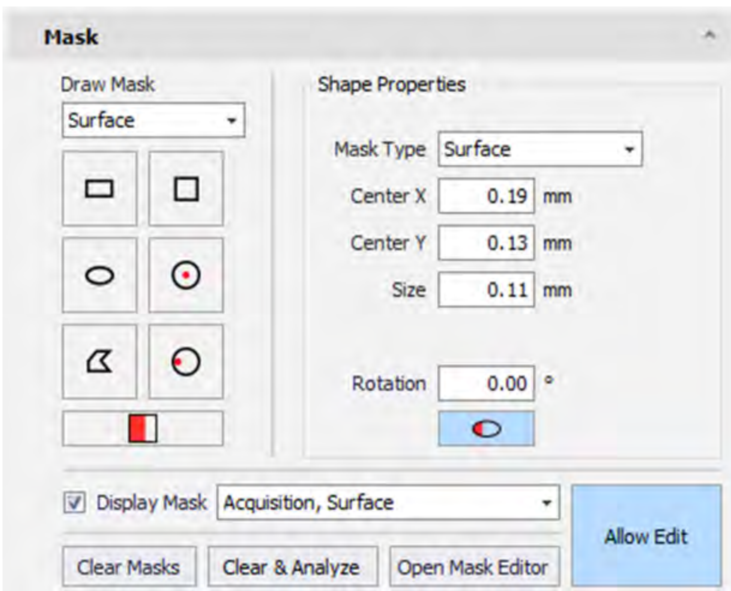
User Options are located in the Measurement Setup panel.

Here the user can add or remove *controls* as desired in the provided Control Grid. See Adding or Removing Items.

Mask

Masks can be used to restrict where data are captured or analyzed, as well as to define regions for specialized measurement types such as Angles or Corner Cube. See What is a Mask?.

The masking controls located in the Measurement Setup panel let you place and adjust masks directly within the Live Display.



Mask Controls

Draw Mask	Determines how the mask shape is applied (such as Surface or Acquisition). The choices may vary based on the selected Measurement Type.
Shapes	Click button to select the desired mask shape. Rectangle Square Ellipse Circle drawn from center Polygon Circle drawn edge to edge
Background Fill	Click to toggle the fill state of the background from include/exclude. This can be useful if you want to exclude a region of data but keep everything else.
Display Mask	When selected, mask shapes for the selected Mask Types will be overlaid on the Live Display.
Clear Masks	Clear all masks (will not automatically perform a new analysis).
Clear & Analyze	Clear all masks and perform a new analysis.
Open Mask Editor	Open the legacy Mask Editor. While generally not needed, this can be useful to access functionality not available from the in-line masking tools, such as loading and saving masks.
Allow Edit	When enabled, mask shapes can be edited in the Live Display.

Mask Shape Properties

Mask Type	Where the mask shape is applied (such as Surface or Acquisition)
Center X	The X coordinate of the shape's center.
Center Y	The Y coordinate of the shape's center.
Diameter/ Size/ Width/ Height	The size of the shape. Available selections depend on the shape type.
Rotation	The rotation angle of the shape.
Shape Fill	Click to toggle the fill state of the shape from include/exclude. Colored shapes are included.

Adding Mask Shapes

To add a mask shape do the following:

1. Select the desired Mask Type using the Draw Mask control.
2. Click the button depicting the desired shape. Options include rectangle, square, ellipse, circle (drawn from center), circle (drawn edge to edge) and polygon.
3. Start drawing the shape by left-clicking in the Live Display at the desired start location.

4. Move the mouse to until the shape is the desired size, then left-click a second time.
5. For polygons, left-click at desired positions for all but the final vertex, then right-click for the final vertex to complete the shape.

A newly drawn shape will be filled (indicating that data within this shape will be included), but this can be toggled to unfilled to exclude data within the shape.

Editing Mask Shapes

Manually Editing Mask Shapes

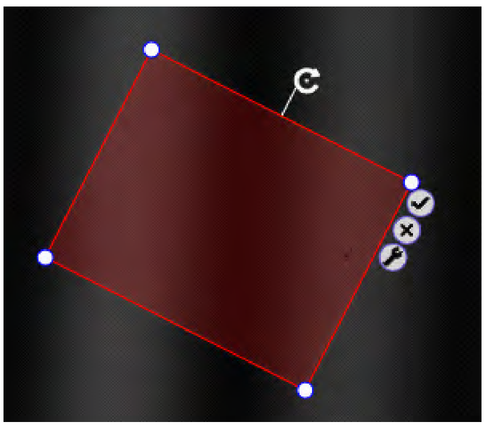
To manually edit a shape select the shape by left clicking it in the Live Display.

Using the fields under Shape Properties, change the Mask Type, change numeric values or toggle the shape fill.

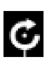
Editing Mask Shape in the Live Display

Existing mask shapes can be modified directly within the Live Display.

Left-click on a shape to display editing handles.



 Resize shape. Click and drag the desired circular handle.

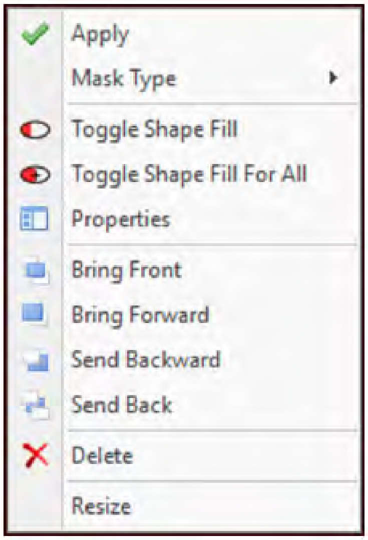
 Rotate shape. Click and drag to rotate.

 Analyze. Click to perform a new analysis based on the updated mask properties.

 Delete. Click to delete the shape.

 Edit Properties. Click to open a Shape Properties dialog to manually edit shape properties.

Shape Edit Menu

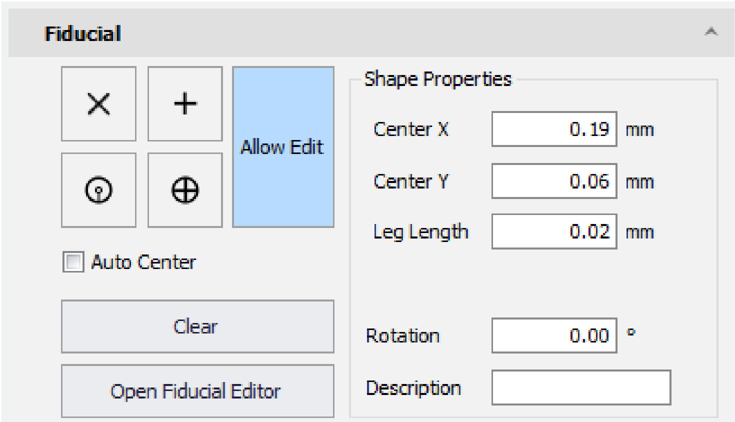


Right-click on a shape to display a menu with additional options.

Apply	Rotate the shape.
Mask Type	Change the Mask Type of the shape.
Toggle Shape Fill	Toggle the fill state of the shape.
Toggle Shape Fill For All	Toggle the fill state of all shapes.
Properties	Opens a Shape Properties dialog to manually edit shape properties.
Bring Front	Move the selected shape to the top within a stack of shapes. Use Bring Front, Bring Forward, Send Backward and Send Back to establish order of precedence with shapes of mixed fill states.
Bring Forward	Move the selected shape up one level within a stack of shapes.
Send Backward	Move the selected shape down one level within a stack of shapes.
Send Back	Move the selected shape to the bottom within a stack of shapes.
Delete	Delete the shape.
Resize	Change the size of the shape by entering a percentage in a dialog.

Fiducial

A fiducial is a reference point on the data that can assist with precise part alignment, or to compare data sets. The fiducial controls located in the Measurement Setup panel let you place and adjust fiducials directly within the Live Display.



Fiducial Controls

Shapes Click button to select the desired fiducial shape.

 X fiducial

 Crosshair fiducial

 Sight fiducial

 Circular crosshair fiducial

Allow Edit When enabled, fiducials can be edited in the Live Display.

Auto Center When selected, a fiducial added to a void in the data will automatically be centered within it.

Clear Clear all fiducials.

Open Fiducial Editor Open the Fiducial Editor. While generally not needed, this can be useful to access functionality not available from the in-line tools, such as loading and saving files.

Fiducial Shape Properties

Center X The X coordinate of the fiducial center.

Center Y The Y coordinate of the fiducial center.

Leg Length The size of the fiducial.

Rotation The rotation angle of the fiducial.

Description Optional label for the selected fiducial.

Adding Fiducials

To add a fiducial do the following:

1. Click the button depicting the desired shape. Options include X, crosshair, sight, and crosshair.
2. Add fiducials by left-clicking in the Live Display at desired locations.
3. Right-click to stop adding fiducials.

Editing Fiducials

Manually Editing Fiducials

To manually edit a fiducial, left-click on it in the Live Display.

To select multiple fiducials, hold down the Ctrl key while left-clicking.

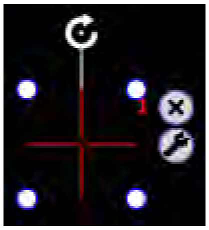
Properties can be modified by using the mouse (see below) or by changing numeric values in the Measurement Setup panel.

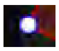
Editing Fiducials in the Live Display

Existing fiducials can be modified directly within the Live Display.

Click and drag on a fiducial to move it.

Left-click on a fiducial to display editing handles.



 Resize fiducial. Click and drag the desired circular handle.

 Rotate fiducial. Click and drag to rotate. If multiple fiducials are selected, the center of rotation is that of the minimum bounding box containing them. Holding down the Shift key constrains rotation to 15° increments.

 Delete. Click to delete the fiducial.

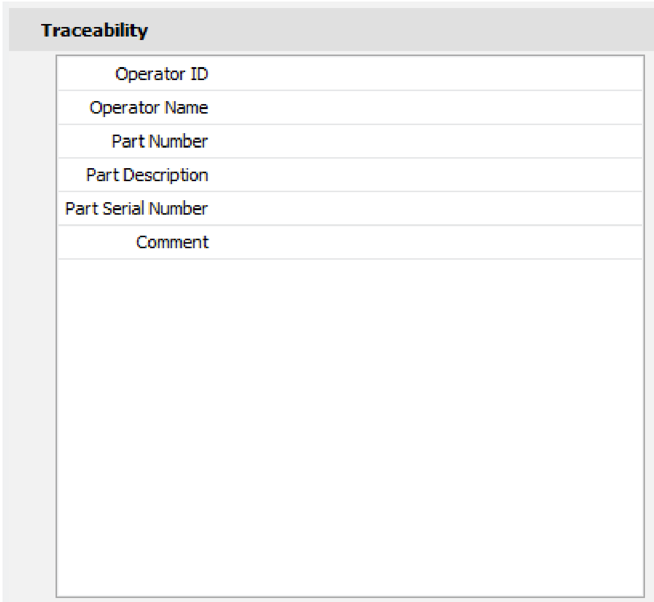
 Edit Properties. Click to open a Shape Properties dialog to manually edit shape properties.

Traceability

Traceability options are located in the Measurement Setup panel.

These controls provide entry for part and user information. They are optional.

These controls are provided in a control grid, wherein desired fields can be added or removed as desired. See Working With Grids. Available user entry and description fields include: Operator ID, Operator Name, Part Number, Part Description, Part Serial Number, Comment, Customer Name, Customer Address, Lot Number, and Measure ID.



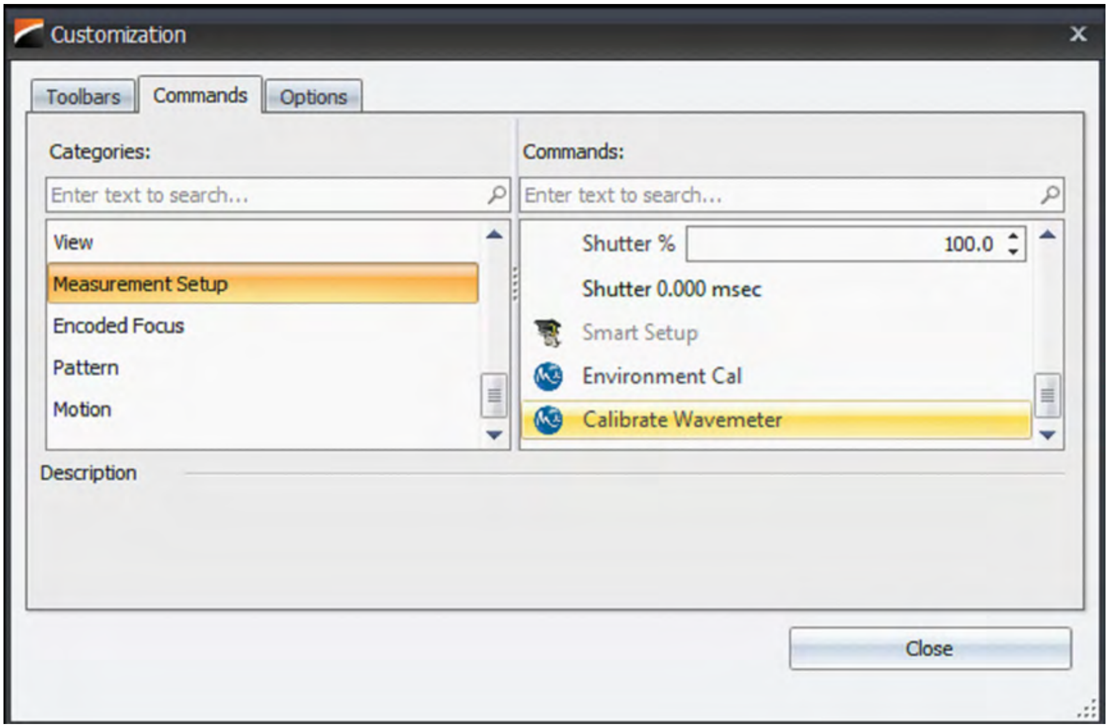
Operator ID	Used to enter identification details for the person doing the analysis.
Operator Name	Used to enter the name of person doing the analysis.
Part Number	Used to enter a part number for the item being tested
Part Description	Used to enter details about the part being tested.
Part Serial Number	Used to enter a serial number for the test part.
Comment	.Used to enter typed remarks. For example, use this field to enter a description of the test setup, customer information, list part fixtures, and record other items of interest.

Wavelength Shifting Controls

These controls and procedures are only applicable for instruments equipped with wavelength shifting hardware.

Wavemeter Calibration

All wavelength shifting systems use a wavemeter to modulate the laser wavelengths during data acquisition. The wavemeter must be calibrated before making measurements. For some older instruments, calibration is required every time power is reset to the instrument and should occur after the laser has stabilized. This function is available as a toolbar button. If it not displayed, customize your toolbar (see Customization) and add the Calibrate Wavemeter button below.

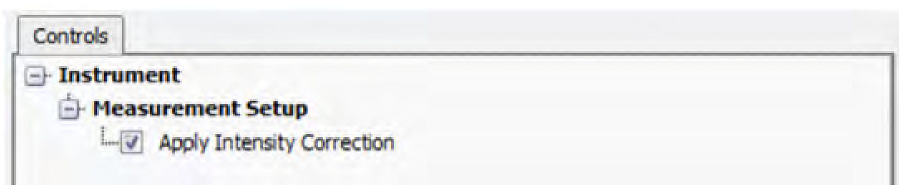


Cavity Length

To perform wavelength shifting measurements, the Cavity Length must be set to determine the excursion and rate for the wavelength shift.

Apply Intensity Correction

Intensity correction is used to improve data acquisition as the wavelength is modulated by compensating for improper intensities. It should be on for all normal usage. The associated control can be found on this path:



FTPSI Controls

These MST controls appear under the FTPSI tab and may also appear under the application's MEASUREMENT tab screen for ease of access. The controls displayed vary based on the selected Measurement Type.

Acquisition/Geometry or Acquisition/Analysis, FTPSI Controls

Total Optical Cavity Length When Measurement Type is Form, this specifies the distance between the front surface of the transmission element and the front surface of the test part.

Max OPD Specifies the maximum optical path distance.

Min OPD Specifies the minimum optical path distance.

Tuning Factor The value selected controls the length of the acquisition.

A longer scan length improves the peak isolation and surface repeatability. Better isolation improves the ability to separate multiple frequencies and signals.

Increased isolation can help improve performance in the presence of vibration, measurements with higher order signals from highly reflective surfaces, multiple surface measurements with mismatched reflectivity and fixed optical assemblies where the cavity spacing is not optimal.

For guidance, a value of 1x provides good baseline performance. For cavity setup, the value should start at 1x as a scan can take many tens of seconds with a large Tuning Factor. When the setup is complete the value should be increased as desired. If fringe print through is visible, an increased Tuning Factor may reduce or eliminate the problem. Before enabling phase averaging it is preferable to increase the Tuning Factor. A larger Tuning Factor provides all of the benefits of phase averaging and also provides improved peak isolation. Once the Tuning Factor is at the maximum, increase average count as desired.

The tuning factor control sets the desired upper limit. The system will scan as close to factor specified as possible.

Harmonic Suppression Specifies the harmonic suppression level. Settings are 2nd (default) or 3rd.

The phase analysis is based upon the first order interference frequency(s); therefore it is necessary to isolate the first order frequencies from each other and from potentially damaging higher order harmonics. When selecting 2nd, all 2nd order harmonics are sufficiently isolated from first order harmonics. When choosing 3rd order, all 2nd and 3rd are sufficiently isolated; this also requires more camera frames. The proper separation of frequencies and isolation from selected harmonics occurs due to the cavity spacing.

The two most common reasons for using 3rd are: 1) Eliminate small amplitude ripple due to third order harmonics. The measurement error due to 3rd order interference is generally not noticeable, however as the cavity reflectivities become higher; third order interference may become significant. 2) Provide additional cavity geometry spacing flexibility.

Part, FTSPI Controls

Part Thickness	Specifies the nominal physical thickness of the test part.
Part Refractive Index	Specifies the refractive index of the part being measured. It is preset to 1.50000. An appropriate index value for the actual material at the measurement wavelength should be entered. Use a standard refractive index look-up table for the test optic material.
Group Index	The refractive index varies with the wavelength of light. This calculated entry takes into consideration the changing of the wavelength during a measurement. This value is calculated when you click Calculate Group Index and enter the index of refraction for a nearby wavelength in the Group Index Calculator.

Constraints, FTPSI Controls

Min Distance TF-Front	Specifies the minimum possible distance from the transmission flat to the front of the part being measured.
Max Distance TF-Front	Specifies the maximum possible distance from the transmission flat to the front of the part being measured.
Min Distance Back-RF	Specifies the minimum possible distance from the back of the part being measured to the reference flat.
Min Distance TF-RF	Specifies the minimum possible distance from the transmission flat to the reference flat.
Max Distance TF-RF	Specifies the maximum possible distance from the transmission flat to the reference flat.

Calculated Geometry

Technically these are not controls; these are based on FTPSI control entries and are used for operator feedback.

Minimum Part Thickness	The smallest measured part thickness for accurate results based on entered part thickness.
Maximum Part Thickness	The largest measured part thickness for accurate results based on entered part thickness.
Number of Frames	The number of camera frames used to make the measurement.
Tuning Range	Tuning Range specifies the total frequency excursion that occurs during the measurement. MST uses wavelength tuning to induce a phase shift (fringe movement). This value indicates by how much the wavelength of the light source will change during a measurement, with wavelength change converted into frequency change. For example, a measurement with a beginning wavelength of 1550 nm and ending wavelength of 1554 nm corresponds to a frequency change (Tuning Range) of approximately 500 GHz.
Cavity Length TF -S1	The recommended dimension in the optical cavity between the transmission flat and the first surface based on calculated geometry.
Minimum TF -S1	The smallest recommended distance between the transmission flat and the first surface.
Maximum TF -S1	The largest recommended distance between the transmission flat and the first surface.
Cavity Length S2 -RF	The recommended dimension in the optical cavity from the second surface to the reference flat based on calculated geometry.
Minimum S2 -RF	The smallest recommended distance between the second surface and the reference flat.
Maximum S2 -RF	The largest recommended distance between the second surface and the reference flat.

For other results including Measured Geometry see MST Results.

4.3 Focus Display

- The focus display is a specialized version of the Live Display for the AccuFlat.
- It provides three tools: a fringe screen, an align screen, and a focus aid.

Focus Display Features

• Shows a live align screen. This is an image of the alignment of the test part to the interferometer.

• Shows a live fringe image of the test part. This is used as a nulling aid.

• Provides a live focus aid with a needle indicator. This ensures correct focus of the part.

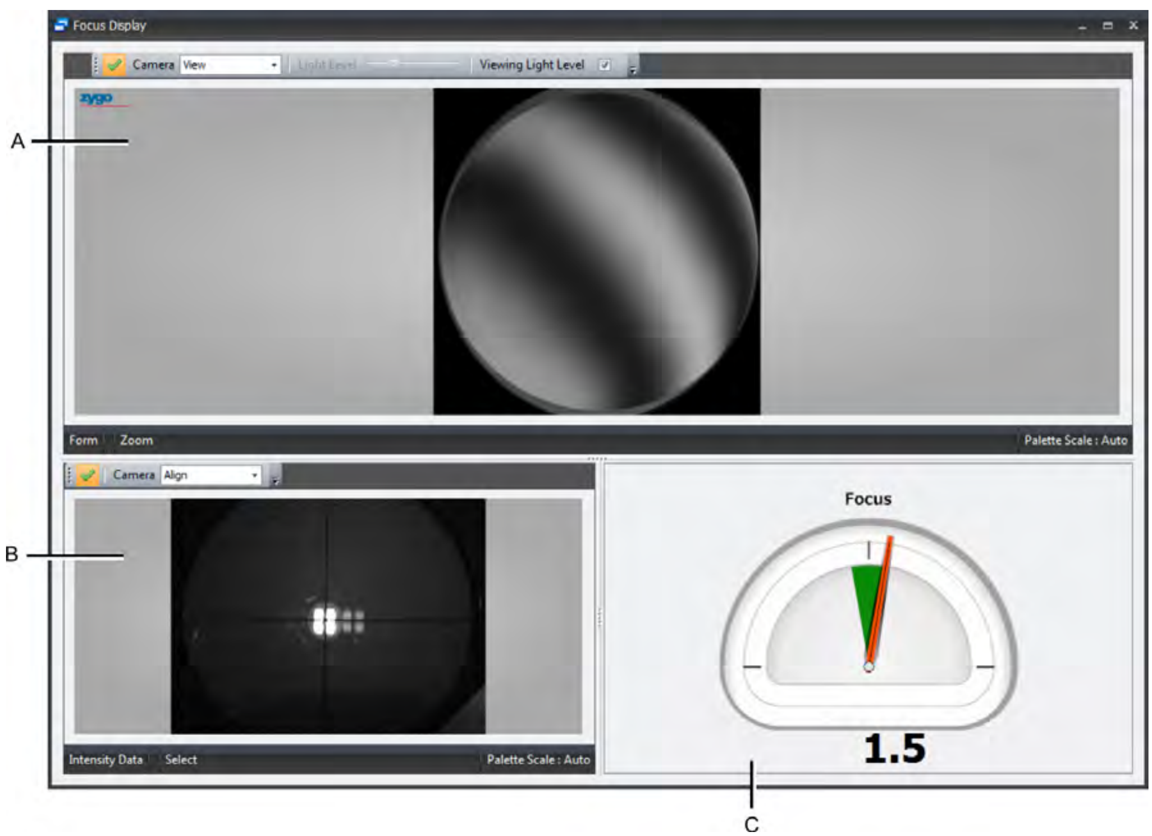
Use Conditions

- Applicable to the AccuFlat interferometer only.
- A live view of the part is only visible if an instrument is connected and working.
- The focus display window always appears in front of the main application window, but items in the application are still functional.

The Focus Display Screen

By default the Focus Display automatically opens when the application is opened.

To open a closed screen or hidden screen, on the Live Display menu, click Display.



A. Fringe screen. **B.** Align screen. **C.** Focus aid.

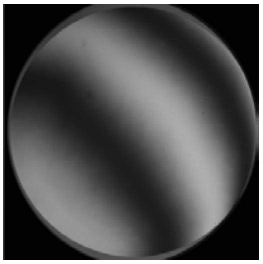
See Also

[AccuFlat Application]

[Focus Calibration]

Focus Display Details

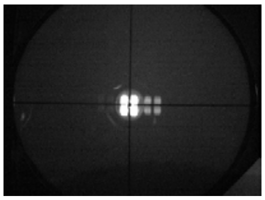
Fringe Screen



The fringe screen shows a live fringe pattern image of the test part.

This is observed when adjusting the fine tilt position of the test part to minimize the number of fringes.

Align Screen



The align screen shows a live alignment view of the relative position of the test part to the interferometer.

Adjust the part location to move the brightest set of dots into the center. This ensures that the test part surface is coincident with the focal plane of the interferometer.

The test part must be aligned to the interferometer before its tilt position can be nulled or the Focus aid can be optimized.

Focus Aid

The focus aid provides live feedback on the correct focus of the test part surface. Adjust the part location along the z-axis to move the needle into the green zone.

The number indicates relative part focus. Ideal focus is 0.0 (zero). A positive number denotes before focus (toward the instrument) and a negative number denotes past focus (away from the instrument).

4.4 Data Acquisition Details

This section provides greater details on specific laser interferometer data acquisition techniques, such as PSI, QPSI, FTPSI, and DynaPhase.

PSI

PSI stands for phase-shifting interferometry. PSI is a well established technique for obtaining metrology data under relatively stable environmental conditions.

During PSI data acquisition, the optical path difference between the reference and measurement beams in the interferometer are changed in steps of 1/8 wavelength (equivalent to introducing additional phase differences of 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315°), and the corresponding values of the intensity at each data point in the interference pattern are captured. After 13-camera frame acquisitions, the data is processed by the computer to determine the phase of the wavefront at each point when the interfering wavefronts have undergone a predetermined phase shift in relation to one another. The result is a very accurate map of the wavefront and, therefore, of the quality of the component being tested.

The shifting of the phase with the laser interferometer is done either by:

- Mechanical phase shifting, where a surface that defines the cavity (usually the reference surface) is moved, hence changing the optical path length of the cavity.
- Wavelength shifting, where the wavelength of the light is changed so that the optical path difference of the cavity, in wavelengths of light, changes.

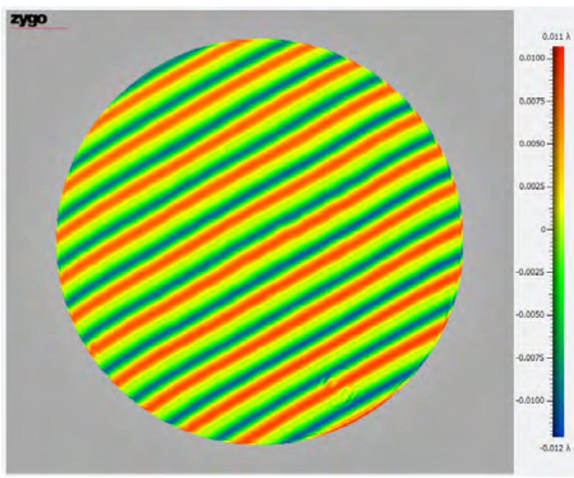
QPSI

QPSI is a vibration robust phase-shifting data acquisition algorithm. It acquires multiple frames and uses statistical analysis to minimize piston and tilt variation in the measurement cavity to optimize data integrity.

QPSI Features

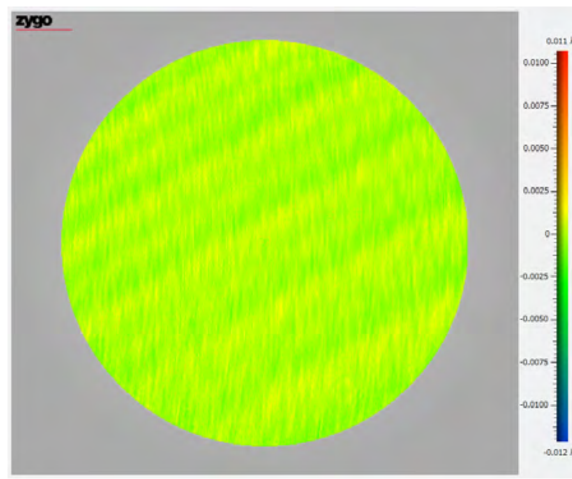
- Improves measurement performance in the presence of vibration.
- Compensates for the true rigid body motion (piston/tilt) of the measurement cavity.
- Minimal user interaction required.

Measurement Mode- PSI



Data acquired with PSI shows ripple caused by movement in the measurement cavity.

Measurement Mode- QPSI



Data acquired in the same environment but with QPSI has minimized the ripple and improved data integrity.

The color scale is the same for both plots.

QPSI Use Conditions

- Applicable to compatible laser interferometers only.
- QPSI requires licensing to function.
- Select with the Measurement Mode control.
- Use the Shutter control and averaging to optimize results.
- If a data acquisition is beyond the capability of QPSI, the screen remains blank instead of displaying questionable results.

QPSI Recommendations

QPSI measurement requires freezing the fringe images so that no “smearing” occurs in the individual intensity data frames. To achieve this, use the Shutter control. A good starting place for this is 10%.

To test for smearing, align a cavity with 4 - 6 tilt fringes, measure, and decrease the Shutter value to reduce any remaining ripple in the measurement, if needed. Short shutter values may also freeze the image of moving ground glass in the imaging system. To reduce the “streaking” effect this produces, increase the shutter value and/or increase the averaging of the measurement.

- Start with a Shutter value of 10%.
- Use averaging to improve the signal-to-noise level. A typical Number is from 10 to 30 averages.

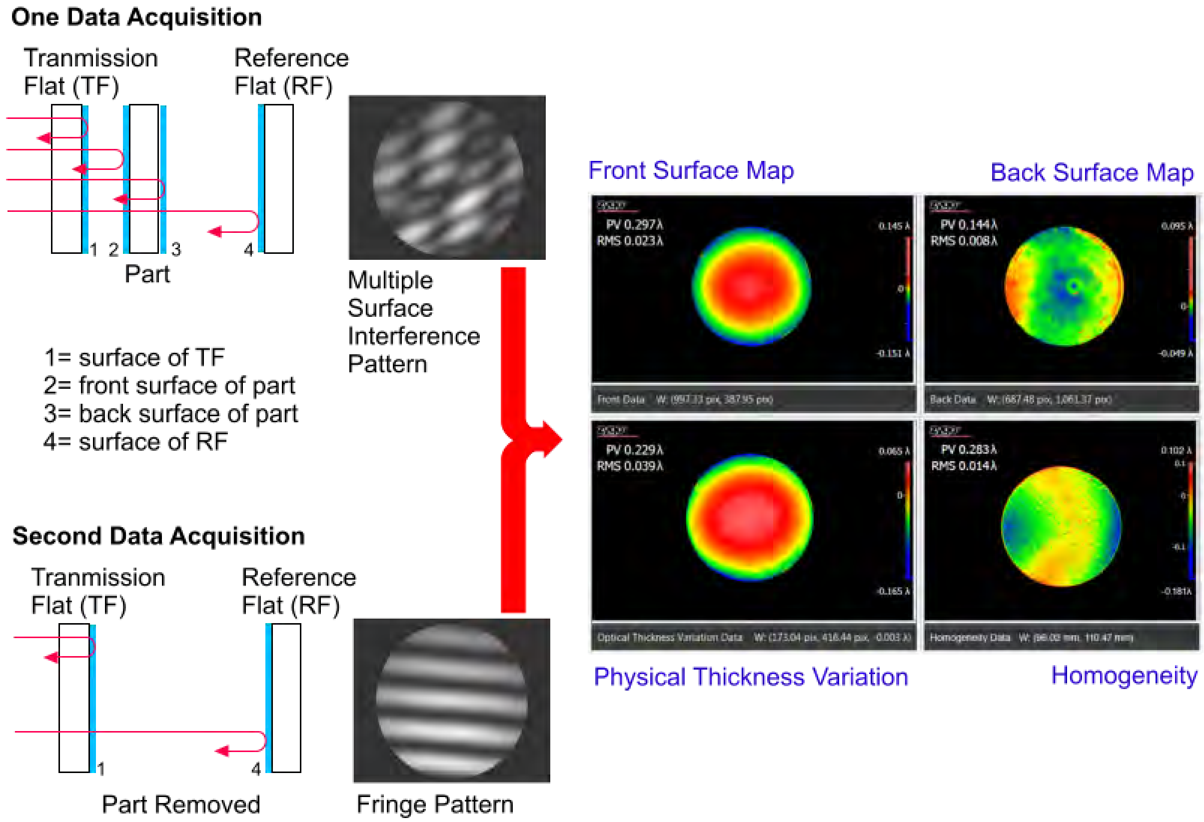
FTPSI

Fourier Transform Phase-Shifting Interferometry (FTPSI) is the next step beyond phase-shifting interferometry. FTPSI is a unique data capture and analysis technique that enables the VeriFire MST to simultaneously measure two-surface, three-surface, and four-surface cavities; in most cases with a single measurement. In one data acquisition, you can measure the front surface map, optical thickness variation, and the back surface. In two data acquisitions (one with the part in place and the second of the test cavity), you can measure front surface map, back surface map, physical thickness variation, optical thickness variation, and linear and nonlinear homogeneity.

FTPSI uses a wavelength-tuned acquisition and a complete Fourier analysis of the interferograms to extract the frequencies and phases of all optical cavities in the interferometer setup. This advanced analysis technique resolves multiple-surface interference patterns and naturally suppresses artifacts.

FTPSI Use Conditions

- Applicable to ZYGO MST laser interferometers equipped with wavelength phase shifting.
- Available only when using the MST.appx application.
- Select a corresponding multi-surface measurement with the Measurement Type control.



FTPSI- A Quick Way to Get a Large Amount of Information

With two acquisitions, the following data is available:

- front surface map (part)
- back surface map (part)
- physical thickness variation (wedge)
- optical thickness variation
- refractive index variation (nonlinear and linear homogeneity)

DynaPhase

DynaPhase™ Features

- DynaPhase is a unique data acquisition mode that captures phase data under dynamic or changing conditions.
- Typical cavity setup and alignment are similar to those used with phase-shifting interferometry.
- Based on a carrier fringe algorithm using a single frame acquisition.
- Includes in-situ self-calibration (retrace correction) of any residual rigid-body errors using the part under test and with no shape limitations.
- Provides factory calibrated correction for plano measurements.
- Provides simplified operator interaction through a "wizard".
- Allows the user to decide whether to pass the data onto data processing and analyses, or redo the measurement.

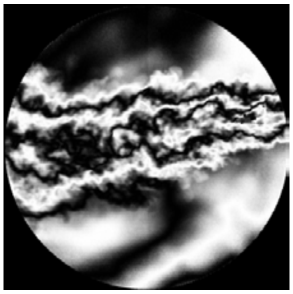
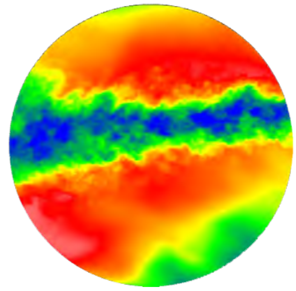


Image of test part with moving fringes.



Data captured with DynaPhase.

DynaPhase Use Conditions

- Applicable to laser interferometers only.
- DynaPhase requires licensing to function. Refer to Licensing.
- Select with the Measurement Mode control and click Measure to start the wizard.
- Lateral Calibration is recommended before measuring, since some software features require this to function. Refer to Lateral Calibrator (Laser Interferometer).
- Acquisition is optimized to accommodate measurement of a single parts (Single), repeated measurements of the same part or a series of kinematically mounted similar parts (Production), real-time viewing of phase data with Zernike coefficients (LivePhase), or acquisition of phase movies at various rates (Movie). Selected with the Measurement Options control.
- If Source Mode is set to Ring, and Ring Mode is set to Convergence, the Convergence Tool is used.

DynaPhase Use Cases

- Measure parts in a production environment without a vibration isolation table.
- Measure components on separate metrology frames, such as with vacuum based testing.
- Acquire data in setups with a long path length prone to air turbulence, such as large telescope optics.
- Resolve part features such as ripples and diamond turning marks.
- Create a movie of the phase data plot as it changes over time.

DynaPhase Controls

This control is located in the Measurement Setup panel under Measurement Mode, or in the Measurement Setup toolbar.

Measurement Options	*Single*	For measuring a single part or many different parts.
	Production	For repeated measurements of the same part, or measuring a series of similar parts that can be kinematically referenced to the first.
	LivePhase	For viewing real-time phase data with Zernike reporting for alignment and monitoring.
	Movie	For recording phase data over time to visualize dynamic measurement conditions. Creates a movie file.

These controls are located in the Measurement Setup panel under Measurement Mode.

DynaPhase Alignment

Selects which axis is adjusted in DynaPhase rough align and fine align steps. Choices are Part (default) or Reference. Sometimes the cavity setup dictates which alignment selection is valid.

> When the Measurement Options control is Production or Live, the Alignment section must be the same as that used during in situ calibration (or Single mode).

Part- The test part surface is adjusted. This includes:

- Tip/Tilt on the test surface.
- X/Y on the test surface.
- X/Y on the reference surface
  (optically equivalent to adjusting X/Y on the test surface).

Reference- Tip/Tilt on the reference optic.

Calibration Threshold

Specifies the acceptable amount of residual astigmatism after two calibration steps. The default is 10 nm. If the specified threshold is exceeded, two additional measurements are made to remove residual astigmatism.

These DynaPhase controls are available through a Control Grid. See Working With Grids.

Calibration

Selects the calibration technique used to check for residual astigmatism. Choices are Two Step, Auto (default), or Four Step.

Two Step- the calibration for residual astigmatism is based on a two step process.

Auto- checks for residual astigmatism and performs additional steps if required.

Four Step- the calibration for residual astigmatism is based on a four step process.

Power Correction

When selected (default), the measurement is adjusted for power and spherical error introduced by tilt fringes. This is particularly important when measuring flat surfaces.

Target Pixels Per Fringe

Selects the target carrier fringe frequency in pixels per fringe (PPF). This is specified in the orthogonal pixel direction.

Algorithm

Selects the DynaPhase algorithm response when capturing data. Choices are Extended (default) or Symmetric.

Extended- Captures periodic data out to 0.7 Nyquist (when Actual Pixels Per Fringe = 4) with an assymetric response to periodic features beyond 0.5 Nyquist (where small amplitude periodic surface features repeat every 4 pixels).

Symmetric- Captures periodic data out to 0.6 Nyquist (when Actual Pixels Per Fringe = 4) with a symmetric response to periodic features. Use of this algorithm may be appropriate if RMS wavefront repeatability below 0.5 nm RMS is required.

DynaPhase Setup Guide

General Setup Guidelines

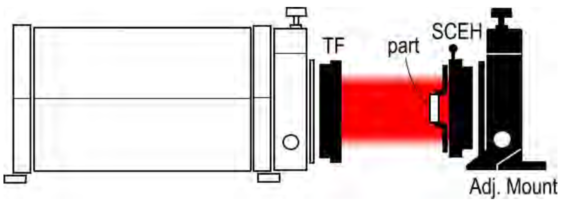
- In some setups, either the test part or reference optic can be adjusted.
- Always minimize cavity length when possible.
- Some setups may have slight edge truncation (data clipping at the edge).

Abbreviations for accessories used in the setup drawings

TF transmission flat	RF reference flat	SCEH self centering element holder
TS transmission sphere	RS reference sphere	

Surface Flatness

Measure the overall flatness of a test part.



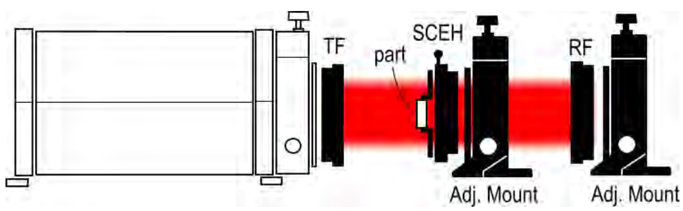
DynaPhase Alignment: Part (all cavity lengths) or Reference (cavities shorter than 500 mm only).

Interferometer focus: Surface under test.

Notes: For long cavities- 1) tilting the part may vignette the measured aperture if large enough, and 2) tilting the reference will decenter the detected illumination.

Plano Transmitted Wavefront

Measure the transmitted wavefront quality of an optic or lens.



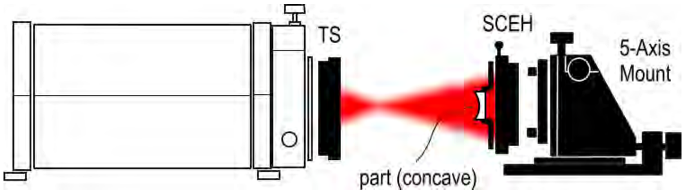
DynaPhase Alignment: Part (all cavity lengths) or Reference (cavities shorter than 500 mm only).

Interferometer focus: reference flat.

Notes: For long cavities- 1) tilting the part may vignette the measured aperture, and 2) tilting the reference will decenter the detected illumination.

Concave Surface Figure

Measure the surface quality of a concave part.



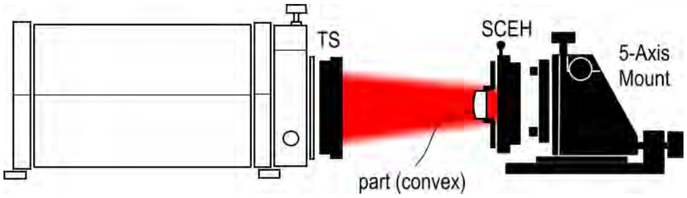
DynaPhase Alignment: Part.

Interferometer focus: sphere.

Notes: For TS f/1.5 or faster, adjust either part X/Y or reference X/Y (if TS is mounted in an X/Y mount – not standard). For TS f/3.3 or slower adjust part X/Y. The greater the mismatch of the TS radius to the part radius, the greater the edge truncation.

Convex Surface Figure

Measure the surface quality of a convex part.

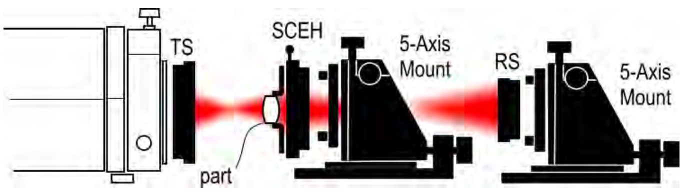


DynaPhase Alignment: Part.

Interferometer focus: sphere.

Notes: For TS f/1.5 or faster, adjust either part X/Y or reference X/Y (if TS is mounted in an X/Y mount – not standard). For TS f/3.3 or slower adjust part X/Y. The greater the mismatch of the TS radius to the part radius, the greater the edge truncation.

Finite Conjugate Lens Test

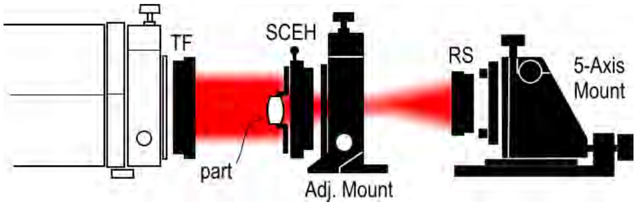


DynaPhase Alignment: Part.

Interferometer focus: on clear aperture of part.

Notes: For TS f/1.5 or faster, adjust either part X/Y or reference X/Y (if TS is mounted in an X/Y mount – not standard). For TS f/3.3 or slower adjust part X/Y. Use longer radius reference spheres to minimize wavefront shear and edge truncation.

Infinite Conjugate Lens Test

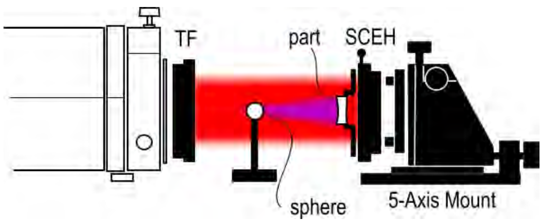


DynaPhase Alignment: Reference.

Interferometer focus: on clear aperture of part.

Notes: Adjust TF reference Tip/Tilt. Minimize long cavities as tilting the reference will decenter the detected illumination.

Parabola Surface Figure

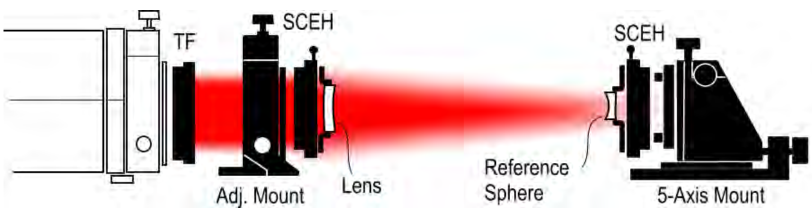


DynaPhase Alignment: Reference.

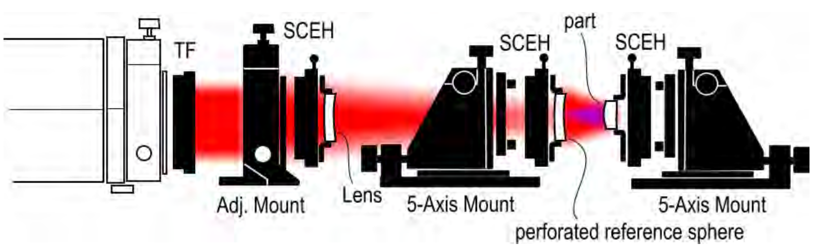
Interferometer focus: minimize diffraction near parabola surface.

Notes: Adjust TF reference Tip/Tilt.

Hyperbola Surface Figure



Before making the actual hyperbola measurement, make a system reference file of the non-reference converging lens and subtract this from the measurement.



DynaPhase Alignment: Reference.

Interferometer focus: minimize diffraction near hyperbola surface.

Notes: Adjust TF reference Tip/Tilt. Alignment of a non-reference converging lens to mainframe axis is critical; use reference subtract function (or Fit Remove User Remove) to subtract converger wavefront. For long cavities- tilting the reference may decenter the detected illumination.

Making a DynaPhase Measurement

1. Mount and align a transmission element in the laser interferometer.
2. Open Measurement Setup.
3. Select DynaPhase in the Measurement Mode control or Measurement Setup toolbar.
4. Select the DynaPhase mode of operation with Measurement Options.
5 Click Measure or press F12.
6. Follow the on-screen instructions in the wizard.

The wizard is modal, which means it must be completed or canceled before you can work in the main program.

Basic DynaPhase Wizard Steps

The Align control determines whether the part or reference is adjusted. For the following procedure, DynaPhase Alignment is set to Part.

1. **Set Zoom (And Mask)**

   Set instrument zoom and define an acquisition mask (optional). For details on using the Mask Editor refer to the Mask Editor section.

2. **Calibration** (calculates residual rigid-body retrace for correction). For Dynamic Convergence see SmartAveraging Tool.

   Rough Align- adjust part tip tilt to align bright dot in green circle.

   Fine Align- adjust part tip tilt to null (minimize number of) fringes.

3. **Measurement** (measures part and provides results to review)

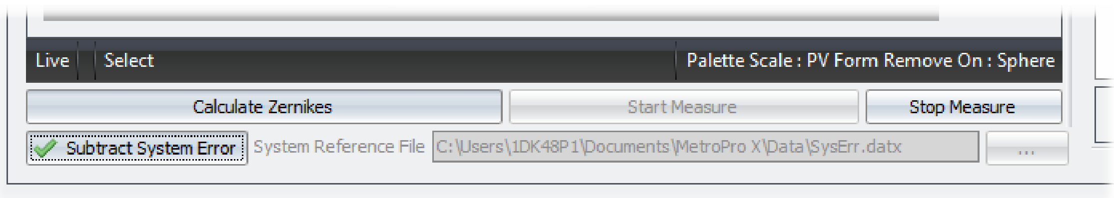
   Rough Align- adjust part tip tilt to align bright dot in green circle.

   Fine Align- adjust part tip tilt to null (minimize number of) fringes.

In the Fine Align steps, it is recommended to have less than 1 fringe of power to avoid residual spherical error in the measurement. The greater the power, the more spherical aberration is introduced into the final result, and this scales as a function of the TS f/#. The object is to null the cavity.

Subtracting System Errors in DynaPhase

- DynaPhase data acquired in either Single or Production mode can be passed onto the data stream and the system error subtracted using the Subtract tool.
- DynaPhase data acquired in either LivePhase or Movie mode can have system errors subtracted directly within the wizard.
- When the controls shown below are used in the LivePhase mode, the file selected is automatically entered in the Subtract tool.
- When a system reference file is used in the Movie mode, in the Analysis Sequence, the file is specific within the movie function only and not passed into the data stream.



1. A file cannot be loaded when the screen is being actively updated. Click Stop Measure.
2. To locate and/or browse to an existing System Reference File click ... .
3. In the dialog box, navigate to the directory location of the data file, select the file and click Open.
4. To activate the function click Subtract System Error. A check mark is displayed when on.
5. Click Start Measure.

DynaPhase Wizard Details

Navigating the Wizard

Step through the wizard with the instrument's remote control and/or by using the mouse.

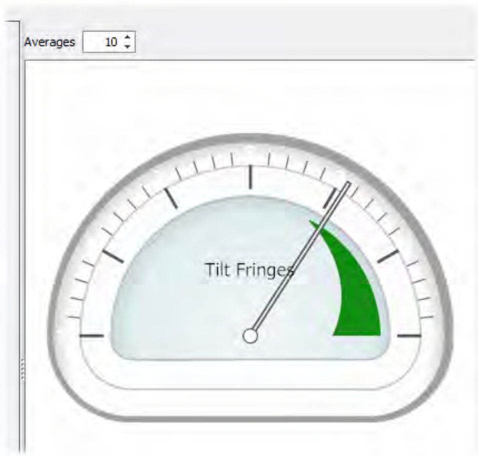
The instrument's remote control buttons can be used in the wizard.

Wizard Toolbar Controls

See the descriptions below for recommended DynaPhase settings.

Align	This is the DynaPhase Alignment control renamed. Once the choice is made, it cannot be changed after the first rough align step.
Target Pixels Per Fringe	Use to adjust the instrument signal sensitivity. Available in Rough Align steps. Specifies the carrier fringe frequency in pixels per fringe that you would like to obtain. (Actual Pixels Per Fringe is what the software does.) The default setting is 5. Recommended settings are between 4-8 PPF; 4 PPF yields highest spatial resolution for surfaces with low figure error, and 6-8 PPF may be preferred for cavities with poor contrast. Maximum is 16.
Actual Pixels Per Fringe	This is the calculated actual pixels per fringe used for acquisition. Normally this reflects the setting of the Target Pixels Per Fringe control. The next closest option is automatically selected if internal system limits prevent the targeted carrier fringe frequency. It is not meant for user entry. Available in Rough Align steps.
Modulation Threshold	Specifies the pixel modulation required for a data point to be valid. Lower the value to fill in spots where there is data dropout. However, when set too low the greater the likelihood of noise. Default is 7 and is typically a good compromise. Lower settings may be required for cavities with poor fringe contrast. Available in Fine Align steps.
Shutter	Specifies the time, as a percentage of the camera frame rate, that the image sensors are open to record the image from the test part. Available in Fine Align steps. Use to freeze fringes to prevent smearing of fringes and loss of contrast. When viewing Synthetic fringes in the Wizard, fringes washing out appear as larger blocks of no data in the synthetic fringes; lower the value until data dropout is eliminated. This is the same control in the Measurement Setup tool under Measurement Preparation.
Shutter (μsec)	This is an attribute of the Shutter control displayed in microseconds.
Light Level	The functionality varies based on the wizard step. For Rough Align steps, it adjusts the light level for the rough alignment. Move the slider to change the intensity of the return dot. For Fine Align steps, it adjusts the light level for the fine alignment, but only when the Viewing Light Level check box in Measurement Setup tool is cleared.
Store Light Setting	Click to store the light level setting for the rough align steps for the current and future measurements. This resets on software restart to the default value.

Tilt Fringes Gauge



For fine alignment steps, a Tilt Fringes meter is provided to assist you when adjusting fringes. The closer the needle is to the green, the better the null. If the gauge is always in the green, then 1/20th wave testing can be achieved.

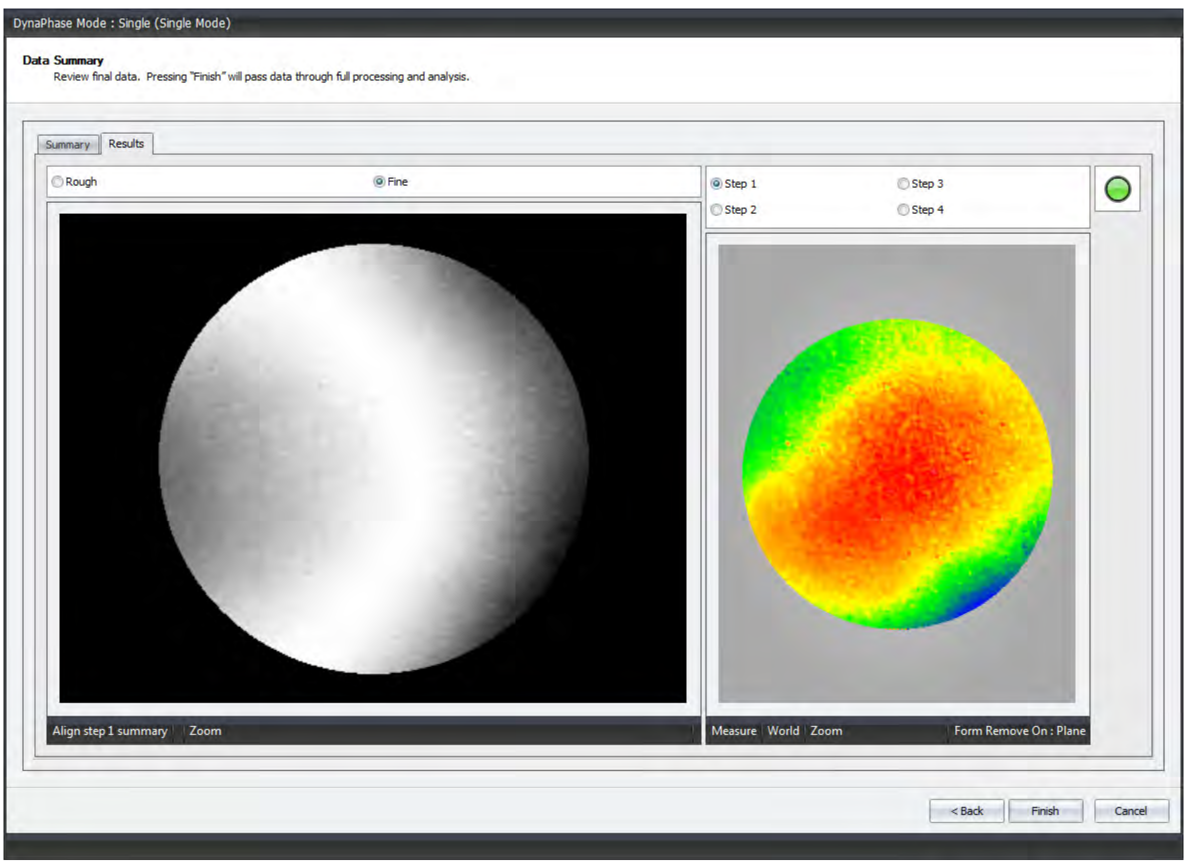
DynaPhase Tilt Averages

Selects the number of camera frames averaged for calculating tilt. The larger the number, the longer the Tilt Fringes gauge will take to refresh. A value of 10 is recommended for most applications. This aids alignment of a cavity with random motion.

DynaPhase Wizard Data Summary

The last screen in the wizard displays a data summary. This is raw height data. To view data with setup errors removed (i.e. Piston, Tilt, Power, etc.) use the local plot remove options under Details.

Click the Results tab to see greater detail. This screen is useful to help troubleshoot the measurement if required.



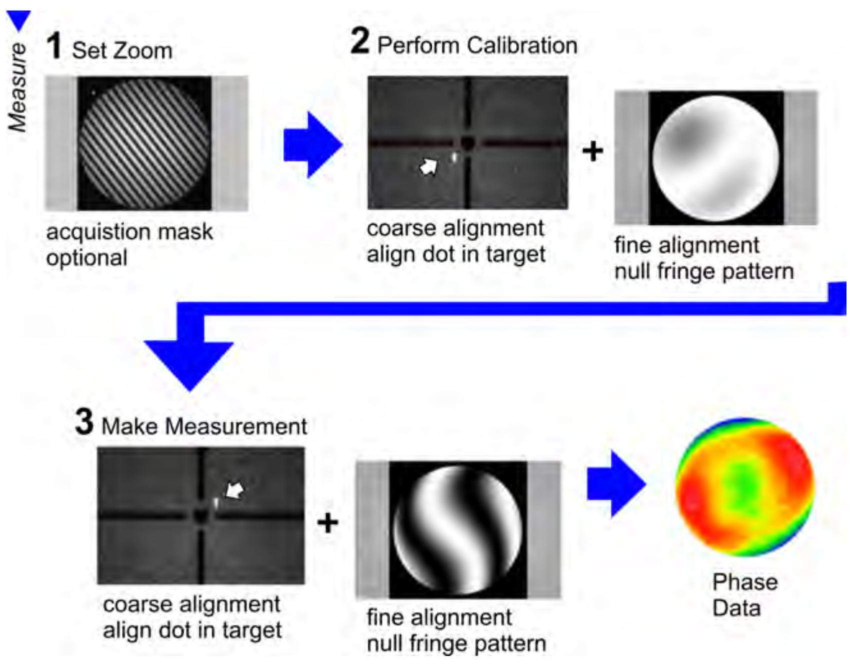
Data Summary How To	Details
Pass results to main application	Click Finish.
View a particular step	Click on the Results tab. Click Step 1 to view results from the first *Calibration* Rough or Fine steps. Click Step 2 to view results from the first *Measurement* Rough or Fine steps. Step 3 and Step 4 are only applicable if you performed a four step calibration process, otherwise the results are blank. Click either Rough or Fine above the data view to display the particular sub-step. The button indicator is green if all steps passed data sign checks.
Redo a step	Click the Back button to cycle backwards through the wizard screens. If a step is done over, the process starts over from that point forward; all steps after that point have to be redone.

DynaPhase- Single

- For measuring a single part or a series of different parts.
- Establishes a new calibration file with each cycle.
- There are 3 basic steps: 1) zoom (mask), 2) calibrate, and 3) measure.

Measurement Mode **DynaPhase**

Measurement Options **Single**



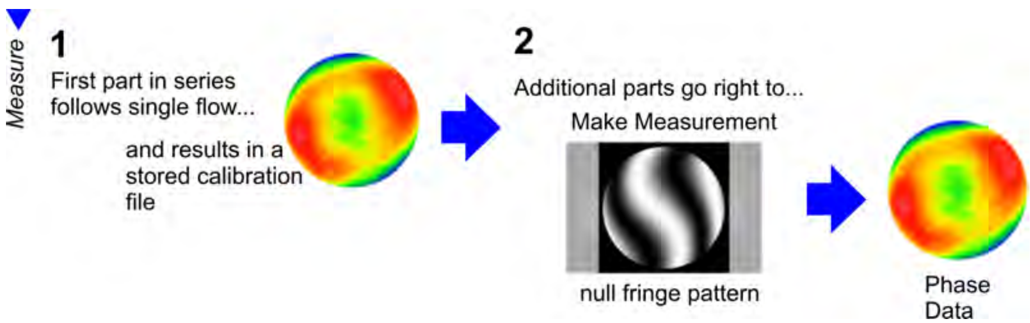
When calibration tolerance criteria is exceeded, two additional calibration steps are added to the process. Refer to Calibration Threshold for more information.

DynaPhase- Production

- For acquiring repeated measurements of the same part, or for measuring a series of similar parts that are kinematically mounted with reference to the first.
- Requires a valid calibration file.
- The first part in the series follows the steps in DynaPhase Single and creates a system reference file if a valid calibration file is not present.

Measurement Mode **DynaPhase**

Measurement Options **Production**

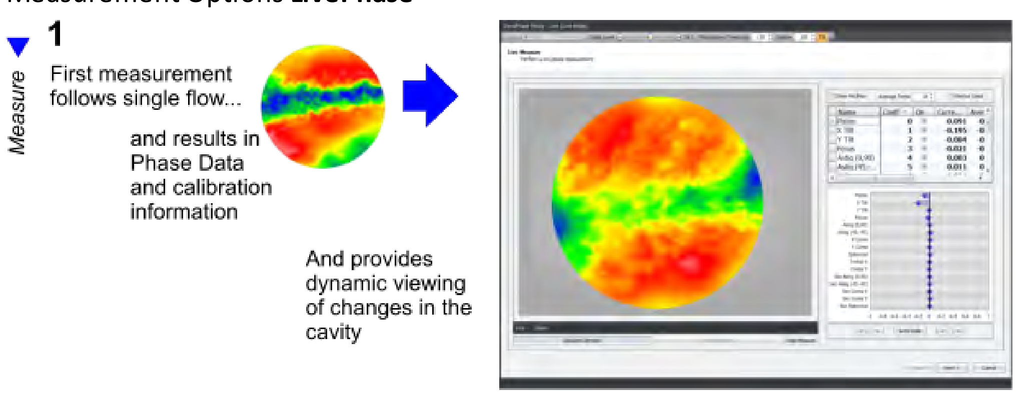


DynaPhase- LivePhase

- Use to view the effect of dynamic events on the phase data, such as environmental changes in the measurement cavity or part alignment.
- Requires valid calibration file.
- The first "live" measurement follows the steps in DynaPhase Single and retains calibration information if a valid calibration file is not present.
- Subsequent measurements display live phase data based on the calibration information.

Measurement Mode **DynaPhase**

Measurement Options **LivePhase**

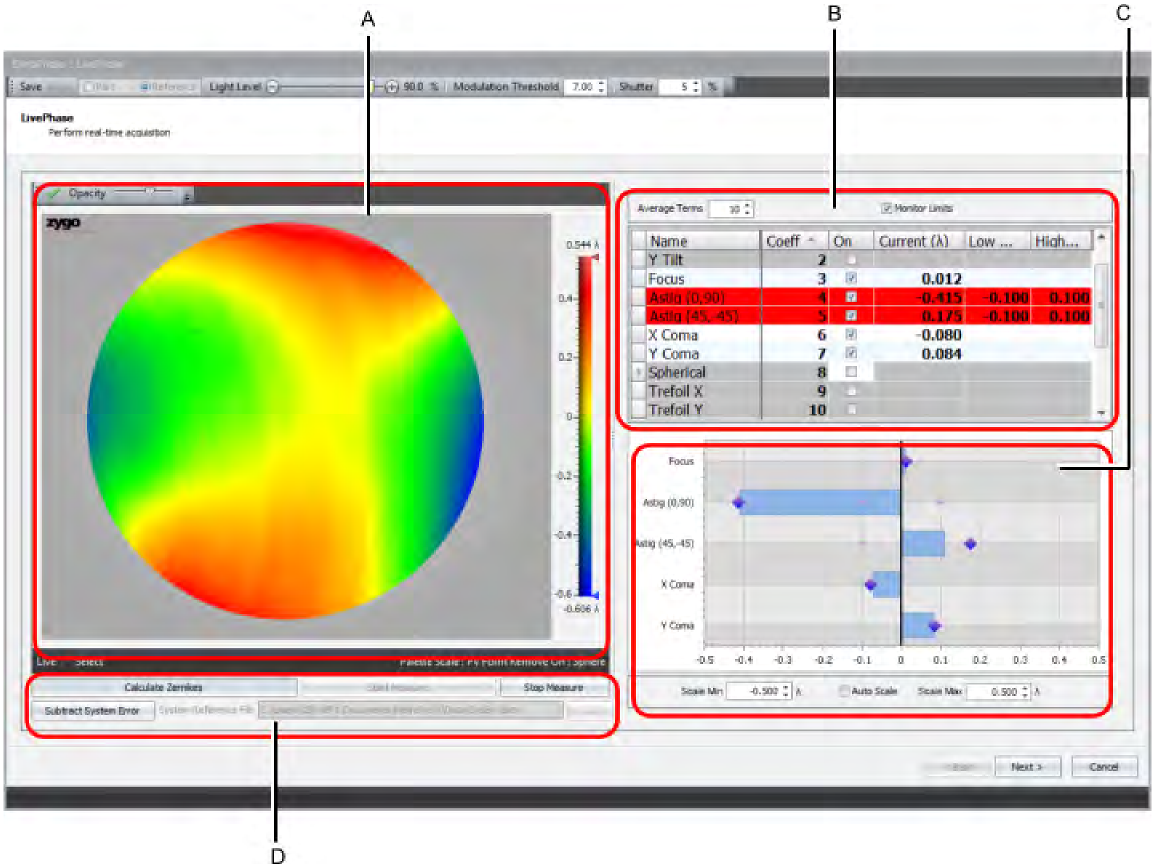


LivePhase Screen

After the LivePhase screen appears, click Start Measure.

Click Calculate Zernikes to display the configuration shown below.

Click Next if you want to take a final measurement with averaging to see a Data Summary with the option to transfer the current data into the main application.



A. Live image of phase data. (This is a regular 2D plot and can be modified by using the context menu.) **B.** Live Zernike coeff table. **C.** Live Zernike bar chart. **D.** Control area.

See Also

[Zernike Coeff Table]

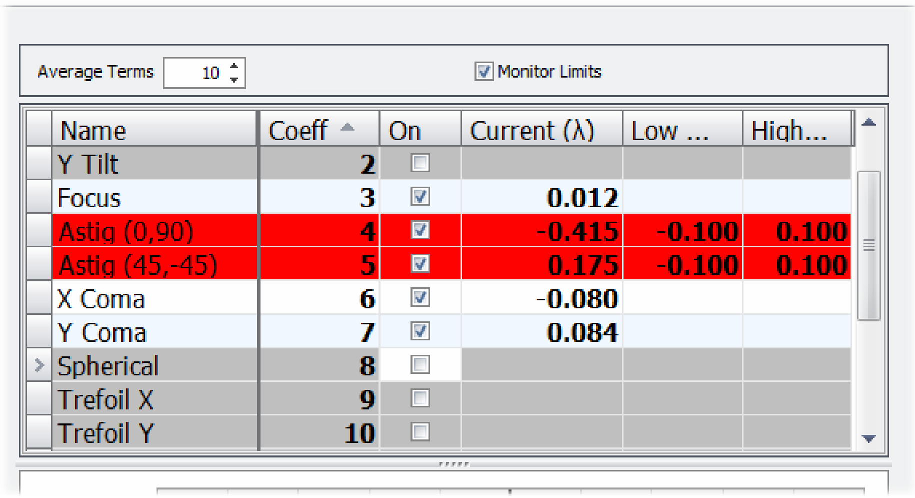
[Zernike Bar Chart]

[Subtracting System Errors in DynaPhase]

Zernike Coeff Table

The LivePhase Zernike coeff table displays the values of the selected Zernike coefficients.

- To display the Zernike table and bar chart click Calculate Zernikes in the LivePhase screen.
- Select the Monitor Limits check box to enable local tolerance monitoring of low and high limits.
- To calculate and display a given a term in the bar chart select the On check box.
- To remove active tracking from a term clear the On check box.
- To change a Low Limit or High Limit, click on the cell and enter a value.
- Red indicates that a term is outside of the specified low limit or high limit when Monitor Limits is checked.



Name	Coeff	On	Current (λ)	Low ...	High...
Y Tilt	2	☐			
Focus	3	☑	0.012		
Astig (0,90)	4	☑	-0.415	-0.100	0.100
Astig (45,-45)	5	☑	0.175	-0.100	0.100
X Coma	6	☑	-0.080		
Y Coma	7	☑	0.084		
Spherical	8	☐			
Trefoil X	9	☐			
Trefoil Y	10	☐			

Column Heading	Description
Name	The Zernike coefficient name. For information on Zernike results in the Name column, refer to Standard Optic Results.
Coeff	The Zernike coefficient term. Numbered from 0 to 15, these start with low order aberrations and progress to higher order errors.
On	Check box to activate calculation and display in the bar chart for a given term (row).
Average (not shown)	The average coefficient value (determined by Average Terms control).
Current	The current coefficient value.
Low Limit	The minimum acceptable value for a given coefficient. The default setting is (negative) -0.5.
High Limit	The maximum acceptable value for a given coefficient. The default setting is (positive) 0.5.

Coeff Table Controls

Average Terms	Selects the number of camera frames averaged for the Zernike bar chart indicator (and the Average column in the table, if displayed). A value of 10 is recommended for most applications.
Monitor Limits	When selected limits are actively monitored in the table. When limits are exceeded the row turns red. Clear the Monitor Limits check box to disable active monitoring.

Working With the Zernike Coeff Table

For general information on using tables, refer to Working With Tables.

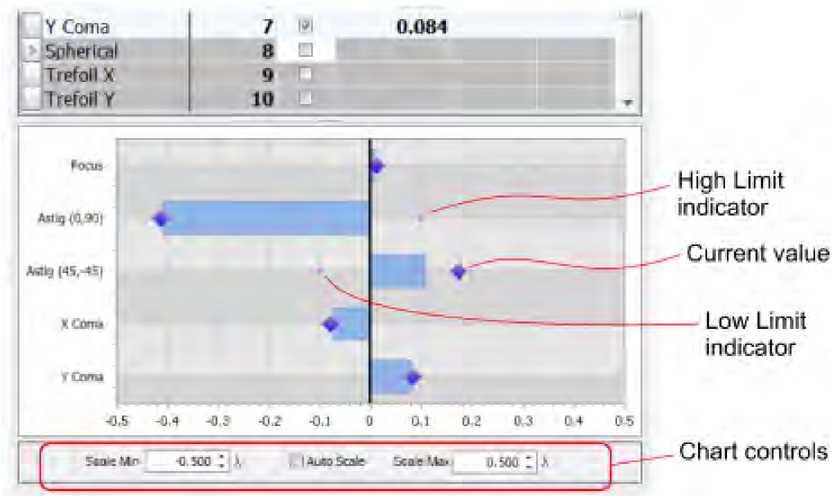
It is easier to work with the table when it is larger. To reduce the size of the 2D display panel (and make the table wider) point to the panel border between plot and the table then left-click and drag the divider.

To...	**Details**
Select Terms to Actively Update	To include a term select the On check box. To exclude a term clear the On check box.
Monitor Limits	Select the *Monitor Limits* check box. When a coefficient value exceeds a low or high limit the table row turns red.
Change a Coefficient Limit Setting	Enter low or high limit values directly in the table cell. Click the limit cell, enter a new value with the; then click on another row to set the value. Limit values can be negative or positive. When a cell is blank the corresponding limit is not monitored.
Change Units	For columns that have units, right-click the column label and choose Select Units and Precision. See Setting Individual Units.
Change the Row Order	Click on the column header to change the sorting order based on that column. A small triangle indicates the sort order.
Display or Hide a Column	Point to the column headings, right-click and select Column Chooser.

Zernike Bar Chart

The LivePhase Zernike bar chart displays the current and average values of the selected Zernike coefficients.

- To display the Zernike table and bar chart click Calculate Zernikes in the LivePhase screen.
- Displays the active terms selected in the Zernike Coeff table.
- Light blue bars indicate the averaged value (update rate based on the number of Average Terms).
- Large diamonds mark the current single-frame value.
- Small downward pointing triangles mark Low Limits.
- Small upward pointing triangles mark High Limits.



Bar Chart Controls

Auto Scale	When selected, the bar chart x-axis scale is automatically sized and shifted to display the preselected coefficient values. Clear the Auto Scale check box to fix the bar chart x-axis and activate the Scale Min and Scale Max entries.
Scale Min	Specifies the minimum value displayed on the bar chart x-axis.
Scale Max	Specifies the maximum value displayed on the bar chart x-axis.

Working With the Zernike Bar Chart

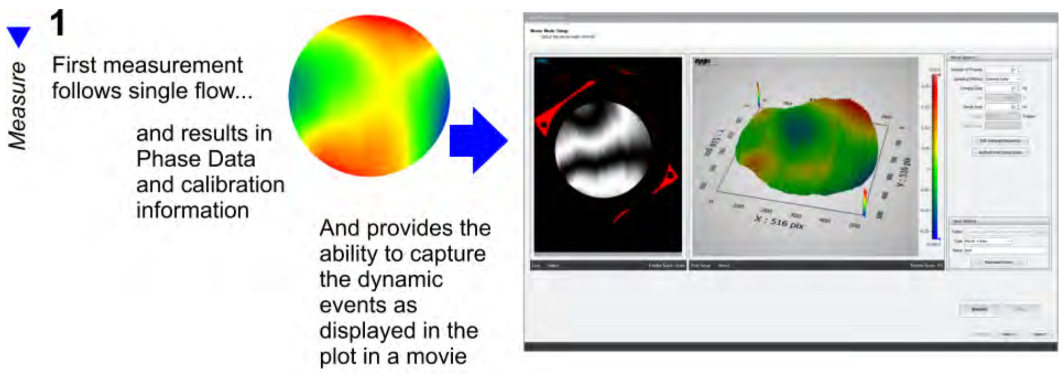
To...	**Details**
Select Terms to Display	Determined by On check boxes in Zernike coeff table. Select the On check box to include a term. Clear the check box to exclude a term.
Display Limit Markers	Small up/down triangles are displayed in the bar chart when values are entered in the Low Limits and High Limits cells.
Adjust the X-axis Scale	Clear the Auto Scale check box to turn automatic chart scaling off. Enter values in the Scale Min and Scale Max controls under the chart to set X-axis extremes.

DynaPhase- Movie

- Use to record a movie of dynamic phase plot data with user specified acquisition rate.
- The first "movie" measurement follows the steps in DynaPhase Single and retains calibration information if no calibration file is present.
- Save the phase plot data as either a movie (avi file) and a raw movie file containing all phase data (drmx file), or just a movie without raw data.
- Saved AVI movies can be viewed with Windows Media Player and other video players.

Measurement Mode **DynaPhase**

Measurement Options **Movie**

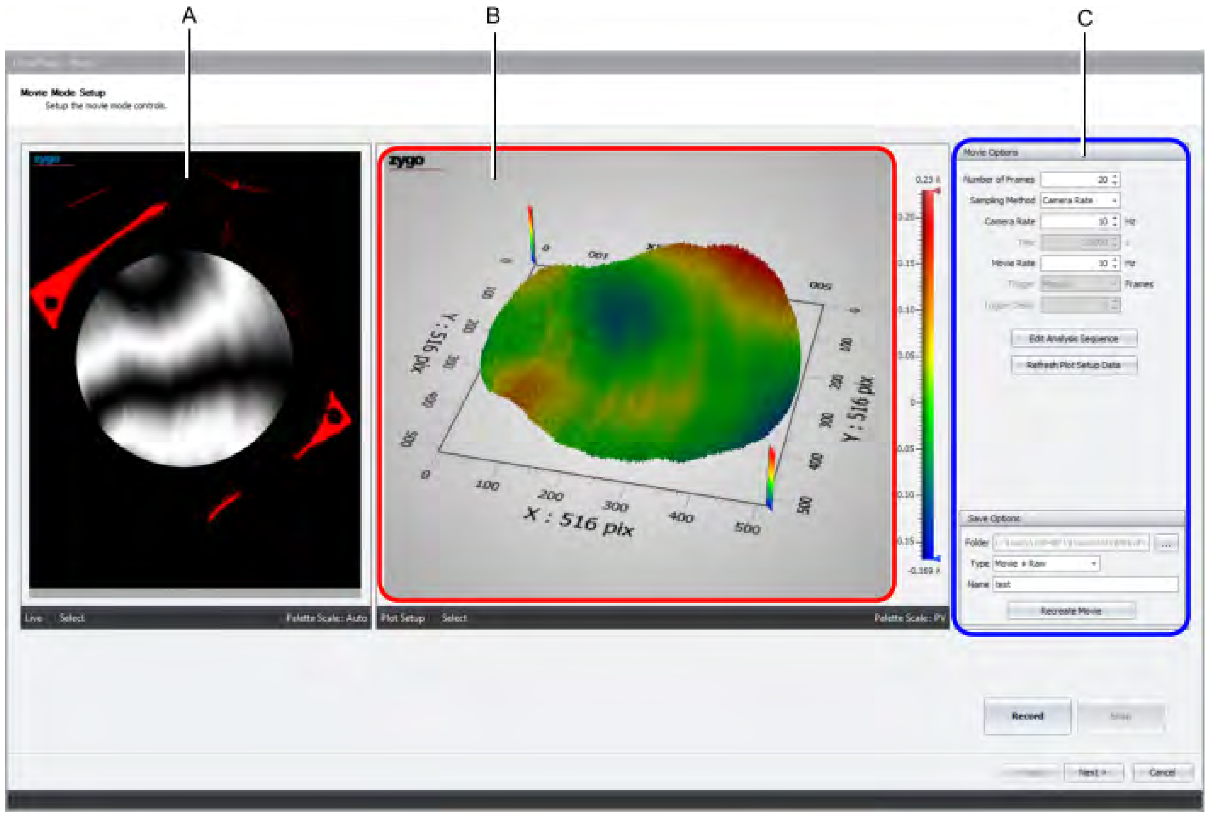


Movie Mode Screen

Set the movie and save options, then click Record to save the movie.

The area captured in the movie is the main portion of the Plot Setup (shown below inside the red box).

Click Next if you want to see a preview of the AVI movie file. Clicking Finish will not pass data into the main application. Navigate to the user specified directory to load and/or playback the movie.



A. Synthetic null intensity image of the part. **B.** Plot Setup (This is a regular 2D or 3D plot and can be modified by using the context menu.) **C.** Movie Options and Save Options.

Movie Resolution

The resolution or pixel by pixel dimension of the movie is based on the screen display. Resize the screen and plot, adjust the plot zoom, and change other plot settings as desired. What is displayed in the Plot Setup is what is captured with each frame.

Analysis Sequence Editor

Within the Movie Mode wizard, click Edit Analysis Sequence. This function uses the Data Manipulate tool to select, order, and specify the data processing performed to the phase data before making the movie.

For details see Data Manipulate.

Movie Options

Recommended Capture Timing

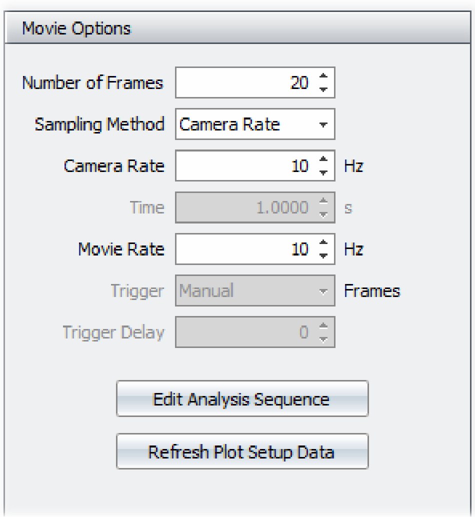
Timing [1]	Use For
> 10 Hz (0.1 sec)	Capturing motion, vibration, or natural modal frequencies of the surface/system under test.
1 Hz – 10 Hz (1 sec – 0.1 sec)	Capturing thermal phase gradients or environmental turbulence within the test cavity.
0.003 Hz – 1 Hz (300 sec – 1 sec)	Capturing slowly changing events like mount induced changes under thermal variance.

(1) Settings greater or equal to 10 Hz use precise digital timing by the camera; set the Sample Method to Camera Rate and enter a value in the Camera Rate control.

Settings less than 10 Hz are timed by software; set the Sample Method to Time and enter a value (in seconds) in the Time control.

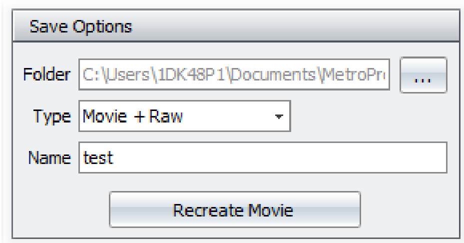
Movie Settings

The length of a movie is determined by the number of frames, the timing interval between each frame, and the playback speed. The frame capture timing interval is based either on the Camera Rate or Time.



Number of Frames	Specifies the number of frames in the movie.
Sampling Method	Selects what is used to control the data sampling. See "Recommended Capture Timing" above. Camera Rate- uses the Camera Rate setting as the interval between each phase plot capture. Time- uses the Time setting as the interval between each phase plot capture.
Camera Rate	Specifies the camera rate timing interval (in hertz) used to capture the phase plot data. A setting of 10 means 10 frames per second. The range of allowable settings is based on the instrument's camera settings. An entry beyond an allowable setting defaults to the nearest value.
Time	Specifies the time (in seconds) interval used to capture the phase plot data.
Movie Rate	Specifies the playback speed (in hertz) of the movie. A setting of 10 means 10 frames per second. The smaller this value the slower the playback. The larger this value the faster the playback.
Trigger	Selects what starts the movie recording. *Manual*- recording is started when the Record button is clicked. *External*- recording is started by an external trigger signal detected through the laser interferometer Trigger connector. Acquisition waits for the trigger signal after the Record button is clicked. This can be used to time the acquisition with an event that causes a disturbance.
Trigger Delay	Specifies how many frames to wait after the trigger input before starting movie capture; actual elapsed time is determined by the sampling method and frame rate or time interval. This can be used to delay capture after the trigger signal to avoid an impulse response that may be desirable to avoid in any further analysis.
Edit Analysis Sequence	Opens the Analysis Sequence Editor, which is used to specify and edit the data processing sequence for each frame of the movie.
Refresh Plot Setup Data	This grabs one frame and pushes the data through the Analysis Sequence, then displays it with the chosen plot setup options. It is used to refresh the plot so that you are sure what you will see when the movie is created.

Movie Save Options



Folder	Specifies the location of the folder to save movie files. To locate and/or browse to an folder click ... .
Type	Selects the type of data to save. *Select All*- saves movie, raw, and surface data during an acquisition. *Movie*- save the series of frames of the phase plot data as an uncompressed movie. *Raw*- save the underlying phase data as a .drmx file; this format allows you to change some options without recording a new sequence. *Surface*- save each frame from an acquisition as individual .datx file. The naming scheme is “Name.#.datx” where the # is the acquired frame number.
Name	Specifies the name of the movie file. The file extension is automatically added and based on the Type selection.
Recreate Movie	Click to recreate an existing movie after changing the Movie Rate (playback timing) and plot settings (such as 2D/3D, zoom, axes, colors, and resolution). This is function is only available with Movie + Raw captures. This button is enabled by pressing the Back button after viewing the preview movie or by filling in valid folder and name information for a file that already exists.

4.5 SmartAveraging Tool

- Applies to laser interferometers.
- Used to insure maximize measurement quality by tracking and displaying spatial and temporal deviation metrics of the accumulated average height or wavefront until a user-set time limit or ÄRMS threshold setting is reached, or the user ends the data acquisition.

Tool Features

- Provides visual feedback as spatial and temporal deviations in the averaged data are driven towards zero.
- The RMS threshold value (plotted in a live control chart) provides the appropriate metrics for monitoring and thresholding any spatial variances in the averaged data over extended periods of time, allowing the effects of cavity air turbulence or other thermally induced phase variations to be minimized with confidence.
- A Peak Pixel Deviation result tracks temporal changes across the averaged data, on a per pixel basis, to time-varying uncertainty. This allows the user to monitor instability and deformations that may compromise the data.

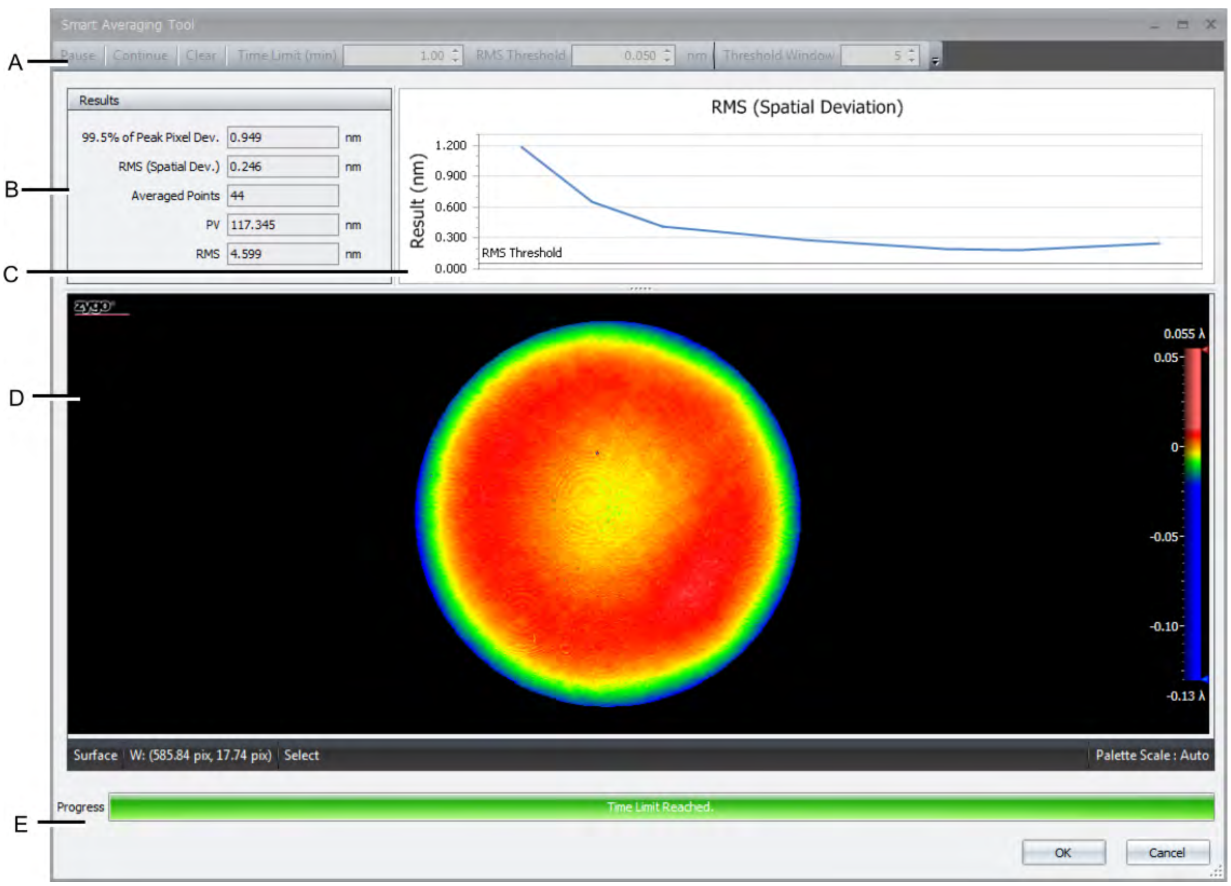
Acquisition Interaction

- Use with PSI/QPSI acquisition for precision metrology to confidently average the noise floor to a predetermined threshold or requirement. Plots and results are updated every 4 acquire/average cycles. The dynamic tool response is slower with PSI acquisition.
- Use with dynamic DynaPhase acquisition to interactively determine when you have averaged enough to eliminate the effects of turbulence or other environmental disturbances. Also use with DynaPhase acquisition to achieve the highest precision metrology in dynamic mode. Plots and results are updated every 16 acquire/average cycles.

Use Conditions

- To turn on this function, selected the SmartAveraging check box in the Measurement Setup panel.
- The SmartAveraging Tool is automatically opened during data acquisition.
- Data is acquired until either the Time Limit or RMS Threshold is met, or the user ends the data acquisition.
- This feature is compatible with CARS (Coherent Artifact Reduction System) and Ring of Fire.

The SmartAveraging Tool Screen



A. Toolbar. **B.** Interactive Results. **C.** RMS Control Chart **D.** Height Map plot. **E.** Progress bar.

See Also

DynaPhase

PSI

SmartAveraging Tool Toolbar

The toolbar appearance may vary. Point to the drop-down arrow ▼ on the toolbar to change.

These controls are grayed out until sufficient frames are captured and processed. To enter or change values, first click Pause.

Pause	Click to temporarily suspend data analysis in order to change control values. Note that data capture and buffering will continue while paused.
Continue	Click to restart data analysis after clicking Pause.
Clear	Click to clear all captured data after clicking Pause, so the process can be continued with new data.
Time Limit	Specifies the length of time to acquire data.
RMS Threshold	Specifies an RMS value that triggers an end to data acquisition. This control works in tandem with the Threshold Window control.
Threshold Window	Specifies the number of continuous acquire/average sequences that the RMS value of the Spatial Deviation map must fall below the user-specified RMS Threshold before ending data acquisition. This ensures that the RMS value has stabilized. Default is 5.

SmartAveraging Tool Results and Plots

Results and plots (including the scales) are dynamically updated as data is acquired and averaged.

SmartAveraging Results

99.5% of Peak Pixel Dev.	A single-value measurand of the time-varying uncertainty for the acquired data. 99.5% of the pixels are below the displayed value.
RMS (Spatial Dev.)	The calculated RMS of the difference between the last set of averages and all previously accumulated averages.
Averaged Points	The total number of averaged data sets.
PV	A "live" PV result.
RMS	A "live" RMS result.

SmartAveraging Tool Plots

Height Map	Displays a "live" height map of the part being measured.
RMS (Spatial Deviation) Control Chart	Tracks the calculated RMS value of the Spatial Deviation map. Each point on the chart represents a single acquire/average cycle; that is 4 averages (PSI) or 16 averages (DynaPhase). The convergence Threshold setting is indicated on the chart. As measurements are made the RMS value should drop and settle. Any spike in the plot indicates a negative influence. No further benefit from averaging is achieved when this plot reaches an asymptotic value (or levels off). See Control Chart for more details.

4.6 Using Fast Transmission Spheres

- Applies to laser interferometers.
- Applies when using "fast" transmission spheres (f/0.65, f/0.75, or f/1.5).

Background

There is a power difference between the visual null and the actual measurement null. During a measurement the sphere is moved in the z-axis. The movement starts at the static aligned position of the transmission sphere. The measurement is centered on the movement. This effect is negligible for slower cavities, but is noticeable with fast transmission spheres in demanding metrology applications.

Finding Measurement Null

The best practice when using fast spheres is to adjust null while watching the Power result of a corresponding Zernike (ZFR 3 for Fringe or ZRN 4 for Standard). The goal is to drive Power as close as possible to zero before making a measurement.

Checking Power

- Add the Power result to a Result grid in most screens or use the Zernike analysis to see the Power term.
- Make test measurements while fine-adjusting the z-axis. Use the null position with the least Power.

Optical Profiler Applications 5

An application is an arrangement of instrument specific components and software features designed to acquire and analyze measurement data. Application files have .appx as a file extension.

Applications typically have a unique navigator, menus, and toolbars. Data processing functions are structured for the specific need.

Application	Filename	Description	Features
Micro	Micro.appx	General purpose default application for optical surface profilers using coherent scanning interferometry	Specialized analyses: Slopes, Films, Regions, Material Ratio, surface texture
MicroLite	MicroLite.appx	Simplified version of the Micro application typically used with the NewView 8050 and ZeGage profilers	Simplified user interface with fewer acquisition and analysis options
MicroPPr	MicroPPr.appx	Simplified version of the Micro application specifically for use with the Nomad portable profiler	Simplified user interface with fewer calibration, acquisition, and analysis options

Default applications cannot be saved. To create your own custom version, on the File menu select Save Application As.

To specify an application to load when the program is opened see Starting With a Specific Application.

To save or load an application see Working With Files.

5.1 Micro Application

- The Micro application (Micro.appx) is a general purpose application for ZYGO optical profilers.
- Provides sophisticated data analysis features, including: PSD, Slopes, and Regions.
- Supports automation.

Micro Application Overview

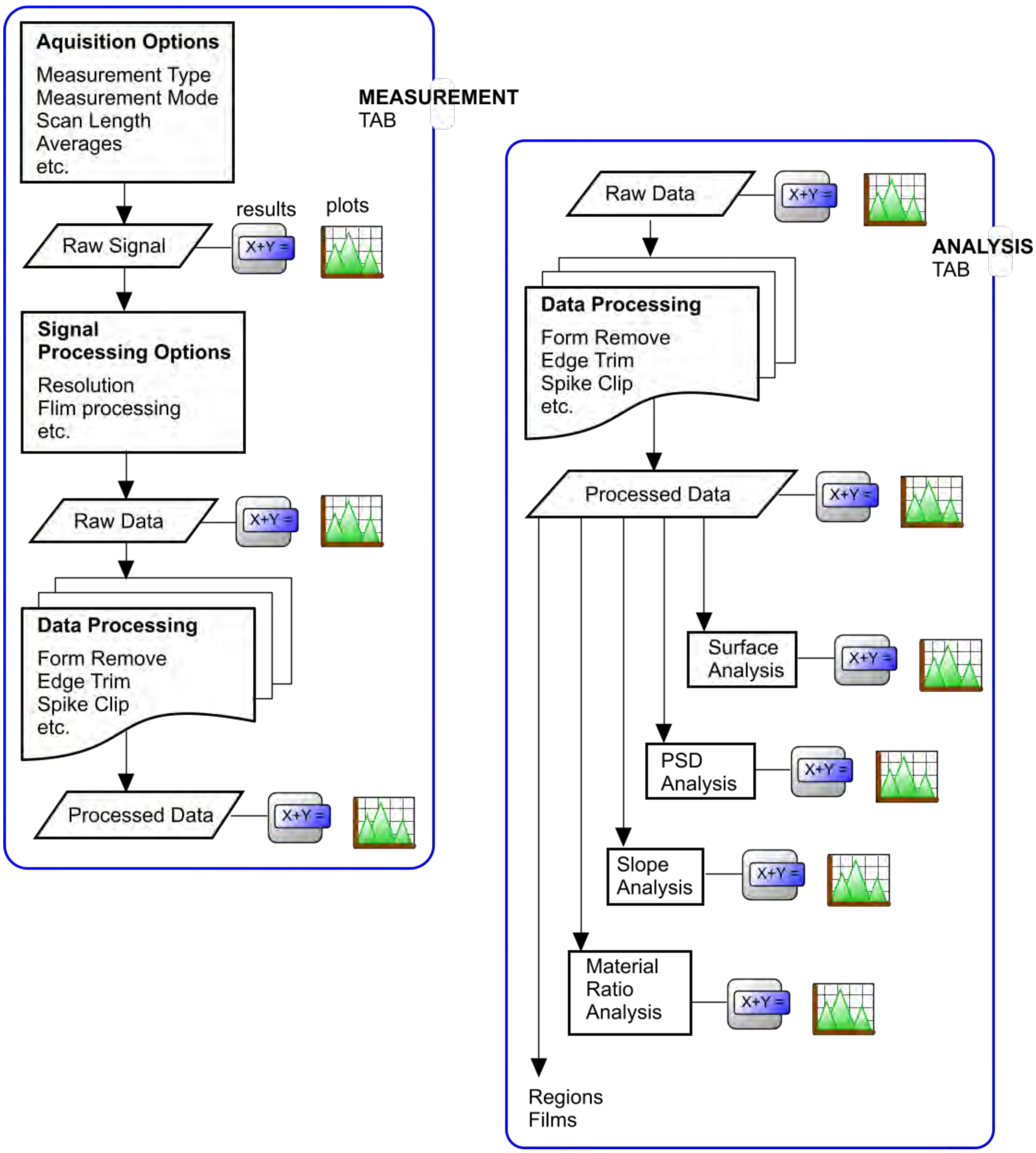
The four main user *actions* are selected with the large tabs and progress from left to right.

CALIBRATION **MEASUREMENT** **ANALYSIS** **AUTOMATION**

See Tabs for more information.

Micro Application Data Flow

The Measure and Analyze functions are depicted below.



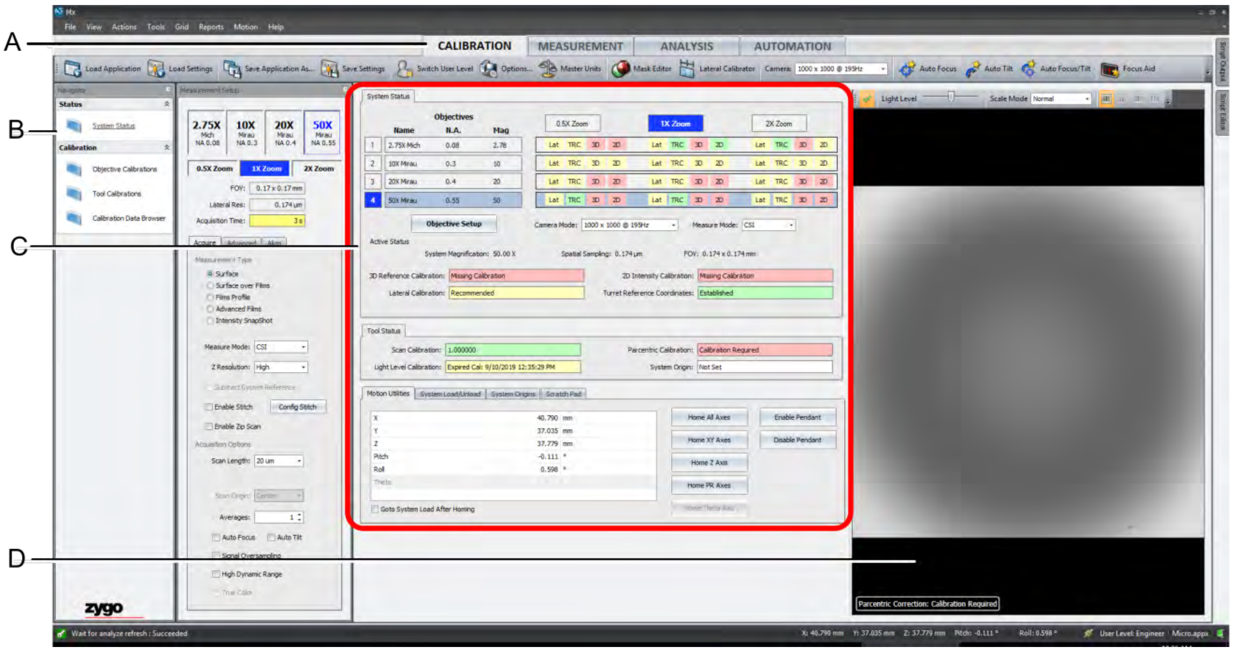
CALIBRATION Tab

Features

- Provides access to all calibration statuses, functions, and controls.
- Displays the detailed calibration status for the current optical configuration.
- Provides an overview of the calibration status for each optical configuration available on the instrument.

For calibration descriptions and procedures see Calibration.

The Calibration Screen



A. CALIBRATION tab. **B.** Pinned Navigator and Measurement Setup panel. **C.** Calibration control panel, varies based on Navigator selection (shown above is System Status). **D.** Live Display from profiler.

Status Attribute Color Codes

Color readouts are relative to re-calibration thresholds and to objective installation time.

Green		Valid calibration
Yellow		Expired calibration, may require user attention
Red		Missing calibration, requires user attention
White		Information only, not critical to calibration

Calibrate Tab Views

- System Status
- Objective Calibrations
- Tool Calibrations

See Also

[Calibration](#)

[Measurement Tab](#)

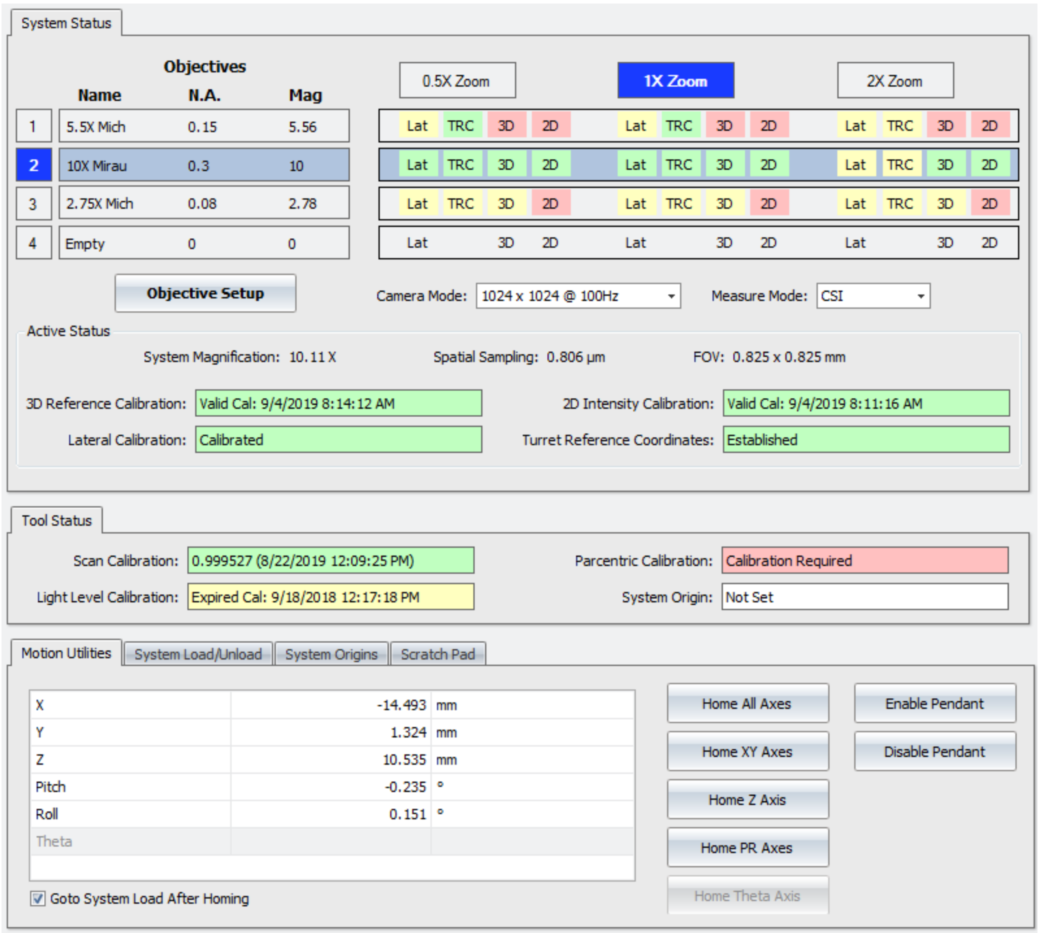
[Analysis Tab](#)

System Status

Shows the current state of all calibrations for the system, with the current optical configuration highlighted in blue.

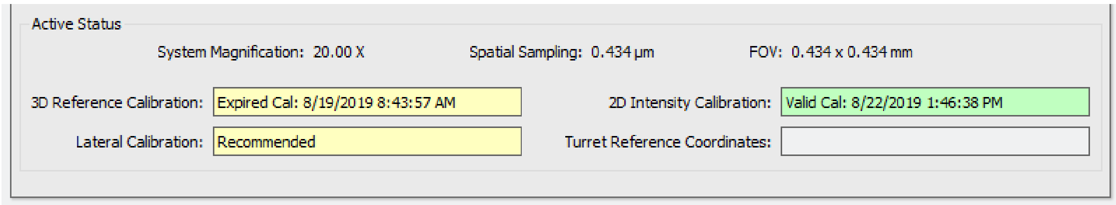
The current objective can be changed using the 4 position buttons on the left.

The current zoom can be changed using the 3 position buttons on the top right.



Active Status

Shows the current state of the objective calibrations for the active optical configuration (Objective + Zoom + Camera Mode + Measure Mode).



Camera Mode, System Mag (based on objective magnification and zoom lens), Lateral Res, and FOV are attributes of the current hardware setup.

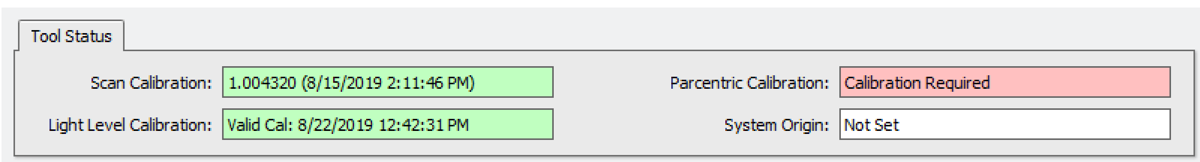
For Lateral Calibration see Lateral Calibrator, Optical Profiler.

For Turret Reference Coordinates see TRC- Turret Reference Coordinates.

For 3D Reference Calibration and 2D Intensity Calibration see Objective Calibrations.

Tool Status

Shows the current state of the tool calibrations that do not depend on a specific objective, zoom, Camera Mode, or Measure Mode.



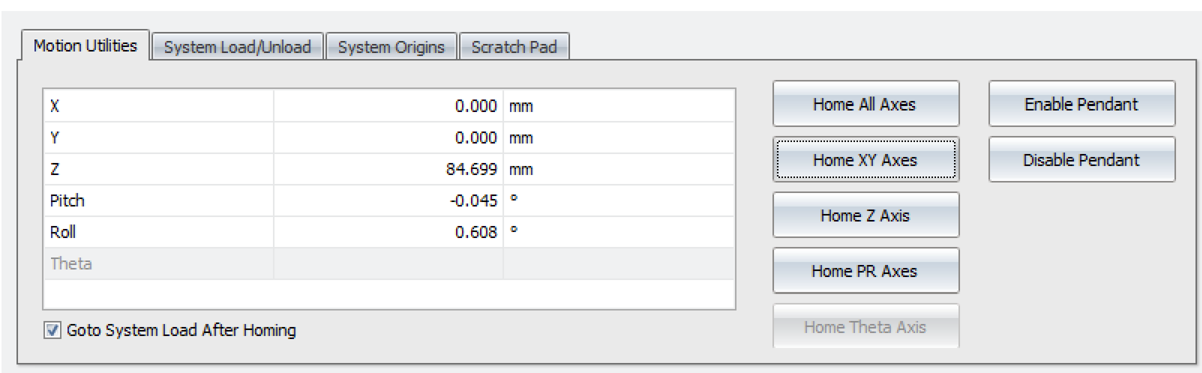
For Scan Calibration and Light Level Calibration, see Tool Calibrations.

For Parcentric Calibration, see Parcentric Calibration.

System Origin will show Established if any axis has a System Origin defined. If no axes have a System Origin defined, Not Set will be shown. See Motion Utilities.

Motion Utilities

This is the same tool that is accessed from the Motion menu; see Motion Utilities.



MEASUREMENT Tab

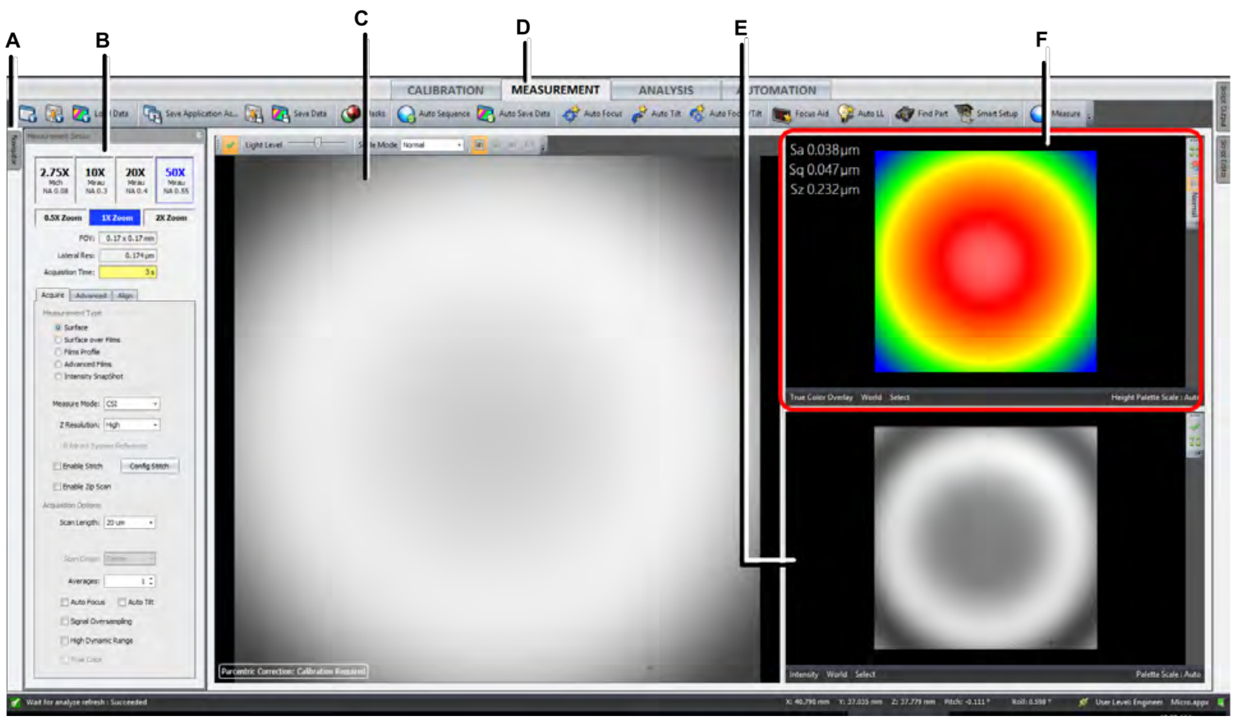
Features

- Use to establish measurement criteria and test settings for a single measurement or a combined (stitch) measurement.
- Direct access to Measurement Setup.
- Provides access to Focus Aid, Find Part, and Smart Setup tools.

Use Conditions

- Applies to optical profilers; included in Micro.appx.
- Lateral calibration is required for some results.
- After data is acquired, go to the Analysis tab.

The Measurement Screen



A. Pinned Navigator. **B.** Measurement Setup tool. **C.** Live display from profiler (red indicates saturation). **D.** MEASUREMENT tab. **E.** 2D plot of intensity data. **F.** 2D plot of processed data.

See Also

Optical Profiler Measurement Setup

Focus Aid

Automated Focus & Setup

Find Part

Smart Setup

Calibration Tab

Stitching

Analysis Tab

ANALYSIS Tab

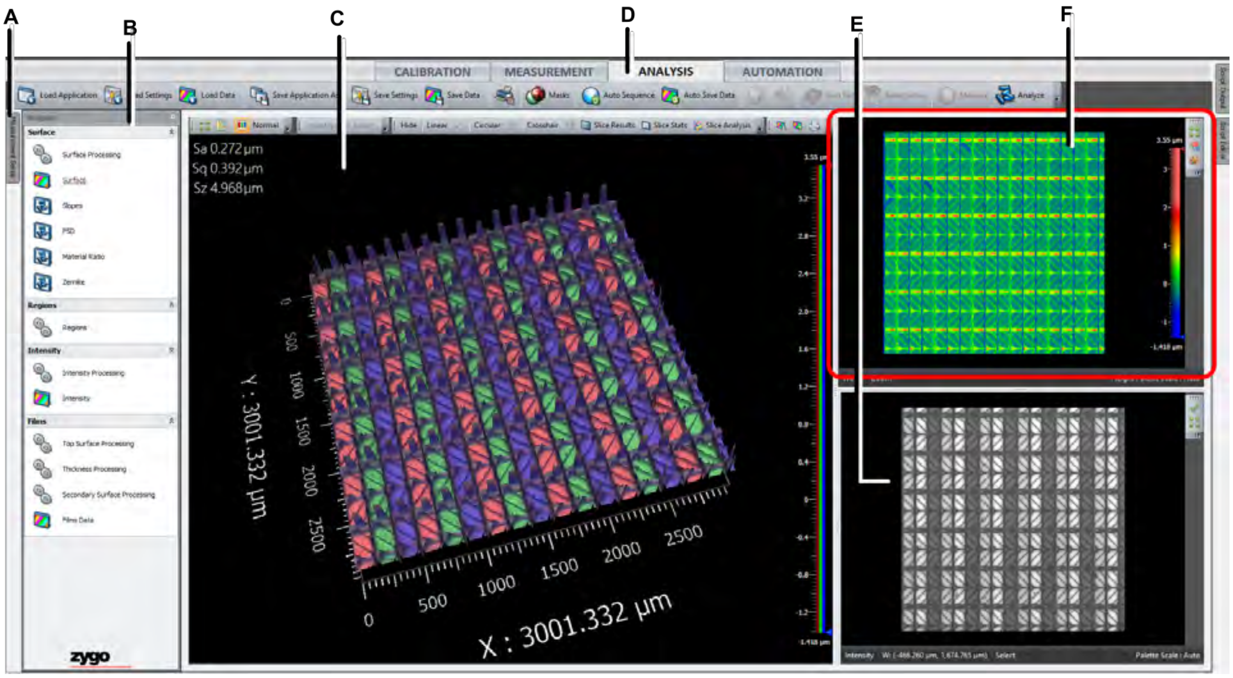
Features

- Use to examine test part features.
- Fully flexible plots, including 2D, 3D, and slices.
- Choose and display applicable results.

Use Conditions

- Applies to optical profilers; included in Micro.appx.
- Data Processing tools on this screen impact visualization only.
- Lateral calibration is required for some results.

The Analysis Screen



A. Pinned Measurement Setup. **B.** Navigator. **C.** 3D Plot of data (see 2D/3D Plot Overview). **D.** ANALYSIS tab. **E.** 2D plot of intensity data. **F.** 2D plot of data.

See Also

Calibration Tab

Measurement Tab

Sequence Tool

AUTOMATION Tab

Features

- Use to automate software and hardware functions.
- Access to patterns (see Pattern Editor) and recipes (see Recipe Sequence Editor).

Use Conditions

- Applies to optical profilers; included in Micro.appx.
- The optical profiler must be equipped with motorized stages.

Making a Micro Measurement

These steps outline a typical measurement under the MEASUREMENT tab. See the operating manual for specific instrument details.

Do not crash the objective into the stage or test part. Use caution when focusing and setting the Z-Stop.

Part Setup

1. Place test part on part stage.
2. Use joystick to drive the part stage in X and Y to locate the test part under the objective.
3. Use joystick to the drive the part stage Pitch and Roll so the readout is close to 0 (zero).

Objective and Z-Stop Setup

1. Install objective.
2. Use joystick focus knob to drive the objective close to test part and then very carefully drive the objective slightly closer than the objective working distance.
3. Press the joystick Z-Stop button to set the software focus stop position.
4. If necessary, open the Lateral Calibrator to designate the objective and perform lateral calibration. See Lateral Calibrator, Optical Profiler.

Measurement Steps

1. In Measurement Setup select the objective, zoom setting, Measurement Type, and Scan Length.
2. Press F9 for auto light level. For other light level keyboard shortcuts see Light Level Keys.
3. To find focus use the Focus Aid tool or use the joystick to adjust the objective in the z-axis to find part focus. Focus for part detail and fringes. See Focus Tips below.
4. If necessary, move the part stage in X and Y to locate the area of interest on the test part.
5. Adjust fine focus for high contrast visible fringes.
6. Adjust light level to ensure that brightest fringe does not saturate on camera.
7. Click Measure or press F12.

Focus Tips

- Drive the part stage to either the edge of the part or to an area on the part with more discernible features.
- Watch the Live Display when focusing; as the objective approaches the correct distance the display will brighten, as the objective departs from the correct distance the image darkens. Sometimes a brief, slight flash can be observed; that is the part focus location as it is passed.
- For featureless parts try using the Focus Aid.

Easy Micro Measurements

These steps outline measurements under the MEASUREMENT tab and apply only to ZYGO NewView 9000 and Nexview NX2 profilers.

Do not crash the objective into the stage or test part. Use caution when focusing and setting the Z-Stop.

Using Find Part

1. In Measurement Setup select the objective, zoom setting, Measurement Type, and Scan Length.
2. Use the joystick to drive the stage to locate the test part under the objective.
3. Use joystick focus knob to drive the objective close to test part and then very carefully drive the objective slightly closer than the objective working distance. Press the joystick Z-Stop button to set the software focus stop position.
4. Click the Find Part toolbar button to quickly find best focus.
5. Click Measure or press F12.

Using Smart Setup

1. In Measurement Setup select the objective, zoom setting, and Measurement Type.
2. Use the joystick to drive the stage to locate the test part under the objective.
3. Use joystick focus knob to drive the objective close to test part and then very carefully drive the objective slightly closer than the objective working distance. Press the joystick Z-Stop button to set the software focus stop position.
4. Click the Smart Setup toolbar button to calculate an appropriate scan length, set light level, *and* perform a measurement.

Measuring Intensity

ZYGO optical profilers produce an intensity map with every measurement, with the approach depending on the selected Measurement Type. For Intensity Snapshot, a static monochrome scene is captured without a topography scan. The remaining Measurement Types perform scans to generate surface topography maps and support additional options for measuring intensity described in this topic.

Modulation vs. Weighted Average

A ZYGO optical profiler measures topography by scanning along the optical axis and looking for an interference signal corresponding to the part surface. The accompanying intensity map can be generated from this interference signal in one of two main ways:

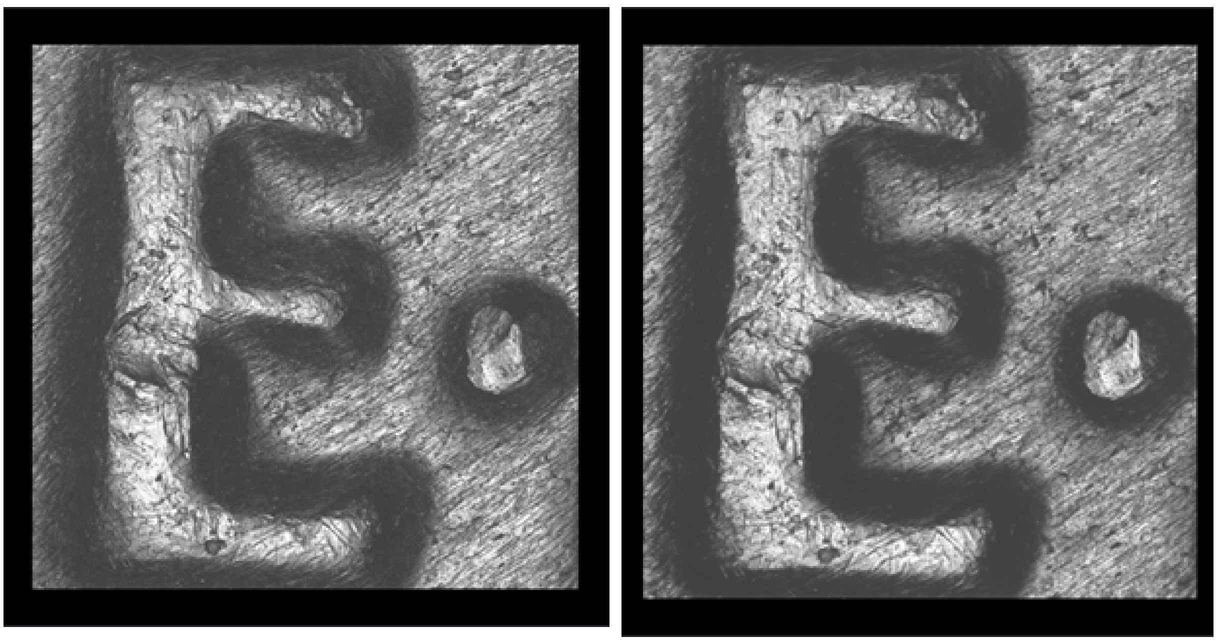
• Modulation captures the strength of the interference signal.

• Weighted Average captures the mean intensity in the vicinity of the interference signal.

Both options provide a best focus image at pixels where a surface was detected. Modulation generally provides a more visually striking image, especially in regions of low reflectance, and is the default for Micro.appx applications shipping with Mx 7.7 and later. But Weighted Average may be preferable in certain cases, as explained later in this topic.

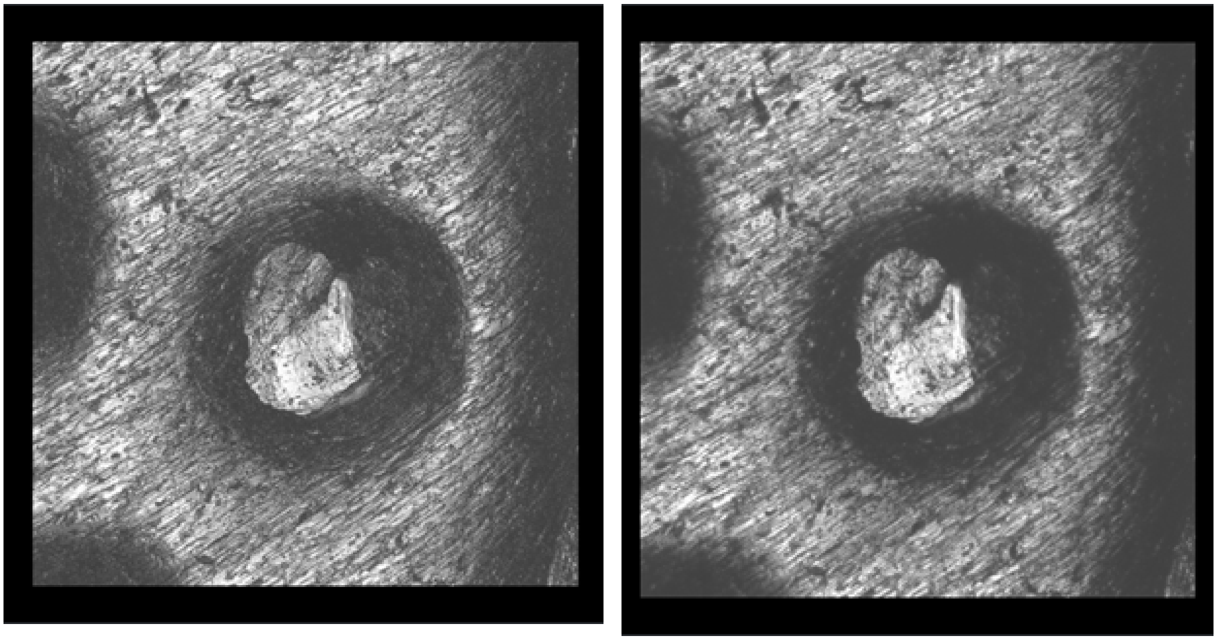
To select the method for computing intensity mode, use the Fringe Removal Algorithm control. If necessary, add this control in a Control Grid and right-click and choose Select items. See Working With Grids.

The following measurements of a US dime, using a Nexview with a 10X Mirau objective, illustrate the relative strengths of Modulation versus Weighted Average. For the first example, measured at 1X zoom, the Modulation map detects much more intensity variation within the sloped edges of the ‘E’, whereas Weighted Average does a slightly better job of revealing variations within high reflectance regions (e.g., within the lower left of the ‘E’).



Intensity measurements of a US dime with a 10X Mirau objective at 1X zoom.
Left: Modulation intensity mode; right: Weighted Average intensity mode.

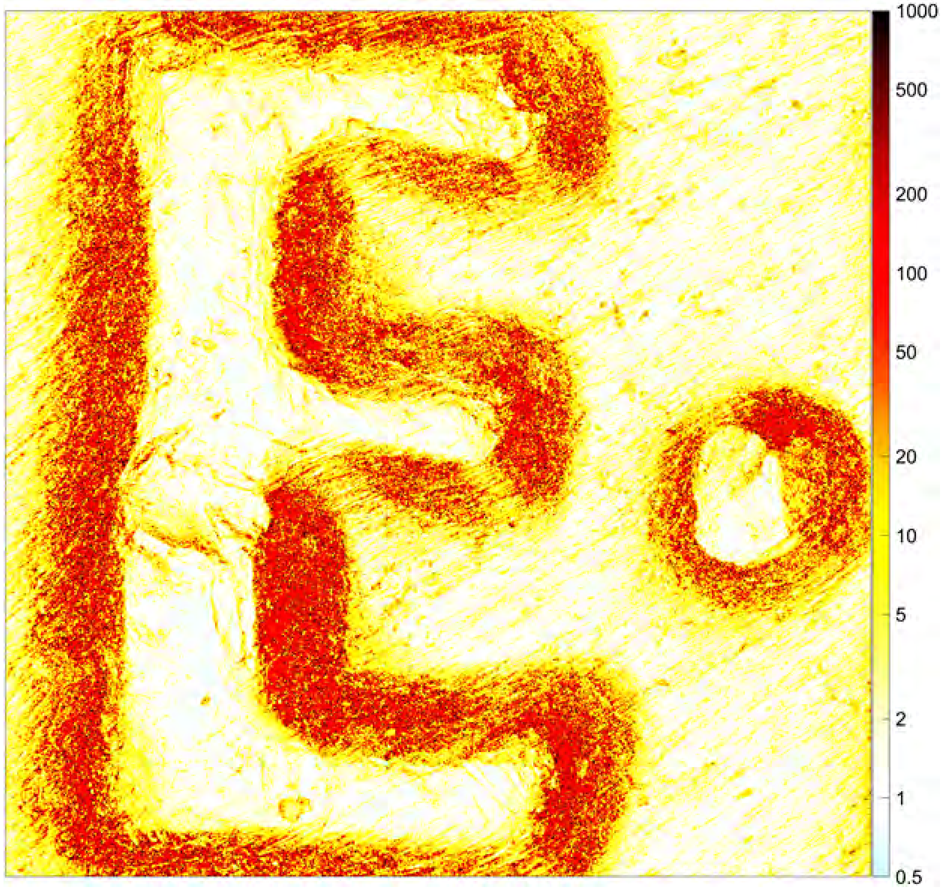
A second example, measured at 2X zoom, further illustrates the benefits of Modulation in low reflectance regions.



Intensity measurements of a US dime with a 10X Mirau objective at 2X zoom.
Left: Modulation intensity mode; right: Weighted Average intensity mode.

To provide a more quantitative comparison of the two Intensity modes, repeatability was measured for the scene of the letter 'E'. A map depicting the ratio of sensitivity to local reflectance is shown below.

Reddish hues indicate where Modulation is more sensitive to the local reflectance. This performance advantage is most obvious in high-slope regions, frequently exceeding a factor of 100 (note the log-scale legend). White indicates regions where relative performance is comparable. Light blue (sparsely distributed within high reflectance regions) indicates where Weighted Average provides a slight sensitivity advantage – never exceeding a factor of 2, which is also the theoretical limit.



Relative sensitivity to reflectance for Modulation versus Weighted Average, for the 'E' shown previously. Reddish hues denote better sensitivity for Modulation, blue hues for Weighted Average. Note the log scale.

While Modulation is the generally recommended default, Weighted Average might be preferable in the following situations:

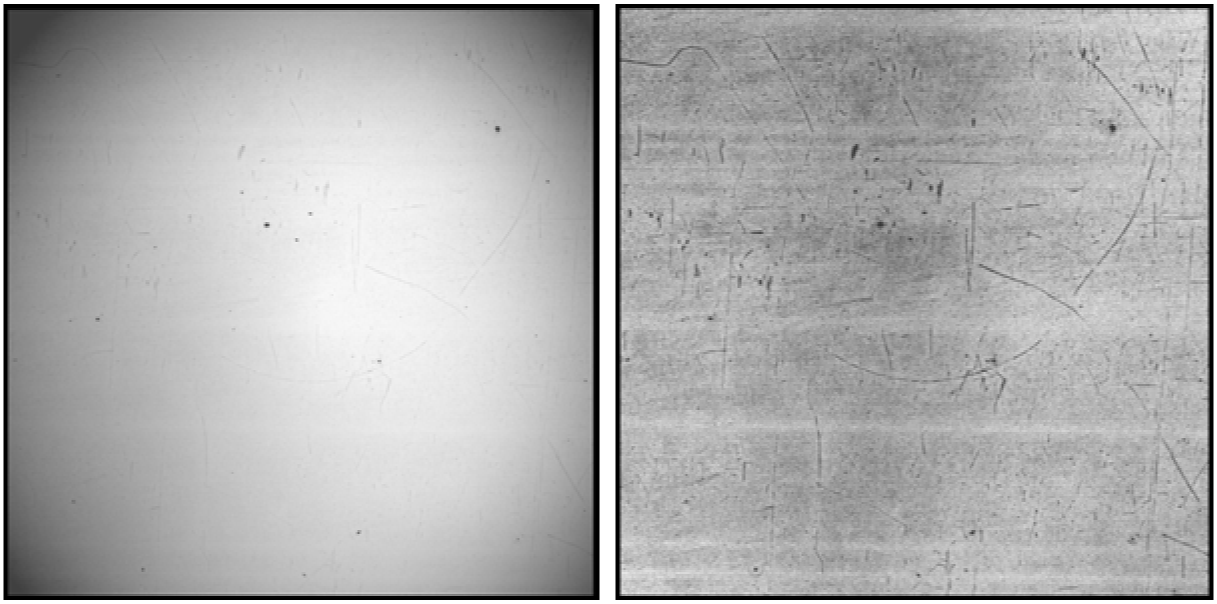
- The field of view includes regions where the surface was beyond the range of the scan – in such regions, Modulation will produce dark intensity values whereas the Weighted Average map may look more natural.
- The regions of interest have high reflectance – Weighted Average can be slightly more sensitive to reflectance variations in such cases.
- The part has a complex surface structure (such as transparent films) – in such cases the preferred option is highly application dependent, and empirical study may be needed to decide.

Field Flattening

Field flattening corrects for systematic variations in intensity over the field of view, for example from non-uniform illumination or aperture effects. It is available with Nexview and NewView profilers. With Field Flattening enabled, any remaining variations in intensity can be attributed to the part being measured.

To enable Field Flattening, first perform a 2D calibration for the desired optical configuration; a SiC optical flat is required for this step. Then ensure that the Field Flattening control is On. If necessary, add this control in a Control Grid and right-click and choose Select items. See Working With Grids.

Field flattening can make it much easier to see defects, as illustrated in the example images below of a glass slide measured on a Nexview with a 10X Mirau objective at 0.5X zoom. The right-hand image is field flattened.

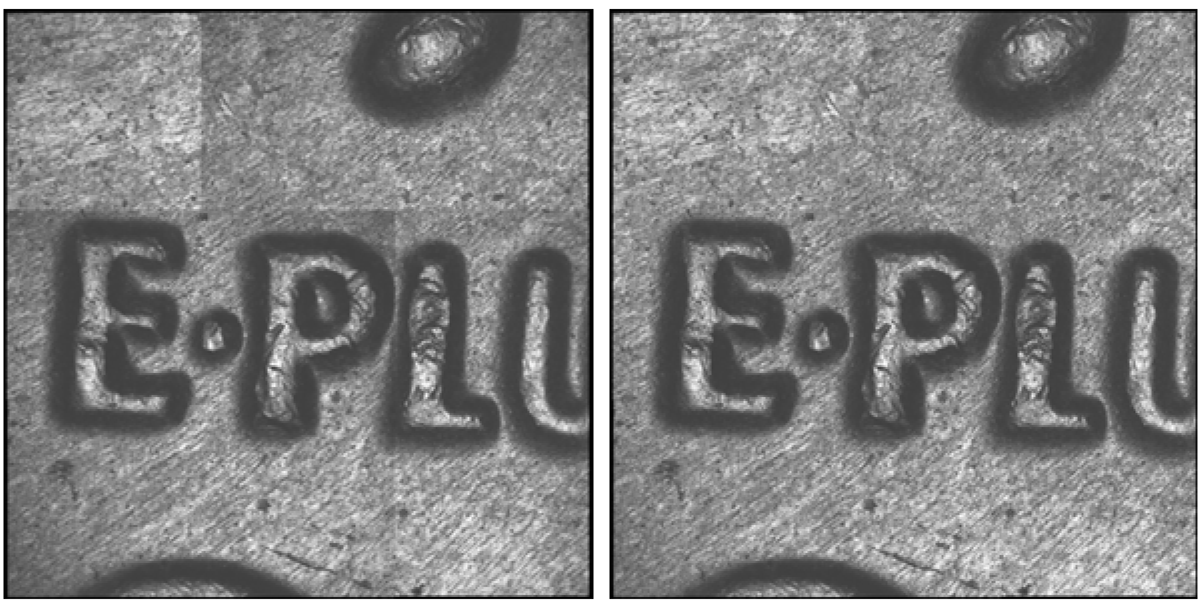


Glass slide measured with 10X Mirau objective at 0.5X zoom. Left: field flattening Off; right: field flattening On. Scratches and striations in the glass are much more easily seen with field flattening.

Stitching and Intensity Blending

Intensity blending when stitching eliminates tile-boundary artifacts. The benefit of intensity blending is illustrated below with a 2x2 stitch of a US dime, measured on a Nexview using a 10X Mirau at 0.5X zoom. The right-hand image has intensity blending enabled.

To enable intensity blending, first enable field flattening (see previous section). Then, in the Stitch Analysis section of the Stitch Panel set Overlap Merge to Blend.



US dime measured with 10X Mirau objective at 0.5X zoom, and a 2x2 stitch. Left: intensity blending Off; right: intensity blending On. Note visible tile boundaries in left image.

Optical Profiler Control

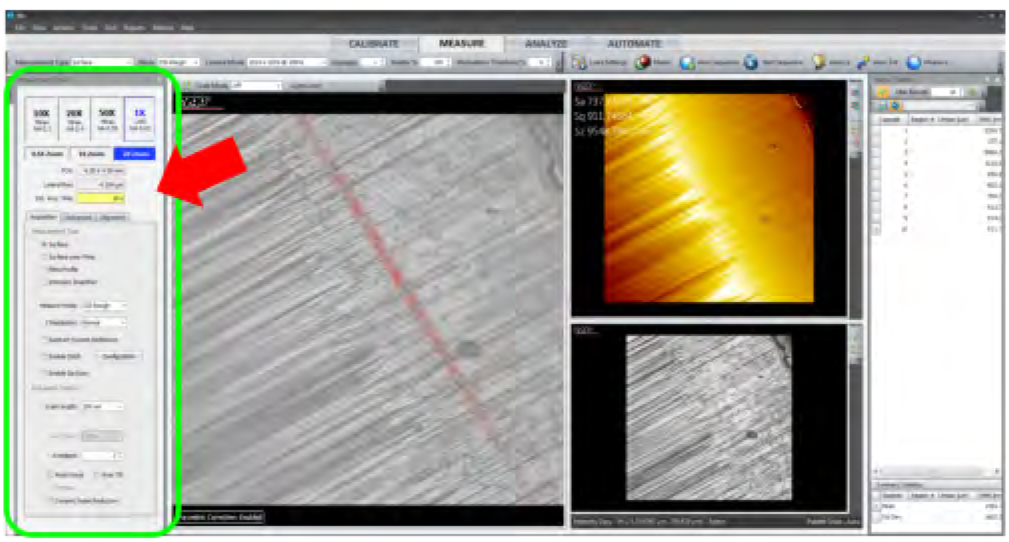
6

This section covers instrument control and topics specific to optical profilers.

For the live image display refer to Live Display.

6.1 Optical Profiler Measurement Setup

Use to control the optical profiler when acquiring data.



Overview

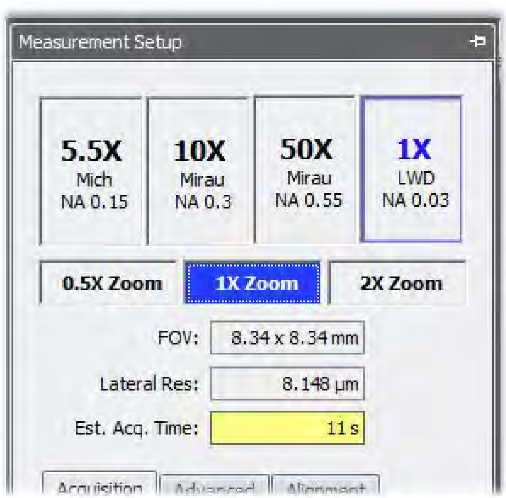
- Provides quick access to commonly used controls.
- Available under multiple tabs.
- Allows customization.
- The actual controls available vary based on hardware and software options. Grayed out controls are not available.
- Control settings can be saved and loaded. See Using Settings.
- The panel can be opened, closed, and pinned. See Working with Panels.

Features

Other tabs may appear as options are selected.

Objective and Zoom Selector	Select the active objective and zoom settings.
Acquire Tab	Control the technique and algorithm used to capture the signal.
Advanced Tab	Provide fine control over acquisition presets.
Align Tab	Specify the constraints of the auto focus, tilt, and center features.

Objective and Zoom Selector



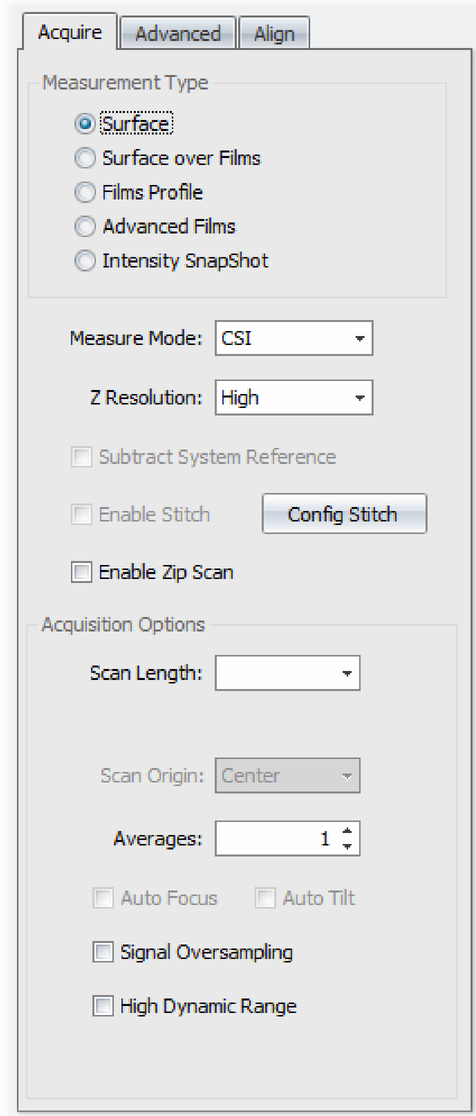
Objective Buttons- click to select the active (blue outline) objective. If the instrument has a motorized turret, the selected objective moves into position. Objectives appear if added using the Lateral Calibrator. Right-click any of the objective buttons or open the Lateral Calibrator (F7) to define the specific objectives that appear for each position.

Zoom Buttons- click to select the active (solid blue highlight) discrete zoom magnification.

FOV	Field of View in object-space for the active objective/zoom combination.
Lateral Res	Pixel size in object-space for the active objective/zoom combination.
Est. Acq. Time	Estimated Acquisition Time for the currently configured measurement. Acquisition time is affected by the Measure Mode, Camera Mode, Scan Length, Averages, and other acquisition options.

Acquire Tab

The profiler Measurement Setup- Acquire tab is used to select basic acquisition settings. These settings determine the techniques used to obtain data.



Click on item to choose options or select a check box to activate a function.

Measurement Type

Selects what characteristics of the test part are to be measured. Available options are determined by the optical profiler model. Films options require licensing.

Surface- Use this mode when measuring surface topography on opaque parts.

Surface Over Films- Use this mode when measuring the top surface topography on a part with transparent films. This mode does not provide any information about the underlying film(s). Adds Films tab.

Films Profile- Use this mode when measuring the top surface topography and/or either the bottom surface topography or the film thickness. This mode only returns information about the top-most film when measuring parts with multi-layer film stacks. Adds Films tab.

Advanced Films- Use this mode when measuring a sub-micron film layer, or correcting for phase change on reflection. This mode requires knowledge of the optical properties of the film materials. Adds MBA tab.

Intensity SnapShot- Use this mode to measure a 2D intensity snapshot of the scene as represented in the Live Display. The mode can be useful for lateral metrology or feature alignment, but will not provide any information about the surface topography.

Measure Mode

When the Measurement Type is set to Surface, this control determines the method by which the measurements are made.

CSI Coherence Scanning Interferometry. This is the default starting point and good for most parts.

CSI-Rough This mode makes CSI measurements using a narrower bandwidth illumination spectrum to improve performance on rough parts and sometimes on parts with high slopes. It generally improves data coverage, but with a decrease in vertical resolution. The improvement is part-dependent and should be compared with CSI results.

3X CSI — This mode makes sub-Nyquist CSI measurements at 3X the nominal scan rate to provide higher throughput, but with a decrease in vertical resolution. 3X CSI measurements are compatible with PZT and extended scans.

5X CSI — This mode makes sub-Nyquist CSI measurements at 5X the nominal scan rate to provide even higher throughput, but with a further decrease in vertical resolution. 5X CSI measurements are only compatible with extended scans.

Smart PSI — SmartPSI combines a CSI scan to focus the instrument and determine the coherence profile of the surface with a series of rapid PSI (phase-shifting interferometry) measurements to determine the high-resolution phase profile of the surface. This mode is ideal for smooth parts with low departure (PV < few microns) and is the best option for super-smooth parts.

Z Resolution

Selects the vertical resolution of the surface height data.

High — The phase and coherence profiles are combined to provide the final height map. Provides highest vertical resolution, but may have fringe order (2ð) errors.

Normal — The coherence profile is taken to be the surface height. Provides most data on challenging parts, but at lower vertical resolution.

Subtract System Reference

Select check box to use a system reference file. This is used to improve instrument performance by minimizing noise. There must be a valid 3D reference calibration for this to function (see Surface Calibration Procedure). No user interaction is required, this feature works automatically when the appropriate calibration information exists.

Stitch and Scan

Enable Stitch — Select check box to measure using a configured stitch routine. Stitching is used to analyze areas larger than a single measurement; multiple measurements are combined together. Click Config Stitch button to open the Stitch Panel.

Enable Zip Scan — Select check box to activate a Zip Scan sequence. A Zip Scan is two or more groups of measurements separated by a vertical distance. A Zip Scan is useful for parts with isolated heights; it effectively extends the scanner range. Adds a Zip tab in the Measurement Setup panel.

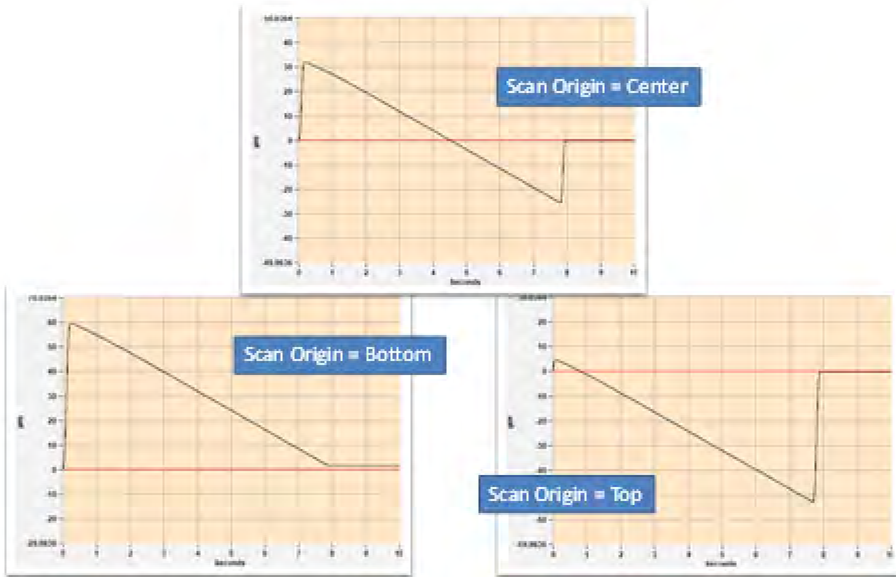
Acquisition Options

Scan Length — Selects the vertical scan length. The longer the scan, the greater the height measuring capability, and the longer the measurement time. It is recommended to set to the smallest value that encompasses the part details.

When set to *Extended*, the user enters the length of the scan, which is longer than the selectable lengths. The value entered should be the vertical range of detail in the part plus 10%.

Scan Origin

Selects the location of the part relative to the full scan range when the scan is initiated. Scan profiles for each control option are shown below.



Averages

Specifies the number of measurements to average together to reduce random measurement noise. Averaging increases measurement time.

Auto Focus

Select the check box to perform auto focus before each measurement.

The Auto Focus function is useful when the surface of the part being measured does not fall within the current scan range of the sensor. Auto focus will automatically scan at faster rate (depending on the controls) over a longer distance in Z (depending on the controls) to find the surface of the part, then move the sensor head so that the part surface is nominally centered in the middle of the sensor's scan range.

Auto Tilt

Select the check box to perform auto tilt before each measurement.

Signal Oversampling

Select the check box to provide increased measurement sensitivity at the expense of longer measurement time. Signal Oversampling is used to extract very weak signals from challenging surfaces such as those with large roughness or steep slopes.

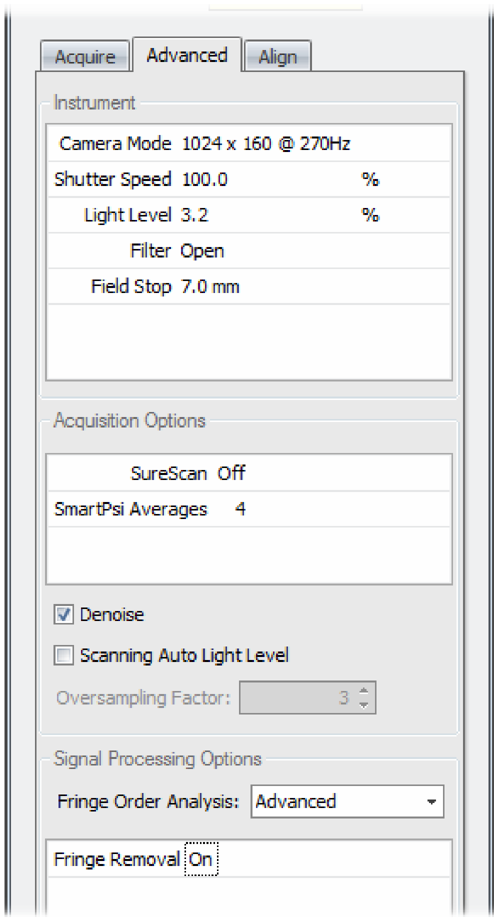
Signal Oversampling can be used in conjunction with CSI or Films measure modes and can be combined with other acquisition options such as Zip Scan, HDR, and True Color. When using oversampling and extended scan, be sure that the SureScan control is set to Off.

High Dynamic Range

Select the check box accommodate parts with a wide variation in reflectivity. This option causes the system to take two sequential measurements at up to 3 discrete light levels to accommodate wide variations in part reflectivity. The two measurements are combined to maximize the amount of data and quality of the surface data produced.

When the High Dynamic Range mode is checked, an HDR tab is added to the Measurement Setup panel for setting the various light levels.

Advanced Tab



The profiler Measurement Setup-Advanced tab is used adjust default settings to maximize acquired data.

Click on item to choose options or select a check box to activate a function.

Additional or hidden controls can be added in the Instrument, Acquisition Options and Signal Processing Options panels. Right-click on a panel and choose Select Items.

Instrument

Controls vary based on the specific optical profiler. Click on item to change.

Camera Mode Selects the effective camera size (pixels) and frame rate (Hz). More pixels resolve smaller details, but increase processing time.

Shutter Speed Specifies the camera shutter speed in % of frame rate. This is used to reduce exposure time to freeze environmental effects such as vibration and air turbulence. This control is automatically set by the instrument when using the Auto Light Level (F9) function.

Light Level Specifies the light level to use when making a measurement. This control is automatically set by the instrument when using the Auto Light Level (F9) function.

Filter The filter setting changes the coherence length of the light to optimize data capture under varying conditions.

Open- no filter (default setting).

ND- Neutral density filter. Use with large field of view objectives for highly reflective parts. Improves light level adjustability under these conditions.

BP 40 nm- 40 nm band pass filter. Use for rougher surfaces or when there is data dropout. Dropout may occur when measuring low contrast surfaces or surfaces with high slopes.

BP 3 nm- 3 nm band pass filter.

Field Stop The Field Stop (F-Stop) controls the diameter of the illuminated region on the part in object-space.

Choices are: 11.0 mm, 7.0 mm, 3.6 mm, or Focus. The appropriate F-Stop is automatically selected by the instrument and does not require user intervention for most measurement cases.

Acquisition Options

SureScan SureScan is a vibration resistant data acquisition technique based on Coherence Scanning Interferometry (CSI). SureScan is always enabled for extended scans.

It can optionally be enabled for CSI piezo scans by pointing to SureScan and selecting On. SureScan is useful when there is mild to moderate vibration that causes fringe print-though into the surface map.

Surface over Films and Films Profile (separate Films license required) measurement types are compatible with SureScan and provide meaningful metrology in noisy environments for film thickness > 4 µm. SmartPSI mode is not compatible with SureScan.

SmartPsi Averages Specifies the number of averages to perform when Measure Mode is Smart Psi. Averaging reduces random measurement noise, but increases measurement time.

Denoise Select the check box to apply a 3x3 Gaussian filter to the raw height data to reduce camera noise. For most measurements using 10X objective magnification and higher, this filter does not adversely affect lateral resolution, however, it may degrade the ITF (image transfer function) for low and some mid-mag objective/zoom combinations.

Scanning Auto Light Level Select the check box to automatically set the appropriate light level during a measurement. Serves as an Automatic Gain Control (AGC).

Oversampling Factor Used to fine tune a measurement when Signal Oversampling is selected. Determines the amount of noise reduction (2X-8X) through CSI oversampling or SmartPSI averages. Measurement throughput is decreased linearly with this setting. Measurement noise is reduced with the square root of this setting.

Signal Processing Options

Fringe Order Analysis

Selects the method used to analyze the phase gap across the field of view. Only applicable when Z Resolution is set to High.

Advanced (default)- The software interprets the surfaced structure to determine the correct interference fringe order on a pixel-by-pixel basis. This is the most generally-applicable fringe order analysis method.

Standard- An option to apply tighter constraints on the assumed variability in surface structure. Use when fringe-order (2ð) errors remain in Advanced mode.

Basic- An option to disable the interpretation of surface structure when resolving fringe order. Use when fringe-order errors remain in Standard mode.

Connect- An option for smooth, continuous surfaces; it is effective when there is a clearly visible interference fringe pattern without interruptions across the sample surface.

Field Flattening

When On and a valid 2D calibration exists, the field of view is corrected for systematic variations in intensity from non-uniform illumination or aperture effects. With field flattening enabled, any remaining variations in intensity can be attributed to the part being measured. See Measuring Intensity.

Distortion Analysis

Select the check box to use phase information to correct coherence map distortions that may be present when using the coherence profile to represent the surface height. Only applicable when Z Resolution is set to Normal. Distortion Analysis is required when using SureScan and cannot be disabled.

Turn Distortion Analysis Off only if fringe order (2ð) errors are present. Though rare when measuring with Normal Z Resolution, this is possible in extreme situations.

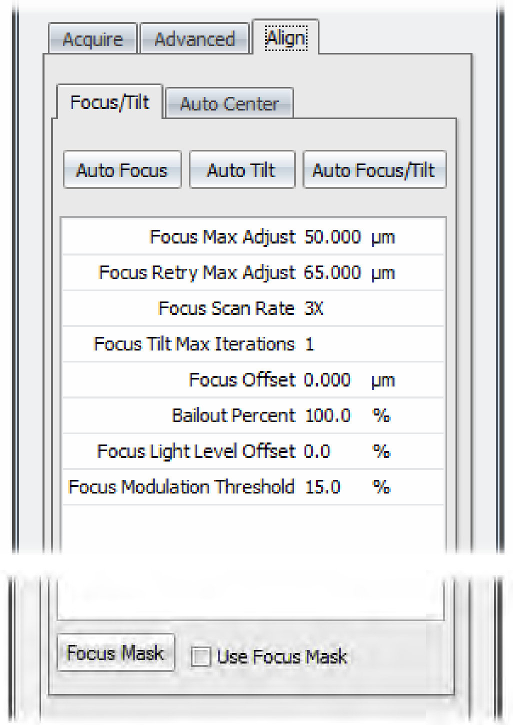
Fringe Removal

When On, a 2D synthesized image representing the best-focus, fringe-free intensity at each pixel is measured along with each 3D surface measurement. When the check box is cleared, the intensity image at the center of the scan is displayed including any interference fringes present at that scan location.

Fringe Removal Algorithm

When set to Modulation (default) the strength of the interference signal is captured. When set to Contrast, the Intensity map has higher contrast and sharper edges. When set to Weighted Average, the Intensity map displays up to 255 gray-scale values. See Measuring Intensity.

Align Tab



The profiler Measurement Setup-Align tab is used adjust Auto Focus, Auto Tilt, and Auto Center settings to maximize acquired data.

Click on item to choose options or select a check box to activate a function.

Controls will vary based on hardware options.

Shared Focus Controls

Auto Focus button	Click to perform an auto focus routine based on the current settings of the focus controls. When performing a Fast Focus, it is required that a Z-Stop be set.
Auto Tilt button	Click to perform an auto tilt routine based on the current settings of the auto tilt controls.
Auto Focus/Tilt button	Click to perform both an auto focus and auto tilt routine. When using Fast Focus, this is done in two phases. First, Fast Focus runs to locate best focus. This Fast Focus uses the Fast Focus control values. Next, a traditional Auto Tilt scan runs, using the Focus/Tilt controls. When using traditional Auto Focus, Auto Focus/Tilt is done in one scan.
Focus Offset	Specifies an offset distance in the z-axis from where focus is obtained. In some cases the ideal focus location may be shifted vertically.
Focus Mode	Selects traditional auto focus (Normal) or Fast Focus (Fast) as the auto focus method. See also Automated Focus & Setup. When Focus Mode is set to Normal, only Focus/Tilt Only and Shared Focus controls apply. When Focus Mode is set to Fast, only Fast Focus and Shared Focus controls apply.
Focus Mask button	Click to open the Mask Editor and define a focus mask. A focus mask is a special acquisition mask used during the auto focus and auto tilt operations. It is not the standard acquisition mask.

Use Focus Mask	Select the check box to enable the use of a focus mask.

Focus/Tilt Only Controls

Focus Max Adjust	Specifies the maximum distance in the z-axis to scan for proper focus.
Focus Retry Max Adjust	Specifies the maximum allowed z-position adjustment if the system must make a second auto focus attempt.
Focus Sensitivity	Selects legacy auto focus (Legacy) or modern high performance (High, Standard) auto focus algorithm. It is recommended to set this to High unless backwards compatibility is required. If throughput is very important, Standard may be preferable because it can save around 0.2 seconds.
Focus Scan Rate	Selects the vertical scan rate used to acquire height data for the auto focus and tilt calculations. It is recommended to set this to 5X to minimize focus time.
Focus Tilt Bailout	Specifies a threshold for early cancellation of auto focus or tilt scans. When this percentage of pixels report valid data, an auto focus or tilt scan will be canceled early.
Focus Light Level Offset	Specifies an additive adjustment (in percent) to the light level, which is applied when performing Auto Focus or Tilt.
Focus Modulation Threshold	This is the minimum modulation (in percent) necessary to obtain a valid data point for use in the auto focus and auto tilt calculation. A lower value includes weakly modulating points; a higher value only includes strongly modulating points. This control only applies when Focus Resolution is set to Low.

Fast Focus Controls

Fast Focus Max Adjust	Specifies the maximum allowed z-axis adjustment to find the focus position. Minimum value of 200 µm.
Fast Focus Retry Max Adjust	Specifies the maximum allowed z-axis adjustment if the system must make a second Fast Focus attempt, after failing to locate focus. Minimum value of 200 µm.
Fast Focus Bailout	Selects whether to use Bailout for Fast Focus. Bailout completes a fast focus scan early when a sufficiently strong return signal is detected.

Auto Center Controls

This function requires a Cognex VisionPro license.

Enable Auto Center	When the check box is selected, the trained feature is centered in the field of view before any acquisition.
Train Feature button	Brings up a Cognex dialog where the user can train a feature on the part for centering.
Distance Tolerance	Defines the allowable tolerance from the found feature to the center of the field of view. Auto Center takes an initial measurement and attempts to find the trained feature in the field of view. If the feature is found within the Distance Tolerance from the center of the field of view, no adjustment is made. Otherwise the stage is moved until the feature is in the center of the field of view.

Find Part Controls

Find Part button	Click to perform a Find Part scan. This will scan rapidly upwards from the current Z position, and attempt to find the part surface.
Part Finder Auto Scan Length	Selects whether to use an automatic scan length for Find Part. The automatic scan length is set to the working distance of the currently selected objective, up to 20 mm.
Part Finder Scan Length	If Part Finder Auto Scan Length is Off, specifies the scan length for a Find Part scan. Default is 2,000 µm, Maximum of 20,000 µm, Minimum of 1,000 µm.
Part Finder Bailout	Specifies whether to use Bailout for Find Part. Bailout On completes a Find Part scan early when a sufficiently strong return signal is detected.
Part Finder Offset	Specifies the offset, in the z-axis, to apply after a Find Part scan completes.

Calculate Only

These usually hidden functions output calculated values but do not actually move stages. They are typically used for systems with custom stages. To use these controls, add them to the control grid under the Focus/Tilt tab.

Auto Center Calculate Only	When set to On, the Auto Center routine calculates the x/y offset, but stages are not adjusted. This works for systems with and without x and y stages. Output is sent to the Auto Center X-Axis Adjust and Auto Center Y-Axis Adjust results.
Auto Focus Tilt Calculate Only	When set to On, the Auto Focus Tilt routine calculates the focus (z) and tip/tilt (roll/pitch), but stages are not adjusted. This works for systems with and without focus, pitch, and roll stages. Output is sent to the Focus Adjust, Pitch Adjust, and Roll Adjust results.

HDR Tab

The profiler Measurement Setup- HDR tab is used to specify discrete light levels when High Dynamic Range is active. Two sequential measurements are made using specified light levels. Set the level controls to accommodate the extreme reflectivity in the test part.

Scan Levels	Selects the number of discrete light levels to using for an HDR measurement sequence. 2 or 3 levels can be used.
Light Level	Specifies the corresponding light level for Level 1, 2, or 3.
Shutter	Specifies the corresponding camera shutter speed in % of frame rate for Level 1, 2, or 3.

Setting HDR Levels

1. Focus on the first surface and press F9 for auto light level.
2. Click the Capture button to copy the Light Level and camera Shutter settings to the corresponding level controls.
3. Repeat for additional level controls.

The Apply button applies the settings displayed in the corresponding level controls to the current measurement.

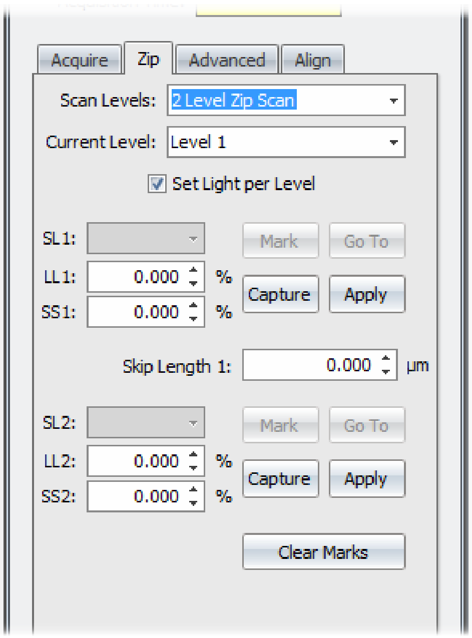
Zip Tab

The profiler Measurement Setup- Zip tab is used to enter Zip Scan options when Zip Scan is active.

Zip Scan Overview

- Zip Scan performs PZT scans at multiple Z-stage locations.
- Useful for measuring step heights within the field of view.
- Works with all CSI scans including SureScan.
- Not compatible when Scan Length is Extended or when High Dynamic Range is active.
- Can be combined with patterns and stitching.

Using Zip Scan



1. In the Measurement Setup panel, select the Enable Zip Scan check box to activate this feature.
2. Go to the Zip tab.
3. Use the Scan Levels control to select the number of vertical locations to scan (from 2 to 4). The corresponding number of controls are displayed.
4. Select the "Set Light per Level" check box to use per-scan exposure control (Light Level and Shutter Speed) at each level.
5. Use Current Level to select the level you want to define or view. The first scan level is numbered 1.
6. For each scan level, set:

   SL (Scan Length)

   Relative Z position (by pressing the Mark button when at the z-location)

   LL (Light Level) (optional)

   SS (Shutter Speed) (optional)

   The Capture button takes the current LL and SS settings and enters them in the corresponding control. The Apply button takes the settings from the corresponding LL and SS controls and sets the profiler to these settings.

   The Skip Length is filled in automatically once the z-axis is moved to the adjacent scan level and it is marked. Skip Length is the distance between one scan level and the adjacent scan level.

7. Move the profiler in z to the each vertical scan location (or level) and repeat steps 5 and 6.
8. A Zip Scan is performed based on the entered criteria whenever the Measure button (F12) is clicked.

Films Tab

The profiler Measurement Setup- Films tab is used to specify films options. The Films option requires a separate license.

Film Type	Determines the underlying algorithm (peak selection) used for analysis. Single Layer assumes there are two interfaces: a film layer, and a substrate. It selects the two strongest peaks above the Films Interface Threshold, and assigns the first to the film layer, and the second to the substrate. Multi-Layer allows for a multiple layered film stack. It selects the first two peaks above the Films Interface Threshold regardless of strength. These signals are assumed to correspond to the interfaces of the top-most film layer. Multi-Layer will give better data quality (i.e. repeatability and noise) when films are thicker than one micron. Sub-Micron (only available for Measurement Type set to Surface over Films with SureScan Off) selects the first signal above the Films Interface Threshold, and is used for films thinner than one micron (down to ~400nm).
Signal Finder	Selects the weighting used when identifying film layers. Signal Finder is part of a software routine that finds the top-most surface with or without the presence of films. Use Robust except for situations when it is necessary to isolate a surface in a single film <1 µm. The effect of changing this control is difficult to predict in a general case, and is highly dependent upon the sample properties. When Films Signal Sensitivity is High this control is hidden. When Films Signal Sensitivity is Normal, Signal Finder is visible for Single-Layer and Multi-Layer film types.
Films Interface Threshold	The interference signal is a modulation of intensity over a portion of the scan. This control determines what percentage of the full intensity range of the camera a signal must modulate by in order to be accepted as a signal. Typically, a reasonable value is 3%, but it depends entirely upon the sample. Low values (under 1%) can begin to introduce noise in the measurement. The default setting is 10%.
Refraction Index	Determines the value of the refractive index used for scaling height values. Film measurement directly measures the optical thickness of the sample. Optical thickness is related to physical thickness by a factor of the index of refraction. The default value of 1 causes all thickness values to be reported as optical thickness values. This is specifically the group index of the material at a wavelength of approximately 550 nm.
Films Signal Sensitivity	Selects the signal sensitivity for Films LSQ measurements. When High, weaker signals are extracted. This is useful for rough films with weak signals. When Normal, the LSQ films behavior is the same as in Mx versions earlier than 7.1.0. If Films Signal Sensitivity is not displayed, the user can add it to the Films tab control grid.

MBA Tab

The profiler Measurement Setup- MBA tab is used to specify Advanced Model Based Films Analysis options. This option requires a separate license.

MBA supports up to two different models to be used in the field of view- Region 1 and Region 2. If the sample contains the same material across the entire field of view, there is no need to define regions – only the Region 1 model is used. If the film stack or material changes across the field of view, two separate models and corresponding areas (region 1 and Region 2) should be defined.

To define regions, open the Mask Editor and set the Mask Type to MBA Region 1 and MBA Region 2. Draw masks corresponding to the two different areas of interest.

Film Specification	Determines whether the film stack is specified by Mx control values, or a film specification file (*.mbaset) on disk. Typically, this control should be set to 'Use control values' unless a film specification file is provided by ZYGO.
Substrate Material	Sets the material of the lower surface of the film stack, used in the generation of the model signals. This is typically the opaque, or very thick, substrate under a single layer film. It could also be air, when measuring a transparent membrane. In the case where there is no film, the substrate is the only material selected.Common materials are listed in the drop-down. If the material is not common, the materials can be described by a constant *n* and *k* across the visible spectrum. To use this function, select Constant n and k, and enter the appropriate values. n and k are the real and complex parts of the index of refraction. The real part, *n*, is commonly known simply as the index of refraction. The complex part, *k*, is the absorptive coefficient. These values are used, across the wavelength range of the Nexview source, to create the model signals. If you are attempting to measure a material with varying n and/or k across the visible spectrum, and it is not available as a material, contact ZYGO.
Film Material	Sets the material of the upper surface of the film stack, used in the generation of the model signals. This is typically the thin (0.1 – 1.2 micrometer) transparent material lying on top of the substrate. In cases where only a bare substrate is being measured, this control should be set to No film (bare substrate). Common materials are listed in the drop-down. To use n and k values see Substrate Material.
Thickness Min. Max.	Sets the minimum and maximum thickness values for which to generate model signals. This limits the possible reported value of the films, and shortens analysis time. Set these controls when the film thickness is approximately known, to increase throughput.
Number Swli Averages	Sets the number of signal averages to perform. Increasing this control will increase measurement time, but increases the signal/noise ratio of the interference signal. A value of 4 is recommended as a good balance between time and performance.
Calibrate Current Configuration button	Performs the Advanced Films calibration for the current optical configuration. The system should be focused on a nulled (leveled) Silicon Carbide flat before this button is pressed. Calibration typically takes well under one minute. Note that this is a required calibration for measurements, and should be performed regularly.

6.2 Automated Focus & Setup

There are several tools available to automate proper alignment of a sample in all axes. Auto Focus, Fast Focus, and Find Part allow for locating the best (z-axis) focus position. Auto Tilt adjusts motorized pitch/roll stages to level a part, and Auto Center adjusts motorized X/Y stages to center an alignment feature.

Auto Focus employs a CSI scan running at 3-5x the standard acquisition rate and uses the interference signal to locate the position of best focus. Since Auto Focus performs a measurement (albeit at high speed), the information gathered can be used to measure the tilt in the sample surface.

Auto Tilt uses this measured tilt to adjust the motorized pitch/roll stages to level the sample.

Fast Focus rapidly determines the position of best focus during measurement setup. It is much faster, typically by a factor of 25-50, than a traditional auto-focus feature on interferometric 3D profilers. Fast Focus is an alternative to standard Auto Focus, performing a bipolar ramp that quickly and automatically finds interference fringes.

Fast Focus and Find Part are supported on the ZYGO NewView 9000 or Nexview NX2 profilers.

Find Part combines Fast Focus with a standard auto focus refinement to further automate part setup. When the Find Part button is selected, an upward Fast Focus ramp is run that looks for the part surface. Afterward, a standard Auto Focus scan refines the focus position, and light level is set. Most Find Part scans are complete in 15 seconds or less.

Find Part is available by clicking the Find Part toolbar button on the Measurement tab. To use, simply set the objective below the focal plane and click Find Part.

Smart Setup goes one step further – using Find Part to determine an appropriate scan length and light level and perform a measurement. This functionality is a leap forward in ease of use for optical profilers, allowing for one button measurement of most surfaces.

Smart Setup is available from the Smart Setup toolbar button on the Measure tab. To use, simply set the objective below the focal plane and click Smart Setup.

Auto Center uses integrated vision analysis software Cognex VisionPro to adjust the X/Y stage to center an alignment feature in the field of view.

Auto Focus Control Interactions

When clicking Auto Focus or running a measurement with the Auto Focus check box enabled, different behavior is available depending upon the value of the Focus Mode and Focus Resolution controls, as well as whether Auto Tilt is also requested. The table below summarizes this behavior.

Focus Mode	**Focus Sensitivity**	**Auto Tilt?**	**Behavior**
Normal	High	Yes	A single traditional Auto Focus/Tilt scan, using the advanced Mx signal processing. Improved algorithm over Standard, for higher resolution adjustments. Adjusts Z and pitch/roll.
		No	A single traditional Auto Focus scan, using the advanced Mx signal processing. Improved algorithm over Standard, for higher resolution adjustment Adjusts Z only.
	Standard	Yes	A single traditional Auto Focus/Tilt scan, using the advanced Mx signal processing. Adjusts Z and pitch/roll.
		No	single traditional Auto Focus scan, using the advanced Mx signal processing. Adjusts Z only.
	Legacy	Yes	single traditional Auto Focus/Tilt scan, using the legacy MetroPro signal processing. Adjusts Z and pitch/roll.
		No	A single traditional Auto Focus scan, using the legacy MetroPro signal processing. Adjusts Z only.
Fast	High	Yes	A Fast Focus scan, followed by a traditional Auto Tilt scan. Each scan respects the appropriate controls for that type of scan, including maximum adjust and bailout. Auto Tilt uses advanced Mx signal processing. Improved algorithm over Standard, for higher resolution adjustments. Adjusts Z, and pitch/roll.
		No	A Fast Focus scan. Adjusts Z only.
	Standard	Yes	A Fast Focus scan, followed by a traditional Auto Tilt scan. Each scan respects the appropriate controls for that type of scan, including maximum adjust and bailout. Auto Tilt uses advanced Mx signal processing. Adjusts Z, and pitch/roll.
		No	A Fast Focus scan. Adjusts Z only.
	Legacy	Yes	A Fast Focus scan, followed by a traditional Auto Tilt scan. Each scan respects the appropriate controls for that type of scan, including maximum adjust and bailout. Auto Tilt uses legacy MetroPro signal processing. Adjusts Z, and pitch/roll.
		No	A Fast Focus scan. Adjusts Z only.

6.3 Calibration

- This function is found under the CALIBRATION tab.
- There are 2 basic types of calibration- objective specific and tool specific.
- Easy-to-follow prompts help a user perform calibration routines.
- During calibration routines, data is automatically saved. It is automatically applied later as needed.
- Calibration data is stored in an Mx managed database repository; no user interaction is needed.
- Calibration status is monitored relative to objective installation times and user-defined re-calibration thresholds.

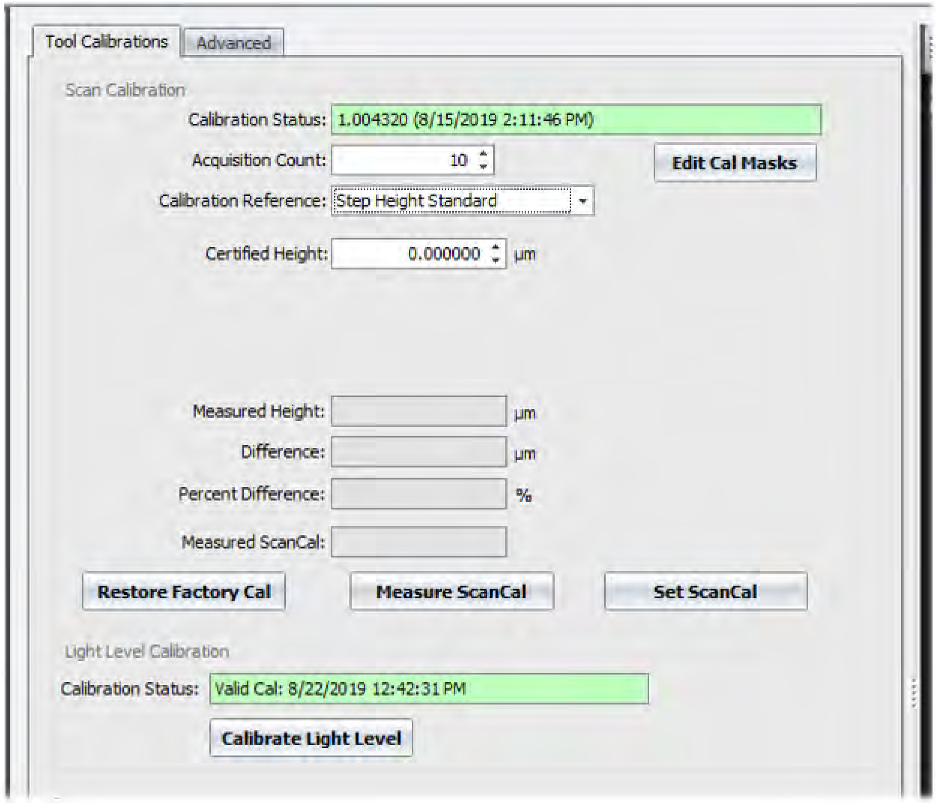
Calibration Status

The current status is shown in the CALIBRATION tab. On Navigator, click System Status. See CALIBRATION tab.

Tool Calibrations

Tool calibrations are instrument-specific and do not depend on Camera Mode, Measure Mode, objective, or zoom settings.

Calibration	Description	Good for...	Requires
Scan Calibration	Determines how raw 3D phase data is scaled to physical surface height. Uses the mean height of the step. Also called Step Height Calibration. Set at the factory to an uncertainty of 0.1%. Specific to each instrument.	months to years	Step Height Standard
Light Level Calibration	Determines the response of the instrument light level controller and provides improved hardware control. Set at factory. Specific to each instrument.	~12 months	SiC Reference Flat



Performing Scan Calibration

Also known as ScanCal or Step Height Calibration.

Factory calibration is performed under very controlled conditions and has an uncertainty of 0.1%. Step Height calibration performed in the field has an uncertainty of 1%.

1. Place Step Height Standard under the objective.
2. Click the CALIBRATION tab.
3. On Navigator, click Tool Calibrations.
4. Under the Tool Calibrations tab:

   Verify Acquisition Count setting; this specifies the number of acquisitions.

   Verify Calibration Reference is Step Height Standard.

   Enter the Certified Height of the step standard. This is supplied on a certificate provided with the standard.
5. Press the Measure ScanCal button to check the calibration.
6. Only press the Set ScanCal button if the measured result exceeds the uncertainty (Percent Difference) in the certified step height value.

Performing Light Level Calibration

1. Remove objective from turret or nosepiece, or select an empty turret position.
2. Click the CALIBRATION tab.
3. Place a SiC Reference Flat on the XY stage under the empty objective position in the optical path. The PR stage should be approximately level (0 degrees). Position the Z stage so that the empty objective mount is less than 100 mm (4 in.) from the SiC flat.
4. On Navigator, click Tool Calibrations.
5. Under Tool Calibrations tab, press the Calibrate Light Level button.

Objective Calibrations

Objective calibrations are specific to the objective, zoom, Camera Mode, and in some cases, Measure Mode.

Calibration	Description	Good for...	Requires
Lateral Calibration (see Automatic Calibration Procedure)	Used to establish the lateral distance between camera pixels in object space. Specific to Camera Mode, objective, and zoom combination. See Lateral Calibrator, Optical Profiler.	replace when objective is installed	Precision Lateral Calibration Standard
Turret Reference Coordinates (see Creating TRC Settings)	These optional coordinates keep the part sample image centered and in focus as objectives are switched with a motorized turret. Commonly called TRC; these coordinates are created using the Lateral Calibrator.	replace when objective is installed	sample part with a feature
2D Intensity Calibration (see Objective Calibration Procedure)	Determines illumination uniformity and bias maps for each illuminator channel. Needed for enhanced, fringe-free, and color Live Display modes. Needed for 3D True Color measurements. Specific to each instrument, Camera Mode, objective, and zoom combination.	~60 days	SiC Reference Flat
3D Reference Calibration	Measures 3D reference height maps used for system reference subtraction and 1D model signals required for Films analysis. Specific to each instrument, Camera Mode, Measure Mode, objective, and zoom combination.	~7 days application dependent	SiC Reference Flat

For details on lateral calibration see Lateral Calibrator, Optical Profiler.

For details on turret reference coordinates see TRC- Turret Reference Coordinates.

Objective Calibration Procedure

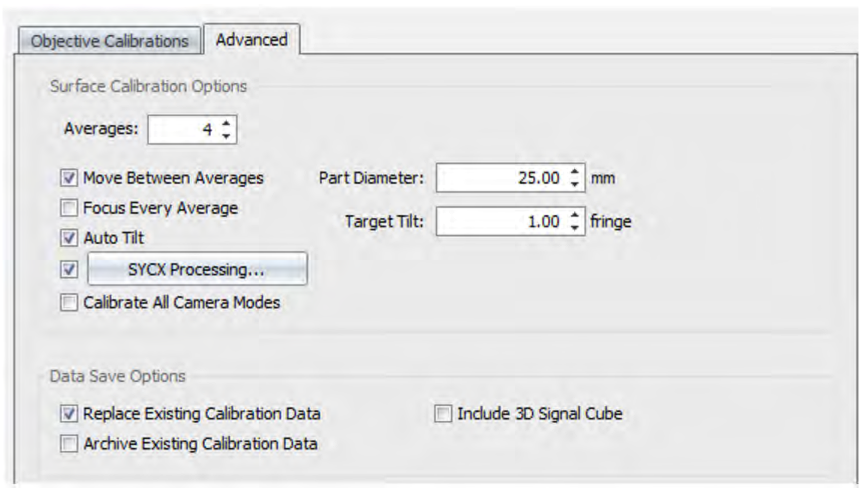
Performing 2D Intensity Calibration and 3D Reference Calibration automatically for all objectives, zoom lenses, measure modes, and camera modes can take many hours. Default calibration settings are appropriate for most situations.

Calibration status is updated as progress is made; data is automatically saved in an Mx managed database.

2D calibration is needed for all ZYGO optical profilers to make use of the enhanced and fringe-free viewing modes. In addition, optical profilers equipped with a color illuminator use 2D calibration for live color and color topography displays (True Color).

3D calibration is needed for all ZYGO optical profilers to use the subtract system reference function and for films analysis.

1. Click the CALIBRATION tab.
2. On Navigator, click Objective Calibrations.
3. Under the Advanced tab:
   - Enter Part Diameter (diameter of the SiC Reference Flat, usually 25 or 40 mm).
   - Verify Averages (4 is default).
   - Focus Every Average, default is off; the system will auto focus (if enabled) before the first iteration only. When selected, an auto focus is performed at each average site.
   - Verify SYCX Processing... check box is selected. (SYCX is predefined data processing and usually does not need to be changed).
   - Only select the Calibrate All Camera Modes check box if you use all Camera Mode settings; by default, only the current Camera Mode will be calibrated.
   - Include 3D Signal Cube and Archive Existing Calibration Data should only be used for advanced application debugging in consultation with ZYGO personnel.
   - Default calibration settings are shown below.



4. Under Objective Calibrations tab:
   - Clear the 2D Intensity Calibration check box to save time if the existing calibration is still valid or if color measurements are not required.
   - Only select the Calibrate All Measure Modes check box if you use all Measure Mode settings; by default, only the current Measure Mode will be calibrated.
   - Press the Calibrate Objective button.
   - Follow any onscreen prompts.

Calibration status is updated as progress is made; data is automatically saved in an Mx managed database.

Re-calibration Thresholds

These controls determine when the status indicators change color to notify that calibration is due. These are saved with the Application; they are not saved on the tool. This means that different applications can utilize different calibration expirations.

1. Click the CALIBRATION tab.
2. On Navigator, click Objective Calibrations.
3. Under Advanced tab:

   Enter value for 3D Reference Re-calibration Threshold (default is 7 days).

   Enter value for 2D Intensity Re-calibration Threshold (default is 60 days).

   Enter value for Light Level Re-calibration Threshold (default is 6 months).

Parcentric Calibration

Parcentric calibration keeps the part in the field of view at the point of focus while the pitch-roll stage is moved. Parcentric calibration is set at the factory and only needs to be repeated if the pitch/roll or x/y stages are removed and replaced.

Parcentric correction requires motorized pitch-roll, x-y part stages. All motorized stages must be homed.

Parcentric Calibration Status

Parcentric calibration status is displayed in the Tool Status section of the System Status view under the CALIBRATION tab.

Message	Description
Not Available (white)	Parcentric calibration is not available with the current configuration.
Enabled (green)	Parcentric calibration has been executed and Parcentric correction is turned on.
Auto Tilt Only (green)	Parcentric Calibration has been executed, but the pendant does not support Parcentric Correction for joystick moves; Parcentric Correction will only be applied during Auto Tilt.
Not Homed (yellow)	Parcentric Calibration has been executed but one or more axes need to be Homed.
Disabled (yellow)	Parcentric Calibration has been executed but Parcentric Correction is turned off.
Calibration Required (red)	Parcentric Calibration needs to be executed; Parcentric Correction is not available.
Objective Parfocal Length Missing (red)	Contact ZYGO; information is missing from a configuration file.

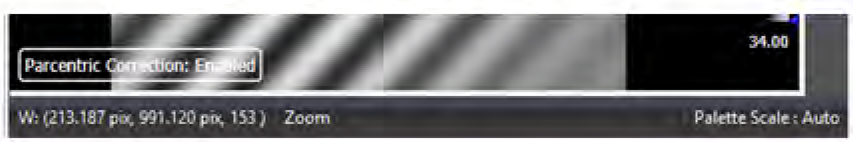
- When Parcentric Correction is available, the status is also indicated on the Live Display windows.
- The Parcentric Correction indicator on the Live Display serves as both a control and a status indicator.
- Click on the Parcentric Correction indicator to toggle from Enabled to Disabled or vice versa.
- The following status messages can be seen on the Live Display indicator.

Message	Description
Enabled	Parcentric calibration is active. Joystick stage control may move multiple axes to keep the sample in view and focus.
Disabled	Parcentric calibration is off. Joystick stage control moves each axis independently.
Not Homed	Motorized stages require homing before parcentric correction is functional. Click the message to initiate a Home All command.
Auto Tilt Only	Pendant does not support parcentric correction. Parcentric correction will only be applied during Auto Tilt. Joystick stage control moves each axis independently.
Calibration Required	Parcentric calibration needed, contact ZYGO.

Parcentric Correction

- Stage Calibration must be executed for Parcentric Correction to be available.
- Joystick parcentric correction moves are handled by the pendant.
- Programmed move parcentric corrections are handled by Mx. Currently, only Auto Tilt utilizes parcentric information.

The state of the correction is displayed on the Live Display. It shows Enabled, Disabled, or Calibration Required.



6.4 Stitching

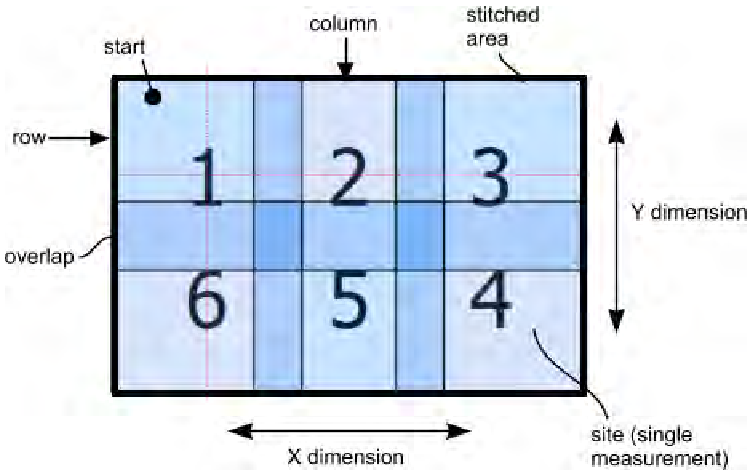
Stitching makes several measurements of the test part as it is moved by a motorized stage and then combines or stitches the multiple data sets into one. Effectively, it increases the field of view without compromising lateral or vertical resolution. The final graphics and results are based on the entire measured area.

After the test area is defined, a stage pattern is automatically created that breaks the larger area into a number of smaller sub-regions or sites. Each site is equal to the optical profiler's field of view (as based on the objective and zoom setting), minus a percentage for overlap.

To use stitch settings when making a measurement select the Enable Stitch check box in the Measurement Setup panel.

Stitching options are set in the Stitch Panel.

Stitching Terminology



Each measurement location is referred to as a "site." A series of sites make up a stitch sequence.

Types of Stitches

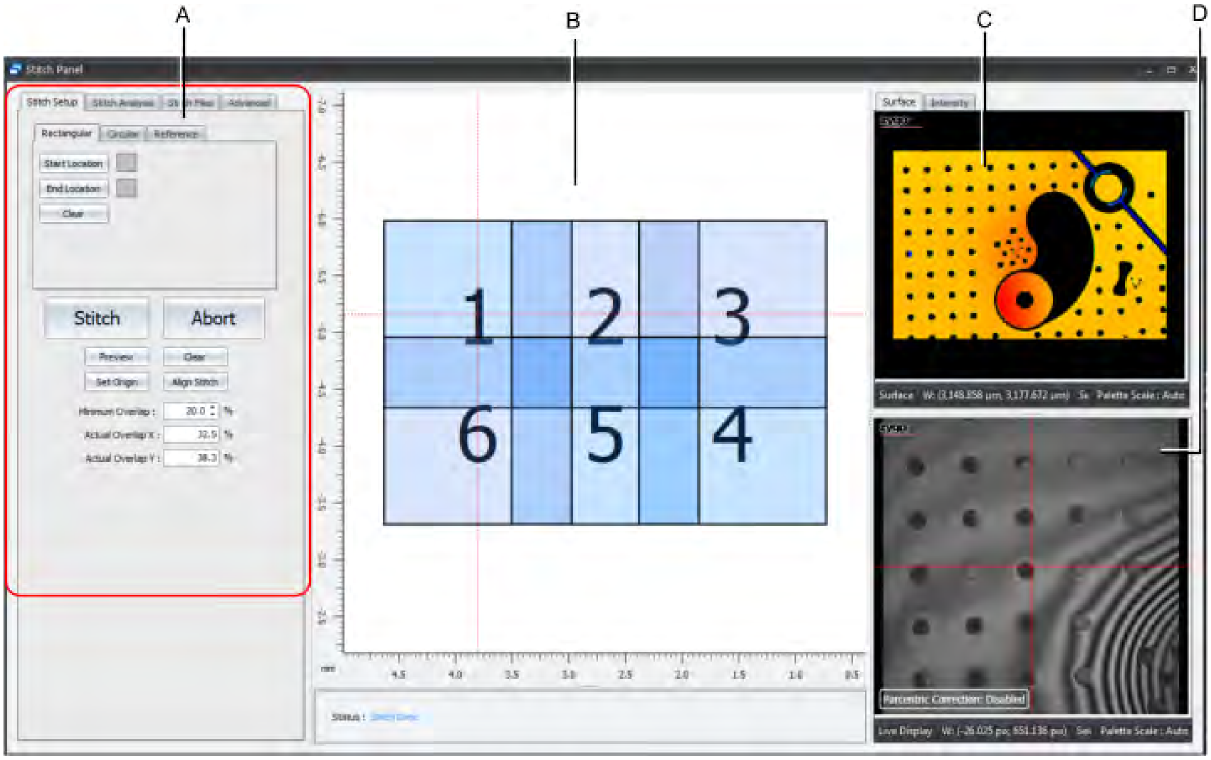
Rectangular	A rectangular box shaped stitched area.
Circular	The stitched area is circular or ring shaped.
Reference	The stitch uses a customer-supplied art reference image as the basis to define the stitch sequence.

Stitch Panel

- Used to define an area larger than a single measurement; it extends the size of the camera.
- Stitched areas can be any set of sites on a grid.
- Supports taught areas defined by a start and end.
- Provides controls to fine-tune the stitch.

The Stitch Panel

On the Measurement Setup panel, click the Config Stitch button.



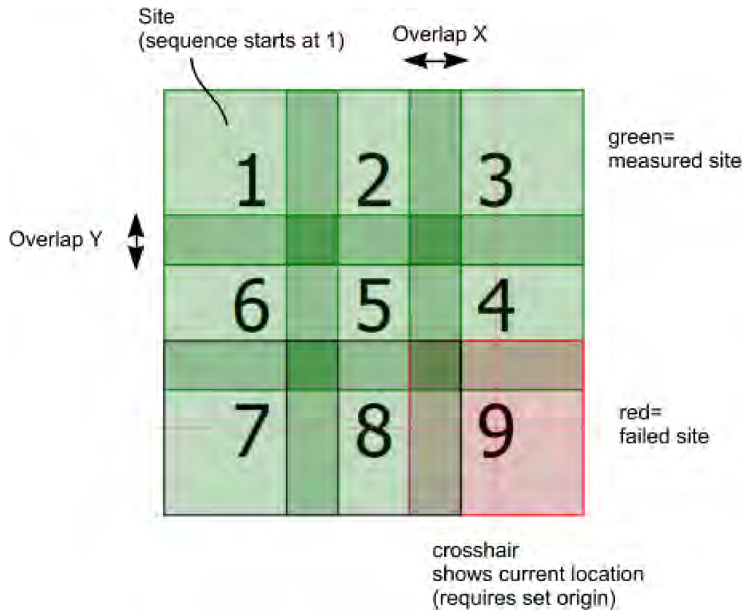
A. Stitch controls. **B.** Graphical representation of stitch sequence. **C.** Plot shows current surface measurement data (individual or combined). **D.** Live Display of current site.

Common Stitch Controls

Stitch	Click to run the stitch sequence.
Abort	Click to stop and cancel the stitch sequence.
Preview	Click to run a site to site intensity preview of the stitch sequence. Intensity part images at each site are displayed.
Set Origin	Click to use the current stage position as the stitch origin position (labeled as 1).
Clear	Click to remove the stitch preview image, if displayed.
Align Stitch	Click to run a stitch pattern alignment. This updates the origin x and y positions and sets the Rotation control value.
Minimum Overlap	Specifies the smallest acceptable amount of overlap between adjacent sites. A recommended starting point is between 15 to 25 %. An overlap region is required for stitching to properly work.
Actual Overlap X	This attribute shows the overlap percent used between sites in the x axis.
Actual Overlap Y	This attribute shows the overlap percent used between sites in the y axis.

Working With Sites

Each location is referred to as a "site". The term site applies to both stitching and patterns.



Site Key

Color	Meaning
Blue	Unmeasured
Green	Measured
Clear (white)	Excluded
Red	Failure

Site Actions

To...	Do This...
Drive part stage to site	Point and click on the site.
Exclude/Include a site	Point to site and press shift-click. Blue sites are included; clear (or white) sites are excluded.
Perform unique actions at a site	Point to site and right-click to access the context menu. See Customizing Sites.

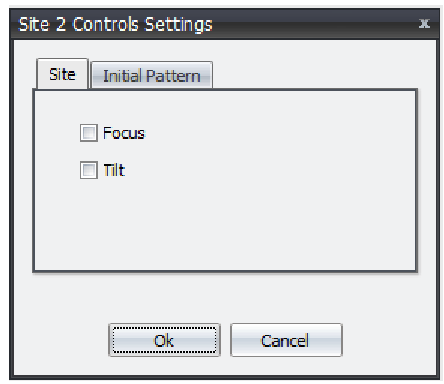
Stitch Site Actions

To...	Do This...
Change starting *stitch* site	Click the Advanced tab and choose the start position with the Origin control.
Remeasuring a failed *stitch* site	If Restitch Mode is selected with the context menu, click on failed site to remeasure.
Relocate entire *stitch* sequence over a previewed image	Point to the stitch sequence image, press Ctrl click and drag the image using the mouse. Release the mouse button when the sequence image is in the desired location.

Customizing Sites

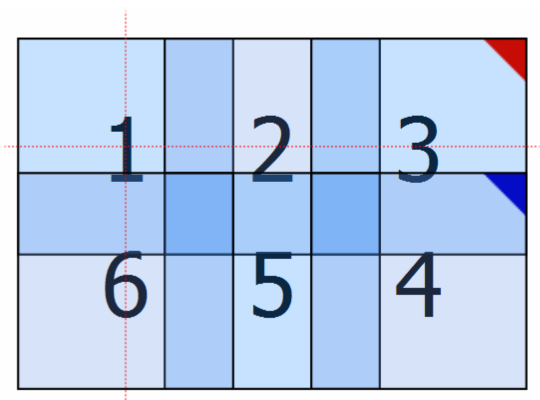
Point to site and right-click. Some options are site specific, others are global to all sites. Some options may be stitching or pattern specific.

Fit To Window	Resize stitch image or pattern image to fit inside the image pane.
Restitch Mode (stitching only)	Turns feature on or off for all sites. Restitch Mode allows you to remeasure individual stitch sites with a mouse click. Remember to deselect this mode to return the mouse to normal operation.
Insert (pattern only)	Select to open an existing pattern file. Insert Pattern inserts the selected pattern as a sub-pattern for the selected pattern site. Insert Pattern for All inserts the selected pattern as a sub-pattern for *all* sites.
Remove (pattern only)	Select to remove sub-pattern from current site or from all sites.
Site Controls	Use to define focus and tilt operations for a site. Also see Site Triangles. The Site tab controls select operations to use at a specific site as the stitch or pattern is running. The Initial Pattern tab controls run the selected operations at the specified site before the actual stitch or pattern runs. This is useful in overcoming issues with an underlying part shape.
Site Properties	Displays a Site Properties dialog that displays information about any site you point to with the cursor. This includes Position X, Position Y, and Position Z; it's row and column location, and any custom site label.
Site Label	Allows a custom label for a site. This label shows up under the Site Properties dialog.



Toggle Site Include/Exclude	Use to select (include) and deselect (exclude) a single site from the stitch or pattern. Same as a shift-click on the site.
Toggle Site Grouping (pattern only)	Use to include or exclude rows and columns in the same grid as the selection. Choices: Include Column, Exclude Column, Include Row, Exclude Row.
Toggle Site Alignment (pattern only)	Marks the current site for Pattern alignment or pre-alignment. When pattern runs, it will visit all the marked sites. Options are Pattern Align or Pre-Align.
Toggle Site Manual Alignment (stitching only)	Marks a site to use when alignment runs by clicking the Align Site button. A site marked this way is indicated in orange. Used to align stitch orientation to the part.
Set Auto Align Feature (pattern only)	Set the site that is marked for alignment or pre-alignment to use a predefined trained feature.
Include All Sites	Use to select all sites. Included sites are shaded.
Exclude All Sites	Use to deselect all sites. Excluded sites are white.
Pattern Size (pattern only)	Use to select the size of the pattern from a grid graphic.
Part Image	Use to Load, Clear, or control the Opacity of the reference image. Opacity displays a slider under the image panel. Adjust the slider to show the reference art file with the site grid. Requires that a reference image is loaded.

Site Triangles



Sites tagged with a red or blue triangle. This denotes Site Controls have been set.

Red indicates options under Site are applied; blue indicates options under Initial Pattern are applied.

Defining a Rectangular Stitch

Rectangular- Teach Method

These steps are typically done from the upper left to the lower right.

1. Select the Stitch Setup tab. Click the Rectangular tab.
2. Drive part stage to stitch beginning.
3. Click Start Location button. The box next to the button turns green.
4. Drive part stage to last site.
5. Click End Location button; the adjacent box turns green.

Rectangular- Direct Select Method

1. Drive the part stage to a corner of the area to be measured.
2. Click Set Origin button.
3. Click and drag the "L" cursor over the stitch graphic area.
4. Release the mouse button. A stitch grid is generated.

Rectangular- Row Column Method

1. Select the Advanced tab.
2. Select Sizing Type: Row Column.
3. Enter values in the Row and Column controls.

Rectangular- Size Method

1. Select the Advanced tab.
2. Select Sizing Type: Size.
3. Enter values for the lateral stitch dimensions in the Size X and Size Y controls. The number of sites is automatically calculated.

Defining a Circular Stitch

Circular- Preview Teach Method

1. Select the Stitch Setup tab. Click the Circular tab.
2. Under Circle Definition choose Preview.
3. Drive the stage to one corner of the area of interest.
4. Click Start Location.
5. Drive the stage to the other corner of the area of interest.
6. Click End Location.
7. Click the Preview button. This displays the underlying part features.
8. Click the Define Outer button.
9. Click on three points on the stitch overlay. This defines the circular perimeter.
10. Click the Generate button. This creates an updated stitch overlay that includes selected options.

Circular- Stage Teach Method

1. Select the Stitch Setup tab. Click the Circular tab.
2. Under Circle Definition choose Stage.
3. Click the Define Outer button.
4. Drive the part stage to first outside perimeter point. Click Okay.
5. Drive the part stage to second outside perimeter point. Click Okay.
6. Drive the part stage to third outside perimeter point. Click Okay.
7. Click the Generate button.
8. If the circular stitch is ring shape, also perform steps 9-11.
9. Click the Define Inner button.
10. Drive the part stage to 3 consecutive inside perimeter points, clicking Okay each time.
11. Click the Generate button.

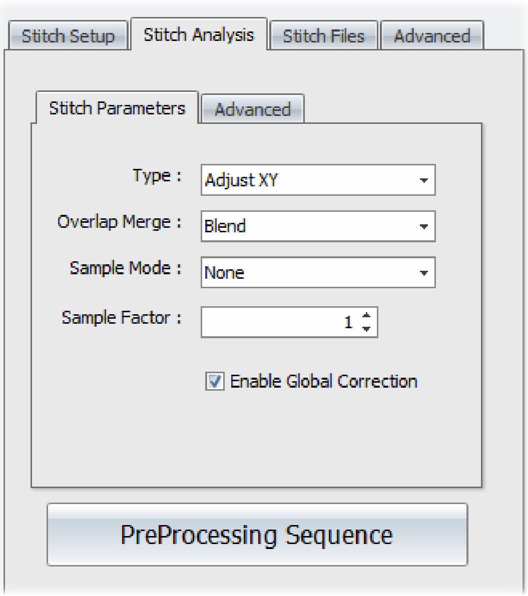
Circular- Include/Exclude Method

1. Create Rectangular stitch. See Defining a Rectangular Stitch.
2. Point to each site to exclude and shift click.

Stitch Panel Stitch Analysis Tab

Stitch Analysis controls are used to specify how sites are aligned and how overlap areas are processed.

1. Open the Stitch Panel by clicking the Config Stitch button in Measurement Setup.
2. Click the Stitch Analysis tab.



Stitch Analysis- Stitch Parameters

Type	Selects how sites are aligned. Options are Adaptive Adjust, Adjust XY, Cartesian, or Overlay. Adaptive Adjust- The most advanced, sub-pixel stitching algorithm, for general purpose use. Adjust XY- Sometimes preferred for stitching low magnification measurements. Adjusts data to pixel boundaries. This stitching time can be faster using this algorithm. Cartesian- The most basic stitching algorithm, can be useful for compatibility with legacy software versions. Overlay- For simple, fast visualization, typically used for diagnostic purposes or specialized applications. It is not intended for metrology purposes. Except for the Overlay type, all sites are aligned in X, Y, Z, pitch and roll (5 axes).
Overlap Merge	Selects what happens in overlap regions. Options are Blend, Average, or No Merge. Blend does an interpolation (fitting) of the sites. Average averages the data in the overlap regions. No Merge does not merge overlapping areas.
Sample Mode	Selects how sites are sub sampled. This is typically used to increase throughput when stitch sequences are large (more than 100 sites). Options are None, Bin, or Skip. None means no sub sampling is performed. Bin uses a convolution of camera data and then down scales and averages data. Skip reduces the number of data points by using row and column data as determined by the Sample Factor control.
Sample Factor	Determines the functionality of the Sample Mode control. When Sample Mode is Bin, it is how many pixels get binned together. When Sample Mode is Skip, it determines the number of rows and columns of pixels to skip (or not use).
Enable Global Correction	When this check box is selected a Cartesian algorithm is also applied after adjusting X,Y position using the Adjust XY algorithm. Only available when Type is Adjust XY.
PreProcessing Sequence	Opens a processing sequence window. This is used to specify data processing operations on the raw stitch data before it is all stitched together. See Data Processing for details on using this feature. For example, if the combined stitch area results in multiple tilted planes with nothing connecting between sites, use the remove form function in the Sequence tool.

Stitch Analysis- Advanced

Search Window	Specifies how much searching is attempted when aligning sites to each other. Too large of a search area increases processing time. Too small of an area may provide insufficient matching. The Automatic setting is determined internally and displayed. To override the Automatic setting, select the Manual radio button and enter a dimension.
Lateral Resolution	This attribute shows the lateral resolution of the current instrument configuration.
Search Window	This attribute shows the size of the search window in pixels.

Stitch Panel Advanced Tab

Controls accessed under the Advanced tab are used to fine-tune stitch sequences.

Sizing Type	Selects how the size of the stitched area is defined. Options are Size or Row Column. *Size* requires lateral dimension entries in the Size X and Size Y controls. *Row Column* requires an entry in the corresponding Row and Column controls.
Row	Specifies the number of horizontal rows in the stitch sequence.
Column	Specifies the number of vertical columns in the stitch sequence.
Size X	Specifies the size of the overall stitched image in the x-axis.
Size Y	Specifies the size of the overall stitched image in the y-axis.
Order	Selects how to traverse the part rows and columns, in a serpentine or raster fashion. Options are Row Raster, Row Serpentine, Column Raster, or Column Serpentine. Raster order measures sites in one direction. At the end of a row or column, the stitch continues after traversing back to the beginning of the row or column. Serpentine order winds back and forth measuring sites as it goes.
Origin Alignment	Selects the site located at the origin; the field of view is aligned such that the origin stage position is either the Center or Corner.
Origin	Selects the corner where the stitch sequence begins. Options are Upper Left, Upper Right, Lower Left, or Lower Right.
Origin X	Specifies or displays the origin of the stitched image in the x-axis.
Origin Y	Specifies or displays the origin of the stitched image in the y-axis.
Origin Z	Specifies or displays the origin of the stitched image in the z-axis.
Origin Pitch	Specifies or displays the origin of the stitched image in the pitch axis.
Origin Roll	Specifies or displays the origin of the stitched image in the roll axis.
Origin Theta	Specifies or displays the origin of the stitched image in the theta axis (if equipped with applicable hardware).

Run Origin Axis	Determines the axes to move when the stitch or pattern runs and goes to the origin position. Options are XY (default) or All. *XY* moves only in x and y at the first site. *All* moves in x, y, z, pitch, and roll at the first site; all others sites only move in x, y, and z.
Run Start At	Determines where the stitch sequence or pattern is started. Options are Origin or Current Position. *Origin* goes to the origin and runs the stitch or pattern. *Current Position* sets the origin at the current site location and runs the stitch or pattern, effectively shifting the locations.
Rotation	Rotates the stitch grid. This useful when the part is skewed in reference to the instrument axes.
Failure Action	Selects the action to take if there is a measurement error during a stitch sequence. See Failure Action.
Leveling	Selects how to adjust in the z axis during the stitch sequence or pattern to compensate for general form in the part being measured. Options are None (default), Linear Manual Adjust, Linear Store, Tilt, Cylinder, or Adaptive Focus. *None* makes no z-axis adjustment between sites. *Linear Manual Adjust* allows the user to manually adjust the z-axis along a row or column to compensate for tilt. *Linear Store* determines the leveling on two stored z-axis locations for leveling along either the row or column. *Tilt* goes to the extreme corners of the stitch or pattern area to determine z-axis positions to account for overall tilt in the whole part. *Cylinder* applies an auto tilt to the center of the stitch or pattern to compensate for cylindrical shaped parts; the stitch or pattern drives to the corners and cardinal sites and does a best fit cylinder then makes adjustments. *Adaptive Focus* attempts to adapt the z-axis position as the stitch sequence is running. This provides an ongoing height adjusted location for the next site to improve throughput. See Adaptive Focus.

Working With Stitch Files

Stitch sequences are saved and loaded from within the Stitch Panel and are identified by the extension .stix.

Saving a Stitch File

1. Open the Stitch Panel by clicking the Config Stitch button in Measurement Setup.
2. Click the Stitch Files tab.
3. Click the Save button.
4. In the Save File dialog, type a file name and click Save.

Loading a Stitch File

1. Open the Stitch Panel by clicking the Config Stitch button in Measurement Setup.
2. Click the Stitch Files tab.
3. Click the Load button.
4. In the Load File dialog, select the file and click Load.

Saving Site Data

Each site has its own data that is later combined into a single data file. The individual site data can be erased after the data sets are joined or each site can be saved as an individual data file.

1. Open the Stitch Panel by clicking the Config Stitch button in Measurement Setup.
2. Click the Stitch Files tab.
3. Select the Save Data check box.
4. Specify the location of saved files in the Base Folder control by clicking  and pointing to a directory location.
5. Enter a file prefix in the Base Filename control. This base name is common for all saved stitched data sets. The last part of the file name is automatically generated as the stitch is performed and corresponds to the site labeling.

Stitching Existing Data

- Data must be valid Mx data files (not generated).
- Data must be collected through stitching on a recent version of Mx.
- The resulting stitch must be less than 10000 x 10000 pixels.
- Each data set must have valid lateral resolution.
- Data files are automatically laterally matched together by examining stage coordinate information in each file.

Loading and Stitching Existing Data

A series of individual site data files can be loaded and stitched.

1. Open the Stitch Panel by clicking the Config Stitch button in Measurement Setup.
2. Click the Stitch Files tab.
3. Click the Load and Stitch button.
4. In the Load file dialog, select a series of data files and click Load.

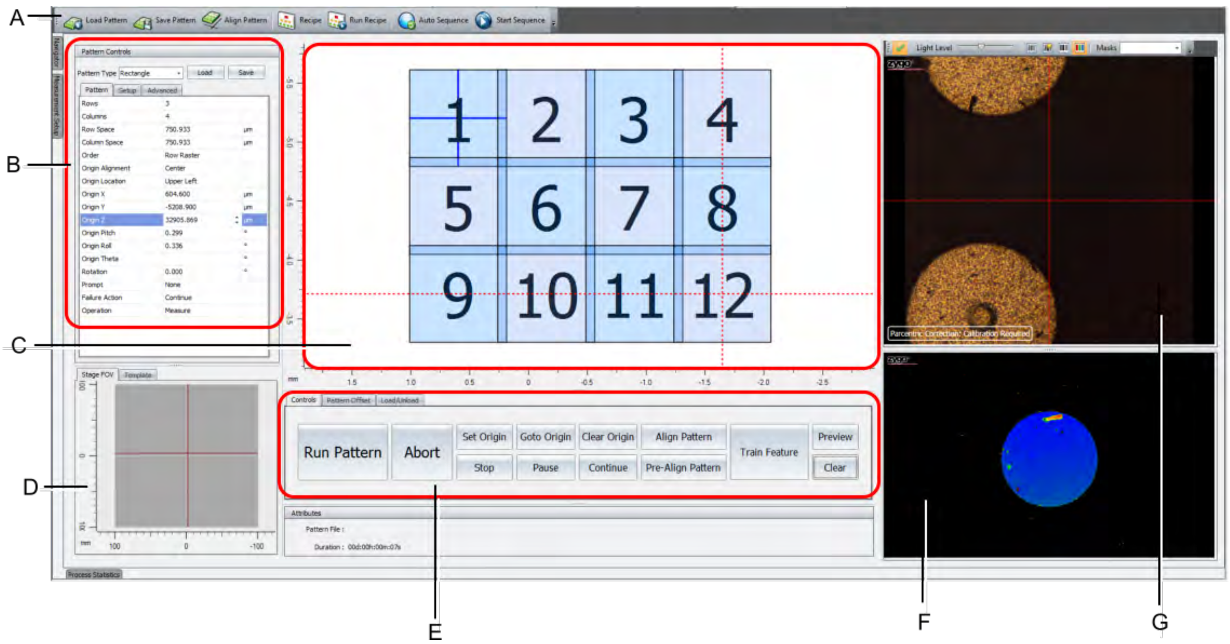
6.5 Pattern Editor

- Used to create, edit, save, and load stage control pattern files.
- Patterns are used to define multiple locations where data is acquired.
- A pattern directs the movement of programmable motorized stages.
- The instrument must be equipped with applicable motorized stages.
- There are similarities between some stitching and pattern controls.
- By default, Process Statistics are cleared (see Clear Process Stats) and then populated each time a pattern is run.
- To save data files at each site use Auto Sequence.

The Pattern Editor

Click the AUTOMATION tab to access.

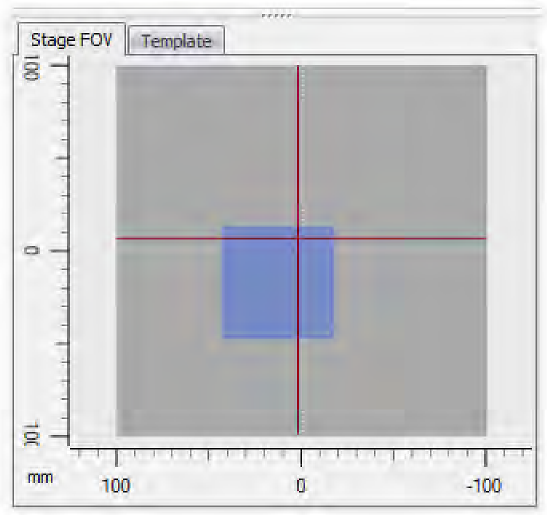
To view the Pattern Editor in a standalone window access the Navigator and click Pattern Popup.



A. Toolbar. **B.** Pattern Controls. **C.** Graphical representation of pattern sites (image pane). **D.** Stage FOV. **E.** General Controls (buttons) **F.** Plot shows surface measurement data of current site. **G.** Live Display of current site.

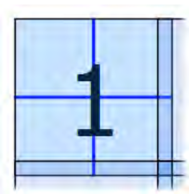
Stage FOV

Shows the current part stage field of view.

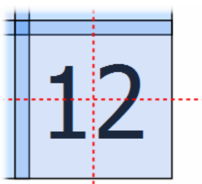


- The large gray square represents the travel range of the stage. In this example it is ± 100 mm.
- The smaller bluish colored box shows the location of the pattern relative to the stage.
- The red crosshair shows the location of the current objective's focal point.
- The dotted white crosshair shows the stage center.

Working With Pattern Sites



Blue crosshair marks the origin. The origin is where the pattern begins.



Red dotted crosshair marks the current site location.

To zoom (enlarge) the image, left click somewhere in the white area, then press the middle mouse button and scroll to zoom in on the image.

To relocate (drag) the graphic about within the image pane, press and hold the middle (scroll) mouse button; move the mouse to reposition the image and release the mouse button when the image is where you want it.

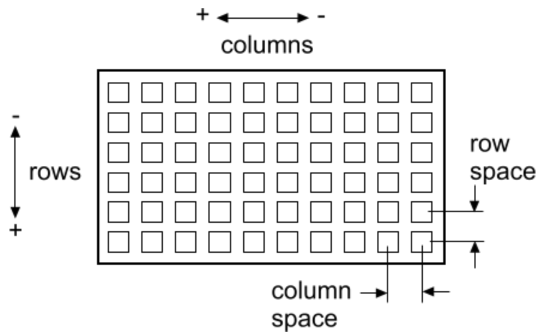
To move the pattern, press the Ctrl key, then press and hold the left mouse button on a pattern site and move the pattern to a new position.

To reset the pattern display to include all sites, point to the image pane, right-click and select Fit to Window.

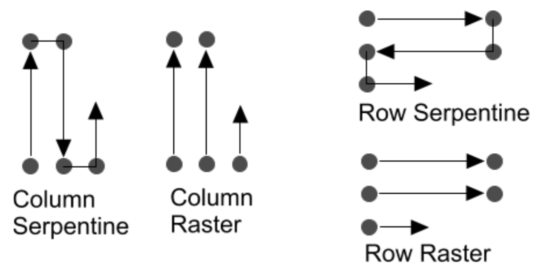
Pattern Terminology

- A *Rectangle* pattern is a grid of sites that have uniformly spaced rows and columns.
- A *Free* pattern defines positions in x and y coordinates that can vary in spacing and location.
- A pattern can also be based on a customer-supplied art reference image. See *Reference Image*.
- Each pattern location is referred to as a site. See Working With Sites and Customizing Sites.
- Pattern sites can be spaced apart or overlap one another.

Typically a pattern is composed of rows and columns of sites separated by spaces. However, sites can also overlap each other.

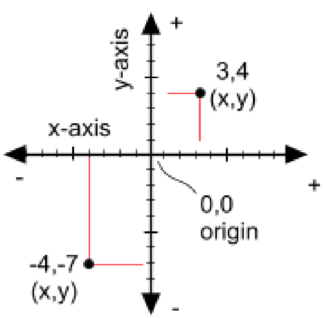


The pattern can be run in a serpentine or raster fashion. Note that the location of the origin is selected with the Origin Location control.

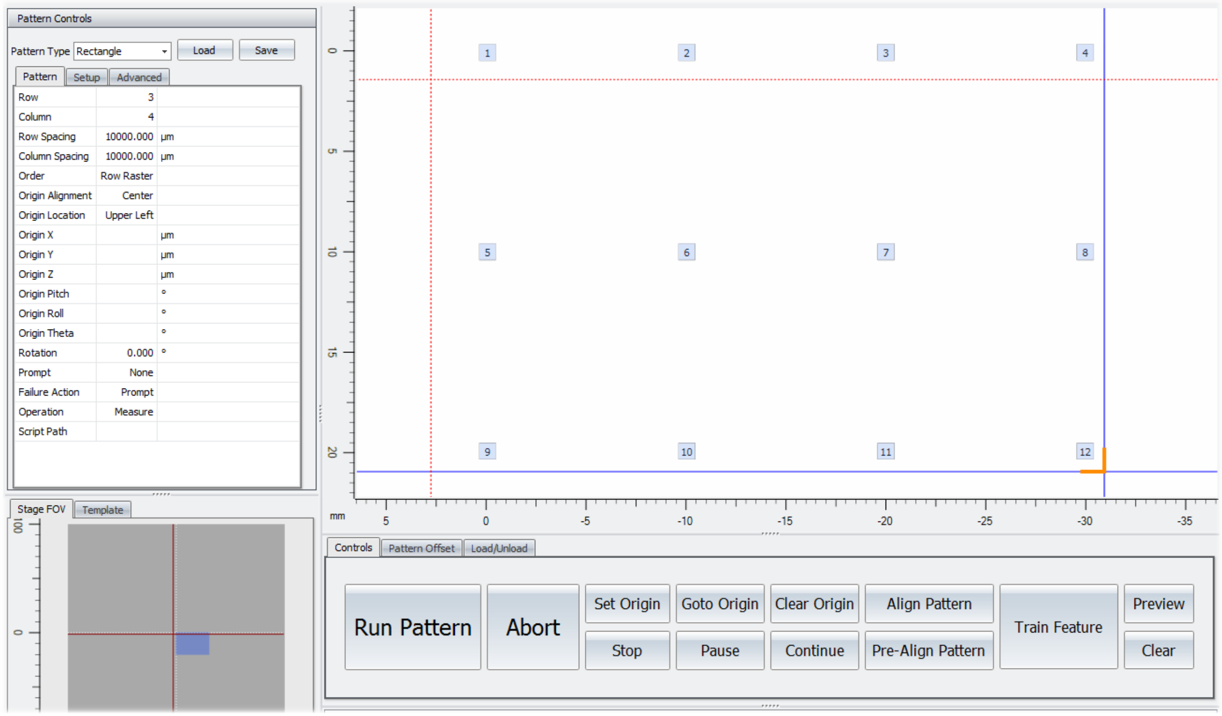


Pattern Coordinates

Rectangle and Free patterns are based on two dimensional Cartesian coordinates.



Creating a Rectangle Pattern



1. Prior to making a pattern, establish the proper measurement settings for the sample you want to measure. In this example, all the sites work with the same measurements settings.
2. Access the AUTOMATION tab and set the Pattern Type control to Rectangle.
3. Drive the stage to the first site.
4. Click Set Origin. This tells the software where to begin.
5. Point to the image pane, press the left mouse button and drag the orange "L" to enlarge or shrink the area. Release the mouse button to complete the selection. The number of rows and columns is automatically determined.

   To resize the pattern grid, point to the graphic, and press and drag the "L" cursor.

   The size of the grid can also be changed using the Rows and Columns controls under the Pattern tab.

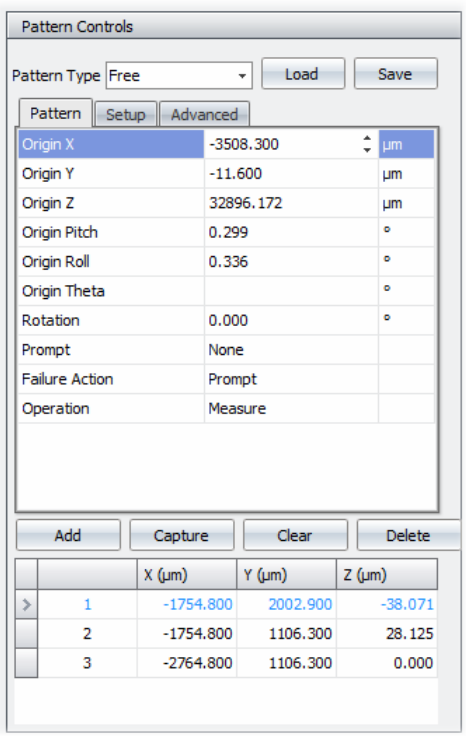
   To exclude a site from being measured, point to the site and press shift and click the site.

   To drive the stage to a site, point and click on the site.

6. Pattern settings can be customized under the Pattern tab.
7. (Optional) To run a test without measuring at each site click Preview. This will show you where measurements will be made. A sample is shown below.

8. By default, numeric results are sent to the Process Statistics (stats are cleared when Run Pattern is pressed). You may want to first configure Process Statistics with the results you want to capture. See Adding or Removing Items.
9. If you want to save data maps that are acquired at each site, use the Auto Sequence tool.
10. Click Run Pattern.

Creating a Free Pattern



1. Prior to making a pattern, establish the proper measurement settings for the sample you want to measure.
2. Access the AUTOMATION tab and set the Pattern Type control to Free.
3. Focus on a part site.
4. Click Set Origin. This tells the software where to begin and captures the first site.
5. Drive stage to second part location.
6. Click Capture.
7. Drive to a third location.

8. Click Add.
9. Repeat steps 7 and 8 for each pattern site location. The X, Y, Z table populates as sites are added. Coordinates are shown under Pattern Terminology.

   To replace a given site, select the > at the beginning of the row, then click Capture.

   To move the stage to an existing site in the table, click on the "#" square in the row.

   To delete a given site, select the > at the beginning of row, then click Delete.

10. By default, numeric results are sent to the Process Statistics (stats are cleared when Run Pattern is pressed). You may want to first configure Process Statistics with the results you want to capture. See Adding or Removing Items.
11. If you want to save data maps that are acquired at each site, use the Auto Sequence tool.
12. Click Run Pattern.

Pattern Editor Pattern Tab

These controls are under the Pattern tab. These are used to setup and edit the pattern. The specific controls displayed vary based on the selection of the Pattern Type control.

Pattern Type	Selects the type of pattern being defined. Options are Rectangle or Free.
Row	Specifies the number of horizontal rows in the stage pattern.
Column	Specifies the number of vertical columns in the stage pattern.
Row Spacing	Specifies the lateral distance between each horizontal row. The direction of motion depends on the sign.
Column Spacing	Specifies the lateral distance between each vertical column. The direction of motion depends on the sign.
Order	Selects how to traverse the pattern rows and columns, in a serpentine or raster fashion. Options are Row Raster, Row Serpentine, Column Raster, or Column Serpentine. See Pattern Terminology. Raster order measures sites in one direction. At the end of a row or column, the pattern continues after traversing back to the beginning of the row or column. Serpentine order winds back and forth measuring sites as it goes. Use this option for quicker throughput.
Order Alignment	Selects the site located at the origin; the field of view is aligned such that the origin stage position is either the Center or Corner.
Origin Location	Selects the corner where the pattern begins. Options are Upper Left, Upper Right, Lower Left, or Lower Right.
Origin X	Specifies or displays the origin of the pattern image in the x-axis.
Origin Y	Specifies or displays the origin of the pattern image in the y-axis.
Origin Z	Specifies or displays the origin of the pattern image in the z-axis.
Origin Pitch	Specifies or displays the origin of the pattern image in the pitch axis.
Origin Roll	Specifies or displays the origin of the pattern image in the roll axis.
Origin Theta	Specifies or displays the origin of the pattern image in the theta axis (if equipped with applicable hardware).
Rotation	Rotates the pattern grid. This useful when the pattern is skewed in reference to the instrument axes.
Prompt	Selects when the operator is prompted at each pattern position. A prompt shows the current position and waits for the user to respond. Options are None (default), Before, After, or Before and After.
Failure Action	Selects the action to take if there is a measurement error during the running of the pattern. See Failure Action.

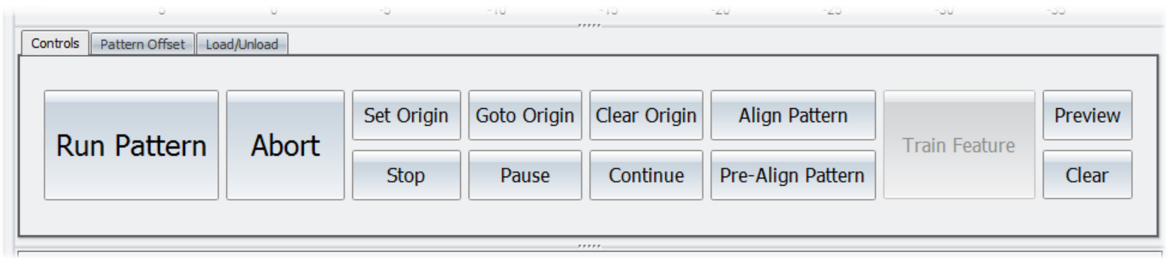
Operation Selects what is done at each pattern site. Options are None or Measure.

Measure takes a measurement at each location. None does nothing; this is useful when checking pattern spacing during pattern development.

Script Path Specifies the path to an optional script file (.py).

Pattern Editor Controls

These buttons provide basic pattern control.



Run Pattern Execute a pattern based on the current settings.

Abort Stop and cancel any running pattern.

Set Origin Set the current stage coordinates as the origin pattern position.

Goto Origin Drive the stages to the origin pattern position.

Clear Origin Erase any origin coordinates.

Align Pattern Click to run a pattern alignment. Then follow the software prompts. This updates the origin x and y positions and sets the Rotation control value.

This is used to align a pattern to a set of defined fiducials for the purpose accurately placing the pattern sites over the part sample.

Stop Stop the currently running pattern after the site is complete.

Pause A temporary stop of the running pattern.

Continue Runs the pattern from the paused position.

Pre-Align Pattern Runs an alignment adjusting the stage theta position.

Train Feature Trains the Cognex VisionPro software tool to recognize a feature to use in Pattern alignment or pre-alignment. This function requires a Cognex VisionPro license.

Preview Run a site to site intensity preview of the pattern. Intensity part images at each position are displayed. This is a useful feature to see if your pattern sites visit all of the specified site location properly.

Clear Remove the pattern preview image, if displayed.

Pattern Editor Pattern Offset

- Pattern Offset allows the user to offset site 1 from the origin position, effectively shifting the pattern. This is used in unique circumstances to bypass normal pattern usage (where site 1 is located at the origin).
- Set Z Safe Position is used to prevent objective crashes in unique conditions.

Setting a Pattern Offset

This shifts the pattern relative to a fixed point or the origin. Pattern offset includes coordinates in x, y, and z axes.

1. Find the pattern origin and click Set Origin button (under Controls tab).
2. Drive the part stage to the offset position.
3. Click the Pattern Offset tab.
4. Click the Capture Stage Position button.

Set Z Safe Position

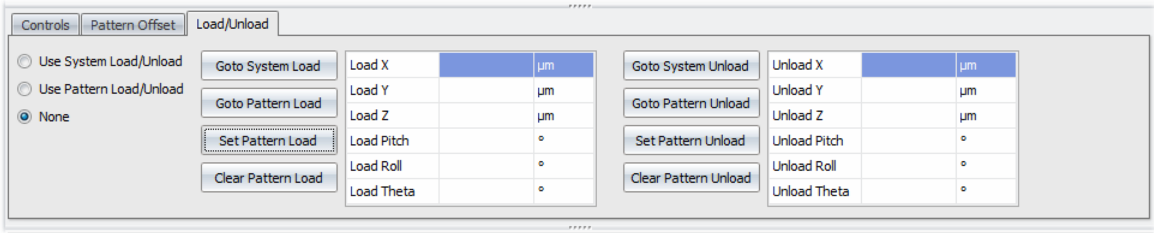
The Z Safe Position is used when the part has features (such as pins) sticking up that will interfere with the objective moving between alignment positions. Only the Z axis is adjusted.

This control is only applicable during pattern alignment.

1. In the Pattern Editor Advanced tab, right click in the grid and select the Use Safe Z Position and Safe Z Position controls to show them in the grid.
2. Move the Z axis high enough to clear the feature.
3. Click Set Z Safe Position button. The Safe Z Position will be set to 0.5 mm above the current Z axis stage position.
4. Set the Use Safe Z Position to On.

Pattern Load/Unload

- Use to define and control pattern load and unload stage positions relative to Home. The load and unload positions are usually locations where it's easier for the operator to reach the part, as well as a "safe" location where the possibility of hitting the instrument with the part or part tray is reduced.
- Pattern locations can be captured by clicking the corresponding "Set" button.
- The positions are stored with the pattern; each pattern can have a different setting.
- For *system* load and unload positions see System Load/Unload.



Goto System Load Press to drive the motorized stages to the set *system* load position.

Goto Pattern Load Press to drive the motorized stages to the set pattern load position.

Set Pattern Load Press to make the current stage positions the pattern load location.

Clear Pattern Load Press to clear any set pattern load positions.

Goto System Unload Press to drive the motorized stages to the set *system* unload position.

Goto Pattern Unload Press to drive the motorized stages to the set pattern unload position.

Set Pattern Unload Press to make the current stage positions the pattern unload location.

Clear Pattern Unload Press to clear any set pattern unload positions.

Setting a Pattern Load Position

1. Drive motorized stage axes to the best/safest position to load a test part.
2. Press the Set Pattern Load button.
3. Select the Use Pattern Load/Unload option button.

Positions are saved with the pattern file.

Setting an Pattern Unload Position

1. Drive motorized stage axes to the best/safest position to unload a test part.
2. Press the Set Pattern Unload button.
3. Select the Use Pattern Load/Unload option button.

Positions are saved with the pattern file.

Pattern Controls Advanced Tab

These controls perform advanced operations.

Leveling Selects how to adjust in the z axis during the pattern to compensate for general form in the part being measured. For a complete description see Leveling.

Leveling Min Points Refer to Adaptive Focus.

Clear Process Stats Selects what to do with Process Statistics when the pattern is run. Options are On Start or Off.

When On Start is selected statistics are cleared when the pattern is run.

Run Origin Axis Refer to Run Origin Axis under stitching.

Run Start At Refer to Run Start At under stitching.

Working With Pattern Files

Pattern files are saved and loaded from within the Pattern Editor and are identified by the extension .patx.

Saving a Pattern File

1. Click the AUTOMATION tab.
2. Click the Save button in the Pattern Controls or click the Save Pattern button in the toolbar.
3. In the Save File dialog, type a file name and click Save.

Loading a Pattern File

1. Click the AUTOMATION tab.
2. Click the Load button in the Pattern Controls or click the Load Pattern button in the toolbar.
3. In the Load File dialog, select the file and click Load.

6.6 Adaptive Focus

- Adaptive focus attempts to adjusts the instrument focus as stitch sites or pattern sites are measured. Designed particularly for overlapping sites.
- After the first site is measured, subsequent focus adjustments are based on the previous site. Uses the piston value or plane fit parameters of the previous measurement to place the z position at the next site.
- Note that an adaptive focus routine is not applied to the first measurement site.
- Compatible with both stitching and patterns.
- Accessed through either the Stitch Panel or Pattern Editor.

Parcentric Correction stage calibration is recommended to properly use this feature.

Guidelines

The stitch or pattern sites should overlap, or at least be next to each other with no gap. In some situations adaptive focus may still work if there is a small gap depending upon the form of the part. However, do not expect adaptive focus to work if sites have large spaces between them.

Adaptive focus uses a specific failure action routine. If adaptive focus is turned on, and the measurement fails on the first attempt, the measurement process automatically performs an Auto Focus and measure. If the second measurement fails, the site is marked “Fail” and the normal stitch or pattern error handling proceeds.

Using Adaptive Focus

1. Go to Advanced tab in the Stitch Panel or Pattern Controls.
2. Set the Leveling control to Adaptive Focus.
3. Set the Min Points control to 1.
4. Select the Fitting control option, either Plane or Piston. The stage pitch and roll has to be normal to the optical axis if Plane is used.
5. Run the Stitch or Pattern.

Adaptive Focus Controls

Fitting Selects how the z position is determined for the site. The options are Piston or Plane.

Piston simply calculates the piston of the data previously acquired and subtracts half the scan length, and sets the new z position for the current site.

Plane requires setting the stage zero positions. Zero position is the reference position where the stage pitch and roll have the optical path perpendicular to the stage plane. This can be done by running the Parcentric Correction calibration. Plane fitting calculates the tilt of the data and based upon the stage tilt and the distance from where the data was measured, it calculates the middle scan location for the next site and sets the z position.

Min Points Specifies the minimum number of valid data points in the measured data to consider the site pass/fail status when the Leveling control is set to Adaptive Focus. A site measurement is considered a failure if the number of data points measured at the site is less than this control value.

6.7 Reference Image

- A reference image refers to a user-provided 2D drawing file.
- Used to facilitate the setup of stitches or patterns.
- Accessed through either the Stitch Panel or Pattern Editor.

Overview

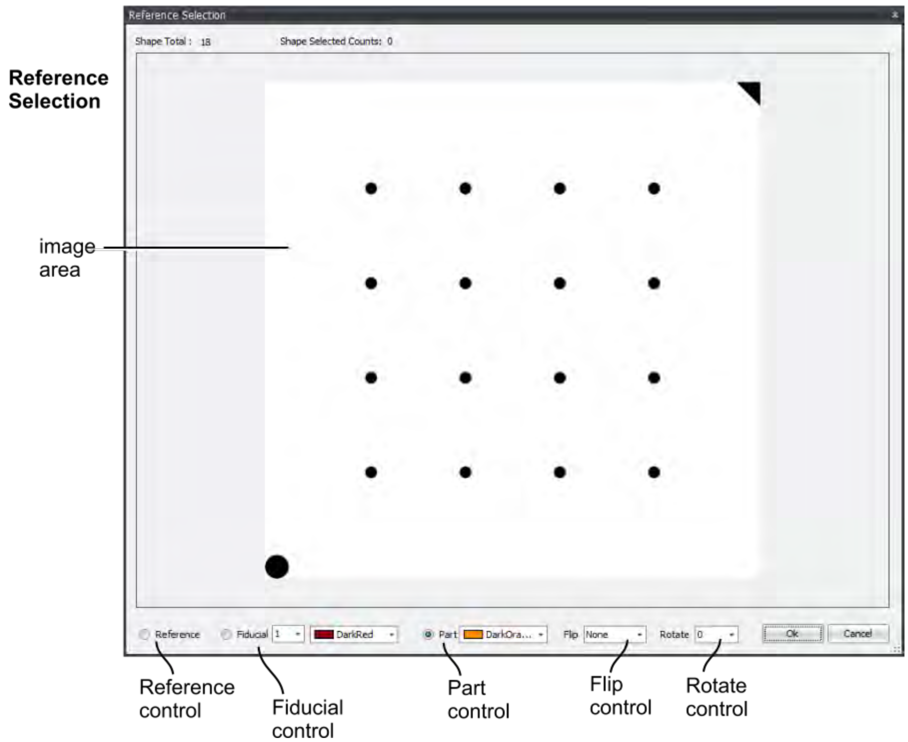
Mx can load Gerber design files (with extensions .art, .gbx, .grb, or .gdo). These files specify the location and size of fiducials or objects to be measured. The information in a Gerber file is a visual 2D representation of the objects found in the actual part. When loaded, Mx displays the contents of this file. The user can then mark objects in the image as fiducials or as measurement points. Both the stitching and pattern tools may use this information in setting up acquisition options, and Regions uses this during analysis. This is particularly helpful when you may want to measure and analyze 100’s or 1000’s of objects.

Example Uses

- Allows pattern generation to measure only areas that contain measurement objects and to automatically exclude regions that contain no measurement objects.
- Provides a method to specify fiducial locations for part and data alignment operations.
- Provides information to the Regions tool to enable results that report the difference between the measured locations of objects and the locations of those objects as specified in the Gerber file.

Using a Reference Image

1. For stitching, under the Stitch Setup tab access the Reference tab. For patterns, under Pattern Controls access the Setup tab and then the Reference tab.
2. Press the Load Reference Image button. In the Open Parts Design dialog, select the reference image file that matches the part being measured. Make sure the correct file extension is selected. Click on the file and press OK.
3. A Reference Selection window opens. The reference image is loaded into the image area exactly as it is defined in the reference image file.
4. Rotate or flip the image if necessary to match the orientation of the part on the stage. Use the Flip or Rotate controls.



To zoom (enlarge) the image, left click somewhere in the white area, then press the middle mouse button to zoom in on the image.

To relocate (drag) the image about within the display panel, press and hold the middle mouse button; move the mouse to reposition the image and release the mouse button when the image is where you want it.

5. Select the Part control. This is used to signify the parts (or shapes) you want to measure. Select or deselect shapes as instructed below.

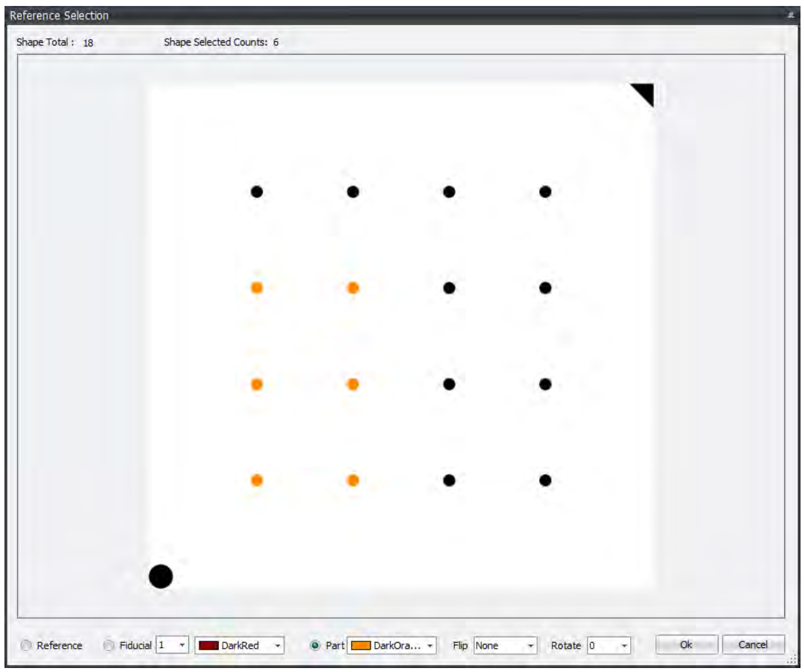
   To select a single item, point and click.

   To deselect or remove a single item, click the item again.

   To select multiple items, left click on a blank area and drag the selection window over a group of shapes, then release the mouse button.

   If the reference image has a boxed area (outline) enclosing many shapes, touching this outline when selecting multiple items will include all features within the outline.

   The color of the selected parts on the display can be changed with the Part control color drop-down list.



6. Select the Fiducial control. This is used to define the features considered as fiducials. Fiducials are shapes that are used to orient the pattern to match the translation and rotation of the actual on the stage; a minimum of 2 fiducials are required. Point and click on the reference image on each shape that is a fiducial.
7. The fiducial number drop-down allows the user to specify the order in which fiducials are visited. All 1s are done first, then 2s, etc. If only one fiducial is assigned to a number, then that is the absolute order. To tag a fiducial with a corresponding number, select a number from the corresponding drop-down list before selecting the shape.

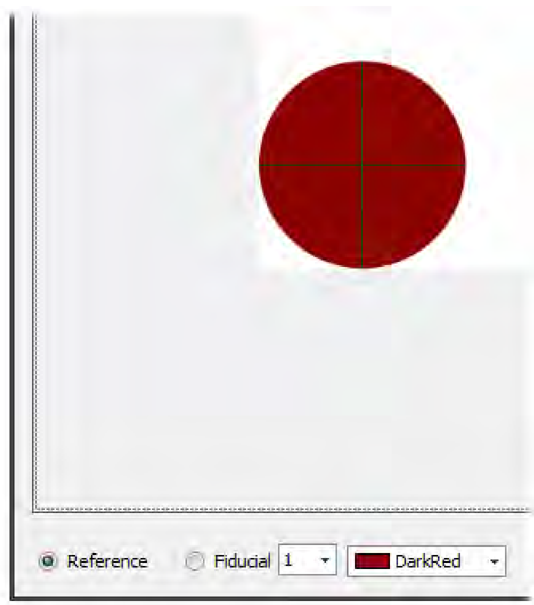
   To select a single item, point and click.

   To deselect or remove a single item, click the item again.

   The color of the fiducials on the display can be changed with the Fiducial control color drop-down list.

   Typically fiducials are used for alignment purposes and are not measured. To deselect a fiducial site so it is not measured, in the Stitch Panel or Pattern Editor point to a fiducial, right-click and select “Toggle Site Include/Exclude.”

8. (Optional) Select the Reference control. This is used to map a point (or virtual pattern) in the Gerber file to the actual part. Point and click on the reference image on the shape that serves as the Reference. It is indicated by a crosshair. You may want to zoom in on the image before selecting the reference.



9. Click Ok to close the Reference Selection window and go back to the previous tool. A stitch sequence or pattern is automatically created to match the selected parts and fiducials.
10. If step 8 was performed, find the same point on an actual part, then click the Set Reference Position button. This is a convenient way of setting the origin for a pattern.

6.8 Failure Action

Selects the action to take if there is a error during the corresponding function (such as when running a recipe, pattern, or stitch). The options vary based on the function and may include the following choices:

Continue	Ignores the error and goes to the next site.
Prompt	Asks the user what they would like to do when a failure is encountered.
Fail	Tags the associated function as a failure.
Retry	Tries to perform the action again; if an error is encountered a second time the user is prompted.
Retry After Completion	Goes back to the sites with errors and tries again.

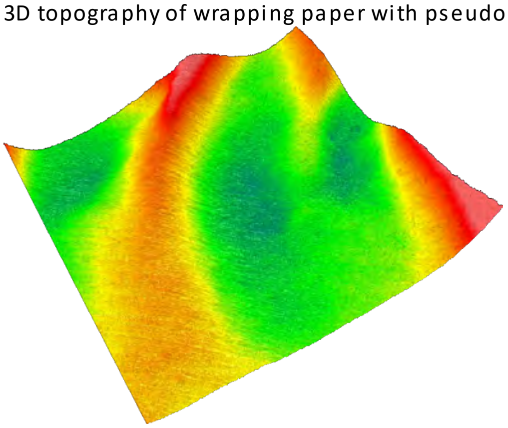
6.9 True Color

- Only available for optical profilers with a multi-color illuminator.
- Enable by selecting the True Color check box in the Measurement Setup panel.
- Immediately following the metrology scan, a secondary acquisition is automatically executed to collect true color information about the surface at the point of best focus for each data point in the camera.
- Provides full color surface image for all data points in the topography map.
- To display color information in the 2D and 3D surface maps, select the True Color icon in the plot toolbar or context menu.
- Color information is stored with the .datx data file format.
- 3D intensity calibration is required. For more information see Calibration.

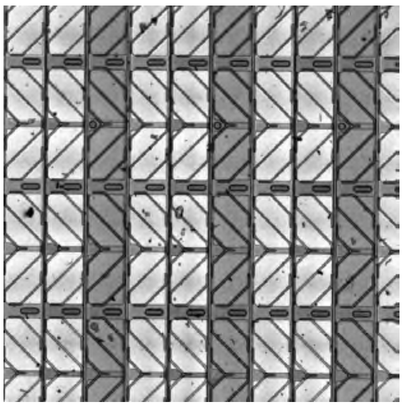
Example Images

Typical Image

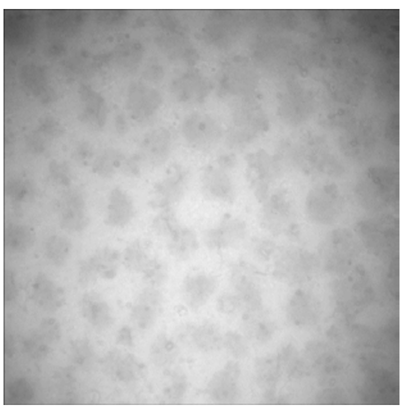
3D topography of wrapping paper with pseudo color



Flat panel display color filter array (monochrome)

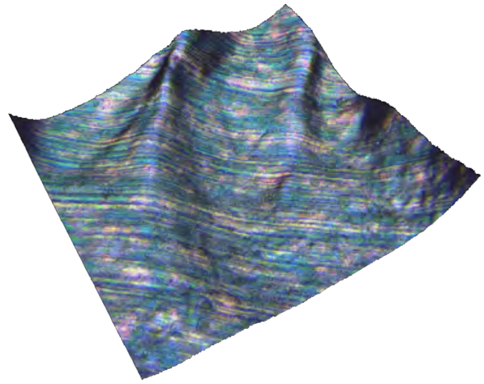


Ink pigments on high-gloss paper

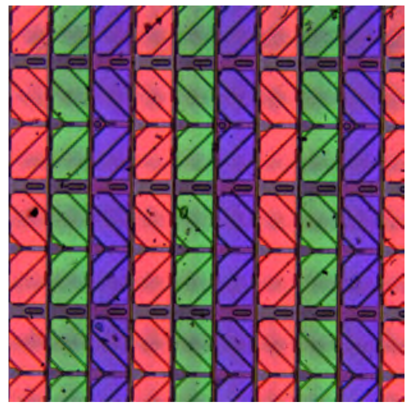


True Color Image

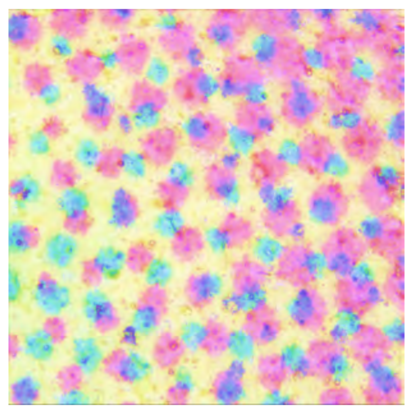
3D topography of wrapping paper with real color



Same color filter array in real color

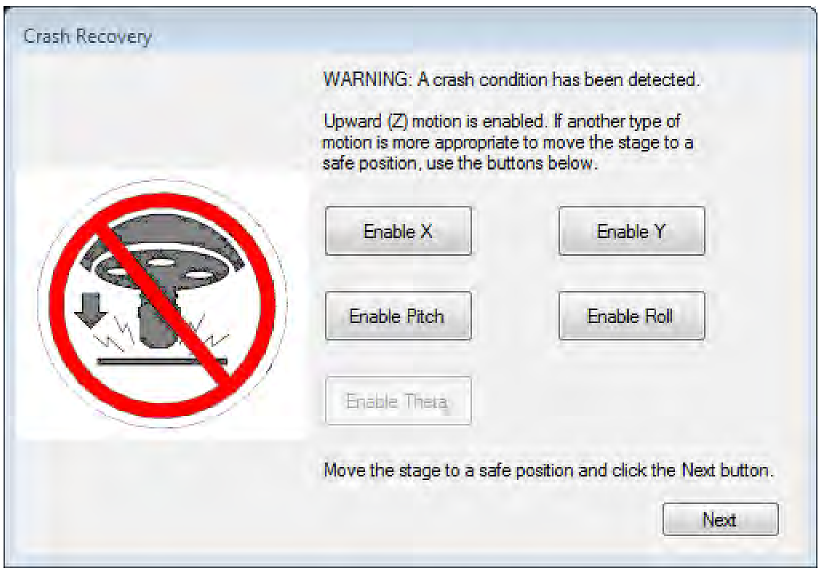


Same ink pigments in real color



6.10 Crash Recovery

- Crash detection is active when there is joystick or application-commanded motion (x/y/z/p/r/turret).
- Crash detection can help to protect the objective, part, and scanner in the event of a crash, but it cannot guarantee that damage will not occur.
- If a crash condition is sensed, all motion is immediately stopped, the PZT scanner is automatically retracted, and a Crash Recovery dialog is displayed (see below).
- Only upward (Z) motion stays active to allow for recovery from the crash condition. Follow the prompts in the dialog to recover. If possible, raise the objective to a safe position. If the objective cannot be moved up without hitting something, enable the applicable axis and move the stage for clearance before raising the objective.



Tools 7

This section covers various tools in Mx. Many are accessed with the Tools menu, and some are only accessed through toolbar buttons. The available tools and functions vary based on the application and instrument.

7.1 Common Tools

This section describes tools that are common to many instruments.

Auto Run Scripts	Run pre-made scripts before a measurement, after a measurement, and/or after the analysis. Add auto run controls to a control grid for access.
Auto Save Files	Automatically save data, reports and statistical results. For data see Auto Save Data.
Auto Sequence	Automatically make multiple measurements and save the data.
Custom Controls	Usually custom controls are based on existing standard controls and are defined using an Expression Editor.
Custom Results	Usually custom results are based on existing standard results and are defined using an Expression Editor.
Environmental Test	Qualify the stability of your work environment.
Fiducial Editor	Define and apply reference locations to measurement data.
Live Display	Show a live image from the instrument camera.
Mask Editor	Define areas to include and/or exclude from the analysis.
Master Units	Choose the measurement units and number of decimal places.
Motion Utilites	Provides readouts, controls and options for instruments with motorized components.
Options	Set startup options and default file directories.
Quick Subtract	Subtract a selected data file from the current data.
Recipe Sequence Editor	Define and use a combination of instrument and software steps to perform a particular task or recipe.
Tolerances	Define low and high limits for numeric results.

See Also

Laser Interferometer Tools

Optical Profiler Tools

Auto Run Scripts

Scripts can selected be to run automatically in the following conditions:

- Before a measurement begins.
- After a measurement completes.
- After Analysis completes.

To enable auto-run scripts, use the controls listed below (see Working With Grids). These controls do not have corresponding attributes.

Condition	Script Enablement	Script Name
Before measurement	System > Automation > Enable Pre Measure Script	System > Automation > Pre Measure Script Name
After measurement	System > Automation > Enable Post Measure Script	System > Automation > Post Measure Script Name
After analysis	System > Automation > Enable Post Analyze Script	System > Automation > Post Analyze Script Name

Scripting calls to instrument.measure() or mx.analyze() will trigger auto-run scripts, provided the scripts are not auto-run scripts themselves. Calling instrument.measure() or mx.analyze() within an auto-run script will measure or analyze but will not trigger any auto-run scripts.

Pre-Measure and Post-Measure Use Conditions

- A stitch is considered a single Measurement: an enabled Pre Measure script will run once before the stitch begins, and an enabled Post Measure script will run once when the stitch ends.
- When running a sequence via Auto Sequence, enabled Pre Measure and Post Measure scripts run on each measurement.
- In a pattern, the Pre and Post measure scripts run at each site if the operation is Measure; they will not run if the operation is Run Script.
- If the Pre Measure script fails, the measurement will not be initiated.
- If the Post Measure script fails, normal analysis will occur and an error will be logged.
- The script command instrument.measure() triggers Pre Measure and Post-Measure scripts.
- The script command instrument.acquire() will not trigger any auto run scripts.

Post Analyze Use Conditions

- The Post Analyze script is only applicable after pressing F11 or loading data, not after a measurement.
- If a Post Analyze script fails, an error will be logged.
- The script command mx.analyze() will trigger an enabled Post Analyze script.

Auto Save Files

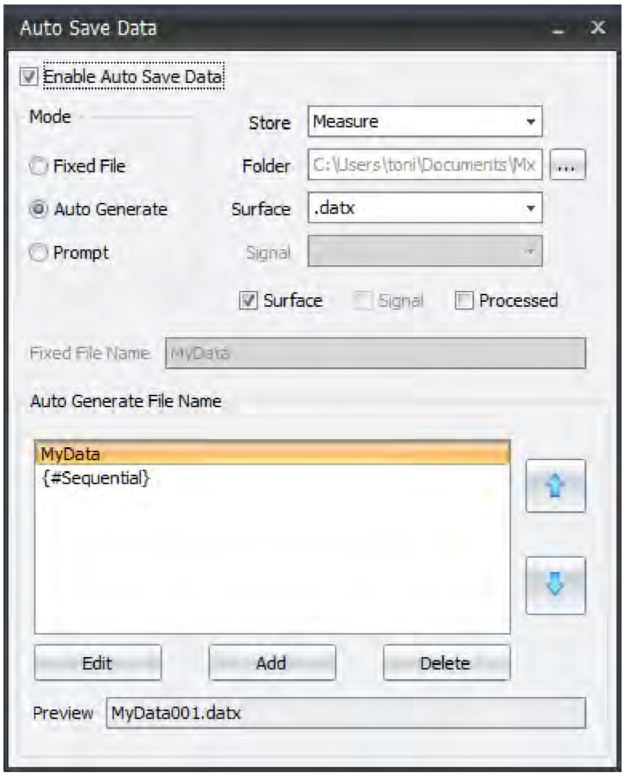
For auto saving data, the feature is available in the Auto Save Data tool.

For auto saving reports, this feature is available in Reports Options; see Auto Save Report.

For auto saving prints, this feature is available in the Recipe Sequence Editor.

For auto logging statistical results, this feature is available in Process Statistics and Regions output.

Auto Save Data



Enable Auto Save Data When selected, the specified file type is automatically saved after each action selected in the Store control.

Mode Selects the type of auto save operation to perform.

Fixed File- Performs a sequence and saves the file with a name and location that is specified by the user.

Auto Generate- Automatically generate a data file name and save it after each measurement. See Auto Generate File Name.

Prompt- Performs a sequence and prompts the user to specify a file location and name.

Store Selects when data is automatically saved.

Measure- The file is generated when the Measure button is clicked (or F12).

Analyze- The file is generated when the Analyze button is clicked (or F11).

Load Data- The file is generated when data is loaded.

Folder Specifies the directory folder location for saving data when the Mode is Fixed File or Auto Generate.

Select the folder by clicking ... and selecting a directory folder location.

Surface Selects the type of surface data or report to save. The choices are .datx, .dat, .xyz, or .asc. For details on file types see Compatible File Types.

The place in the processing flow where data is saved from is determined by the Surface, Signal, and Processed check boxes.

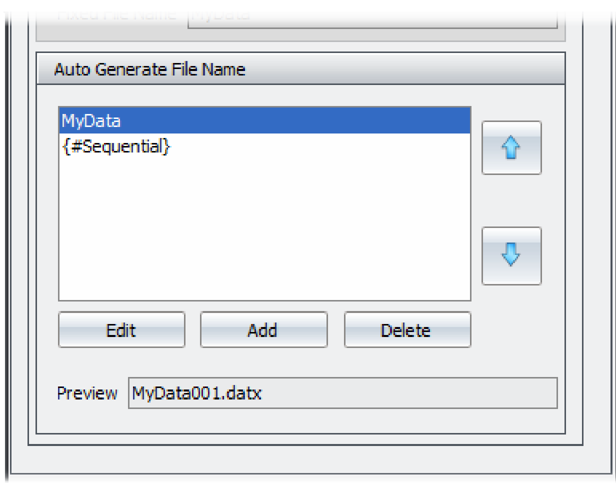
Signal Selects the type of raw signal data to save when the Mode is Fixed File or Auto Generate. A live instrument is required.

Fixed File Name Specifies the name of the file when the mode is Fixed File.

To automatically generate file names see Auto Generate File Name.

Auto Generate File Name

- When Auto Generate is selected, the file name is automatically generated based on entered criteria.
- The main panel is used to build and order components making up the auto generated file name.
- The characteristics associated with each component in the list can be defined and edited.

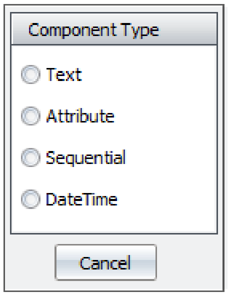


Ordering Components

1. Click on a component (or row) in the panel.
2. Click the up arrow to move component higher (first) on the list.
3. Click the down arrow to move component lower (last) on the list.

Adding File Naming Components

1. Press the Add button.
2. Select a component to add.



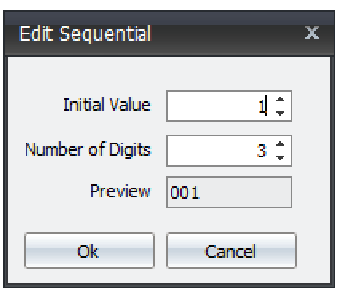
Text	Select to add a new name to naming panel.
Attribute	Select to add a measurement attribute from the Select Attributes dialog, such as serial number, etc. See Attributes.
Sequential	Select to add a new numbering sequence to the naming panel. See Defining a Number Sequence above.
DateTime	Select to add a date and time stamp to the naming panel. See Defining Date Time Format below.

Change the File Name (text component)

1. Select MyData or a text name appearing in the list.
2. Press the Edit button.
3. Enter a name and press Ok.

Defining a Number Sequence

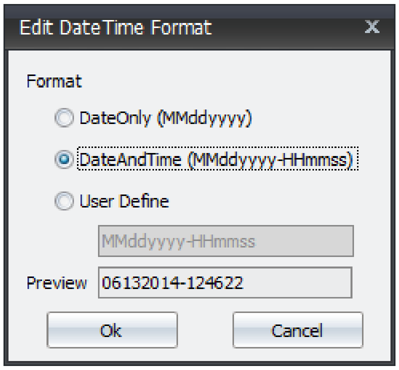
1. Click {#Sequential}.
2. Enter options and click Ok.



Initial Value	Sets the starting number in the auto numbering sequence.
Number of Digits	Selects the number of digits in the auto numbering sequence.
Preview	Shows a sample of the specified numbering scheme.

Defining Date Time Format

1. Press the Add button in the Auto Sequence tool.
2. Select DateTime.
3. Enter options and click Ok.



DateOnly	Adds a 8 digit numeric series for the date to the panel. Date is inserted as follows: 2 digits for the month, 2 digits for the day, and 4 digits for the year.
DateAndTime	Adds the 8 digit date (described above) followed by a 6 digit numeric series for the time. Time is inserted as follows: 2 digits for the hour (based on 24 hour clock), 2 digits for minutes (01-59), and 2 digits for seconds (01-59).
User Define	Select to define a unique date and time code. Some examples are shown below.

User Defined Date Time Examples

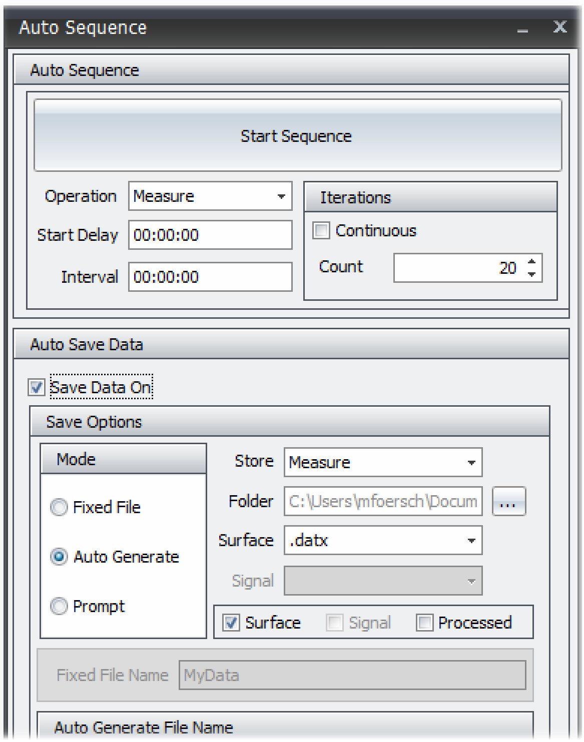
DateTime Pattern:

FullDateTimePattern:	dddd, MMMM dd, yyyy h:mm:ss tt	Example: Monday, May 28, 2012 11:35:00 AM
LongDatePattern:	dddd, MMMM dd, yyyy	Example: Monday, May 28, 2012
LongTimePattern:	h:mm:ss tt	Example: 11:35:00 AM
MonthDayPattern:	MMMM dd	Example: May 28
RFC1123Pattern:	ddd, dd MMM yyyy HH':'mm':'ss 'GMT'	Example: Mon, 28 May 2012 11:35:00 GMT
ShortDatePattern:	M/d/yyyy	Example: 5/28/2012
ShortTimePattern:	h:mm tt	Example: 11:35 AM
SortableDateTimePattern:	yyyy'-'MM'-'dd'T'HH':'mm':'ss	Example: 2012-05-28T11:35:00
UniversalSortableDateTimePattern:	yyyy'-'MM'-'dd HH':'mm':'ss'Z'	Example: 2012-05-28 11:35:00Z
YearMonthPattern:	MMMM, yyyy	Example: May, 2012

Auto Sequence

- Automatically make multiple measurements and save the data.
- Determine instrument repeatability and drift.
- Monitor a surface over a period of time to study temperature effects or distortion.

The Auto Sequence Screen



On the Tools menu, select Auto Sequence.

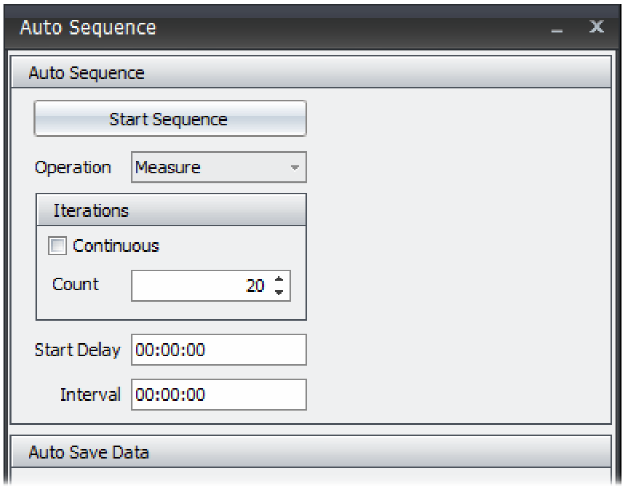
To start a sequence click Start Sequence.

To cancel the sequence or to end a continuous sequence, press the Esc key.

Using Auto Sequence

1. Setup your instrument and make a trial measurement.
2. Select your auto sequence options and enter the number of measurement to make in Count.
3. To save measurement data, select the Save Data On check box.
4. Select applicable auto save data mode options.
5. Click Start Sequence.

Auto Sequence Options



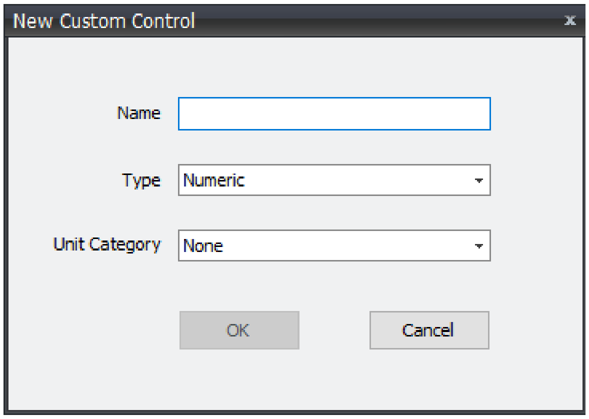
Start Sequence button	Click to begin an auto sequence based on the settings in the Auto Sequence tool.
Operation	Selects the auto sequence mode. Measure means the sequence is a series of measurements.
Iterations	The *Count* entry specifies the number of sequences to perform. When the *Continuous* check box is selected, the sequence is continued until the Esc key is pressed.
Start Delay	Specifies a time delay before a sequence starts once Start Sequence is clicked; in hours:minutes:seconds.
Interval	Specifies a time delay between sequences; in hours:minutes:seconds.

Custom Controls

- Custom controls cannot be based on other custom controls.
- Custom controls are saved with the application (.appx).
- Whenever a Custom Control is created an associated attribute is created.

Creating a Custom Control

1. In the Tools menu select Custom Controls.
2. Click the New button.
3. In the New Custom Control dialog, enter a Name for the control, select Type and Unit Category (applies only when Numeric).



4. Click OK.
5. To display custom controls, under the Grid menu select Add Control Grid.
6. In Controls Grid right click and choose Select Items, choose controls to add and click OK. See [Adding or Removing Items](#).

Deleting a Custom Control

1. In the Tools menu select Custom Controls.
2. Select the control to be deleted.
3. Click the Delete button.

Custom Results

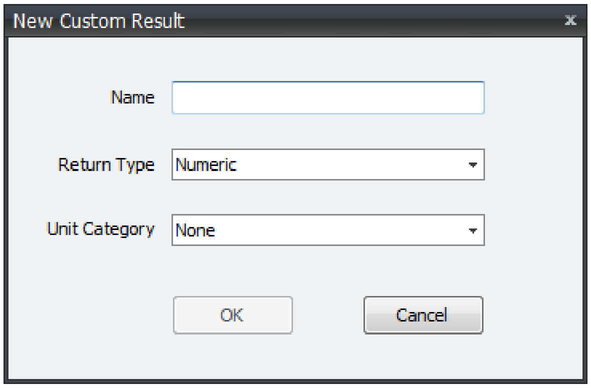
- Custom results are defined using an Expression Editor.
- Usually custom results are based on and built off of existing standard results.
- Custom results cannot be based on other custom results.
- Before making a custom numeric result, it is recommended to determine the Unit category (such as height, lateral, angle, etc.). Avoid custom results based on mixed Unit categories (i.e. height result and lateral result).
- Custom results are saved with the application (.appx).

Creating a Custom Result

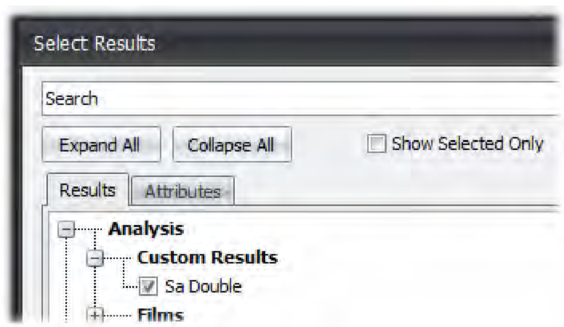
1. In the Tools menu select Custom Results.
2. Click Add/Remove button to provide access to existing results and attributes.
3. In the Select Results dialog, choose results or attributes to add and click OK. See [Adding or Removing Items](#). The items appearing under Results and Attributes serve as building blocks.

   A typical path to common results is Analysis - Surface...
4. Under Custom Results click the New button.
5. In the dialog, enter a Name for the result. Select a Return Type and Unit Category (applies only when Numeric). Click OK.

   For Return Type definitions see below. For Unit Category see [Unit Categories](#); some unit categories are not available for Custom Results.



6. The formula for the result is defined using the Expression Editor.
7. After the result is defined, click OK to close the Custom Result dialog.
8. To display the custom result, add the item to a grid (right-click Select Items) or a plot window (right-click Select Outputs). In the Select Results dialog items appear under Analysis - Custom Results.



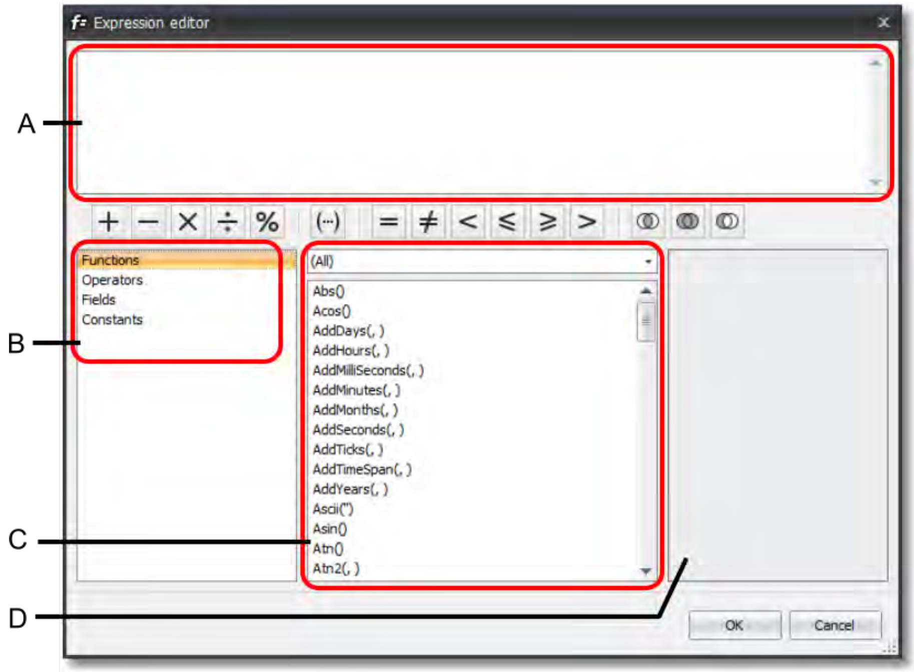
Return Type

Determines the output format of the custom result.

Numeric	Any number, including those with decimals.
Integer	A whole number without a fractional component.
Boolean	Has only two values, true or false.
String	A sequence of textual characters.

Expression Editor

- The Expression Editor is used to create custom calculations and textual expressions.
- An expression is any combination of operators, constants, functions, and other components that evaluates to a single value. You build expressions to create calculation and filter definitions.
- A calculation is an expression that creates a new value from existing values contained within a data item. A filter is an expression that retrieves a specific subset of records.
- User added Mx results appear when Fields is selected.

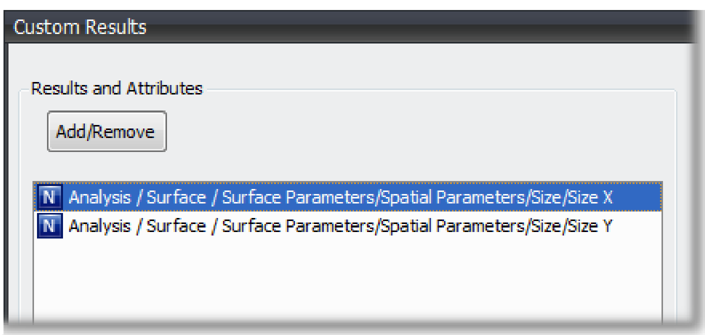


A. Expression building pane. **B.** Tools. **C.** Corresponding tool options. **D.** Description on selected tool option.

Custom Result Example

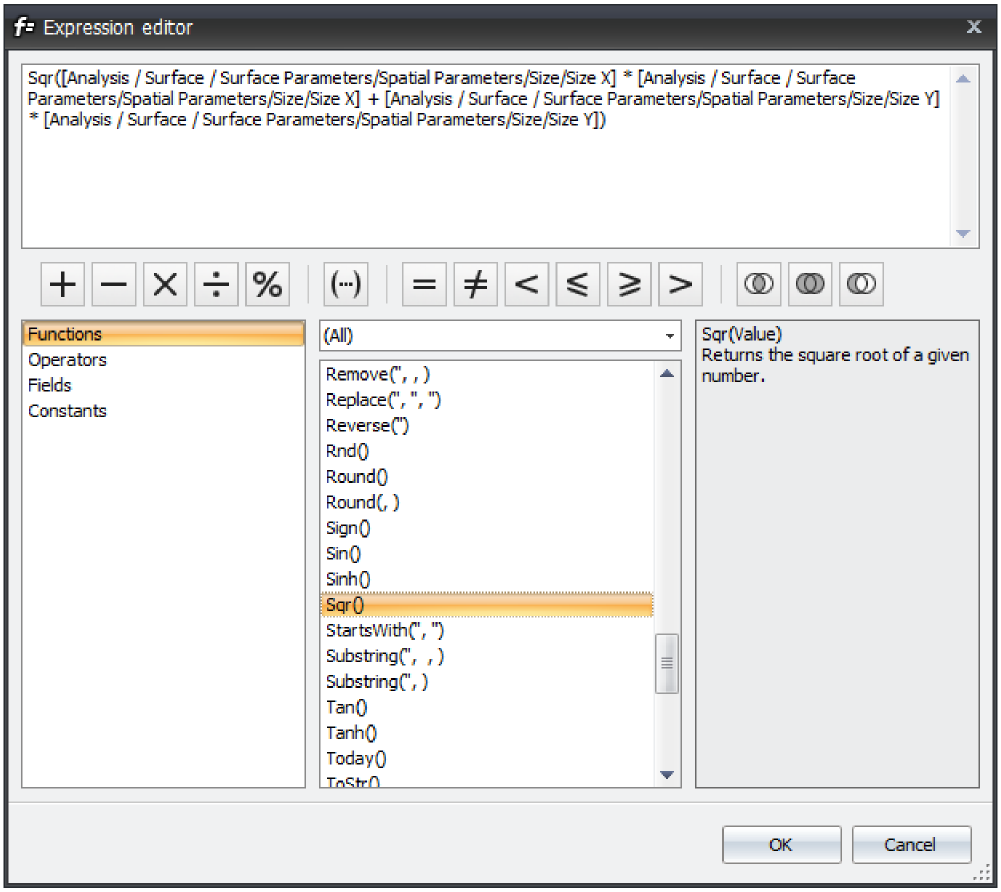
This example creates a result that calculates the diagonal dimension of the data. It requires access to the Size X and Size Y results; and is defined as the square root of Size X^2 plus Size Y^2.

1. In the Tools menu select Custom Results.
2. Click Add/Remove button. Add Size X and Size Y results.



3. Under Custom Results click the New button.
4. In the dialog, enter "Diagonal" as the name for the result. Select Return Type- Numeric and Unit Category- Lateral. Click OK.

5. Construct the formula:
   a. Click Functions, then click Sqr.
   b. Click Fields, then click the Size X descriptor. Click the X operator and then Size X again.
   c. Click the Size Y descriptor. Click the X operator and then Size Y again.
   d. This forms the equation for the custom Diagonal result. Click OK.

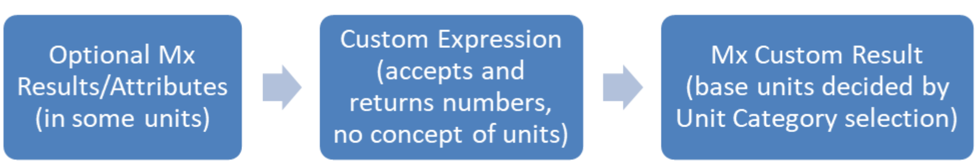


6. Click OK in the Custom Results screen.
7. Add the item to a grid (right-click Select Items) or a plot window (right-click Select Outputs). In the Select Results dialog items appear under Analysis - Custom Results.
8. Click the Analyze button to check the functionality.

Custom Results Units

Custom Results Data Flow

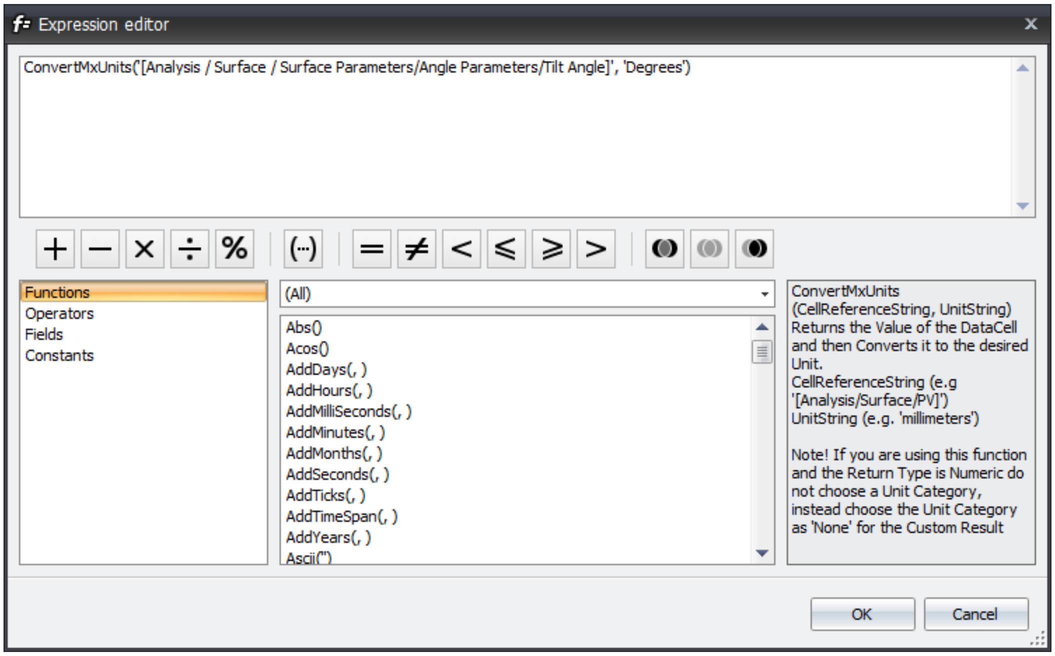
The general flow of custom results is shown below:



The custom Expression Editor takes an input field but has no concept of units. It simply retrieves the field as a number in whatever base units have been setup. Calculations can then be performed on the result in whatever units the user desires. The only requirement is that the result returned from the custom evaluator must match the base units selected by the unit category when the result was created.

Custom calculations can be performed on the value in any form desired. In most cases, the user will want to know the base units, so the custom expression evaluator contains a function called ConvertMxUnits. This function takes two arguments, an input field and a desired unit. The function looks-up the Mx result, queries the units and converts the value to the desired units. That value can then be used for further calculations. However, the final result units must match the selected unit category for the result or Mx will not be able to convert the units properly for display.

An example of the expression evaluator using the ConvertMxUnits function is shown below:



Custom Results Categories

The following table gives the expected output result units from the custom result expression for all the current selectable Unit Category options that are available when the custom result is created.

Custom Result Category Selection	**Expected Output Result Units**
None	Doesn't matter, no unit conversions applied
Angle	Degrees
Area	Square Pixels
Height	Nanometers for profilers Fringes for laser interferometers
Lateral	Pixels
Linear	Micrometers
Volume	Cubic Meters

Custom Results Expressed as a Percent

For results to display as a percentage, the denominator needs to be expressed as a floating point number in the equation. For example: PERCENT BPOINTS equal ["Analysis", "Surface", "Surface Parameters", "Spatial Parameters", "Size", "NPoints"] / **1000.0**

Environmental Test

On the Tools menu, click Environmental Test.

Function Overview

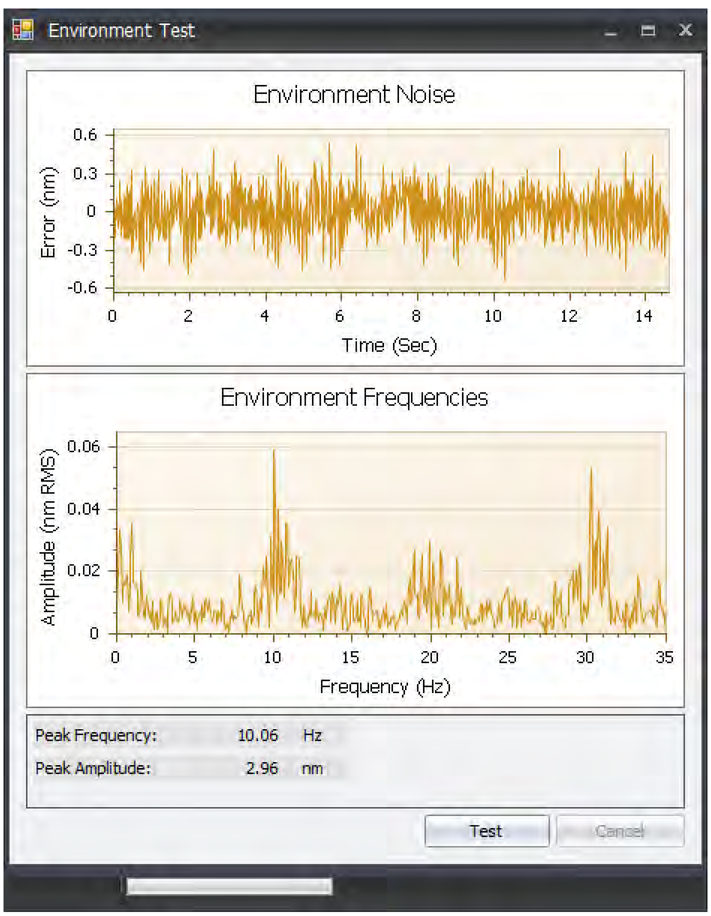
- Use to test the current environmental conditions for vibration and noise.
- This feature makes a series of intensity measurements over a sampling time.
- Before testing, adjust the test part so that there are from 10 to 15 vertical fringes.

Making an Environmental Test

1. Set up a test part to measure.
2. Adjust the test part so there are a series of vertical fringes.
3. Click Test. Results are plotted when the test is completed.

The test takes many seconds. The actual time for the test is based on the camera frame rate; the faster the rate, the shorter the time.

The Environmental Test Screen



Environment Noise

Shows the degree of noise present in the working environment over a period of time.

In this example, the noise (error) is about 1 nm.

Environment Frequencies

Shows the frequencies (in Hz) of the noise present in the working environment.

The spikes in this plot indicate the vibrational frequencies that may have a negative impact on the measurement.

Peak Frequency
The frequency at which the highest peak occurs.

Peak Amplitude
The overall height of the highest peak.

To change the x or y axis settings or to export data, right-click and select from the context menu.

Fiducial Editor

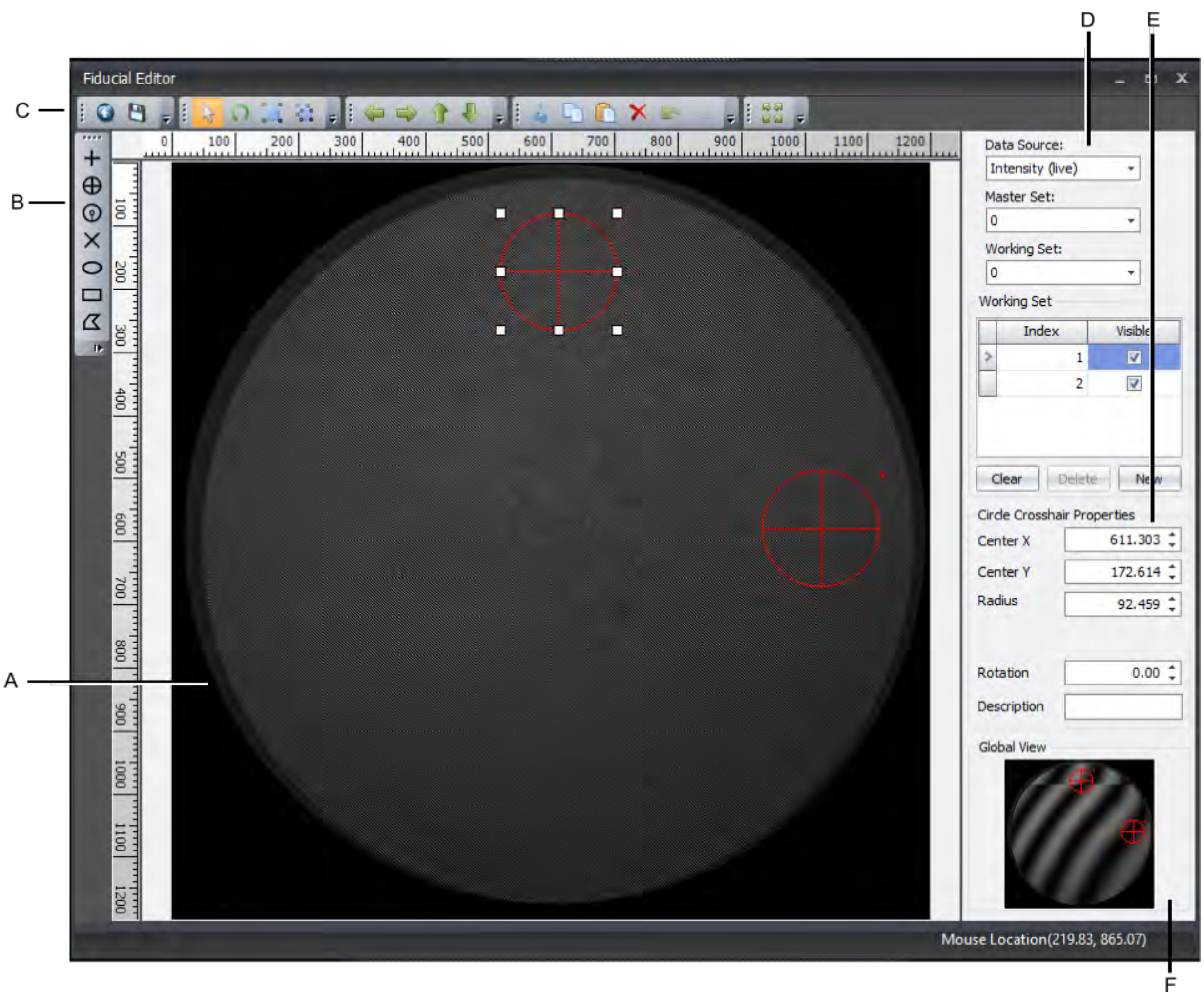
On the Tools menu, select Fiducial Editor or on the toolbar click Fiducial.

For Laser Interferometers, fiducials can be created directly within the Live Display. See Fiducial.

Fiducial Editor Features

- Available in Form.appx and Micro.appx.
- Used to define and apply fiducials.
- A fiducial is a reference point on the data and is used to assist in precise test part alignment. A fiducial can also be used to compare two data sets.
- Defined fiducial reference points are saved along with the data.

The Fiducial Editor Screen



A. Image of data source (test part). **B.** Shape (fiducial) toolbar. **C.** Toolbars- Mode, Move, Edit, Command (undo), Zoom, and File. **D.** Data Source and fiducial set selector. **E.** Fiducial Properties. **F.** Global View.

Global View

This view shows the entire image or global view of the data source. This helps you to see the placement of fiducials relative to other features when the main image area is zoomed in.

Making and Using Fiducials

Greater details on some of the following steps are provided later in this section.

1. Setup your instrument with a part, or load an existing data file, so you have an image.
2. Open the Fiducial Editor.
3. Select the Data Source.
4. Click on the fiducial shape you want to use and create at least two fiducials, positioning them over points of interest on the image.

   By default, the first grouping of fiducials is both the working set and the master set. The master set determines what fiducials appear on the live display.
5. To create a second working set of fiducials, click Add New Set and create fiducials shapes.
6. Click Save to save the sets and fiducials in a fiducial (.fidx) file.

What is a Fiducial?

Fiducials are reference or data location markers that are used as an alignment aid or to compare two data sets. When comparing data sets, fiducials on one data set are compared to a similar set of fiducials on the second data set; if necessary, the second data set is translated, rotated, and scaled until the fiducials align.

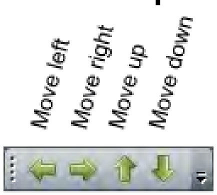
Fiducials are useful in evaluating optical systems and as an alignment aid in tests in which one part must be critically aligned to another. They may also be used as an alignment aid in certain test setups.

Fiducial Editor Toolbars

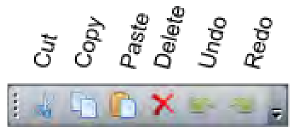
Draw Shapes

Edit Shapes

Move Shapes

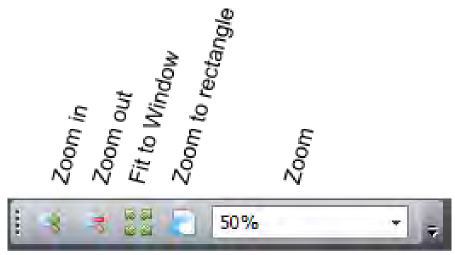


Edit

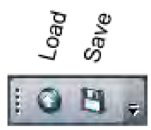


Zoom

Only Fit to Window displayed by default



File



See Also

[Toolbars]

[Changing a Toolbar]

[Working With the Display]

Working With Fiducials

The most common fiducial shape is a crosshair. A fiducial may be a crosshair, circle crosshair, gunsight, X, ellipse, rectangle, or polygon. Draw and position the fiducial over a permanent mark or feature on the test part. When possible, try to match the fiducial shape to the feature. Fiducials are automatically numbered as they are created.

If data sets are being compared, at least two fiducials must be created for each of the data sets. This makes it possible for the software to handle translation and rotation. When three fiducials are defined, the software also performs isomorphic and/or anamorphic scaling. Isomorphic scales both axes equally; anamorphic scales to the best-fit.

Use the Fiducial Properties dialog to view or edit details on individual fiducials.

Creating a Fiducial

1. Click the desired fiducial shape.
2. Position the pointer over the image area.
3. Click the left mouse button at the point you want the center of the fiducial.

Creating a Polygon Fiducial

1. Click the polygon shape.
2. Position the pointer over the image area.
3. Click the left mouse button for the start point.
4. Move the pointer to the next location and click the left mouse button. Repeat as needed.
5. Click the right mouse button to close the polygon.

Selecting Fiducials

Fiducials must be selected before they can be moved, copied, resized, rotated, or deleted.

1. (Single Fiducial) Click anywhere on the fiducial. The selection handles appear and the cursor changes.

or

2. (Multiple Fiducials) Press the left mouse button and drag the rectangular selection box over one or more fiducials. Release the mouse button.

Moving Fiducials

1. Select the fiducial(s), the cursor changes to .
2. Click the left mouse button, drag the mouse to move the fiducial(s) and release the button.

or

3. To move one pixel in a specific direction, press the Up, Down, Left, or Right Arrow keys or click the desired Arrow button.

or

4. To move 10 pixels at a time, hold down the Shift key while performing step 3.

Resizing Fiducials

Polygon fiducials cannot be resized unless it is part of a multiple fiducial selection; only individual points can be repositioned.

1. Select the fiducial(s).
2. Move the cursor to the selection handles around the fiducial, the cursor changes to .
3. Press the left mouse button, drag the mouse to resize the fiducial(s) and release the button.

Rotating Fiducials

1. Click the Rotate Mode button.
2. Select the fiducial(s).
3. Press the left mouse button on the fiducial, drag the mouse to rotate the fiducial(s) and release the button.

or

4. Right-click to access the context menu and choose Properties. In the Rotation Angle box enter a value and click OK.

The Properties dialog applies to individual fiducials.

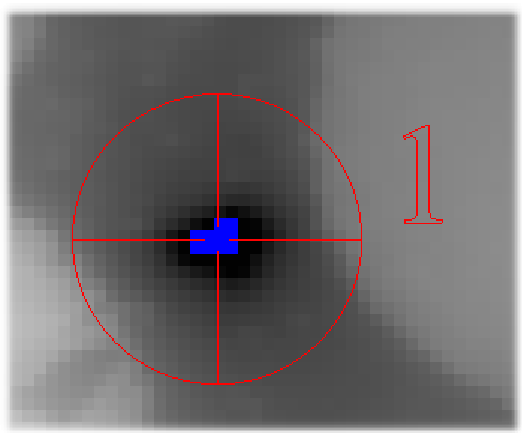
Deleting Fiducials

1. Select the fiducial(s).
2. Press the Delete key or click Delete on the toolbar.

Centering Fiducials

Fiducials can be automatically centered over a hole in the data area.

1. Set Data Source to Surface. This feature will not work when viewing Intensity.
2. If necessary, zoom in on the image to see the data hole.
3. Create or move the Fiducial so the marker location is within the no data area.
4. Select the Fiducial, right-click and choose Center.



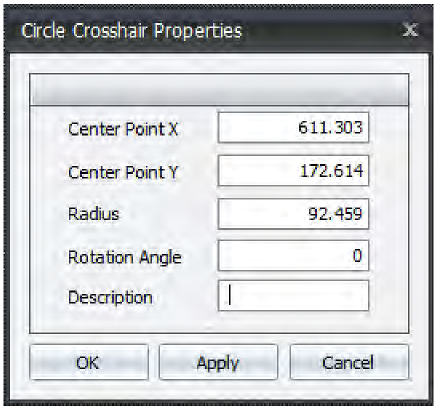
Fiducial Properties

Each shape has associated properties that can be viewed and edited. Use the Properties dialog to:

- Change the size of fiducial shape.
- Specify the exact location of the fiducial.
- Rotate the fiducial at an exact angle.
- Add descriptive text with the Description entry.

Changing Properties

1. Select the fiducial of interest.
2. Right-click to access the context menu and choose Properties.
3. Type in new values for the desired properties and click OK.



Fiducial Sets

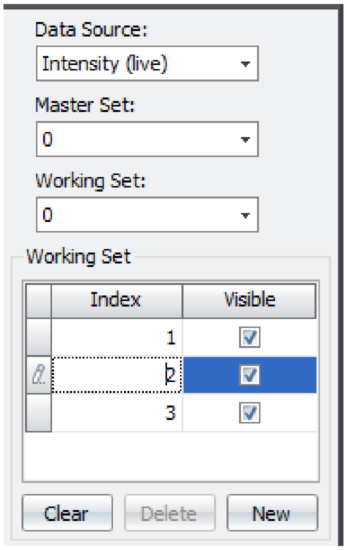
This feature allows you to have multiple user-defined fiducial sets to select from. Each fiducial group is called a working set. One of these fiducial sets is applied to the data and is called the master set. Using sets can be likened to having a fiducial library to select from.

The "Set" Concept

- Two or more fiducial markers are referred to as a working set.
- The number of fiducial markers in a single set is unlimited.
- The number of fiducial working sets is unlimited.
- There can only be one fiducial master set applied to the data at any given time.
- The master set is the grouping of reference markers displayed on the live display in white.
- Individual fiducial markers can be either visible or invisible on the live display.

Sets are numbered starting at 0.

The Fiducial Selector



Master Set	Selects the working set to use as the "master" fiducial set. The master set is displayed in white on the live display window, and all other visible fiducial sets are displayed in gray.
Working Set	Selects which set of fiducials to display in the Fiducial Editor image area.

Index is the identifying number displayed next to the fiducial. This number is automatically assigned when the fiducial is made and is based on the order of creation, starting with 1.

When the *Visible* check box is selected, the fiducial is displayed in red. When the Visible check box is cleared, the fiducial is displayed in black; this indicates that it will not be displayed on the live display.

The Visible check box is nonfunctional when fiducial markers are grouped. Apply Visible characteristics to individual markers.

Set Buttons

Clear	Click to delete the fiducials from the current working set, but not the set itself.
Delete	Click to remove the displayed fiducials and the set. The existing working sets are automatically renumbered.
New	Click to create a new working set. Define fiducial as needed.

Fiducial Files

Fiducials, including working sets, are saved and loaded from within the Fiducial Editor and are identified by the extension .fidx.

Saving a Fiducial File

1. Click Save in the toolbar.
2. In the Save Fiducial file dialog, type a file name and click Save.

Loading a Fiducial File

1. Click Load in the toolbar.
2. In the Load Fiducial file dialog, select the file and click Load.

Live Display

- Shows a live image of the part under test.
- Used to help focus and align the part before making the measurement.
- Available in most 2D plots.
- View fringes and measured data simultaneously with the Opacity slider. Observe how fringes correspond to actual data.
- Displays saturated or over-exposed areas in red.

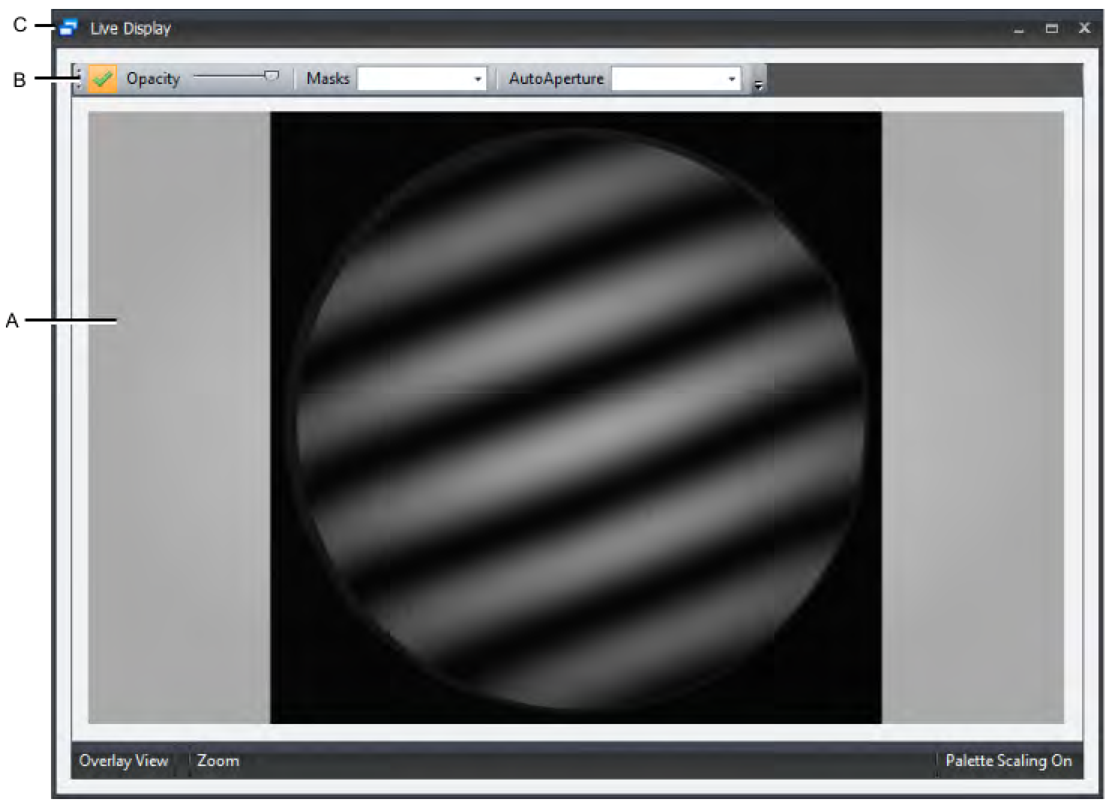
Sometimes the Live Display is called a fringe monitor, as the image is made up of light and dark bands called fringes.

Use Conditions

- A live view of the part is only visible if an instrument is connected and working.
- The instrument must be properly aligned and adjusted to view test part images.

The Live Display Screen

To make any 2D plot into a Live Display, right-click on the plot and select Tool Bars ▶ Live Display (or right-click on the plot toolbar area and select Live Display).



A. Image of test part. **B.** Live Display toolbar. **C.** Title bar.

Modifying the Live Display

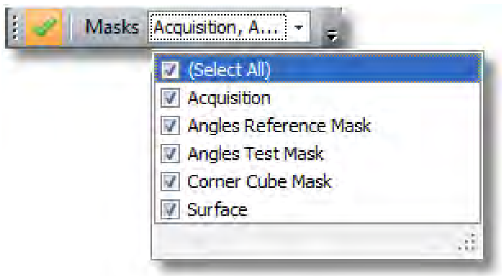
Adding Results to the Live Display

See Displaying Results.

Showing Auto Aperture, Masks, or Fiducials on the Live Display

Depending on the application, some of these items can be displayed on the Live Display. You may have to change the toolbar.

1. Point to the drop-down arrow ▾ on the toolbar.
2. Select Add or Remove Buttons ▶ Live Display ▶ and select an item to included it.
3. Select corresponding options with the Masks, Auto Aperture, or Fiducials drop-down list.



Showing the Align Reticle

This displays a set of crosshair fine lines in the display; these are used during alignment.

1. On the Tools menu select Options.
2. Select the Show align mode reticle on live display check box.

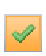
Live Display Toolbar

The actual functions available will vary based on the application.

The Live Display toolbar can appear in different forms. In the Home screen, the toolbar is configured with only the On/Off switch. The Focus Display is configured with an On/Off switch and a Camera selector. When the toolbar is displayed in a 2D plot panel, there may be additional items.

Live Display Toolbar Options

The toolbar appears in different configurations. Point to the drop-down arrow ▾ on the toolbar to change.

	Selects the image display. When on, the Live Display shows a live fringe image from the instrument's camera (live instrument required). When off, the Live Display shows a 3D plot of the data.
	Selects what camera image is displayed within the screen image area. Click to switch between View or Align. Mimics the interferometer's remote View/Align button. View displays an image from the interferometer's view camera. Align shows an image from the interferometer's align camera. View and Align settings are used in the Focus Display.
Opacity	Determines the opacity of the live image. Sets the degree to which the live image blocks the underlying data from showing. Anything less than 100% shows the data along with the fringes.  The underlying data only appears after a measurement is made.

Scale Mode

Selects how the intensity values of an image are converted for display purposes. Options are Normal or High Contrast.

Normal displays the camera frames directly within the Live Display without any form of contrast enhancement.

High Contrast is a contrast enhancement option where the range of intensity values within the camera image are scaled to use the entire available gray scale range of an image. For example, if the image has intensity values that range from 0 – 100 where 255 is saturation, an image will be displayed with a range of 0 to approximately 250.

Masks

Selects if predefined masks are displayed. If masks are loaded, and the check box is selected, a mask is applied to the Live Display.

To display a mask type, click the masks arrow to display the options, select a check box, and then click outside the box. To remove a mask from being displayed, clear the check box.

For this to function, masks must be already defined with the Mask Editor.

AutoAperture

Selects if a predefined auto aperture is displayed. If an auto aperture is defined, and the check box is selected, the aperture is displayed as an overlay on the Live Display.

To display an aperture, click the AutoAperture arrow to display the options, select a check box, and then click outside the box. To remove an aperture from being displayed, clear the check box.

For this to function, an auto aperture must be already defined with the Auto Aperture tool.

Fiducials

Selects if predefined Fiducials are displayed. If fiducials are loaded, and the check box is selected, fiducials are displayed as an overlay on the Live Display.

To display a fiducials, click the Fiducials arrow to display the options, select a check box, and then click outside the box. To remove Fiducials from being displayed, clear the check box.

For this to function, fiducials must be already defined with the Fiducial Editor.

Live Display Mode

- Determines what type of image is displayed in the Live Display.
- Appear as toolbar buttons (or can be added if not displayed).
- Mono options are available for all profilers.
- Color options are only available for profilers with a multi-color illuminator.
- Applies to optical profilers; included in Micro.appx.

Button	Mode	Description
	Mono	Shows raw camera monochrome data. The typical Live Display image.
	Mono Enhanced	Shows field flattened, scaled monochrome images. Heightens contrast and is helpful in finding fringes on difficult parts.
	Mono Fringe Free	Mono enhanced with fringes removed. Useful for seeing part details.
	Color	Shows field flattened, scaled color images. Color part imaging with fringes.
	Color Fringe Free	Color with fringes removed. Useful for seeing realistic part details.

The Scale Mode control has an effect on what is displayed in each mode.

Standalone Live Display

- Applies to laser interferometers.
- To open a separate standalone window, on the Live Display menu, click Display.
- The standalone Live Display always appears in front of the main application window, but items in the application can still be accessed and used.

A typical laser interferometer standalone Live Display toolbar is shown below.

Using Live Display on 2nd Monitor

Moving the Display

This is used to relocate the standalone Live Display screen onto a computer configured with a second display. Applicable to laser interferometers.

1. Point to the window title bar.
2. Press and drag the window to a new location and release the mouse button.

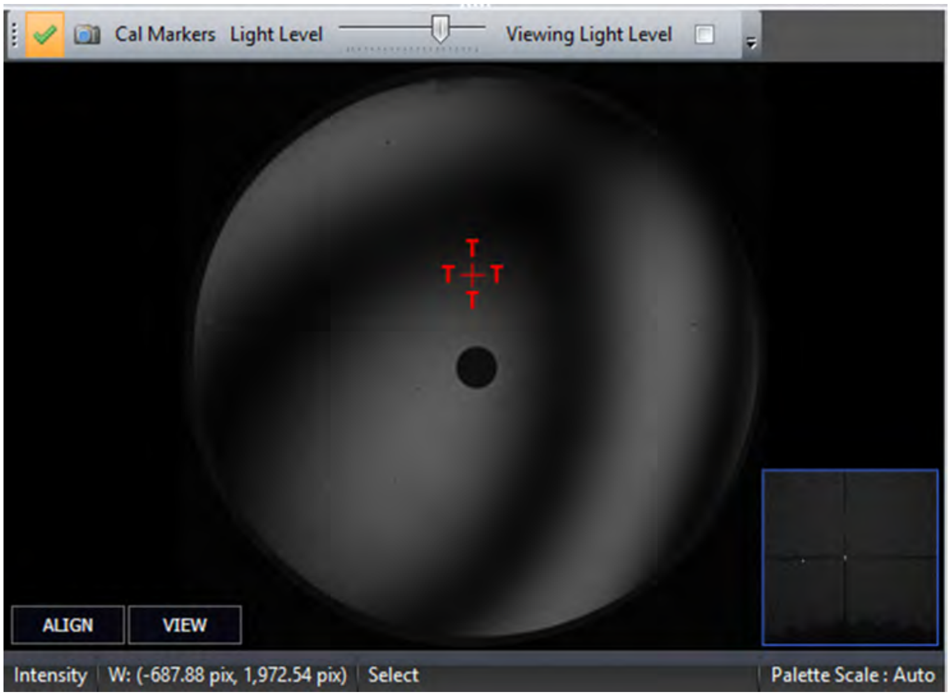
Resizing the Display

1. Position the cursor over the window border. The cursor changes to a double arrow ↔.
2. Press and drag the window border to resize it and release the mouse button.

Picture-In-Picture Display

With some Laser Interferometer systems, outputs from the Align and View cameras can be shown simultaneously in the Live Display.

To enable picture-in-picture display, right-click in the Live Display and select Show ▶ Live Display PiP.



The output from the primary camera will fill the Live Display, and the output from the secondary camera will display in an inset image in a corner of the Live Display.

Switching the Primary Camera

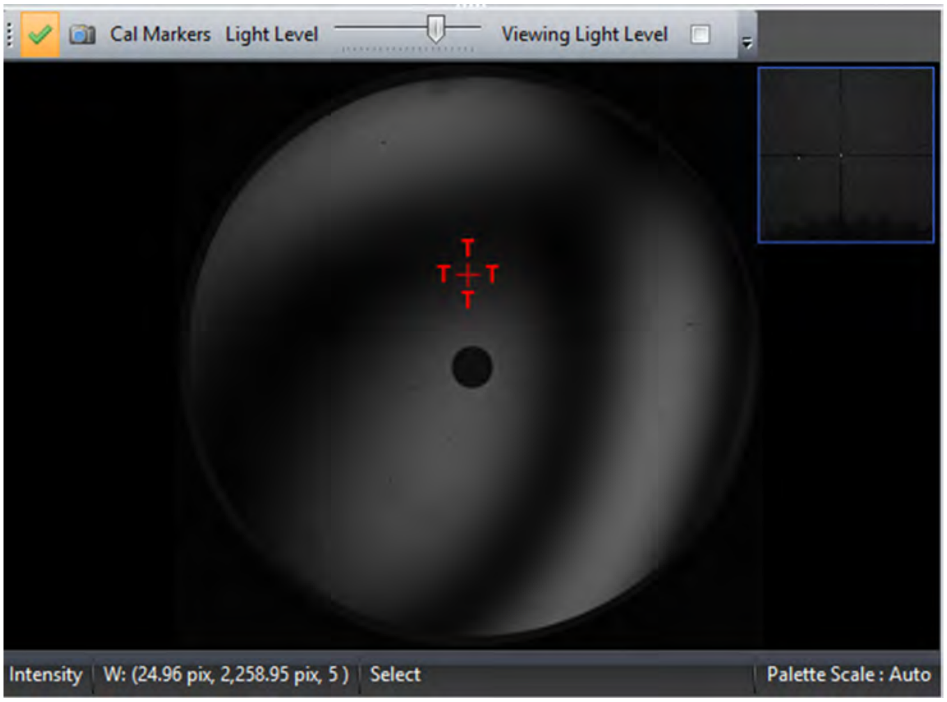
To select the primary camera, mouse over the Live Display and click the corresponding button (Align or View) in the lower left corner. The output from the other camera appears in the picture-in-picture display if this option is enabled.

Adjusting the Inset Display

To collapse the picture-in-picture display, mouse over it and click the collapse button  that appears. The closed PiP display is represented by an small button.

To expand the picture-in-picture display, mouse over it and click the expand button 

To move the picture-in-picture display to a different corner left-click on it and drag it to the desired location. The example below shows a picture-in-picture display in the upper right corner of the Live Display.



Mask Editor

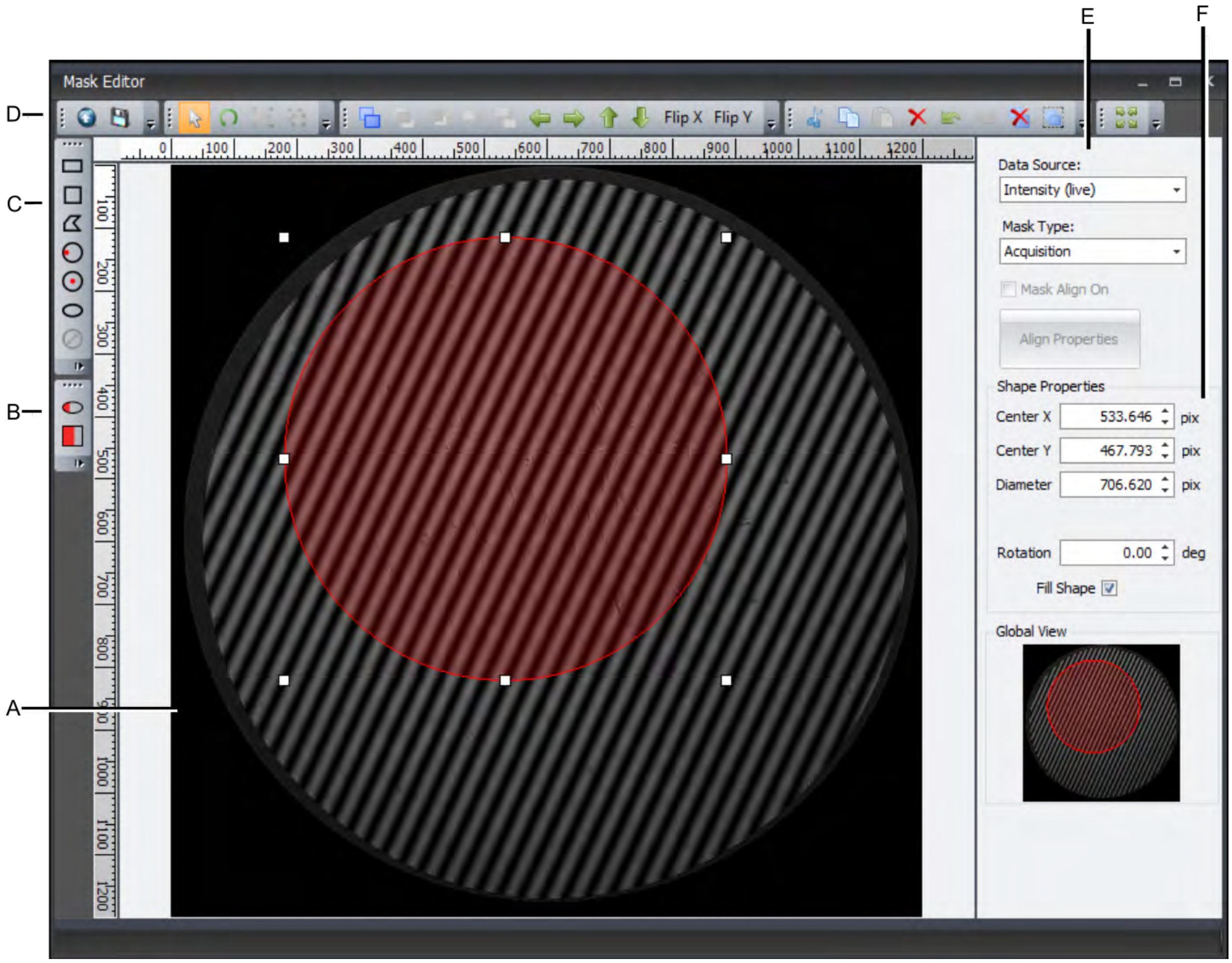
On the Tools menu, select Mask Editor; on the toolbar click Masks or Mask Editor.

For Laser Interferometers, masks can be created directly within the Live Display. See Mask.

Mask Editor Details

- The Mask Editor is used to define and apply masks.
- A mask is an area of interest on the test part.
- Masks are used to include or exclude areas from the measurement.
- When the Mask Editor is closed an Analyze function (F11) is performed.

The Mask Editor Screen



A. Image of data source (test part). **B.** Fill Shapes toolbar. **C.** Draw Shapes toolbar. **D.** Toolbars- Edit Shapes, Move Shapes, Zoom, and Edit. **E.** Data Source and Mask Type controls. **F.** Shape properties (blank unless shape is selected).

Zooming and Panning the Image

See Zoom, Pan, Rotate.

Making and Using Masks

Greater details on some of the following steps are provided later in this section.

1. Setup your instrument with a part, or load an existing data file, so you have an image.
2. Open the Mask Editor.
3. Select the Data Source.
4. Select the Mask Type.
5. Click on the shape you want to use and draw the shape over the image. Move and size the shape so it covers the desired area.

   Remember that only red colored areas are included in the analysis.

6. Create and position additional shapes as desired.
7. Click Save to save the shapes in a mask (.masx) file.

Data Source

The Data Source control determines the source of the image in the editor.

Surface	The image is based on surface data.
Intensity	The image is based on intensity data.
Intensity (live)	The image is based on live intensity data (active instrument required).

Palette Scale Option

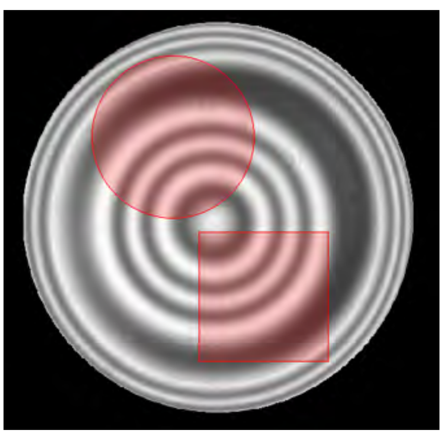
1. Right-click on the image and select Palette Scaling.
2. Choose an option and click Close.

For details on the options see 2D/3D Palette Scaling.

What is a Mask?

A mask identifies a subset of the full camera image, which can either be included or excluded from a measurement. If masks are not used the entire camera image is acquired and analyzed. A mask makes it possible to select one or more areas of interest on the test part.

Masks can be very helpful when there is a known bad area, such as a defect in the surface that you want to exclude from the measurement. Other uses of a mask include speeding up the measurement cycle, comparing one area of a part to another area on the same part, or isolating various test areas on the part.



A mask is made up of one or more shapes. Shapes that are colored in light red are included, areas not colored (or filled) are excluded.

Mask Type

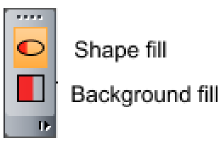
The Mask Type control determines how the mask is applied. The choices may vary based on the selected Measurement Type.

Acquisition	An acquisition mask is applied to data while it is being acquired, before it is converted to surface or phase data, and before analysis occurs. It is used to exclude areas that cause problems during the acquisition of data. Some of these problems include: excessive slopes from part edges, extreme differences in reflectivity, and excessive spurious data. The acquisition mask can also be used to speed up processing since it reduces the number of data points used during analysis.
Surface	A surface mask is applied to data after it is acquired.
Angles Reference Mask	Defines a reference area in the test setup against which the angles test mask is compared during the angles analysis. Must be used with an angles test mask when the Measurement Type is Angles.
Angles Test Mask	Defines an area of interest on the test part; this area is compared to a reference area on the same test setup during the angles analysis. Must be used with an angles reference mask when the Measurement Type is Angles.

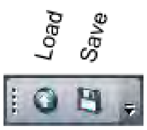
Mask Editor Toolbars

Draw Shapes

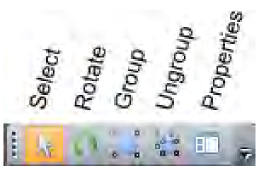
Fill Shapes



File

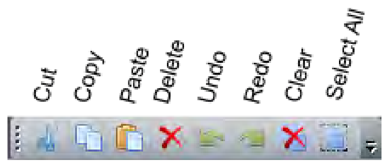


Edit Shapes



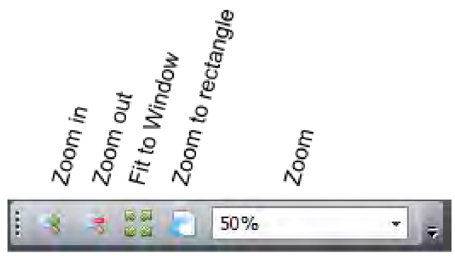
Move Shapes

Edit



Zoom

Only Fit to Window displayed by default



See Also

[Toolbars]

[Changing a Toolbar]

[Working With the Display]

Working With the Mask Display

The image is determined by the Data Source selection.

The image can be zoomed in for a magnified view or zoomed out for a global view.

Zooming with the Zoom Toolbar

Various viewing options are available:

Action	Procedure
Enlarge	Click Zoom In to enlarge the view in stepped magnifications.
Reduce	Click Zoom Out to reduce the view in stepped magnifications.
Display entire	Click Zoom Fit to fit the entire image area inside the display. Same as Fit to Window.
Set Size	Click Zoom and choose a percent from 25% to 1600%, or Fit to Window. The zoom percent is the percentage to either enlarge or reduce the image from its original size.

Zooming With the Mouse

1. Place the cursor over the image area.
2. Turn mouse scroll wheel; up to enlarge, down to reduce.

Changing the Global View (Pan)

Repositions the image within the panel.

1. Press the mouse scroll wheel and drag to move, release to set the position.

Creating Shapes

Creating a Rectangle, Square, Circle, or Ellipse Shape

1. Click the desired shape tool.
2. Position the pointer over the image area.
3. Press the left mouse button for the start point. Drag the mouse and release the button when the shape is the desired size.

Creating a Polygon or Curve Shape

1. Click the polygon or curve tool.
2. Position the pointer over the image area.
3. Click the left mouse button for the start point.
4. Move the pointer to the next location and click the left mouse button. Repeat as needed.
5. Click the right mouse button for the last point.

Selecting Shapes

Shapes must be selected before they can be moved, copied, resized, grouped, filled, unfilled, rotated, or deleted.

Selecting	Procedure
Single shape	1. Click anywhere on the shape. The shape selection handles appear and the cursor changes.
Multiple shapes, one at a time	1. Select a single shape. 2. To add another shape to the selection, hold the Ctrl key and click anywhere on the shape.  Shapes can be removed from the selection by holding the Ctrl key and clicking on the shape to deselect it.
Multiple shapes, many at once	1. Press the left mouse button and drag the rectangular selection box over one or more shapes. 2. Release the mouse button. This automatically groups all selected shapes.
All Shapes	1. Click the Select All button.

Working With Shapes

Filling and Unfilling Shapes

1. Select the shape(s).
2. Click the Shape Fill tool.

Moving Shapes

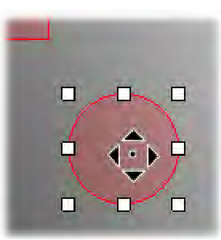
1. Select the shapes(s), the cursor changes to .
2. Press the left mouse button, drag the mouse to move the shapes(s) and release the button.

or

3. To move one pixel in a specific direction, press the Up, Down, Left, or Right Arrow keys or click the desired Arrow button.

or

4. To move 10 pixels at a time, hold down the Shift key while performing step 3.



The circle shape is selected and the cursor indicates the shape can be moved.

Rotating Shapes

1. Select the shape(s). See Selecting Shapes.
2. Click the Rotate button.
3. Press the left mouse button on the shape, drag the mouse to rotate the shape(s) and release the button.

or

4. Right-click to access the context menu and choose Properties. In the Rotation box enter a value and click OK.

The Properties dialog only applies for single shapes; it is not applicable for grouped shapes.

Deleting Shapes

1. Select the shape(s). See Selecting Shapes.
2. Press the Delete key or click Delete on the toolbar.

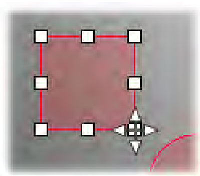
or

3. To remove all currently displayed shapes click the Clear button.

Resizing Shapes

Most shapes can be resized using the procedure below. A polygon or curve shape can be resized with the Resize command or when it is part of a group. Individual points of polygon and curve shapes can be repositioned.

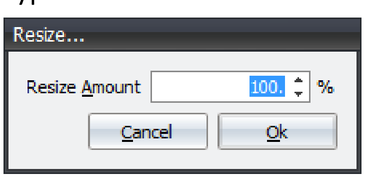
1. Select the shape(s). See Selecting Shapes.
2. Move the cursor to the selection handles at the corner of the shape(s), the cursor changes to .
3. Press the left mouse button, drag the mouse to resize the shape(s) and release the button.



The square shape is selected and the cursor indicates the shape can be resized.

Resize by Percent

1. Select the shape of interest.
2. Right-click and choose Resize.
3. Type the Resize Amount and click OK.



Working With Multiple Mask Types

In effect, each Mask Type selection is like a unique layer within the Mask Editor. This covers how to see and edit masks superimposed on one another. A mask file can contain multiple Mask Types.

Showing All Mask Types

1. Click the Show All button.

The active Mask Type shapes display as light red.

Other Mask Types shapes display as light blue.

Editing Mask Layers

New shapes can only be created on the active Mask Type (layer).

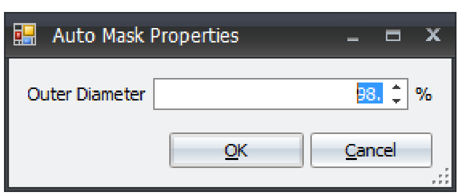
1. Select the shape(s). See Selecting Shapes.
2. Move, Resize, Fill, Rotate, or Delete shapes. See Working With Shapes.

Auto Mask Function

The auto mask function creates a circular mask automatically centered on the data. The auto mask function is disabled when the Show All button is active.

Creating an Auto Mask

1. Click Auto Mask on the toolbar. An Auto Mask Properties dialog opens.



2. Change the Outer Diameter percentage if desired.
3. Click OK.

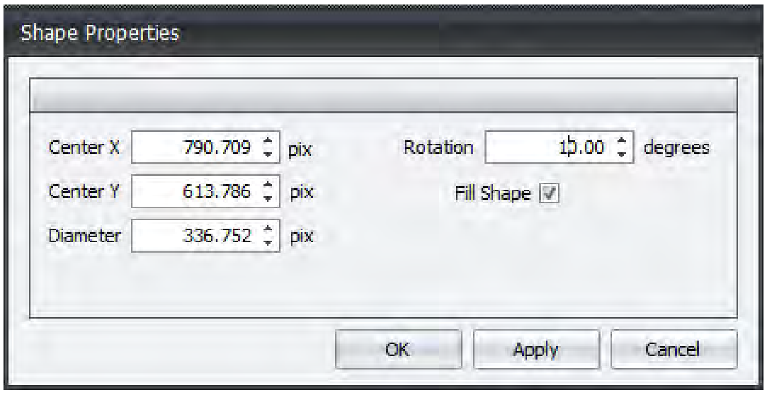
Shape Properties

Each shape has associated properties that can be viewed and edited. Use the Properties dialog to:

- Change the size.
- Specify the exact location.
- Precisely rotate the shape.
- Change from filled to unfilled.

Changing Properties

1. Select the shape of interest.
2. Right-click and choose Properties.
3. Type in new values for the desired properties and click OK.



Mask Files

Masks are saved and loaded from within the Mask Editor and are identified by the extension "masx".

Saving a Mask File

1. Click Save on the toolbar.
2. In the Save Mask file dialog type a file name and click Save.

Loading a Mask File

1. Click Load on the toolbar.
2. In the Load Mask file dialog select the file and click Load.

Master Units

Measurement units, such as micrometers (metric) or microinches (English), can be set *universally* (referred to as master) or *individually* for plots and results. Also, the precision or number of decimal places can be selected.

Lateral calibration is required to use lateral units other than pixels.

Be sure to choose a sufficient number of decimal places so the result you see is not impacted by rounding off.

To set master units see Using Master Units.

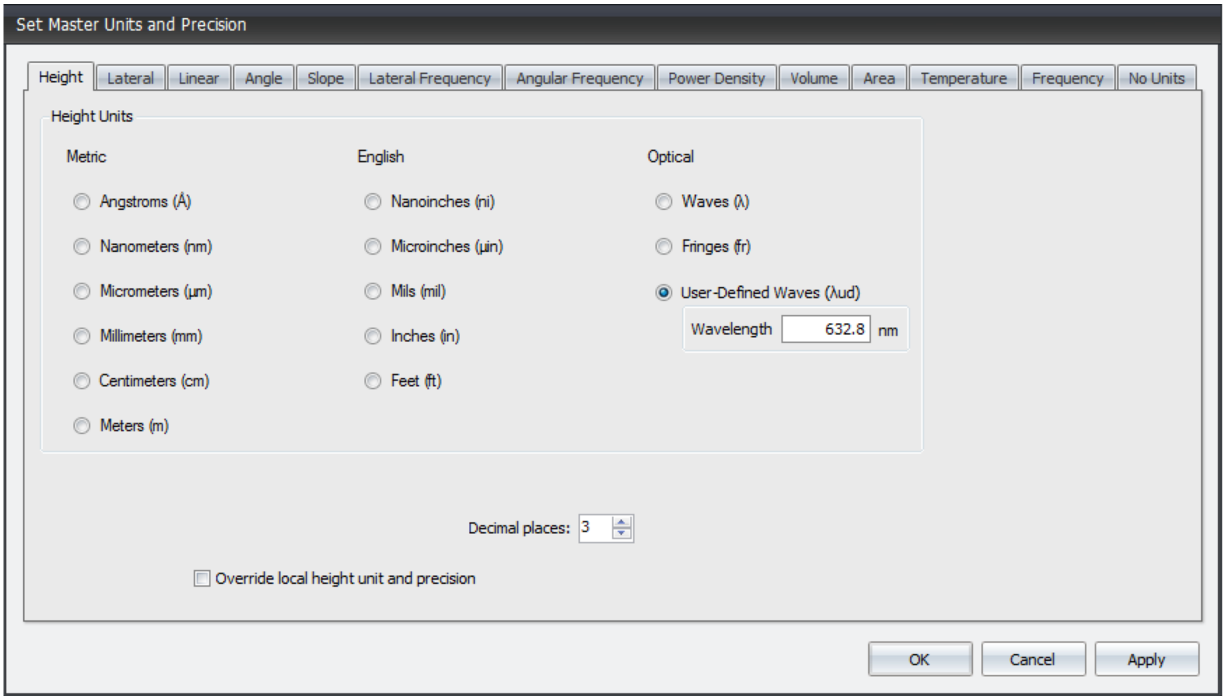
To set units for a single result see Setting Individual Units.

Using Master Units

Set Master Units and Precision

On the Tools menu, click Master Units, or click Master Units on the toolbar.

This tool is used to set the "master" measurement units and precision for plots and results. The different categories of units are selected with tabs. The actual units that appear differ based on the application.



Unit Categories

Tab	Description
Height	Selects the master unit system for all height-based results. It affects the Z units in the Filled plot and 3D plot, and the Y units in the Profile plot. It also applies to most results, such as AvgHgt, H, Peak, PV, Ra, RadCrv, RMS, R3z, Rtm, Rz, Sag, and Valley.
Lateral	Selects the master unit system for all lateral based results. It affects the X units in the Profile, MTF Profile, Autocovariance, and Power Spectrum plots, and the X-Y units in the 3D plot. Applies to any measurement derived from camera pixel positions, such as Length/Circum, RadCrv, and Radius.
Linear	Selects the master unit system for all linear based results. Applies to items such as Wavelength-In and Camera Res.
Angle	Selects the master unit system for all angle based results. It applies to results such as TltAng, TltMag, Tilt X, Tilt Y, and Seidels.
Slope	Selects the master unit system for all slope-based results. It applies to slope analysis and accompanying results.
Lateral Frequency	Selects the master units for the PSD analysis.
Angular Frequency	Selects the master units for the diffraction analysis when PSF Mode is Afocal.
Power Density	Selects the master units for the PSD analysis.
Volume	Selects the master units for all volume results.
Area	Selects the master units for all area results.
Temperature	Selects master temperature units such as Fahrenheit or Celsius.
Frequency	Selects master frequency based units such as Hz, KHz, or MHz.
No Units	Selects the master setting for number of decimal places when a result does not have an associated measurement unit.

Applying Master Units

1. On the Tools menu, click Master Units and Precision.
2. Click the applicable unit category tab.
3. Click the unit choice and select then number of Decimal places.

To apply your choices to all plots and results in the unit category, select the Override local unit and precision check box and click the Apply button.

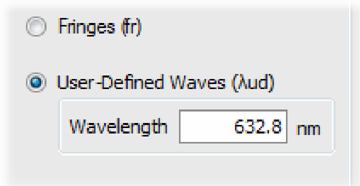
4. Click OK.

See Also

User-Defined Waves

Setting Individual Units

User-Defined Waves



This choice is available for Height units. Click to select and then enter a Wavelength value.

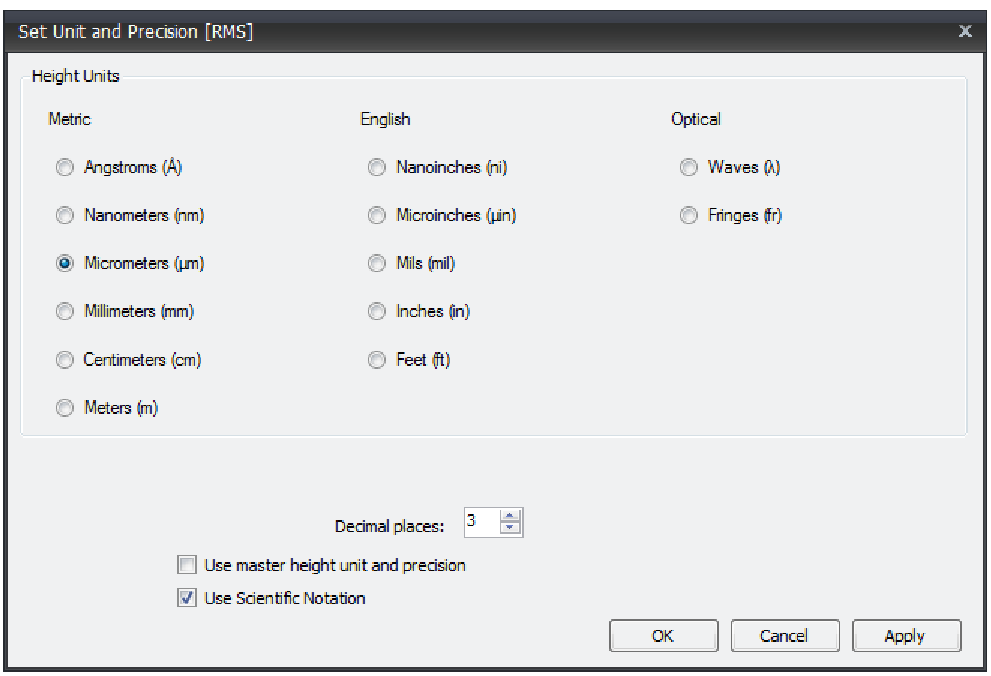
(ud) stands for user defined.

This specifies the wavelength of the data displayed within the application. It is used to display results as if the measurement was performed at a wavelength other than 632.8 nm. When User-Defined Waves (λud) is selected, the data is scaled in terms of the entered wavelength. This is useful to see how an optic performs at another wavelength. It affects results that use waves as the measurement unit. It does not affect PSF and MTF results.

Setting Individual Units

Set Unit and Precision

- For results, right-click the result and choose Select Units and Precision.
- For plots, right-click the plot and choose Units ▸ X-Y Units (or other options).
- When the Use master unit and precision check box is selected, local setting are ignored.
- The specific dialog is determined by the item.



1. Click the unit choice and select Decimal places.

To activate this function for an individual result it may be necessary to clear the "Use master unit and precision" check box.

2. Click OK.

Scientific Notation

Scientific notation is ideal for very large numbers or very small numbers and can be selected for results and attributes.

Example	*Scientific Notation*
0.0000000056	5.6×10^{-9}
46600000	4.66×10^{7}

1. Right-click the result or attribute and choose Select Units and Precision.
2. Select the Use Scientific Notation check box.
3. Click OK.

See Also

User-Defined Waves

Using Master Units

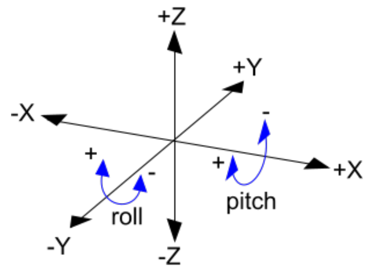
Motion Utilities

- On the Motion menu select Utilities.
- Applies to instruments with motorized stages.
- Shows the current stage positions relative to home.
- Provides controls for homing axes and for part load and unload positions.
- Provides a Scratch Pad to Set and Goto custom stage positions.
- The features are not functional unless connected to an instrument.

Home

Home is an absolute reference position for an axis. All stage coordinates are calculated from the factory set "home" position. This ensures that programmable stage motion is repeatable. Typically, home positions are shown below. See also Instrument Axes.

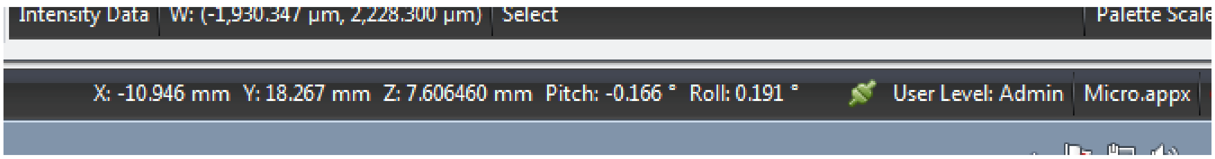
Axis	**Home Position**
Z	All the way up (full positive).
X/Y	All the way to the left and toward the user (full negative).
Pitch/Roll	Set level (0°).



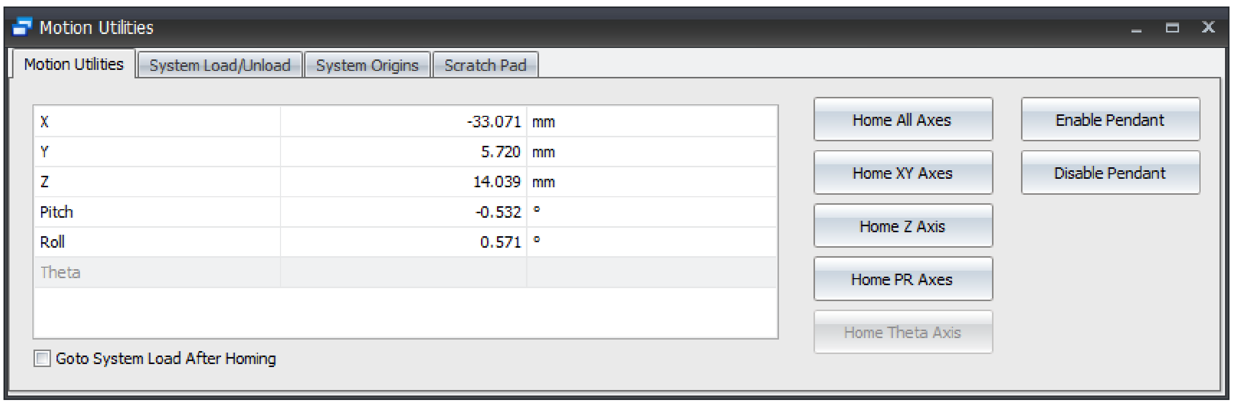
Stage Readout

At the bottom left corner of the application window, the current positions of the motorized stages are displayed. X, Y, Z, Pitch, Roll refer to the axes identified in Home (above).

The units and precision of the displayed positions match the units and precision shown on the Motion Utilities tab. To change either the units or the precision of an axis, right click in the box showing the unit for the axis you want to change. The standard Units and Precision dialog will open. Axes units and precision can be saved in an application file; they are not saved in settings files.



Motion Utilities Tab



- Current axes positions or stage readouts are shown on the left show.
- The Home buttons perform the corresponding action when clicked (see below).

If the instrument has two sets of stages the user interface displays both. They are referred to as stage set 1 and stage set 2 (labeled with -2); each set of stages is commanded separately.

Home Stage 1 Axes Press to home the primary set of motorized stages.

Home Stage 2 Axes Press to home the second set of motorized stages, if present.

Home XY Axes Press to home the primary motorized x-axis and y-axis stages.

Home XY-2 Axes Press to home the second motorized x-axis and y-axis stages, if present.

Home Z Axis Press to home the primary z-axis stage.

Home Z-2 Axis Press to home a second z-axis stage, if present.

Home PR Axes Press to home the primary pitch and roll stages.

Home PR-2 Axes Press to home the second pitch and roll stages, if present.

Home Theta Axis Press to home the primary theta stage, if present.

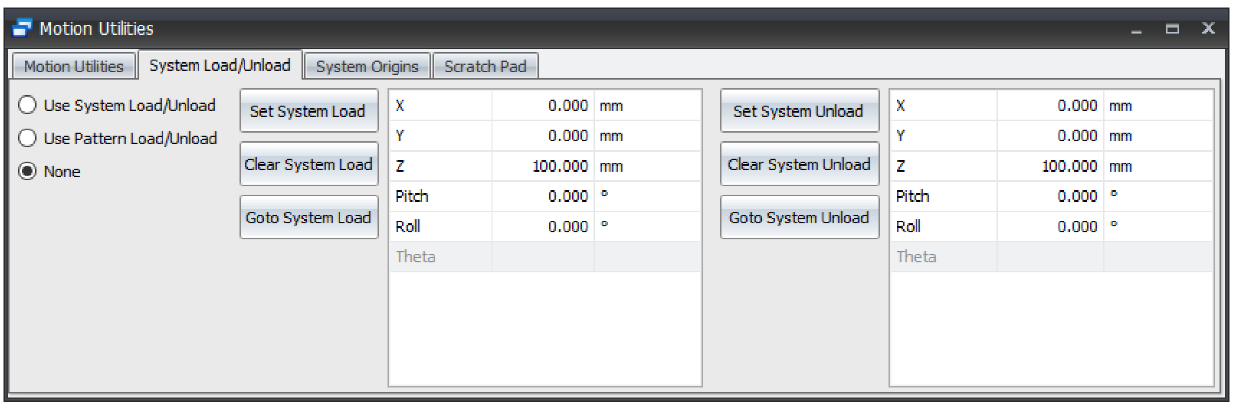
Home Theta-2 Axis Press to home the second theta stage, if present.

Home All Axes Press to home all available motion axes. This moves all motorized stages to a pre-determined home location.

Enable Pendant Press to make the stage control device (usually a Joystick) active.

Disable Pendant Press to make the stage control device inactive.

System Load/Unload Tab



- Used to specify part load and part unload stage positions relative to Home.
- A system load/unload position serves as a "master" pattern load/unload position. The system load/unload is used when you want every pattern to use the same load/unload positions or if you want to move to a load/unload position regardless of what pattern is loaded.
- System load/unload positions override pattern load/unload positions.
- Applies to optical profilers with motorized stages.

Load/Unload Buttons

Set System Load	Press to make the current stage positions the system load location.
Clear System Load	Press to clear any set load positions.
Goto System Load	Press to drive the motorized stages to the set load position.
Set System Unload	Press to make the current stage positions the system unload location.
Clear System Unload	Press to clear any set unload positions.
Goto System Unload	Press to drive the motorized stages to the set unload position.

Setting a Load Position

1. Drive motorized stage axes to the best/safest position to load a test part.
2. In the Motion Utilities window, under the System Load/Unload tab, press the Set System Load button.
3. Select the Use System Load/Unload option button.

Positions are automatically saved.

Setting an Unload Position

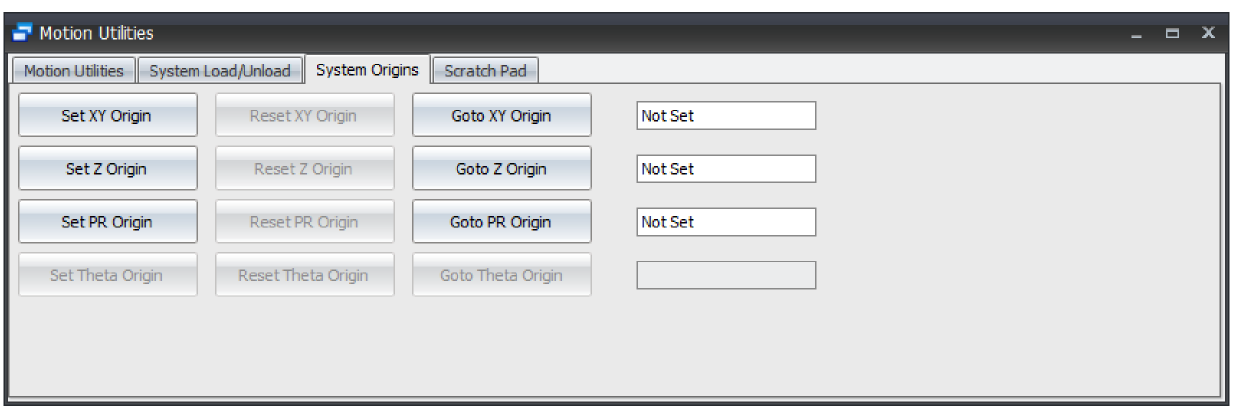
1. Drive motorized stage axes to the best/safest position to unload a test part.
2. In the Motion Utilities window, under the System Load/Unload tab, press the Set System Unload button.
3. Select the Use System Load/Unload option button.

Positions are automatically saved.

Using Pattern Load/Unload

Patterns can also define and use load and unload positions; see Pattern Load/Unload. The Use Pattern Load/Unload option button must be selected.

System Origins Tab



- Used to set zero points for the various stages.
- Origins are automatically preserved for all applications/users.
- Supports two sets of stages.

To set a System Origin for an axis:

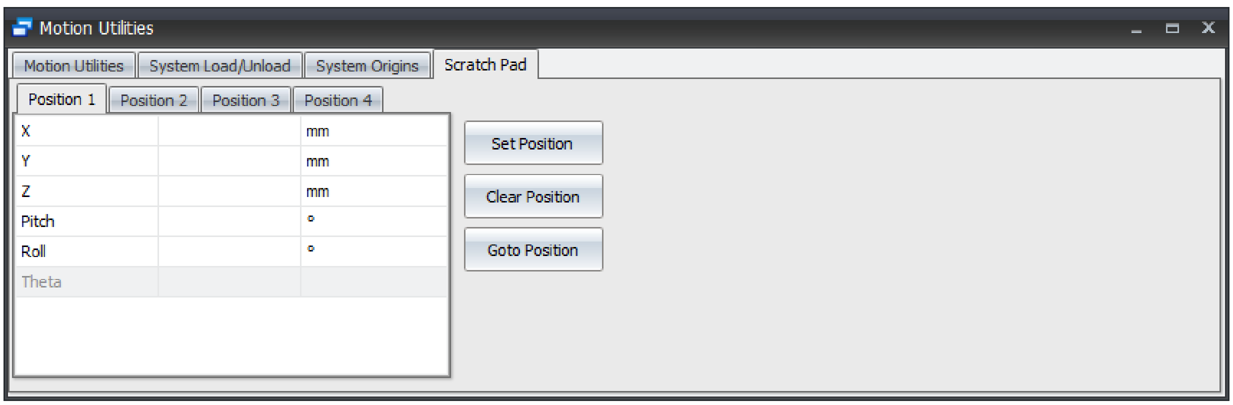
1. Select the tab for the appropriate stage system. (Most systems only have a single stage system.)
2. Press the Set...Origin button for the desired axes.
3. The current corresponding axes positions are now set as the new zero position.

When the origin is set or cleared (reset), the change is immediately reflected in the status bar position display and anywhere else the current stage positions are shown.

Button	**Function**
Set...	Makes the corresponding current stage position the new zero point.
Reset...	Clears the corresponding user defined zero and restores the default zero point.
Goto...	Moves the corresponding axes to the zero point.

The stage origin information is stored in a file outside of the application. This means that the user defined origins persist across runs of Mx; they are the same regardless of which application is loaded and are shared between all users.

Scratch Pad Tab



- Used to set and store up to four custom stage positions.
- Positions are automatically preserved for all applications/users.

To set a position:

1. Select a Position tab.

   To change the name of a Position tab from the default name, right-click on the tab, enter a name and click Ok.

2. Drive the stages to the desired position and press Set Position.

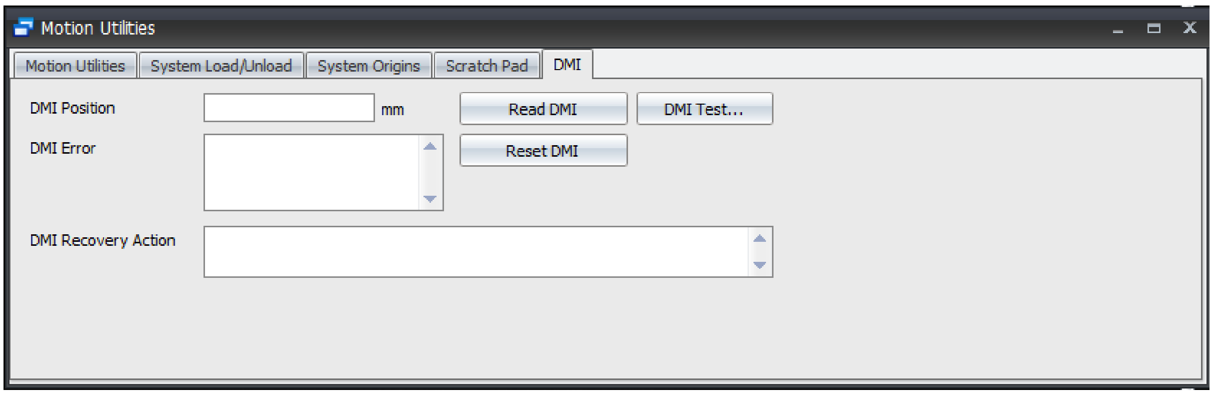
or

3. Manually type in the stage locations in the grid.

Button	**Function**
Set...	Records the corresponding current stage positions.
Clear...	Sets all axis positions to blank. Axes that have a blank position value are not moved when the Goto button is clicked.
Goto...	Moves the corresponding axes to the recorded position.

The stage position information is stored in a file outside of the application. This means that the user defined positions persist across runs of Mx; they are the same regardless of which application is loaded and are shared between all users.

DMI Tab



- Used to read, reset and display displacement measuring interferometer (DMI) locations.
- These controls are frequently used for a laser interferometer interferometric radius of curvature solution that provides position feedback via a DMI mounted at the end of the rail. The DMI monitors the z-axis location of a retroreflector that is mounted in the 5-axis mount.

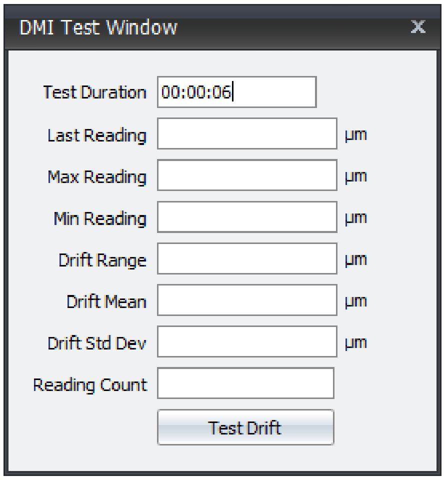
DMI Position Displays a numeric value for the z-axis location as indicated by the DMI when Read DMI is clicked.

DMI Error Displays errors or problems with the DMI. Many errors require a shutdown and restart of the computer and software.

DMI Buttons

Read DMI	Click to read the current z-axis location from the DMI; the result is displayed in DMI Position.
Reset DMI	Click to clear errors, reset the DMI counter to 0, and to clear positions. This is used when the operator accidentally breaks the beam between the retroreflector and the DMI. This also clears confocal and catseye positions. In systems where the Z-Axis of the motion subsystem is the DMI, the DMI position is set to the Z-Axis position, so they match, when Mx starts up and when the Z-Axis is homed. After that, pressing the Reset DMI button resets the DMI position to zero, and the two position readouts (Z-Axis stage position in the application status bar and the DMI position) will no longer match.
DMI Test...	Click to open a dialog that is used to check the test the drift or stability of the environment during a measurement cycle.
Distance Readout On	Click to toggle on/off a position tracking feature. When the readout is on, the distance traveled in millimeters and inches is displayed in the Live Display and in a Slide Distance readout in the Radius Scale window.
Reset Motion	Click to reset motion control software and communication to the joystick. After this button is clicked it may be necessary to home all axes before continuing. Disabled when there is no motion hardware.
Home Z Axis	Click to drive the z-axis mount to a pre-determined home position. For the radius scale tool, this moves the z-axis away from the transmission sphere to the limit and then sets zero position so the actual z position matches the scale on the rail.
Home All Axes	Click to drive all motorized axes to their pre-determined home positions. For the radius scale tool, the x and y axes are moved to the limit and then the zero position is set at the center of travel. The X and Y axes are moved to zero position as part of the homing process. The z-axis homing process is described above.

DMI Test



To perform a check, enter a value in Test Duration that corresponds to the time required to make both catseye and confocal measurements, and click the Test Drift button.

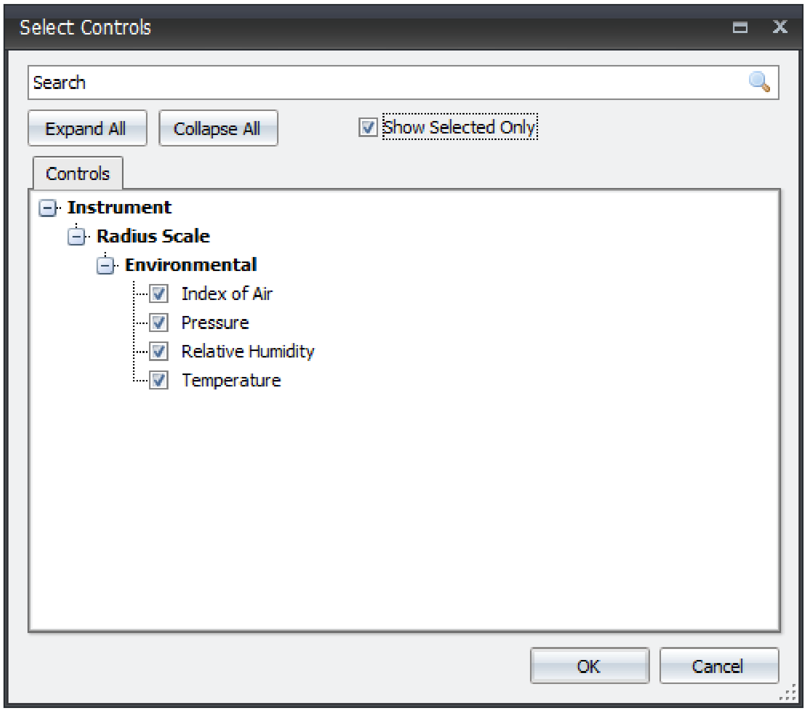
To cancel the test press the Esc key.

Test Duration	Specifies the time in hours:minutes:seconds for the DMI drift test. Enter a value that approximates the amount of time it takes to make a radius measurement.
Last Reading	The last value obtained from the DMI.
Max Reading	The maximum value from the DMI during the sample period.
Min Reading	The minimum value from the DMI during the sample period.
Drift Range	The maximum reading minus the minimum reading.
Drift Mean	The arithmetical average of all readings from the DMI.
Drift Std Dev	The standard deviation or variation of readings from the DMI.
Reading Count	The number of readings from the DMI.
Test Drift	Click to start a drift test of the interferometric radius of curvature components. This helps determine the system performance in the current operating environment.

Enviromental Controls

These specialized controls are used to enter the current environmental conditions to determine the Index of Air, which in turn effects the wavelength of the DMI. This is typically done in conjunction with the interferometric radius of curvature solution.

These controls are not typically presented in default applications, in which case they can be added to a control grid. See Adding or Removing Items.



Humidity Specifies the current relative humidity of the test area in %. The default setting is 50.

Pressure Specifies the current barometric pressure of the test area in Torr. A Torr is a unit of pressure equal to 1/760 atmosphere or 1 mmHg. The default setting is 760.

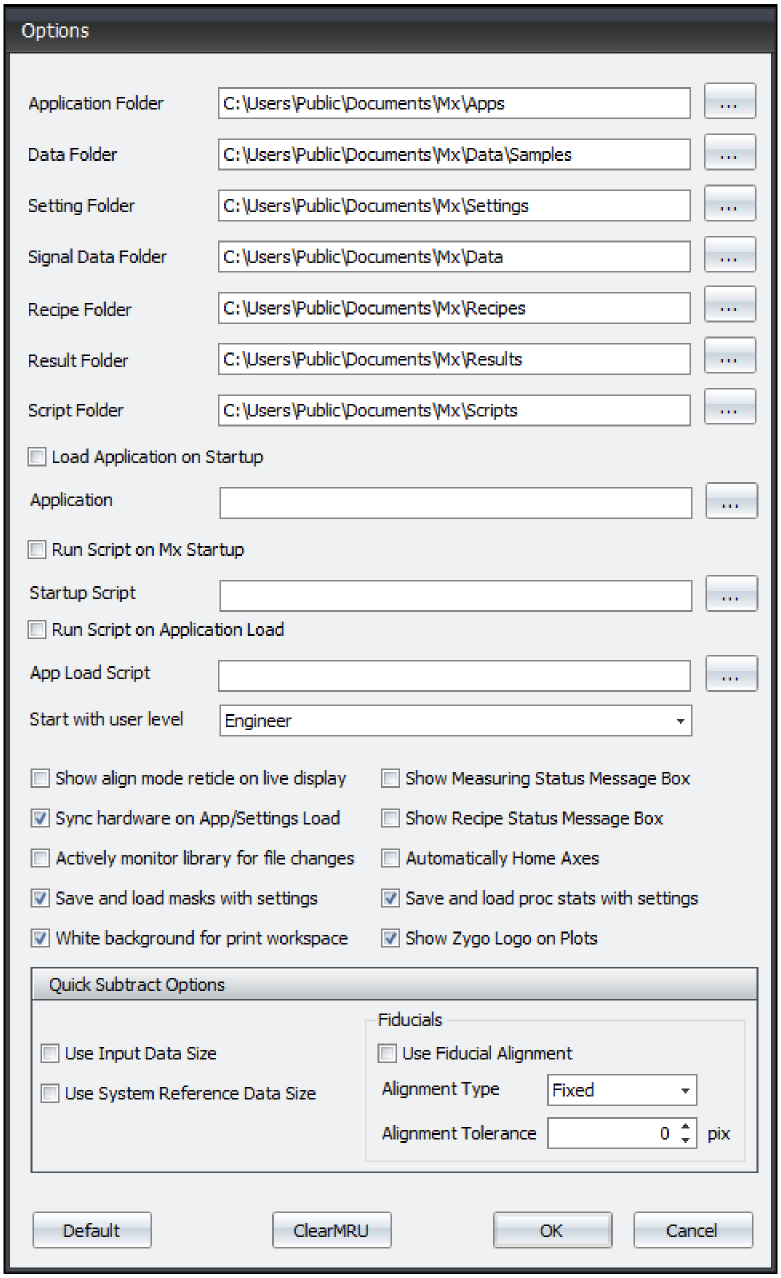
Temperature Specifies the current temperature of the test area in °C. The default setting is 20.0.

Index of Air Displays the refractive index of air, as based on the entries in Temperature, Pressure, and Humidity. It is updated whenever a new value is entered in the Temperature, Pressure, and Humidity controls. This value is used to compensate for changes in the wavelength of the laser beam caused by changing environmental conditions.

Options

On the Tools menu select Options.

Click the Default button to reset all Options back to the original settings.



File Folders, Directory Locations

Load Options

Miscellaneous Options

Quick Subtract Options

File Folders

This feature is used to specify default "open" and "save" directory locations for the corresponding file types.

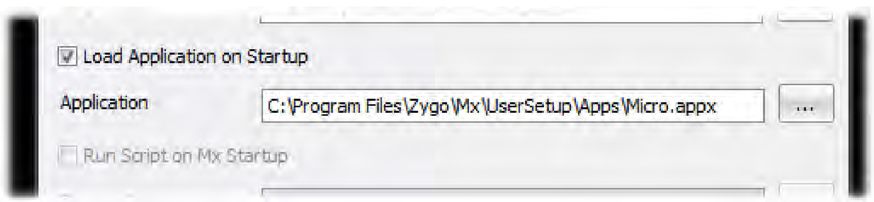
1. Enter the desired folder locations for listed file type. You can browse to a new location by clicking .
2. Click OK.

Load Options

These controls and selections are used to set start up options.

Load Application on Startup	When the check box is selected, the designated application file is opened when Mx is started. See Starting With a Specific Application.
Run Script on Mx Startup	When the check box is selected, the designated script file is run when Mx is started.
Run Script on Application Load	When the check box is selected, the designated script is run when the application is loaded.
Start with user level	Selects the Mx user level, this applies to any application that is loaded. See User Levels.

Starting With a Specifc Application



1. On the Tools menu select Options.
2. Select the Load Application on Startup check box.
3. Enter the path and file name to load in the Application field. You can browse to and choose the file by clicking .
4. Click OK.

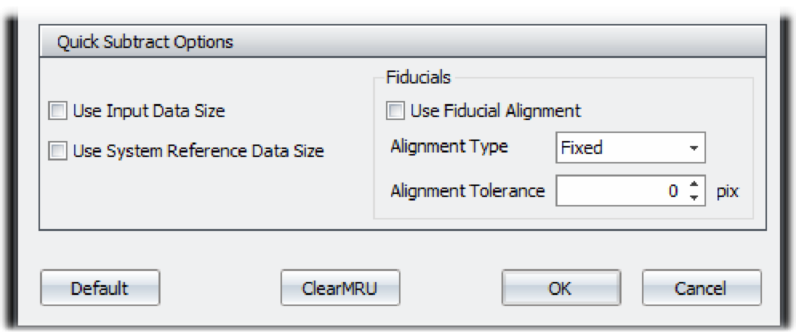
For more information see Options.

Miscellaneous Options

Show align mode reticle on live display	For laser interferometers. When enabled a red reticle is displayed on the align mode Live Display.
Sync hardware on App/Settings Load	For optical profilers. When enabled, hardware changes like filters and aperture stops will be changed automatically, or the user will be prompted to change them, when loading an application or settings which was saved in a different hardware configuration.
Save and load masks with settings	When enabled, masks are saved and loaded as part of settings files. Clear the check box to disable this function.
White background for print workspace	When enabled, using the Print Workspace function will cause plots to switch to a white background.
Show Measuring Status Message Box	When enabled, a status box is displayed during acquisition to indicate an in-process measurement. Clear the check box to measure without a status box.
Show Recipe Status Message Box	When enabled, a status box is shown during a recipe run to indicate the in-process recipe. Clear the check box to run a recipe without a status box.
Automatically Home Axes	When enabled, any system with motorized motion will prompt the user to home the stages, if required, when Mx is started.
Save and load Proc stats with settings	When enabled, process statistics grids will save and load with settings.
Show Zygo logo on plots	When enabled, the Zygo logo is shown in the top left corner of all plots

Quick Subtract Options

1. On the Tools menu select Options.
2. Choose the desired options and click OK.



For a description of these options see Subtract Options.

Quick Subtract

This tool is a simplified version of the Subtract function; it subtracts a user-selected data file from the current data file. This can be used to see the effect of subtracting a known data "reference" from the displayed data.

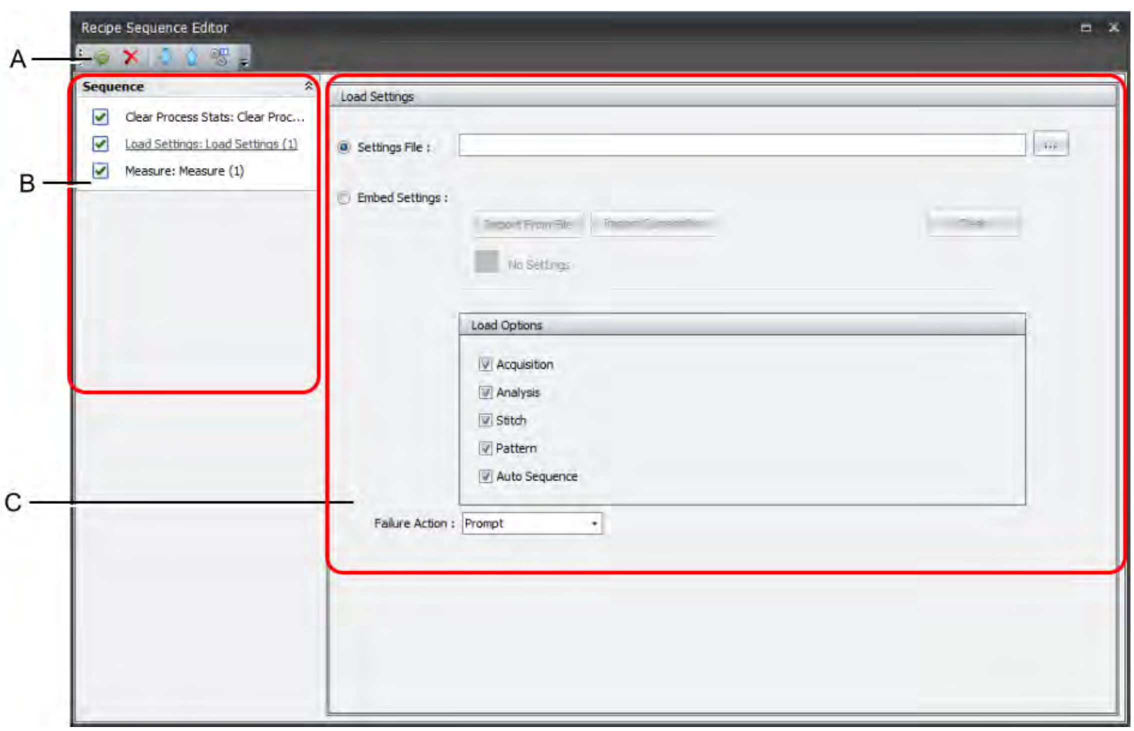
1. On the Tools menu select Quick Subtract, or on the toolbar click Quick Subtract.
2. In the Load Data dialog specify the appropriate file to load.
3. Click Open.

To cancel the action press the Esc key, or click the dialog close or cancel button.

Recipe Sequence Editor

- Recipes are applicable for both Micro.appx and Form.appx.
- Use to create and edit recipes (.rcpx files).
- A recipe simplifies instrument operation and requires minimal user input.
- Steps or actions are listed in sequential order (top down) in the Sequence panel.
- Specific step functions are selected and/or entered in the main panel.
- This editor is similar in concept to the Processing Tool.
- Invoked by the Edit Recipe toolbar button.

The Recipe Sequence Editor



A. Toolbar. **B.** Sequence panel (use to select and order steps). **C.** Step options for the current or selected step.

About Steps

- Step names are automatically generated as they are added to the sequence panel.
- A number (1) indicates the first occurrence of a step; subsequent versions of the same step are numbered 2, 3, etc. Duplicate actions are numbered sequentially; the numbering is based on when they are added to the sequence and does not refer to the order.
- Click on a step name to select step settings.
- Only checked steps are used when the recipe runs.
- Individual step names can be changed; see Step Properties.

Recipe Sequence Editor Toolbar

1 2 3 4

1 Run (Execute) the recipe from the first active step to the currently selected step. Note that the main toolbar Run Recipe button runs all active steps.

2 Delete the selected step.

3 Load (Import) an existing recipe sequence.

4 Save (Export) the current actions as a recipe sequence.

Recipe Actions

Right-click on the Sequence panel and select an action to add a step to the recipe.

Failure Action is common to many recipe actions.

Action	Function
Clear Process Stats	Use to remove and clear all values out of Process Statistics. For example, in one analysis you can take multiple measurements and accumulate 100's of measurements. Within the recipe you can change the analysis and take a different set of measurements with unique results. In this case when you switch the measurement from one to another you will want to clear the previous set of statistics.
Data Merge	This action is designed to combine, sort, and remove duplicate numeric results. See Data Merge.
Delay	Adds a user specified time delay into the recipe sequence. Enter a timer in Hours: Minute: Second. Select the Show Window check box to display a countdown dialog.
Load Pattern	Use to load a pattern file. There are multiple ways to select the file to load. Pattern File specifies a directory location to an existing pattern file. Click ... to choose and navigate to a directory location. Embed Pattern includes the pattern as part of the recipe. The embedded file can be imported or created from current pattern settings. Click Import From File to navigate to a directory location and choose an existing file. Click Import Current Mx to grab the current pattern settings and embed it in the recipe. Click Clear to remove an embedded file.
Load Settings	Use to load a settings file. There are multiple ways to select the file to load. Settings File specifies a directory location to an existing settings file. Click ... to choose and navigate to a directory location. Embed Settings includes the settings file as part of the recipe. The embedded file can be imported or created from current software settings. Click Import From File to navigate to a directory location and choose an existing file. Click Import Current Mx to grab the current settings and embed it in the recipe. Click Clear to remove an embedded file. The Load Options allows you to select portions of settings to load, such as Acquisition, Analysis, Stitch, and so on. This allows changing settings on a subset level without changing all settings. To avoid potential recipe errors when creating a recipe, clear the Auto Sequence check box.

Measure — Performs a measurement.

Motion — Provides a tool to move the corresponding stage axes. Move Type can be Absolute or Relative. Absolute moves stages to an absolute location regardless of where the sensor is current located. Relative moves the stages as an offset relative to the current location.

To specify any given stage to move, click on a corresponding entry box and enter a value. To assist in using this functionality, Capture, Clear, and Go To buttons are provided. The Capture button grabs the current stages positions and automatically populates the fields. Clear erases and stage position values. Go To moves the corresponding stages to the entered values.

Objective Turret — Select to verify reference coordinates for objectives and zoom turret. Failure Action can be selected.

Print — Provides a step to print screen graphics. The radio button determines what is printed when the Save Print On check box is selected. See Print Workspace.

For details on the Save Options see Auto Save Options.

For details on automatic file naming see Auto Generate File Name Options.

Prompt — Allows the user to enter a message that is displayed to the operator when the recipe is run.

The Cancel check box adds a Cancel button to the message so it can be ignored.

Read Id — This is used to specify the location of an optional bar code reader in reference to the main sensor.

Run Executable — Allows the recipe to run an external program. This could be used for any variety of purposes, such as to move stages, move saved data to a database, etc.

Command Line Arguments provides a place to type in commands.

Select the Wait For Process End check box to have the recipe wait until the external program is complete. The Redirect Standard Output check box allows you to specify where the output of the external program is directed.

Run Pattern — This runs the current pattern file.

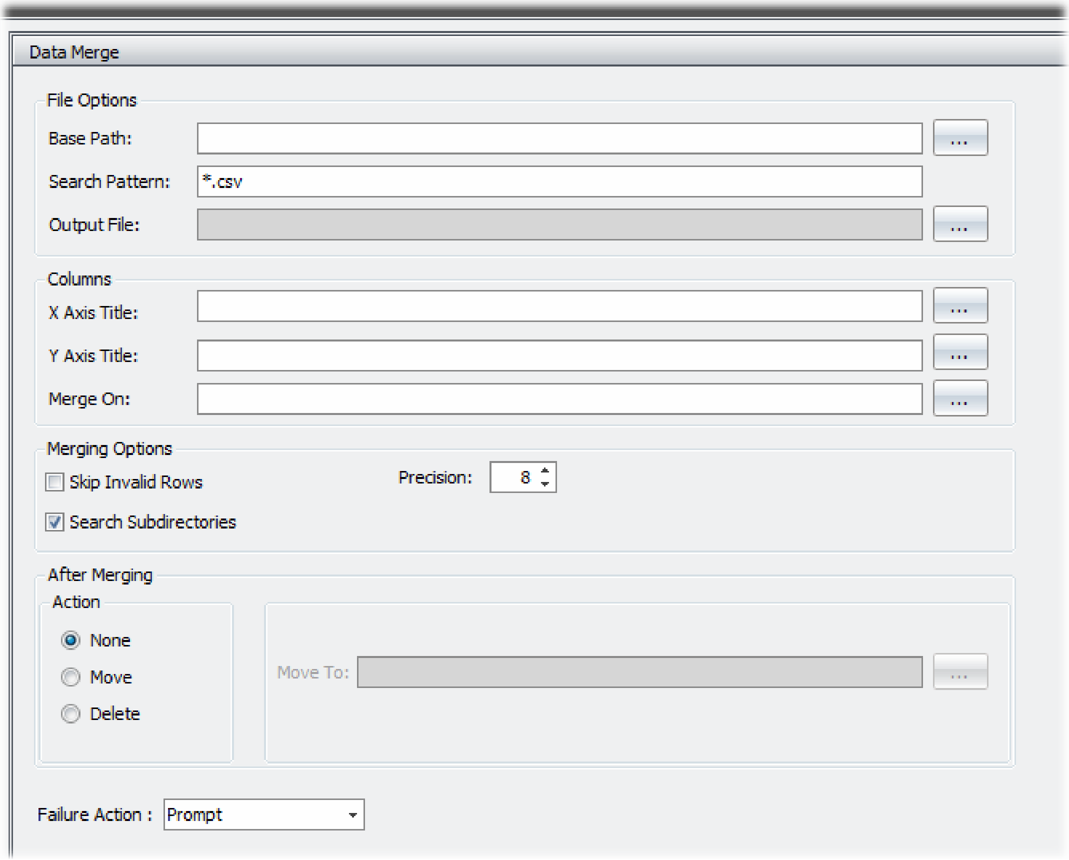
Run Script — This runs the selected script file. Failure Action can be selected.

Temperature — Provides interaction with an optional temperature sensor. The Sensor drop-down list is used to select a specific installed sensor. The second drop-down list provides a selection of conditions. Enter the corresponding temperature requirement in the °C control. Failure Action can be selected.

Actual temperature sensor results are available.

Data Merge

- Designed to combine, sort, and remove duplicate part (.csv) numeric results.
- Combining, sorting and removing treats each XY coordinate as a discrete value. When two rows have the same XY coordinate, the column with the largest “Merge On” value is kept. For data sets with a single unique column, the X Axis Title and Y Axis Title can be the same.



Base Path	Specifies the location files to be merged.
Search Pattern	Specifies the naming pattern of the files that the program searches for. In the default case, find all .csv files.
Output File	Species the directory location and name of the merged file.
X Axis Title	The name of the column which contains the X coordinate.
Y Axis Title	The name of the column which contains the Y coordinate.
Merge On	The value to consider when merging duplicated X Y coordinates.
Merging Options	Skip Invalid Rows- When this check box is selected rows with missing information are skipped. Search Subdirectories- When this check box is selected the program searches in directories below the Base Path as well as the base path directory. Precision- specifies number of decimal places to consider when trying to match parts by location.
After Merging	Selects what to do with the base files that were merged. None- leaves the input file(s) in the current base path directory. Move- moves the input file(s) to the directory location specified in Move To. Delete- erases the input file(s) from the directory.

Creating a Recipe

1. Click the AUTOMATION tab. For applications without an AUTOMATION tab, the function can be displayed by right-clicking on the toolbar and selecting the Automate Tab check box.
2. Click the Edit Recipe icon. This opens the Recipe Sequence Editor.
3. Right-click on the Sequence panel and select an action to add a step to the recipe.
4. Repeat to add additional steps.

   To change order of the steps drag and drop a step.

   To turn off a step, deselect the check box.

   To delete an action from the list, select the step and click the Delete icon.

5. Under each recipe action step, set/enter the desired function(s) you want to perform. See Recipe Actions.
6. Click the Save Recipe icon. In the save file dialog, specify a path and enter a name for the recipe file ending with the file extension .rcpx and click Save.

   Existing unsaved sequences are preserved until the application is closed.

Running a Recipe

1. Click the AUTOMATION tab.
2. Click the Edit Recipe icon to open the Recipe Sequence Editor.
3. Either create a new recipe or click the Import icon in the Recipe Sequence Editor to load an existing recipe file.
4. To run the recipe, click the Run Recipe icon or click the Execute icon in the Recipe Sequence Editor.

Tolerances

On the Tools menu, click Tolerance, or click Tolerances on the toolbar, or click the Tolerance icon in the status bar.

Tolerance Tool Features

- Set low limits and/or high limits for any/all numeric results.
- Results that exceed set values are flagged. See Tolerance Status.
- Tolerance status is displayed in the status bar.
- The selections and entries in the Tolerance Tool are saved in a settings file. See Using Settings.

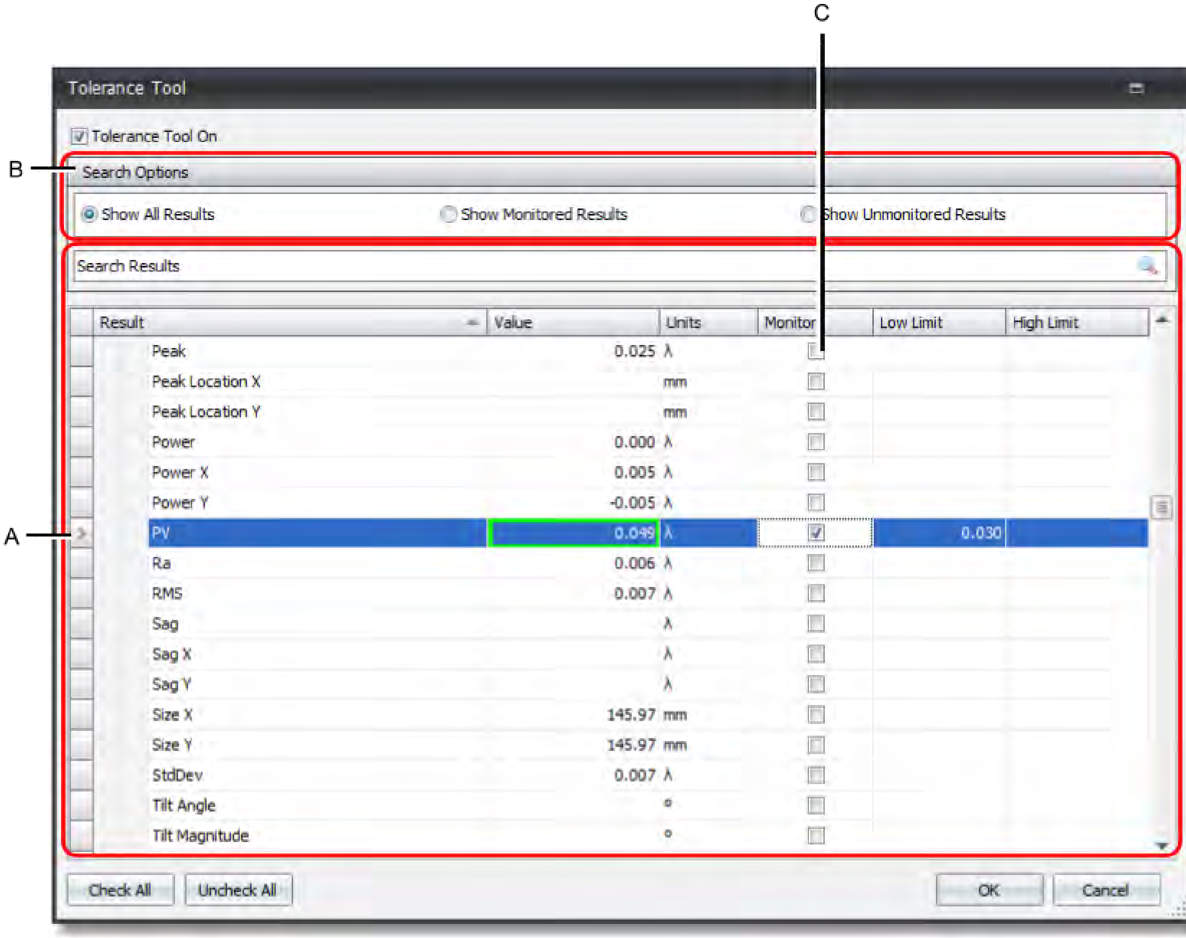
Example Uses

- Set a High Limit so you know when a result has exceeded some user-set limit.
- Set a Low Limit so you know a preset quality level is met for a given manufacturing process.
- Use as a visual status of results; green meaning pass and red meaning fail.

The Tolerances Screen

To activate this function select the Tolerance Tool On check box.

The numbers displayed in the Value column are from the current data set.



A. Results that match the criteria in the Search Options. To enter limits, select row and enter values in Low Limits and/or High Limits column. **B.** Search Options (see below). **C.** Monitor check boxes; when selected, the result is monitored for compliance with the Low Limit and/or High Limit entries.

Search Options

Determines what results are shown in the tool.

Show All Results	Displays all results available in the application.
Show Monitored Results	Displays only results that have the Monitor check box selected.
Show Unmonitored Results	Displays only results that have the Monitor check box cleared.

Setting Limit Values

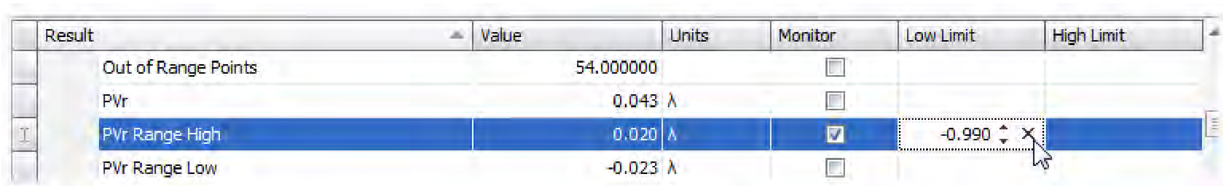
1. On the Tools menu, click Tolerance, or click Tolerances on the toolbar.
2. In the Tolerances tool, scroll down the list until you find the results of interest.
3. Select the Monitor check box for a result of interest.
4. Click on either the Low Limit or High Limit column.
5. Enter a value for the limit.
6. Repeat steps 3 thru 5 for additional results.
7. Select the Tolerance Tool On check box.
8. Click OK to close the Tolerances tool.

Selecting All Results

Click Check All to select all Monitor check boxes.

Clearing Limit Values

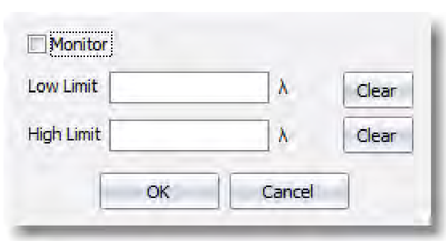
1. Click on the result of interest.
2. Click the limit entry in either the Low Limits or High Limits column.
3. Click the X next to the limit entry.



Entering Result Limits Directly

This method is used to quickly enter limits without using the Tolerance tool.

1. Point to the result, right-click and select Set Limits.
2. Enter limit values.



3. Select the Monitor check box to activate.
4. Click OK.

Tolerance Status

Status Bar Indicators

Located in the lower right corner of the window.

 Tolerances or limits are not set.

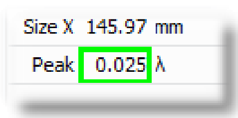
 Tolerances or limits are within range.

 Tolerance or limits are exceeded.

Result Indication

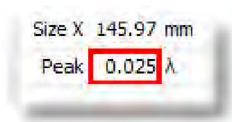
The status for results with set tolerances is indicated by a green or red frame.

Result is within set limits



pass or okay

Result outside of set limits



fail or exceeded

7.2 Laser Interferometer Tools

This section describes tools that are specific to the laser interferometer.

Calibration Marker	Define and apply calibration markers for wavelength shifting interferometry.
Data Generate	Create simulated data files for the laser interferometer.
Lateral Calibrator	Establish the lateral resolution of each camera pixel; required for lateral units other than pixels.

See Also

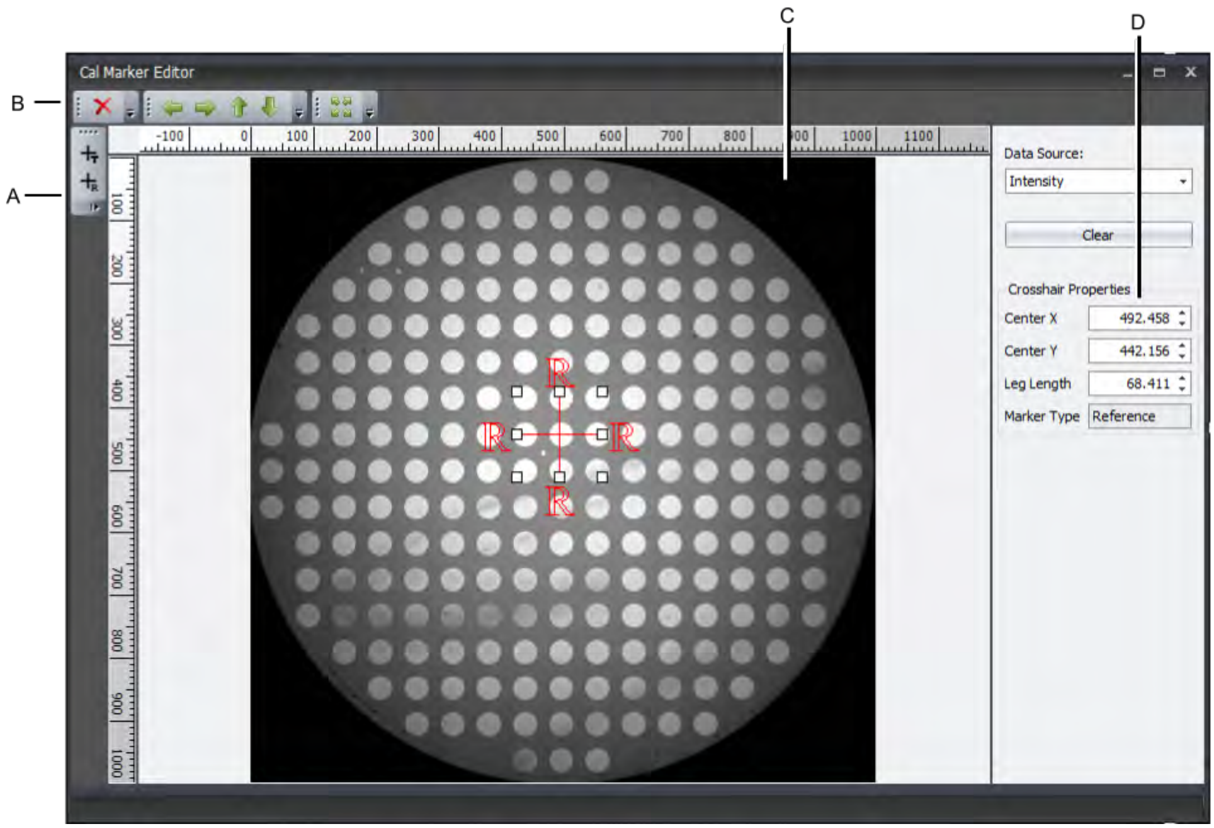
Common Tools

Cal Marker Editor (Legacy)

Since Mx 8.0.0, cal marker functionality is easily accessible using built-in tools in the Measurement Setup panel.

To use the legacy Cal Marker Editor, on the Tools menu, select Cal Marker Editor or on the toolbar click Cal Marker Editor.

The Cal Marker Editor (Legacy) Screen



A. Draw Shapes (cal marker) toolbar (T= Test, R= Reference). **B.** Toolbars- Edit, Move Shapes, and Zoom. **C.** Image of data source (test part). **D.** Marker Properties.

Making and Using a Cal Marker

1. Setup your instrument with a part so you have an image.
2. Open the Cal Marker Editor.
3. Click on the appropriate Draw Shape tool. T (test) is used for all FTPSI measurements. R (reference) is used for homogeneity when the empty cavity is larger than the part under test. Place the "R" marker where there is no overlap with the test part cavity.
4. Position the mouse cursor over the part image and left click to place the marker.

The marker should be on a modulating area of the test part and not centrally located.

Data Generate

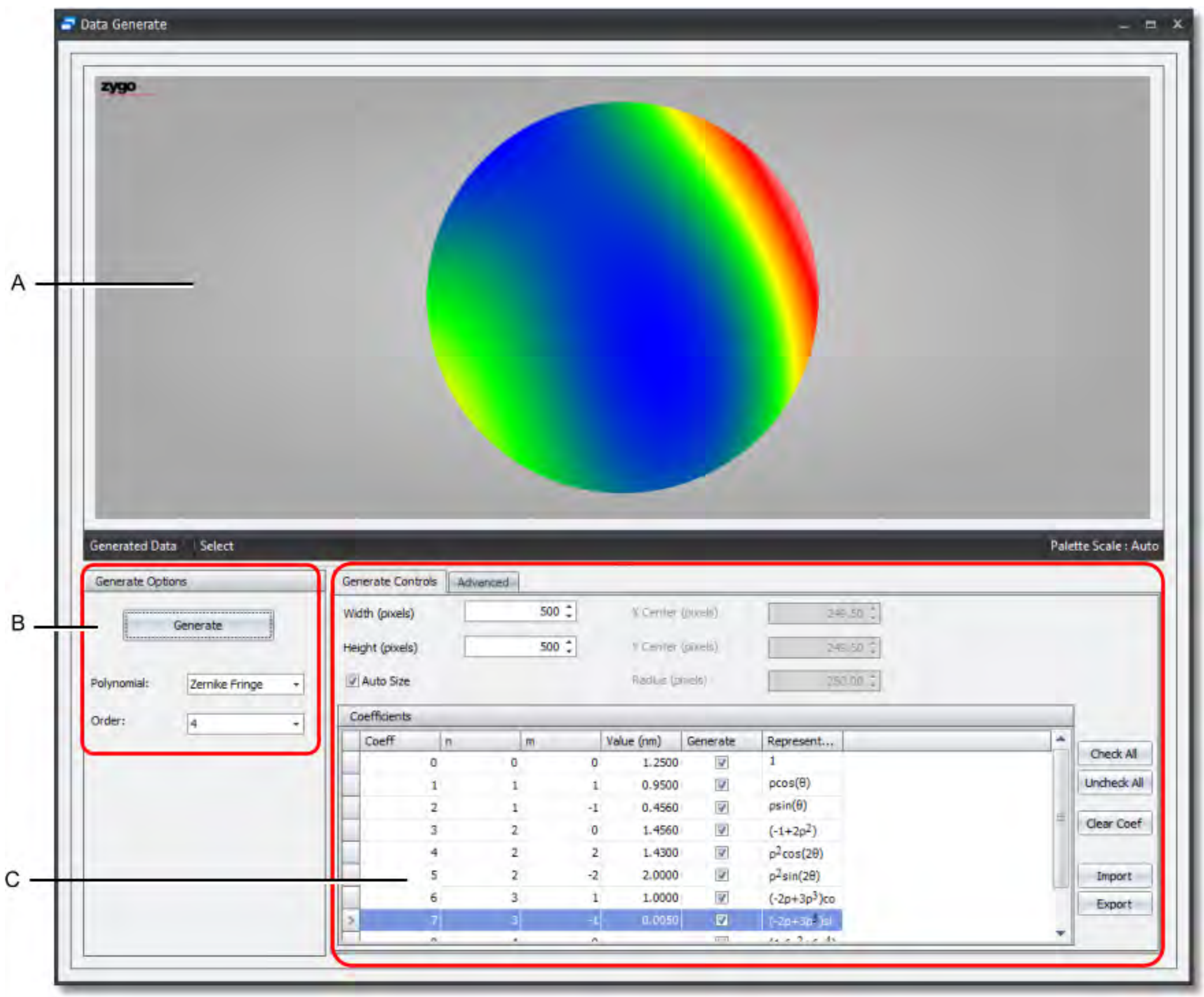
Applicable to laser interferometers; available in Form.appx.

On the User Tools menu, select Data Generate.

Data Generate Details

- Use to create simulated data sets.
- Allows you to select the type of surface and the order of the generation.
- Shares some common features with the Fit and Remove tool.
- Provides optional user entry for coefficient values, lateral size, and center location of the data.
- Supports import and export of data in INT format.

The Data Generate Screen



A. Generated data. **B.** Generate options. **C.** Generate Controls and Coefficients table.

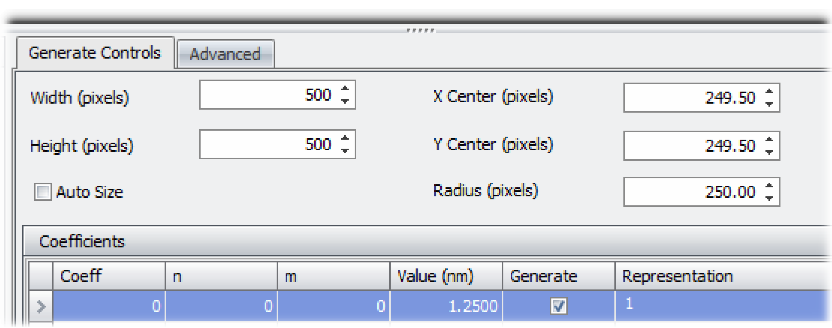
Generate Options

Generate (button)	When clicked, a data set is generated and loaded into the analysis.
Polynomial	Selects the basis of functions to use to make the simulated surface. A Zernike choice implies a circular data set. For a detailed explanation see Polynomial.
Order	Selects the terms available in the coefficients table. For a detailed explanation see Order.

Data Generate Use Cases

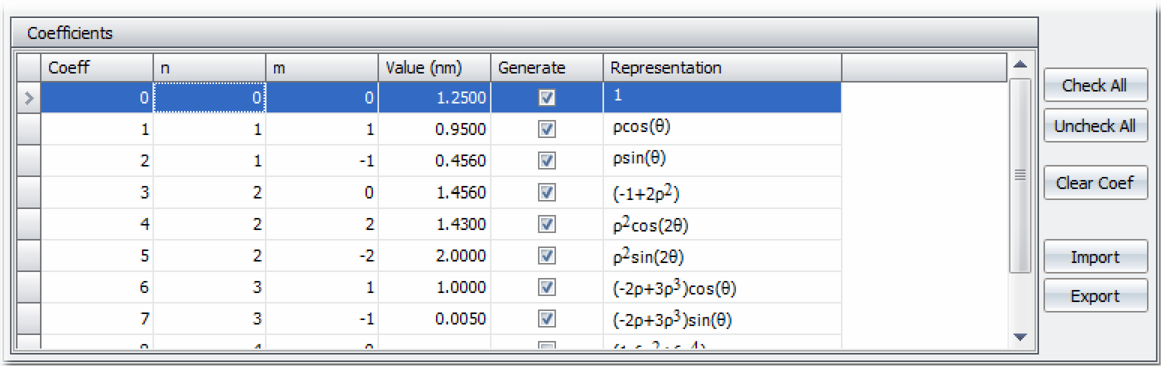
- Use for exploratory or research purposes to better understand analyses statistics and filtering on specific polynomial form errors.
- Use as a convenient tool to generate a user-specified surface or wavefront for export as an INT Zernike Surface or INT Grid surface for use in simulating surface errors within ray-trace code, such as CODE V, ZEMAX, and OSLO.
- Use as a tool for confirming an entered surface error that can later be imported into User Remove for subtraction from each subsequent measurement.
- Use as a diagnostic utility to confirm calculated statistics and correlate to other packages that utilize the same polynomial basis.

Generate Controls



Auto Size	When this check box is selected, X Center, Y Center, and Radius values are automatically generated as based on the Width and Height entries.
Width	Specifies the camera width used when generating a data set.
Height	Specifies the camera height used when generating a data set.
X Center	Specifies the center of the generated data set in the x-axis. Clear the Auto Size check box to allow entry.
Y Center	Specifies the center of the generated data set in the y-axis. Clear the Auto Size check box to allow entry.
Radius	Specifies the radius of the generated data set. Clear the Auto Size check box to allow entry.

Coefficients Table



For an explanation refer to Polynomial Table.

To generate a surface coefficient, the Generate check box must be selected. Only active rows (selected by the Order control) are used or allow user entry.

Use the Check All or Uncheck All buttons to select or clear all Generate check boxes simultaneously.

Using the Table

Refer to Working With Tables and Sorting Table Data.

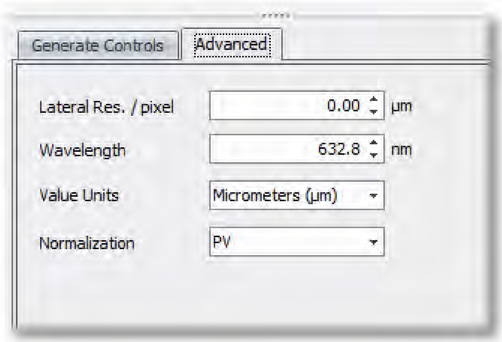
Generating a Data Set

1. Select a Polynomial type and expansion Order.
2. The coefficient table is automatically populated. To enter a value for a coefficient row, click on a selected value cell and type in a number.
3. Select coefficient rows to use by selecting the Generate check box.
4. Click the Generate button to generate the surface and insert into the analysis flow.
5. To save the data set, click Save Data and enter a name for the file in the Save Data dialog box.

Importing or Exporting INT Files

INT files can be imported, exported, and copied with the clipboard. See Exchanging Coefficients.

Data Generate Advanced Tab



Lateral Res. /pixel	Specifies the lateral dimension between pixels.
Wavelength	Specifies the instrument wavelength.
Value Units	Selects the units displayed in the Value column under the Generate Controls tab.
Normalization	Selects the coefficient normalization. PV expresses the coefficient value in terms of PV coefficient. RMS normalizes the coefficient by adding a square root term to the local polynomial. For a detailed explanation see Normalization.

Data Manipulate

This feature is no longer available as of Mx 8.0 and has been replaced with the surface Processing Tool.

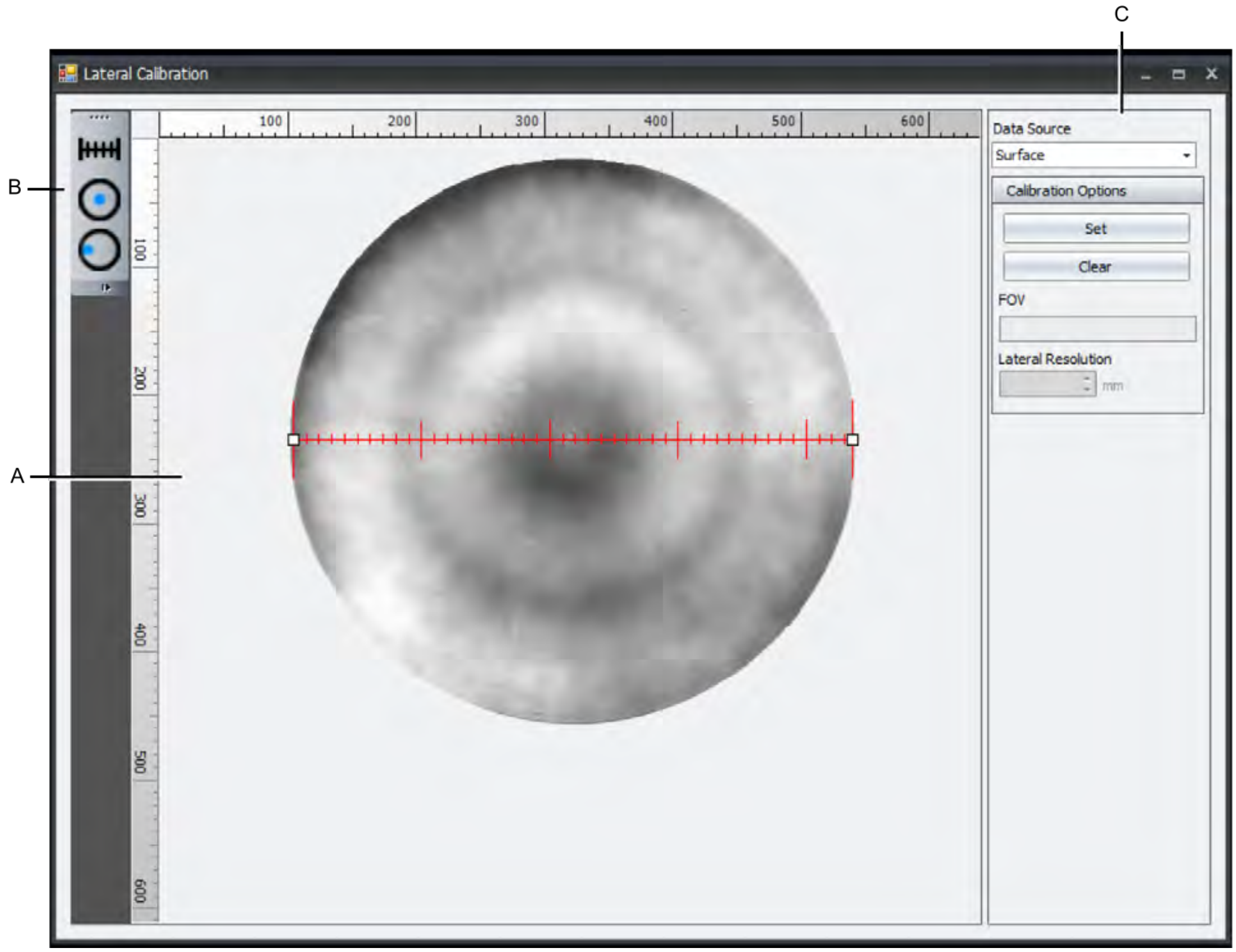
In older versions of Mx, the Data Manipulate function was used with laser interferometer applications to select, order, and specify the processing of data to customize or enhance data display.

Laser Interferometer Lateral Calibration (Legacy)

Prior to Mx 8.0.0, this was the Lateral Calibration (also known as Lat Cal) tool for the laser interferometer. Since Mx 8.0.0, lateral calibration is created directly within the Live Display using built-in tools in the Measurement Setup panel. See Lateral Calibration.

For the legacy Lateral Calibration screen, on the Tools menu, click Lateral Calibrator, or click Lat Cal on the toolbar, or press F7.

Lateral Calibration Screen



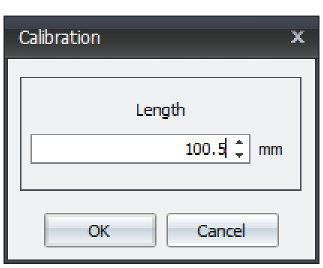
A. Image of test part. **B.** Shape toolbar (other toolbars are hidden). **C.** Data Source box, Calibration Options buttons, and results (blank if not calibrated).

Selecting Calibration Units

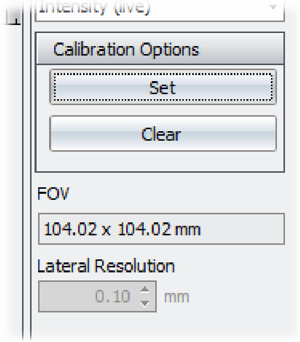
1. Click Units on the toolbar.
2. Select desired Units. See [Set Unit and Precision].

Lat Cal (Legacy), Perform Calibration

1. Select the Data Source.
2. Click on the desired calibration shape (Ruler or Circle).
3. Position the pointer over the part image and press the left mouse button, move the mouse to draw a line across some portion of the image, and release the mouse button. The longer the line or the larger the circle, the greater the accuracy.
4. Click Set and enter the length of the line (or diameter of the circle) in the Calibration dialog.



5. Click OK. Dimensions are displayed in the calibrations results (FOV and Lateral Resolution).



FOV is the Field of View.

Lateral Resolution is the dimension from one camera pixel to the next.

Clearing Calibration

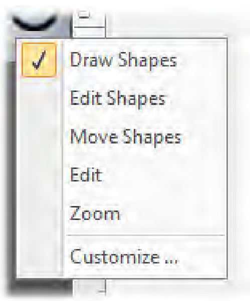
1. Click Clear.

Lat Cal (Legacy), Toolbars

This section describes toolbar options for the Legacy Lateral Calibrator.

The actual tool functions available may vary based on the application.

By default, the Draw Shapes toolbar is shown on the Lateral Calibration screen. To display other available toolbars, right-click on the toolbar area and select from the menu.



See Also

Toolbars

Changing a Toolbar

Lat Cal (Legacy), Edit Shapes

This section describes how to edit shapes using the Legacy Lateral Calibrator.

Selecting Shapes

Shapes must be selected before they can be moved, resized, rotated, or deleted.

1. Click anywhere on the shape. The shape selection handles appear and the cursor changes.

Resizing Shapes

1. Select the shape.
2. Move the cursor to the selection handles at the corner of the shape(s), the cursor changes to .
3. Press the left mouse button, drag the mouse to resize the shape(s) and release the button.

Moving Shapes

1. Select the shapes, the cursor changes to .
2. Press the left mouse button, drag the mouse to move the shapes(s) and release the button.

or

3. To move one pixel in a specific direction, press the Up, Down, Left, or Right Arrow keys or click the desired Arrow button.

or

4. To move 10 pixels at a time, hold down the Shift key while performing step 3.

Deleting Shapes

1. Select the shape.
2. Press the Delete key on the keyboard.

or

3. Click the Delete button on the toolbar.

or

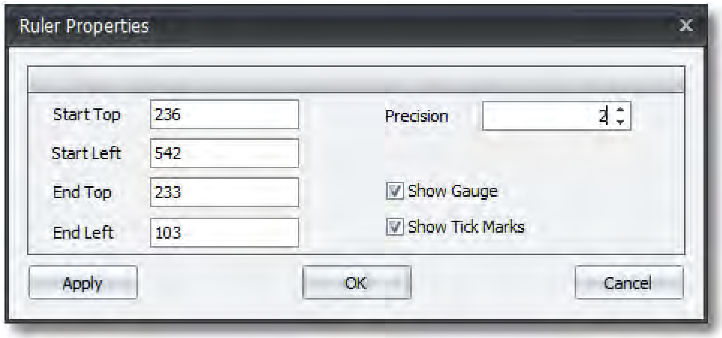
4. Right-click to access the context menu and select Delete.

Lat Cal (Legacy), Shape Properties

This section describes how to edit shape properties.

With the Legacy Lateral Calibrator, the calibrator ruler or circle has associated properties that can be viewed and edited. Use the Ruler Properties to:

- Fine-tune the location or size of the shape.
- Change the look of the ruler.
- Change the number of decimal places (precision) for the ruler.



Changing Properties

1. Select the shape.
2. Right-click to access the context menu and choose Properties.
3. Type in new values for the desired properties and click OK.

Lat Cal (Legacy), Enter Calibration

This technique is used to enter the lateral resolution directly without performing actual calibration.

1. On the Tools menu, click Lateral Calibrator.
2. Click Set.
3. Enter the known lateral resolution in the Calibration dialog.
4. Click OK.

7.3 Optical Profiler Tools

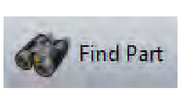
This section describes tools that are specific to the optical profiler.

Find Part	Use to find the part surface.
Focus Aid	Use to help find part focus.
Objective Focus	Used to fine-tune objectives for the best possible contrast.
Lateral Calibrator	Establish the lateral resolution of each camera pixel; required for lateral units other than pixels.
Smart Setup	Use to find the part surface, adjust light level and make a measurement.

See Also

Common Tools

Find Part



Click the toolbar button to perform a Find Part scan. This scans rapidly upwards from the current Z position and attempts to find the part surface.

For greater detail see Easy Micro Measurements and Automated Focus & Setup.

Focus Aid

- Use to help find part focus, especially with low magnification objectives and featureless test parts.
- Works for all objectives and surface finishes.
- Provides live display with crosshair target.
- Indicates direction from focus. Spots above center indicate objective too high; spots below indicate objective too low.
- When focus is found, the center spot is bright, sharp, and centered.

Use Conditions

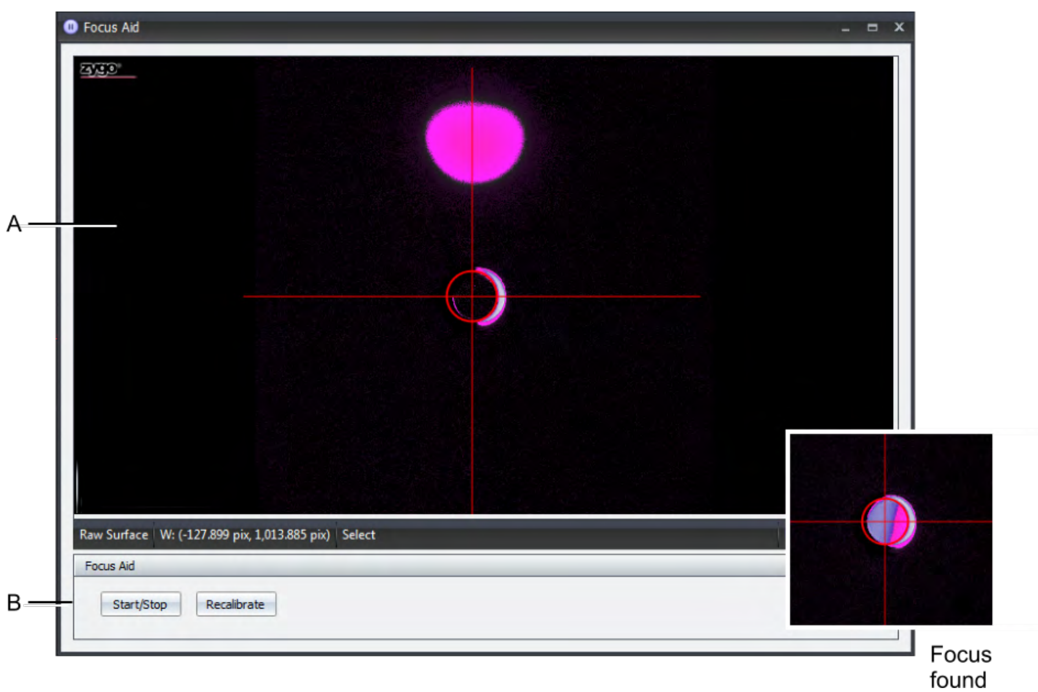
- Applies to optical profilers; included in Micro.appx.
- Accessible from any Live Display toolbar or under the Tools menu.

Using the Focus Aid

Exercise caution when using the Focus Aid for parts with holes, as there is a greater risk of crashing the objective into the part.

1. At the Measure tab on the live display panel, click Focus Aid.
2. Adjust instrument in Z-axis (focus) until spot moves into the center of the crosshair circle.
3. Fine-tune instrument focus until spot is bright, sharp and centered.
4. When done, click the Close button (X).

The Focus Aid Screen



A. Image of test part. **B.** Basic controls.

Start/Stop button	Press to toggle the image between a live image and the crosshair focus aid.
Recalibrate button	Press to calibrate the current objective. Raises the z-axis away from the part and takes a reference image, which is used when providing focus feedback. On some optical profilers, recalibration is performed automatically when the focus aid is opened if the focus reference is more than 7 days old.

Objective Focus

Applicable to optical profilers; available in Micro.appx.

On the Tools menu, select Objective Focus.

Objective Focus Features

- Used to fine-tune objectives with equal path rings for the best possible contrast (focus).
- Requires a focus grating calibration artifact.
- Primarily used as a factory tool during objective assembly.

Adjusting Objective Focus

1. Install the objective (must have an equal path ring).
2. Adjust rough focus on the focus grating.
3. Access the Tools menu and select Objective Focus.
4. For Test Mode, select Real Time Intensity.
5. Click the Test button.
6. Finely adjust the objective equal path ring so the red and blue lines overlap in the Grating Contrast plot. The Defocus result should be less than 0.1 µm.

Optical Profiler Lateral Calibrator

On the Tools menu click Lateral Calibrator; or Press F7; or Point to an Objective button in the Measurement Setup panel, right-click and select Lateral Calibrator.

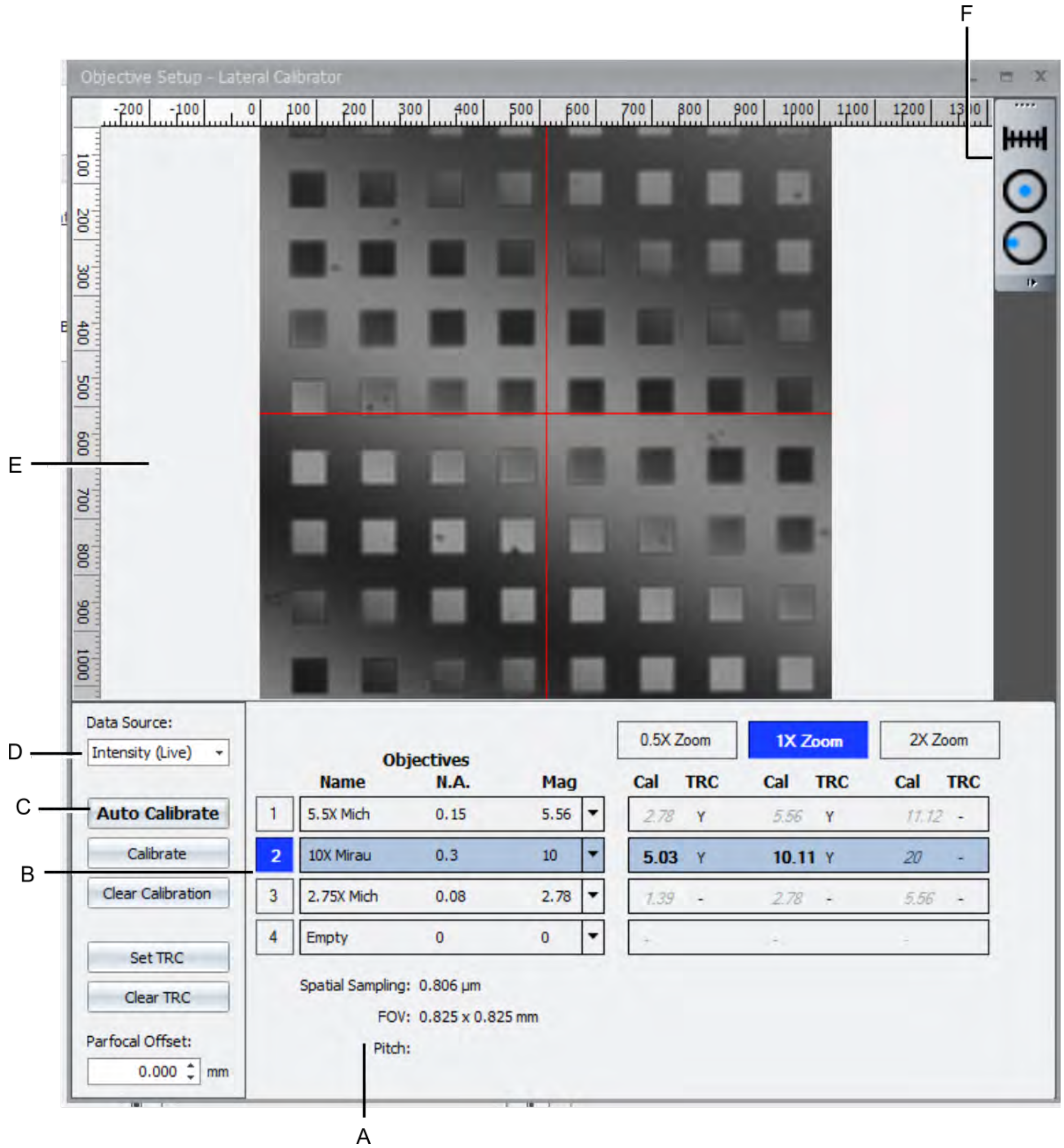
Lateral Calibrator Features

- Use to specify what objectives appear in Measurement Setup panel.
- Calibration establishes the lateral resolution of each camera pixel.
- Calibration is required to use lateral dimensions other than pixels.
- Perform calibration whenever a zoom lens or objective is removed and replaced.

Use Conditions

- Calibration can only be performed if an instrument is connected and working.
- Calibration must be made before making measurements.
- You cannot recalibrate existing data.
- Metric units are used for calibration. Units shown in results and plots are user selectable.

The Objective Setup - Lateral Calibrator Tool

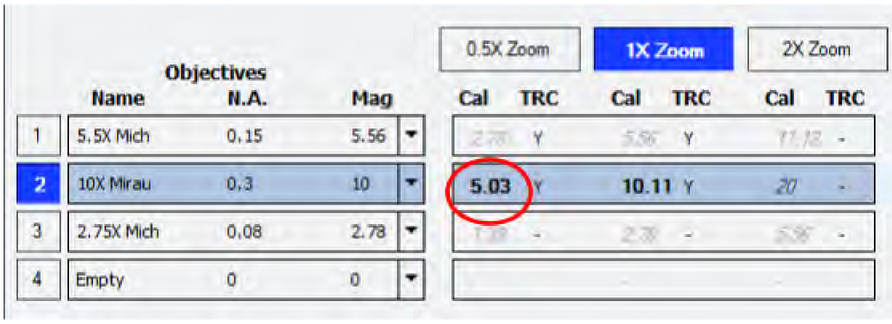


A. Calibration results (blank if not calibrated). **B**. Objective listing, magnification, and discrete zoom variables. **C.** Auto Calibrate button. **D.** Data Source box. **E.** Image of standard. **F.** Toolbar- Draw Shapes (other toolbars are hidden).

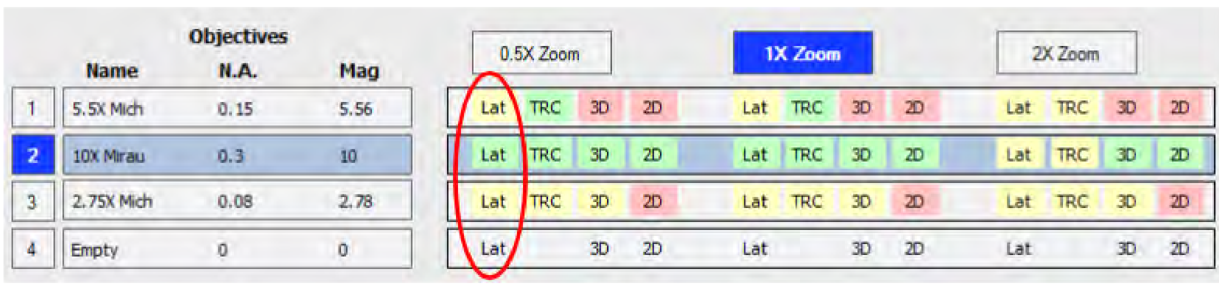
Lateral Calibration Status

Current status for objective lateral calibration is displayed in:

- Objective Setup - Lateral Calibrator tool.
- CALIBRATION tab, Navigator - System Status.



In the Lateral Calibrator, calibrated objectives are indicated by bold type under the Cal columns.



In the System Status and Calibration Data Browser, status is indicated by color:

Lateral calibration (Lat): green - set, yellow - not set

Turret reference coordinates (TRC): green - set, yellow – not set, white - not available

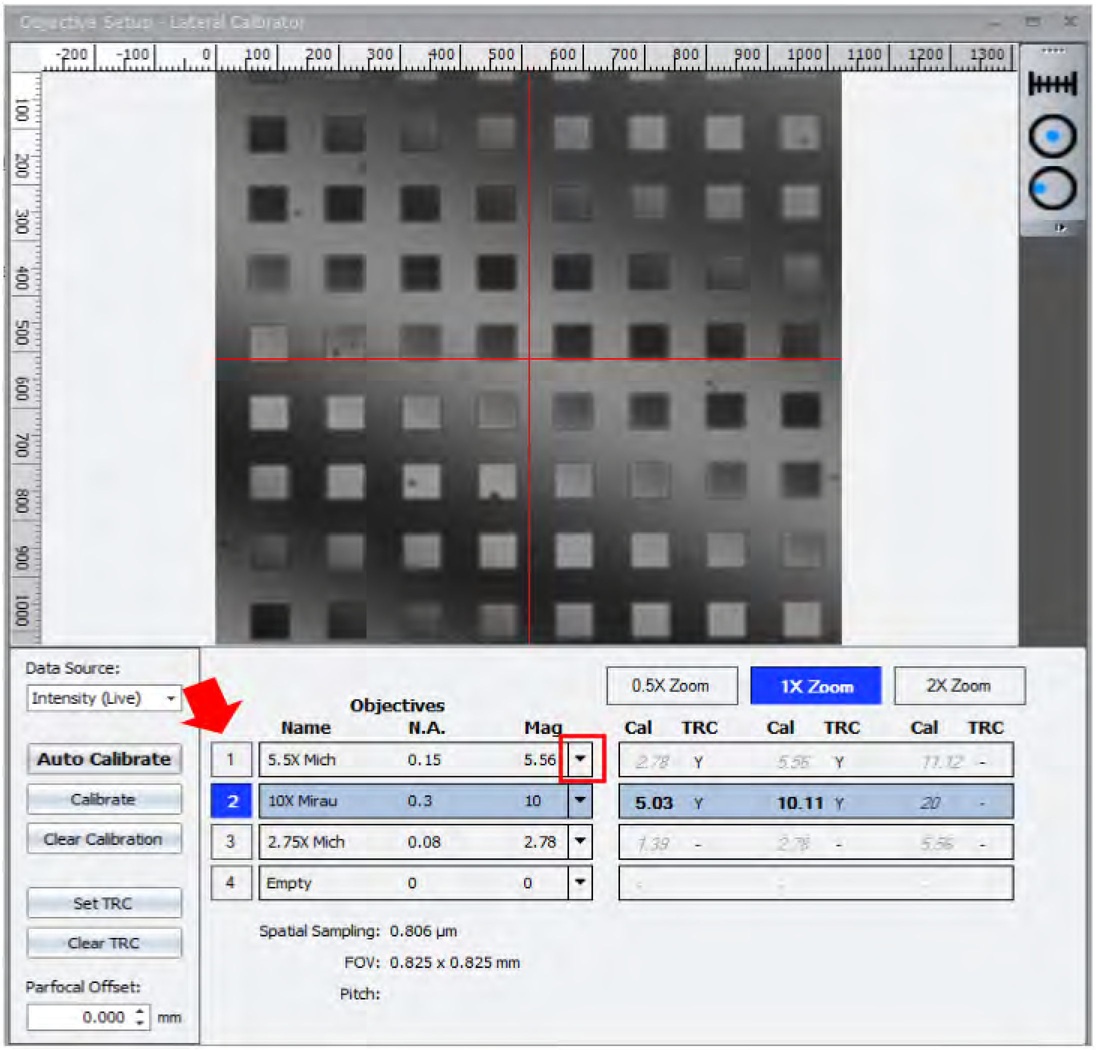
3D/2D calibration: green - valid, yellow - expired, red - missing

Designating Objectives

This procedure determines the objective choices in the Measurement Setup panel and associates a specific objective with a turret position.

Install objectives and turret as instructed in the operating manual.

1. Open the Lateral Calibrator (press F7).



2. Click on [1] (position) button.

If using a motorized turret, it rotates the turret to position 1. If using a manual turret, the current position is linked to position 1; if need be, manually rotate the turret.

3. Point to the drop-down arrow ▾ for position [1] and select the objective in use.
4. If using a turret with additional objectives, repeat steps 2 and 3 after clicking the appropriate position button [2] [3] or [4]. Turn the manual turret to the corresponding position.
5. Continue assigning all occupied turret positions with objectives. Select “empty” when there is no objective to designate.
6. Objective locations and install date/time are automatically saved.

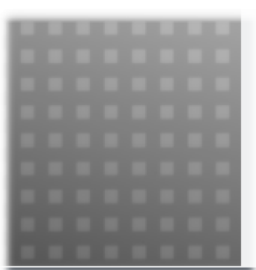
Precision Lateral Calibration Standard

- The *recommended* standard for accurately determining camera pixel-to-pixel spacing for lateral measurements.
- It features 6 areas of precision squares corresponding to 3 µm, 10 µm, 30 µm, 100 µm, 200 µm, and 500 µm pitch spacing.
- NIST traceable; supplied with calibration certificate.
- When not in use, store in the included protective case.
- Available as an accessory.

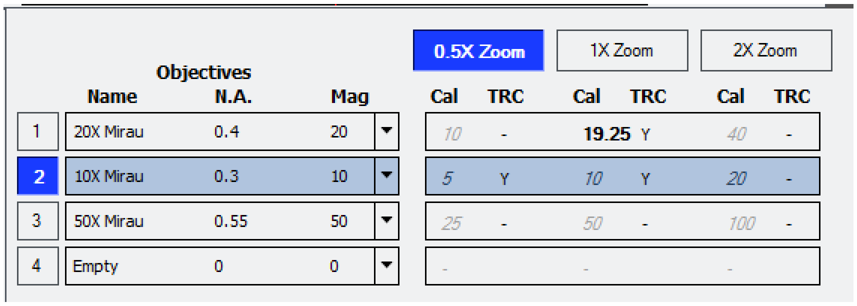
Handle the Standard with care. The features are very fine and are easily damaged. Do not touch the measurement surface. To remove dust from the Standard, use a short burst of dry, filtered air. Store the Standard in its case when not in use.

Calibration Basics

- Calibration requires a ZYGO Precision Lateral Calibration Standard.
- Using the Precision Standard significantly improves the lateral measurement performance.
- Calibration provides true three-dimensional measurements. A true three-dimensional measurement precisely maps height (z) data to the lateral dimensions of the part.
- Lateral calibration is not required for height-based results, such as Sa or Sq.
- Before performing Calibration, align the squares on the Precision Standard to border of the Lateral Calibrator window to a reasonable degree.



- Bold numbers under the Cal columns for each Zoom setting indicate that calibration is available for the corresponding objective.

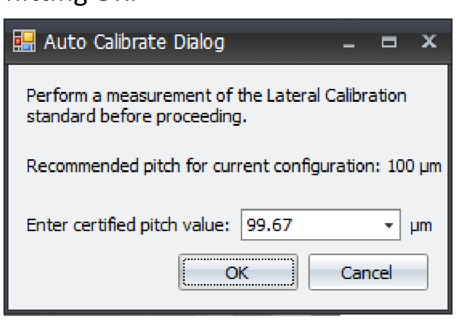


Automatic Calibration Procedure

This procedure is applicable to Micro.appx and MicroLite.appx.

1. Before beginning, make sure the microscope is ready to perform measurements by homing the stages and designating objectives.
2. In the Measurement Setup panel, click on the Advanced Tab. Make sure the Camera Mode control is set to the highest available resolution; this applies even if measurements are made at different Camera Mode settings.
3. Open the Lateral Calibrator by selecting it from the Tools menu or pressing F7.
4. Select the objective you wish to calibrate, either by selecting the appropriate position button (if using a motorized turret), rotating the turret to the proper objective (manual turret), or mounting the desired objective (single dovetail).
5. Position the Precision Lateral Calibration Standard under the objective.
6. Select the appropriate test area on the standard for the objective magnification and zoom. Press “Auto Calibrate” to see a recommended pitch selection.

   Align the squares across the field of view to the border of the Lateral Calibrator window.
7. Focus the objective on the standard until the dots are clearly visible. Adjust light level if necessary.
8. Make sure that the small squares either fill the view screen or are centered within the field of view. The squares should be aligned parallel to the borders of the Live Display. Adjust the rotation of the standard if it is skewed more than the distance between two squares.
9. Focus the objective and null the fringe pattern. There should be at most three fringes visible. Set light level (press F9) to eliminate over-saturation and resultant data drop out.
10. Perform a measurement of the lateral calibration standard.
11. In the Lateral Calibrator, select Auto Calibrate. Enter the certified pitch value and verify the data shown is the lateral calibration standard. If not, press F12 to measure the standard before hitting OK.



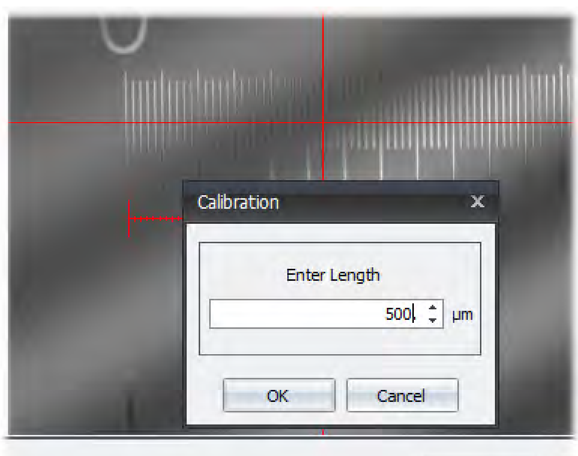
12. Repeat steps 6 to 11 for any other objective and zoom settings that require calibration. ZYGO recommends calibrating in order from lowest to highest magnification, or vice versa, to minimize the number of times a new pitch pattern must be used.
13. Calibration data is automatically saved when the Lateral Calibration window is closed.

Manual Calibration Procedure

This procedure is applicable to Micro.appx and MicroLite.appx.

While not as precise as automatic calibration using a Precision Lateral Calibration Standard, manual calibration is an available option that can be useful for very low magnification objectives or when a Precision Standard is not available.

1. Before beginning, make sure the microscope is ready to perform measurements by homing the stages and designating objectives.
2. In the Measurement Setup panel, click on the Advanced Tab. Make sure the Camera Mode control is set to the highest available resolution; this applies even if measurements are made at different Camera Mode settings.
3. Open the Lateral Calibrator by selecting it from the Tools menu or pressing F7.
4. Select the objective you wish to calibrate, either by selecting the appropriate position button (if using a motorized turret), rotating the turret to the proper objective (manual turret), or mounting the desired objective (single dovetail).
5. Focus on a surface with a known feature size, such as a ruler or circle/hole of known size.
6. To calibrate using measured height data, select Data Source: Surface. To calibrate using measured Intensity data, select Data Source: Intensity. To calibrate using the Live Display, select Data Source: Intensity (Live).
7. Select the appropriate drawing tool from the toolbar in the lateral calibrator. Draw on the plot (using the mouse wheel to zoom when appropriate).
8. Select the Calibrate button and enter the length or diameter of the drawn shape.



9. Repeat steps 5 through 8 for any other objective and zoom combinations that require calibration.
10. Calibration data is automatically saved when the Lateral Calibration window is closed.

TRC- Turret Reference Coordinates

- Requires a motorized turret and motorized stages.
- Coordinates keep the sample part image centered and in focus as objectives are switched.
- Automatic stage adjustment is performed on 5 axes (Z, X-Y, and pitch-roll).

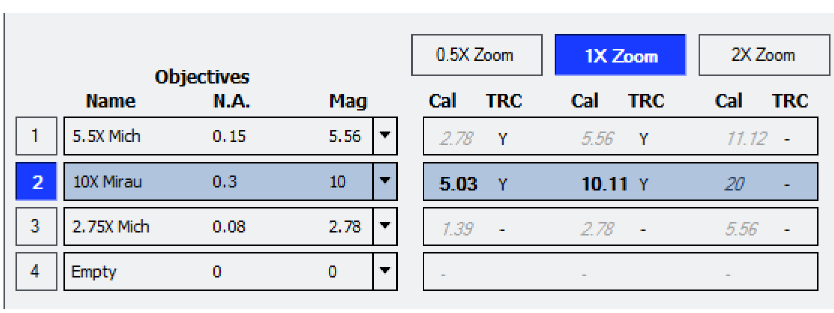
Creating TRC Settings

New TRC values must be established for all installed objectives when an objective is removed, remounted, replaced, and/or the turret itself is removed and replaced.

1. Mount all desired objectives into the motorized turret.
2. Open the Lateral Calibrator (press F7).
3. Assign objectives to turret positions (see Designating Objectives).
4. Click on a position button to select an objective.
5. Click the Set TRC button.
6. Focus and null the profiler on a feature on a sample part. Move the stage to locate the feature under the on-screen crosshair.
7. After the objective is properly focused and nulled, click Yes.
8. Repeat steps 4 through 7 for other installed objectives.

   Only small movements of the stage are expected when switching objectives. The error message: "A turret reference coordinate is out of range. No stage axis was moved." indicates that an objective's TRC's were not properly set up, or an objective was switched or replaced.

9. Coordinates are automatically saved.
10. Objective zoom combinations that have TRCs set will indicate this with a Y under TRC in the Lateral Calibrator.



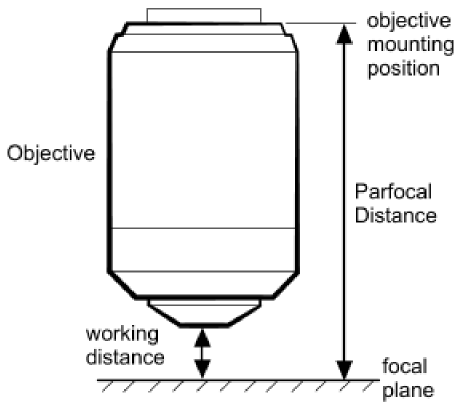
Clearing TRC Settings

1. To remove stored coordinates, click Clear TRC.
2. Select the appropriate options in the dialog box.

Using Parfocal Offset

Parfocal Offset is the difference between the tool's actual parfocal distance and the longest stored parfocal distance of all turret installed objectives.

What is Parfocal Distance?



Each objective has a parfocal distance (or length) that is defined as the distance between the top of the objective and the objective focal plane. This information is stored in the software in a master objective list configuration file. The software keeps track of the largest parfocal distance of the installed objectives.

When multiple objectives are loaded in a turret, it is assumed that extension tubes are used to get all objectives nominally parfocal.

If the parfocal distance of the tool does not match the largest of the installed objectives, the Parfocal Offset can be used to correct it.

Parfocal Offset Examples

Installed objectives:

5.5X Mich (60 mm parfocal distance) with a 60 mm extender tube

2X GC (120 mm parfocal distance)

Parfocal Offset: 0 mm

The software uses 120 mm as the parfocal distance, and since both objectives have the same parfocal distance, and the offset is 0. Note this is the case because the 5.5X has an extender tube.

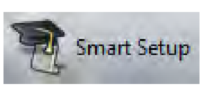
Installed objectives:

5.5X Mich (60 mm parfocal distance) with a 60 mm extender tube

Parfocal Offset: 60 mm

The software uses 60 mm as the parfocal distance, but because a 60 mm extender is used, an offset value of 60 mm is required.

Smart Setup



Click the toolbar button to perform a Smart Setup measurement. This function scans the part using the Find Part function to determine an appropriate scan length, adjusts the light level and then performs a measurement.

For greater detail see Easy Micro Measurements and Automated Focus & Setup.

Data Processing 8

This section covers data processing functions. The available tools and tool names may vary based on the application. Data processing is defined as the collection and manipulation of data to produce meaningful information.

For a list for functions see Processing Tool List.

8.1 Processing Sequences

- Affects the processing of data after it has been acquired.
- Use to enhance or improve the analysis.
- Use to improve data display.

The following data processing sequence tools all share a similar tool interface:

Surface Processing	In Form and Micro applications. The operations and order are user configurable. This processing applies to the Surface or Phase map. In the Films analysis section, processing tools are available for each acquired data area- Top Surface Processing, Thickness Processing and Secondary Surface Processing. In the Multisurf application, processing tools are available for each of the Test Surfaces 1 through 5. In the MST application, processing tools are available for each measured surface.
Intensity Processing	In Form and Micro applications. The operations and order are user configurable. This processing applies to the Intensity map.
Pre-Segmentation Processing, Region Processing, Reference Processing	These sequence tools are available in the Regions Analysis Tool, and apply to the data prior to segmentation, after segmentation, or the reference surface (respectively).

A generic term for all processing tools is *Sequence Tool*.

Processing Tool

In some applications, this appears as "... Processing" within the Navigator. Click the tool in the Navigator to open.

Click  to turn the tool on or off.

Processing Tool Overview

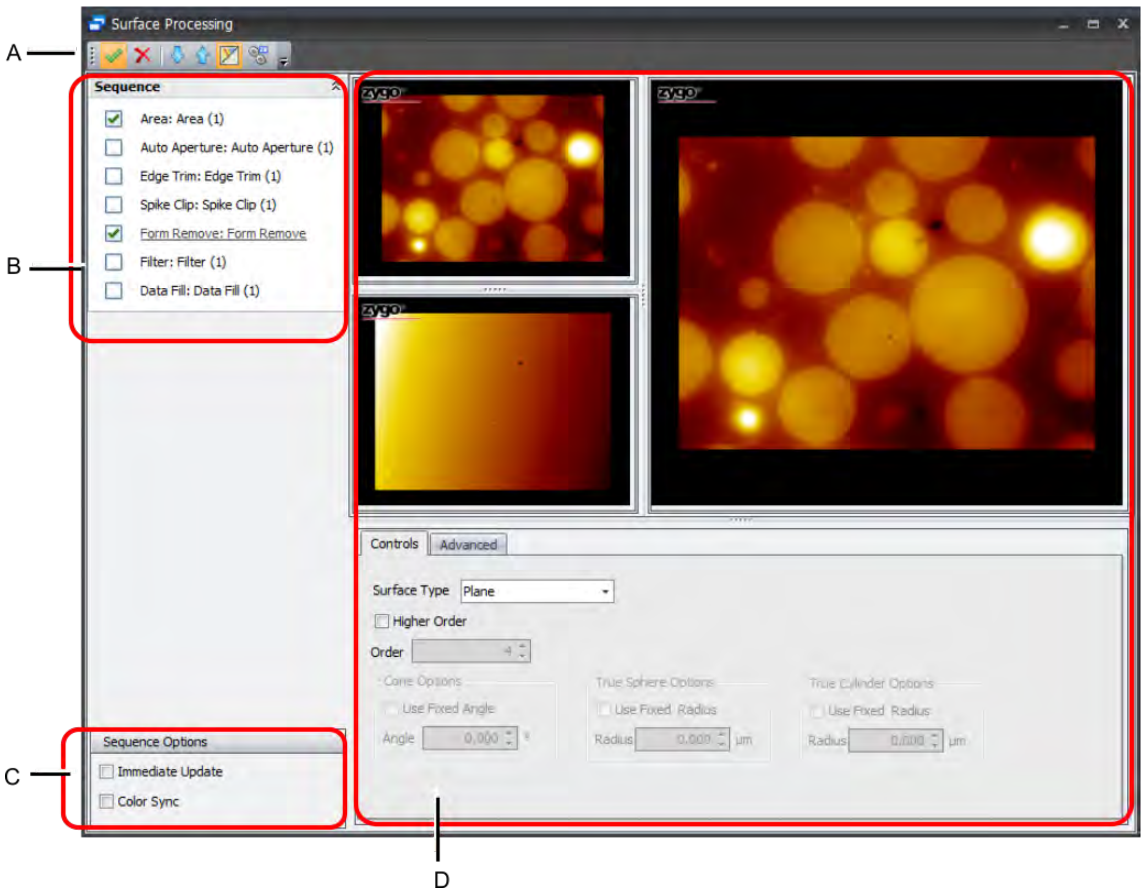
- Select, order, and specify the processing of data.
- Provides an editor for rearranging the data processing order.
- Use to customize or enhance data display.

This tool is extremely powerful and if misused can distort and or cripple the data analysis. Use tools and functions with caution.

The Processing Screen

Select the Immediate Update check box to display the impact of the settings in the tool.

To input changes into the data analysis stream close the window (or click Analyze).



A. Toolbar. **B.** Sequence (or tool) panel (use to select and order sequences). **C.** Sequence Options. **D.** Data display and processing options for the current or selected step.

About Tool Names

- Tool names are automatically generated.
- A number (1) indicates the first occurrence of a tool; subsequent versions of the same tool are numbered 2, 3, etc.
- Individual names can be changed; see Step Properties.

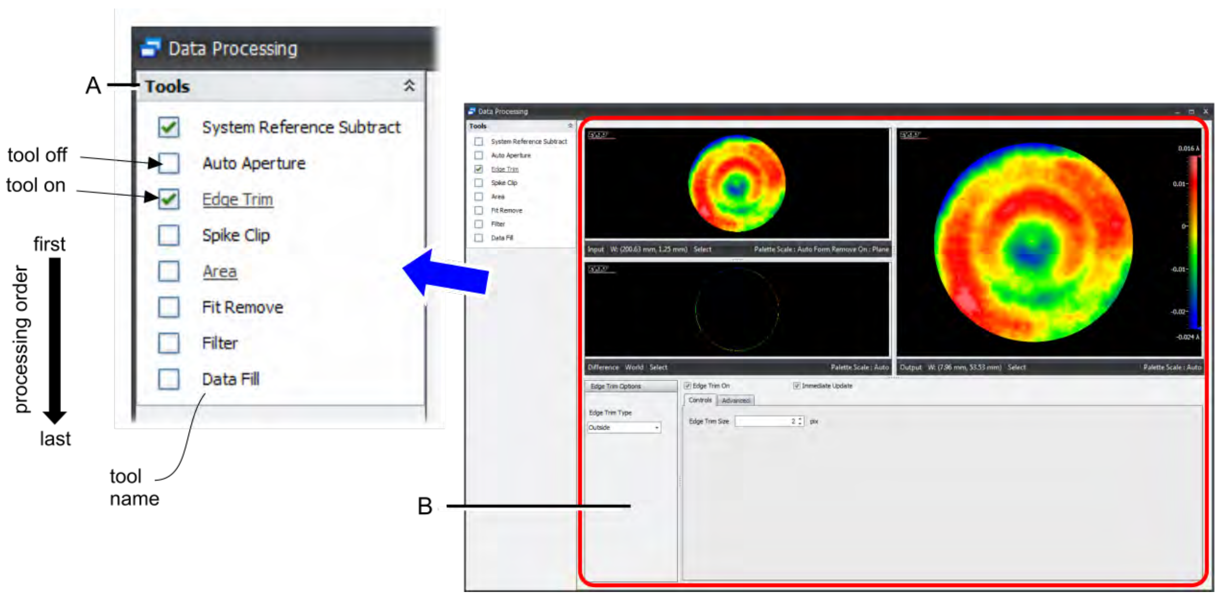
Surface Processing

Navigator : Surface Processing

The Surface Processing Screen (Fixed)

- To open, click Surface Processing in the Navigator.
- The relative and *fixed* order of processing is implied by the order in the Tools column.
- See Common Sequence Functions.

It is suggested to work with tools in a progressive manner, starting with the tools first in the tools list. This helps minimize confusion as tools are applied to the analysis.

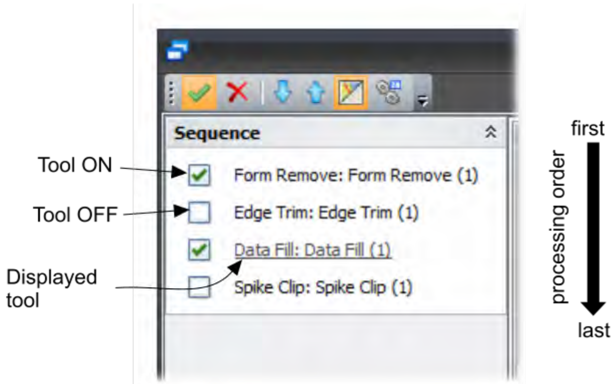


A. Tools selector (fixed); see Common Sequence Functions. **B.** Tool area.

Common Sequence Functions

Tool/Sequence List

- The functional state of each tool is indicated by the check box (no check- off, check- on).
- The currently displayed tool is underlined.
- Tools are applied in sequence from top down.



Selecting a Tool

Left-click on the tool name.

Applying Tools

To update the plots within a tool, select the tool's Immediate Update check box.

To apply tool selections to the data analysis, click the Analyze button or close the screen.

Deactivating or (Deactivating) a Tool

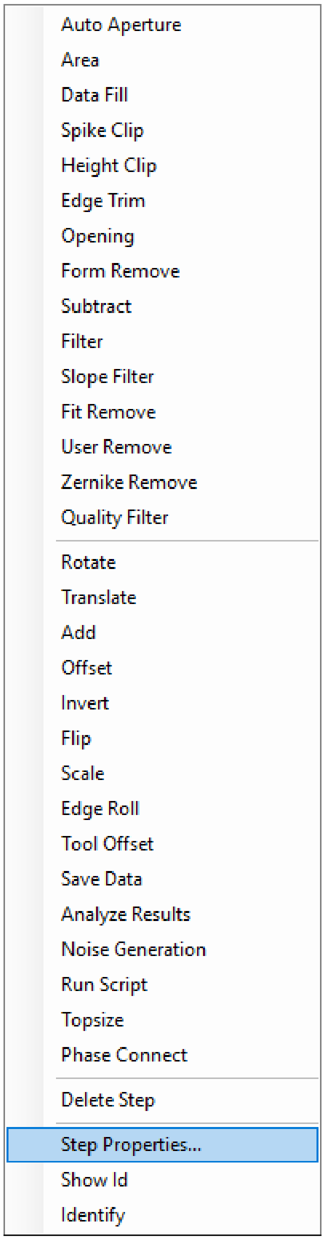
Activate (or Clear) the tool check box in the Tool panel.

Sequence Options

Immediate Update	Select the check box to update the display as changes are made.
Color Sync	See Sync Color Scale.

Adding a Tool

1. Point to the Sequence panel.
2. Right-click and select an option from the menu.
3. Repeat to populate the column with additional functions.



The first group of context menu items is a list of the available data processing tools.

For details on specific tool properties or options displayed in the editor, see the corresponding tool description. See Processing Tool List for a comprehensive summary.

The second group of menu items are advanced manipulate functions.

The last items are for basic control functions.

Ordering Steps (or Changing the Sequence)

The order of processing is based on the list order in the Sequence panel column. To change the sequence:

1. Point to a function.
2. Press and drag the function to a new position in the column.
3. Release the mouse button.

Removing a Step

1. Point to an item in the Sequence panel.
2. Right-click and select Delete Step.

or

3. To delete the displayed or active function, click Delete Step on the editor toolbar.

Step Properties

To edit the name of a sequence step:

1. Click on the desired step to display it.
2. Right-click on the sequence panel and select Step Properties.
3. Enter a name for the step and click Ok. Up to 60 characters can be typed.

Sequence Files

Sequence files are saved and loaded from within the processing tool and are identified by the extension "seqx".

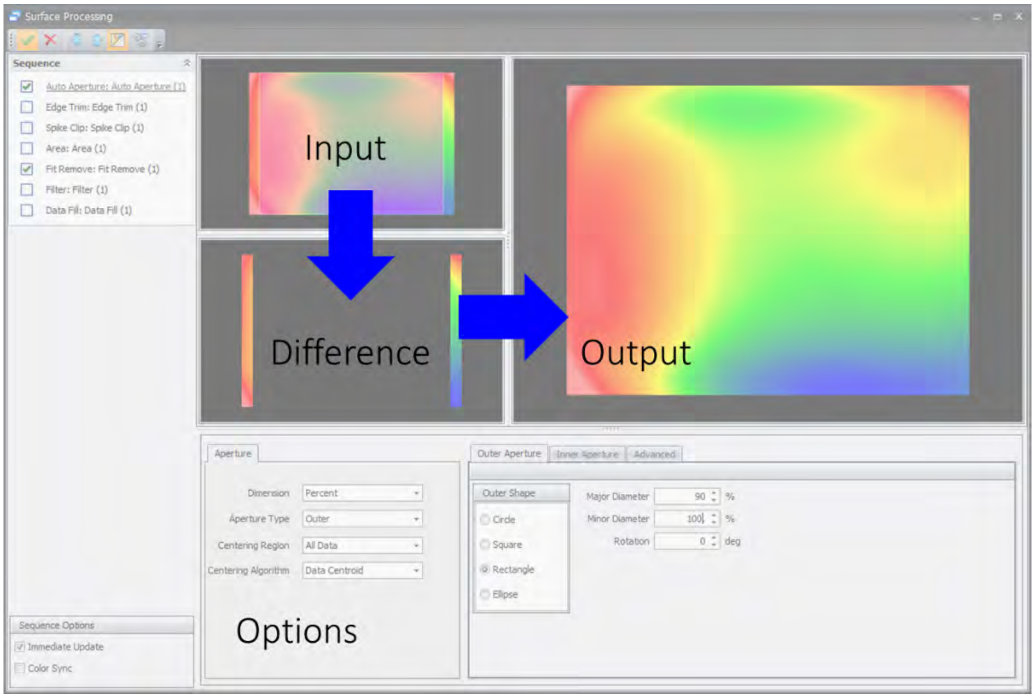
Exporting (or Saving) a Sequence File

1. Click Export on the editor toolbar or right-click and select Export.
2. In the Save File dialog type a file name and click Save.

Importing (or Loading) a Sequence File

1. Click Import on the editor toolbar or right-click and select Import.
2. In the Load File dialog select the file and click Load.

Data Processing and Plots



Input	Displays the input data.
Difference	Shows what data the tool affected; or the portions removed by processing.
Output	Shows the data with the applied tool settings (when Immediate Update is checked). It may include results.
Options	Panel with tool and control selections.

Processing Tool List

All the functions in this section are *not* applicable to all instruments and options.

Tool	Function
Area	Specifies the smallest and largest areas of continuous pixels to comprise valid data regions.
Auto Aperture	Limits data acquisition to a specified area.
Data Fill	Fills areas of no acquired data with synthesized data.
Edge Trim	Removes questionable pixel layers from edges and around isolated holes. Trim refers to removal of pixels laterally (in x and y axes).
Filter	Separates the various frequency components (form, waviness, roughness, noise) that make up a part's surface.
Fit Remove	Fits a best-fit shape to the input data and removes this shape if desired. It is generally used to reveal greater surface details without the influence from the overall form.
Form Remove	Fits and removes the selected form from the data. A simplified version of Fit Remove.
Height Clip	Removes spurious data based on their height relative to a selected reference to improve segmentation. Works different than Spike Clip.
Mask	Applies a Surface mask to the data and discards the unmasked portion of the data.
Opening	Use to separate barely-connected areas into disconnected islands.
Quality Filter	Uses the signal-to-noise ratio of a given pixel to determine if it is valid.
Slope Filter	Removes data based on its slope relative to surrounding pixels.
Spike Clip	Removes questionable data based the height relative to other data. Clip refers to removal of pixels based on height (in the z-axis).
Step Height	Calculates the height of a chosen test area (optional) relative to a reference surface. Does not affect the output map.
Subtract	Subtract an existing data file or Zernike file.
User Remove	Fits a user-specified shape to the input data and removes this shape.
Zernike Remove	Fits user-specified Zernike coefficients to the input data and removes this shape.

Advanced Manipulate Functions

Right-click and select an option from the menu to add to the sequence. For illustrations of axes and angles see Coordinate Systems. To visualize the impact of a change, enter function options and click Analyze.

Function	**Description**
Rotate	Rotate data in the direction as specified in Angle.
Translate	Move data laterally as specified in X Translation and Y Translation.
Add	Add an existing data file. *Add File* specifies the directory path and file name to add. *Alignment* selects if the data is aligned to the existing data. The choices are None (no alignment performed), or Fiducials. To use Fiducials alignment, both the loaded data and existing data files must have a similar set of fiducials previously defined. Isomorphic scaling needs at least 2 fiducials, while Anamorphic needs 3 fiducials. See Fiducials. *Alignment Scaling* selects how the second data set is scaled in x and y to the existing data. Isomorphic scales both axes equally. Anamorphic scales to the best fit.
Offset	Shift data up or down in the z-axis. Z Offset adds the entered amount to the z axis.
Invert	Switch data signs; high becomes low, low become high. Z Datum slides the PV range up or down by twice amount of the entered value.
Flip	Flip data in x or y axis. Axis selects the flip direction; X Axis flips horizontally, Y Axis flips vertically.
Scale	Scale or size the Z-axis height data by the multiplier specified in Scale.
Edge Roll	Calculates an edge roll result in the ring shaped region defined by the Inner and Outer Aperture entries. The result is accessed in a Result Grid. Inner Aperture specifies the inner aperture of the calculation as a percentage of the OD of the part under test. Outer Aperture specifies the outer aperture of the calculation as a percentage of the OD of the part under test.
Tool Offset	Removes tool offset from the existing data. Confocal Aperture is the diameter of the part when at the confocal position; the Use Confocal Aperture check box must be selected to enter a value. Tool Offset Radius and Tool Offset Sign are described under Tool Offset.
Save Data	Used to automatically name and save data files. The options are identical to those described at Auto Save Options.
Analyze Results	Adds selected results into the process flow. MER refers to Minimum Enclosing Rectangle. Results are accessed in a Result Grid.

Noise Generation	Creates noise based on the entry in Peak Amplitude and adds this to the existing data.
Run Script	Runs the specified script file and selects Failure Action. Failure Action selects what to do if there is a failure when the script is running. Prompt asks the user what they would like to do. Continue ignores the error and continues the script. Fail alerts the user the script has failed and provides buttons to Continue or Abort.
Topsize	Used for highly specialized applications to determine the lateral extent of a raised feature at a specified height below the peak.
Phase Connect	Used for highly specialized applications to re-run phase unwrapping over a surface that is known to be smooth.

Processing Task Guide

Task	**Tool**
Define which pixels to analyze...	*Area* *Auto Aperture* *Spike Clip* *Height Clip* *Edge Trim* *Mask Editor*
Define and remove overall shape, form, or noise...	*Filter* *Fit Remove*
Improve data display...	*Data Fill* *Edge Trim* *Filter*

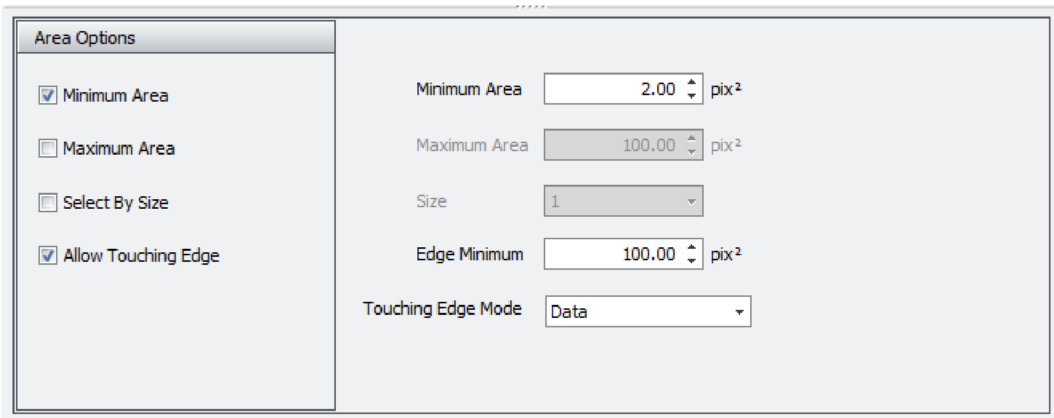
8.2 Area

- The area function is used to specify the minimum and or maximum size of valid data regions.
- Used to remove unwanted areas from the measurement based on their size.
- In some cases, it serves as an alternative to masking.
- Actual controls may vary based on the specific application.

Area Options

Select the appropriate check box to activate the function.

Select the Immediate Update check box to display the impact of the settings in the tool.



The above screen is from the Micro.app.

These Area Options determine the criteria for valid data regions.

Minimum Area	When selected, the Minimum Area control is active.
Maximum Area	When selected, the Maximum Area control is active.
Select by Size	When selected, the Size control is active.
Allow Touching Edge	When selected, the Edge Minimum and Touching Edge Mode controls are active. Allows pixels touching the edge of the camera or the edge of the data to be included.

Area Controls

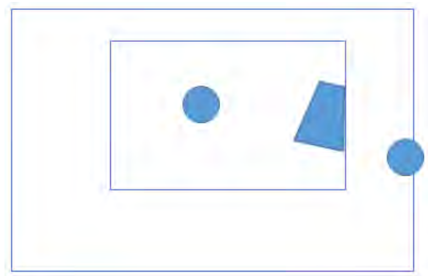
Minimum Area Specifies the smallest size in the selected units (typically pixels) of contiguous data points in a valid region of data. It removes small isolated data areas from the measurement.

Maximum Area Specifies the largest size in the selected units (typically pixels) of contiguous data points in a valid region of data. It removes large isolated data areas from the measurement.

Size Selects or deselects 10 largest contiguous data areas. To select or deselect areas by size, click the drop down arrow and select the corresponding check boxes.

Edge Minimum Specifies the smallest size in pixels of isolated regions bordering the minimum enclosing rectangle of valid data or the camera frame. It removes edge-touching regions with an area less than the entered value.

Touching Edge Mode Selects where the Touching Edge function is applied. Choices are Camera or Data.



For example in this figure, the large rectangle is the camera and the small rectangle is the bounding box of the data.

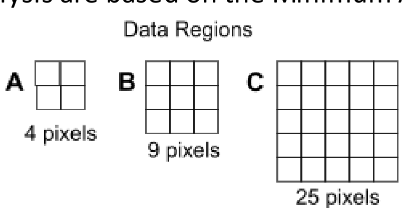
In Camera or Data mode, the object on the left remains since it is inside of both boxes and does not touch either edge.

In Camera mode, the middle object remains since it is within the camera box and does not touch its edge. The object to the right is touching the camera edge and would be subject to the Touching Edge controls.

In Data mode, the right object would not be seen so the logic doesn't apply to that one. The middle object is touching the edge of the data and therefore would be subject to the Touching Edge controls.

Area Function Example

Shown below are three different data regions within the same data view. The regions used in the analysis are based on the Minimum Area and Maximum Area settings.



Minimum Area value	*Maximum Area value*	*Regions Used*
4	100	A, B, C
5	24	B
10	10000	C

8.3 Auto Aperture

- The auto aperture function is used to define and apply an automatic data acquisition mask for one or more regions. Results are only calculated on the selected region(s).
- It is an automatic acquisition masking function used to select regions based on the auto aperture controls.
- Various features of the auto aperture can be specified including the shape, location, centering, and size.
- Auto aperture is based on a center priority algorithm.
- Auto aperture options may appear different than shown here, but the function is identical.

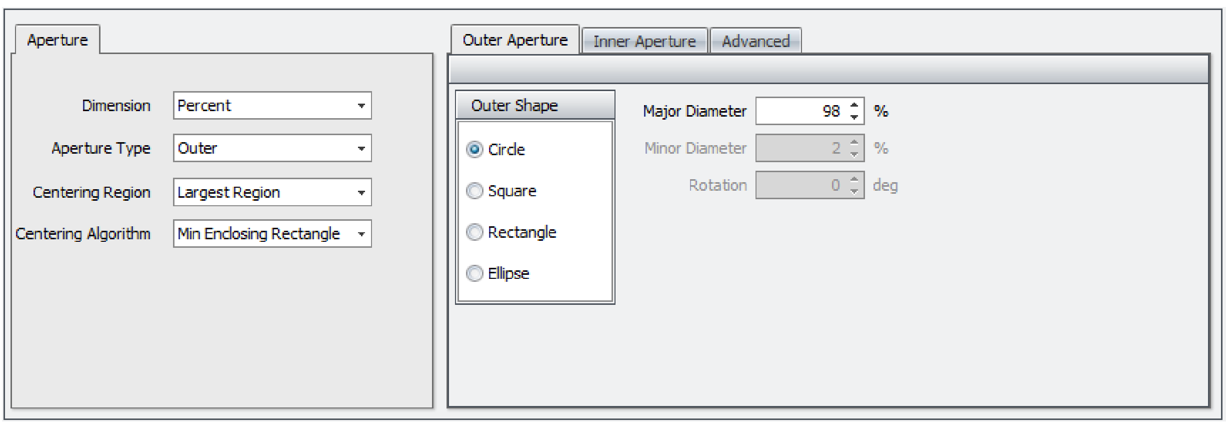
Example Uses

- Use as an auto masking function to minimize edge effects.
- Control edge data loss by automatically removing questionable pixels.
- Define a consistent measurement area for many data samples.

Auto Aperture Options

Select the Auto Aperture On check box to activate the function.

Select the Immediate Update check box to display the impact of the settings in the tool.



Dimension

Selects the way the aperture is specified as either percent(age) of the aperture or Fixed based on an entered dimension.

Aperture Type

Outer	When selected, the automatic aperture mask is applied to the outside of the data. Data outside the shape is excluded.
Inner	When selected, the automatic aperture mask is applied to the inside of the data. Data inside the shape is excluded.
Outer and Inner	When selected, both outer and inner apertures are applied based on the settings of the applicable controls.

Auto Aperture Centering

These controls determine how the shape is centered to the input data. These selections are displayed under the Centering tab.

Centering Algorithm

Selects how the shape is centered to the data.

Min Enclosing Rectangle uses the center of the minimum enclosing rectangle.

Data Centroid uses the center of all valid data points.

Filled Data Centroid uses the center of all data points, including valid data points and inside no data areas that are considered to be filled (or valid).

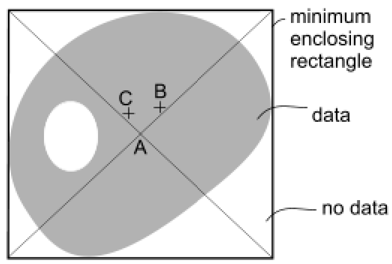


Diagram of Centering Selections

A is the center for Min Enclosing Rectangle.

B is the center for Data Centroid.

C is the center for Filled Data Centroid.

Centering Region

Selects which data points are used to calculate the center of the regions.

All Data uses all individual regions when placing and sizing the mask.

Largest Region uses the largest contiguous region.

Outer Aperture and Inner Aperture Tabs

Outer and inner apertures settings are specified separately at the corresponding tab.

Outer Shape Select the shape of the outer aperture with the option button: Circle, Square, Rectangle, or Ellipse.

Inner Shape Select the desired shape of the inner aperture with the option button: Circle, Square, Rectangle, or Ellipse.

Major Diameter Specifies the percentage of data to use to create the major diameter of the auto aperture. The entry is specific to the selected shape.

Circle	Diameter.
Square	Length of the sides.
Rectangle	Length in the x-axis before rotation.
Ellipse	Length in the x-axis before rotation.

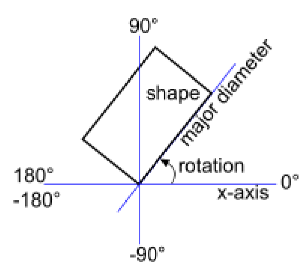
The entries for major and minor diameter are in percent of the minimum enclosing rectangle width and height dimensions, before rotation. The major diameter percentage applies to the smaller dimension of the minimum enclosing rectangle for square and circular aperture.

Minor Diameter Specifies the percentage of data to use to create the minor diameter of the auto aperture. The entry is specific to the selected shape.

Rectangle	Length in the y-axis before rotation.
Ellipse	Length in the y-axis before rotation.

It is possible to actually make the minor dimension longer than the major dimension. The major and minor labels apply when the shape is first defined before rotation. If this is done, it is up to the user to keep track of the major and minor dimensions.

Rotation Specifies the angle of rotation in degrees, for the major diameter of the selected shape, from the x-axis.



Auto Aperture Advanced Tab

Max Fill Size Specifies the maximum size in pixels of an area to fill. Use to fill the auto aperture when the Centering algorithm is set to Filled Data Centroid. See Auto Aperture Centering.

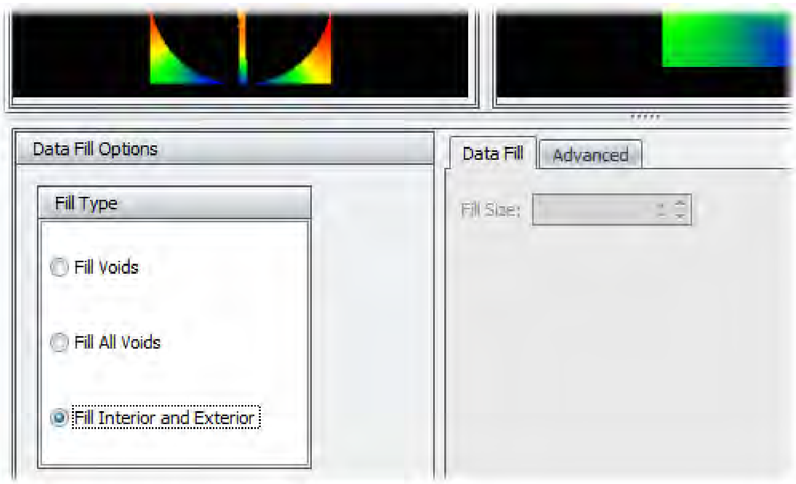
8.4 Data Fill

- The data fill function is used to fill in missing data points within a data matrix.
- Options determine what type of data fill operation to perform and how the new data is fitted to the existing data.
- Data fill is cosmetic only, it does not affect results.

Data Fill Options

Select the appropriate check box to activate the function.

Select the Immediate Update check box to display the impact of the settings in the tool.



Fill Type

Determines the type of fill to apply.

Fill Voids	Voids or openings on the interior of discrete regions with a size in pixels less than or equal to the Fill Size control are filled.
Fill All Voids	All areas without data (or voids) within the interior of discrete regions are filled.
Fill Interior and Exterior	All areas without data on both the interior and exterior of the incoming data's bounding window are filled no matter the size.

Data Fill Tab

Fill Size	Specifies the maximum size, in square pixels, of an interior region to fill. All regions less than or equal to this size are filled.

Data Fill Advanced Tab

Fit Type

Selects the fitting algorithm used for the data fill operation.

Piston, Plane, Sphere, and Cylinder are Cartesian fit types; these preserve the form within the enclosing rectangle or the overall shape of the data nearby. For Cartesian fit types, each hole is filled, based on a least-square fit of the specified shape, to the data within the minimum enclosing rectangle around the hole. The fit type selected should match the overall shape of the data for best results.

Piston fills the void based on a z-axis offset or shift.

Plane fills the void with a flat or tilted surface.

Sphere fills the hole based on a spherical or round shape.

Cylinder fills the void based on a cylindrical shape (which can be likened to a section of the surface of a football).

Laplace fit preserves continuity across the edge of void, and ignores the overall form of the data nearby. Key properties of a Laplace surface are: it is continuous with the edge of the hole, and it does not introduce peaks or valleys within the boundary of the hole. If filled areas show questionable edge effects, try using the Edge Trim tool to cut some pixel layers around each void.

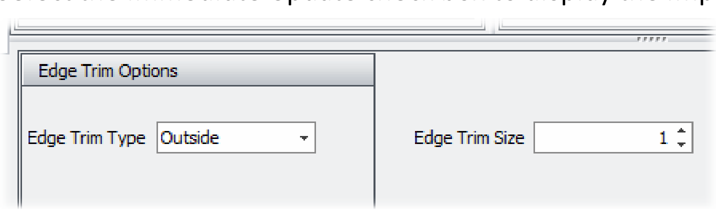
8.5 Edge Trim

- The edge trim function specifies the number of pixel layers removed from edges and around isolated holes.
- Use to remove questionable data from the measurement, such as that occurring at the edge of the part.

Edge Trim Options

Select the appropriate check box to activate the function.

Select the Immediate Update check box to display the impact of the settings in the tool.



Edge Trim Type

Selects how data is trimmed.

All trims pixel layers at the edges of all data, including outside edges and edges around internal holes.

Outside trims pixel layers at the outside edge only. This is useful for removing edge effects such as diffraction.

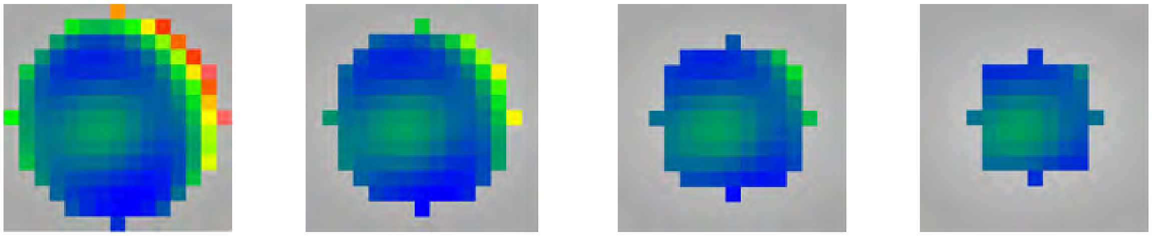
Edge Trim Size

Specifies the number of pixel layers to remove based on the setting of the Edge Trim Type.

Edge Trim Details

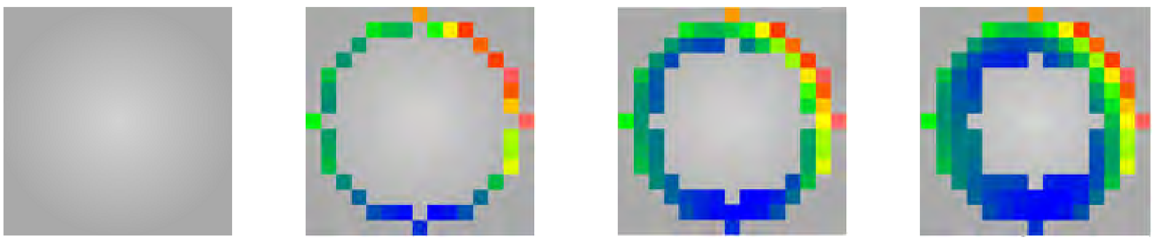
The edge trim algorithm is based on row and column erosion. Note that using Edge Trim on a circular or elliptical data set, results in something non-circular after trim is applied. The following example shows how a circle becomes square in shape as the edge trim increases.

Remaining Data



Edge Trim Size = 0 | Edge Trim Size = 1 | Edge Trim Size = 2 | Edge Trim Size = 3

Trimmed Data



8.6 Filter

- The filter tool provides a method for looking at and separating the waviness components from the roughness components of a data set.
- It is useful not only for noise reduction, but as a way of evaluating data within certain frequency ranges.
- High frequencies are associated with roughness, and low frequencies with waviness.

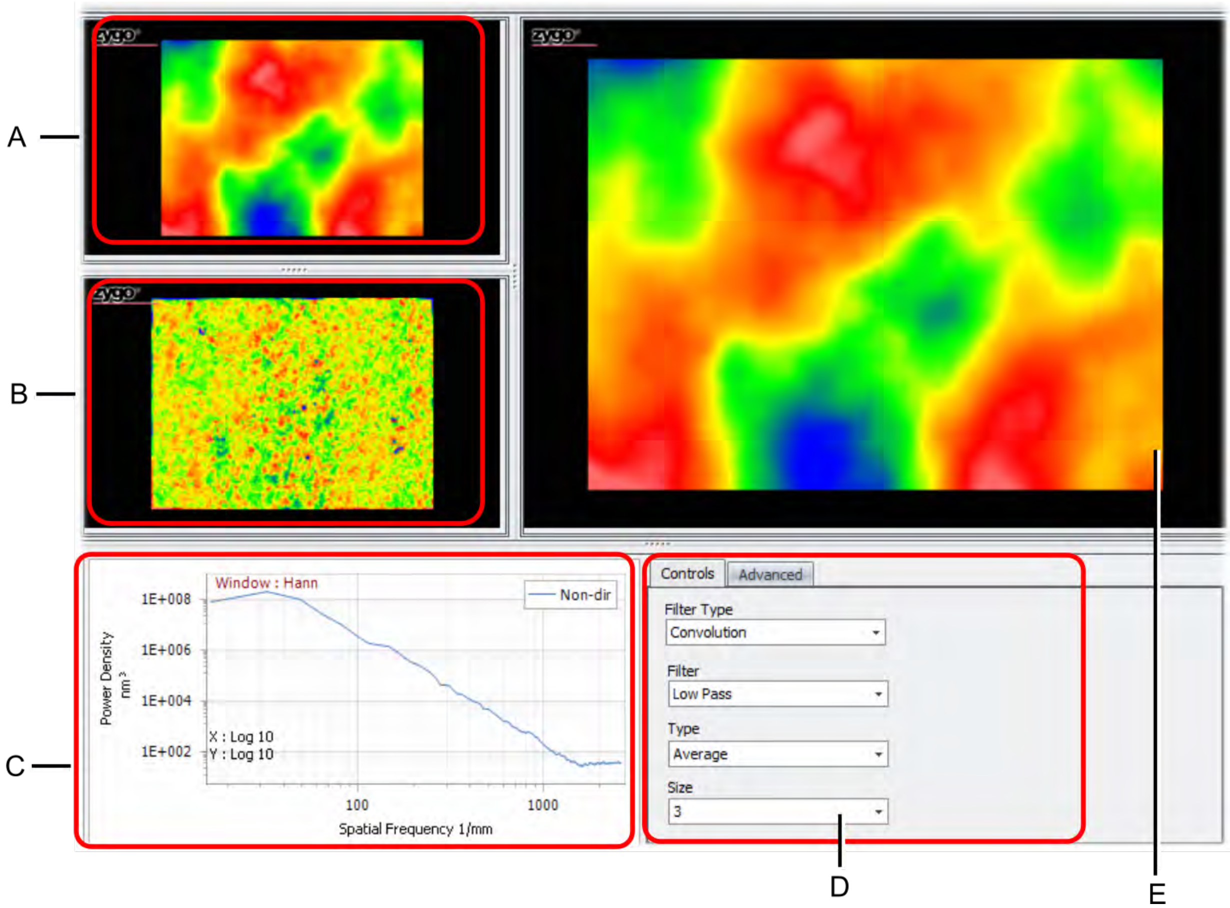
Example Uses

- Filtering helps isolate the frequency components of the data.
- Use filtering to identify and remove noise.
- Use filtering carefully, as it can dramatically alter results and good data can be mistakenly discarded.

The Filter Tool Screen

Select the appropriate check box to activate the function.

Select the Immediate Update check box to display the impact of the settings in the tool.

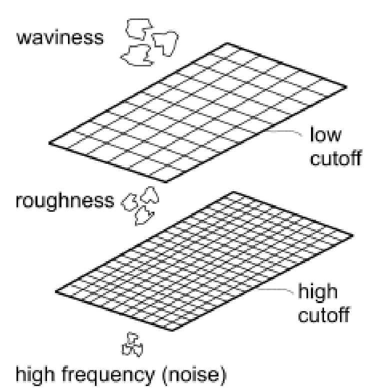


A. Input data. **B.** Data this is removed by the filter settings **C.** Non-directional PSD plot (referred to as the Filter PSD plot). **D.** Filtering options. **E.** Output data (outcome of filtering).

About Filtering

Digital filtering is used to separate data into waviness, roughness, and high frequency components.

One analogy to filtering is sifting dirt or sand. The size of the holes and number of screens determine what you end up with. Two screens divide material into three different grades. One screen divides material into two grades. A low pass filter gives you large particles. A high pass filter gives you small particles. And the screens can be likened to cutoffs.



Filtering Terminology

Term	Waviness	Roughness	High Frequency
Frequency	low	middle	high
Period	long	moderate	short

Refer to Frequency or Period for additional information.

Filter Type

Select the type of filtering you want to use.

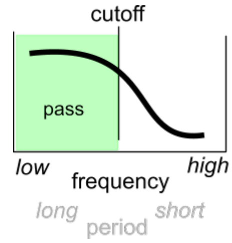
Convolution	A basic general purpose filter that uses a standard windowing function, with the degree of filtering determined by the window size.
FFT	Fast Fourier Transform filter that provides automatic or user input cutoffs.
Spline	Retains original part roughness detail with less distortion and provides automatic or user input cutoffs.

Filter Options

This section describes the selections available in the Filter drop-down box. The choice varies based on the filter type.

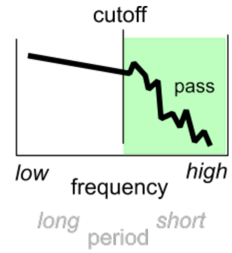
Low Pass — Passes low frequencies, but attenuates (reduces the amplitude of) frequencies higher than the cutoff frequency.

Allows the low spatial frequency components to pass through the filter, removing roughness, and highlighting the waviness data. The effect varies based on the type of filter, kernel size (Convolution) or cutoff selection (FFT and Spline).



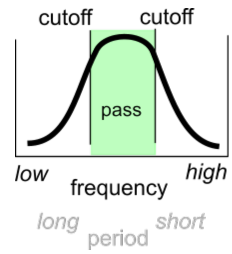
High Pass — Passes high frequencies, but attenuates (reduces the amplitude of) frequencies lower than the cutoff frequency.

Allows the high spatial frequency components to pass through the filter, removing waviness, and highlighting the roughness data. The effect varies based on the type of filter, kernel size (Convolution) or cutoff selection (FFT and Spline).



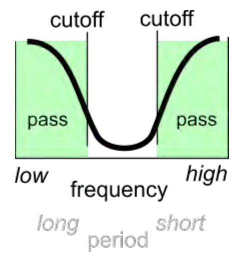
Band Pass — Passes frequencies within a certain range and rejects (attenuates) frequencies outside that range. A lower and upper cutoff is used.

Data in the center of the band is analyzed. The effect varies based on the type of filter and cutoff selection (FFT and Spline).



Band Reject — Rejects frequencies within a certain range and passes frequencies outside that range. A lower and upper cutoff is used.

Data outside the center of the band is analyzed. The effect varies based on the type of filter and cutoff selection (FFT and Spline).



Convolution Filter

- A basic general purpose filter.
- The larger the (kernel) Size, the greater the filtering affect.
- Lateral Calibration is not required.

Filter See Filter Options.

Type Selects the filtering algorithm.

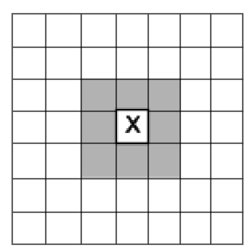
Average- Uses all valid data points in each filter kernel (as determined by the Size entry) and averages them. The averaged value is then used to replace the data point at the center of the kernel. These averaged values are used to generate a new data array.

Median- The median is the value of the middle point when the points are sorted from smallest to largest; it selects the middle or median value of all of the valid data points in each kernel. The median value is then used to replace the data point at the center of the kernel. These median values are used to generate a new data array. The median algorithm preserves edge detail better than the average algorithm.
A good use for a median filter is to filter out spikes or shot noise without affecting adjacent data values since the median filter does not average pixels but simply selects its final value from the values in the kernel.

2 Sigma- Uses data points that are within 2 times the rms value in each filter kernel and disregards data values that are out of this range. Points within the 2 Sigma range are averaged. The averaged value is then used to replace the data point at the center of the kernel. These averaged values are used to generate a new data array.

Savitsky-Golay- Calculates the best-fit second-order polynomials in both the x and y directions to the data within the window, and uses them to estimate the actual or best height of the center data cell. See Savitsky-Golay.

Size The matrix size to be used for the kernel. It defines the number of data points used to generate a new filtered data point when Average, Median, or 2 Sigma are used. As the kernel size is increased, the effects of filtering are increased.



This drawing represents a data array of 49 points. Each square represents a data point. X is the data point being filtered. Kernel size 3 includes the shaded points. Kernel size 7 includes all of the points shown. As the kernel size is increased, more data points are included in the filtering algorithm and processing time increases.

FFT Filter

- Fast Fourier Transform (FFT) filter.
- Lateral calibration required for units other than pixels.
- FFT Auto automatically selects filter cutoff points based on the test data.
- FFT Fixed sets filter cutoffs based on entries in the corresponding Period or Frequency box.
- Numeric cutoff values for "fixed" can be selected using the calipers on the PSD plot.

Filter See Filter Options.

Type Selects the type of Fast Fourier Transform.

FFT Auto- automatically chooses cutoff(s) based on the test data. It is recommended to use these values only as a starting point for manually entering cutoffs.

FFT Fixed- allows user entry of cutoff(s) in either the Frequency or Period boxes (depends on Mode selection) and direct entry with the filter PSD plot.

Preprocessing See below.

Cutoffs For details on using auto or fixed cutoffs refer to Cutoffs. Mode, Period, and Frequency controls are also explained under Cutoffs.

Preprocessing

Because FFT filtering by definition does not handle no data values, preprocessing is used to remove no data values. Various methods of data fill are provided under the Preprocessing pull down menu.

For each option, filling of no data values is only done internally and will not change which pixels have valid data in the final map. Internally this means that the original data inputs are copied, the temporary data is filled with the selected preprocessing option, and then FFT filtering is applied. After filtering is done, no data pixels are set back to no data.

Zero No Data No data values are set to zero.

Cylinder Remove Data is filled by removing cylinder and setting no data values to zero. Cylinder Remove is what was used in MetroPro software.

Cylinder refers to Mx cylinder surface and not a true cylinder.

Cylinder Fill Data is filled by fitting a cylinder to the data. See the note under Cylinder Remove.

Plane Fill Data is filled by fitting a plane to the data.

Laplacian Data is filled with the Laplace data fill option with fill type set to fill interior and exterior. See Fit Type for details on Laplace.

Radial Fill Data is filled with a specialty algorithm which is based on radial symmetry of the input data.

Spline Filter

- Retains original part detail with less distortion.
- Lateral calibration required for units other than pixels.
- Auto filter settings automatically select filter cutoff points based on the test data.
- Fixed filter settings base cutoff locations on entries in the corresponding Period or Frequency box.
- Numeric cutoff values for "fixed" can be selected using the calipers on the PSD plot.

Filter See Filter Options.

Type Selects the type of spline filter. The robust versions handle end regions better and eliminate outliers.

Gaussian Spline Auto- automatically determines Period cutoff(s) for the Gaussian Spline filter.

Gaussian Spline Fixed- allows user entry of cutoff(s) for the Gaussian Spline filter in either the Frequency or Period controls (depends on Mode selection).

Robust Gaussian Spline Auto- automatically determines Period cutoff(s) for the Robust Gaussian Spline filter.

Robust Gaussian Spline Fixed- allows user entry of cutoff(s) for the Robust Gaussian Spline filter in either the Frequency or Period controls (depends on Mode selection).

For details on using auto or fixed cutoffs refer to Cutoffs. Mode, Period, and Frequency controls are also explained under Cutoffs.

Cutoffs

- This information applies to FFT and Spline filter types.
- A cutoff is a location in the data where data is either passed or rejected.
- The specific cutoffs available are based on the Filter selection (Low Pass, High Pass, Band Pass, or Band Reject) and the filter type (Spline or FFT).
- When an "auto" Type is selected, applicable cutoff values are automatically entered based on the input data.
- When a "fixed" Type is selected, the corresponding cutoff controls are active for direct user input.
- The location of cutoff markers are displayed in the filter PSD plot.

Use the "auto" Type settings to quickly view data without having to figure out cutoff values. For sequential or production measurements, the "fixed" Type settings should be used.

Auto Cutoffs Tab

Applicable for FFT and Spline filters when the Type control selection ends with "Auto".

Mode	Selects whether Frequency or Period cutoffs are reported. See Frequency or Period.
Low Frequency	Displays the automatically calculated Low Frequency cutoff.
High Frequency	Displays the automatically calculated High Frequency cutoff.
Short Period	Displays the automatically calculated Short Period cutoff.
Long Period	Displays the automatically calculated Long Period cutoff.

Cutoffs for "Auto" are automatically calculated based on the size of the data matrix. The low cutoff is 10 cycles per data-width and the high cutoff is 30 cycles per data-width.

Fixed Cutoffs Tab

Applicable for FFT and Spline filters when the Type control selection ends with "Fixed".

Mode	Selects the mode of the fixed cutoff entries. Choices are: Frequency or Period.
Low Frequency	Specifies the Low Frequency cutoff value when Mode is Frequency.
High Frequency	Specifies the High Frequency cutoff value when Mode is Frequency.
Short Period	Specifies the Short Period cutoff value when Mode is Period.
Long Period	Specifies the Long Period cutoff value when Mode is Period.

Setting Fixed Cutoffs

Fixed FFT and Spline filtering cutoffs can be set with filter PSD plot cutoff markers or the numeric Frequency or Period controls. The markers and controls are dynamically linked together and update automatically. See Using the Filter PSD Plot.

Selection of Cutoff Filters

Cutoff filters are used to isolate the roughness wavelength band.

- For roughness, the cutoff value is the longest nominal wavelength to be included in roughness.
- Longer wavelengths are filtered out. Shorter wavelengths are included in roughness.
- Wavelengths longer than the roughness cutoff are usually included in waviness.

(λc) Roughness Cutoff Lengths

- The cutoff selected must be short enough to exclude long wavelengths (waviness).
- The cutoff selected must be long enough for a valid sample (at least 10 tool-marks per cutoff).
- Lengths are defined in ASME and ISO standards.

Spacing (periodic)	Roughness (non-periodic)		Cutoff	Sampling Length/ Evaluation Length
Sm (mm)	**Rz** (µm)	**Ra** (µm)	λ_c (mm)	L_r / L_n (mm)
> 0.013...0.04	> 0.025...0.1	> 0.006...0.02	**0.08**	0.08 / 0.4
> 0.04...0.13	> 0.1...0.5	> 0.02...0.1	**0.25**	0.25 / 1.25
> 0.13...0.4	> 0.5...10	> 0.1...2	**0.8**	0.8 / 4
> 0.4...1.3	> 10...50	> 2...10	**2.5**	2.5 / 12.5
> 1.3...4	> 50...200	> 10...80	**8**	8 / 40

The roughness profile results are from high-pass filtering the primary profile according to the cutoff selection for ëc (DIN EN ISO 4288, ASME B46.1). This results in the cut-off of the long-wave portion of the profile. The resulting parameters can be identified by R.

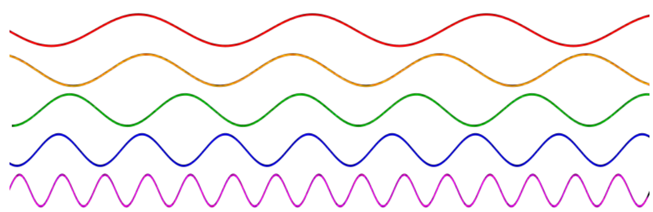
Frequency or Period

Frequency is the number of occurrences of a repeating event per unit of measurement.

The period of a wave is the distance (or time) for a particle to make one complete vibrational cycle.

The period is the reciprocal of the frequency.

Also refer to Filtering Terminology.



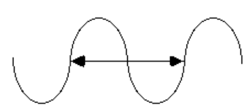
This drawing shows sinusoidal waves of various frequencies; the bottom waves have higher frequencies than those above.

A given surface can be comprised of a number of frequencies superimposed over one another.

The distance (or time) it takes to complete a cycle is the period. Frequency is the inverse of this, the number of cycles in a given distance (such as cycles/m). The distance the wave travels during one period is the wavelength. All this is related by the equations:

$P = 1/f$ $\lambda = s/f$

Where λ is wavelength, P is period, f is frequency, and s is the speed.



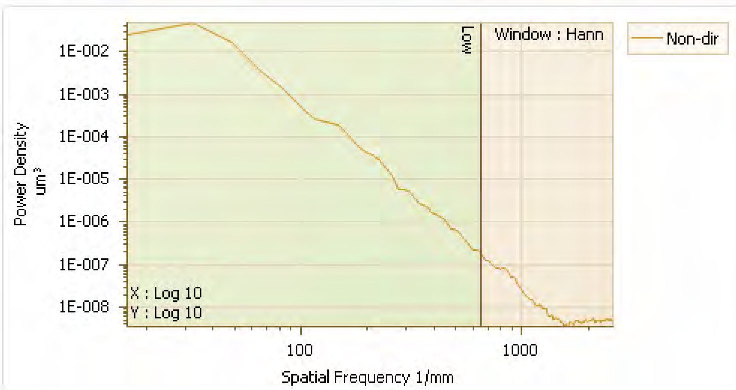
This drawing shows one wave. The arrow indicates one cycle.

Using the Filter PSD Plot

- The Filter PSD plot is a customized version of the standard PSD plot.
- Provides *visual* feedback for the FFT and Spline filter "Auto" cutoff modes.
- Provides an *interactive* tool for the FFT and Spline filter "Fixed" cutoff modes.

The Filter PSD Plot

Cutoff location markers are displayed in the filter PSD plot. The data in the green colored area is passed.



Use- Visual Feedback

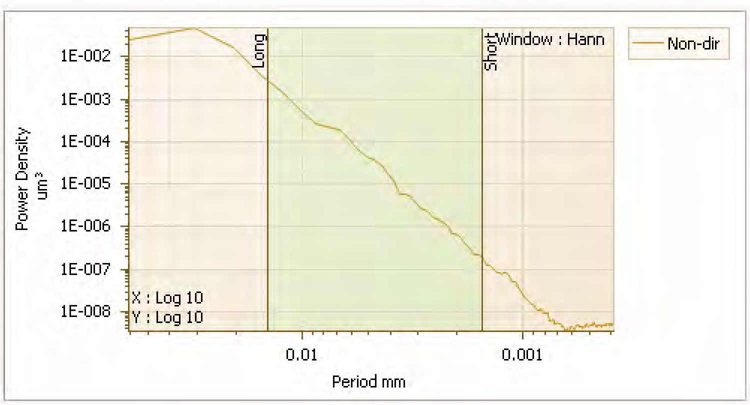
Filter Type: FFT

Filter: Low Pass

Type: FFT Auto

Mode: Frequency

In this example, all data to the left of the Low cutoff marker is passed. The Low marker corresponds to the automatically calculated Low Frequency value.



Use- Interactive Cutoff Tool

Filter Type: Spline

Filter: Band Pass

Type: Gaussian Spline Fixed

Mode: Period

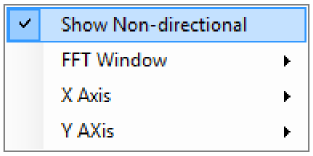
In this example, all data in between the Long and Short cutoff markers is passed. The Long and Short markers are directly linked to the values in the Long Period and Short Period controls.

Setting Fixed Cutoffs With the Filter PSD Plot

1. Point to the cutoff marker on the PSD plot. The cursor changes to .
2. Press and drag the line, release the mouse button to fix the position. The corresponding Frequency or Period control value is automatically updated.

Changing the Filter PSD Plot

Point to the plot and right-click to access the menu.



Show Non-directional — Same as Show Non-directional as described at Changing the PSD Plot. For a description of this refer to Non-directional PSD Details.

When this is not selected, a slice must be defined in the input data to display a directional PSD plot.

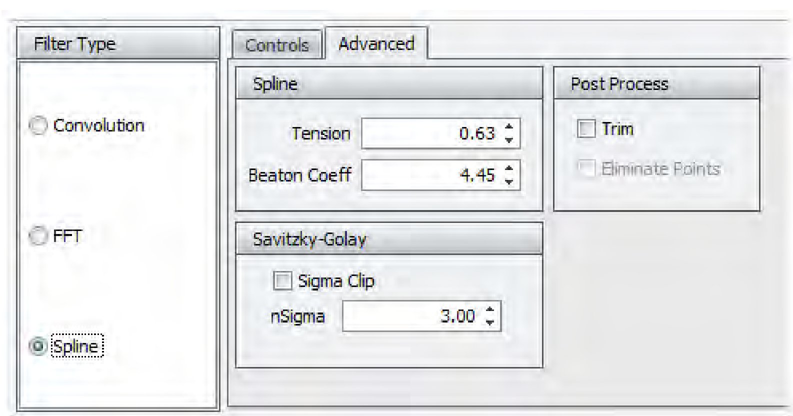
FFT Window — Same as the FFT Window control described in PSD Advanced Settings.

X Axis — Use to select the PSD units for the x axis. See Changing the PSD Scale.

Y Axis — Use to select the PSD units for the y axis. See Changing the PSD Scale.

To use units in the Filter PSD plot beside pixels, the input data must have lateral calibration done when it was acquired.

Filter Advanced Tab



Spline

To activate, select Filter Type- Spline.

Tension — Specifies the tension for the spline filter. Enter a value between 0 and 1 inclusive. The lower the value, the closer the curve to the data points. The higher the value, the smoother the curve as it deviates further from the original data points.

Applies only to the Spline filter.

Beaton Coeff — Specifies a coefficient for the robust spline filter. Enter a value greater than 0. It is used to scale the weighting coefficient and reapplies the spline filter until convergence.

Applies only to the robust Spline filters.

Savitsky-Golay

To activate, select Filter Type- Convolution and Type- Savitsky-Golay.

Sigma Clip **nSigma**	If Sigma Clip is selected and filter Type is Savistzky-Golay, extreme height values are identified after the 2nd order polynomials are fit. Then the 2nd order polynomials are re-calculated, ignoring those extreme values, and the center data cell height value is re-estimated. Extreme values ignored during the second fit are identified in the following manner: a) Calculate the standard deviation of height value differences of all the cells in the window from the values specified by the best-fit second-order polynomials. b) Multiply the value specified by the best-fit 2nd order polynomial for each cell by the factor entered into the nSigma control. c) Compare the raw height value for each cell in the window to the product calculated in step (b). If the original or raw height value exceeds this product, then that data cell is considered extreme and is ignored during the second calculation of the best-fit 2nd order polynomials. If the surface data is such that no extreme data points are identified, then the second iteration of 2nd order polynomial fitting does not occur.

Post Process

Trim	When selected it controls the preservation of data edges during the filtering process. Select the Trim check box to perform normal filtering with some loss of edge data; this setting removes ringing effects at the data edges. Applies to all filter types. When Filter Type is Convolution, the number of pixel layers removed is based on the matrix size. Pixels Removed = Window Size -1 divided by 2. When Filter Type is FFT or Spline, 5 pixel layers are removed. Clear the Trim check box to preserve edge data that is usually lost due to filtering.
Eliminate Points	Applicable when using the Convolution filter and the filtering algorithm Type is Median. Input pixels with fewer than two additional valid neighbors within their convolution kernel are removed.

Using the Filter Tool

1. Open the Filter tool.
2. Select the Filter On check box to activate the Filter tool.
3. Select the Filter Type (Convolution, FFT, or Spline).
4. Select the filter type (Low Pass, High Pass, Band Pass, Band Reject).
5. If using Convolution, select Size.
6. If using FFT or Spline filter, enter Cutoff values.
7. Select applicable options on the Advanced tab.

8.7 Fit and Remove Functions

This section explains the concepts and functions of the fit and remove tools in their various forms.

Fit Remove Overview

- Fit fits a specified shape or coefficients to the incoming data.
- Remove removes the fit shape from the input data.
- Fit and remove are separate events and can be used individually or together as required.
- Fit and remove is used to minimize alignment errors and to reveal underlying features in the data.

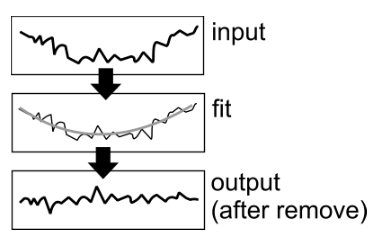
Fit and Remove Tools

Fit Remove	Use to specify Cartesian or Zernike coefficients to fit and to select which coefficients to remove. Separates the fit from the remove function if desired.
Form Remove	Use to specify an overall form to remove.
Zernike Remove	Use to specify basic Zernike coefficients to both fit and remove.
User Remove	Use to enter specific values for Cartesian or Zernike coefficients to fit and to select which coefficients to remove.
Local Remove	Applies a form removal to the data within the tool or plot view after the tool functions are applied.

Fit and Remove Concept

Fit uses a least-squares fit on the input data to match a general overall shape to the data.

Remove takes the best-fit shape and removes it from the input data before further analysis. Most commonly, this is used to remove alignment errors so the quality of the surface or wavefront can be more easily determined. For example, removing a plane presents tilted input data as flat, thus revealing greater surface details without the overall form influencing the display and results.



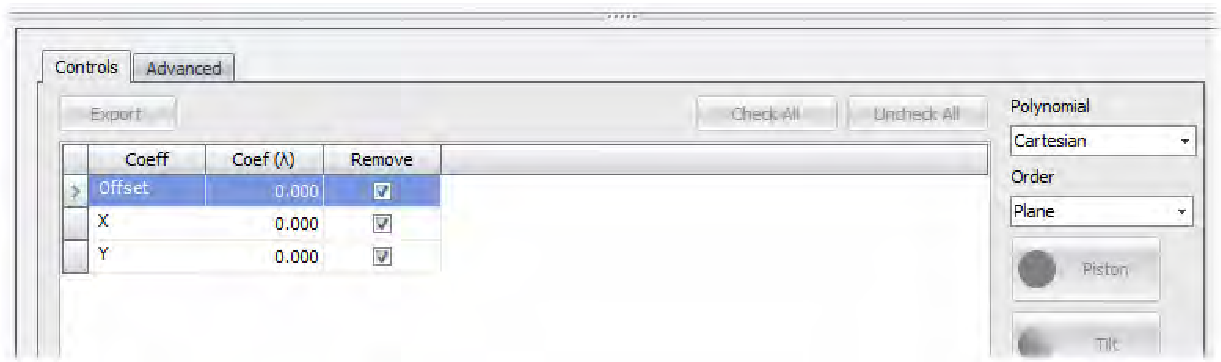
Some fit options are comprised of multiple shapes applied simultaneously. A user might choose to remove a low-order form (for example: more complicated than tilt or power) to better reveal mid- and/or high-spatial frequency content.

Remove performs a least-squares fit of a user selected function to the input data matrix. The least-squares fit minimizes the rms (root-mean-square) difference between the selected “remove” shapes and the actual data by optimizing the numeric coefficients for the selected function. When Fit is applied, these coefficients are used to generate a mathematical surface that is subtracted from the data, thus producing a residual map of the input data minus the best-fit map.

Fit Remove

Use to specify Cartesian or Zernike coefficients to fit and to select which coefficients to remove.

This section describes Fit Remove as it appears in Data Manipulate (Form.appx) and in the optical profiler application (Micro.appx).



1. Select the desired Polynomial type.
2. Select the Order. Rows are automatically added or removed from the coefficient table.
3. To remove a coefficient, the Remove check box must be selected.

Remove and Results

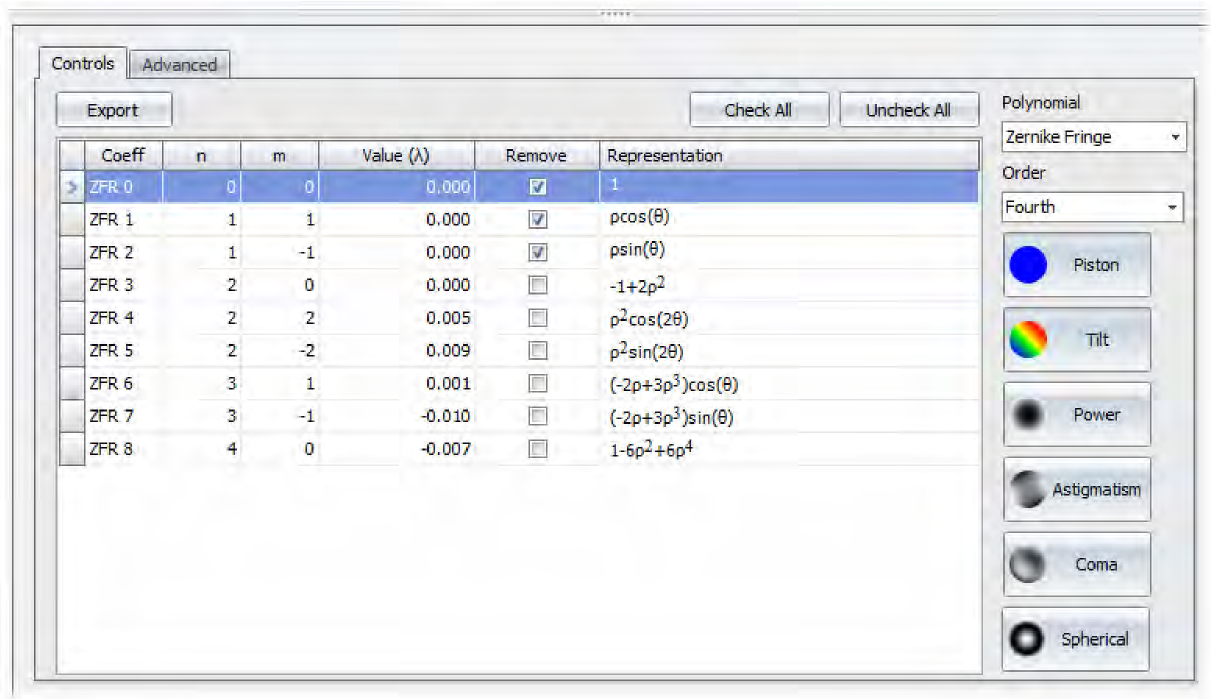
Results Calculated Before Remove by the Fit Remove Tool

Due to the nature of result parameter definitions, some results are calculated by the fit and remove tool before it performs the removal operation. These results are:

Power, Radius of Curvature, Sag, Sag X, Sag Y, Seidels, Tilt X, Tilt Y, Tilt Angle, Tilt Magnitude, and Zernikes.

For result definitions see Results and Attributes.

Fit Remove Zernike Coefficients



For details on working coefficients, see Polynomial Table.

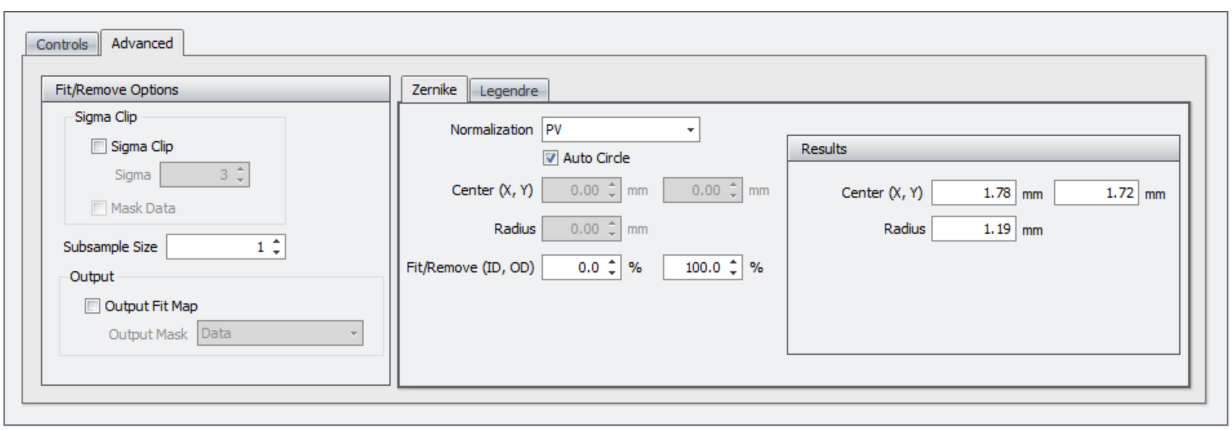
For Polynomial see Polynomial.

For Order see Order.

For Zernike Buttons see Zernike Removal.

Advanced Fit/Remove Tab

This tab is active when Polynomial is set to Zernike Fringe or Zernike Standard.



For Sigma Clip, Sigma, and Mask Data see Sigma Clip Options.

For Subsample Size see Subsample Size.

For Normalization see Zernike Normalization.

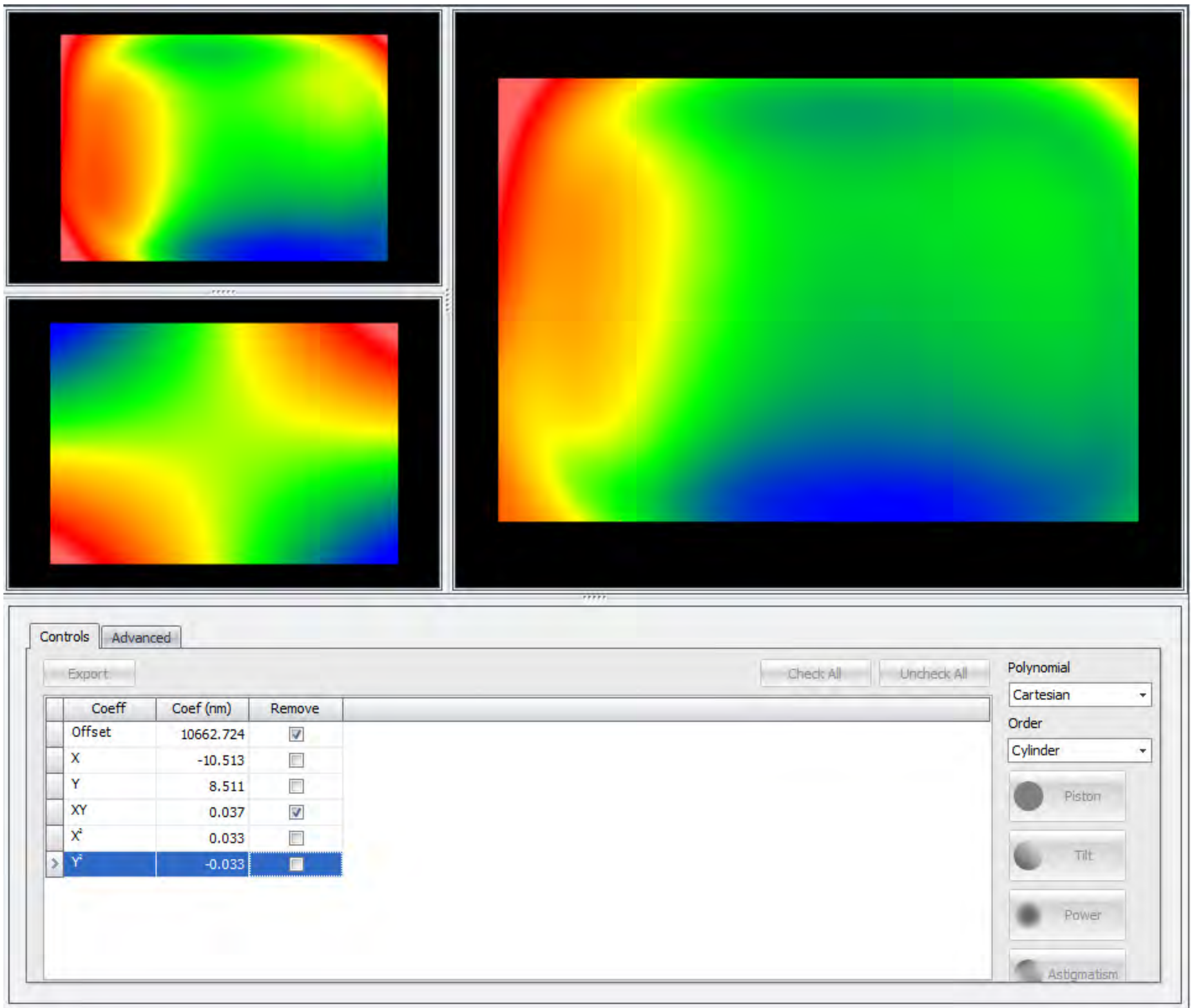
For Center X, Center Y, Radius, Fit/Remove ID, Fit/Remove OD see Zernike Auto Circle Function.

For Sync Color Scale see Sync Color Scale .

Using Fit Remove for Twist

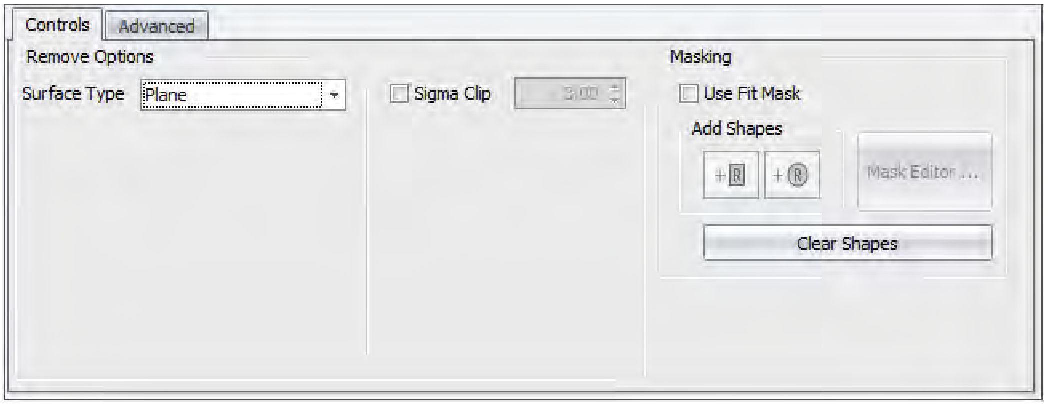
To remove twist:

1. Click Surface Processing in the Navigator.
2. Set the Polynomial control to Cartesian.
3. Set the Order control to Cylinder.
4. Under the Remove column in the Coefficients table uncheck all terms except the XY term.
5. Press F11 to Analyze.



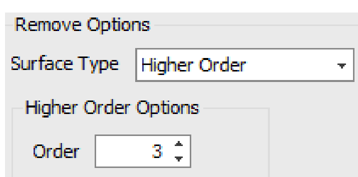
Form Remove

Use to specify an overall form to remove. The default tool for optical profiler applications.

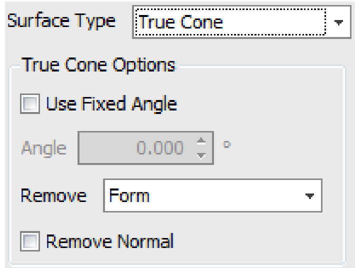


Surface Type

Selects the surface form to remove from the data.

Surface Type	Description
None	Fit and remove nothing. Useful when the surface is not continuous, when the surface has an asymmetrical structure such as a large hole or slope, or when you want to see the tilt.
Piston	Fit and remove z-axis offset.
Plane	Fit and remove tilt or slant (including piston).
Sphere	Fit and remove a quadratic polynomial approximating a spherical shape (including plane and piston).
Cylinder	Fit and remove a polynomial approximating cylindrical shape (including plane and piston).
Higher Order	Fit and remove a polynomial including powers at 3 or higher. (Power of 0, 1 and 2 correspond to Surface Type - Piston, Plane, and Sphere/Cylinder respectively.)  The Order control limits the sum of the X and Y exponents in any given term in the polynomial. It follows standard 2D Polynomial ordering. For example, Order 4 includes the terms X4, X3Y, X2Y2, XY3, Y4.

True Cone Fit and remove a best-fit cone, with specialized advanced options.

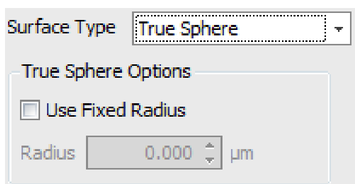


When Use Fixed Angle is selected, the cone angle used to fit and remove is based on the value specified by the Angle control. Otherwise the cone angle is calculated by the algorithm.

The Remove control specifies how the best-fit cone is applied to the input data. 'Form' removes the best-fit cone (including tilt) with no XY adjustment. 'Tilt Only' retains the form of the cone, transforming the data such that the cone axis is parallel with Z and centered in the field of view. 'Tilt and Form' additionally removes the form of the cone.

When Remove Normal is checked, the resulting map represents normal-projection deviation to the best-fit cone surface. Otherwise a Z-projection deviation is produced.

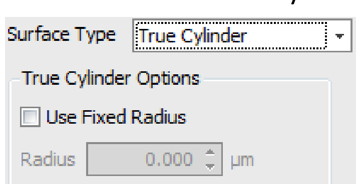
True Sphere Fit and remove a true sphere.



When Use Fixed Radius is selected, the radius used to fit and remove is based on the value specified by the Radius control. A positive value denotes a convex surface; a negative value denotes a concave surface.

When Use Fixed Radius is not selected, the radius is calculated by the algorithm.

True Cylinder Fit and remove a true cylinder (including piston).



When Use Fixed Radius is selected, the radius used to fit and remove is based on the value specified by the Radius control. A positive value denotes a convex surface; a negative value denotes a concave surface.

When Use Fixed Radius is not selected, the radius is calculated by the algorithm.

Mode Finds the dominate slope in both X and Y directions, and remove a plane corresponding to the slope.

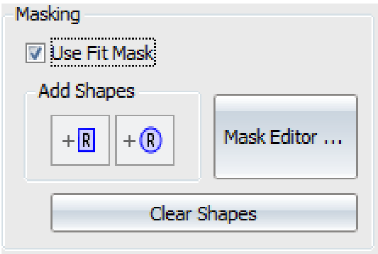
Sigma Clip

Sigma Clip is used to prevent outliers such as spikes and other extraneous data from unduly influencing the fit. For details, see Sigma Clip Options.

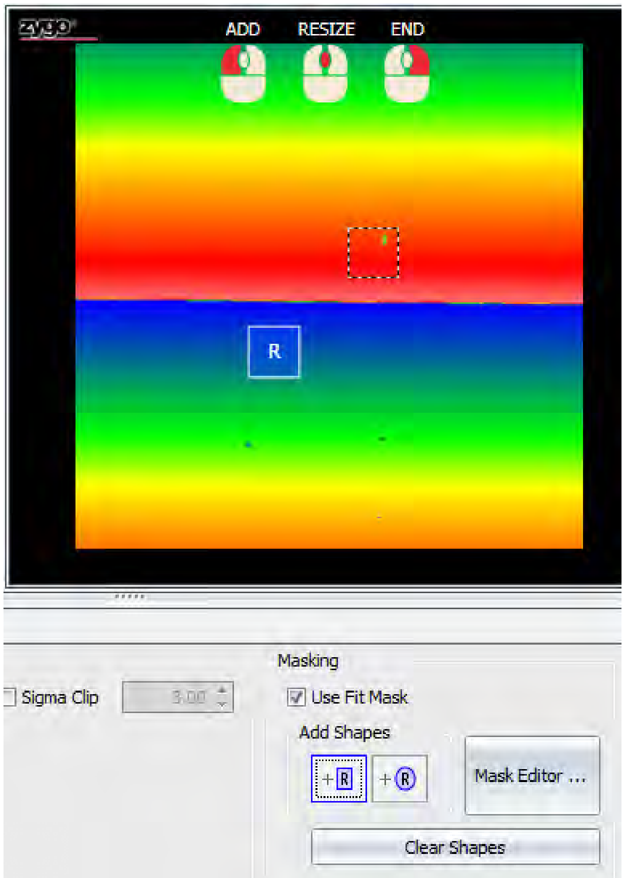
To remove points identified as outliers, see Form Remove Advanced Tab.

Masking

When Use Fit Mask is enabled, only the data selected by the configured mask is used for calculating the best fit surface to remove from the data. This allows, for example, the simple leveling of a measurement of a wear scar to an unworn reference area. If no mask is configured, the entire data set is used for fitting.



The Add Shapes buttons can be used to add simple shapes (rectangles and ellipses) directly on the map. After clicking an Add Shape button, move to the map and left-click where shapes are desired. Right-click or click outside the map when done. Existing simple shapes can be resized and rotated directly within the map.



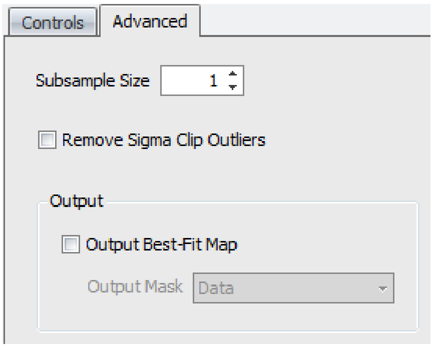
For more complex masking (e.g., with complex or unfilled shapes), click Mask Editor .... For details, see Mask Editor.

The Clear Shapes button deletes all mask shapes.

Advance Tab

For advanced operations, see Form Remove Advanced Tab.

Form Remove Advanced Tab



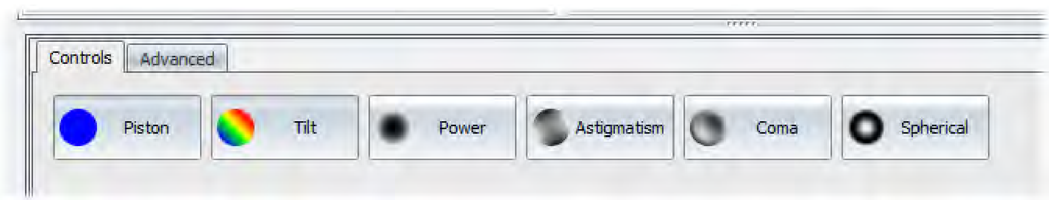
For Subsample Size see Subsample Size.

The Remove Sigma Clip Outliers control is used only if Sigma Clip is enabled on the main Controls tab. If checked, points identified as outliers by the Sigma Clip operation will be removed. For more details, see Mask Data in Sigma Clip Options.

For Output Fit Map see Output Fit Map.

Zernike Remove

Use to specify basic Zernike coefficients to both fit and remove.



For a description of Piston, Tilt, Power, etc. see Zernike Removal Buttons.

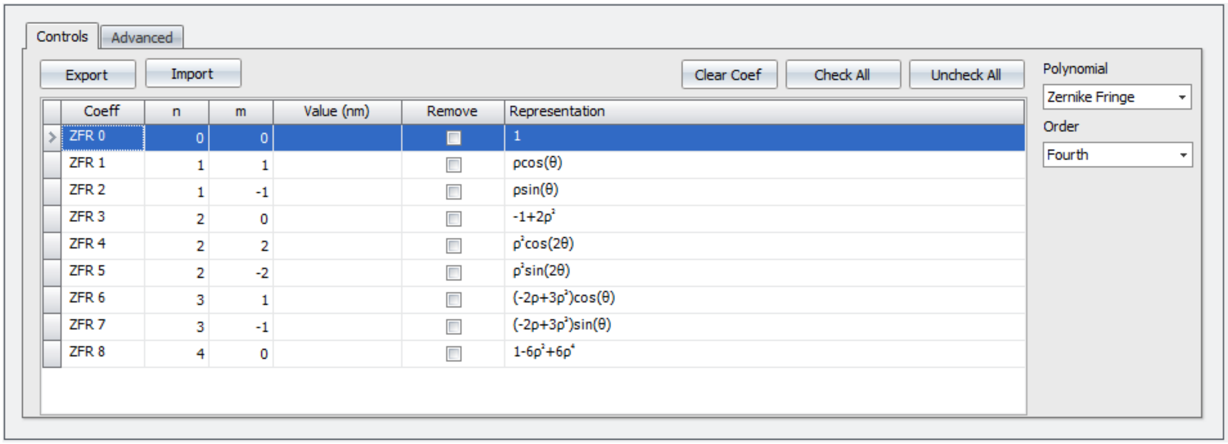
For Sigma Clip, Sigma, and Mask Data see Sigma Clip Options.

For Subsample Size see Subsample Size.

For Output Fit Map see Output Fit Map.

User Remove

Use to enter specific values for Cartesian or Zernike coefficients to fit and to select which coefficients to remove. This feature also supports importing and exporting of coefficients.



To enter a specific coefficient value, click a row under the Value or Coef (unit) column.

For details on the Polynomial control see Polynomial; for Order control see Order.

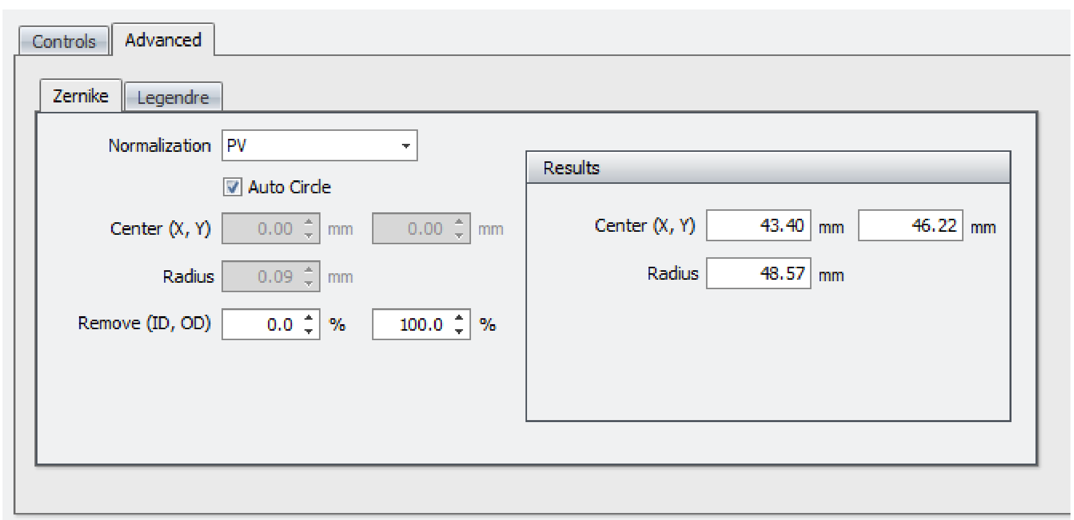
For details about the Cartesian coefficients see Cartesian Coefficient Table.

For details on the Zernike coefficients see Zernike Polynomial Table.

To use and enter Cartesian coefficients see Fit Remove- Using Cartesian.

To use and enter Zernike coefficients see Fit Remove- Using Zernike.

Advanced User Remove Tab



For Normalization see Zernike Normalization.

For Center X, Center Y, Radius, Fit/Remove ID, Fit/Remove OD see Zernike Auto Circle Function.

Common Fit Remove Elements

This section provides details on the elements that are shared by the fit and remove functions.

Polynomial

Selects the basis of functions to use for the fit and remove surface.

Cartesian	Defines the fit surface using a non-orthogonal basis of low-order monomial coefficients based on a square or rectangular x and y coordinate system.
Zernike Fringe	Defines the fit surface based on a classic subset of orthogonal Zernike polynomials (up to 37 terms) that have historically been used to describe typical polishing errors within a unit circle in a polar (r, q) coordinate system.
Zernike Standard	Defines the fit surface based on a larger set of Zernike polynomials (up to 91 terms) that retains all radial and azimuthal functions up to order 12 within a unit circle in a polar (r, q) coordinate system.
Zernike Annular	This selection is only available in the Zernike analysis. This selection will calculate Zernike coefficients (up to 37 terms) when the part has an annular hole.
Legendre	Defines the fit surface based on the Legendre polynomials, which are an orthogonal set of polynomials for rectangular data.

Order

Selects the fit order or terms available in the polynomial table.

Polynomial	**Order Choices**
Cartesian	Piston, Plane, Sphere, and Cylinder. See Cartesian Removal.
Zernike Fringe	Even numbers: Second, Fourth, Sixth, Eighth, Tenth, or Twelfth.
Zernike Standard	First, Second, Third, Fourth, Fifth, Sixth, Seventh, Eighth, Ninth, Tenth, Eleventh, or Twelfth.
Legendre	1 through 10.

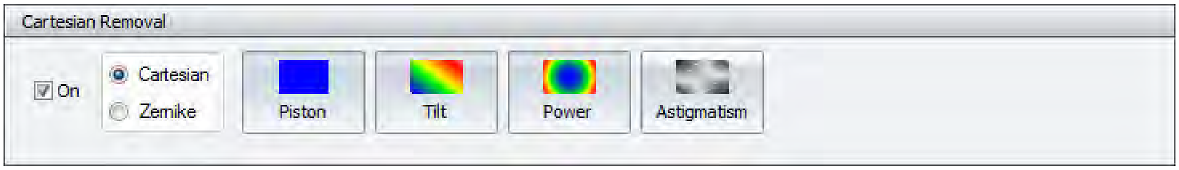
Also see Order under Form Remove.

Cartesian Removal

Defines the fit surface using a non-orthogonal basis of low-order monomial coefficients based on a square or rectangular x and y coordinate system. When using Cartesian Coefficients to fit and remove, see Cartesian Coefficient Table.

Cartesian Removal Buttons

- Buttons are the basic fit and remove controls, each corresponding to a particular shape.
- Click button(s) to apply fit and remove function(s). More than one function can be applied.
- Color buttons indicate an applied fit shape; grayed button indicates shape not applied.
- These buttons are available only in laser interferometer applications.



Button	Term(s) Fit and Removed	Use Case
Piston	Offset	Normalizes data to zero.
Plane	Offset, X, Y	Tilted sample appears flat; compensates for tilt in the setup.
Sphere	Offset, X, Y, X2, Y2	For surface with a spherical shape.
Cylinder	Offset, X, Y, XY, X2, Y2	For surface with a cylindrical shape.

Cartesian Term Definitions

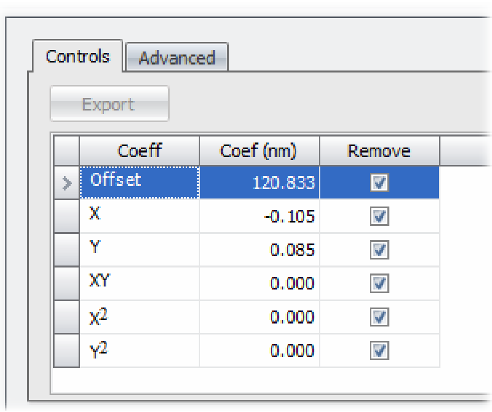
$\text{Piston}(x,y) = C_0$

$\text{Plane}(x,y) = C_0 + C_1x + C_2y$

$\text{Sphere}(x,y) = C_0 + C_1x + C_2y + C_3(x^2 + y^2)$

$\text{Cylinder}(x,y) = C_0 + C_1x + C_2y + C_3x^2 + C_4y^2 + C_5xy$

Cartesian Coefficient Table



Header	Description
Coeff	These are the individual components making up the Cartesian shapes. For more details see [Cartesian Removal]().
Coef (unit)	The actual fit value to the input data. In User Remove this value is user entered. To change the units, right-click on the column header and choose Select Units and Precision.
Remove	Check box to activate the remove function for a given term. Note that when

Working With Coefficients

To...	Do This...
Change number of coefficients	Select choice with Order control.
Remove a particular set of terms	Select or clear the appropriate Remove check boxes.
Enter a Coef value	Click on the numeric value and type a different value. Not applicable to all tools.

Fit Remove- Using Cartesian

Input data can be circular or non circular.

1. Select Cartesian with the Polynomial control.
2. Select the Order option. This automatically determines what terms are removed.

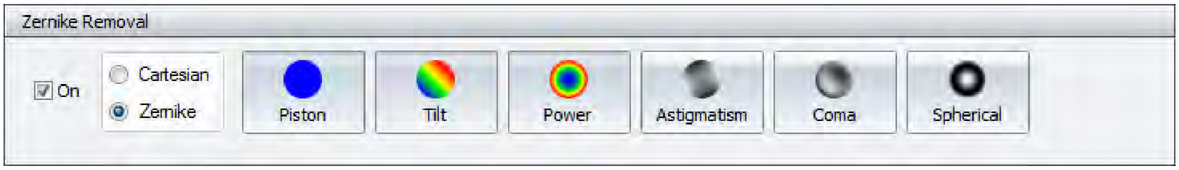
When using Cartesian terms, a Remove check box indicates the term is removed, they cannot be cleared. The terms fit and removed are preset based on the Order selection and cannot be changed.

Zernike Removal

Defines the fit surface based on a classic subset of orthogonal Zernike polynomials that describe typical errors within a unit circle in a polar coordinate system. When using Zernike Polynomials to fit and remove, see Zernike Polynomial Table.

Zernike Removal Buttons

- Buttons are the basic fit and remove controls, each corresponding to common low-order aberrations, based on coefficients.
- Click button(s) to apply fit and remove function(s). More than one function can be applied.
- Color buttons indicate an applied fit shape; grayed button indicates shape not applied.
- These buttons are available only in laser interferometer applications.

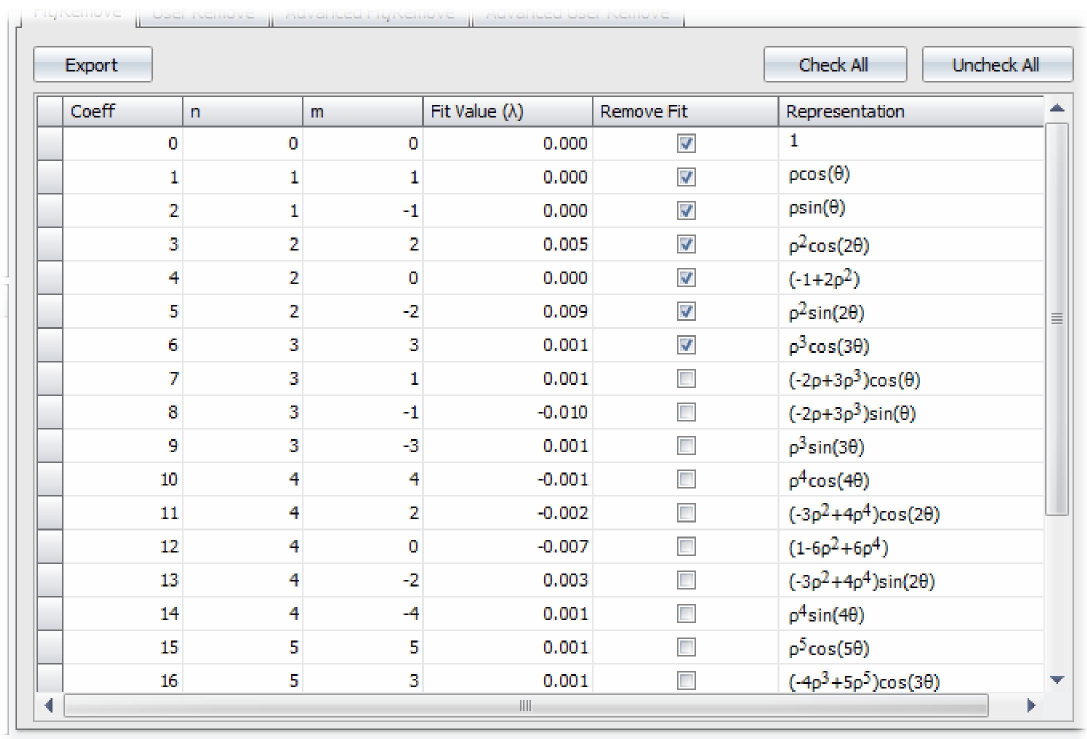


Button	Function	Use Case
Piston	Removes z-axis offset.	Normalizes data to zero.
Tilt	Removes tilt or slant.	Tilted sample appears flat; compensates for tilt in the setup.
Power	Removes z-axis offset.	For spherical surfaces; compensates for cavity defocus in the setup.
Astigmatism	Removes 4th-order astigmatic aberration.	For cylindrical shaped surfaces or a surface that is a part of a prolate spheroid (football).
Coma	Removes 4th-order comatic aberration.	Most commonly used for testing lens systems to view residual transmitted wavefront errors.
Spherical	Removes 4th-order spherical aberration.	Most commonly used for testing lens systems to view residual wavefront errors.

Zernike Polynomial Table

Zernike polynomials are an infinite set of polynomials orthonormal on the unit circle. Polynomials are generally used to characterize wavefront errors in an optic because they correlate to well known transmitted wavefront aberrations and classic polishing errors. Refer to Zernike Definitions for additional information.

A similar table is available in Fit Remove, the Data Generate tool (Coefficients), and the Zernike analysis (Zernike Fit); the exact implementation may vary.



Coeff	n	m	Fit Value (λ)	Remove Fit	Representation
0	0	0	0.000	☑	1
1	1	1	0.000	☑	$\rho\cos(\theta)$
2	1	-1	0.000	☑	$\rho\sin(\theta)$
3	2	2	0.005	☑	$\rho^2\cos(2\theta)$
4	2	0	0.000	☑	$(-1+2\rho^2)$
5	2	-2	0.009	☑	$\rho^2\sin(2\theta)$
6	3	3	0.001	☑	$\rho^3\cos(3\theta)$
7	3	1	0.001	☐	$(-2\rho+3\rho^3)\cos(\theta)$
8	3	-1	-0.010	☐	$(-2\rho+3\rho^3)\sin(\theta)$
9	3	-3	0.001	☐	$\rho^3\sin(3\theta)$
10	4	4	-0.001	☐	$\rho^4\cos(4\theta)$
11	4	2	-0.002	☐	$(-3\rho^2+4\rho^4)\cos(2\theta)$
12	4	0	-0.007	☐	$(1-6\rho^2+6\rho^4)$
13	4	-2	0.003	☐	$(-3\rho^2+4\rho^4)\sin(2\theta)$
14	4	-4	0.001	☐	$\rho^4\sin(4\theta)$
15	5	5	0.001	☐	$\rho^5\cos(5\theta)$
16	5	3	0.001	☐	$(-4\rho^3+5\rho^5)\cos(3\theta)$

Header	**Description**
Coeff	Numbered from 0 and up, these start with low order aberrations and progress to higher order errors. The ordering follows that of the classic FRINGE set. The Zernike analysis displays either Zernike Fringe (ZFR) or Zernike Standard (ZRN) fit coefficients. See Zernike Results.
n	The fundamental radial order.
m	The fundamental angular frequency (or mode).
Fit Coef *Fit Value* *Value*	The actual fit value to the input data. To change the units, right-click on the Fit Value column header and choose Select Units and Precision.
Remove *Remove Fit*	Check box to activate the remove function for a given term.
Generate	Check box to activate the generate function for a given term. Unique to the Data Generate tool.
Representation	Polynomial representation of the term. This varies based on the Zernike Normalization.

In Fit Remove, the table shows the resultant fit values. To remove a coefficient from the input data, the Remove (or Remove Fit) check box must be selected. Only active rows (the number is determined by the Order selection) are used and allow user entry.

Working With Coefficients

To...	Do This...
Change number of coefficients	Select choice with Order control.
Remove a particular set of terms	Select or clear the appropriate Remove check boxes.
Enter a Coef value	Click on the numeric value and type a different value. Not applicable to all tools.

Fit Remove- Using Zernike

The input data must be circular for orthogonality conditions to be met. For non-circular data the Cartesian polynomial may be the better choice.

1. Select Zernike Fringe or Zernike Standard with the Polynomial control.
2. Select the Order option.
3. To remove a given term, the applicable Remove Fit check box must be selected.
4. Clear the Remove check box to disable a particular term.

Note that the Fit is performed for all selected terms (determined by the Order control) but that Remove is only performed for terms with the Remove (or Remove Fit) check boxes selected.

Zernike Normalization

Selects the coefficient normalization and changes what is displayed in the Representation column in the Polynomial table. PV expresses the coefficient value in terms of PV coefficient. RMS normalizes the coefficient by adding a square root term to the local polynomial. These two different normalizations- PV or rms, can be applied to both Fringe and Standard polynomial sets.

With PV normalization, the resulting coefficient for a given term represents the value at the peak of a surface generated solely by that term; the peak is always located at the edge of the aperture. For rotationally varying Zernike terms, with PV normalization, the coefficient represents one half of the PV of a surface generated solely by that term. For rotationally invariant Zernike terms, with PV normalization, the coefficient represents one half or less (depending on the term) of the PV of a surface generated solely by that term. PV normalization was provided in MetroPro.

With RMS normalization, the resulting coefficient for a given term represents the rms of a surface generated solely by that term. The rms for a best-fit Zernike surface described by more than one coefficient is the sum in quadrature (square root of the sum of squares) of the rms normalized coefficients. When rms is used, the normalization multiplier is displayed with the polynomial in the Representation column. On the other hand, the PV terms do not sum to the best-fit surface PV because the peaks (and valleys) of each Zernike term would have to be spatially correlated for that to happen, and they most likely will not be. rms normalization was not offered in MetroPro, but is available in some optical design programs.

Note that the difference in the polynomials between PV and rms normalization is a factor that depends on the radial and azimuthal orders for the term in question.

Zernike Auto Circle Function

The Auto Circle function is used to define the unit circle (or unit disk) on the input data on which the fit (or fit and remove) is performed.

- For automatic mode, select the Auto Circle check box. The size and center of the unit circle are based on a minimum enclosing rectangle around the input data.
- For manual operation, clear the Auto Circle check box and enter values in Center X, Center Y, and Radius.
- In both cases, the ID and OD entries can be used if tweaking of the unit circle is desired.

Auto Circle
When selected, the unit circle that defines the fit is automatically centered and sized based on the minimum enclosing rectangle around the input data.

The numbers used in calculating the auto circle function are shown in the accompanying Results or Attributes.

Center X
Specifies the dimension (based on camera coordinates) to the center of the unit circle in the x-axis.

Center Y
Specifies the dimension (based on camera coordinates) to the center of the unit circle in the y-axis.

To change the units, right-click on the item and choose Select Units and Precision.

Radius
Specifies the radius of the unit circle; it is the dimension from its center to its perimeter. For units other than pixels lateral calibration must be preformed.

To change the units, right-click on the item and choose Select Units and Precision.

Fit/Remove ID
Specifies a percentage of the unit circle inside diameter to exclude from the fit and remove sequence. This removes center defects that may adversely affect the fit.

Use of an ID breaks the orthonormal conditions of the Zernike fit.

Fit/Remove OD
Specifies a percentage of the auto circle outside diameter to exclude from the fit and remove sequence. This reduces the overall size of the unit circle and removes edge defects that may adversely affect the fit.

Fit ID
Specifies a percentage of the unit circle inside diameter to exclude from the fit. This removes center defects that may adversely affect the fit. This is in the Zernike analysis.

Use of an ID breaks the orthonormal conditions of the Zernike fit.

Fit OD
Specifies a percentage of the auto circle outside diameter to exclude from the fit. This reduces the overall size of the unit circle and removes edge defects that may adversely affect the fit. This is in the Zernike analysis.

Sigma Clip Options

These advanced controls are used to fine-tune the fit function when the part has extraneous data points.

Sigma Clip

Sigma Clip is used to produce a fit that is not unduly influenced by spikes and other extraneous data. When the check box is selected, fitting is done in two stages, first to identify outlying points, and second in a final pass using only the remaining data. Greater details on these two stages is provided below.

The outlying data remains in the output map unless the Mask Data check box is selected.

In the first stage, all data are fit to the selected polynomial. The product of the RMS of the fit residual (i.e. the difference between the raw data and the fit) and the multiplier defined by the Sigma control defines a threshold for identifying outlying data. Points whose residual exceeds this threshold are excluded from subsequent fits. This process iterates until no further points are excluded.

In the second stage, a final polynomial fit is performed which ignores the outlying points identified in the first stage. The displayed fit coefficients and the Fit Remove surface correspond to this final fit.

This clipping function, when Mask Data check box is selected, is the same as that found in the Spike Clip tool.

Sigma

(Also known as nSigma) Specifies a multiplier used in conjunction with RMS values computed during Sigma Clip. Decimal numbers are allowed. A typical starting point is 3. Lower the value to aggressively disqualify outliers from influencing the fit.

Mask Data

When selected, points identified as outliers by Sigma Clip are removed from the output. Areas removed are displayed as no data.

Any data processing following the Fit/Remove analysis will be void of these masked data points; this includes the final result on the Home view.

When this check box is cleared, the Sigma Clip is applied for fitting purposes but in the end no data is clipped.

Subsample Size

Determines the sampling density of pixels to use for the Zernike or Legendre fit. The default of 1 uses every pixel; 2 uses every second row and column; 3 uses every third row and column, etc... This is useful when processing existing multiple data sets.

Output Fit Map

- This feature is available in the Fit Remove, Form Remove and Zernike Remove process tools.
- When Output Fit Map is selected, the sequence step outputs the fitted form, instead of outputting the form-removed surface. It basically turns Fit Remove from a high-pass filter into a low-pass filter.

Output Mask

Determines the kind of fit map to output.

Data	Use the input to mask to the generated fir map, the result is outputted.
Min Encl Rect	The minimum enclosing rectangle of the input is used to mask the generated fit map.
Camera	Use the input data window to mask the generated fit map.

8.8 Height Clip

The Height Clip removes spurious data based on a function of height relative to a selected reference and is typically used for data segmentation.

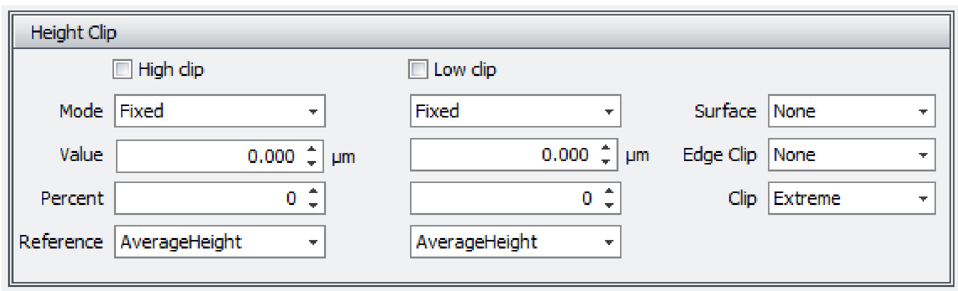
Height Clip Overview

- Use to exclude or clip data points based on a function of height.
- High clipping removes data at some height value and higher.
- Low clipping removes data at some height value and below.
- Optional to fit a surface shape to the input data before clipping.
- The reference point within the data, to which clipping is relative, is selectable. High and low clip can use different reference points. Reference points can be a fixed value or a percentage of the input data.
- The action of clipping at the edges of data is selectable.

Height Clip Controls

Select the appropriate check box to activate the clipping function.

Select the Immediate Update check box to display the impact of the settings in the tool.



High Clip	When checked, data is removed above a specified height.
Low Clip	When checked, data is removed below a specified height.

Height Clip Options

Surface

Selects the monomial surface fit to the data before clipping is performed. Fit uses a least squares fit on the input data to match a general overall shape to the data. This is used to minimize the affect the underlying form may have on the clip function.

None bases clipping on the input data, no surface is fit.

Piston fits an offset to the input data (shifts data in z-axis) before clipping.

Plane fits a plane to the input data to minimize slant or tilt before clipping.

Sphere fits a spherical or round shape to the input data before clipping.

Cylinder fits a cylindrical, rod, or football shape to the input data before clipping.

Edge Clip

Selects how height data is clipped at data edges.

All clips data points at both external and internal edges according to the height clip parameters.

Outside removes data points along outside edges according to the height clip parameters.

Inside removes data points along internal holes according to the height clip parameters.

High Clip
Low Clip

See High Clip and Low Clip Controls.

High Clip and Low Clip Controls

The high and low clip locations within the data are determined by a combination of the selected reference point (Reference) and the entered offset (Mode). These controls provide similar function for both high and low clip; the location of the control determines to which one it applies.

Mode

Selects how the clip is applied to the data. Mode determines the offset from the selected Reference.

Fixed specifies a fixed value in real units.

Percent Peak specifies a percentage of the input data's peak value.

Percent Valley specifies a percentage of the input data's valley value.

Percent Peak Valley specifies a percentage of the input data's PV value.

Percent Mean specifies a percentage of the input data's average height value.

Percent Points specifies a percentage of the input data's area (in pixels).

Value

Specifies the actual height relative to the reference where clipping occurs when the Mode is Fixed.

To change the units, right-click on the item and choose Select Units and Precision.

Percent Specifies the height in percent of data to the low or high clip relative to the reference when the Mode is Percent...

Reference Selects the reference point from which the height clipping parameters are applied.

Zero reference point is the zero height location in the data.

Peak reference point is the highest data point.

Valley reference point is the lowest data point.

Mean reference point is the arithmetical average of all data points.

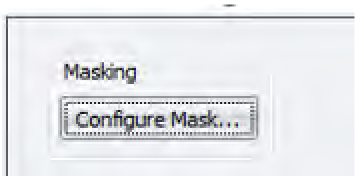
Rpk Threshold reference point is the threshold between the Rpk and Rk regions on the Bearing Ratio plot.

Rvk Threshold reference point is the threshold between the Rk and Rvk regions on the Bearing Ratio plot.

Rk MidPoint reference point is the middle point of the Rk region on the Bearing Ratio plot.

8.9 Masking

The Mask sequence step allows for the definition of a region of interest for analysis. Select Configure Mask to open the Mask Editor. Any unmasked data is discarded.



8.10 Opening

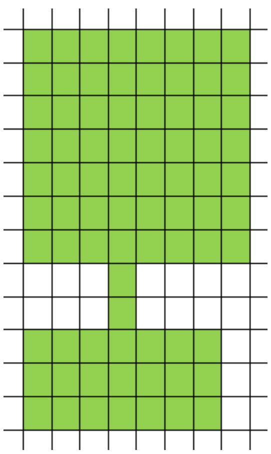
The general use for the Opening operator is to remove extraneous data from the perimeter of a data set. The extraneous data may be in the form of spiky edges or filaments of data sticking out from the edge. An Opening tool works by first eroding data at the edge by N user specified times and then dilating it by the same.

For a smoothed edged object, this operation will have little effect. For an object with noisy edges or where two data regions are connected by a small isthmus, then the effect will be to remove those noisy regions and to separate the regions.

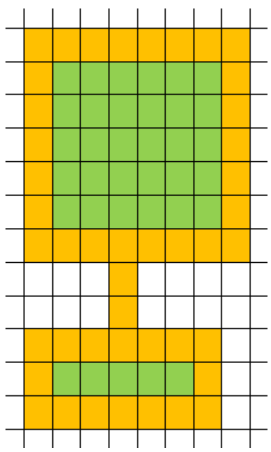
Pixels Specifies the size of the structuring element.

Iterations Specifies how many times the dilation and erosion are sequentially repeated (a series of erosion is followed by the series of dilations).

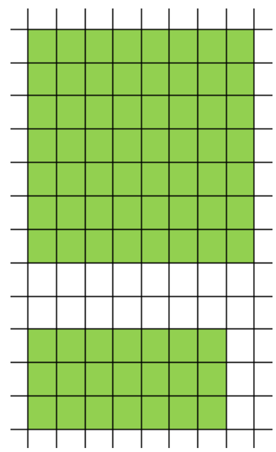
Opening Example



Example data before Opening operator.



Intermediate view of interaction on data. Edges and filaments are identified and eroded.



After a small filament is removed, the data edges are dilated.

8.11 Quality Filter

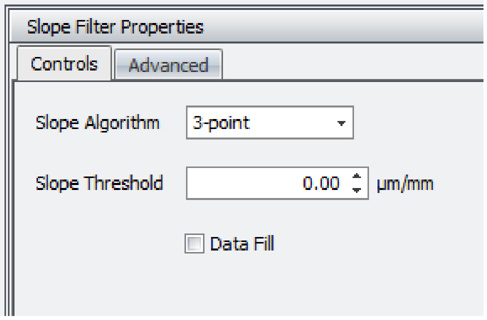
Uses the signal-to-noise ratio of a given pixel to determine if it is valid. The greater the setting the greater the signal-to-noise ratio required.

8.12 Slope Filter

- Filters or removes data based on its slope (or the angle formed from one pixel to the surrounding pixels).

Slope Filter Properties

Select the Immediate Update check box to display the impact of the settings in the tool.



Slope Algorithm	See Algorithm.
Slope Threshold	Specifies the starting angle to remove slopes from the data.
Data Fill	Select check box to fill areas removed by the Slope filter using a Laplace fit.
Output Clipped Data	Available on the Advanced Tab.) Causes the Slope Filter step to output the high slope data it originally removed.

8.13 Spike Clip

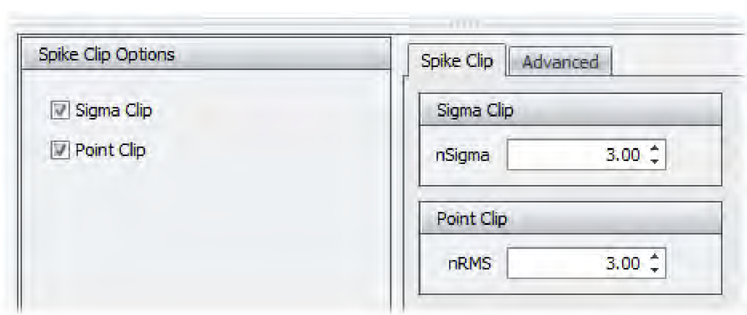
- The Spike Clip tool removes spurious data based on their height relative to other data.
- Use to minimize the effect of artifacts and defects and to improve repeatability.
- Options determine the clipping function and extent.
- Point Clip and Sigma Clip options can be used alone or together.

This tool works best on continuous and smooth surfaces. It is not recommended for patterned or stepped surfaces.

Spike Clip Options

Select the appropriate check box to activate the trimming function.

Select the Immediate Update check box to display the impact of the settings in the tool.



Sigma Clip	Areal height removal based on the extent of deviation. When Sigma Clip is selected, the nSigma control value and advanced settings are used to determine spike removal. Points are removed that deviate by more than the nSigma (N rms) amount. For more details, see Sigma Clip Algorithm.
Point Clip	Single point height removal based on a cylinder fit and windowing filter. When Point Clip is selected, the nRMS control value is used to determine spike removal. Single points are removed when its height deviates from the average of its local square more than a given amount. For more details, see Point Clip Algorithm.

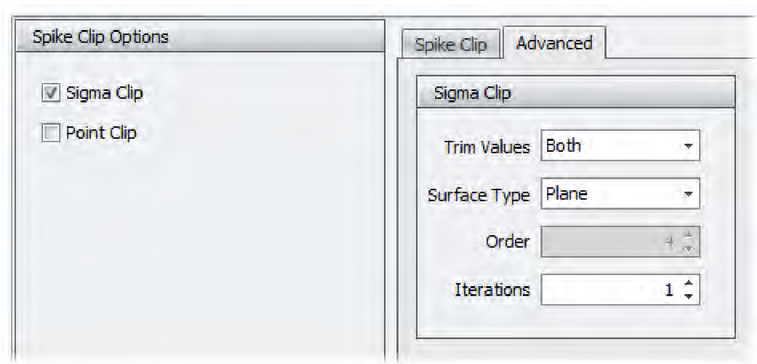
Spike Clip Tab

nSigma	Specifies a multiplier for the sigma clip function.
nRMS	Specifies a multiplier for the spike clip function. The default is 3.

Spike Clip Uses

- Delete known cosmetic artifacts that drive the PV parameter; use in place of masking.

Spike Clip Advanced Tab



Items under Sigma Clip are only applicable when the Sigma Clip check box is selected.

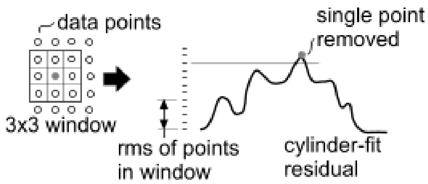
Trim Values	Selects the location of the sigma clip only. *Above* removes the areas above the value entered in the Sigma Clip control. *Below* removes the areas below the value entered in the Sigma Clip control. *Above and Below* removes the asperities both above and below the value entered in the Sigma Clip control.
Surface Type	Selects the surface to remove before calculating the RMS of the data to apply the Sigma Clip value to. Available choices are Piston, Plane, Sphere, Cylinder, or Higher Order.
Order	When Surface Type is Higher Order this specifies the order to fit and clip the data.
Iterations	Specifies the number of times to apply the sigma clipping routine.

Spike Clip Function

This section provides a functional overview of the two techniques.

Point Clip Algorithm

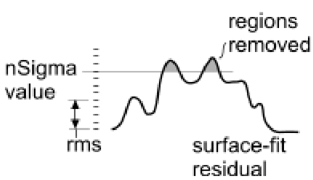
Single point height removal based on a cylinder fit and windowing filter.



1) Fit a cylinder to the original surface.
2) Calculate the RMS of the global cylinder fit.
3) Subtract the best-fit cylinder from a copy of the original surface.
4) Scan a 3x3 window over the fitted surface and calculate the average height of the pixels in the window.
5) Remove from the original surface any central pixel in the window that differs from the mean value of the window by more than the amount specified in the nRMS multiplied by the global RMS.

Sigma Clip Algorithm

Areal height removal based on the extent of deviation.



1) Fit the specified surface type to a copy of the surface.
2) Calculate the RMS of the fit.
3) Remove the fit surface from the data copy using coefficients from the fit.
4) Remove from the data copy any point whose absolute height value is larger than the nSigma value times the RMS.
5) For each iteration (as specified in the Iteration control) steps 1-4 are repeated and additional points are removed.
6) Remove any identified points from the original surface.

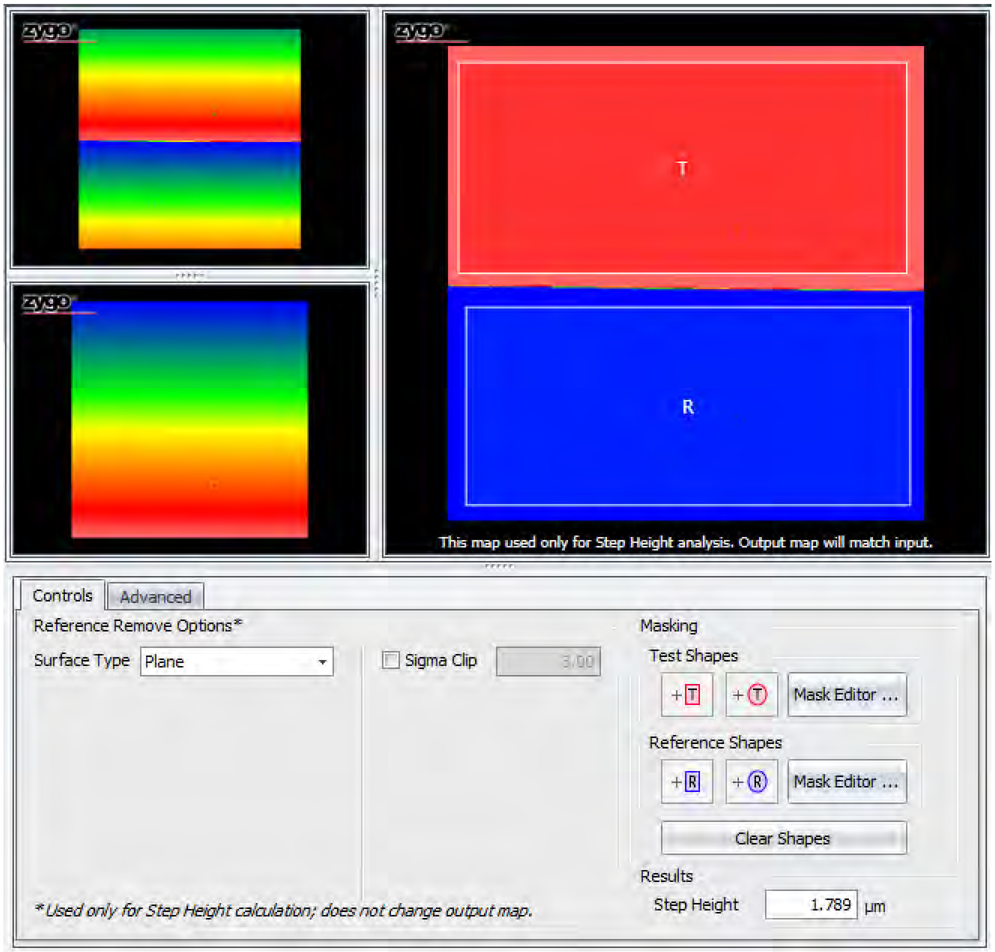
8.14 Step Height

The Step Height tool computes the average height over a test area defined by mask shapes.

Step Height Overview

- Optionally, the computed height can be relative to a reference surface.
- The step height does not change the output map. The output map will match the input map, even when a reference surface is used.

The Step Height Screen



Reference Remove Options

Use these controls to optionally define a reference surface relative to which the step height result will be determined. This reference surface is used only within the Step Height tool, it does not affect the map output from the Step Height tool, which will always match the input.

For Surface Type see Surface Type under Form Remove. If no reference surface is needed, set Surface Type to None.

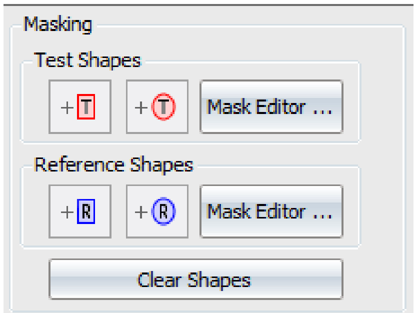
For Sigma Clip see Sigma Clip.

Select the Immediate Update check box to display the impact of the settings in the tool.

Step Height Advanced Tab

If analysis time is an issue, for example for large data-sets or complex surface types, the subsample control can sometimes help. See Subsample Size for details.

Step Height Masking

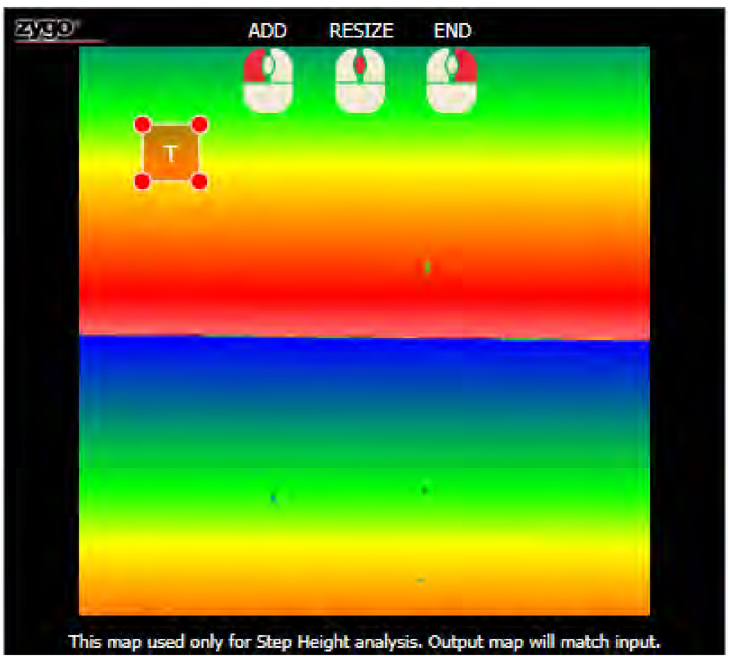


Masking is used to define the area over which the step height will be computed, using one or more Test Shapes. The Add Test Shapes buttons can be used to add simple shapes (rectangles and ellipses) directly on the map. After clicking an Add Test Shape button, move to the map and left-click where shapes are desired. Right-click or click outside the map when done. Existing simple shapes can be resized and rotated directly within the map.

For more complex masking (e.g., with complex or unfilled shapes), click on the Mask Editor ... buttons. For details, see Mask Editor.

Using a Reference Surface

If a reference surface is being subtracted (Surface Type not set to None), a reference mask can optionally be used to restrict the data used to calculate the corresponding best fit surface. If no mask is configured, the entire data set is used for fitting.



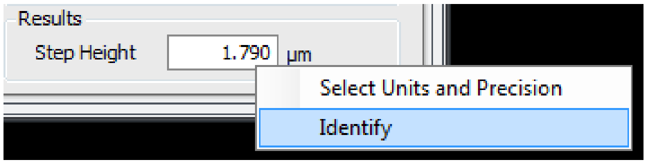
Reference Shapes can be defined just as for Test Shapes, using the Add Reference Shape buttons to add simple shapes directly to the map, or the Mask Editor for more complex masking.

The Clear Shapes button deletes all mask shapes.

Step Height Result

The displayed step height result represents the average over the aggregate Test mask, with the reference surface removed if specified. This result can also be reported elsewhere (e.g., in a Result Grid) or accessed via scripting.

To see the path to the step height result, right-click and select Identify.



8.15 Subtract

- System errors can be minimized by subtracting a data file made from a measurement of a known high quality part or standard.
- Subtracting system errors improves measurement accuracy by subtracting instrument aberrations during the analysis cycle.
- Subtract can also be used to compare data in a before/after experiment.

Recommendations

Laser Interferometer	Use an optic 2 times better than transmission element.
Optical Profiler	Use multiple measurements of a high quality surface, such as a SiC flat.

System reference files are specific to the instrument's optical components and camera settings.

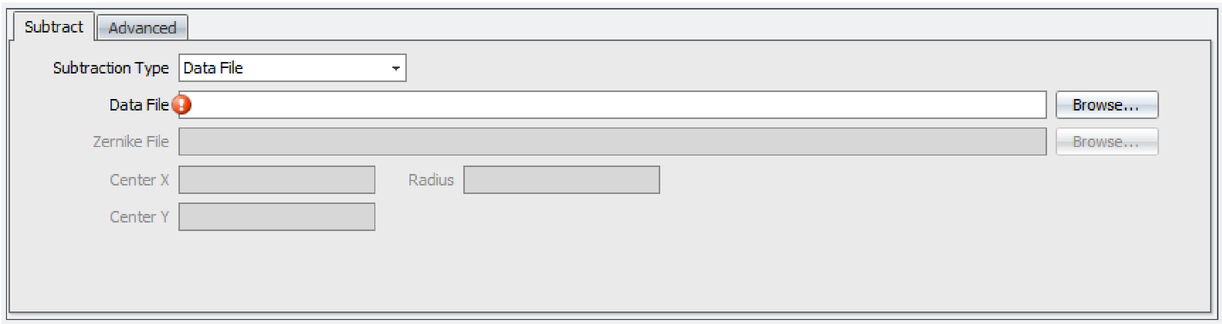
When To Make a System Reference File

- When the transmission element (laser interferometer) or objective (optical profiler) is removed and installed.
- When the Camera Mode or optical setup is changed.
- When environmental conditions change.
- When more precise control over the system reference file is required than is available using the built-in Calibration routine (optical profilers).

Use Conditions

- The system reference file is a standard data file (.datx) made by measuring a reference or high quality part with the instrument set to match the conditions of the test part measurement.
- The system reference subtract function expects the camera size and lateral resolution of both data sets to match.
- The system reference file must either already exist or be created for the specific instrument setup in use, before activating this function.
- The intersection of the input and reference data sets defines the area subtracted.
- Use to subtract a data file or Zernike file from the current data.

Subtract Options



Subtraction Type Selects the type of file to subtract. Choices are Data File or Zernike File.

Data File Specifies the name of a data file to subtract from measurements. The file is sometimes referred to as a system error file, error file, or sys err file.

Type in the path and data file name or click Browse to access the Open Data dialog box. In the dialog box, navigate to the directory location of the data file, select the file and click Open.

Zernike File Specifies the name of a Zernike (.int or .zfr) file to subtract from measurements when Subtraction Type is Zernike File.

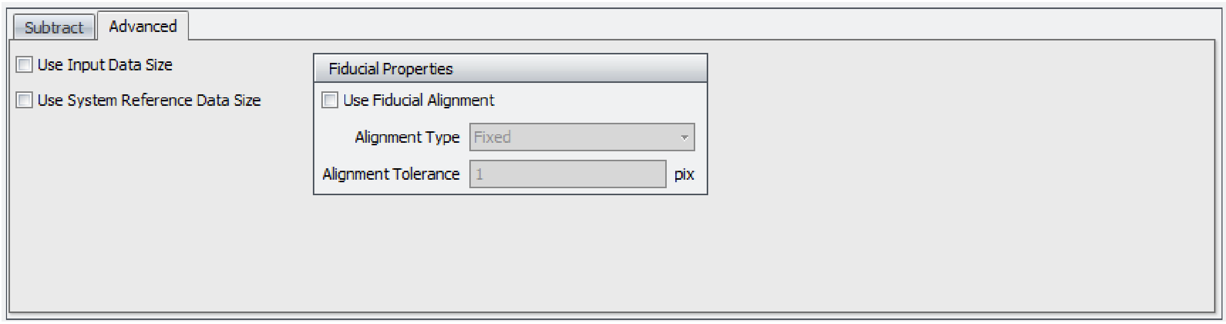
Type in the path and Zernike file name or click Browse to access the Open Data dialog box. In the dialog box, navigate to the directory location of the file, select the file and click Open.

Center X specifies the dimension (based on camera coordinates) to the center of the unit circle in the X-axis.

Center Y specifies the dimension (based on camera coordinates) to the center of the unit circle in the Y-axis.

Radius specifies the radius of the unit circle; it is the dimension from its center to its perimeter.

Subtract Advanced Tab



Subtract Options

For system reference subtract to work, two things must match in both the reference data file and the input data: 1) camera size (width x height), and 2) lateral resolution. These check boxes are used to try and work around situations when the lateral resolution and/or camera size don't match.

In the system reference subtract function, the camera size of both the reference and input are compared. If they don't match an error is indicated. When one "Use...Data Size" check box is selected, the applicable *data size* is compared to the camera size of the other. When both "Use...Data Size" check boxes are selected, data sizes are compared to each other. The sizes in all cases must match for a valid system reference subtract, or an error is indicated.

Use Input Data Size — When selected, the data file size (instead of the camera size) of the input data is compared to the size of the reference data file.

This option can be useful in overcoming minor camera differences when using a older MetroPro data file as the reference file.

Use System Reference Data Size — When selected, the data file size (instead of the camera size) of the reference data is compared to the size of the input data file.

Fiducials

These controls will attempt to align the reference data to the input data using predefined fiducials.

Use Fiducial Alignment — Select the Use Fiducial Alignment check box to align the system reference data to the input data using fiducials.

To use Fiducials, both the input data and system reference subtract files must have a similar set of fiducials previously defined. A "fixed" alignment type needs at least 2 fiducials, while "variable" needs 3 fiducials.

Alignment Type — Selects the fiducial alignment type. The choices are Fixed or Variable. Fixed scales both axes equally to align fiducial marks. Variable scales to the best fit to align fiducial marks.

Alignment Tolerance — Specifies how many pixels the fiducials may be misaligned between the reference data and the input data.

Making Static System Reference File

This procedure measures a high quality part in one fixed location.

1. Set the instrument settings (such as: objective, transmission element, zoom, camera mode) identical to the conditions used to measure the test part.
2. To maximize the quality of the measurement, it is recommended to use averaging so the result is based on multiple acquisitions. In Measurement Setup, set Averaging to 8.
3. Focus the instrument on a known high quality test part and null the interference pattern.
4. On the toolbar click Measure.
5. On the toolbar click Save Data. In the save dialog box enter a file name and click OK.

   Use a file name that has an inherent meaning, such as "SysRefFile_partXX.datx".
6. Click Data Processing in the Navigator and select System Reference Subtract.
7. Click the System Reference Subtract On check box and enter the file name after System Reference File. Or click the Browse button and locate the file.
8. Close the Data Processing window.
9. To turn off the averaging function, set averaging to 0.
10. Subsequent measurements will have system errors subtracted from the data.

Analyses 9

An "analysis" is a workspace configuration or view of graphics, results, and tools for a particular function. Analyses are selected with the Navigator. Analyses are application specific.

The general order of data flow and application of tools is implied by the order in the Navigator.

About Analyses

- Analyses come after Data Processing in the data flow.
- Some of the analyses described in this section may not be applicable to your instrument and options.
- For specific details on plots and results, refer to the item in question.
- For information on the statistical process function, see Process Statistics.

9.1 Common Analyses

This section describes analyses that are common to many instruments.

See Also

Laser Interferometer Analyses

Optical Profiler Analyses

Home

Home is term given to the default screen for a particular instrument and application.

In the Actions menu select Home to bring you to the MEASUREMENT tab.

For more information on features within this view see the item by name or refer to the application by name.

PSD

ANALYSIS tab, Navigator : Surface : PSD

PSD or Power Spectral Density analysis reports the power of sinusoidal components of the surface as a function of frequency. The analysis can be used to highlight or tolerance periodic surface features in general. One-dimensional PSD is based on profile data.

The PSD Limit Line feature complies with ISO 10110-8.

Use Conditions

- Applies to all instruments, both laser interferometers and optical profilers.
- Lateral calibration is required.

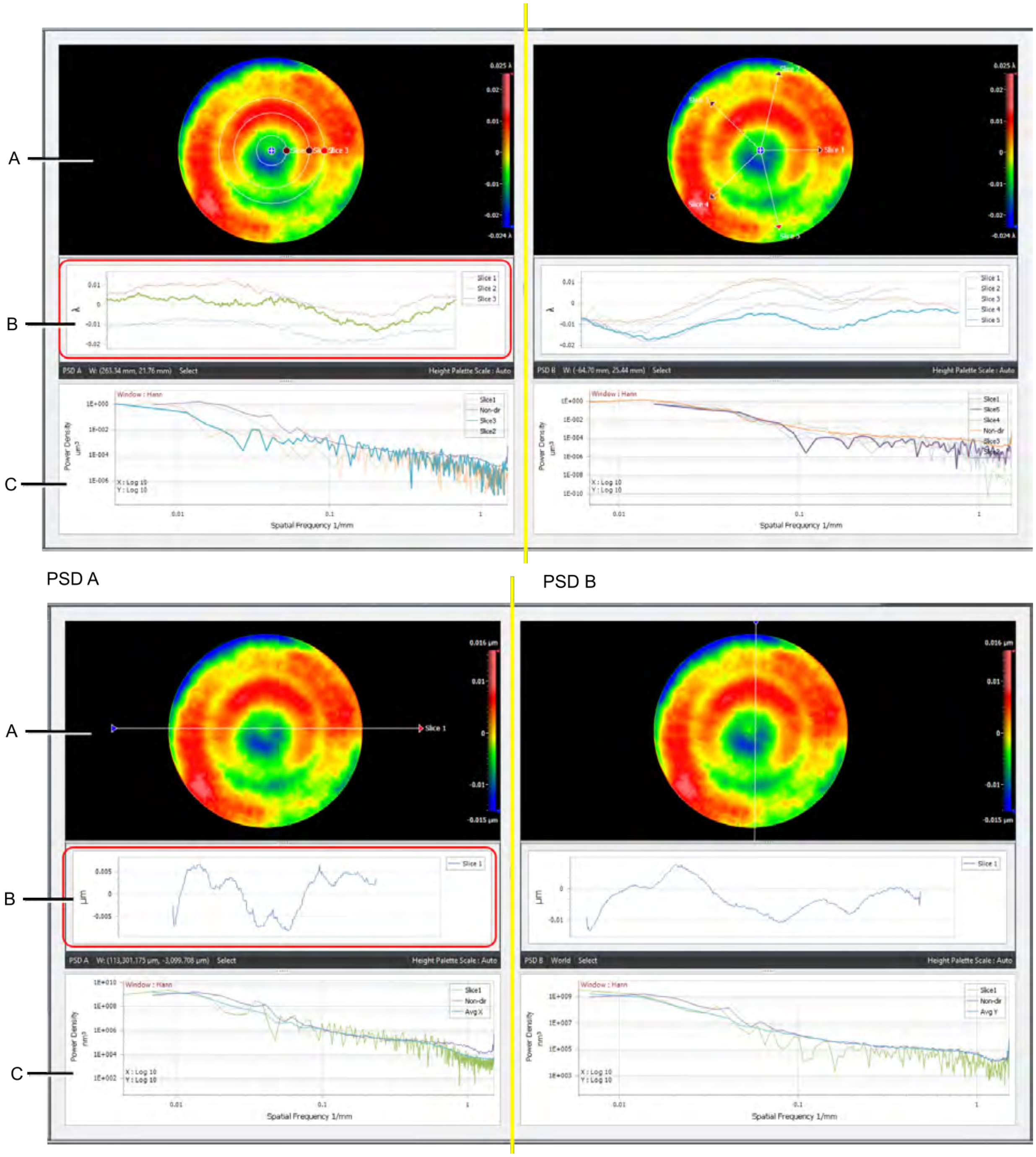
PSD Use Cases

- Quantify the presence of surface features in terms of their lateral size.
- Highlight the individual effects of multiple machining or polishing processes that have been applied to a surface.
- Quantify how a smooth polished surface will scatter incident radiation due to high-frequency defects.
- Identify if the part surface is anisotropic (directionally dependent).
- Evaluate a PSD tolerance (limit line) over a specified frequency interval.
- Calculate surface RMS over a specified frequency interval through integration of PSD.

The PSD Screen

The PSD screen has two sides with similar features. The PSD plot displayed on each side is dependent on the slices defined in the 2D plot.

The first screen is from the Form application; the second is from the Micro application.



A. Input data (phase map after any data processing). **B.** Profile plots and statistics based on slice(s). **C.** PSD plot based on the input profile data; FFT band pass filtering and a Gaussian cutoff are applied to the input profile data.

The PSD analysis is preconfigured with two different slice types for the user who wants to constrain the PSD analysis to a direction and location on the part. However, a PSD plot based on slices is vulnerable to selection bias. A non-directional PSD is of use to metrologists in that the user does not need to slice the surface in the right place and direction across the texture. A non-directional PSD reports all frequency content of the surface, potentially including information that slice-based analysis might miss. See Changing the PSD Plot.

PSD A

- Useful for quantifying spoke patterns.
- In the Form application, the PSD plot is defaulted to circular slices(s) fixed to the data center.
- In the Micro application, the PSD plot is defaulted to a horizontal linear slice.

PSD B

- Useful for quantifying bull's-eye or ringing patterns.
- In the Form application, the PSD plot is defaulted to 5 centered radial slices.
- In the Micro application, the PSD plot is defaulted to a vertical linear slice.

References for PSD

ISO 10110-8 : Optics and photonics -- Preparation of drawings for optical elements and systems -- Part 8: Surface texture.

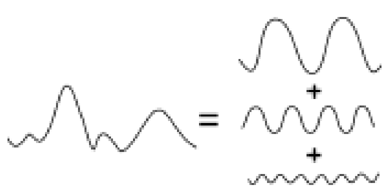
"ISO 10110 Optics and Optical Instruments- Preparation of Drawings for Optical Elements and Systems: A User's Guide," by OSA Standards Committee, Edited by Ronald E. Kimmel and Robert E. Parks.

“NIF Large Optics Metrology Software: Description and Algorithms,” by Wade H. Williams. 15 October 2002, sponsored by Department of Energy's (DOE) (report number UCRL-MA-137950-REV-1).

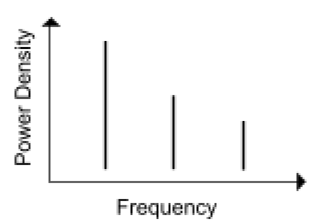
PSD Fundamentals

PSD is the amount of *power* per unit (*density*) of frequency (*spectral*) as a function of the frequency. The Power Spectral Density describes how the power (or variance) of a time series is distributed with frequency. Mathematically, the area under the PSD curve is equivalent to the RMS OPD (optical path difference) of the surface.

The PSD analysis displays spatial frequency data. Picture any given test surface as being made up of a combination of sine waves. When displayed as bars, every sine wave component of the test surface appears as a vertical line. Its height represents the power density and its position represents its frequency. Logarithmic scaling is often used to compress large values and expand small ones.



Any profile can be reduced to a summation of sine waves described by various amplitudes (or phase heights) and frequencies (how often it occurs per unit of length).



The results are plotted as power density versus frequency.

Why Use PSD?

During the manufacture of smooth surfaces, such as a silicon wafer or an optical surface, the machining or finishing process can create a repetitive structure or ripple. The frequency and magnitude of these ripples have a direct impact on how the object scatters light striking its surface. For an optical surface, scattering may degrade its performance, and ripple may limit resolution capabilities when used in an imaging system due to mid-spatial frequency transmitted wavefront error. For a silicon wafer, ripple can limit the size of the features that can be printed on the surface.

Advantages of PSD

PSD is useful to distinguish parts with similar roughness results. It is possible for a random surface and an extremely periodic surface to produce the same rms roughness value. However, the random surface will have almost no peaks in the PSD plot, where the periodic surface will have strong peaks.

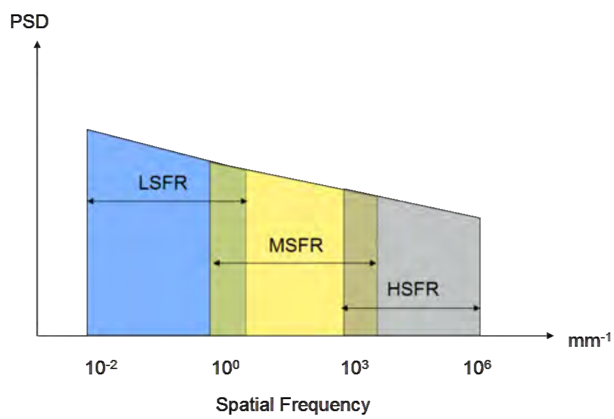
PSD analysis is a robust tool for characterizing mid-spatial frequency content in the finish of a surface (PV and RMS do not quantify this well as a function of spatial frequency). PSD can be a powerful method for analyzing surface finish quality where wavefront slope must be well controlled over a certain frequency band of interest.

Measuring slope gradients directly is often not fruitful because: 1) artifacts in the measurement process can greatly distort slope results (especially PV); and 2) slope does not provide direct insight into a culprit frequency or pattern.

PSD is effective at highlighting distinct spatial frequencies that result from the machining or polishing process; this can provide feedback necessary to improve fabrication. The PSD analysis can quantify the surface so that periodic structure in the part can be minimized during manufacture.

Because of how non-directional PSD is computed, it is most sensitive to periodic circular surface structure.

PSD and Frequency Limits



The PSD of a surface may be represented as in the figure above. Different instruments are needed to measure different regions of this curve since the useful spatial frequency range is a function of both the field-of-view and the sampling. A useful rule-of-thumb for a given instrument is the following:

- A useful low spatial frequency limit is a period 1/3 of the clear aperture diameter. For example, if the test aperture is 100 mm, then the useful low limit is 0.03 c/mm (33 mm period).
- A useful high spatial frequency limit is a period 5x the projected pixel size. For example, if the lateral calibration is 0.1 mm/pixel, then the useful high limit is 2 c/mm (0.5 mm period).

Consequently, a single instrument cannot test the PSD over the entire spatial frequency range of interest. There is some overlap as indicated in the figure above, but the instrumentation required may be broadly categorized as follows:

- LSFR (low-spatial frequency range): laser interferometer.
- MSFR (mid-spatial frequency range): optical profiler.
- HSFR (high-spatial frequency range): atomic force microscope.

PSD and Optical Profilers

Most surfaces tend to show less periodic structure when examined over increasingly smaller regions, such as when using higher power objectives. The lower power objectives tend to show much more waviness than high power objectives (10X and up). A change in magnification effectively applies a different filter to the measured spatial frequencies.

Raw Data

MEASUREMENT tab, Navigator : Raw Data : Raw Data

This view shows the raw surface. This view is the signal from the sensor processed to create the basic surface or wavefront map. It does not have any data processing (filter, trim, etc.) applied.

For more information on features within this view, see 2D Plot and Histogram.

Raw Intensity

MEASUREMENT tab, Navigator : Raw Data : Raw Intensity

This view shows the first frame of intensity data directly from the instrument's camera.

For more information on features within this view, see 2D Plot and Histogram.

Regions

Navigator : Regions : Regions

Regions is a specialized analysis tool which allows for the segmentation of a surface measurement into distinct regions. There are two types of regions: test and reference. A reference region is used to define the *zero* of the measurement. It is similar to the idea of a datum. This is the reference where measurements are taken relative to. The test regions are the regions of interest. Results and statistics can be calculated for test regions, and these results can be tabulated, filtered, and reported.

Typically, Regions is used whenever there is a need to automatically identify and analyze a feature in the field of view, or compare different areas in a measurement to each other. There are several different segmentation modes and various ways of defining the reference surface. Sequences can be used anywhere in the data flow to assist in isolating the regions of interest.

For details on using the Sequence tools available within the Regions analysis see Processing Tool.

Use Conditions

- Applies to optical profilers and laser interferometers.
- Lateral calibration is required to display lateral based results in units other than pixels.

Regions Data Flow

Regions always begins the analysis with the raw input data; any processing applied in the Surface Processing window is not applied. This section describes the flow of data in the Regions analysis, which is primarily determined by the Segmentation Mode control.

Pre-Segmentation Processing

Select the Enable Regions check box to make Regions active; if this check box is cleared, no analysis is performed.

If Surface Pre-Processing... is enabled, the raw input data is first processed by the associated sequence. This provides the option of processing data before segmentation occurs- for example, removing a complex form or using Data Fill to fill in small holes.

Some segmentation modes can optionally use Intensity to define region bounds, with the regions themselves are still formed using Height Data. In such cases the following controls are available:

Map To Use For Segmentation	Determines if segmentation should be done with input (Surface) data or Intensity data. When Intensity is selected, regions are still formed from Height Data, using pixels identified from Intensity data. Applicable when Segmentation Mode is Peaks, Z Relative, or Watershed.
Intensity Pre-Processing...	Click this button to open the Sequence Editor and add a sequence that applies to Intensity data before it is used to perform segmentation. The Segment Using control must be set to Intensity. The sequence is activated using the adjacent check box.
View Processed Intensity…	Click this button to open a plot window showing the (possibly processed) Intensity data used for segmentation.

Segmentation Mode

The Segmentation Mode control is used to create test regions; the various choices and corresponding data flow are detailed below. Segmentation processing is applied after Pre-segmentation Processing.

Islands

Islands segmentation creates regions from islands of data. An island is a contiguous set of pixels completely surrounded by no data (including the edge of the field of view). Islands analysis is appropriate whenever the analysis should compare discrete blocks of data to each other. Optionally, the data can be reversed, to allow for analysis of holes.

The Islands data flow is as follows:

1. If Reverse Data is enabled, every pixel of no data within the field of view is made valid, and vice versa.
2. Islands are identified. Every connected region of data is entered into the regions grid list.

Masks

Mask segmentation allows for definition of regions by drawing shapes known as Masks, directly on the data set. There are several Masks segmentation methods that vary in their ability to define a reference. Masks mode uses masks configured directly by the user by clicking the Configure Masks… button. The reference selection is consistent with most other segmentation types.

The Masks data flow is relatively simple: a region is created for each Test mask drawn in the Segmentation Mask Setup screen.

Masks Single Reference

Masks Single Reference is similar to standard Masks segmentation. However, the Reference must be defined by clicking the Configure Masks… button and creating a reference mask, not through the Reference Options panel. This enables the use of Mask Align to move a set of test masks and a reference mask in sync.

Masks Multiple Reference

Masks Multiple Reference is similar to standard Masks segmentation. However, the Reference is defined for each test region individually, in the Configure Masks… dialog, not through the Reference Options panel. This enables the use of Mask Align to move test and reference masks together, pairwise.

Masks to Holes

Masks to holes allows for the automatic placement of a mask, relative to each hole located in the data set. A hole is a region of no data entirely surrounded by data; this is the inverse of an Island. Holes are located in the data set, which can optionally be processed for hole location only with the Masks to Holes Processing sequence.

The Masks to Holes data flow is as follows:

1. If Map Processing Before Finding Holes is enabled, the segmentation data is processed.
2. Holes are identified in the segmentation data.
3. If Min Hole Size (pix) or Max Hole Size (pix) are enabled, holes which are too small or too large are removed from the internal list of holes.
4. Each hole has the configured mask placed on it, and any valid data pixels in the original data are collected into a region and placed in the region grid list.

Peaks

Peaks segmentation calculates a histogram from the segmentation data and attempts to find peaks (local maxima). The segmentation data can be either the Surface or Intensity map. No matter what data is chosen for the segmentation data, regions are always calculated from the Surface data. The processing applied in steps 1 through 3 below apply only to the segmentation data, and only affect the segmentation process.

The Peaks analysis processing flow is as follows:

1. If Pre-histogram leveling is turned on, the segmentation data is leveled using the selected form.

2. The histogram is calculated from segmentation data, with a number of bins equal to Histogram Bins and the specified Smoothing applied.
3. A number of peaks equal to the Find number are identified, with no two peaks closer than the "spaced by at least" Separation.
4. The histogram is divided into ranges defined for each found peak. Boundaries between peak ranges are placed according to the Divide Peaks At control.
5. Pixels in the Surface data are grouped by histogram range. This creates a number of regions equal to the number of located peaks.
6. If Clip enclosed regions is turned off, any region which is entirely surrounded by another will be merged into the region surrounding it.

Watershed

Identifies regions by analyzing the surface as if it were a landscape. Regions are identified as either Hills (delimited by a course line) or Dales (delimited by a ridge line).

Z Relative

Z Relative segmentation allows for more manual control of regions segmentation. In this mode, regions are created by user-defined high and low limits for each region. These limits can be defined relative to landmarks in the surface, such as the peak, valley, or mean.

The Z Relative data flow is as follows:

1. If Pre-Histogram Leveling is turned on, the segmentation data is leveled using the selected form.
2. Z Relative offers Peaks Segmentation capability and Found Peaks can be used as reference positions.
    a. The histogram is calculated from segmentation data, with a number of bins equal to Histogram Bins. Histogram Smoothing is applied.
    b. A number of peaks equal to Expected Count are located; with no two peaks closer than the Minimum Separation.
3. A number of rows equal to Number of Surfaces is generated in the Z Relative configuration grid. A region is generated from each row in this grid, according to the user controls.
4. Z Relative regions can be optionally sub-segmented bu islands and clustered. For each region:
    a. If Sub-Segment is turned on, each individual island of data will become its own region. An island is a set of connected pixels of data, entirely surrounded by No Data. Regions will be sorted by Name (peak number) and Sub-Name (island number).
    b. If Cluster is turned on, any islands that are within the specified distance (center to center) will be merged into a single region.

Sub-segmenting and Clustering

Some segmentation modes offer options to sub-segment and/or cluster regions before Region Processing.

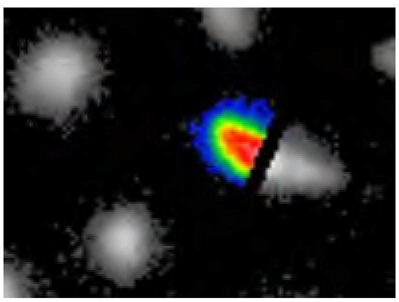
Sub-Segment by Islands	When enabled, performs islands segmentation on each Peaks region.

Cluster Distance	Islands which are this distance apart are joined into a single region. This can help prevent the creation of many small islands which are only a few pixels apart. This control is enabled if Sub-Segment by Islands is selected as well as the adjacent check box.

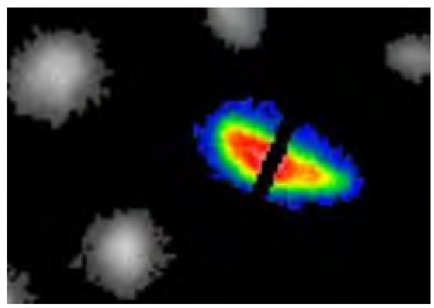
1. If Sub-Segment by Islands is turned on, each individual island of data will become its own region. An island is a set of connected pixels of data, entirely surrounded by No Data. Regions will be sort-ed by Name (peak number) and Sub-Name (island number).
2. If Cluster Distance is turned on, any islands that are within the specified distance (center to center) will be merged into a single region.

Clustering Example

The first regions image below shows multiple separate regions. But suppose the highlighted region should be connected to the region adjacent to it. First, use a ruler on the plot to measure the distance between the two regions. In this case, it is approximately 3.8 µm. Round up to 5 µm to give a bit of working space and enter that as the Cluster Distance. As seen below, the two regions are now joined as one while regions more than 5 µm apart will not be joined.



Before Cluster Distance



After Cluster Distance

Region Processing

1. If Min Area or Max Area are enabled, any regions containing fewer pixels than Min Area or more pixels than Max Area are removed from the Region list. If Include regions at boundary is disabled, any region touching the edge of the field of view is removed from the Region list.
2. If enabled, Processing… is applied to each Region. Depending on Reference Processing controls, this may occur after Reference processing.

Naming Options

These controls determine how regions are sorted and named, along with how they are output to other parts of Mx.

Order	Determines the order in which regions are named (i.e. given the label Peak 1, Peak 2, Peak 3, etc). Default behavior (None) names regions from Largest to Smallest for most segmentation modes. Design Coordinates is an advanced option that uses part design information embedded in the data.

Show Labels	Determines whether or not to show text labels on the Regions input plot for each Region in the Region grid list.
Configure Outputs...	Opens a dialog which allows the user to configure how regions are output to other portions of Mx.

If Naming Order is set to Design Coordinates, regions are associated with objects described in a design file embedded in the data, guided by center-to-center distances along with the following controls.

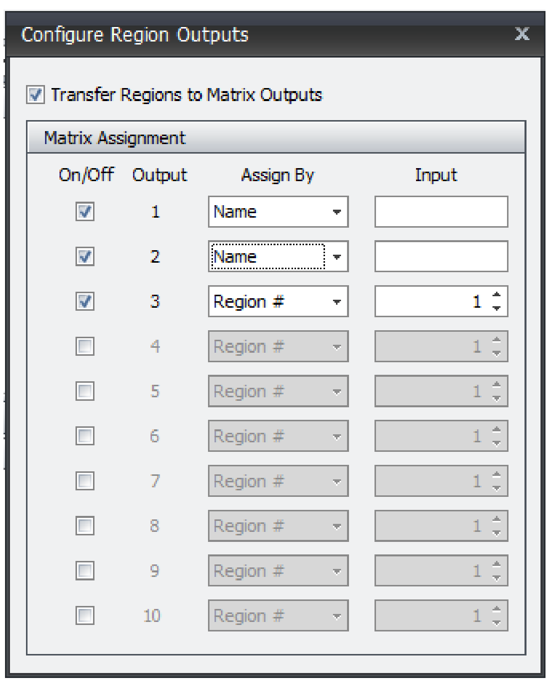
Include object only if	When Fully in FOV is selected, only design objects fully contained within the measurement area are considered. For Center in FOV, objects are considered provided their center is within the measurement area.
Fit used for computing centers	The selected fit will be applied to each region in order to determine its center location.
Distance threshold	Sets the maximum center-to-center distance for a region to be associated with a design object.
Max region count per object	Limits the maximum number of regions that can be associated with a design object.
Show options	These controls determined whether shapes or IDs are overlaid on the input map, along the overlay color.

Configure Outputs

Configure Outputs allows the user to configure how regions are output to other portions of Mx. This feature is particularly useful when using Segmentation Mode: Masks.

To access this function under Naming options click the Configure Outputs... button.

To activate this function, select the Transfer Regions to Matrix Outputs check box.



On/Off Turns an individual matrix output On (checked) or Off (unchecked).

Output The destination output matrix that will receive the data

Assign By Assigns the output by either Region # or Name. The # refers to the row in the Regions output grid.

Input Choice/entry based on the Assign By control.

When Region #, Input is a number 1...N.

When Name, enter the name of region you want to assign. In the case of Masks, this name doesn't change. The name is case insensitive, and leading and trailing spaces are trimmed. If a name entry is duplicated, the first item in the grid that finds a match is used, others are ignored.

Reference Subtraction

When Reference is enabled, reference surface(s) are generated according to the selected options and subtracted from segmented regions.

1. If Reference Type is set to One Reference For All, a common Reference surface is created and subtracted from all test regions.
2. If Reference Type is set to Local Reference For Each Region, a separate Reference surface is created for each test region, and then subtracted from it.
3. If Segmentation Mode is Masks Single Reference or Masks Multiple Reference, the Reference is defined through the Configure Masks... dialog in the Mask Segmentation section.
4. If enabled, Reference Processing is applied to the Reference surface(s).

   If Segmentation Mode is Masks Multiple Reference, Reference Processing is defined independently for each Test/Reference pair.

5. A best-fit is then performed to processed reference surface(s), using the specified Form Remove type and options.

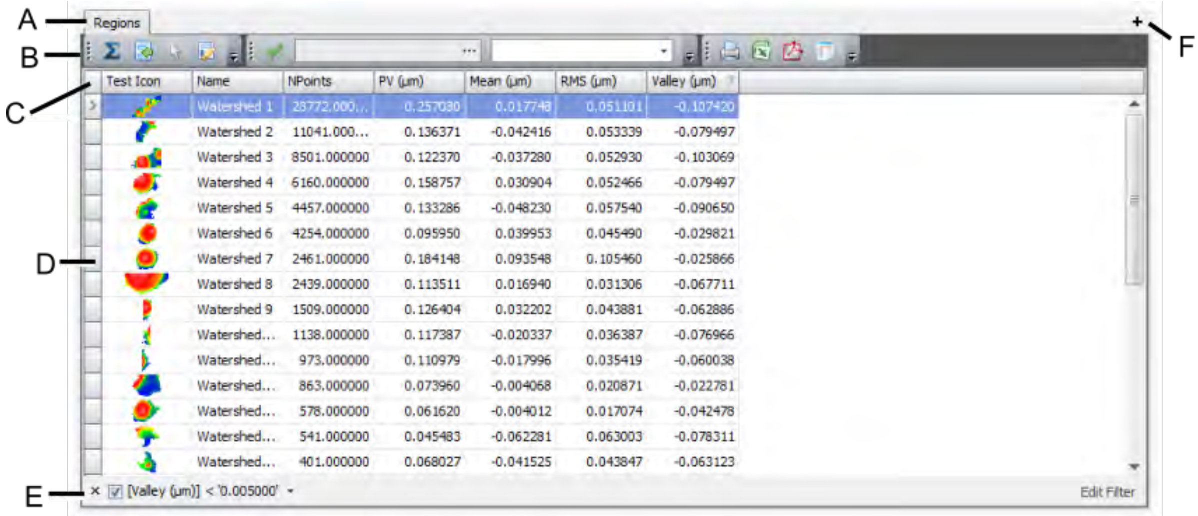
   If Segmentation Mode is Masks Multiple Reference, Form Removal is defined independently for each Test/Reference pair.

6. If Process Regions is set to Before Leveling, regions are processed before a reference surface is subtracted from them. If Process Regions is set to After Leveling, reference surface(s) are subtracted from regions before Region Processing occurs.

   If Segmentation Mode is Masks Multiple Reference, this sequence is specified independently for each Test/Reference pair.

Regions Output Grid

The Regions output grid list is similar to Process Statistics and shares much functionality.

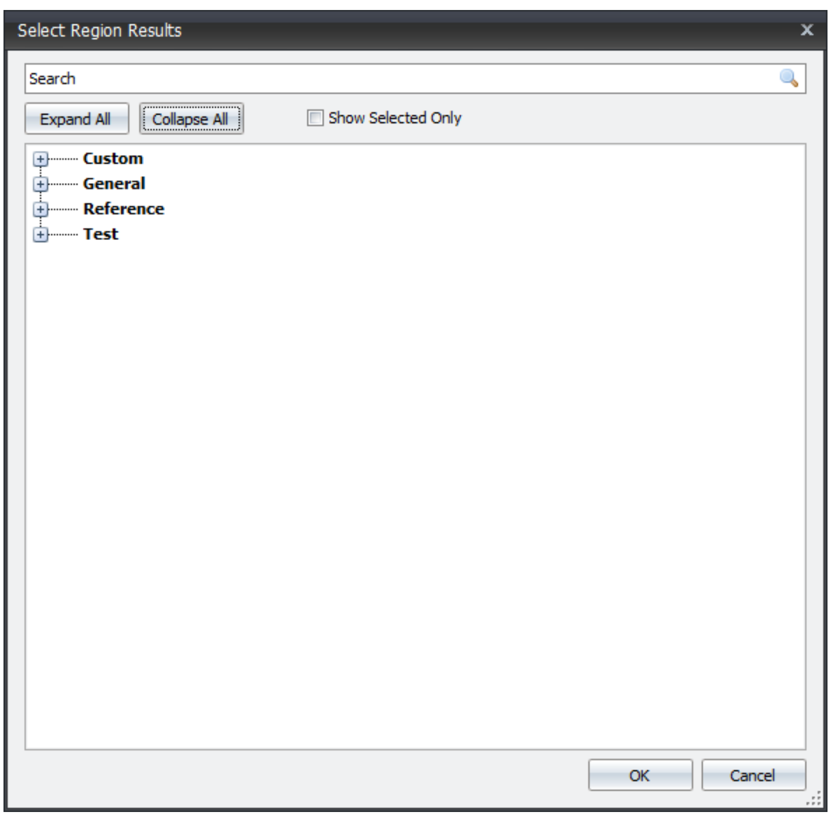


A. Tabs allow for organization of results. **B.** Toolbars contain display and output options. **C.** Column headers allow for sorting and filtering. **D.** The main results grid shows test icons, names, and results. **E.** Any active filters are shown along the bottom of the results grid. **F.** Click the + (plus) to create new tabs.

Regions Results

Adding New Results

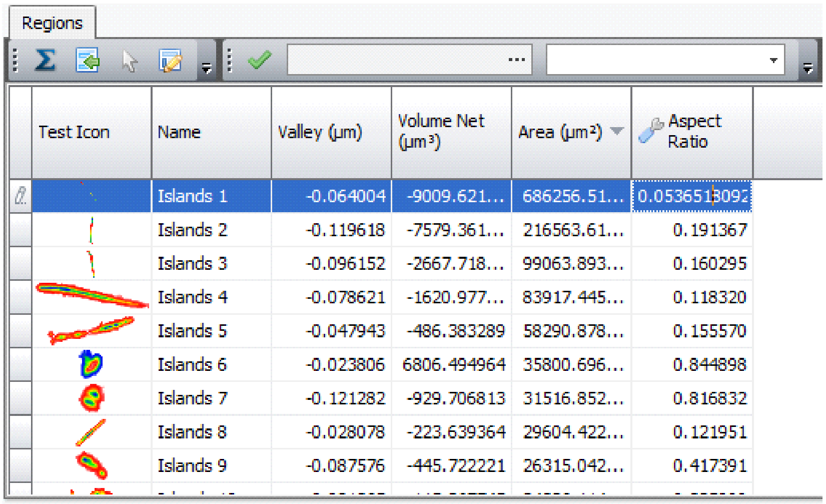
To add new results to the Regions Output Grid, either click the Select Items icon from the toolbar, or right click in the output grid and choose Select Results. This opens the Select Results dialog.



Search for the desired result and select it to add to the output grid.

Configurable Results

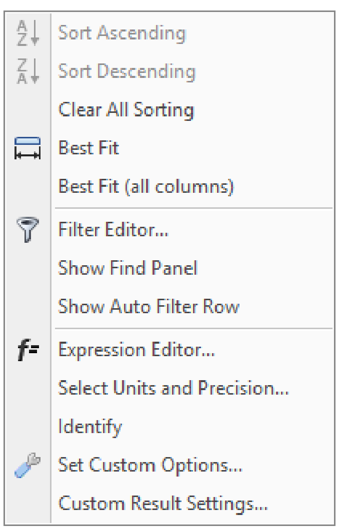
Some regions results are configurable. These results are indicated by a wrench icon on the column header. Right clicking the column header will provide a list of options. To choose options for the result select Set <Result> Options... from the menu.



Many configurable results deal with fitting shapes to regions, such as Aspect Ratio, Minimum Enclosing Rectangle, and Circle results. The options will allow for the display of the fit shape on the regions data map.

Custom Results

Custom Results can be added and defined to the regions grid. To begin, add a new result and select Custom Result 1 (or more) from the Results Selection dialog. Then right-click the Custom Result column header and select form the available options.



Custom Result Settings... provides options for setting the Unit Category of the result, as well as changing the displayed name. The unit category is required for the result to properly display with units, and to use the built-in Mx Unit Converter.

The Expression Editor is where the calculation of a Custom Result is done. Custom results are made up of arithmetic combinations of other regions results and mathematical functions. Custom results also support basic string manipulation and Boolean logic. When creating a custom result, take care that the calculation produces a result of the selected unit category, or the results may not be meaningful.

Reference Results versus Test Results

Any result in the Results Selection Dialog which is contained in the Reference category is calculated for the reference area of each region. As regions can each have a unique reference, this is a useful way to view results for both a test and reference region at once.

Results which are in the Test category are calculated for the displayed region.

Regions Grid Tabs

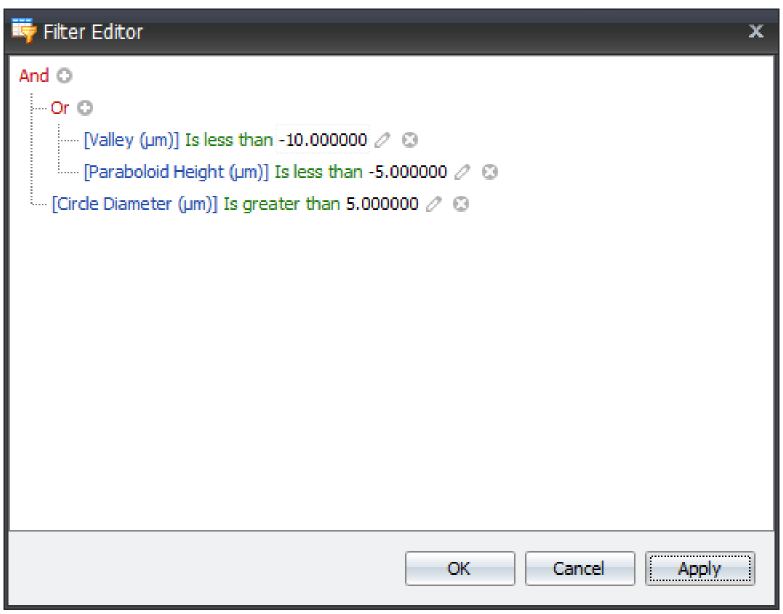
Tabs are used to organize results. A typical use of additional tabs is to use filtering to show results from regions that meet a criterion. For example, one tab can show minimum size. In a second tab, with different filters, regions are displayed which meet a separate criterion. This can also be used to show different families of results in separate views, such as a tab which contains volume results for each region, and a separate tab for roughness parameters.

To add a new tab to the regions grid, click the **+** icon in the top right corner of the grid. Right-click the tab title and select Set Tab Title... to rename it.

Filtering Regions Results

Right-click the column header of any result and select Filter Editor... to open the Filter Editor tool. This tool allows for filtering of results to remove them from the regions output grid.

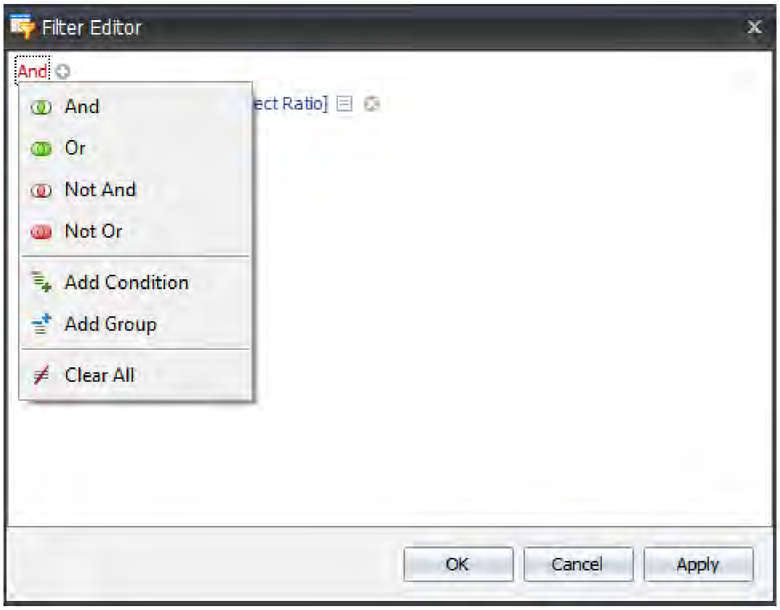
Multiple filters can be configured, and additional conditions can be added, to create a compound Boolean expression. The filter expression shown in the Filter Editor below is equivalent to the statement: (Circle Diameter > 5) AND ((Valley < -10) OR (Paraboloid Height < -5))

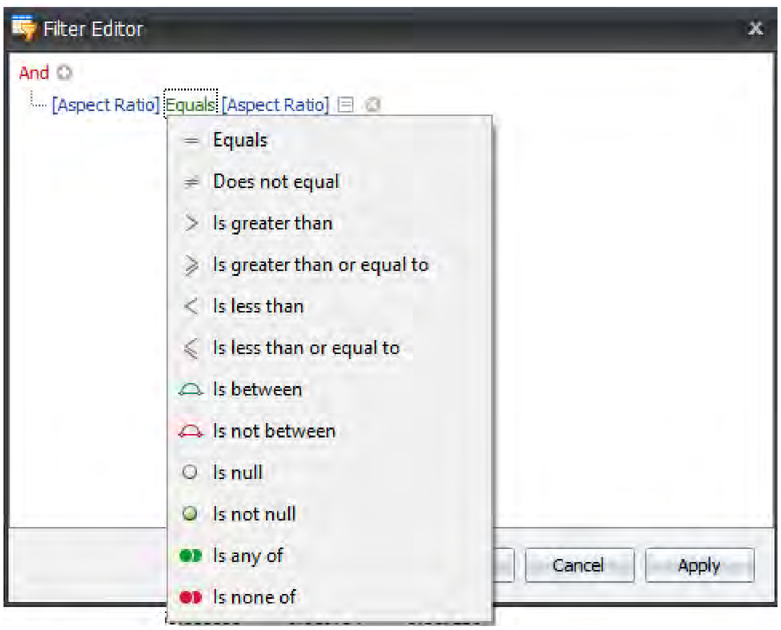


To add a new condition, select the (+) symbol in the desired group.

Right-clicking on a result and selecting Filter Editor automatically opens the Filter Editor and adds a condition which uses that result.

Point to an item in the Filter Editor and left-click to select and configure various options.





Regions Grid Data Output

The regions grid data can be output in several formats by using the toolbar buttons.

Additionally, Regions can be configured to automatically output results upon Measure, Analyze, or Load Data. In the output grid toolbar, enable the Auto Log function by clicking the check-mark, then click the … icon to configure the output filename. In the drop-down, select when the logging should occur (check all that apply).

For details on the output formats and File Name Options see Auto Save Options.

For details on automatic file naming see Auto Generate File Name Options.

Segmentation Controls

These are general segmentation controls.

Surface Pre-Processing...	Click this button to open the Sequence Editor and add a sequence that applies to data before it is passed into any Segmentation analysis. The sequence is activated using the adjacent check box.
Segmentation Mode	Selects how regions are determined. See Segmentation Mode.
Map To Use For Segmentation	Determines if segmentation should be done with input (Surface) data or Intensity data. When Intensity is selected, regions are still formed from Height Data, using pixels identified from Intensity data. Applicable when Segmentation Mode is Peaks, Z Relative, or Watershed.
Intensity Pre-Processing...	Click this button to open the Sequence Editor and add a sequence that applies to Intensity data before it is used to perform segmentation. The Segment Using control must be set to Intensity. The sequence is activated using the adjacent check box.
View Processed Intensity…	Click this button to open a plot window showing the (possibly processed) Intensity data used for segmentation.
Min Area (pix)	Any region whose unprocessed size is less than this value, is removed from the Regions list. Control must be activated with adjacent check box.
Max Area (pix)	Any region whose unprocessed size is greater than this value, is removed from the Regions list. Control must be activated with adjacent check box.
Region Processing...	Click this button to open the Sequence Editor and add a sequence that applies to each individual region, after segmentation. The sequence is activated using the adjacent check box.
Include Regions At Boundary	Determines whether or not regions touching the edge of the data set are included. When the check is cleared, any region touching the edge of the field of view is removed from the Regions grid.
Naming Order	Determines the order in which regions are named (i.e. given the label Peak 1, Peak 2, Peak 3, etc.). Default behavior (None) names regions from Largest to Smallest for most segmentation modes.
Show Region Labels	Determines whether or not to show text labels on the Regions input plot for each Region in the Region grid list.
Configure Outputs…	Opens a dialog which allows the user to configure how Regions are output to other portions of Mx.

Islands Specific Controls

These are controls specific to Islands segmentation.

An Island is a contiguous block of data entirely surrounded by empty pixels or the data outer border. A Void is a contiguous block of empty pixels entirely surrounded by data.

Reverse Data	When Checked, Islands segmentation identifies every void, rather than every island. Useful for characterizing holes.
Histogram Bins	Selects the number of bins to display in the calculated histogram. For Islands segmentation, this is for visual purposes only.
Islands Histogram	Shows a histogram of the distribution of Island sizes (in pixels). This histogram is intended as a visual aid.

Islands segmentation supports cluster and Cluster Distance controls.

Peaks Specific Controls

These are controls specific to Peaks segmentation.

Pre-Histogram Leveling	Determines what, if any, surface should be fit and removed from the data prior to histogram calculation. This control will change segmentation results, but does not modify the regions themselves. This control is enabled with the adjacent check box.
Histogram Bins	The number of bins into which to divide the histogram. A lower value will have a smoothing effect on the histogram, similar to the Histogram Smoothing control.
Histogram Smoothing	Performs smoothing on the calculated histogram with a low pass convolution filter (in units of histogram bins). Larger values perform more aggressive smoothing. Larger values can reduce the noise in the histogram and remove small local maxima. However, too large of a value can merge together nearby peaks and make segmentation more difficult.
Histogram	Displays the distribution of height values in the segmentation data. Red lines with labels indicate the found peak locations, and dashed lines indicate the dividing lines that form individual regions.
Expected Peak Count	The number of peaks to locate in the histogram. There will never be more regions than this number located, but there can be fewer if the histogram does not contain enough local maxima.
Minimum Peak Separation	The minimum distance (in Z) between located peaks. Peaks closer together than this will never be reported. Values too small will allow the Peak Finder to locate local maxima that are very close together.
Divide Peaks At	After peaks are located in the histogram, the histogram is divided to form regions. This control determines if the dividing lines are placed at the Lowpoint between two peaks, or the Midpoint.

Peaks segmentation also supports Sub-segmenting and Clustering.

Watershed Specific Controls

These are controls specific to Watershed segmentation.

Watershed Type	Determines if segmentation should look for positive or negative features. Dale segmentation identifies basins in the surface – areas that water will flow into. Hill segmentation identifies hills – areas that water will flow away from.
Wolf Pruning	A procedure by which small regions are merged into neighboring larger regions. A larger value will produce fewer, larger regions.

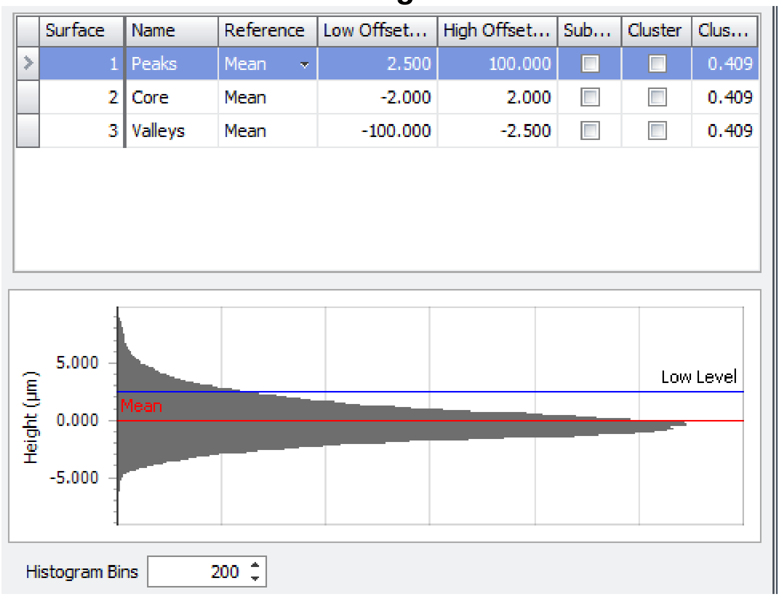
Z Relative Specific Controls

These are controls specific to Z Relative segmentation. Z Relative allows for the definition of a Reference surface using a located peak.

The available peak finder controls (Expected Peak Number, Minimum Peak Separation, Histogram Smoothing) work similarly to those described in the Peaks Specific Controls.

Pre-Histogram Leveling	Determines what, if any, surface should be fit and removed from the data prior to histogram calculation. This control will change segmentation results, but does not modify the regions themselves. The control is enabled with the adjacent check box.
Histogram Bins	The number of bins into which to divide the histogram. A lower value will have a smoothing effect on the histogram, similar to the Histogram Smoothing control.
Histogram	This plot (shown below) displays the distribution of height values in the segmentation data. Red lines with labels indicate the defined reference, and blue lines indicate high and low offsets.
Number of Surfaces	The number of user-defined surfaces, each of which defines a region. One row will be added to the Z Relative Table for each surface.
Z Relative Table	This table (shown below) is where Z Relative surfaces are defined. A number of rows equal to Number of Surfaces are populated. Each row must have a valid Reference, Low Offset, and High Offset to produce a region. Name, Sub-Segment by Islands, Cluster, and Cluster Distance are optional.

Z Relative Table and Histogram



Z Relative Table Reference

A Z Relative region consists of all pixels whose height values (after Leveling Method is applied, if relevant) fall within the band defined by the Low Offset and High Offset, relative to the selected reference.

To select a Reference options, click on the text under Reference in the Z Relative Table and select from one of the options:

> **Mean** The mean of the data.
>
> **Zero** Zero of the data. Equal to the mean if Piston, Plane, Cylinder, or Sphere are selected in Leveling Method.
>
> **Peak** The peak, or highest point, of the data.
>
> **Valley** The valley, or lowest point, of the data.
>
> **Rvk Threshold** The Reduced Valley Depth, calculated from the Bearing Ratio Curve.
>
> **Rpk Threshold** The Reduced Peak Height, calculated from the Bearing Ratio Curve.
>
> **Rk Midpoint** The Core Roughness, calculated from the Bearing Ratio Curve.
>
> **Peak Found N** A located peak in the histogram.

The reference for the currently selected (highlighted) surface is shown in red on the histogram plot. The High and Low Offsets are also indicated, in blue.

Regions may be optionally sub-segmented by Islands, with optional Clustering.

Regions Reference Controls

Reference	The Reference controls are active when the check box is selected. The reference region is a portion of the input data that is used to define the point of zero height for a test region.
Show on Input Map	When selected the reference is highlighted on the input plot for whichever test region is selected.

Reference Type	Determines if there is a single reference used for all test regions (One Reference For All) or an individual reference region calculated for each test region (Local Reference For Each Test Region). The value of this control influences the valid choices for "Define By…"
Define By	Selects the reference definition method. When Reference Type is Local Reference For Each Test Region, the valid choices are Mask and Auto Aperture. The reference will be defined relative to the test region via a user defined mask, or a configurable Auto Aperture. This process occurs automatically, effectively generating a unique reference for each test region. When Reference Type is One Reference For All, valid choices are: All, All Test Regions, All But Test Regions, Height, Size, Mask, Touching Center, Touching Edge. The reference is defined via the selected option for all test surfaces.
Reference Processing...	Click this button to open the Sequence Editor and add a sequence that applies to the reference surface. This allows for processing of the reference surface prior to the Reference Remove. The sequence is activated using the adjacent check box.
Configure Reference...	Click to open a Mask Editor for creating a Local Reference Mask. Visible only when "Define By: Mask" is selected, or Segmentation Mode is set to Masks Single Reference or Masks Multiple Reference.
Reference Processing...	Click this button to open the Sequence Editor and add a sequence that applies to the reference surface. This allows for processing of the reference surface prior to the Reference Remove. The sequence is activated using the adjacent check box.
Reference Remove	Selects the reference remove method. Choices are: None, Plane, Piston, Sphere, Cylinder, True Cone, or Higher Order. The indicated choice defines the surface which is fit to the reference surface. The fit surface is then removed from both the reference, and the test regions which correspond to that reference.
Remove Options...	Click to open a dialog used to select reference remove options, such as Higher Order, True Cone Options, Sigma Clip and Subsample Size.
Regions Processing Sequence	Determines when Region Processing is applied to test regions, relative to reference removal. Choices are: After Leveling or Before Leveling. When set to Before Leveling, Region Processing is applied to each individual region. Then, the reference is generated depending upon the selected Reference definition controls. When set to After Leveling, the reference is generated depending upon the selected Reference definition controls. Then, Region Processing is applied to each individual region.

Segmentation Examples

This section shows specific example uses for Regions using pre-existing data sets.

To download these data sets go to www.zygo.com/library/software/samples/

Islands, Scratch Analysis

Peaks, Step Height Calculation

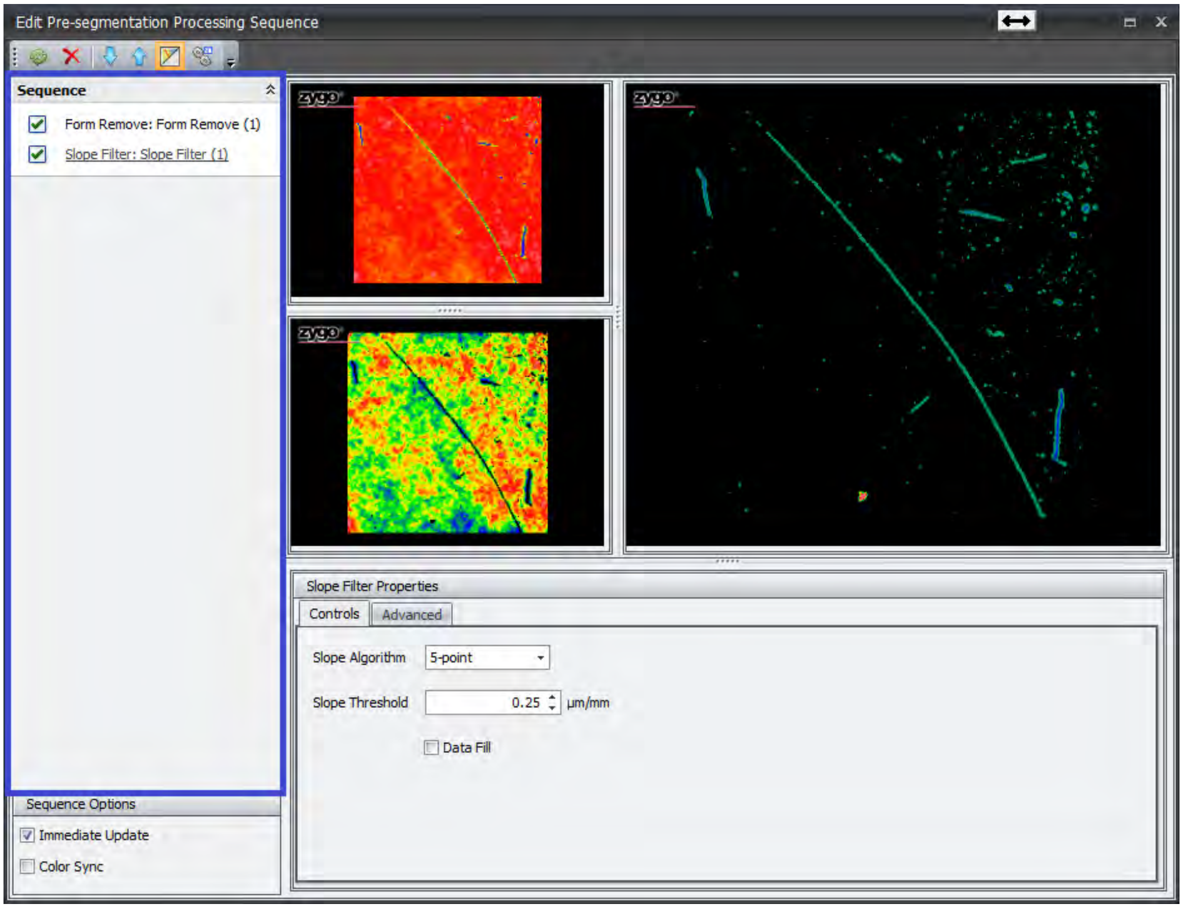
Watershed, Bacteria Study

Z Relative, Pits Analysis

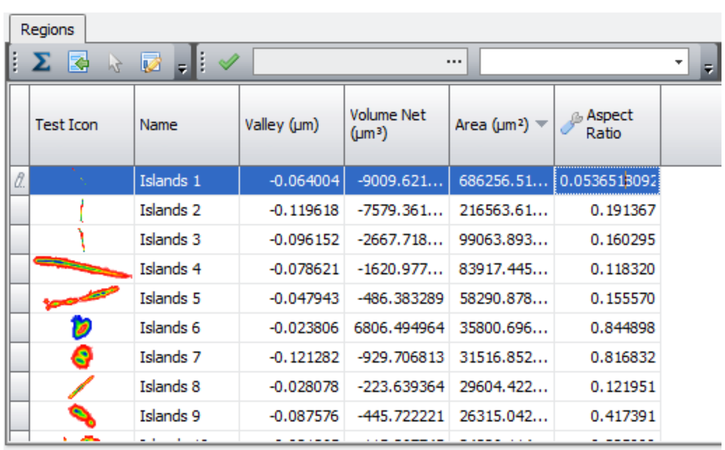
Islands, Scratch Analysis

This example uses Pre-Segmentation Processing and Islands segmentation to isolate and analyze scratches and defects in a smooth surface. Often, scratches will be too shallow to reliably segment using Peaks or Z Relative. This method uses the high local slope of defects to isolate them.

1. Navigate to Regions, and turn Segmentation On. Load the sample data set named ''Islands – Scratch.datx".
2. Enable Surface Pre-Processing. This processing sequence modify the data before it is passed into Regions analysis. In the Processing Sequence, right click in the Sequence box and add Form Remove and Slope Filter. (To aid in visualization, enable Plots on the top toolbar, and check Immediate Update in the lower left.)
3. In the Form Remove step, enable a 4th order Form Remove. This is used to remove any curvature from the surface. Another option would be to use a mild High Pass filter.
4. In Slope Filter, set Slope Algorithm to 5-point, Slope Threshold of 0.25 µm/mm, and on the Advanced Tab, select Output Clipped Data. This configures the Slope Filter to remove any data points which have a slope less than 0.25 µm/mm – which nicely isolates scratches and defects. Change the value of Slope Threshold and see the effect on the output data. Note how values ranging from ~0.15 to 1 produce reasonable outputs. This is reassuring- it means the scratches are much higher slope than the bulk of the surface, which will make this method more robust.



5. Exit Pre-Segmentation Processing and set Segmentation Mode to Islands. This will produce a list of ~20 regions representing the different islands of data.
6. In the Regions grid, add the results Valley, Volume Net, Area, and Aspect Ratio.
7. Note how the result Aspect Ratio has a wrench icon on the column header. This icon indicates that the result has configurable options. Right click the column header and select Set Aspect Ratio Options. Enable Show Aspect Ratio Windows and close the window. This will display the minimum enclosing rectangle used to calculate the aspect ratio of the region. Results which involve fitting circles, rectangles, ellipses, ridgelines, and more are all configurable to display the best fit shape.


Regions

Test Icon	Name	Valley (µm)	Volume Net (µm³)	Area (µm²)	Aspect Ratio
	Islands 1	-0.064004	-9009.621...	686256.51...	0.0536513092
	Islands 2	-0.119618	-7579.361...	216563.61...	0.191367
	Islands 3	-0.096152	-2667.718...	99063.893...	0.160295
	Islands 4	-0.078621	-1620.977...	83917.445...	0.118320
	Islands 5	-0.047943	-486.383289	58290.878...	0.155570
	Islands 6	-0.023806	6806.494964	35800.696...	0.844898
	Islands 7	-0.121282	-929.706813	31516.852...	0.816832
	Islands 8	-0.028078	-223.639364	29604.422...	0.121951
	Islands 9	-0.087576	-445.722221	26315.042...	0.417391

8. There are several ways to filter this output data. Perhaps a scratch is only a concern if the area, length, or depth are above a certain value. Further, filtering on aspect ratio will limit the reported results to scratches, and not digs. See Filtering Results.

Peaks, Step Height Calculation

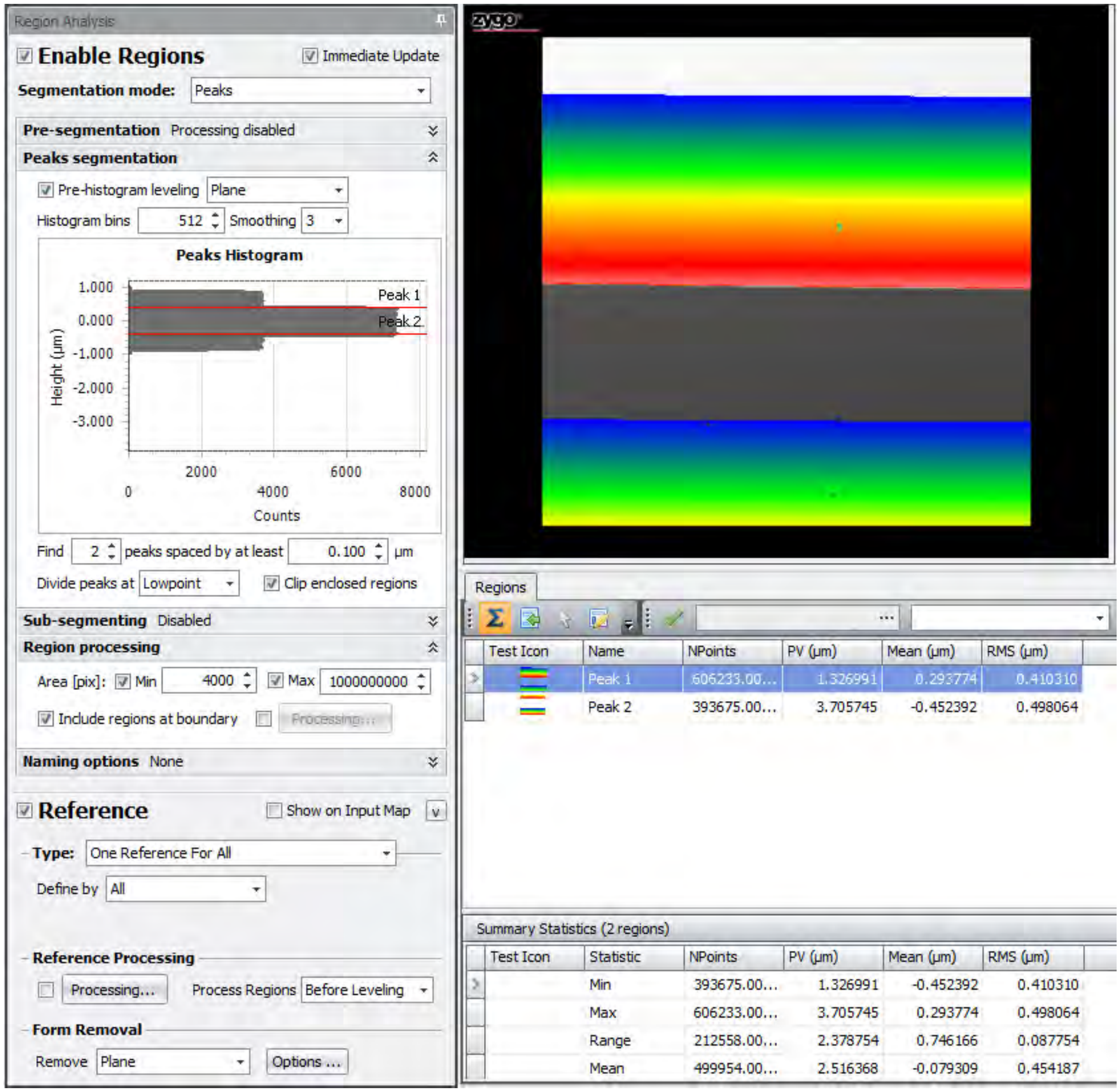
Measuring a step height is a common application, whether for verification of tool performance or as metrology in its own right. Regions allows for precision, automated step height measurement utilizing the full area of the measurement and requiring no operator interaction. This gives it an advantage in repeatability and precision over other methods of data analysis. In this example, Peaks segmentation is used to calculate a step height on a step height standard, and a more complex surface.

Basic Step Height Setup

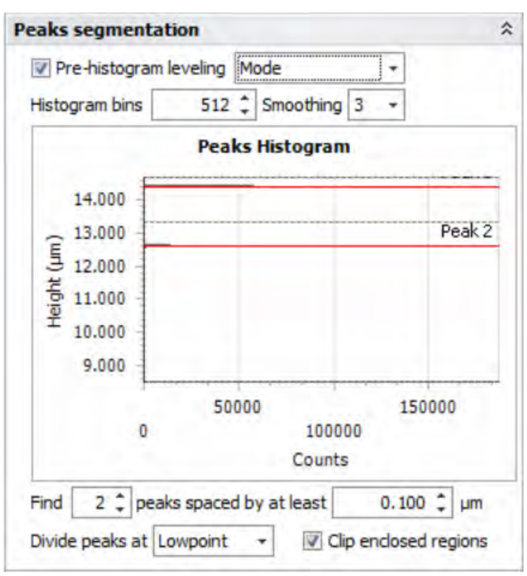
The goal here is to create a test region whose Mean result will be the value of the step height. This measurement should be unaffected by edge effects near the step transition, and remove any debris or damage on the top and bottom surface.

1. Begin by loading the sample data set named "Peaks - Step Height.datx". Navigate to Regions, and turn Segmentation On.
2. Set Segmentation Mode to Peaks.

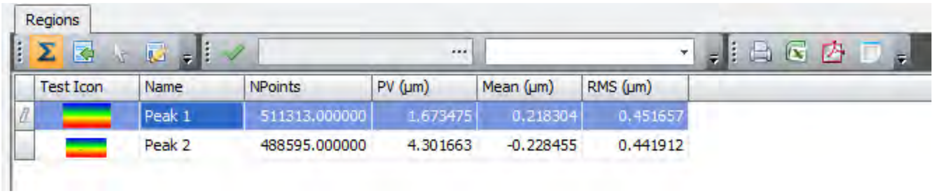
   Since the Pre-Histogram Leveling is set to Plane, the step height is being leveled into a sawtooth shape. This is evident in the Peaks Histogram plot, which doesn’t exhibit the two sharp peaks that we’d expect. This is a common mistake when performing step height analysis.



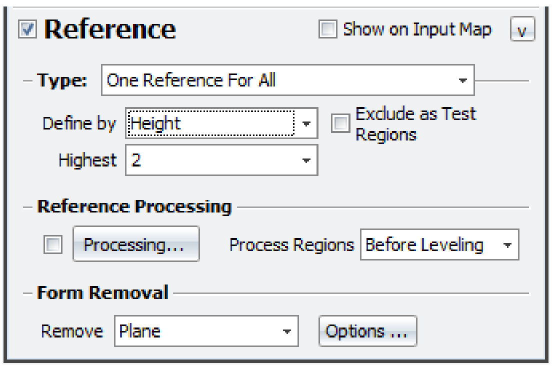
3. Set the Pre-histogram Leveling control to Mode. Mode leveling will attempt to find the most dominant slope in the surface and remove that. This should level the step height. In some cases, Piston (or None) will provide satisfactory results as well. The histogram should now contain two very narrow, sharp peaks – these correspond to the two levels of the step height.



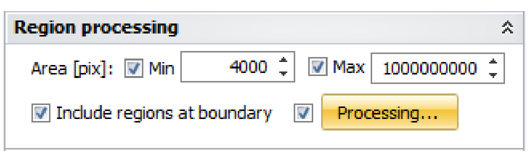
4. In this case, the default values for the Expected Peak Count (2) and Minimum Peak Separation (0.1 µm) are appropriate for the surface. As a general rule, Minimum Peak Separation should be set to 20 – 80% of the nominal step value, to prevent the Peaks analysis from incorrectly locating two peaks very close to each other. There should be two regions in the Regions grid. Notice that each individual region is tilted, and the values given in the Mean column aren't very meaningful.



5. The next step is to properly level the test regions by appropriately defining a reference. The reference surface must be defined as the lower surface of the step. In Reference Options, set Define By to Height. Also for Highest choose 2. Now that we've defined the second highest surface as the reference, the test regions are properly leveled.

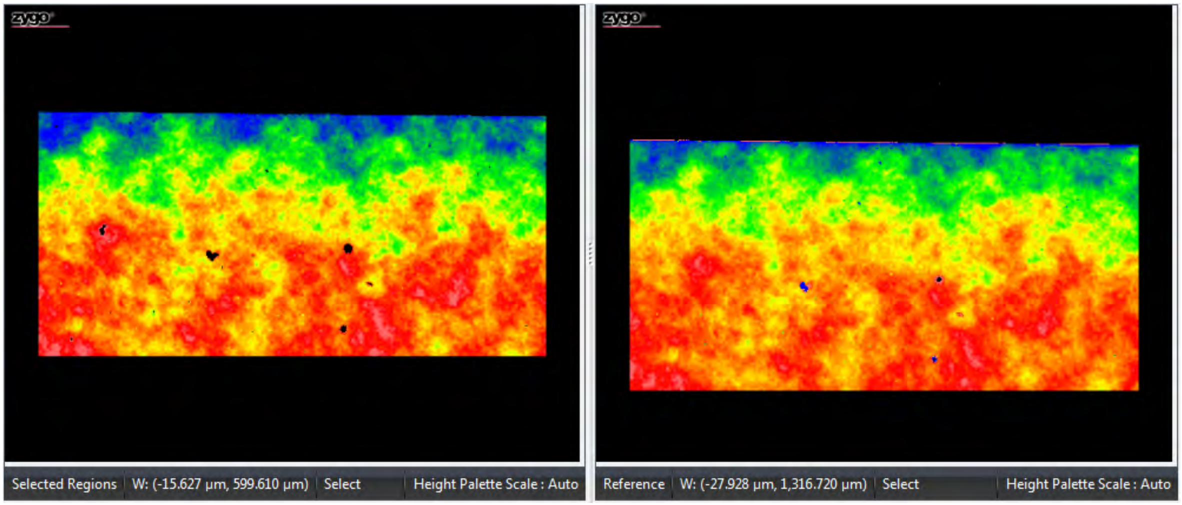


6. However, it's clear that the transition region of the step is affecting our data, and there are numerous surface defects that should be removed from our analysis. We can solve both problems with Region Processing. Select the check box next to Region Processing and open the processing sequence.



7. In the Sequence screen add an Edge Trim step and a Spike Clip step. In this case, an Edge Trim of 10 pixels, and a Spike Clip performing Sigma Clip at 3-sigma is sufficient to clean up the step surfaces.

8. While the test regions have been processed, the Reference has not. Note that the reference and the region that it was created from are no longer the same. This is because Test Processing is set to After Leveling. Change Test processing to Before Leveling; this will generate the reference after any Region Processing is applied. Another option would be to create a Reference Processing sequence which mirrors the Region Processing sequence – but in this case, changing the Test Processing control is simpler.

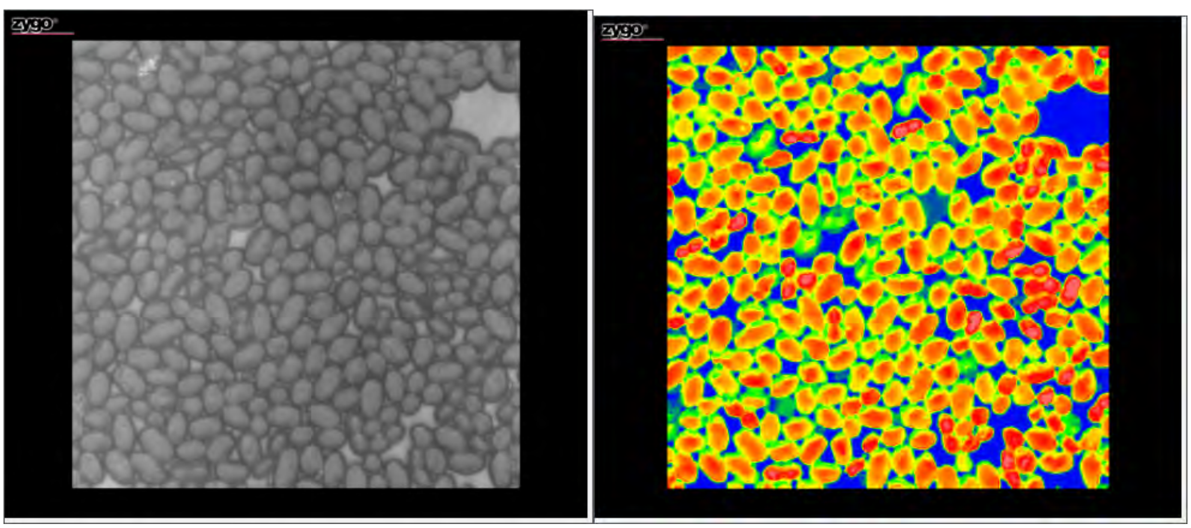


9. *Optional*: The Exclude Reference control will remove the reference region from the Regions list. This can be useful to isolate only regions whose values are of interest.

We now have an analysis that will automatically segment a step height standard measurement into a test and reference region. The Mean result will be a stable, repeatable measure of the step height – with no operator influence.

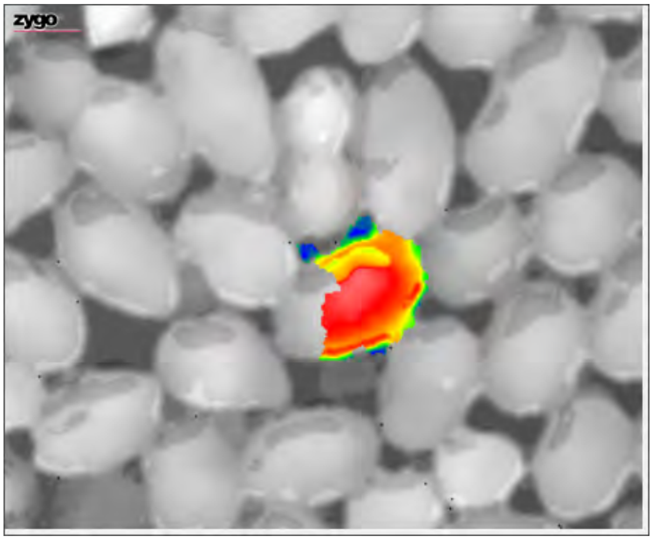
Watershed, Bacteria Study

This example uses watershed segmentation to locate bacteria cells on a glass slide. Many of the features are touching, and would be quite difficult to segment with a mode like Islands or Peaks. The intensity (left) and height (right) data are shown below. In the case of this data set, we can perform watershed segmentation using either height (Surface) data, or Intensity data. In each case, the features are individually visible and have a strongly contrasting border.

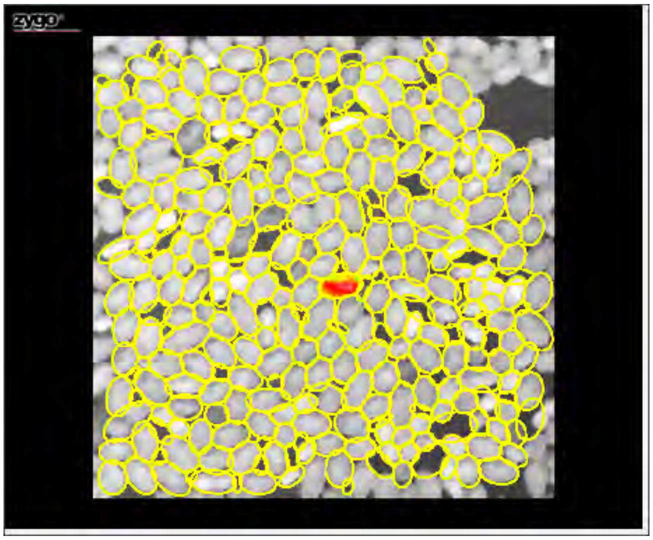


1. Navigate to Regions, and turn Segmentation On. Load the sample data set named ''Watershed – Bacteria.datx".
2. Set the Segmentation Mode to Watershed. Watershed segmentation attempts to locate catch basins. Imagine the surface as a landscape, flooding in a rainstorm. Watershed segmentation locates regions that form unique drainage points for the water, separated along the ridgelines between them.

3. The first thing to recognize the center of each feature is brighter (in intensity) or higher (in height) than its border. This means that we want to find locations that water flows from, not toward, on the surface. To do this, switch the 'Watershed Type' control from the default Dale to Hill. The default setting provide surface that is well segmented. However, many of the features are split in half (oversegmented). Additionally, the glass substrate is included, as well as partial features touching the edge of the image.



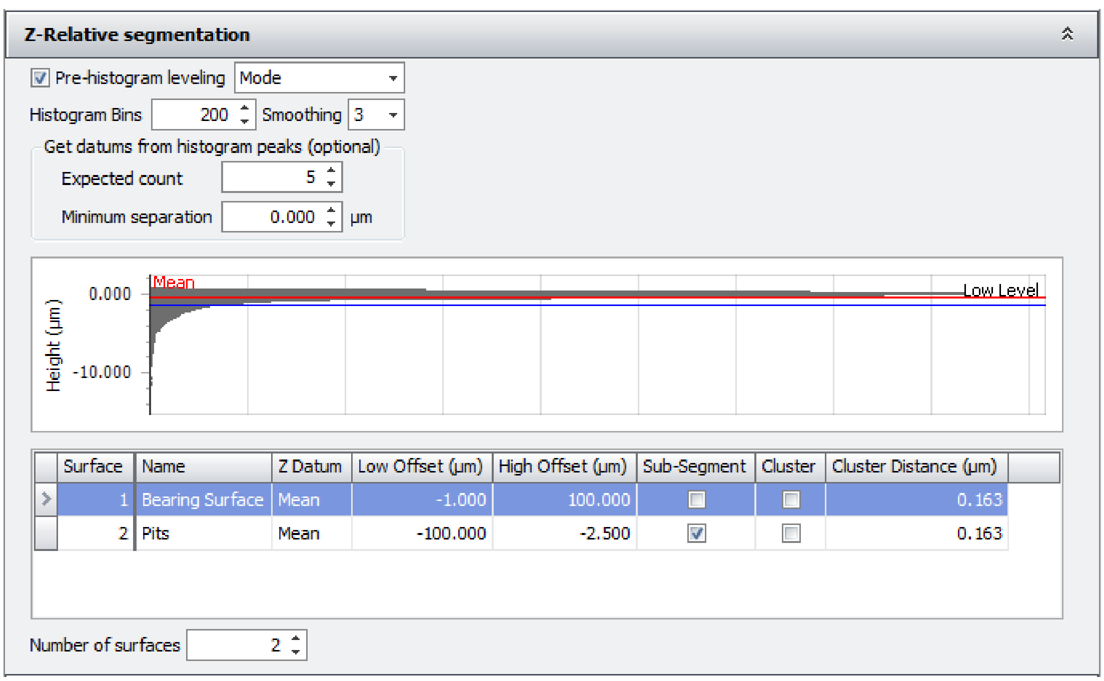
4. To remedy this, adjust the degree of segmentation with the Wolf Pruning control. Increase Wolf Pruning from 5% to 10% in 1% increments, viewing the effect on the number of regions. As the Wolf Pruning value increases, less regions will be located. At 10%, most of the bacteria are properly separated from the background.
5. Next, we can perform filtering on the Mean result to remove the glass substrate, which will always be lower than the bacteria sitting on its surface. Apply a filter Mean > -0.2 µm. Additionally, filtering on Area (pixels) to be between 500 and 10000 will remove most other spurious regions.
6. Unchecking "Allow Touching Edges" will remove the partial features cut by the edge of the field of view.
7. Useful results for characterizing these features are Moments Ellipse values. These values can provide the major and minor diameter, as well as the eccentricity, of each feature. The peak result will give a measure of the height of each cell, providing full 3-D statistical results.
8. This segmentation is not perfect, some features are merged together, and others are excluded. Experiment with segmenting on Intensity (with Intensity Pre-processing) and Height, as well as the Wolf Pruning value, to see if it can be improved.



Z Relative, Pits Analysis

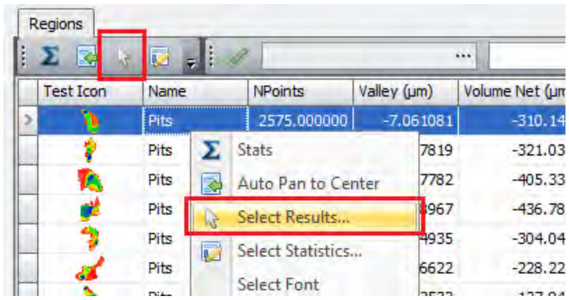
This example demonstrates using Z Relative segmentation to manually control which data is used for the generation of test regions. The goal of this analysis is to produce a list of pits in the surface of a ceramic bearing surface, to analyze Volume, Area, and Count.

1. Begin by loading the sample data set named "Z Relative – Pits.datx".
2. Navigate to Regions and turn Segmentation On.
3. Turn Segmentation On, and set Segmentation Mode to Z Relative.
4. The key to Z Relative segmentation is selecting the Number of Surfaces properly. In this case, our data consists of a flat bearing surface pock-marked with pits. Set Number of Surfaces to 2, and configure the controls as shown here.

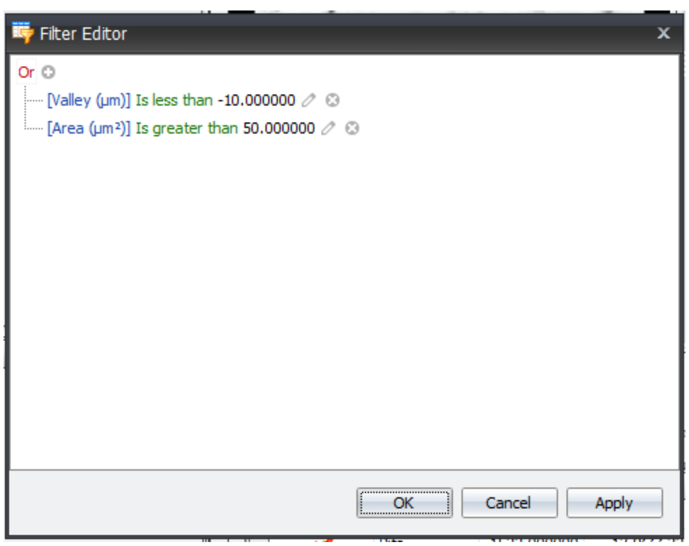


The upper surface is defined as everything from -1 micron, to 100 microns, relative to the mean of the entire data set. The lower surface, named Pits, is everything deeper than -2.5 microns from the mean. By additionally sub-segmenting by Islands, we create a test region for each pit. Note how the results change as the value of the Surface 2 High Offset is changed. As the offset value approaches 0 (the mean), the pits will grow and merge together. A lower value will reduce the size and number of located regions.

5. Next, configure the Reference as the Top surface – either by Size or by Height, and exclude it from the test results. For more details on defining the reference, see the Peaks, Step Height Calculation example.
6. Configure the results grid to contain relevant results for pits analysis. Select the Select Items icon from the toolbar, or right click in the results grid and choose Select Items.



7. In the resulting dialog, find the results 'Valley', 'Volume Net', and 'Area'. Add them to the results by checking the box next to each result and selecting OK. Results can additionally be filtered.
8. Right click any column header and select the Filter Editor. Filters for multiple results can be added and configured in the Filter Editor dialog. This allows for the selection of only pits which are above a certain size, or deeper than a threshold value. Note the selection of the "Or" logical condition in the top left, rather than the default of "And".



9. Results can also be output to Excel or other statistical analysis software for further analysis or presentation. See Regions Grid Data Output.

Slopes

ANALYSIS tab, Navigator : Surface : Slopes

This view shows the slopes analysis. Slope is the local gradient, evaluated over a specified integration length, at each pixel or super-pixel, and is often used to highlight obscured defects. Slope can be interpreted as the difference between slope of the theoretical surface and the measured slope. Gradients are calculated in X and Y and combined to yield a magnitude and direction.

The analysis has 3 sections- Slope X, Slope Y, and Slope Magnitude. Each section shows a 2D plot, a histogram, and numeric slope results.

For descriptions of results see Slope Results.

Why Use Slopes?

- Slopes provide a visual representation of the relative gradients in the surface or wavefront.
- Visually highlight small defects that may be hidden by the overall surface or large errors.
- Slope error is commonly used by optics manufacturers as an indicator of finish quality.
- Slope specifications may also be used as optical tolerances. Care must be taken to always specify slope tolerance in combination with spatial resolution and integration length. In addition the preferred algorithm (or derivative) should be specified.

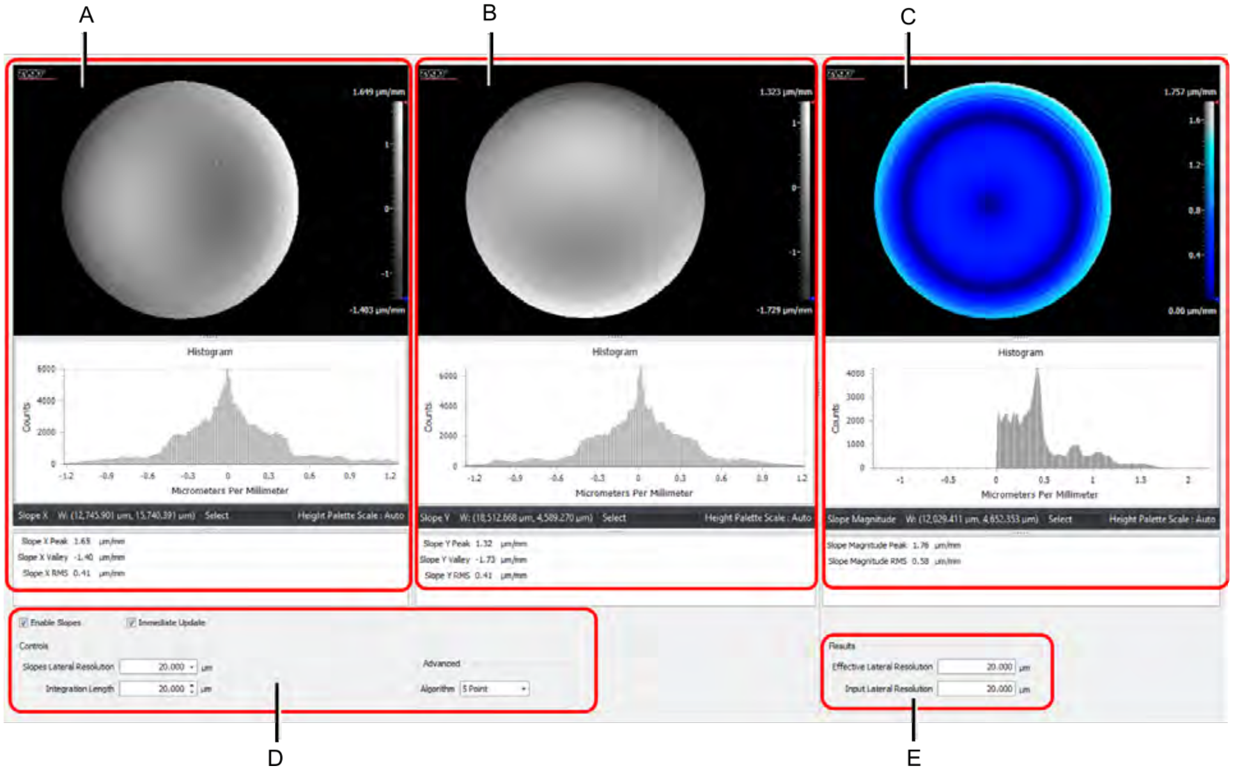
Use Conditions

- Applies to all instruments, both laser interferometers and optical profilers.
- Lateral calibration is required to display slope results; without calibration only slope maps are calculated.

The Slopes Screen

Select the Enable Slopes check box to activate.

Select the Immediate Update check box to display the impact of the settings after each change without pressing the Analyze button.



A. Slope X (gradient in the x-axis) analysis with a 2D plot matrix, histogram, and results. **B.** Slope Y (gradient in the y-axis) analysis. **C.** Slope Magnitude (gradient in both x and y axes) analysis. **D.** Slopes controls. **E.** Slopes results.

Choosing Slope Results to Display

1. Point to a Slope results area in either Slope X, Slope Y, or Slope Magnitude.
2. Right-click and choose Select Items.
3. Select the result check boxes to display and clear check boxes of results to hide.
4. Click OK.

Slope Fundamentals

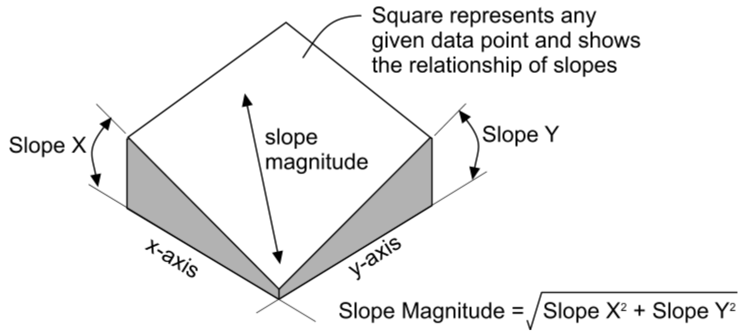
Slope X

Displays slope information occurring in the x-axis. Each data point is determined by comparing the values of data points in the x-axis. X-axis slopes are highlighted by what appears to be a light source to the left of the plot.

Slope Y

Displays slope information occurring in the y-axis. Each data point is determined by comparing the values of data points in the y-axis. Y-axis slopes are highlighted by what appears to be a light source below the plot.

Slope Magnitude



Displays information about slopes occurring in both x and y axes. The areas of steepest slope appear the brightest regardless of whether the slope is positive or negative, while areas of least slope appear darkest. Only the rising and the falling edges (areas of steepest slope) of wavefront features are shown.

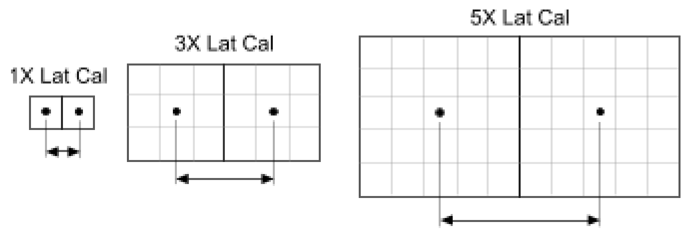
Slopes Controls

Lateral Resolution

Selects the lateral distance or spatial sampling resolution on the surface to treat as one pixel (or super-pixel).

The default and minimum value is equal to 1 times the lateral calibration. The choices in the pull-down menu are defined by odd pixel increments, but are displayed in real units if laterally calibrated.

A super-pixel is equal to the mean height of the combined camera pixels. The spatial sampling resolution is indicated by the arrows in the drawing below.



This control *does* affect the displayed slope maps.

Integration Length

Specifies the lateral distance on the surface over which the slope is averaged for each pixel result.

The integration length does not have to be an exact multiple of the effective lateral resolution; slope values are calculated for exact integration lengths above and below the user input value and reports values associated with the integration length that has the higher rms slope.

Algorithm

Selects the Slopes processing algorithm. Choices are 3 Point or 5 Point. This is the evaluation length commonly referred to the ISO standard.

3 Point- Uses adjacent pixels or super pixels (p i-1, p i+1) to calculate the X-slope or Y-slope at the *i*th pixel. The measured aperture is reduced by a 2 point-wide margin.

5 Point- Uses a line of 5 pixels or super pixels (p i-2, p i-1, pi, p i+1, p i+2) to calculate the X-slope or Y-slope at the *i*th pixel. The measured aperture is reduced by a 4 point-wide margin.

This control *does* affect the displayed slope maps.

Slope Terms Illustrated

Figure A

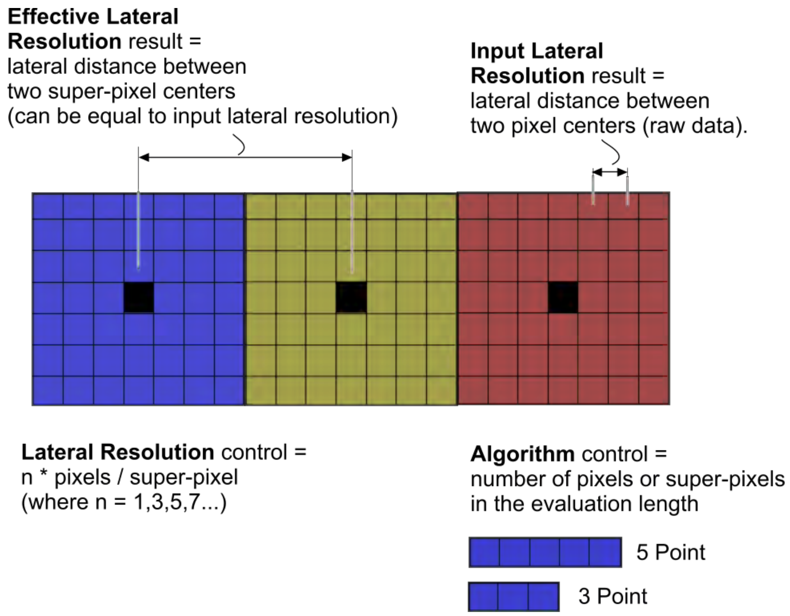
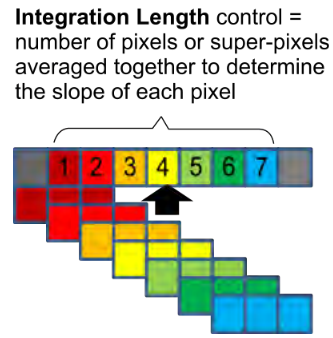


Figure B



Notes for Figure B

Shows a the 3 Point algorithm, or derivative.

Square 4 is the pixel or super-pixel for which slope is calculated.

Each pixel or super-pixel is used in the calculation of 3 "raw" slopes (except the first and last, which are each only used in 2 calculations). For example, the height of pixel number 4 is used in the calculation of slopes for each of pixels 3, 4, and 5; "raw" slopes are then averaged to calculate the average slope over the integration length.

Surface

ANALYSIS tab, Navigator : Surface : Surface

This view shows the measured surface. This view serves as the main screen on which additional examination can be performed.

For more information on features within this view see the item by name, such as 2D Plot, 3D Plot, Surface Processing, PSD Analysis, or Slope Analysis.

Zernike

Navigator : Surface : Zernike

This view shows plots, Zernike fit coefficients, and Seidels. Zernike polynomials are a sequence of polynomials that are orthogonal on the unit disk (circle) and are used to mathematically model circular wavefronts with aberrations.

For descriptions of results, see Zernike Results and Seidels.

Use Conditions

- Applies to all instruments, both laser interferometers and optical profilers.
- Appropriate for circular apertures.
- Either Zernike Fringe (ZFR), Zernike Standard (ZRN) or Zernike Annular (ZAR) fit results can be displayed, output (in print, pdf, or Excel form), and exported as coefficients.
- The number of coefficients displayed depends on the Order selection.
- The incoming data may have Data Processing functions applied, such as Fit Remove, Edge Trim, or Spike Clip.

Appropriate Data for Zernike Analysis

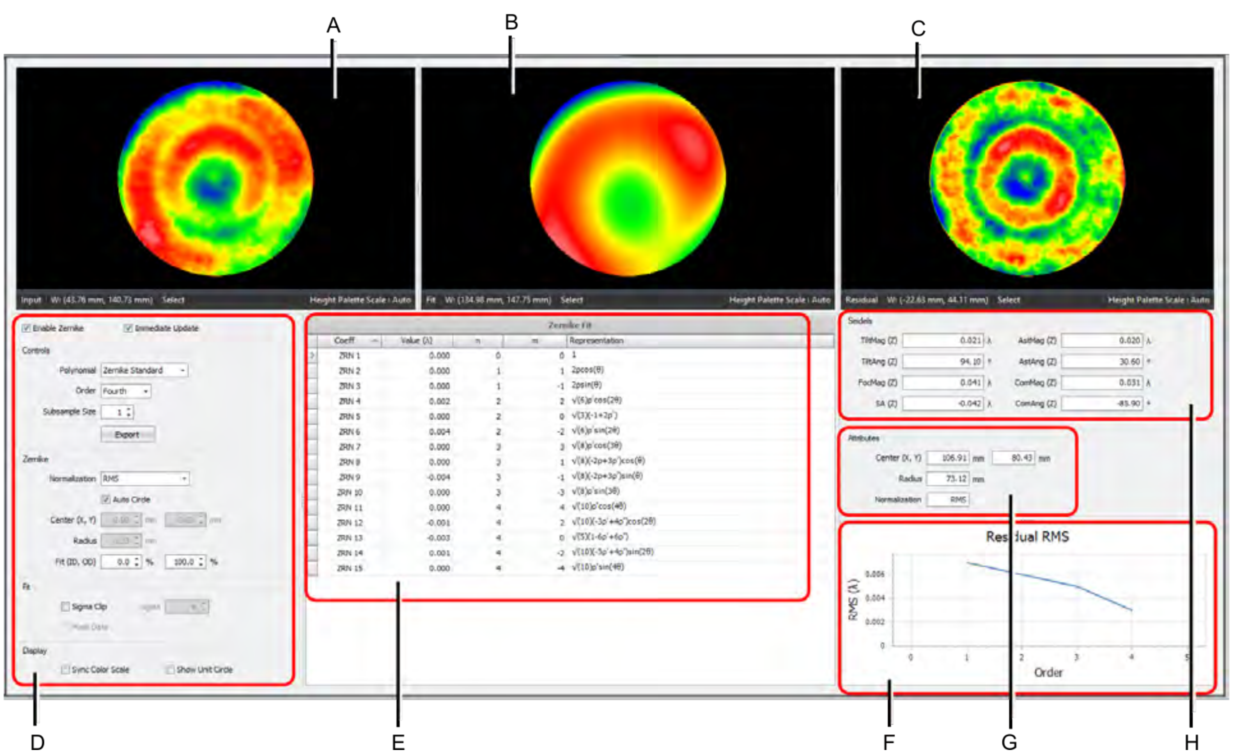
Zernike polynomials apply to a circular domain for continuous functions. When the domain (data) becomes non-circular in any way, or the data is less continuous and more pixelated (small number of data points), the fitting process is no longer orthogonal and strange/inconsistent results can occur. One method of mitigating this is to reduce the order of the fit to the minimum that provides the polynomial terms of interest.

The Zernike Screen

Select the Enable Zernike check box to activate.

Select the Immediate Update check box to display the impact of the settings after each change without pressing the Analyze button.

It is recommended to select the Sync Color Scale check box to aid in the visualization of Zernike fit.



A. Input plot (shows data input from any existing processing). **B.** Fit plot (shows the calculated fit surface). **C.** Residual plot (shows what remains after the Zernike fit is removed from the input data). **D.** Controls. **E.** Zernike Fit coefficients table (the type displayed is determined by the Polynomial control, the number displayed is determined by the Order control). **F.** Residual RMS plot (shows the residual RMS at each active Zernike order). **G.** Attributes about the Zernike fit. **H.** Seidels results.

Zernike Fit Table

The Zernike Fit coefficients table shows each term of the Zernike fit. The actual content is determined by the Polynomial and Order controls. It is used to view individual terms and to output terms as ZFR or ZRN coefficients to other optical programs (i.e. CODE V).

When Polynomial is Zernike Fringe, the terms start at ZFR 0 (up to ZFR 36). When Polynomial is Zernike Standard, the terms start at ZRN 1 (up to ZRN 91). When Polynomial is Zernike Annular, the terms start at ZAR 0 (up to ZAR 36).

References for Zernikes

ISO 10110-5 : Optics and photonics -- Preparation of drawings for optical elements and systems, Part 5 (surface form tolerances).

Malacara, Daniel; Servin, Manuel; and Malacara, Zacarias. "Interferogram Analysis for Optical Testing."

Born, Max and Wolf, Emil. "The Diffraction Theory of Aberrations." Chapter 9 in Principles of Optics: Electromagnetic Theory of Propagation, Interference, and Diffraction of Light, 6th ed. New York: Pergamon Press, pp. 459-490, 1989.

Malacara, Daniel. "Optical Shop Testing."

Eric W. Weisstein et al., "Zernike Polynomial", at www.MathWorld.com.

Using the Zernike Analysis

For information on	See...
Controls	Polynomial and Order
Zernike Fit table	Polynomial Table, Zernike Results, Working With Tables
Seidels	Seidels
Advanced settings	Sigma Clip Function, Zernike Normalization, Zernike Auto Circle Function
Exporting fit coefficients	Exchanging Coefficients

Outputting or Exporting Zernikes

1. Select data in the table. See Selecting Table Data.
2. Right-click and select an output option.

The selected Zernike Fit table contents can be copied to the clipboard using Ctrl-C and then pasted into other programs.

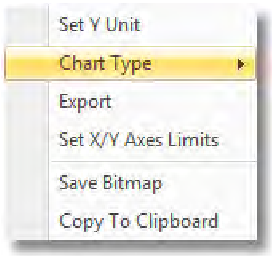
Residual RMS Plot

This plot shows the residual RMS value for a given Zernike or Legendre order.

Changing the Residual RMS Plot

To change the number of data points, select a different Order.

To change the plot, right-click on the plot and bring up the context menu.



Set Y Unit	Select to change the units for the (vertical) y-axis. See Setting Individual Units.
Chart Type	Select to change the way data is displayed. See Chart Type.
Export	Select to export underlying numeric data in another format. See Export Chart Data.
Set X/Y Axes Limits	Set the minimum and/or maximum values displayed on the x-axis or y-axis. See Axes Limits.

Understanding Zernikes

Named after Frits Zernike, the Zernike “polynomials” are a set of functions that correspond both to canonical manufacturing aberrations in optical elements and to canonical optical aberrations in transmitted light. They allow most real-world optical forms to be represented merely as a short string of coefficients. Consequently, Zernike polynomials play an important role in geometrical optics.

In addition to their convenient shapes, they have convenient mathematical properties that provide for fast, simple, and accurate analysis of optical surfaces and wavefronts:

1. They are independent (orthogonal) when used over a circular-shaped domain.
2. They are relatively simple to compute, being nearly polynomial in form.
3. They are complete – any well-behaved function can be exactly described by a series of weighted Zernike polynomials, with fairly quick convergence.
4. The above expansion is unique for functions defined over a circle.

Users of Zernike polynomials should note that orthogonality and uniqueness are only guaranteed over a circular or disk domain. Any holes in the domain, such as missing data points, break these properties.

Common Applications of Zernike Polynomials

- Precision optical manufacturing, to characterize low-order errors observed in interferometric analyses.
- Adaptive optics, to effectively cancel out atmospheric distortion with minimal computation.
- Zernike files are compatible with the Fringe Zernike (ZFR-type) interferogram (.INT) format developed by Optical Research Associates as used in CODE V software.
- Zernike polynomials are included in the ISO drawing standard for optical surfaces (ISO 10110).

See Also

Zernike Definitions

Zernike Sample Images

9.2 Laser Interferometer Analyses

This section describes analyses that are specific to the laser interferometer.

Diffraction	Analyze the imaging performance of an optical system, with features such as MTF and PSF.
ISO 10110-5	Provides standardized surface form tolerances.
Legendre	Analyze the surface using Legendre polynomials.
PVr	Provides detailed PVr or Robust Peak-to-Valley analysis.
Sub-Aperture	Use to examine the input data with a series of smaller apertures.
Zernike	Analyze the surface using Zernike polynomials.

See also Common Analyses.

Diffraction

Navigator : Surface : Diffraction

This view shows diffraction calculations that describe the imaging performance of an optical system, and includes PSF, MTF, EE, and Strehl Ratio. When evaluating the transmitted wavefront of an optical system these analyses enable the user to qualify the optical system at a single field point for imaging performance through a circular exit pupil. These results can be compared and contrasted with the predicted performance of the analog calculations in ray-trace design code at the equivalent wavelength.

For descriptions of results see Diffraction Results.

Included Analyses

- Point Spread Function or PSF.
- Modulation Transfer Function or MTF.
- Encircled Energy or EE.
- Strehl Ratio.

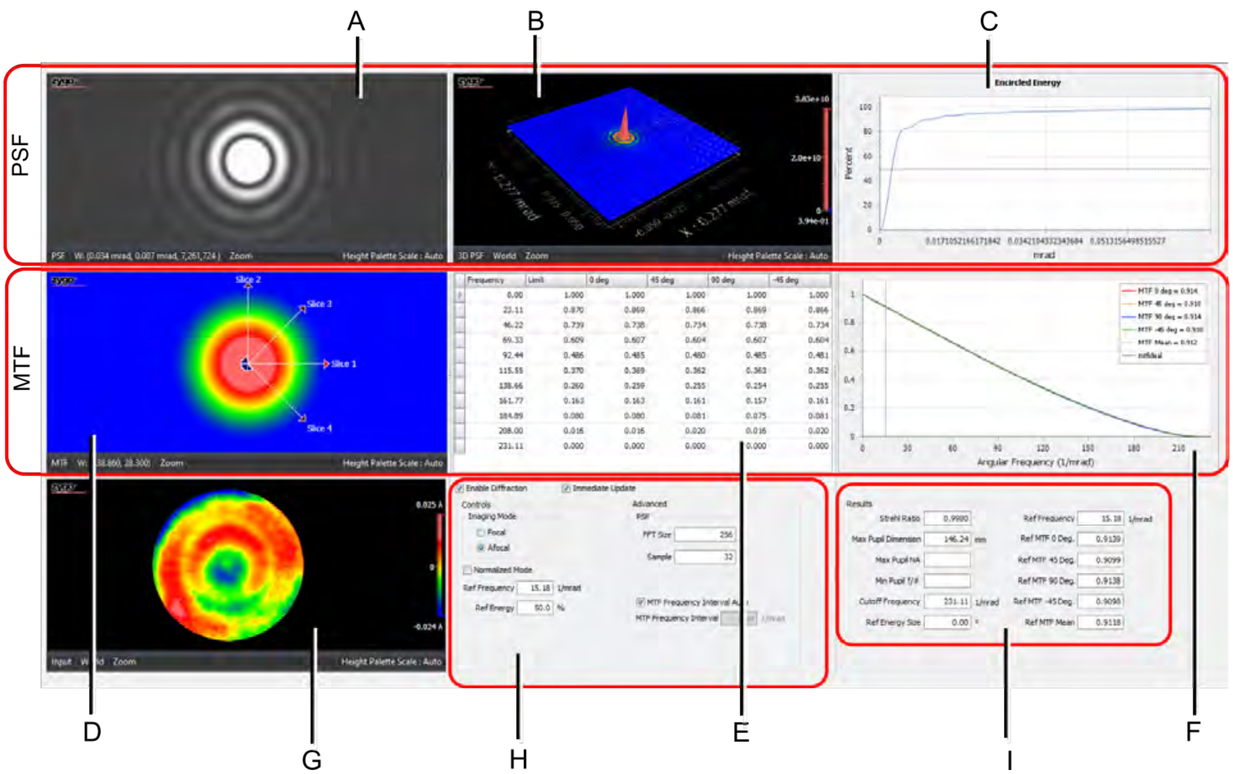
Use Conditions

- Applies to laser interferometers.
- Applies to transmitted wavefront testing.
- (Recommended) Enter the Numeric Aperture or TS f-number of the lens. If necessary, these controls can be added to a Control grid.
- Lateral calibration required.
- Units are based on whether the modeled system is Focal (PSF: mm, MTF: cycles/mm) or Afocal (PSF: mrad, MTF: cycles/mrad).

The Diffraction Screen

Select the Enable Diffraction check box to activate.

Select the PSF Mode; for *Focal* enter the Exit Pupil NA value; for *Afocal* a diameter value is automatically determined based on the maximum inscribed circle of the laterally calibrated input data.



A. PSF 2D plot. **B.** PSF 3D plot. **C.** Encircled Energy plot. **D.** MTF 2D plot. **E.** MTF table. **F.** MTF profile plot. **G.** Input plot (shows input data). **H.** Settings and controls. **I.** Diffraction results.

References for Diffraction Analysis

Warren J. Smith, “Modern Optical Engineering: The Design of Optical Systems,” 2nd Edition, McGraw-Hill, 1990.

Joseph W. Goodman, “Introduction to Fourier Optics,” 2nd Edition, McGraw-Hill, 1996.

Glenn D. Boreman, "Modulation Transfer Function in Optical and Electro-Optical Systems," SPIE Press Book, 2001.

Diffraction Controls

Imaging Mode	Select to match the design of the lens under test. It also determines the lateral units for PSF and the frequency units for MTF. Focal units are cycles/mm and Afocal units are cycles/mrad. A Focal lens converges (or focuses) the beam to a spot. An Afocal lens produces no net convergence or divergence of the beam.
Normalized Mode	When the Normalized Mode check box is selected the frequency domain of the MTF slice plot is normalized so that the cutoff frequency is 1. When this is used output plot x-y units are removed.
Ref Frequency	Specifies the analysis frequency for Ref MTF results. If the number entered appears as a dotted vertical Ref Frequency inspector line on the MTF profile plot. See MTF and Using Ref Frequency.
Ref Energy	Reports and sets the position on the percentage axis on the Encircled Energy plot where the Ref Energy Size result is calculated. See Using Ref Energy.

Diffraction Advanced Controls

FFT Size and Sample values pertain to pre-processing that is performed upon the input data. Before diffraction results are calculated, the data is resampled and padded with empty space. This is done to laterally zoom the PSF plot.

These controls are for the advanced user with optical design background. Reasonable default settings are automatically entered based on the input data. See Diffraction Example.

FFT Size	Specifies the size (number of rows and columns) of the 2D array upon which the FFT is performed. All of the space that is larger than the FFT Size is populated with zeros before performing the FFT.
Sample	Specifies the number of samples taken across the width of a minimum circle enclosing the data when the resampling is performed. It is the number of rows and columns in the grid of resampled data. The input data is either reduced or enlarged to this value before being “padded” with zeros out to the amount specified by FFT Size.
MTF Frequency Interval	Specifies the numbering interval displayed in the MTF table. Select the MTF Frequency Interval Auto check box to automatically determine the interval.

Other Controls

These controls are available to add to a Control grid.

Numeric Aperture	Specifies the numerical aperture for a focal lens in the Diffraction analysis. The default value is 0.5. Numeric Aperture and TS f-number are linked; when one value is entered, the corresponding value is calculated.
TS f-number	Specifies the f-number of the transmission sphere in the Diffraction analysis. The f/# of an optic is a number expressing the ratio of its focal length to the diameter of its aperture. The default value is 1. Linked with Numeric Aperture.

Diffraction Example

An optical system's PSF is calculated by performing an FFT upon the complex wavefront emerging from the system. A PSF generated in this way usually looks tiny. For a perfect system with a circular aperture, the PSF is practically zero everywhere except a cluster of maybe 5 pixels at the center of the window. Diffraction analysis applies an interpolation scheme that allows the user to increase apparent (but not actual) lateral resolution in either the MTF or PSF plot, to increase computational speed, and to ensure lateral near-isometry in either of the plots.

For example, based on the following criteria and control settings:

- Input Data Size X,Y = (300, 300)
- FFT Size = (150)
- Sample Size = (75)

Translates to an array of size (150, 150) as input to the FFT, where an area of size (75, 75) contains a sub-sampled copy of the original data, and the rest of the elements are zero.

Diffraction Analysis Characteristics

- The FFT Size and Sample Size preserve lateral isometry in the frequency domain (as long as the input data is laterally isometric).
- The size of the PSF and MTF plots, in pixels, is FFT Size.
- The lateral resolution of the PSF plot is proportional to the ratio (FFT Size / Sample). Increasing this ratio spreads out the PSF spot over a larger number of pixels, and shrinks the MTF spot onto a smaller number of pixels.
- The lateral resolution of the MTF plot is proportional to the ratio (Sample / FFT Size).
- The lateral resolutions of the PSF and MTF plots will equal their true theoretical values when the above ratio is 1. However, information is only preserved at these resolutions if Sample Size is set to no less than the diameter of the data in pixels.
- Whenever the sample size is less than the diameter of the data in pixels, information is lost.

See Also

PSF Details

MTF Details

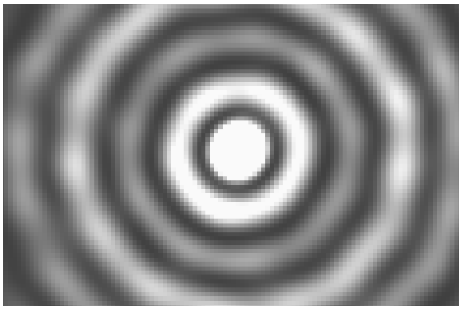
PSF

Point Spread Function represents the light amplitude distribution in the output of a lens or optical system for an ideal point source object.

PSF 2D Plot

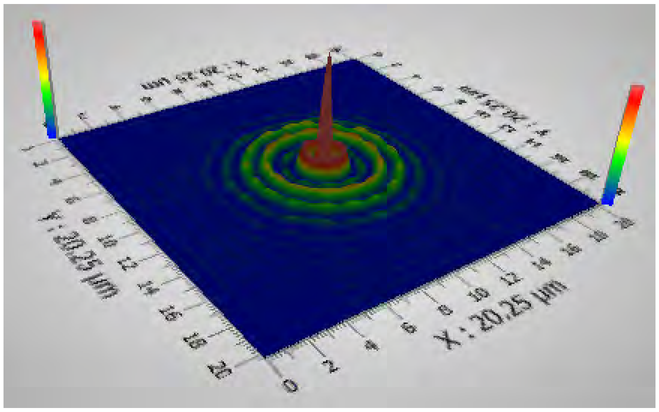
This 2D point source image plot provides a relative indication of the performance of the lens system.

For example, the resolution of the output of a perfect lens system is limited by diffraction, and this is evident when the PSF looks like a bright central spot surrounded by rings of decreasing brightness. This pattern is commonly referred to as an "Airy disk."



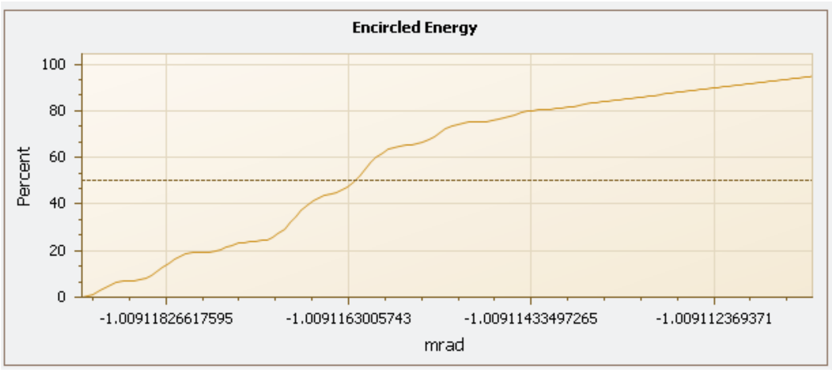
PSF 3D Plot

This is a three-dimensional representation of the point source image; it is also used as a relative indicator.



Encircled Energy Plot

The Encircled Energy plot is also known as a Fractional Energy plot. This plot displays quantitative information on the distribution of energy within the PSF plot. The form of the fractional energy profile is dependent on the wavefront quality, the wavelength of the light, and the size and the shape of the aperture.



The dashed horizontal line is a Ref Energy inspector. See Using Ref Energy.

To envision the encircled energy plot, think of the plot as a drawing of circles with increasing radii centered over the PSF spot. For each circle the amount of energy it encloses is measured. This value is normalized by the total energy in the spot and plotted on the y-axis as a percentage. The x-axis is the radius of the circle. The plot for a well corrected lens system will quickly rise (almost vertical) and then level off. The plot for a poorer quality lens does not rise as quickly.

The Encircled Energy plot is useful in determining a radial “spot size” which contains some fraction of the energy in a point image. This may be helpful in determining the resolvable separation between two points.

Defined as follows for a circle of radius *a*:

$$Encircled\ Energy = \int_0^a \int_0^{2\pi} PSF(r',\theta')r'dr'd\theta'$$

Using Ref Energy

The Ref Energy control and/or the Ref Energy inspector in the Encircled Energy Plot specifies the percentage used for the Ref Energy Size result.

Entering the Ref Energy

1. Enter a value, greater than zero, directly in Ref Energy control (under Settings). The Ref Energy inspector is displayed on the Encircled Energy plot along the y-axis at the value entered.

Changing the Ref Energy

1. Point to the horizontal Ref Energy inspector line, press and drag the line to a new location, and release the mouse button.

or

2. Enter a value in Ref Energy control.

PSF Details

The diffracted image of a point object is called the PSF (also known as the impulse response in linear systems theory). PSF captures the extent and shape of the blurring of an ideal point of light, and represents the energy distribution of that point at the image plane.

This quantity is based on the acquired wavefront data by calculating the squared modulus of the diffracted amplitude which is a function of the complex pupil function.

1. An amplitude distribution *A(x,y)* and wavefront aberration *W(x,y)* are combined to form the complex pupil function *P (x, y)*:

   $P(x,y) = A(x,y)\exp[ikW(x,y)]$ where $k = 2\pi / \lambda$

   In the analysis, the amplitude distribution A(x,y) is assigned a value of unity everywhere in the aperture, and zero elsewhere.

2. Using the Kirchhoff approximation, the diffracted amplitude U(x',y') is given by:

$$U(x',y') = \frac{i}{\lambda}\iint_A P(x,y)\frac{\exp[-ikR']}{R'}dA$$

where A is the area of the pupil and R' describes the distance from the pupil (x,y) sphere point to the imaging point (x',y'). In most interesting cases the above may be approximated well by:

$$U(x',y') = \frac{i\exp[-ik(R+\varepsilon(x',y'))]}{\lambda M_R R}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} P(x,y)\exp\left[i\frac{2\pi}{\lambda R}(xx'+yy')\right]dxdy$$

where R is the radius of the reference sphere at the exit pupil, *e(x',y')* is a quadratic phase factor, and MR is the z-direction cosine of the reference ray. Frequency variables are then:

$$\nu_x = \frac{x'}{\lambda R} \quad \text{and} \quad \nu_y = \frac{y'}{\lambda R}$$

3. After evaluating an approximation of *U(x',y')* in the well known form of a Fourier Transform, the irradiance, or squared modulus of *U(x',y')*, is termed the point spread function:

$$PSF(x',y') = |U(x',y')|^2$$

and the terms in front of the Fourier Transform integral of *U(x',y')* become inconsequential since when plotting the PSF it is common to normalize relative to the diffraction-limited (i.e., zero aberration) PSF.

4. For an ideal system the wavefront aberration is ZERO, and the pupil function is just the amplitude of the spherical wavefront in the exit pupil. Assuming uniform illumination the PSF is simply the squared modulus of the Fourier transform of the exit pupil shape. A circular pupil of radius=*a* results in the Airy disk pattern.

$$PSF_{DiffLim}(r') = \left(\frac{2J_1(b)}{b}\right)^2 ; \quad r' = \sqrt{x'^2+y'^2}$$

where J_1 is the Bessel function of the first kind of order 1 and

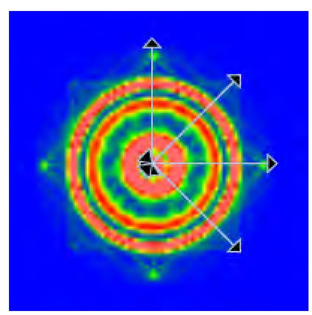
$$b = \frac{2\pi a r'}{\lambda R} = \frac{2\pi}{\lambda_0}NA\cdot r'$$

MTF

The Modulation Transfer Function of an optical system indicates the ability of a system to resolve detail as a function of the spatial frequencies present in the object. MTF is a measure of the resolvable spectrum of the diffracted image of an ideal point source and is related to Fourier transform of the PSF.

MTF 2D Plot

This 2D plot shows the frequency response and a relative indication of the performance of a lens system. A symmetric cone shape indicates a well assembled, centered lens system performing near the diffraction limit. An asymmetrical shape indicates a lens system where the rotational symmetry has been affected due to fabrication or design. This plot has four *fixed* slices at 0, 45, 90, and -45 degrees.



MTF Table

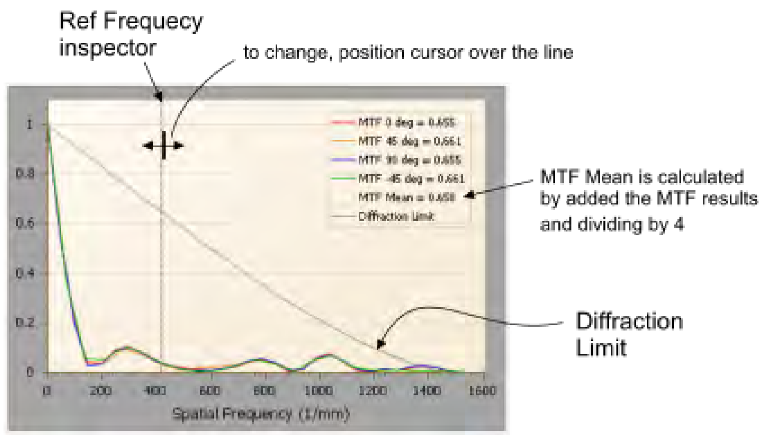
This table lists MTF results in quantitative numerical form in four orientations: 0, 45, 90, and -45 degrees. This is equivalent to creating profiles in four directions from the center of the MTF plot to the edge and listing the modulation values at various spatial frequencies.

Frequency	0 deg	45 deg	90 deg	-45 deg
0.00	1.000	1.000	1.000	1.000
158.03	0.038	0.042	0.030	0.057
316.06	0.095	0.083	0.091	0.093
474.08	0.023	0.014	0.020	0.021
632.11	0.012	0.022	0.015	0.012
790.14	0.051	0.049	0.055	0.045
948.17	0.025	0.030	0.023	0.033
1106.19	0.029	0.027	0.033	0.029
1264.22	0.012	0.008	0.010	0.008
1422.25	0.020	0.006	0.020	0.006
1580.28	0.000	0.000	0.000	0.000

MTF Profile Plot

This plot shows a quantitative profile of the MTF data in the orientations specified on the MTF 2D plot. The functional form of the MTF curve is dependent on the wavefront quality, the wavelength of the light, and the size and shape of the aperture. The y-axis is the relative response; the x-axis is the spatial frequency in cycles per lateral unit.

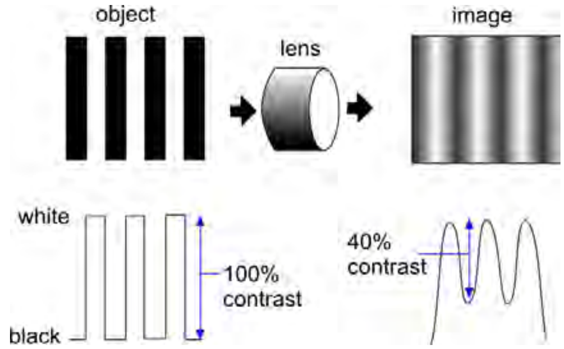
The Diffraction Limit line is defined by the Airy disk of a perfect point source.



Understanding MTF

Typically, MTF is used to characterize the resolution of an imaging lens. The MTF of a lens is a measurement of the lens' ability to transfer contrast at a particular resolution level from the object to the image. MTF is useful because it incorporates resolution and contrast data into a single specification. An ideal lens would perfectly transmit 100% of the light that passes through it. But, no lens is perfect, and therefore there are losses. When these losses are measured in terms of contrast this is called the modulation of contrast. In other words, how much contrast is lost; modulation is just another word for variance.

A way to interpret MTF results is to visualize an imaging target with black and white lines. No lens at any resolution can fully transfer this contrast to the image because of the diffraction limit. And as the line spacing is decreased and the frequency increases on the target, it becomes increasingly difficult for the lens to transfer this contrast.



An MTF profile plot graphs the proportion of transferred contrast versus the frequency of the lines. Contrast (also known as modulation) is shown on the y-axis and is the image contrast ratio expressed in terms of one (where 1 = white on black and 0 = gray on gray). The higher the values on the MTF profile plot y-axis the better the lens. A "good" lens has MTF values close to the diffraction limit.

Using Ref Frequency

The Ref Frequency control and/or the Ref Frequency inspector specifies the analysis frequency for Ref MTF results.

Entering the Ref Frequency

1. Enter a value, greater than zero, directly in Ref Frequency control (under Settings). The Ref Frequency inspector is displayed on the MTF profile plot along the x-axis at the value entered.

   The initial default value for Ref Frequency may be so large it is off the MTF profile plot. Enter a value in the control that matches a value on x-axis of the plot.

Changing the Ref Frequency

1. Point to the vertical Ref Frequency inspector line, press and drag the line to a new location, and release the mouse button.

or

2. Enter a value in Ref Frequency control.

MTF Details

1. The Optical Transfer Function (OTF) is the normalized Fourier transform of the PSF and can also be expressed as the autocorrelation of the pupil function.

$$OTF(\nu_x,\nu_y) = \frac{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} PSF(x',y')\exp\left[i2\pi\left(\nu_x x'+\nu_y y'\right)\right]dx'dy'}{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} PSF(x',y')dx'dy'}$$

   The incoherent cutoff frequency (where OTF goes to zero) for a circular exit pupil of diameter (D) can be derived as:

$$\nu_{0,focal} = \frac{D}{\lambda \cdot R} = \frac{2 \cdot NA}{\lambda_0} \qquad \text{(units = cycles/mm)}$$

   where λ is the wavelength in image space, and λ_0 is the vacuum wavelength.

2. If the image is Afocal (image at infinity) then the following conversion is used:

$$\frac{cycles}{mm} = R \cdot \frac{cycles}{rad}$$

and the incoherent cutoff frequency for a circular exit pupil of diameter D is:

$$\nu_{0,afocal} = \frac{D}{\lambda}$$ (units = cycles/rad)

3. The Modulation Transfer Function (MTF) is simply the modulus (or absolute value) of the OTF and is equivalent to the ratio of the modulation in the image to the modulation in the object at a given spatial frequency.

$$MTF(\nu_x, \nu_y) = \left| OTF(\nu_x, \nu_y) \right|$$

If we define modulation M as:

$$M(\nu) = \frac{E_{\max} - E_{\min}}{E_{\max} + E_{\min}}$$

then the MTF may be expressed as the ratio described above and shown below:

$$MTF(\nu) = \frac{M(\nu)_{image}}{M(\nu)_{object}}$$

Strehl Ratio Details

The ratio of the peak value of the PSF to the peak value of the PSF for an equivalent perfect system. For the case of a circular exit pupil:

$$Strehl\ Ratio = \frac{PSF(r')}{PSF_{DiffLim}(r')}$$

For small wavefront aberrations, the Strehl Ratio can be related to the variance (or RMS OPD) of the wavefront by:

$$Strehl\ Ratio \cong \left(1 - 2\pi^2\sigma^2\right)^2$$

Image quality is questionable when the Strehl Ratio is less than 0.5.

ISO 10110-5

Navigator : Surface : ISO 10110-5

This view shows a detailed analysis with surface form results that conform to the International Organization for Standardization's tolerance specifications detailed in ISO 10110-5 and 14994-4. Standardized maximum permissible surface form tolerances include sagitta deviation, irregularity, and/or rotationally invariant irregularity. Optionally, tolerances for rms total, rms irregularity, and rms rotationally varying irregularity may be specified.

For descriptions of results see ISO 10110-5 Results.

What is ISO 10110-5?

ISO 10110-5 is part of the ISO 10110 series which specifies the presentation of design and functional requirements for optical elements and systems in technical drawings used for manufacturing and inspection. ISO 10110-5 specifies rules for indicating the tolerance for surface form and applies to surfaces of both spherical and aspheric form.

Use Conditions

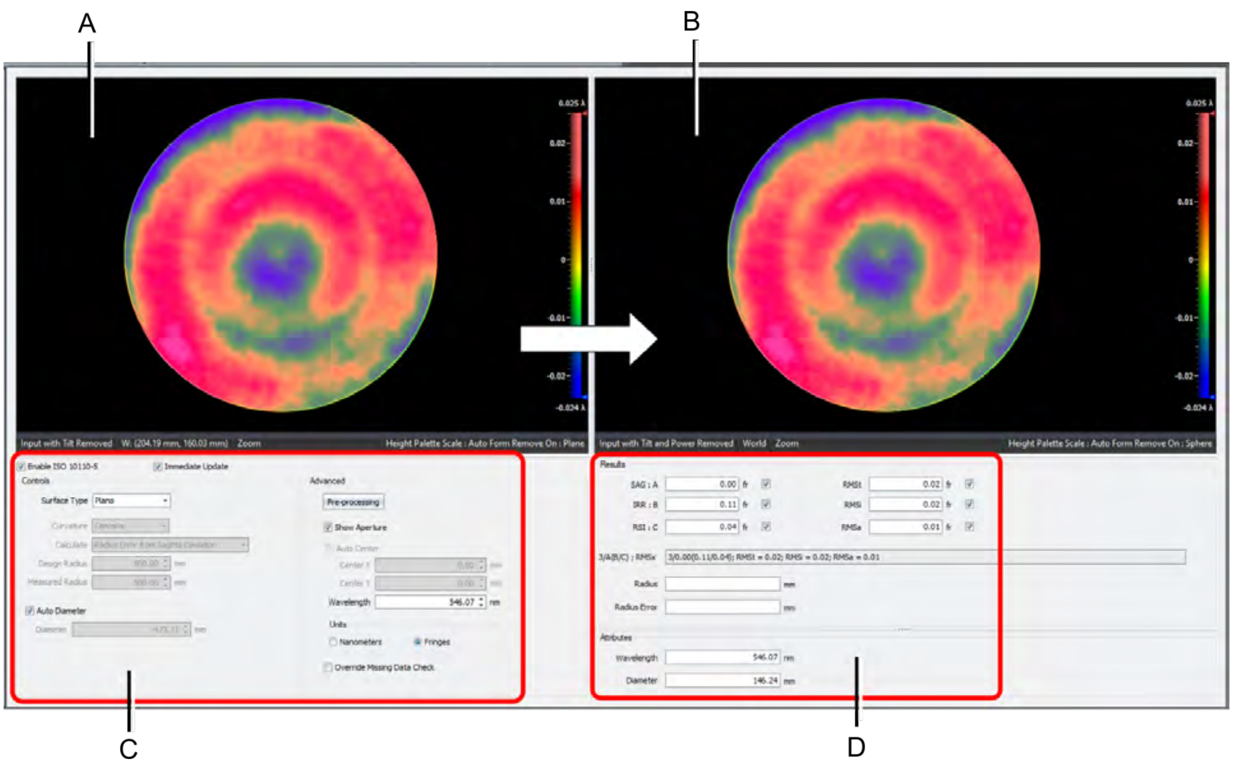
- Applies to laser interferometers.
- Not applicable to transmitted wavefront testing.
- Ignores Auto Aperture settings.
- Results are calculated *after* filtering, data trim, edge trim, and masking; but *before* data fill, and fit and remove.
- Uses a Cartesian polynomial fitter for set-up misalignments. This retains valid low-order form removal (piston, tilt, sphere) on all data shapes (circular, rectangular, elliptical, etc.).

The ISO 10110-5 Screen

Select the Enable ISO 10110-5 check box to activate.

Select the Immediate Update check box to display the impact of the settings after each change without pressing the Analyze button.

Select the result check boxes you want to calculate.



A. Input data with tilt removed. **B.** Input data with tilt and power removed. **C.** ISO 10110-5 Controls. **D.** ISO 10110-5 Results.

References for ISO 10110-5

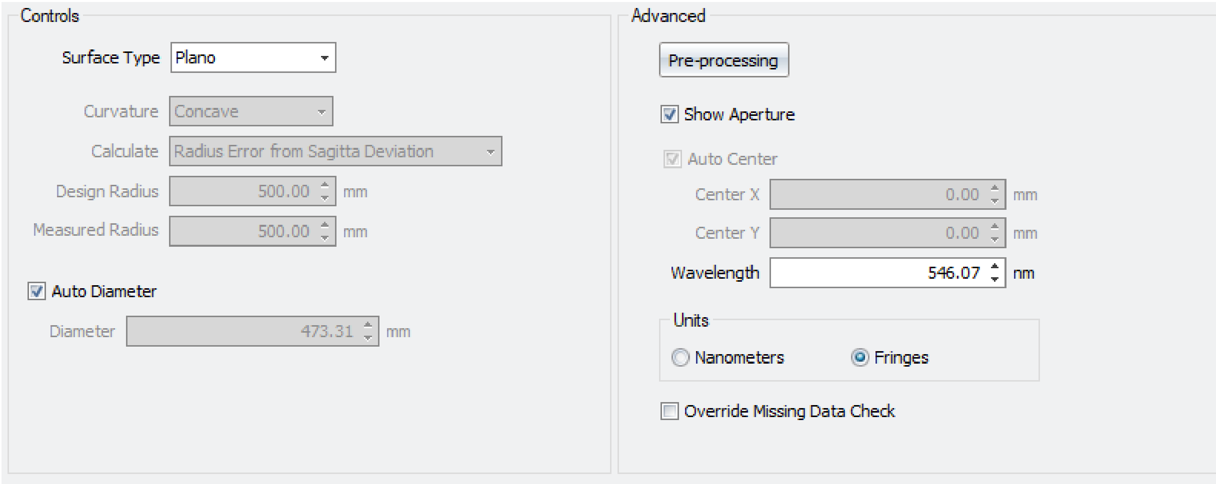
ISO 10110-5: Optics and photonics -- Preparation of drawings for optical elements and systems -- Part 5: Surface form tolerances.

ISO 14999-4: Interpretation and evaluation of tolerances specified in ISO 10110.

"ISO 10110 Optics and Optical Instruments- Preparation of Drawings for Optical Elements and Systems: A User's Guide," by OSA Standards Committee, Edited by Ronald E. Kimmel and Robert E. Parks.

ISO 10110-5 Controls

When Surface Type is Plano the majority of controls are nonfunctional and grayed out.



Surface Type	Selects the type of surface being analyzed. Choices are Plano (flat) or Spherical (round).
Curvature	Selects the curvature of the spherical surface. Choices are Concave (inward curve) or Convex (outward curve). Surface Type must be Spherical for this control to be active.
Calculate	Selects how the sagitta error (SAG : A) result is calculated. Surface Type must be Spherical for this control to be active. *Radius Error from Sagitta Deviation*- The software uses the measured power in the cavity, and the user provided design radius, to calculate a radius error for the part under test. This assumes that the user has placed the spherical part at a known location using tooling, and a master part or calibrated reference. This is typically done in a production environment in which the operator sets up the tooling with a master part, and then places parts on the tooling with no further adjustment to the cavity. *Sagitta Deviation from Measured Radius*- The software uses the user provided values for measured radius, design radius, and part diameter to calculate the sagitta error. This assumes that the user has independently measured the radius of the part (using radius scale, spherometer, etc.). This is more likely to be used in a low-volume or one-off manufacturing environment.
Design Radius	Specifies the radius of curvature of the part by design. Surface Type must be Spherical for this control to be active.
Measured Radius	Specifies the radius of curvature of the measured part. Calculate must be Sagitta Deviation from Measured Radius for this control to be active.
Auto Diameter	When selected, it automatically finds the diameter of the largest circle, centered by Auto Circle or at Center X and Center Y, that includes the edges of the data set. This circle is used for fitting and result calculations. When the Auto Diameter check box is cleared, the Diameter control is active.

Diameter	Specifies the diameter of the unit circle of the analysis mask for fitting and result calculation. See also ISO 14999-4. The recommended units are millimeters if the instrument is laterally calibrated, or pixels if it is not.

ISO 10110-5 Advanced Controls

Show Aperture	When selected, regions (pixels) outside of the specified diameter are shaded to indicate exclusion from the analysis.
Auto Center	When selected, the center coordinates for the valid circular aperture are calculated from the minimum enclosing rectangle around the input data. When the check box is cleared, values can be entered in Center X and Center Y.
Center X **Center Y**	Manually specifies the center location in the x and y axes for the unit circle (specified in camera space). The Auto Circle check box must be cleared. To change the units, right-click on the item and choose Select Units and Precision.
Wavelength	Specifies the wavelength for calculation of the output results only if unit selection is Fringes; does not affect calculation if unit selection is nm. This defaults to 546.07 nm as specified by the standard. Click to enter a value.
Units	Selects the units of the ISO 10110-5 results.

ISO 10110-5 Implementation Notes

ISO 14999-4

The wavefront functions (WS, WI, WRI, WD, WI and WRV), described in ISO 14999-4, are computed from the measured wavefront deformation (MWD) within the calculated or specified Diameter.

Sequence of Computations

1. WD (wavefront deformation): Fit an equation of type plane in MWD within the specified aperture by minimizing the residual root mean square to get the plane function TLT and compute WD = MWD – TLT.
2. WS (wavefront spherical approximation): Fit a function of a spherical form that best approximates WD (minimum rms).
   Sag is computed for Plano surface type as Diameter^2 / (8 R_{sph}), where R_{sph} is radius of sphere curvature fit. Sag is also calculated this way when the Calculate option is "Radius Error from Sagitta Deviation". Sag is modified when the Calculate option is "Sagitta Deviation from Measured Radius" by taking into account the difference between the measured radius and the design radius.
3. WI (wavefront irregularity): WI = WD – WS.

4. WRI (wavefront aspheric approximation): A rotationally invariant aspherical function that best (in the sense of the rms fit) approximates the wavefront irregularity WI.
   Mx uses a computational algorithm without Zernike approximations. This is a direct computation based on the extraction of circular slices and averaging of phase values for every slice. The spatial frequency of these slices is determined by camera resolution, or, in another words, slices are computed with radii incremented by one pixel starting from the center and limited by control parameter Diameter. This algorithm produces very similar results to Zernike approximation for smooth optical surfaces and does a more precise job in the case of higher frequency azimuthal harmonics, and it is more appropriate for the analysis of test samples of a non-circular nature.
5. WRV (rotationally varying wavefront deviation): WRV = WI – WRI

ISO 10110-5 results A, B, C, RMSt, RMSi, and RMSa are computed as peak-to- valley values or root mean squares of corresponding wavefront functions (except SAG A as explained above) within an aperture defined by parameter Diameter.

Legendre

Navigator : Surface : Legendre

This view shows plots and Legendre fit coefficients. Legendre polynomials are a sequence of orthogonal polynomials based on Cartesian coordinates and support square and rectangular data sets.

Legendre polynomials are not recommended for aperture shapes other than rectangular. The fitting algorithms will still function but the functions will be unconstrained in the areas where there is no data.

Use Conditions

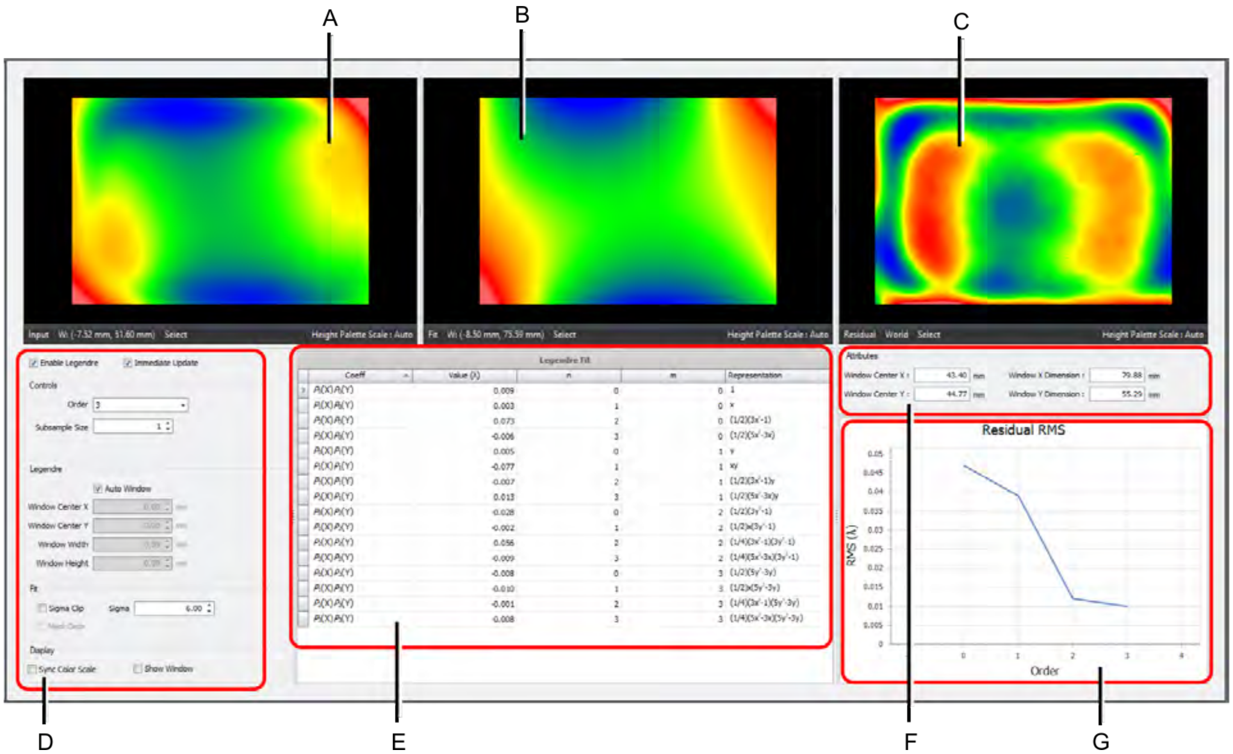
- Applies to laser interferometers.
- Appropriate for square and rectangular apertures.
- The fit results can be displayed, output (in print, pdf, or Excel form), and exported as coefficients.
- The number of coefficients displayed depends on the Order selection.
- The incoming data may have Data Processing functions applied, such as Fit Remove, Edge Trim, or Spike Clip.

The Legendre Screen

Select the Enable Legendre check box to activate.

Select the Immediate Update check box to display the impact of the settings after each change without pressing the Analyze button.

It is recommend to select the Sync Color Scale check box under the Advanced tab to aid in the visualization of the fit.



A. Input plot (shows data input from any existing processing). **B.** Fit plot (shows the calculated fit surface). **C.** Residual plot (shows what remains after the Legendre fit is removed from the input data). **D.** Controls. **E.** Legendre Fit coefficients table (the number displayed is determined by the Order control). **F.** Attributes about the fit window. **G.** Residual RMS plot (shows the residual RMS at each active Legendre order).

Legendre Fit Table

The Legendre Fit coefficients table shows each term of the fit. The actual content is determined by the Order control. The columns are similar to those used with Zernike polynomials; for column definitions see Zernike Polynomial Table.

References for Legendre Polynomials

"Legendre Polynomial", at www.MathWorld.com or www.wikipedia.org.

Using the Legendre Analysis

Controls Tab

Order	The Order control limits the sum of the X and Y exponents in any given term in the polynomial.
Subsample Size	Determines the sampling density of pixels to use for the fit. The default of 1 uses every pixel; 2 uses every second row and column; 3 uses every third row and column, etc...

Advanced Tab

Auto Window	When selected, windowing functions are automatically determined based on the input data set. If the incoming data is circular the windowing controls are non-functional.
Window Center X	When Auto Window is off, specifies the center of the fit window in the X or horizontal axis.
Window Center Y	When Auto Window is off, specifies the center of the fit window in the Y or vertical axis.
Window Width	When Auto Window is off, specifies the width of the fit window.
Window Height	When Auto Window is off, specifies the height of the fit window.
Fit controls	For Sigma Clip, Sigma, and Mask Data, see Sigma Clip Function.
Display controls	For Sync Color Scale, see Sync Color Scale. Show Window- When selected, the fit window area is superimposed over the input plot.

Additional Information

For information on	**See...**
Legendre Fit table	Working With Tables, Zernike Polynomial Table
Attributes	Window Dimension
Residual RMS plot	Residual RMS Plot
Exporting fit coefficients	Exchanging Coefficients

Outputting or Exporting Legendre Polynomials

1. Select data in the table. See Selecting Table Data.
2. Right-click and select an output option.

The selected Coefficient table contents can also be copied to the clipboard using Ctrl-C and then pasted into other programs.

PVr

Navigator : Surface : PVr

This view shows detailed PVr or Robust Peak-to-Valley analysis. PVr is the sum of the PV of a 36 term Zernike fit (after removing those terms set to zero (piston and tilt for flats; piston, tilt, and power for spheres) plus 3 times the rms of the residual after fitting to 36 terms.

For descriptions of results see PVr Results.

Advantages of PVr

- Largely insensitive to the camera resolution, making comparison of data taken on instruments with differing resolution more reliable and consistent.
- Does not require user interaction or data transforms such as masks, trim, or clipping to remove systematic artifacts that are driving the peak-to-valley result.

Use Conditions

- Applies to laser interferometers.
- Useful where systematic coherent artifacts or diffraction spikes may lead to local phase errors.
- Appropriate for circular apertures, only due to the use of a Zernike fit.
- Typically, PVr is analyzed without any prior data filtering; use filtering with caution.

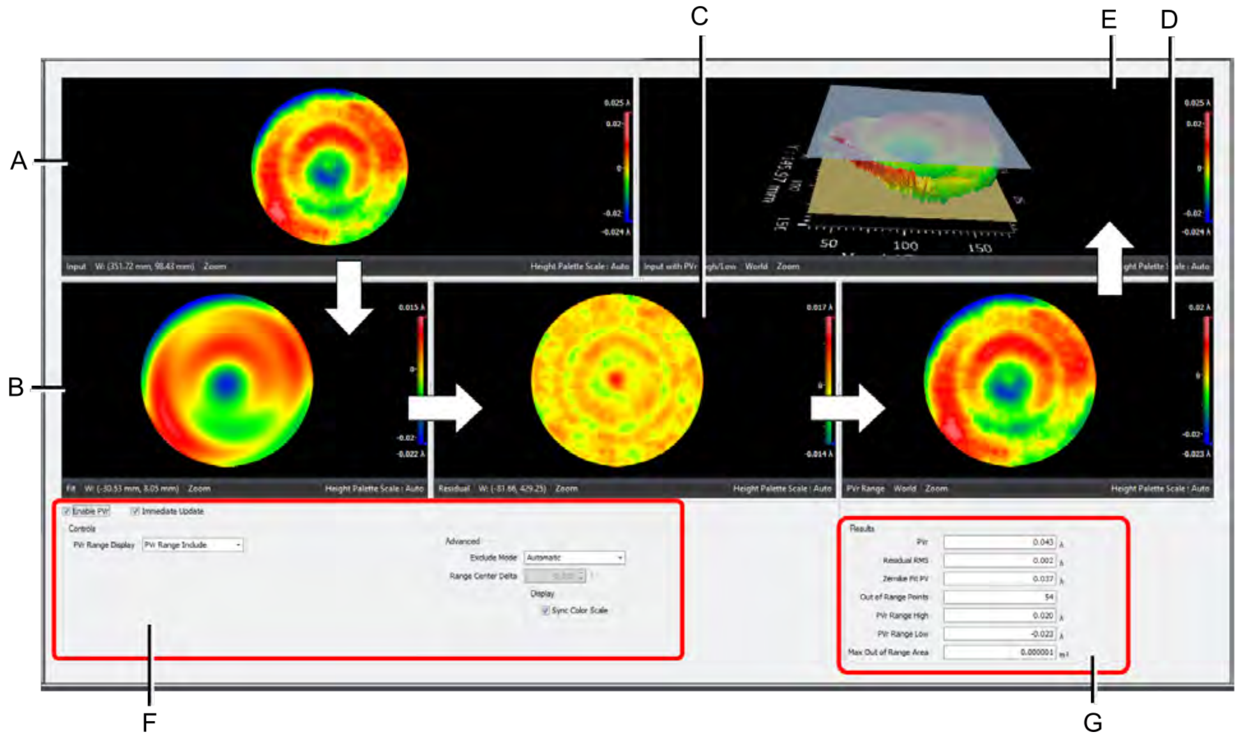
Limiting Values

- Measured PVr must be less than PV. There are cases in which mid and high spatial frequency structure of sufficient amplitude may yield a residual rms that influences too strongly the PVr calculation. Note that this does not affect the two-point PV calculation.
- PVr should be greater than or equal to 6 times the residual RMS. If the optic is extremely good, and the PVr of the 36 term Zernike fit is very close to zero, 3 times the residual rms becomes a poor estimate of the amplitudes comprising the surface.

The PVr Screen

Select the Enable PVr check box to activate.

Select the Immediate Update check box to display the impact of the settings after each change without pressing the Analyze button.



A. Input plot (shows input data). **B.** Fit plot (shows generated surface based on Zernike fit to input data). **C.** Residual plot (shows input data with Zernike fit removed). **D.** PVr Range plot (shows input data clipped using PVr range). **E.** Output plot (shows outcome). **F.** PVr controls. **G.** PVr results.

Reference for PVr

"PVr - a robust amplitude parameter for optical surface specification" by Chris Evans. *Optical Engineering 48* (4), 043605 April 2009.

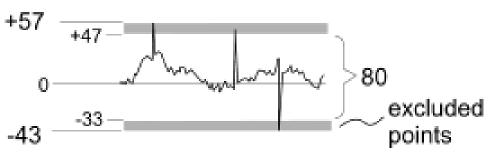
PVr Controls

PVr Range Display	Selects what is displayed in the PVr Range plot. PVr Range Include- shows all data points that fall within the PVr Range. PVr Range Exclude- shows all data points that fall outside of the PVr Range.
Exclude Mode	Selects what to exclude in the PVr analysis. See Exclude Mode Example. *Automatic* (default)- automatically find the midpoint value that minimizes the number of points falling outside of the range defined by PVr. *Equal*- the range of the points excluded is equally divided between high and low values. *Manual*- Allows the user to specify the midpoint (center) delta to "slide" the range up or down.
Range Center Delta	Specifies an absolute height value that defines the delta from the midpoint location of the mean of the input data matrix. Only active when Exclude Mode is Manual.
Sync Color Scale	See Sync Color Scale.

Exclude Mode Example

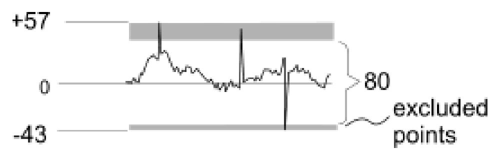
Below is data with a PV = 100 nm, with a peak value at +57 nm and minimum value at -43 nm; and a PVr = 80 nm.

Exclude Mode Equal



Points between +57 and +47 nm and between -33 and -43 nm are excluded. Points are equally removed from highs and lows.

Exclude Mode Manual



When a negative value is entered in Range Center Delta, the included range is shifted downward. In this example, a greater number of points would be removed from the highs.

Sub-Aperture

Navigator : Surface : Sub-Aperture

The Sub-Aperture analysis is used to examine the input data through a series of smaller apertures and collect statistics on each of the smaller sub-apertures. The size and shape of the sub-apertures are user-selected.

Use Conditions

- Applies to all instruments, both laser interferometers and optical profilers.
- Lateral calibration is required to display lateral based results in units other than pixels.

Sub-Aperture Use Cases

- Characterize part data through a series of smaller apertures (displayed as grid lines) and user-selected results.
- Use to identify local areas with the greatest deviation for a particular result.
- Provide statistics for each region and all regions combined.
- Display a particular region of interest.

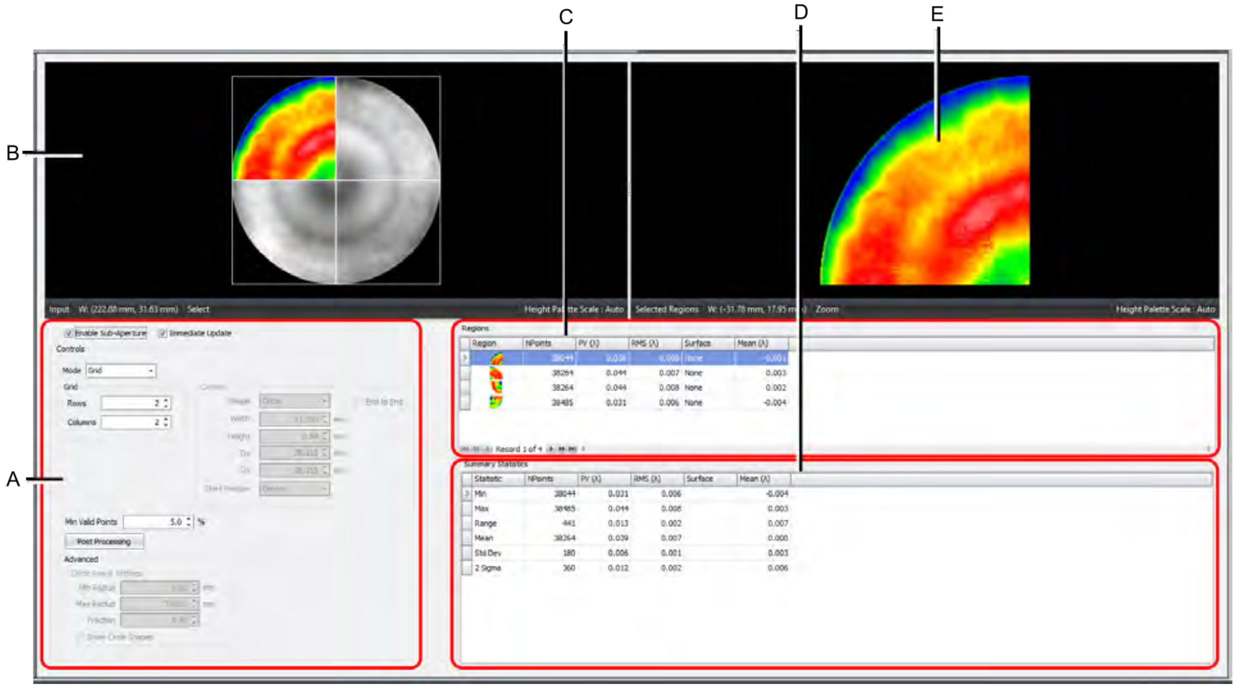
It is normal that some sub-apertures are clipped with areas of no data.

The Sub-Aperture Screen

Select the Enable Sub-Aperture check box to activate.

Select the Immediate Update check box to display the impact of the settings after each change without pressing the Analyze button.

Some settings of this tool can create thousands of isolated regions that can take time to calculate. You may find it easier to clear the Immediate Update check box and to specify the sub-aperture region first. Or press Ctrl+C to cancel the current update.



A. Sub-Aperture controls **B.** Plot of Entire Region (input data) with selected region in color. **C.** Regions result table (click row to select a region to display). **D.** Summary statistics of all regions. **E.** 2D plot of Selected Region(s).

Sub-Aperture Controls

Mode Selects the method used to sub-sample the input data.

Grid applies a pattern of regularly spaced horizontal and vertical rectangular shapes. It sub-divides the minimum enclosing rectangle of the input data into a grid of rectangular shaped regions, the number of which are determined by the Grid or Center controls. Sub-areas are edge-to-edge; where one region ends the next starts.

Center applies the selected shape, size, and spacing criteria to divide the input data into regions.

Rows Specifies the number of horizontally spaced divisions in the grid when Mode is Grid.

Columns Specifies the number of vertically spaced divisions in the grid when Mode is Grid.

Min Valid Points Specifies the minimum percentage of valid data required in a region for it to be valid to analyze. If a region has less pixels it is ignored.

The following controls are active when Mode is Center.

Shape Selects the shape of sub-aperture. Choices include: circle, ellipse, or rectangle.

Width Specifies the width (horizontal) dimension of the ellipse and rectangle or the diameter of the circle.

Height Specifies the height (vertical) dimension of the ellipse and rectangle.

Dx Specifies the step distance in the x-axis from one sub-aperture to the next.

> Depending on the values for Dx and Dy, the sub-apertures can overlap or be spaced apart with gaps between each region.

Dy Specifies the step distance in the y-axis from one sub-aperture to the next.

Start Position Selects where the sub-sampling of data begins in reference to the upper left corner of the input data set. Choices are Border or Center.

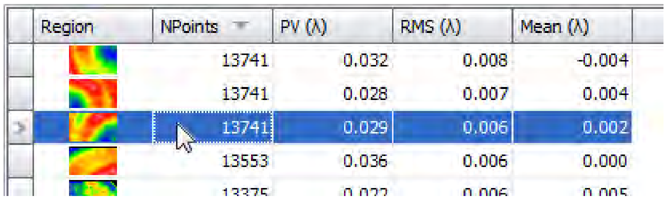
Border places the first row and column sub-apertures coincident with the perimeter of the data set.

Center places the center of the first row and column sub-apertures on the perimeter of the data set.

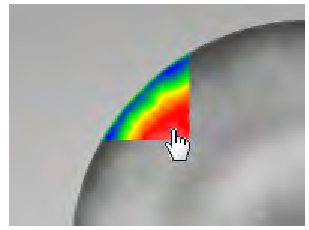
End to End Select to automatically control the x axis and y axis sub-aperture distribution so there is no overlap or gaps between regions.

Viewing and Selecting Regions

Click rows in the Regions table and/or click directly on the Entire Region plot.



Region	NPoints	PV (λ)	RMS (λ)	Mean (λ)
	13741	0.032	0.008	-0.004
	13741	0.028	0.007	0.004
	13741	0.029	0.006	0.002
	13553	0.036	0.006	0.000
	13375	0.022	0.006	0.005



Point and click on a row in the Regions table.

Point and click on an area in the Entire Region plot.

With the Regions Table

View or Select	Details
One region	Click the row in the Regions table (when viewed as Grid). The region in the Entire Regions plot is colorized.
Multiple regions	Click one row; press the Ctrl key and click to add or subtract additional rows.
Multiple regions (contiguous)	Click on the first row you want to highlight; press the Shift key and click on last row to add.
All regions	Point to the left top corner of the Regions table and click.

With the Entire Region Plot

View or Select	Details
One region	Point and click on an area in the Entire Region plot. The row in the Regions table is highlighted.
Multiple regions	Click on one area of the plot; press the Ctrl key and click to add or subtract additional regions.

Working with Region Results

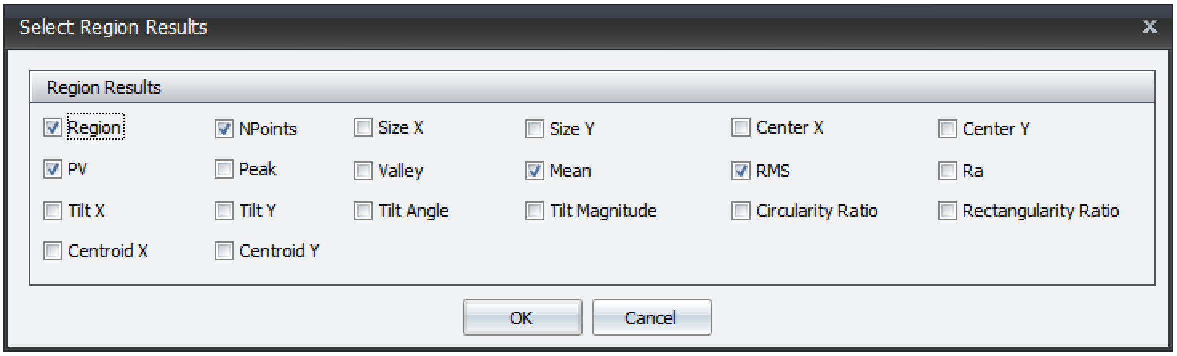
The Regions table is a specialized form of Process Statistics.

- Each row in the Regions table shows the results for a single region.
- To set pass/fail criteria for results in the Regions table see Using Limits on Table Data.
- For definitions of results, see General Results and Standard Optic Results.

Selecting Region Results

1. Right-click on the table and choose Select Results.
2. Select a check box to include the result; clear the check box to exclude the result.

3. Click OK.



The Region check box displays a column with a small graphic image of the regions.

Other Table Functions

Function	See
Sort Regions	Sorting Table Data.
Filter Regions	Filtering Table Data.
Export Regions	Exporting Table Data.
Set Limits for Results	Using Limits on Table Data.

Region Summary Statistics

Region Summary Statistics are similar to the standard Summary Statistics.

9.3 Optical Profiler Analyses

This section describes analyses that are specific to the optical profiler.

Material Ratio Analysis	Used to measure machined surfaces for wear and lubrication properties.
Films	Used to analyze parts that have coated surfaces.
Advanced Films	Used to measure thin or complex films.

See also Common Analyses.

Material Ratio Analysis

Navigator : Surface : Material Ratio Analysis

Material Ratio Analysis is a method for describing the surface texture of an object. It is commonly used to evaluate lapped, ground or honed surfaces. Material Ratio Analysis is particularly useful in the manufacturing of piston cylinder bores for internal combustion engines. It is also useful for understanding sealing and bearing surfaces, adhesion and lubrication performance and material removal. Fixed and interactive material ratio plots are provided for areal (3D) data and profile (2D) data. Areal (S) parameters are calculated in accordance with ISO 25178-2:2012. Profile (R) parameters are calculated in accordance with ISO 13565-2:1995.

The material ratio curve (aka bearing area curve or Abbot-Firestone curve) is the cumulative distribution function of the surface.

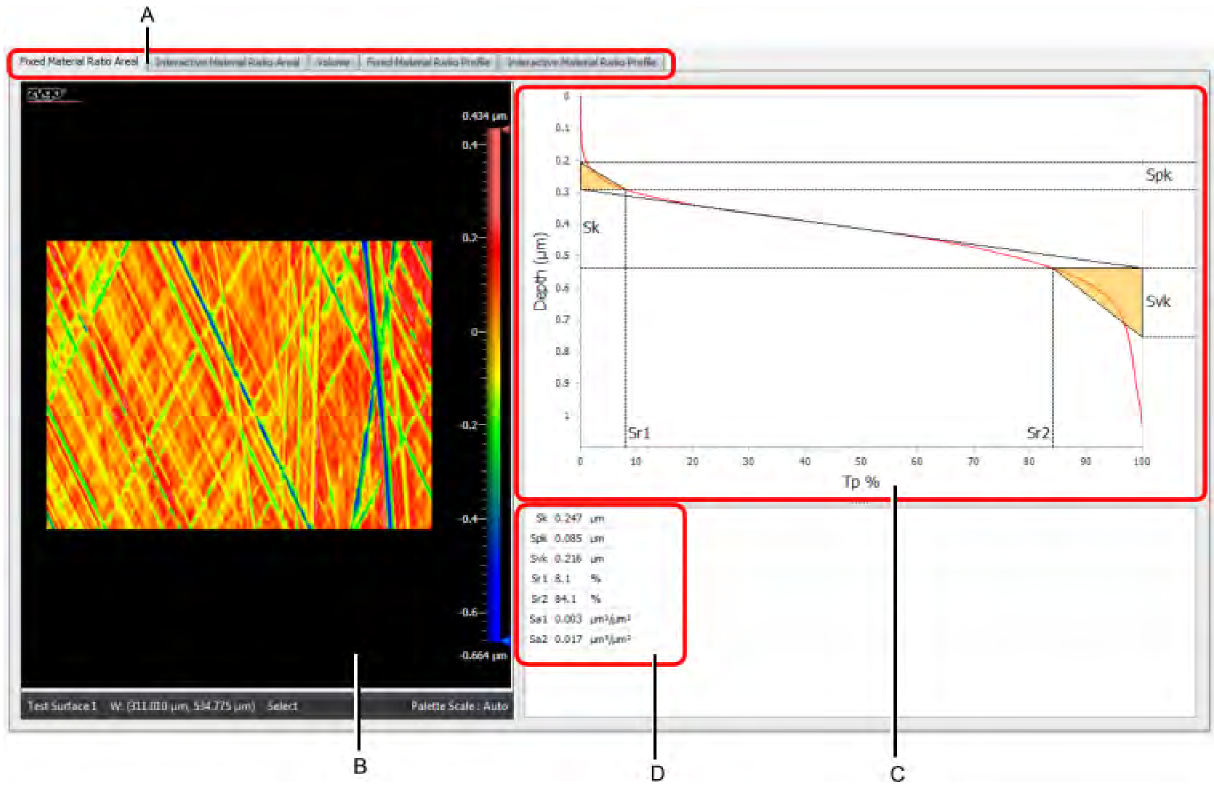
Use Conditions

- Applies to optical profilers.
- Lateral calibration is required to display lateral based results in units other than pixels.

Assumes incoming data is roughness data. Data should have Form Removed and be filtered with a high pass Gaussian filter.

The Material Ratio Analysis Screen

In some cases values may not be calculated for some results. In these instances, the material ratio curve may not have a single point of inflection (an “S” shape as outlined in ISO 13565-2:1996/ISO 25178-2:2012). Such conditions are more likely to occur with non-machined surfaces and may be addressed by verifying proper form has been removed.



A. Analysis option tabs **B.** Plot of incoming Test Surface (input data). **C.** Bearing Area Curve (actual plot varies depending on the tab selected). **D.** Material Ratio controls/results (varies depending on the tab selected).

Interactive Plots

Three of the Material Ratio plots are "interactive".

- Click and drag bearing ratio (Tp%) limits.
- Enter numeric values for exact (Tp%) positioning.
- Easily determine Tp% at a specified depth.

1. Point to a Tp% control line; the cursor changes to ✥.
2. Click and drag the line to a different location.

or

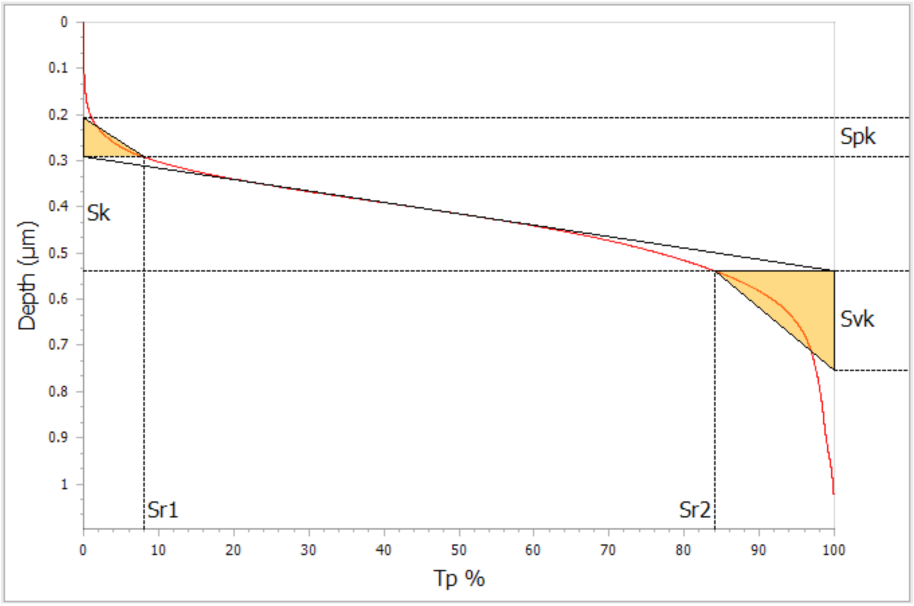
3. Enter a percentage in the corresponding control.

How are Material Ratio Parameters Derived?

ISO 13565 Standard parameters are derived from the Material Ratio Curve calculated within the evaluation length. The material ratio parameters are determined by: fitting a straight line to a sliding 40% of the points along the curve, selecting the range so that the line has the smallest possible slope, then extending this line to 0% and 100% and making two horizontal intersection lines where the line intersects 0% and 100%. These intersections separate protruding peaks from the core roughness and the lower line separates deep valleys from the core roughness.

Fixed Material Ratio Areal

- Curve based on a three-dimensional surface.
- Shows the statistical distribution of peaks and depths of an area.
- Material components output is fixed.

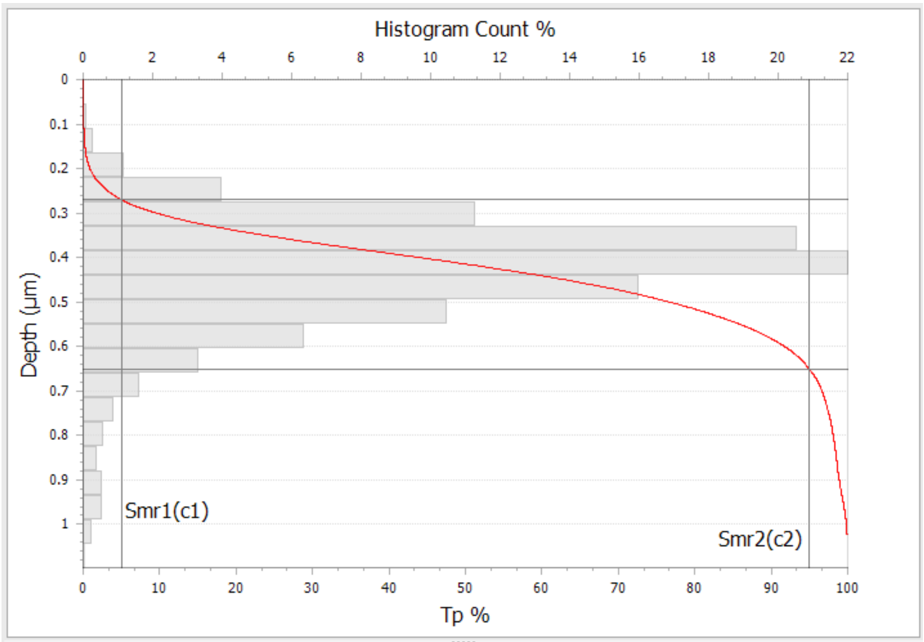


Fixed Areal Results

Sk	Core Roughness Depth. A measure of the "core" roughness (peak-to-valley) of the surface with the predominant peaks and valleys removed. This is a measure of the nominal roughness (peak-to-valley) and may be used to replace parameters such as Sz when anomalous peaks or valleys may adversely affect the measurement.
Spk	Reduced Peak Height. The area above the region of the material ratio curve which delimits the core roughness. A measure of the peak height above the core roughness. During a running in operation, Spk is the nominal height of the material that may be removed. A large Spk implies a peak dominant surface.
Svk	Reduced Valley Depth. A measure of the valley depth below the core roughness. Svk impacts a surfaces ability to retain lubricant and trap debris.
Sr1	Peak Material Component. Sr1 represents the upper limit of the core roughness profile. This parameter is derived from the bearing ratio plot.
Sr2	Valley Material Component. Sr2 represents the lower limit of the core roughness profile. This parameter is derived from the bearing ratio plot.
Sa1	The peak surface area between the upper intersection line and the Material Ratio Curve. Displayed in the plot as a shaded area.
Sa2	The valley surface area between the lower intersection line and the Material Ratio Curve. Displayed in the plot as a shaded area.

Interactive Material Ratio Areal

- Curve based on a three-dimensional surface.
- Shows the statistical distribution of peaks and depths of an area.
- User selectable Smr1 and Smr2 levels.
- The number of bins and bin width can be changed using Histogram Properties.



Interactive Areal Controls

Mode	Selects the interactive operational mode. When Mode is set to Distribution (default), the upper and lower limits are bearing ratio (Tp) percentages. When Mode is set to Depth, the upper and lower limits are depth (height) values.
c1	Specifies/displays the depth at c1 when Mode is Depth.
c2	Specifies/displays the depth at c2 when Mode is Depth.
Smr(c1)	Surface Material Ratio control 1. Specifies/displays the areal material ratio percentage at c1 when Mode is Distribution. Default value is 5% (ISO 25178-3:2008).
Smr(c2)	Surface Material Ratio control 2. Specifies/displays the areal material ratio percentage at c2 when Mode is Distribution. Default value is 95% (ISO 25178-3:2008).

Interactive Areal Results

c1 Height (or depth) at c1.

c2 Height (or depth) at c2.

c2 - c1 Height Difference.

Smr(c1) Surface Material Ratio at height c1. The ratio (expressed as a percentage) of the cross sectional area of the surface as a height (c1) relative to the evaluation cross sectional area.

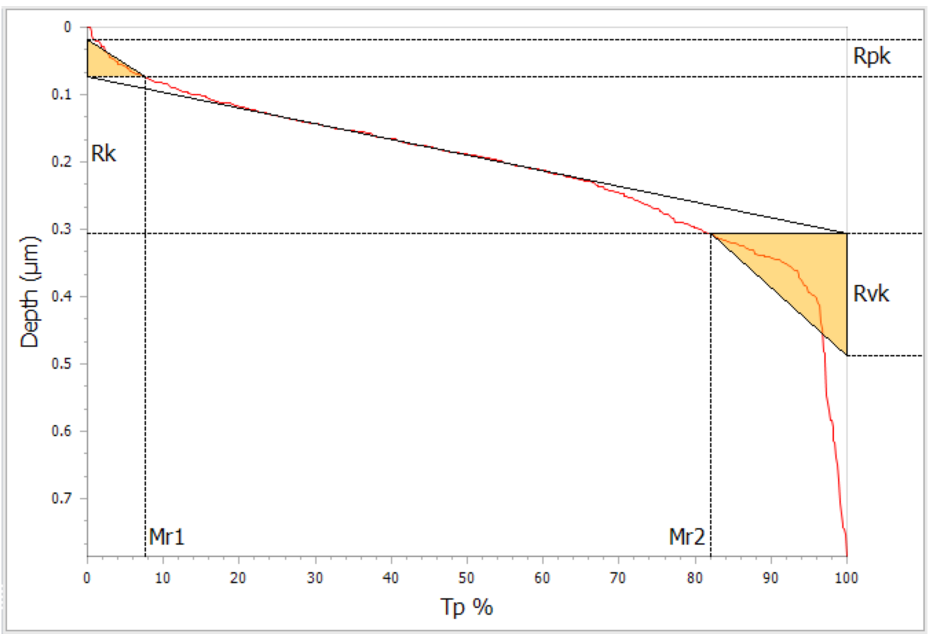
Smr(c2) Surface Material Ratio at height c2. The ratio (expressed as a percentage) of the cross sectional area of the surface as a height (c2) relative to the evaluation cross sectional area.

Smr(c2) - Smr(c1) Surface Material Ratio Difference.

Fixed Material Ratio Profile

- Curve based on profile (slice) data.
- Shows the statistical distribution of peaks and depths of points of a profile.

For best results, the Linear slice should be perpendicular to the part lay.



Fixed Profile Results

A1 Peak area defined by Rpk. Displayed in the plot as a shaded area.

A2 Valley area defined by Rvk. Displayed in the plot as a shaded area.

Mr1 Peak Material Component. The upper limit of the core roughness profile. This parameter is derived from the bearing ratio plot.

Mr2 Valley Material Component. The lower limit of the core roughness profile. This parameter is derived from the bearing ratio plot.

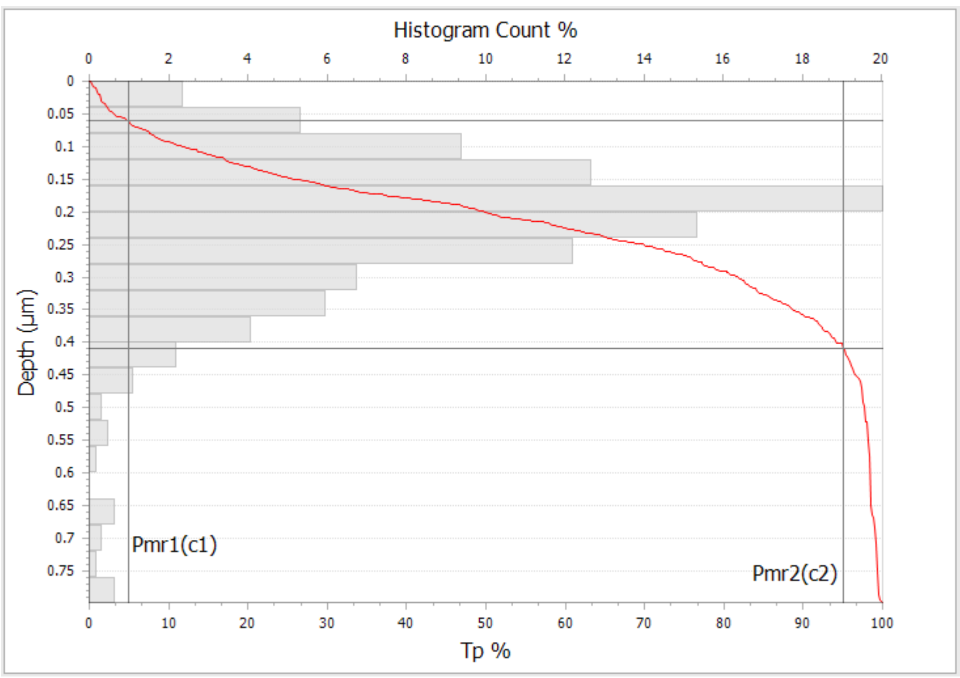
Rpk Reduced Peak Height. Peak height above the core roughness. During a running-in operation, Rpk is the nominal height of the material that may be removed.

Rvk Reduced Valley Depth. Valley depth below the core roughness. Rvk impacts a surfaces ability to trap debris and retain lubricant.

Interactive Material Ratio Profile

- Curve based on profile (slice) data.
- Shows the statistical distribution of peaks and depths of points of a profile.
- User selectable Pmr1 and Pmr2 levels.
- The number of bins and bin width can be changed using [Histogram Properties](#).

For best results, the Linear slice should be perpendicular to the part lay.



Interactive Profile Controls

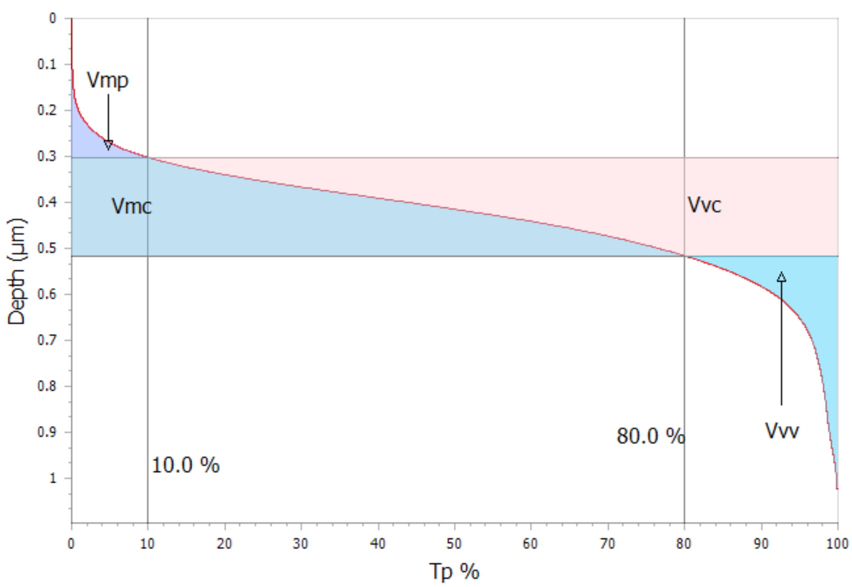
Mode	Selects the interactive operational mode. When Distribution, the upper and lower limits are percentages. When Depth, the upper and lower limits are height (depth) values.
c1	Specifies/displays the depth at c1 when Mode is Depth.
c2	Specifies/displays the depth at c2 when Mode is Depth.
Pmr(c1)	Profile Material Ratio control 1. Specifies/displays the Material Ratio percentage at c1 when Mode is Distribution. Default value is 5% (ISO 25178-3:2008).
Pmr(c2)	Profile Material Ratio control 2. Specifies/displays the Material Ratio percentage at c2 when Mode is Distribution. Default value is 95% (ISO 25178-3:2008).

Interactive Profile Results

c1	Height (or depth) at c1.
c2	Height (or depth) at c2.
c2 -c1	Height Difference.
Pmr(c1)	Profile Material Ratio percentage at height c1. The ratio (expressed as a percentage) of the cross sectional area of the profile as a height (c1) relative to the evaluation cross sectional area.
Pmr(c2)	Profile Material Ratio percentage at height c2. The ratio (expressed as a percentage) of the cross sectional area of the profile as a height (c2) relative to the evaluation cross sectional area.
Pmr(c2) - Pmr(c1)	Profile Material Ratio Difference.

Volume

The Volume plot shows the void volume and the material volume. It is used to evaluate wear and lubrication retention on the entire areal surface. The V1/V2 (Tp%) controls are interactive.



Volume Controls

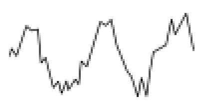
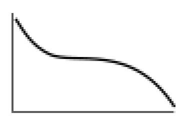
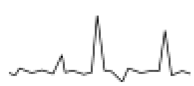
V1	The material ratio control setting where Vmp and Vmc meet. Default value is 10% (ISO 25178-3:2008); however, it is user adjustable.
V2	The material ratio control setting where Vmc and Vvv meet. Default value is 80% (ISO 25178-3:2008); however, it is user adjustable.

Volume Results

Vmp	Peak Material Volume. The volume of material bound by the surface texture at a height of V1 to the highest peak (Tp = 0%). The default value of V1 is 10% (ISO 25178-2:2012).
Vmc	Core Material Volume. The volume of material bound by the surface texture between heights of “V1” and “V2”. The default values of V1 and V2 are 10% and 80% respectively (ISO 25178-2:2012).
Vvc	Core Void Volume. The void volume enclosed from V1 to V2 of surface material ratio and normalized to the unit sampling area.
Vvv	Valley Void Volume. The volume of space bound by surface texture at a height of V2 to the lowest valley (Tp = 100%). The default value of V2 is 80% (ISO 25178-2:2012).

Understanding Material Ratio

The material ratio curve is a reflection of the distribution of heights that comprise a surface. The curve relates directly to surface topography as shown below.

Description	**Profile**	**Material Ratio Plot**
Ground surface with random heights		
Honed surface with peaks removed		
Turned surface with dominating peaks		

Limitations of Material Ratio

- It tends to ignore the geometric form and waviness of the test surface, which may have much more to do with the bearing contact of two surfaces than does a roughness profile.
- In practice, two contacting surfaces are involved and the surface features of each contribute towards wear.

Films

Navigator : Films : Films Data

The Film analysis application is designed to measure surfaces in the presence of films. It can provide results on the top surface topography and roughness, the thickness of the film, and surface topography and roughness of the lower or substrate surface. Film analysis is accomplished by a special FDA analysis function that analyzes multiple intensity modulation signals to determine the substrate and film surfaces. The top and bottom surface, as well as the thickness variation, of samples can be measured.

Use Conditions

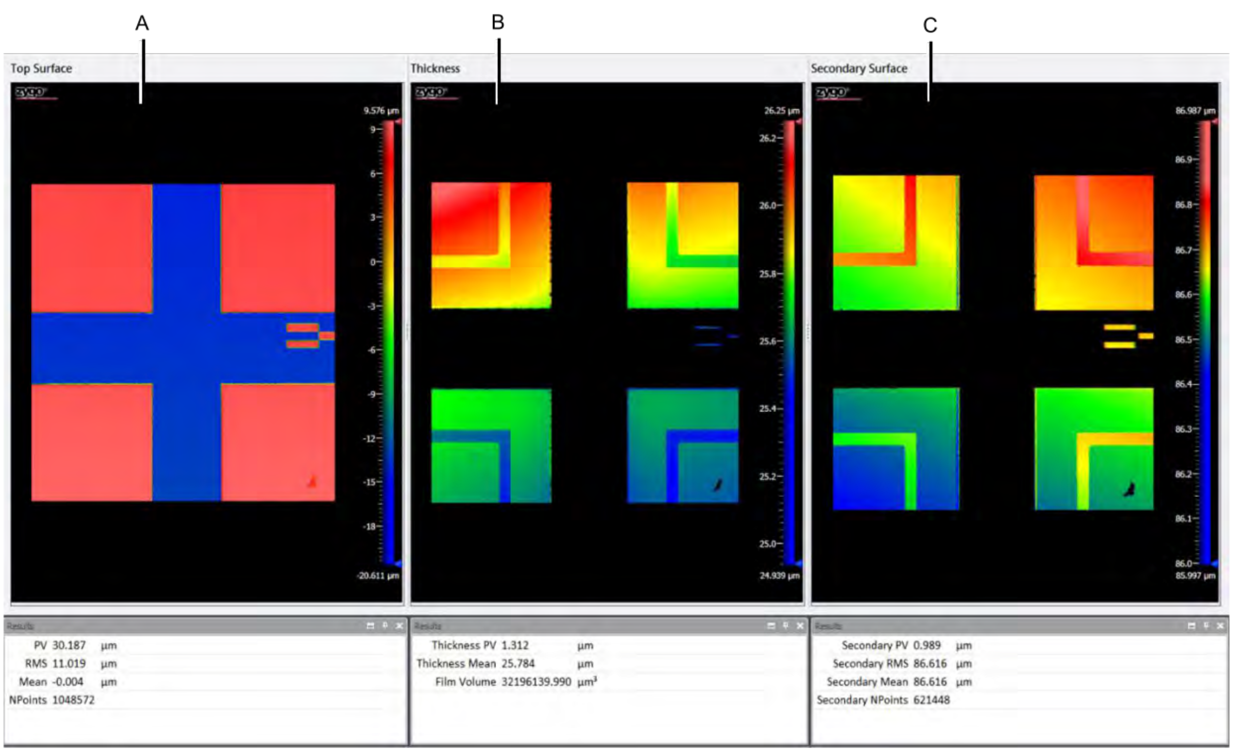
- Applies to optical profilers.
- Films requires a separate license to make measurements.
- 3D Reference Calibration is required.

Films Criteria

In order to be measurable, the film(s) should be:

- Transparent at optical wavelengths between 500-600 nm.
- Thinner than 150 µm optical thickness (physical thickness x index of refraction).
- Thicker than 1.5 µm optical thickness for thickness top and bottom surface characterization.
- Thicker than 0.5 µm for top surface characterization only.

The Films Data Screen



A. Top Surface data and results. **B.** Thickness data and Results. **C.** Secondary Surface data and results.

Top Surface	Displays the top surface data. The processing applied to this data is controlled by either Top Surface Processing or Surface Processing. This means that by default, a best fit plane is removed from this data.
Thickness	Shows the Thickness data. The applied processing is determined by Thickness Processing controls. Areas of no data are regions in which a film was not detected, while color variations indicate thickness variations. The Thickness Mean result gives the average thickness over all valid points – be careful not to be misled by this value if the thickness has large variation.
Secondary Surface	Displays Secondary Surface data. The applied processing is determined by Secondary Surface Processing controls. Areas of no data are regions in which a film was not detected, and thus there was no bottom surface, only a top surface.

Making a Films Measurement

Objective Selection

In general, the higher the objective magnification, the weaker the secondary films signal is. This is due to the higher numerical aperture of these lenses, which causes more dispersion through the volume of the film. Since this is a material effect, there is no absolute guideline on how thick of a film can be measured with each objective. A general guideline is that thickness should be less than 100 µm with a 20X objective and less than 75 µm with a 50X objective.

Aperture Stop Setting

On a NewView system, it is recommended the aperture stop be partially closed (via the knob on the side of the head) if using a 10X, 20X, or 50X objective. To set the aperture stop, focus on a Silicon Carbide flat and set the light level to approximately 30% (using either the slider or the Light Level control on the Advanced tab of the Measurement Setup panel). Close the aperture stop by pulling the knob out until the intensity of the fringes is appropriate for measurement.

On the Nexview, the aperture stop setting is automatic. Refer to Films Troubleshooting.

Measurement Type Selection and Calibration

Select the appropriate Measurement Type in the Measurement Setup panel. For top surface measurement only, the Measurement Type- Surface Over Films should be selected. For a film thickness measurement, select Films Profile.

Next, perform a 3D Reference Calibration for your chosen measure mode, objective, and zoom combination:

1. Place a Silicon Carbide flat or other highly polished, spatially random surface on the sample stage.
2. Click the CALIBRATION tab. Select Objective Calibrations in the navigator.
3. Focus on the center of your calibration sample and select Calibrate Objective. The automated routine will now produce a system calibration file.

Note that this calibration must be performed for each objective and zoom that will be used for measurements.

The 3D Reference Calibration is used to create a model signal which is used during films analysis. It also creates a system reference measurement, to remove systematic error from measurements. It should be re-done regularly, and especially if anything changes in the system, such as focusing an objective or changing the aperture stop.

Films Measurement

1. Focus on the sample surface, and set Light Level, Scan Length, and other measurement settings.
2. For Surface Over Films: On the Films tab in the Measurement Setup panel, select Film Type: Standard if your film is > 1 micron in thickness. For thinner films, select Film Type: Sub-Micron.
3. For Films Profile: If your film consists of a single transparent layer of a substrate, select Single Layer. If there are multiple transparent layers, select Multi-Layer to analyze only the top two interfaces.
4. Set the Refraction Index to the refractive index of your film. This converts optical thickness into physical thickness.
5. If necessary, set the Films Interface Threshold based on the strength of the secondary film signal. Values in the range of 1% to 4% are typical. When this value is too high, no (or little) films data is reported. Setting this value too low increases noisy or spurious data.
6. On the MEASUREMENT tab click the Measure button or press F12.

Films Troubleshooting

Weak Secondary Signal Through a Thicker Film

Reduce the Aperture stop to increase fringe contrast, to an extent. On a NewView, pull out the aperture stop knob on the side of the optical head. The stop should be closed only partially, as it is important to maintain a proper light level on the sample. On a Nexview, the aperture stop will change automatically, but can be manually controlled by adding the Aperture Stop control to a Control Grid.

Calibration should be re-done when the stop is changed. If the fringe contrast cannot be improved, using a lower magnification objective can also help.

Low Signal-to-Noise Ratio (weak secondary signals)

Averaging can improve this ratio, particularly "signal averaging". Add the Number Swli Averages control to a Control grid, or turn on Signal Oversampling.

Advanced Films

Advanced Films analysis is licensed as Advanced Model Based Films Analysis and is commonly called MBA. MBA provides pixel-by-pixel thickness information, as well as top and bottom surface topography of the film and substrate. Additionally, MBA allows for the correction of phase-change-on-reflection errors due to dissimilar materials, which will function for transparent or opaque materials. Under Films in the Navigator, results are displayed as Top Surface, Thickness, and Secondary Surface plots and results.

Requirements

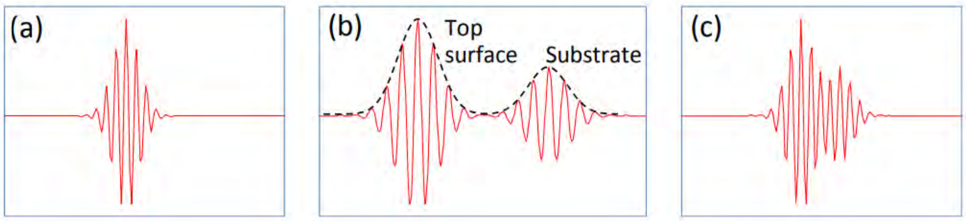
- Nexview (not available for NewView or ZeGage profilers).
- Advanced Model Based Films Analysis license and Mx version 6.4.0 and later.
- Silicon Carbide Flat.
- ZYGO interferometric objective.

Sample Criteria

- A thickness of 0.1 – 1.2 microns.
- Well known optical properties (n and k) for the film and substrate.
- Transparent enough at optical wavelengths for a return signal.

Background

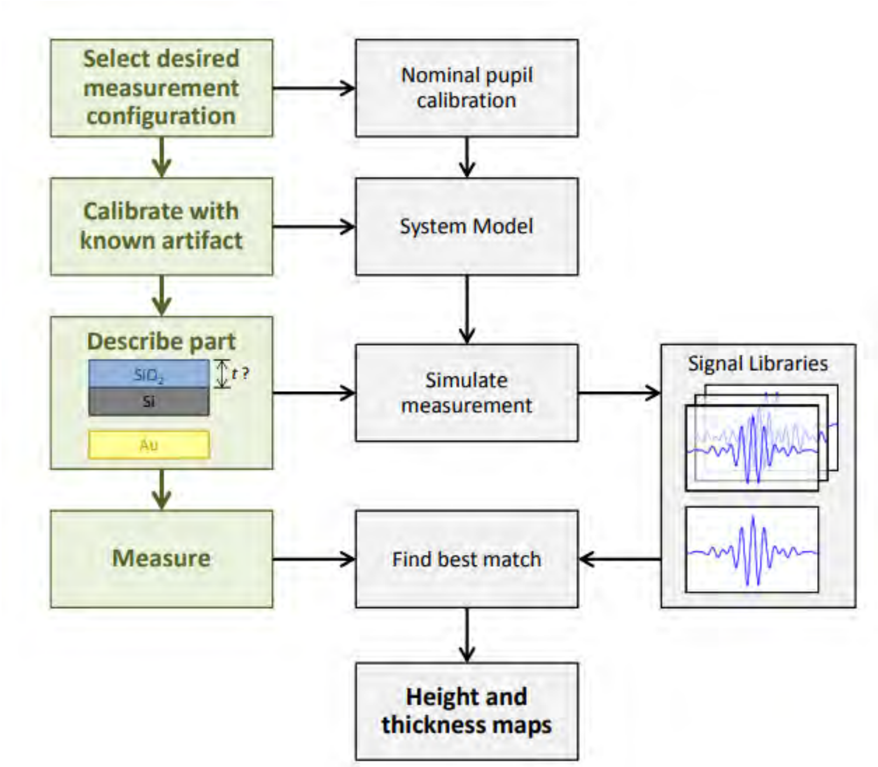
ZYGO optical profilers function using CSI – coherence scanning interferometry. This technique provides topography measurement using a localized coherence signal. This signal is produced by interference between reflections from a test part and a reference surface. An example of this signal scan on different surfaces is shown below.



(a) A typical white light interference signal for a surface with no film. (b) A white light interference signal in the presence of a film thicker than the coherence length. (c) A white light interference signal in the presence of a thin film, showing overlapping interferograms.

A transparent film will typically produce a second signal (b), due to reflections from the top of the film and the substrate. When these signals are well separated, traditional analysis methods can separate them and provide thickness and topography information. As film thickness decreases below a micron, the signals begin to merge, and are no longer separable.

MBA is a technique intended to solve this problem by modeling the CSI signal in the presence of thin films, and comparing the modeled signal to the measured signal.



The measurement process for the advanced films capability. Only steps shown in green are performed by the user.

An on-system calibration is performed when the instrument is manufactured, and an in situ calibration is performed with an optical flat, by the user, for a given optical configuration. This allows for modeling of the optical system. With the user input of the optical properties of the sample being measured, a library of model signals is generated. After part measurement, the best match model signal is used to calculate thickness and topography across the entire field of view.

It is important to remember that the signal modeling depends heavily upon the accuracy of the optical properties given for the sample. Incorrect n and k values can produce a model signal that leads to data that looks trustworthy, but is incorrect.

Making an MBA Measurement

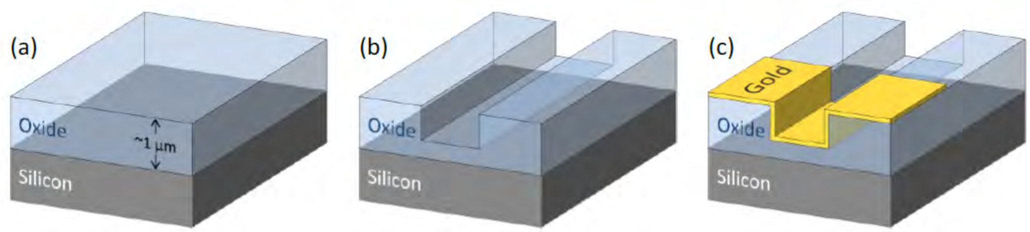
1. In the Measurement Setup controller, select the Advanced Films Measurement Type. A new MBA tab appears. MBA measurements use the selected Scan Length, Auto Focus, and other control values, so set them appropriately.
2. Focus on the Silicon Carbide flat, null the fringes, and click the Calibrate Current Configuration button located at the bottom of the MBA tab. This calibration should be done regularly, and is required for each different combination of objective and zoom.
3. Focus on your sample.
4. If there are two regions, open the Mask Editor and set the Mask Type to MBA Region 1 and MBA Region 2. Draw masks corresponding to the two different areas of interest.
5. Once regions are properly defined, the model parameters should be filled out in the corresponding Region areas. If the Substrate and Film are common materials, they may be available in the material drop-down. If not, and the materials can be described by a constant n and k across the visible spectrum, select Constant n and k, and enter the appropriate values.
6. Once the material properties are entered, select a thickness search range. In the most general case, the thickness search range can be 0 to 1.2 microns.

7. Set 4 for Number Swli Averages.
8. On the MEASUREMENT tab click the Measure button or press F12.

Interpretation of Results

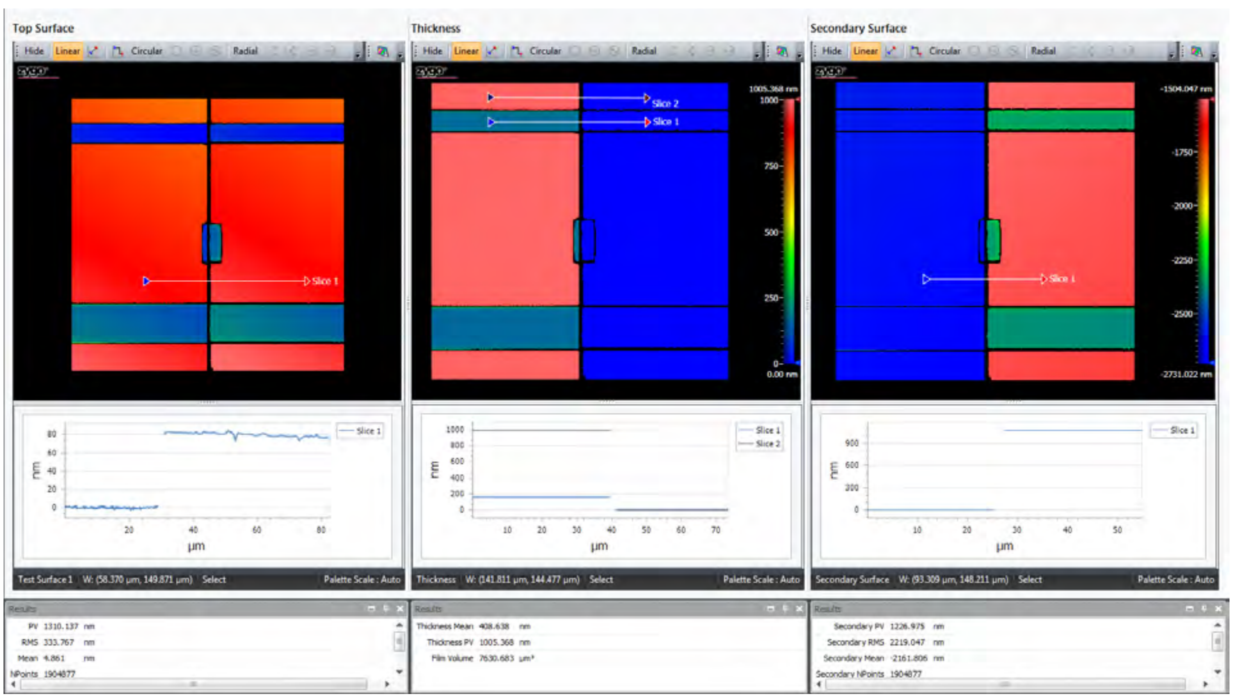
A successful measurement produces three height maps – the Top Surface, Thickness, and Substrate. Switch to the Analysis tab, and select Films Data from the Navigator.

Consider a sample with two regions. Region 1 consists of a layer of oxide-on-silicon, including a trench with a thin layer of oxide remaining at the bottom. Region 2 is the same sample, but with an opaque gold overcoat.



Fabrication of the oxide trench sample with partial gold overcoat. (a) ~1 um of oxide is grown on a silicon substrate. (b) The oxide is masked and partially etched, leaving a thin layer of oxide underneath. (c) A gold overcoat is applied over part of the sample.

The measurement results for this sample are shown below. The region of gold overcoat is in the right half of the field of view.



In the Top Surface image at left, we can observe the thickness of the gold overcoat by placing a profile across the two regions. The trench depth can also be measured and compared between the two regions (not shown).

In the Thickness map, we see the thickness of the oxide in the etched vs unetched region. Note that the portion of the measurement with gold overcoat has a thickness of 0, indicating there is no film.

The Secondary Surface map is formed by the subtraction of the top surface and thickness map. Since the film thickness is 0 in the gold coated region, the secondary surface map is identical to the top surface map in this region. The secondary surface in the transparent oxide region shows a flat secondary surface – the underlying silicon wafer – at a height lower than the gold overcoat by the thickness of the oxide.

This example demonstrates the wealth of information available from an MBA measurement. PCOR corrected gold coating thickness, film thickness, top and bottom surface topography, and trench depths can all be extracted from this measurement.

MBA Troubleshooting

Quality Filter

A Quality Filter can remove pixels where the confidence in the model fit isn't very high. On the Analysis tab, open Thickness Processing. Enable the sequence with the green check-mark, and then right click in the empty Sequence area and add a Quality Filter. A value of 2 is a good default for removing very weak matches.

"Hash" and Dual Solutions

If the resultant thickness map has relatively large jumps on a pixel-to-pixel basis, the model may have found two solutions of similar confidence. This can cause variations in the reported thickness between two values. The most common cause of this is a material model which does not accurately represent the part. If a more accurate model can't be obtained, limiting the thickness search range can remove the erroneous solution – but be warned that an inaccurate model can give inaccurate results.

Film Thickness Mean is 0

This can occur if Form Remove is applied to the film thickness map – verify in the 'Thickness Processing' sequence that there is no unexpected processing. This can also occur if the material model is incorrect, and the best solution being found is for no film. Verify that your optical parameters are appropriate for the material being measured, and that a film is present.

Graphic Results 10

Graphic Results Overview

- Graphic results are visual representations or *plots* of the part surface or a particular data analysis.
- All of the plots may not be applicable to your instrument and applications.
- 1D, 2D, or 3D plots are displayed where appropriate in the data flow and analyses.
- Plot axes are based on the Cartesian coordinate system.
- For a basic list of graphic results see Plot Types.

Saving Plot Configurations

The size, orientation, and other settings are preserved with the application.

1. Click Save Application or select File ▶ Save Application.

Printing Plots

Applies to 2D and 3D plots. 2D output includes profile data if displayed.

1. Place the cursor over the plot.
2. Right-click and select Print Plot. See Printing.

Saving the Plot Image

The plot screen can be saved as png, jpg, bmp, or tif image formats.

1. Place the cursor over the plot.
2. Right-click and select Save Bitmap.
3. Choose the file type with the Save as type drop-down box.
4. Type a name for the file after File name.
5. Click Save.

See Also

Exporting as Image

Copying the Plot Image

The plot screen can be copied to the clipboard.

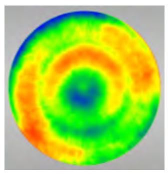
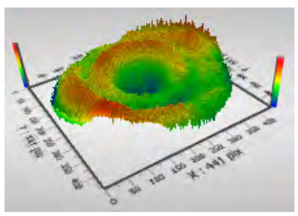
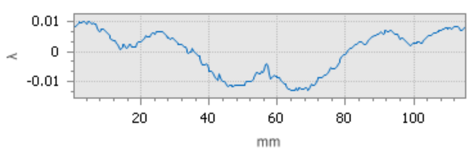
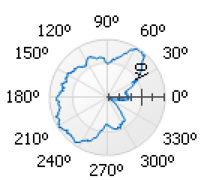
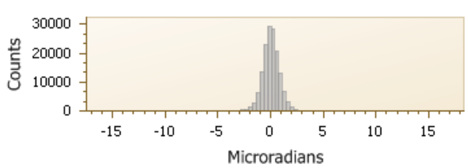
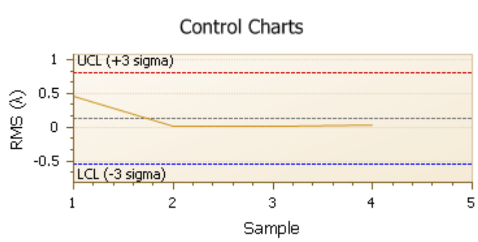
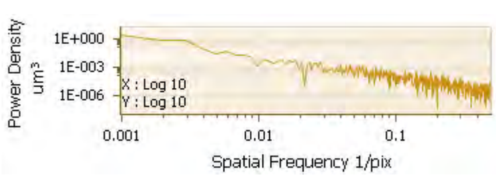
1. Place the cursor over the plot.
2. Right-click and select Copy To Clipboard.
3. Switch to a program that supports the pasting of images.
4. Perform a paste operation.

Exporting Plot Data

The underlying data for most 1D plots can be exported.

1. Place the cursor over the plot.
2. Right-click and select Export. See Export Chart Data.

10.1 Plot Types

Plot	Example	Description
2D		Two-dimensional (2D) view with heights represented in different colors or shades.
3D		Three-dimensional (3D) model.
Line Profile		A 1D plot that shows a slice or profile through two-dimensional data.
Circular Profile		A 1D plot that shows profile data in a circular representation.
Histogram		A 1D chart showing the spread or distribution of data.
Control Chart		Shows a historical record of one result over multiple measurements.
PSD		The power spectral density 1D plot captures the frequency content of the data and helps identify periodicities.

Some plots are specific to an analysis and are explained in the section describing the analysis.

10.2 Common Plot Functions

Zoom, Pan, Rotate

Axes Limits

Sync Color Scale

Color

See also Common Processing Functions

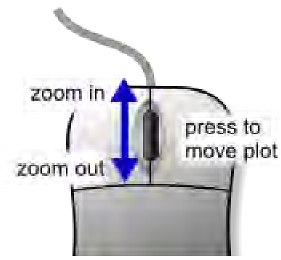
Zoom, Pan, Rotate

Zoom: magnify or shrink a portion of a graphic display by pressing and rotating the mouse scroll wheel.

Pan: move a graphic display both horizontally and vertically by holding down the mouse scroll wheel and then moving the mouse.

Rotate: move a three dimensional graphic about its axes.

Mouse Scroll Wheel Function



Action	Graphic	How to Use
Zoom	Profile 2D 3D	Point to graphic and turn mouse scroll wheel. Zoom is centered over the cursor location. Zoom in- turn scroll wheel forward to enlarge. Zoom out- turn scroll wheel backward to reduce. To display the entire graphic, right-click and select Fit Window or Reset Chart.
Pan	Profile 2D 3D	To reposition the graphic within the panel, press the mouse scroll wheel and drag to move, release to set the position.
Rotate	3D	Press the left mouse button and drag the plot to rotate, release to set the position.

See Also

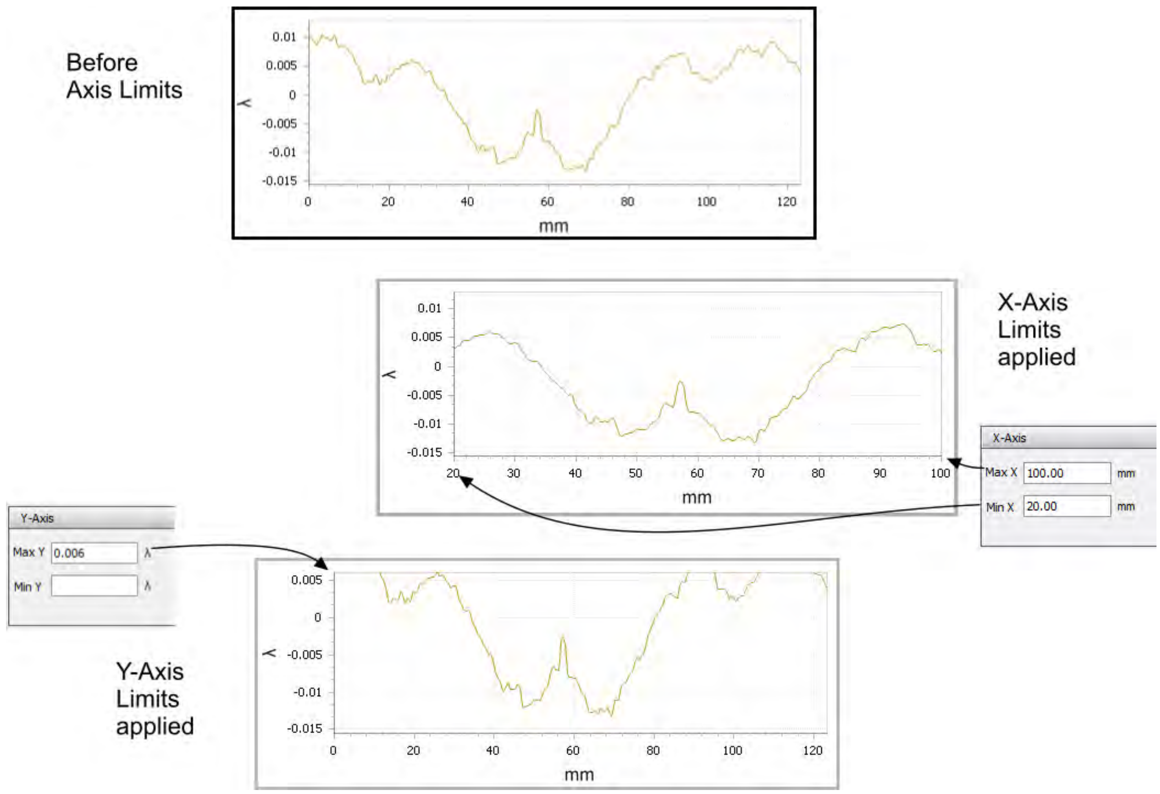
2D/3D Plot Views

Axes Limits

This feature lets you enter the minimum and/or maximum values displayed on the (horizontal) x-axis or (vertical) y-axis.

Data clipping can occur.

If necessary to refactor the plot view to match the set limits, place the cursor over the plot and turn the mouse wheel.



For a profile plot, right-click on the plot and choose Chart Controller, then click the Linear Axes tab.

For a control chart, right-click on the chart and choose Set X/Y Axis Limits.

Max X	The largest value to display in the horizontal plot axis.
Min X	The smallest value to display in the horizontal plot axis.
Max Y	The largest value to display in the vertical plot axis.
Min Y	The smallest value to display in the vertical plot axis.

Changing Plot Characteristics

Auto Hiding Plot Toolbars

1. To enable Auto Hide for plot toolbars, right-click on the plot and choose Select ▶Auto Hide Toolbar. When Auto Hide is enabled, toolbars on plots will disappear whenever the mouse pointer is not on them.

Showing or Hiding Zygo Logo

1. Access the Tools ▸ Options... menu.
2. Select or deselect the Show Zygo Logo on Plots check box.
3. Click OK.

Changing Plot Fonts

1. Place the cursor over the plot.
2. Right-click and select Plot Controller.
3. Under the Axes tab, enter the desired font selections.
   - Choose Font, Font Style, Size, and Color options.
   - Make sure the Show Axes check box is selected.
4. Click Close.

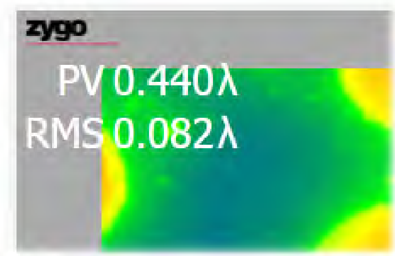
Changing Axis Labels

1. Place the cursor over the plot.
2. Right-click and select Plot Controller.
3. Under the Axes tab and Axis Label enter the desired text for the axes.
   - Tick Marks displays graduations on the axis labels.
   - Hide Two Axes hides two of the possible four axes labels for the plot.
4. Click Close.

Displaying Results

Results and attributes (outputs) can be displayed on the plots.

Results may be dragged and dropped into the corners, edges, or the center of the plot.



Adding/Removing Results from the Plot Display

1. Place the cursor over the plot.
2. Right-click and choose Select Results.
3. Use the Select Results dialog to add and/or remove results from the display. See Adding or Removing Items for more details.

Changing Result Order

1. Place the cursor over the result.
2. Press and drag the Result to a different position.

Changing Result Location

1. Point to a result with the cursor.

2. Press and drag to a new grid location.

or

3. Shift-click and drag to *any* location and release the mouse button.

Changing All Result Locations

1. Place the cursor over the plot.
2. Right-click and select Plot Controller.
3. Click the Outputs tab.
4. Select the Output Location: Top Left, Top Right, Bottom Left, or Bottom Right.
5. Click Close.

Changing Result Fonts

1. Place the cursor over the plot.
2. Right-click and select Plot Controller.
3. Click the Outputs tab.
4. Select from the Font, Font Style, Size, and Color options.
5. Click Close.

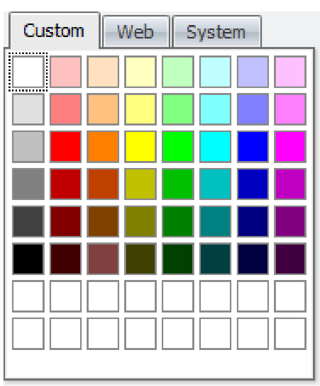
Color Selection

Some features provide color selection, such as:

(For plots) Right-click and select Plot Controller; color for fonts is under Axes tab.

(For plot slice) Right-click on the Slice and select Properties; the color of the slice is specified with Slice Color.

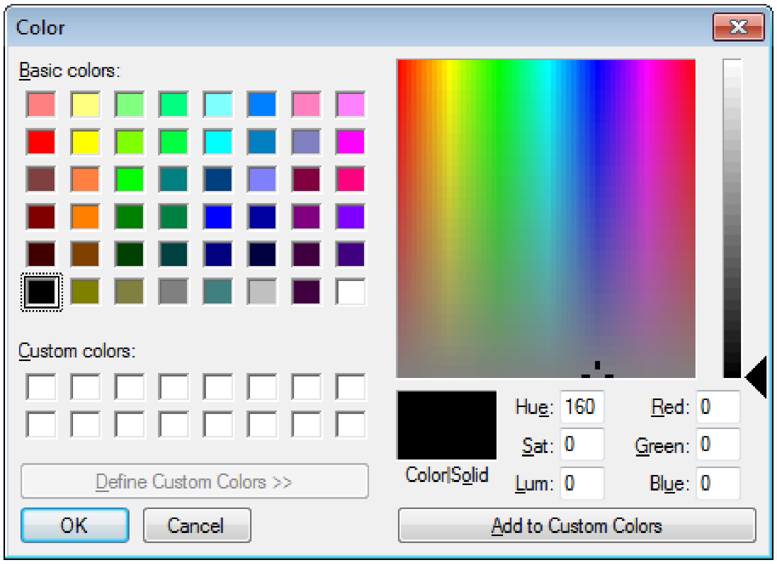
1. Click the Color pull-down. Color selections appear. Typically there are Custom, Web, and System tabs.



2. To change the existing color, click a color chip.

Custom Colors

1. To create a custom color, right-click on a blank chip located on the lower portion of the color chart (shown above).



2. Click on a blank under Custom colors.
3. Enter values between 0 and 255 in the Red, Green, and Blue fields.

   You can combine red, green, and blue in various proportions to obtain any color in the visible spectrum. The higher the value, the more intense the color. For example, 255 in the Red field and 0 in the Green and Blue fields creates an intense red.

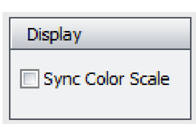
or

4. Select the new color by moving the color picker cursor and by moving the triangular luminance slider.

then

5. Click Add to Custom Colors.
6. Click on the newly created color chip under Custom colors.
7. Click OK.

Sync Color Scale

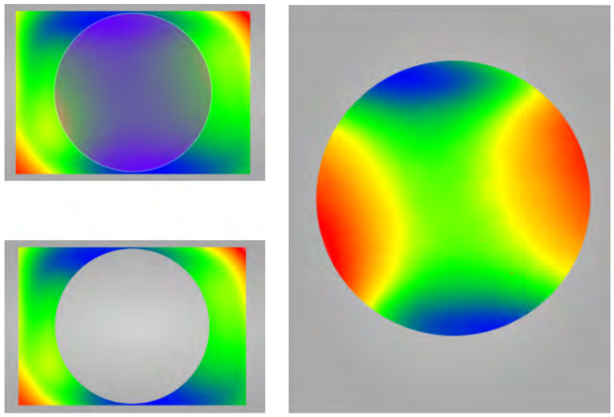


Select the Sync Color Scale check box to synchronize plot colors within the current tool or view.   This means that within a particular view or tool that all the plots use the same vertical color scale. Generally, this makes it easier to visualize the effect of the tool.

Sync Color Scale should not be confused with palette scaling.

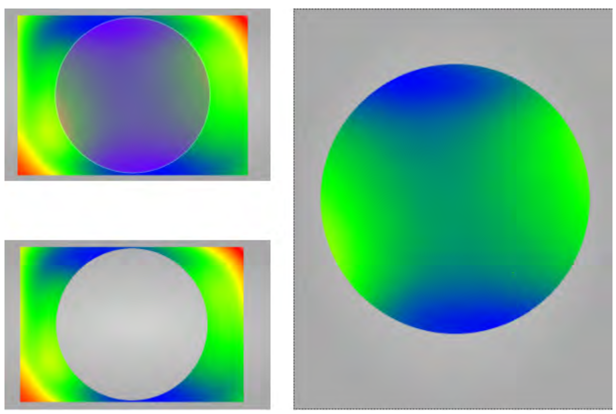
When the Sync Color Scale check box is clear, the plot colors in each location are based on the extent of the data within the localized view.

Sync Color Scale Example



Sync Color Scale *OFF*

This example shows plots in the Auto Aperture tool. The output in the large 2D plot has colors that do not match the input plot in the upper left. (The purple colored circle indicates the aperture defined in the tool.)



Sync Color Scale *ON*

The colors displayed within all plots match.

Saving/Exporting Plot Data

This function saves processed data, or data modified with data processing functions such as filtering, fit remove, edge trim, spike clip, etc.

Save plot data as datx, dat, xyz, or asc files.

Export plot data as int, sdl, or stl files.

1. Place the cursor over the plot.
2. Right-click and select Output ▸ Save Processed Data (or Export Data).
3. Choose the file type with the Save as type drop-down list.
4. Type a name for the file after File name.
5. Select other dialog options.
6. Click Save.

10.3 2D/3D Plot Overview

This information applies to 2D and 3D plots.

Plot settings are saved with the application (.appx) file.

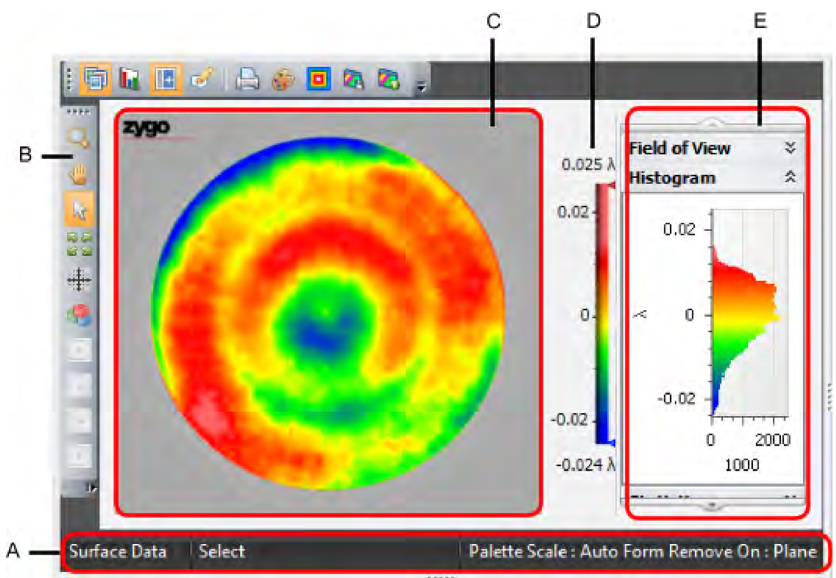
Identifying the Plot

Information about the plot can be displayed at the bottom of the plot panel. See Plot Status Bar.

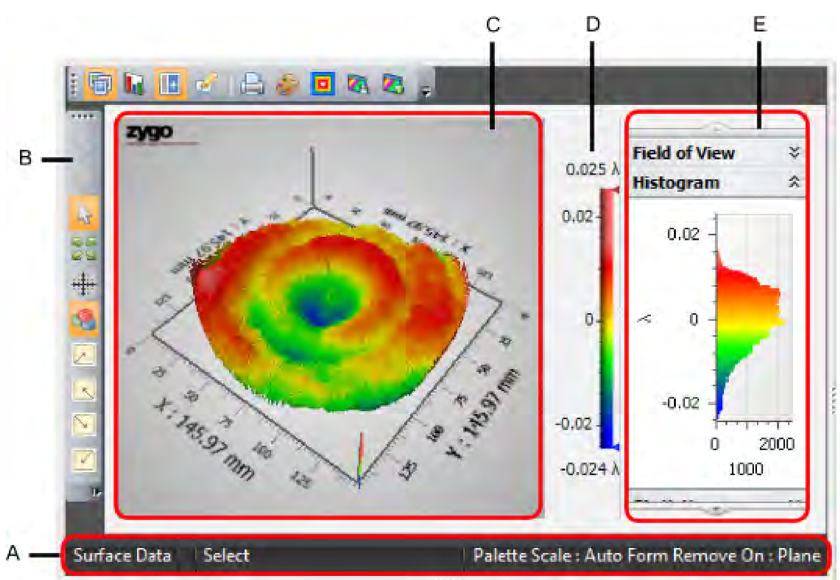
Plot Nomenclature

The following images illustrate the common features of 2D and 3D plots.

2D



3D



A. Status bar. **B.** Toolbars. **C.** Plot graphic (3D shown with axes). **D.** Legend **E.** Details panel.

2D/3D Plot Views

Switching Between 2D and 3D Displays

1. Position the cursor over the plot.
2. Right-click and select 2D or 3D to switch between plots.

Fit Window

Click to fit the plot and displayed axes into the current plot window.

1. Position the cursor over the plot.
2. Right-click and select Fit Window.

Full Screen Views

1. Position the cursor over the plot.
2. Double-click to open a new full screen plot.
3. Click the Esc key to close the window. All changes made in the full screen view are incorporated.

2D/3D Plot Fixed Views

Fit Window

2D and 3D plots.

Click to fit the plot and displayed axes into the current plot window.

1. In the Mode toolbar, click Fit Window.

1X and 2X Views

2D only.

Click to change the magnification of the 2D plot.

1. In the Mode toolbar, click 1X to display 1:1 data (pixels at 100%), or 2X to display 2:1 data (pixels at 200%).

When 1X or 2X is cleared, the plot reverts to fit window size.

Oblique Views

3D only.

Click to position the 3D plot in one of four preset oblique orientations.

1. In the Mode toolbar, click Bottom Left , Bottom Right, Top Left, or Top Right.

2D/3D Plot Toolbars

- Vary based on the plot type.
- Can be hidden or displayed.
- Can be moved.

To Hide or Show a Plot Toolbar

1. Position the cursor over the plot.
2. Right-click and select Select ▶ Tool Bars ▶.
3. Checked items are displayed. Clear a check box to hide the corresponding toolbar.

Moving a Plot Toolbar

Toolbars can be positioned horizontally or vertically within the plot display area.

1. Point to the dots on the toolbar segment. The cursor changes to ✥ .
2. Press and drag the toolbar to new location and release the button.

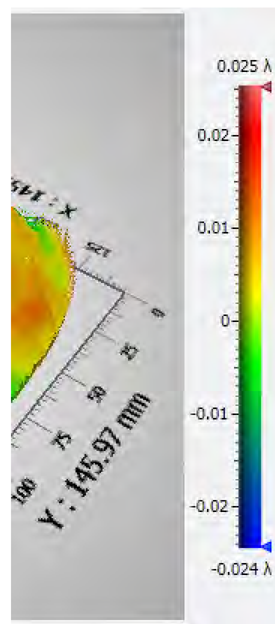
See Also

Toolbars

Changing a Toolbar

2D/3D Plot Legend

The legend is the height or z-axis shaded or colored scale on the right side of the plot.



Show/Hide the Legend

1. Place the cursor over the plot.
2. Right-click and select Show ▶ Legend.
3. To hide the legend, repeat the above steps.

Changing Legend Units

Legend units are based on the plot Z units.

1. Place the cursor over the plot.
2. Right-click and select Select ▶ Units ▶ Z Units.

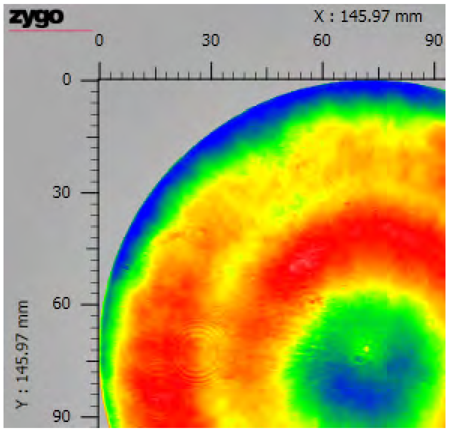
See Setting Individual Units for additional information.

2D/3D Plot Axes

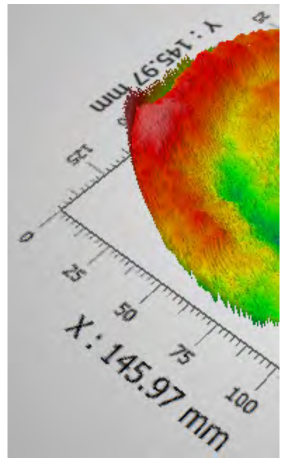
Axes are reference lines displayed along the sides of the plot and are based on the Cartesian coordinate system.

To display units other than pixels, perform Lateral Calibration.

2D Plot Axes



3D Plot Axes



Show/Hide the Plot Axes

1. Place the cursor over the plot.
2. Right-click and select Plot Controller.
3. Under the Axes tab, select the Show Axes check box.
4. To hide the axes, repeat the above steps and clear the Show Axes check box.
5. Click Close.

Changing Axes Units

Axes units are based on the plot X-Y units.

1. Place the cursor over the plot.
2. Right-click and select Select ▶ Units ▶ X-Y Units.

See Setting Individual Units for additional information.

2D/3D Plot Colors

Spectrum	Height values are displayed in a fully visual spectrum of colors. Shows the greatest detail in the center of plotted height values.
Red White and Blue	Height values are displayed in red, white, and blue. Also referred to as RWB.
Grey	A grayscale or shaded view.
CYMK	The scale is made up of cyan, yellow, magenta, and black.
Icy Cool	Height values are displayed in shades of blue.
Neon	A variation of spectrum that shows the greatest detail near the top and bottom of plotted height values.
Red Hot	Height values are displayed in shades of bright red.
Bands	Height values are displayed in up to 16 different colors.
Gold	Height values are displayed in shades of gold.
Red	Height values are displayed in shades of red and gold.
Binary	Black and white only.

Changing Plot Colors

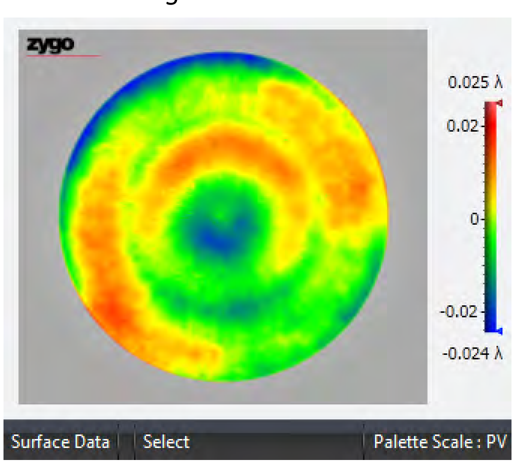
Select the color of the plot display.

1. Place the cursor over the plot.
2. Right-click and select Select ▸ Palette ▸ and choose a color.

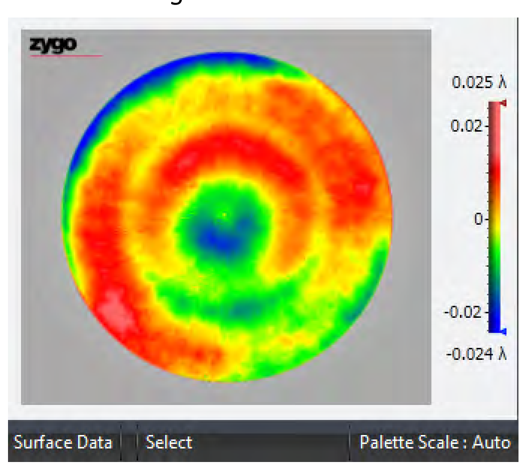
2D/3D Palette Scaling

Palette scaling adjusts the mapping of the plot colors to the height (z-axis) of the data; it is used to enhance the visual display of data. It does not affect numeric results; it is for display only. A typical use for palette scaling is to remap a monochromic plot to multiple colors, thus highlighting the intrinsic data.

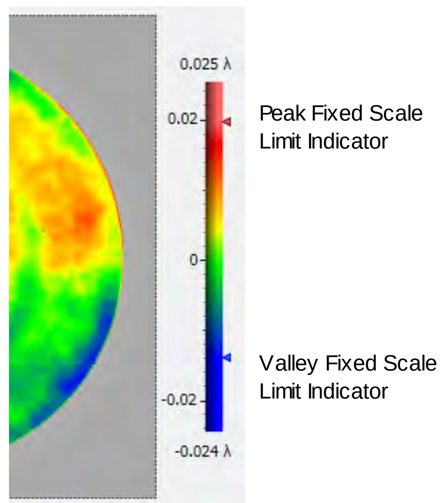
Palette Scaling: PV



Palette Scaling: Auto



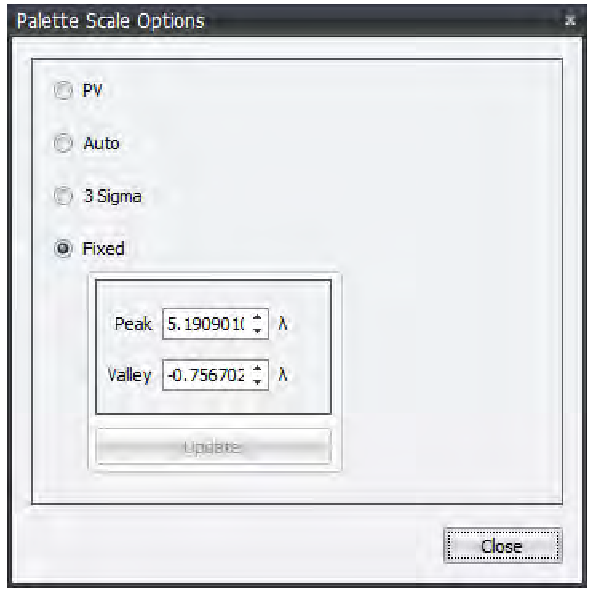
Option	Description
PV	PV maps colors to the PV (peak-to-valley) of the data.
Auto	Automatically applies a linear scaling of the color map to the data to remove extremes. The top and bottom 0.5% of the data are mapped to the highest color and lowest colors respectively. The height data starting from bottom 0.5% to top 99.5% uses the full palette. This setting is useful to show details when there are spikes in the data.
3 Sigma	Automatically scales the color map based on 3 sigma cutoffs. Points above 3 times the rms of the mean of the data are mapped to the highest color. Points below 3 times the rms of the mean of the data are mapped to the lowest color. All points in between the cutoffs are mapped to the full palette.
Fixed	Sets the single color peak/valley plot cutoff height locations based on direct user entry. User entry can be either with the plot legend limit indicators or with the Peak and Valley numeric entries in the Palette Scale Options dialog. Heights above the peak fixed scale limit indicator are a single color, and points below the valley fixed scale limit indicator are a single color. The plot legend must be displayed for interactive limit indicators. Click and drag either/both of the fixed scale limit Indicators (triangles) to use fixed scaling.



Note that the current palette scaling option is shown in the plot's status bar.

Changing Palette Scaling

1. Place the cursor over the plot.
2. Right-click and select Select ▶ Palette ▶ Palette Scaling.
3. Make scaling selections. See the PV, Auto, 3 Sigma, and Fixed options described above.
4. Click Close.



2D/3D Plot Details

This feature displays information about the plot data within the same panel.

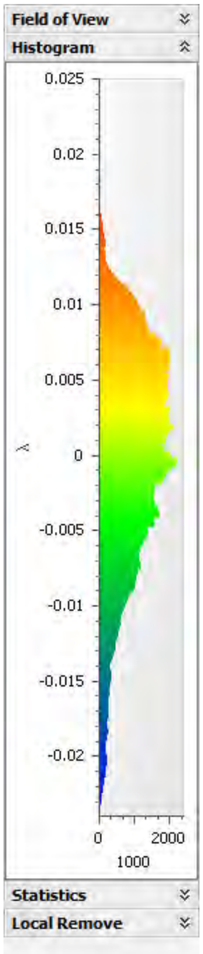
Show/Hide Details

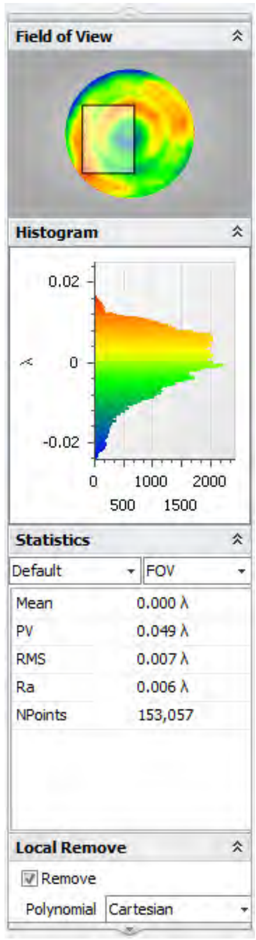
1. Place the cursor over the plot.
2. Right-click and select Show ▶ Details.
3. To hide the details, repeat the above steps and clear the selection.

Changing the Detail Panel

Click down arrows to expand (show) a detail.

Click up arrows to collapse (hide) a detail.





Field of View

Shows the relationship of the entire data matrix to what is displayed in the plot panel (represented by the box).

Histogram

A predefined form of the regular histogram that shows the distribution of data according to heights.

The histogram displayed is based on the data within the field of view or the region specified in the Statistics section.

Statistics

Shows predefined results about the area or region under view.

Local Remove

When the Remove check box is selected, a form removal is applied to the data within the plot panel.

Local Remove Details

These controls applies a form removal to the data within the plot view after the tool functions are applied. Generally, it is used to minimize the effect of the overall part shape and to emphasize part detail.

Local remove is not applied to the data analysis, it is applied only within the currently displayed view. To actually remove form from the data use the Fit Remove tool.

The interaction of the Cartesian selection is shown below.

Select	To Remove ...	Also Removes ...	Cartesian Terms Removed
None	nothing	-	-
Piston	z-axis offset	-	Offset
Plane	tilt or slant	Piston	Offset, X, Y
Sphere	spherical shape	Piston, Plane	Offset, X, Y, X^2, Y^2
Cylinder	cylindrical shape	Piston, Plane	Offset, X, Y, XY, X^2, Y^2

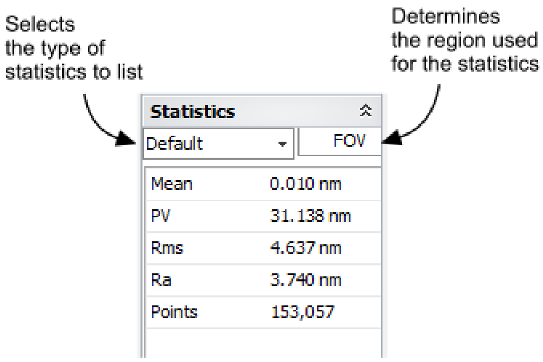
For the equations used to calculate these Cartesian terms see Cartesian Term Definitions.

The interaction of the Zernike selection does is shown below.

Select	To...
Piston	Adjust for any z-axis offset in the data.
Tilt	Adjust for any residual tilt or incline in the data. For most measurements, remove Piston and Tilt to compensate for the tilt inherent in the equipment setup and in the nulled fringes.
Power	Compensate for curvature in spherical surfaces; they appear flat. This allows you to observe surface features instead of the dominant spherical shape.
Astigmatism	Compensate for curvature in astigmatic or cylindrical surfaces; they appear flat. This allows you to observe surface features instead of the dominant astigmatic shape.
Coma	Compensate for coma in the data. Coma and Spherical are usually used when testing lens systems to view residual wavefront errors after removing known aberrations. The residual errors are usually an indication of misalignment or fabrication errors of the elements in the optical system.
Spherical	Compensate for spherical aberration in the data.

2D/3D Plot Statistics

Statistics in the Plot Details show localized statistics based on the specified region.



The statistic *type* (Default drop-down) determines what grouping of results to list. For individual parameter definitions, see [Results and Attributes](#).

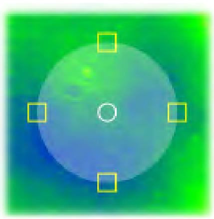
The statistic *region* (FOV drop-down) determines the region or area used to calculate the statistics on, and the area used for the histogram detail.

Specifying a Statistics Region

FOV uses the area displayed within the 2D plot panel. As an alternative, a circle, square, rectangle, or an ellipse region can be defined over the data matrix. The FOV or the shape region is used to calculate statistics and for the histogram.

 This must be performed while in 2D mode.

1. Point to FOV or the right drop-down.
2. Click and select a shape from the list. The shape or region appears on the plot.



Shown is an example of a circle positioned over a 2D matrix.

The circle handle is used to position the shape.

The square handles are used to resize the shape.

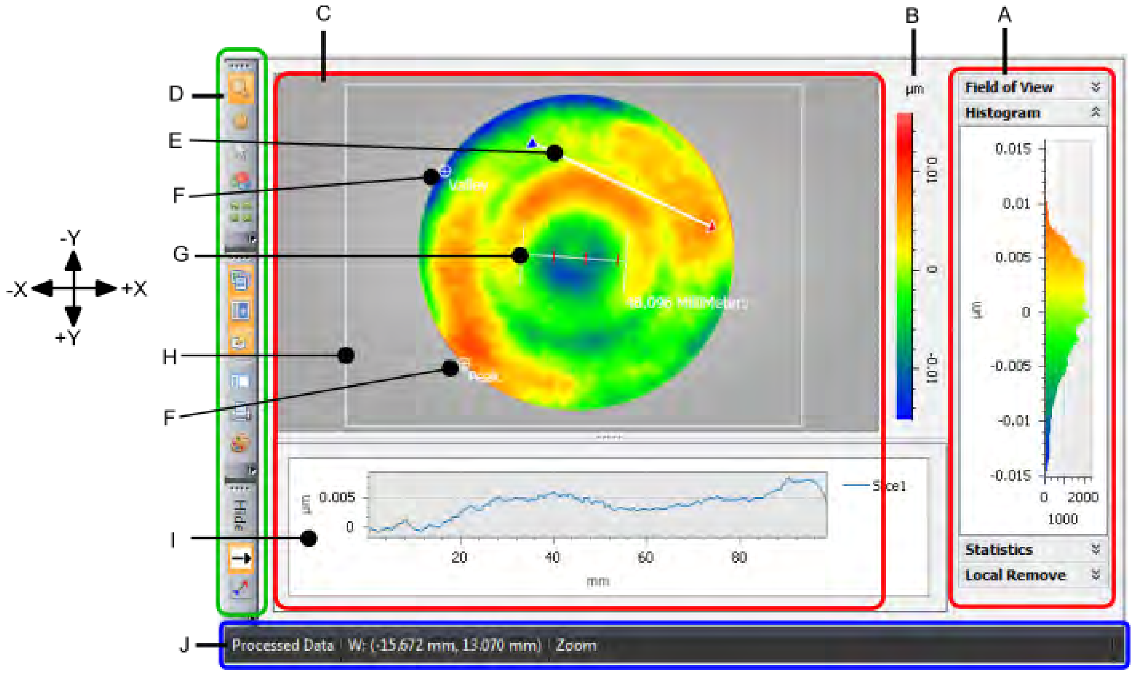
3. To move the region, point to the circle at the center of the shape, and press and drag it.
4. To size the region, point to a square on the outside border, and press and drag it.

10.4 2D Plot

2D Plot Overview

- Heights are displayed in different colors or shades, like a topographical contour map.
- Used to create, edit, and view slices.
- Surface data is displayed as a function of magnitude as viewed along the instrument's z-axis.
- User-configurable with toolbars and context menu.
- Plot settings are saved with the application.

The 2D Plot Display



A	Details	Extra optional information displayed to the right of the plot. It may include Field of View, Histogram, Statistics, and Local Remove.
B	Legend	The color key and Z-axis scale to the right of the plot.
C	Display Area	Shows current or loaded graphic of the test part based on selected options.
D	Toolbars	The small icon based bars that reside near the plot, which are used to change and control the plot display.
E	Slice	A user-defined line or area upon which profile data is derived.
F	Peak Valley	Marks the highest (peak) and lowest (valley) data points.
G	Ruler	A user-defined line to measure lateral dimensions directly on the data.
H	FOV	A border representing the camera field of view.
I	Profile Plot	Slices are used to define the one-dimensional data chart, which typically is based on a cross section through the data matrix.
J	Status Bar	Shows information about the plot, cursor position, and mode.

Changing the 2D Plot

For panning (moving) and zooming (viewing size) see Zoom, Pan, Rotate.

For details on showing the plot Legend and selecting Z-axis units, see 2D/3D Plot Legend.

For details on showing plot axes and selecting X-Y units, see 2D/3D Plot Axes.

For details on changing plot colors, see 2D/3D Plot Colors.

For information on plot details, see 2D/3D Plot Details.

For information on Investigation Tools, see Investigation Tools.

Show/Hide Peak Valley Markers

Marks the highest (peak) and lowest (valley) data points on the 2D plot.

1. Place the cursor over the plot.
2. Right-click and select Show ▸ Peak Valley.
3. To hide the markers, repeat the above steps and clear the selection.

Show/Hide Camera Field of View

Shows the context of the plot in reference to a border representing the camera field of view (FOV).

This is different than the Field of View available in plot details, which shows the context of the entire plot matrix to the current view.

1. Place the cursor over the plot.
2. Right-click and select Show ▸ Camera FOV.
3. To hide the FOV border, repeat the above steps and clear the selection.

See Also

Using Rulers

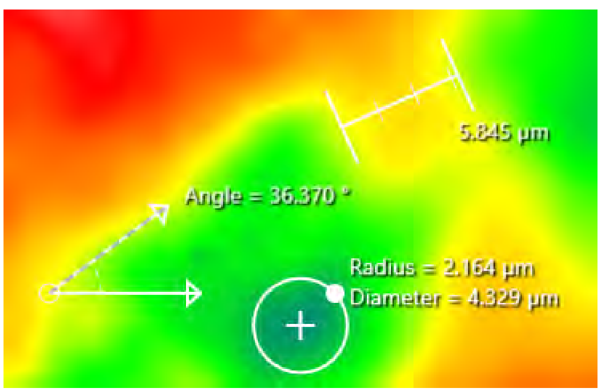
2D/3D Plot Overview

2D/3D Plot Toolbars

Using Rulers

Rulers are used to measure dimensions directly on the 2D plot data. They are adjustable and can be hidden and recalled.

Ruler Types



Ruler (Linear)	A straight ruler for measuring along a line.
Diameter	A circular ruler for measuring diameter and radius.
Angle	A tool for measuring the angle between two adjustable lines.

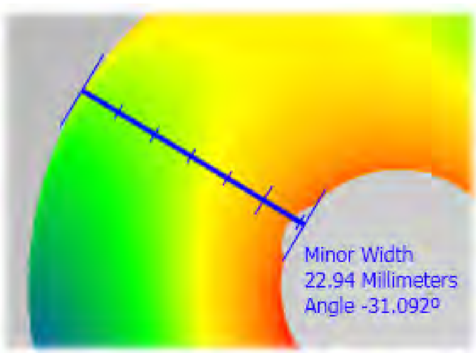
Creating a Ruler

1. Place the cursor over the plot.
2. Right-click and select Rulers ▸ New Ruler, New Diameter, or New Angle.

Working with Rulers

Ruler How To	Details
Add additional rulers	Right-click on the plot and select Rulers ▸ New...
Move a ruler	Point to center of the ruler, center crosshair of the circle, or vertex of the lines for the angle; press and drag the ruler, and release the mouse button.
Change the length or angle of the ruler	Point to the end of the straight ruler, press and drag the end, and release the mouse button.
Change diameter	Point to the dot on the circular ruler, press and drag the dot, and release the mouse button.
Change angle	Point to one of the lines on angle ruler, press and drag the line, and release the mouse button. To restrain the angle lines to move in 15 degree increments, hold the shift key when changing the angle.
Change units	Units are based on the X-Y units of the plot. To change, right-click on the plot and select Select ▸ Units ▸ X-Y Units.
Change decimal places	The number of decimal places are based on the X-Y units settings of the plot.
Hide all rulers	To hide rulers, right-click and select Rulers ▸ Show Rulers to deselect.
Delete a ruler	Point to center of the ruler. Press the Delete key.

Customizing Rulers



An example of a ruler that has been changed:

Color- blue
Label- Minor Width (added)
Line Size- increased to 3 pixels
Show Angle- selected
Show Tickmark- selected

Choosing a Color

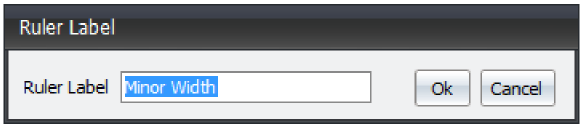
Change the color of the ruler and the color of the label.

1. Point to the ruler. The selected ruler is highlighted.
2. Right-click and select Color.
3. See Color Selection for additional information.
4. Click Ok.

Adding a Text Label

Add a displayed text label to the ruler.

1. Point to the ruler. The selected ruler is highlighted.
2. Right-click and select Label.



3. Type a name after Ruler Label and click Ok.
4. To remove a label, delete the entry and click Ok.

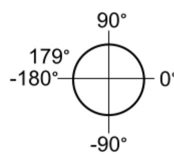
Changing the Line Size

Change the thickness of the ruler.

1. Point to the ruler. The selected ruler is highlighted.
2. Right-click and select Line Size.
3. Select or enter a the size in pixels (5 maximum) and click Ok.

Showing the Angle

Add an angle readout next to the ruler. The drawing illustrates positive and negative values.



1. Point to the ruler. The selected ruler is highlighted.
2. Right-click and select Show Angle.
3. Click Ok.

Showing Tickmarks

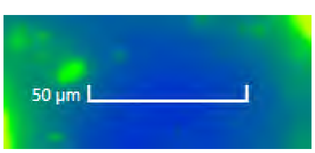
Show tickmarks on the ruler.

1. Point to the ruler. The selected ruler is highlighted.
2. Right-click and select how Tickmark.
3. Click Ok.

Using a Scale Bar

A Scale Bar can be displayed and positioned on 2D plots.

Show/Hide Scale Bar



1. Place the cursor over the 2D plot.
2. Right-click and select Plot Controller.
3. Under the Axes tab select the Show Scale Bar check box.

Moving the Scale Bar

1. Point to the Scale Bar.
2. Press and drag the Scale Bar to a different location on the plot.

Resizing the Scale Bar

The bar scales automatically based on the data size and zoom.

The units are tied to the X-Y Units of the 2D plot.

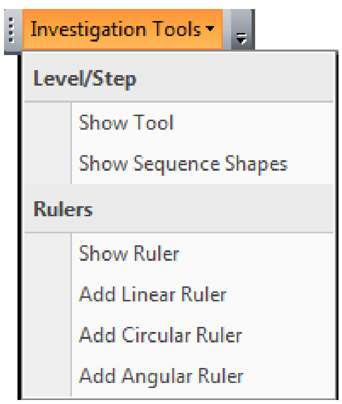
Investigation Tools

Investigation tools can be used interactively with plots in Mx, and are accessed through the plot toolbar. They allow in-map measurements of length, diameter, and angle. For height maps, investigation tools also provide interactive leveling and step-height measurements.

To Hide or Show the Investigation Tools Toolbar

1. Position the cursor over the 2D plot.
2. Right-click and select Select ▶ Tool Bars ▶ Investigation.

Investigation Tools



Level/Step Options

Select Show Tool to display the Level/Step Toolbox and start a Level/Step investigation. For more details see Level Step Toolbox.

Select Show Sequence Shapes to enable in-plot display of any masks used within the Processing Sequence for the associated map. Point to a mask element to show the associated step in the Processing Sequence. An example is shown below.

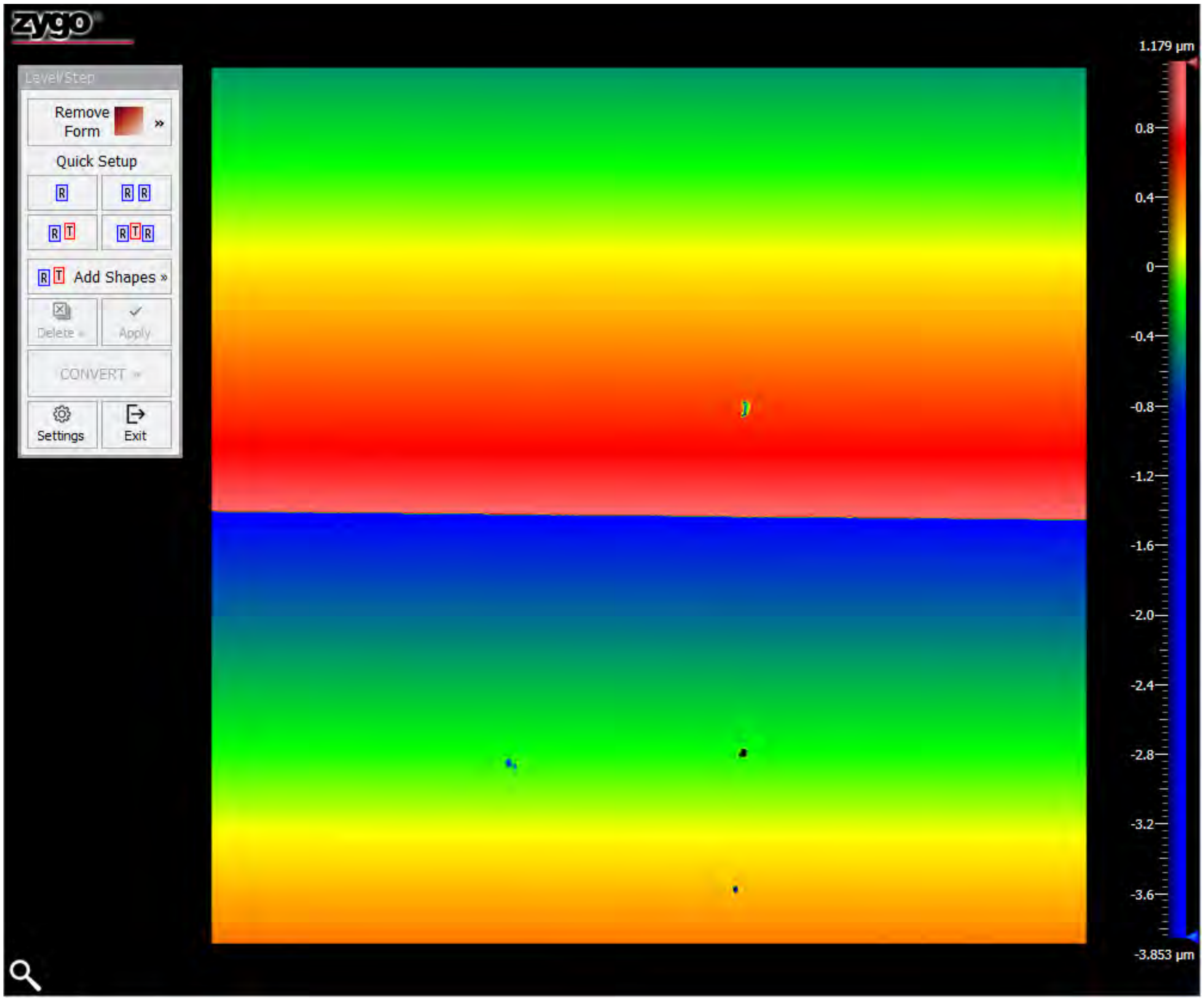
Rulers Options

Select Show Ruler to toggle the display of rulers on or off.

Add Linear Ruler, Add Circular Ruler, and Add Angular Ruler provide in-map measurements of linear distance, diameter, and angle respectively. For more details see Using Rulers.

Level/Step Toolbox

The Level/Step Toolbox allows investigative leveling and step height measurements within any height plot in Mx, without changing results outside that plot. It is accessed through the Investigation Tools menu in the plot toolbar. For details see Investigation Tools.

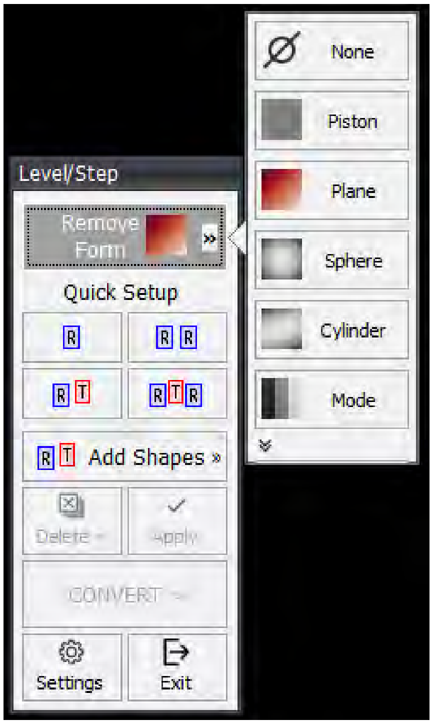


When the Level/Step Toolbox is open, a magnifying glass appears in the lower left of the plot to indicate the plot is in Investigative mode. Level/Step tools can be used without fear of disrupting results outside the plot. Exiting the Level/Step Toolbox returns the plot to its original state.

An investigation can also be converted to corresponding Processing Sequence tools – see Level/Step to Processing Sequence Conversion.

Working with Level/Step Tools

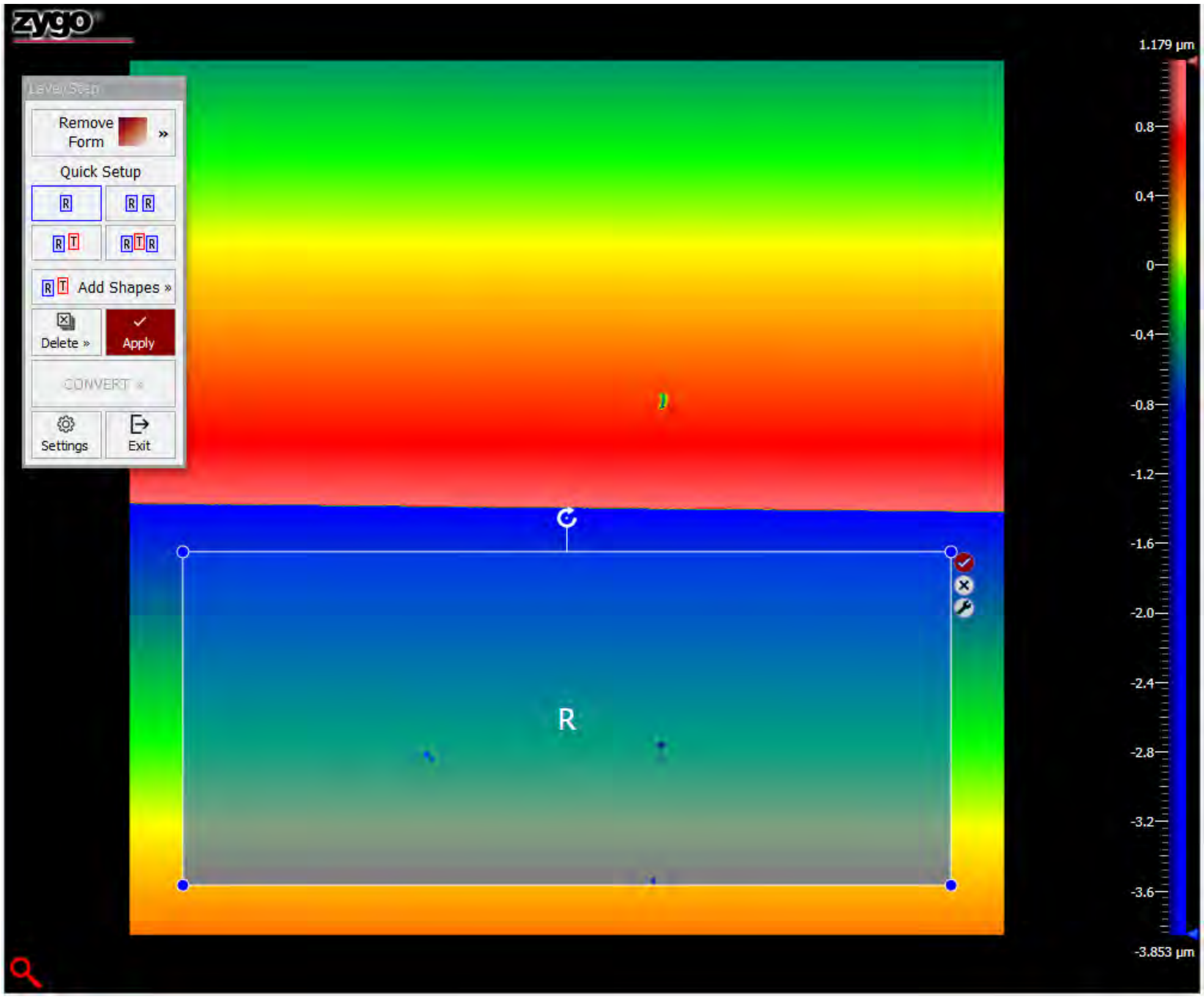
Leveling the Map



To change the surface type to be fit and removed, click the Remove Form button to display available options. For details on these options see Surface Types. Select None if no form removal is desired.

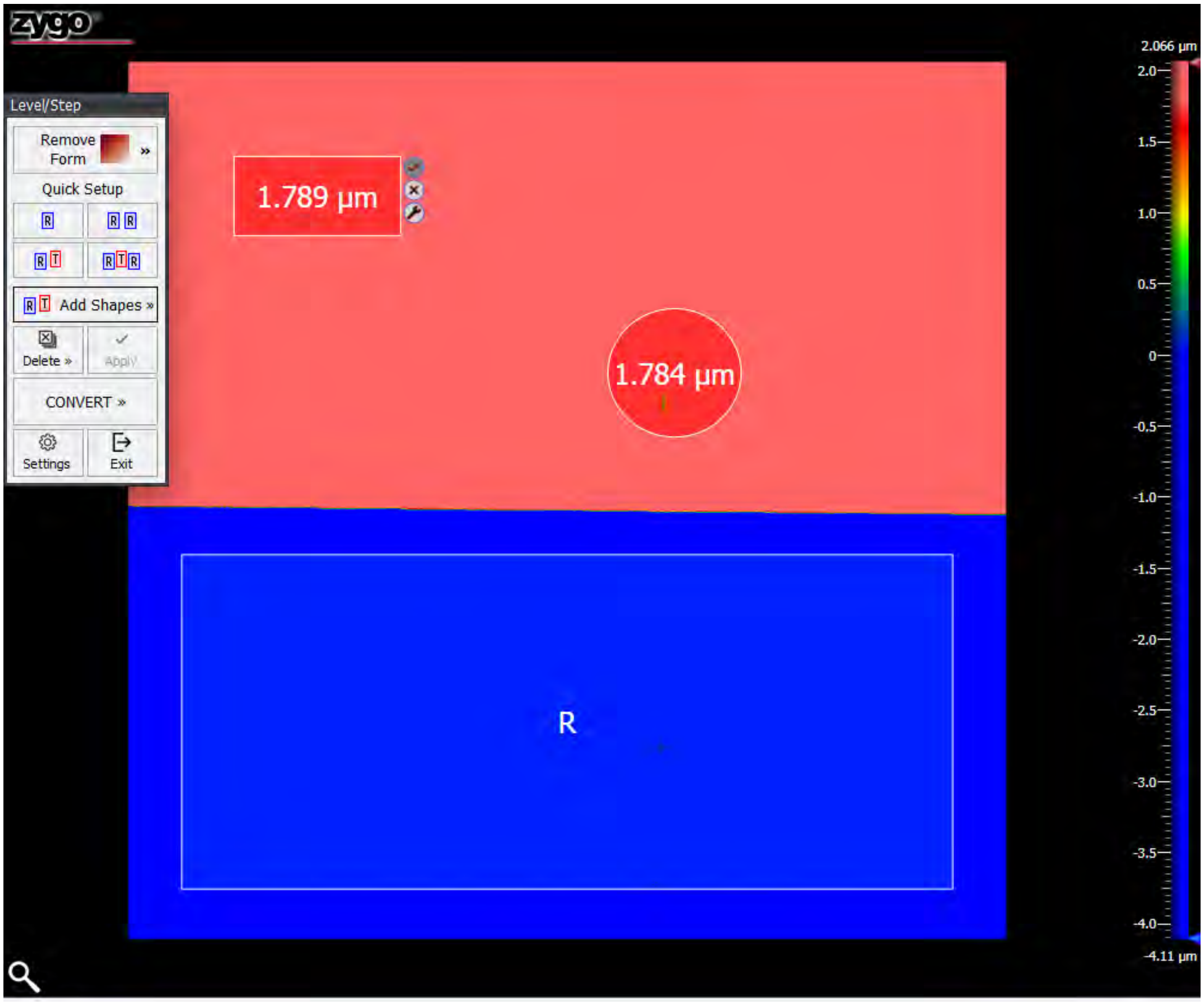
To restrict the data used for calculating the best fit, reference mask shapes can be added and adjusted directly within the map, as described in the Add Shapes section.

After adding or adjusting reference shapes, click Apply to update the plot. Apply buttons are available both in the Toolbox and beside the currently selected mask shape.



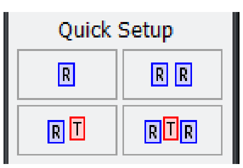
Measuring Steps

The average height within sub-regions of the plot can be displayed by adding test mask shapes, as described in the Add Shapes section. Results are displayed for each individual test mask shape.

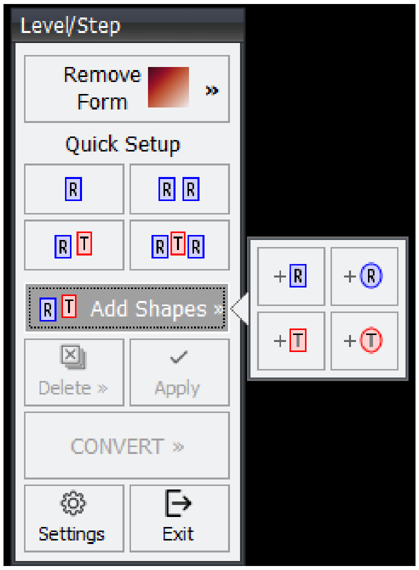


Quick Setup and Add Shapes

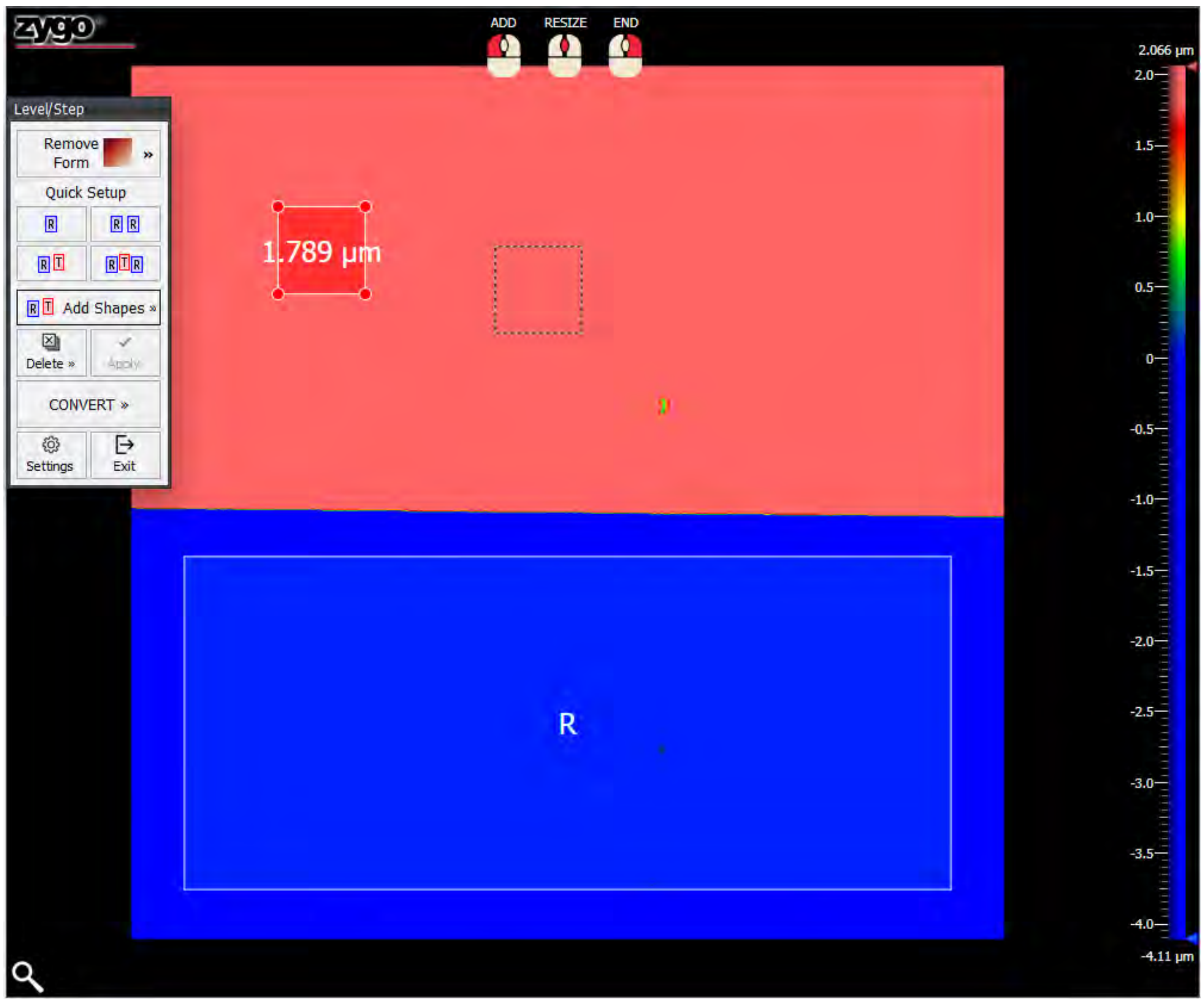
The Quick Setup buttons provide shortcuts to some of the more common arrangements of test (T) and reference (R) masks. Clicking a Quick Setup button will clear any existing masks and place new masks in the displayed arrangement. Shapes can be adjusted as needed, and new shapes added.



To add mask shapes, click the Add Shapes button and select the desired shape type.



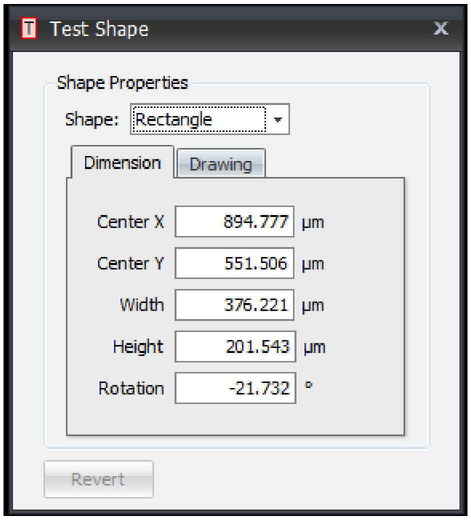
Then, left-click in the map to add the desired shapes, then right-click when done.



Adjusting Mask Shapes

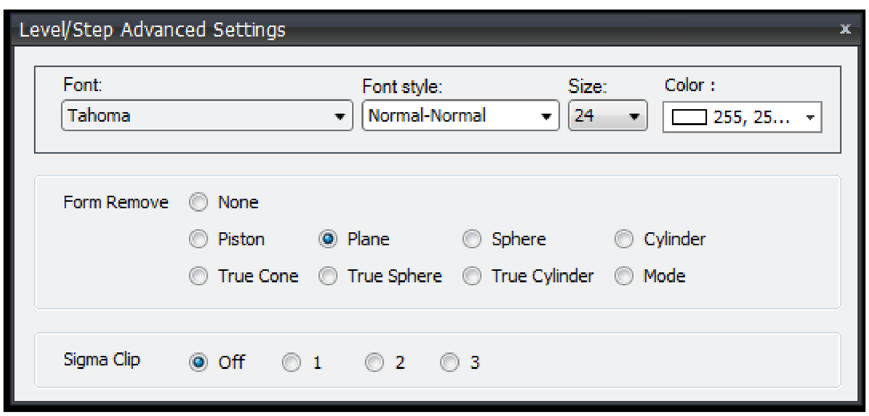
Mask shapes can be resized or rotated interactively by selecting corresponding handles with the mouse. When rotating, hold down the Shift key to constrain the angle to multiples of 15 degrees.

Alternatively, shape properties can be edited by clicking on the wrench icon to open the Shape Properties dialog:



Level/Step Advanced Settings

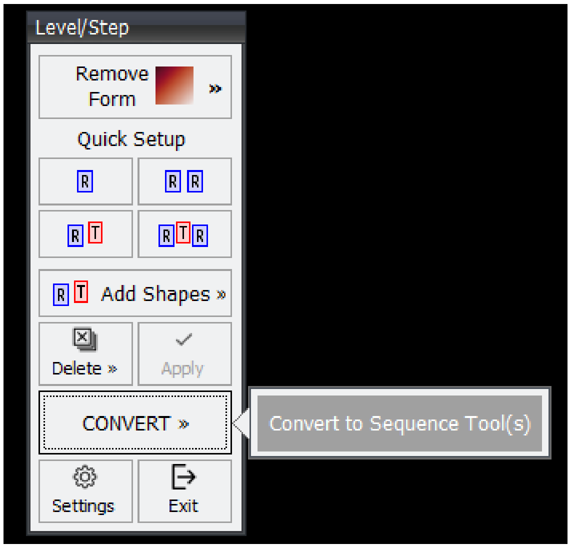
Click the Settings button to open the Level/Step Advanced Settings dialog. This allows adjustment of the font used for Investigative labels, as well as access to Sigma Clip Options.



Level/Step to Sequence Tool Conversion

Exiting the Level/Step Toolbox returns the plot to its original state, with no change to results outside the plot. However, an investigation can also be converted to corresponding Processing Sequence tools, which will apply the specified leveling to the associated map and produce formal step height results.

To perform this conversion, click the CONVERT button and then select Convert to Sequence Tool(s). If leveling is active, a Form Remove sequence tool is added to the associated Processing Sequence. A Step Height sequence tool is added for each displayed Test Mask Shape.

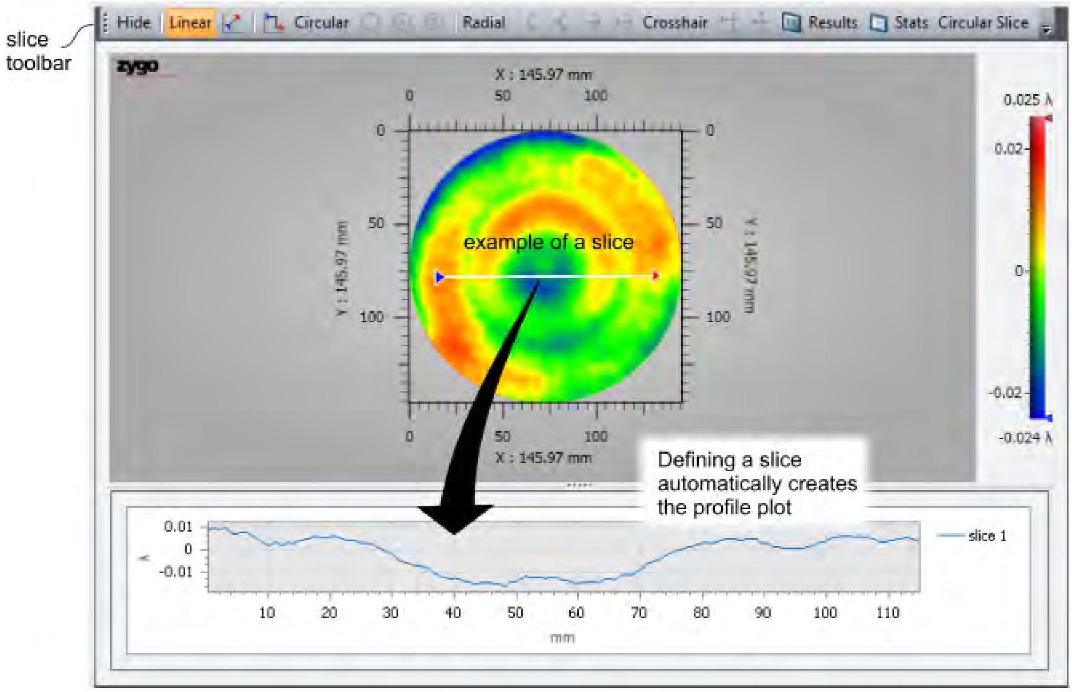


This option is not available for the Operator user level.

10.5 Slices

- Drawing a line over a 2D plot is called "slicing". Profile refers to the plot.
- Slicing is used to define a line or lines (or areas) from which profile data is derived.
- The Slice toolbar is used to create and view slices.

The profile plot is automatically created and displayed when slicing is used.



Slicing Quick-Start

Click one of the "master" slice buttons to show and work with a slice family.

Creating	Begin with left-click, end with right-click.
Moving	Point to slice, press and drag to move (some slice types can't be moved).
Resizing	Point to line end marker (triangle or circle), press and drag to change.
Delete	Click the slice, then press the Delete key; or right-click the slice and choose Delete.

Showing and Accessing Slices

These "master" Slice toolbar items activate a slice family to view and work within the category.

Label	Function
Hide	Click to hide/show defined slices and profile plot(s).
Linear	Show and activate linear slices.
Circular	Show and activate circular slices.
Radial	Show and activate radial slices.
Crosshair	Show and activate crosshair slices.

Slice Types

Slices are accessed and created with the Slice toolbar.

Linear Slices

Linear	Straight line slice. Freely positionable, one or more.
Poly	Multi-segmented line slice. Freely positionable, one or more.

Circular Slices

Circular	Circle shaped slice. Freely positionable, one or more.
Circular Center	Circle shaped slice fixed to the center of the data array. One or more.
Circular Min PV	Circle shaped slice for use with spheres and cones, with the center automatically fixed to the minimum PV value in the center ±3 pixels of the data array. One or more.

Radial Slices

Radial	Straight line slice that radiates from a point. Freely positionable, one or more radii.
Radial Center	Straight line slice radiating from the center of the data array. One or more radii.
Average Radial	A straight line slice that represents multiple circular slices. Each pixel along the slice represents the average of all the corresponding points on circle. Each point on the profile plot is the result of averaging the height along a circular slice. Freely positionable.
Average Radial Center	A straight line slice that represents multiple circular slices and is fixed to the center of the data array. See Average Radial.

Crosshair Slices

Crosshair	Two straight linear slices perpendicular to each other, one vertical and the other horizontal, with the end points fixed to the size of the data. The horizontal slice is positionable in the y-axis and the vertical slice is positional in the x-axis. One or more.
Crosshair Center	Two straight linear slices perpendicular to each other, one vertical and the other horizontal, fixed to the center of the data array, with the end points fixed to the size of the data.

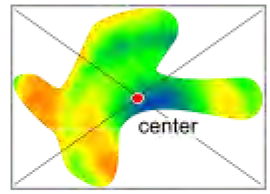
Miscellaneous

Slice Results	Shows/hides a slice result panel next to the plot. See Slice Results.
Slice Statistics	Shows/hides slice statistic column next to the plot. See Slice Statistics.
Circular Slice	Selects how circular slices are displayed. See Circular Slice Display.

Slice Concepts

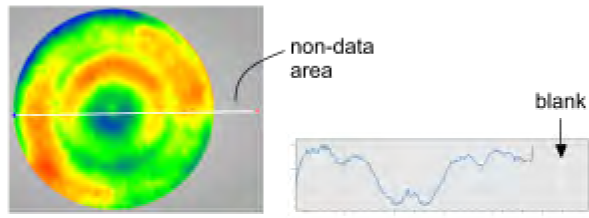
Data Center

The center of a data matrix is the middle of a hypothetical minimum enclosing rectangle.



Blank Areas

Portions of the profile plot are blank when the slice is drawn over non-data areas.

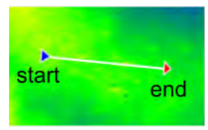


Filled Plot

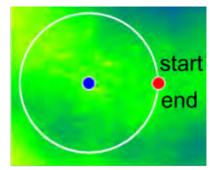
Profile Plot

Start and End Points

Each slice has a start point (blue) and end point (red). Linear slices are marked with directional triangles. Circular slices are marked with colored points.



linear slice



circular slice

Profile Plot Direction

A linear slice is always plotted left to right on the profile plot, no matter what direction the slice is.

linear slice

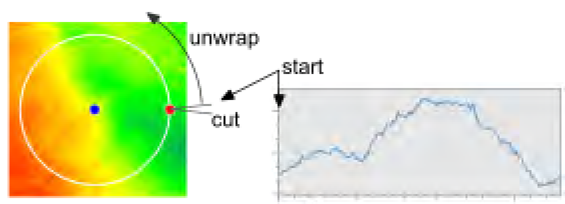
profile plot

Slice Numbering

Slices are automatically numbered as they are created. Point to a slice to select it and see its label.

Unwrapping Circular Slices

Circular slices are automatically cut and unwrapped to create the profile plot.



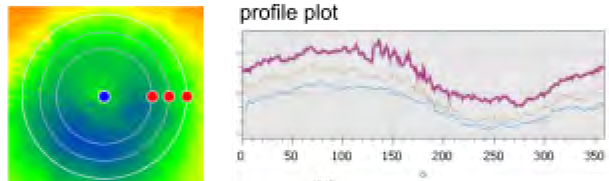
circular slice

profile plot

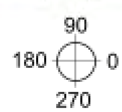
Plotting Circular Slices

Circular slices are normalized to 360 degrees of a circle in the profile plot.

profile plot

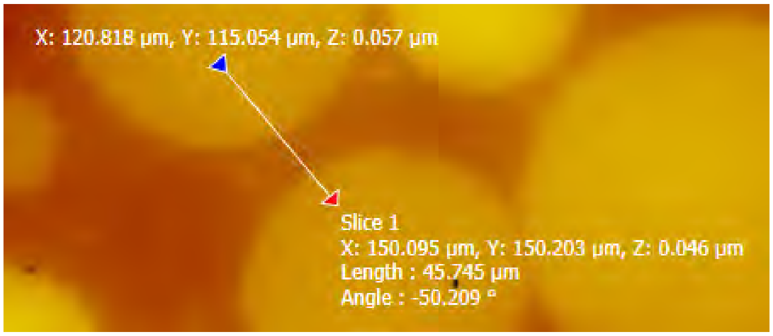


series of circular slices



circular slice degree mapping

Slice Coordinates



- Slice X, Y, Z coordinates and dimensions are *temporarily* shown as a slice is drawn or adjusted.
- X, Y, Z coordinates are based on Cartesian coordinates. The Length of the slice is based on the current data; lateral calibration is required to display lateral units other than pixels. The Angle of the slice is based on a polar grid relative to the start/end points of the slice.
- To display coordinates and dimensions *continually* for the slice, point to the slice, right-click and select Properties. In the dialog box select the Show Angle, Show Coordinate, Show Length check boxes. See Customizing Slices and Slice Properties.

Selecting Slices

- The last created slice is automatically selected.
- To select a slice, point and click on the main segment or center point. The segment or point temporarily becomes bold to indicate it is selected.

Working with Slice Groups

1. Select one of the slices in the plot to make it active.
2. Press Ctrl-A to select all slices.
    - Press arrow keys to move selected slices.
    - Press Ctrl-V to add another set of selected slices.
    - Press the Delete key to delete all slices.

Moving and Adjusting Slices

Moving an Entire Slice- Coarse

All "Center" slice types are fixed to the center and cannot be moved.

1. In the Slice toolbar, click on the applicable Slice type.
2. Point to the slice line segment (Linear, Radial, Crosshair) or slice center point (Circular).
3. Press and drag the slice.
4. Release the mouse button to fix the position.

Moving an Entire Slice- Fine

1. In the Slice toolbar, click on the applicable Slice type.
2. Point and click on the slice line segment (Linear, Radial, Crosshair) or slice center point (Circular) to select the slice.
3. Press the arrow keys to move the slice one pixel at a time in the corresponding direction.

Adjusting a Slice Point- Coarse

1. In the Slice toolbar, click on the applicable Slice type.
2. Point to one of the slice end points (Linear, Radial), slice middle points (Linear- Poly), or slice outer point (Circular).
3. Press and drag the slice point to a new location.

   For linear and radial slices, hold the Shift key to snap the slice endpoint to the nearest 15 degree increment.
4. Release the mouse button to fix the position.

Adjusting a Slice Point- Fine

1. In the Slice toolbar, click on the applicable Slice type.
2. Point and click on slice start or end points (Linear, Radial), slice middle points (Linear- Poly), or slice outer point (Circular).
3. Press the arrow keys to move the slice point one pixel at a time in the corresponding direction. Only the left/right arrow keys work with Circular slices.

Copying and Pasting Slices

1 Right-click a slice and select Cut (or Ctrl+X) or Copy (or Ctrl+X).

2. Right-click a slice and select Paste (or Ctrl-V) to paste the copied/cut slice.

or

3. To roughly position the slice, point to a place on the plot and press Ctrl-V.

   Slices cannot be copied from one plot into another.

Working with Slices in 3D Plot

- Reposition movable slice types. "Center" slice types are fixed.
- Adjust slice end points.

See Moving and Adjusting Slices.

All slice functions are available in the 2D Plot.

Working with Linear Slices

This section covers Linear and Linear- Poly slice types.

Creating a Linear Slice

1. In the Slice toolbar, click on Linear.
2. Click Linear.
3. Position the cursor over the 2D plot and click the left mouse button.
4. Move the mouse to where you want the slice to end and right-click.

Hold the Shift key to snap the slice to the nearest 15 degree increment.

Creating a Poly (Multi-line) Slice

1. In the Slice toolbar, click on Linear.
2. Click Poly.
3. Position the cursor over the 2D plot and click the left mouse button.
4. Move the mouse to where you want the first line segment to end and the second segment to start and click.
5. Repeat step 4 for additional line segments.
6. Move the mouse to where you want the slice to end and right-click.

Moving, Resizing, and Adjusting a Linear Slice

See Moving and Adjusting Slices.

Working with Circular Slices

This section covers Circular, Circular Center, and Circular Min PV slice types.

Creating a Circular Slice

1. In the Slice toolbar, click on Circular.
2. Click on desired slice type.
3. Position the cursor over the 2D plot and click the left mouse button.

   The "center" type is fixed to the center of the data array.

4. Move the mouse to adjust the desired radius and angular origin and right-click.
5. To constrain the angular origin to increments of 15 degrees, hold down Shift during the adjustment in Step 4.

Changing the Angular Origin

The outer slice hollow dot nearest the label determines the origin of the plot.

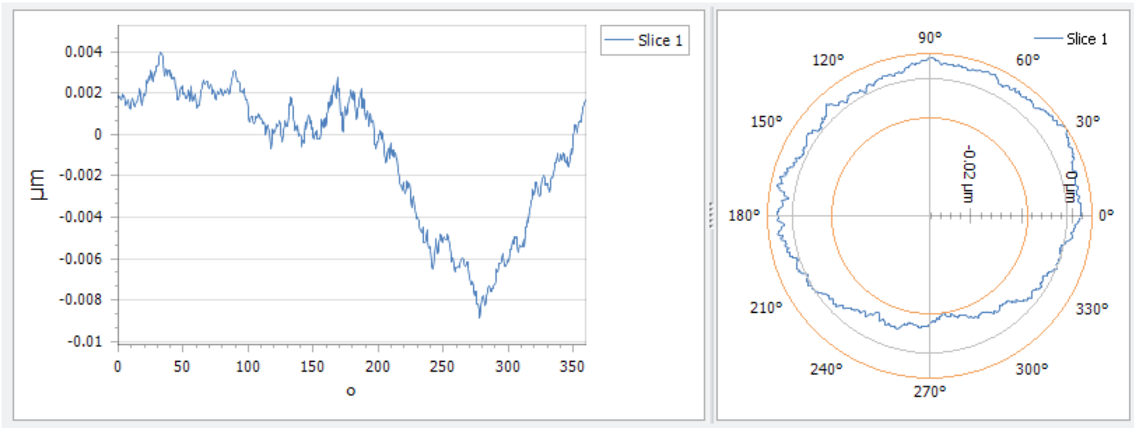
1. Click on the hollow outer circular dot, press and drag to move the dot, and release the mouse button.

Moving, Resizing, and Adjusting a Circular Slice

See Moving and Adjusting Slices.

Circular Slice Display

This determines how circular slices are displayed. The circular slice is shown as a linear chart (left) and a polar chart (right).



1. To access display options, right-click on the chart and select Chart Controller.

Tab	**Options**
Circular Slice Display	*Select Chart*- Determines what 1D plots are displayed when circular slices are defined. To remove a chart type clear the check box. Show Linear displays the data unwrapped as a linear chart when checked. Show Polar displays the data as a polar chart when checked. *Set Linear Chart X Unit Type*- Selects what units are display on the linear chart x-axis when it is based on circular slices. Angle uses degrees of a circle; see Plotting the Circular Slice. Default uses units based on the Set Unit and Precision dialog.
Linear Chart Style	Choose how data is displayed on the linear chart.
Linear Axes	Specify the limits of the linear chart plotting area. The X-Axis and Y-Axis minimum and maximum values can be entered.
Polar Axes	Specify the inner and outer radius diameters of the plotting area of the polar chart.

Working with Radial Slices

This section covers Radial, Radial Center, Average Radial, and Average Radial Center slice types.

Creating a Radial or Radial Center Slice

Creates multiple line slices radiating from a central hub.

1. In the Slice toolbar, click on Radial.
2. Click on desired slice type.
3. Position the cursor over the 2D plot and click the left mouse button.

   The "center" type is fixed to the center of the data array.

4. Move the mouse to where you want the slice to end and left-click.

   Hold the Shift key to snap the slice to the nearest 15 degree increment.

5. Repeat step 4 to create additional line segments.
6. Move the mouse to where you want the last slice to end and right-click.

Creating an Average Radial or Average Radial Center Slice

Creates a slice that resembles a circular slice.

1. In the Slice toolbar, click on Radial.
2. Click on desired slice type.
3. Position the cursor over the 2D plot and click the left mouse button.

   The "center" type is fixed to the center of the data array.

4. Move the mouse to where you want the slice to end and right-click.

Deleting a Radial Line Segment

1. In the Slice toolbar, click on Radial.
2. Left-click on the outer end marker.
3. Press the Delete key.

   Pressing the Delete key again will remove the next lower numbered radial segment.

Moving, Resizing, and Adjusting a Radial Slice

See Moving and Adjusting Slices.

Working with Crosshair Slices

This section covers Crosshair and Crosshair Center slice types.

Creating a Crosshair Slice

Creates a perpendicular set of movable slices.

1. In the Slice toolbar, click on Crosshair.
2. Click on Crosshair slice type.
3. Position the cursor over the 2D plot.
4. Move the mouse to where you want the center of the crosshair and right-click.
5. Repeat steps 2 thru 4 to create additional crosshairs.

Creating a Crosshair Center Slice

Creates a perpendicular set of fixed slices.

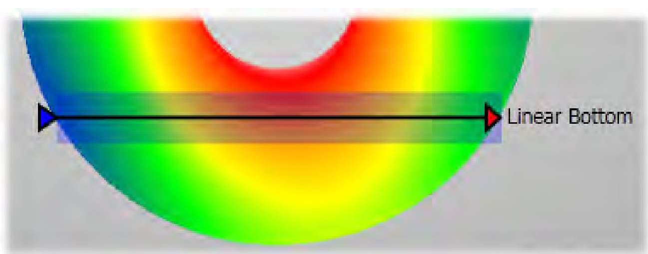
1. In the Slice toolbar, click on Crosshair.
2. Click on Crosshair Center slice type.
3. Position the cursor over the 2D plot and left-click.

The "center" type is fixed to the center of the data array.

Moving, Resizing, and Adjusting a Crosshair Slice

See Moving and Adjusting Slices.

Customizing Slices



An example of a slice that has been changed:

Color- black
Label- Linear Bottom (added)
Line Size- increased to 2 pixels
Width- increased to 1.5 mm

Choosing a Color

Change the color of the slice and the color of the label.

1. Point to the slice. The selected slice is highlighted.
2. Right-click and select Properties.
3. Choose a color after Slice Color. See Color Selection for additional information.
4. Click Ok.

Adding (or Removing) a Slice Label

Add a text label next to the slice.

1. Point to the slice. The selected slice is highlighted.
2. Right-click and select Properties.
3. Type a name after Slice Label and click Ok.
4. To remove a label, delete the entry and click Ok.

Changing the Line Size

Change the thickness of the displayed slice.

1. Point to the slice. The selected slice is highlighted.
2. Right-click and select Properties.
3. Select or enter the size in pixels (5 maximum) and click Ok.

Specifying the Slice Width (Wide Slice)

Change the actual width of the slice used for slice data calculation and to highlight the area in the plot being used.

1. Point to the slice. The selected slice is highlighted.
2. Right-click and select Properties.
3. Enter a value in the Slice Width entry and click Ok.

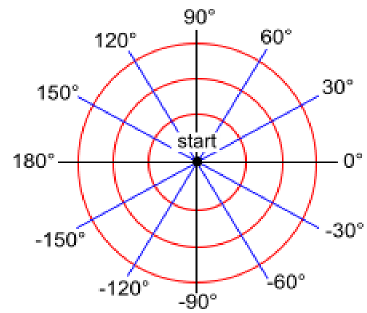
Slice Properties

Slice Properties are used to customize slice options. Available options vary based on the specific slice.

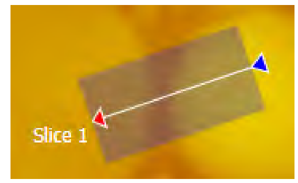
1. Point to the slice. The selected slice is highlighted.
2. Right-click and select Properties.

Slice Properties

Slice Angle — The angle between the start and the end of the slice in a polar coordinate system.



Slice Width — The width of the slice. This width is used to calculate the profile plot and statistics for the slice. It is denoted by a gray area surrounding the slice.



Slice Length — The overall length of the slice.

Slice Radius — The dimension from the center to the outside of the circle.

Slice Snap — This is the angle grid that a slice will conform to when the Shift key is held down and the end point is moved.

Slice Points — These series of entry/readout controls show the location of points and pivots defining the slice. Values can be entered and applied by clicking Ok.

Show Angle
Show Coordinate
Show Length — These check boxes are used to always display the corresponding slice characteristics on screen.

Slice Label — This is the name of slice as it appears on screen. By default they are labeled Slice 1, Slice 2, etc. Type a different name to replace the default name or delete the text if no label is wanted.

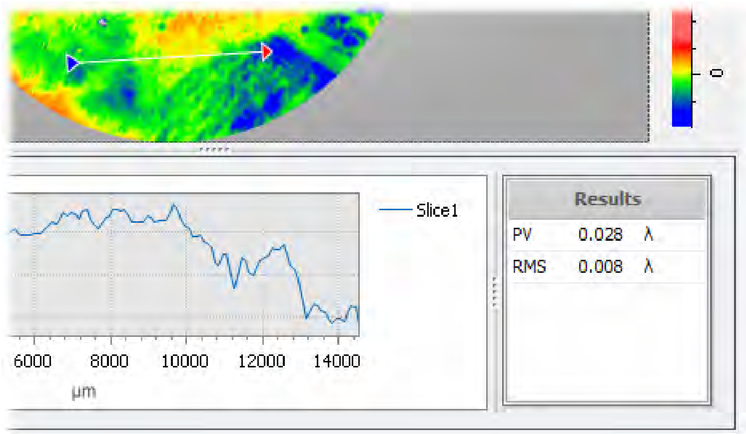
Slice Color — This selects the color for the line section and text associated with the slice.

Slice Size — The specifies the width in pixels of the slice displayed on the plot. This is different than Slice Width.

To use these features see Slice Coordinates or Customizing Slices.

Slice Results

Slice Results provide numeric results on the current or selected slice. Results are for usually for a single slice (active or selected) only.



Show/Hide Slice Results

If there are no defined slices the numbers are missing.

1. Right-click the profile (slice) plot and select Results/Attributes (or click Results on the Slice toolbar).

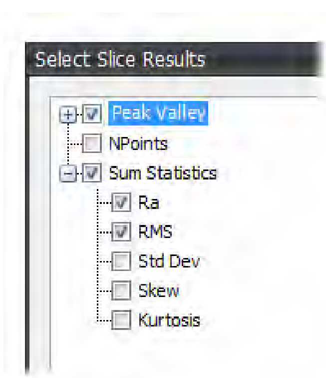
Picking the Slice for the Results

Results are shown for only one slice at a time.

1. To select which slice to display in Results, click on the slice.

Changing the Listed Results

1. Point to the result panel.
2. Right-Click and select Select Results.
3. Select the result check box to include, and clear the result check box to exclude.
4. Click OK.



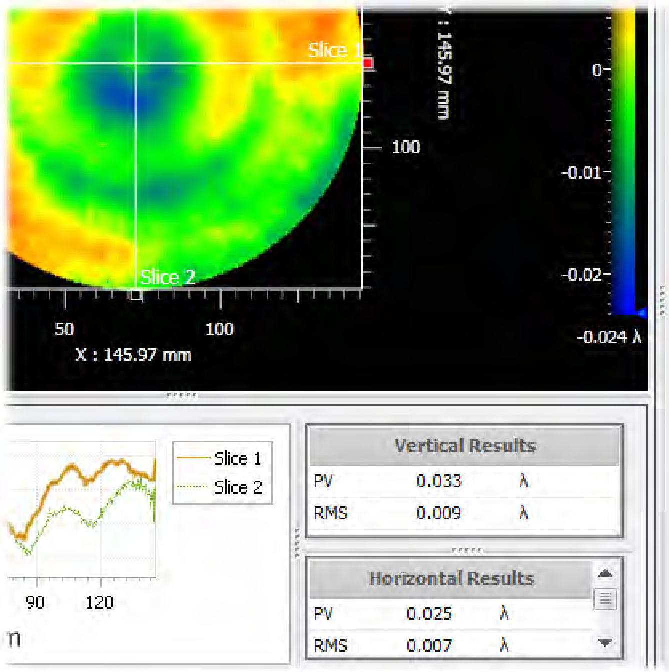
Changing Result Units

1. Point to the result parameter.
2. Right-Click and select Set Unit and Precision. See Setting Individual Units.

Crosshair Slice Results

Crosshair results are displayed for both the x-axis (Horizontal Results) and the y-axis slices (Vertical Results).

1. First, create the Crosshair slice. See Working With Crosshair Slices.
2. To display slice results, right-click the profile (slice) plot and select Results/Attributes (or click Results on the Slice toolbar).



Slice Analysis

- Provides form remove and filtering functions to all slices within the local window.
- Use to minimize extremes when calculating slice statistics.
- Use to mimic stylus profiler results.

Modifying Slices

1. Press the Slice Analysis button in the plot toolbar.

   To add the button to the Slices toolbar, point to ▾ on the plot toolbar and select Add or Remove Buttons ▸ Slices ▸ Slice Analysis.

2. Select the Form Remove check box and/or the Filter check box and choose options.

   To visualize the effects without closing the dialog, click Apply.

3. Click OK.

Remove Form

When the Remove Form check box is selected, the selected Remove Order is fit and removed from the slice(s).

Piston	Fit and remove z-axis offset.
Line	Fit and remove tilt or slant (including piston).
Circle	Fit and remove circular shape (including line and piston).
Third *Fourth* *Fifth*	When Third, Fourth, or Fifth are selected, a line is fit and removed based on an order setting that is more complex than Piston, Line, or Circle. These specify best-fit surfaces whose mathematical polynomial descriptions incorporate powers of X, Y and XY higher than 3.

N-Cycle

When the N-Cycle check box is selected, the selected Harmonic (and all lower harmonics) are removed from the slice(s). N-Cycle is only applied to circular slices. This is useful to remove repetitive machining artifacts or chatter from the slice plots and the slice results. The fundamental waveform is the 1st harmonic, a 2nd harmonic has a frequency twice that of the fundamental, the 3rd harmonic has a frequency three times the fundamental, and so forth.

Filtering

When the Filter check box is selected, the specified filter options are applied to the slice(s). Note that remove form is applied before filtering. Available slice filter types are listed below.

Convolution	A basic general purpose filter that uses a standard windowing function, with the degree of filtering determined by the window size.
FFT	Fast Fourier Transform filter that provides automatic or user input cutoffs.
Spline	Retains original part roughness detail with less distortion and provides automatic or user input cutoffs.
UPR	(Undulations Per Revolution) This setting is only used to filter circular slices. In roundness filtering, the closed surface is considered to be comprised of sinusoids whose wavelengths are fractions of the circumference of the part. The cutoff in roundness filtering is in units of undulations per revolutions. The corresponding Filter and Cutoffs settings can be selected to remove all information above or below a certain frequency. Lowering the cutoff will filter the data more heavily.

10.6 Line Profile Plot

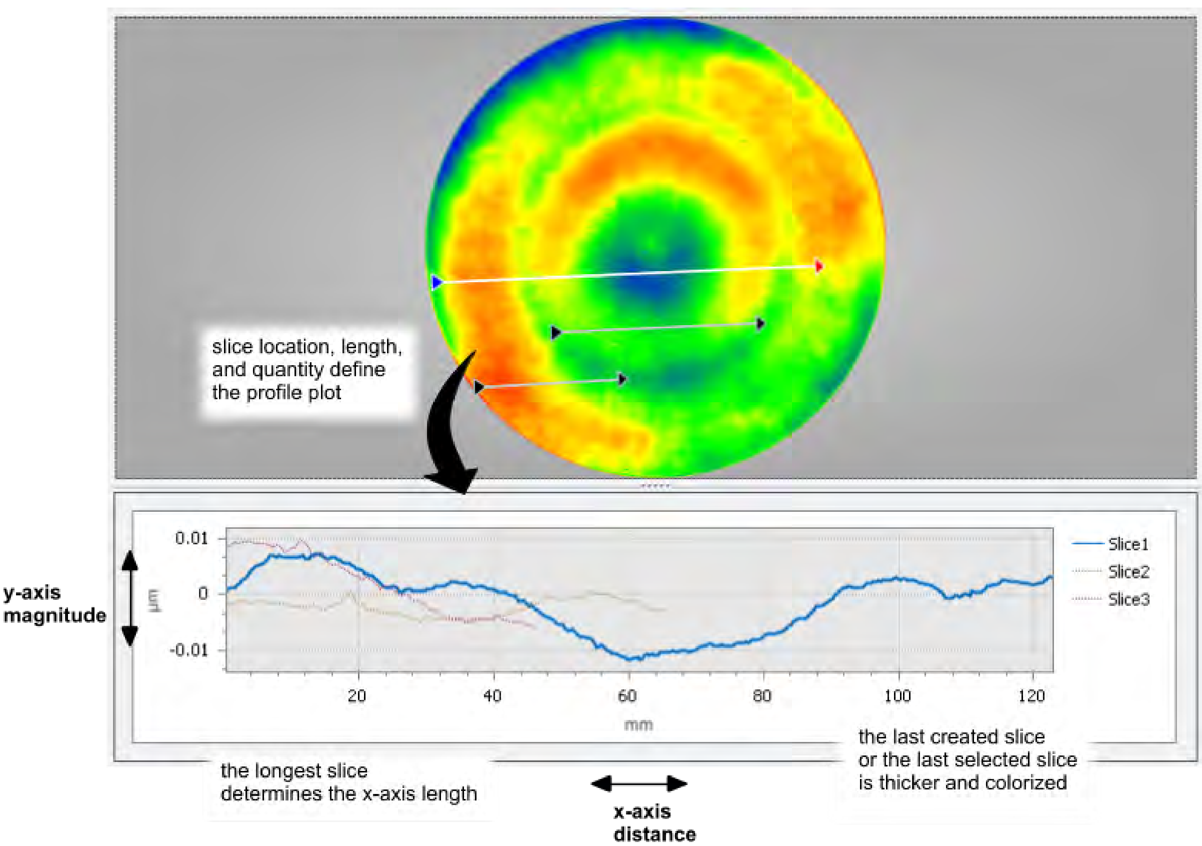
Line Profile Plot Overview

- Shows a one dimensional display of the data based on a slice or cross section through data map.
- The horizontal, or x-axis, shows distance, which is determined by the length of the slice.
- The vertical, or y-axis, shows magnitude, which is based on the data itself.
- Automatically displayed when slices are used.
- Slices drawn over non-data areas are represented as blank areas on the plot.

Use Conditions

- Based on corresponding slices in the same panel.
- Slices must be defined or the plot is empty.
- Lateral calibration is required to display lateral units other than pixels.

The Line Profile Plot Display



See Also

[Slices]

[Working With Linear Slices]

[Highlighting a Particular Line]

Highlighting a Particular Line

When there are multiple slices, the profile plot has multiple lines (these are labeled in the plot). The last created or edited slice is thicker and in front of the other slices. To highlight a particular slice:

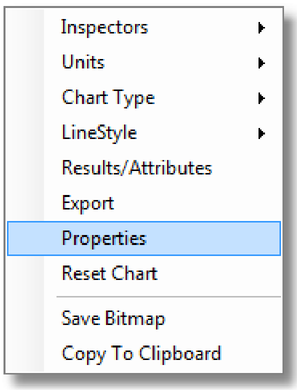
1. Point and click on the slice on the 2D plot.

   For a Linear slice or Radial slice click on the line.

   For a Circular slice click on the outer end circle marker.
2. The associated line plot is highlighted in the profile plot.

Changing the Line Profile Plot

Much of the plot itself is determined by the defined slices. To change features within the plot, right-click to open the context menu.



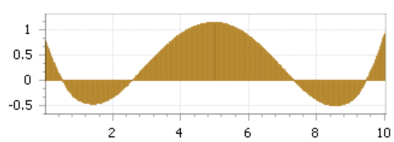
Inspectors Use to select inspector and caliber options. See Inspectors and Calipers.

Units Use to change the measurement units for the plot axes. See Setting Individual Units. Lateral calibration required to display units other than pixels.

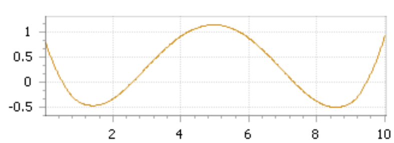
Set X Unit- select to choose horizontal x-axis units.

Set Y Unit- select to choose vertical y-axis units.

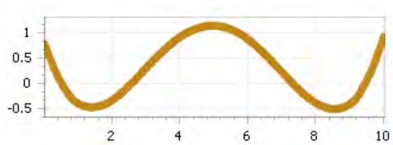
Chart Type Determines how the data is displayed. Choices are Bar, Line, or Points.



Bar



Line



Points (numerous individual points may appear as a line)

Line Style	Determines the style of lines in the plot. *Highlight On*- when selected, the last created, edited, or selected (current) slice is bolder than other present slices. *Color Secondary Slices*- when selected, slices other than the primary or current slice are in color. *Gray Secondary Slices*- when selected, slices other than the primary or current slice are gray.
Result/Attributes	Select to display a result/attribute panel next to the plot. Deselect to hide.
Export	Select to export underlying numeric data in another format. See Export Chart Data.
Properties	Open Slice Properties for setting Chart Type, Line Style, and Axes Limits.
Reset Chart	Select to change the chart back to the original size and position. This is useful if you have zoomed in or out of the chart and/or panned to an obscure location.

Inspectors and Calipers

Displaying an Inspector or Caliper

1. Place the cursor over the plot.
2. Right-click and select Inspectors ▸.

Moving an Inspector or Caliper

1. Point to the inspector or caliper line. The cursor changes to .
2. Press and drag the line, release the mouse button to fix the position.

Inspector vs Caliper

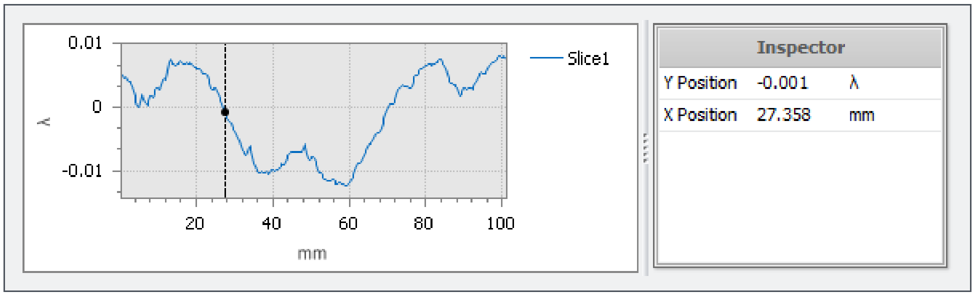
An inspector is used to examine data points that are part of the profile line plot. Inspector locations are fixed to the profile line data. Inspector locations appear as dots in the accompanying 2D plot.

If there are multiple slices, Inspector positions are shown for the current or last selected slice. To show Inspector positions for a different slice, point and click on the slice in the 2D plot.

A Caliper is a set of crosshairs that can be located over any area within the profile plot. Calipers are not locked to the profile line data. There is no indication of caliper location in the accompanying 2D plot.

Show Inspector 1

Displays a moveable point or inspector location on the line profile plot and lists the position of the inspector.



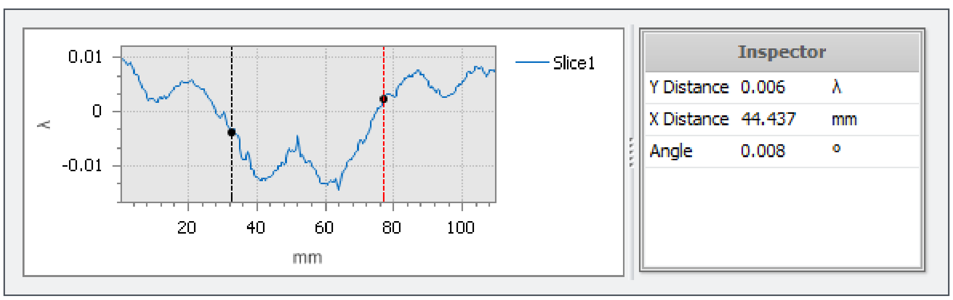
Y Position The location of the inspector in the vertical or Y-axis.

X Position The location of the inspector in the horizontal or X-axis.

Show Inspector 2

Displays two moveable points on the line profile plot and Inspector results between these two points. Inspector 1 is the point on the black dotted line. Inspector 2 is the point on the red dotted line.

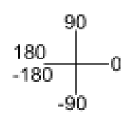
Values displayed in the Inspector result box are relative to inspector 1.



Y Distance The dimension between inspector 1 and 2 in the vertical or Y-axis.

X Distance The dimension between inspector 1 and 2 in the horizontal or X-axis.

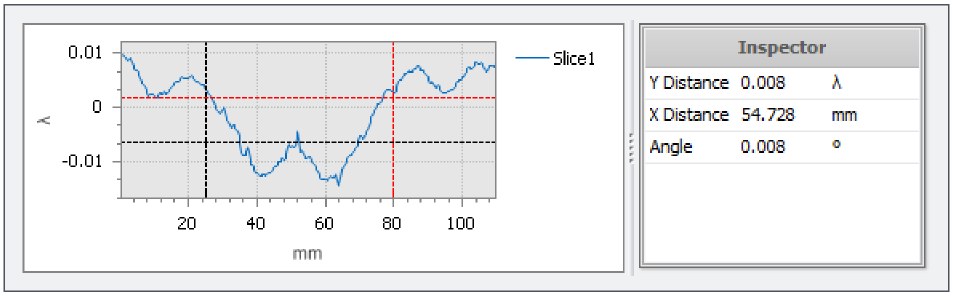
Angle The angle between inspector 1 and 2 in degrees, as based on the 2D data. Note this is not the angle between the two points on the actual line profile.



Show Caliper

Displays two freely moveable sets of crosshairs on the line profile plot and Inspector results between these two locations. These crosshairs can located over any area within the plot and are not locked to the profile data.

Values displayed in the Inspector box are relative to black crosshairs. For Inspector results, see Show Inspector 2 (above).



10.7 Circular Profile Plot

Circular Profile Plot Overview

- Automatically displayed when circular slices are used.
- Shows the height values of the slice and its polar grid location in degrees.
- The distance from the center of the plot shows its relative value, with the smallest value at the center.
- By default, the minimum value of the circular slice is mapped to an inner circle with a radius 60% of the outer diameter.

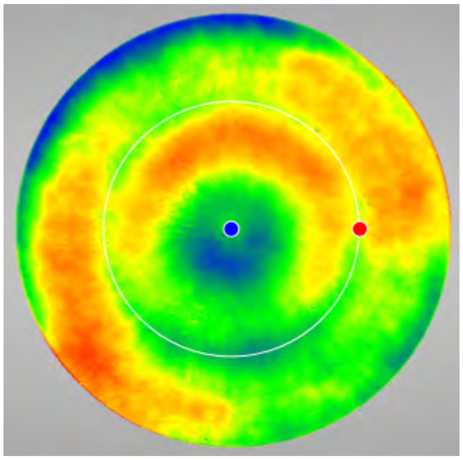
Use Conditions

- Based on corresponding slices in the same panel.
- Requires a defined circular slice to display.

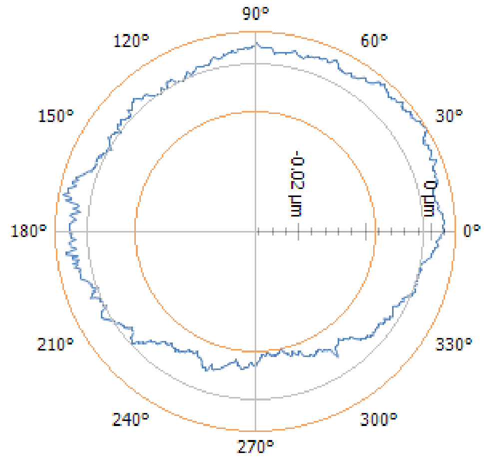
The Circular Profile Plot Display

The circular profile plot more accurately represents the values along the circular slice than the line profile plot because the angular indicators have a direct correspondence to their location on the slice.

2D Plot with Circular Slice



Circular Profile Plot



See Also

[Slices]

[Working With Circular Slices]

[Highlighting a Particular Line]

Changing the Circular Plot

Using the Mode control, axes can be set to fixed limits or as a percentage of the total range. When Mode is Percent, the peak and valley of the data are plotted at the indicated percent of the full size of the polar plot.

Other plotting options are available with the plot's context menu.

Changing the Circular Slice Display

It is possible to display a linear and/or polar plot based on the circular slice. The linear plot is an unwrapped version of the polar plot.

1. Point to the circular plot.
2. Right-click and select Chart Controller.
3. Under the Circular Slice Display tab, select options under Select Chart.

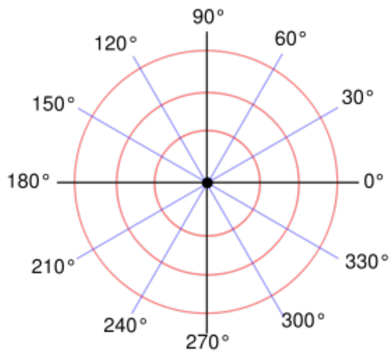
Configuring the Polar Axes

1. Point to the circular plot.
2. Right-click and select Chart Controller.
3. Under the Polar Axes tab, enter values for Outer Radius Diameter and Inner Radius Diameter.
4. Select the Show Mean Circle check box to show a line on the circular plot through the mean of data.

When Mode is Percent, the minimum value of the circular slice is mapped to an inner circle, whose radius defaults to 60% of the outer diameter.

Plotting the Circular Slice

The circular slice degree mapping matches directly to the degree indicators of the circular profile plot.



See Also

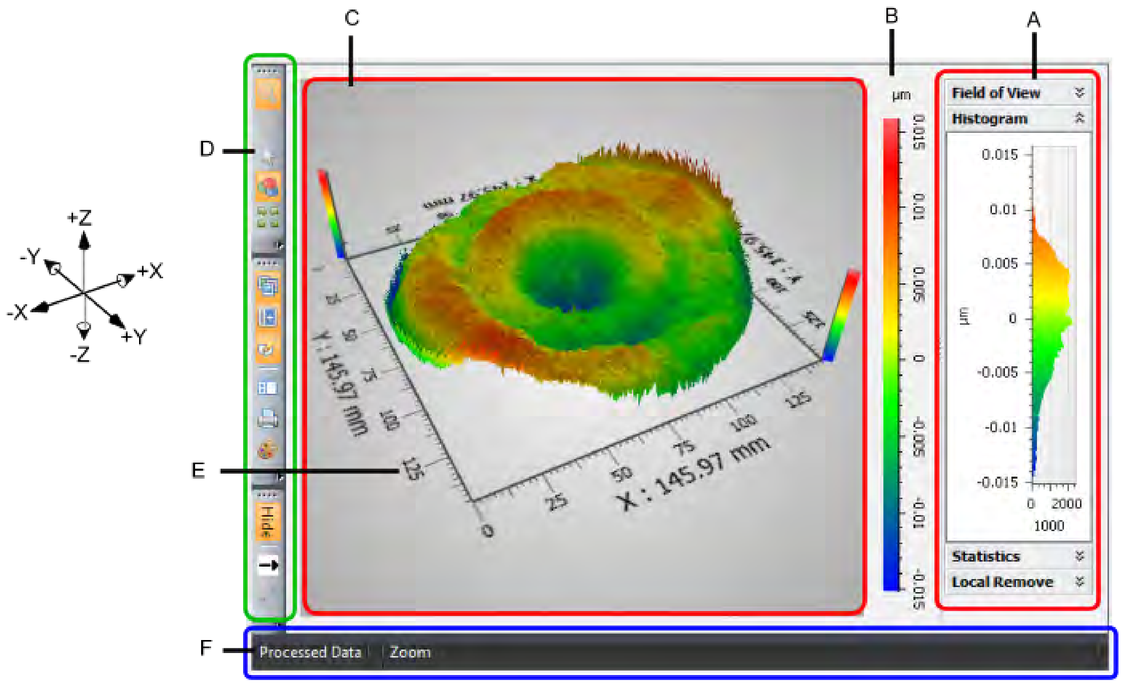
Circular Slice Display

10.8 3D Plot

3D Plot Overview

- Data is shown in fully positionable three-dimensional model view.
- Heights are displayed in different colors or shades.
- Surface data is displayed as a function of magnitude as viewed along the instrument's z-axis.
- User-configurable with toolbars and context menu.
- Plot settings are saved with the application.

The 3D Plot Display



A	Details	Extra optional information displayed to the right of the plot. It may include Field of View, Histogram, Statistics, and Local Remove.
B	Legend	The color key and Z-axis scale to the right of the plot.
C	Display Area	Shows current or loaded graphic of the test part based on selected options.
D	Toolbars	The small icon based bars that reside near the plot, which are used to change and control the plot display.
E	Axes	X-Y reference lines.
F	Status Bar	Shows information about the plot, cursor position, and mode.

Changing the 3D Plot

For panning (moving) and zooming (viewing size) see Zoom, Pan, Rotate.

For details on showing the plot Legend and selecting Z-axis units, see 2D/3D Plot Legend.

For details on showing plot axes and selecting X-Y units, see 2D/3D Plot Axes.

For details on changing plot colors, see 2D/3D Plot Colors.

For information on plot details, see 2D/3D Plot Details.

Viewing the 3D Plot

Find the best angle and size to view the data.

1. Place the cursor over the plot.
2. Press and drag to rotate the plot. Release the mouse button to fix the position.
3. Turn the mouse scroll wheel up or down to zoom in or out.

See Also

3D Plot Controller

2D/3D Plot Overview

2D/3D Plot Toolbars

Showing 3D Slices

Slices can be displayed and moved in the 3D Plot.

1. First, create the slice(s) in the 2D plot.
2. Right-click on the plot and select 3D to switch to the 3D plot.

3D Plot Controller

Right-click on the 3D plot and select Plot Controller.

Tab	Use to
Axes	Customize x and y axes. Hide or show axes; change x and y axes font and wording. See 2D/3D Plot Axes.
3D Display	Customize Z-axis options. See 3D Plot Controller 3D Display Tab.
Outputs	Customize the display of results on the plot screen. See Displaying Results.
Planes	Display up to 3 superimposed planes on the plot. Define location (high, mean, low), color, and transparency (alpha level). See 3D Plot Controller Planes Tab.

3D Plot Controller 3D Display Tab

These controls are used to specify options for the 3D plot lighting and Z axis.

3D Display Sliders

Height Scale	This slider determines how z-axis height data is scaled. Typically, z-axis data is scaled at 20 to moderately emphasize height values. Lowering the scale flattens the model. Raising the scale exaggerates height values. Click Reset to set the scale to 20.
Z-Axis Offset	This slider determines the z-axis location of the underlying plot and axes display. The smaller the value the closer it is to the 3D plot. Click Reset to set the scale to 20.

3D Display Controls

Zoom	This control is used to set a relative zoom viewing size for the 3D plot. It updates as the plot zoom is adjusted.
True Z Aspect Ratio	When the check box is selected, the Height Scale is set to 1.
Show Projection	When the check box is selected, a flat 2D surface map is displayed under the 3D plot.
Surface Map Palette	Specifies the color of the underlying flat surface map. It includes all the typical color choices for plots.

3D Plot Controller Planes Tab

These controls are used to display up to three superimposed planes on the 3D plot.

Displaying and Defining Planes in the Model

Up to three planes can be displayed. The High plane and Low plane reference and position are adjustable. The Mean plane is fixed to the arithmetical average of the data matrix.

1. Select the Visible check box to display a particular plane.
2. Specify the color with the Color drop-down list.
3. Specify the transparency of the plane by entering a value in Alpha Level.
4. If desired, specify reference and position settings for High and Low planes.
5. Click Close.

Planes Controls

Color	Selects the base color of the plane.
Alpha Level	Specifies the transparency of the plane. The lower the number, the greater the transparency. The range is from 0 (invisible) to 255 (solid). A setting of 100 is a good starting point.
Reference	Selects the base line from which the plane position is calculated. For the High plane, the choices are Peak or Mean. For the Low plane, the choices are Valley or Mean. Mean refers to the arithmetical average.
Reference Unit	Selects how the plane height is specified in the Position control. Percent or Height.
Position	Specifies the vertical location of the plane to the selected reference.

Saving 3D Display Settings

3D plot display properties can be saved and load. The file type is .m3dx.

1. Place the cursor over the plot.
2. Right-click and select Plot Controller.
3. Under the 3D Display tab, click the Save button.
4. Enter a File name.
5. Click Save.

10.9 PSD Plot

PSD Plot Overview

- The PSD (Power Spectral Density) plot is typically based on a cross section or slice through the input data.
- Displays the frequency spectrum of the surface roughness measured in inverse length units.
- The horizontal or x-axis position indicates the frequency.
- The vertical or y-axis, indicates the power density of a component sine wave.
- Both x-axis and y-axis units are selectable.
- For a functional description of the Power Spectral Density analysis, see PSD.

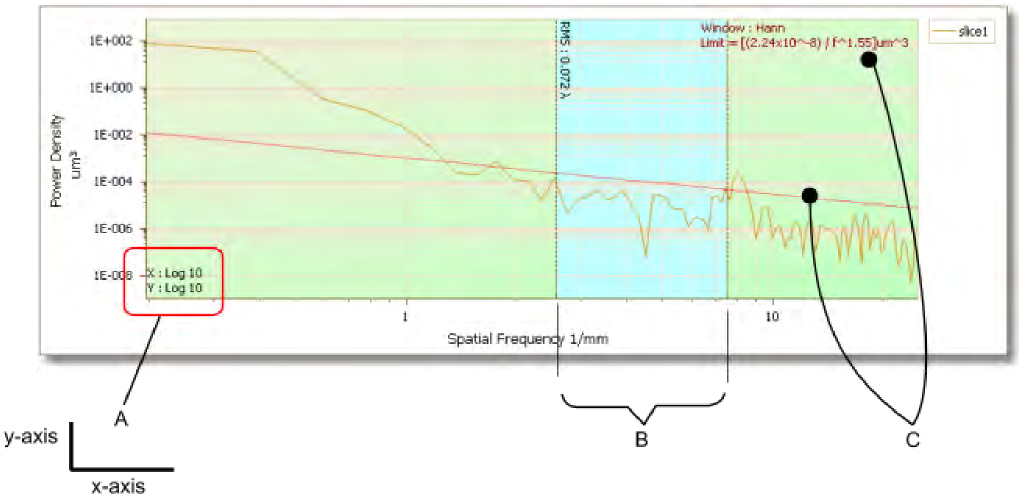
Use Conditions

- Typically, the PSD plot is based on a slice through the input data. However, this is not the case with the Non-directional, Average X, and Average Y PSD calculations; these use the whole surface as input.
- If the PSD plot is based on slices, test part surface characteristics are best highlighted when the slice is perpendicular to the dominant lay of the surface.

The PSD Plot Display

PSD in general quantifies the oscillation of the data at a range of frequencies/periods. Examples of what a PSD plot can highlight include: the average spacing of regularly-spaced features, the frequency/period of the dominant texture, or the number and frequencies/periods and relative amplitudes of multiple textures present in a surface. Various statistical quantities can be derived from the plot, such as the RMS roughness values over selected bandwidths.

Point to the plot and right-click to make changes.



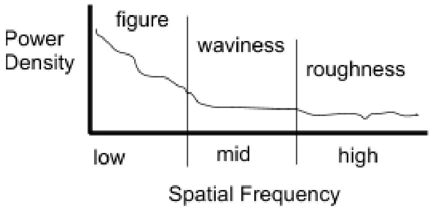
A. Plot axes, y-axis is the power density or extent of the surface feature; x-axis is the frequency or spacing of the surface feature. (Note the selected plotting format for the x and y axis is displayed in the lower left corner.) **B.** RMS of the surface as calculated in-between the two frequency markers. **C.** Limit line showing the tolerance limit and the equation used to calculate it. Above the equation is the FFT Window type selected in the PSD Advanced Settings dialog.

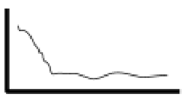
Colors and Calipers

Color	Purpose	To Display	To Adjust
Blue	Shows the area over which the contribution to the total RMS is calculated.	Right-click on the plot and select Show RMS. The RMS value is displayed vertically.	Point, click, and drag the dashed vertical (caliper) lines or right-click the plot and select Properties (see PSD RMS).
Green	Shows the area over which the dashed red ISO 10110-8 limit line is plotted.	Right-click on the plot and select Show Limit Line. The limit line formula is displayed at the upper right.	Point, click, and drag the red vertical (caliper) lines or right-click the plot and select Properties (see PSD Limit Line).

Reading the PSD Plot

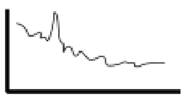
The PSD chart shows the distribution of the various frequency components of the part surface. Low spatial frequency components indicate overall figure and shape, while high spatial frequency components indicate roughness.





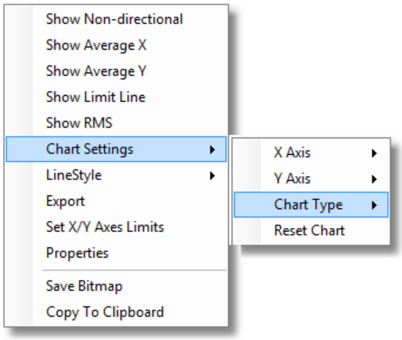
Surface with prominent waviness.

Surface dominated by roughness.



Spike shows the spatial frequency due to a machining process.

Changing the PSD Plot



Depending upon the selected views, the PSD plot can show both slice based PSD results and PSD evaluation based on all the input data.

1. Point to the plot.
2. Right-click to access the context menu.

Show Non-directional	When selected, a non-directional PSD is displayed on the plot. Normally the PSD plot is only useful for analyzing texture when the profile is perpendicular to the dominant surface lay; this PSD plot does not depend upon the slice direction. See Non-directional PSD Details. The Non-directional, Average X, and Average Y PSD calculations ignore slices, and instead use the whole surface data as input.
Show Average X	When selected, a PSD is performed upon every row individually and then averaged. The average is weighted; each row is assigned a weight proportional to the number of valid data points it contains and is plotted on the PSD. It is most useful for analyzing texture that lies along the x direction.
Show Average Y	When selected, a PSD is performed upon every column individually and then averaged. The average is weighted; each column is assigned a weight proportional to the number of valid data points it contains and is plotted on the PSD. It is most useful for analyzing texture that lies along the y direction.
Show Limit Line	Displays a red tolerance limit line and the equation used to plot it.
Show RMS	Displays the RMS of a surface calculated by integrating the PSD between two frequencies.
Chart Settings	Use to select the PSD units for the x axis and y axis. See Changing the PSD Scale. Select Chart Type to change the way data is displayed. See Chart Type. Select Reset Chart to change the chart back to the original size and position.
LineStyle	Selects options for displaying the lines shown in the plot.
Export	See Export Chart Data.
Set X/Y Axes Limits	Set the minimum and/or maximum values displayed on the x-axis or y-axis. See Axes Limits.
Properties	Opens the advanced settings dialog for the PSD chart.

Non-directional PSD Details

With a 2D Fourier transform of the surface, each point represents the amplitude (for a PSD, the square of the amplitude) of a sinusoid at a certain frequency and direction. The spectrum map (Figure A) has two directional slices that determine the amplitude data for each of the frequencies found only on these slices and plotted in the spectrum profile (Figure B) as green and blue lines. The two 1D PSDs shown in Figure B are directional, showing the frequency content in two distinct, specific directions on the surface or wavefront.

Figure A

Spectrum map with two directional specific slices.

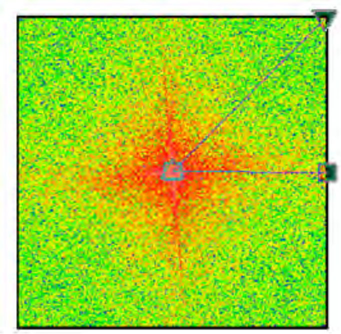
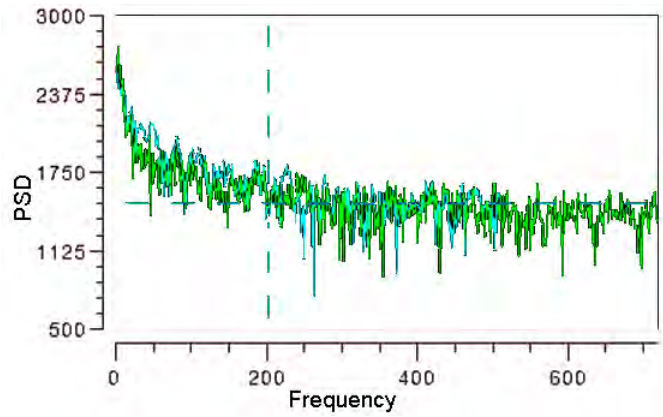


Figure B

Resultant 1D PSD plot showing the frequency and amplitude along the two directional slices.



By summing the 2D PSD data for a single frequency, in all directions – that is, integrating the amplitude data that lie on a circle at a specific frequency (such as 200 cycles per millimeter as indicated by the circle in Figure C and marked on Figure B as a vertical dashed line), we obtain the overall amplitude of 200-cycle sinusoids that are present in the data, regardless of their directionality. When this is done repeatedly for each frequency for which there is data, the result is a Non-directional PSD (Figure D).

Figure C

The spectrum map with a circle at 200 cycles per mm.

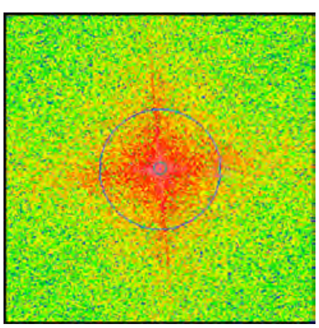
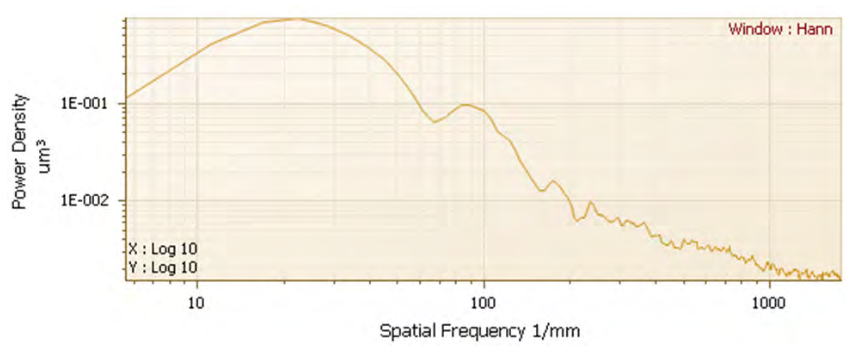


Figure D

Non-directional PSD.



Non-directional PSD Mathematical Representation

Non-directional PSD is PSD as a function of frequency magnitude. The value of NPSD for a given frequency magnitude $|\vec{f}|$ is the spectral power density contributed by all frequencies of magnitude $|\vec{f}|$, calculated by summing the PSD over all such frequencies. Generalized to arbitrary dimension, this calculation is written:

$$NPSD(|\vec{f}|) = \int_{\vec{f}':|\vec{f}'|=|\vec{f}|} PSD(\vec{f}')dS_{|\vec{f}|}$$

where $S_{|\vec{f}|}$ is the subset of the frequency domain for which the magnitude of the frequency is $|\vec{f}|$. In the 2D domain, this is the angular integral of the 2D PSD, defined as:

$$NPSD(|\vec{f}|) = \int_0^{2\pi} PSD(\vec{f}')|\vec{f}'|d\theta_{f'}$$

where $$\tan\theta_f = \frac{f_y}{f_x}$$

In related literature, various calculations appear under the names “angular PSD” and “radial PSD”, which would seem nominally to be the contributions to the 2D PSD from frequencies with a given angle or magnitude, respectively. However, those calculations often neglect the Jacobian factor $|\vec{f}'|$ required by a polar integral, so that the results do not directly reflect the contribution to the PSD as a function of frequency angle or magnitude. This is named “non-directional PSD” instead of “radial PSD” in order to avoid confusion with this practice, and also to avoid confusion with the completely unrelated concepts of radial or mean radial slicing in the spatial domain.

Changing the PSD Scale

The logarithmic scale options (Log 10, Log 2, and Log e) are usually the best way to display PSD data because they display values in a more meaningful representation that expands small values and compresses large values.

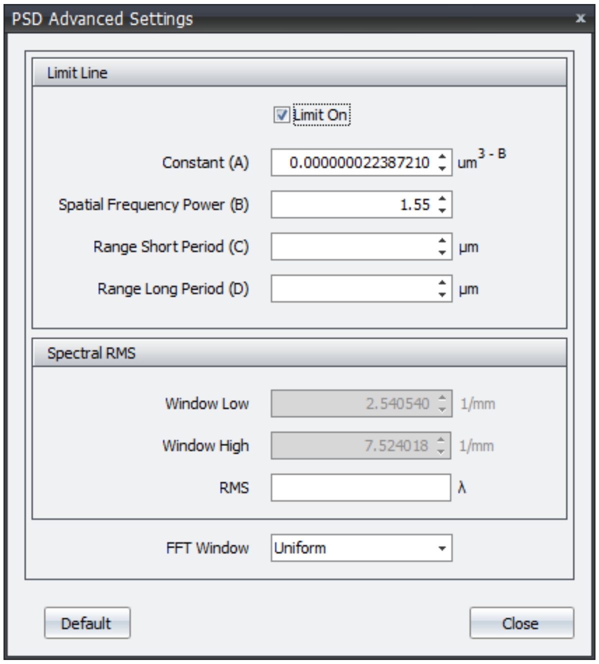
To change an axis scale, right-click on the plot and select Chart Settings ▸ X Axis (or Y Axis) ▸ Scale ▸.

Linear	The axis grid lines are based on uniformly spaced values.
Log 10	The axis grid lines are based on base 10 logarithms and powers of 10.
Log 2	The axis grid lines are based on base 2 logarithms and powers of 2.
Log e	The axis grid lines are based on natural logarithms and powers of e.

PSD Advanced Settings

Use this dialog to specify the criteria for the Limit Line and Spectral RMS calculation. To access this dialog, right-click on the plot and select Properties.

This dialog cannot be changed unless the Limit Line and RMS are already displayed on the PSD plot by previously right-clicking on the plot and selecting Show Limit Line and Show RMS.



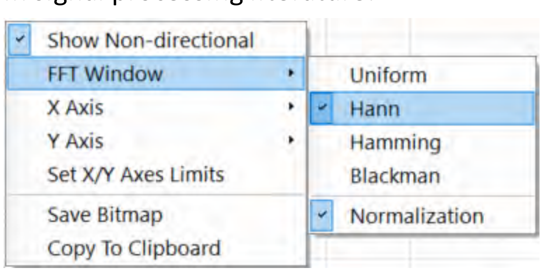
See PSD Limit Line for explanation of the Limit Line entries.

See PSD Spectral RMS for an explanation of the Spectral RMS entries.

FFT Window

Selects the windowing or apodization function multiplied by the data in the spatial domain before the PSD is calculated. Choices are Uniform, Hann, Hamming, or Blackman. It is recommended to set FFT Window to Uniform when the slice type is unbroken circular slices. For other types of slices Uniform is not the best option.

Apodization helps mitigate some of the undesirable artifacts that are inevitable when attempting to perform FFT-based analysis upon data that is not periodic in the domain interval. Windowing is typically used to reduce edge effects. Uniform means no apodization is applied. Apodization is a well-studied technique, and the definitions of Hann, Hamming, and Blackman are commonly found in signal processing literature.



Normalization applies to the windowing function being used and indicates a scaling value applied to the windowing function such that 1/sqrt(sum(weights^2)). When Normalization is On, weights are normalized to an energy of 1.0. When Normalization is Off, weights are normalized such that the peak is equal to 1.0.

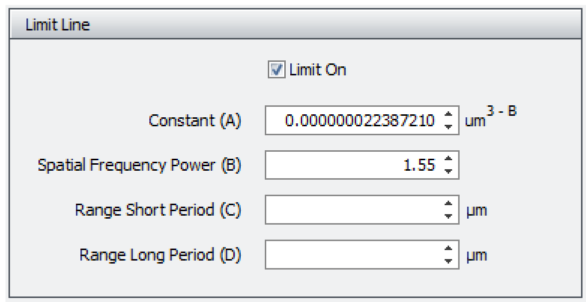
For Average X and Average Y PSD, a 1D function is applied per-slice/row/column. For the Non-directional PSD, an analogous 2D function is applied.

PSD Limit Line

To display the limit line, right-click on the plot and select Show Limit Line.

To view or edit the limit line, right-click on the plot and select Properties.

All four constants for the Limit Line (A,B,C,D) are based off of the ISO description of the PSD power law and serve to define a PSD tolerance for a given surface. If the PSD measurement goes above the Limit Line, this indicates a failure to meet the tolerance over the specified frequency band.



The initial settings for the limit line are based on a NIF tolerance specification, which is a specific case of the power law model documented in ISO 10110-8.

Changing values for the Limit Line do not take effect until the Limit On check box is cleared and then selected.

Limit Line Constants A, B, C, and D

The PSD Limit Line and the A, B, C, and D constants shown in the Advanced Settings follow ISO 10110-8 convention:

$$PSD(f) = \frac{A}{f^B}[\mu m^{+3}]$$

over [C,D] in units of mm.

Where the spatial frequency range is inversely related to the spatial periods by:

$$\frac{1}{1000 \cdot D} \le f \le \frac{1}{1000 \cdot C}$$

in units of μm^{-1}.

The constants and frequency used in the limit line calculation are defined as follows:

A is a constant, expressed in μm^{3-B}. This entry determines the height of the limit.

f is the spatial frequency of the surface roughness, in reciprocal micrometers (μm^{-1}).

B is the value of the exponent (or power) which the PSD falls off with increasing spatial frequency. For most classically polished surfaces, $1 < B < 3$. This entry changes the slope of limit line.

C Specifies the short period (right side) of the band pass filter.

The terms C and D define visually on the PSD curve the tolerance bounds. The limit line is displayed in the frequency interval defined by these terms.

D Specifies the long period (left side) of the band pass filter.

Note that the Range Short Period (C) and Period Range Long (D) units in Advanced Settings do not match the units in the PSD plot x-axis. To determine useable numbers to enter in C or D, base the values on actual part dimensions or predetermined specifications.

PSD Spectral RMS

To display RMS, right-click on the plot and select Show RMS.

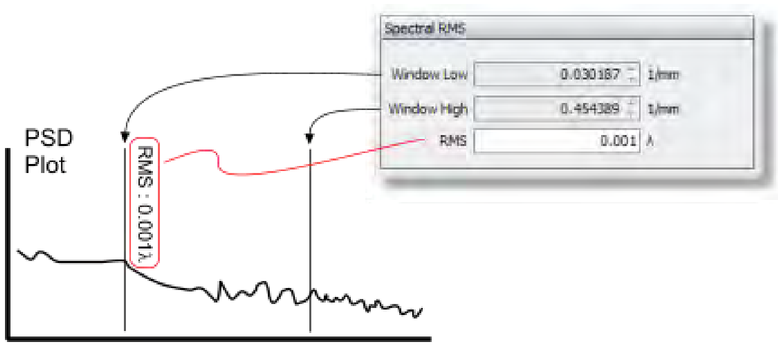
To change the frequency bands used in calculating the RMS:

1. Click and drag the RMS marker on the PSD plot. Release the mouse button to set the frequency and recalculate RMS.

or

2. Right-click on the plot and select Properties.
3. Modify or enter values in the Spectral RMS portion of the dialog.

Relationship of Advanced Settings and RMS Display



The entries in the Advanced Settings dialog cannot be changed unless RMS is already displayed on the PSD plot by right-clicking on the plot and selecting RMS.

Results and Attributes

11

- Results are numeric descriptors of the test part.
- Results are also known as parameters.
- Results appear on plots, in result grids, and in process statistics.
- Attributes display conditions relative to the measurement.

Results

- Numeric results are described in this section. For plots, see Graphic Results. For statistical tools see Statistical Results.
- For specific details on a result, refer to the result by name.
- Results are specific to the data view in which they appear. For example, PV and RMS are available in multiple views; but the context must be considered to interpret the numbers.
- Results may appear within the application displays and are also available through a result grid.

Result Categories

Category	Description
Attributes	Provide information about the measurement.
Common	Non-instrument or non-industry specific results.
Surface	Basic three dimensional surface results.
Areal ISO	Three dimensional optical profiler results based on ISO standards.
Profile	Results specific to two dimensional profile data.
Profile ISO	Two dimensional optical profiler results based on ISO standards.
Optical	Laser interferometer results; includes PVr, ISO 10110-5, and Zernike.
Slope	Results derived from slope data.
Films	Results specific to the Films analysis.
MST	Results specific to the MST interferometer.
AccuFlat	Results specific to the AccuFlat interferometer.

11.1 Working With Results

This section provides basic procedures to add or change results.

Adding or Removing Results

1. Right-click inside the panel and choose Select Items or Select Results.
2. Select the check box of an item you want to appear in the panel.
3. Clear the check box of an item you want to remove.

See Adding or Removing Items.

For displaying results on a plot see Displaying Results.

Changing Results and Attributes

Setting Measurement Units

Right-click the result and Choose Select Units and Precision. See Setting Individual Units.

For results without units, only the number of decimal places can be changed.

Setting Result Limits

This allow user input tolerances for results and flags values within or outside entered values.

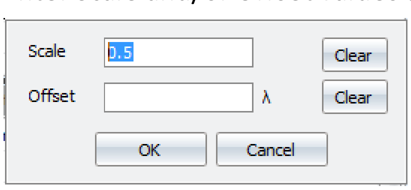
Right-click the result and choose Set Limits. See Entering Result Limits Directly. See also Tolerance Status.

Adjustments

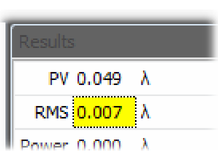
This allows you to change or adjust numbers displayed within a result grid. Adjusting a numeric result does not change original or saved data.

Scale	Modifies the original value by the entered multiplier. Enter 0 (zero) to make the result 0.
Offset	Adds or subtracts (minus sign) the entered value from the original value.

1. Right-click the result and choose Adjustment.
2. Enter Scale and/or Offset values and click OK.



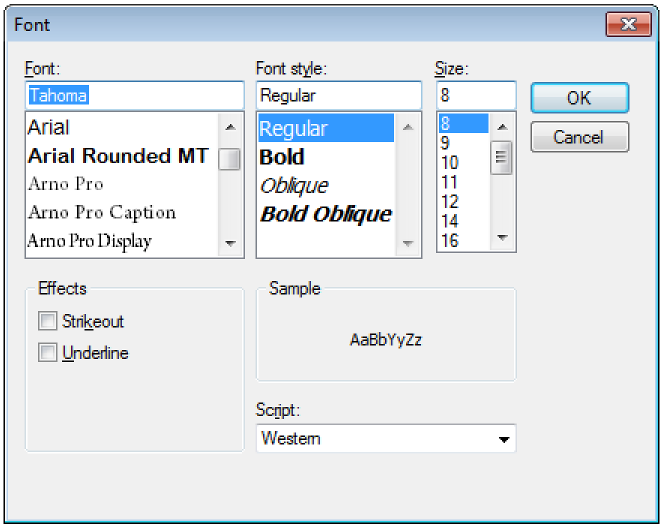
3. When a result is modified it is highlighted in yellow.



Select Font

Change the style and size for *all* displayed text in the corresponding Attribute or Result grid.

1. Right-click within the grid and choose Select Font.
2. Make Font, Font style, and Size choices and click OK.



The default font is Tahoma Regular 8 point.

See Also

[Working With Grids](#)

Renaming Results

Renaming a Results or Attributes in a Grid

To change the name of an attribute or result in a grid:

1. Place the cursor over the name.
2. Right click and select Rename Item.
3. In the Name field enter the new name.
4. Click OK.

Renaming a Result Displayed on a Plot

To change the name of an overlay result:

1. Place the cursor over the result name. If the + cursor doesn't appear, try switching the plot to 2D mode.
2. Right click and select Rename.
3. In the Name field enter the new name.
4. Click OK.

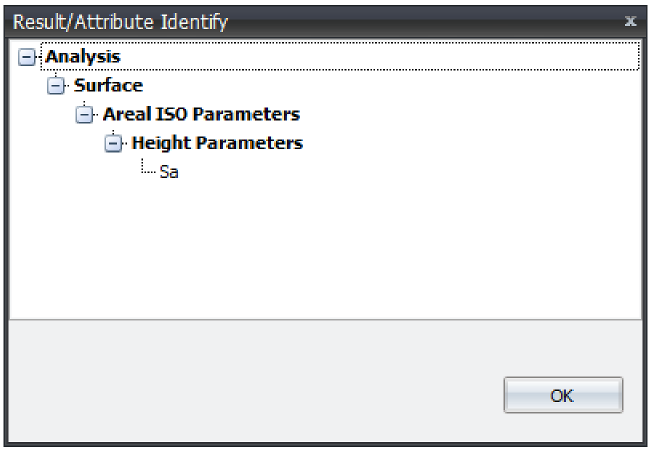
Renaming a Result in Process Statistics

1. Place the cursor over the result or attribute name at the top of the column.
2. Right click and select Rename Item.
3. In the Name field enter the new name.
4. Click OK.

Identifying Results

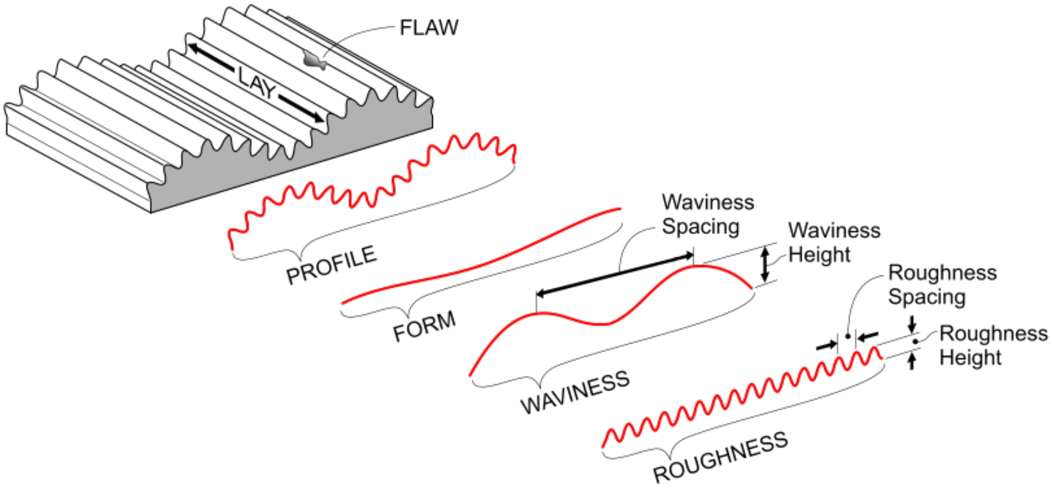
To see if a result or attribute has been renamed, or to find out what it is:

1. Place the cursor over the result name.
2. Right click and select Identify.
3. The original name is shown at the end of the string.



4. Click OK.

Surface Texture Terminology



Lay	Direction of finish pattern.
Form	General shape of the surface (inaccurate machine, stressed part).
Waviness	Widely spaced irregularities (vibration, chatter).
Roughness	Closely spaced irregularities (cutting tool marks, grit of grinding wheel).

11.2 Attributes

- Attributes display information about the measurement, such as the setting of controls, the date of the measurement, and the name of data file.
- Attributes are used to check the conditions under which the measurement was taken, and the settings of the various data processing tools.
- Attributes cannot be changed; they are used to provide information.
- Attributes are listed in alphabetical order.

Attributes that reflect the setting of a control are not listed. To find information about a control, use the index, or look for details in the discussion about the tool or analysis in which the control appears.

Attribute List

Actual Pixels Per Fringe

The actual pixels per fringe spacing used during rough align, acquisition, and analysis; equals Target Pixels Per Fringe when possible. Applicable only when Measure Mode is DynaPhase.

Aperture Center X

Displays the location in the x-axis of the center of the data in the Auto Aperture tool.

Aperture Center Y

Displays the location in the y-axis of the center of the data in the Auto Aperture tool.

Camera Height

Displays the vertical dimension of the camera acquisition frame in the y-axis.

Camera Name

Displays the name of the camera.

Camera Width

Displays the horizontal dimension of the camera acquisition frame in the x-axis.

Data Filename

Displays the name of the last saved or loaded data file.

Input Camera Height

Displays the height in pixels in the y-axis of the camera used for the input data. The input data is the data coming into the system reference subtract tool.

Input Camera Width

Displays the width in pixels in the x-axis of the camera used for the input data. The input data is the data coming into the system reference subtract tool.

Input Comment

Displays the user entered comment for the input data. The input data is the data coming into the system reference subtract tool.

Input Data Height

Displays the height in pixels in the y-axis of the input data. The input data is the data coming into the system reference subtract tool.

Input Data Width

Displays the width in pixels in the x-axis of the input data. The input data is the data coming into the system reference subtract tool.

Input Interf Scale Factor

Displays the Interf Scale Factor control setting used for the input data. The input data is the data coming into the system reference subtract tool.

Input Lateral Resolution

Displays the lateral resolution of the input data. The input data is the data coming into the system reference subtract tool.

Input Measure Mode

Displays the Measure Mode control setting used for the input data. The input data is the data coming into the system reference subtract tool.

Input Part Number

Displays the user entered part number for the input data. The input data is the data coming into the system reference subtract tool.

Input Part Serial Number

Displays the user entered part serial number for the input data. The input data is the data coming into the system reference subtract tool.

Input Time Stamp

Displays the time the input data was measured. The input data is the data coming into the system reference subtract tool.

Instrument Wavelength

Displays the wavelength that the displayed data was measured at.

Lateral Resolution

Displays the lateral resolving power of each camera pixel. For laser interferometers, the transmission element must be calibrated, otherwise this attribute is blank. For optical profilers, while the default resolution is provided, it is recommended that calibration be performed. Also known as Spatial Sampling or Camera Resolution.

Magnification

Displays the magnification at which the measurement was performed.

Pattern Current Column

Displays the current column number of the active pattern.

Pattern Current Row

Displays the current row number of the active pattern.

Pattern Current Site

Displays the current site number of the active pattern.

Settings Filename

Displays the name of the currently loaded settings file.

Shutter

The camera shutter speed in milliseconds (ms). 1000 milliseconds equals 1 second. 8 milliseconds equals 1/125 of a second. This attribute is available in the Measurement Setup toolbar, but applies only to certain measurement modes.

System Reference Camera Height

Displays the height dimension in the y-axis of the camera used for the reference data. The reference data is the data file subtracted with the system reference subtract tool.

System Reference Camera Width

Displays the width dimension in the x-axis of the camera used for the reference data. The reference data is the data file subtracted with the system reference subtract tool.

System Reference Comment

Displays the user entered comment for the reference data. The reference data is the data file subtracted with the system reference subtract tool.

System Reference Data Height

Displays the height in pixels in the y-axis of the reference data. The reference data is the data file subtracted with the system reference subtract tool.

System Reference Data Width

Displays the width in pixels in the x-axis of the reference data. The reference data is the data file subtracted with the system reference subtract tool.

System Reference Fiducial Alignment Error

Displays the RMS error in pixels between the automatically assigned fiducials for the input data and the reference fiducials after aligning the reference fiducials to the input fiducials. This is part of the system reference subtract function.

System Reference Interf Scale Factor

Displays the Interf Scale Factor control setting used for the reference data. The reference data is the data file subtracted with the system reference subtract tool.

System Reference Lateral Resolution

Displays the lateral resolution of the reference data. The reference data is the data file subtracted with the system reference subtract tool.

System Reference Measure Mode

Displays the Measure Mode control setting used for the reference data. The reference data is the data file subtracted with the system reference subtract tool.

System Reference Part Number

Displays the user entered part number for the reference data. The reference data is the data file subtracted with the system reference subtract tool.

System Reference Part Serial Number

Displays the user entered part serial number for the reference data. The reference data is the data file subtracted with the system reference subtract tool.

System Reference Time Stamp

Displays the time the reference data was measured. The reference data is the data file subtracted with the system reference subtract tool.

System Serial Number

Displays the serial number of the instrument.

System Type

Displays the instrument type in use when the measurement was made (for example- VeriFire IQ).

Time Stamp

Displays the time the currently displayed data was measured.

Tolerance Status

Displays the state of results with tolerances.

User Wavelength

Displays the wavelength the user set in the Master units controller. Also known as wavelength out.

Window Center X

Displays the dimension in the X-axis to the center of the Legendre window.

Window Center Y

Displays the dimension in the Y-axis to the center of the Legendre window.

Window X Dimension

Displays the overall dimension in the X-axis of the Legendre window.

Window Y Dimension

Displays the overall dimension in the Y-axis of the Legendre window.

11.3 Common Results

This section describes results that are non-instrument and non-industry specific. This includes height and optical parameters. These results may be used to describe 2D (profile) data or 3D (areal) data.

See Also

Surface Parameters

Areal ISO Parameters

Profile Parameters

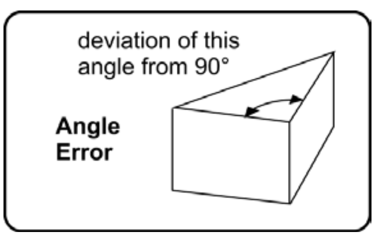
Profile ISO Parameters

Optical Parameters

These are basic optical parameters and may apply to either a laser interferometer or an optical profiler. For specific laser interferometer results see Optical Results .

Angle Error

The amount a right-angle prism is off from 90 degrees. A negative value indicates less than 90 degrees. It is also referred to as angular deviation. The prism vertex must be oriented vertically during the test setup for valid results.



AstAng

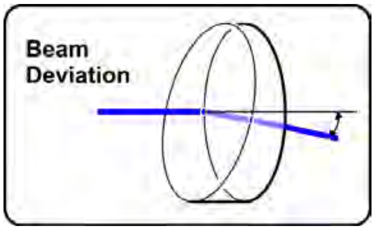
Astigmatism Angle is the angle in the instrument coordinate system at which astigmatism occurs. See AstAng (Z).

AstMag

Astigmatism Magnitude is the overall astigmatism. See AstMag (Z).

Beam Deviation

The amount that the part under test deviates a beam (or optical wave) from its desired direction of propagation.



Homogeneity

A measure of the uniformity or purity of an optical material. The lower the Homogeneity, the better the uniformity. Homogeneity is given by:

$$\Delta n = [n\,(T - C) - (n-1)\,(S2 - S1)]\,/t$$

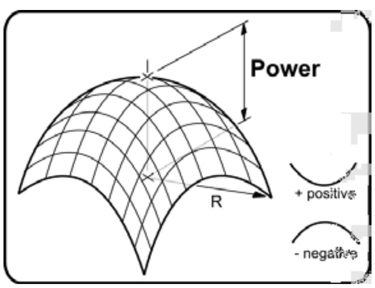
Where n is the refractive index, t is the part thickness, and T, C, S1, and S2 are the measurements.

Homogeneity RMS

The root-mean-square deviation of all points from a plane fit to the test part surface.

Power

A measure of the curvature of the surface or wavefront without distinguishing between the X and Y dimensions. It is equivalent to the height difference between the center point and the point farthest from the center. The Power result is derived from a best-fit spherical surface. Power is positive for a concave surface and negative for a convex surface.



Equations used are:

$$Z(X,Y) = C_0+C_1X+C_2Y+C_3(X^2+Y^2)$$

$$\text{Power} = C_3R^2$$

Where Cx are coefficients derived by fitting the surface, and R is the radius or the distance between the center point and the point farthest from the center.

Power X

A measure of the curvature of the surface or wavefront in the x-axis. Used when measuring cylindrical surfaces to indicate the amount of power in the measurement, regardless of the setting of the remove function. Lateral calibration is required.

Equations used are:

$$Z(X,Y) = C_0+C_1X+C_2Y+C_3X^2+C_4Y^2+C_5XY$$

$$\text{Power } X = C_3X^2$$

Where Cx are coefficients derived by fitting the surface.

Power Y

A measure of the curvature of the surface or wavefront in the x-axis. Used when measuring cylindrical surfaces to indicate the amount of power in the measurement, regardless of the setting of the remove function. Lateral calibration is required.

Equations used are:

$$Z(X,Y) = C_0+C_1X+C_2Y+C_3X^2+C_4Y^2+C_5XY$$

$$\text{Power } Y = C_4Y^2$$

Where Cx are coefficients derived by fitting the surface.

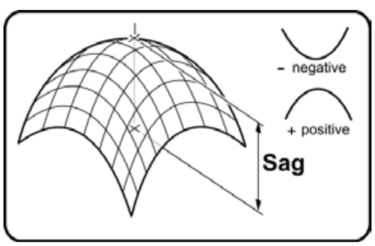
Quality Factor

This serves as an indicator of vibration severity for QPSI data acquisition. As vibration increases, the quality factor number increases until a threshold is reached and then the instrument does not return a measurement. The threshold for plano cavities is 1.4; the threshold for spherical cavities is 1.0.

Sag

A measure of the curvature of the surface or wavefront without distinguishing between the X and Y dimensions. It is equivalent to the height difference between the center point and the point farthest from the center. The Sag result is derived from a best-fit cylindrical surface.

Sag is negative for a concave surface and positive for a convex surface. The Sag result is intended for measuring circular regions (normally optical components). It may also be used to measure square regions. The Sag result is incorrect when measuring regions of other outlines. Sag is not very meaningful for a surface of arbitrary outline or orientation.



Equations used are:

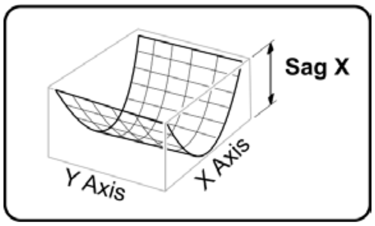
$$Z(X,Y) = C_0+C_1X+C_2Y+C_3XY+C_4X^2+C_5Y^2$$

$$\text{Sag} = -\frac{(C_4+C_5)}{2}R^2$$

Where Cx are coefficients derived by fitting the surface, and R is the radius or the distance between the center point and the point farthest from the center.

Sag X

A measure of the curvature of the surface or wavefront in the X dimension only. The Sag X result is derived from a best-fit cylindrical surface. Sag X is negative for a concave surface and positive for a convex surface.



Equations used are:

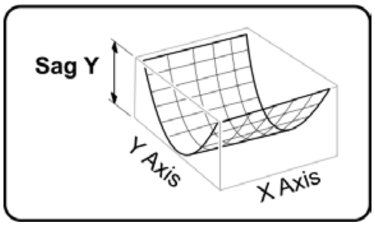
$Z(X,Y) = C_0+C_1X+C_2Y+C_3XY+C_4X^2+C_5Y^2$

$\text{Sag } X = -C_4X^2$

Where Cx are coefficients derived by fitting the surface, and X is the component of the radius which is in the x direction.

Sag Y

A measure of the curvature of the surface or wavefront in the Y dimension only. The Sag Y result is derived from a best-fit cylindrical surface. Sag Y is negative for a concave surface and positive for a convex surface.



Equations used are:

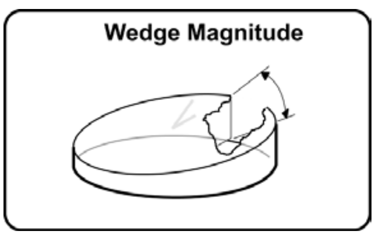
$Z(X,Y) = C_0+C_1X+C_2Y+C_3XY+C_4X^2+C_5Y^2$

$\text{Sag } Y = -C_5Y^2$

Where Cx are coefficients derived by fitting the surface, and Y is the component of the radius which is in the y direction.

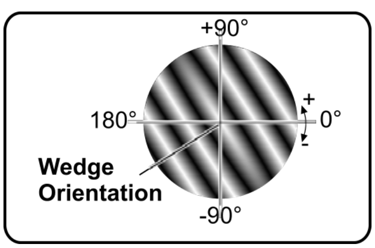
Wedge Magnitude

The overall wedge or non parallelism in the optic. Lateral calibration is required.



Wedge Orientation

The direction or orientation angle of the wedge. This angle represents the thinnest portion of the wedge and is perpendicular to the fringes.



Wedge X

The wedge or incline of the part relative to the reference surface in the X direction. Lateral calibration is required.

Wedge Y

The wedge or incline of the part relative to the reference surface in the Y direction. Lateral calibration is required.

Temperature Sensors

Temp Sensor 1-4

Outputs the temperature reading of a corresponding optional ZYGO temperature sensor. Temperature probes are sometimes used in specialized ZYGO projects, systems, or applications and can be accessed by Mx software. Up to four temperature sensor readings can be displayed; they are numbered 1, 2, 3, and 4. Temp Sensor results can be added to a Result grid.

Temperature sensors can be configured as part of a recipe in the Recipe Sequence Editor.

11.4 Surface Parameters

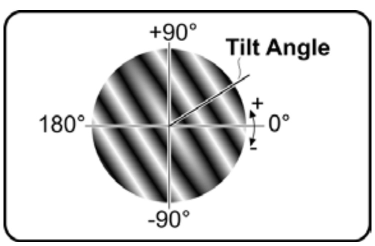
These 3D results relate to the entire surface. For surface height results see Height Parameters. For common optical results see Optical Parameters.

Angle Parameters

Tilt Angle

The direction of tilt in the data.

For laser interferometers, this can be seen on the live display as the direction perpendicular to the fringes. The wavefront is highest at the specified angle. Lateral calibration is required.

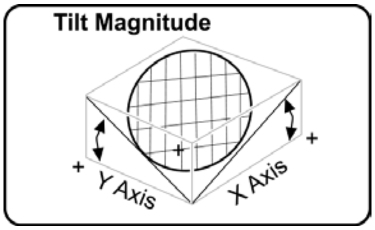


$$\text{Tilt Angle} = \text{Tan}^{-1}\left(\frac{\text{Tilt Y}}{\text{Tilt X}}\right)$$

For profilers, if the measured surface is a perfectly tilted plane, the tilt angle is the azimuthal angle about the Z axis. Tilt Angle is the direction that water would flow if it was poured onto the plane.

Tilt Mag

Tilt Magnitude. The overall angle of inclination between the reference and test beams of the interferometer. If measuring a surface, tilt is the angle between the reference and test surface. If measuring a transmitted wavefront, tilt is the angle of the beam deviated by the optic. It can be thought of as lying in the plane of the reference surface, or the live display. Lateral calibration is required.



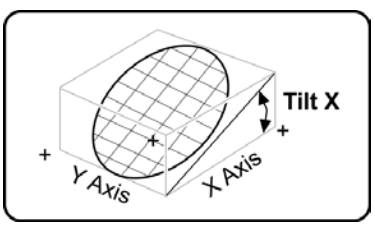
$$\text{Tilt Magnitude} = \sqrt{\text{Tilt X}^2 + \text{Tilt Y}^2}$$

Tilt PV

The PV of a surface defined by a plane with the same tilt as the data, and masked by the valid data pixels.

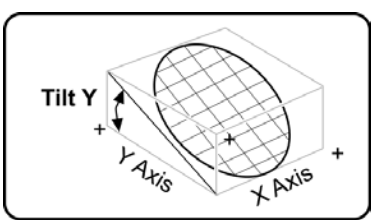
Tilt X

The tilt of the part relative to the reference surface in the X direction. Lateral calibration is required.



Tilt Y

The tilt of the part relative to the reference surface in the Y direction. Lateral calibration is required.

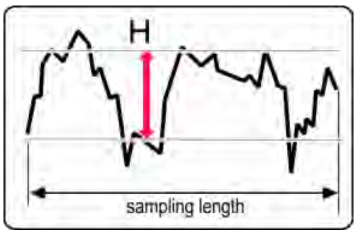


Height Parameters

These are basic height parameters; many apply to both profile and areal data. See also Areal ISO Height Parameters and Profile ISO Height Parameters.

H

Swedish height. The roughness between two predefined reference lines. The upper line exposes 5% of the data, and the lower line exposes 90%. H is less sensitive to data spikes than peak-to-valley.



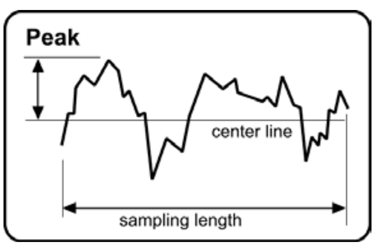
Mean

The arithmetic average of a set of values. It is calculated by summing the data and dividing by the number of points. The mean is often quoted along with the standard deviation- the mean describes the central location of the data, and the standard deviation describes the spread.

$$\bar{X} = \frac{1}{n} \cdot \sum_{i=1}^{n} X_i$$

Peak

Peak is the maximum distance between the center line and the highest peak point within the sample. The center line is defined as the best-fit surface selected with the remove function. Peak is the value of the highest data point.



Peak Location X

The x-axis location in camera coordinates of the highest point.

Peak Location Y

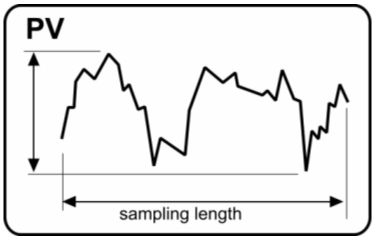
The y-axis location in camera coordinates of the highest point.

Pts in PV Spec

Percentage of Points within the Peak-to-Valley Specification is the percentage of valid data points within a user specified high limit for the corresponding PV result. It is linked to the PV result and displays a percentage result only if a high limit is set on the corresponding PV result. When a percentage is displayed, it represents the percentage of data points within the set limit.

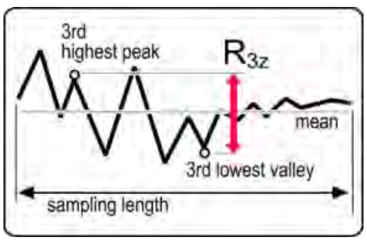
PV

(Peak-to-Valley) The distance between the highest and lowest points within the sampled data area. PV is the worst case point-to-point error in the data set. PV compares the two most extreme points on the surface; thus, it is possible for two very different surfaces to have the same PV value. Also known as Peak Valley.



R3z

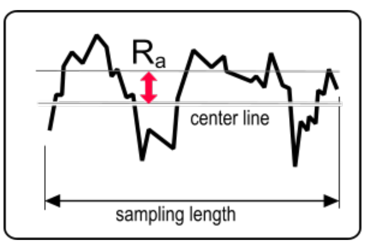
Base roughness depth. The distance between the third highest peak and the third lowest valley. A peak is a portion of the surface above the mean line and between center line crossings. Available for profile and areal data.



Ra

Arithmetical mean deviation. The average roughness or deviation of all points from a plane fit to the test part surface. Available for profile and areal data.

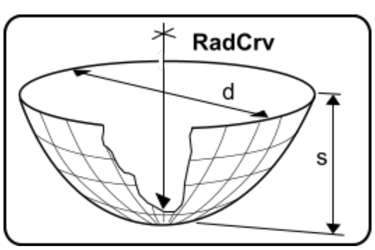
When displayed in Slice Statistics, piston is automatically removed.



$$R_a = \frac{1}{L}\int_0^L |z(x)|dx$$

RadCrv

RadCrv (Radius of Curvature) is the distance from the part being measured to the center of the curvature of the surface. Radius of curvature is for a sphere. It is typically represented in millimeters or inches. A positive value corresponds to a convex surface or wavefront; a negative value corresponds to a concave surface or wavefront. The instrument must be calibrated for this result to be accurate.



RadCrv = $(d/2)^2$ /2s

Where d is the diameter and s is the sag.

RadCrv X

RadCrv X is the curvature in the x-axis.

RadCrv Y

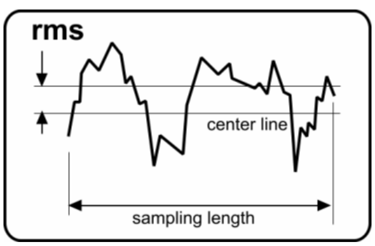
RadCrv Y is the curvature in the y-axis.

RMS

(Root-Mean-Square) The root-mean-square deviation from the center line. This is a method of calculating an average by squaring each value and then taking the square root of the mean. The center line is defined as the best-fit surface selected with the remove function. The RMS result is the root-mean-square of surface figure error or transmitted error relative to a reference surface. The RMS result is an area weighted statistic; when used for optical components, it more accurately depicts the optical performance of the surface being measured than the PV statistic because it uses all the data in the calculation.

The RMS result is calculated as the standard deviation of the height (or depth) of the test surface relative to the reference at all data points in the data set. Since RMS is a roughness parameter, surface figure should be removed from the data with the remove function for this result to be meaningful.

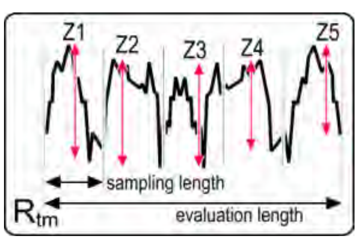
When displayed in Slice Statistics, piston is automatically removed.



$$\text{rms} = \left(\frac{y_1^2 + y_2^2 + y_3^2 \cdots + y_N^2}{N} \right)^{1/2}$$

Rtm

Mean peak-to-valley roughness. It is determined by the difference between the highest peak and the lowest valley within multiple samples in the evaluation area. For profile data it is based on five sample lengths. Available for profile and areal data.



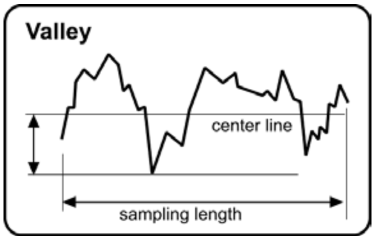
$$R_{tm} = \frac{Z1 + Z2 ... + Zn}{n}$$

StdDev

(Standard Deviation) A simple measure of the variability or dispersion of a data set. A low standard deviation indicates that the data points tend to be very close to the same value (the mean), while high standard deviation indicates that the data are “spread out” over a large range of values.

Valley

The maximum depth between the center line and the lowest point within the sampled data. The center line is defined as the best-fit surface selected with the remove function. Valley is the value of the lowest data point.



Valley Location X

The x-axis location in camera coordinates of the lowest point.

Valley Location Y

The y-axis location in camera coordinates of the lowest point.

Spatial Parameters

These categories include Centroid, Min Enclosing Rectangle (also called MER), Moments, and Size.

Centroid

These spatial parameters relate to data centers.

Centroid X

Dimension in the x-axis to the center of all valid data points.

Centroid X = (x1 + x2 + x3 + ... Xn) /n

Centroid Y

Dimension in the y-axis to the center of all valid data points.

Centroid Y = (y1 + y2 + y3 + ... Yn) / n

Weighted Centroid X

The location in the x-axis of the center of the data, as based on a weighted average. Calculated using the height of each point (relative to the valley) to weight the coordinates.

Weighted Centroid Y

The location in the y-axis of the center of the data, as based on a weighted average. Calculated using the height of each point (relative to the valley) to weight the coordinates.

Min Enclosing Rectangle

These spatial parameters relate to minimum enclosing rectangles.

Mean MER Maj Dim

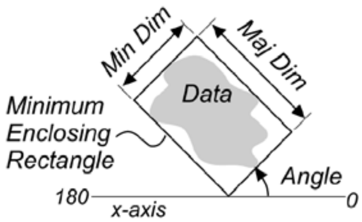
The mean length of a part analyzed along the direction of the Major Dimension in the Minimum Enclosing Rectangle. The mean length is derived by placing slices inside the Minimum Enclosing Rectangle with the same angle as the Major Dimension and finding the distance from the first valid point to the last valid point for each slice and then calculating the average.

Mean MER Min Dim

The mean length of a part analyzed along the direction of the Minor Dimension in the Minimum Enclosing Rectangle. The mean length is derived by placing slices inside the Minimum Enclosing Rectangle with the same angle as the Minor Dimension and finding the distance from the first valid point to the last valid point for each slice and then calculating the average.

MER Angle

The angle between the major or long side of the minimum enclosing rectangle and the x-axis.



MER Center X

The X coordinate of the center of the Minimum Enclosing Rectangle relative to the data dimension.

MER Center Y

The Y coordinate of the center of the Minimum Enclosing Rectangle relative to the data dimension.

MER Maj Dim

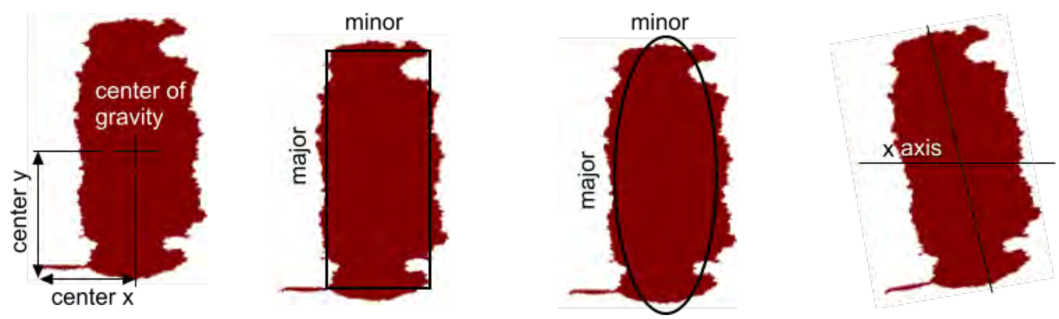
The dimension of the minimum enclosing rectangle along the major or longer side of the rectangle.

MER Min Dim

The dimension of the minimum enclosing rectangle along the minor or shorter side of the rectangle.

Moments

These spatial results determine the mean width/length of an object or region by fitting a rectangle or ellipse to it. A region is an area of contiguous surface or image points. Moments refers to mathematical methods involving the weighted averages of point coordinates. Moments results are relative to the camera field of view coordinate system.



Contiguous region Fit rectangle Fit ellipse Angle

Moments Angle

The angle of the ellipse or rectangle major axis relative to the X axis. If the Mx Regions "Design Corrdinates" (Gerber file) option is selected, then Moments Angle is relative to the part angular coordinate system.

Moments Center X

The location in the X axis of the center of gravity of the region.

Moments Center Y

The location in the Y axis of the center of gravity of the region.

Moments Eccentricity

This is a number from 0 to 1 that indicates ellipse elongation. If eccentricity is 0, the ellipse is a circle. If eccentricity is small, then orientation is less useful.

Moments Ellipse Maj Dim

The major (long) dimension of the fitted ellipse.

Moments Ellipse Min Dim

The minor (short) dimension of the fitted ellipse.

Moments Rect Maj Dim

The major (long) dimension of the fitted rectangle.

Moments Rect Min Dim

The minor (short) dimension of the fitted rectangle.

Size

These spatial parameters relate to data size.

Area

Area is a quantity that expresses the extent of a two-dimensional surface.

Mean Size X

This is the mean dimension of the data set in the x-axis of the live display. This result is the average width based on every row of data in the data set. If a test mask is defined and applied, it is the dimension in the test mask area.

For this result to be accurate, lateral calibration is required.

Mean Size Y

This is the mean dimension of the data set in the y-axis of the live display. This result is the average width based on every column of data in the data set. If a test mask is defined and applied, it is the dimension in the test mask area.

For this result to be accurate, lateral calibration is required.

NPoints

The number of points or pixels in a valid data region or slice. Also know as Number of Points.

S2A

S2A is the lateral area of tiling following the ISO standard.

Both S2A and S3A tile the data with triangles in the manner prescribed via ISO 25178-2. S3A and S2A are the numerator and denominator, respectively, of the ratio used as the definition of Sdr. S3A is the surface area of the triangle tiling, and S2A is the lateral area of this tiling.

Both S2A and S3A tend to report a slightly smaller area than the Area result because data samples are considered between valid points in space rather than as pixels. This results both in a domain smaller than the pixel domain by a half-pixel on all sides, and also effectively widens, with respect to the pixel model, the holes introduced by missing data.

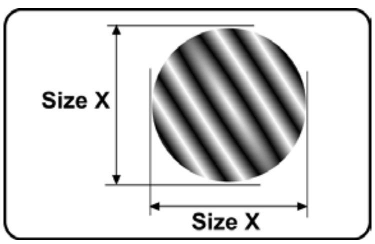
S3A

Surface Area of the triangular tiling following the ISO standard. See S2A.

Size X

The size or extent of the data in the x-axis. Lateral Calibration required to display units.

In the Sub-Aperture view, it is the size in the x-axis of the virtual sub-aperture, not the size of valid data in the sub aperture.



Size Y

The size or extent of the data in the y-axis. Lateral Calibration required to display units.

In the Sub-Aperture view, it is the size in the y-axis of the virtual sub-aperture, not the size of valid data in the sub aperture.

Volume Parameters

Volume results are calculated relative to the zero datum of the data set. Mx offers several ways to set the zero location of a data set. For example:

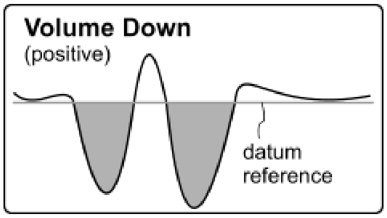
- Using the Regions Reference functionality, and then viewing Volume results in the Regions Results.
- Using the Surface Processing Form Remove Fit Mask functionality.

Volume results are then calculated over all valid pixels. To restrict the area of calculation, consider:

- Using the Regions segmentation functionality.
- Using the Surface Processing Mask step.
- Using a Surface or Acquisition Mask. See Mask Editor.

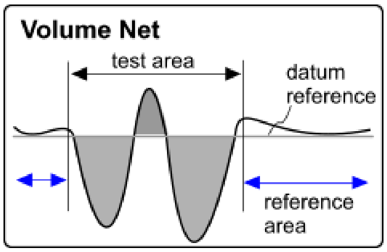
Volume Down

Volume Down is the volume of the test area which is lower than the reference area. Positive Volume Down can be thought of as the space occupied by pits on the test area; a negative Volume Down result would protrude above the reference area.



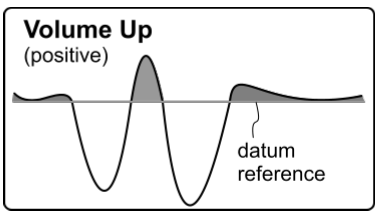
Volume Net

Volume Net is the overall volume of the test area. It is equal to the Volume Up minus the Volume Down.



Volume Up

Volume Up is the volume of the test area which is higher than the reference area. Positive Volume Up can be thought of as the space occupied by bumps on the test area; a negative Volume Up result would extend below the reference area.



Calculate Only Parameters

These results are typically used for systems with custom stages, where the stage adjustment calculation is made, but the stage is not moved because it is controlled outside Mx.

Auto Center X-Axis Adjust

The X-Axis offset calculated during the Auto Center operation.

Auto Center Y-Axis Adjust

The Y-Axis offset calculated during the Auto Center operation.

Focus Adjust

The focus adjustment (Z-Axis) distance calculated when Auto Focus Tilt Calculate Only is On.

Pitch Adjust

The pitch (tilt) adjustment angle calculated when Auto Focus Tilt Calculate Only is On.

Roll Adjust

The roll (tip) adjustment angle calculated when Auto Focus Tilt Calculate Only is On.

Legacy Parameters

These roughness parameters were available in previous software products.

SR3z

Base roughness areal depth. The height of the 3rd highest peak from the 3rd lowest valley per sampling area. The base roughness depth is found in each sampling area and then averaged.

SRmax

Maximum peak-to-valley height over the entire areal evaluation area.

SRpm

Mean valley areal height. The mean peak height based on one peak per sampling area. The single highest peak is found in each sampling area and then averaged.

SRtm

Mean peak-to-valley areal roughness. The mean peak-to-valley roughness based on one peak and one valley per sampling area. The single largest deviation is found in each sampling area and then averaged.

SRvm

Mean valley areal depth. The mean valley depth based on one peak per sampling area. The single deepest valley is found in each sampling area and then averaged.

SRz

Average radial peak-to-valley areal roughness. The average of the largest half of many individual Rz results determined by slicing the areal data array about its center through 360 degrees. The Rz results are sorted by magnitude and SRz is calculated by averaging the largest 50% of the Rz values. A line-generation algorithm is used to determine the actual pixel-to-pixel path of each slice; there is no interpolation between pixels. SRz covers the entire array, and due to its radial generation it is lay independent.

This parameter corresponds to the SRz ISO result in MetroPro. Slight differences can be expected due to differences in rounding and interpolation.

SRzr

The average of the largest half of individual Rz results determined for every row and column of the data. This parameter corresponds to the SRz result in MetroPro. Slight differences can be expected due to differences in rounding and interpolation.

11.5 Areal ISO Parameters

- Applicable to optical profilers.
- Calculated on the entire 3D areal surface.
- Named with the capital letter S (or V) followed by a suffix of one or two small letters.
- Based on ISO 25178 standard for surface texture (except for Birmingham Parameters).

Birmingham Parameters

These areal ISO functional index parameters deal with bearing and fluid retention.

Sbi

Surface Bearing Index. For Gaussian, Sbi=0.61 , High Sbi= good bearing surface.

Sci

Core Fluid Retention Index. For Gaussian, Sci= 1.56, smoother = smaller Sci.

Svi

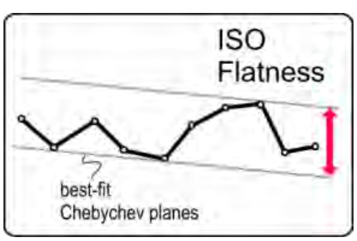
Valley Fluid Retention Index. For Gaussian, Svi= 0.11, Good Fluid Retention = larger Svi.

Areal ISO Amptitude (Height) Parameters

These areal ISO parameters involve only the statistical distribution of height values along the z axis.

ISO Flatness

Areal flatness deviation. Also known as FLTt. The measure of surface deviation from perfectly flat. It is the distance between two parallel planes obtained by applying a Chebychev fit to the surface data. The Chebychev fit is a mathematical technique that effectively uses two parallel planes to "squeeze" the surface data points from both inside and outside, adjusting the angle to minimize the distance between the planes. This result requires lateral calibration to calculate; otherwise it will be blank.



Sa

Arithmetical mean height of the surface. Sa and Sq parameters represent an overall measure of the texture comprising the surface. Sa and Sq are insensitive in differentiating peaks, valleys, and the spacing of the various texture features.

Sku

Kurtosis of height distribution. Sku indicates the presence of inordinately high peaks/ deep valleys (Sku>3.00) or lack thereof (Sku<3.00) making up the texture. Sku is useful for indicating the presence of either peak or valley defects which may occur on a surface.

Sp

Maximum peak height.

Sp, Sv, and Sz are parameters evaluated from the absolute highest and lowest points found on the surface. Sp is the height of the highest point; Sv is the depth of the lowest point (expressed as a negative number). Sz is equal to Sp – Sv. Sp, Sv, and Sz results are calculated after all surface processing.

Sq

Root mean square height of the surface.

Ssk

Skewness of height distribution. Ssk represents the degree of symmetry of the surface heights about the mean plane. The sign of Ssk indicates the predominance of peaks (i.e. Ssk>0) or valley structures (Ssk<0) comprising the surface.

Sv

Maximum valley depth.

Sz

Maximum height of the surface.

Areal ISO Feature Parameters

This section covers areal surface topography feature parameters found in the regions analysis. All feature parameters are calculated after a discrimination by segmentation using a Wolfpruning of 5% of the value of the Sz parameter (maximum height).

Spd

Density of peaks. Spd is the number of peaks per unit area.

Spc

Arithmetic mean peak curvature. Spc is the arithmetic mean of the principle curvatures of peaks within a definition area.

S10z

Ten point height of surface. S10z is the average of the heights of the five peaks with largest global peak height added to the average value of the heights of the five valleys with the largest global valley depth within a definition area.

S5p

Five point peak height. S5p is the average of the heights of the five peaks with largest global peak height within a definition area.

S5v

Five point valley height. S5v is the average of the heights of the five valleys with largest global valley depth within a definition area.

Areal ISO Functional Parameters

Smq

The material ratio at which the line-fits of the two characteristic linear regions of the material probability curve intersect.

Spq

The root-mean-square average of the height deviations in the peak or plateau portion of the Material Probability plot.

Svq

The root-mean-square average of the height deviations in the valley portion of the Material Probability plot. This result is useful as a predictor of original surface roughness before the removal of more material in subsequent processes.

Sxp

Peak Extreme Height. A measure of the difference in heights on the surface from the areal material ratio value of "p" and the areal material ratio of “q”. According to the ISO standard, the default value for p is 2.5% and the default value for q is 50%.

For the following Material Ratio parameters, see Fixed Areal Results for greater details.

Sa1

Surface Area defined by Spk.

Sa2

Surface Area defined by Svk.

Sk

Core Roughness Depth.

Spk

Reduced Peak Height.

Spk Threshold

The threshold between the Sk and Spk regions; it is an absolute height.

Sr1

Peak Material Component.

Sr2

Valley Material Component.

Svk

Reduced Valley Depth.

Svk Threshold

The threshold between the Sk and Svk regions; it is an absolute height.

For the following Material Ratio parameters, see Interactive Areal Results for greater details.

c1

Areal depth at c1.

c2

Areal depth at c2.

c2 - c1

Areal Depth Difference.

Smr(c1)

Surface Material Ratio percentage at height c1.

Smr(c2)

Surface Material Ratio percentage at height c2.

Smr(c2) - Smr(c1)

Surface Material Ratio Difference.

For the following Material Ratio parameters, see Volume Results for greater details.

V1 Output

The Tp% for lowest valley.

V2 Output

The Tp% for the highest valley.

Vmc

Core Material Volume.

Vmp

Peak Material Volume.

Vvc

Core Void Volume.

Vvv

Valley Void Volume.

Areal ISO Hybrid Parameters

These areal ISO parameters relate to the spatial shape of the data.

Sdq

Root mean square gradient of the surface. Sdq is a general measurement of the slopes which comprise the surface and may be used to differentiate surfaces with similar average roughness (Sa).

Sdr

Developed area ratio. Expressed as the percentage of additional surface area contributed by the texture as compared to an ideal plane the size of the measurement region.

Areal ISO Spatial Parameters

These areal ISO parameters involve the spatial periodicity of the data, specifically its direction.

Sal

Fastest decay auto-correlation rate. A measure of the distance over the surface such that the new location will have minimal correlation with the original location. The direction over the surface chosen to find Sal is the direction which yields the lowest Sal value.

Std

Surface texture direction. A measure of the angular direction of the dominant lay comprising a surface. Std is defined relative to the Y axis. Thus a surface with a lay along the Y axis will return a Std of 0 deg. Std is useful in determining the lay direction of a surface relative to a datum by positioning the part in the instrument in a known orientation.

Str

Texture aspect ratio of the surface. A measure of the spatial isotropy or directionality of the surface texture. Str is useful in determining the presence of lay in any direction. For applications where a surface is produced by multiple processes, Str may be used to detect the presence of underlying surface modifications.

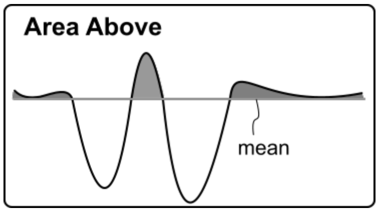
11.6 Profile Parameters

These results are related to slices or profile plots. For profile height results see Height Parameters.

Area Parameters

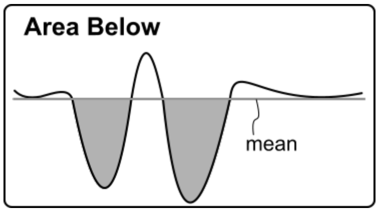
Area Above

Area Above is the area of the profile data above the mean. Instrument calibration is required for this result. The mean is the best fit surface to the data.



Area Below

Area Below is the area of the profile data below the mean. Instrument calibration is required for this result. The mean is the best fit surface to the data.

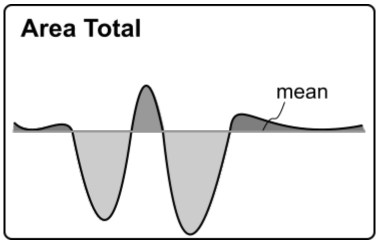


Area Net

Area Net is the overall area of the profile data. It is equal to the Area Above minus the Area Below. Instrument calibration is required for this result.

Area Total

Area Total is the sum of the Area Above and the Area Below the mean of the profile data. Instrument calibration is required for this result. The mean is the best fit surface to the data.



Dimension Parameters

Length/Circum

The length or circumference of the slice.

NPoints

The number of points or pixels in a slice.

Radius

The radius of a circular slice.

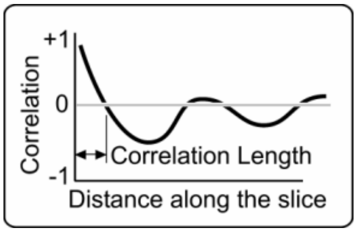
Size

The overall extent of the profile plot.

Hybrid Parameters

Correlation Length

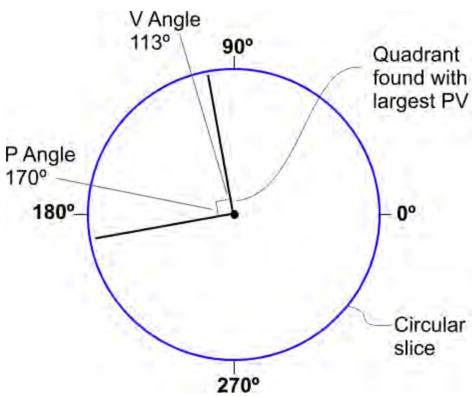
Correlation Length is the length along the x-axis where the Autocovariance (ACF) function first crosses zero. Autocovariance is used to determine the periodicity of a surface; it shows the dominant spatial frequencies along a cross section of the test surface. ACF is a measure of "self-similarity" of a profile - the extent to which a surface waveform pattern repeats. If the surface is random, the plot drops rapidly to zero. If the plot oscillates around zero in a periodic manner, then the surface has a dominant spatial frequency.



$$ACF = \sum_{i=1}^{N-m} Y_i \, Y_{i+m}$$

Quad Test Results

The Quad Test locates the largest peak-to-valley departure occurring with any 90° segment (quadrant) of a circular slice.



Quad PV

The difference between the peak and valley results for the quadrant with the largest PV.

P Angle

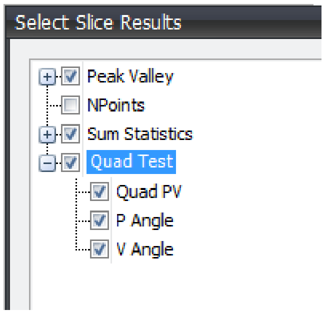
The angle at which the peak for the quadrant occurs, referenced to the zero position.

V Angle

The angle at which the valley for the quadrant occurs, referenced to the zero position.

Accessing Quad Test Results

1. Create a circular slice in 2D plot.
2. Point to the Result panel under the plot, right-click and choose Select Results.
3. Select the quad results to display.



4. Click OK.

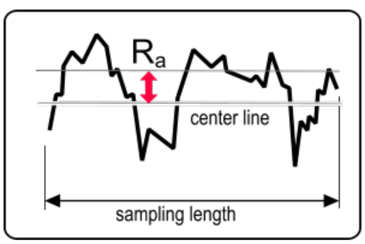
11.7 Profile ISO Parameters

- Applicable to optical profilers.
- Calculated on the a slice (profile) through the surface data.
- Comply with ISO standards.

Profile ISO Height Parameters

Ra

Arithmetical mean deviation. The average roughness or deviation of all points from a plane fit to the test part surface.



$$R_a = \frac{1}{L}\int_0^L |z(x)|dx$$

Rsk

Rsk or skew is a measure of symmetry of the profile about the mean line. Negative skew indicates a predominance of valleys, while positive skew indicates a “peaky” surface. Skew is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point.

Available in Slice Statistics; piston is automatically removed.

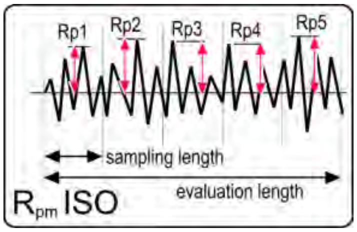
Rku

Rku or Kurtosis is a measure of the randomness of heights, and of the sharpness of a surface. A perfectly random surface has a value of 3; the farther the result is from 3, the less random and more repetitive the surface is. Surfaces with spikes are higher values; bumpy surfaces are lower.

Available in Slice Statistics; piston is automatically removed.

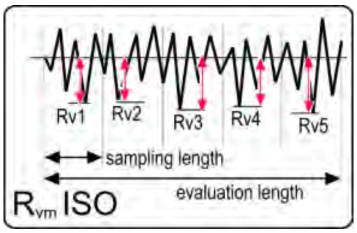
Rpm

Mean peak profile height. The mean peak height based on one peak per sampling length. The single highest peak is found in five sampling lengths and then averaged.



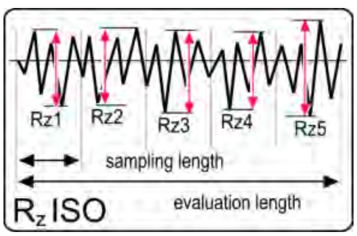
Rvm

Mean valley profile depth. The mean valley depth based on one peak per sampling length. The single deepest valley is found in five sampling lengths and then averaged.



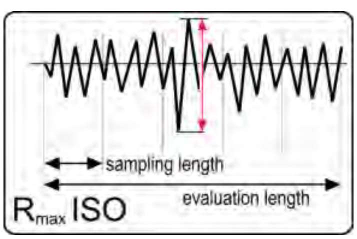
Rz

Average peak-to-valley profile roughness. The average peak-to-valley roughness based on one peak and one valley per sampling length. The single largest deviation is found in five sampling lengths and then averaged.



Rmax

Maximum peak-to-valley profile height. The greatest peak-to-valley distance within any one sampling length.



Profile ISO Functional Parameters

For the following Material Ratio parameters, see Fixed Profile Results for greater details.

A1

Area defined by Rpk.

A2

Area defined by Rvk.

Mr1

Peak Material Component.

Mr2

Valley Material Component.

Rk

Core Roughness Depth. The long term running surface which will influence the performance and life of the bearing surface.

Rk Midpoint

The middle point of the Rk region; it is an absolute height.

Rpk

Reduced Peak Height.

Rpk Threshold

The threshold between the Rpk and Rk regions; it is an absolute height.

Rvk

Reduced Valley Depth.

Rvk Threshold

The threshold between the Rk and Rvk regions; it is an absolute height.

For the following Material Ratio parameters, see Interactive Profile Results for greater details.

c1

Profile depth at c1.

c2

Profile depth at c2.

c2 - c1

Profile Depth Difference.

Pmr(c1)

Profile Material Ratio percentage at height c1.

Pmr(c2)

Profile Material Ratio percentage at height c2.

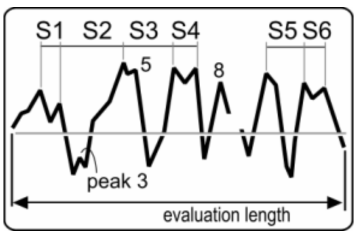
Pmr(c2) - Pmr(c1)

Profile Material Ratio difference.

Profile ISO Hybrid Parameters

S

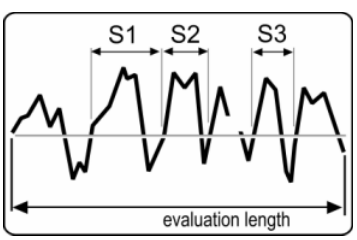
The average spacing between local peaks over the evaluation length. A local peak is the highest point between two adjacent minima.



The average spacing for this example is: $S = \frac{S1 + S2 ... + S6}{6}$

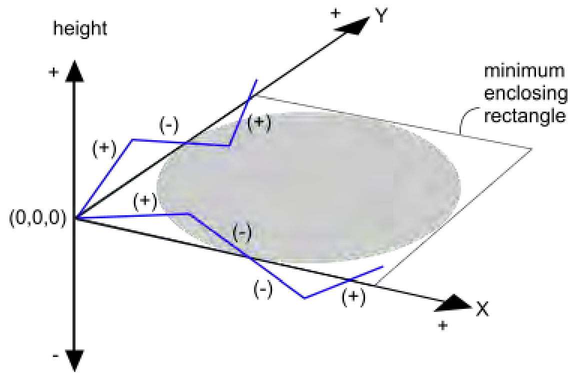
Sm

The average spacing between peaks at the mean line over the evaluation length. A peak is the highest point between an upwards and downwards crossing of the mean line. It is calculated by summing all the peak spacing and dividing by the number of spaces.



11.8 Slope Results

Slope results are derived from slope data. These results are available in the Slopes analysis. These are categorized into Slope X, Slope Y, and Slope Magnitude results.



This illustrates how Slope X and Slope Y results can be negative or positive.

Effective Lateral Resolution

Displays the lateral distance on the part that is treated as one pixel (local to Slope Analysis).

Input Lateral Resolution

Displays the lateral distance on the part for the input data that is equal to one pixel.

Slope X

Slope X Mean

The arithmetical average of all the values in the slope x data.

Slope X NPoints

The number of points or pixels in the slope x data.

Slope X Peak

The highest single point in the slope x data.

Slope X Peak X

The location in the x-axis, in camera coordinates, of the highest single point in the slope x data.

Slope X Peak Y

The location in the y-axis, in camera coordinates, of the highest single point in the slope x data.

Slope X PV

The distance between the highest and lowest points (Peak-to-Valley) in the slope x data.

Slope X Ra

The average roughness or deviation of all points from a plane fit to the slope x data.

Slope X RMS

The Root-Mean-Square of slope x data.

Slope X Valley

The lowest single point in the slope x data.

Slope X Valley X

The location in the x-axis, in camera coordinates, of the lowest single point in the slope x data.

Slope X Valley Y

The location in the y-axis, in camera coordinates, of the lowest single point in the slope x data.

Slope Y

Slope Y Mean

The arithmetical average of all the values in the slope y data.

Slope Y NPoints

The number of points or pixels in the slope y data.

Slope Y Peak

The highest single point in the slope y data.

Slope Y Peak X

The location in the x-axis, in camera coordinates, of the highest single point in the slope y data.

Slope Y Peak Y

The location in the y-axis, in camera coordinates, of the highest single point in the slope y data.

Slope Y PV

The distance between the highest and lowest points (Peak-to-Valley) in the slope y data.

Slope Y Ra

The average roughness or deviation of all points from a plane fit to the slope y data.

Slope Y RMS

The Root-Mean-Square of slope y data.

Slope Y Valley

The lowest single point in the slope y data.

Slope Y Valley X

The location in the x-axis, in camera coordinates, of the lowest single point in the slope y data.

Slope Y Valley Y

The location in the y-axis, in camera coordinates, of the lowest single point in the slope y data.

Slope Magnitude

Slope Magnitude Mean

The arithmetical average of all the values in the slope magnitude data.

Slope Magnitude NPoints

The number of points or pixels in the slope magnitude data.

Slope Magnitude Peak

The highest single point in the slope magnitude data.

Slope Magnitude Peak Location X

The location in the x-axis, in camera coordinates, of the highest single point in the slope magnitude data.

Slope Magnitude Peak Location Y

The location in the y-axis, in camera coordinates, of the highest single point in the slope magnitude data.

Slope Magnitude PV

The distance between the highest and lowest points (Peak-to-Valley) in the slope magnitude data.

Slope Magnitude Ra

The average roughness or deviation of all points from a plane fit to the slope magnitude data.

Slope Magnitude RMS

The Root-Mean-Square deviation of all points from the best-fit surface to the slope magnitude data.

Slope Magnitude Valley

The lowest single point in the slope magnitude data.

Slope Magnitude Valley Location X

The location in the x-axis, in camera coordinates, of the lowest single point in the slope magnitude data.

Slope Magnitude Valley Location Y

The location in the y-axis, in camera coordinates, of the lowest single point in the slope magnitude data.

11.9 Optical Results

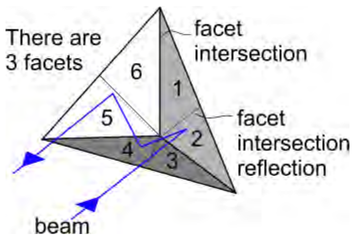
This section describes results that are related to optics and optical testing using a laser interferometer. For common optical results see Optical Parameters.

Corner Cube Results

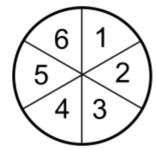
These results are part of the Corner Cube Measurement Type. To display Corner Cube results not shown see Changing Displayed Results and Additional Corner Cube Results.

Corner Cube Nomenclature

Like a corner of a box, three surfaces meet at 90 degrees to each other.



Corner cube facets and intersections.



Typical sector numbering.

Beam Deviation (1)...(6)

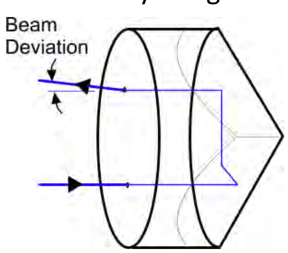
Individual beam deviation results for each of the six sectors. Results for all six are displayed when using the single pass setup. With double pass setups, beam deviations for sectors 4, 5, and 6 are not shown as they duplicate the results for sectors 1, 2, and 3.

Dihedral Angle Error 1-2 or 4-5
Dihedral Angle Error 2-3 or 5-6
Dihedral Angle Error 3-4 or 6-1

The amount that the named facets deviate from being truly perpendicular to one another. The numbers refer to intersections of sectors, for example: 1-2 refers to the intersection of sectors 1 and 2. A positive number indicates that the dihedral angle is greater than 90 degrees; a negative value denotes less than 90 degrees.

Max Beam Deviation

Beam deviation is the angle that a retroreflected ray of light deviates from being parallel to the incident ray of light. This result displays the maximum of the individual sector results.



Additional Corner Cube Results

For nomenclature see Corner Cube Results.

For the results described here, single pass setup yields 6 sectors, while the double pass setup yields 3 sectors.

Count (All)

The average number of data points in each sector.

Peak (1)...(6)

The highest point in the corresponding sector.

Peak (All)

The average of all the highest points in all sectors.

Peak Location X (1)...(6)

The x-axis location in camera coordinates of the highest point in the corresponding sector.

Peak Location X (All)

The average x-axis location in camera coordinates of the highest point in each sector.

Peak Location Y (1)...(6)

The y-axis location in camera coordinates of the highest point in the corresponding sector.

Peak Location Y (All)

The average y-axis location in camera coordinates of the highest point in each sector.

Peak Valley (1)...(6)

The transmitted wavefront peak-to-valley of the corresponding sector.

Peak Valley (All)

The average transmitted wavefront peak-to-valley of all the sectors.

Rms (1)...(6)

The transmitted wavefront root-mean-square of the corresponding sector.

Rms (All)

The average transmitted wavefront root-mean-square of all the sectors.

Tilt Angle (1)...(6)

The direction of tilt in the corresponding sector.

For a more detailed explanation of tilt results see Standard Optic Results.

Tilt Mag (1)...(6)

The overall tilt in the corresponding sector.

Tilt PV (1)...(6)

The amount that the tilt of the corresponding sector contributes to the sector’s PV result.

Tilt X (1)...(6)

The tilt in the x-axis in the corresponding sector.

Tilt Y (1)...(6)

The tilt in the y-axis in the corresponding sector.

Valley (1)...(6)

The lowest point in the corresponding sector.

Valley (All)

The average of all the lowest points in all sectors.

Valley Location X (1)...(6)

The x-axis location in camera coordinates of the lowest point in the corresponding sector.

Valley Location X (All)

The average y-axis location in camera coordinates of the lowest point in each sector.

Valley Location Y (1)...(6)

The y-axis location in camera coordinates of the lowest point in the corresponding sector.

Valley Location Y (All)

The average y-axis location in camera coordinates of the lowest point in each sector.

Dihedral Angle Error Calculations

The corner cube Dihedral Angle Error results are not measured directly, but are calculated from the Beam Deviation results. The equations used to calculate Dihedral Angle Error are explained in this section.

There are six possible pairs of adjacent wavefront sectors. Each sector pair has a rotation angle, θ, defined as follows:

Sector Pairs	*Rotation Angle "θ" (degrees)*
1-2	60
2-3	120
3-4	180
4-5	240
5-6	300
6-1	0

Note that the rotation angles are not standard Cartesian angles since zero degrees corresponds to the twelve o'clock position and the angles increase in the clockwise direction.

Now consider sector pair A-B. Each sector in the pair is fit with a plane to obtain the following beam deviation results:

t_{AX} = tilt of sector A in the X direction

t_{AY} = tilt of sector A in the Y direction

t_{BX} = tilt of sector B in the X direction

t_{BY} = tilt of sector B in the Y direction

Tilts in a direction perpendicular to the bisector are calculated by applying a rotational transform to the tilt components:

t_A = tilt of sector A in the new direction

$= t_{AX}\cos\theta - t_{AY}\sin\theta$

t_B = tilt of sector B in the new direction

$= t_{BX}\cos\theta - t_{BY}\sin\theta$

The Dihedral Angle Error for the sector pair is calculated as shown below. Where n is the refractive index.

$$e = \left(\frac{3}{4\sqrt{6}}\right)\frac{t_A - t_B}{n}$$

The above constant is derived in "Method of Calculating Retroreflector-Array Transfer Functions" by D. A. Arnold.

For single pass test setups, all six dihedral angle errors are calculated and opposite pairs are averaged.

For double pass test setups, three dihedral angle errors are calculated: 1-2, 2-3, and 3-4. Sector 4 tilts are obtained by negating the sector 1 tilts.

A positive dihedral angle error indicates that the dihedral angle is greater than 90°. A negative dihedral angle error indicates that the dihedral angle is less than 90°.

Diffraction Results

These results are part of the Diffraction analysis. Other results not displayed in the analysis are available through a Result Grid.

Cutoff Frequency

The maximum frequency that can be resolved by a lens performing at the diffraction limit; it is where the theoretical MTF goes to zero. The exact definition varies based on the whether PSF Mode is Focal or Afocal.

PSF Mode	Description
Afocal	This is the theoretical maximum angular frequency resolvable by an ideal optical system with the given aperture. This result always assumes a circular aperture with a calculated diameter (1). This frequency is defined as 2*diameter/wavelength.
Focal	This is the theoretical maximum spatial frequency resolvable by an ideal optical system with the given aperture. This limit is due to the effects of diffraction. This result always assumes a circular aperture with a calculated diameter (1). This frequency is defined as 2*NA/wavelength (NA is the numerical aperture input by the user).

(1) The diameter of the maximum size circle enclosed by the data; data outside this circle is not used in calculations.

Max Pupil Dimension

The diameter of the minimum enclosing circle before the diffraction analysis. Only applicable when PSF Mode is Focal.

Max Pupil NA

The NA (numerical aperture) of an imaginary disk-shaped pupil filling the Max Pupil Dimension used in Diffraction analysis.

Min Pupil f/#

The minimum f-number of an imaginary disk-shaped pupil used in Diffraction analysis.

Ref Energy Size

The reference energy size value at the specified Ref Energy percent on the Encircled Energy plot. The Ref Energy percent can be set with either a numeric entry in the Ref Energy control or by positioning the Ref Energy inspector in the Encircled Energy plot.

Physically, this value is the radius of the disk on the PSF plot, centered on the peak value, that contains an amount of relative energy equal to Ref Energy.

Ref Frequency

When in the focal mode, this indicates the reference spatial frequency used to inspect in the MTF profile.

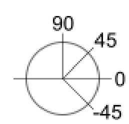
The user can enter a spatial frequency in the Ref Frequency control in the Settings tab to get the results for the MTF slices at 0 degrees, 45 degrees, 90 degrees, -45 degrees, and the Mean of all of them at the specified spatial frequency. The Ref Frequency result is updated to reflect the value in the control.

When in the afocal mode, this indicates the reference angular frequency to inspect in the MTF profile.

The user can enter an angular frequency in the Ref Frequency control in the Settings tab to get the results for the MTF slices at 0 degrees, 45 degrees, 90 degrees, -45 degrees, and the Mean of all of them at the specified angular frequency. The Ref Frequency result is updated to reflect the value in the control.

Ref MTF 0 Deg

The modulation value at 0 degrees, at the frequency specified by Ref Frequency. The orientation of MTF values is shown here.



Ref MTF 45 Deg

The modulation value at 45 degrees, at the frequency specified by Ref Frequency.

Ref MTF 90 Deg

The modulation value at 90 degrees, at the frequency specified by Ref Frequency.

Ref MTF -45 Deg

The modulation value at -45 degrees, at the frequency specified by Ref Frequency.

Ref MTF Mean

The average modulation value of the MTF values at 0, 45, 90, and -45 degrees, at the frequency specified by Ref Frequency.

Strehl Ratio

The ratio of the peak intensity of light in an aberrated point image to the peak intensity of light in an unaberrated point image from an aperture of the same size and shape. See Strehl Ratio Details.

ISO 10110-5 Results

These results are part of the ISO 10110-5 analysis. These results calculate surface form deviation of an optical surface conforming to ISO 10110-5. Other results not displayed in the analysis are available through a Result Grid.

3/A(B/C); RMSx

SAG, IRR, and RSI in ISO form. RMSx is the surface form call out following ISO 10110-5 drawing conventions. Also called ISO 10110-5 Combination.

Center X

The dimension to the center of the analyzed data in the x-axis. The result is based on the minimum enclosing rectangle around the input data. It is automatically generated when the Auto Center or Auto Circle check box is selected.

Center Y

The dimension to the center of the analyzed data in the y-axis. The result is based on the minimum enclosing rectangle around the input data. It is automatically generated when the Auto Center or Auto Circle check box is selected.

Diameter

The default minimum circumscribed circular aperture or the user specified circular aperture. The length of a straight line segment that passes through the center of the circle and whose endpoints are on the circle. The result may be blank if the units do not match the units in the corresponding control.

Error With Design Radius

This is an error indicator. If the specified Design Radius is too small, this result is true, indicating an error. False denotes an acceptable design radius.

IRR : B

Irregularity (IRR) is the PV (peak-to-valley) value of the wavefront irregularity. It is the tolerance on surface form error that remains after sagitta error (SAG: A), or best-fit sphere, is removed.

Radius

The measured radius of curvature. Only calculated when Surface Type is Spherical and Calculate is Radius Error from Sagitta Deviation.

Radius Error

The difference between the specified Design Radius and the calculated measured radius. Only applicable when Surface Type is Spherical.

RSI : C

Rotationally Symmetric Irregularity (RSI) is the PV (peak-to-valley) value of the rotationally invariant component of the wavefront irregularity (IRR : B). It is the tolerance on the rotationally symmetric component of the surface form error after the best-fit sphere is subtracted.

RMSa

RMS rotationally varying irregularity is the rms (root-mean-square) value of the rotationally varying wavefront deformation. Residual RMS after removal of plane and all rotationally symmetric (or invariant) components.

RMSi

RMS irregularity is the rms (root-mean-square) value of the wavefront irregularity (IRR : B).

RMSt

RMS total is the rms (root-mean-square) value of the wavefront deformation after removal of a best-fit plane.

SAG : A

Sagitta deviation is the PV (peak-to-valley) value of the approximating spherical wavefront. It is the tolerance on the power or focus of the surface when positioned within the bounds of the tolerance placed on the nominal radius of curvature.

Wavelength

The wavelength used for calculation of ISO 10110-5 results in units of Fringes. This defaults to 546.07 nm as specified by the standard and corresponds to the green emission line of mercury.

PVr Results

These results are part of the PVr analysis. Other results not displayed in the analysis are available through a Result Grid.

Max Out of Range Area

The size of the largest single area that falls outside of the range defined by PVr.

Out of Range Points

The number of input data points that fall outside of the range defined by PVr.

PVr

(Robust Peak-to-Valley) PVr is a robust amplitude parameter, that unlike PV, is largely insensitive to the camera detector size, does not require data transforms by the user, and is less sensitive to coherent systematic phase artifacts from dust and debris. PVr is appropriate for circular apertures only.

PVr is the sum of the PV of a 36 term Zernike fit (after removing those terms set to zero (piston and tilt for flats; piston, tilt, and power for spheres) and three times the rms of the residual after fitting to 36 terms.

$PVr = PV_{36\ Zernikes} + 3 \times \sigma_{36\ Zernike\ Residuals}$

The first term on the right-hand side in the above equation is the PV of the surface generated using the 36 term Zernike fit to the data. The second term is three times the rms of the residual after fitting and removing the 36 terms.

PVr greater than PV

A boolean check on the validity of the PVr calculation. If true, then PVr is assigned the value of PV.

PVr less than 6 x Rms Res

A boolean check on the validity of the PVr calculation. If true, then PVr is assigned the value of PV.

PVr Range High

The Peak value of the PVr range (may be used to clip the input data if that option is selected for tool output).

PVr Range Low

The Valley value of the PVr range (may be used to clip the input data if that option is selected for tool output).

Residual RMS

The root-mean-square of the residual data after the 36-term Zernike fit has been removed from the input data.

Zernike Fit PV

The two-point peak-to-valley value of the 36-term Zernike fit.

Radius of Curvature Results

Catseye Error

The distance error contributed by the residual power at the catseye position when measuring radius of curvature.

Catseye Power

The amount of residual power present in the test cavity at the catseye position when measuring radius of curvature.

Confocal Error

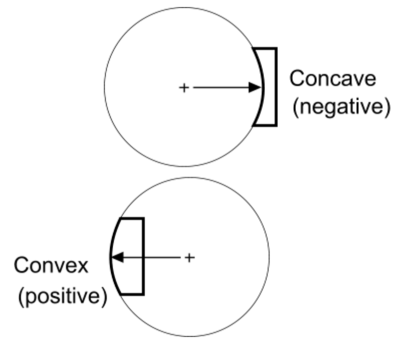
The distance error contributed by the residual power at the confocal position when measuring radius of curvature.

Confocal Power

The amount of residual power present in the test cavity at the confocal position when measuring radius of curvature.

Radius of Curvature

The radius of curvature of the tested sphere. It is the distance from the surface, or from the best-fit spherical equivalent, to the center of curvature. Convex surfaces are positive numbers, whereas concave surfaces are negative numbers.



Slide Distance

The actual distance the mount traveled between confocal and catseye positions when measuring radius of curvature.

Ritchey-Common Quality Results

These results are part of the Ritchey-Common measurement. The accuracy of Ritchey-Common measurements depends on quality of input data, transmission sphere and reference sphere calibrations, alignment, and setup/fixturing accuracy. The following quality results provide feedback to determine if test conditions are satisfactory or should be improved. The basis for the error results is a comparison between the Angle 1 and Angle 2 measurements.

Other results not displayed in the analysis are available through a Result Grid.

Error PV

The difference in PV between Angle 1 and Angle 2 measurements after misalignment terms (piston, power and tilt) are computed and removed.

Error rms

The difference in rms between Angle 1 and Angle 2 measurements after misalignment terms (piston, power and tilt) are computed and removed.

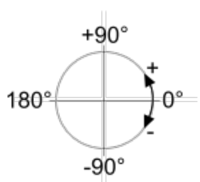
Lateral Resolution Error

The percentage difference in lateral resolution between the Angle 1 and Angle 2 measurements. Lateral resolution is based on the input data and setup parameters.

Zernike Results

For the polynomial mathematical representation see the Representation column in the Fit Remove tool.

The angle coordinates are:



ZFR (0 to 36)

Displays the fit value for the corresponding Zernike Polynomial coefficient created when Polynomial is Zernike Fringe. The number of terms displayed is based on the setting of the Order control. ZFR stands for Fringe Zernike Polynomials.

The commonly used FRINGE set of Zernike polynomials is composed of 37 terms and is ordered as follows:

Coeff	n	m	Name
ZFR 0	0	0	Piston
ZFR 1	1	1	Tilt X
ZFR 2	1	-1	Tilt Y
ZFR 3	2	0	Focus
ZFR 4	2	2	Astigmatism (0°,90°)
ZFR 5	2	-2	Astigmatism (±45°)
ZFR 6	3	1	Coma X
ZFR 7	3	-1	Coma Y
ZFR 8	4	0	Spherical
ZFR 9	3	3	Trefoil X
ZFR 10	3	-3	Trefoil Y
ZFR 11	4	2	Secondary Astigmatism (0°,90°)
ZFR 12	4	-2	Secondary Astigmatism (±45°)
ZFR 13	5	1	Secondary Coma X
ZFR 14	5	-1	Secondary Coma Y
ZFR 15	6	0	Secondary Spherical
ZFR 16	4	4	Tetrafoil (0°,90°)
ZFR 17	4	-4	Tetrafoil (±45°)
ZFR 18	5	3	Secondary Trefoil X
ZFR 19	5	-3	Secondary Trefoil Y
ZFR 20	6	2	Tertiary Astigmatism (0°,90°)
ZFR 21	6	-2	Tertiary Astigmatism (±45°)
ZFR 22	7	1	Tertiary Coma X
ZFR 23	7	-1	Tertiary Coma Y
ZFR 24	8	0	Tertiary Spherical
ZFR 25	5	5	Pentafoil X
ZFR 26	5	-5	Pentafoil Y
ZFR 27	6	4	Secondary Tetrafoil (0°,90°)
ZFR 28	6	-4	Secondary Tetrafoil (±45°)
ZFR 29	7	3	Tertiary Trefoil X
ZFR 30	7	-3	Tertiary Trefoil Y
ZFR 31	8	2	Quaternary Astigmatism (0°,90°)
ZFR 32	8	-2	Quaternary Astigmatism (±45°)
ZFR 33	9	1	Quaternary Coma X
ZFR 34	9	-1	Quaternary Coma Y
ZFR 35	10	0	Quaternary Spherical
ZFR 36	12	0	Quinternary Spherical

ZRN (1 to 91)

Displays the fit value for the corresponding Zernike Polynomial coefficient created when Polynomial is Zernike Standard. The number of terms displayed is based on the setting of the Order control. ZRN stands for Standard Zernike Polynomials.

The commonly used STANDARD set of Zernike polynimials is composed of 91 terms and is ordered as follows:

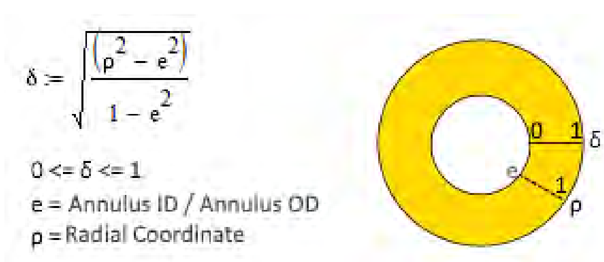
Coeff	n	m	Name
ZRN 1	0	0	Piston
ZRN 2	1	1	Tilt X
ZRN 3		-1	Tilt Y
ZRN 4	2	2	Astigmatism (0°,90°)
ZRN 5		0	Focus
ZRN 6		-2	Astigmatism (±45°)
ZRN 7	3	3	Trefoil X
ZRN 8		1	Coma X
ZRN 9		-1	Coma Y
ZRN 10		-3	Trefoil Y
ZRN 11	4	4	Tetrafoil (0°,90°)
ZRN 12		2	Secondary Astigmatism (0°,90°)
ZRN 13		0	Spherical
ZRN 14		-2	Secondary Astigmatism (±45°)
ZRN 15		-4	Tetrafoil (±45°)
etc.	etc.	etc.	etc.

Note that individual Zernike polynomials, $Z_n^m(r,\theta)$, are identical between Fringe and Standard Zernike, only the selection and ordering is different. Also note that the first 37 terms in Fringe are not the same group of Zernike polynomials as the first 37 terms in Standard.

ZAR (0 to 36)

Displays the fit value for the corresponding Zernike Polynomial coefficient created when Polynomial is Zernike Annular. The number of terms displayed is based on the setting of the Order control. ZAR is a mnemonic for Annular Zernike Polynomials. Annular Zernike Polynomials are based on standard Zernike polynomials, they have been modified to be orthogonal over an annular data domain. They have significantly different shapes from standard Zernike polynomials and they do not correspond to Seidel aberrations directly.

Definition of Delta ä



Annular Zernike polynomials are modified standard Zernike polynomials taking into an account a central obscuration with relative radius e.

Normalized radial coordinate ä varies from 0 to 1.

RMS normalization is the preferred way to use Annular Zernike polynomials.

The annular set of Zernike polynomials is composed of 37 terms and is ordered as follows:

Coeff	n	m	Representation
ZAR 0	0	0	1
ZAR 1	1	1	2äcosè
ZAR 2	1	-1	2äsinè
ZAR 3	2	0	√(3)(-1+2δ^{2})
ZAR 4	2	2	√(6)δ^{2}cos(2è)
ZAR 5	2	-2	√(6)δ^{2}sin(2è)
ZAR 6	3	1	√(8)(-2δ+3δ^{3})cos(è)
ZAR 7	3	-1	√(8)(-2δ+3δ^{3})sin(è)
ZAR 8	4	0	√(5)(1-6δ^{3}+6ä^{4})
ZAR 9	3	3	√(8)δ^{3}cos(3è)
ZAR 10	3	-3	√(8)δ^{3}sin(3è)
ZAR 11	4	2	√(10)(-3δ^{2}+4ä^{4})cos(2è)
ZAR 12	4	-2	√(10)(-3δ^{2}+4ä^{4})sin(2è)
ZAR 13	5	1	√(12)(3δ-12δ^{3}+10ä^{5})cos(è)
ZAR 14	5	-1	√(12)(3δ-12δ^{3}+10ä^{5})sin(è)
ZAR 15	6	0	√(7)(-1+12δ^{3}-30ä^{4}+20ä^{6})
ZAR 16	4	4	√(10)δ^{4}cos(4è)
ZAR 17	4	-4	√(10)δ^{4}sin(4è)
ZAR 18	5	3	√(12)(-4δ^{3}+5ä^{5})cos(3è)
ZAR 19	5	-3	√(12)(-4δ^{3}+5ä^{5})sin(3è)
ZAR 20	6	2	√(14)(6δ^{3}-20ä^{4}+15ä^{6})cos(2è)
ZAR 21	6	-2	√(14)(6δ^{3}-20ä^{4}+15ä^{6})sin(2è)
ZAR 22	7	1	4(-4ä+30ä^{3}-60ä^{5}+35ä^{7})cos(è)
ZAR 23	7	-1	4(-4ä+30ä^{3}-60ä^{5}+35ä^{7})sin(è)
ZAR 24	8	0	3(1-20ä^{3}+90ä^{4}-140ä^{6}+70ä^{8})
ZAR 25	5	5	√(12)δ^{5}cos(5è)
ZAR 26	5	-5	√(12)δ^{5}sin(5è)
ZAR 27	6	4	√(14)(-5δ^{4}+6ä^{6})cos(4è)
ZAR 28	6	-4	√(14)(-5δ^{4}+6ä^{6})sin(4è)
ZAR 29	7	3	4(10ä^{3}-30ä^{5}+21ä^{7})cos(3è)
ZAR 30	7	-3	4(10ä^{3}-30ä^{5}+21ä^{7})sin(3è)
ZAR 31	8	2	√(18)(-10δ^{3}+60ä^{4}-105ä^{6}+56ä^{8})cos(2è)
ZAR 32	8	-2	√(18)(-10δ^{3}+60ä^{4}-105ä^{6}+56ä^{8})sin(2è)
ZAR 33	9	1	√(20)(5δ-60δ^{3}+210ä^{5}-280ä^{7}+126ä^{9})cos(è)
ZAR 34	9	-1	√(20)(5δ-60δ^{3}+210ä^{5}-280ä^{7}+126ä^{9})sin(è)
ZAR 35	10	0	√(11)(-1+30δ^{3}-210ä^{4}+560ä^{6}-630ä^{8}+252ä^{10})
ZAR 36	12	0	√(13)(1-42δ^{3}+420ä^{4}-168ä^{6}+3150ä^{8}-2772ä^{10}+924ä^{13})

Cartesian Coefficients

Cartesian coefficients are low-order monomial coefficients based on a square or rectangular x and y coordinate system. The Cartesian polynomial selections (piston, plane, sphere, and cylinder) and coefficient definitions are described below.

$Piston(x,y) = A$

$Plane(x,y) = A + Bx + Cy$

$Sphere(x,y) = A + Bx + Cy + G(x^2 + y^2)$ where $G = E = F$

$Cylinder(x,y) = A + Bx + Cy + Dxy + Ex^2 + Fy^2$

Fit Offset

The Cartesian coefficient, A, that describes the best-fit piston offset in height.

Fit X

The Cartesian coefficient, B, that describes the best-fit tilt in the x direction.

Fit Y

The Cartesian coefficient, C, that describes the best-fit tilt in the y direction.

Fit XY

The Cartesian coefficient, D, that describes the best-fit orientation of the cylinder axis.

Fit X2

The Cartesian coefficient, E, that describes the best-fit quadratic dependence in the x direction.

Fit Y2

The Cartesian coefficient, F, that describes the best-fit quadratic dependence in the y direction.

Seidels

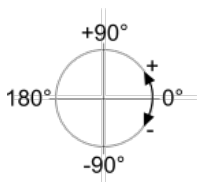
These results are part of the Zernike analysis.

The five basic types of aberration which are due to the geometry of lenses or mirrors, and which are applicable to systems dealing with monochromatic light, are known as Seidel aberrations.

Seidel aberrations are the first and third order wavefront aberrations of an optical system. The aberrations of the third order are: (1) aberration of the axis point; (2) aberration of points whose distance from the axis is very small, less than of the third order — the deviation from the sine condition and coma here fall together in one class; (3) astigmatism; (4) curvature of the field; (5) distortion.

The mathematical expressions shown in this section are based on Zernike Fringe (see Zernike Fringe), PV normalization (see Normalization), with the order set to 4 or higher (see Order).

The angle coordinates are:



AstAng (Z)

AstAng (Astigmatism Angle based on Zernikes) is the angle in the instrument coordinate system at which astigmatism occurs. The range of values for AstAng is ±90°. For an explanation of astigmatism, see AstMag. Zernike polynomials are used to calculate Seidel results; at least 9 Zernike terms must be analyzed to display this result.

$$\text{AstAng} = 0.5 \arctan\left(\frac{z5}{z4}\right)$$

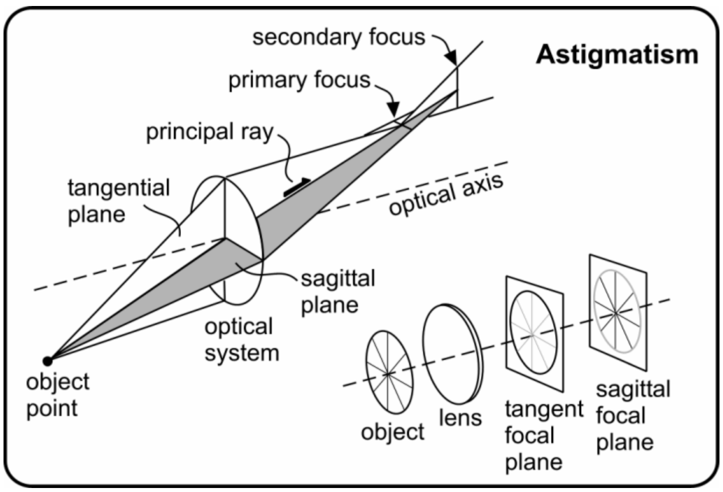
AstMag (Z)

AstMag (Astigmatism Magnitude based on Zernikes) is a third order wavefront aberration where the rays in two orthogonal axes do not come to focus on the same plane.

A schematic view of an optical system imaging an off axis point is shown to illustrate astigmatism. There are two planes: the tangential plane and the sagittal plane. Rays in the tangential plane come to focus closer to the lens (primary focus) than rays in the sagittal plane (secondary focus). The overall affect of astigmatism is illustrated by the wagon wheel, where the rim and spokes do not come to focus at the same point.

In a perfectly aligned and fabricated optical system, astigmatism is only found at image points off the optical axis. In real optical systems, astigmatism can be found anywhere in the image plane. If aberrations are found on axis they are an indication of fabrication or alignment errors. Zernike polynomials are used to calculate Seidel results; at least 9 Zernike terms must be analyzed to display this result.

$$\text{AstMag} = 2\sqrt{z4^2 + z5^2}$$



ComAng (Z)

ComAng (Coma Angle based on Zernikes) is the angle in the instrument coordinate system at which coma occurs. The range of values for ComAng is ±180°. For an explanation of coma, see ComMag. Zernike polynomials are used to calculate Seidel results; at least 9 Zernike terms must be analyzed to display this result.

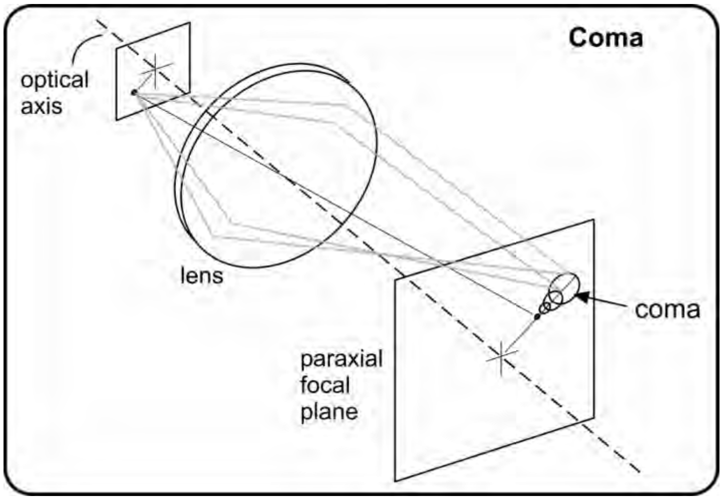
$$\text{ComAng} = \arctan\left(\frac{z7}{z6}\right)$$

ComMag (Z)

ComMag (Coma Magnitude based on Zernikes) is a third order wavefront aberration that appears when light is brought to a focus at points off the optical axis. The name coma is Latin for comet, which is the shape of the aberrated image of an off-axis point. Zernike polynomials are used to calculate Seidels, and at least 9 Zernike terms must be analyzed to display the result.

$$\text{ComMag} = 3\sqrt{\left(z6^2 + z7^2\right)}$$

The imaging of an off-axis point source by a lens with positive transverse coma is shown here. Each cone of rays passing through a circle of the lens surface is imaged as a comatic circle and not a point. The overall image is shaped like a comet. Rays passing through the center of the lens form a point image at the vertex of the cone. In a perfectly aligned and fabricated optical system, coma is only found at image points off the optical axis. In real optical systems, coma can be found anywhere in the image plane. If aberrations are found on axis they are an indication of fabrication or alignment errors.

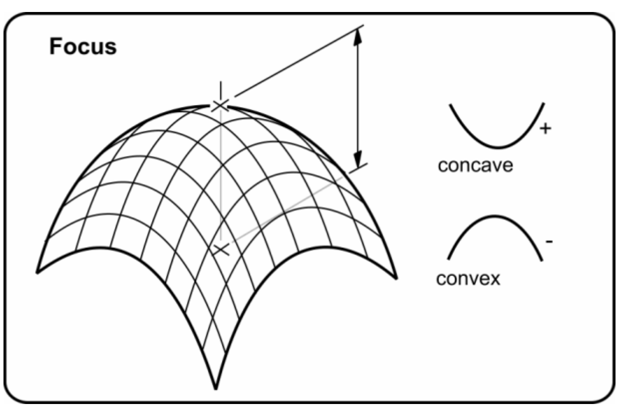


In third order aberration theory, coma may be positive or negative. For negative coma, the tail points away from the optical axis and for positive coma, the tail points toward the axis. ComMag as computed in the software is always positive. Its orientation is given by ComAng. This modification of the definition was necessary because the location of the optical axis is unknown to the interferometer.

FocMag (Z)

FocMag (Focus Magnitude based on Zernikes) is a first order wavefront aberration; it is a measure of the sag of the surface or wavefront without distinguishing between the X and Y dimensions. It is the height difference between the center point and the point farthest from the center. FocMag is positive for a concave surface and negative for a convex surface. Zernike polynomials are used to calculate Seidels, and at least 9 Zernike terms must be analyzed to display the result.

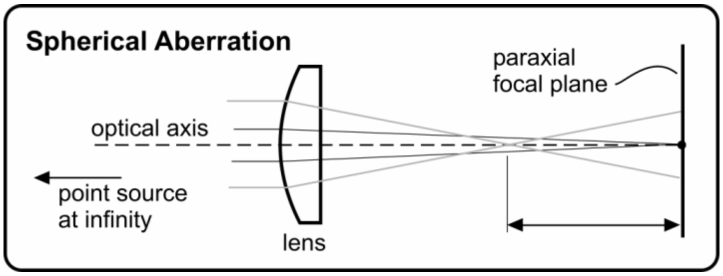
FocMag = 2 (z3) - 6 (z8)



SA (Z)

SA (Spherical Aberration based on Zernikes) is a third order wavefront aberration; it is the failure of a lens or lens system to form a perfect image of a point source axial object. When rays from a point on the axis passing through the outer lens zones are focused closer to the lens than rays passing the central zones, the lens has negative spherical aberration; if the outer zones have a longer focal length than the inner zones, the lens has positive spherical aberration. Zernike polynomials are used to calculate Seidel results; at least 9 Zernike terms must be analyzed to display this result.

$$SA = 6.0\,(z8)$$



TltAng (Z)

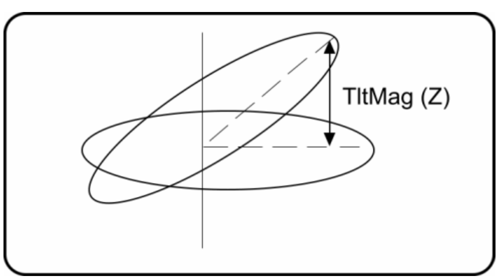
TltAng (Tilt Angle based on Zernikes) is the direction of tilt. Visually, this can be seen on the Video Monitor as the direction perpendicular to the fringes. TltAng is typically expressed in degrees and is defined over ±180°. The wavefront is highest at the specified angle. See TltAng. Zernike polynomials are used to calculate Seidel results; at least 9 Zernike terms must be analyzed to display the result.

$$\text{TltAng} = \arctan\left(\frac{\text{y tilt}}{\text{x tilt}}\right)$$

TltMag (Z)

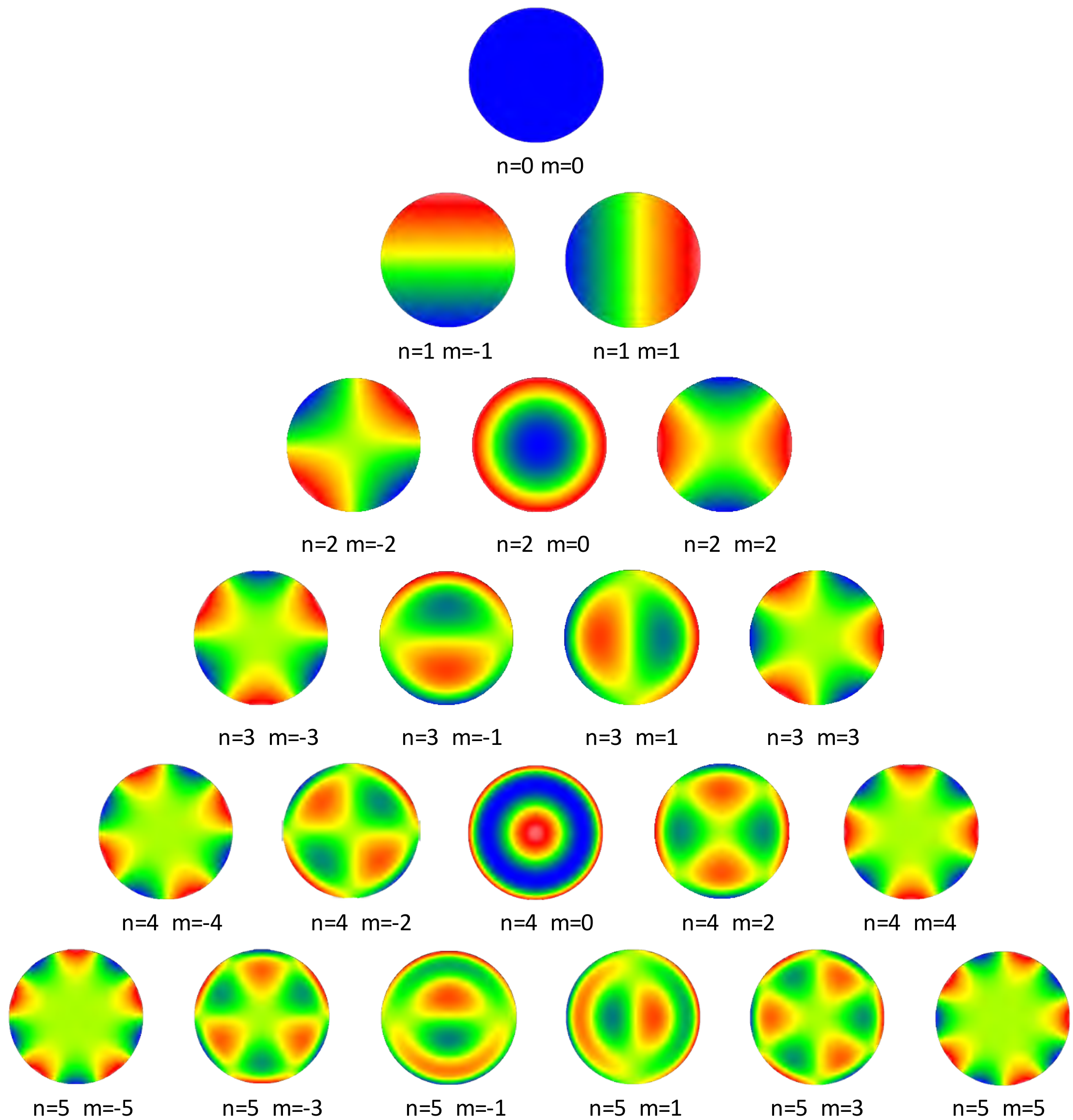
TltMag (Tilt Magnitude based on Zernikes) is the overall tilt of the part in both x and y axes. TltMag is expressed in height units and is always positive. Tilt refers to the angle of inclination between the reference and test beams of the interferometer. If measuring a surface, tilt is the angle between the reference and test surface. If measuring a transmitted wavefront, tilt is the angle of the beam deviated by the optic. Zernike polynomials are used to calculate Seidel results; at least 9 Zernike terms must be analyzed to display the result.

$$\text{TltMag} = \sqrt{\text{xtilt}^2 + \text{ytilt}^2}$$



Zernike Sample Images

This is an example of the first 5 orders (n) for Zernikes. The zero order mode is piston. First order modes are tilt x and tilt y. Second order modes are sphere and astigmatism. Third order modes and above are known as higher-order aberrations.



Zernike Definitions

The Zernike Polynomial expansion is defined as follows:

$$Z(r,\theta) = C_0^0 + \sum_{n=1}^{\infty}\left[\sum_{m=0}^{n} C_n^m \cdot N_n^m \cdot R_n^{|m|}(r)\cdot cos(m\theta) + \sum_{m=n}^{-1} C_n^m \cdot N_n^m \cdot R_n^{|m|}(r)\cdot sin(|m|\theta)\right], \quad (1)$$

where *r* is the radial coordinate ranging from 0 to 1, *è* is the azimuthal component ranging from 0 to 2π, C_n^m define the individual polynomial coefficients, N_n^m is the corresponding normalization factor, and $R_n^m(r)$ is the radial polynomial defined below. The index *n* describes the highest power (order) of the radial polynomial, and the index *m* describes the azimuthal frequency of the sinusoidal component. The radial functions satisfy the orthogonality relation:

$$\int_0^1 R_n^m(r)\cdot R_{n'}^m(r)\cdot r\cdot dr = \frac{1}{2(n+1)}\cdot \delta_{nn'}\cdot R_n^m(1), \quad (2)$$

and are normalized so that:

$$R_n^m(1) = 1. \quad (3)$$

Orthogonality is fulfilled only in the absence of any “no data” regions within the unit circle. Useful for transforming between polar and Cartesian coordinate systems are the following relationships:

$$r = \sqrt{x^2+y^2}, \quad \theta = tan^{-1}(y/x), \quad x = r\,cos(\theta), \text{ and } \quad y = r\,sin(\theta), \quad (4)$$

Alternatively, Equation (1) can be expressed in terms of even and odd polynomials:

$$Z(r,\theta) = C_0^0 + \sum_{n=1}^{\infty}\left[\sum_{m=0}^{n} C_n^m \cdot Z_n^m(r,\theta)\right] + \sum_{n=1}^{\infty}\left[\sum_{m=1}^{n} C_n^{-m} \cdot Z_n^{-m}(r,\theta)\right], \quad (5)$$

where the even polynomials are given by:

$$Z_n^m(r,\theta) = N_n^m \cdot R_n^m(r)\cdot \cos(m\theta) \quad (6)$$

and the odd polynomials are given by:

$$Z_n^{-m}(r,\theta) = N_n^m \cdot R_n^m(r)\cdot \sin(m\theta). \quad (7)$$

The radial polynomial can be written generally as:

$$R_n^{|m|}(r) = \begin{cases} \displaystyle\sum_{s=0}^{(n-|m|)/2} \frac{(-1)^s (n-s)!}{s!\,((n+|m|)/2-s)!\,((n-|m|)/2-s)!} r^{n-2s} & ;\ \text{for n - }|m|\text{ even} \\ 0 & ;\ \text{for n - }|m|\text{ odd} \end{cases}, \quad (8)$$

while the normalization factor is defined as:

$$N_n^m = \begin{cases} 1 & ;\text{for non - normalized PV coeff.} \\ \sqrt{\dfrac{2\cdot(n+1)}{1+\delta_{m0}}} & ;\text{for normalized RMS coeff.} \end{cases}, \quad (9)$$

where δ_{m0} is the Kronecker delta function:

$$\delta_{m0} = \begin{Bmatrix} 1 \ ; \ \text{for } m = 0 \\ 0 \ ; \ \text{for } m \neq 0 \end{Bmatrix}, \tag{10}$$

Under PV normalization, the maximum absolute values of the radial polynomials are 1 (this occurs at the edge of the circle). Under RMS normalization, the polynomials are orthonormal, and the sum in quadrature of the fit coefficients is equal to the energy of the function being fit.

Zernike Terms Comparison

This table shows a comparison of Zernike coefficient terms; in parenthesis are (n,m).

- ZEMAX refers to software for optical system design.
- Loomis refers to the work by John Loomis at the Optical Sciences Center, University of Arizona.
- Malacara refers to Zernike classifications by Daniel Malacara in *Optical Shop Testing*.

#	Mx ZFR	Mx ZRN		#	ZEMAX	#	Loomis	#	Malacara
0	Z(0,0)	1	Z(0,0)	1	Z(0,0)			1	Z(0,0)
1	Z(1,1)	2	Z(1,1)	2	Z(1,1)	1	Z(1,1)	2	Z(1,-1)
2	Z(1,-1)	3	Z(1,-1)	3	Z(1,-1)	2	Z(1,-1)	3	Z(1,1)
3	Z(2,0)	4	Z(2,2)	4	Z(2,0)	3	Z(2,0)	4	Z(2,-2)
4	Z(2,2)	5	Z(2,0)	5	Z(2,2)	4	Z(2,2)	5	Z(2,0)
5	Z(2,-2)	6	Z(2,-2)	6	Z(2,-2)	5	Z(2,-2)	6	Z(2,2)
6	Z(3,1)	7	Z(3,3)	7	Z(3,1)	6	Z(3,1)	7	Z(3,-3)
7	Z(3,-1)	8	Z(3,1)	8	Z(3,-1)	7	Z(3,-1)	8	Z(3,-1)
8	Z(4,0)	9	Z(3,-1)	9	Z(4,0)	8	Z(4,0)	9	Z(3,1)
9	Z(3,3)	10	Z(3,-3)	10	Z(3,3)	9	Z(3,3)	10	Z(3,3)
10	Z(3,-3)	11	Z(4,4)	11	Z(3,-3)	10	Z(3,-3)	11	Z(4,-4)
11	Z(4,2)	12	Z(4,2)	12	Z(4,2)	11	Z(4,2)	12	Z(4,-2)
12	Z(4,-2)	13	Z(4,0)	13	Z(4,-2)	12	Z(4,-2)	13	Z(4,0)
13	Z(5,1)	14	Z(4,-2)	14	Z(5,1)	13	Z(5,1)	14	Z(4,2)
14	Z(5,-1)	15	Z(4,-4)	15	Z(5,-1)	14	Z(5,-1)	15	Z(4,4)
15	Z(6,0)	16	Z(5,5)	16	Z(6,0)	15	Z(6,0)	16	Z(5,-5)
16	...		...	36	...	16	...	36	Z(7,-7)
36	Z(12,0)	91	Z(12,-12)	37	Z(12,0)	36	Z(12,0)	37	Z(8,-8)

11.10 System Results

These results are available under the System tree.

Pattern Results

Alignment Fit RMS

When using a reference image, it is a measure of how well the measured alignment sites line up with the alignment sites in the pattern.

Alignment Offset X

When using a reference image, it is the difference between the original Origin X value and the new Origin X value.

Alignment Offset Y

When using a reference image, it is the difference between the original Origin Y value and the new Origin Y value.

Alignment Rotation

When using a reference image, it is the difference between the original Rotation value and the new Rotation value.

Alignment Scale X

When using a reference image, it is the amount of scaling in the X axis needed to make measured and expected alignment sites line up. This may be fixed to 1.

Alignment Scale Y

When using a reference image, it is the amount of scaling in the Y axis needed to make measured and expected alignment sites line up. This may be fixed to 1.

Environmental Test Results

Peak Amplitude

The overall height of the highest peak in the Environmental Test tool.

Peak Frequency

The frequency at which the highest peak occurs in the Environmental Test tool.

Info Results

Free Drive Space

The amount of free hard drive space in GB available on the drive that the software is running on.

Free Drive Space Label

The name of the hard drive, if labeled, that the software is running on.

Memory Usage

The amount of memory in MB that the software is using.

11.11 Intensity Results

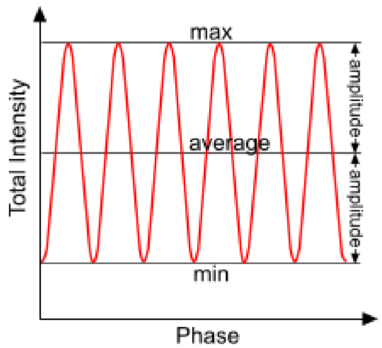
This result is available in the Form.appx under the Intensity tree.

Fringe Visibility

A percentage representing the contrast of interferogram fringes at the time of acquisition. The result can range from 0 (no contrast) to 100 (perfect contrast).

Fringe visibility quantifies the contrast of interference. The interference pattern (or fringes) are the result of a coherent summation of two waves, one from the test part and the second from a reference surface. As the phase between these waves change the power or intensity of the resulting wave oscillates. The ratio of the oscillation amplitude to the sum of the powers of the individual waves is defined as the visibility.

$$\text{Fringe Visibility} = \frac{\text{amplitude}}{\text{average}} = \frac{\max - \min}{\max + \min}$$



11.12 Films Results

This section lists results unique to the optical profiler films analysis.

For Top Surface PV, RMS, or Mean results see Height Parameters for the basic definitions of PV, RMS, and Mean.

Thickness Mean

The arithmetic average of the values in the films thickness data.

Thickness PV

The distance between the highest and lowest points within the films thickness data.

Film Volume

The overall volume of the films thickness data.

Secondary PV

The distance between the highest and lowest points within the films secondary surface data.

Secondary RMS

The root-mean-square deviation from the center line of the films secondary surface data.

Secondary Mean

The arithmetic average of the values in the films secondary surface data.

Secondary NPoints

The number of data points in the films secondary surface data.

11.13 MST Results

This output is specific to the MST application. The results available vary based on the selected Measurement Type.

Homogeneity

A measure of the uniformity or purity of an optical material. The lower the Homogeneity, the better the uniformity. Homogeneity is given by:

$$\Delta n = [n\ (T - C) - (n-1)\ (S2 - S1)]\ /t$$

Where n is the refractive index, t is the part thickness, and T, C, S1, and S2 are the corresponding cavities. T is the transmission cavity where the beam travels through the test part and reflects off the reference flat; C is the empty cavity where the beam reflects off the reference flat; and S1 and S2 are the test part front surface and rear surface cavities.

Homogeneity Size X

The dimension in the x-axis of the homogeneity map. Lateral calibration required.

Homogeneity Size Y

The dimension in the y-axis of the homogeneity map. Lateral calibration required.

Optical Thickness PV

The PV of interference between the front and back surfaces of the part.

Optical Thickness RMS

The RMS of interference between the front and back surfaces of the part.

Optical Thickness Size X

The dimension in the x-axis of the optical thickness map. Lateral calibration required.

Optical Thickness Size Y

The dimension in the y-axis of the optical thickness map. Lateral calibration required.

Optical Thickness Wavefront Tilt

The tilt in the wavefront of the optical thickness map.

RF-Back PV

The PV of the map representing the cavity between the back surface of the part and the reference flat.

RF-Front PV

The PV of the map representing the cavity between the reference flat and the front surface of the part.

RF-Back RMS

The RMS of the map representing the cavity between the reference flat and the back surface of the part.

RF-Back Size X

The dimension in the x-axis of the map representing the cavity between the reference flat and the back surface of the part.

RF-Back Size Y

The dimension in the y-axis of the map representing the cavity between the reference flat and the back surface of the part.

TF-Back RMS

The RMS of the map representing the cavity between the transmission flat and the back surface of the part.

TF-Back Size X

The dimension in the y-axis of the map representing the cavity between the transmission flat and the back surface of the part. Lateral calibration required.

TF-Back Size Y

The dimension in the y-axis of the map representing the cavity between the transmission flat and the back surface of the part. Lateral calibration required.

TF-Front PV

The PV of the map representing the cavity between the transmission flat and the front surface of the part.

TF-Front RMS

The RMS of the map representing the cavity between the transmission flat and the front surface of the part.

TF-Front Size X

The dimension in the x-axis of the map representing the cavity between the transmission flat and the front surface of the part. Lateral calibration required.

TF-Front Size Y

The dimension in the y-axis of the map representing the cavity between the transmission flat and the front surface of the part. Lateral calibration required.

Measured Geometry

This output is specific to the MST application. The results available vary based on the selected Measurement Type.

Results with automatic set limits provide user feedback; when within limits the result is outlined in green; when outside limits the result is outlined in red.

Measured Cavity Length S2 -RF

The actual measured distance between the second surface and the reference flat. This result features automatic set limits based on the Minimum and Maximum S2 -RF calculated geometry parameters.

Measured Cavity Length TF -RF

The actual measured distance between the transmission flat and the reference flat.

Measured Cavity Length TF -S1

The actual measured distance between the transmission flat and the first surface. This result features automatic set limits based on the Minimum and Maximum TF -S1 calculated geometry parameters.

Measured Part Thickness

The actual measured physical thickness of the test part. This result features automatic set limits based on the Minimum and Maximum Part Thickness calculated geometry parameters.

11.14 AccuFlat Results

This section lists results in the AccuFlat application.

Flatness Results

Flatness is a broader component of the test part surface that denotes the overall form or shape.

Flatness Mean

The arithmetic average of the flatness data. It is calculated by summing the height data and dividing by the number of points.

Flatness NPoints

The number of points or pixels in the flatness data.

Flatness Peak

The maximum distance between the reference surface and the highest point within the flatness data. The reference surface is the best-fit surface selected with the remove function.

Flatness Peak Location X

The x-axis location in camera coordinates of the highest point in the flatness data.

Flatness Peak Location Y

The y-axis location in camera coordinates of the highest point in the flatness data.

Flatness PV

The greatest distance between the highest and lowest points (Peak-to-Valley) within the flatness data.

Flatness Ra

Arithmetical mean deviation of the flatness data. The average roughness of the data or deviation of all points from a plane fit to the test part surface.

Flatness RMS

The root-mean-square of the flatness data relative to a reference surface. The reference surface is the best-fit surface selected with the remove function.

Flatness Size X

The size or extent of the flatness data in the x-axis.

Flatness Size Y

The size or extent of the flatness data in the y-axis.

Flatness Valley

The maximum depth between the reference surface and the lowest point within the flatness data. The reference surface is the best-fit surface selected with the remove function.

Flatness Valley Location X

The x-axis location in camera coordinates of the lowest point in the flatness data.

Flatness Valley Location Y

The y-axis location in camera coordinates of the lowest point in the flatness data.

Waviness Results

Waviness is a coarser spacing component of the test part surface that denotes finer irregularities than flatness. It is a low spatial frequency component usually occurring due to machine or work deflections, residual stress, vibrations, or heat treatment.

Waviness Mean

The arithmetic average of the waviness data. It is calculated by summing the height data and dividing by the number of points.

Waviness NPoints

The number of points or pixels in the waviness data.

Waviness Peak

The maximum distance between the reference surface and the highest point within the waviness data. The reference surface is the best-fit surface selected with the remove function.

Waviness Peak Location X

The x-axis location in camera coordinates of the highest point in the waviness data.

Waviness Peak Location Y

The y-axis location in camera coordinates of the highest point in the waviness data.

Waviness PV

The greatest distance between the highest and lowest points (Peak-to-Valley) within the waviness data.

Waviness Ra

Arithmetical mean deviation of the waviness data. The average roughness of the data or deviation of all points from a plane fit to the test part surface.

Waviness RMS

The root-mean-square of the waviness data relative to a reference surface. The reference surface is the best-fit surface selected with the remove function.

Waviness Size X

The size or extent of the waviness data in the x-axis.

Waviness Size Y

The size or extent of the waviness data in the y-axis.

Waviness Valley

The maximum depth between the reference surface and the lowest point within the waviness data. The reference surface is the best-fit surface selected with the remove function.

Waviness Valley Location X

The x-axis location in camera coordinates of the lowest point in the waviness data.

Waviness Valley Location Y

The y-axis location in camera coordinates of the lowest point in the waviness data.

µWaviness Results

µWaviness (microwaviness) is a fine spacing component of the test part surface. It is a mid spatial frequency parameter.

µWaviness Mean

The arithmetic average of the µwaviness data. It is calculated by summing the height data and dividing by the number of points.

µWaviness NPoints

The number of points or pixels in the µwaviness data.

µWaviness Peak

The maximum distance between the reference surface and the highest point within the µwaviness data. The reference surface is the best-fit surface selected with the remove function.

µWaviness Peak Location X

The x-axis location in camera coordinates of the highest point in the µwaviness data.

µWaviness Peak Location Y

The y-axis location in camera coordinates of the highest point in the µwaviness data.

µWaviness PV

The greatest distance between the highest and lowest points (Peak-to-Valley) within the µwaviness data.

µWaviness Ra

Arithmetical mean deviation of the µwaviness data. The average roughness of the data or deviation of all points from a plane fit to the test part surface.

µWaviness RMS

The root-mean-square of the µwaviness data relative to a reference surface. The reference surface is the best-fit surface selected with the remove function.

µWaviness Size X

The size or extent of the µwaviness data in the x-axis.

µWaviness Size Y

The size or extent of the µwaviness data in the y-axis.

µWaviness Valley

The maximum depth between the reference surface and the lowest point within the µwaviness data. The reference surface is the best-fit surface selected with the remove function.

µWaviness Valley Location X

The x-axis location in camera coordinates of the lowest point in the µwaviness data.

µWaviness Valley Location Y

The y-axis location in camera coordinates of the lowest point in the µwaviness data.

Statistical Results 12

Statistical process control is the application of statistical methods to the monitoring and control of a process to ensure that it operates at its full potential to produce conforming product.

These statistical process control features are discussed:

Histogram	Graphically display the distribution of data.
Process Statistics	Display statistics about results over multiple measurements.
Slice Statistics	Display statistics about profile (slice) data over multiple measurements.
Control Chart	Graphically monitor the variation of results over multiple measurements.

12.1 Histogram

Some views are preconfigured with histograms. Histograms can be added wherever there is a plot display by using Show Histogram (found on Tools toolbar or plot context menu).

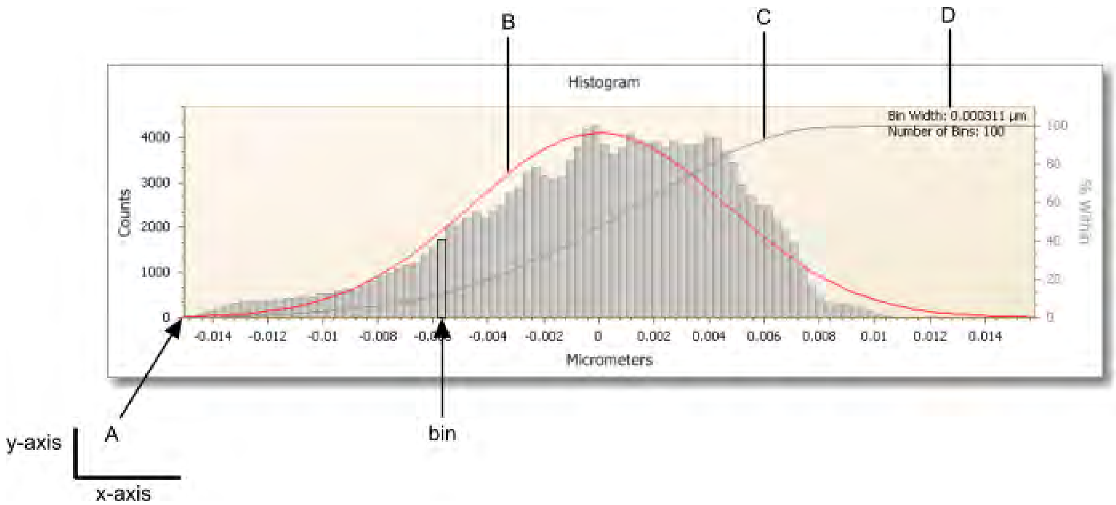
Histogram Plot Overview

- Shows the spread or distribution of data.
- Shows what proportion of the numeric values fall into a particular category or bin.
- The horizontal or x-axis, shows the numeric value.
- The vertical or y-axis, shows the number of similar values in the bin.
- Each vertical bar represents a group or bin of similar heights.
- High bars indicate more points in a category, and low bars indicate less points.
- When based on a 3D data matrix, it shows the variation of the surface.
- When based on a 2D slice, it shows the variation of the slice.
- The number of bins and bin width can be changed using Histogram Properties.

The Histogram Display

The histogram is a summary graph showing a count of the data points falling in various ranges. The effect is a rough approximation of the frequency distribution of the data.

The zoom and pan function work with the histogram. Turn the mouse scroll wheel to zoom in or out. Press the scroll wheel to pan or reposition the data within the panel.



A. Plot axes, y-axis is the number of points in a bin; x-axis is value of the points within a bin. **B.** Gaussian Curve fit to the data. **C.** Distribution Curve shows the percentage of values within a given number. **D.** Bin information.

Creating a Histogram

1. Click Show Histogram on the plot's Tools toolbar.

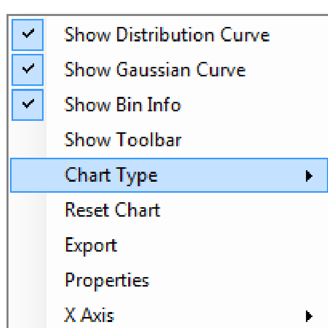
or

2. Right-click on the plot and select Show Histogram.

Working With a Histogram

The histogram is based on the incoming data, either a two-dimensional or three-dimensional data matrix.

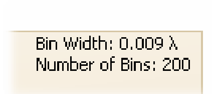
To change features within the plot, right-click to open the context menu.



Show Distribution Curve When selected, the distribution curve (shown in black) is shown over the data. This curve shows the percentage of the total data matrix and adds a % Within legend to the right side of the plot.

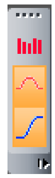
Show Gaussian Curve When selected, a Gaussian curve (shown in red) is fit to the data. The peak of the Gaussian curve is the average of all classes; it is the sum of all the measured data divided by the total number of data points.

Show Bin Info



When selected, the Bin Width and Number of Bins are displayed in the upper right corner of the histogram. See Histogram Properties.

Show Toolbar Displays the histogram toolbar.



Plot Type- click to toggle through the chart type choices.

Gaussian Curve- click to show/hide the curve.

Distribution Curve- click to show/hide the curve.

Chart Type Selects how the data is displayed. See Chart Type.

Reset Chart Adjusts the size of the displayed data so it fits inside the given space.

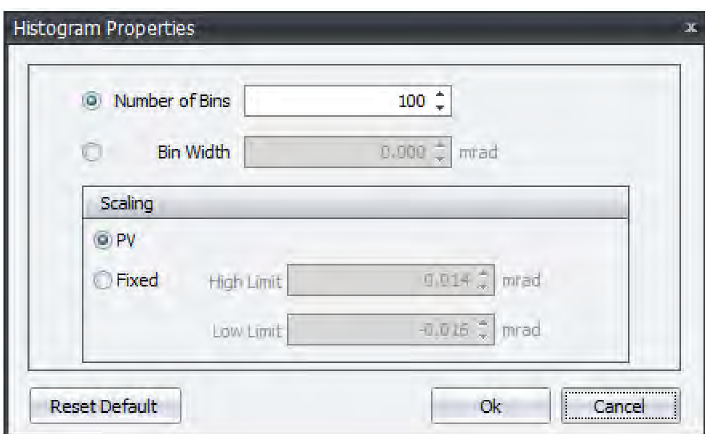
Export Select to export underlying numeric data in another format. See Export Chart Data.

Properties Use to customize bins and data limits. See Histogram Properties.

X Axis Use to change the units for the x axis. See Setting Individual Units. To change the x-axis scaling see Histogram Properties.

Histogram Properties

To access this dialog, right-click on the plot and select Properties.



Number of Bins — When selected, it specifies the number of categories or bins (including zero height bars) in the histogram. When the histogram is displayed as bars each bar represents a bin.

Bin Width — When selected, it specifies the width of each bin displayed in the x-axis. The width is the x-axis distance between the left and right edges of each bin in the histogram.

> If the value entered is too large or too small the histogram may appear empty.

PV — When selected, the x-axis low and high values are based on the PV of the data. The x-axis scaling is based on the data peak-to-valley.

High Limit — When Fixed is selected, high limit is the highest x-axis value displayed in the histogram. The x-axis scaling is based on a fixed low and high entries.

Low Limit — When Fixed is selected, low limit is the lowest x-axis value displayed in the histogram.

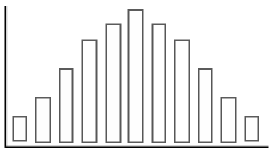
Reset Default — Click to set the Number of Bins, Bin Width, and Scaling control values back to their default values.

Determining Bins and Bin Width

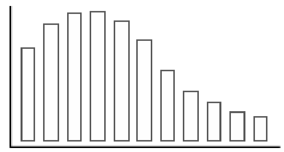
There is no best number of bins, and different bin sizes can reveal different features of the data. Some theoreticians have attempted to determine an optimal number of bins, but these methods generally make strong assumptions about the shape of the distribution. You should always experiment with bin widths before choosing one (or more) that illustrate the salient features in your data.

Reading Histograms

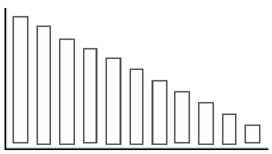
A histogram is helpful to recognize patterns; they provide information on the degree of variation of the data as well as indicate a distribution pattern. Dispersion of the data can produce a wide variety of shapes depending upon the data you are viewing.



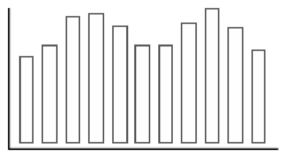
Normal
Most values fall toward the center of the distribution and the variation on both sides of the center is balanced.



Skewed
A skewed histogram has a long tail on one side. This can indicate a shift of some variable.



Precipiced
Most values appear shifted to one of the sides. This could occur when the data has been sorted or when there is some natural barrier.



Bi-Modal
There appear to be two peaks. This usually occurs when two different data groups are mixed.

Display the Gaussian curve on the histogram to help read the data. A surface with random features has a height distribution that fits the Gaussian curve. A surface with a dominant shape has a non-Gaussian height distribution.

12.2 Process Statistics

Process Statistics may or may not appear within the application. Process Statistics can be added to most views; on the Grid menu select Add Process Statistics. Multiple occurrences of Process Statistics can be synchronized or independent.

Process Statistics Overview

- Serves as a statistical process tool.
- Displays results (samples or records) and summary statistics for multiple measurements.
- Useful when comparing measurement results on similar parts.
- Supports loading of multiple data files at one time.
- To sync multiple Process Statistics screens, the Sync On/Off button must be on. To use independent statistics, the Sync On/Off button must be off.
- Statistics can be exported in numerous file formats and image formats. These include: Excel, CSV, RTF, MHT, HTML, text, PDF, BMP, EMF, WMF, GIF, JPG, PNG, and TIFF. See Outputting Statistics.

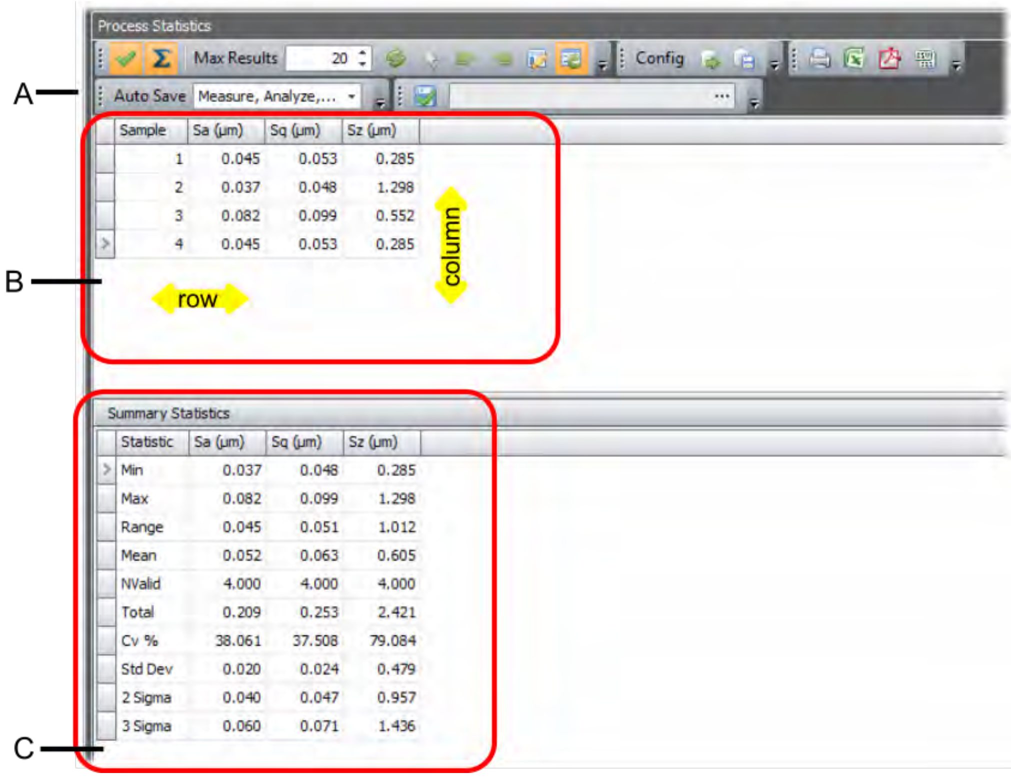
Use Conditions

- Results (vertical columns) displayed are determined by the Select Results dialog.
- The maximum number of samples displayed and stored is based on the Max Results box.
- The conditions under which data is stored are based on the Auto Save box.
- Rows appear as measurements are made and when data files are loaded.

Process Statistics Screen

To activate, click the On/Off button.

Process Statistics are empty until measurements are made or data is loaded.



A. Toolbar. **B.** Process Statistics panel. **C.** Summary Statistics panel.

Creating Process Statistics

See Creating a Statistical Grid.

Using Process Statistics

This is a quick overview of this feature.

1. Click On/Off button to activate the function.
2. To add/remove results to the tool, right-click and choose Select Items. For details see Adding or Removing Items.
2. Select when you want to store data with the Auto Save box.
3. Select the number of results to store with the Max Results box.
4. To choose the result columns to display, click the Select Items button.

5. Adjust the columns as desired. Change results units, adjust the column order, and adjust the column width.
6. To choose summary statistics, click the Select Statistics button.
7. To input data into the panels, make measurements or load existing data files, or click the Snapshot button when you want to capture the current data.
8. To export data, click the Print, Excel, or PDF button.
9. To save the existing configuration of the process statistics, click the Save button.

Working With Table Data

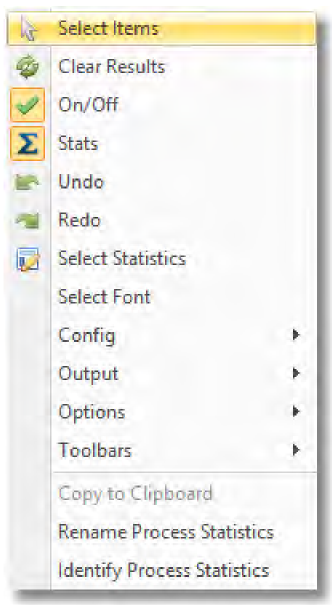
Refer to Working With Tables.

Working With Process Statistics

To change the order of columns, delete columns, or to change result units, refer to Working With Tables.

The statistical content is based on the incoming data.

To change features within the panel, right-click to open the context menu. Some functions duplicate toolbar functions (see Statistics Toolbars).



Selecting Items	Opens a dialog used to select what results to display. See Selecting Results.
Clear Results	Clears or deletes the statistics from display. Statistics are repopulated when an existing data is loaded or measurements are made.
On/Off	Turn storage of samples on/off.
Stats	Selects if summary statistics are displayed or not.
Undo	Removes the last sample.
Redo	Adds the last sample removed with Undo.
Select Statistics	Opens a dialog used to select summary statistics. See Summary Statistics.
Select Font	Change the style and size of the displayed text. See Select Font.
Config	Work with configuration files. See Statistics Configuration Files.

Output	Output data in numerous formats. See Outputting Statistics.
Options	Selects general options for the table, such as auto formatting, Auto Save, and Max Results. The Table options are: *Auto Width*- adjusts the column widths to fill the panel space. *Auto Height*- adjust row heights when needed. *Line Highlight*- shades every other line in the table.
Toolbars	Displays the selected toolbars.
Copy to Clipboard	Copies the alphanumeric content of the selected rows in the Slice or Summary Statistics panel to the clipboard.
Rename Process Statistics	Changes the name of the process statistics grid to a user entered name.
Identify Process Statistics	Shows the program location/path to the statistics.

Auto Log Feature

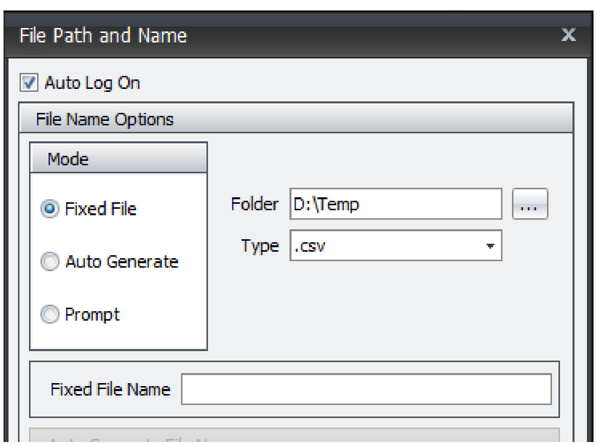
Numerical results and textual fields in Process Statistics can be automatically logged (saved). Options are selected with the Auto Log toolbar.

Auto Log Toolbar

Log on/off	Turns the logging feature on or off. When on, the icon is highlighted as shown above.
Log File	Displays/specifies the log file path and name.

File Name Options

1. To specify file naming options, click the Log File control ellipse ⋯.
2. Enter options in the File Path and Name dialog. Auto Log must be on to choose/specify options.



Mode — Selects the type of auto log operation to perform. The Auto Save control determines when statistics are logged. See Auto Save Toolbar.

Fixed File- Statistics are saved to the location specified after the Folder control using the name entered in the Fixed File Name control.

Auto Generate- Automatically generate a file name and save it. See Auto Generate File Name for details.

Prompt- Prompts the user to specify a file location and name after each auto log.

Folder — Specifies the directory folder location for logging statistics when the Mode is Fixed File or Auto Generate.

Choose the folder by clicking and selecting a directory folder location.

Type — Selects the type of format to log. The choices are .csv (comma separated values) or xml (extensible markup language). For Log the choices are Select All, .csv, .jpg, or .xml

Fixed File Name — Specifies the name of the file when the mode is Fixed File. Click to enter a name.

To automatically generate file names see Auto Generate File Name.

Standard Format Control

This control must be placed on a toolbar before it can be selected. It determines the .csv format.

1. Right-click on the Process Statistics toolbar and select Customize...
2. In the Customization dialog, click the Commands tab.
3. Under Categories click AutoLog.
4. Under Commands click and drag Standard Format to the Auto Log toolbar.
5. Close the Customization dialog.
6. Click the Standard Format icon to turn on/off the formatting option. Options are described below; examples are also shown.

When On (icon is highlighted), the csv file is output with column headers in the first line and then the comma separated data values below. No units are output.

```
PV,NPoints
0.030,76800
0.000,44463
0.124,250259
0.055,379605
4.968,1048477
1.105,197317
```

When Off, the csv has a title line (Zygo Mx Report); each result is output as “title”, “value”, “unit” with all results for a single measurement or data file loaded on a separate line.

```
Zygo Mx Report
"PV",0.030,"µm","NPoints",76800,""
"PV",0.000,"µm","NPoints",44463,""
"PV",0.124,"µm","NPoints",250259,""
"PV",0.055,"µm","NPoints",379605,""
"PV",4.968,"µm","NPoints",1048477,""
"PV",1.105,"µm","NPoints",197317,""
```

12.3 Slice Statistics

Slice Statistics Overview

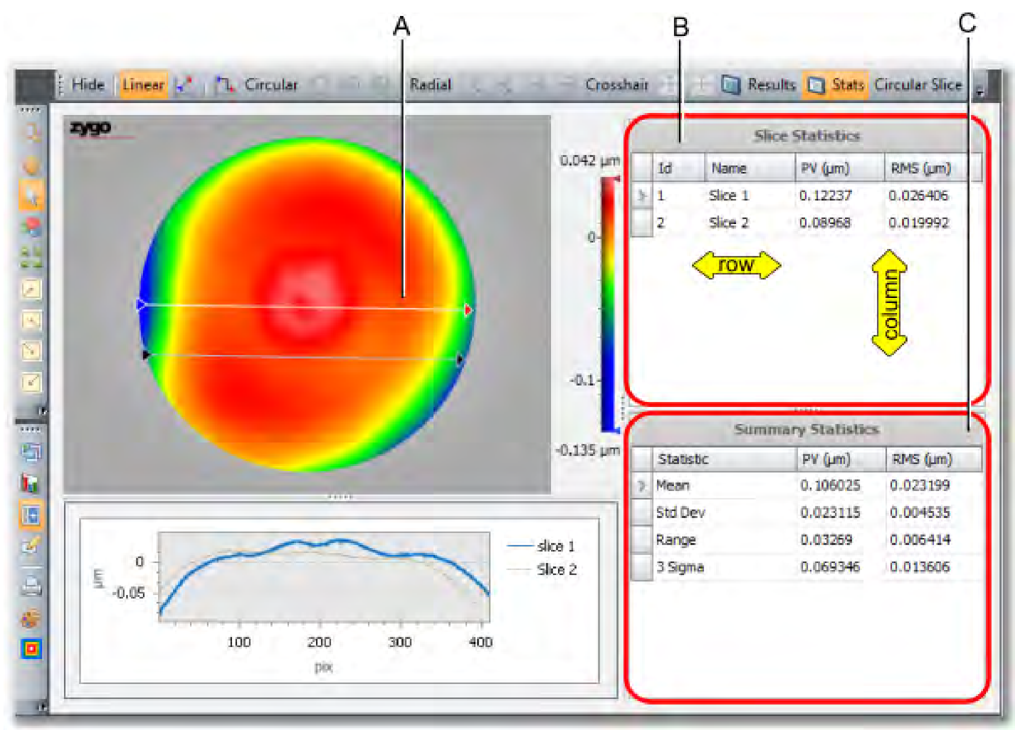
- Serves as a statistical process tool.
- Displays numeric results and summary statistics for multiple slices.
- Each (horizontal) row shows the statistics for one slice.
- The numeric results for the slices are in (vertical) columns.
- Statistics can be exported in numerous file formats and image formats. See Outputting Statistics.

Use Conditions

- Statistics are added as slices are created.
- Statistics are updated when slices are moved or when a different slice type is clicked in the Slice toolbar.
- Statistics are displayed only for the displayed slice type (Linear, Circular, Radial, Crosshair).
- Will be blank if there are no slices or slicing is hidden.

Slice Statistics Screen

Slice Statistics are empty until slices are created and there is data.



A. Defined slices on 2D Plot. **B.** Slice Statistics panel. **C.** Summary Statistics panel.

Creating Slice Statistics

1. Create slice(s) on the 2D plot. See Slicing.
2. Click Stats on the plot's Slices toolbar.
3. Resize the panel if necessary. See Working With Panels.

Hiding Slice Statistics

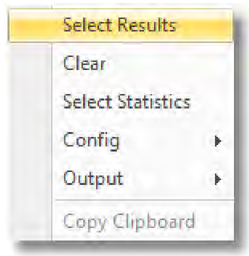
1. Click Stats on the plot's Slices toolbar.

Working With Slice Statistics

To change the order of columns, delete columns, or to change result units, refer to Working With Tables.

The statistical content is based on defined slices and the selected slice type.

To change features within the statistics, right-click to open the context menu.



Selecting Results	Opens a dialog used to select what results to display. See Selecting Results.
Clear	Clears or deletes the statistics from display. Statistics are repopulated when an existing slice is moved or when the panel is closed and reopened.
Select Statistics	Opens a dialog used to select summary statistics. See Summary Statistics.
Config	Work with configuration files. See Statistics Configuration Files.
Output	Output data in numerous formats. See Outputting Statistics.
Copy to Clipboard	Copies the alphanumeric content of the selected rows in the Slice or Summary Statistics panel to the clipboard.

12.4 Control Chart

Control Chart Overview

- Shows the historical record or variation of one result over multiple measurements.
- Use to track the variation of a result over multiple parts.
- The horizontal or x-axis, shows the number of samples or measurements.
- The vertical or y-axis, shows the result value.
- Points on the chart track a result and typically represent a range of measurements taken over time.
- Upper control limits (UCL) and lower control limits (LCL), if displayed on the chart, indicate the threshold at which the process output is considered statistically unlikely.
- The mean of the result using all the samples is calculated and displayed as a center line.
- The location of the control lines can be user defined, though typically they are drawn at 3 standard errors from the center line.
- Control charts for most results can be added in most data views.

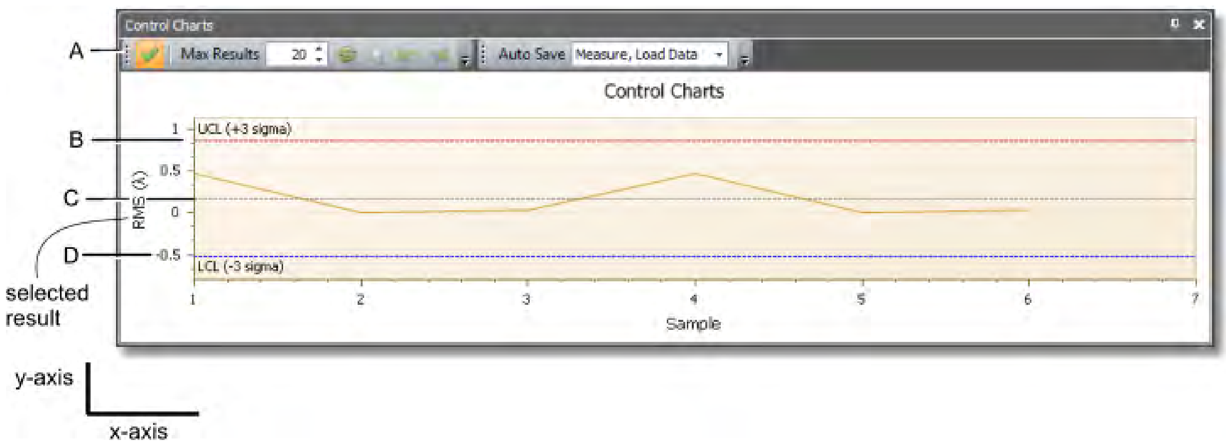
Use Conditions

- The chart is populated as measurements are made and when data files are loaded.
- The conditions under which data is stored are based on the Auto Save control.
- When the control limits are not computed from a large amount of data, the actual properties might be quite different from what is assumed.

The Control Chart Display

The control chart shows the variation of the selected result parameter.

To use this feature, on the Grids toolbar click Add Control Chart, then right-click on the chart and choose Select Result.



A. Toolbars. **B.** UCL (Upper Control Limit). **C.** Center line (mean of the statistic). **D.** LCL (Lower Control Limit).

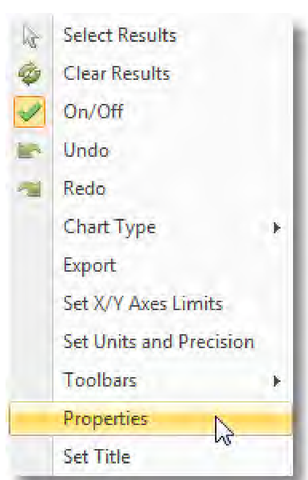
Creating a Control Chart

See Creating a Statistical Grid.

Working With a Control Chart

The chart content is based on the incoming data.

To change features within the chart, right-click to open the context menu. Some functions duplicate toolbar functions (see Statistical Toolbars).



Select Results	Choose results to display in the chart. See Adding or Removing Items.
Chart Type	Determines how the data is displayed. Choices are Bar, Line, or Points. See Changing the Line Profile Plot.
Export	Select to export underlying numeric data in another format. See Export Chart Data.
Set X/Y Axes Limits	Enter minimum and/or maximum values displayed on the (horizontal) x-axis or (vertical) y-axis of the chart. See Axes Limits.
Set Units and Precision	Select to change the result units for the y axis. See Setting Individual Units.
Toolbars	Displays the selected toolbars.
Properties	Select to change the control limits. See Changing the Control Limits.
Set Title	Opens a dialog to change the title bar on the corresponding grid. See Renaming a Grid.

Changing the Control Limits

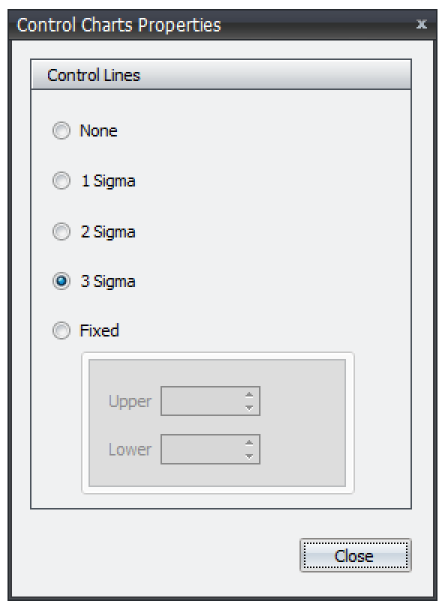
Right-click the plot and select Properties.

Control Limits are automatically calculated based on the displayed results and the setting of this dialog.

Control Limits provide a guide to the analysis. They are not specification limits, but a reflection of natural variability.

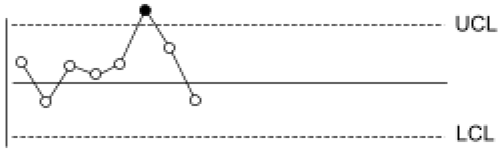
Control Limits are used to determine if the process is in a state of statistical control (i.e., is producing consistent output).

Specification Limits are used to determine if the product will function in the intended fashion.

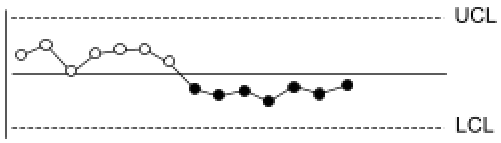


None	Control limits are not displayed in the chart.
1 Sigma	The UCL and LCL are based on the 2 sigma standard deviation of all the samples.
2 Sigma	The UCL and LCL are based on the 2 sigma standard deviation of all the samples.
3 Sigma	The UCL and LCL are based on the 3 sigma standard deviation of all the samples.
Fixed	Control limits normally change with every measurement. When Fixed is selected the lines become specification limits and are based on the values entered in Upper (becomes a fixed UCL) and Lower (becomes a fixed LCL).

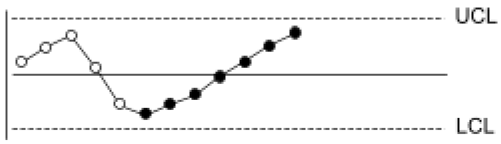
Reading Control Charts



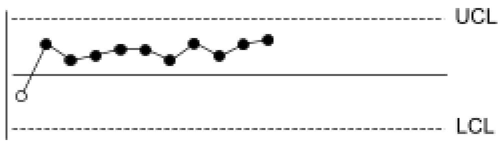
Point Outside of Limit
Control limits are calculated to measure the natural variability of a process. Any point outside the limit is considered abnormal and requires investigation.



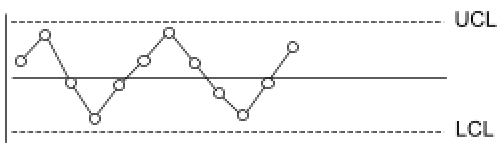
Run
A series of seven points on one side of the center line is considered abnormal.



Trending
Seven points in a continuous upward or downward direction.



Grouping
A majority of points on one side of the center line is considered abnormal. A majority is defined as: 10 out of 11, 12 of 14, or 16 of 20.



Cycling
Any repetitious up and down trend is abnormal and requires investigation.

12.5 Common Statistical Features

There are similarities between the statistical tools, such as creating, selecting results, and using summary statistics.

Creating a Statistical Grid

Applies to Process Statistics and Control Charts.

1. On the Grids menu select Add Process Statistics or Add Control Chart.
2. Or use the Grids toolbar (available in the main toolbar) and click Add Process Statistics or Add Control Chart. Refer to Working With Grids.

   When first created the chart is blank. It is updated as measurements are made or as existing data is loaded.
3. Resize the panel if necessary. See Working With Panels.
4. Right-click and choose Select Results or Select Items. See Adding or Removing Items.
5. For Control Charts, right-click and choose Select Results, then select the result you want to track and click OK.

Selecting Statistic Results

Applies to Process Statistics and Slice Statistics.

The result columns displayed in statistics are based on the selections in the Select Results dialog box.

1. For Process Statistics, click the Select Items button, or right-click the statistics panel and choose Select Items.

   For Slice Statistics, right-click the statistic panel and choose Select Results.

   See Adding or Removing Items for more details.
2. Select a check box to include and clear a check box to exclude a result.
3. Click OK.

See Also

Working With Tables

Selecting Table Data

Sorting Table Data

Filtering Table Data

Using Existing Data

Applies to Process Statistics and Control Charts.

Typically, data is tracked as measurements are made, but existing data can also be tracked.

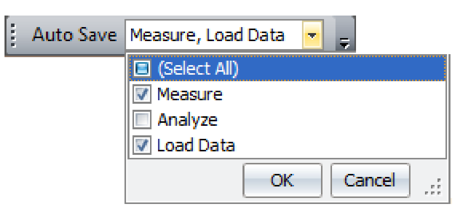
1. On the File menu select Load Data, or on the toolbar click Load Data.
2. In the Open dialog box select one or more files and click Open.

To select multiple files one by one, hold down the Ctrl key and click on each file. To select a range of files, click the first file, press the shift key and then click on the last file; all files between the two choices are selected. Files are loaded in the order in which they are selected.

Statistical Toolbars

Applies to Process Statistics and Control Charts.

Auto Save Toolbar



Selects when result data is saved as a sample. Select or clear check boxes and click OK.

Measure- saves data as sample whenever there is a measurement.

Analyze- saves data as sample whenever the Analyze button is clicked.

Load Data- saves loaded data files as samples.

Tools Toolbar

This toolbar may appear in different forms.

On/Off Turn storage of samples on/off.

Stats Show/hide Summary Statistics panel. Available in Process Statistics.

Max Results Specify the total number of samples to store.

Note that once you input more than Max Results, that the storing overwrites previous rows starting at row 1.

Clear Results Clear the panel of all samples.

Select Items Selects the items to display in the grid or chart.

Undo Undo last sample.

Redo Redo last undo.

Select Statistics Selects the statistics displayed in Summary panel. Available in Process Statistics.

Sync On/Off When On (highlighted), results are synchronized for all Process Statistics grids no matter where they appear. When Off, statistics are unique to their location.

Summary Statistics

Applies to Process Statistics and Slice Statistics.

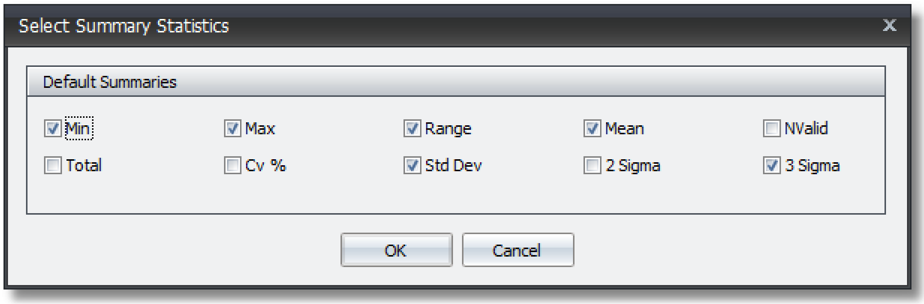
Summary Statistics Overview

- Displays summary statistics on all results in the statistics panel.
- Columns are based on displayed results. See Selecting Statistic Results.
- Rows are based on selected items in Select Summary Statistics dialog (shown below).

Selecting Summary Statistics

To select what summary statistics are displayed in the summary panel follow these steps.

1. Click the Select Statistics button, or right-click the Statistics screen and choose Select Statistics.
2. Select a check box to include and clear a check box to exclude a statistic.
3. Click OK.



Summary Definitions

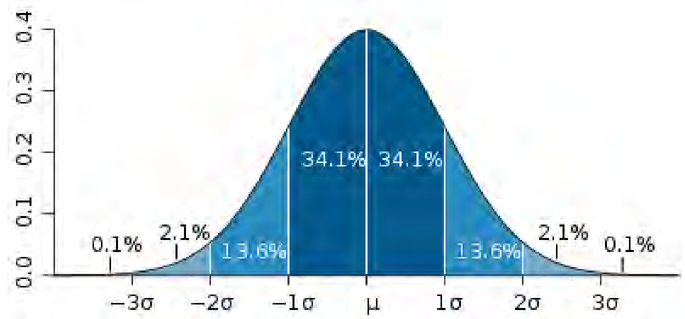
Min	The minimum value of all results in the column.
Max	The maximum value of all results in the column.
Range	The maximum value minus the minimum value in the column.
Mean	The arithmetical average of all the values in the column.
NValid	The number of valid measurements.
Total	The sum of the values in the column.
Cv %	The coefficient of variation times 100. Cv is equal to Std Dev divided by Mean.
Std Dev	The standard deviation (1 sigma) of all the values in the column.
2 Sigma	The 2 sigma standard deviation of all the values in the column.
3 Sigma	The 3 sigma standard deviation of all the values in the column.

Displaying Summary Statistics

To display or hide this panel, click the Stats button, or right-click the Process Statistics screen and select Stats.

Standard Deviation

Std Dev or Standard deviation is a measure of the variability or dispersion of multiple numeric results. A low standard deviation indicates that the result values tend to be very close to the same value (the mean), while high standard deviation indicates that the result values are “spread out” over a large range of values.



In this representation, the mean is the center of the bell curve. The central dark blue area is less than one standard deviation from the mean. For the normal distribution, this accounts for 68.2 % of the set.

Two standard deviations from the mean (medium and dark blue areas) account for 95.4%, and three standard deviations (light, medium, and dark blue) account for 99.6% of the set.

Outputting Statistics

These features are accessible with the context menu or toolbar buttons if available.

Feature	Output Options
Histogram	Export underlying numeric data in another format.
Control Chart	Right-click and select Export. See Export Chart Data.
Process Statistics	Output contents in various formats.
Slice Statistics	Point the statistic panel then right-click and select Output (or click one of the Process Statistics toolbar buttons listed below).

Print	Open print Preview; used to output contents in numerous ima data formats.
Excel	Export contents as XLS file.
PDF	Export contents as PDF file.
CSV	Export Contents as comma separated values in a text file.

See Also

Toolbars

Changing a Toolbar

Statistics Configuration Files

Applies to Process Statistics and Slice Statistics.

The configuration of the statistics views can be saved and loaded as an .sfgx file. This format preserves the selected results, the selected summary statistics, result units, and the order of the result columns; it does not preserve the column width, filter settings, or the actual sample data.

The arrangement of histograms and control charts is saved with the application (.appx file).

Saving Statistics Settings

1. On the toolbar click Save, or right-click and select Config ▶ Save.
2. In the save dialog box, enter a File name and click Save.

Loading Statistics Settings

Do this before making measurements or loading data. Loading configuration settings will clear any previously stored samples.

1. On the toolbar click Load, or right-click and select Config ▶ Load.
2. In the open dialog box, click on the file you want to load and click Open.

Output 13

This section describes the various output options.

Printing	Use to output the selected items to a connected printer.
Files	Use to output the selected items as a specified file type.
Images	Use to output the selected items as a specified image file format.
Reports	Use to create custom reports with graphics and text.

13.1 Printing

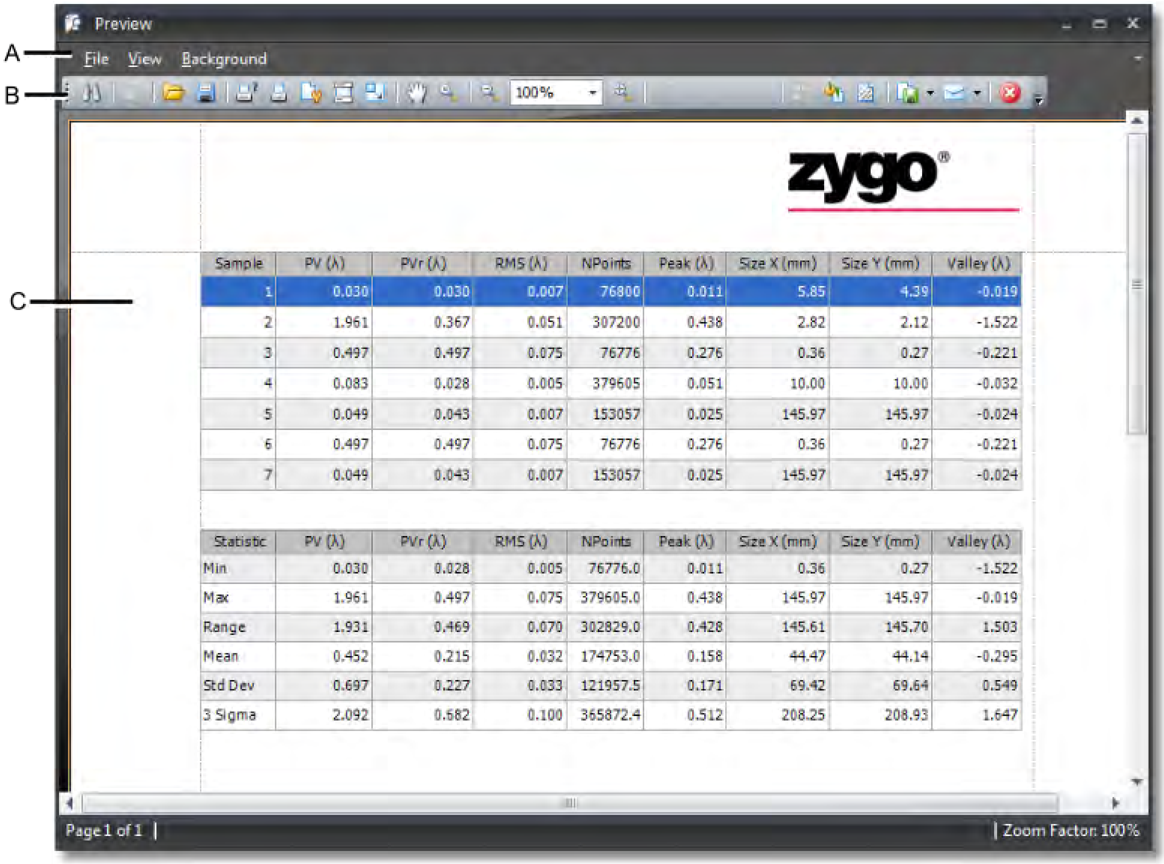
This function is accessible at various locations in the user interface.

To open the Preview screen, click the Print button, or right-click and select Print or Output ▶ Print.

Printing Overview

- Format the layout of the output.
- Save output in native xml printer format (.prnx).
- Export output as PDF, HTML, MHT, RTF, Excel, CSV, Text, or Image file.
- Export output in the following image formats: BMP, EMF, WMF, GIF, JPEG, PNG, or TIFF.
- Send output as email (network or internet connection required).

The Preview Screen



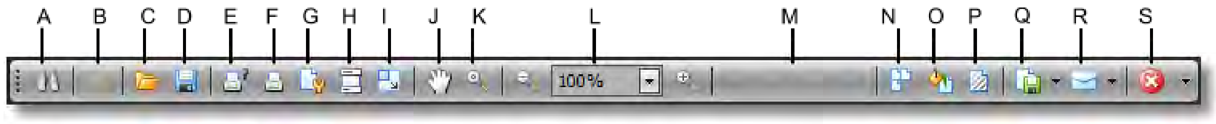
A. Menus. **B.** Toolbar. **C.** Output page(s).

Print Workspace

File ▸ Print outputs the entire software screen.

File ▸ Print Workspace outputs the workspace and whatever is on top of it. This does not include the menu bar, toolbars, Navigator, or the status bar.

Preview Toolbar

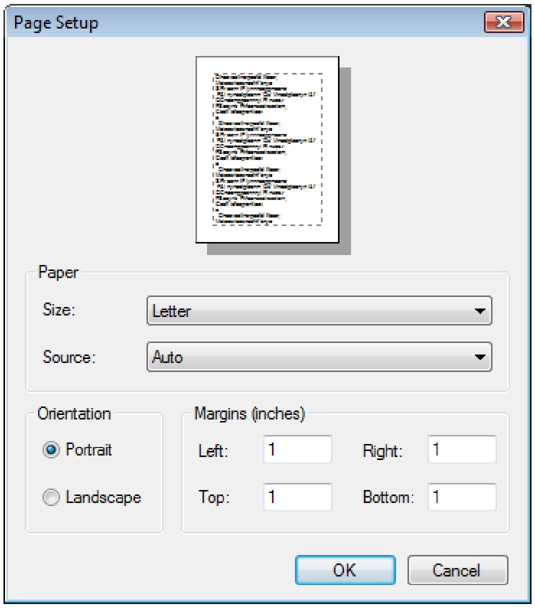


A	**Search**	Opens a Search dialog used to search for text with the preview page(s).
B	**Customize**	Presently disabled.
C	**Open**	Open the dialog used to select .prnx file to load.
D	**Save**	Open the dialog used to save the output as a .prnx file.
E	**Print**	Click to open Print dialog used to select a printer and specify printing preferences.
F	**Quick Print**	Click to quickly print the Preview output to your default printer.
G	**Page Setup**	Selects the paper size, margins, and orientation of the preview page(s).
H	**Header And Footer**	When printing from Process Statistics opens the Header and Footer dialog, which is used to specify what appears at the header (top) and at the footer (bottom) of the preview page(s).
I	**Scale**	Select to resize the actual content of the Preview output.
J	**Hand Tool**	Use to grab and move the page.
K	**Magnifier**	Use to alternate between zoom levels.
L	**Zoom**	Use to select magnification: Zoom Out, Zoom Percent, Zoom In.
M	**Page**	Use for page navigation: First Page, Previous Page, Next Page, Last Page.
N	**Multiple Page**	Specifies the number of pages to display in the Preview.
O	**Color**	Select the background color of the preview page(s).
P	**Watermark**	Specify text and/or image file that appears as a shaded marking on the preview page(s).
Q	**Export Document**	Open the dialog used to export the contents as a selected file format.
R	**Send via E-Mail**	Open the dialog used to export contents within an email message.
S	**Exit**	Close the Preview screen.

Changing the Preview Layout

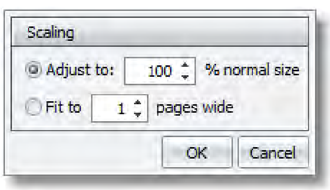
Page Options

On the Preview toolbar, click the Page Setup button to open the Page Setup dialog, which is used to select the paper size, orientation, and margins of the preview page(s).



Scaling

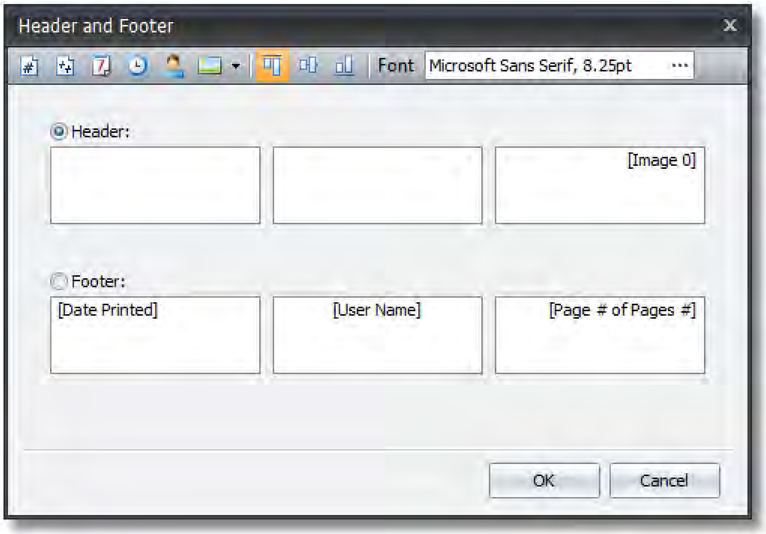
On the Preview toolbar, click the Scale button to specify the scale or size of the output within the preview page(s).



Header And Footer

On the Preview toolbar, click the Header And Footer button to open the Header and Footer dialog, which is used to control what is displayed at the top and bottom of the preview page(s).

This capability is only available when printing from Process Statistics.

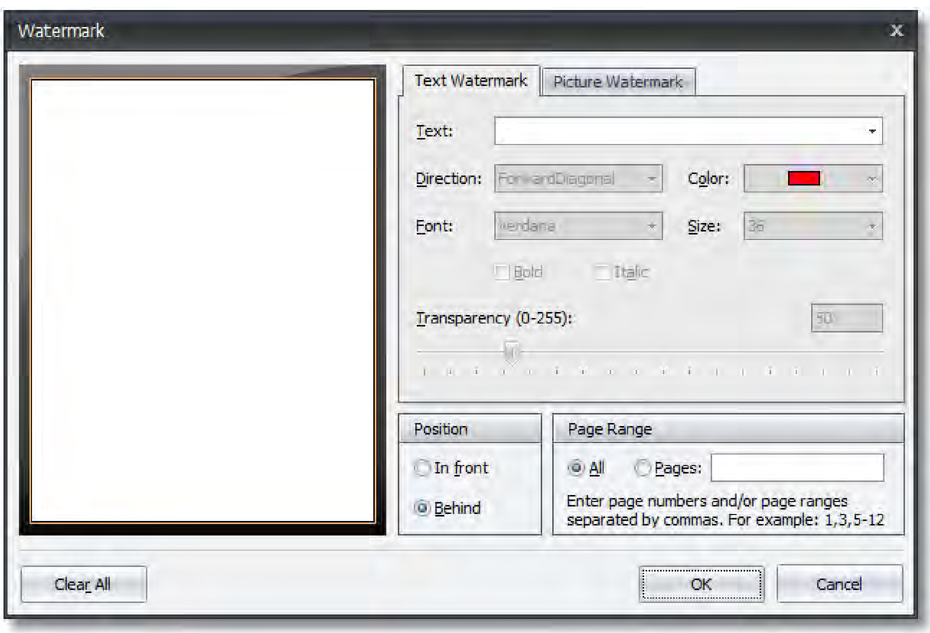


Color

On the Preview toolbar, click the Color button to open a color pallet, which is used to select the background color of the preview page(s).

Watermark

On the Preview toolbar, click the Watermark button to open the Watermark dialog, which is used to specify text and/or an image file to appear above or underneath the output on the selected range of preview page(s).



Preview Document Files

The pages displayed in the Preview screen can be saved and loaded as an .prnx file. This native XML printer format saves the pages as they appear within the Preview, complete with graphics, text, and numbers.

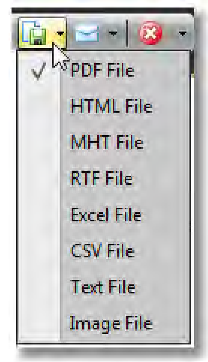
Saving Preview Documents

1. On the Preview toolbar click Save.
2. In the Save dialog box, enter a File name and click Save.

Loading Preview Documents

1. On the Preview toolbar click Open.
2. In the Open dialog box, click on the file you want to load and click Open.

Exporting as File



1. On the Preview toolbar, click the Export Document button, or on the File menu select Export Document, and choose the desired output format.
2. Each file type has its own dialog box. Enter the applicable file options and click OK.
3. In the Save As dialog box, enter a File name and click Save.

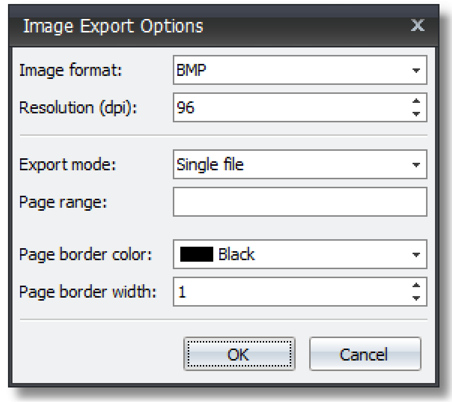
Also see Exporting as Image.

Supported File Types

PDF	Portable Document Format, is a file format created by Adobe Systems for document exchange. PDF is used for representing two-dimensional documents in a manner independent of the application software, hardware, and operating system.
HTML	HyperText Markup Language, is the predominant markup language for web pages. It provides a means to describe the structure of text-based information in a document.
MHT	Short for MIME HTML, is a web page archive format used to bind resources which are typically represented by external links (such as images) together with HTML code into a single file.
RTF	Rich Text Format, is a document file format developed by Microsoft for cross-platform document interchange.
Excel	Or XLS file, is a spreadsheet file format developed by Microsoft.
CSV	Comma Separated Values, is a text based file format with each group of information separated by a comma, and typically used is spreadsheet applications.
Text	A format in which information is made up of basic unformatted alphanumeric characters.

Exporting as Image

1. On the Preview toolbar, click the Export Document button, or on the File menu select Export Document, and choose Image File.
2. Select the Image format and applicable options in the Image Export Options dialog and click OK.
3. In the save as dialog box, enter a File name and click Save.



Supported Image File Types

BMP Bitmap, is an image file format used to store bitmap digital images.

EMF Enhanced Metafile, is a 32-bit graphics file format containing both vector and bitmap components developed by Microsoft.

WMF Windows Metafile, is a 16-bit graphics file format containing both vector and bitmap components developed by Microsoft.

GIF Graphics Interchange Format, is a bitmap image format that supports up to 8 bits per pixel, allowing a single image to reference a palette of up to 256 distinct colors chosen from the 24-bit RGB color space.

JPEG Joint Photographic Experts Group, is a compressed bitmap image format that works best on photographs of realistic scenes with smooth variations of tone and color.

PNG Portable Network Graphics, is a bitmapped image format that employs lossless data compression.

TIFF Tagged Image File Format, is a file format for storing images, including photographs and line art which include high-color-depth images.

See Also

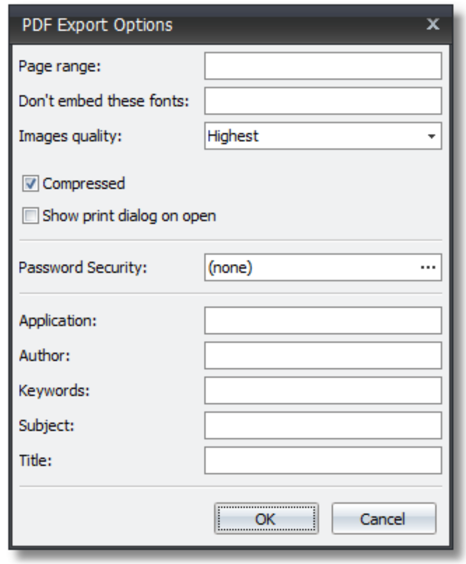
Saving the Plot Image

Sending as Email

This feature saves the preview pages as a document, and then opens your email client with the document attached, ready for you to compose and send.

This feature may not be supported on your computer. Email software plus network or internet connection is required.

1. On the Preview toolbar, click the Send via E-Mail button, or on the File menu select Send via E-Mail, and choose the file format of the attached preview file. The file types are same as when Exporting as File.
2. Each file type has its own dialog box. Enter the applicable file options and click OK. Entries are optional.
3. In the Save As dialog box, enter a File name and click Save.
4. In your email software, enter an email address, compose your message and send.



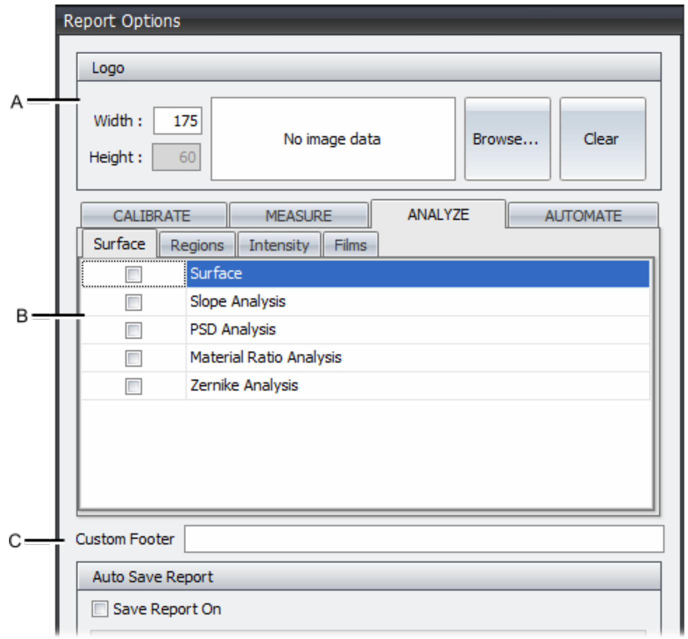
13.2 Reports

Reports Overview

- Gather and print user-selected graphic images from multiple screens within the application.
- To start, define the report with the Reports Options screen.
- Add a company logo or graphic image for a custom look.
- Reports can be saved or output for use in other programs.
- Reports can be automatically created and saved.
- The settings of the Reports Options screen can be exported (saved) or imported (loaded) as report configuration (.repx) files.

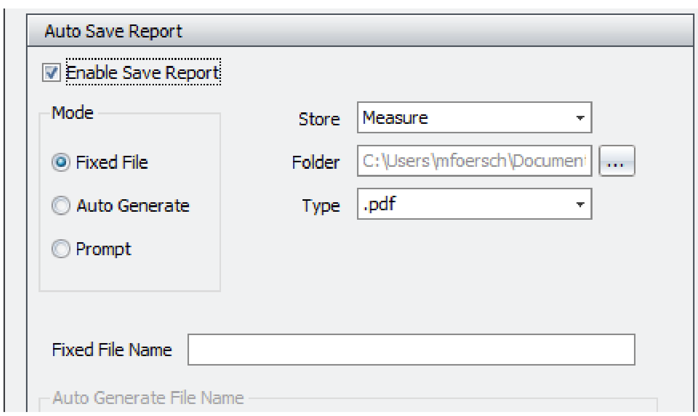
The Reports Options Screen

To access the screen, on the Reports menu select Report Options.



A. Logo (graphic) settings. **B.** Screen selection tool (contents application specific). Note the tabs correspond to tabs in the specific application. **C.** Custom Footer text. For Auto Save Report functionality, see Auto Save Options and Auto Generate Reports.

Auto Save Report



Enable Save Report	When selected, the corresponding file type is automatically saved after each measurement, as based on the save options. Clear the Enable Save Report check box to run without saving data.
Mode	Selects the type of auto save operation to perform. *Fixed File*- Performs a sequence and saves the file with a name and location that is specified by the user. *Auto Generate*- Automatically generate a file name and save it after each measurement. See Auto Generate Reports. *Prompt*- Performs a sequence and prompts the user to specify a file location and name.
Store	Selects when data or reports are automatically saved. *Measure*- The file is generated when the Measure button is clicked (or F12). *Analyze*- The file is generated when the Analyze button is clicked (or F11). *Load Data*- The file is generated when data is loaded.
Folder	Specifies the directory folder location for saving reports when the Mode is Fixed File or Auto Generate. Select the folder by clicking ... and selecting a directory folder location.
Type	Selects the file format type to save. The choices are .pdf or .rtf.
Fixed File Name	Specifies the name of the file when the mode is Fixed File.

To automatically generate file names see Auto Generate Reports.

Preparing a Report

1. On the Reports menu select Report Options.
2. To include a data screen, select the corresponding check box in the screen selection tool. Click tabs to access available screens.
3. (Optional) To add a graphic image to the upper left corner, click Browse and select an existing image. See Working With Logos.
4. (Optional) To add text centered at the bottom of the report, enter it after Custom Footer. It is recommended to limit the length of this entry, as excessive characters are clipped.
5. (Optional) Select the Save Report On check box to activate automatic report saving options. See Auto Save Files.
6. (Optional) If Auto Generate is selected, specify the Auto Generate file naming options. See Auto Generate Reports.
7. (Optional) To save the configuration of the Reports Options screen, click Export and save the file.

Working With Reports

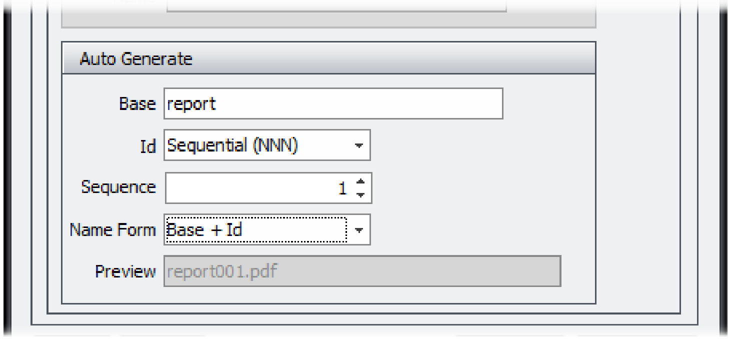
To	Procedure
View the report before printing	On the Reports menu select Preview Reports. This gathers a report based on the current screens and opens it in a Preview screen.
Print the report	On the Reports menu select Print Reports. This prints directly to the currently selected printer and bypasses printer dialogs.
Output the report as a file	On the Reports menu select Save Reports. This opens a save file dialog. The report can be saved in .pdf (portable document format) or .rtf (rich text format). Selected screens are saved in an image format and not as text or data.

Working with Logos

- Supports .bmp, .gif, .jpg, .png, and .tif image formats.
- All selected graphics are fit to the specified Width. The default size is 175 x 60 pixels. The width can be changed but the height is always 60 pixels.
- For best appearance, the logo image should be proportional to the fit area, such as 175 x 60 pixels or 350 x 120 pixels. If necessary, modify the existing logo to match the size constrains before selecting it.

Auto Generate Reports

This feature automatically generates report files in .rtf or .pdf format based on the entered criteria when Auto Generate is selected.



Base	Specifies the base string of text or numbers used in auto file naming.
Id	Selects the file naming convention. Choices are Sequential (NNN), Date/Time, or Date/Sequential.
Sequence	Selects the starting number of the sequence.
Name Form	Selects what is first in the generated file name, the Base entry or the Id selection.
Preview	Shows a sample file name based on the Type, Base, Id, and Name Form settings.

Auto Report Naming Examples

The examples are based on the base entry of REPORT. The columns are the Id control choices.

Sequential (NNN)	Date/Time	Date/Sequential
REPORT001.pdf	REPORT06152010-091032.pdf	REPORT06152010001.pdf
base entry with sequence number	06152010 is the date- month/day/year 091032 is the time- hour/minutes/seconds	06152010 is the date 001 is the sequence number

See also Auto Generate File Name.

Report Configuration Files

The reports options configuration is saved and loaded from within the Reports Options screen; configuration files are identified by the extension "repx".

Exporting (or Saving) a Reports File

1. Click Export on the Reports Options screen.
2. In the Save File dialog type a file name and click Save.

Importing (or Loading) a Reports File

1. Click Import on the Reports Options screen.
2. In the Load File dialog select the file and click Load.

Customizing 14

This section provides information for customizing Mx. The ability to change the look of items is built into the software. Specialized tools for the advanced user will be supported in future versions of the software.

14.1 Minor Customizing

What is Automatically Saved?

- Default directory locations for applications and data (Tools ▶ Options).
- What application is loaded at startup (Tools ▶ Options).
- Modifications to the main program toolbar. This includes which ones are shown or hidden, their location, and any customization (made with the Customization dialog).

What is Saved With the Application (.appx)

- Screen size.
- Panel sizes and their pin "state". Note that some panels cannot be pinned.
- Grid modifications. This includes whether the grid is added or removed, its pin "state", and what items have been added or changed in the grid itself. These features are available as grids: Control, Attribute, Result, and Process Statistics.
- Plot modifications. This includes details such as the size, color selections, legend options, unit selection, and defined slices.
- Control settings.
- Modifications to minor toolbars, such as those in a plot display or in Process Statistics.

What is Saved With Settings Files (.setx)

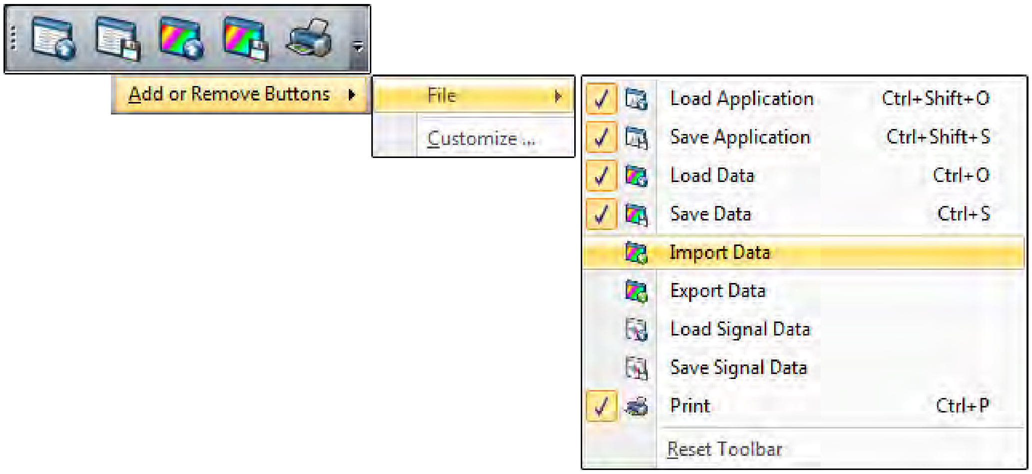
- The selections made to controls. This allows you to quickly change many control settings.

What is Saved With Configuration Files (.sfgx)

- The arrangement or configuration of process statistics.

14.2 Changing a Toolbar

The following steps can be used to change an individual toolbar and the items that are displayed.



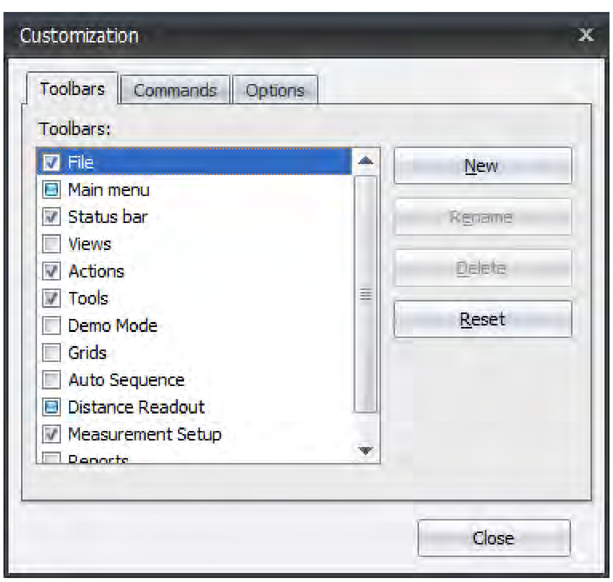
1. Point to the drop-down arrow ▼ on the toolbar.
2. Select Add or Remove Buttons ▶ File (the name of the toolbar) ▶ and select an item to included it.
3. Remove an item by clearing the check next to the item.

Reset Toolbar

Select Reset Toolbar to put the toolbar in the default state. This is useful when the toolbar has been modified and you want to go back to the state it was in before any customization.

14.3 Customization

This feature is used customize the main program toolbars and other program options.



Making a Custom Toolbar

1. Point to the main toolbar area, right-click and choose Customize...
2. Click New.
3. Enter a Toolbar Name and click OK.
4. Click the Commands tab.
5. Click on an item in the Categories column; the available Commands are displayed on the right.
6. Click on an item in the Commands column.
7. Press and drag the item to the toolbar and release the mouse button.

This technique can also be used to add items to any toolbar.

8. Click Close.

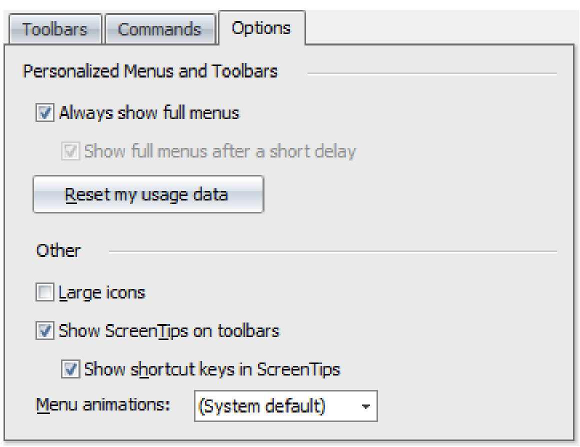
Removing a Custom Toolbar

1. Select the toolbar in the list under Toolbars.
2. Click Delete.

To hide the toolbar without deleting it, point to the main toolbar area, right-click and choose the toolbar to clear the check box.

Customization Options Tab

Use this section to choose menu display options, change the size of icons in the toolbar, and whether tips are displayed when you point to an item.



14.4 Custom Workspace

- Provides a customizable screen that is accessible from the Navigator. For example, a workspace can be configured to list results and show plots from multiple windows, and incorporate controls and other functionality.
- The contents of a Custom Workspace can float freely within its space.
- Multiple workspaces can be created and utilized.
- Workspaces are saved with the application (.appx).
- Workspaces can be deleted.

Creating a Custom Workspace

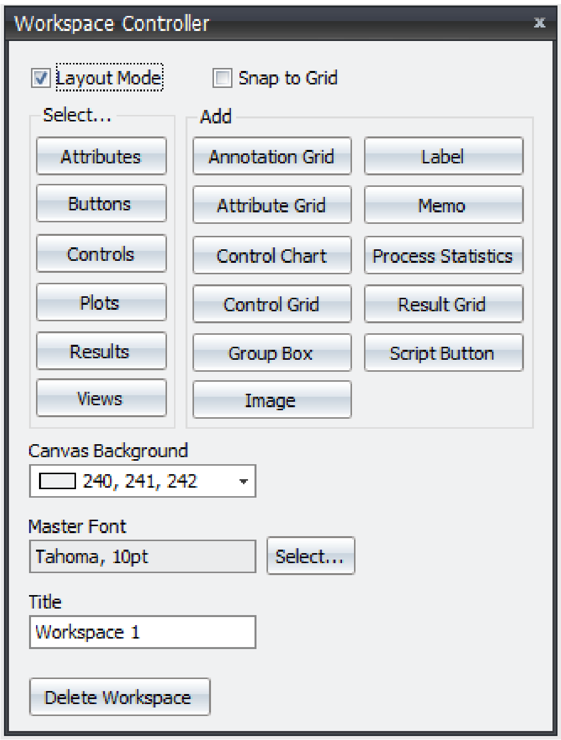
1. Navigate to the tab in which the workspace is desired.
2. On the View menu select Add Custom Workspace.

The new workspace is created and added to the Navigator and named by default as Workspace 1. Upon creation, the workspace is selected automatically and the Workspace Controller is shown.

Configuring a Workspace

When created, the workspace is blank.

To get started with configuration, right click anywhere on the workspace and open the Workspace Controller.



From the Workspace Controller, most of the main user interface elements of Mx can be added to the workspace.

- The items listed under 'Select...' open the item selection dialog. These items will be placed directly onto the workspace when selected.
- The items listed under 'Add' create a new element on the workspace without any dialog prompt.

When Layout Mode check box is selected, normal interaction with items on the workspace is disabled, but configuration options such as font size, or deleting or duplicating an item are available.

Snap to Grid shows a grid of snap points. Most items snap with their top left corner. For results, controls, and attributes, snapping is performed to the point between the label and value, see below.

The workspace background color can be changed to any user selectable value. The default value of Transparent will match the standard Mx container background which will change based on the selected Theme.

Master Font will overwrite the font of any text-based elements on the workspace. Individual items can always have their font customized, but this allows for an easy way to standard on a single font size across a workspace.

The Title control specifies the name of the custom workspace in the Navigator.

Deleting a Workspace

1. Right-click on the workspace and select Workspace Controller.
2. Click the Delete Workspace button.

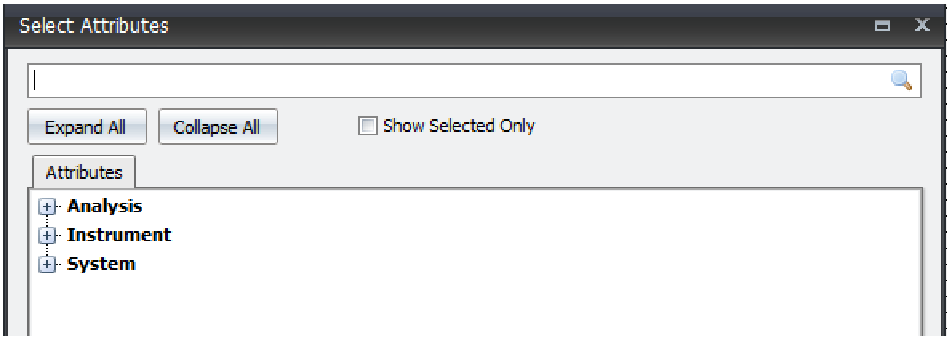
Workspace Elements

Every item in the workspace, in Layout Mode, has common context menu options:

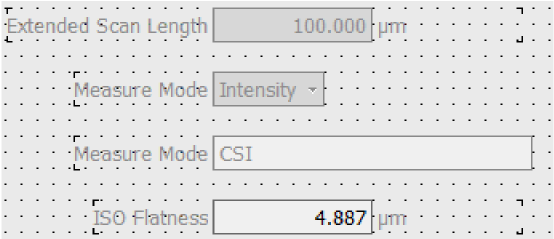
- Bring to Front/Send to Back – Determines how items are drawn when overlapping.
- Delete Item – Deletes the item from the workspace.
- Duplicate Item – Creates a copy of the same item on the workspce.

Results, Controls, and Attributes

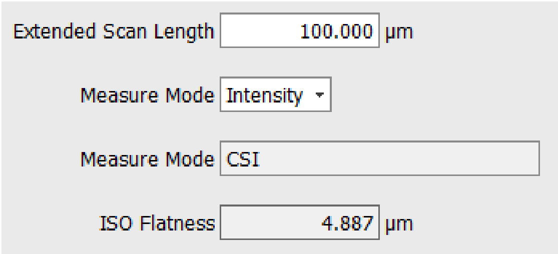
When Selecting Results, Controls, or Attributes, the standard selection dialog is shown. See Adding or Removing Items.



When in Layout Mode, results, controls and attributes are bookended to show the maximum size of the item.



When Layout Mode check box is cleared layout indicators disappear.



The right-click context menu for these items in Layout Mode includes:

Set Label	Changes the display name of the item.
Select Font	Changes the display font of the item. Can be over-ridden by the Workspace Master Font, or Group Box font

The above shown elements consist of three parts: a Name (ISO Flatness), Value (4.887), and Unit (µm).

When Snap to Grid is enabled, the snap point is the upper left corner of the Value box.

The amount of space taken up by the Name is determined by its length and Font Size, and the amount of size reserved for Units is fixed. Resizing the item by dragging from the right side indicators will change the amount of space dedicated to the Value box. Changing the Font Size also resizes these items.

Results and Attributes have a gray background for the Value, while Controls have a white background to indicate interactivity.

Plots

When selecting plots, the selection dialog lists all available plots in the current application.

In Layout Mode, plot toolbars are disabled and interaction with the plot is restricted.

The right-click context menu for plots in Layout Mode contains only the default options.

When Snap to Grid is enabled, Plots snap to their top left corner when moved. When resizing by dragging from any corner or side, the size of the plot snaps to the grid as well.

Buttons

When selecting buttons, the selection dialog lists all available top-level toolbar buttons available in the current application. Buttons that exist on plot toolbars are not listed, nor are buttons that do not exist on a toolbar (e.g. Calibrate Objective in the Micro application).

In Layout Mode, the button is grayed out and disabled.

Buttons are displayed as either an Icon and Label (default) or an Image and Label. The image will fill the button while maintaining its aspect ratio. To hide the label, simply set it to a blank string.

The right-click context menu for buttons contain:

Set Label	Changes the displayed label of the button.
Select Font	Changes the font of the label.
Set Image	Removes the icon of the button and paints the button with the selected image.
Clear Image	Clears the selected image. Does not restore a default or custom icon.
Restore Default Icon	Restores the default button icon.
Restore Default Label	Restores the default button label.

Buttons snap to grid at the top left corner. Buttons are resizable from any corner or edge and snap to the grid when resized.

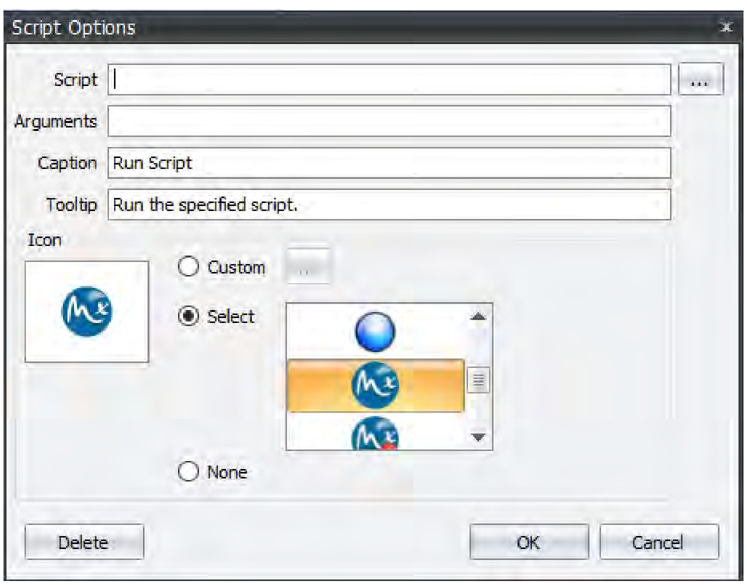
Any Script Buttons that have been created via the toolbar button Add Script Button is selectable in the Button selection dialog. These buttons will respect the configuration done in the toolbar, and vice versa. To create a new script button without using the Toolbar button, see the Script Buttons section below.

Script Buttons

Adding a Script Button will create a new button and place it on the workspace. This button will be available in the list of selectable buttons as well as to add to toolbars in Mx. A Script Button can be configured to run an Mx Python script.

The right-click context menu in Layout Mode matches standard Buttons.

Outside of Layout Mode, the right-click menu contains Script Options. Access to Script Options is disabled when User Level: Operator.



Script	Selects the script file (*.py) to run when button is pressed.
Arguments	Arguments passed to the script, accessible in python as sys.argv
Caption	The visible label for the button.
Tooltip	The mouse-over tooltip for the button.
Icon	The visible icon for the button.

For script buttons, the icon and label can be set in two different locations. One location is Script Options, and the other is in the Custom Workspace Layout Mode right click menu. Configuring the button via Script Options will change every instance of that script button, be it on a workspace or a toolbar. Changing locally via the Layout Mode right click menu changes only that specific instance of the button.

Grids, including Process Statistics

This section describes Annotation Grids, Attribute Grids, Control Charts, Control Grids, Images, and Process Statistics. (Images behave in the same way as Image Grids.)

When the corresponding button for any of these items is selected, a new grid is created on the workspace.

Grids snap to the grid at the top left corner. Grids are resizable from any corner or edge and snap to the grid when resized.

Configuration of the contents of a grid is done outside of Layout Mode, as with standard grids seen in other areas of Mx.

Group Box

A Group Box is a unique workspace item. Items dropped into a group box are moved with it, allowing for easier configuration of the workspace.

In Layout Mode, items can be dropped into the group box. The mouse cursor should be inside of the group box when releasing the item being added to the group. Items larger than the group box, or near the edge, can be obscured by the edge of the group box. Moving the group box by grabbing an unoccupied area or the label will move all ‘child’ items along with the group box.

If the group box is moved behind other items, they will not be added to the group box, unless they are specifically placed into it.

The right-click context menu contains:

Select Contents Font	Sets the font for all applicable items inside the group box.
Set Label	Sets the label of the group box, shown in the top left.
Select Title Font	Sets the font of the group box label.

Group boxes snap to the grid at the top left corner. Group boxes are resizable from any corner or edge and snap to the grid when resized.

Label

The Label is a unique workspace item. The label is intended as a way to add text to a workspace that cannot be edited outside of layout mode.

The right-click context menu contains:

Set Label	Sets the displayed text.
Select Font	Changes the font of the Label.

Labels are not addressable from Mx Scripting – for text that can be changed by a script, the use of string Controls such as Text1 – Text20 are recommended.

Memo

The Memo is a unique workspace item. The memo is intended as a way to add text to a workspace outside of layout mode, so a user can take notes or add information to a report.

The right-click context menu contains:

Set Label	Sets the displayed text.
Select Font	Changes the font of the Label.

Exchanging Data 15

The standard Mx data file format is a datx file. Mx uses an HDF5 file format to store measurement data. It is assumed the reader is familiar with HDF5 as a file format and the tools used to work with the file format. For more information, visit the HDF5 web site.

See also Compatible File Types.

15.1 datx Format

File Version

The current version of the datx file format is 1 and uses HDF5 version 1.8.1. The file version is noted by a 32-bit integer attribute called File Layout Version in the Attributes group. If the File Layout Version attribute is missing, the file version is 0. For datx version 0 files, please see "DATX Version 0." All file discussions refer to version 1 unless specifically noted. Mx v5.8.1.9 and later saved files in the version 1 format; earlier Mx builds saved in version 0 format.

Also of note is that files saved with Mx earlier than v5.25.0.1 were saved with szip compression On; szip compression was turned off for Mx v5.25.0.1 and later.

File Organization

A datx file is divided into three parts: the meta-data, the raw data, and the logical access to the raw data. The meta-data describes the data within the file, which data and attributes are related, and the path to the data within the HDF5 file. The raw data section is where the datasets and data attributes are stored. The logical access section offers a second view or access to the data according to the structure and names described by the meta-data.

Meta-Data

The meta-data is stored in the MetaData section as an array of compound data types. The compound data type consists of three variable length ASCII strings called Source, Link, and Destination. The Source field identifies the node that owns the link. The Link field names a link or value within a node. The Destination field contains either the target node (for a link) or the value (for a data field).

Raw Data

All data is stored in the Data group. The data is further organized based on the name/type of the dataset (i.e. Surface, Intensity) and a GUID. For example:

/Data/Surface/{5C7C7ADF-4773-407A-932D-1652DF7788A4}

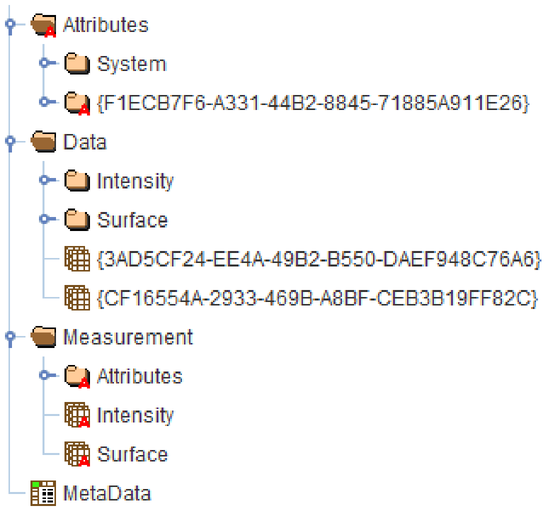
/Data/Intensity/{6B8BC78D-9F55-4FB2-9A75-CACD7AFF94B0}

Each type of dataset has a different set of attributes associated with it. The Attribute Types are defined below. The dataset type is identified by the MpxDataType attribute.

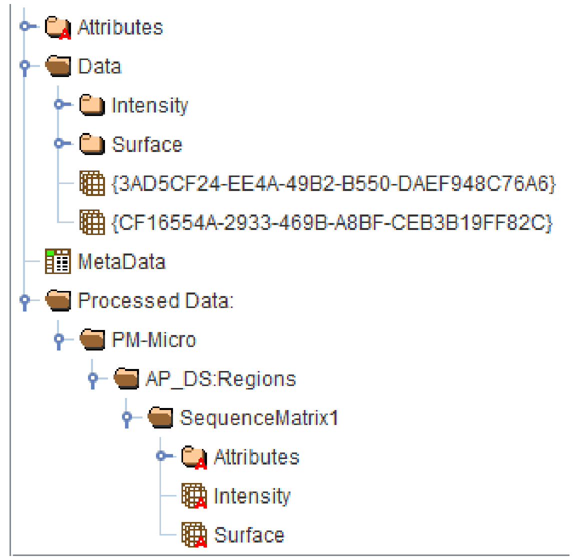
Dataset Type	Attributes Name	Attributes Type
DoubleMatrix2D (Surface)	Coordinates X Converter Y Converter Z Converter No Data Additional attributes for height data: Interferometric Scale Factor Obliquity Factor Wavelength	Window 2D Unit Converter Unit Converter Unit Converter Double Double Double Double
FloatMatrix2D (Surface)	Coordinates X Converter Y Converter Z Converter No Data Additional attributes for height data: Interferometric Scale Factor Obliquity Factor Wavelength	Window 2D Unit Converter Unit Converter Unit Converter Float Double Double Double
IntMatrix2D (Intensity)	Coordinates X Converter Y Converter Z Converter No Data Additional attributes for height data: Interferometric Scale Factor Obliquity Factor Wavelength	Window 2D Unit Converter Unit Converter Unit Converter Int32 Double Double Double

Logical Access

HDF5 file viewers use this section to organize and present the file data is a more readable way since GUIDs are used as the name of datasets within an HDF5 file. In the version 1 file format picture below, the Measurement section of the tree represents the Logical Access data, while the Attributes and Data sections of the tree represent the Raw Data data; both sections point to the same data. When processed data is saved from a plot, the name of the Logical Access element will be Processed Data: instead of Measurement.



Measured Data



Processed Data

Reading Data

To read surface or intensity data from a datx file, perform the following steps:

1. Get the HDF5 path to the dataset via the meta-data.
2. Open the dataset.
3. Read the dataset's attributes; attributes noted as Optional are not required to read the data from the file.

a. Coordinates:	Identifies location of data within the camera FOV; Optional
b. No Data Value:	Identifies the value used to represent a pixel that does not contain data
c. X Unit Converter:	Identifies the lateral resolution, or pixel size, in the X direction; Optional
d. Y Unit Converter:	Identifies the lateral resolution, or pixel size, in the Y direction; Optional
e. Z Unit Converter:	Identifies required parameters for converting data values between various units

4. Read the size of the dataset and resize data memory.
5. Read the dataset into data memory.
6. Convert dataset no data values into desired no data values.
7. Convert data memory from file units to desired units.

Get HDF5 Path to Datasets via Meta-data

The meta-data has one node with a fixed name called "Root." All of the other node names are generated when the file is saved using GUIDs. The following tables show the sequence of nodes to follow in order to get the desired HDF5 path to the data. If at any point in the sequence a link cannot be found on a node, that means that the desired data does not exist in the file.

Meta-data sequence to get HDF5 path for Surface data

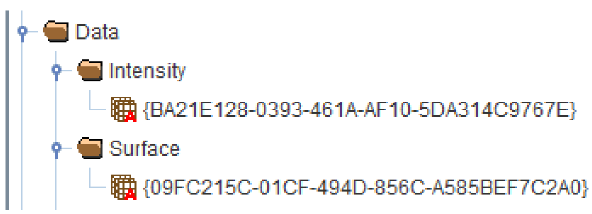
Source Node	**Link**	**Node or Path**
Root	Measurement	[Measurement Node]
[Measurement Node]	Surface	[Data Information Node]
[Data Information Node]	Path	HDF5 Path for Surface Data

Meta-data sequence to get HDF5 path for Intensity data

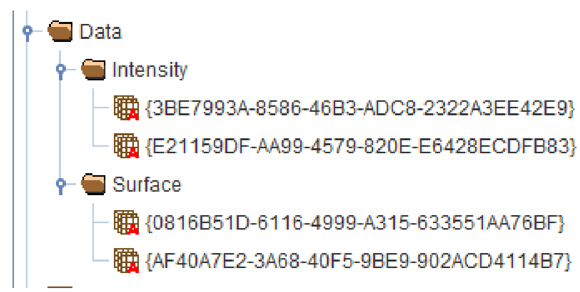
Source Node	**Link**	**Node or Path**
Root	Measurement	[Measurement Node]
[Measurement Node]	Intensity	[Data Information Node]
[Data Information Node]	Path	HDF5 Path for Intensity Data

Data Values

Most data files will have a single dataset for Surface and for Intensity. For measurements that require multiple acquisitions, such as a Radius Scale measurement, each acquisition will be in a separate group (GUID) under the dataset node. Surface data is located in the Data > Surface group. Intensity data is located in the Data > Intensity group.



Single Acquisition Measurement



Multi-Acquisition Measurement

Converting Height Data

Microscopes and Large Aperture systems save Surface data in different units. Microscopes use nanometers while Large Aperture systems use fringes. The Z Unit Converter contains the Interferometric Scale Factor, Obliquity Factor, and Wavelength; these are used to convert between fringes and meters using the following formulas:

To **convert fringes to waves**, multiply each data value by (S * O).

To **convert fringes to meters**, multiply each data value by (S * O * W).

Where:

S = Interferometric Scale Factor;
O = Obliquity Factor;
W = Wavelength in meters.

datx Data Types

The following data types are used in Mx datx files.

Standard HDF5 Types

Data Type	Definition
Int8	H5::PredType::STD_I8LE
UInt8	H5::PredType::STD_U8LE
Int16	H5::PredType::STD_I16LE
UInt16	H5::PredType::STD_U16LE
Int32	H5::PredType::STD_I32LE
UInt32	H5::PredType::STD_U32LE
Int64	H5::PredType::STD_I64LE
UInt64	H5::PredType::STD_U64LE
Float	H5::PredType::IEEE_F32LE
Double	H5::PredType::IEEE_F64LE

Simple Derived Types

Data Type	Definition
ASCII String	Variable length string based on H5::PredType::C_S1 H5::StrType(H5::PredType::C_S1, H5T_VARIABLE)
UTF8 String	Variable length string based on H5::PredType::C_S1 using UTF8 character set strType = H5::StrType(H5::PredType::C_S1, H5T_VARIABLE) strType.setCset(H5TCSET_UTF8)
Double Array	Variable length array of Double H5::VarLenType(Double)

Compound Data Types

It Is recommended that only v2 data types be used to ensure that all available information is read.

Data Type	Definition
Meta-Data Info	Compound data type Source ASCII String Link ASCII String Destination ASCII String
Unit Converter	Compound data type v1 Category ASCII String (see Unit Category below) BaseUnit ASCII String (see category Units lists below) Parameters Double Array Compound data type v2 Category ASCII String (see Unit Category below) BaseUnit ASCII String (see category Units lists below) SubCategory ASCII String (see Unit Category below) SubUnit ASCII String (see category Units lists below) Parameters Double Array
Unit Number	Compound data type v1 Converter Unit Converter v1 Value Double Compound data type v2 Converter Unit Converter v1 Value Double
Window 2D	Compound data type RowStart Int32 ColumnStart Int32 Width Int32 Height Int32

Enumerations

Enumeration values are stored as ASCII String values.

Unit Category

A Unit Category identifies a family of units, such as Height, Linear, and Lateral. Height (Z axis) units can be linear units or optical units. Linear units measure length. Lateral units measure the length in camera pixels; there is a scalar conversion from pixels to some fixed linear unit. The Counts category is used for values without units.

Category	Parameters
CountsCat	None
HeightCat	1. Not Used 2. Wavelength in meters 3. Interferometric scale factor 4. Obliquity factor
LinearCat	1. Not used 2. Pixel size in converter's base unit 3. Pixel offset in pixels
LateralCat	1. Not used 2. Pixel size in converter's base unit 3. Pixel offset in pixels (used for optical coordinates only)

HeightCat Units

These are the height units used by Mx.

Angstroms
CentiMeters
Feet
FringeRadians
Fringes
Inches
Meters
MicroInches
MicroMeters
MilliMeters
Mils
NanoInches
NanoMeters
Waves

LinearCat Units

These are the linear units used by Mx.

Angstroms
CentiMeters
Feet
Inches
Meters
MicroInches
MicroMeters
MilliMeters
Mils
NanoInches
NanoMeters

LateralCat Units

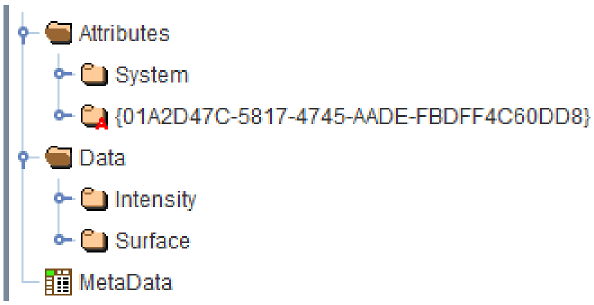
These are the lateral units used by Mx. Multiplying a value in Pixels by the Lateral Resolution gives you a value in the base unit of the unit converter; typically, Meters.

Angstroms

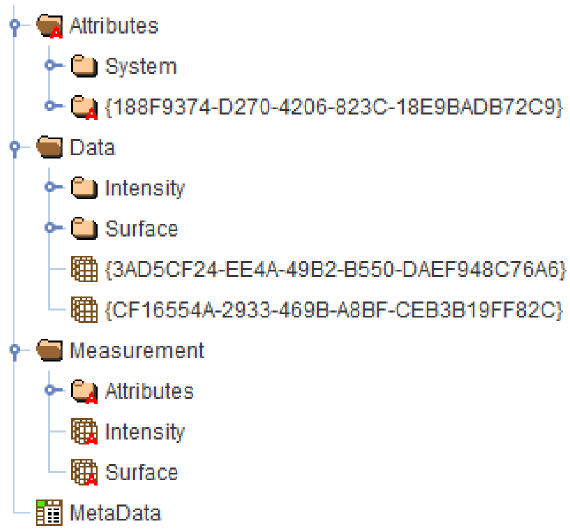
CentiMeters
Feet
Inches
Meters
MicroInches
MicroMeters
MilliMeters
Mils
NanoInches
NanoMeters
Pixels

datx Version 0 Files

The difference between a version 0 file and a version 1 file is the existence of the Logical Access section. The same technique is used to access the data and the attributes for both versions.



Version 0 File Format



Version 1 File Format

datx MatLab Code Example

This MatLab code example will only work for datx files that are NOT szip compressed.

```
function Out = ReadDatx(fileName)
%ReadDatx   Extract maps stored in a .datx file generated by ZYGO's Mx software
%   ReadDatx(fileName) reads data from the specified file. If 'fileName' is
%   not specified a file browser dialog will appear.
%
%   The output is a structure with fields for each extracted map, typically
%   including Surface and Intensity. Other possible fields include
%   Thickness, Substrate, and Color.
%
%   Each top-level field is itself a structure with contents:
%      - matrix         Raw map data
%      - zUnit          Unit (in Z) for map data
%      - xySampling   1x2 array of lateral pixel sampling in (X,Y)
```

```
%      - xyUnit          Lateral units (in X,Y)
%
%   Copyright 2018-2019 ZYGO Corporation

global MetaData MeasurementNode FileName
MeasurementNode = '';
Out = [];

%% Open the HDF5 file
if ~exist('fileName', 'var')
   [fileRoot, filePath] = uigetfile('*.datx');
   FileName = fullfile(filePath, fileRoot);
   if isequal(FileName,0)
      return
   end
else
   FileName = fileName;
end

if ~exist(FileName, 'file')
   error('Could not find file ''%s''', FileName);
end

%% Read MetaData
MetaData = h5read(FileName, '/MetaData');
MeasurementNode = GetNode('Root', 'Measurement');

if isempty(MeasurementNode)
   error('No measurement node found');
end

%% Surface data
surfacePath = GetMapNode('Surface');
if isempty(surfacePath)
   disp('No surface data');
else
   Out.Surface = ExtractZData(surfacePath);
   PlotHeightData(Out.Surface, 'Surface');
   fprintf('Extracted surface data\n');
end

%% Thickness data
thicknessPath = GetMapNode('Thickness');
if ~isempty(thicknessPath)
   Out.Thickness = ExtractZData(thicknessPath);
   PlotHeightData(Out.Thickness, 'Thickness');
   fprintf('Extracted thickness data\n');
end

%% Bottom surface (substrate) data
substratePath = GetMapNode('Bottom Surface');
if ~isempty(substratePath)
```

```
    Out.Substrate = ExtractZData(substratePath);
    PlotHeightData(Out.Substrate, 'Substrate');
    fprintf('Extracted substrate data\n');
end

%% Intensity data
intensityPath = GetMapNode('Intensity');
if isempty(intensityPath)
    disp('No intensity data');
else
    Out.Intensity = ExtractZData(intensityPath);
    PlotIntensityData(Out.Intensity, 'Intensity');
    fprintf('Extracted intensity data\n');
end

%% Color data
colorPath = GetMapNode('ColorData');
if ~isempty(colorPath)
    colorHdf = GetMapHdf(colorPath, true);

    % Extract (R,G,B) components
    [sizeY, sizeX] = size(colorHdf.matrix);
    Out.Color = [];
    Out.Color.matrix = zeros(sizeY, sizeX/3, 3);
    Out.Color.matrix(:,:,1) = colorHdf.matrix(:, 1:3:end);
    Out.Color.matrix(:,:,2) = colorHdf.matrix(:, 2:3:end);
    Out.Color.matrix(:,:,3) = colorHdf.matrix(:, 3:3:end);
    Out.Color.matrix  = Out.Color.matrix  / (pow2(16) - 1);

    % Get lateral data
    [Out.Color.xySampling, Out.Color.xyUnit] = GetLateralSamplingWithUnits(colorHdf);
    [~,~, xVector, yVector] = GetLateralGrid(Out.Color.xySampling, [sizeY, sizeX/3]);

    % Plot color map
    figure('Name','Color', 'NumberTitle','off');
    image(xVector, yVector, flipud(Out.Color.matrix));
    SetupAxesAndLabels('Color', Out.Color.xyUnit, '')

    fprintf('Extracted color data\n');
end

%% Support functions
% Assumes MetatData and MeasurementNode are properly defined
function mapNode = GetMapNode(dataName)
global MeasurementNode
mapNode = '';
% Get Data Information node
infoNode = GetNode(MeasurementNode, dataName);
if ~isempty(infoNode)
    mapNode = GetNode(infoNode, 'Path');
end
```

```
function node = GetNode(source, link)
global MetaData
node = '';
sourceMatch = strcmp(source, MetaData.Source);
linkMatch = strcmp(link, MetaData.Link);
iNode = find(sourceMatch & linkMatch);
if ~isempty(iNode)
  node = MetaData.Destination{iNode};
end

function mapData = GetMapHdf(node, isColorData)
global FileName
if ~exist('isColorData', 'var')
  isColorData = false;
end
mapData = [];
try
  mapData.matrix = rot90(h5read(FileName, node));
catch ME
  if (strfind(ME.message, 'szip'))
    fprintf(2, ['\nFile uses szip compression, which is not supported by this demonstration
script.\n'
    'This may indicate that the .datx file was created using a very early version of Mx,\n' ...
    'in which case a remedy is to load into Mx and resave.\n\n']);
  end
        rethrow(ME)
end
mapData.xConverter = h5readatt(FileName, node, 'X Converter');
mapData.yConverter = h5readatt(FileName, node, 'Y Converter');
if ~isColorData
  mapData.zConverter = h5readatt(FileName, node, 'Z Converter');
  mapData.NoDataVal = h5readatt(FileName, node, 'No Data');
  if ~isnan(mapData.NoDataVal)
    mapData.matrix(mapData.matrix >= mapData.NoDataVal) = NaN;
  end
else
  mapData.zConverter = [];
  mapData.NoDataVal = [];
end

function zData = ExtractZData(node)
zData = [];
mapHdf = GetMapHdf(node);
[zData.matrix, zData.zUnit] = GetZDataWithUnits(mapHdf);
[zData.xySampling, zData.xyUnit] = GetLateralSamplingWithUnits(mapHdf);

function [height, unitOut] = GetZDataWithUnits(mapHdf)
unitOut = 'um';
unitIn = mapHdf.zConverter.BaseUnit{:};
switch unitIn
  case 'NanoMeters'
    zScale = 1e-3;
```

```
  case 'MicroMeters'
    zScale = 1e+0;
  case 'MilliMeters'
    zScale = 1e+3;
  case 'Meters'
    zScale = 1e+6;
  case 'Fringes'
    S = mapHdf.zConverter.Parameters{:}(3);
    O = mapHdf.zConverter.Parameters{:}(4);
    W = mapHdf.zConverter.Parameters{:}(2);
    zScale = 1e6 * S * O * W;
  otherwise
    unitOut = unitIn;
    zScale = 1;
end
height = mapHdf.matrix * zScale;

function [xySampling, unit] = GetLateralSamplingWithUnits(mapHdf)
xRes_um = 1e6 * mapHdf.xConverter.Parameters{:}(2);
yRes_um = 1e6 * mapHdf.yConverter.Parameters{:}(2);
if (xRes_um > 0 && yRes_um > 0)
  xySampling = [xRes_um, yRes_um];
  unit = 'um';
else
  xySampling = [1, 1];
  unit = 'pix';
end

function [X, Y, x, y] = GetLateralGrid(xySampling, mapSize)
x = (0 : mapSize(2) - 1) * xySampling(1);
y = (0 : mapSize(1) - 1) * xySampling(2);
[Y, X] = ndgrid(y, x);

function hFig = PlotHeightData(mapData, label)
[X, Y] = GetLateralGrid(mapData.xySampling, size(mapData.matrix));
hFig = figure('Name',label, 'NumberTitle','off');
surf(X, Y, mapData.matrix);
shading flat;
SetupAxesAndLabels(label, mapData.xyUnit, mapData.zUnit)

function hFig = PlotIntensityData(mapData, label)
hFig = PlotHeightData(mapData, label);
colormap gray;
view([0 90]);

function SetupAxesAndLabels(plotTitle, latUnit, zUnit)
title(plotTitle);
rawAspect = daspect();
daspect(rawAspect([1 1 3]));
xlabel(sprintf('X [%s]', latUnit));
ylabel(sprintf('Y [%s]', latUnit));
zlabel(sprintf('Z [%s]', zUnit));
```

axis tight;

datx C++ Code Example

```
// DatxSample.cpp : Defines the entry point for the console application.
//

#include "stdafx.h"

#include <stdio.h>
#include <stdlib.h>
#include <limits>
#include <map>

/*
Downloaded HFD5 v1.8.21 from https://www.hdfgroup.org/
Installed HDF5 v1.8.21 to "C:\Program Files\HDF_Group\HDF5\1.8.21"

Built using Visual Studio 2017

Modifications to the default project settings
- VC++ Directories / Include Directories -- add "C:\Program
Files\HDF_Group\HDF5\1.8.21\include"
- VC++ Directories / Library Directories -- add "C:\Program
Files\HDF_Group\HDF5\1.8.21\lib"
- C/C++ / Preprocessor / Preprocessor Definitions -- add H5_BUILT_AS_DYNAMIC_LIB
- Linker / Input / Additional Dependencies -- add hdf5.lib
*/
#include "hdf5.h"

#pragma region Data Structures

struct MetaData
{
	char* source;
	char* link;
	char* destination;

	MetaData() : source(nullptr), link(nullptr), destination(nullptr) {}

	~MetaData()
	{
		if (this->source != nullptr)		free(this->source);
		if (this->link != nullptr)		free(this->link);
		if (this->destination != nullptr) free(this->destination);
	}
};

struct MetaDataNode
{
	std::string name;
	std::map<std::string, MetaDataNode*> links;

	static std::map<std::string, MetaDataNode> nodes;
};
std::map<std::string, MetaDataNode> MetaDataNode::nodes;

struct Window2D
{
	int rowStart;
```

```
		int columnStart;
		int width;
		int height;
	};

	struct UnitConverter
	{
		char* category;
		char* baseUnit;
		char* subCategory;
		char* subUnit;
		hvl_t parameters;

		UnitConverter() :
			category(nullptr), baseUnit(nullptr), subCategory(nullptr),
	subUnit(nullptr), parameters({ 0, nullptr })
		{
		}

		~UnitConverter()
		{
			if (this->category != nullptr)		free(this->category);
			if (this->baseUnit != nullptr)		free(this->baseUnit);
			if (this->subCategory != nullptr) free(this->subCategory);
			if (this->subUnit != nullptr)		free(this->subUnit);
			if (this->parameters.p != nullptr) free(this->parameters.p);
		}
	};

	struct UnitNumber
	{
		UnitConverter unitConverter;
		double value;
	};

	#pragma endregion

	#pragma region Global Variables

	namespace
	{
		hid_t file_id;
		MetaDataNode metaData;

		hid_t string_id;
		hid_t metaData_id;
		hid_t window2D_id;
		hid_t unitConverter_id;
		hid_t unitNumber_id;

		double* surfaceData = nullptr;
		double surfaceMean;
		double surfacePeak;
		double surfaceValley;
		int surfacePointCount;
		Window2D surfaceWindow;
		UnitConverter surfaceConverterZ;

		int* intensityData = nullptr;
		double intensityMean;
```

```
        int intensityPeak;
        int intensityValley;
        int intensityPointCount;
        Window2D intensityWindow;

        std::string softwareName;
        std::string softwareVersion;
        double lateralResolution = 0;
        int cameraWidth;
        int cameraHeight;
}

#pragma endregion

void CreateDataType()
{
        // Variable length string
        // - Used by several other data types
        string_id = H5Tcopy(H5T_C_S1);
        if (string_id < 0)
        {
                return;
        }
        H5Tset_size(string_id, H5T_VARIABLE);

        // Meta-Data
        metaData_id = H5Tcreate(H5T_COMPOUND, sizeof(MetaData));
        if (metaData_id < 0)
        {
                return;
        }
        size_t offset = HOFFSET(MetaData, source);
        H5Tinsert(metaData_id, "Source", offset, string_id);

        offset = HOFFSET(MetaData, link);
        H5Tinsert(metaData_id, "Link", offset, string_id);

        offset = HOFFSET(MetaData, destination);
        H5Tinsert(metaData_id, "Destination", offset, string_id);


        // Window2D
        window2D_id = H5Tcreate(H5T_COMPOUND, sizeof(Window2D));
        if (window2D_id > 0)
        {
                size_t offset = HOFFSET(Window2D, rowStart);
                H5Tinsert(window2D_id, "RowStart", offset, H5T_NATIVE_INT32);

                offset = HOFFSET(Window2D, columnStart);
                H5Tinsert(window2D_id, "ColumnStart", offset, H5T_NATIVE_INT32);

                offset = HOFFSET(Window2D, width);
                H5Tinsert(window2D_id, "Width", offset, H5T_NATIVE_INT32);

                offset = HOFFSET(Window2D, height);
                H5Tinsert(window2D_id, "Height", offset, H5T_NATIVE_INT32);
        }

        // Unit Converter
```

```
        // - Used by Unit Number and as by itself
        // - Uses a variable length array of doubles
        hid_t arrayType = H5Tvlen_create(H5T_NATIVE_DOUBLE);
        if (arrayType > 0)
        {
                unitConverter_id = H5Tcreate(H5T_COMPOUND, sizeof(UnitConverter));
                if (unitConverter_id > 0)
                {
                        size_t offset = HOFFSET(UnitConverter, category);
                        H5Tinsert(unitConverter_id, "Category", offset, string_id);

                        offset = HOFFSET(UnitConverter, baseUnit);
                        H5Tinsert(unitConverter_id, "BaseUnit", offset, string_id);

                        offset = HOFFSET(UnitConverter, subCategory);
                        H5Tinsert(unitConverter_id, "SubCategory", offset,
string_id);

                        offset = HOFFSET(UnitConverter, subUnit);
                        H5Tinsert(unitConverter_id, "SubUnit", offset, string_id);

                        offset = HOFFSET(UnitConverter, parameters);
                        H5Tinsert(unitConverter_id, "Parameters", offset,
arrayType);
                }
        }

        // Unit Number
        if (unitConverter_id > 0)
        {
                unitNumber_id = H5Tcreate(H5T_COMPOUND, sizeof(UnitNumber));
                if (unitNumber_id > 0)
                {
                        size_t offset = HOFFSET(UnitNumber, unitConverter);
                        H5Tinsert(unitNumber_id, "Converter", offset,
unitConverter_id);

                        offset = HOFFSET(UnitNumber, value);
                        H5Tinsert(unitNumber_id, "Value", offset,
H5T_NATIVE_DOUBLE);
                }
        }

}

void OpenFile(char* fileName)
{
        printf("Opening data file...\n");

        // Open the HDF5 file
        file_id = H5Fopen(fileName, H5F_ACC_RDONLY, H5P_DEFAULT);
        if (file_id < 0)
        {
                printf("- error opening data file\n");
                return;
        }

        // Read the meta-data so we know where data is stored
        // 1. Create type that tells HDF5 API how to copy data to our structure
```

```
        // 2. Read the data
        // 3. Convert the data to nodes to make searching easier

        // 1. Create type that tells HDF5 API how to copy data to our structure
        CreateDataType();
        if (metaData_id < 0)
        {
               printf("- error creating HDF5 data types\n");
               return;
        }

        // 2. Read the data
        // - Open the dataset
        // - Query the size of the dataset
        // - Read data into newly allocated memory
        hid_t data_id = H5Dopen(file_id, "/MetaData", H5P_DEFAULT);
        if (data_id < 0)
        {
               printf("- error opening meta-data\n");
               return;
        }

        // - Query the size of the dataset
        hid_t space_id = H5Dget_space(data_id);
        if (space_id < 0)
        {
               printf("- error getting meta-data size\n");
               return;
        }
        hsize_t count = H5Sget_simple_extent_npoints(space_id);

        // - Read data into newly allocated memory
        MetaData *rawData = new MetaData[count];
        int error = H5Dread(data_id, metaData_id, H5S_ALL, H5S_ALL, H5P_DEFAULT,
rawData);
        if (error < 0)
        {
               printf("- error reading meta-data\n");
        }

        // 3. Convert the data to nodes to make searching easier
        // - Since we're making copies of the nodes, we need to put them
        //   back after modifying them
        for (hsize_t idx = 0; idx < count; idx++)
        {
               MetaDataNode& source = MetaDataNode::nodes[rawData[idx].source];
               if (source.name.size() == 0)
               {
                      source.name = rawData[idx].source;
               }

               MetaDataNode& dest = MetaDataNode::nodes[rawData[idx].destination];
               if (dest.name.size() == 0)
               {
                      dest.name = rawData[idx].destination;
               }

               source.links[rawData[idx].link] = &dest;
```

```
        }

        metaData = MetaDataNode::nodes["Root"];
}

void ReadSurface()
{
        printf("Reading surface data...\n");

        if (file_id < 0)
        {
                printf("- data file not opened\n");
                return;
        }

        // 1. Get the path to the surface data
        MetaDataNode* node = metaData.links["Measurement"];
        if (node != nullptr) node = node->links["Surface"];
        if (node != nullptr) node = node->links["Path"];
        if (node == nullptr)
        {
                printf("- file does not contain surface data\n");
                return;
        }

        // Declare all the variables the need to be cleaned up
        // - Using goto is
        hid_t data_id = 0;
        hid_t file_space_id = 0;
        hid_t memory_space_id = 0;
        hid_t attr_id;
        int error;
        double fileNoData;

        // 2. Open the dataset
        data_id = H5Dopen(file_id, node->name.c_str(), H5P_DEFAULT);
        if (data_id < 0)
        {
                goto Exit;
        }

        // 3. Read the dataset's attributes
        // 3a. coordinates
        if (H5Aexists(data_id, "Coordinates") > 0)
        {
                attr_id = H5Aopen(data_id, "Coordinates", H5P_DEFAULT);
                error = H5Aread(attr_id, window2D_id, &surfaceWindow);
                if (error < 0)
                {
                        // Failed to read attribute, we'll fill in default
information later
                        surfaceWindow = { 0, 0, 0, 0 };
                }

                H5Aclose(attr_id);
        }
        else
        {
                // Attribute doesn't exist, we'll fill in default information later
```

```
            surfaceWindow = { 0, 0, 0, 0 };
        }

        // 3b. No Data Values
        if (H5Aexists(data_id, "No Data") > 0)
        {
            attr_id = H5Aopen(data_id, "No Data", H5P_DEFAULT);
            error = H5Aread(attr_id, H5T_NATIVE_DOUBLE, &fileNoData);
            if (error < 0)
            {
                // Failed to read the attribute, pretend it is NaN
                fileNoData = std::numeric_limits<double>::quiet_NaN();
            }
            H5Aclose(attr_id);
        }
        else
        {
            // Attribute doesn't exist, pretend it is NaN
            fileNoData = std::numeric_limits<double>::quiet_NaN();
        }

        // 3c. X Unit Converter
        //     - This is optional. Since we are getting the lateral resolution
from
        //       the data attributes, we don't need to get it here.

        // 3d. Y Unit Converter
        //     - This is optional. Since we are getting the lateral resolution
from
        //       the data attributes, we don't need to get it here.

        // 3e. Z Unit Converter
        if (H5Aexists(data_id, "Z Converter") > 0)
        {
            attr_id = H5Aopen(data_id, "Z Converter", H5P_DEFAULT);
            error = H5Aread(attr_id, unitConverter_id, &surfaceConverterZ);
            if (error < 0)
            {
                // Failed to read attribute, reset the data
                surfaceConverterZ.category = nullptr;
            }
        }
        else
        {
            // Attribute doesn't exist, reset the data
            surfaceConverterZ.category = nullptr;
        }

        // 4. Read the size of the dataset and resize data memory
        // Open the data space
        file_space_id = H5Dget_space(data_id);
        if (file_space_id < 0)
        {
            goto Exit;
        }

        // Get the size of the data
        hsize_t dims[2];
```

```
        error = H5Sget_simple_extent_dims(file_space_id, dims, nullptr);
        if (error < 0)
        {
                goto Exit;
        }

        // Allocate unmanaged memory for the data
        surfaceData = new double[dims[1] * dims[0]];
        if (surfaceData == nullptr)
        {
                goto Exit;
        }

        // Create the memory space
        memory_space_id = H5Screate_simple(2, dims, dims);
        if (memory_space_id < 0)
        {
                goto Exit;
        }

        // Fill in missing coordinate information
        if ((surfaceWindow.width == 0) || (surfaceWindow.height == 0))
        {
                surfaceWindow.width = (int)dims[1];
                surfaceWindow.height = (int)dims[0];
        }

        // 5. Read the dataset into memory
        error = H5Dread(
                data_id,
                H5T_NATIVE_DOUBLE,
                memory_space_id,
                file_space_id,
                H5P_DEFAULT,
                surfaceData);
        if (error < 0)
        {
                delete[] surfaceData;
                surfaceData = nullptr;

                goto Exit;
        }

        // 6. Convert dataset no data values into desired no data values
        if (!std::isnan(fileNoData))
        {
                for (double *ptr = surfaceData, *end = ptr + (int)(dims[0] *
dims[1]); ptr != end; ptr++)
                {
                        if (*ptr >= fileNoData)
                        {
                                *ptr = std::numeric_limits<double>::quiet_NaN();
                        }
                }
        }

        // 7. Convert data memory from file units to desired units
        if (strcmp(surfaceConverterZ.category, "HeightCat") == 0)
```

```
        {
                double scalar = 1;
                if (strcmp(surfaceConverterZ.baseUnit, "NanoMeters") == 0)
                {
                        // Convert nanometers to micrometers
                        scalar = 1e-3;
                }
                else if (strcmp(surfaceConverterZ.baseUnit, "Fringes") == 0)
                {
                        // To convert fringes to waves, multiply each data value by
(S * O).
                        // To convert fringes to meters, multiply each data value by
(S * O * W).
                        // Where:
                        //      S = Interferometric Scale Factor
                        //      O = Obliquity Factor
                        //      W = Wavelength in meters
                        double S = ((double*)surfaceConverterZ.parameters.p)[2];
                        double O = ((double*)surfaceConverterZ.parameters.p)[3];
                        double W = ((double*)surfaceConverterZ.parameters.p)[1];

                        // Convert fringes to meters
                        scalar = S * O * W;

                        // Convert meters to micrometers
                        scalar *= 1e6;
                }

                // We don't need to worry about no data since any operation with
                // NaN gives us NaN
                for (double *ptr = surfaceData, *end = ptr + (int)(dims[0] *
dims[1]); ptr != end; ptr++)
                {
                        *ptr *= scalar;
                }
        }

        // Analyze the data
        surfaceMean = 0;
        surfacePeak = std::numeric_limits<double>::min();
        surfaceValley = std::numeric_limits<double>::max();
        surfacePointCount = 0;
        for (double *ptr = surfaceData, *end = ptr + (int)(dims[0] * dims[1]);
ptr != end; ptr++)
        {
                if (!std::isnan(*ptr))
                {
                        surfacePointCount++;
                        surfaceMean += *ptr;
                        if (*ptr > surfacePeak) surfacePeak = *ptr;
                        if (*ptr < surfaceValley) surfaceValley = *ptr;
                }
        }
        if (surfacePointCount > 0) surfaceMean /= surfacePointCount;

Exit:
        if (memory_space_id > 0)
        {
                H5Sclose(memory_space_id);
```

```
        }
        if (file_space_id > 0)
        {
                H5Sclose(file_space_id);
        }
        if (data_id > 0)
        {
                H5Dclose(data_id);
        }
}

void ReadIntensity()
{
        printf("Reading intensity data...\n");

        if (file_id < 0)
        {
                printf("- data file not opened\n");
                return;
        }

        // 1. Get the path to the intensity data
        MetaDataNode* node = metaData.links["Measurement"];
        if (node != nullptr) node = node->links["Intensity"];
        if (node != nullptr) node = node->links["Path"];
        if (node == nullptr)
        {
                printf("- file does not contain intensity data\n");
                return;
        }

        // Declare all the variables the need to be cleaned up
        // - Using goto is
        hid_t data_id = 0;
        hid_t file_space_id = 0;
        hid_t memory_space_id = 0;
        hid_t attr_id;
        int error;
        int fileNoData;

        // 2. Open the dataset
        data_id = H5Dopen(file_id, node->name.c_str(), H5P_DEFAULT);
        if (data_id < 0)
        {
                goto Exit;
        }

        // 3. Read the dataset's attributes
        // 3a. coordinates
        if (H5Aexists(data_id, "Coordinates") > 0)
        {
                attr_id = H5Aopen(data_id, "Coordinates", H5P_DEFAULT);
                error = H5Aread(attr_id, window2D_id, &intensityWindow);
                if (error < 0)
                {
                        // Failed to read attribute, we'll fill in default
information later
                        intensityWindow = { 0, 0, 0, 0 };
                }
```

```
            H5Aclose(attr_id);
        }
        else
        {
            // Attribute doesn't exist, we'll fill in default information later
            intensityWindow = { 0, 0, 0, 0 };
        }

        // 3b. No Data Values
        if (H5Aexists(data_id, "No Data") > 0)
        {
            attr_id = H5Aopen(data_id, "No Data", H5P_DEFAULT);
            error = H5Aread(attr_id, H5T_NATIVE_INT32, &fileNoData);
            if (error < 0)
            {
                // Failed to read the attribute, pretend it is NaN
                fileNoData = std::numeric_limits<int>::max();
            }
            H5Aclose(attr_id);
        }
        else
        {
            // Attribute doesn't exist, pretend it is INT_MAX
            fileNoData = INT_MAX;
        }

        // 3c. X Unit Converter
        //      - This is optional. Since we are getting the lateral resolution
from
        //        the data attributes, we don't need to get it here.

        // 3d. Y Unit Converter
        //      - This is optional. Since we are getting the lateral resolution
from
        //        the data attributes, we don't need to get it here.

        // 3e. Z Unit Converter
        //      - This is optional. With intensity data, the units are counts and
        //        there is no need to convert to other units.

        // 4. Read the size of the dataset and resize data memory
        // Open the data space
        file_space_id = H5Dget_space(data_id);
        if (file_space_id < 0)
        {
            goto Exit;
        }

        // Get the size of the data
        hsize_t dims[2];
        error = H5Sget_simple_extent_dims(file_space_id, dims, nullptr);
        if (error < 0)
        {
            goto Exit;
        }

        // Allocate unmanaged memory for the data
```

```
        intensityData = new int[dims[1] * dims[0]];
        if (intensityData == nullptr)
        {
                goto Exit;
        }

        // Create the memory space
        memory_space_id = H5Screate_simple(2, dims, dims);
        if (memory_space_id < 0)
        {
                goto Exit;
        }

        // Fill in missing coordinate information
        if ((intensityWindow.width == 0) || (intensityWindow.height == 0))
        {
                intensityWindow.width = (int)dims[1];
                intensityWindow.height = (int)dims[0];
        }

        // 5. Read the dataset into memory
        error = H5Dread(
                data_id,
                H5T_NATIVE_INT32,
                memory_space_id,
                file_space_id,
                H5P_DEFAULT,
                intensityData);
        if (error < 0)
        {
                delete[] intensityData;
                intensityData = nullptr;

                goto Exit;
        }

        // Analyze the data
        intensityMean = 0;
        intensityPeak = std::numeric_limits<int>::min();
        intensityValley = std::numeric_limits<int>::max();
        intensityPointCount = 0;
        for (int *ptr = intensityData, *end = ptr + (int)(dims[0] * dims[1]); ptr
!= end; ptr++)
        {
                if (*ptr < fileNoData)
                {
                        intensityPointCount++;
                        intensityMean += *ptr;
                        if (*ptr > intensityPeak) intensityPeak = *ptr;
                        if (*ptr < intensityValley) intensityValley = *ptr;
                }
        }
        if (intensityPointCount > 0) intensityMean /= intensityPointCount;

Exit:
        if (memory_space_id > 0)
        {
                H5Sclose(memory_space_id);
```

```
        }
        if (file_space_id > 0)
        {
                H5Sclose(file_space_id);
        }
        if (data_id > 0)
        {
                H5Dclose(data_id);
        }
}

void ReadAttributes()
{
        printf("Reading data attributes...\n");

        if (file_id < 0)
        {
                printf("- data file not opened\n");
                return;
        }

        // Get the path to the data attributes
        MetaDataNode* node = metaData.links["Measurement"];
        if (node != nullptr) node = node->links["Attributes"];
        if (node == nullptr)
        {
                printf("- file does not contain data attributes\n");
                return;
        }

        // Initialize information we are reading, in case of error
        softwareName = "Unknown";
        softwareVersion = "Unknown";
        lateralResolution = 0;
        cameraWidth = 0;
        cameraHeight = 0;

        // Open the data attributes group
        hid_t group_id = H5Gopen(file_id, node->name.c_str(), H5P_DEFAULT);
        if (group_id < 0)
        {
                return;
        }

        // Read the software name
        std::string attrName = "Data Context.Data Attributes.Software Info Name";
        if (H5Aexists(group_id, attrName.c_str()) > 0)
        {
                hid_t attr_id = H5Aopen(group_id, attrName.c_str(), H5P_DEFAULT);
                if (attr_id > 0)
                {
                        char* szData;
                        int error = H5Aread(attr_id, string_id, &szData);
                        if (error >= 0)
                        {
                                softwareName = szData;
                                free(szData);
                        }
```

```
                H5Aclose(attr_id);
            }
        }

        // Read the software version
        attrName = "Data Context.Data Attributes.Software Info Version";
        if (H5Aexists(group_id, attrName.c_str()) > 0)
        {
            hid_t attr_id = H5Aopen(group_id, attrName.c_str(), H5P_DEFAULT);
            if (attr_id > 0)
            {
                char* szData;
                int error = H5Aread(attr_id, string_id, &szData);
                if (error >= 0)
                {
                    softwareVersion = szData;
                    free(szData);
                }
                H5Aclose(attr_id);
            }
        }

        // Read the lateral resolution
        attrName = "Data Context.Lateral Resolution";
        if (H5Aexists(group_id, attrName.c_str()) > 0)
        {
            hid_t attr_id = H5Aopen(group_id, attrName.c_str(), H5P_DEFAULT);
            if (attr_id > 0)
            {
                UnitNumber data;
                int error = H5Aread(attr_id, unitNumber_id, &data);
                if (error >= 0)
                {
                    // data.unitConverter.baseUnit is "Meters"
                    lateralResolution = data.value;
                }
                H5Aclose(attr_id);
            }
        }

        // Read the camera width
        attrName = "Data Context.Data Attributes.Camera Width";
        if (H5Aexists(group_id, attrName.c_str()) > 0)
        {
            hid_t attr_id = H5Aopen(group_id, attrName.c_str(), H5P_DEFAULT);
            if (attr_id > 0)
            {
                UnitNumber data;
                int error = H5Aread(attr_id, unitNumber_id, &data);
                if (error >= 0)
                {
                    // data.unitConverter.baseUnit is "Pixels"
                    cameraWidth = (int)data.value;
                }
                H5Aclose(attr_id);
            }
        }
```

```
        // Read the camera width
        attrName = "Data Context.Data Attributes.Camera Height";
        if (H5Aexists(group_id, attrName.c_str()) > 0)
        {
                hid_t attr_id = H5Aopen(group_id, attrName.c_str(), H5P_DEFAULT);
                if (attr_id > 0)
                {
                        UnitNumber data;
                        int error = H5Aread(attr_id, unitNumber_id, &data);
                        if (error >= 0)
                        {
                                // data.unitConverter.baseUnit is "Pixels"
                                cameraHeight = (int)data.value;
                        }
                        H5Aclose(attr_id);
                }
        }

        // Cleanup
        H5Gclose(group_id);
}

void CloseFile()
{
        printf("Closing file...\n");
        if (file_id > 0)
        {
                H5Fclose(file_id);
                file_id = 0;
        }
}

void PrintAttributes()
{
        printf("Data Attributes\n");
        printf("\tSoftware Info:      %s v%s\n", softwareName.c_str(),
softwareVersion.c_str());
        printf("\tLateral Resolution: ");
        if (lateralResolution > 0)
        {
                double pix2um = lateralResolution * 1e6;
                printf("%0.4g m/pix\n", lateralResolution);
                printf("\tCamera Size:        %d x %d pix\n", cameraWidth,
cameraHeight);
                printf("\tCamera Size:        %0.3f x %0.3f um\n", cameraWidth *
pix2um, cameraHeight * pix2um);
        }
        else
        {
                printf("undefined\n");
                printf("\tCamera Size:        %d x %d pix\n", cameraWidth,
cameraHeight);
        }
        printf("\n");
}

void PrintSurface()
{
        if (surfaceData == nullptr)
        {
```

```
		printf("No Surface Data\n");
	}
	else
	{
		printf("Surface Information\n");
		printf("\tOrigin:           (%d, %d)\n",
surfaceWindow.columnStart, surfaceWindow.rowStart);
		printf("\tSize:             %d x %d\n", surfaceWindow.width,
surfaceWindow.height);
		printf("\tValid Point Count: %d\n", surfacePointCount);
		printf("\tMean:             %0.3f um\n", surfaceMean);
		printf("\tPeak:             %0.3f um\n", surfacePeak);
		printf("\tValley:           %0.3f um\n", surfaceValley);
		printf("\tPV:               %0.3f um\n", surfacePeak -
surfaceValley);
	}
	printf("\n");
}

void PrintIntensity()
{
	if (intensityData == nullptr)
	{
		printf("No Intensity Data\n");
	}
	else
	{
		printf("Intensity Information\n");
		printf("\tOrigin:           (%d, %d)\n",
intensityWindow.columnStart, intensityWindow.rowStart);
		printf("\tSize:             %d x %d\n", intensityWindow.width,
intensityWindow.height);
		printf("\tValid Point Count: %d\n", intensityPointCount);
		printf("\tMean:             %d\n", (int)(intensityMean + 0.5));
		printf("\tPeak:             %d\n", intensityPeak);
		printf("\tValley:           %d\n", intensityValley);
		printf("\tPV:               %d\n", intensityPeak -
intensityValley);
	}
	printf("\n");
}

int main(int argc, char* argv[])
{
	if (argc != 2)
	{
		printf("USAGE: DatxSample.exe fileName.datx\n");
		return -1;
	}

	OpenFile(argv[1]);
	ReadSurface();
	ReadIntensity();
	ReadAttributes();
	CloseFile();

	printf("\n");
	printf("Summary for %s\n", argv[1]);

	PrintAttributes();
```

```
        PrintSurface();
        PrintIntensity();

    return 0;
}
```

15.2 dat Format

The dat format is the native MetroPro binary data file format. It is called “binary” because the values are stored in low-level machine representations (e.g. bytes and words instead of lines of text). The files cannot be read or written with an ordinary text editor.

The following information about the binary data file format is provided so that a programmer can develop:

- Reader software to read and correctly interpret files.
- Writer software to create files that can be read and correctly interpreted by ZYGO software.

File Structure

The general file structure is as follows:

Data Set 1 (required)

Data Set 2…N (optional)

Most binary data files contain just one Data Set. Only a few of the various types of applications create binary data files containing multiple Data Sets (e.g. MST applications).

A Data Set is structured as follows:

Header (required)

Intensity Data Matrix (optional)

Phase Data Matrix (optional)

A Data Set will always contain at least one, often both of the two types of matrices: Intensity and Phase.

Every binary data file begins with a Header (the one associated with the first Data Set).

The Header contains many data items or fields. Only a few of these values are essential to properly access and interpret the Intensity and Phase data matrices. Most of the other fields may be considered non-essential attributes (e.g. ancillary information about the measurement setup).

The Header fields have various data types and byte orders indicated by the key letters in the following table:

Key Letter	Meaning
I	Integer numeric field
F	Floating point numeric field (IEEE standard format)
B	Numeric field stored in big-endian byte order
L	Numeric field stored in little-endian byte order
S	String field, null terminated
C	Character field

The first 10 bytes of the Header contain three fields that serve as a “signature” for the binary data file. These fields are described in the following table:

Key	Bytes	Length	Field Name
IB	0001-0004	4	magic_number
IB	0005-0006	2	header_format
IB	0007-0010	4	header_size

There are only three recognized combinations of these values as shown in the following table:

magic_number (hex)	header_format	header_size (bytes)
0x881B036F	1	834
0x881B0370	2	834
0x881B0371	3	4096

Reader software that is rigorous should read all three values and validate them per the above table.

dat Intensity Data Matrix

The Intensity Data Matrix is typically a matrix of pixel intensity values grabbed from the instrument camera. (In MetroPro, this is normally displayed in an Intensity Map data window.) This matrix may contain multiple camera frames or “buckets”. Or, it may contain a single frame that is the result of a transform applied to multiple frames (e.g. Remove Fringes).

The essential Header fields required to access and properly interpret the Intensity Data Matrix are described below.

Key	Bytes	Length	Field Name
IB	0049-0050	2	ac_org_x
IB	0051-0052	2	ac_org_y
IB	0053-0054	2	ac_width
IB	0055-0056	2	ac_height
IB	0057-0058	2	ac_n_buckets
IB	0059-0060	2	ac_range
IB	0061-0064	4	ac_n_bytes

(The prefix ac_ stands for acquired.)

The **ac_org_x** and **ac_org_y** values are the coordinates of the origin (upper left) of the intensity data matrix relative to the origin of the camera (upper left).

The **ac_width** and **ac_height** values are the X and Y dimensions of the matrix, respectively.

The **ac_n_buckets** value is the number of frames in the matrix.

The **ac_range** value is the maximum expected intensity value (e.g. 255 for an 8-bit frame grabber).

The **ac_n_bytes** value is the total number of bytes occupied by the intensity matrix in the file.

If the Intensity Data Matrix is present in the Data Set, then it begins immediately after the Header.

Each data point is an unsigned 16-bit (2-byte) integer stored in big-endian byte order. The points are in row-major order, beginning at the upper left.

The total number of points is: ac_width • ac_height • ac_n_buckets.

Valid points are in the range [0,ac_range]. Invalid points (dropouts) have value 65535 (hex 0xFFFF).

dat Phase Data Matrix

The Phase Data Matrix typically represents a surface or wavefront map (e.g. this matrix would normally be displayed in a MetroPro Surface/Wavefront Map data window). It was named “phase data” because when it was conceived, the data was obtained using phase modulating interferometry.

The essential Header fields required to access and properly interpret the Phase Data Matrix are described in the following table:

Key	Bytes	Length	Field Name
IB	0065-0066	2	cn_org_x
IB	0067-0068	2	cn_org_y
IB	0069-0070	2	cn_width
IB	0071-0072	2	cn_height
IB	0073-0076	4	cn_n_bytes
FB	0165-0168	4	intf_scale_factor
FB	0169-0172	4	wavelength_in
FB	0177-0180	4	obliquity_factor
IB	0219-0220	2	phase_res

(The prefix cn_ stands for connected.)

The **cn_org_x** and **cn_org_y** values are the coordinates of the origin (upper left) of the phase data matrix relative to the camera origin (upper left).

The **cn_width** and **cn_height** values are the X and Y dimensions of the matrix, respectively.

The **cn_n_bytes** value is the total number of bytes occupied by the matrix in the file.

If the Phase Data Matrix exists in the data set, then it begins immediately after the Intensity Data Matrix, if that exists. If the Intensity Data Matrix does not exist, then the Phase Data matrix begins immediately after the Header.

Each phase data point is a signed 32-bit (4-byte) integer stored big-endian byte order. The points are in row-major order, beginning at the upper left.

The total number of points is: cn_width • cn_height.

Valid points are normally in the range [–2097152,2097151]. Invalid points (dropouts) have values greater than or equal to 2147483640 (hex 0x7FFFFFF8).

The phase data values are in units of “zygos”. A zygo is a fraction of a fringe of interference.

To convert a phase data value to waves, meters or some other standard unit, it is necessary to utilize four other values obtained from the Header.

The **intf_scale_factor** value is a unit-less positive number. It is a scale factor corresponding to the interferometric setup (e.g. 0.5 for double-pass). (This value is set by the MetroPro Intf Scale Factor control.)

The **wavelength_in** value is a positive number in meters specifying the wavelength of the interferometer light source (e.g. 6.328e-7 m for a HeNe laser). (This value is set by the MetroPro Wavelength-In control.)

The **obliquity_factor** value is a unit-less positive number. It is a scale factor, usually close to 1, that corrects for a non-normal mean angle of incidence in interferometric microscopes.

The **phase_res** value is an integer indirectly specifying the resolution of a zygo. (This is set by the MetroPro Phase Res control.) Note that the interpretation of the **phase_res** value changed when the **header_format** was changed from 1 to 2. The following table shows how to determine the resolution value (R) based on the **header_format** and **phase_res** values:

header_format	phase_res	R
1	0	4096
1	1	32768
2 or 3	0	4096
2 or 3	1	32768
2 or 3	2	131072

The resolution of a zygo is (1/R) fringe.

To convert a phase data value from zygos to a height, use these formulas:
S = intf_scale_factor
W = wavelength_in
O = obliquity_factor
R = resolution from above table

To convert to a height in **waves**, multiply by (S • O / R).

To convert to a height in **meters**, multiply by (W • S • O / R).

15.3 int Format

The int (or INT) file format is an industry standard format (originally developed by Optical Research Associates) for describing interferogram data in optical design software. It is used as a generic file format for interferometric wavefront deformation data, surface deformation data, or transmission data in the form of ASCII text files. The file extension is .int.

An INT (or interferogram) file contains general information and a series of numbers representing the surface or phase map. Information is represented as either a regular grid of points or as Zernike polynomials. INT files, including grid (GRD), standard Zernike (ZRN), and fringe Zernike (ZFR) can be exported and imported.

INT Data File Format

The INT format is used by CODEV for a variety of data types. In its simplest form, an INT file contains general header information and a series of numbers representing the data described in the header. An INT file includes the following:

- Multiple comment lines for user notations. A comment begins with the "!" character. All information in the line following the "!" is ignored.
- A title; up to 80 characters long; required for full compatibility with other programs.
- A parameter line indicating whether the data is in the form of a rectangular grid (GRD) of points, a Standard Zernike polynomial (ZRN), or a Fringe Zernike (ZFR) polynomial. Only those parameters specified by Mx are displayed.
- INT values.

Parameter line for rectangular grid data supported by Mx

```
GRD x_size y_size SUR|WFR|FIL WVL wavelength SSZ scale_size NDA
no_data_value
```

Parameter line for polynomial data

```
ZRN|ZFR num_terms SUR|WFR WVL wavelength SSZ scale_size
```

Parameter line definitions

`GRD x_size y_size`	The size of the data grid in pixels (x_size always precedes y_size). When exported from Mx these are the camera dimensions in pixels.
`ZRN | ZFR num_terms`	Number of terms in the standard Zernike polynomial (ZRN) or FRINGE Zernike polynomial (ZFR). ZFR is limited to a maximum of 37 terms. ZRN may have any number of terms, although Mx currently limits this number to 91.
`SUR | WFR | FIL`	Defines how the optical design package interprets data. Options are surface height data (SUR), wavefront data (WFR), or intensity apodization filter data (FIL). New versions of CODEV have additional options for this parameter. Only SUR, WFR, and FIL are supported by Mx.
`WVL wavelength`	The measurement wavelength (in micrometers).
`SSZ scale_size`	The value of the input data that is equal to one wave of deformation (SUR and WFR data) or that corresponds to a transmission of unity (FIL data). Mx sets this to 1.0 for export of polynomial INT files so that the coefficients are recorded in units of waves.
`NDA no_data_value`	It is the value of the input data that is interpreted as no data, or missing data. When used in optical design packages this will block rays. This is used for GRD data only.
`XSC non-unity`	Because grid interferograms are assumed to cover a square area, the XSC value is used to describe the relative shape of the data; 1 = square data; >1 = horizontal rectangle; <1 = vertical rectangle. Because Mx works with square pixels, XSC is x_size/y_size.

INT Values

The data in a grid INT file is literally a grid of values (7 digit integers) with 10 per record (row). There are the same number of values as the product of the size of the grid. Data is read by rows from -X to +X (left to right) starting at +Y (top). The coordinate system is Positive up and Positive right.

The values in a Zernike INT file are real numbers that correspond to the number of polynomial terms.

Importing INT Files

To import a grid (GRD) formatted INT file, select Import Data from the File menu. Refer to Importing Data.

To import a polynomial (ZRN or ZFR) formatted INT file, click the Import button found either in the Data Generate tool or in the Fit Remove tool (under User Remove tab). Refer to INT File Import.

Exporting INT Files

To export a GRD formatted INT file select Export Data from the File menu (saves raw data), or right-click on any given plot and select Export Data from the context menu (saves processed data). Refer to Exporting Data.

To export a ZRN or ZFR formatted INT file click on the Export button found either in the Data Generate tool or in the Fit Remove tool (under Fit/Remove tab and User Remove tab). Refer to INT File Export.

INT File Examples

Example INT GRD File

```
!6 inch f/7.2 Transmission Sphere
!
MetroProX
GRD 443 443 SUR WVL 0.6328 SSZ 1299063.869328 NDA -32768
  -32768  -32768  -32768  -32768  -32768  -32768  -32768  -32768  -32768  -32768
  -32768  -32768  -32768  -32768  -32768  -32768  -32768  -32768  -32768  -32768
...
  -32768  -32768  -32768  -32768  -32768  -32768  -32768  -32768  -32768  -32768
  -32768  -32768  -18137  -19782  -21765  -22974  -24322  -25095  -25709  -26205
  -26740  -27473  -28207  -28841  -29059  -29039  -28901  -28326  -27295  -26581
  -26007  -25749  -25412  -25689  -26145  -26304  -26482  -26344  -26363  -26978
  -27037  -26661  -26522  -26304  -26304  -26264  -26284  -26363  -26403  -26165
  -25927  -25590  -25709  -25947  -25828  -25055  -24302  -23113  -21408  -20119
...
   14054   11021   11536   11992   11794   11973   12111   11477   11398   12052
   12349   12290   12250   12250   12250   12052   11735   11953   12092   11675
   12072   12191   11675   11735   12191   12270   12052   11794   11695   11675
   11913   11219   10189    9396    8464    7969    8127    9237   10050    9257
    8464    8147    8761    9634   10030   10089    9852    9138    8722    8722
    8940    8860    8821    9534    9634    9257    8583    9079    9871   10367
    9852    9257    8821    8702    8900    8979    8880    8920    9416    9812
```

In the above example-

Line 1 is based on Comments field user entry.

Line 3 is based on Title user entry.

Line 4 is based on file attributes; no data has a value of -32768.

Line 5 and below is a long listing of grid data values, which have been greatly shortened for this example.

This .int file example is from an File > Export Data function.

Example INT ZFR File

```
!Zygo Corporation
!7/15/2010 12:18:18 PM
!
!test int output
!
INT file created in Fit Remove
ZFR 9 WFR WVL 0.632799981303833 SSZ 1
-0.632810150232923
-0.33538323794348
-0.537913433735918
-0.708766351489655
-2.05348635161802
-0.854962563145111
-0.53867745664552
-0.0115714350251705
-0.00755260996728151
```

In this example-

Line 1 and 2 are auto generated.

Line 4 is based on Comments field user entry.

Line 6 is based on Title field user entry.

Line 7 is based on file attributes.

Line 8 and below is a list of polynomial terms; in this example these are the fit values in the Fit Remove tool.

This .int file example is from a Fit Remove tool export (Export Fit Coefficients).

Exchanging Coefficients

INT File Import

Available in the Fit Remove tool (under User Remove tab) or in the Data Generate tool.

Use to import coefficients.

1. Click the Import button.
2. In the Open file dialog, locate the file you want to open.
3. Click Open.

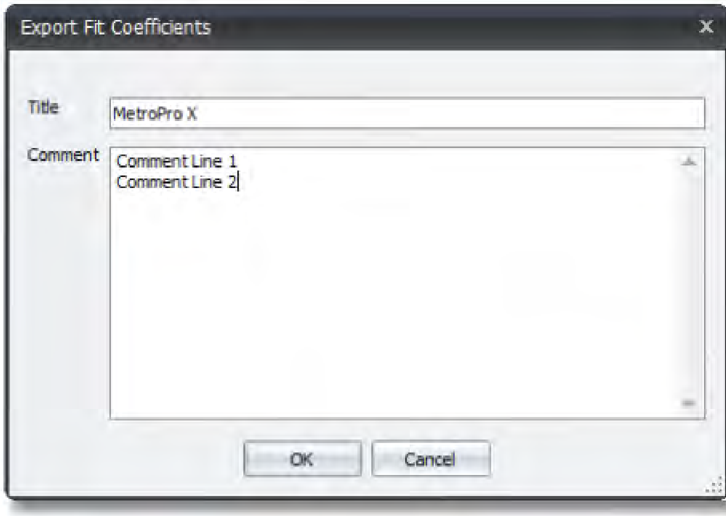
INT File Export

Available in the Fit Remove tool (under Fit/Remove tab and User Remove tab), in the Data Generate tool, and in the Zernike analysis.

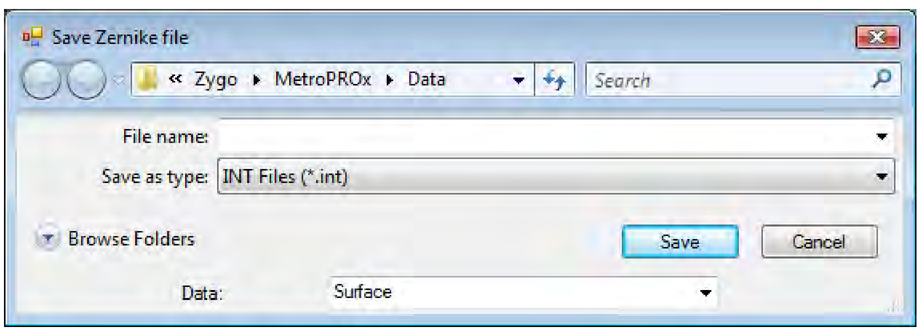
Use to export coefficients.

The scale factor in the INT file saves all Coefficients within the text file in waves.

1. Click the Export button or right-click and select Export.
2. In the Export Fit Coefficients dialog, type a title and a comment, if desired. Then click OK.



3. In the Save Zernike file dialog type a file name, and select the Data as Surface or Wavefront. Then click Save.



Pasting Coefficients into Microsoft Excel

1. Select rows in the polynomial table. Selected rows are highlighted.

   To select or deselect one row, press Ctrl and click the row. To select multiple rows or a range of rows, click on one row, move the pointer to another row, then press the Shift key and click a mouse button.

2. Press Ctrl-C.
3. Go to Excel and press Ctrl-V.

15.4 asc (ASCII) Format

This section describes the format of an ASC (or ASCII) data file. The file is made up of three parts: header, intensity data, and phase data. Each part is followed by a line containing a sharp (#) character. At least one of the data sets must be present. ASC files can be imported and exported.

Importing ASC Files

Refer to Importing Data.

Exporting ASC Files

Refer to Exporting Data.

ASCII Data File Programming Notes

This section provides notes for persons writing programs to create compatible ASCII data files.

- The string fields must be blank-padded to the indicated fixed length.
- If a data set is not present, its concluding line containing a sharp character must still be present.
- Many of the fields in the header can be assigned null values since they are not used in calculations. Null values are zero for numeric fields or blanks for string fields. The following paragraphs indicate which fields must have true values.
- The IntensOriginX, IntensOriginY and PhaseOriginX, PhaseOriginY coordinates must be non-negative.
- The IntensWidth, Height and NBuckets values must correctly indicate the number of points in the intensity data matrix.
- The PhaseWidth, PhaseHeight values must correctly indicate the number of points in the phase data matrix.
- The CameraWidth, CameraHeight fields must describe a camera coordinate system that encloses the intensity and phase data matrices.
- In order that phase values be correctly analyzed, the IntfScaleFactor, ObliquityFactor, WavelengthIn, and PhaseRes fields must have true values.
- In order that intensity values be correctly analyzed, the IntensRange field must have a true value.
- If lateral dimensions are to be reported in units other than pixels, the CameraRes field must have a true value.
- In order to obtain correct encircled energy and MTF cutoff frequency results, the NumericAperture field must have a true value.

ASCII Header Information

The header consists of 13/14 required lines of information. Line 1 is a string constant (not enclosed in quotes). The remaining lines contain named fields.

There are 2 types (or formats) of ASCII files. Format 1 does not have Line 14. Format 2 has Line 14. Mx reads both formats but writes Format 2.

Line	Field Name
1	Zygo ASCII Data File - Format 2
2	SoftwareType MajorVers MinorVers BugVers SoftwareDate
3	IntensOriginX IntensOriginY IntensWidth IntensHeight NBuckets IntensRange
4	PhaseOriginX PhaseOriginY PhaseWidth PhaseHeight
5	Comment
6	PartSerNum
7	PartNum
8	Source IntfScaleFactor WavelengthIn NumericAperture ObliquityFactor Magnification CameraRes TimeStamp
9	CameraWidth CameraHeight SystemType SystemBoard SystemSerial InstrumentId ObjectiveName
10	AcquireMode IntensAvgs PZTCal PZTGain PZTGainTolerance AGC TargetRange LightLevel MinMod MinModPts
11	PhaseRes PhaseAvgs MinimumAreaSize DisconAction DisconFilter ConnectionOrder RemoveTiltBias DataSign CodeVType
12	SubtractSysErr SysErrFile
13	RefractiveIndex PartThickness
14	ZoomDesc

Header Field Descriptions

Each header field in an ASCII data file is described below. The types of fields are: integer, real, and string. The integer fields are always whole numbers. The real fields may be whole numbers, decimal, or exponential notation. The string fields are fixed-length (blank padded) and enclosed in double-quotes (“ ”).

SoftwareType This integer indicates what program created the data file. The programs are: unknown (0) (includes Mx), MetroPro (1), MetroBASIC (2), and d2bug (3).

MajorVers, MinorVers, BugVers These integers contain the version numbers of the program that created the data file.

SoftwareDate This 30-character string contains the time and date that the program was created.

IntensOriginX, IntensOriginY These integers are the coordinates of the origin of the intensity data matrix. They refer to positions in the camera coordinate system. The origin of the camera coordinate system (0,0) is located in the upper left corner of the video monitor.

IntensWidth, IntensHeight These integers are the width (columns) and height (rows) of the intensity data matrix. If no intensity data is present, this value is zero.

NBuckets This integer is the number of buckets of intensity data that are stored. Currently, one bucket of intensity data is stored. If no intensity data matrix is present, this value is zero.

IntensRange This unsigned integer is the maximum possible value of an intensity data point.

PhaseOriginX, PhaseOriginY These integers are the coordinates of the origin of the connected phase data matrix. They refer to positions in the camera coordinate system. The origin of the camera coordinate system (0,0) is located in the upper left corner of the display.

PhaseWidth, PhaseHeight These integers are the width (columns) and height (rows) of the connected phase data matrix. If no phase data is present, these values are zero.

Comment This 81-character string is a user-entered remark line.

PartSerNum This 39-character string is a user-entered serial number for the part measured.

PartNum This 39-character string is a user-entered identifier of the part measured.

Source This integer indicates the source of the data. A value of 0 indicates the data is from an instrument; 1 indicates that the data was generated.

IntfScaleFactor This real number is the interferometric scale factor. It is the number of waves per fringe as specified by the user.

WavelengthIn This real number is the wavelength, in meters, at which the interferogram was measured.

NumericAperture This real number is 1 / (2 * f-number).

ObliquityFactor This real number is a phase correction factor required when using a Mirau objective on a microscope. A value of 1.0 indicates no correction factor was required.

Magnification This real number is reserved for future use.

CameraRes This real number is the lateral resolving power of a camera pixel in meters/pixel. A value of 0 means that the value is unknown.

TimeStamp This integer is the system representation of the date and time the data was measured or generated. It is the number of seconds since 0:00:00 January 1, 1970.

CameraWidth, CameraHeight These integers are the width (columns) and height (rows) of the usable camera field in pixels.

SystemType This integer indicates the type of system used to make the measurement. The system may be: Mark IVxp (1), Maxim•3D (2), Maxim•NT (3), GPI-XP (4), NewView (5), Maxim•GP (6), NewView/GP (7), Mark to GPI conversion (8), or none (0), if the data was software generated.

SystemBoard This integer indicates which system board was in use when the data measurement was taken. Valid values range from 0 to 7.

SystemSerial This integer indicates the serial number of the instrument.

InstrumentId This integer indicates the instrument unit number. Valid values range from 0 to 7.

ObjectiveName This is an 11-character string. For the microscopes, this field indicates the objective in use when the measurement was taken. For laser interferometers, this field indicates the aperture in use when the measurement was taken. If the data was generated, this field is blank.

AcquireMode This integer indicates the setting of the Acquisition Mode control. The settings are: phase (0), fringe (1), or scan (2).

IntensAvgs This integer is the number of intensity averages performed. Values of 0 or 1 indicate no averaging.

PZTCal This integer indicates whether or not the modulation amplitude was automatically adjusted during acquisition. A value of 1 indicates adjustment; a value of 0 indicates no adjustment.

PZTGain This integer specifies the modulation amplitude value used during data acquisition.

PZTGainTolerance This integer specifies a PZT error range if PZT calibration was adjusted.

AGC This integer indicates whether or not automatic gain control was performed during data acquisition. A value of 1 indicates AGC was used; a value of 0 indicates AGC was not used.

TargetRange This real number is the acceptable tolerance limits of the light intensity used during AGC.

LightLevel This integer is the light level setting used during data acquisition.

MinMod This integer is the minimum value of modulation needed to calculate a phase value. MinMod is equal to 10.23 * MinMod(%). MinMod(%) is a user setting indicating a percentage of full modulation each camera pixel must have in order to be accepted as a valid data point.

MinModPts This integer is the minimum number of data points required to pass MinMod criteria during AGC.

PhaseRes This integer indicates the resolution of the phase data points. A value of 0 indicates normal resolution, with each fringe represented by 4096 counts. A value of 1 indicates high resolution, with each fringe represented by 32768 counts.

PhaseAvgs This integer is the number of phase averages performed.

MinimumAreaSize This integer is the minimum number of contiguous data points required for a valid data region. Any smaller regions are deleted.

DisconAction This integer indicates the action taken when the system encountered discontinuities in phase data. The discontinuity actions are: delete regions (0), filter regions (1), and ignore (2).

DisconFilter This real number specifies the degree to which discontinuities were removed when DisconAction was filter. Valid values range from 0 (none) to 100 (all).

ConnectionOrder This integer specifies the order in which separate regions of phase data were processed. The order may be by location (0) or by size (1).

RemoveTiltBias This integer indicates whether or not the tilt bias was removed from the phase data. A value of 1 indicates it was removed; a value of 0 indicates it was not removed.

DataSign This integer indicates the sign of the data. The data sign may be normal (0) or inverted (1).

CodeVType This integer indicates whether the phase data represents a wavefront (0) or a surface (1). This information is used by the CODE V program.

SubtractSysErr This integer indicates whether or not the system error was subtracted from the phase data. A value of 1 indicates that it was subtracted; a value of 0 indicates it was not subtracted.

SysErrFile This 14-character string is a user-entered name of the file containing the system error data.

RefractiveIndex This real number is the index of refraction as specified by the user. Currently, this value is used only in the calculation of corner cube dihedral angles.

PartThickness This real number is the thickness, in meters, of the part measured. Currently, this value is only relevant to the calculation of homogeneity.

ZoomDescr This 7-character string is the value of the image zoom used during data acquisition.

ASCII Intensity and Phase Data

ASCII Data File Intensity Data

Each data point is an integer. The data is written 10 data points per line in row-major order. Acceptable values are from 0 to the value specified in IntensRange. An invalid point is indicated by a value ≥ 65535. A line containing only a sharp character (#) is output after the data. The number of intensity data points is:

*IntensWidth * IntensHeight * NBuckets*

ASCII Data File Connected Phase Data

Each data point is an integer. The data is written 10 data points per line in row-major order. Acceptable values are in the range from -2097152 to +2097151. An invalid point is indicated by a value ≥ 2147483640. A line containing only a sharp character (#) is output after the data. The number of connected phase data points is:

*PhaseWidth * PhaseHeight*

The phase data points are in internal units representing a scaled number of fringes. To convert a value to waves, multiple by (S * O)/R.

Where: S = IntfScaleFactor, O = ObliquityFactor, and R = 4096 for normal PhaseRes or 32768 for high PhaseRes.

ASCII Data File Example

Following is an example data file containing tiny 6x6 intensity and phase data matrices. Note that line 5 containing the Comment field is truncated.

Header Fields

```
Zygo ASCII Data File - Format 1
1 1 6 6 “Thu May 23 15:36:21 EDT 1991 “
122 118 6 6 1 1023
122 118 6 6
“
“     “
“     “
0 0.5 6.328e-07 0 1 0 0 671819076
262 235 1 0 5555 0 “Sm Aperture”
0 0 1 1686 3 1 0.1 40 71 50
0 0 20 1 0 0 0 0 0
0 “   “
0 0
0
#
```

Intensity Data Matrix

```
404 414 414 423 434 448 422 431 435 442
452 459 459 460 456 458 465 470 464 453
449 445 456 474 459 462 457 450 444 457
453 444 440 425 421 430
#
```

Phase Data Matrix

```
2530 2566 2606 2649 2698 2751 2693 2731 2773 2812
2868 2913 2860 2905 2944 2990 3036 3094 3030 3072
3121 3161 3207 3261 3206 3255 3298 3337 3381 3423
3356 3410 3452 3503 3548 3592
#
```

15.5 sdf Format

An sdf file is made up of three parts: header, phase data, and trailer. All sections are followed by a line consisting of an asterisk (*). A semi-colon (;) is used to comment the remaining line. SDF files in binary format is supported.

sdf Header Information

The header consists of 13 required lines of information. Line 1 is a string constant (not enclosed in quotes). The remaining lines contain information about the measurement system and data file. They have the following format: record_name " = " value. A list of record_names is shown in the table below.

Information	ASCII Record Name	Binary Data Type	Binary Length (bytes)
Version Number		unsigned char	8
Manufacture's ID	ManufacID	unsigned char	10
Creation Time and Date	CreateDate	unsigned char	12
Last Modification Time and Date	ModDate	unsigned char	12
Number of Points per Profile	NumPoints	unsigned int	2
Number of Profiles	NumProfiles	unsigned int	2
X-Scale	Xscale	double	8
Y-Scale	Yscale	double	8
Z-Scale	Zscale	double	8
Z-Resolution	Zresolution	double	8
Compression Type	Compression	unsigned char	1
Data Type	DataType	unsigned char	1
Check Sum Type	CheckType	unsigned char	1

SDF Data File Header Field Descriptions

Each header field in a SDF data file is described below. The types of the fields are noted in the above table.

Version Number	This field must be the first line of the data file. It indicates what version of SDF format was used to generate the data file. The only valid value for this field is "aBCR-1.0".
Z-Scale	This is the lateral resolution of the z-axis. Value is in meters.
Manufacture's ID	This field specifies what version of MetroPro was used to create the data. The first two characters are MP for MetroPro and the remaining characters are the version number of MetroPro.
Creation Time and Date	This is the time and date the original data file was created. It is in the format DDMMYYYYHHMM and zero padding is required (i.e. 0307 for July 3rd versus 37). The hour is in 24 hour format. Therefore, 120719971421 is July 12, 1997 at 2:21PM.
Last Modification Time and Date	This field is similar to the Creation Time and Date except it represents the last time the SDF file was changed.
Number of Points per Profile	This is the number of columns in the data set. This number is stored in a word cannot exceed 65535.
Number of Profiles	This is the number of rows in the data set. This number is stored in a word cannot exceed 65535.
X-Scale	This is the lateral resolution between data points along the x-axis. Value is in meters.
Y-Scale	This is the lateral resolution between data points along the y-axis. Value is in meters.
Z-Scale	This is the lateral resolution of the z-axis. Value is in meters.
Z-Resolution	This is the lateral resolution of the z-axis. Value is in meters.
Compression Type	This field specifies what type of compression is used on the data. Since no compression is used, this field is zero (0).
Data Type	This field what format the data is in. MetroPro SDF data file stores its data as unsigned long so this value is always two (2). Any data values equal to maximum value of an unsigned long (4,294,967,295) represent an invalid data point which should not be used in calculations.
Check Sum Type	This field is always zero (0).

sdf Data File Data

Each data point is an unsigned long integer. The data is written 10 data points per line in row-major order. Acceptable values are less than 4,294,967,295. The data points values are scaled; to convert to meters, multiply valid the data point value by Z-Scale. A line consisting of only an asterisk (*) is output after the data. The number of data points is:

*NumPoints * NumProfiles*

SDF Data File Trailer

The trailer section is used to store additional information not stored in the header. This information consists of every field in the Binary Data File header and is used to ensure proper conversion back to Binary format. Although most fields are optional, the following are required to convert from SDF to Binary: camera_width, camera_height, obliquity_factor, num_aperture, lateral_res, intf_scale_factor, wavelength_in and phase_res. The format of this information if the same as in the header.

SDF Data File Programming Notes

This section provides notes for persons writing programs to read MetroPro SDF data files.

- The data file format consists of series of records terminated with CR (#13), LF (#10) or CR+LF.
- Additional “white space” characters (#9, #10, #13, #32) are ignored including those in the data section.
- All real numbers are composed of the following characters ‘0’ … ‘9’, ‘.’, ‘e’, ‘E’, ‘+’, ‘-’.
- All three sections are of the file (header, data, and trailer) are terminated with a single record containing the character ‘*’ (#42). Thus the final ‘*’ record identifies the end of the data file.
- All three sections are of variable length.
- Any record information following a ‘;’ (#59) character is considered a comment and is ignored.
- Elements of the header are given as separate records for readability and ease of file I/O.
- The first record of the data file is always the version number.
- All other records pertaining to the header may be placed in any order in the header section.
- Each record in the header contains three (3) parts: the record ID, a separator (=), and the value.

sdf Data File Example

```
aBCR-1.0                      ; This is always the first line
ManufacID = MP6.5.6           ; the following records
;                             can be presented in
;                             any order
CreateDate = 210819971517     ; Aug 21, 1997 @ 3:17PM
ModDate = 020219981407        ; Feb 2, 1998 @ 2:07PM
NumPoints = 132
NumProfiles = 169
Xscale = 1.19246e-05
Yscale = 1.19246e-05
Zscale = 9.67234e-12
Zresolution = 9.67234e-12
Compression = 0               ; NONE
DataType = 2                  ; UNSIGNED LONG
CheckType = 0                 ; NONE
*
201658 201855 202180 202237 201903
201983 202030 202194 201937 202100
202365 202366 202260 202583 202624
202904 202322 202875 202645 202927
202991 203169 203354 203555 204347
205257 206923 4294967295      ; last point is a bad data point
1241499 1241611 1241771 1241923 1242201
…
1242252 1242104 1242048 1242157 1242029
*
; Additional Information
operator = Don Trump
shift = 1
* ; End Of File
```

15.6 xyz Format

This section describes the format of a XYZ data file. The file is made up of two parts: header and measurement data. The parts are separated by a line containing a sharp (#) character.

XYZ Data File Header Information

This section is identical to the ASCII data file header. See ASCII Header Information.

XYZ Data File Connected Phase Data

The data in this section is organized by phase origin. Each line contains three pieces of data. The first two columns contain the column (y) and row (x) location of the data, beginning at the phase origin. The third number on the line can be either the character string “No Data” or a floating-point number corresponding to the measurement in microns.

XYZ Pixel Resolution

The camera resolution is found on the eighth line of the header (CameraRes) (in meters/pixel). Multiply this number by the appropriate factor to obtain the resolution needed. The horizontal and vertical pixel resolution can be calculated as follows:

CameraRes = 1.81512e-005

To get microns (10-6 meters): (.000018512)*(1000000) = 18.512 microns.

The horizontal and vertical pixel resolutions are the same.

XYZ Data File Notes

Be aware that the resultant file will be larger than the original file due to it being ASCII, not binary, and requiring three fields (x, y, z) for the original phase data. Intensity data will be lost when the file is converted back to binary (.dat) format, since it is not maintained in the .xyz file.

xyz Data File Example

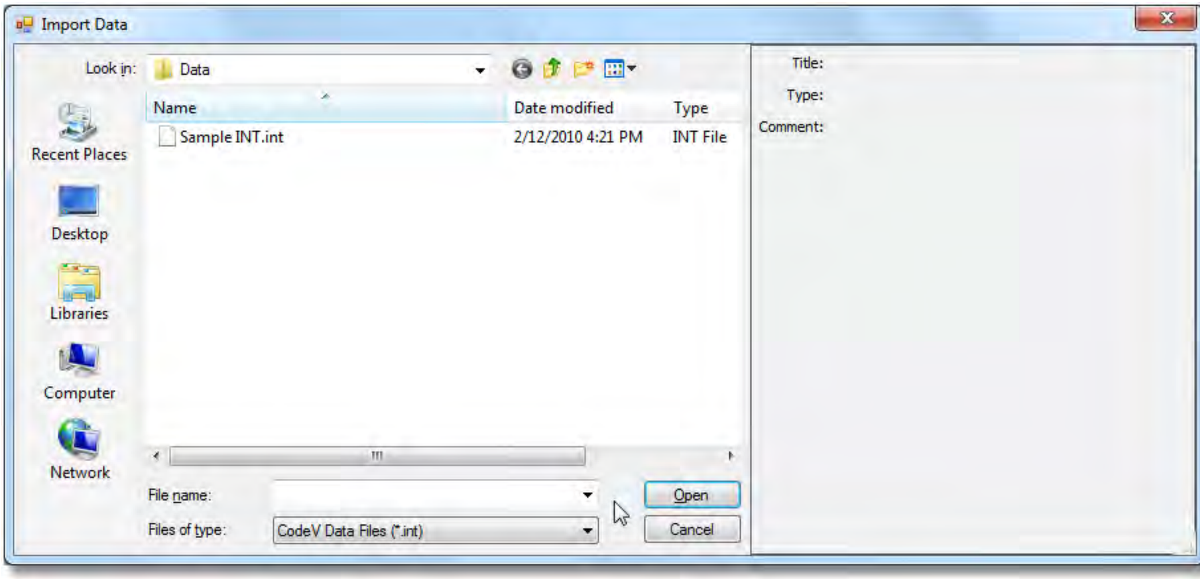
```
Zygo XYZ Data File - Format 1
1 7 3 2 "Thu May 25 10:05:01 2017     "
0 0 560 420 1 255
130 5 413 412
"Xxxxxx Engine Company, Inc.            "
"                                       "
"4001896- Armature & Plunger            "
0 0.5 6.48e-007 0 1 0 1.81512e-005 908907731
560 420 11 0 -15531 0 "2.5X  Mich "
2 0 0 0 0 0 0 28.7912 10 0
0 0 7 1 60 0 0 0 0
0 "               "
1 0
#
130 5 No Data
131 5 No Data
132 5 No Data
133 5 No Data
134 5 No Data
…
330 5 No Data
331 5 2.434588
332 5 2.459188
333 5 2.447323
334 5 2.434904
…
537 417 No Data
538 417 No Data
539 417 No Data
540 417 No Data
541 417 No Data
#
```

15.7 Importing Data

General File Import

To open a dat, xyz, or an asc file, on the File menu select Load Data.

1. On the File menu select Import Data.



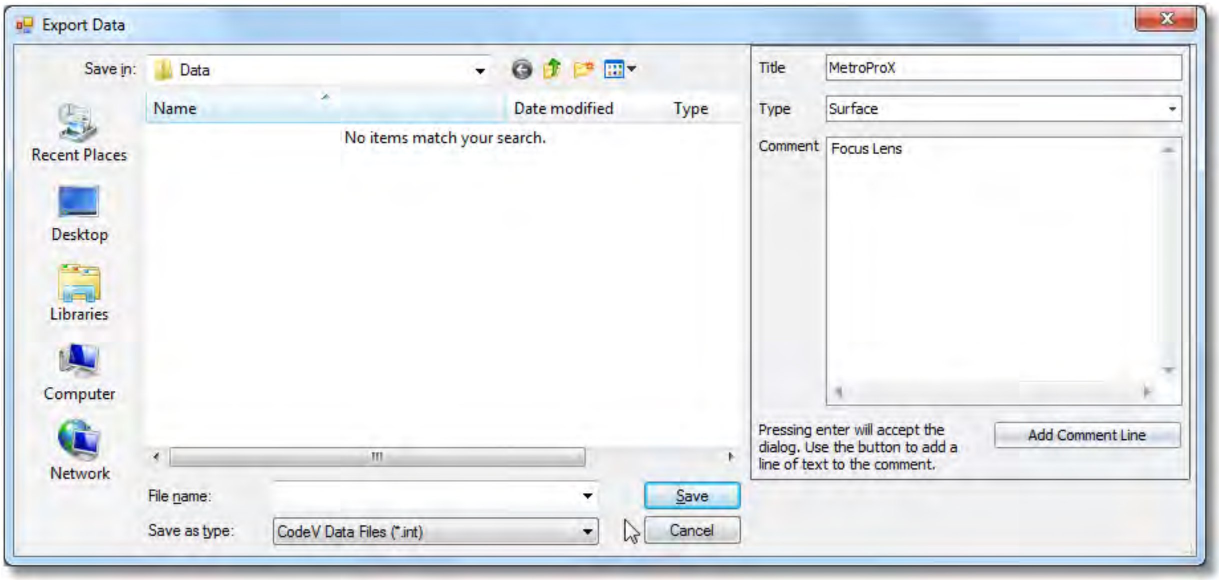
2. Choose the file type with the Files of type drop-down list.
3. Click the file from the list or type a file name.
4. Click Open.

15.8 Exporting Data

General File Export

The Export Data command in the File menu saves raw data. A plot context menu Export Data command saves processed data.

1. On the File menu select Export Data.



To save existing measurement data as a dat, xyz, or an asc file, on the File menu select Save Data.

2. Choose the file type with the Save as type drop-down list.
3. Enter or select appropriate details in file information panel on the right side of the dialog.

   For INT files, select Type (Wavefront, Surface, or Filter). The Title and Comment are optional.

   For SDF files, enter user-specific details. Optionally select the Binary check box.

   For SUR files, no additional entry is needed.

   For STL files, select the desired output units.
4. Type a File name and click Save.

15.9 Exporting Table Data

- This information applies to Process Statistics and the Polynomial Table in the Fit Remove tool.
- The contents of table cells is output in an alphanumeric format data with the actual underlying numbers with all the original precision.
- The shading and selection of cells is also retained when exporting as Excel or PDF.

See Printing and Export Chart Data for additional exporting capabilities.

For details on working with tabular data see Working With Tables.

Exporting as an Excel File

Makes an Excel file of the currently displayed statistics.

1. Click the Excel button, or right-click and select Output ▶ Excel (or Export ▶ Excel).
2. In the Export to Excel dialog, specify the directory location, enter a File name, and press Save.

Excel output retains the exact look as it appears in the Process Statistics and Summary Statistics. This is particularly true for the number of significant digits. If 2 significant digits are displayed in the process statistics, Excel is formatted the same way. If you want greater precision in Excel, you can simply re-format the data cell since data is exported in full precision.

Exporting as a PDF File

Makes a PDF file of the currently displayed statistics.

1. Click the Pdf button, or right-click and select Output ▶ Pdf (or Export ▶ Pdf).
2. In the Export to Pdf dialog, specify the directory location, enter a File name, and press Save.

PDF output retains the exact look as it appears in the Process Statistics and Summary Statistics.

Using the Clipboard

Use to export data as tab separated text.

1. Select the desired cells (see Selecting Cells).
2. Press Ctrl-C, or right-click and select Copy to Clipboard.
3. Go to the external program where you want the data, and press Ctrl-V.

Exporting as an Image

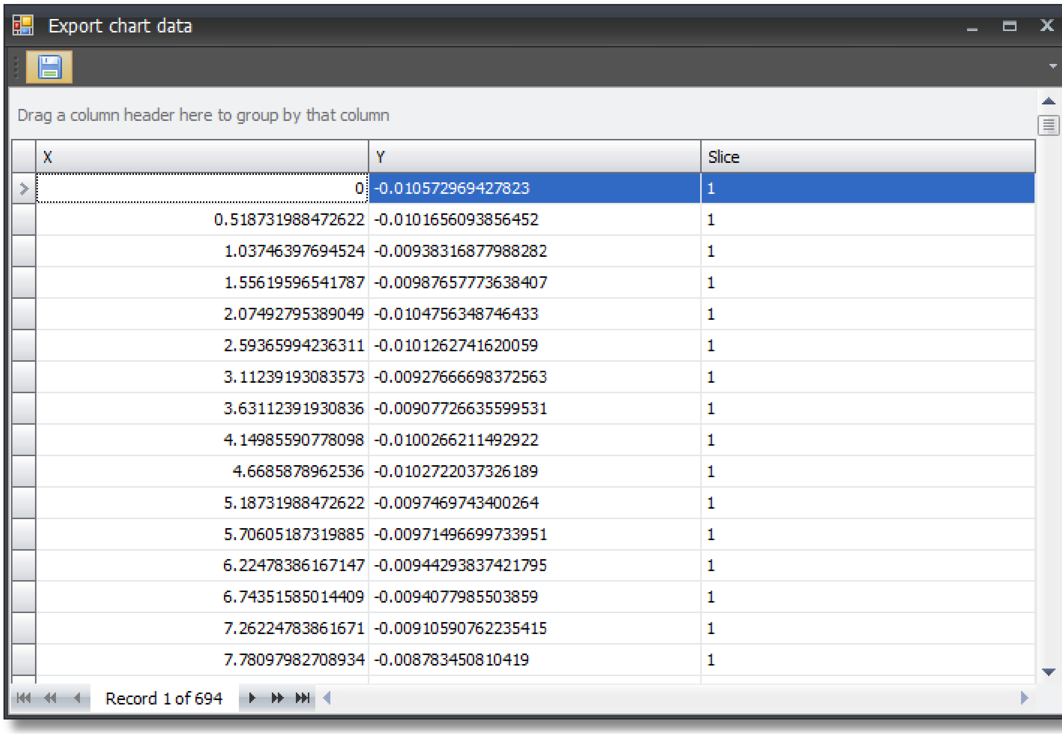
Some tables may be exported as an image format.

See "Exporting as Image".

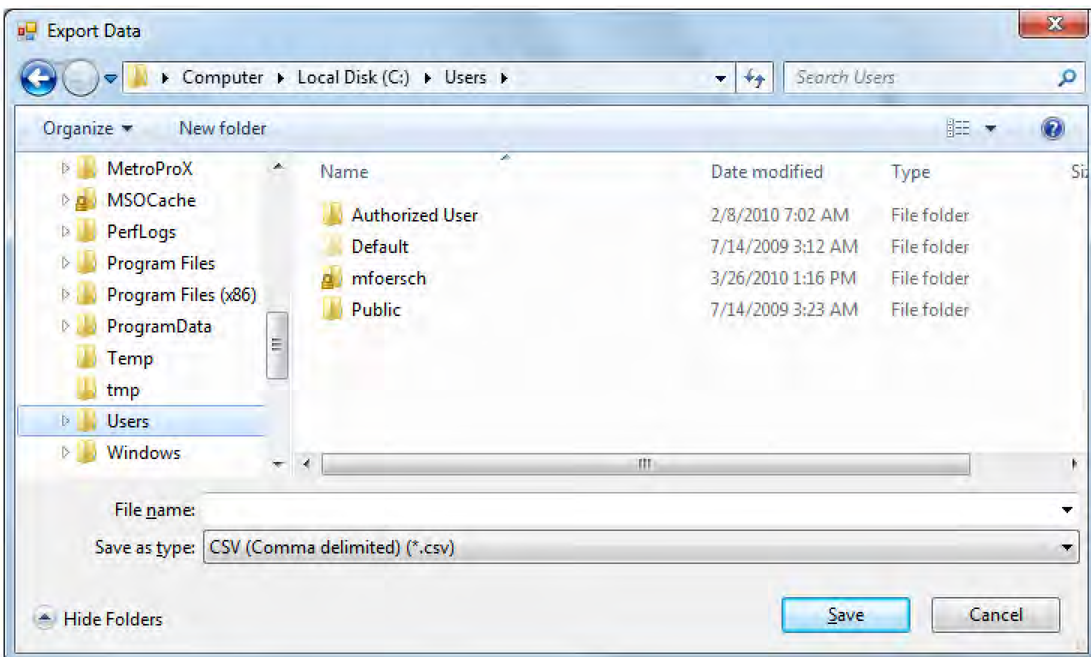
15.10 Exporting Chart Data

- This information applies to most 1D plots, such as: line profile plots, circular profile plots, histograms, control charts, and PSD plots.
- The data is exported with the actual underlying numbers with all the original precision.

1. Right-click on the plot and select Export.



2. Click the Save button.



3. Use the Windows Explorer panel to choose the directory location.
4. Choose the file type with the Save as type drop-down box.
5. Type a name for the data after File name.
6. Click Save.

Export File Types and Extensions

Type	Extension	Description
CSV	csv	Comma Separated Values or comma delimited, is a text based file format with each group of information separated by a comma, and typically used is spreadsheet applications.
Text	txt	A format in which information is made up of basic unformatted alphanumeric characters.
PDF	pdf	Short for Portable Document Format. A file format created by Adobe Systems for easy document exchange.
Excel Workbook	xlsx	The default spreadsheet file format for spreadsheets data in Microsoft Excel 2007. It is a combination of XML architecture and ZIP compression for size reduction.
Excel 97-2003 Workbook	xls	A spreadsheet file format developed by Microsoft. This format contains data in worksheets, charts, and macros.
Web Page	html	Short for HyperText Markup Language. A text based format using a markup language for web pages.
Single File Web Page	mht	Short for MIME HTML. A web page archive format used to bind resources which are typically represented by external links (such as images) together with HTML code into a single file.
Rich Text Format	rtf	A formatted text based file format developed by Microsoft for cross-platform document interchange.

15.11 Exporting DynaPhase Movies

This information covers the exporting of a DynaPhase movie for use in MATLAB.

- Requires use of MovieExtractor.exe program.
  (located in C:\Program Files\Zygo\MX\Utilities\Movie Utilities)
- The program extracts a CSV and BIN file from a DynaPhase movie (.drmx) file.
- The CSV file stores data file header information in “Name, Value, Unit” format.
- The BIN (binary) file stores the movie data, which is a series of surface maps.

Binary File Format- Header

Offset (bytes)	Size (bytes)	Data Type	Name
0	4	32-bit signed integer	Column Count
4	4	32-bit signed integer	Row Count
8	8	64-bit IEEE floating point	No Data Value

Binary File Format- Data

The data is stored as a number of 2D arrays using 64-bit IEEE floating point values in row-major order; the units are Nanometers. Data point values that are less than the No Data Value are valid; data point values greater than or equal to the No Data Value are invalid.

The number of arrays can be determined using the following formula:

$$ArrayCount = \frac{FileSize - 16}{RowCount * ColumnCount * 8}$$

MATLAB Example

The following is example code that uses MATLAB to read the extracted BIN file and display the first 25 frames.

```
%% Read Zygo Dynafiz Phase Movie file and display results
% Script for importing data from a move file which has been extracted
% from a .drmx file using the MovieExtractor utility.
%
% This Matlab script gets the size of the frames and the number of frames
% and then reads the frames into a data cube in memory.  It then displays
% the first 25 frames.
%
% B. Truax 20-March-2015


%clear all existing data from memory
clear all;
% display a file dialog allowing the user to select the movie file.
[filename, pathname] = uigetfile('*.bin', 'Select a phase movie bin file');
filename = sprintf('%s%s',pathname,filename);
% open the file
fileID = fopen(filename);
% get the file data so that we can determine the file size
s=dir(filename);
Dimensions= fread(fileID,2,'int32',0);
NoDataToken=fread(fileID,1,'double',8);
% comoute the number of frames in the file
frames = ( s.bytes-16)/(Dimensions(1)*Dimensions(2)*8)
%create the data cube
images = [];
% read the images
for (i=1:frames)
   % read an image
   A = fread(fileID,[Dimensions(1) Dimensions(2)],'double');
   % replace all no data values with nan's
   A(A==NoDataToken)=nan;
```

```
   % add the frame to the cube
   images(:,:,i)=A;
end
% plot the first 25 images
scrsz = get(0,'ScreenSize');
windowTitle = sprintf('Phase Movie Plots for %s',filename);
f1=figure('Position',[scrsz(3)/2 10 scrsz(3)/2 scrsz(4)
*.9],'Name',windowTitle,'NumberTitle', 'off');
if (frames >=25)
    numberOfPlots = 25;
else
    numberOfPlots = frames;
end
for (i=1:numberOfPlots)
    subplot(5,5,i);
    contourf(images(:,:,i));
end
```

MATLAB is a registered trademark of The Mathworks, Inc.

15.12 PatchDataX Utility

PatchdDataX is a command line utility that can be used to adjust Mx data file attributes in .dat and .datx files. Not all options are applicable to all data. The table below shows which options can be applied to different types of data.

The utility can be found in C:\Program Files\Zygo\Mx\Utilities\PatchDataX. The entire directory can be copied to whereever the user would like it. The utility is called like this:

PatchDataX option(s) file(s)

One or more Options may be specified. One or more existing Zygo binary data file(s) (extension .dat or .datx) must be specified. The input files are always overwritten with the requested adjustment. If the original data needs to be preserved, be sure to make a copy of the file before running the utility. Profiler is short for optical profiler; OT is short for optical test (laser interferometers).

Options	Description	.dat	.datx	
			Profiler	OT
\?	Will display a Help summary of all of the options/parameters for the utility			
-cd X,Y,Z,P,R,T	Set stage coordinates needed for stitching. There are no spaces in the comma-separated coordinate list. X, Y, and Z coordinates are in millimeters and are required. Pitch, Roll, and Theta are in degrees and are optional. Use * to leave a coordinate unchanged.	No	Yes	Yes
-ch X	Set camera height to X in pixels	Yes	Yes	Yes
-cm S	Set comment to S (quoted text up to 81 chars)	Yes	Yes	Yes
-cr X	Set camera resolution to X in µm	Yes	Yes	Yes
-cw X	Set camera width to X in pixels	Yes	Yes	Yes
-ep X	Set exit pupil diameter to X in mm	Yes	No	No
-fd X,Y	Set fiducial center coordinate to (X,Y) in pixels; up to 7 fiducials can be specified	Yes	Yes	Yes
-id X	Set instrument serial number to X	Yes	Yes	Yes
-is X	Set interferometric scale factor to X	Yes	Yes	Yes
-na X	Set numeric aperture to X	Yes	Yes	No
-of X	Set obliquity factor to X	Yes	Yes	No
-ph X	Set pixel height to X in µm	Yes	No	No
-pn S	Set part number to S (quoted text up to 39 chars)	Yes	Yes	Yes
-pr X	Set phase resolution to X (0=Normal, 1=High or 2=Super)(phase data will be scaled)	Yes	No	No
-pt X	Set part thickness to X in mm	Yes	No	Yes
-pw X	Set pixel width to X in µm	Yes	No	No
-rf X	Set remove fringes to X; valid values are 0, 8, and 64	Yes	Yes	No
-ri X	Set refractive index to X	Yes	Yes	No
-sc	Strip (remove) color data	No	Yes	No
-sh	Shorten header	Yes	No	No
-si	Strip (remove) intensity data	Yes	Yes	Yes
-sn S	Set part serial number to S (quoted text up to 39 chars)	Yes	Yes	Yes
-sp	Strip (remove) phase data	Yes	Yes	Yes
-sq	Strip (remove) quality data	No	Yes	No
-wi X	Set wavelength-in to X in nm	Yes	Yes	Yes
-zm X	Set the encoded zoom magnification for Optical Test data to X	Yes	No	Yes

Error Reporting 16

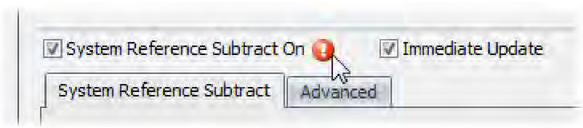
This section provides details about errors. Errors have varying degrees of severity. For some errors, the user is immediately notified via a dialog box. For other errors, the user may not be directly notified but the errors are posted to the Event View.

16.1 Error Indicators

Information Indicator

The red ! indicates that some user action is required.

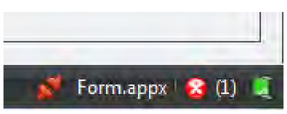
Point to the exclamation mark to read the message.



Status Bar- Error Indicator

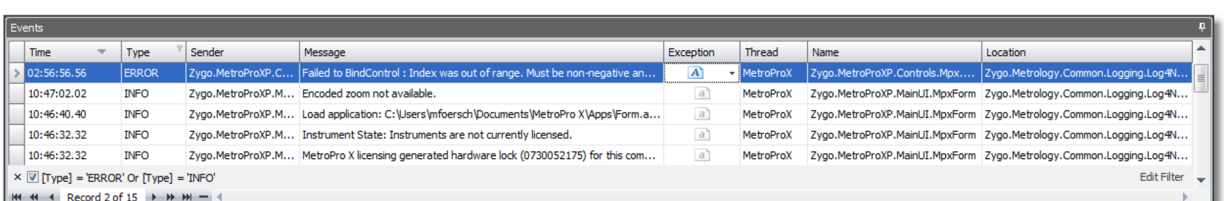
The red X denotes an error, followed by the number of errors currently accumulated in the Event View.

Double click the error to open the Event View.



16.2 Event View

On the View menu, click Event View; or click the error indicator on the status bar.



Examine the Message column for additional information.

Glossary 17

Aberration

Departures of the performance of an optical system from the predictions of paraxial optics. Aberration leads to blurring of the image produced by an image-forming optical system. It occurs when light from one point of an object after transmission through the system does not converge into (or does not diverge from) a single point.

Accuracy

The degree of exactness which the final product corresponds to the measurement standard.

Acquisition

Controlling the instrument to obtain data.

Analysis

Examination and modification of acquired data so it is easier to comprehend.

Application

The overall arrangement of software components designed for a particular instrument and for particular functions.

Areal

A three-dimensional surface area.

Asperity

Unevenness of surface; rugged or sharp outlying areas considered to be of questionable quality.

Averaging

The combining of multiple data acquisitions to improve the measurement quality or overcome environmental issues.

Cartesian Coordinates

A mathematical system used to describe the location of data points. The two-dimensional system uses length and width coordinates. The three-dimensional system provides the three physical dimensions of space — length, width, and height.

Cavity

The empty area between an instrument's optics and the part being measured.

Clip

Refers to the removal of pixels in the z-axis (height).

Connect

The process of joining data points together into a map representing the test part.

Context Menu

A menu that appears with a right mouse click on some program features.

Cutoff Filter

Determines the wavelength at which the surface structure is differentiated between roughness and waviness data. Proper selection of the correct filter cutoff in software is critical to measurement accuracy.

Data Analysis

Analyzing processed data into a meaningful array and displaying the results in appropriate graphic and numerical forms.

Data Processing

Modifying or transforming raw data by such methods as fit and remove, trimming, and filtering.

Evaluation Length

The area from which data is obtained. It is a three-dimensional area that corresponds to the instrument field of view, or a two-dimensional profile that corresponds to the length of the slice as defined in the filled plot.

Fiducial

A reference or data location marker used as an alignment aid or when comparing data sets.

Fit

A mathematical process that uses a least squares fit on the input data to match a general overall shape to the data.

Flaw

Irregularities that occur at one place or relatively infrequent in a part surface. Includes: cracks, holes, ridges, and scratches. Flaws are not included in roughness measurements.

Fringe Pattern

A light and dark banded image of the test part caused by interference between the measurement and reference wavefronts. It indicates the surface structure of the part.

Fringes

The light and dark bands viewed on the live display.

HDF5

A library and multi-object file format for the transfer of graphical and numerical data between computers.

Hybrid Parameters

These parameters are combinations of spacing and roughness parameters.

Interference

The superposition of two or more waves that result in a new wave pattern.

Laser Interferometer

The generic term used for ZYGO instruments that use a laser as a light source.

Lateral Calibration

Using the Lateral Calibrator to determine the actual measurement units of the instrument in the x and y axes .

Lay

A repetitive pattern, usually made by a machining or finishing process, on the surface of a part.

Live Display

An active image direct from the instrument's camera. It may also be referred to as a "fringe monitor".

Map

A three dimensional view of data. It is comprised of two lateral (x, y) axes and one height (z) axis.

Mask

A defined subset in the imaging area that is either included or excluded from the analysis.

Mean Line

A straight line that is generated by calculating a weighted average for each data point resulting in equal areas above and below the line. Also known as center line.

Metrology

The science of measurement. From Ancient Greek metron (measure) and logos (study of).

Modal

A modal window or dialog blocks all other workflow in the main program until the window is closed or the operation is completed.

Navigator

The panel used to select, view, and interact with the data analysis stream.

Null or Nulling

To minimize the number of fringes.

Optical Profiler

The generic term use for ZYGO instruments that use objectives.

Palette

Refers to the color scheme.

Preciseness

Refers to the degree of exactness which a measuring instrument can determine accuracy (actually, inaccuracy).

Profile

A two-dimensional slice through an area or map.

Reliability

Refers to the consistency of accurate results over consecutive measurements.

Remove

The subtracting of the best-fit shape from the input data. It is used to remove the overall predominant shape so the actual quality of the surface can be determined.

Retrace Error

This error refers to the beam taking an aberrated path back through the interferometer. Interferometers are fundamentally well corrected when the cavity is nulled. As the cavity alignment deviates from that, systematic measurement errors are introduced. The magnitude and type of errors is depend on the cavity length and aperture, the magnitude and type of misalignment, and the degree of aberration correction in the optical design of the interferometer and reference accessory.

Roughness

The non-periodic finer irregularities in the surface texture which are inherent in the production process. These are a measure of the vertical characteristics of the surface.

Sampling Length

The area selected for assessment and evaluation of the roughness parameter having the cutoff wavelength. Any surface irregularities spaced farther apart than the sampling length are considered waviness. Also known as cutoff length.

Slice

A line or group of lines on a data map along which profile data is obtained.

Spacing

A measure of the horizontal or lateral periodic characteristics of the surface.

Surface Texture

The topography of a surface composed of certain deviations that are typical of the real surface. It includes roughness and waviness.

SWLI

Scanning white light interferometry.

Traceability

Refers to the ongoing validations that the measurement of the final product conforms to the original standard of measurement.

Trim

Refers to the removal of lateral pixel layers.

View

A configuration of tools, graphics, and results for a particular analysis.

Wavelength

The distance between repeating units of a propagating wave. It is commonly designated by the Greek letter lambda. In the electromagnetic spectrum, the visible band as perceived by the human eye includes wavelengths from 380 to 760 nanometers.

Waviness

A larger component of surface texture upon which roughness is superimposed.

Workspace

The central region of the window used to view and interact with measurement results.

XML

XML (Extensible Markup Language) is a generic framework for storing text or data whose structure can be represented as a tree.

Zernike Polynomials

A sequence of polynomials that are used to characterize higher-order optical errors. A polynomial is a mathematical expression constructed from variables and constants, using the operations of addition, subtraction, multiplication, and constant non-negative whole number exponents.

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