4Sight™

Advanced Wavefront Analysis Software

User Manual

Version 2.0 Rev A, January 2010

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1

Introduction to 4Sight

4D Technology's 4Sight™ software is a significant step forward in the state-of-the-art in optical wavefront analysis. 4Sight provides the most advanced wavefront acquisition and analysis, with dozens of tools, filters, plots and analyses to help you extract the most information from your interferometric data.

4sight software is designed to function on a stand-alone workstation, with 4D Technology's dynamic interferometer products, or as an upgrade for other manufacturers' temporal phase-shifting interferometers. This manual describes the setup and operation of 4Sight software and its many associated analyses and tools.

New in Version 2.0

4Sight is being continuously improved to bring you new features and added functionality. Here are the main new features in Version 2.0:

Higher Order Zernikes An error was corrected in the calculation of fits based on more than 35 Zernike terms on the *Zernike Worksheet*. This issue was resolved in 4Sight Version 1.9.

Measurement Validation These options let you automatically accept or reject a measurement based on modulation or peak-to-valley height range (PVq).

Measurement Speed 4Sight has been optimized to improve measurement speed by 20-30%.

Live Video A new Floating Live Video window displays the live signal from the instrument camera. It gives you constant live signal for alignment or other uses while you are simultaneously making measurements or analyzing data.

Mask Format Appendix A5 details the format of the 4Sight mask format, allowing you to import masks created in other software programs.

Optical Thickness Analysis This analysis, which is an option for systems with short coherence length laser sources, reports the pixel-by-pixel thickness of transparent optics.

Version 1.9 of 4Sight introduced these improvements:

Measurement Screen The Meas Screen button displays the current content of the Measurement Screen.

Measurement Note	A note field now appears on all analysis windows.
Digital Zoom	Zoom tool functionality has been improved, and the options for maintaining the zoomed view have been increased.
Setting Lateral Scaling	Improved method for setting lateral scaling to real-world units.
Island Options	A new, combined dialog box contains all the parameters that affect *Island Analysis*, *Prism and Corner Cube Analysis*, and *Step Analysis*.
Direct Cavity Analysis	This analysis, for use with 4D interferometers with a short coherence length laser source, enables measurements in which the front surface of a test sample serves as the reference while the back surface is measured. Wedge and other parameters can be obtained.
Thickness Analysis	This analysis, for use with 4D interferometers with a short coherence length laser source, provides the pixel-by-pixel thickness of a transparent optic.
Zernike Table	The 3rd Order Seidels aberrations can now be displayed using the conventions of 4Sight, Vision32 or MetroPro software.
Status Bar	The Status Bar at the bottom of the 4Sight window now displays the video array size, video display rate, current *User Configuration* file and memory management monitor.
Remote Desktop	4Sight can now be operated from a remote computer using this feature of Windows XP Professional.
User Configurations	Options have been added for automatically opening and saving user configuration files.

About This Manual

This user manual is regularly updated to reflect the latest release of 4Sight. Nevertheless, there may be discrepancies between the written manual and the actual software functions in your release. Please feel free to report any discrepancies by using the **Report a Bug Via Web** function in 4Sight's Help menu. We always welcome and appreciate any constructive comments you may have regarding our software, manuals, service and support.

Manual Conventions

We will use several conventions in this manual to highlight important features and concepts:

Menu > **Option**	Menu bar selections will be shown in bold text separated by the ">" symbol. For example, **Display** > **Toolbar** > **Standard** indicates that you should click the **Display** menu, then click **Toolbar**, then **Standard**.
Note	These notes indicate tips or additional info regarding the use of 4Sight.
WARNING	These notes signify important considerations that will help you to avoid losing data or damaging hardware.
Italics	When browsing the electronic version of this manual, click on these italic cross-references to view other pertinent sections of the manual.

Hardware and Operating System Requirements

4Sight software is designed to run under Microsoft Windows XP® operating system on a PC computer meeting the following requirements:

CPU Speed	>2.8 GHz
RAM	>1 GB
Disk Size	>160 GB
CD	>24x CD-RW
Display Resolution	1280 x 1024 pixels
USB ports	>1 Slot
Operating System	Microsoft Windows XP.

Hardware Key

4Sight requires a USB hardware key (a “dongle”) to run. Two dongles are typically provided with each 4D interferometer: one to operate the software with the instrument, and one to operate as a stand-alone workstation. The dongle must be inserted into a USB port on each computer when the program starts up and while it is running. You may install the software on multiple computers, but the dongle must be present in order for 4Sight to start up.

Note: There is a charge to replace a lost hardware key.

Operation with 4D Interferometers

4Sight serves as both an instrument controller and data analysis platform for all 4D Technology instruments. If you are running 4Sight on a computer supplied by 4D Technology, the 4Sight software will be pre-installed and tested.

Note: You must be logged on to the computer as a local administrator to operate 4Sight.

Workstation Operation

4Sight may also run without an instrument present for off-line data analysis. In this “workstation” mode you will be able to import data for complex analysis, freeing up the interferometer for data collection. You can generate “synthetic” datasets for modeling, testing, etc. *Simulator Mode* allows you to mimic data acquisition to assist with training, script testing, etc. In all cases the hardware dongle must be present in order for the software to function.

Note: You must be logged on to the computer as a local administrator to operate 4Sight.

Operation with Other Interferometers

Adding 4Sight software lets you turn your older interferometer into a state-of-the-art analysis and experiment control system. Contact your 4D sales representative for more information. Some hardware may be required.

Remote Desktop

The Remote Desktop feature in Windows XP can be used to control 4Sight from a remote computer. The *Hardware Key* must be installed in the computer that is running 4Sight. You must be a local administrator for the 4Sight computer to run the software remotely.

More information on setting up a remote connection is available in the Windows XP user documentation.

Installing 4Sight

4Sight is pre-installed for all new systems. The latest version can also be installed from your 4Sight CD—insert the CD in your computer's drive and follow the on-screen instructions.

Note: Remove the 4Sight software dongle from your computer's USB port before running the installer.

What is Installed

The following items are installed on your computer:

- 4Sight program and associated files (typically in C:\Program Files\4Sight[version])
- Shortcut to 4Sight on the desktop
- 4Sight User Manual (typically in C:\Program Files\4Sight[version]\Docs)
- Rainbow Technology's Sentinel drivers for 4Sight's security dongle
- Interface hardware-specific files and drivers (typically in Program Files/4Sight and System folder)
- Configurations folder (typically C:\4D)
- Script examples.

You will also have the option to install Adobe® Acrobat® Reader for viewing 4Sight's user documentation.

During installation, the contents of the C:\4D\config and C:\4D\system folders will be archived to a .zip file located in C:\4D\archive. The configuration files in these folders may be modified when you run the newer version of 4Sight; the archiving process safeguards the existing files, allowing you to restore them later if necessary. See *Configuration Archiving* for more.

Running 4Sight

To run 4Sight you must be logged on to the computer as Administrator, and the 4Sight dongle must be installed. Next, double-click on the 4Sight icon on your desktop:

The program will open, revealing the 4Sight splash screen (*Figure 1*). When the splash screen closes, you are ready to work in 4Sight.

You can check the currently installed version by choosing **Help>About 4Sight**.

Figure 1: 4Sight splash screen.

Getting Help

We work hard to make our software and hardware as easy-to-use and intuitive as possible. When you need more assistance you may refer to the PDF version of this manual, which is available from the 4Sight Help menu. Or, contact our Support department by email at info@4dtechnology.com. Our office during normal business hours, 8:00am - 5:00pm Mountain Standard Time, Monday-Friday. Arizona does not participate in Daylight Savings Time. This means that during the summer months, Arizona is on the same time as California.

If you are outside of the United States you may also contact your local sale/service representative for assistance. Our list of representatives and their contact information is available on the Contact page of our web site.

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Chapter

2

4Sight Basics

Introduction

In this chapter, we look at some of the basics of operating 4Sight™ software.

4Sight is a Microsoft® Windows® based program, so its modes of operation should be familiar to anyone accustomed to Windows programs.

Mouse button conventions are similar to most standard Windows programs. **Left clicking** the mouse button selects an object or pushes a virtual software button. **Right clicking** an object displays a menu of options. Most 4Sight screens include right click options for quick access to pertinent functions.

Some actions are accessible through the keyboard **Function** keys (**F2, F3**, etc) or through "shortcut" key combinations (**Ctrl-C**, **Ctrl-T**, etc) on standard Windows keyboards. These appear in 4Sight's menus to the right of the actions they control.

User Interface

Figure 2 shows the 4Sight interface and its major features: the menu bar, toolbar, display area and Measurement Stack. Each of these areas will be described in detail below.

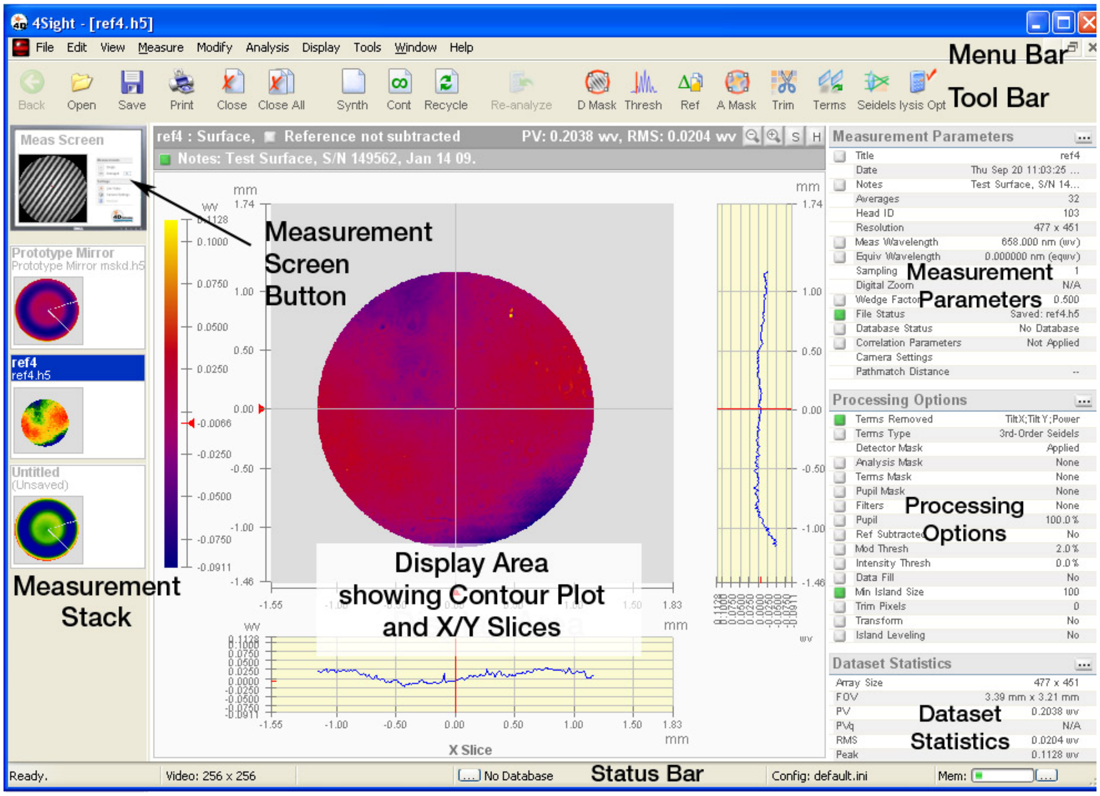


Figure 2: 4Sight screen layout.

Menu Bar

The 4Sight menus are your access point for most of 4Sight's functions (*Figure 3*):

Figure 3: 4Sight main menu bar.

The individual menus group these important operations:

File Open, close, save and print measurement files or configurations files.

Edit Alter text, titles, etc; edit the current dataset's masks, units and optical parameters.

View Choose the dataset(s) to display.

Measure Generate new data, set up measurement options, and configure *Simulator Mode*.

Modify Alter the data, with filters, arithmetic functions, etc.

Analysis Choose an analysis to apply to the data.

Display Select how the analyzed data appears on screen.

Tools Configure the database, scripts, preferences, etc.

Window Arrange the analysis windows.

Help Open the 4Sight manual, report a bug, view 4Sight release version and date.

Toolbar

The tool bar gives you quick access to common functions. To display the toolbar button labels select **Display** > **Toolbar** and check the **Show Labels** option. You can also choose **Tools** > **Preferences** > **Visual** > **Show Toolbar Button Labels** (*Figure 4*).

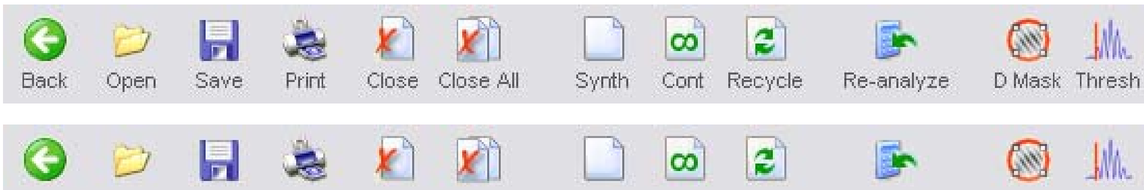
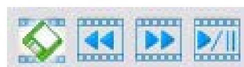


Figure 4: The 4Sight toolbar, with and without Toolbar Button Labels.

The set of buttons on the toolbar depends upon the options selected under **Display** > **Toolbars**. For example, the “movie” buttons for viewing the multiple frames of a *Grouped Measurement*:



can be toggled on and off by clicking **Display** > **Toolbar** > **Movie**. You can also right click on the toolbar (between icons) to toggle buttons on or off.

Some toolbar buttons may be grayed out, indicating that these functions are not available for the current data type or operating mode. For example, the movie controls are grayed out for a single-frame measurement:

Some users may be more accustomed to the original 4Sight toolbar. To choose this style choose **Tools>Preferences>Visual>Old-Style Toolbar** (*Figure 5*).

Figure 5: Old-style 4Sight toolbar.

Display Area

4Sight's Display Area shows either the **Measurement Screen**, which is the data acquisition screen (*Figure 6*):

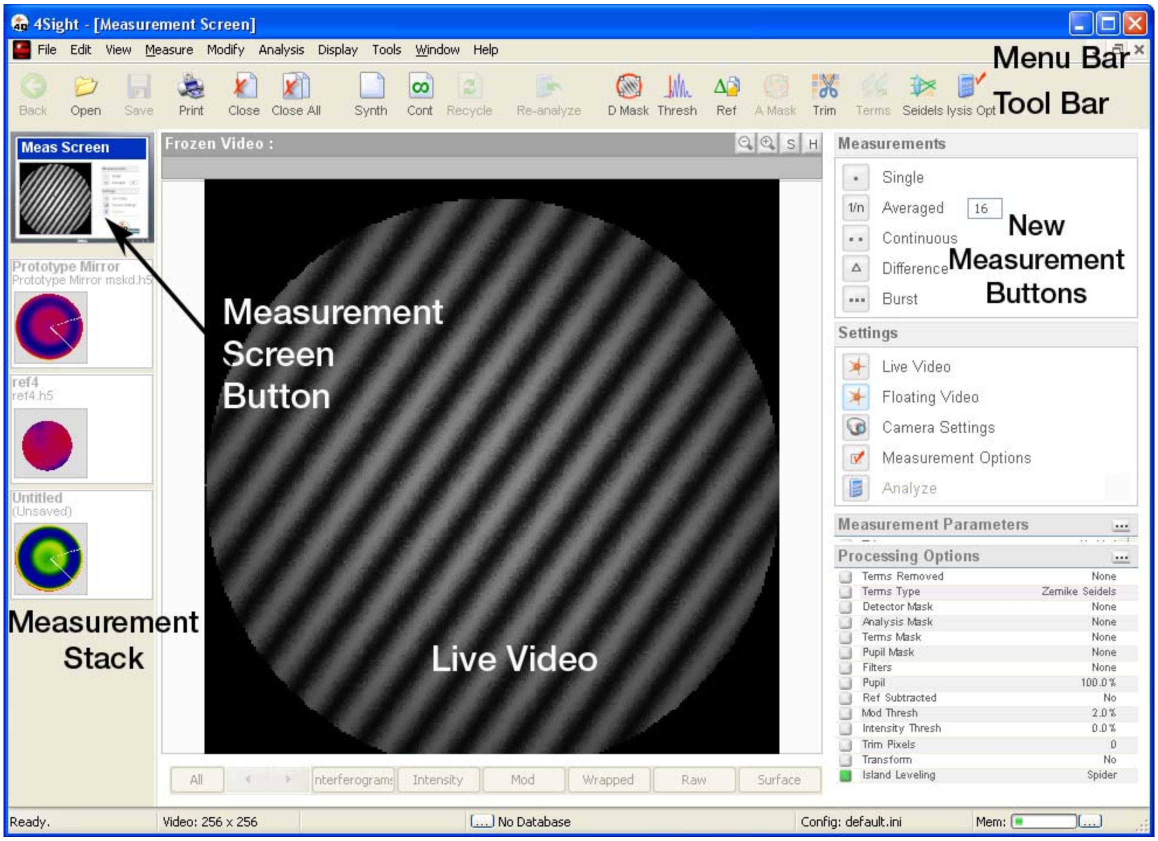


Figure 6: Display area showing Measurement Screen with Live Video.

or it can display one or more **Analysis windows**, each of which shows an analyzed measurement (*Figure 7*).

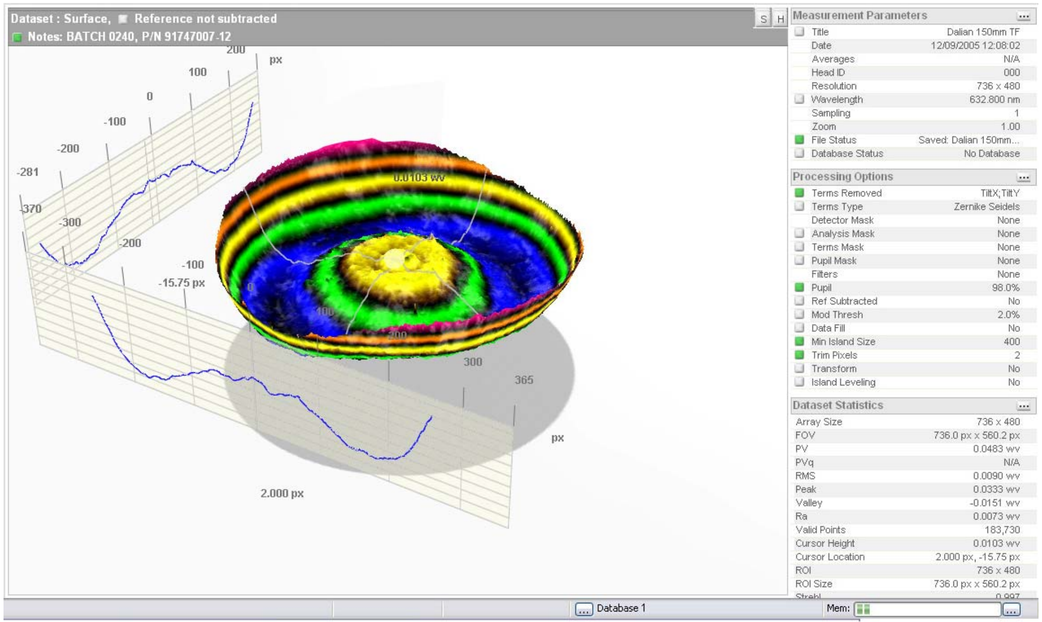


Figure 7: Display area showing analyzed measurement.

Clicking the **Meas Screen** button brings the Screen to the foreground; clicking on an item in the Measurement Stack (described next) displays that dataset's analysis window instead.

Measurement Screen

The Measurement Screen is the interface for taking new measurements. To view this interface click the **Meas Screen** icon in the upper left corner of the 4Sight window.

The Measurement Screen shows either the Live Video feed from the interferometer's camera or the last acquired measurement. Note that the Meas Screen button will update to show you the current contents of the Measurement Screen.

There is only room for the most recently acquired measurement in the Measurement Screen. That measurement will be displaced by any subsequent measurement.

Measurement Stack

The **Measurement Stack** provides storage for multiple analyzed measurements. You can move data from the Measurement Screen onto the Stack and/or open saved data onto the Stack, then recall the data to the display area later for further analysis or manipulation. You can also perform operations requiring multiple measurements, such as adding or subtracting, *Absolute Calibration (3-Flat Test)* or *Absolute Calibration (3-Sphere Test*).

Clicking a measurement in the Stack opens it to an analysis window in the display area. The active item in the Stack will be shown with a blue title banner (*Figure 8*).

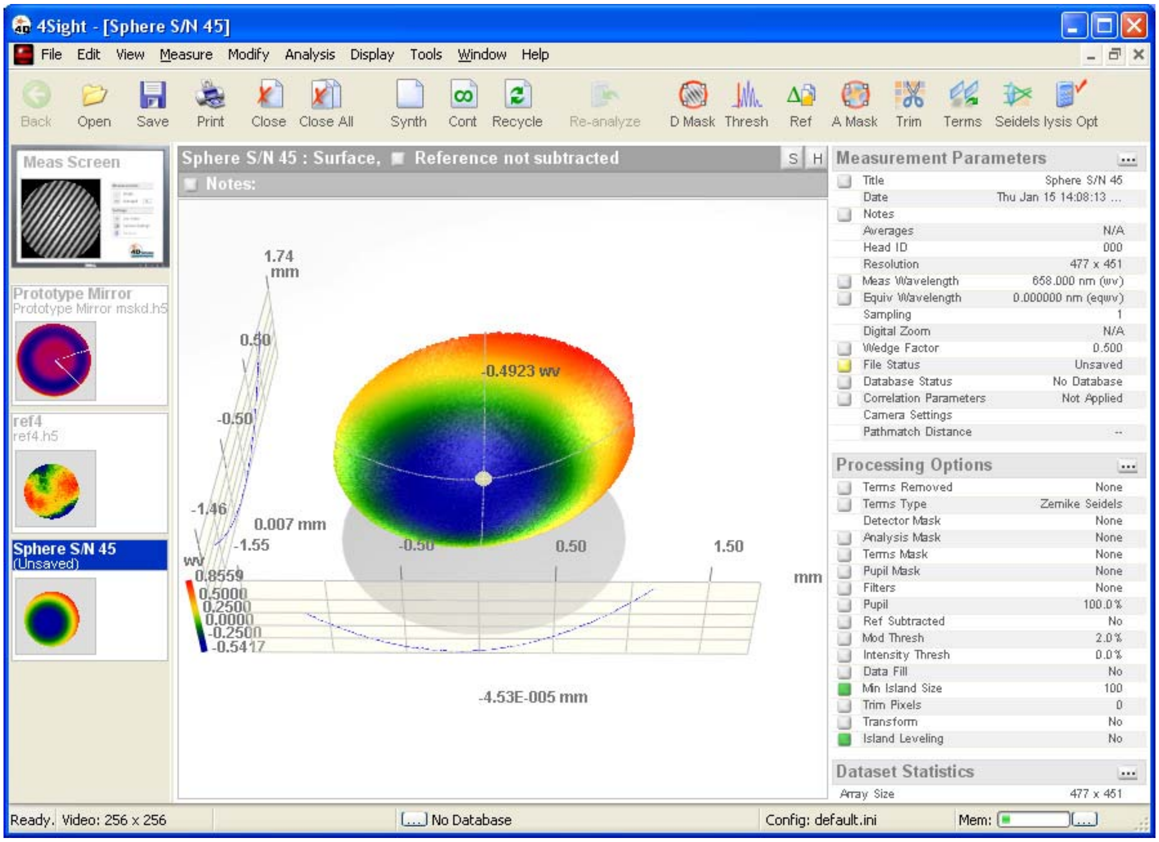


Figure 8: The third measurement from the Stack displayed as a 3D plot.

If you have multiple measurements in the Stack you can also show multiple analysis windows in the display area. 4Sight's default view shows just the active measurement, maximized to fill the entire display area. However, all open measurements are listed in the **Windows** menu (*Figure 9*). Click on any item in the menu list to bring it to the foreground, or use the **Next** and **Previous** toolbar buttons to step through open measurements.

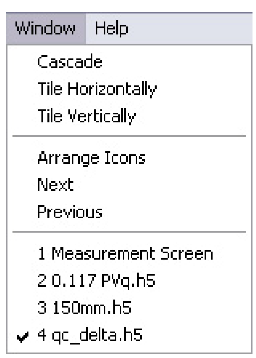


Figure 9: Open measurements displayed in the Windows menu.

Click the Windows **Restore Down** button  to un-maximize the front-most analysis window, allowing you to view and position all windows. Choose one of the "tiling" options from the **Windows** menu (**Cascade, Tile Vertically** or **Tile Horizontally**) to show all of the open analysis windows (*Figure 10*).

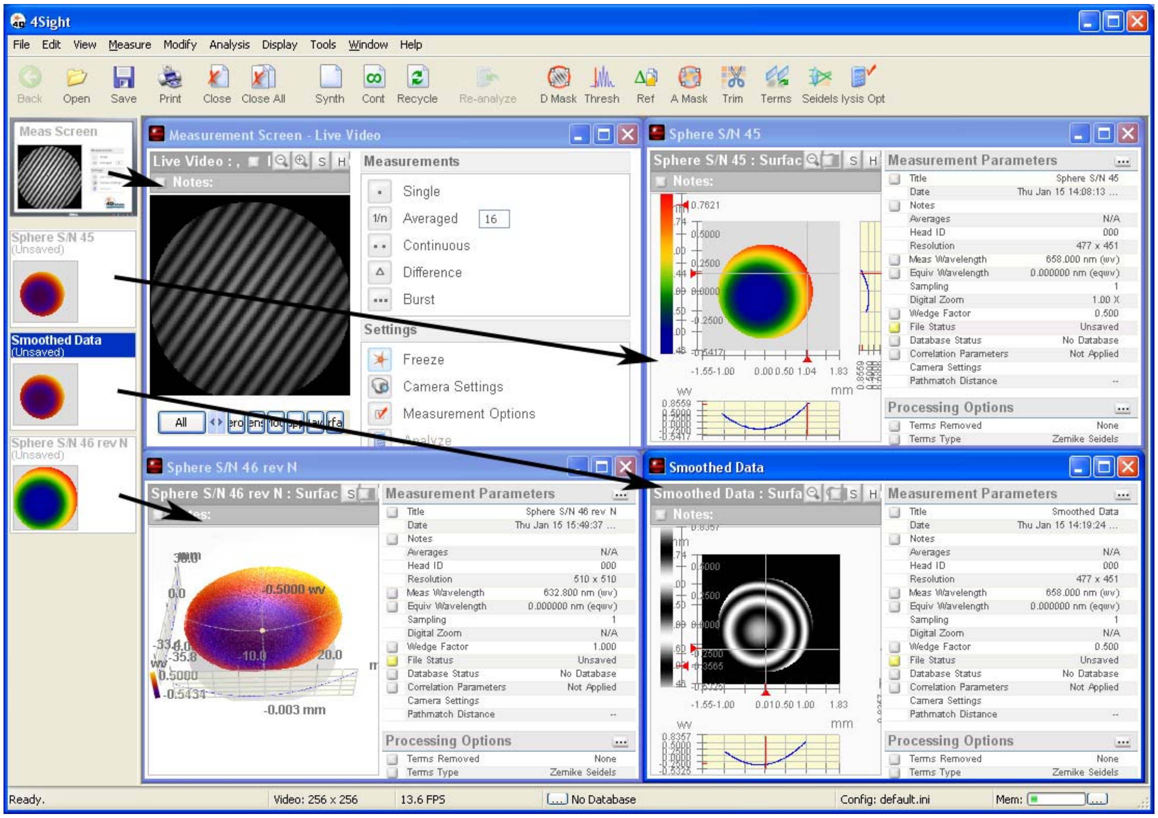


Figure 10: Multiple measurements from the Stack tiled for viewing.

Left clicking either the title bar of the analysis window or of the measurement icon in the Stack makes it the active data.

Measurement Notes

The Notes area lets you enter additional details about the measurement and the conditions under which it was taken. Notes are shown at the top of every analysis window. To enter or edit notes:

- click on the Notes button at the top of the Display Area
- click on the Notes button in the *Measurement Parameters* list
- Right click on the measurement icon in the Measurement Stack and choose **Change Notes**.

Any of these actions opens the Measurement Notes dialog box, where you can enter a note up to 1000 characters long (*Figure 11*). Carriage returns in the note will appear as vertical lines in the note displayed above the Display Area.

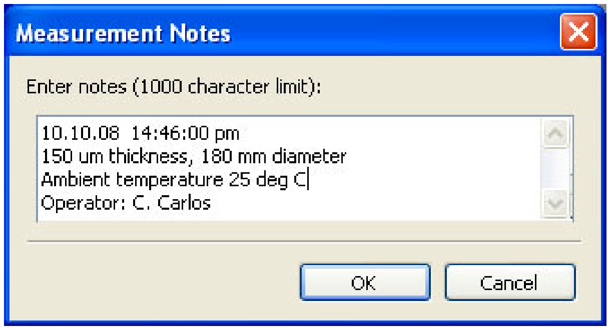


Figure 11. Measurement Notes dialog box.

Choose **Measure** > **Measurement Options** > **Titles and Saving**, then check the **Use last note for new measurements** box to attach the same note to all subsequent measurements.

You can select and copy the text, then paste it into another program to print the contents of the note field.

Status Bar

The status bar at the bottom of the 4Sight main window shows:

- The size of the data array for the active measurement
- The frame rate at which the live video signal is being displayed (note that this is *not* the rate at which a *Burst Measurement* can be saved to disk)
- The *User Configuration* file currently in use
- The current memory usage (see *Minimum Memory Consumption Mode*).

Back Button

The Back toolbar button 

lets you scroll backwards through the recent series of data views for a measurement. This is a useful shortcut for reviewing and comparing data, or for returning to previous states of a complex, multi-step analysis.

Dataset Statistics

This block of text on each analysis window shows important parameters for the particular dataset:

Array Size	The number of pixels in the dataset.
FOV	The Field-of-View, or the real-world size of the measurement.
PV	The largest peak-to-valley difference in the dataset based on the lowest and highest pixels only.
PVq	The peak-to-valley height based on a percentage of the highest and lowest pixels in the dataset. See **Analysis Options** > ***Statistics*** for details.
RMS	The root-mean-square roughness for the region of interest.
Peak	The largest z-height in the region of interest.

Valley The lowest z-height in the ROI.

Ra The average roughness of the ROI.

Valid Points The number of points that pass all validity criteria in the ROI.

Unit Circle Displays the x/y coordinates and radius of the *Unit Circle*.

Cursor Height The magnitude of the dataset at the current cursor location. See *Contour Plot* for details.

Cursor Location The X and Y coordinates of the current cursor location.

ROI The number of pixels in the current region of interest.

ROI Size The real-world, XY dimensions of the region of interest.

Strehl The Strehl ratio of optic quality for the ROI.

Individual Dataset Statistics can be shown or hidden, depending on your requirements. Click the ... button to view all potential options (*Figure 12*). Click the box next to each parameter to view or hide it. Parameters with a green box will be shown; those with gray boxes will be hidden. Click the "All" box at the top of the list to show or hide all parameters in the list.

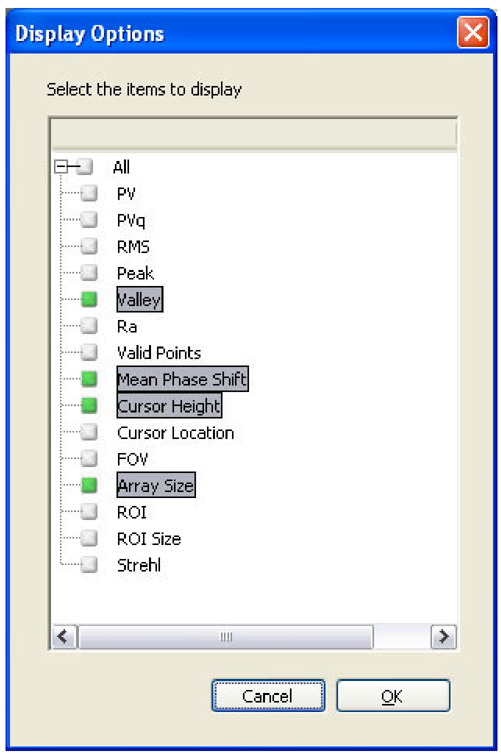


Figure 12: Dataset Statistics display options dialog box.

Measurement Parameters

The Measurement Parameters area displays information regarding the conditions under which the current measurement was created. These options are available on the Measurement Screen and in analysis windows. This area also provides useful shortcuts to commonly-used features and options.

Title	The Title applied to the current data. Click the gray box to the left of the title to add/change the title. See *Title* for details.
Date	The time and data at the beginning of the measurement.
Notes	Create *Measurement Notes* to store additional information regarding the measurement. The maximum length is 1000 characters. Click the gray box to open the Measurement Notes dialog box, where you can view and edit the note. The note text is also displayed above each analysis window plot.
User Config	The *User Configuration* file used to generate the measurement.
Averages	The number of measurements that were averaged to create the current measurement. See *Averaged Measurement*.
Head ID	The serial number of the interferometer's laser.
Resolution	The number of pixels in the array in the X and Y axes.
Meas Wavelength	The wavelength of the interferometer's laser. Click the gray box to the left of the wavelength to open the **Optical Parameters** dialog box, where you can change the wavelength. See *Optical Parameters.*
Equiv Wavelength	An alternate wavelength which can be used to calculate height values, as if a measurement was made using a different source than the interferometer's laser. Click the gray box to the left of Equiv wavelength to open the **Units** dialog box. Select "EQWV" as the vertical units, then enter the equivalent wavelength. See *Setting and Changing Units.*
Sampling	The spacing between pixels sampled in the array, as set under **Measure > Measurement Options > Sampling**. "1" means that all pixels are sampled; "4" means that every fourth pixel is used.
Digital Zoom	Displays the zoom factor at which you are currently viewing the active measurement. See *Digital Zoom*.
Optical Zoom	On systems with optical zoom and encoders this parameter will update to show the current effective magnification of the system. See *Automatic Lateral Spacing with Zoom Encoders*.
Wedge Factor	The conversion factor from the number of fringes in the wavefront to the number of waves of aberration in the system under test. Click the gray box to open the **Optical Parameters** dialog box, where you can change the wedge. See *Optical Parameters.*
File Status	Indicates whether the current measurement has been saved to disk or not. Click the yellow box to **Save** the current measurement. See

Saving and Opening Data.

Database Status	Indicated whether a *Database* is associated with the current measurement. Click the gray box to activate a database into which to store current measurement statistics.

Correlation Parameters For *Disk Analysis* and *Microwaviness* analysis, indicates whether correlation values are applied to analysis results to equate them to results from other systems or software.

Camera Settings Displays the Camera Gain ("G") and Exposure ("E") for the current configuration. This option will not be available for some older systems. See *Camera Settings.*

Path match Distance For systems with an internal Automatic Path matching system, this number displays the most recent path matching location. It will be either the last position found by auto path matching, or the last position manually specified using the **Move to Cursor** function. Please refer to your hardware manual for more information.

Phase Algorithm Displays the algorithm used to combine the frames of phase data into wavefront data.

Individual Measurement Parameters can be shown or hidden, depending on your requirements. Click the  button to view all potential options. Click the box next to each parameter to view or hide it. Parameters with a green box will be shown; those with gray boxes will be hidden. Click the "All" box at the top of the list to show or hide all parameters in the list.

Processing Options

The Processing Options area shows which options were used to generate the current measurement. This area also provides useful shortcuts to commonly-used features and options.

Terms Removed Indicates whether *Aberrations Removal* has been applied to the measurement, and if so which terms have been removed. a Green box indicates that terms have been removed; otherwise, the box will be gray. Click the box to open the Aberrations Removal dialog box.

Terms Type For *Aberrations Removal,* indicates whether Zernike or 3rd order Seidel terms are removed. Click the gray box to open the Aberrations Removal dialog box.

Detector Mask Indicates whether a *Detector Mask* has been applied. A Green box means that the mask is applied; otherwise, the box will be gray. Click the box to open the Edit Masks dialog box.

Analysis Mask Indicates whether an *Analysis Mask* has been applied. A Green box means that the mask is applied; otherwise, the box will be gray. Click the box to open the Edit Masks dialog box.

Terms Mask Indicates whether a *Terms* has been applied. A Green box means that the mask is applied; otherwise, the box will be gray. Click the box to open the Edit Masks dialog box.

Pupil Mask Indicates whether a *Pupil* has been applied. A Green box means that the mask is applied; otherwise, the box will be gray. Click the box to open the Edit Masks dialog box.

Filters Shows whether *Filters* (high pass, low pass, etc) have been applied to the data. A Green box means that a filter has been applied; otherwise, the box will be gray. Click the box to open the **Measurement Options** dialog box.

Pupil Shows whether a *Unit Circle* of different size than the *Pupil* has been specified for calculating Zernike fits. A green box indicates that a different unit circle is being used; otherwise, the box will be gray. Click the box to open the **Analysis Options** dialog box.

Ref Subtracted Shows whether you are currently *Subtracting a Reference* from data. A Green box means that a reference has been subtracted; otherwise, the box will be gray. Click the box to open the **Reference Subtraction** dialog box.

Mod Thresh Indicates the level to which the intensity must modulate across interferograms in order for a pixel to be considered "valid." Click the gray box to open the **Signal Thresholds** dialog box. See *Signal Thresholds* for details.

Intensity Thresh Indicates an intensity level required for a pixel to be considered "valid." Click the gray box to open the **Signal Thresholds** dialog box. See *Signal Thresholds* for details.

Data Fill Shows whether 4Sight's Data Fill option is being used to fill holes in the interior of the data. Click the gray box to open the **Analysis Options** dialog box. See *Surface Correction* for details.

Min Island Size Island processing ensures that only pixels from sufficiently large areas of data are considered valid for each measurement. A green box indicates that a number greater than zero has been entered as the minimum island size; otherwise, the box will be gray. Click the box to open the **Measurement Options** dialog box. See *Min Size Tab*.

Trim Pixels The *Trim Pixels* function erodes pixels on the edge of the part being measured to eliminate unreliable data. A green box means that pixels are being trimmed from the edges of data; otherwise, the box will be gray. Click the box to open the **Trim** dialog box.

Transform Indicates that *Data Modification* options are currently being applied. A green box means that data modification is being applied; otherwise, the box is gray. Click the box to open the **Data Transformation Options** dialog box.

Island Leveling The **Island leveling** tools allow you to adjust the relative heights of islands, either manually or automatically, when measuring discontinuous surfaces. A green box indicates that leveling is currently being used; otherwise, the box will be gray. Click the box to open the Island Options *Leveling Tab*.

Individual Processing Options Parameters can be shown or hidden, depending on your requirements. Click the  button to view all potential options. Click the box next to each parameter to view or hide it. Parameters with a green box will be shown; those with gray boxes will be hidden. Click the "All" box at the top of the list to show or hide all parameters in the list.

Chapter

3

Making a Measurement

In this chapter we look at the various types of measurements that can be made using 4Sight, different ways to make those measurements, and methods for managing the output.

A Quick Measurement

To begin the chapter we will make a quick measurement to show you the basic data flow.

1. First, open 4Sight. You will need to have the *Hardware Key* inserted into a USB port on the compute in order to run 4Sight. You must also be logged on to Windows as an Administrator.

2. Click the **Meas Screen** button (*Figure 13*) to view the Measurement Screen. You should see live (or simulated data—see *Simulator Mode*) video in the center of the screen.

3. Set up the hardware such that the sample part is aligned, with high-quality fringes. (please consult your hardware manual for greater detail).

Note: If you are working from a PC that is not connected to an instrument you can mimic data acquisition by checking the **Tools** > **Preferences** > **Configurations** > **Initialize Simulator** box, and un-checking the **Desktop Mode** box. Restart 4Sight for the changes to take effect.

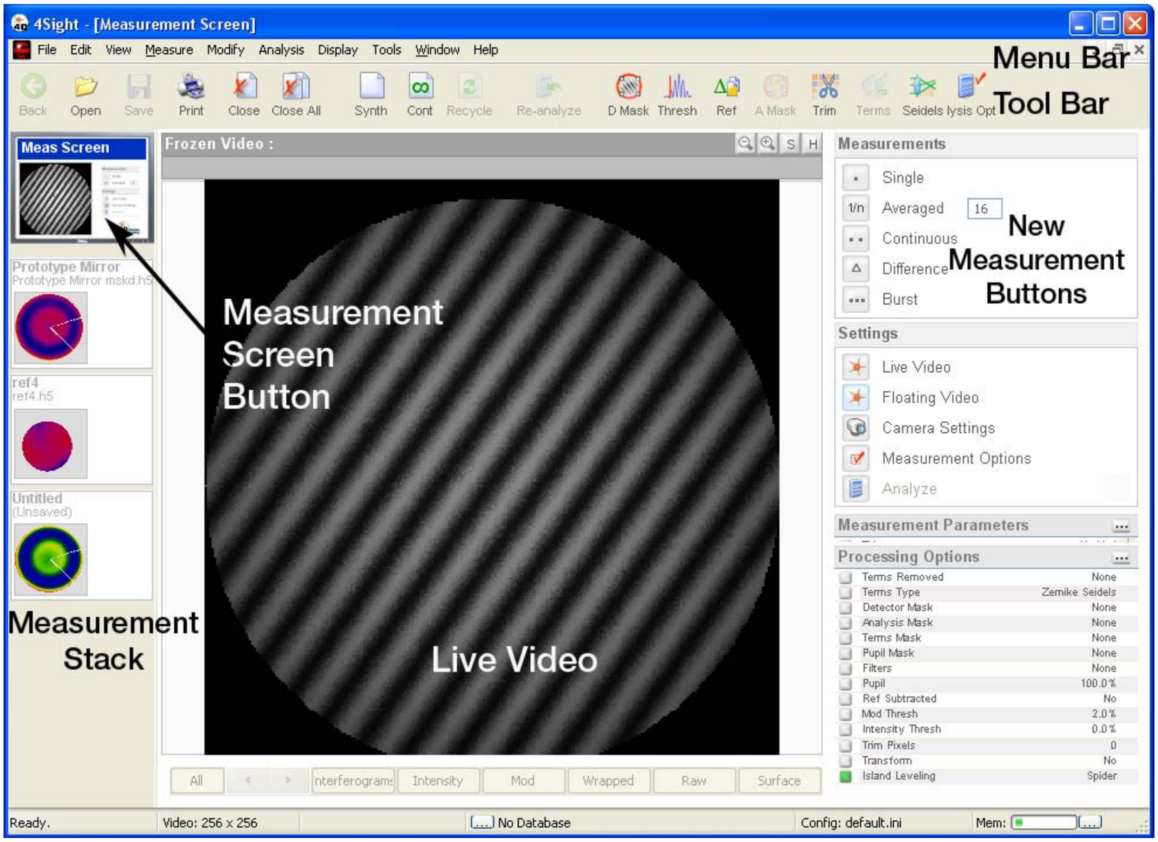


Figure 13: Measurement Screen.

4. Press the **Single** new measurement button. 4Sight will acquire a measurement. The result will be displayed using the default *Contour Plot* (*Figure 14*).

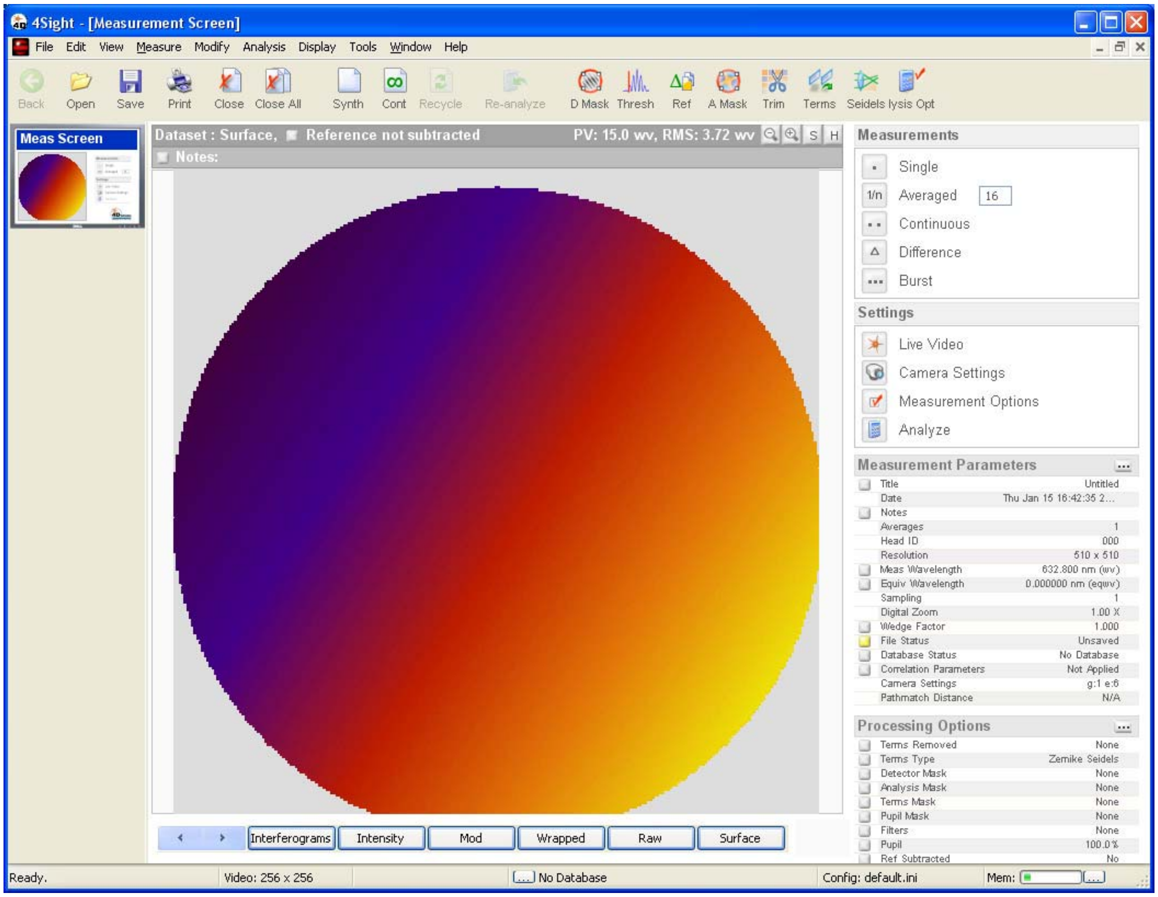


Figure 14: Single Measurement displayed in the Measurement Screen.

5. Now click the **Single** button again. Another new measurement will be taken, overwriting the first. There can only be one measurement in the Measurement Screen.

6. Click the **Analyze** button on the right side of the screen. The data will be analyzed using the current default analysis, mask, and other settings. The result will be added to the Measurement Stack at the left of the screen (*Figure 15*).

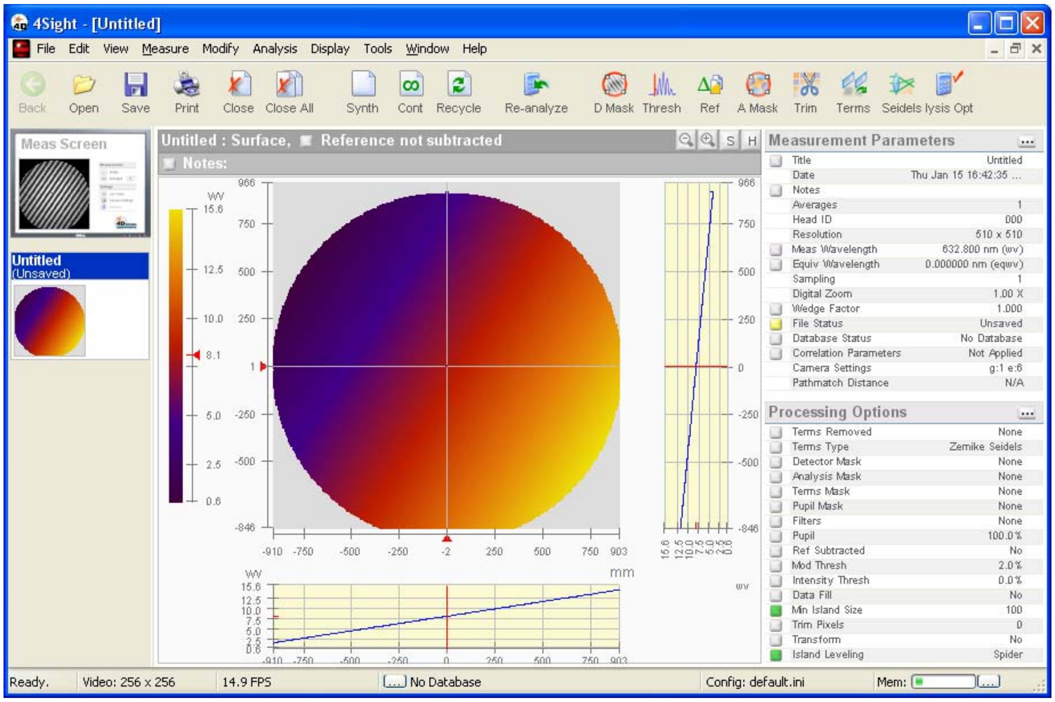


Figure 15: Analyzed measurement added to the Stack, displayed as Contour Plot.

7. Click the **Meas Screen** button again to bring the Measurement Screen to the foreground. (You can also choose **Measure** > **Measurement Screen**, or click the **F2** key.)

8. Beneath the data plot you will see several options for viewing the different datasets that make up the measurement. For example, click **Mod** to view the modulation dataset (*Figure 16*).

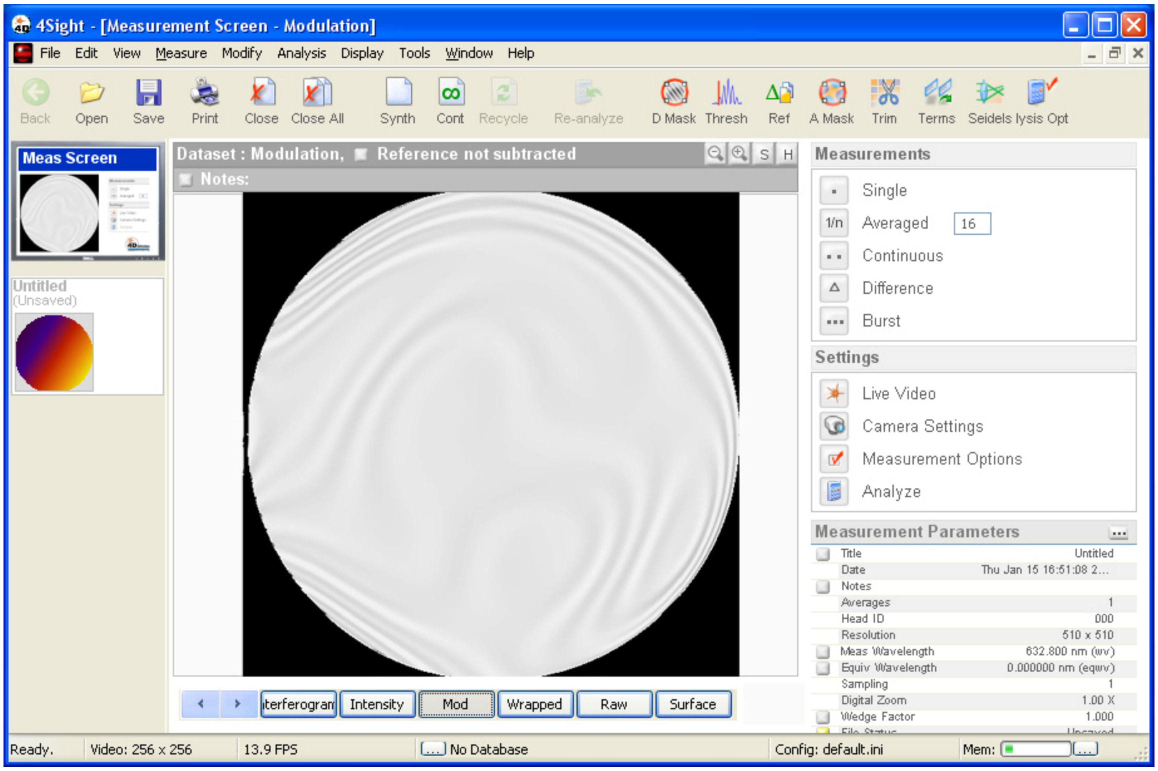
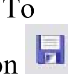


Figure 16:Click the Mod button to view the Modulation dataset.

9. Analyzing a measurement does *not* save it to your hard drive—doing so maintains the measurement in RAM memory for use during the current 4Sight session. To permanently save the current data to your hard drive, click the **Save** button  on the toolbar, or choose **File** > **Save**. You will be prompted for a file name and a location to which to save the data.

10. Right click the measurement in the Stack and choose **Close This Measurement**. The data will be removed from the Measurement Stack and its analysis window will be closed. If you had not yet saved the data to disk, 4Sight would have prompted you to save before closing the data.

11. Choose **File** > **Open** and navigate to the measurement you just saved and closed. Select it, and click **Open**. The measurement will be added to the Stack and it will appear in its own analysis window in the display area.

This exercise should have given you a general idea of how data is created, stored on the Measurement Stack, analyzed and saved in 4Sight. We will now go into greater detail about these important functions.

What is in a Measurement

4Sight can associate a great deal of information with each measurement. This information includes several datasets, analysis options (modulation threshold, aberrations to remove, etc.), time and date, masks, analysis results and other information. Taken together, these items are called a “Measurement.”

The following datasets can be associated with each measurement:

Interferograms These are the actual frames of intensity data parsed from a single exposure of the interferometer's camera. In a system with a pixelated phase mask (such as the FizCam), or a quadrant mask (such as early PhaseCam systems), all the interferograms are acquired in a single exposure, or "interference frame."

Intensity Data Displays an average of the interferograms. Averaging the interferograms effectively cancels the fringes, producing an image that looks like it was taken with the reference beam blocked. This can be useful for seeing features on a sample that might otherwise be obscured by dark areas of the fringes.

Modulation Data The modulation values provide a measure of "signal strength" and are used to determine where valid data exists in the measurement. This dataset contains the modulation values computed from the interferograms.

Wrapped Data Wrapped data is the optical phase computed from the interferograms *before* two-pi phase ambiguities are removed.

Raw Data Raw data is the optical phase computed from the wrapped data *after* two-pi phase ambiguities are removed.

Surface (OPD) Data The raw data is further processed by *Subtracting a Reference*, *Masking* portions of the data, and applying *Aberrations Removal*. This is generally the most pertinent dataset; for this reason it is displayed automatically when you press a measure button.

As we saw in the example measurement above, you can view and manipulate each dataset using the buttons across the bottom of the Measurement Screen. 4Sight manages this collection of information for you, automatically saving the data and settings needed to recreate the measurement from the file later (See *Saving, Printing, Exporting Data*).

Note: In the most complete case, *all* of these arrays are stored with each measurement, and therefore these measurements can become quite large, in particular for systems with 4 mega-pixel cameras. Maintaining a large Measurement Stack can seriously impede system performance as your computer's memory becomes increasingly full. We will discuss options for data management in the *Minimum Memory Consumption* Mode section below.

Types of Measurements

4Sight lets you acquire several types of measurements from the Measurement Screen (*Figure 17*):

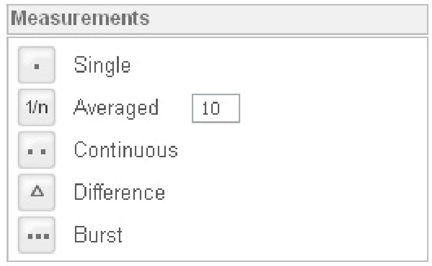


Figure 17:Measurement types available on the Measurement Screen.

Single Measurement

Pressing the **Single** button generates one measurement. You can also choose **Measure** > **New Measurement,** or click **Ctrl-T**, takes a new Single measurement.

Averaged Measurement

In an **Averaged** measurement, several measurements are acquired and averaged together to remove random noise sources such as air turbulence or mechanical vibration. Enter the number to measurements to acquire in the box to the right of the **Averaged** button, then press the **Averaged** button.

During an Averaged measurement, 4Sight maintains a “running average” of the raw (unwrapped) data. It does *not* keep the interferograms, intensity, modulation, or wrapped phase data from the individual measurements, so you cannot view these datasets for an averaged measurement (these buttons are therefore disabled on the Measurement Screen following an Averaged measurement).

The first time you make an Averaged Measurement 4Sight will open the **Averaging** tab of the **Measurement Options** dialog box (*Figure 18*).

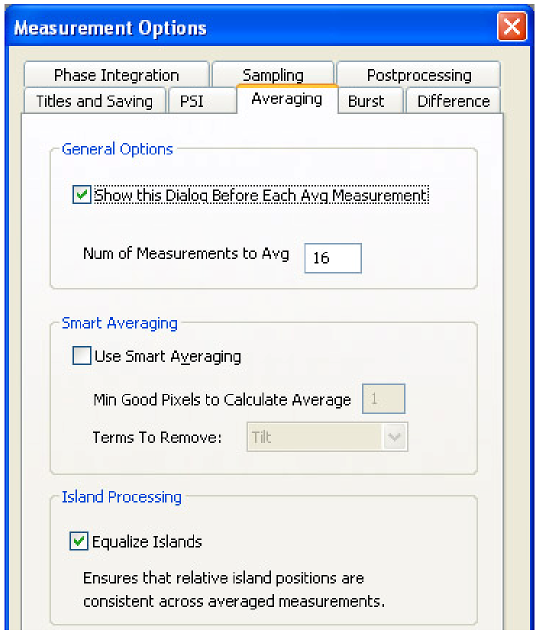


Figure 18: Averaging Measurement Options dialog box.

These options give you additional flexibility when measuring large steps, data with significant drop-out, etc. The options, which are described below under *Averaging*, can always be accessed by choosing **Measure** > **Measurement Options** > **Averaging**.

Continuous Measurement

The **Continuous Measurement** button causes the system to measure repeatedly until you press the **Stop** button (which replaces the **Continuous** button once the measurement begins). Each measurement overwrites the last, allowing you to freeze the data when a suitable measurement occurs. This useful and unique 4Sight feature allows you to align and/or assemble optical systems in real time, using the constant stream of measurement results to guide your adjustments. Only the last measurement in a Continuous measurement can be analyzed and promoted to the Stack — all previous measurements are discarded.

A continuous measurement can be conducted within the Measurement Screen, with the data displayed as a contour plot or a 3D plot. You can also run a particular analysis from the **Analysis** menu, then choose **Measure** > **Continuous** to view continuous data in that analysis format. Choose **Measure** > **Continuous** again to stop.

Note: Since continuous measurements may use considerable processor power, it is best to stop the measurement if you want to look at another window or switch to another application.

Note: Continuous mode is disabled when Measurement *Validation* is turned on.

Difference Measurement

In a **Difference Measurement** 4Sight acquires two frames of data and calculates the difference between them. This is one of two types of "Group Measurements" in which multiple frames of data are analyzed and stored together (see *Grouped Measurement*).

The first time you make a Difference Measurement 4Sight will open the **Difference** tab of the **Measurement Options** dialog box (*Figure 19*).

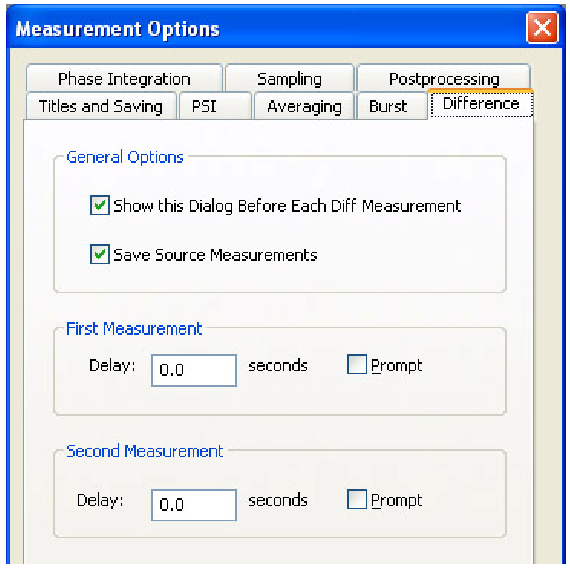


Figure 19: Difference Measurement Options dialog box.

These options give you control over the timing during acquisition. The options are described under *Difference* and can always be accessed by choosing **Measure > Measurement Options > Difference**.

Burst Measurement

A burst measurement is the second type of Group Measurement, in which multiple frames of data are acquired at a very rapid rate—up to the maximum speed of the interferometer's camera. The measurements are analyzed individually and then stored together as a single file (see *Grouped Measurement*). A "wavefront movie" can then be created by showing the individual measurement frames in rapid succession.

The first time you make a Burst Measurement 4Sight will open the **Burst** tab of the **Measurement Options** dialog box (*Figure 20*).

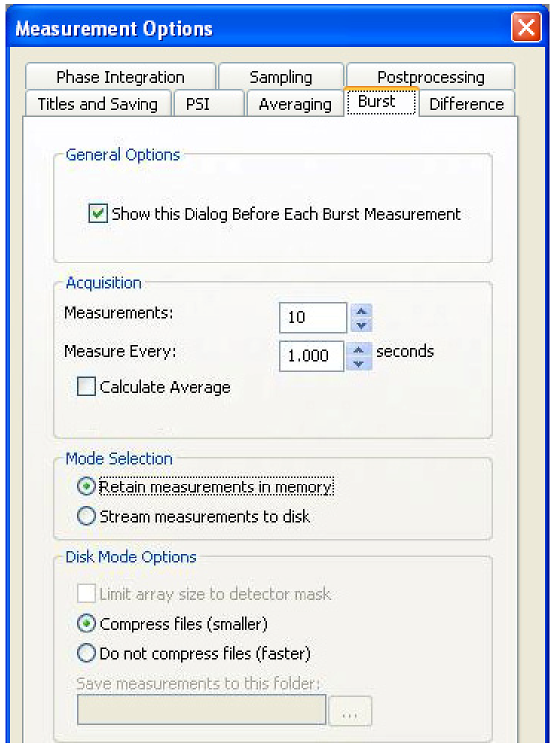


Figure 20: Burst Measurement Options dialog box.

These options give you control over the timing during acquisition and how the files will be stored. The options are described under *Burst* and can always be accessed by choosing **Measure > Measurement Options > Burst**.

When you click **Burst**, the system will begin acquiring the individual measurements. When acquisition of all the interferograms is complete, 4Sight will process the data and place a grouped measurement on the Measurement Stack. The grouped measurement will be titled "Burst [x]," where x will be 1, 2, 3…*n* for each new burst measurement in the Stack. The number of measurements in the burst will be displayed in the lower right corner of the Stack icon.

Note: Continuous mode is disabled when Measurement *Validation* is turned on.

Note: Burst Measurement is not available for quadrant-based systems such as the PhaseCam 4000.

Grouped Measurement

"Grouped Measurements" are sets of measurements with unique datasets but sharing common analysis options and masks. For example, you might record a Burst of 10 consecutive measurements to show a mirror's deformation over time, the result would be a group of 10 measurements.

You can view all measurements within a group sequentially, as if playing a movie. The **Movie** controls on the toolbar let you **Play/Pause** the sequence, step to the **Next** or **Previous** measurement, or **Save** the Burst measurement to disk as a ".avi" file (see *Creating and Saving Movie Files*).

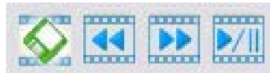


Figure 21: Movie toolbar buttons for grouped measurement playback.

To promote an individual measurement out of a group, use the movie toolbar buttons to display the correct measurement's analysis window. Then right click on the measurement and choose **Promote**.

When you save a grouped measurement, 4Sight automatically saves all the data of a single file on your hard drive.

You can access several group measurement functions by right clicking on a group in the *Measurement Stack* and clicking **Group**. Choose **Manage** to open the Group Measurement dialog box (*Figure 22*).

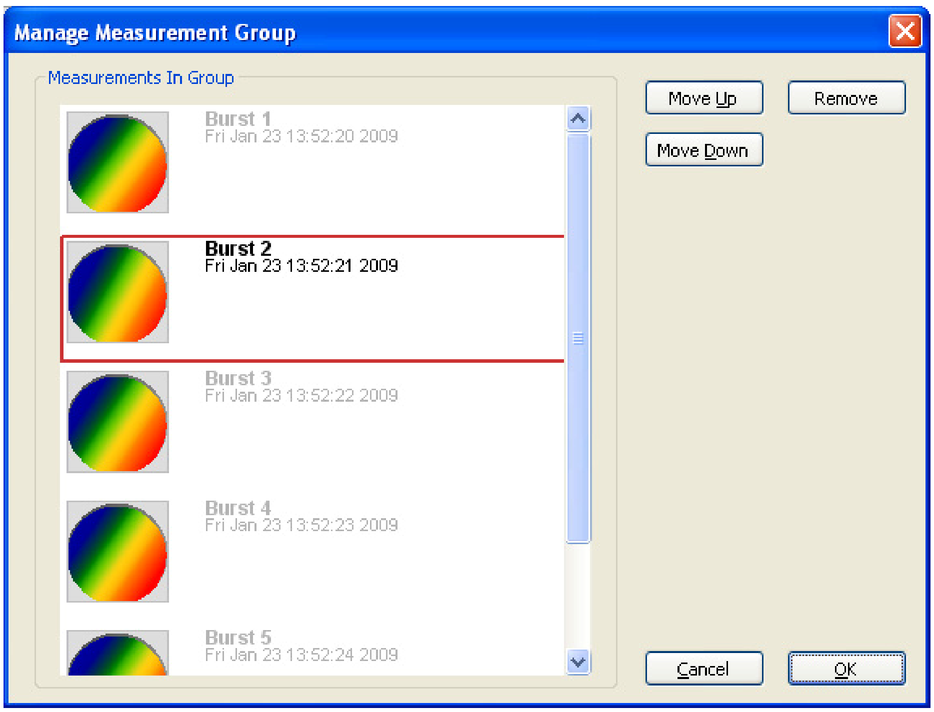


Figure 22: Group Measurement dialog box.

Click on a measurement in the list to select it, then click **Move Up** or **Move Down** to change its position in the group. You can also click **Remove** to delete the selected measurement.

Data Flow and the Measurement Stack

Each time you take a new measurement or open a data file an icon is added to the *Measurement Stack*, and a new analysis window is created. Subsequent operations on that measurement will be displayed in the same analysis window.

You can display each measurement by clicking on the Measurement Stack icons. The active measurement's icon in the Stack icon will be highlighted in blue, and it will be moved to the foreground in the *Display Area*.

Open, Close, Save Stack Data

The Measurement Stack is a temporary storage place for your data. If your measurement is on the Stack, it will remain in memory until you explicitly close the measurement or exit 4Sight.

To permanently save a measurement from the Stack, first left click to select it. Then choose **File** > **Save As** to save the data as a new file, or choose **File** > **Save** to update a previously saved file.

To close a single measurement, right click on its icon in the Stack and choose **Close This Measurement**, or choose **File** > **Close** > **Current Measurement**.

Note: If you try to close an unsaved measurement, 4Sight will prompt you to save it.

Tip: Pressing the **F4** key or clicking the **Close All** toolbar button also closes all measurements.

You can also choose **File** > **Close Current Window** to close the current view of the active measurement. Closing windows clears unneeded views from the display area—it does not remove the data from the Measurement Stack.

You can give a measurement in the Stack a more descriptive *Title* by choosing **Edit** > **Change Title**, or by right clicking on an icon in the Stack and choosing **Change Title**.

Promotion and Analysis

When you make a measurement, you'll click **Analyze** to add the analyzed measurement to the *Measurement Stack*. You can then click on this Stack icon to make it the active measurement—it will be displayed in a new analysis window in the display area.

Running additional analyses on the data may generate additional analysis windows but not additional Stack icons. Often it is useful to "promote" the result of such an analysis to the Measurement Stack as a new, separate measurement. To do so, right click the plot in the analysis window, then choose **Promote This Dataset**. Promoting a dataset detaches it from the original measurement, and 4Sight will then treat it as a fully-fledged measurement with a new icon on the Measurement Stack.

Promotion is an important feature because it allows levels of data analysis, letting you cascade analyses or create your own analyses. For example, to calculate the second derivative of a surface, you could calculate its *Slope*, promote the resultant dataset, then calculate slope magnitudes on the promoted dataset. You can also zoom in on a region of interest, then promote the zoomed area to treat it as a unique dataset (see *Digital Zoom*).

Note: Not all data is stored when a dataset is promoted. Only the analyzed surface data is maintained, meaning you cannot subsequently *Reanalyze* a promoted dataset. Masked data will also be discarded, which reduces data to only the necessary pixels.

Measurement Flow

4Sight provides the useful ability to view how your measurement data looks as it passes through every stage of processing. To do so, choose **View** > **Measurement Flow**. Each stage of *Masking*, *Trimming*, and other processing will be displayed (*Figure 23*).

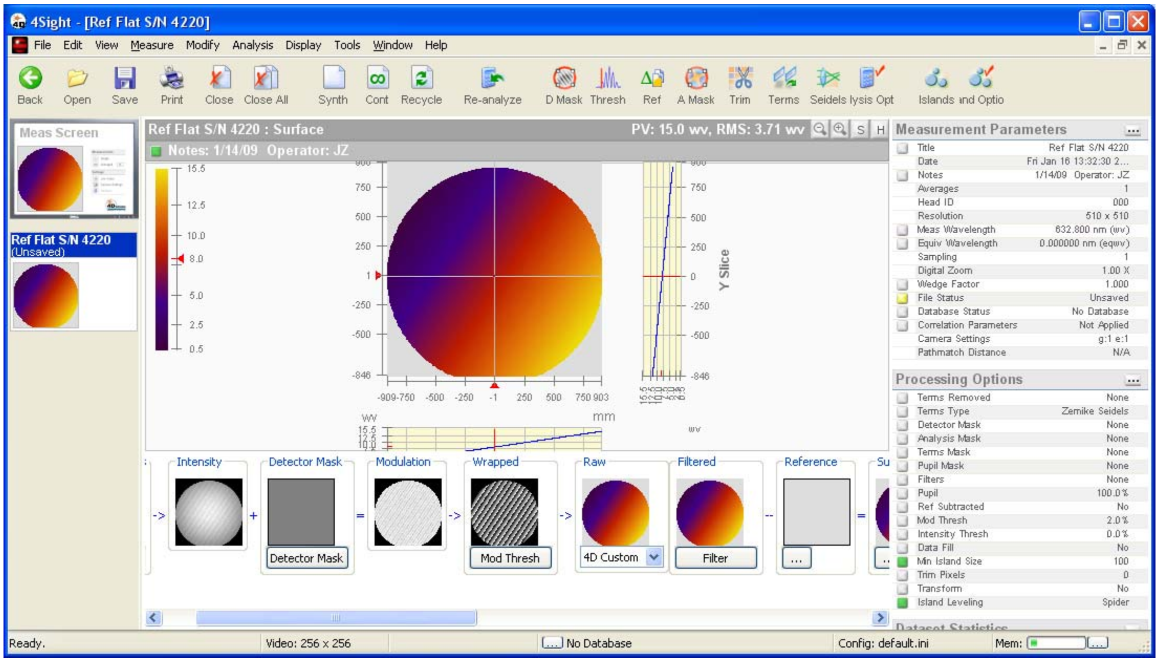


Figure 23: Measurement Flow screen.

Use the scroll bar at the bottom of the *Display Area* to move back and forth across the measurement flow. Click on any stage in the flow to view that data in the plot above. You can promote the data from any stage by right clicking and choosing **Promote This Dataset**.

For a detailed data flowchart, see the *Measurement Flowchart* appendix.

Note: Clicking on some stages of the measurement flow will open options dialog boxes for that stage. For example, clicking the **Reference** stage will open the Reference Subtraction dialog box.

Recycle

Often we want to look at the same analysis result, say a *PSF* (Point Spread Function), for each measurement we acquire. It can be cumbersome to repeatedly take a measurement on the Measurement Screen, open an analysis window, then perform the desired measurement. **Recycling** automates this process. To use this feature, take a measurement and analyze it, setting up all the options as necessary. Then press the **Recycle** toolbar button  or choose **Measure > Recycle Current Measurement**. 4Sight will take a new measurement, perform the analysis per the options you've chosen, and display the results in the same analysis window.

Tip: Making a *Continuous Measurement* is the same as repeatedly pressing the Recycle button. To recycle continuously, choose **Measure > Continuous**.

Minimum Memory Consumption Mode

Because so much data can be stored with each measurement it is essential to consider the amount of memory that 4Sight functions may require. Certain operations, such as *Burst Measurement* and *Continuous Measurement*, can put significant strain on your computer's resources. Maintaining a large number of measurements in the Measurement Stack can also lead to sluggish computer response. The Memory Usage gauge in the *Status Bar* helps you monitor memory usage (*Figure 24*).

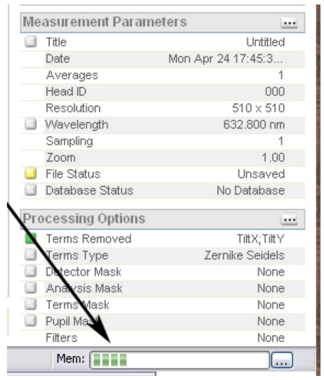


Figure 24: Memory Usage meter.

4Sight includes a Minimize Memory Consumption mode which dramatically reduces the amount of data stored in active memory for each measurement. To activate this mode choose **Tools** > **Preferences** > **Memory**, then check the **Minimize memory consumption** box (*Figure 25*).

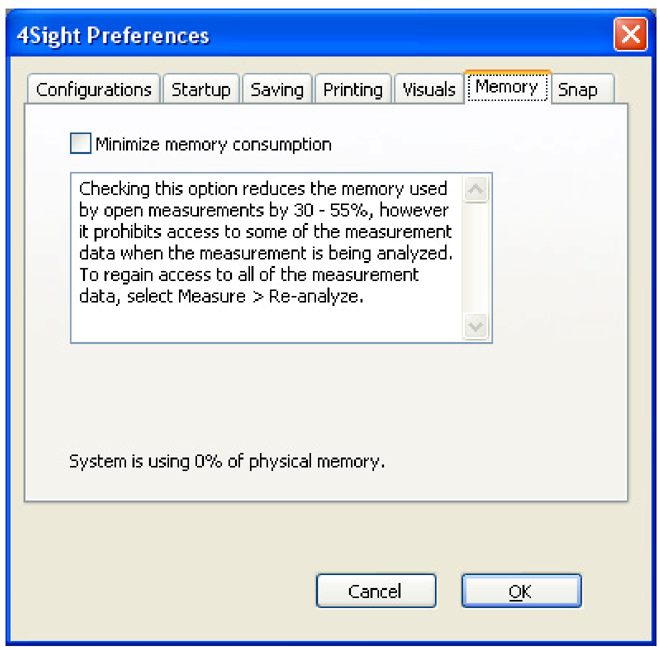


Figure 25: Memory Consumption dialog box.

In Minimum Memory Consumption Mode, once the measurement is analyzed and added to the *Measurement Stack* it contains only the original intensity frame (i.e., all of the interferograms as delivered from the camera), the Raw data and the surface data. The intermediate datasets are not retained in active memory but can be recalculated by using the **Reanalyze** command, described next.

Reanalyze

The Reanalyze command pulls data from the Measurement Stack and places it back into the Measurement Screen. If you are working in *Minimum Memory Consumption Mode* this operation will rebuild the intermediate datasets that are not stored with the measurement. In this way a subset of data can be stored but the complete measurement can be reconstituted at any time.

To reanalyze data, select the measurement in the Stack and click the Reanalyze toolbar button. You can also choose **Measure** > **Reanalyze This Measurement**.

Note: If a dataset has been promoted, it will not contain the original interferograms and cannot, therefore, be reanalyzed. In this case the Reanalyze button and menu option will be gray.

Generating a Synthetic Measurement

For testing and planning purposes it is often useful to generate a synthetic measurement from either Seidel or Zernike coefficients. To do so, click the Synth toolbar button , choose **File** > **New** > **Synthetic Dataset** or click **Ctrl-N**. All three functions open the **Synthetic Wavefront Generation** dialog box.

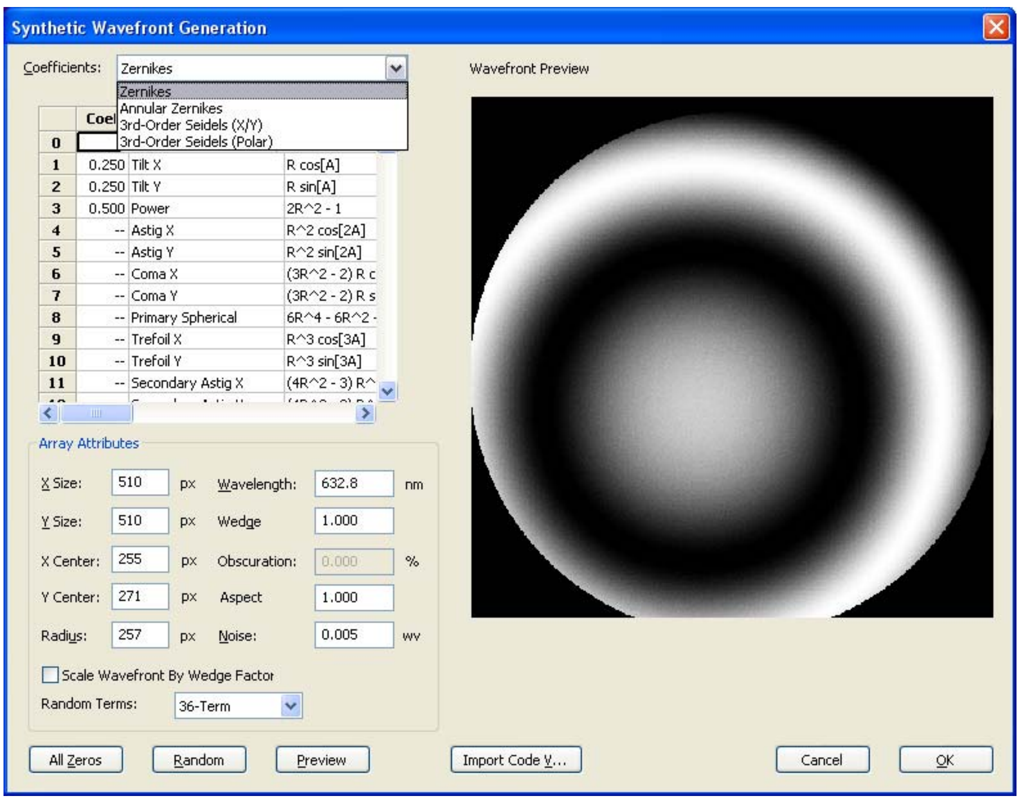


Figure 26. The New Data dialog box for generating synthetic data.

Enter the dimensions, location, and physical parameters of the desired dataset. Next, select the type of coefficients (**Zernike**, **Annular Zernike**, **3rd Order Seidels**) from which you wish to generate the data. Enter coefficients for any of the terms within these groupings, or click **Random** to enter randomized numbers for the coefficients. Click **All Zeroes** to reset all coefficients to zero. You can also import data from Code V® optical design software.

Note: On the **Tools** > **Preferences** > **Startup** tab select **Show Synthetic Data** to automatically open the **Synthetic Wavefront Generation** dialog box when you launch 4Sight.

You may check the **Scale Wavefront by Wedge** box to apply the *Wedge Factor* to the synthetic data. If you generate a surface using a wedge factor of 0.5 and then analyze the resultant measurement using one of the *Zernike Polynomials* analysis screens, the Zernike coefficients will be one half of the original input values. Be sure that the Pupil fits within the measurement (i.e., set the radius to one pixel less than 1/2 the smallest dimension of the measurement). This will ensure that the fitted Zernike terms match the input values.

Once the coefficients and options are set, click **Preview** to view the synthetic data, or press OK to generate the measurement and add it to the *Measurement Stack*.

Simulator Mode

Simulator Mode lets you mimic data acquisition as if the computer were connected to actual hardware. To turn on the simulator, choose **Tools** > **Preferences** > **Configurations**, check the **Initialize Simulator** box and un-check the **Desktop Mode** box if necessary. Restart 4Sight for the change to take effect.

After restarting you can now choose **Measure** > **Simulator Setup** to open the **Simulator Setup** dialog box (*Figure 27*).

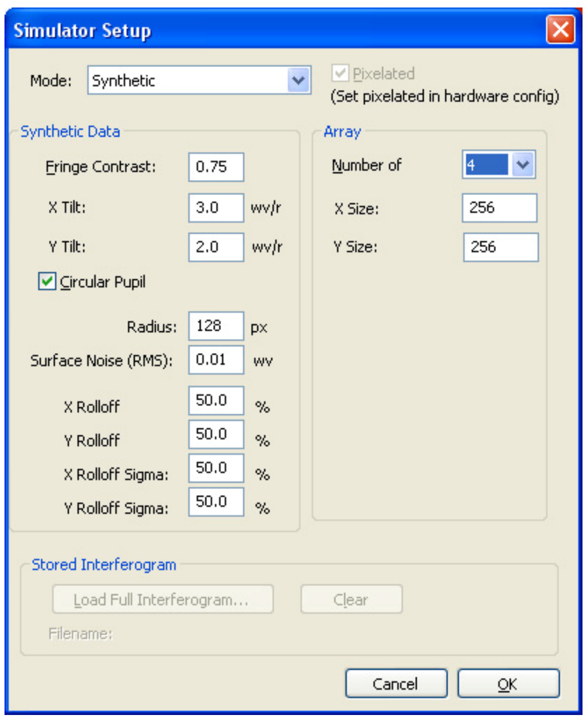


Figure 27: Simulator Setup dialog box.

Set up the following options:

Mode Choose the simulator mode:

- **Synthetic** generates simulator data per the **Synthetic Data** options on the dialog

- **From Interferogram Files** uses actual interferograms from a prior measurement. Click **Load Full Interferogram** to choose the measurement; click **Clear** to remove it.
- **From Surface File** uses the interferograms from the current measurement.
- **Grid** generates an array of data islands for quality control.

Pixelated	Denotes whether a pixelated phase mask would be used with the simulated system. This value is set in the hardware configuration.
Fringe Contrast	The intensity difference across the pupil.
X/Y Tilt	The amount of tilt induced in the X and Y directions.
Circular Pupil	Check this box to force the data into a circular pupil.
Radius	The pupil radius, in pixels.
Surface Noise	The amount of random noise introduced to generate realistic data.
X/Y Rolloff Center	The location of peak intensity, expressed as a percentage of the total pixels in X and Y.
XY Rolloff Sigma	Specifies how quickly the intensity falls off as you move from that center toward the edges of the pupil. 100% means intensity does not roll off from center to edge. A low percentage means the intensity falls off very quickly, producing a small center of light.
Number of Frames	The number of frames of live data to simulate, from **1 to 9**. This value allows you to represent vibration, etc, from an actual system.
X/Y Size	The number of pixels in the dataset, in the X and Y directions.

You can also open and analyze a dataset, then right click on its contour plot and choose **Send Dataset to Simulator**. Its fringe pattern will appear in the Measurement Screen icon. Click the icon to open the Measurement Screen—you will see that all of the intermediate datasets and the interferograms have been “backed out” from the dataset, as if the measurement had been made from actual hardware.

Chapter

4

Measurement Settings

In this chapter we will discuss the many options in 4Sight™ for acquiring, scaling, and otherwise manipulating data for display.

Measurement Screen Display Options

As we've seen, the Measurement Screen provides access to the settings you need to make a measurement.

Live Video

When you open the Measurement Screen, live video from the camera will be displayed. Taking a measurement replaces the live video with the measured data. You can press the **Live Video** button to return to viewing live camera output. The last measurement will be discarded.

When video is showing, the **Live Video** button is replaced by a **Freeze** button which allows you to pause on a video frame. Live video will also stop automatically if you make a measurement or close the Measurement Screen.

Note: On the **Tools** > **Preferences** > **Startup** tab select **Show Live Intensity** to automatically open the **Measurement Screen** and display live video when you launch 4Sight.

Click the **Floating Video** button on Measurement Screen to open a separate, floating Live Video window (*Figure 28*). This window will continue to show live camera output regardless of what is shown in the Measurement Screen (Live Video, frozen video or measurement data).

The Floating Video display can be particularly handy if you have two monitors connected to your computer. The Floating Video can be displayed on one monitor, which can be placed close to the measurement setup and used for alignment. The other monitor can be placed at the operator workstation for completing measurements and analyzing data.

The Floating Live Video window includes standard Microsoft Windows buttons at the top for minimizing, maximizing and closing the window. You can also click **Floating Video** on the Measurement Screen to close the window if it is open.

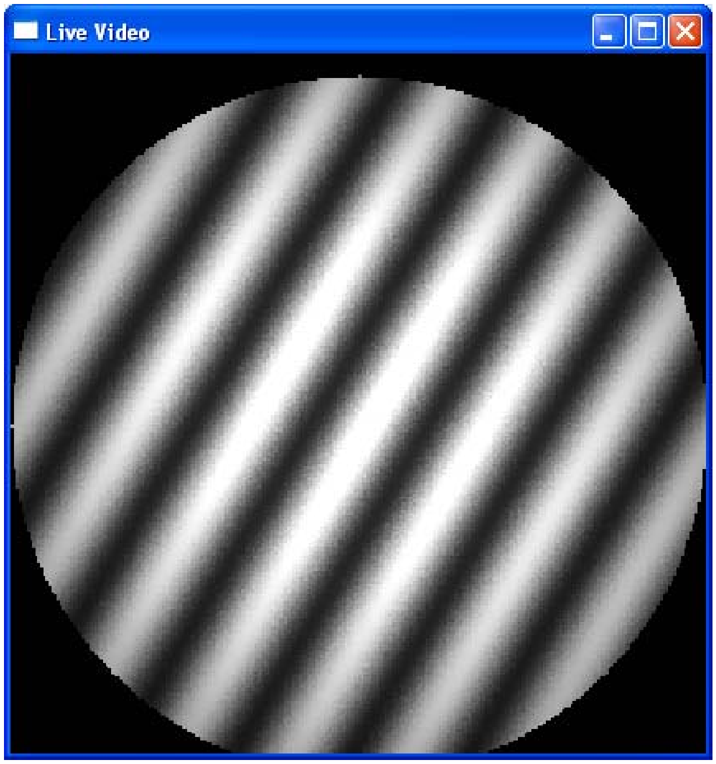


Figure 28. Floating Live Video display.

Hide and Show

The Measurement Screen's standard display is a *Contour Plot*. As such, all the contour plot options are available: cursors, x and y profiles, legend, etc. (see *Contour Plot*). These options can be turned on and off using the **Show (S)** and **Hide (H)** buttons in the upper right of the plot (*Figure 29*).

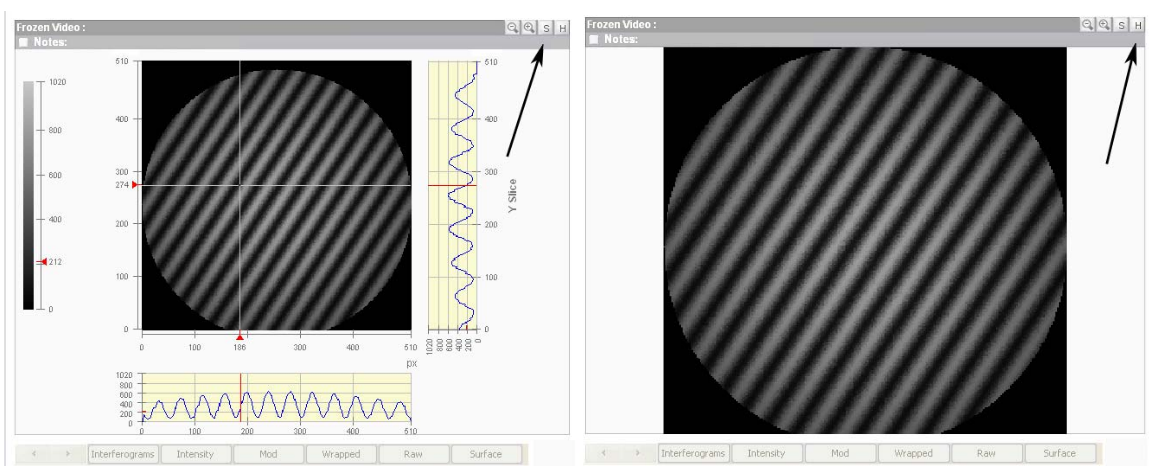


Figure 29: Measurement Screen with options shown *and* hidden.

There are many circumstances in which these display options are useful, but they can also slow the live video display rate, and they take up some screen space. Therefore, when you do not require these features click the **H** button to hide them.

Note: The *Masking* dialog box may also slow down the display. The **H** (Hide) button will not close the Masking dialog.

Dataset Buttons

Below the contour plot are several buttons which allow you to view the various datasets which comprise a measurement. These buttons are enabled or disabled depending on the active measurement. For example, if you are viewing live video, you cannot view surface data. Similarly, if you take an *Averaged Measurement* you will not be able to view intensity, modulation, or wrapped phase data (since these arrays are discarded for the individual measurements in an average).

The following is an explanation of each button and the corresponding dataset. For a detailed data flowchart, see the *Measurement Flowchart* appendix.

Interferograms	Display the measurement's interferograms. Click the **arrow buttons** to move to the previous or next interferogram; hold down either arrow button to scroll.
Intensity	Intensity values for each pixel.
Mod	The modulation data.
Wrapped	The data prior to phase unwrapping.
Raw	The raw data, with pixels that have insufficient modulation rejected.
Surface	The analyzed data (sometimes referred to as OPD data).

Note: The **All** interferograms button found in prior versions has been removed. You can still step through the individual interferograms by using the < and > arrows.

For more detailed descriptions of these arrays see *What is in a Measurement* above.

Camera Settings

All measurements depend upon the camera being set up correctly. For most systems, camera settings are stored with each of your *User Configuration*, making it easy to switch setups for different applications (e.g., frequently measuring parts with different reflectivity). Some older systems will not have this feature.

To change the camera settings, click the **Camera Settings** button on the Measurement Screen (*Figure 30*).

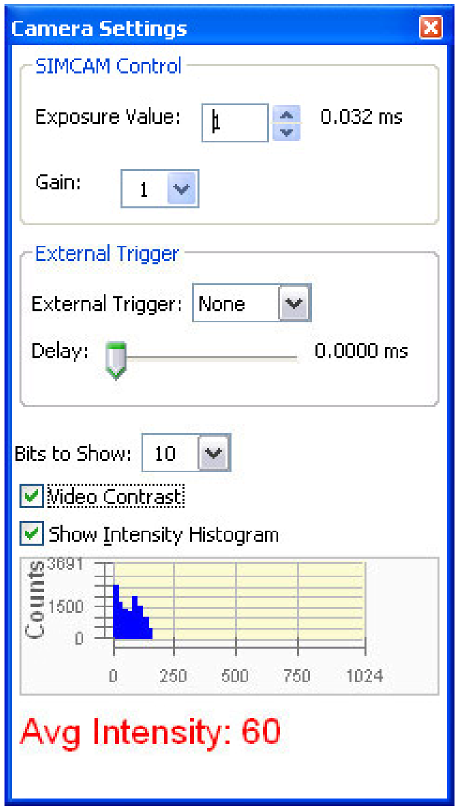


Figure 30: Camera Settings Options.

Camera Control

For each measurement set the **Exposure Value** and **Gain** such that the intensity of all pixels remains just below saturation. While watching the Live Video display, raise the **Exposure Value** until red pixels appear, indicating saturation (*Figure 31*). Then reduce the value to the point where saturation disappears. This ensures that the full dynamic range of the camera is used.

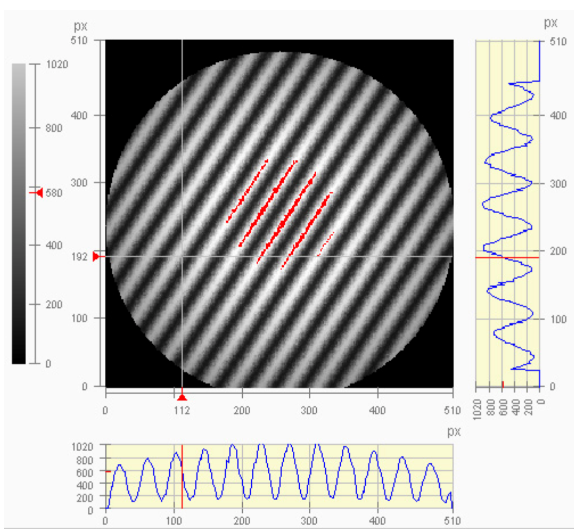


Figure 31: Live Video showing saturated(red) pixels in center.

If the Exposure Value does not provide sufficient range to produce clear, sharp fringes you can increase the **Gain** in the **Camera Settings** dialog as well (if your camera includes a Gain option). Increasing gain may increase the noise level on some cameras. Consult your camera documentation for details.

Check the **Show Intensity Histogram** box to use a histogram of intensity values as a visual guide while setting the exposure. Increase the **Exposure Value** until the histogram nearly reaches the right edge of the plot (the saturation point).

Note: In either case Live Video display must be active. If you have clicked the **Freeze** button on the Measurement Screen to stop the video, click **Live Video** again to restart it.

The **Bits to Show** option allows you to view fewer than the full number of bits from the camera. For example, if you have a 10-bit camera, you can choose to display only the eight most significant bits, which would effectively boost the signal level in the live video display (at the expense of resolution). This can be useful for aligning a part and obtaining fringes in low light conditions. It does *not* affect measurements, which are always made using the full number of camera bits.

When viewing an interferogram, check the **Video Contrast** box to increase the grayscale palette so the fringes have higher contrast for easier viewing. Dark shades will be made darker but lighter shades will not change, so the saturation point will not be affected. The option on changes the display palette and does not affect the video data or the measurement (surface) data.

The **Avg Intensity** value at the bottom of the **Camera** shows the average intensity across the currently displayed video frame. The units are in camera counts—a 10-bit camera, for example, can have intensity values from 0 to 1024 (2^10) counts.

Alignment Mode

For some systems, checking the **Alignment Mode** box displays alignment aids to help you roughly align your part with the interferometer. The type of alignment aids depends on the system, but typically involves a set of dots or crosshairs. When you've aligned the dots or crosshairs, uncheck the Alignment Mode box to hide these tools.

External Trigger

Some systems support an **External Trigger** which causes the camera or frame grabber to wait for a hardware trigger before acquiring a frame. In the **External Trigger** box select **TTL0**, then move the **Delay** slider to set the delay (in milliseconds) between the time a trigger is received and the time the measurement is acquired. if the **External Trigger** is set to **None** the camera is in free-running (asynchronous) mode.

Measurement Options

4Sight's measurement options give you considerable control over the measurement process. Click the **Measurement Options** button on the Measurement Screen, or choose **Measurement > Measurement Options** to open the Measurement Options dialog box. The dialog consists of several pages which can be accessed by clicking the tabs at the top.

Changes made in this dialog will be in effect with the next new measurement and for the remainder of the 4Sight session. To use these options in future sessions as well choose **File > Save Config as Default**.

Check the **Show this dialog…** button to open the Measurement Options dialog box before each subsequent *Single Measurement*. When the dialog opens it will show the tab that was active when you click the **Show this dialog…** button.

PSI Tab

These options apply to *Multiple Measurement Mode* systems and control how temporal phase-shifting measurement will be completed (*Figure 32*).

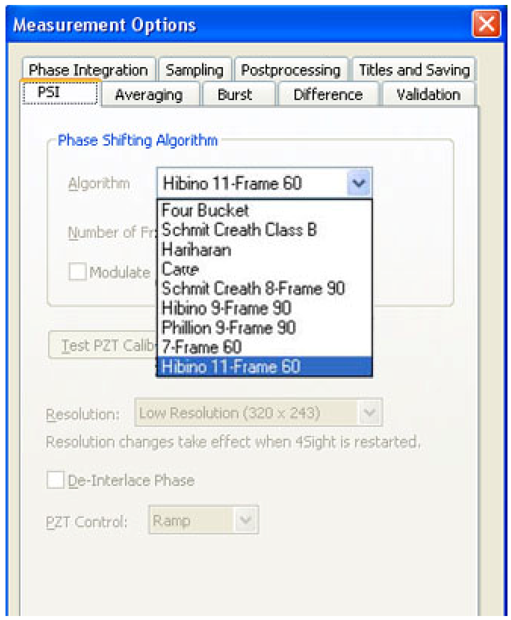


Figure 32: Measurement Options: PSI tab.

Algorithm	The phase shifting algorithm. Choose from several 90-degree and 60-degree options.
Number of Frames	The number of interferograms to record. 4D recommends that you select at least 5 frames for the best results.
Modulate Starting Phase	*Averaging* measurements can help remove the effect of noise and artifacts from a measurement. In temporal measurements, however, if the first measurement is taken at the same phase each, the averaged measurement might still retain some artifacts. Choosing this option can improve averaged measurements by changing the starting phase for the individual measurements.
Test PZT Calibration…	Verify the PZT calibration (see *Multiple Measurement Mode*).
Resolution	For Wyko® interferometers you can select Low Resolution (320 x 243) or High Resolution (640 x 486). Low resolution provides less spatial resolution (i.e., fewer pixels) but eliminates interline, or odd/even artifacts associated with the camera at higher resolution. Low Resolution is recommend unless the higher spatial resolution is absolutely necessary.
De-Interlace Phase	This option offers another approach to fixing the odd/even artifacts for Wyko systems in high resolution mode. This feature calculates

the average height (phase) in each of the odd and even fields, then offsets them so they match.

PZT Control This option determines how the PZT moves while the frames are acquired. In **Ramp** mode the PZT moves at a constant velocity, acquires all frames, then stops. In **Step** mode the PZT locates, acquires one frame, and repeats this process for each frame. Step mode can introduce transients and can take longer, leaving more opportunity for vibration and test part to drift. For this reason, Ramp mode is recommended.

Averaging

Making an *Averaged Measurement* helps reduce the effects of excessive external noise by averaging the results of several measurements. Some data may present ambiguities which could skew averaged measurements, however. In these situation the options on the **Averaging** tab help improve the results (*Figure 33*).

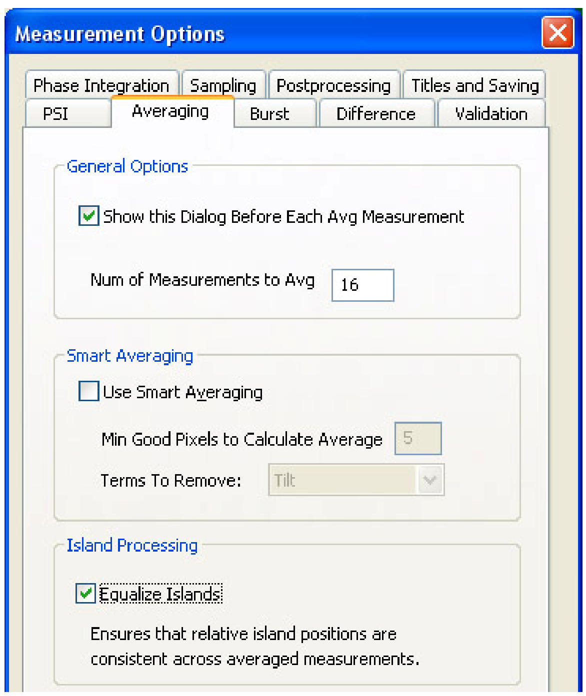


Figure 33: Measurement Options: Averaging tab.

Check the **Show this Dialog**…box to open the Averaging options before each Averaged measurement.

In the **Num of Measurements to Avg** box enter the number of measurements to be completed to obtain the averaged measurement. This box is equivalent to the box on the **Measurement Screen**, and changes made here will be reflected there as well.

Smart Averaging

With some samples low lighting, poor reflectivity, high slopes, etc, make it difficult to obtain data at every point in every measurement. Checking **Use Smart Averaging** accommodates some data dropout while still acquiring as many good pixels as possible to use in calculating the average.

Min Good Pixels to Calculate Average sets the minimum number of measurements in which a pixel must be considered "valid" (i.e., the contrast must be sufficient) in order for the pixel to be considered in the averaged measurement. For example, if you are averaging ten measurements, you might enter "7," specifying that only pixels which are valid in seven or more measurements should be used in the average. A pixel that is valid in all 10 measurements will be averaged over all 10 values. A pixel that is valid in 8 measurements is still used but will be averaged across the 8 values. A pixel that is valid in only 4 measurements will be not be computed in the average, leaving a blank (or invalid) point in the data.

Terms to Remove removes tilt, or tilt + curvature, from each individual measurement before calculating the average.

Note: If Smart Averaging is turned off, then a pixel must be valid in *every* measurement to be used to compute the average. Therefore, it is strongly recommended that you check the **Smart Averaging** option when averaging data. Setting the **Minimum to compute average** number to 3 or so will normally produce a good result.

Island Processing

Island processing is useful when making averaged measurements of large steps or discontinuous regions ("islands"), or continuous surfaces that are broken into discrete regions by "spiders" or other structures in front of the test surface. If the step between two islands approaches one fringe (typically one-half wave), or measurement disturbances are large enough to induce a height difference between islands, then the relative step height becomes ambiguous. One individual measurement in the average might show island A higher than island B, but the next might show B higher than A.

Although 4Sight cannot resolve this ambiguity and decide which measurement is correct, it *can* make the individual island heights consistent across the averaged measurements. Checking the **Equalize Islands** box forces each island to have approximately the same relative height across all measurements in the average (although the measured step might be off by a half-wave due to the fundamental ambiguity).

Burst

Making a *Burst Measurement* creates a single group measurement file containing a user-specified number of individual measurements (*Figure 34*).

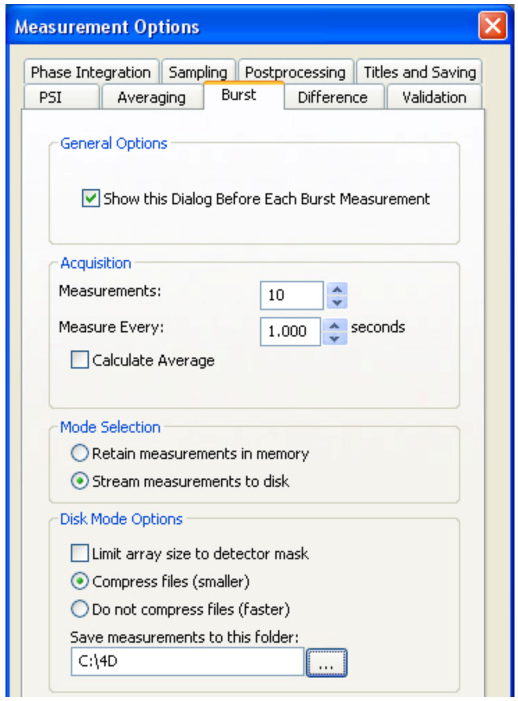


Figure 34: Measurement Options: Burst tab.

Check the **Show this Dialog…** box to open the Burst options before each *Burst Measurement*.

Burst Acquisition

These options control how the individual Burst measurements will be obtained. Enter the number of **Measurements** in the burst. In the **Measure Every** box indicate the time (in seconds) between the start of each measurement. This number must be greater than 0.

Check the **Calculate Average** box to automatically determine the average of all measurements in the burst. The average will appear on the measurement stack in addition to the Burst measurement.

Burst Mode Selection

4Sight provides two modes for obtaining Burst measurements.

Check **Retain measurements in memory** to generate a burst, with all of its component measurements, which will appear on the Measurement Stack. The maximum number of measurements in the burst is limited by available computer memory. If you try to take too much data in Burst mode, your computer's processing speed may decrease dramatically. This mode is best for Bursts of 20-30 measurements maximum.

Note: When *Minimum Memory Consumption Mode* is on, only the interferograms and surface data will be stored in memory. You can recreate the intermediate datasets later by using the ***Reanalyze*** command.

Check **Stream measurements to disk** to stream raw camera frames to disk for offline analysis. Because there is very little processing during acquisition, high measurement rates can be achieved, and the duration of the burst is limited only by disk space.

Disk Mode Options

When **Stream measurements to disk** is selected, these options indicate how data will be stored to disk.

Check the **Limit array size to detector mask** to only save the pixels contained inside the boundaries of the *Detector Mask*.

Check **Compress files** to apply compression to the stored HDF5 files (for smaller file sizes) or **Do not compress files** to store the uncompressed data (for faster acquisition).

Note: This option will override the **Compress HDF5 files when saving** general option in **Tools > Preferences >Saving**.

In the **Save measurements to this folder** box specify the location on hard disk to store the measurements. The Burst group will be stored as Burst 1, Burst 2, etc.

Difference

In a **Difference Measurement** 4Sight acquires two frames of data and calculates the difference between them (*Figure 35*).

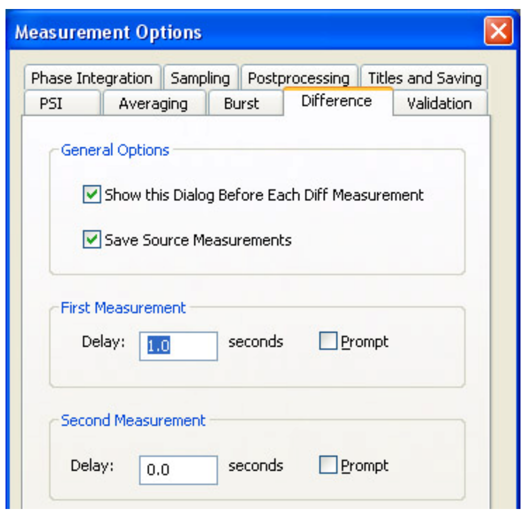


Figure 35: Measurement Options: Difference tab.

Check the **Prompt** boxes to manually initiate either or both measurements.

You can also set **Delay** times before the frames are acquired. The delays will be implemented whether the measurements are taken automatically or when prompted.

If you check the **Save Source Measurements** box, a measurement group containing the two measurements will be added to the Measurement Stack, as well as the Difference result. The group will be titled “Diff 1 of 2.”

Check the **Show this Dialog Before Each Diff Measurement** to bring up the dialog before each Difference measurement.

Validation

These options automatically accept or reject measurements based on thresholds for Modulation Threshold (see *Signal Thresholds*) and/or the PVq (see *Statistics*) parameter (*Figure 35*).

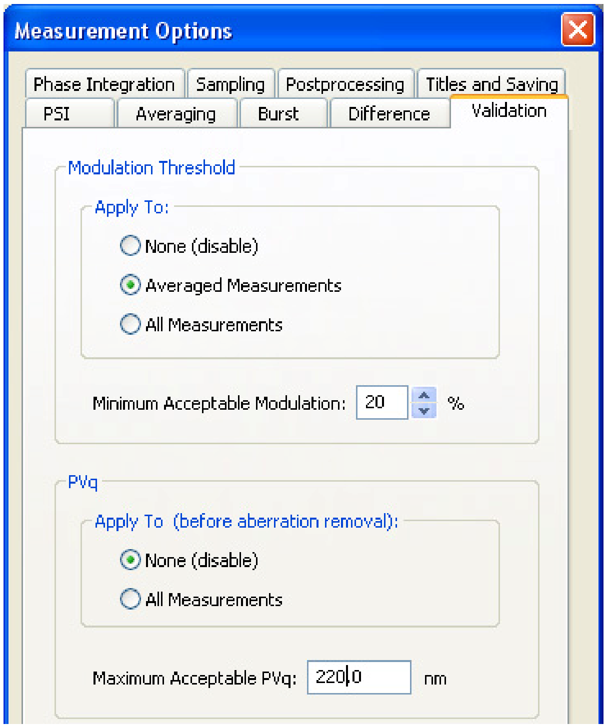


Figure 36: Measurement Options: Validation tab.

Validation by Modulation Threshold

The **Modulation Threshold** allows you to reject measurements in which the average pixel modulation (change in intensity between interferograms) is insufficient. Only pixels in the active, unmasked portions of the dataset are considered. Modulation Threshold validation takes place immediately after each frame of data is acquired.

Note: This Modulation Threshold lets you accept or reject an entire measurement based on its average modulation. The Modulation Threshold in the *Signal Thresholds* dialog box is used to accept individual pixels within a measurement based on modulation.

In the Modulation Threshold area enter the **Minimum Acceptable Modulation** value (in %). Typical values range from 0.5 (%) to 50.0 (%). Then, choose to apply Modulation Threshold validation to **Averaged Measurements** or **All Measurements**, or choose **None** to disable the feature.

The following outcomes are possible, depending on the type of measurement:

Single	If the measurement meets the modulation threshold then processing continues. If it does not meet the criterion then 4Sight will continue to acquire data until a measurement with sufficient modulation is found. Click **Cancel** to end the cycle.
Averaged	4Sight will acquire frames for the first measurement until one is found that meets the modulation threshold. Once one is found 4Sight will repeat the process for each subsequent measurement. Click **Cancel** to end the cycle.
Continuous	This option is disabled when Measurement Validation is turned on.
Difference	4Sight will acquire frames for the first measurement until one is found that meets the modulation threshold. Once it is found 4Sight will repeat the process for the second measurement. Click **Cancel** to end the cycle.
Burst	This option is disabled when Measurement Validation is turned on.

Validation by PVq

The PVq parameter is a more robust measure of the shape than PV as it disregards the highest and lowest pixels in the array and records the peak-to-valley height of the remaining **Q Percent** of pixels. See *Statistics* for more.

To accept or reject a measurement based on PVq, in the PVq area of the Validation tab enter the **Maximum Acceptable PVq** value. Then, choose to apply the PVq threshold to **All Measurements**, or choose **None** to disable the feature. Measurements are validated before *Aberrations Removal* takes place.

The following outcomes are possible, depending on the type of measurement:

Single	If the measurement meets the PVq threshold then processing continues. If it does not meet the criterion then the measurement will be rejected.
Averaged	4Sight will acquire each measurement and will continue unless one fails the PVq threshold. If a measurement fails then the averaged measurement will be rejected.
Continuous	This option is disabled when Measurement Validation is turned on.
Difference	4Sight will acquire each measurement and will continue unless one fails the PVq threshold. If either measurement fails then the difference measurement will be rejected.
Burst	This option is disabled when Measurement Validation is turned on.

Phase Integration

Phase integration, also called unwrapping, is the process of resolving two-pi phase discontinuities in the wrapped phase data to create the unwrapped, or raw, data. Many integration techniques have been developed, and 4Sight supports two of them.

The **4D Custom** unwrapper, which is the default method, attempts to unwrap the most reliable data first, then fills in the less reliable data. As a result, the overall shape tends to be the most correct.

The **Flood Fill** algorithm is simpler and faster and may work better in some situations. For the most part, however, it is more likely to produce errors. These errors generally propagate along the direction of unwrapping, and produce vertical artifacts in the phase which extend from the location of the error all the way to the top, or bottom, of the array.

Tip: Either algorithm can produce anomalies under certain conditions, such as excessive local slopes, or optical effects at the edge of the part. You can improve unwrapping by:

- Setting the modulation threshold as high as possible without masking wanted data
- Use a detector (not analysis) mask to obscure edges of the part
- Null the fringes as much as possible, favoring problem areas if necessary.

Sampling

Sampling allows you to reduce the size of each measurement's datasets as the data is acquired, to increase the speed of live video and measurement as well as reducing the file size (*Figure 37*).

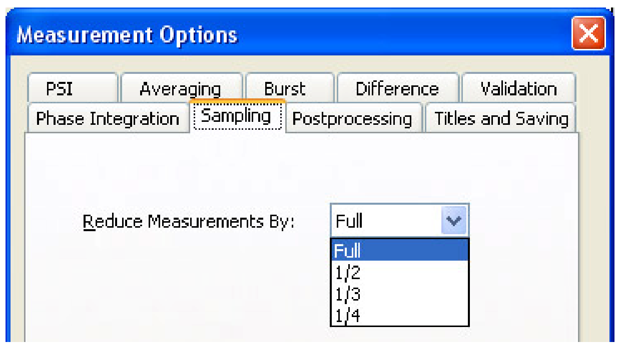


Figure 37: Measurement Options: Sampling tab.

From the **Reduce Measurements By** list choose **Full** to use all pixels, or **1/2**, **1/3**, or **1/4** to reduce the data to every second, third or fourth pixel.

Postprocessing

Postprocessing options let you reduce the dataset size after each measurement (*Figure 38*).

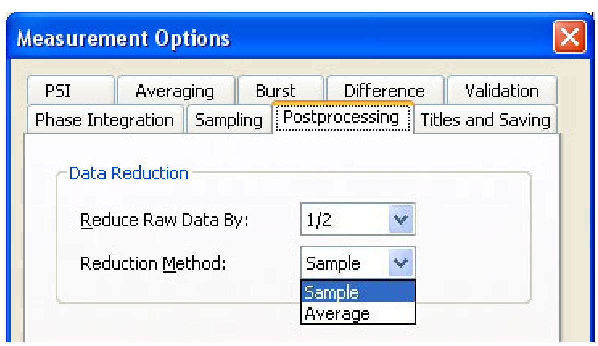


Figure 38: Measurement Options: Postprocessing tab.

Data Reduction

Reducing the size of a dataset can speed up processing for time-intensive tasks such as Zernike analysis. It also creates a more conveniently sized measurements for export to other programs with limited capacity.

To enable data reduction, select a reduction rate in the **Reduce Raw Data By** list. The **Full** option will retain every pixel, while **1/2** samples every second pixel, and **1/4** samples every fourth pixel.

Next, select a **Reduction Method**. The **Sample** method uses the value of every 1, 2 or 4th pixel. The **Average** method uses the average of every two or four pixels and is usually more accurate and less noisy.

Note: Data Reduction is applied *during* calculation of the raw phase. The interferograms are *not* reduced, and therefore this method does not significantly reduce memory usage or the size of saved measurements. It will, however, proportionally reduce the size of a promoted raw or analyzed (surface) dataset.

We recommend using the options on the *Sampling* tab rather than Data Reduction for more effective data reduction, if the Sampling options are available for your system.

Titles and Saving

These settings control how new measurements are handled and saved (*Figure 39*).

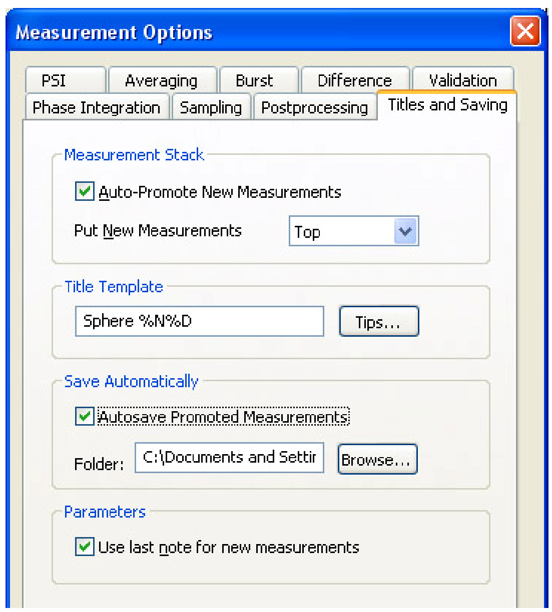


Figure 39: Measurement Options: Titles and Saving.

Measurement Stack

When you promote or analyze a new measurement it is placed into the *Measurement Stack*. Select whether to put new measurements on either the **Top** or **Bottom** of the Stack.

Check **Auto-Promote New Measurements** to analyze each new measurement and add it to the Measurement Stack automatically.

Note: The Measurement Stack can quickly become quite large using the Auto-Promote option, thus taxing your system's resources. Be sure to monitor the Memory Usage meter in the lower right of the 4Sight screen to avoid affecting system performance.

Title

4Sight can automatically assign a title to each new measurement based on a specified **Title Template**. The template may contain plain text as well as codes which 4Sight will replace with values as each measurement occurs. Click the **Tips** button to view a list of available codes (*Figure 40*).

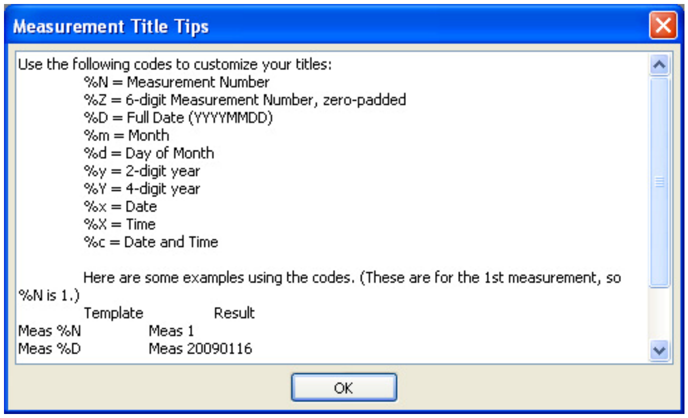


Figure 40: Title Template codes.

As an example, the Title Template, "Sphere %N %D" uses the '%N' code to create sequential numbering, and the '%D' code to include the current date. The first measurement will be titled, "Sphere 1 20060430," the second measurement will be titled, "Sphere 2 20060430," and so on. Sequence numbers restart at 1 for each new 4Sight session.

If you do not specify a title template, each new measurement will be called "Untitled." You can change a title at any time by choosing **Edit** > **Change Title**.

Save Automatically

These options save each new measurement to disk each time they are promoted or analyzed. Check the **Autosave Promoted Measurements** box to enable this feature, and select a folder to which measurements will be saved.

Parameters

Check the **Use last note for new measurements** box to apply the last written *Measurement Notes* to all subsequent measurements.

Optical Parameters

You can specify the optical parameters of your system by choosing **Edit** > **Optical Parameters** (*Figure 41*). These parameters are applied to each new measurement and will remain active for the duration of the current 4Sight session. Choose **File** > **Save Config as Default** to use these settings in subsequent sessions as well.

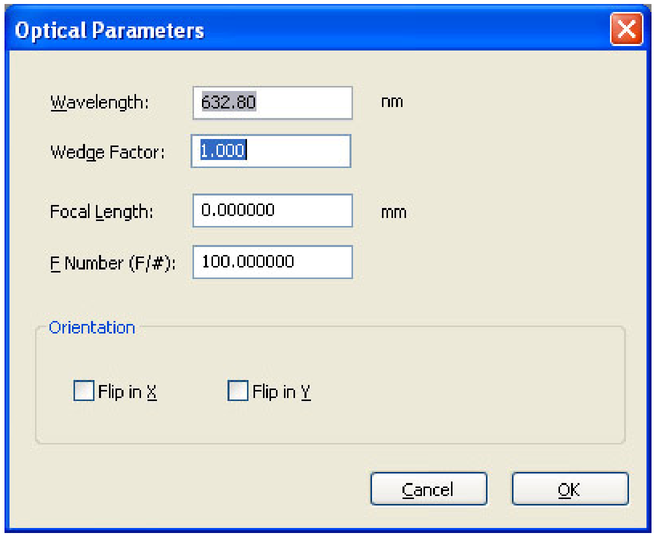


Figure 41: Optical Parameters dialog box.

Wavelength

This is the wavelength of the laser in your interferometer. The wavelength is used along with the Wedge factor to convert a number of fringes into real-world units (see *Scaling Lateral Dimensions to the Real World* below).

Wedge Factor

The optical wedge is the conversion factor between the number of fringes in the wavefront and the number of waves of aberration in the system under test. For an optical surface such as a mirror, the wedge factor should be set to 0.5, meaning 0.5 waves per fringe on the surface. Most measurements require the wedge value to be set to 0.5.

Focal Length

This is the physical focal length of the system under test. The focal length is used to scale the *PSF*, *MTF, PSD*, and *Autocovariance* functions.

F/#

The F/# is equal to the focal length divided by the diameter of the optical system under test. The F/# is used for scaling the *MTF* and *PSD* functions.

Orientation

These options allow you to alter 4Sight's coordinate system to match that of another program, or to suit your preference. Choosing **Flip in X** (which mirrors data across the Y axis) or **Flip in Y** (which mirrors data across the X axis) takes data from the camera and inverts (or mirrors) it on screen and in saved data.

Note: The intensity data *does not flip*—only the displayed image is changed. When the **Flip** option is turned on data will be saved as it was received from the camera but will appear flipped when displayed.

Digital Zoom

Digital Zoom Tools

4Sight's Measurement Screen and *Contour Plot* allow you to zoom in on a region of interest (ROI) for closer inspection. Digital zoom changes the amount of data that is displayed; it does not alter the data array.

Note: Digital Zoom should not be confused with the Optical Zoom feature on some systems, which changes the actual magnification of the instrument.

You have several options for zooming in on a region of interest:

1. Right click in the Live Video area or on a contour plot and select **Zoom in 2X.** The center portion of the data will be magnified by 2X. Choose this option repeatedly to progressively zoom in (*Figure 42*).

2. Click the **Zoom In** button  in the upper right corner of the Live Video display or contour plot. The cursor will change to a magnifying glass. Click in the contour plot to zoom in on the central portion of the data by 2X (*Figure 42*). Click repeatedly to progressively zoom in.

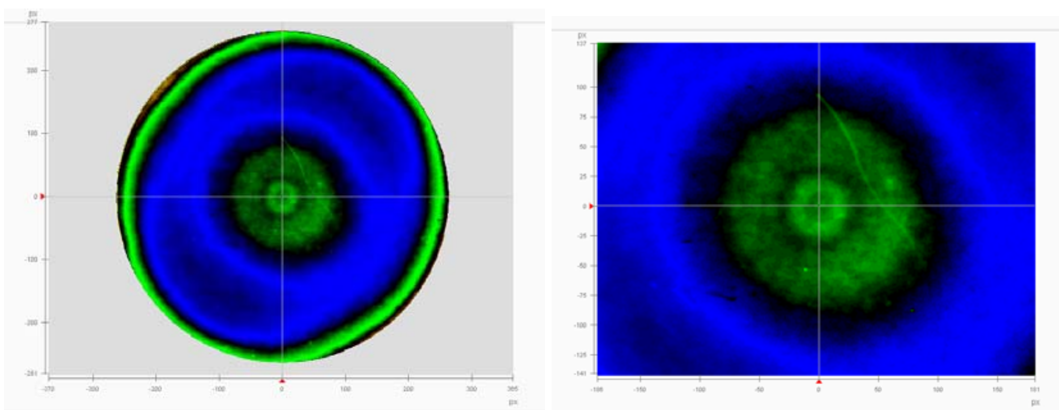


Figure 42: Contour plot at full and 2X magnification.

3. Click the **Zoom In**  button, then click and drag within the Live Video display or contour plot to define a rectangular region of interest. When you release the mouse button the region will be magnified such that its longest dimension fills the display area. The aspect ratio of the selection box will be maintained.

When data is zoomed you can pan across the dataset by clicking and dragging the scroll handles above and to the right of the data. You can zoom further by again choosing **Zoom in 2X** or selecting another region of interest with the **Zoom In** tool.

To show all data, right click in the Live Video or contour plot and click the **Zoom Out** button , or right click in the plot area and choose **Zoom All**. If you have zoomed more than once you can also right click and choose **Zoom Out 2X** to double the viewed area (which may still be smaller than the entire dataset).

Under *Measurement Parameters*, the **Digital Zoom** parameter shows the current zoom factor. Under *Dataset Statistics* the **ROI** parameter shows the size of the region of interest in pixels, while **ROI Size** shows the real-world dimensions based on the current *Lateral Units* setting.

Note: When you are viewing a zoomed region, the *Measurement Parameters* and *Dataset Statistics* will reflect the region of interest.

Tip: You can use the **Zoom to Shape** command on the Edit Masks dialog to magnify small shapes while defining masks. See *Defining a Mask* for more on working with mask shapes.

Digital Zoom Persistence

As mentioned earlier, digital zoom affects how data is displayed, but it does not determine which data will be acquired. If you zoom on an area of the Live Video screen then take a measurement, the entire, full-sized area will be measured, though the resulting contour plot will show just the zoomed view.

The digital zoom factor is also maintained as part of a measurement, when you:

- Click Analyze to place the data on the Measurement Stack
- Click the data in the Measurement Stack to open it in an analysis window
- Select a different analysis to display
- change the *Sampling* settings
- Save the dataset to disk
- Reopen stored data.

Throughout these steps *all* of the data will be imaged and maintained. At any time you can click the **Zoom Out** button , or right click in the plot area and choose **Zoom All**, to view the entire dataset and the statistics for the entire dataset.

Finally, the digital zoom factor will be maintained when you close and reopen 4Sight. Click the **Zoom Out** button, or right click in the plot area and choose **Zoom All**, to view all data.

Note: The digital zoom factor will be lost if you perform certain *Arithmetic* functions, such as adding or subtracting datasets with different zoom factors.

Promoting a Zoomed Region of Interest

As mentioned earlier, zooming in can highlight an area of interest, but it does not alter the data array. All analyses continue to act on the entire data array.

If, however, you zoom on an area, right click and choose **Promote This Dataset**, only the zoomed region will be promoted. You can then analyze the region of interest specifically.

Scaling Lateral Dimensions to the Real World

By default, 4Sight displays lateral (X and Y) dimensions in units of pixels. Default vertical (Z) dimensions are given in waves (default is 1 wave = 632.8 nm.). Other analyses are dimensioned using an appropriate derivative of pixels and waves; for example, *Slope* data is displayed in units of "waves/pixel."

If you provide 4Sight with lateral scaling information, then it can display lateral dimensions in real-world units (millimeters, inches, etc). Similarly, if you specify the correct wavelength of your laser, then 4Sight can display vertical dimensions in real-world units.

Setting the Lateral Coordinate Origin

Set the lateral origin to either the center or to the lower-left corner of the measurement by choosing **Analysis** > **Analysis Options** > **Coordinate System**, and choose **Pupil Center** or **Bottom Left** as the location of the origin.

Setting Lateral Scaling

You can set lateral scaling (pixel spacing) from the Measurement Screen to apply to all subsequent measurements, or you can change the scaling for a particular measurement within its analysis window. Two methods are available to set the scale: using a line, or using the pupil.

Using a Line

To set the lateral scaling by drawing a line, right click on any *Contour Plot* (or within Live Video on the Measurement Screen) and choose **Specify Lateral Scaling**. This opens the **Lateral Spacing** dialog box (*Figure 43*).

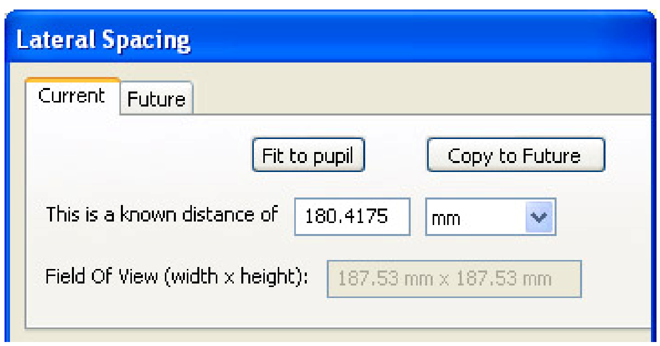


Figure 43: Pixel Scaling dialog box.

The dialog box has two tabs: one for applying options to the current measurement, and one to affect future measurements.

Note: If you click **Specify Lateral Scaling** with Live Video showing then the options on the Current tab will be disabled, since there is no current measurement. The changes you make will apply to subsequent measurements.

When the Lateral Spacing dialog box opens, the plot will show a line with targets at either end. Click and drag each of the targets to move them to the edges of a feature of known size (such as the diameter of the sample). You can also click away from the targets and drag to draw the line from scratch. While you move the targets the **Field of View** field will update in the Lateral Spacing Dialog box.

Tip: Use the *Digital Zoom Tools* to help you finely position the targets at known locations.

Once you have established the targets at known points, enter the **known distance**. 4Sight can now report lateral dimension in real-world units as well as pixels.

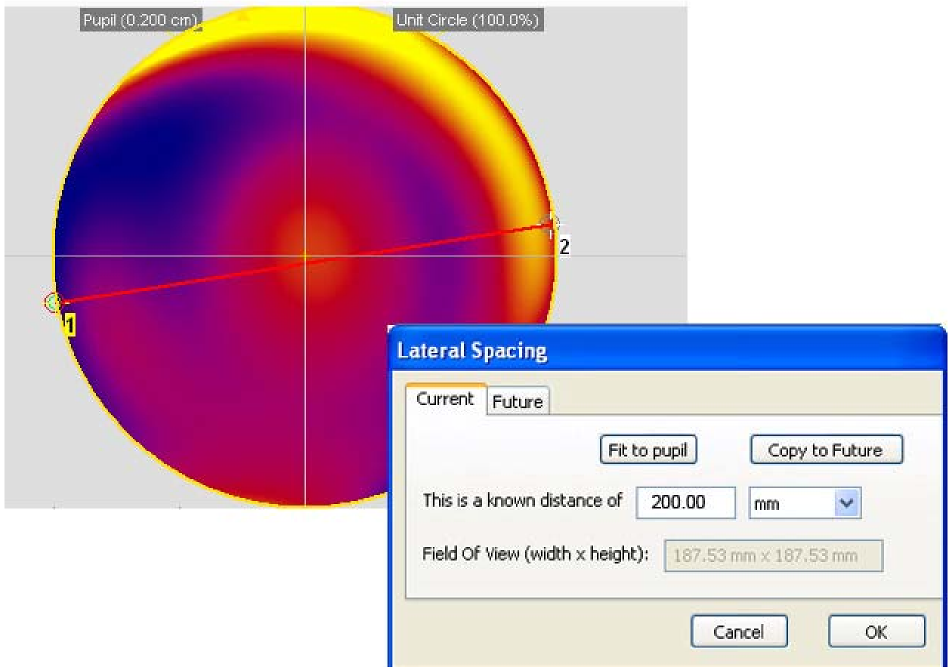


Figure 44: Contour Plot while specifying lateral scaling.

Tip: Use the magnifying glass button above the plot to magnify an area of the data and finely place the end points. Once you have positioned the end points, enter the actual length in the **This is a known distance of** box, and select the units. Click **OK** to accept the new spacing for this measurement. Click **Apply to Future** to use the new pixel spacing for this measurement *and* all subsequent measurements.

Tip: Click the Future tab to see which options will be applied to subsequent measurements.

Using the Pupil

The pupil is the circle encompassing the data under test. 4Sight will automatically create a circular pupil, regardless of the data's actual shape, by finding the maximum extent of the data in X and Y, then setting the pupil diameter to the smaller of these two dimensions. 4Sight can accurately locate a circular pupil even when it is not entirely visible in the field of view. In *Figure 45* the circular sample falls partially beyond the field of view. 4Sight determines the diameter of the assumed circular sample, then includes all of the area that falls with in the field of view.

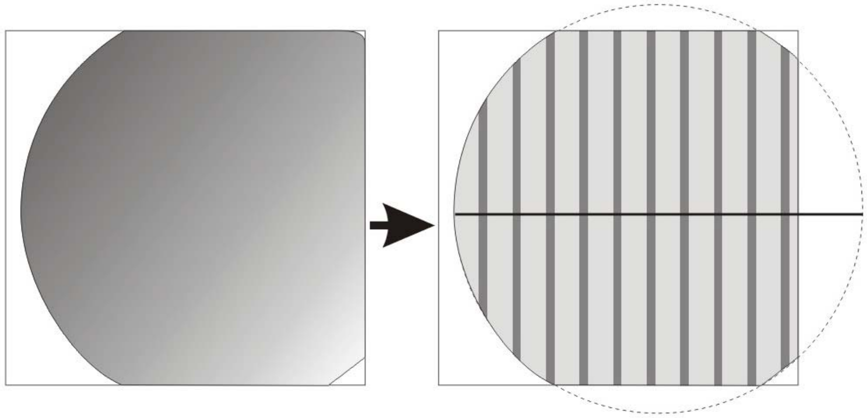


Figure 45: Determining the diameter of a pupil partially outside the field of view. The calculated pupil is shown in gray stripes.

To let 4Sight automatically determine the pupil:

1. Right click on any *Contour Plot* (or within Live Video on the Measurement Screen) and choose **Specify Lateral Scaling**.
2. In the **Lateral Spacing** dialog box (*Figure 43*) check the **Fit to Pupil** box. 4Sight will automatically set the end points of the line to the maximum extent of the data.
3. In the **This is a known distance of** box enter the actual diameter of the sample, in the appropriate units. The **Field of View** field will update accordingly.
4. Click **OK** to accept the new spacing for this measurement. Click **Apply to Future** to use the new pixel spacing for this measurement *and* all subsequent measurements.

To manually define the pupil:

1. Make a measurement and analyze it.
2. Choose **Edit > Masks > Pupil** to open the **Edit Masks** dialog box (*Figure 46*).

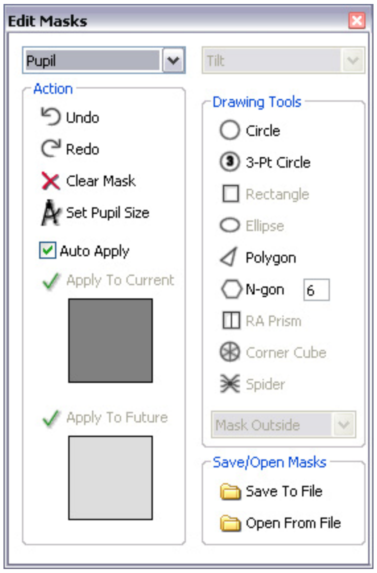


Figure 46: Edit Masks dialog box.

3. On the right side of the box, click the **Circle** or **3-Pt Circle** button to create a circle on the contour plot.

4. Click and drag its square handles until the circle fits the diameter of the data (*Figure 47*).

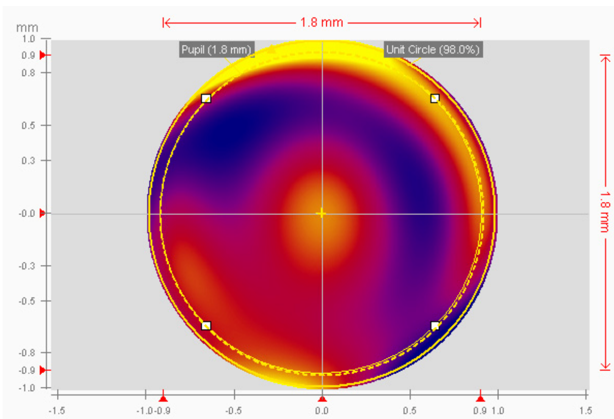


Figure 47: Creating a circular pupil mask.

5. Click **Set Pupil Size**, which will close the Mask Editor and open the **Lateral Spacing** dialog box.

6. In the **This is a known distance of** box enter the actual diameter of the sample, in the appropriate units. The **Field of View** field will update accordingly.

7. Click **OK** to accept the new spacing for this measurement. Click **Apply to Future** to use the new pixel spacing for this measurement *and* all subsequent measurements.

Note: When you open the Edit Masks dialog box from the Measurement Screen you will only see a Future tab. The changes you make will apply to subsequent measurements.

Automatic Lateral Spacing with Zoom Encoders

Some systems include a motorized zoom system with optional encoders that track the zoom position. With these systems 4Sight is able to automatically scale lateral dimensions based on the current zoom setting. The **Optical Zoom** parameter in *Measurement Parameters* displays the current effective zoom. The displayed dimensions will update when you click **Show Live Video**, take a new measurement, show the ruler, click **Show** or **Hide** on a *Contour Plot*, or open the **Lateral Spacing** dialog box..

Note: For the highest accuracy, set the optical zoom, then reset the later scaling manually using the techniques described above.

Unit Circle

The unit circle is a mathematical construct used to fit Zernike aberrations to your measurement data. It can have a significant impact on the value of the Zernike terms that best fit the data. You can view the unit circle by right clicking on a contour plot and selecting **View Options** > **Annotations**. The unit circle typically closely outlines the edge of your measurement.

To control how the unit circle is determined, choose **Analysis** > **Analysis Options** > **Pupil** (*Figure 48*).

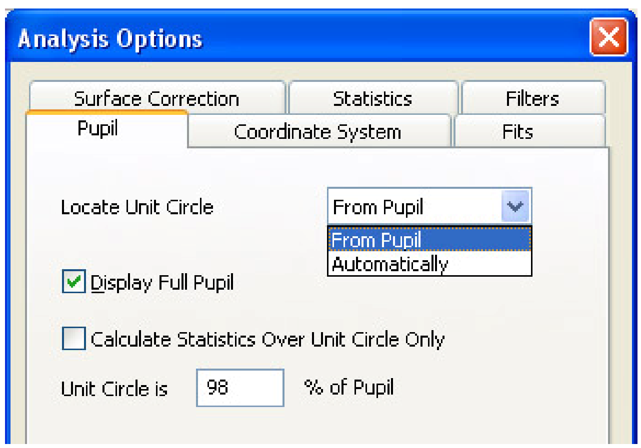


Figure 48: Analysis Options: Pupil.

From the **Locate Unit Circle** list select **Automatically** to fit the unit circle to the extent of the measurement, or masked data, if *Masking* is applied (*Figure 49*). Choose **From Pupil** to match the unit circle to the diameter of a manually defined pupil (*Figure 50*).

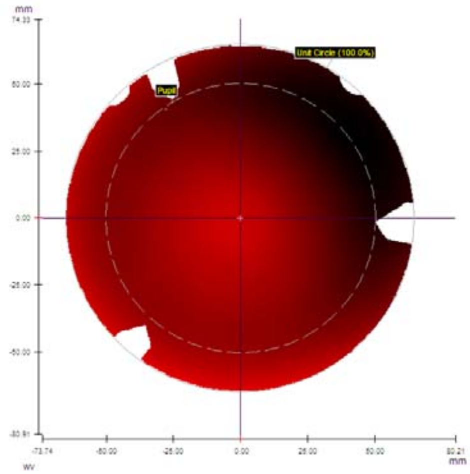


Figure 49: Unit circle found automatically *to edges of extent of measurement.*

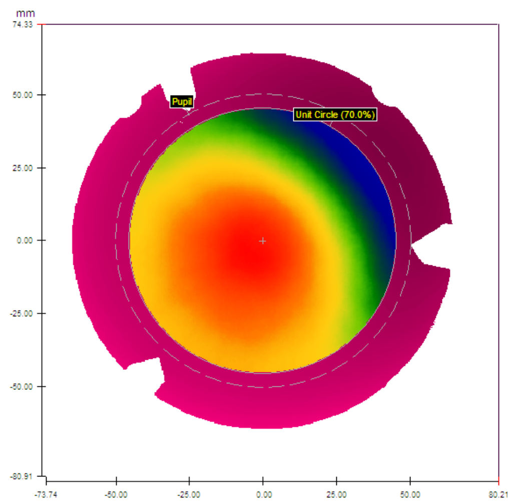


Figure 50: Unit circle found from pupi*l, with Percent Clear Aperture at 90%.*

Check the **Display Full Pupil** box to display the entire extent of the data, even if the unit circle has been manually defined to a smaller size. Check the **Calculate Statistics Over Unit Circle Only** box to disregard any data outside of the selected unit circle.

Finally, enter a value in the **Unit Circle Is** box to define the unit circle as a percentage of the pupil for each measurement. This represents the "clear aperture" (CLAP) to be used when fitting terms to the data.

Setting and Changing Units

Once you've set the lateral and/or vertical scaling, you can view measurements using any of several real-world units. To select the units to view, choose **Edit > Units** (*Figure 51*). Set the units, then press **OK** to apply the changes to the current measurement and to all subsequent measurements.

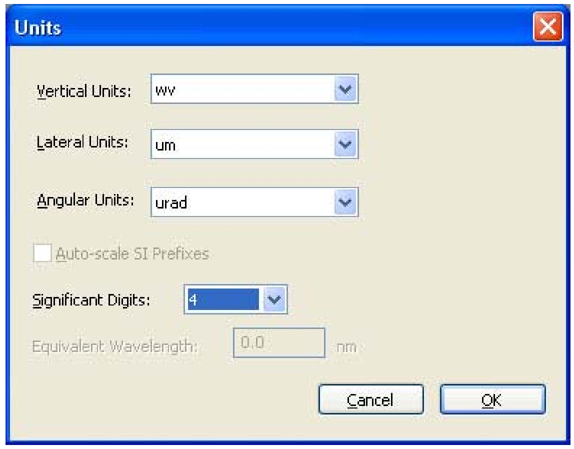


Figure 51: Units dialog box.

Vertical Units

Vertical measurements may be viewed in waves (wv), English units or metric (SI) units.

An additional option lets you use an alternative wavelength to calculate heights, as if a different laser source had been used to make the measurement. This is useful, say, when a part specification is described using a different wavelength than that of your interferometer. Select "eqwv" (Equivalent Wavelength) as the Vertical Units, then enter the wavelength under Equivalent Wavelength. Vertical measurements will be updated to reflect this wavelength (*Figure 52*).

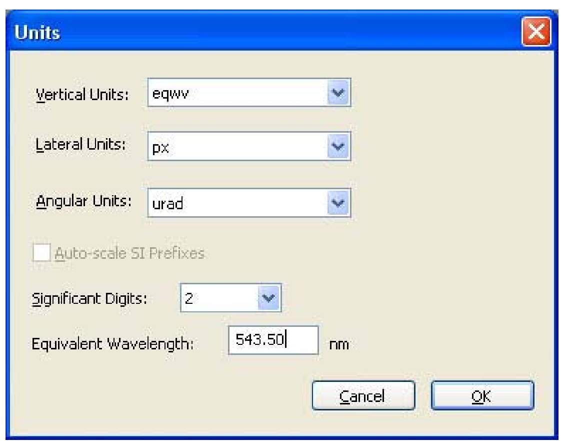


Figure 52: Entering vertical units of Equivalent Wavelength

Lateral Units

Lateral measurements may be viewed in pixels (px), English units or metric (SI) units. Choose **Normalized** units to automatically center the *Unit Circle* at the origin, with a radius of 1. You can also specify the number of significant digits to display.

Angular Units

Angular measurements can be displayed using English (degrees, minutes and seconds) or Metric (radians, urads, mrads) units.

Chapter

5

Displays

4Sight™ provides many interactive screens to help you analyze and visualize your 2D and 3D data.

Default Display

By default 4Sight displays new measurements and opened files using a “contour plot.” To use a different default display choose **Display** > **Display Options** > **Default Display** (*Figure 53*). Each of these options will be described below.

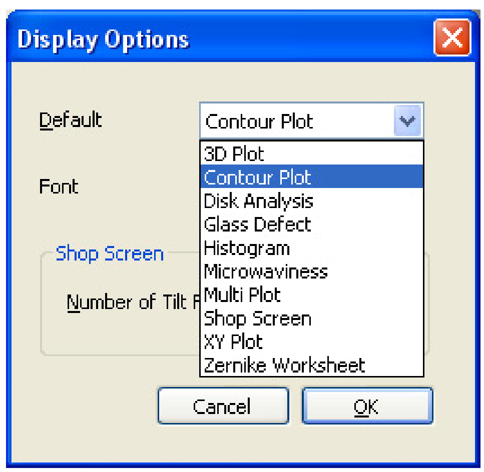


Figure 53: Default Display options.

Contour Plot

Contour plots are two-dimensional displays in which the color at each pixel represents its height. For most operations the contour plot is the default. You can also open a contour plot by clicking the **Contour** toolbar button 

or by choosing **Display** > **Contour Plot** (*Figure 54*).

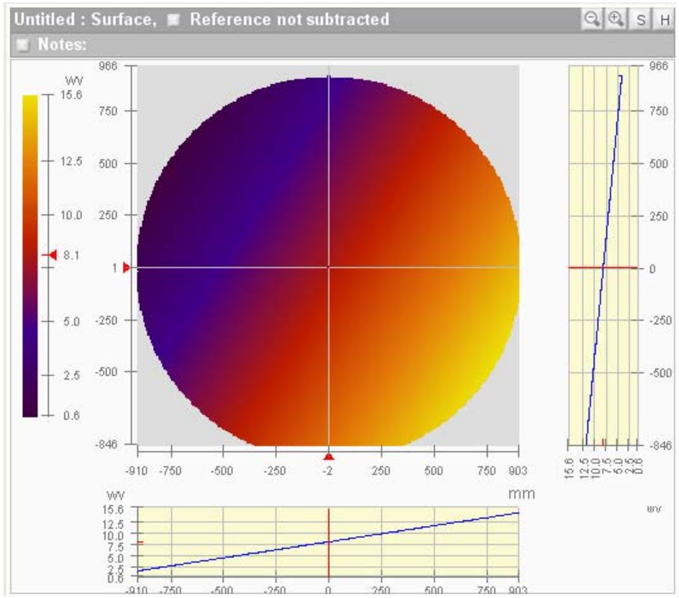


Figure 54: Contour plot.

To view the many components of the contour plot click the **S** button in the upper right of the screen. Click **H** to hide these features and increase the size of the plot itself. By default all features are shown.

The contour plot shows X and Y profile slices through the pixel denoted by the crosshair cursor. Click and drag the cursor anywhere within in a dataset to inspect that location. Statistics will be reported in the boxes on the right. Right click on either profile and choose **Analyze X/Y Slice** to magnify a section of the profile for further analysis. Right click and choose **Hide Profiles** to close the profiles.

Tip: Right click in the plot and choose **Move Cursor To,** to specify an exact location.

The **legend** relates plot color to data value. The "0" value for the legend is based on your choice under **Analysis** > **Analysis Options** > **Fits**. Choose **Average** to set "0" to the dataset average, or **Minimum Height** to set "0" to the lowest value in the dataset (*Figure 55*).

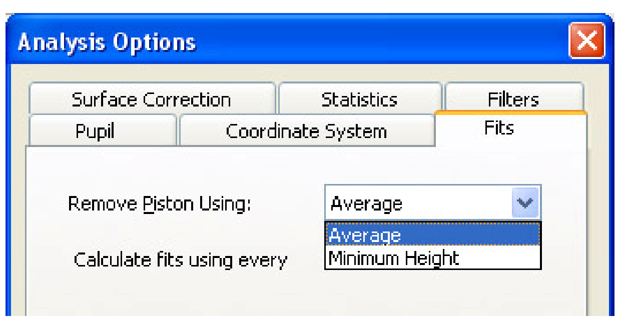


Figure 55: Setting the "0" value for the contour plot legend.

Various display options are available by right clicking in the contour plot (*Figure 56*):

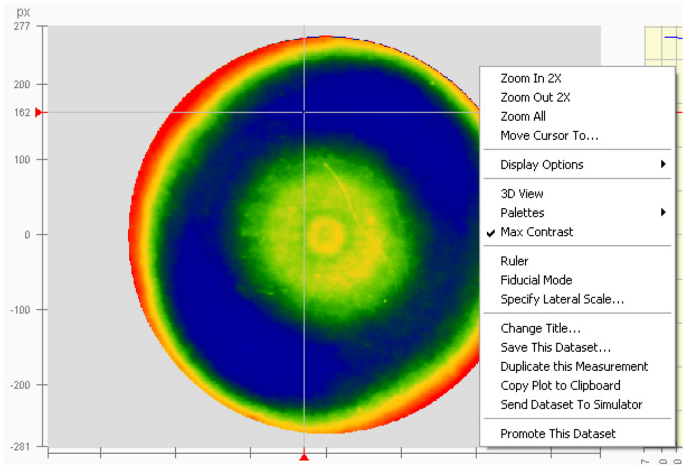


Figure 56: Contour Plot: Right click options menu.

Zoom in 2X	Zoom the central pixels by 2X. Use this function repeatedly to magnify in further. See *Digital Zoom*.
Zoom out 2X	Increase the number of viewed pixels by 2X in both X and Y. This option is only available if you have already magnified an area. See *Digital Zoom*.
Zoom All	Increase the viewing area to include the entire dataset. This option is only available if you have already magnified an area. See *Digital Zoom*.
Move Cursor To	Specify an exact location for the XY cursor.
View Options > Annotations	Show/hide information such as the *Unit Circle* and pupil. A check mark indicates this option is shown. Select it again to hide.
View Options > Cursors	Show/hide the crosshair cursor.
View Options > Profiles	Show/hide the X and Y profiles.
View Options > Legend	Show/hide the Z height legend at the left of the plot.
View Options > Axes	Show/hide the axes at the bottom and left of the plot.
View Options > Grid	Apply grid lines to the contour plot**.**
View Options > Show All	Show all optional display elements. This is equivalent to clicking the **S** button in the upper right of the plot.
View Options > Hide All	Turn off all optional display elements, equivalent to clicking the **H** button.
3D View	Change the display to a *3D Plot*, described below.
Palettes	Select the colors used to represent Z (height) values.

Max Contrast	Compress the colors in the palette such that the data is displayed with the largest possible color variation. Noisy data pixels near the minimum or maximum of the dataset are displayed using the same color as their nearest neighbors. The height legend will be compressed to reflect the change in values, as below. See *Max Contrast*. Max Contrast is disabled when *Color Scaling* is applied.
Ruler	This option provides a quick method for determining lateral dimensions of features, particularly when they occur diagonally rather than purely in X or Y. When you choose **Ruler** the cursor will change to a "pencil" tool. Click and drag in the plot to draw a straight line between two points. The distance will be displayed on the line. The Ruler option will automatically be deselected once you have drawn your line.
Fiducial Mode	Check this option to add fiducial marks in your dataset. (See *Fiducials* for details.)
Specify Lateral Scale	Lets you draw a line across a known distance, then define its real length. (See *Scaling Lateral Dimensions to the Real World*).
Change Title	Edit the dataset's title.
Save this dataset	Permanently save the data to disk.
Duplicate this Measurement	Create a duplicate of the current measurement on the Measurement Stack. All datasets are copied to the duplicate file.
Copy Plot to Clipboard	Place a bitmap image of the current contour plot, including any active display options, to the clipboard for transfer to another program.
Send Dataset to Simulator	When *Simulator Mode* is on, the current dataset is made available on the Measurement Screen, as if it had been created from actual hardware.
Promote this Dataset	Promotes the current measurement to the Measurement Stack (see *Promotion and Analysis*).

3D Plot

Any dataset can be displayed as a 3D surface by clicking the **3D** toolbar button , choosing **Display > 3D Plot**, or right clicking on a contour plot and choosing **3D Plot**. The figure below shows a 3D plot of surface data. Other data, such as modulation or *Slope*, can be displayed in 3D as well. The data will be shown with both Z (vertical) heights *and* colors to represent those magnitudes.

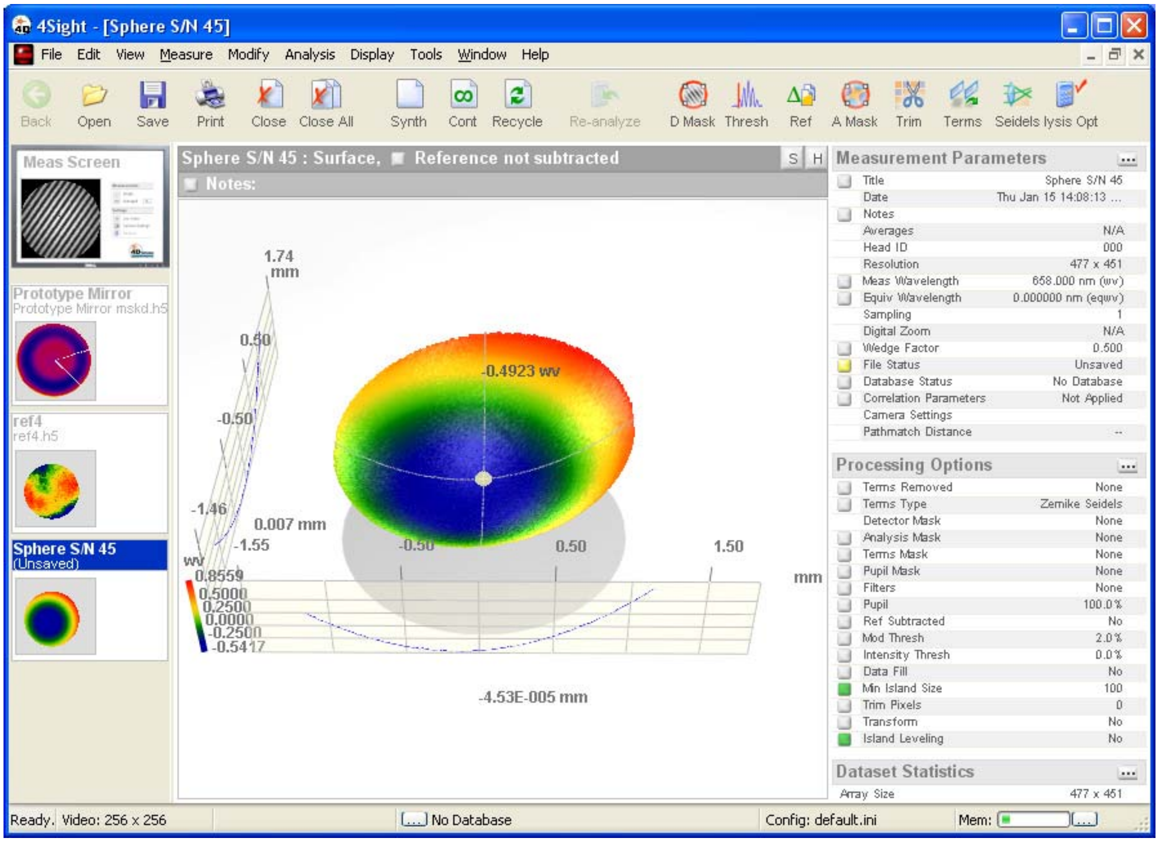


Figure 57: 3D Plot.

You can change the elevation and rotation of the 3D plot by clicking in the plot and dragging the cursor. Hold down the **Ctrl** button while dragging to change the magnification. Hold down the **Shift** key while dragging to change the Z (height) scale.

The 3D plot includes a crosshair cursor which lets you inspect the X and Y profiles through any point on the surface. To move the cursor, click and drag the circle at the intersection of the crosshairs. The X and Y profiles will change as you move the cursor.

You can select various display options by right clicking in the plot area and choosing a command from the menu:

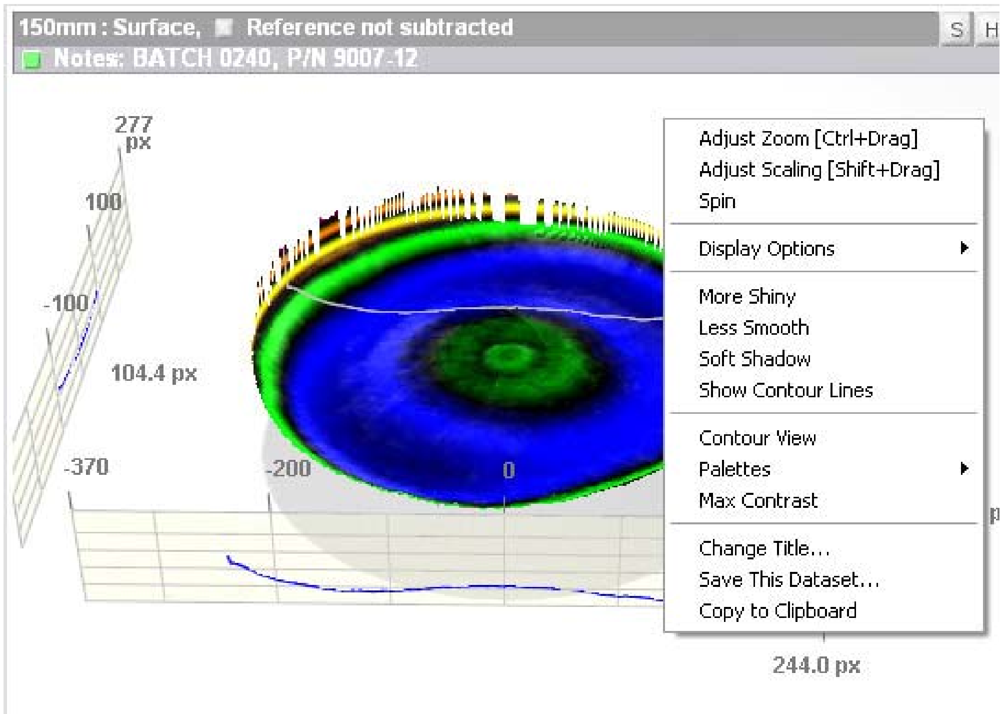


Figure 58: 3D Plot Display Options.

Adjust Zoom	Switch to a mode in which you can magnify or de-magnify an area of the data by dragging the mouse in the plot area. Once you have changed the magnification this option will automatically deselect.
Adjust Scaling	Switch to a mode in which you can change the vertical scaling of the plot by dragging the mouse in the plot area. Once you have changed the scale this option will automatically deselect.

Tip: You can also adjust magnification and scale by holding down the **Ctrl** or **Shift** key, respectively, while dragging your mouse in the plot.

Spin	Animates the plot by rotating about a Z-axis positioned at the center of the dataset. After you have selected Spin this option switches to **Stop Spinning** which you can choose to freeze the plot.
View Options	Show/hide additional plot options. These options are identical to those of the *Contour Plot*, described above.
More Shiny	Increase the specular component used to render the 3D surface. After you have selected More Shiny this option will switch to **Less Shiny**, which returns you to the default view.
Less Smooth	Increase or decrease the glossiness of the rendered 3D surface. This option only affects how light is reflected off the surface—it does not change any height values. After you have selected Less Smooth this option will switch to **More Smooth**, which returns you to the default view.
Soft Shadow	Reduces and blurs the drop shadow behind/below the data.
Contour Lines	Adds topographic contour lines to the data.

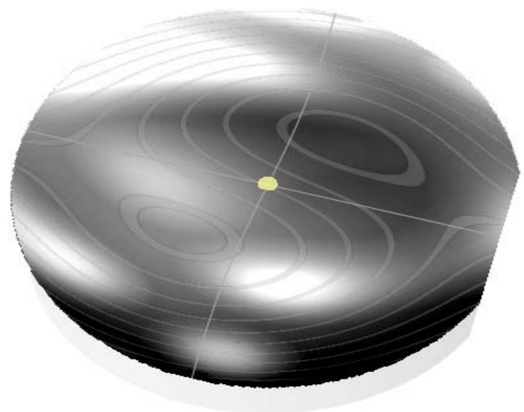


Figure 59: 3D Plot contour lines

Contour Plot Display the data as a contour plot.

Palettes Change the colors used to represent Z (height) values.

Max Contrast. Compress the colors in the palette such that the data is displayed with the largest possible color variation. Noisy data pixels near the minimum or maximum of the dataset are displayed using the same color as their nearest neighbors. The height legend will be compressed to reflect the change in values, as below. See *Max Contrast*. Max Contrast is disabled when *Color Scaling* is applied.

Change Title Edit the dataset's title. You can also choose **Edit > Change Title**.

Save This Dataset Permanently save the data to disk.

Copy to Clipboard Place a bitmap version of the 3D plot, including any active display options, to the clipboard for transfer to another program.

Promote Dataset Promote the currently viewed measurement to the Measurement Stack.

Histogram Plot

The histogram plot displays the distribution of heights in the dataset. To open the histogram click the **Histogram** toolbar button 

or choose **Display > Histogram**. Height values are shown on the X axis, with the number of points at each height on the Y axis. The blue plot curve represents the actual histogram, while the red curve is the best fit Gaussian curve. A *Contour Plot* of the data is also displayed at lower left for reference.

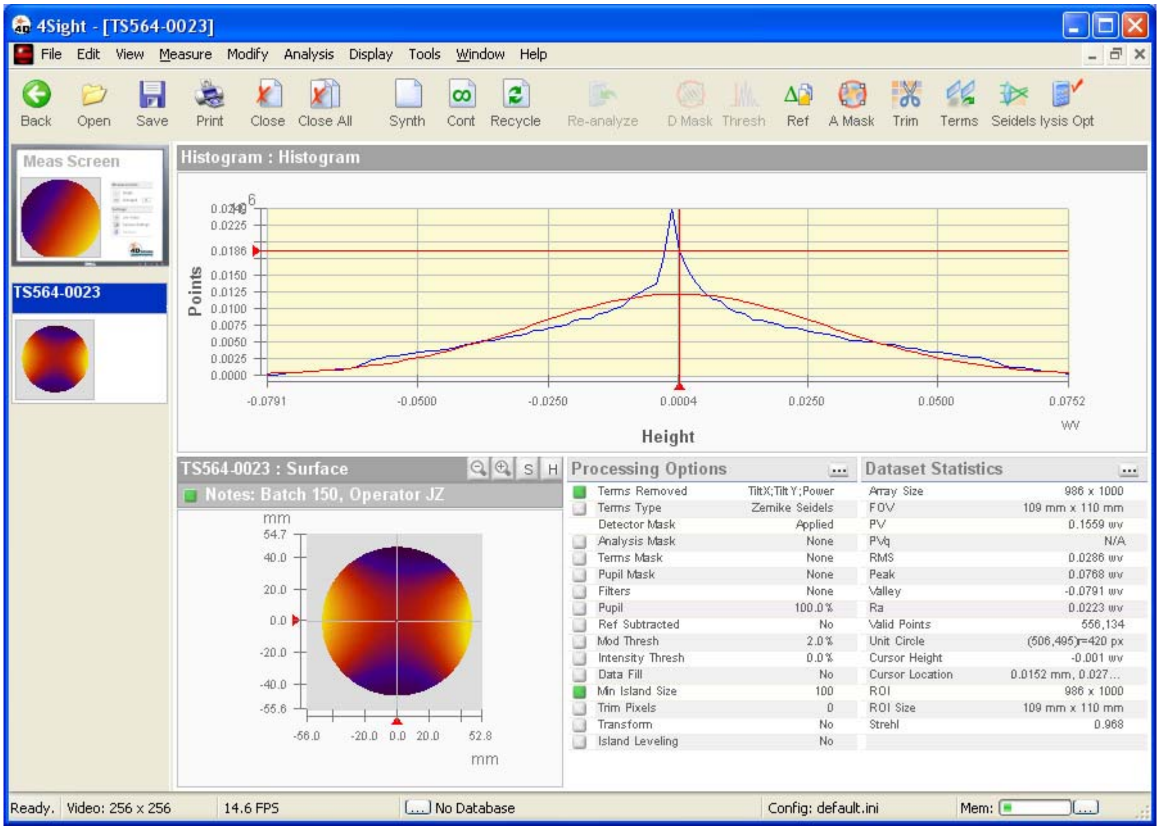


Figure 60: Histogram plot.

You can inspect the histogram using up to two cursors. By default one cursor will be shown—click and drag it to a height position and reading the number of points at that height. To add a second cursor, right click in the plot area and click **New Cursor.** You can then inspect the relative height difference between the cursors.

Right click on the histogram to access these options:

Show All/Selected Slices	Turn on or off the Gaussian fit (i.e., the red line).
New Cursor	Add a cursor to the plot. You can display up to two cursors. When two cursors are shown this option changes to **Remove Cursors**.
Zoom Between Cursors	When two cursors are displayed select this option to magnify the area between them. The data between the cursors will be magnified to occupy the entire plot display. This option will change to **Zoom All**, allowing you to show the entire histogram again.
Activate Next Trace	Attach the cursors to the histogram (blue) curve or Gaussian best fit (red) curve.
User Limits	Open the User Limits dialog box, allowing you to scale the X and Y axes manually.

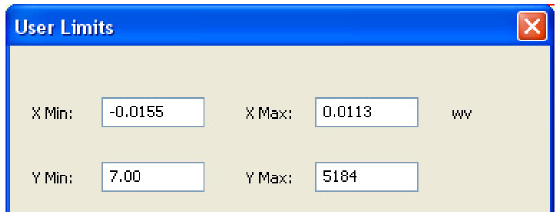


Figure 61: User Limits dialog box.

Export Trace Data — Generate a text (.txt) file with three columns: the X coordinate, the actual data value, and the Gaussian fit value.

Mask Below/Above — Mask the data below or above a single cursor. The histogram will be adjusted such that the masked portion of the data covers the entire extent of the display. The masked dataset is also added to the *Measurement Stack*.

When two cursors are shown you can choose to mask **Inside** or **Outside** the cursors.

Copy to Clipboard — Place the histogram, contour plot and statistics on the clipboard for transfer to another program.

Note: The number of bins used to calculate the histogram is fixed at 100.

XY Slice

The XY slice plot provides detailed views of the horizontal and vertical cross-sections at a cursor position. To open the XY Slice plot click the **Profiles** toolbar button 

or choose **Display > XY Slice**. The information is essentially the same as the *Contour Plot*; however, in this display the contour is reduced and the profile graphs are larger, and separate cursors are available in the slice graphs.

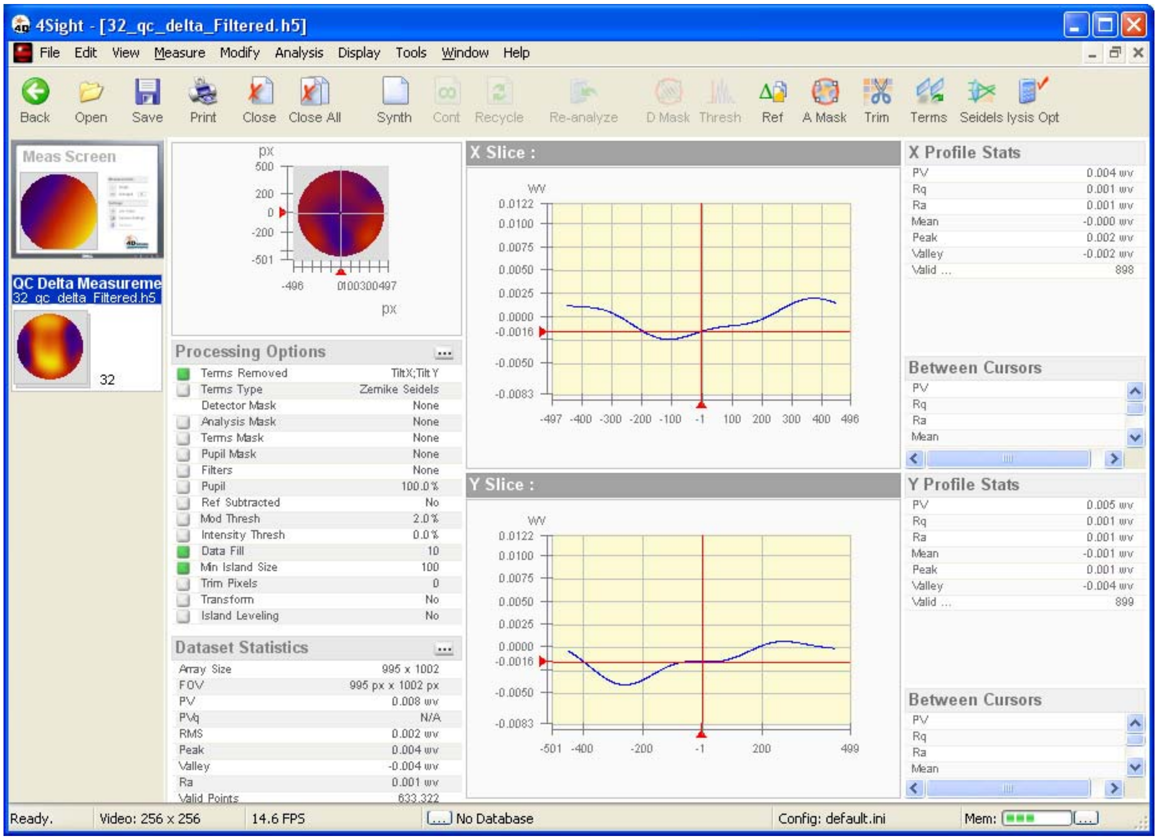


Figure 62: XY plot.

Right-clicking in the X or Y slice plots makes these options available:

New Cursor Add a cursor to the plot. You can display up to two cursors. When two cursors are shown this option changes to **Remove Cursors**.

Zoom Between Cursors When two cursors are displayed, magnify the area between the cursors to occupy the entire plot display. This option will change to **Zoom All**, allowing you to show the entire histogram again.

User Limits Open the User Limits dialog box to scale the X/Y axes manually.

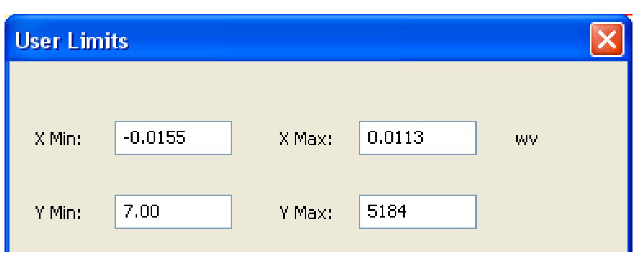


Figure 63: User Limits dialog box.

Export Trace Data Generate a text (.txt) file with three columns: the X coordinate, the actual histogram value, and the Gaussian fit value.

Copy to Clipboard Based on where you click in the plot, this option places either the X slice, Y slice or contour plot on the clipboard for transfer to another program.

Multi-plot

The multi-plot display is the most comprehensive representation of a measurement. This display includes a contour plot, X and Y profiles, a histogram, and a 3D display. To use the Multi-plot click the **Multi** toolbar button 

or choose **Display** > **Multi Plot**.

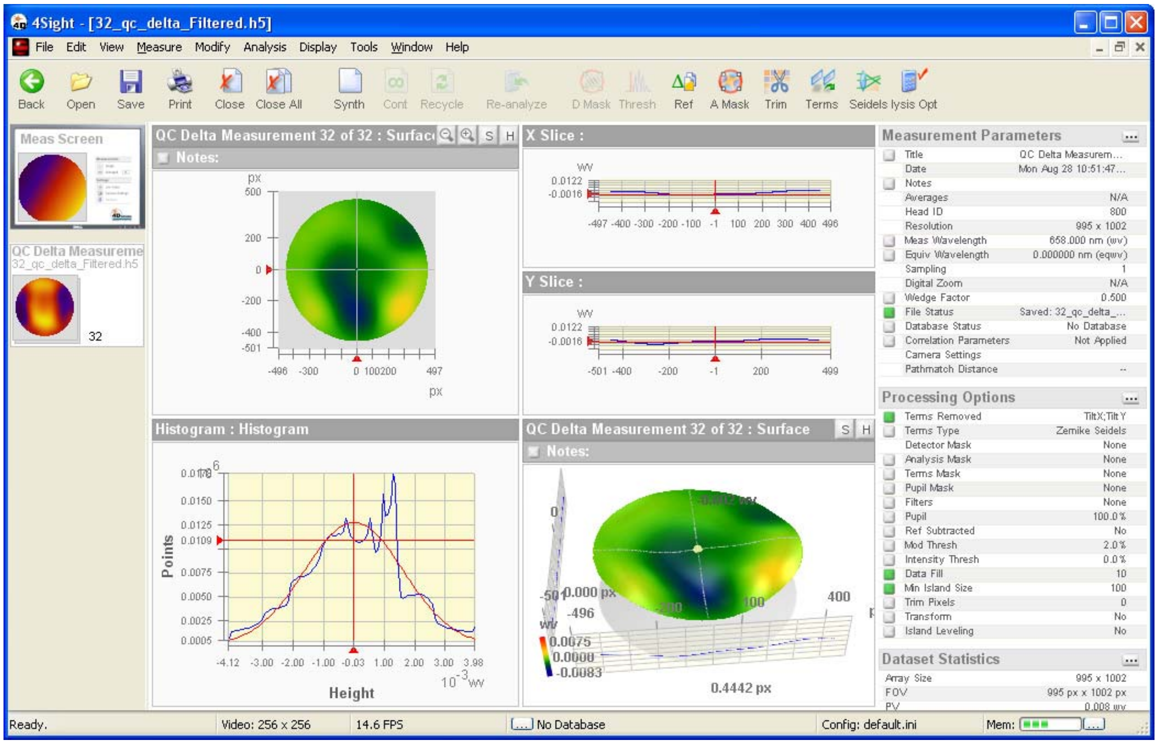


Figure 64: Multi-plot.

All of the right-click options that are available on single-plot displays, such as magnification, 3D spinning, etc, are available in each of the panes of the multi-plot window.

Shop Screen

The shop screen provides a traditional view of two interferograms along with the measured surface. Historically, a snapshot of an interferogram has served as a quick measure of quality. If you purchase an optical component, it might ship with such a snapshot. Even though phase-shifting interferometry makes it unnecessary to interpret the interferograms visually, you might want to use the shop screen to document the quality of the parts you've tested.

To open the shop screen click the **Shop** toolbar button 

, or choose **Display** > **Shop**. The shop screen includes a basic contour plot and statistics on the right side, and two interferograms on the left. The interferograms shown on the shop screen are not the actual interferograms as measured; instead, 4Sight generates the interferograms by adding a certain amount of tilt to the measured surface and calculating the interferograms from the tilted surface. You can specify the number of tilt fringes under **Display** > **Display Options**. In the figure below, the top interferogram has four fringes of tilt in the X direction, and the bottom interferogram has four fringes of tilt in the Y direction.

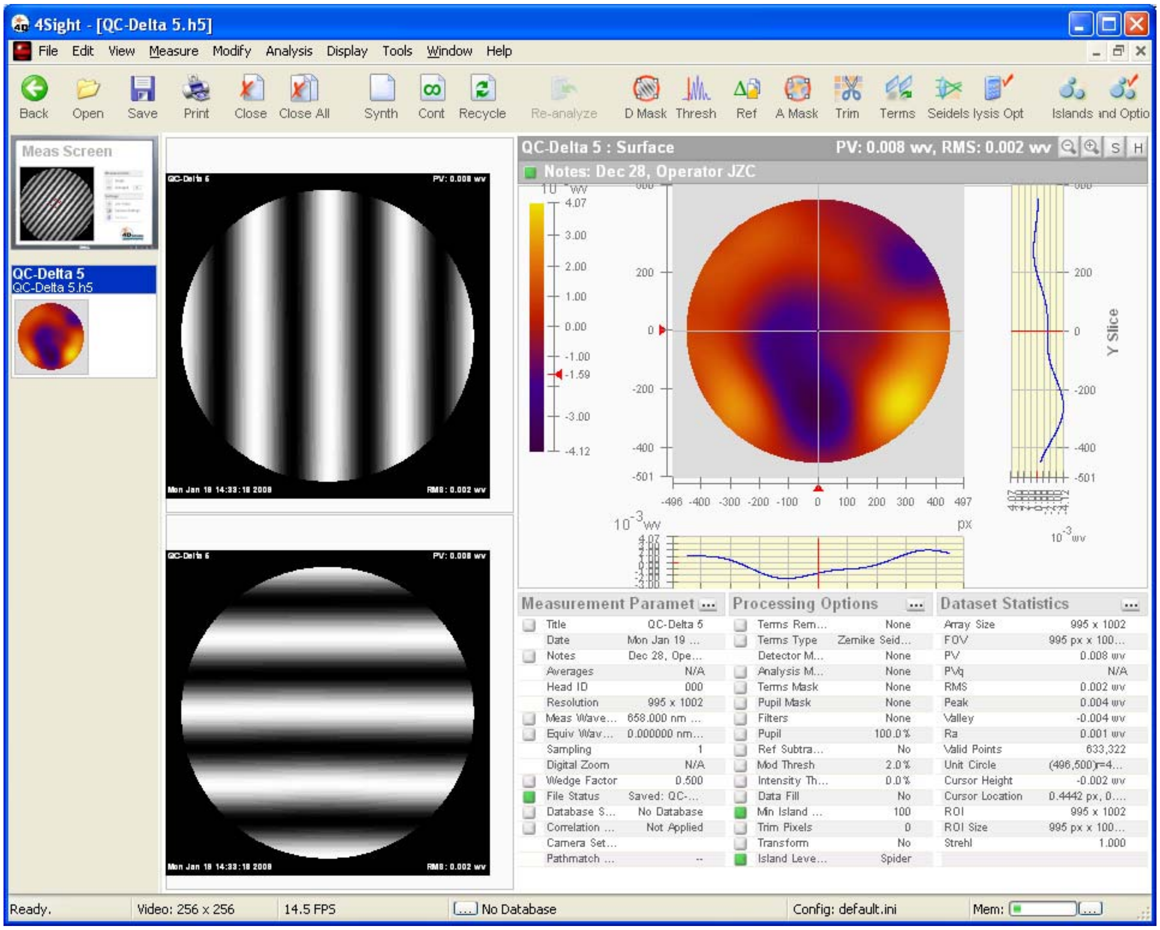


Figure 65: Shop Screen.

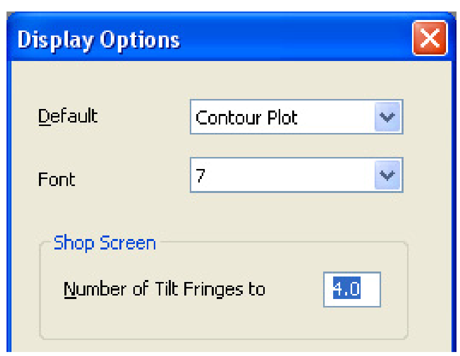


Figure 66: Display Options .

Palette

Palettes are the color schemes that 4Sight uses to display different heights in contour and 3D plots. Changing between color palettes can be more than just a matter of taste: a change in palettes may highlight aspects of the data which may not otherwise be clear.

To change the color scheme, right click on a contour or 3D plot, then click **Palette**. You will be able to select from a list of 4Sight's standard palettes:

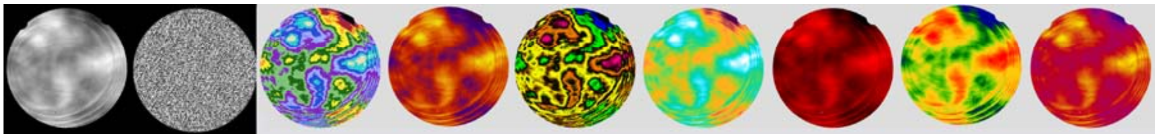


Figure 67: 4Sight's included color palettes.

The active measurement will be re-rendered using this palette, and the palette selection will become the default for the particular type of data currently displayed. This distinction allows you to display certain kinds of data using different palettes; for example, you may choose to show interferograms in gray scale but modulation data using a red palette. Each data type (interferograms, modulation, wrapped phase, surface, diffraction, slopes, etc) may be assigned its own palette option.

You can also alter a palette to create your own color scheme. To do so, right click in a contour or 3D plot and choose **Palette > Edit Palettes**. You can also choose **Display > Palettes > Edit Palettes**. Either action opens the **Palette Editor** dialog box.

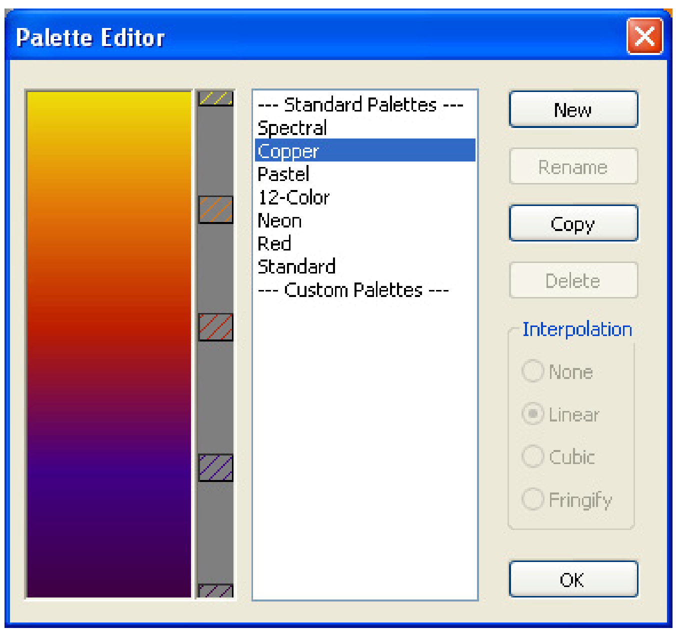


Figure 68: Palette Editor dialog box.

To create a custom palette, either click the **New** button to modify a gray scale palette, or select a standard palette and click **Copy** to use its colors as a starting point. Click and drag the "control points" (the boxes with angled lines) to adjust the scaling. Click above or below the existing control points to add another control point. Double-click the control point boxes to change their colors. Right click on a control point and choose **Delete** to remove it.

4Sight interpolates palette colors between control points to define the full palette. You can control the type of interpolation performed between control points:

None Use no interpolation, leaving banding color, as in the 12-Color palette.

Linear Interpolate evenly between the control point colors.

Cubic Interpolate a smooth curve between the control point colors.

Fringify Apply dark bands to the palette to produce a fringe effect. Each fringe in the palette will correspond to a fringe of OPD on the rendered measurement, if the lateral scaling has been set. The Neon palette is an example of a false color fringe pattern using the "fringify" option.

Click **OK** to name the custom palette. It will now appear in the palette list.

Note: You can **Rename** or **Delete** custom palettes from the Palette Editor dialog box. You cannot rename or delete the standard palettes.

Max Contrast

The Max Contrast option compresses the colors in the palette such that the data is displayed with the largest possible color variation. Noisy data pixels near the minimum or maximum of the dataset are displayed using the same color as their nearest neighbors. The height legend will be compressed to reflect the change in values, as below. Max Contrast is disabled when *Color Scaling* is applied.

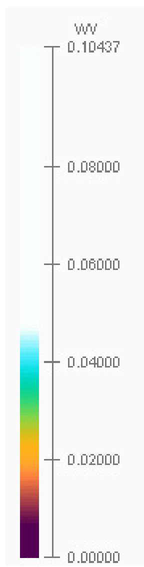


Figure 69: Contour Plot height legend is compressed when Max Contrast is on.

Color Scaling

The color range scale is, by default, set automatically based on the content of each measurement. Often it is useful to manually set this range such that several measurements can be compared using identical color gradients. To change the color scale manually, choose **Display** > **Z-Scale**. From the **Z Scale Setting** list select **User**, then enter **Minimum** and **Maximum** height limits that will encompass all of the data being compared. Click **OK** to apply the scaling to the current measurement, or check the **Set As Default** box to apply to all subsequent measurements as well.

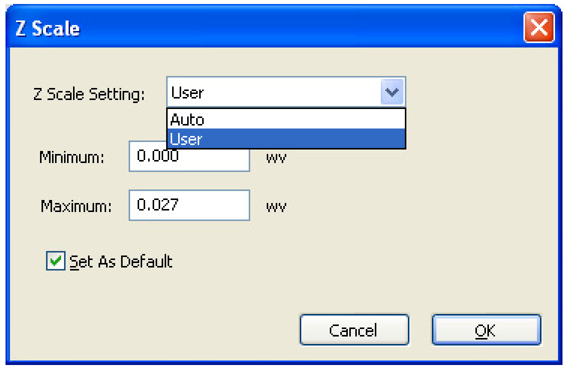


Figure 70: Z Scale dialog box.

Note: Max Contrast is not available when Z-Scaling is applied.

Chapter

6

Analyses

In addition to its interactive displays, 4Sight™ provides a suite of standard optical calculations for further analysis of your measurements.

Slope Analysis

Slope Analysis helps you locate high spatial frequency changes in an optical system. The slope analyses calculate the first derivative for each pixel in a measurement. At each point, the slope in X, slope in Y, and slope magnitude are calculated, as follows:

$$X\_slope = \partial f(x, y) / \partial x$$

$$Y\_slope = \partial f(x, y) / \partial y$$

$$Slope\_Magnitude = \sqrt{\left(\partial f(x, y) / \partial x\right)^2 + \left(\partial f(x, y) / \partial y\right)^2}$$

To use the analysis, choose **Analysis** > **Slope** and choose to display **X Slope**, **Y Slope**, **Slope Magnitude**, or **All** three (*Figure 71*):

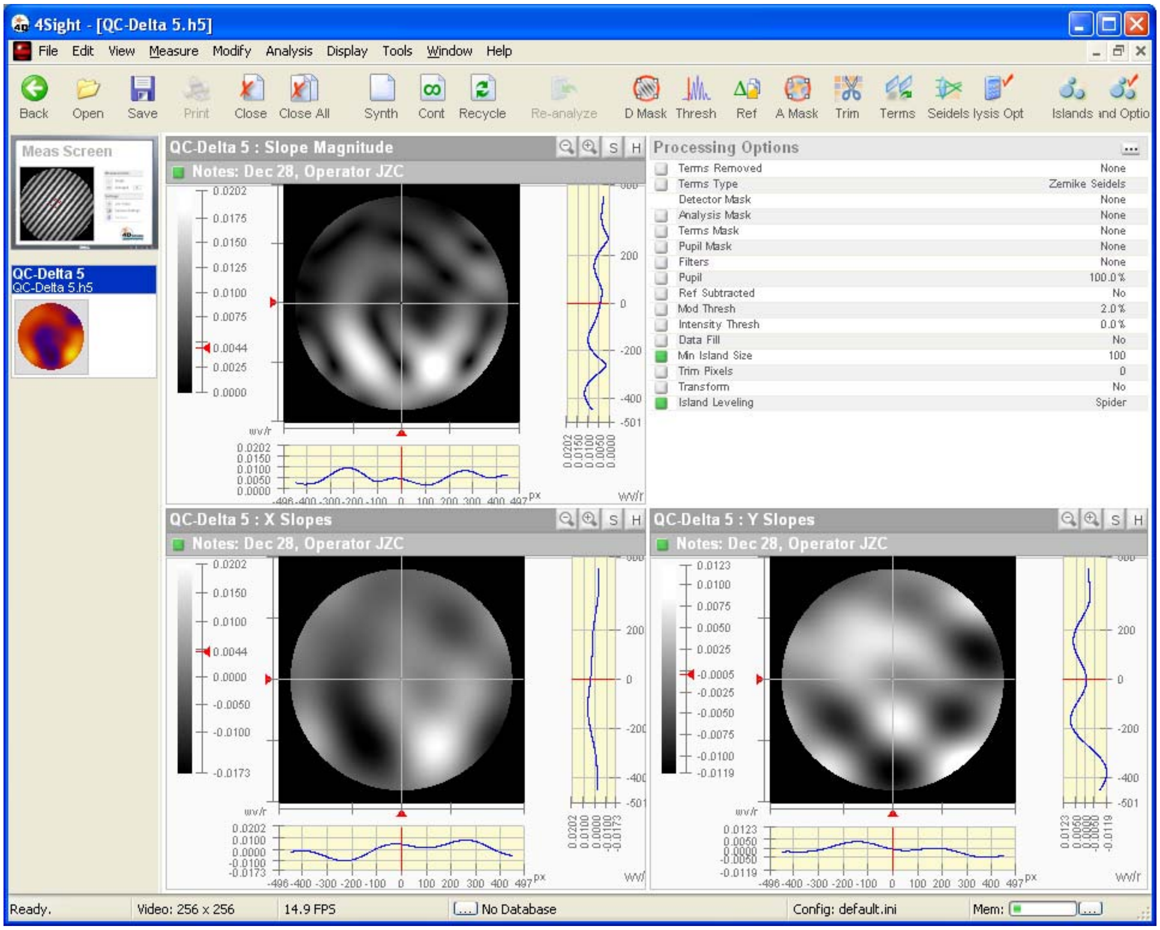


Figure 71: Slope Analysis.

The units of the resultant slope dataset depend on the current optical parameters and the options set under **Edit** >**Units**, but will generally be in vertical units/horizontal units.

Tip: To best display slope data, right click on the plot, then check the **Max Contrast** option.

Note: The slope calculations are performed using a single pixel of shear—that is, the slopes are calculated between immediately neighboring pixels.

Diffraction Analyses

The diffraction analyses are FFT (Fast Fourier Transformation) based calculations that characterize how a wavefront is transformed as it passes through an optical system.

Diffraction Options

The diffraction analyses all respect the options set under **Analysis** > **Diffraction** > **Diffraction Options**. Here you can change the parameters of the FFT calculation used to perform diffraction calculations to increase spatial resolution or enhance the vertical (Z) scaling of the FFT data.

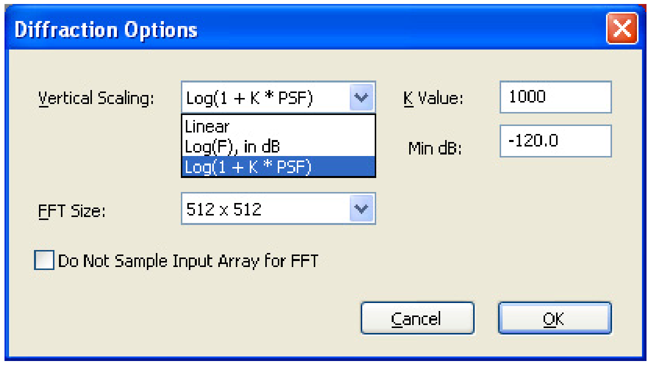


Figure 72: Diffraction Options dialog box.

Vertical Scaling Sets the scale over which to display the plot. The figure below shows a wavefront containing 2.4 waves of 3rd order coma. The data is plotted using the Linear, Log (1+K*psf(x,y)) and Log(psf(x,y)) scaling options. Log scaling makes it easier to view low level lobes.

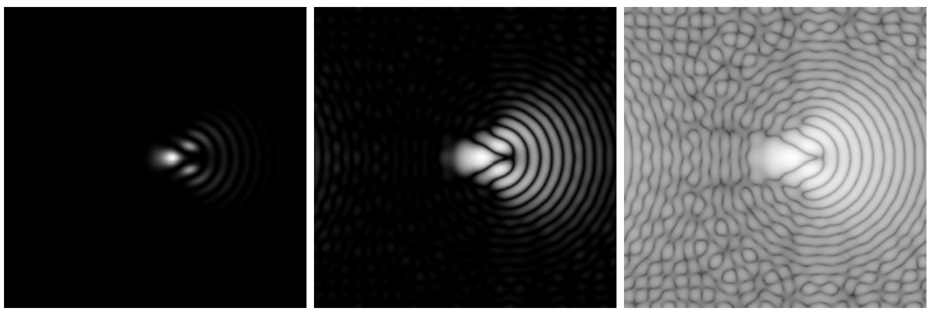


Figure 73: PSF analysis using various Vertical Scaling options.

K Value Controls the visibility of low level lobes. The higher the K value, the more data will be visible. The recommended values for 'K' are 100 to 1000. The figure below shows a wavefront containing 2.4 waves of 3rd order coma. The data is plotted using the Log (1+K*psf(x,y)) scale, with K=100, 1000 and 10000.

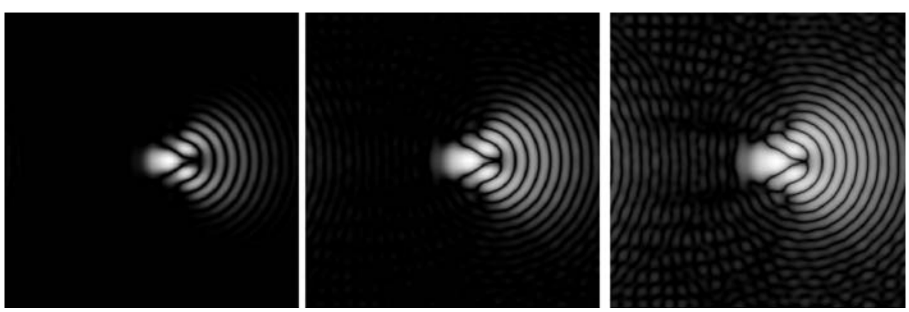


Figure 74: PSF analysis using varying values of K.

Min dB The smallest value that will be displayed in the plot.

FFT Size. The size of the array used to calculate the diffraction analyses. Use the smaller **512 x 512** array for faster calculations, or the larger **1024 x 1024** array for maximum resolution.

For *PSF* analysis the array is typically sampled to ensure correct scaling. Check the **Do Not Sample Input Array for FFT** box to disable this feature if necessary.

Autocovariance

The autocovariance of a surface is a measure of how well the surface correlates with itself as a function of lateral shift. Autocovariance is often used to highlight periodic features in noisy data. The Autocovariance function is computed by taking the inverse Fourier transform of the Power Spectral Density (PSD):

$$A(x, y) = \Im^{-1}\{PSD(u, v)\}$$

Autocovariance is always at a maximum at the origin of the coordinate system, which represents zero shift, where the surface is perfectly correlated with itself.

To calculate Autocovariance choose **Analysis** > **Diffraction** > **Autocovariance**.

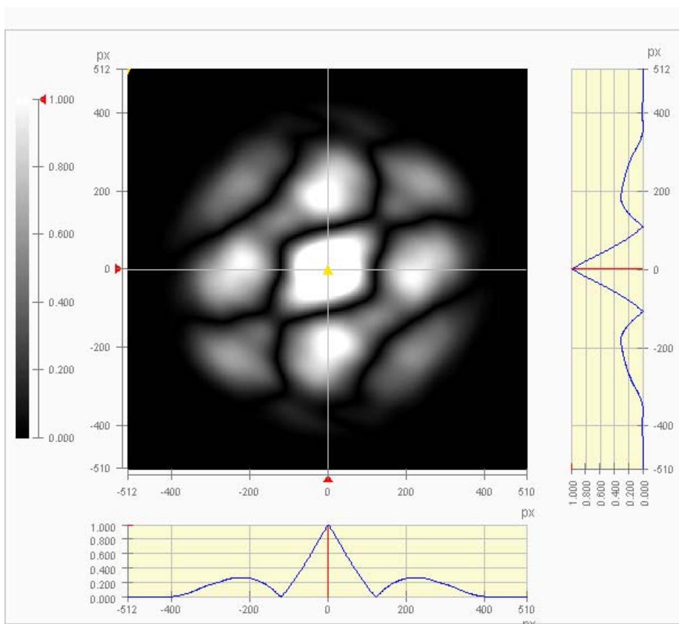


Figure 75: Autocovariance analysis.

The point of first zero crossing in any direction is defined to be the correlation length of the data for that direction. The correlation length is the distance over which the data “does not change much.” Data points separated by more than this distance are considered to be statistically unrelated.

4Sight plots the autocovariance by dividing the result by the number of data points. This gives a maximum at the center of the function equal to the RMS of the input data.

The cursors, 2D profiles, and right-click options on the Autocovariance plot are the same as those for the *Contour Plot*.

Note: Autocovariance is best displayed using the **Linear** option under **Vertical Scaling** on the *Diffraction Options* dialog box.

MTF

The Modulation Transfer Function, or MTF, shows how different spatial frequencies are transmitted through an optical system. The MTF is the inverse Fourier transform of the Point Spread Function (*PSF*):

$$MTF(u,v) = K\Im^{-1}\left\{PSF(u,v)\,|_{u=x/\lambda f,\,v=y/\lambda f}\right\}$$

where K is a normalization factor to set the maximum value to 1.

To calculate the MTF choose **Analysis** > **Diffraction** > **MTF**.

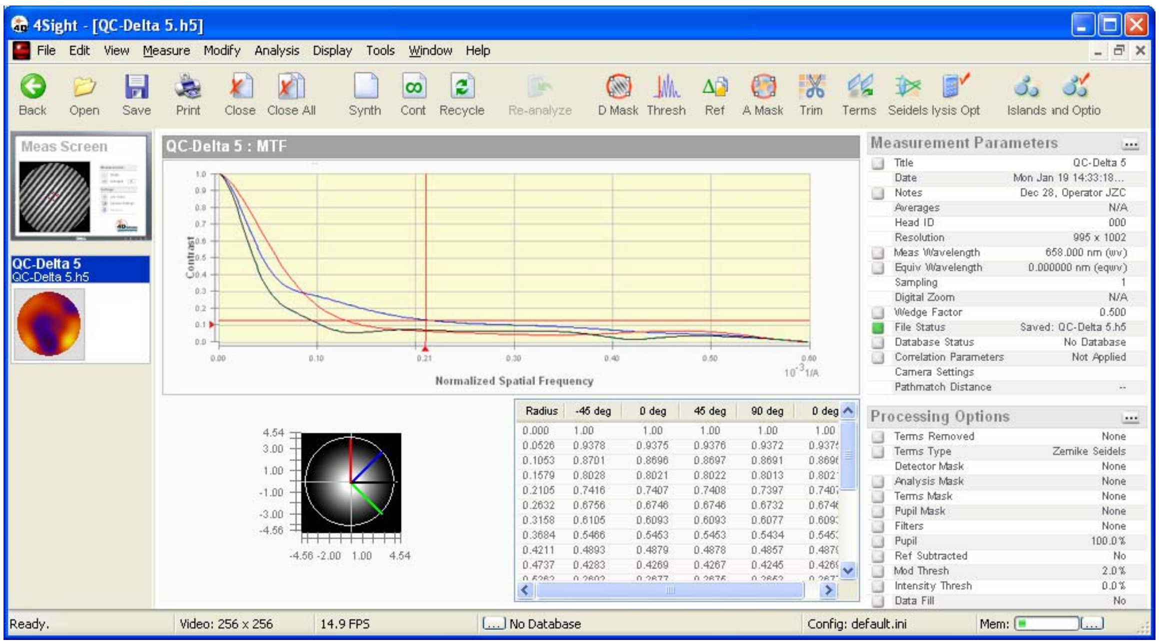


Figure 76: Modulation Transfer Function (MTF) analysis.

The traces on the plot correspond to the radial lines at 0, 45, 90 and 135 degrees shown on the plot at the bottom of the window. Plot scaling will be based upon the options selected in the *Diffraction Options* dialog box. Statistics for each trace are shown in the lower right.

The MTF will be normalized to units of wv/radius unless the optical parameters are set in the **Edit** > **Optical Parameters**.

The right-click options are the same as those on the *XY Slice* plot. The plot in the lower left includes the same right-click options as a *Contour Plot*.

Right click in the data table to **Copy** data for further analysis in other programs.

PSD

PSD, or Power Spectral Density, shows the power at all spatial frequencies. The power spectrum is computed by taking the square modulus of the Fourier transformed data:

$$PSD = P(u,v) = \left|\Im\{f(x,y)\}\right|^2$$

The PSD output is expressed in units of spatial frequency, with units of inverse length.

To calculate the PSD choose **Analysis** > **Diffraction** > **PSD**.

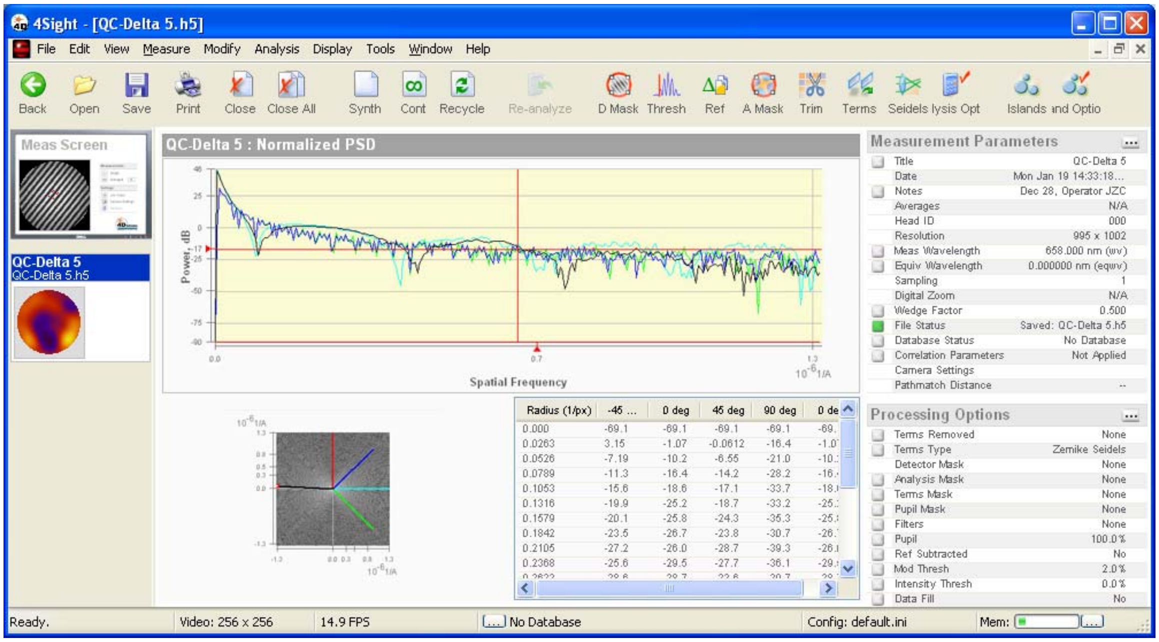


Figure 77: Power Spectral Density (PSD) analysis.

The traces on the plot represent the data at 0, 45, 90 and 135 degrees, corresponding in color to the lines on the plot at the bottom of the window. The fifth, black trace can be rotated to any angle by clicking and dragging it on the contour plot. Scaling will be based upon the options selected in the *Diffraction Options* dialog box.

The right-click options are the same as those on the *XY Slice* plot. The plot in the lower left includes the same right-click options as a *Contour Plot*.

You can copy and paste data from the table in the lower right of the window for further analysis in other programs.

PSF

The Point Spread Function, or PSF, is the response of an optical system to an ideal point source. In 4Sight, the pupil is assumed to be uniformly illuminated and the output is normalized to 1. The PSF is calculated as follows:

$$PSF(u,v) = K\left|\Im(t(x,y))\right|^2$$

where:

k = normalization factor

$t(x,y) = t_0(x,y)e^{j\phi(x,y)}$ = complex pupil function

$t_0(x,y) = 1$ = aperture function (uniform intensity)

$\phi(x,y)$ = phase of wavefront through pupil (measured by the interferometer).

The calculation of PSF using the diffraction method begins to lose validity when slopes over a large portion of the pupil become excessively large. A rule of thumb is that the PSF is valid when aberrations remain smaller than 2 waves peak-to-valley; for more specular surfaces that number may be lower**.** In general, when the PSF begins to become smeared and difficult to discern it is best to use the geometric calculation of PSF (the *Spot Diagram)* instead, by choosing **Analysis** > **Geometric** > **Spot Diagram.**

To calculate the PSF choose **Analysis** > **Diffraction** > **PSF**.

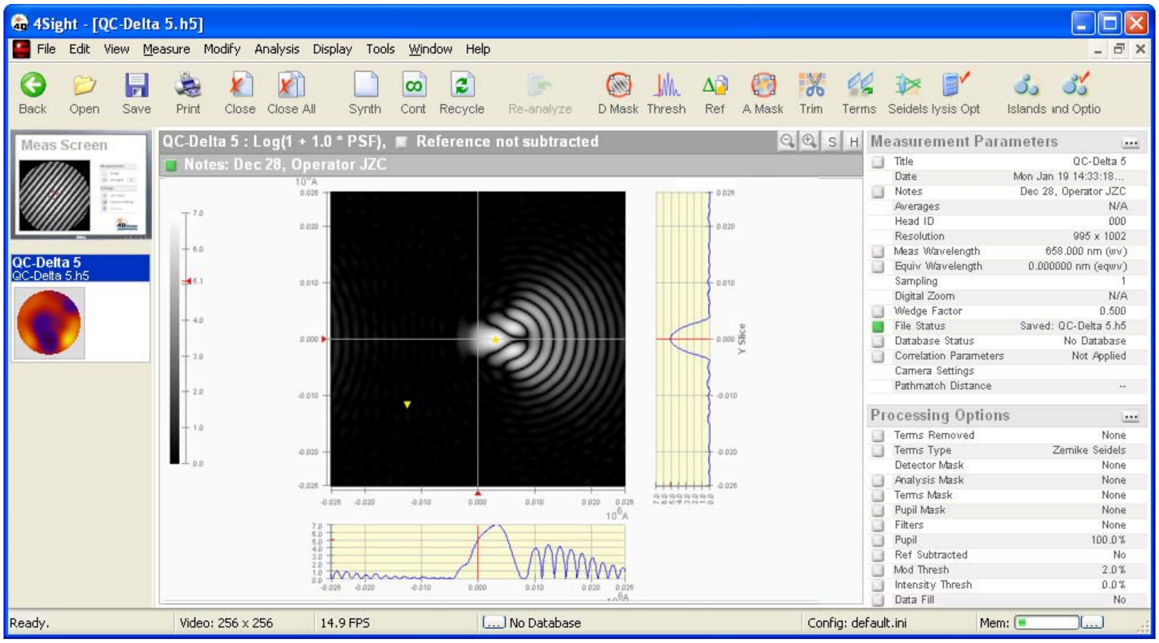


Figure 78: Point-Spread Function (PSF) analysis.

The PSF can be scaled to match your the optical parameters of your system by setting the “optical parameters” **Edit** > **Optical Parameters**. Scaling will be based upon the options selected in the *Diffraction Options* dialog box.

Encircled Energy (Diffraction)

The Encircled Energy analysis calculates the percentage of total energy in a point spread function enclosed by a circle of increasing diameter. It is particularly useful when you are aligning a system to pass light through a pinhole, indicating the power that would pass through holes of varying diameter. This plot is normalized so that the total energy is always 1 (100%).

The center is chosen to be the center of the FFT array. Therefore, it is important to remove tilt from the measurement. To do so, click the **Seidels** toolbar button  to open the **Aberrations Panel**, shown below. Check the **Tilt in X** and **Tilt in Y** boxes, then click **Apply**.

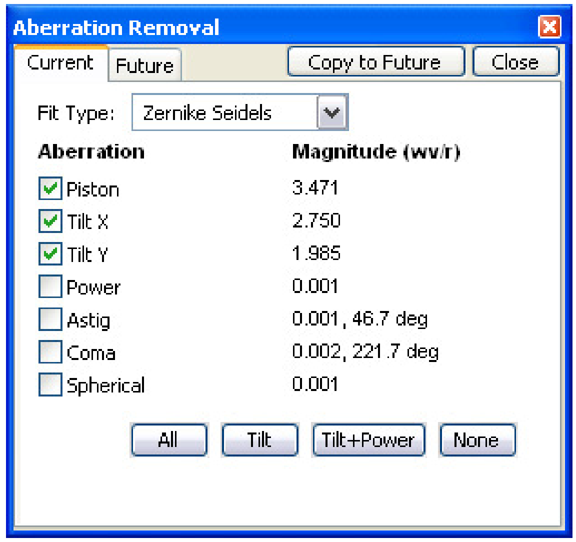


Figure 79: Aberration Removal dialog box.

To calculate the Encircle Energy, choose **Analysis** > **Diffraction** > **Encircled Energy**.

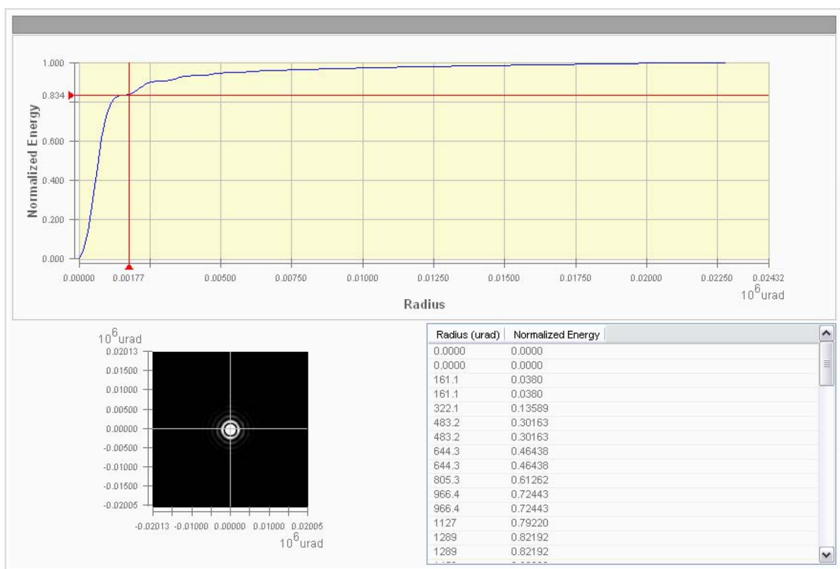


Figure 80: Encircled Energy analysis.

The right-click options for the main plot are the same as those for the *XY Slice* plot. The plot in the lower left includes the same right-click options as a *Contour Plot*. You can copy and paste data from the table in the lower right of the window for further analysis in other programs.

The calculation of encircled energy using the diffraction method is valid providing that there is not “too much” aberration in the test pupil. A good rule of thumb is that the encircled energy plot is valid for aberrations smaller that 2 waves. If your data includes larger aberrations choose **Analysis** > **Geometric** > **Encircled Energy** to use the geometric calculation.

Ensquared Energy

Ensquared Energy is identical to Encircled Energy except that the energy is calculated over a square, rather than circular, cross section. Ensquared energy is more appropriate the encircled energy when your optical system is imaged onto a rectangular detector, such as CCD. To run the analysis choose **Analysis** > **Diffraction** > **Ensquared Energy**.

As with encircled energy, the calculation of ensquared energy using the diffraction method is valid when the data contains aberrations smaller than about 2 waves. If the data includes larger aberrations choose **Analysis** > **Geometric** > **Ensquared Energy** to use the geometric calculation.

Spot Analysis

See *Spot Analysis* under Special Measurements.

Geometric Analyses

These analyses are similar to the diffraction analyses except that pure geometric calculations are performed by tracing rays through the optical system and calculating where the rays would appear at the output. Geometric analyses should be used instead of diffraction calculations when the input measurement has large aberration, typically greater than about two waves peak-to-valley.

Spot Diagram

The Geometric Spot Diagram is a plot of the rays traced through an optical system. The input rays are distributed across either a rectangular or polar grid and their positions at the output focal position are calculated and displayed as a scatter plot. Choose **Analysis** > **Geometric** > **Spot Diagram** to display the spot diagram plot.

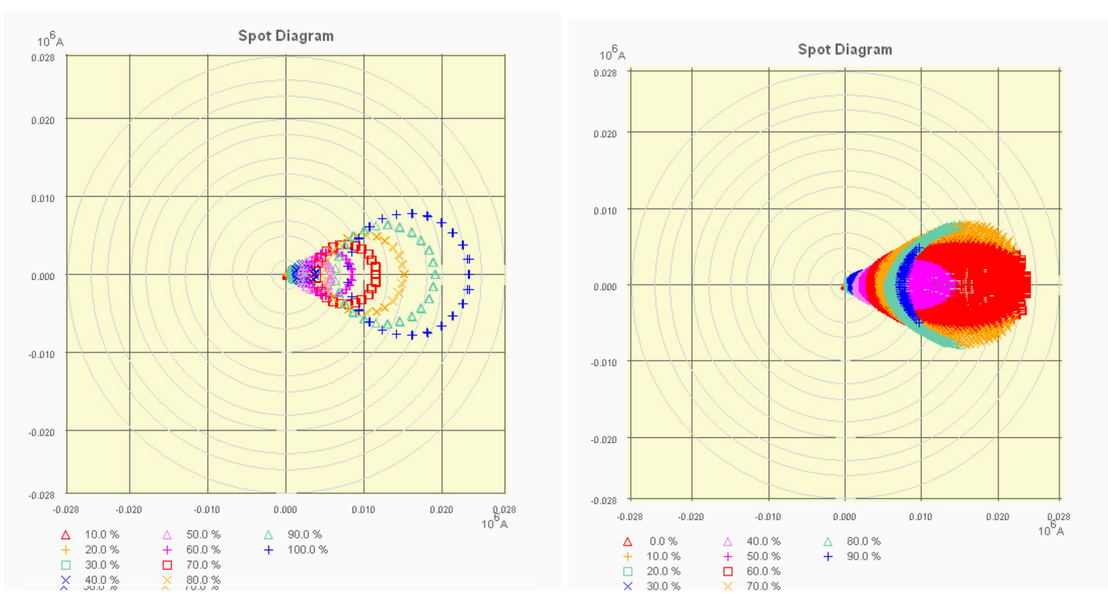


Figure 81: Geometric spot diagram using Polar *and* Rectangular *coordinates.*

Rays are grouped according to their radial zone, or distance from the optical center. Rays within the same zone appear with the same symbol and color in the scatter plot.

Right click on the plot to open the **Spot Analysis Options** dialog box:

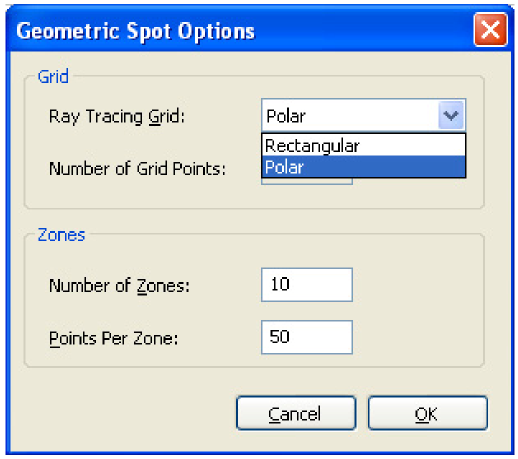


Figure 82: Spot Diagram Options dialog box.

Ray Tracing Grid Choose to view the diagram using **Rectangular** or **Polar** coordinates, as in the example below.

No. of Zones Enter the number of distinct radial regions to map. They will be differentiated by color and character shape.

No. of Grid Points With **Rectangular** coordinates, set the number of points to plot.

Points Per Zone With **Polar** coordinates, set the number of points to plot within each zone.

Encircled Energy

As with the diffraction calculation of Encircled Energy, Geometric Encircled Energy calculates the percentage of total energy enclosed by circles of increasing radii as a wavefront is transmitted through an optical system. To run this analysis choose **Analysis** > **Geometric** > **Encircled Energy**. The plot will be similar to the diffraction calculation of encircled energy, described earlier in this chapter.

This plot is normalized so that the total energy is always 1 or 100%. The circles are centered about the center of the unit circle of the input measurement. If the spot data is not centered about the (0, 0) origin, remove tilt from the measurement using the *Aberrations Removal* dialog box.

Ensquared Energy

Geometric Ensquared Energy is identical to Geometric Encircled Energy except that rectangles are used instead of circles to calculate the enclosed energy.

Zernike Polynomials

4Sight provides two comprehensive displays to investigate the Zernike polynomial composition of your surface or wavefront. 4Sight provides two methods for analyzing the Zernike composition. Both the Zernike worksheet and Zernike table, described below, are calculated *after* the options under **Analysis** > **Aberration Removal** have been applied. See *Aberrations* for details. Appendix *A1* lists the Zernike polynomials.

4Sight's sign conventions match those of other software, including Veeco's Vision32, Zygo's MetroPro and CODE V.

Note: Zernike data can also be imported from optical design software such as ZEMAX®. See *Importing Zernikes from ZEMAX* for more.

Zernike Worksheet

The Zernike Worksheet is an interactive display that shows the **Input** dataset, **Zernike Fit** dataset, and **Residual** dataset, statistics for each, and a table of individual Zernike term contributions and Seidel approximations. To open the worksheet choose **Analysis** > **Zernikes** > **Worksheet** (*Figure 83*).

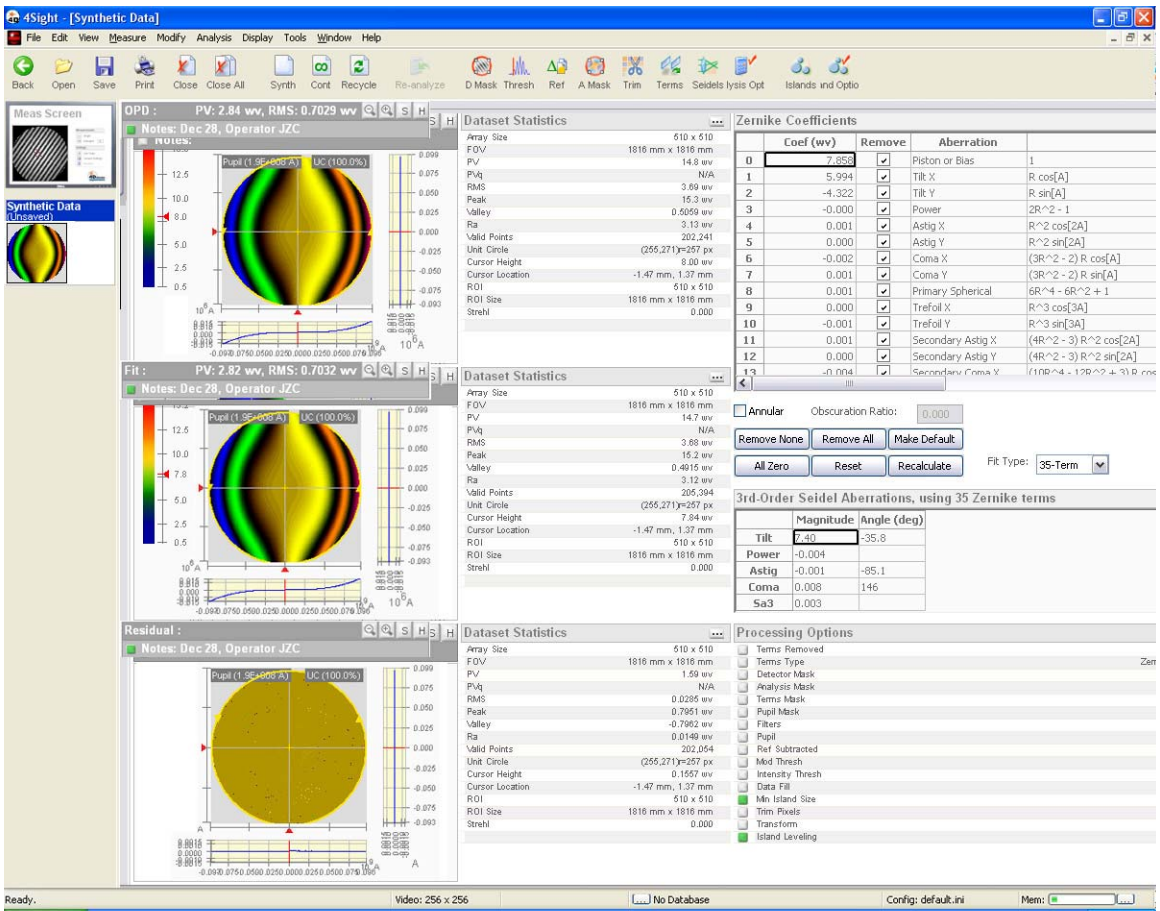


Figure 83: Zernike Worksheet.

Zernike Worksheet Plots

The three plots on the left of the display show the Input, Fit and Residual (the difference between the Input and Fit) datasets. All three are *Contour Plots*, and therefore all contour plot viewing and right click options apply to each.

Zernike Coefficients Table

The Zernike Coefficients table allows you to change individual coefficients in your fit and examine the effect on the residual dataset.

First, determine which coefficients should be removed. The **Fit Type** sets the number of terms (2 to 120) that 4Sight will remove. The higher the number, the more accurate the fit; however, removing larger numbers of coefficients will require longer processing time. Check or uncheck the **Remove** boxes next to each particular term to include or exclude those terms. Choose **Remove None** or **Remove All** to uncheck or check all of the boxes.

Next, determine how the terms should be calculated. By default Zernike terms are calculated over a circular region. Check the **Annular** box to use a donut-shaped region instead; set the **Obscuration Ratio** to define the radius of the central unused region as a proportion of the overall radius (e.g., 0.10 will obscure a central region with a radius 10% of the pupil).

Third, click on a cell in the coefficients table and enter new values as necessary. Values that differ from the original fitted values will be displayed in red. Click **All Zero** to enter zero values for every coefficient. You can right click on a cell (or cells) and choose **Freeze Selected Rows** to lock those values for subsequent measurements. This is useful, say, if the exact value of a particular aberration is known and you want to use it throughout a *Continuous Measurement*. Choose **Unfreeze All Rows** to change all values in subsequent measurements.

Tip: Hold down the **Shift** key, then click and drag across a group of cells to select the entire group. Hold down the **CTRL** key, then click on multiple non-contiguous cells to select them.

Finally, click **Recalculate** to update the plots and statistics to reflect the current set of coefficients. Click **Make Default** to use the updated set of coefficients with subsequent measurements. **Reset** returns all values to the default state and updates the plots and statistics.

The complete list of Zernike polynomials used by 4Sight is listed in Appendix A1.

Zernike Coefficient Export Options

4Sight provides several options for exporting the Zernike coefficients for use in other programs. To access these options, right click on the Zernike Coefficients table and select one of the following:

Copy cell to Clipboard. Copy the content of a single cell to the clipboard. If multiple cells are select you can choose the **Copy Selection to Clipboard** option.

Copy Zernike Table to Clipboard. Copy the table, with column titles and row numbers, to the clipboard.

Copy to Clipboard as Code V Zernikes. Place the coefficient values on the clipboard with the appropriate header for use in Code V optical design software.

Export Code V FRINGE Zernikes to File. Export the coefficients to a separate file for import into Code V. This option will export up to the first 36 terms only. The file will have a .int extension.

Export Code V Regular Zernikes to File. Export the coefficients to a separate file for import into Code V. This option will export up to the full 120 calculated terms. The file will have a .int extension.

3rd Order Seidel Aberrations

The 3rd Order Seidel aberrations area on the right side of the display shows these aberrations in the Fit dataset. Remember that the Zernike analysis operates on analyzed (surface) data *after* the option under **Analysis** > **Aberration Removal** have been applied. See *Aberrations* for details. Right click in the table and select **Column Chooser** to toggle the table columns on or off.

Zernike Table

The Zernike Table (*Figure 84*) is a non-interactive tabular display of the Zernike polynomial coefficients, suitable for printing. Appendix *A1* lists the Zernike polynomial coefficients.

To open the worksheet choose **Analysis** > **Zernikes** > **Table.**

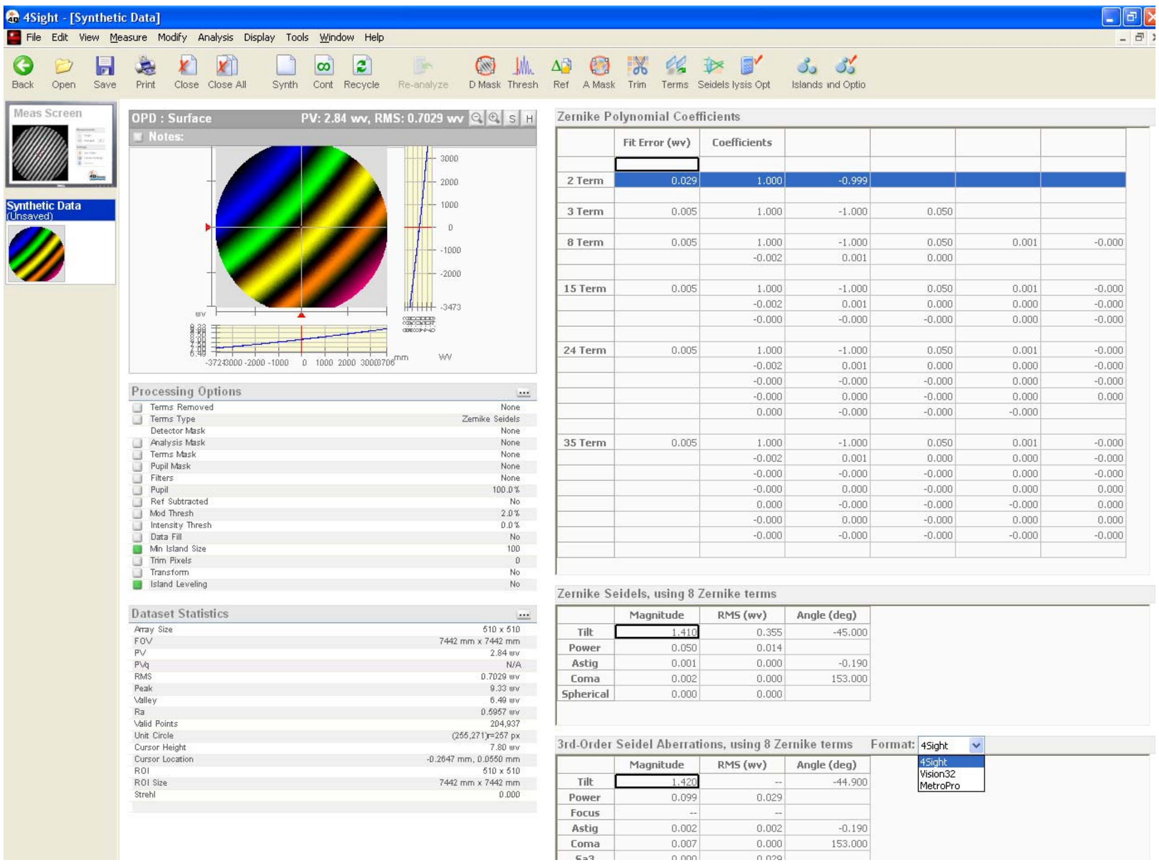


Figure 84: Zernike Table.

The plot in the upper left of the display is a *Contour Plot* of the surface data. All contour plot viewing and right click options apply.

Right click in the Zernike or Seidel tables to copy cells, or the entire table, to the clipboard. Right click and choose **Save** to save the entire table as a comma-separated (csv) or tab-separated (tsv) file.

Right click in either table and select **Column Chooser** to toggle the table columns on or off.

Note: To export the Zernike coefficients to a separate file, use the *Zernike Worksheet* instead of the Zernike Table.

In the **3rd Order Seidel Aberrations Table** you can display the data based on the conventions of 4Sight, MetroPro or Vision32 software.

When **4Sight** is selected the table will display:

Tilt $= \sqrt{(Z_1 - 2Z_6)^2 + (Z_2 - 2Z_7)^2}$

Power $= 2Z_3 - 6Z_8 \pm \sqrt{Z_4^2 + Z_5^2}$

where the sign of the radical is selected to minimize the magnitude.

Astigmatism $= \pm 2\sqrt{Z_4^2 + Z_5^2}$

where the sign of the radical is the opposite of that in the power calculation.

Coma $= 3\sqrt{Z_6^2 + Z_7^2}$

Spherical $= 6Z_8$

When **Vision32** is selected the following values change:

- *Power* is calculated as $2Z_3$.
- *Focus* is calculated as $2Z_3 - 6Z_8 - \sqrt{Z_4{}^2 + Z_5{}^2}$.

When **MetroPro** is selected the following values change:

- Power is not calculated.
- Focus is calculated as $2Z_3 - 6Z_8$.

Island Processing

Four analyses in 4Sight involve the comparison of separate islands of data: *Island Analysis*, *Prism and Corner Cube Analysis*, and *Step Analysis*. All four of these analyses require the settings in the Island Options dialog box.

Island Options

To open the Island Options dialog box click the **Isl Opts** toolbar button 

, or choose **Analysis** > **Island** > **Island Options**. The dialog has multiple tabs, all of which can apply to the **Current** measurement or to **Future** measurements. If you make changes to the Current settings you can click **Copy to Future** to have them apply to subsequent measurements as well.

Note: If you open the dialog box while viewing Live Video only the **Future** tab options will be available since there would be no current measurement.

Leveling Tab

When measuring a discontinuous surface, as in a step or segmented mirror, it is possible to have phase ambiguities, where one island is offset in height by one fringe relative to the other islands. The **Leveling** tab (*Figure 85*) tools allow you to adjust the relative heights of islands to resolve any ambiguity.

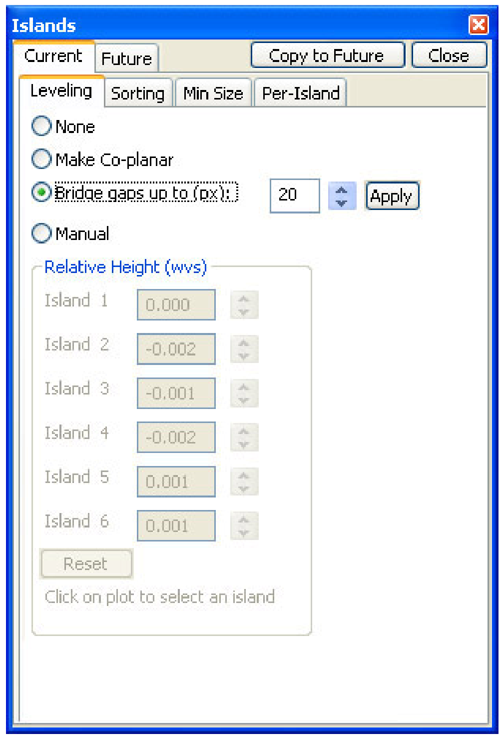


Figure 85: Islands Dialog Box Leveling tab.

Select the **None** option to skip leveling, or select one of the leveling options:

1. **Make Co-Planar**. This method is effective when each individual island has tilt and piston but minimal shape. It uses the following algorithm:

    a. Identifies the largest islands.

    b. Removes tilt from the largest n islands.

    c. Adjusts the piston of all islands in increments of "wedge" waves (typically one fringe) until they are as nearly equal in height as possible.

    d. Restores the removed tilt to each island.

2. **Bridge Gaps**. This options is useful when data is divided into islands by narrow strips, as when a "spider" support structure obscures portions of mirror data. Enter the maximum number of pixels to "bridge" from both sides of the missing strips to reestablish the missing data. If you are adjusting a grouped measurement, press the **Apply** button; otherwise, your offset will be applied automatically.

    The algorithm attempts to carry the local slopes across the missing strips, as follows:

    a. Takes the derivative of the trimmed surface in X and Y to get the slope datasets.

b. Fills in slope data across the strips to achieve continuous local slopes.

c. Integrates the data-filled X and Y slopes to recover the corrected surface, starting with one pixel and using a flood-fill integration, to ensure that all pixels are co-referenced.

d. Uses the corrected surface to get the approximate island offsets.

e. Rounds to an integer number of fringes of offset and adjusts the original surface accordingly.

3. **Manual Island Leveling**. Larger differences, typically those greater than a half-wave, can be resolved only by using *a priori* knowledge of the relative heights. In this case you can use the **Manual** island leveling method:

    a. Ensure that the data is broken into islands.

    b. Identify the island you wish to raise or lower by clicking on the island in the contour plot or 3D plot. The Relative Height box for that island will be highlighted in red.

    c. Use the up or down arrows next to the **Relative Height** box to raise or lower the selected island (the number is given in waves).

    d. At any time you can press the **Reset** button to set the relative offsets to zero.

Sorting Tab

These options let you choose how the islands will be numbered in the Island, Prism and Corner Cube analyses (*Figure 86*):

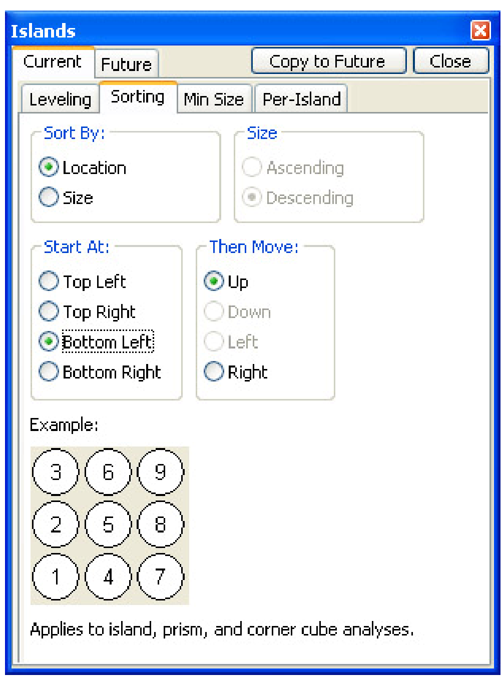


Figure 86: Island Dialog Box Sorting tab.

Sort By Choose to number the islands according to location (based on the **Start At/Then Move** settings described below) or by **Size**. When size is selected you can choose to number the islands in **Ascending** or **Descending** order.

Start At/Then Move These options determine the order in which the islands will be numbered when **Sort By: Location** is chosen. The **Example** in the lower left corner of the dialog box indicates how the numbering will occur.

Min Size Tab

Islands of interest typically include a substantial number of pixels. Small islands of data may be present as well, but these small islands may not be of interest. Click on the **Min Size** tab (*Figure 87*) to exclude these islands for Island, Prism and Corner Cube analyses. In the **Discard islands smaller than** field enter the number of pixels necessary for a set of contiguous pixels to be considered a "valid" island. Smaller islands will be ignored.

Figure 87: Analysis Options Dialog- Islands tab.

Tip: You can see the results of the Minimum Island Size by viewing the *Measurement Flow*.

Per-Island Tab

For Island, Prism and Corner Cube analyses you can choose to remove terms from each individual island with respect to the zero plane of the dataset. As with global *Aberrations Removal* you can remove Piston, Tilt, Power, Astigmatism, Coma and Sphere from each island.

To remove aberrations per island click the **Per Island** tab (*Figure 88*).

Figure 88: Per Island Aberrations Removal dialog box.

Check the boxes next to the terms to be removed from each island. Select the **Fit Type** (Zernike or 3rd Order Seidels) as well. The terms will appear in red until you click **Apply**.

Note: To avoid misinterpretation of the data turn off global *Aberrations Removal* when using per island terms removal.

Island Analysis

Island Analysis calculates statistics for each group of contiguous pixels in the data, including the Peak-to-Valley, Mean Height, Tilt, and the number of valid pixels.

To use the Island Analysis, select the desired measurement from the *Measurement Stack*. Then click the **Islands** toolbar button 

, or choose **Analysis** > **Island** > **Island Analysis**. In this example an *Analysis Mask* was used to divide the data into three islands.

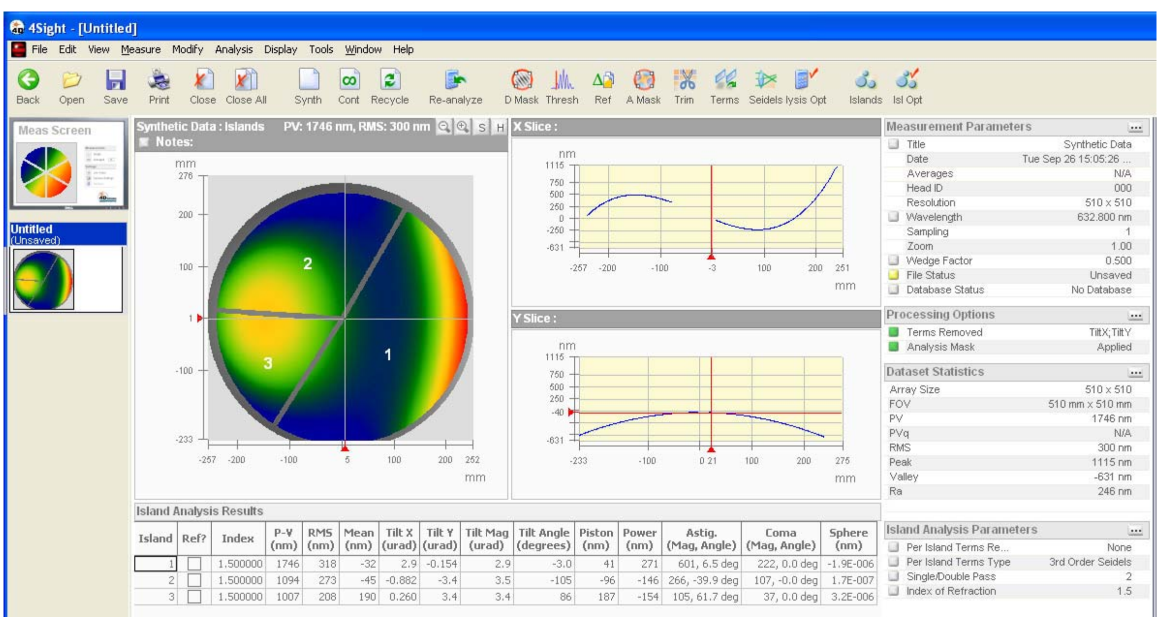


Figure 89: Island Analysis.

The *Contour Plot* shows all found islands—they will be numbered sequentially based on the options in the Island Options *Sorting Tab*. Move the cursor on the contour plot to view the *XY Slice* plots through any pixel on the plot.

Statistics for each island are shown in the table at the bottom of the window. By default, the statistics are determined using the entire dataset as the reference. Check the **Ref** box next to one of the islands to use it as the zero reference instead; the reference island's tilt and piston will be removed from *all* data, and the statistics for all islands will be recalculated based upon the new location of the reference island. The selected region will be labeled "Ref" in the contour plot. Click the **Ref** box again to deselect it.

Right click in the table to **Copy** cells, or the entire table, to the clipboard. Right click and choose **Save** to save the entire table as a comma-separated (csv) or tab-separated (tsv) file.

You can also right click in the table and select **Column Chooser** to toggle the table columns on or off. The following statistics are calculated and available in the table:

Island	The serialized island number, sorted by descending size.
Ref	The island which is selected as the reference.
Index	The refractive index for the island.
P-V	The peak-to-valley height difference within each individual island.
P-Vq	The peak-to-valley height difference within each individual island. This parameter will only be available if the **Calculate Q Peak Valley** box is checked under **Analysis Options** > ***Statistics***.
RMS	The root-mean-square roughness for each island.
Tilt X/Y*	The tilt in X and Y relative to the reference island, or relative to the measurement's coordinate system when no reference is selected.
Tilt Mag*	The maximum tilt magnitude relative to the reference island, or relative to the measurement's coordinate system when no reference is selected.
Tilt Angle*	The angle where maximum tilt occurs.
Valid Pts	The number of valid pixels in each island.
Diam	The diameter of the unit circle for each island.
X/Y Sag	To calculate X and Y sag, the best fit cylinder is calculated in X and Y. Sag is read from the lowest point in the best-fit cylinder to the height where the unit circle intersects the cylinder.
Sag	To calculate maximum sag, the best fit curve is calculated. Sag is read from the lower point in the best-fit curve to the height where the unit circle intersects the curve.
Window Wedge*	The difference between the angles of the front and back surfaces of a sample window. Note that the *Wedge* value must be set to **1** in order to correctly calculate the window wedge. This bases the calculation on beam deviation, rather than surface tilt.

Piston* The difference between the island's average height and the zero plane for the measurement.

Mean* The mean height for the island. "0" is the average height of the reference island, or the origin for the measurement's coordinate system when no reference is selected.

Power* Power for each island.

Astigmatism* Astigmatism for each island.

Coma* Coma per island.

Sphere* Spherical error per island.

* These values are listed in the table both before and after Per Island Aberration Removal. See *Per-Island Tab* for more.

The **Island Analysis Parameters** in the lower right of the window shows the aberrations removed from individual islands, as well as the type of terms removed, the test setup (single- or double-pass, as in *Figure 90*) and the index of refraction for the sample.

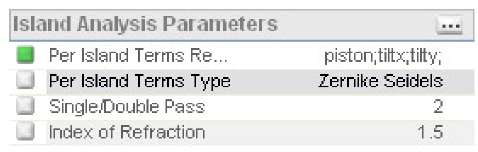


Figure 90: Island Analysis parameters.

Prism and Corner Cube Analysis

4Sight calculates the retroreflection errors of prisms and corner cubes, based on the relative tilt between faces, the index of refraction of the part, and the number of passes through the optic.

To run the analyses choose either **Analysis** > **Prism** > **Right Angle Prism** or **Analysis** > **Prism** > **Corner Cube**. When you choose these options the **Prism Analysis Options** dialog box will open (you can also open this dialog by choosing **Analysis** > **Prism** > **Options)**.

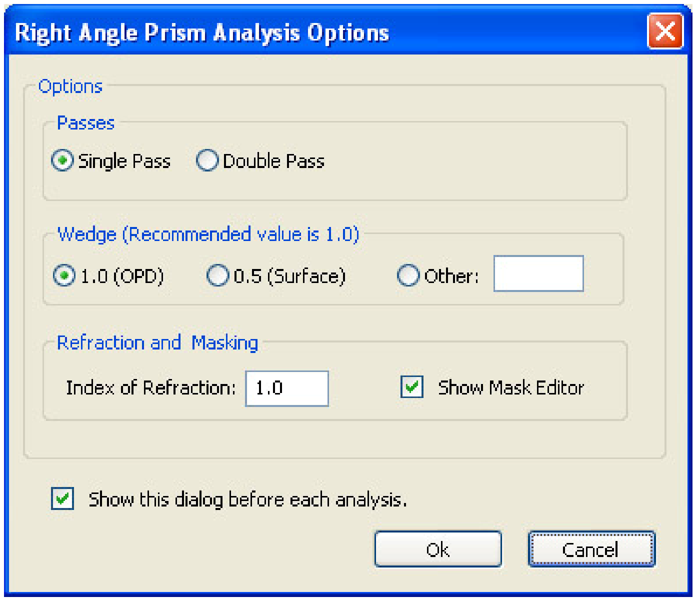


Figure 91: Prism Analysis Options dialog box.

In this dialog you will set the following:

Passes

Select whether the measurement configuration will be **Single** or **Double Pass**, as per the diagram below.

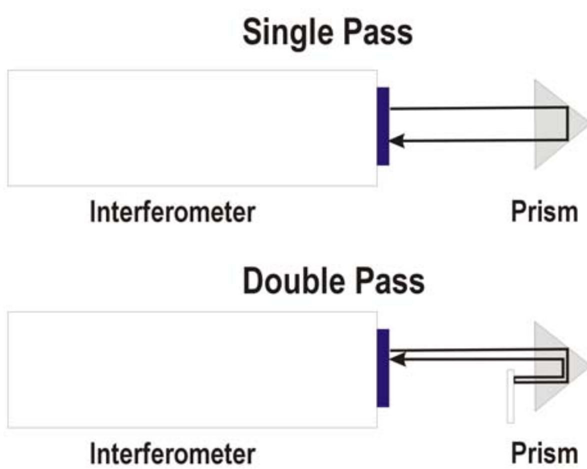


Figure 92: Single Pass and Double Pass measurement configurations.

Wedge

The ***Wedge*** value for each new measurement is based on the setting in the *Optical Parameters* dialog box. Here you can change the wedge value for the current measurement. Prism analyses are almost always completed with wedge=1, though the option is available to use 0.5 or another value.

Note: Since Wedge is specific to each measurement the option will be grayed out until a measurement has been made.

Mask Editor

Check the **Show Mask Editor** box to open the **Edit Masks** dialog box each time the Prism Analysis dialog box is opened. To perform the prism or corner cube analysis, measurement data must first be broken into islands. Therefore, you can choose to have 4Sight **Show Mask Editor** whenever the Prism Analysis Options are displayed. The Mask Editor will automatically provide a right angle prism or corner cube *Analysis Mask* when you choose either analysis. Drag the mask's handles to adjust its size and rotation to match the sample data. See the *Masking* section for details.

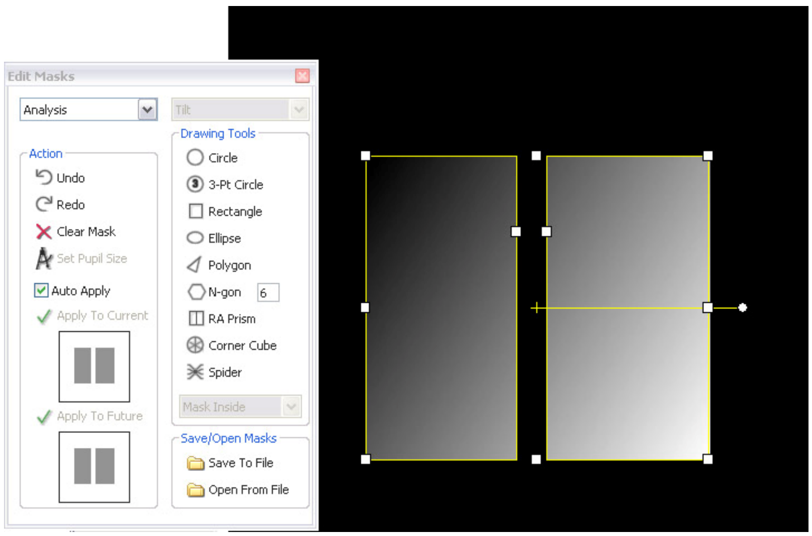


Figure 93: Right angle prism mask.

Note: The Mask Editor option will be grayed until a measurement has been made.

Parameters

4Sight will calculate the following parameters as part of the prism analyses:

Beam Deviation is calculated for each prism face. It is the angle of the reflected beam relative to the reference and is equivalent to the tilt magnitude for each face. Wedge must be set to 1 for this calculation to report correct results.

The **Retroreflection Error** is the deviation between the outgoing and incident beam for each round-trip pass through the prism. It is calculated as the average of beam deviation errors for each set of opposing faces. In a corner cube opposing faces (1 and 4, 2 and 5, 3 and 6) will therefore have the same results.

Retroreflection errors are displayed in waves per radius, arc-seconds, or user-selected units based on your settings under **Edit** > **Units**.

Note: You must specify lateral scaling to see real tilt units, including arc-seconds. See *Scaling Lateral Dimensions to the Real World* for details.

Dihedral Angle Error is the physical deviation of the glass from a perfect angle between faces. It is given by:

$$\varepsilon = \frac{\alpha}{4mn\sin\theta}$$

where

α = beam deviation

θ = the angle between the roof edge and the incident beam

m = number of passes

n = index of refraction.

For a right angle prism one Angle Error will be reported (between the two roof faces). For a corner cube, three calculations are reported:

C (1-2) The angle between faces 1 and 2 across edge C.

B (2-3) The angle between faces 2 and 3 across edge B.

A (3+1) The angle between faces 3 and 1 (flipped) across edge A. This is equivalent to the angle between faces 3 and 4; however, since, only faces 1, 2 and 3 are available in double-pass mode, 4Sight calculates the angle using the flip of face 1.

The sign of the dihedral angle will be reported as **obtuse** if it is larger than the anticipated angle, or **acute** if it is smaller than the anticipated angle. The measured **Angle** between each pair of faces is also displayed.

See *Malacara, Optical Shop Testing, Third Edition, p 68-69* for more.

Labeling Prism Seams and Faces

For a right angle prism the topmost and/or leftmost face will be labeled **1**, and the other face labeled **2**.

The labeling for a corner cube's seams and faces will be based upon the corner cube mask. As in the figure below, the seam that is 90 degrees from the mask's rotation handle will be labeled **A**. The others seams will be labeled clockwise from there.

The first face clockwise from Seam A will be labeled **1**. The other faces will be numbered clockwise from there.

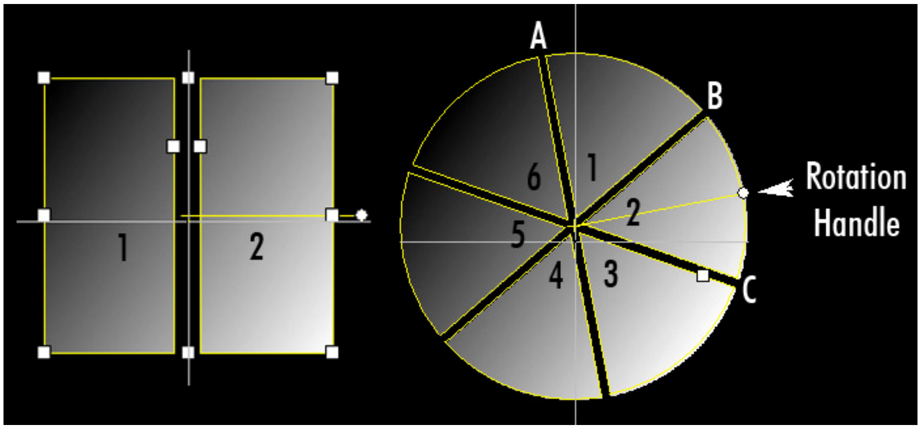


Figure 94: Labeling of seams and faces for right angle prism and corner cube.

Prism Analysis Results

Choosing **Analysis > Prism >Right Angle Prism** will generate the following data:

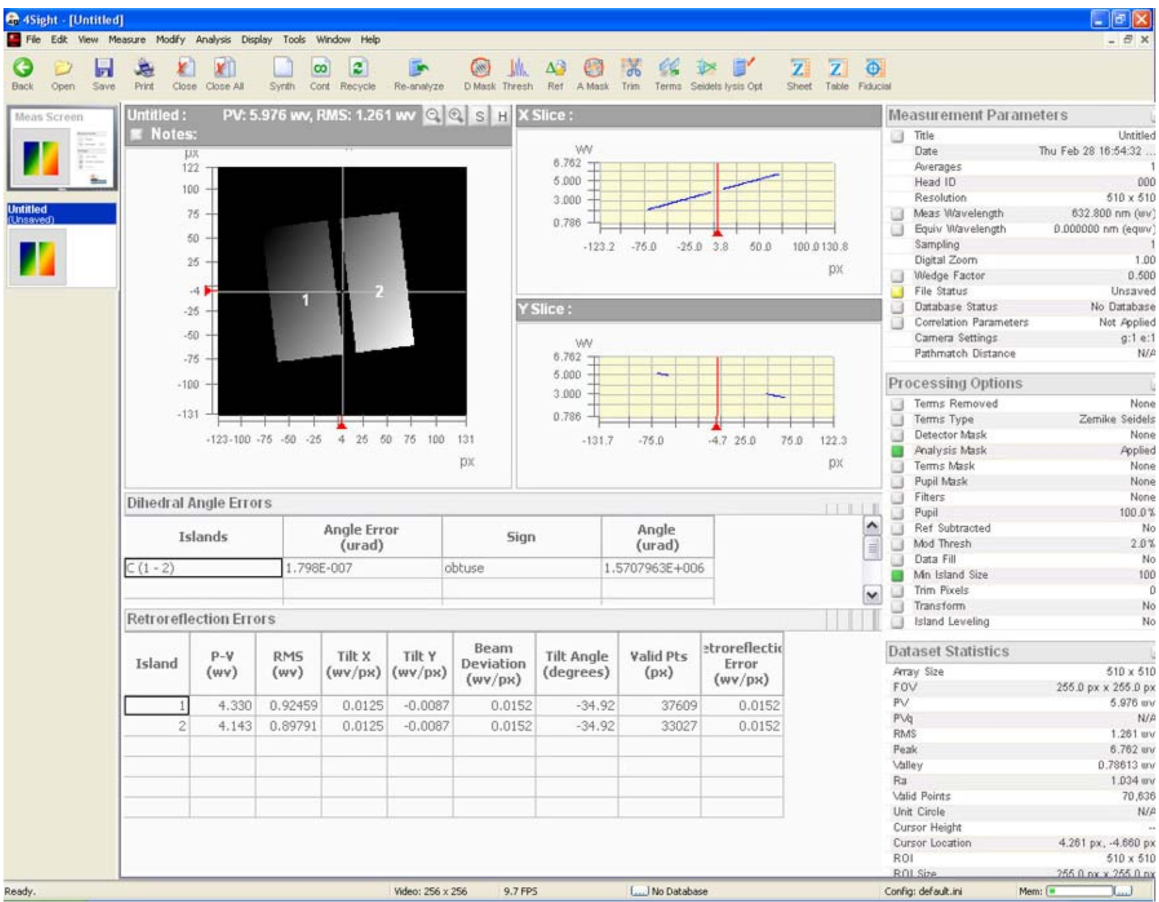


Figure 95: Right Angle Prism Analysis.

Choosing **Analysis > Prism >Corner Cube** will generate the following data:

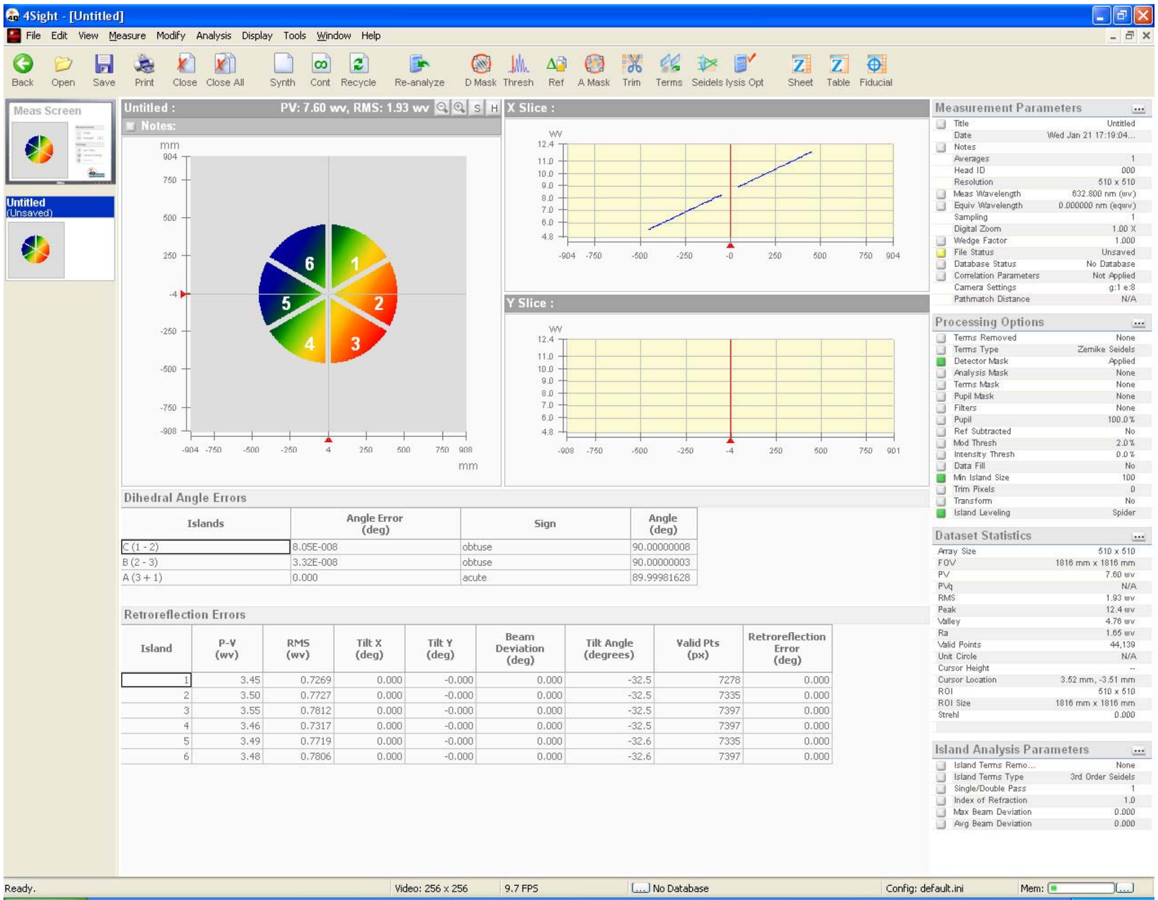


Figure 96: Corner Cube Analysis.

The *Contour Plot* in the upper left shows the found islands, numbered sequentially for identification. Click and drag the cursor on the contour plot to view the *XY Slice* plots through any pixel on the plot.

Note: If Per Island Aberration Removal is enabled, aberrations will be removed from each face during the Prism Analysis. Removing Tilt from each face would render the angle values meaningless, however. Therefore, a warning will appear in the Island Analysis Parameters area () when Per Island Aberration Removal in conjunction with Prism or Corner Cube analyses. See *Per-Island Tab* for more.

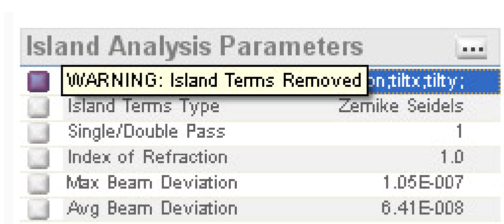


Figure 97: Island Analysis Parameters warning.

Right click in either of the tables at the bottom of the screen to copy cells or to copy the entire table to the clipboard. Right click and choose **Save** to save the entire table as a comma-separated (csv) or tab-separated (tsv) file. Right click in the table and select **Column Chooser** to toggle the table columns on or off.

Step Analysis

Step Analysis calculates the relative height and tilt differences between each pair of islands in a dataset. When you choose **Analysis > Step**, 4Sight first performs an *Island Analysis*, then calculates and displays the differences in the Step Height Results table. Islands are determined based on the parameters in the *Island Options* dialog box.

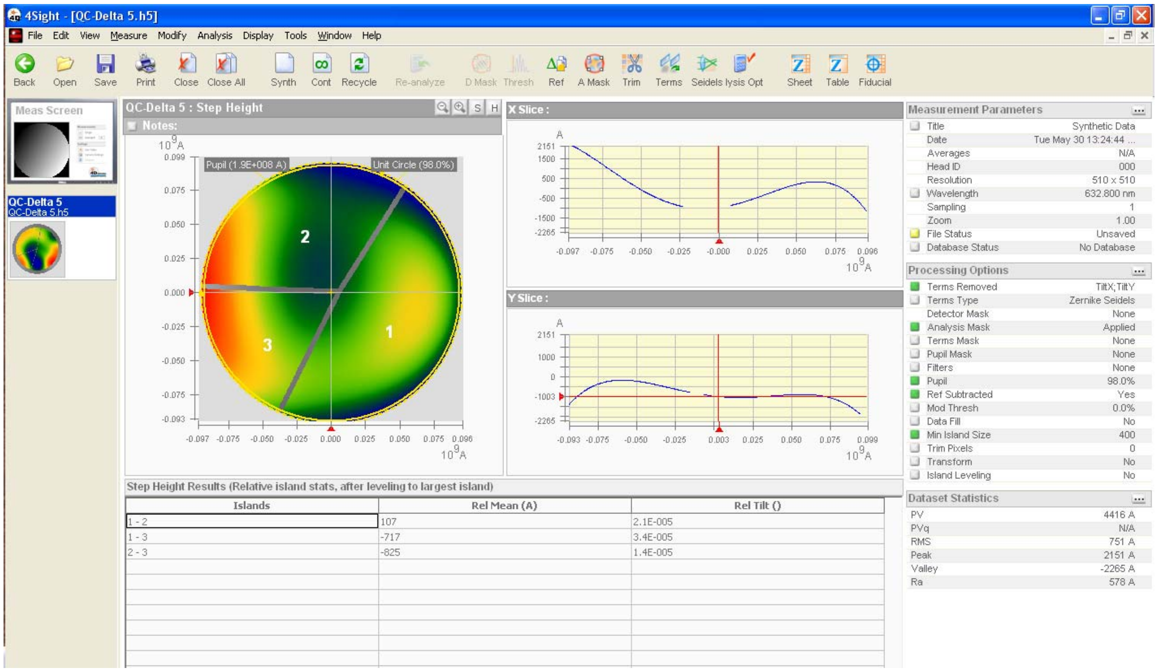


Figure 98: Step Height Analysis.

The *Contour Plot* shows the found islands—they will be numbered sequentially for identification. Move the cursor on the contour plot to view the *XY Slice* plots through any pixel.

The differences between the individual islands are reported in the table at the bottom of the window. Right click in the table to copy cells, or to copy the entire table, to the clipboard. Right click and choose **Save** to save the entire table as a comma-separated (csv) or tab-separated (tsv) file.

Right click in the table and select **Column Chooser** to toggle the table columns on or off.

Direct Cavity Analysis

The Direct Cavity Analysis is for use with 4D interferometers with a short coherence length laser source. This source enables “direct cavity” measurements, in which the front surface of a test sample serves as the reference while the back surface is measured. The result of the Direct Cavity analysis is a measurement of the degree and direction of wedge angle between the front and back surfaces.

To run the analysis:

1. Choose **Analysis > Direct Cavity > Options** to open the Direct Cavity Island Analysis Options dialog box (*Figure 99*). Enter the **Index of Refraction** for the sample part and click **OK**.

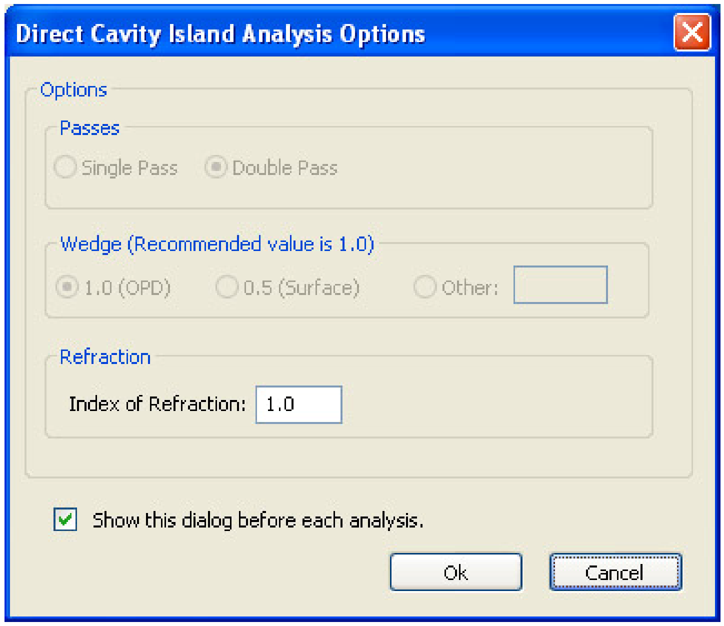


Figure 99: Direct Cavity Island Analysis Options Dialog Box.

2. Align the sample part in front of the interferometer. The measurement can be completed with or without a transmission flat in place.

3. Path match to the cavity created by the front and back surfaces of the sample. This cavity length is the optical thickness of the sample.

4. Adjust focus and intensity, and measure.

5. Choose **Analysis** > **Direct Cavity** > **Direct Cavity Island Analysis**. The resulting analysis screen will show the wedge magnitude and the Tilt Angle, which is the direction of the wedge (*Figure 100*). "0 degrees" tilt angle indicates that the sample is thickest at the right side of the display; "90 degrees" indicates that it is thickest at the top of the display (*Figure 101*).

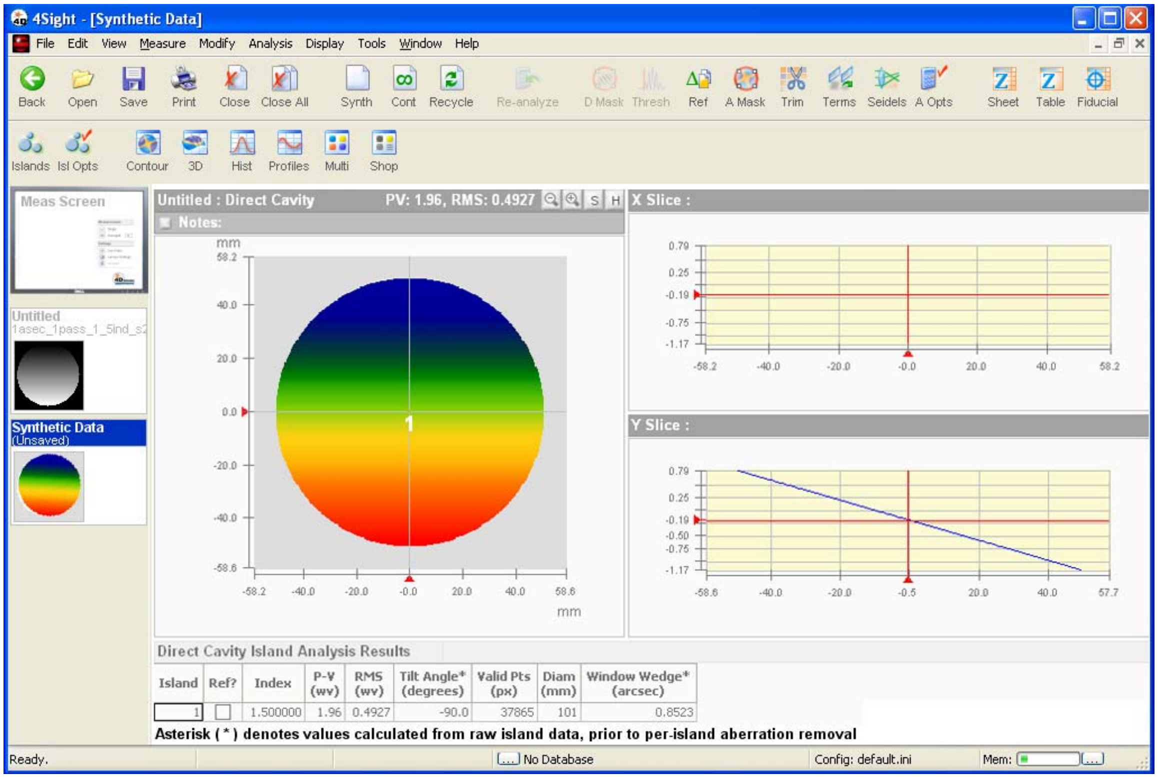


Figure 100: Direct Cavity Island Analysis.

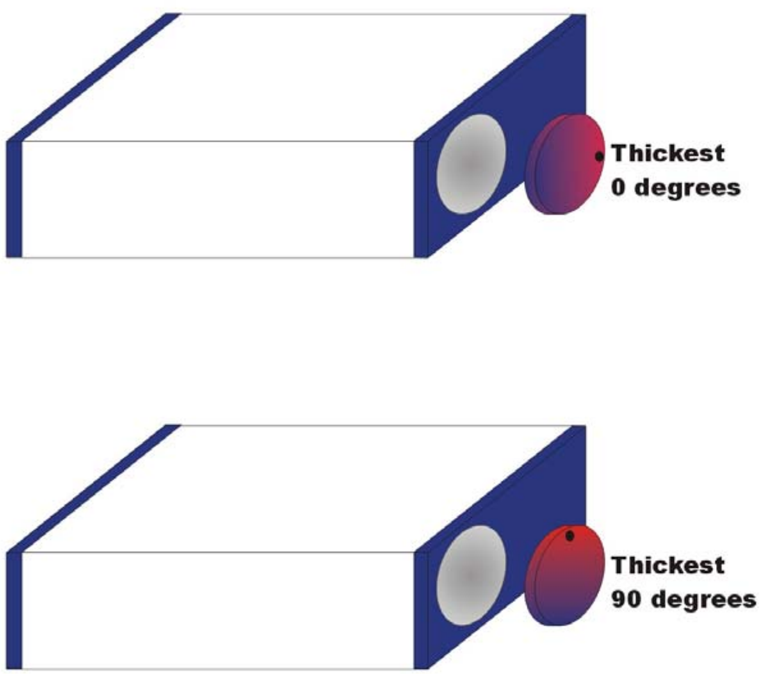


Figure 101: Tilt Angle direction for Direct Cavity Island Analysis.

Intensity Distribution Analysis

The Intensity Distribution analysis fits a dataset's intensity distribution to a Gaussian profile and reports the deviation from a perfect Gaussian fit. To perform the analysis, first measure the sample and click **Analyze**. Then choose **Analysis > Intensity Distribution.**

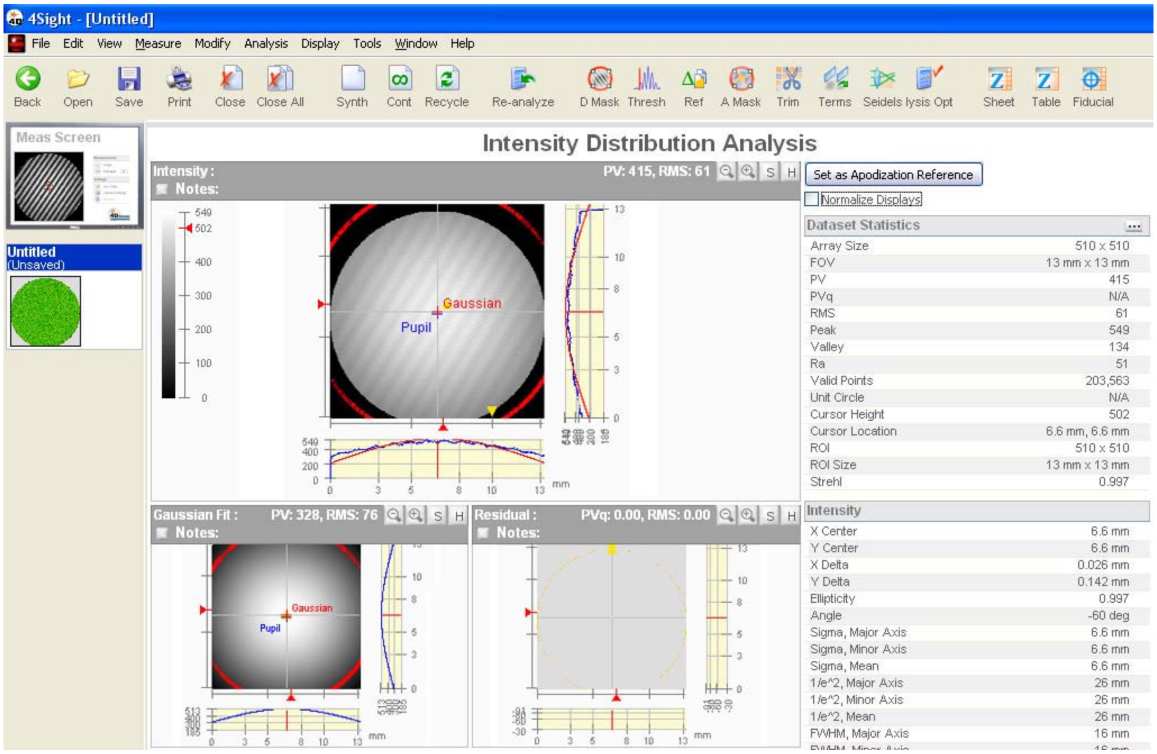


Figure 102: Intensity Distribution Analysis.

The Intensity Distribution display shows the intensity of the actual dataset, the best-fit Gaussian distribution, and the residual difference between the two. All three are *Contour Plots*, and therefore all contour plot viewing and right click options apply to each. The red circle indicates the 1/e limit for the Gaussian fit.

Click the cursor in any of the three plots to update the X and Y traces below and to the right of the plot. The slice plots show the actual distribution in blue and the Gaussian fit in red. Check the **Normalize Displays** box to view the distributions on a 0-1 scale. Right click in the X or Y slice plots and choose **Analyze Slice** to view and manipulate the traces in greater detail (see the *XY Slice* section for details).

Click the **Set As Apodization Reference** box to use the current dataset as the *Apodization* Reference. This reference will be applied to subsequent measurements and will be used for various operations including *Spot Analysis*.

Analysis Options

The Analysis Options dialog box contains several options that apply to analyses we've discussed above.

Pupil

These options determine how the pupil and *Unit Circle* are determined.

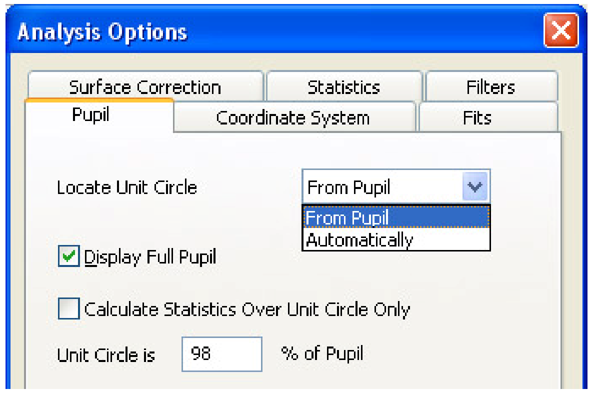


Figure 103: Analysis Options Dialog- Pupil tab.

The pupil is the circle encompassing the data under test. See *Using the Pupil* for more. The Unit Circle is a mathematical construct used to fit Zernike aberrations to your measurement data. See *Unit Circle* for more.

From the **Locate Unit Circle** list select **Automatically** to fit the unit circle to the extent of the measurement, or masked data, if *Masking* is applied. Choose **From Pupil** to match the unit circle to the diameter of a manually defined pupil.

Check the **Display Full Pupil** box to display the entire extent of the data, even if the unit circle has been manually defined to a smaller size.

Check the **Calculate Statistics Over Unit Circle Only** box to disregard any data outside of the selected unit circle.

Enter a value in the **Unit Circle Is** box to define the unit circle as a percentage of the pupil for each measurement. This represents the “clear aperture” (CLAP) to be used when fitting terms to the data.

Coordinate System

These options determine the location of 4Sight’s coordinate systems. Choose to locate the origin of the coordinate system at the **Pupil Center** or **Bottom Left**. See *Setting the Lateral Coordinate Origin* for details.

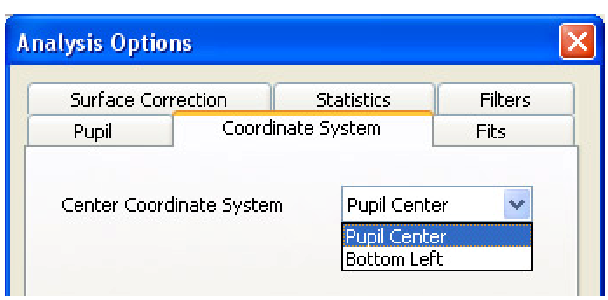


Figure 104: Analysis Options Dialog- Coordinate System tab.

Fits

On the Fits tab you can choose how to remove the Piston aberration term. If you choose to remove piston, 4Sight will remove the piston term by setting either the **Minimum Height** or **Average Height** to zero. See *Aberrations* for details.

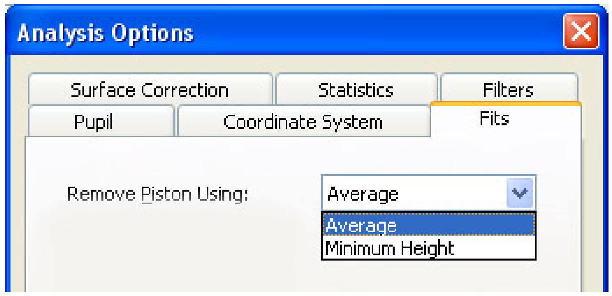


Figure 105: Analysis Options Dialog- Fits tab.

Surface Correction

On the Surface Correction tab, you can choose whether to use 4Sight's Data Fill option. Data Fill can fill holes in the interior of the data, using a progressive linear interpolation technique. The number of iterations determines the maximum size of holes it can fill. To enable **Data Fill**, check the Data Fill box and enter the desired number of **Iterations**.

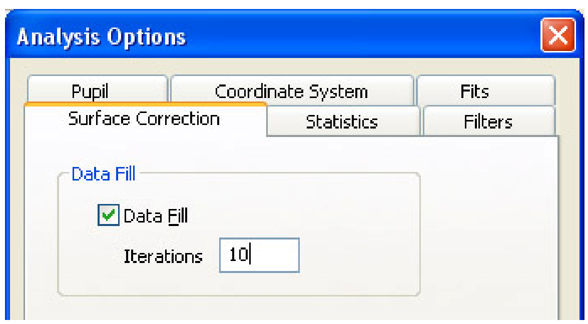


Figure 106: Analysis Options Dialog- Surface Correction tab.

Statistics

On the statistics tab, you can choose whether to calculate **Q Peak-Valley** (PVq). 4Sight always calculates the total peak-to-valley (PV), the difference between the highest point and lowest point in a measurement. While PV is a common and useful figure, it depends on only two points and is thus susceptible to noise spikes. PVq provides a more robust measure of the shape, allowing you disregard the highest and lowest pixel and only consider the remaining **Q Percent** of pixels.

To calculate PVq, 4Sight generates a histogram of surface heights, then determines the narrowest band of the histogram that contains the Q Percent of pixels. If you choose to calculate PVq, the result is displayed on the *Dataset Statistics* table found on many of 4Sight's screens.

Since the PVq calculation requires a time-consuming histogram calculation, you might choose to disable this option if you're not using it.

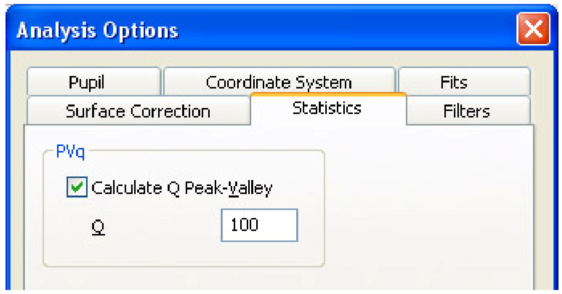


Figure 107: Analysis Options Dialog- Statistics tab.

Filters

Filters can be used to highlight, or remove, certain spatial components of data. The filter selected here will automatically be applied to the raw data for each subsequent measurement and will affect both the raw and analyzed (surface) data.

You can choose to apply any of the following filter types:

Lowpass Applies a Fourier low pass filter, removing data above the specified cutoff **Frequency**.

Highpass Applies a Fourier high pass filter, removing data below the specified cutoff **Frequency**.

Smoothing Replaces each pixel with the mean of the pixels within a smoothing window of specified **Window Size**.

Median Sorts the pixels within a window of specified **Window Size** then determines the median pixel in that window. The center pixel is assigned this median value.

Sigma Smoothes noisy or "spiky" data. The filter sorts the pixels within a window of specified **Window Size**. It then calculates the mean value of pixels within the window, discarding those that fall beyond the specified **Sigma Width** (i.e., number of standard deviations) from the mean. The center pixel in the window is then assigned this mean value.

Note: These filter options function identically to those selected under **Modify** > **Filters**; however, here the filters are automatically applied to all subsequent measurements.

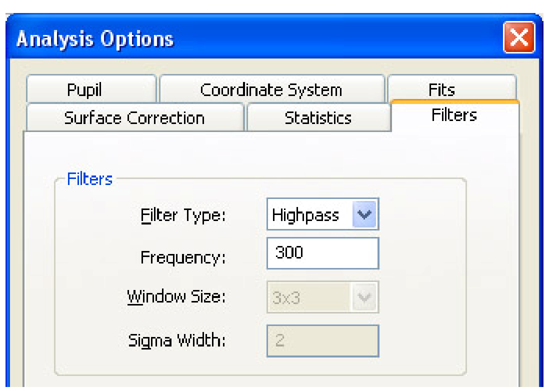


Figure 108: Analysis Options Dialog- Filters tab.

Chapter

7

Masking

Masking lets you define the regions from which data should be kept and analyzed. 4Sight™ provides four types of user-definable masks, Detector, Analysis, Terms and Pupil, all of which have unique purposes. To work with these masks, choose **Edit > Masks** then select the mask type. All are created using the same set of drawing tools, described below.

Detector Mask

The Detector Mask acts like a piece of cardboard in front of the camera, excluding areas that are not of interest, such as the area outside of the diameter of a circular optic. The detector mask is also useful for blocking stray light from unwanted reflections in the optical system.

A detector mask can only be applied in the Measurement Screen, not within analysis windows. Pixels masked by a detector mask are shown in blue in the Live Video display, as shown below. Pixels excluded by a detector mask are still acquired and saved within 4Sight, so a detector mask can be modified later, even for stored measurements (provided they are saved in the native H5 file format). To modify the detector mask on stored data, choose **Measure > Reanalyze**, then modify the mask.

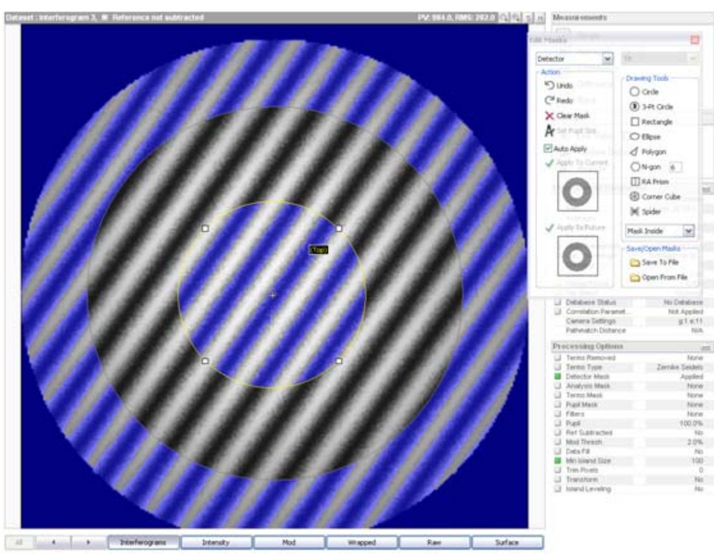


Figure 109: Detector mask. Masked areas are denoted in blue.

Analysis Mask

An Analysis Mask defines the regions to be used for fitting aberrations and calculating statistics. The analysis mask can be created within analysis windows or the Measurement Screen (though not with Live Video showing), and it can be changed at any time. With each change the fitted aberrations and statistics will be automatically recalculated. Analysis-masked pixels are shown as gray on surface plots.

Terms Mask

The Terms Mask allows the removal of tilt, curvature (power), or both tilt and curvature from the defined region. The Terms Mask is applied *before* aberrations are removed from the entire measurement. In order to use the Terms Mask, you must first turn off the removal of tilt and/or power by choosing **Analysis > Aberration Removal** (see *Aberrations* for details).

Pupil Mask

The pupil mask defines the diameter of the optic under test, from which the *Unit Circle* is derived for Zernike and Seidel calculations. 4Sight will automatically define the pupil mask based upon the maximum extent of the data; if you explicitly define a pupil mask it will override the automatic setting. For complete details about the pupil and unit circle, see *Scaling Lateral Dimensions to the Real World*.

Defining a Mask

All four types of masks are defined using the same set of drawing tools. To create a mask first ensure that you are viewing analyzed (surface) data (choose **View > Analyzed Surface** if necessary). Next, choose **Edit > Masks** and select the mask type. You can also click the **D Mask**, **A Mask**, or **Terms** toolbar buttons to create a Detector Mask, Analysis Mask or Terms Mask, respectively.

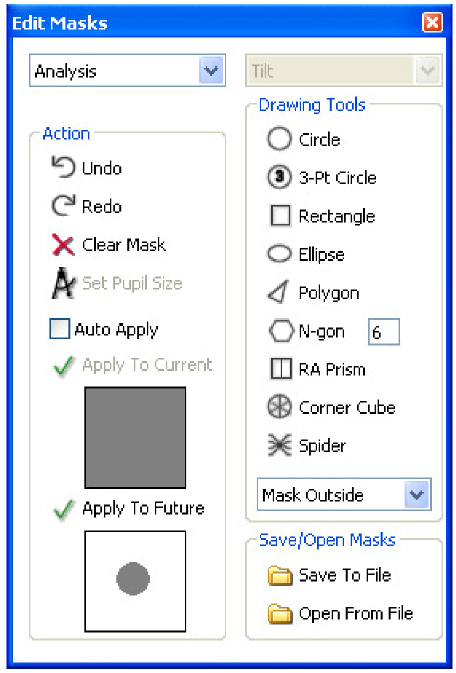


Figure 110: Edit Masks dialog box.

Tip: The Edit Masks dialog box can remain open while you perform other tasks within 4Sight. However, this may slow down the video display rate. It is typically best to close the Masking dialog box when it is not required.

The type of mask you are defining will be shown in the upper left—you can change the type if necessary by selecting it from the pull-down list.

Next, click on one of the **Drawing Tools** to begin creating the mask. You can then refine the shape by clicking and dragging its handle boxes:

- for the Circle tool, the square handles adjust the diameter.
- for the 3-point circle tool, the square handles set the circle's three anchor points.
- for the Rectangle tool, the side handles adjust size in one dimension while the corner handles change the size in both dimensions. The circular handle changes the rotation and overall size.
- for the Ellipse tool, the square handles change the width and height.
- for the Polygon tool, click on the plot to define the vertices—double-click when you have created the last vertex. You can then click and drag each vertex to adjust the shape. The circular handle changes the rotation and overall size.
- for the N-gon tool, set the number of sides in the box to the right of the tool, then click N-Gon to create the shape. The corner handles adjust the vertices while the side handles skew the shape. The circular handle changes the rotation and overall size.
- the RA Prism tool lets you define the facets of a right angle prism. The corner handles adjust the overall height while the side handles set the individual facet widths. The circular handle changes the rotation and overall size.

- The Corner Cube tool lets you define the equal facets of a retro-reflector cube. The square handle adjusts the spacing between the facets, while the circular handle changes the rotation and overall size.
- The **Spider Tool** lets you mask a series of radial spokes as you might find in the support structure for a large lens. Click the **Spider** tool, then enter the number of spokes to define. The square handle adjusts the width of the spokes, the gray circles adjust the individual spoke angles, and the circular handle changes the rotation and overall size.

For all shape tools, click and drag inside the shape to move the shape around the plot.

Tip: For tools with a Rotation (circular) handle, hold down the **Shift** key while dragging the circular handle to lock rotation to 45 degree increments.

You can also enter precise values for a shape's properties by right clicking on the shape and selecting **Edit Shape**. The Shape Properties dialog box allows you to enter dimensions, rotation, etc., as well as the logical function.

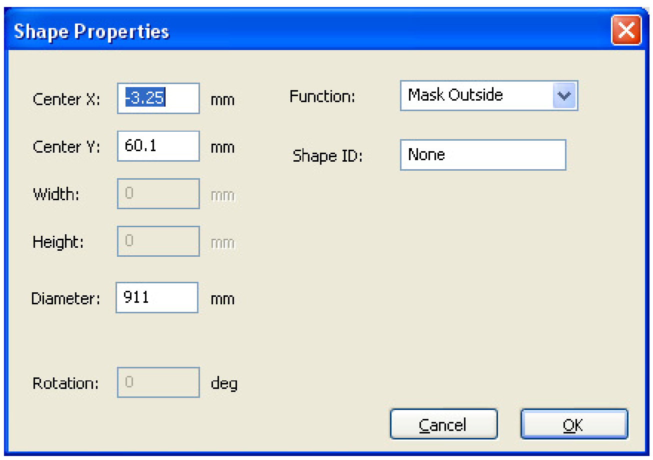


Figure 111: Shape Properties dialog box.

Tip: When working with small mask shapes you can right click on the shape, then choose **Zoom to Shape** to magnify it for precise positioning.

Set the logical function of the shape by selecting **Mask Inside**, **Mask Outside**, or **Pass Inside**.

To flip the shape in the vertical or horizontal axis, right click on the shape, select **Flip**, then choose **Flip Shape in X** or **Flip Shape in Y**.

Creating Multiple Shapes for One Mask

Any number of shapes can be combined to form complex Detector, Analysis and Terms masks (the Pupil mask can only be circular). As an example, the analysis mask below was created using three "mask inside" circles to remove portions of a mounting fixture from analysis:

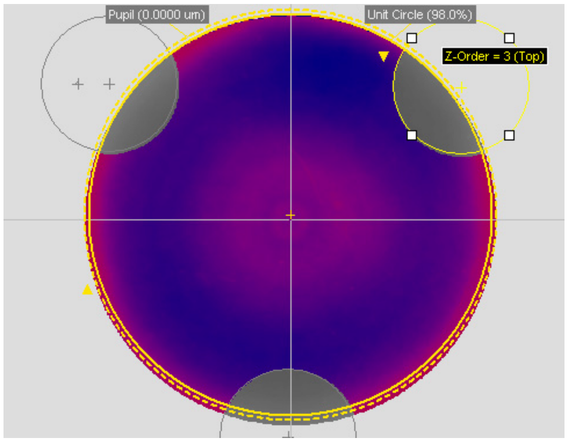


Figure 112: Complex mask created from basic shapes.

To create a complex mask, create the first shape, then select another tool from the Edit Masks dialog box and create the next shape. To duplicate a shape, right click on the shape and select **Copy Shape** (or click **Ctrl-C**), then right click on the plot and select **Paste Shape** (or click **Ctrl-V**). To delete a shape, right click and select **Delete Shape**.

To select multiple shapes hold down the **Ctrl** key while clicking each shape. You can resize, rotate, delete, or copy-and-paste multiple shapes in this manner.

As you add more shapes, the order in which they are created will be the “order” in which they are applied. As an example, consider two concentric circles: a large "Pass Inside" circle and a small "Mask Inside" circle. If the small circle is on top, the unmasked data will be a donut shape. But if the large circle is on top, the small circle will have no effect.

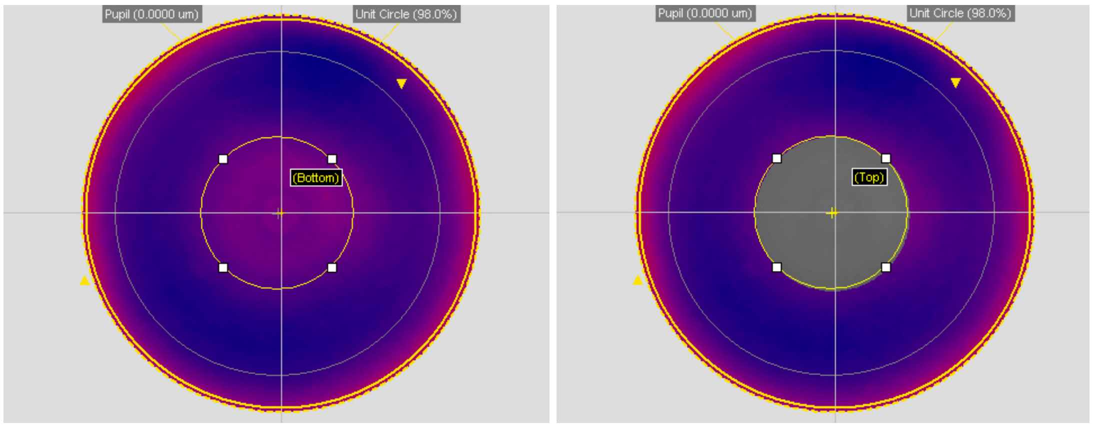


Figure 113: Effect of order on a mask consisting of multiple shapes.

To move a shape up or down in order, right click on the shape, select "Arrange," then choose one of the four options: **Move Up**, **Move Down**, **Bring to Top** or **Send to Bottom**.

At any time you can press the **Undo** button in the Edit Mask Dialog to undo the last operation. The **Redo** button performs the opposite function. Click **Clear Mask** to erase all shapes in the current mask. If you accidentally Clear the mask, just press Undo.

Applying Masks

While you are positioning the mask shape, it will remain transparent so that you can more easily position it against the data. Once you've positioned the mask shapes as desired, click **Apply To Current** on the Edit Masks dialog to apply the mask to the current measurement. A thumbnail version of the mask will appear in the Edit Masks dialog as a reference. 4Sight will then recalculate the statistics as necessary.

To apply the mask to future measurements as well, click the **Apply To Future** button. Again, a thumbnail of the mask will be displayed, and the mask will be applied to future measurement for the remainder of the 4Sight session.

If you check the **Auto Apply** box, your changes will be applied to current and future measurements automatically, without pressing the **Apply To Current** button. A thumbnail of the current mask is displayed in the Mask tools panel.

Saving Masks

Saving a mask as a file makes it available for future 4Sight sessions as well as the current one.

There are two methods for saving a mask. If you typically measure the same type of sample you will likely need only one mask of each type (one Detector Mask, etc.). In this case, the easiest method is to choose **File > Save Config as Default**. This will save your current Detector Mask, Analysis Mask, Terms Mask, and Pupil Mask as part of the configuration which will automatically load each time you start 4Sight.

If you measure multiple types of samples you may need to manage more masks, in which case it is best to save each mask to a file. From the Edit Masks Dialog, select the **Mask Type** you wish to save, then click **Save To File**. You will be prompted for a file name and location to which to save the file. This operation saves only the currently-selected mask type, so you should repeat this step for each mask you wish to save. For example, you might save the Detector Mask as a file called "MyDetectorMask.mask," and save the Analysis Mask as a file called "MyAnalysisMask.mask."

To retrieve a mask from a previous 4Sight session, open the Edit Masks dialog box, then click **Open From File**.

Chapter

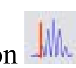
8

Trimming

The masking tools described in the previous chapter allow you to manually define static masks. Sometimes, however, it is useful to define masks which can change depending upon the content of the measurement. With 4Sight™ you can dynamically mask pixels that fail to meet certain criteria. These criteria are designed to help you keep the most reliable pixels, while eliminating less reliable and potentially problematic pixels.

Signal Thresholds

The **Modulation Threshold** allows you to mask pixels that do not modulate, or change in intensity, sufficiently across the interferograms. Similarly, you can reject pixels that fail to reach a certain **Intensity Threshold**. Both options are useful for eliminating background noise.

To set these thresholds, click the **Threshold** toolbar button , or choose **Measure** > **Modulation Threshold** or **Measure** > **Intensity Threshold**. All of these actions open the **Signal Thresholds** dialog box.

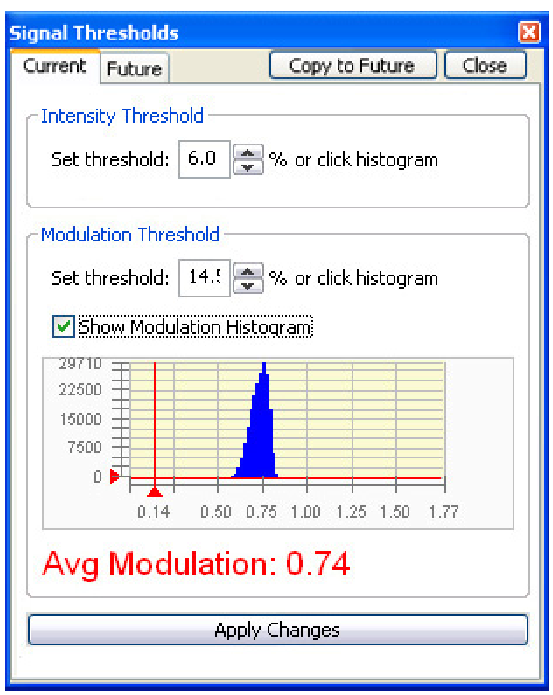


Figure 114: Signal Thresholds dialog box.

The most direct way to set the thresholds is to enter values in the Intensity or Modulation **Set Threshold** boxes, then press the **Apply Changes** button. The optimal values depend on the interferometer and the sample, so setting the thresholds is typically an iterative process. While viewing a measurement, increase the threshold value and press **Apply**, repeating until the desired pixels are rejected.

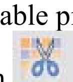
You can also check the **Show Modulation Histogram** box to display a histogram of modulation values. Click and drag on the chart to set the cursor to the new Modulation Threshold, then press **Apply Changes**.

Tip: Typical Modulation Threshold values range from 0.5 (%) to 50.0 (%).

Click the **Copy To Future** button to apply the threshold values to future measurements as well.

Note: A histogram of intensity can also be viewed in the *Camera Settings* dialog box.

Trim Pixels

The **Trim Pixels** function erodes the less reliable pixels at the edges of the data. To trim pixels from the edges, click the **Trim** toolbar button  or choose **Measure** > **Trim Pixels**. Either action opens the **Trim** dialog box.

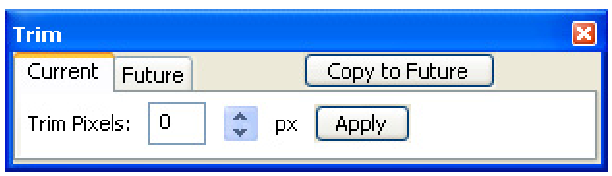


Figure 115: Trim Pixels dialog box.

In the **Trim Pixels** box enter the number of pixels to ignore around the edges of the sample, then press **Apply**. Click **Copy to Future** to trim the same number of pixels from future measurements.

Saving the Trim Settings

The Modulation Threshold, Intensity Threshold, Trim Pixels setting, and Minimum Island Size are saved with the configuration. To save your settings for the next 4Sight session, select **File** > **Save Config as Default**.

Chapter

9

Subtracting a Reference

4Sight™ allows you to subtract a known “reference” measurement from subsequent measurements so that you can view and analyze only the difference from this known baseline condition.

To specify a reference measurement click the **Ref** toolbar button , or choose **Analysis** > **Reference Subtraction**. Either action opens the Reference Subtraction dialog box. Depending on your particular system this dialog box will include one or more options, as described below.

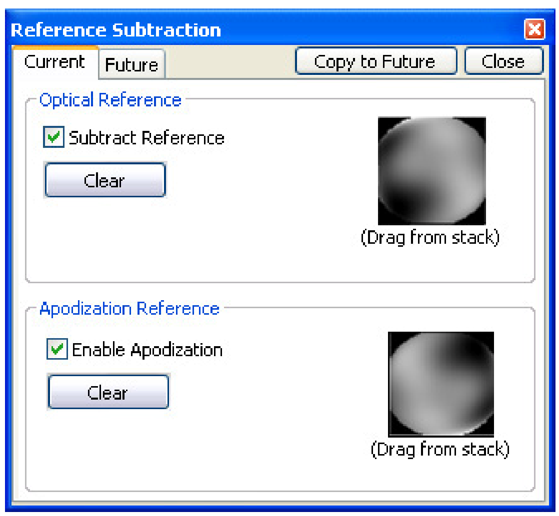


Figure 116: Reference Subtraction dialog box.

Optical Reference

The optical reference represents the total error introduced by the optical system itself. Subtracting this reference removes the system induced error.

To subtract the optical reference, first take a measurement of a known, precision optic, and analyze it. Drag that measurement from the *Measurement Stack* to the gray box in the **Optical Reference** portion of the dialog box. The thumbnail image will show the reference measurement, and the **Subtract Reference** box will be checked. This measurement will be subtracted from the current measurement.

Click the **Copy to Future** button to use this reference with all subsequent measurements in the current 4Sight session. Choose **File** > **Save Config As Default** to use the reference in future 4Sight sessions as well.

Un-checking the **Subtract Reference** box will deactivate it but will retain the measurement in the configuration for later use. Click the **Clear** button to remove the reference measurement completely. Click **Copy To Future** to cease to subtract the reference from future measurements.

Note: Reference subtraction lets you subtract the same measurement from several subsequent measurements. There are other ways to subtract measurements in 4Sight. To subtract two open measurements, use **Modify** > **Arithmetic** > **Subtract** (see *Data Modification* for details). If you need to transform and subtract misaligned measurements, use the *Fiducials* functions.

Apodization Reference

This reference applies primarily to 4D Technology's WaveCam systems. When measuring pickup heads, the transmission is brightest in the center of the pupil and tapers at the edges in a Gaussian distribution. The apodization reference lets you take into account both the shape of the pupil and the distribution of light across that pupil.

To subtract the apodization reference, measure a known pickup head and analyze it. Drag the measurement from the *Measurement Stack* into the gray box in the Apodization Reference area. The thumbnail image will show the reference measurement, and the **Subtract Reference** box will be checked. This measurement will be subtracted from the current measurement.

Tip: You can also use the *Intensity Distribution Analysis* to generate an apodization reference.

Click the **Copy to Future** button to use this reference with all subsequent measurements in the current 4Sight session. Choose **File** > **Save Config As Default** to use the reference in future 4Sight sessions as well.

Un-checking the **Subtract Reference** box will deactivate it but will retain the measurement in the configuration for later use. Click the **Clear** button to remove the reference measurement completely. Click **Copy To Future** to cease to subtract the reference from future measurements.

Note: While it is typically not suggested, 4Sight does allow you to subtract both an optical *and* apodization reference.

Interferogram Reference

Some 4D Technology systems allow you to measure diffuse surfaces, such as ground glass, composite materials, etc. With such surfaces it is not possible to extract the surface shape from a regular interferogram. However, it *is* possible to take two measurements of the surface, subtract them from each other, and then apply the phase unwrapping algorithms to the residual in order to map the surface change.

The Interferogram Reference lets you subtract the same measurement from all subsequent measurements. Unlike the optical reference described above, this reference is applied prior to the phase unwrapping algorithms. The baseline reference should be a single measurement, not an average.

To specify an Interferogram Reference, first measure the part in a reference state, and click **Analyze**. Drag the analyzed measurement from the *Measurement Stack* into the gray box in the

Interferogram Reference area. The thumbnail image will show the reference measurement, and the **Subtract Reference** box will be checked. This measurement will be subtracted from the current measurement.

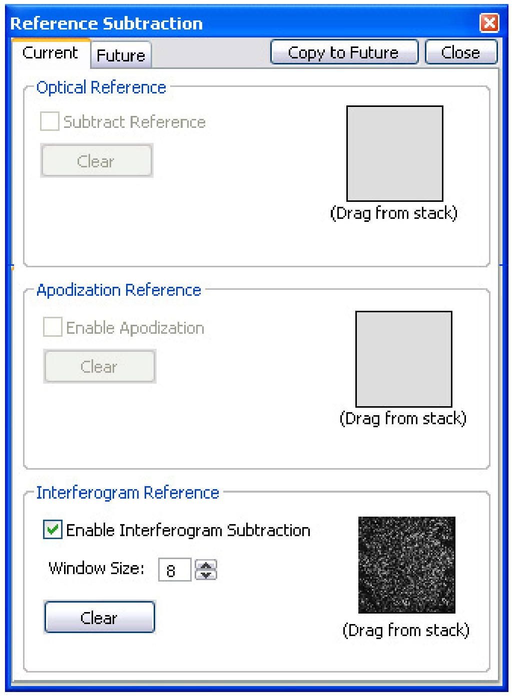


Figure 117: Reference Subtraction dialog box with Interferogram Reference.

Select a **Window Size** to smooth the inherent noise of speckle measurements. A window size of "8" means that an 8 x 8 pixel smoothing window is applied.

Click the **Copy to Future** button to use this reference with all subsequent measurements in the current 4Sight session. Choose **File > Save Config As Default** to use the reference in future 4Sight sessions as well.

Un-checking the **Subtract Reference** box will deactivate it but will retain the measurement in the configuration for later use. Click the **Clear** button to remove the reference measurement completely. Click **Copy To Future** to cease to subtract the reference from future measurements.

Note: While it is typically not suggested, 4Sight does allow you to subtract both an optical *and* Interferogram reference.

Chapter

10

Aberrations Removal

It is often necessary to remove alignment-induced aberrations from your measurement. 4Sight™ provides the ability to fit and remove 3rd order Seidel or Zernike Seidel aberrations from wavefront data.

Subtracting and Displaying Seidel Aberrations

4Sight performs wavefront fitting as follows:

1. Wavefront data is computed from the measured interference patterns.
2. The *Analysis Mask* is applied to the data.
3. 4Sight computes the *Unit Circle* that best fits the masked measurement.
4. 4Sight then computes the first eight Zernike terms over the masked measurement within the unit circle.
5. The aberrations selected in the **Remove Aberrations** dialog box (described below) are removed.

Click the **Seidels**  toolbar button or choose **Analysis** > **Aberration Removal** to open the **Aberration Removal** dialog box.

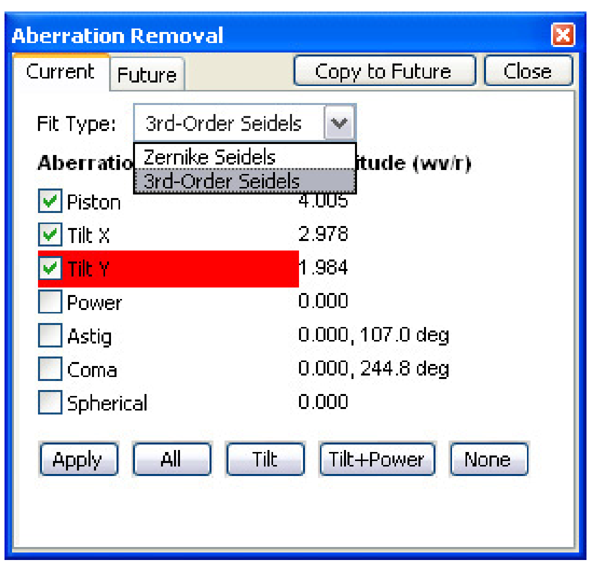


Figure 118: Aberration Removal dialog box.

4Sight can remove either of two types of Seidel aberrations: Zernike Seidels or 3rd-Order Seidels, both of which are defined shortly. Choose which Seidel aberrations to remove using the **Fit Type** drop list.

Select the aberrations that you wish to remove by checking or un-checking any combination of aberrations in the left hand column. You can also click the preset buttons (**All**, **Tilt**, **Tilt+Power**, or **None**) as shortcuts. The **Magnitude** in the right column displays the amount of each aberration present in the measurement.

The aberration's check box will turn red to indicate that you have made a change but have not yet applied your new options to the measurement. Press the **Apply** button to remove the selected aberrations from the measurement. Click **Copy to Future** to remove these aberrations from subsequent measurements during this 4Sight session. Choose **File > Save Config As Default** to remove the aberrations in future 4Sight sessions as well.

Note: As you remove aberrations the magnitudes shown in the right column will not change; these numbers always reflect the magnitudes *before* any aberration removal.

Definitions of Seidel Aberrations

4Sight defines the two types of Seidel aberrations as follows:

The **Zernike Seidels** are computed from the first nine Zernike terms as follows:

Term	Name	Value
Z0	Piston or Bias	constant
Z1	Tilt X	$\rho \cos\theta$
Z2	Tilt Y	$\rho \sin\theta$
Z3	Power	$2 \rho 2 - 1$
Z4	Astig X	$\rho 2 \cos 2\theta$
Z5	Astig Y	$\rho 2 \sin 2\theta$
Z6	Coma X	$(3 \rho 2 - 2) \rho \cos\theta$
Z7	Coma Y	$(3 \rho 2 - 2) \rho \sin\theta$
Z8	Primary Spherical	$6 \rho 4 - 6 \rho 2 + 1$

Keep in mind that the Zernike terms are orthogonal functions over the *Unit Circle*. Each Zernike term contains the amount of each of the lower terms needed to minimize the RMS variance of that term. Since the terms are orthogonal, we can subtract one or more terms from the fitted data without affecting the coefficients of the other terms.

The Zernike polynomials also have the property that the sum of the variance of each term will equal the total variance of the full polynomial fit. It is recommended that you use the Zernike Seidels to subtract alignment induced aberrations from your data (as is done in most other optical wavefront analysis programs).

Tip: You can also use the *Zernike Worksheet* to view and fit up to 120 Zernike terms.

The 3rd order Seidels are defined as follows:

Term	Name	Value
W_{00}	Piston or Bias	a_{00} = constant
W_{11x}	Tilt X	$a_{11}\rho \cos\theta$
W_{11y}	Tilt Y	$a_{11}\rho \sin\theta$
W_{20}	Power	$a_{20}\rho 2$
W_{22}	3rd Order Astigmatism	$a_{22}\rho 2 \cos 2\theta$
W_{31}	3rd Order Coma	$a_{31}\rho 3 \cos\theta$
W_{40}	3rd Order Spherical	$a_{40}\rho 4$

These coefficients are computed from the first nine Zernike terms as follows:

Tilt $$W_{11} = \sqrt{(Z_1 - 2Z_6)^2 + (Z_2 - 2Z_7)^2} \qquad \theta = \tan^{-1}\frac{(Z_2 - 2Z_7)}{(Z_1 - 2Z_6)}$$

Power $$W_{20} = 2Z_3 - 6Z_8 \pm \sqrt{Z_4^2 + Z_5^2}$$

Where the sign of the radical is selected to minimize the magnitude.

Astigmatism $$W_{22} = \pm 2\sqrt{Z_4^2 + Z_5^2} \qquad \theta = 0.5\tan^{-1}\left(\frac{Z_5}{Z_4}\right)$$

Where the sign of the radical is selected as the opposite of the power calculation.

Coma $$W_{31} = 3\sqrt{Z_6^2 + Z_7^2} \qquad \theta = \tan\left(\frac{Z_7}{Z_6}\right)$$

Spherical $$W_{40} = 6Z_8$$

Unlike the Zernike terms, the 3rd order Seidels are not orthogonal functions. Removing each aberration will not minimize the variance of the wavefront.

One useful application for using the 3rd order Seidels might be for looking at pure cylinder on a surface. Using the 3rd order Seidel option, it is possible to "sweep up" and remove all of the power terms—leaving only the astigmatic terms. In general, the 3rd order Seidel terms should *not* be used to remove alignment induced aberrations.

Tip: In the *Zernike Table* you can view the 3rd Order Seidel terms based on the conventions used in 4Sight, MetroPro and Vision32 software.

Chapter

11

Data Modification

4Sight™ enables the following image processing operations:

- **Arithmetic** (Add, Subtract, Average, Combine, Scale Z)
- **Geometric Transform**: (Flip, Rotate, General Transformation)
- **Filter** (Fourier, Smoothing, Median, Sigma)
- **Islands** (Separate, Re-Combine, Level, Mask Small Islands)
- **Resize**
- **Integrate Phase**.

All of these data modification operations produce a new measurement and add it to the *Measurement Stack* while keeping your original measurement unchanged.

When you modify data, only the analyzed surface is modified and promoted to the Measurement Stack. Since the underlying interferograms, modulation, etc., are not included with the modified and promoted data, you cannot *Reanalyze* the modified surface.

Arithmetic

The **Add** and **Subtract** functions allow you to combine two measurements (we'll call them measurements A and B). To use Add or Subtract:

1. Select the first measurement from the Measurement Stack.
2. While viewing measurement A, select **Modify** > **Arithmetic** > **Add** (or **Subtract**). The Data Selection dialog box prompts you to select measurement B.

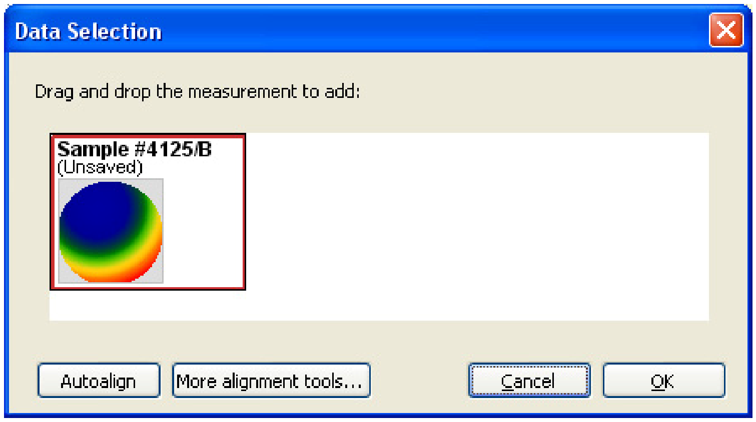


Figure 119:Data Selection dialog box.

3. Click and drag the second measurement from the Measurement Stack to the dialog box, then click **OK**. The sum (or difference) will be displayed and added to the Measurement Stack.

The **Average** function is similar to Add and Subtract, but where those functions act on two measurements only, any number of measurements can be averaged. To use Averaging, select the first measurement from the Stack, then choose **Modify** > **Arithmetic** > **Average**. Click and drag all of the other measurements from the Measurement Stack to the Data Selection dialog box. Press **OK** to display the average and promote the averaged measurement to the Measurement Stack.

The **Combine** function is similar to Average except for the way in which it operates on invalid pixels. Averaging produces an invalid pixel if *any* of the input pixels are invalid. Combining produces an invalid pixel only when *all* of the input pixels are invalid, but produces an average of the valid pixels otherwise. Averaging preserves only the most reliable data, while Combine preserves more data.

The **Scale Z** function increases the vertical scale of all pixels on the surface. Choose **Modify** > **Arithmetic** > **Z Scale**, then enter a scaling factor (1.00, or 100%, is the default). The scaled dataset will be added to the Stack.

The **AutoAlign** function translates and scales the dragged measurement such that its pupil center and diameter will match those of the other measurement. You can also click **More Alignment Tools** to open the *General Transformation* dialog box, which provides more options for transformation.

Note: Measurements must be the same size in order for them to be added, subtracted, etc. 4Sight will report an error when the array sizes do not match.

Geometric

The Geometric Transform functions operate on single datasets and are divided into two menu groupings: Array Operations and General Transformation.

Array Operations

The Array Operations allow you to perform specific transformations of a dataset. Choose **Modify** > **Geometric Transform** > **Array Operations**, then select one of the following:

Flip Mirrors the data about the X, Y or Z axis.

Rotate Rotates the data in increments of 180 degrees, 90 degrees clockwise (CW) or 90 degrees counterclockwise (CCW).

The Array Operations preserve the data completely; no interpolation is used to generate the resultant database.

General Transformation

The General Transformation gives you more options for transformations; however, it typically requires some interpolation of the data. To use the Geometric Transform operations, select the dataset to transform from the *Measurement Stack*, Then select **Modify > Geometric Transform > General Transformation**.

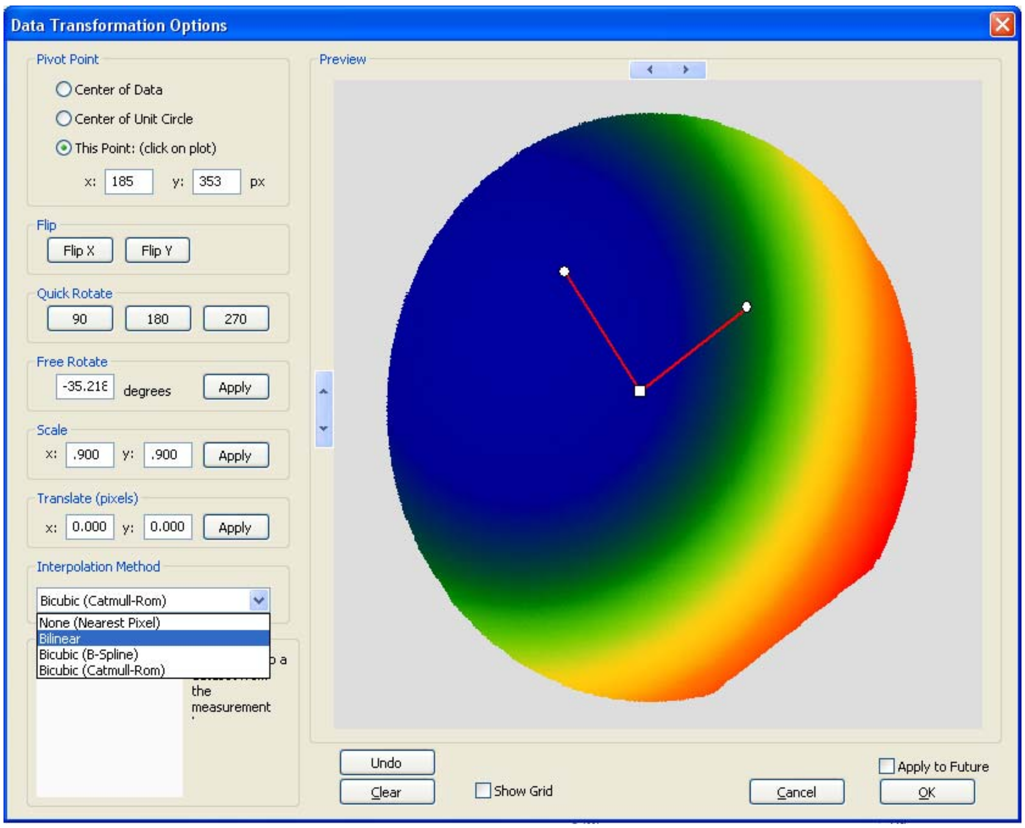


Figure 120: Data Transformation Options dialog box.

The Data Transformation Options dialog box lets you specify precise, arbitrary transformations. For example, you can rotate 30 degrees about the center of the data, flip about the x axis, and translate the result 10 pixels to the right. The large plot shows a preview of the currently selected transformations. You can make the following transformations to a dataset:

Pivot Point Sets the point about which the dataset will rotate. Choose **Center of Data**, **Center of Unit Circle**, or click on the plot to choose a specific point (you can also enter the XY position of the point to use).

Flip Flips the dataset across the X and/or Y axes.

Quick Rotate Rotates the dataset by 90 degree increments.

Free Rotate Rotates by the selected increment. Click **Apply** to preview. You can also click and drag the handles on the plot's crosshair cursor to rotate.

Scale Scales the data in the X and/or Y dimensions (enter scaling factors in X and Y). Click **Apply** to preview.

Translate Translates the data in X and/or Y by the given number of pixels. Click **Apply** to preview.

Autoalign Sets the center and pupil diameter of the dataset equal to that of a Target dataset. Drag the target from the Measurement Stack to the Autoalign box.

Tip: Autoalign is also part of the **Modify** > **Arithmetic** > **Add/Subtract** functions.

The Data Transformation Options can be applied iteratively, so you can gradually transform and preview the data until a desired result is achieved. For example, you could enter "1 degree" in the **Free Rotate** box, and repeatedly hit the Free Rotate Apply button to gradually rotate the data.

At any time you can click **Undo** to remove the last applied transformation, or click **Cancel** to undo all transformations.

When you are satisfied with the preview, click **OK**. This creates a new dataset and adds it to the Measurement Stack. Click **Apply to Future** to use the transformations for all subsequent measurements during the current 4Sight session. Choose **File > Save Config As Default** to use these options for future 4Sight sessions as well.

General transformations mathematically alter the data array—the values that were recorded at each pixel location will now typically fall somewhere between "pixels" in the transformed array. 4Sight therefore must interpolate the data to produce a data array with the same number and location of data points as the original array.

Four types of interpolation are available under **Interpolation Method**: None (Nearest Pixel), Bilinear, Bicubic (B-Spline), and Bicubic (Catmull-Rom). For many datasets, the Catmull-Rom algorithm produces the most accurate results. However, if there are steps in the data, the Bilinear or B-Spline algorithms may be better choices as the introduce less "ringing" at sharp edges.

Note: While the General Transformation capability is quite powerful, there are many applications for which it may be more appropriate to use *Fiducials* for alignment.

Filters

4Sight supports four standard filters. To use the filters, select **Modify** > **Filter** then choose the desired filter type.

Fourier Blocks spatial frequencies below (High Pass), above (Low Pass) or between the selected cutoff frequencies.

First, choose the type of filter from the **Pass Region** list, then select the appropriate cutoff frequency (or frequencies). The units will be given in waves/pixel unless you have specifically set the lateral dimensions under **Edit** > **Units**.

Next, from the **Rolloff** list select whether to use a **Rectangular** or **Butterworth** window with the filter. The difference in filter types affects the transition near the cutoff frequency. The rectangular filter simply passes or blocks frequencies up to the cutoff, which may produce "ringing" when the data is transformed back to the spatial domain. The Butterworth filter applies a more gradual transition near the cutoff frequency to reduce ringing.

For the Butterworth filter you must also enter an **Order**, which determines the steepness of the filter roll-off near the transition frequency. The higher the order, the more closely the filter approximates the Rectangular filter.

Check the **Re-Mask Output** box to apply any masks from the unfiltered measurement to the new, filtered measurement. Typically this option is suggested; however, some high-frequency information near the mask boundary may be masked, which may affect certain diffraction analyses.

Check the **Put Transfer Function on Stack** to also promote a *Contour Plot* of the window (rectangular or Butterworth) applied in the frequency domain. This box will always be unchecked when you open the dialog box. *Figure 121* shows the Transfer Function added to the stack. In the left image a Band-pass filter with a Rectangular window was applied. In the right image a 3rd order Butterworth window was used instead.

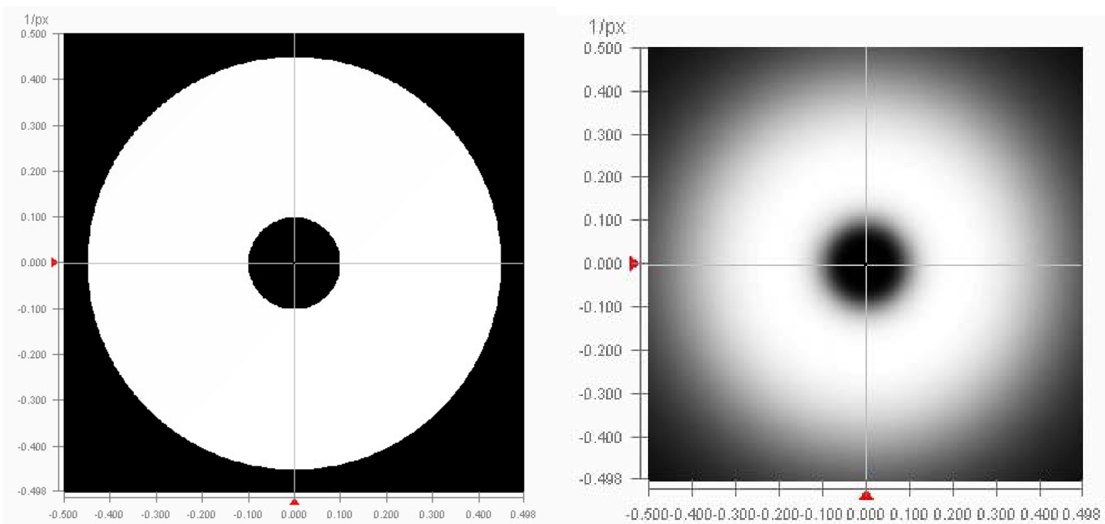


Figure 121: Transfer Functions added to stack.

Smoothing Averages pixels within a user-defined window to remove high-frequency noise. Specify the size of the smoothing window.

Median Applies the median value of pixels within a user-defined window to remove high-frequency noise. Specify the size of the smoothing window.

Sigma Smoothes noisy or “spiky” data. The filter sorts the pixels within a window of specified size. It then calculates the mean value of pixels within the window, discarding those that fall beyond the specified **Sigma Width** (i.e., number of standard deviations) from the mean. This mean value is then assigned to the center pixel in the window. Specify the **Window Size** (in pixels) and **Sigma Width.**

Each filter promotes a new, filtered measurement to the Measurement Stack.

Note: The function of these filters is identical to those selected on the **Analysis Options** > **Filters** tab. Those filters, however, are applied automatically to all subsequent measurements, whereas filters here are applied only to the active measurement.

Islands

Some measurements contain "islands" of valid, contiguous pixels separated by invalid pixels. The invalid pixels may have been masked or rejected because of insufficient modulation or intensity.

The **Modify** > **Islands** > **Separate Islands** function breaks one dataset into a *Grouped Measurement* in which each dataset contains one island. You can then play through the islands like the frames of a movie, viewing the statistics for each. Right click on any of the datasets and choose **Promote this Dataset** to promote that single island. To recombine a group of single-island datasets into a single composite dataset, select **Modify** > **Islands** > **Recombine Islands**.

Tip: This section shows you how to *modify* the data based on its islands. You might also wish to *analyze* islands by using *Island Analysis* or *Prism and Corner Cube Analysis*.

Resize

The Resize function lets you shrink or increase the number of pixels in the dataset while maintaining the correct aspect ratio. Where the *Data Modification* and *Fiducials* functions transform the data without changing the array size, Resize actually changes the number of pixels in the dataset.

To resize a dataset, select **Modify** > **Resize**. Enter a new **X Size**, **Y Size**, or **Scale By** factor—the other two boxes will update automatically. When you are finished, click **OK** to promote the resized dataset to the Measurement Stack.

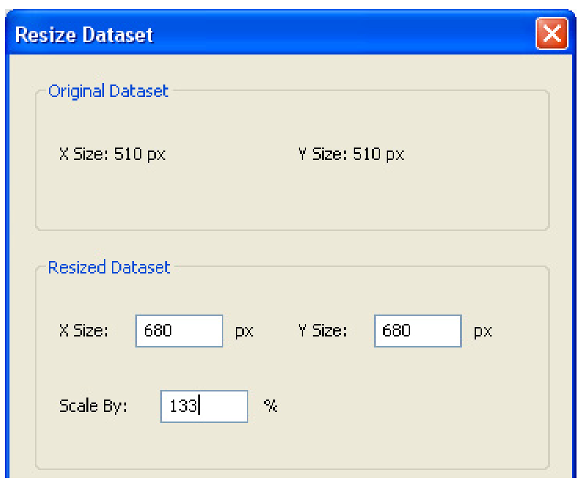


Figure 122: Resize Dataset dialog box.

Integrate Phase

A key step of an interferometric measurement is the phase integration (or unwrapping) of the data. This step converts wrapped phase data by resolving two-pi height differences between adjacent pixels. Normally this step is performed automatically when you take a measurement.

Occasionally, however, you might have a dataset of wrapped phase data that you would like to unwrap. Or, you might have an unwrapped dataset that you have masked or otherwise modified and would like to re-integrate. To do so, first select the integration method under **Measure** > **Measurement Options** > **Phase Integration**. Then choose **Modify** > **Integrate Phase** to apply the specified method. The new dataset will be promoted to the Measurement Stack.

Chapter 12

Fiducials

Consider the following two examples. In the first, a mirror is being iteratively polished and measured. We would like to compare measurements between each series of steps, to see the effect of processing, and to guide subsequent polishing. To do so, we could attempt to place the mirror in an identical position for each measurement, but this is sometimes impractical and is always laborious.

In a second example the measurement of an optic must be transformed into a user-defined “real” coordinate system, such as the global coordinate system of a complex optical setup.

In both cases, 4Sight lets you manually place fiducial marks on the measurement data to map the measurement to another coordinate system or another measurement. In the first example, we transform an **Image** into a **Target measurement**. In the second example, we transform an **Image measurement** into a **Target coordinate system**. The **Fiducial Worksheet** supports each of these operations.

Fiducial Worksheet

4Sight provides a worksheet page for working with fiducial transformations. To open the Fiducial Worksheet, click the **Fiducial** toolbar button or choose **Modify** > **Fiducial Transform**. The Fiducial Worksheet (*Figure 123*) will open. It consists of several sections:

Image Plot	Displays the measurement to be transformed.
Target Plot	Displays the coordinate system into which the Object will be transformed. The Target may be a measurement (first example) or a user-defined “real” coordinate system (second example).
Transformed Image Plot	Displays the Image transformed into the Target.
Fiducials Table	Displays the locations of the Image, Target and Transformed fiducials. It also displays the mismatch error between the Transformed Object fiducial and the corresponding Target fiducial. Right click in the table and select **Column Chooser** to toggle the table columns on or off.
Transformation Options Area	Lets you choose which transformations to apply, and how to interpolate the data between Image and Target.
Calculated Transform Table	Shows how much of each transformation will be required to match Image to Target.

Error Analysis Table	Shows the max, mean, and RMS error remaining between Image and Target fiducials after the transformation. This is also shown graphically on the **Error Graph**.

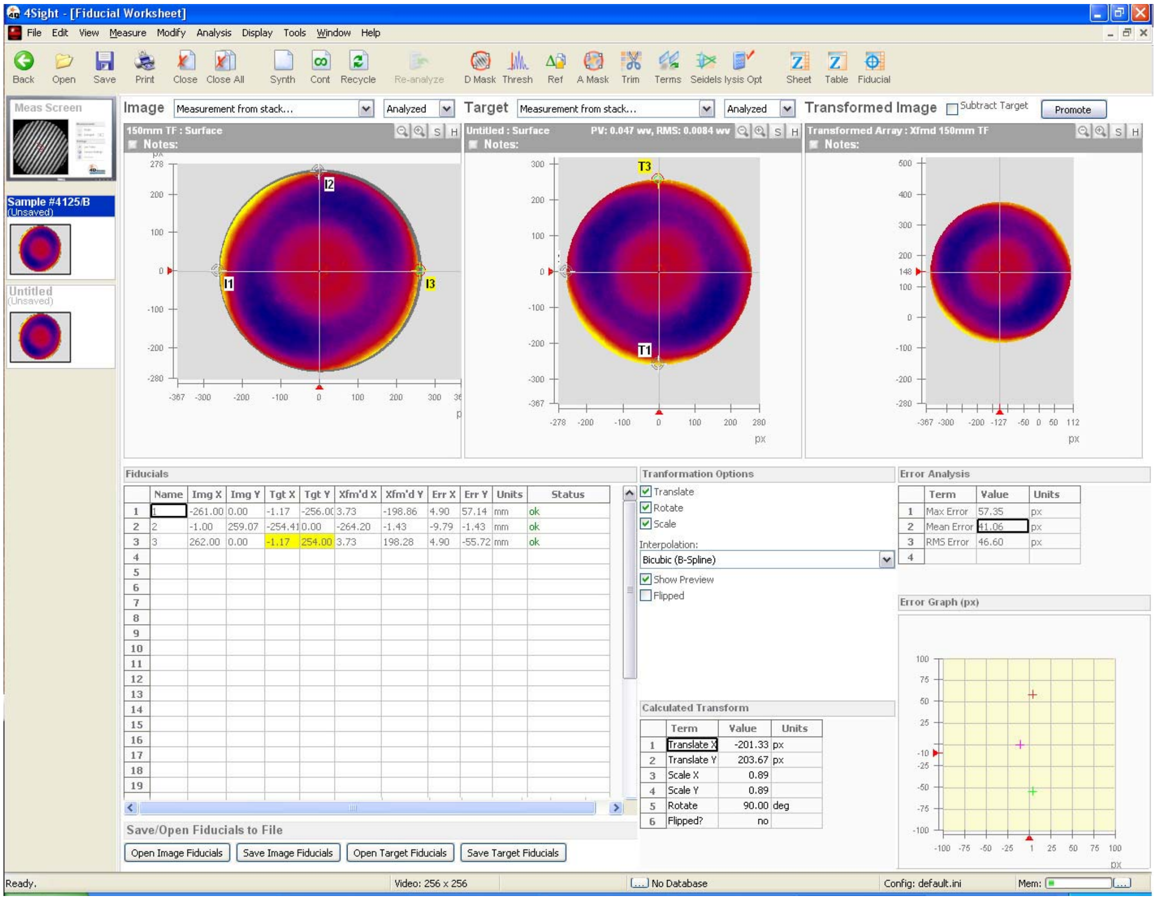


Figure 123: Fiducials Worksheet.

Transforming an Image to a Target measurement

Selecting the Image and Target

To begin working with fiducials, select the Image measurement in the *Measurement Stack* then choose **Modify** > **Fiducial Transform**. This will open the Fiducials Worksheet. You can also drag and drop a measurement from the Stack into the Image plot area, or select **Measurement From Stack** from the box above the plot to choose from available measurements.

Once you have selected the Image measurement, select the dataset (Analyzed, Raw, Modulation, etc) to view in the box to the upper right of the plot. This view is for visual convenience, so select the dataset that makes it easiest to place the fiducials; for example, it is often easier to place fiducials on the interference data if it is available.

Select a Target Measurement from the list above the Target Plot. You can select a Target measurement in any of three ways:

Measurement from Stack	Select any measurement from the Measurement Stack.

Saved Measurement Select a measurement saved to a file.

Current Reference Select the current *Optical Reference* measurement as the Target.

Define Coordinate System Define the minimum and maximum values of a Target coordinate system rather than a target measurement. Enter either the width and height of the array, or enter the four corners that define the **Extent** of the array.

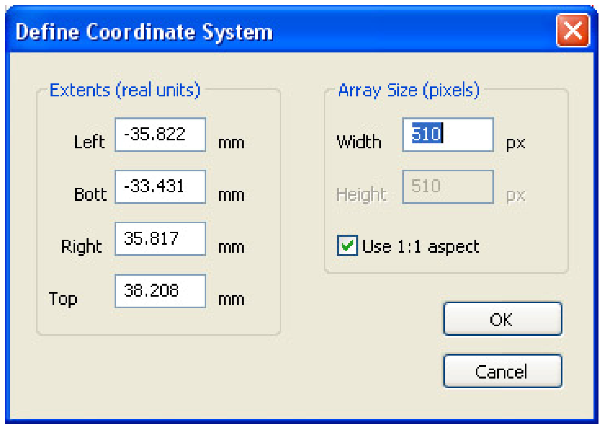


Figure 124: Define Coordinate System dialog box.

Note: It is important that the lateral units of the Image and Target measurements match. See *Setting Lateral Scaling* for details.

Placing Fiducials

Click and drag within the image plot to create and position the first Image fiducial. It will be labeled "I1" and its coordinates will appear in yellow in the Fiducials table below. Click again in the Image plot to create each additional fiducial (up to 32 if necessary). Place fiducials on the Target measurement in the same way.

Tip: You can enter X and Y coordinates for each new fiducial in the Fiducials table. When working with large numbers of fiducials you may also copy them from a spreadsheet program and paste them into the table.

Note: The Fiducials table shows the **Status** for each fiducial. If it is defined for both the Image and Target then the status will be **OK**. If it is defined for only one of the measurements then the status will appear in red and will tell you in which measurement it still needs to be defined.

You have several options for finely positioning each fiducial:

1. Right click on a fiducial and choose **Zoom to Shape** to magnify the area around the fiducial. Use the **Zoom In 2X** and **Zoom Out 2X** options to provide the best view. You can then click and drag the fiducial to its exact location. Right click and choose **Zoom All** to view the entire plot again.

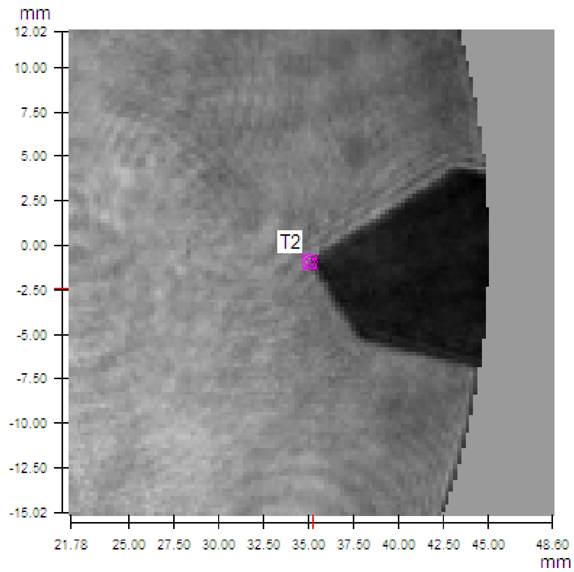


Figure 125: Zooming on a region to place a fiducial.

2. In the Fiducials table enter the exact X and Y coordinates for each fiducial. Similarly you can right click a fiducial and choose **Edit Shape** to enter its location.

3. 4Sight includes two options for automatically "snapping" fiducials to automatically align them to specific features. The snap options are set under **Tools** > **Preferences** > **Snap** (*Figure 126*). Check the **Snap to Islands** box to snap fiducials to the centroid of the closest island of data. Choose **Snap to Corners** to snap fiducials to the nearest vertex of a data island (for example, the intersection of two spokes from a mounting structure). Use the **Corner** slider to set the sensitivity of the snap feature: set it higher when corners are closer together over smoother edges, and set it lower for rougher edges. To snap a fiducial to a corner or island, right click on the fiducial and choose **Snap Fiducial**.

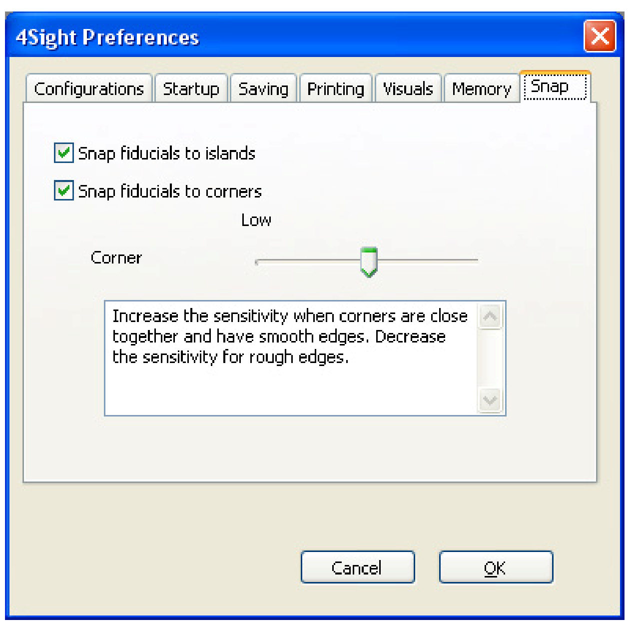


Figure 126: Snap fiducials preferences.

To delete a fiducial, right click on it and choose **Delete Shape**. Right click on a fiducial and choose **Delete All Fiducials** to clear them from the Image or Target. You can also delete them from the Fiducials table by right-clicking on a row number and choosing **Delete**.

Tip: You can create fiducials on any contour plot in 4Sight by right-clicking and selecting **Fiducial Mode**. Fiducials created in this manner will stay with a measurement for the duration of the 4Sight session. If you later open that measurement in the Fiducials Worksheet its fiducials will be displayed as well.

Selecting the Transformations

Depending upon your system, 4Sight includes either one or two methods for transforming data. The **Rigid Body** method, available on all systems, allows basic translation, rotation and scaling in X and/or Y.

In the center of the screen, click the Rigid Body button. You can then choose from three standard rigid-body transformations that 4Sight can apply to attempt to align the fiducials: **Translate, Rotate** and **Scale.** If the Image measurement is of the front side of an optical component and the Target measurement is of the back side, check the **Flipped** box to instruct 4Sight to flip the Image measurement before attempting to align it to the Target using the fiducials. Choose from one of the **Interpolation** options to describe how 4Sight should generate the transformed measurement. For many measurements, the Catmull-Rom algorithm produces the most accurate results. However, if there are steps in the data, the Bilinear or B-Spline algorithms may be better choices.

Check the **Show Preview** box to update the Transformed Image plot as you choose the various options.

4Sight calculates two-dimensional, rigid-body transformations. It does *not* perform non-linear transformation (morphing) to keep each fiducial perfectly aligned with the target. Instead, it calculates and applies the rigid-body translation, scaling, and rotation which yields the minimum RMS mismatch error between Image and Target fiducials.

Rotation is applied about the z-axis only—not about x or y. This means that only two fiducials are sufficient to fully specify the transformation. The rules for allowed transformations are as follows:

1. If one fiducial is specified, only translation can be calculated; scaling is unity and rotation is zero. The transformed Image fiducial will match the Target exactly, thus the mismatch error will be zero.
2. If two fiducials are specified, translation, rotation, and scaling are calculated. The transformed Image fiducials will match the Target exactly, and the mismatch error will be 0. .
3. If three or more fiducials are specified, the system is over-constrained and mismatch errors will occur. Small mismatch errors are not necessarily undesirable: in fact, it is generally more accurate to use several well-placed fiducials rather than just one or two.

Calculating Error and Residual

When you've finished defining all fiducials you can click the **Promote** box to add the Transformed Image to the Measurement Stack. Or, check the **Subtract Target** box to display the residual difference between the Transformed Image and the Target. This data can be promoted as well.

The Error Analysis table will show the Max, Mean and RMS error between all pairs of Image and Target fiducials. The Error Graph shows the magnitude of the error in location between each pair of fiducials. The X, Y, and overall magnitude of error for each fiducial will appear in the Fiducials table.

Transforming a Measurement into a Coordinate System

In addition to comparing measurements you can also map a measurement to a target coordinate system. To do so, first select the Image measurement, then choose the dataset to view, as described above.

Next, in the box above the Target plot, select **Define coordinate system.** Enter the minimum and maximum values for the desired coordinate system. Enter the desired array size in pixels of the Target—the Transformed Image will be this size after the transformation is applied. The Target area will show a blue box rather than a target measurement.

Place fiducials on the Image measurement and on the Target coordinate system, using the methods described above. When you've finished defining all fiducials, you can view the error analysis, **Promote** the transformed measurement or the residual error, etc, as described above.

Saving Fiducials

Fiducials are not saved as part of a measurement configuration; instead, they can be saved as individual files for use with multiple measurements. To save the fiducials from the worksheet to a file, click the **Save Image Fiducials** or **Save Target Fiducials** button at the bottom of the screen. Choose a file name and location, then click **OK**. The fiducials will be saved to a file with a .fid extension.

To use previously-saved fiducials, choose **Open Image Fiducials** or **Open Target Fiducials** then select a file. The fiducials will appear on the worksheet for either the Image or Target plot, and the statistics will be calculated accordingly.

Chapter

13

Managing Configurations

A “configuration” is a set of options used to generate measurements or control interferometer functions. All 4Sight configurations are saved as files ending with “.ini”. The various types of configuration files are described below.

User Configurations

A “user configuration” contains the set of options, including *Measurement Options*, *Analysis Options*, etc., used to measure a particular type of sample or in a particular set of conditions. You can store multiple user configuration files then recall them later to use while measuring similar parts.

For each measurement the **User Config** Measurement Parameter displays the configuration that was used to create it.

Opening a Configuration

To open a configuration file choose **File** > **Open Config**, then select the file. The file’s name will appear in the *Status Bar*, indicating that the configuration is being used to create new measurements.

Startup Configuration

“default.ini” is the default configuration that 4Sight uses for creating new measurements. It is typically stored in the **C:\4D\Config** directory.

To set the configuration that is loaded when 4Sight launches choose **Tools** > **Preferences** > **Configurations** (*Figure 127*). Choose **Load default configuration** to use default.ini at startup, or choose **Load last configuration** to use the last-used configuration instead.

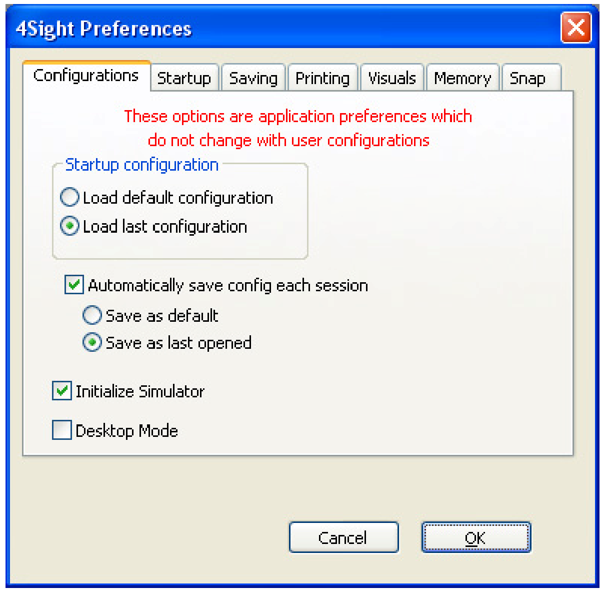


Figure 127: Preferences for selecting the configuration to load at startup.

Saving Configurations

To save the current settings as a unique configuration, choose **File** > **Save Config As** and enter an appropriate filename. Or, choose **File** > **Save Config as Default** to save the current settings to default.ini.

Tip: Use an easily-recognized naming convention to make it easy to locate the files later.

4Sight can automatically save settings when you exit the software so that you will never lose your most recent setup. Under **Tools** > **Preferences** > **Configurations** check the **Automatically save config each session** box. Choose **Save as Default** to automatically save the latest settings to default.ini at the end of a session. Or, choose **Save as last opened** to save the latest settings as part of the last-used configuration file.

Configuration File Password Protection

User configuration files can be password protected to ensure that the settings aren't inadvertently changed. To protect a configuration:

1. Choose **File** > **Password Protect Config File**.
2. Select the configuration file to protect and click **OK**. The **New Configuration Password** dialog will open (*Figure 128*):

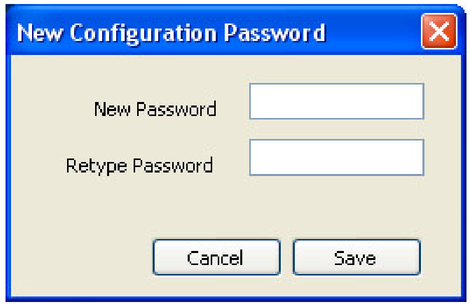


Figure 128: New Configuration Password dialog box.

3. Enter and confirm the password for this configuration file.
4. Click **Save**.

This configuration can now only be altered if the password is provided. If any changes are made that affect the configuration you will be prompted for the password when you exit 4Sight (*Figure 129*):

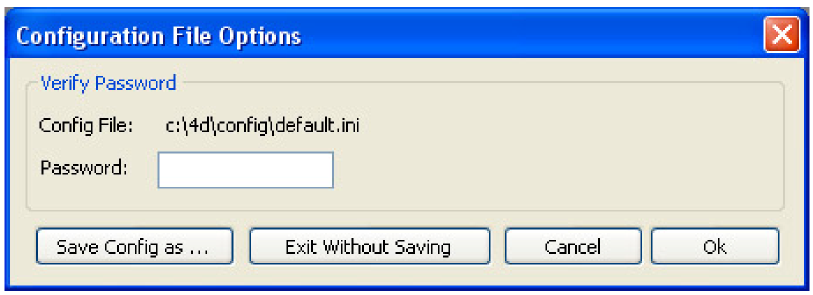


Figure 129: Configuration File Options dialog box.

When this dialog box appears you can make one of four choices:

1. Enter the **Password** and click **OK** to save changes to the configuration and exit 4Sight.
2. Choose **Save Config As**…to save the configuration under a different file name. The original, password-protected configuration will not be altered.
3. Choose **Exit Without Saving** to exit 4Sight but leave the configuration file unaltered.
4. Click **Cancel** to return to 4Sight.

To remove the password from a configuration:

1. Choose **File > Remove Configuration Password**.
2. Select the configuration file.
3. Enter the **Password** for that configuration file and click **OK**.

This configuration file can now be changed without providing a password.

Hardware Configuration

The hardware configuration file describes the hardware installed on a particular system. For example, it might contain information about a frame grabber or camera. The hardware configuration is set up at the factory and should not be changed.

If you use your computer with more than one interferometer, you will have a hardware configuration for each interferometer. You can tell 4Sight which hardware configuration to use by selecting **File > Select Hardware Config**. The hardware configuration name typically corresponds to the serial number of the interferometer.

Configuration Archiving

During installation of 4Sight versions 1.8 and higher, the contents of the C:\4D\config and C:\4D\system folders will be archived to a .zip file located in C:\4D\archive. The zip file will include the current date and time in its title (e.g., 24Mar2008_12_50_13_archive.zip). The configurations in these folders may be modified when you run the newer version of 4Sight; the archiving process safeguards the existing files, allowing you to restore them later if necessary.

To revert to the settings after an installation, go to 4D\BackupUtils to access the restoration utility, retrieve_archive.exe. Choose the archived version you want to restore—the contents of the config and system folders will be replaced with the archived files. Note that any user settings changed since the files were archived will be lost.

Both the archive (create_archive.exe) and restoration utilities can be found in 4D\BackupUtils.

Chapter

14

Saving, Printing, Exporting Data

4Sight™ allows you to work with measurements in several data formats. This section describes saving, opening, manipulating and printing using these various file formats.

File Formats

You can save and open measurements in several widely-used data formats:

HDF5 — 4Sight's native file format is HDF5, short for *Hierarchical Data Format, Version 5*. If you save a measurement in HDF5 format you will be able to change the settings later to re-analyze the measurement. For example, you can change the *Trimming* options or the masks after you've opened a saved measurement file. HDF5 was developed by the National Center for Supercomputing Applications (NCSA), which provides continued development and a suite of utilities to manage HDF5 files. Since HDF5 is a public format, you can write your own code to open and analyze 4Sight measurements. For more information about HDF5, see the NCSA web site at **http://hdf.ncsa.uiuc.edu/HDF5**.

4Sight's HDF5 schema are described in Appendix *A3*.

HDF4 — 4Sight can save data to HDF4, the previous version of NCSA's HDF file format. HDF4 files are similar in structure to HDF5 files, yet differences in their organization generally make them binary-incompatible.

Veeco/Wyko OPD — 4Sight can both read and write Veeco Vision® OPD files. Masks and fiducials are not preserved in this format. These files carry a .OPD extension.

Opticode — 4Sight can read PhaseShift Opticode™ MAP files. Currently fiducials are not imported. These files carry a .MAP extension.

MetroPro — 4Sight can open and save .dat files used in conjunction with Zygo MetroPro software.

CODE V Grid — This file format is used for export to Code V optical design software and carries a .int extension.

Comma-separated text	This standard file format includes all data points in the measurement separated by commas. You can save these files with .csv or .txt extensions—the formats are identical.
ESD HDFR	This format is used for export to IntelliWave software and carries a .HDF extension.

HDF Explorer

The **HDF Explorer** (*Figure 130*), from Space Research Software, is a program that lets you visualize Hierarchical Data Format files such as HDF4 and HDF5. An installer for HDF Explorer (HDFExplorerSetup.exe) can be found in C:\Program Files\4Sight[version]\util. The program includes extensive on-line Help, as well as a link to additional web resources, in the program's Help menu.

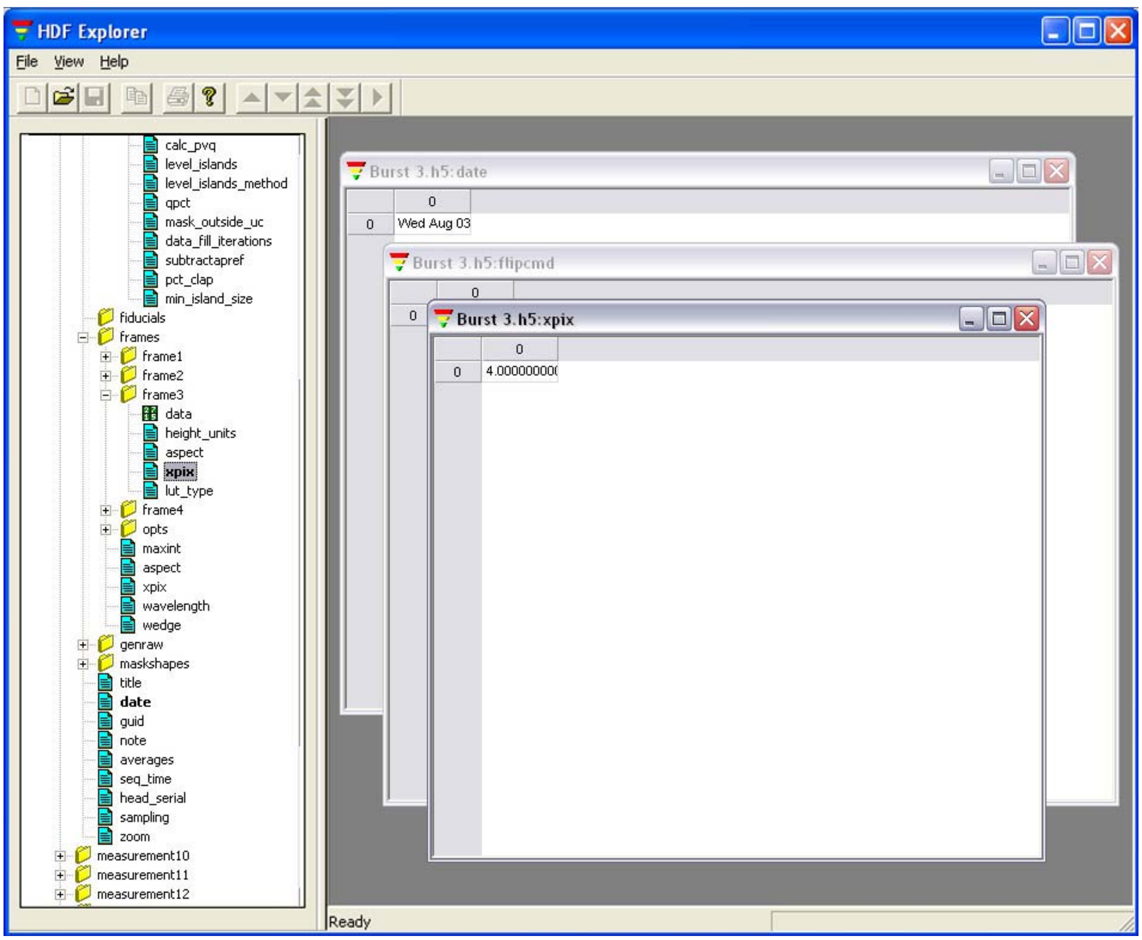


Figure 130: HDF Explorer lets you view HDF formatted data files.

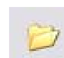
Saving and Opening Data

Usually you will save your measurements in the HDF5 (".h5") format, by clicking the **Save** toolbar button  or choosing **File** > **Save** or **File** > **Save As**. Otherwise, choose a different format from the **Save As Type** list.

In HDF5 format 4Sight saves all the data and settings it needs so it can recreate the measurement from the file later: the interferograms, basic measurement statistics, analysis options, references, masks, etc.

If the measurement includes interferograms, 4Sight does *not* save the analyzed surface, because the surface can be recreated from the interferograms. When you open a file containing interferograms 4Sight recreates the surface by performing the phase calculations, applying the saved analysis options, and applying the saved masks.

If interferograms are not available, (i.e., if the dataset was promoted), 4Sight saves the surface data instead of interferograms. Saving a promoted dataset rather than a measurement reduces the file size but limits your ability to change analysis options and re-analyze the measurement later.

To open a saved measurement, click the **Open** toolbar button  or choose **File** > **Open**. Select the type of file, and the particular file to open.

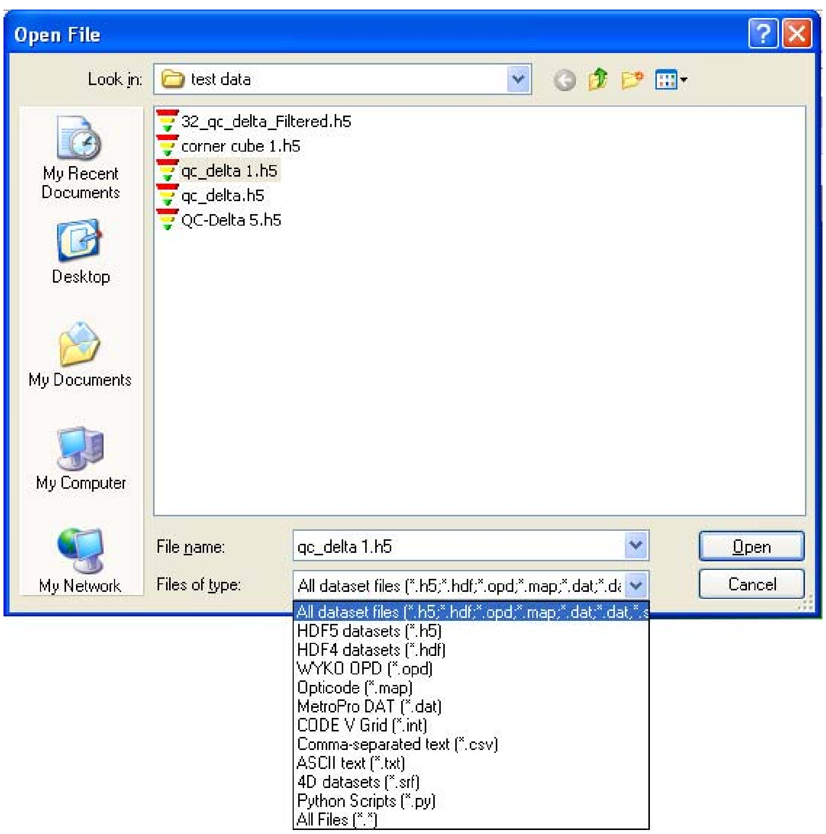


Figure 131: Open File dialog box.

If the file contains interferograms, 4Sight opens the interferograms, applies the analysis options saved in the file, and displays the resulting analyzed surface. If the file does not contain interferograms, 4Sight will display the saved, analyzed surface.

When saving as CSV or ASCII formats the file will include the following header information as well as the array of pixel data:

xsize:	Number of pixels in the data array, in the x axis
ysize:	Number of pixels in the data array, in the x axis
type:	Always “phase”
badpixel:	Designator for bad pixels in the array
date:	Date
title:	Dataset title
wavelength:	Instrument wavelength
wedge:	Wedge
xpix:	Center-to-center pixel pitch, in the x axis
aspect:	Pixel aspect ratio
delimiter:	File suffix

For the file formats of other compatible software please see that software’s documentation.

Saving and Opening Grouped Measurements

Saving a *Grouped Measurement* is identical to saving a single measurement. When you choose **File** > **Save** or **File** > **Save As** a single file will be created containing all of the measurements in the group. You can also save a grouped measurement in a standard Windows .avi video file format for playback as a movie in other programs by choosing **File > Save Movie**.

Open a grouped measurement just as you would a single measurement, by selecting **File** > **Open**. You can also open files as a group that were saved individually by choosing **File** > **Open Files As Group**. The individual files must all be in the same folder to use this option. Hold down the **Ctrl** or **Shift** key while clicking each file to add to the group.

Creating and Saving Movie Files

Movies can be generated from any collection of saved *Single Measurements* and/or *Grouped Measurements*. To generate a movie:

1. Acquire all data and save the files to disk.
2. Choose **File** > **Make movie from file**.
3. Select the measurement files to add to the movie. Hold down the **Shift** key while clicking to select a range of files, or hold down the **Ctrl** while clicking to select more than one nonconsecutive file.

4. Click **Open**. The **Manage File Order** dialog will open. Here you can switch the order of the files, remove files or add additional files.

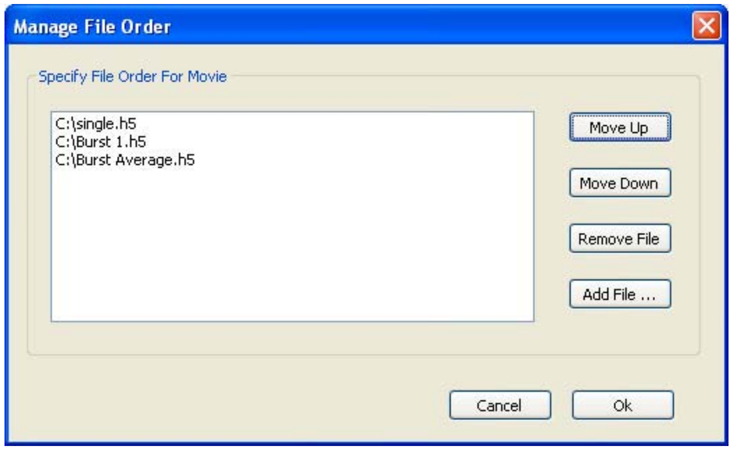


Figure 132: Manage File Order dialog box.

5. Click **OK**. 4Sight will display the first measurement of the first file and will show the following message:

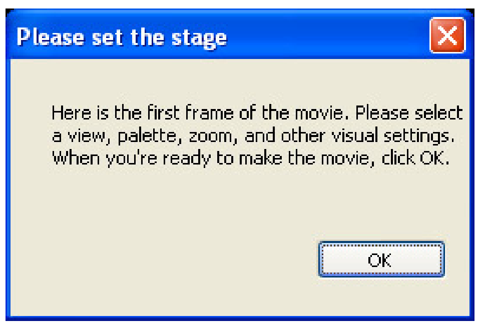


Figure 133: Setting the view parameters for the movie.

6. Choose the view, palette, magnification and other settings as you would like the movie to appear.

7. Click. **OK**. 4Sight will apply the view settings to each frame in the movie. This process may take a few moments for larger movies.

8. Select the name and location for the .avi file.

9. Click **OK**. 4Sight will generate a movie of all of the frames. If you included a *Grouped Measurement* in the movie, all frames of that group will be included, in order.

Importing Zernikes from ZEMAX

Zernike Polynomials data can be imported from optical design programs such as ZEMAX, as follows:

1. Create a Zernike surface in ZEMAX.

2. In ZEMAX choose **Wavefront Map**. A **Wavefront Map** window will open.

3. In the Wavefront Map window click the **Text** menu item. A text version of the data will open.
4. In the Text window choose **Window** > **Save Text**. Save the file with a .txt extension.
5. Open the text file in a text editor, and replace all of the header information above the data array with the following 4Sight header information. You can get an example of this header information by saving a 4D file as text from within 4Sight. The text in brackets indicates the expected values.

xsize:	Number of pixels in the data array, in the x axis
ysize:	Number of pixels in the data array, in the x axis
type:	Always "phase"
badpixel:	Designator for bad pixels in the array
date:	Date
title:	Dataset title
wavelength:	Instrument wavelength
wedge:	Wedge value
xpix:	Center-to-center pixel pitch, in the x axis
aspect:	Pixel aspect ratio
delimiter:	File suffix

6. Save the text file.
7. In 4Sight choose **File** > **Open**.
8. Under **File Type** choose **.txt**.
9. Locate the file and click **Open**.

Closing Files

As you add more measurements to the *Measurement Stack*, or as you open more analysis windows, the computer system consumes more of its resources, including memory. When you are finished with a measurement or a window, it's a good idea to close it.

To close measurements or windows, select **File** > **Close**, then select whether to close the current analysis window, all windows, the current measurement or all measurements.

Remember that a measurement can be viewed using multiple analysis windows. Closing *windows* leaves the measurement on the Measurement Stack—you will not lose a measurement by closing its windows. Closing *measurements* removes them from the Stack and frees the associated memory. You will be prompted to save a measurement before closing if you haven't already done so.

Tip: You can also close a measurement by right clicking on the Measurement Stack and selecting **Close This Measurement**. This will remove the measurement from the Stack and close all associated analysis windows.

Printing

Printing in 4Sight is, with few exceptions, WYSIWYG (What You See Is What You Get). You can print any screen in 4Sight by pressing the Print toolbar button  or by selecting **File** > **Print**. When you print, 4Sight uses the same colors and magnification as you see on the screen.

Choose **Tools** > **Preferences** > **Printing** to control how windows will print from 4Sight. Select **Use white color scheme** to reduce most plot elements to black and white, or choose **Use screen colors** to print plots as they appear on screen.

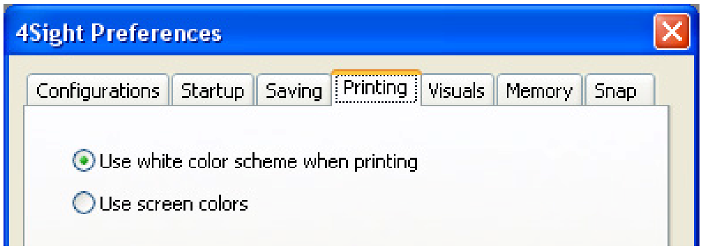


Figure 134: Printing preferences.

Exporting

4Sight fully supports export of your data and graphics via the Windows clipboard.

To copy the complete contents of an analysis window as a bitmap, choose **Edit** > **Copy**, or click **Ctrl-C**. This bitmap can then be pasted into other programs.

To copy the contents of a particular plot rather than the entire window, right click in the plot and choose **Copy To Clipboard**.

You can copy the contents of most tables as text objects by selecting a range of cells, then right clicking in the cells and selecting the appropriate copy operation. Tabular text data can be pasted directly into a word processor or spreadsheet program.

Note: Many tables include a right-click option which lets you toggle columns on or off for viewing. Some exportable data, therefore, may be hidden. Be sure to right click on the table and select **Column Chooser** to view all available data.

Interfacing with Other Programs

An API (Application Programming Interface) available through 4D's optional Web Service allows you to interface 4Sight with external languages and/or software. Please contact 4D Technology Sales for more information on 4D Web Service.

Chapter

15

Database

4Sight™ can log basic measurement results to a comma-separated-variable (.csv) text file for analysis and export to spreadsheet and word processing applications. A database can include information from multiple measurements and logging can be automatic or manual.

A different database can be stored with each *User Configuration,* so you can quickly switch between application-specific setups.

Create a Database

To create a database, click the **Database** button at the bottom of the 4Sight screen, then click the **Create** button. You can also choose **Tools** > **Database** > **Create**. You will first be prompted for the name and location to store the database.

Next, select the parameters to store in the database. Click the box next to each parameter to log it—selected parameters will show a green box. Some parameters are grouped; click the "+" box to view a group's individual parameters, or the "-" box to hide them. Click the box at the top of a group to log the entire group to the database. Click **OK** to generate the database.

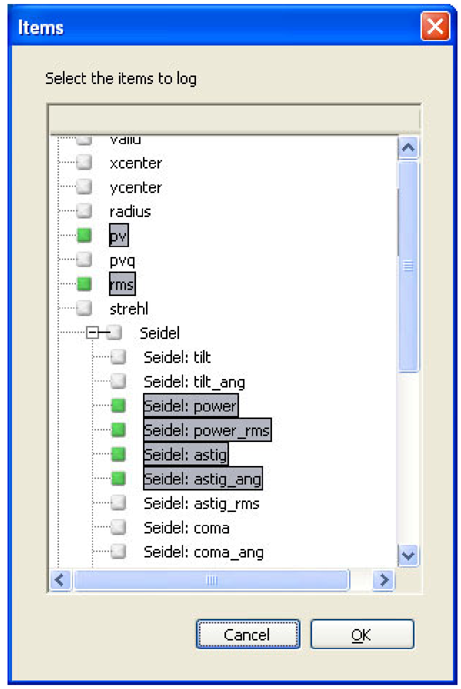


Figure 135: Selecting parameters to log to the database.

The following parameters can be added to the database:

Date, Time	The date and time at which the measurement was completed.
Sequence Time	In a *Burst* , the elapsed time from the beginning of the burst to the start of the particular measurement.
Title	The *Title* assigned to the measurement.
Aberrations removed	The terms (piston, tilt, etc.) removed from the measurement.
Valid	The number of valid pixels in the measurement.
X, Y Center	The coordinates of the center of the measurement pupil.
Radius	The radius of the pupil.
PV	The two-point peak-to-valley height.
PVq	The peak-to-valley height using a percentage of the highest and lowest points in the measurement.
RMS	The root-mean-square roughness.
Strehl Ratio	A quality control number indicating how well an optical system focuses energy.
Seidel terms	Log the Seidel tilt, tilt angle, power, RMS power, etc.
nZ	The number of Zernike terms removed.
zrms	The root-mean-square roughness of the Zernike residual.
Zernike terms	The first 2, 3, 8, 15, 24 or 36 terms, each as their own column.

Glass Defect Stats	The location, height and shape of errors found in the Glass Defect Analysis.
Disk Analysis	Parameters from the *Disk Analysis*.
Microwaviness	Parameters from the *Microwaviness* analysis.

To open another database click the **Open** button at the bottom of the Database window, or choose **Tools** > **Database** > **Open**.

To close the database click the **Deactivate** button at the bottom of the Database window, or choose **Tools** > **Database** > **Close**. The database will still be visible but logging will be deactivated.

Click **Clear** to remove all data from the database, or choose **Tools** > **Database** > **Clear**.

Click **Save Copy As…** to create a duplicate of the current database, or choose **Tools** > **Database** > **Save As**.

Click **Open in Excel** to view the data in Microsoft® Excel® spreadsheet application.

Right click in the database area and select **Column Chooser** to display or hide individual columns.

Pass/Fail Criteria

4Sight allows you to create maximum and minimum pass/fail criteria for each logged parameter. If the parameter falls below the lower limit (LPFC) it will be flagged in orange in the database and at the bottom of the 4Sight screen as well. If a parameter exceeds the upper limit (UPFC) it will be flagged in red.

To set up pass/fail criteria, first create the database with the parameters you need. At the top of the Database window, enter the UPFC and/or LPFC for a parameter, then press **Enter**. 4Sight will check all data currently in the database and will flag out-of-range values. To remove a pass/fail criterion, select its cell in the database, press the **Delete** key, then press **Enter**.

Logging Data

To automatically log data for each measurement choose **Tools** > **Database** >**Auto-log New Measurements To Database**. Each new measurement will be added as a row in the database. For a *Grouped Measurement* each measurement in the group will be logged as a separate row. Select the option again to uncheck it and suspend automatic logging.

To manually log data, choose **Tools** > **Database** > **Log Current Measurement to Database Now**. A new row will be added to the database for the current measurement. Once you have logged data for a particular measurement this option will no longer be available.

A complete database is shown below. Note that three “YCenter” values failed the LPFC criterion, and two values failed the UPFC criterion for peak-to-valley height (PV).

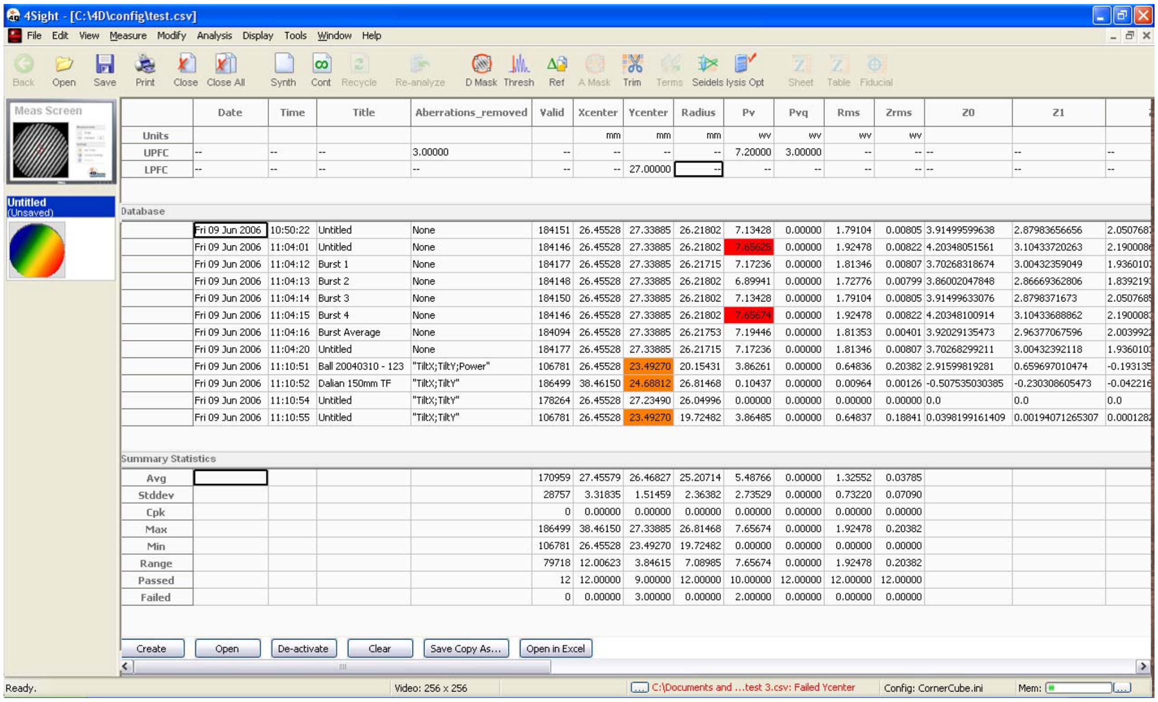


Figure 136:Database with pass/fail criteria.

Chapter

16

Special Measurements

In addition to the general-use analyses described earlier in this manual, 4Sight™ also includes several analyses designed for particular applications.

QC Measurement

The QC Screen provides a convenient interface for performing measurements to verify system and setup repeatability. Typically these measurements consist of multiple *Averaged Measurements*. To view this screen choose **Measure** > **QC Measurement**.

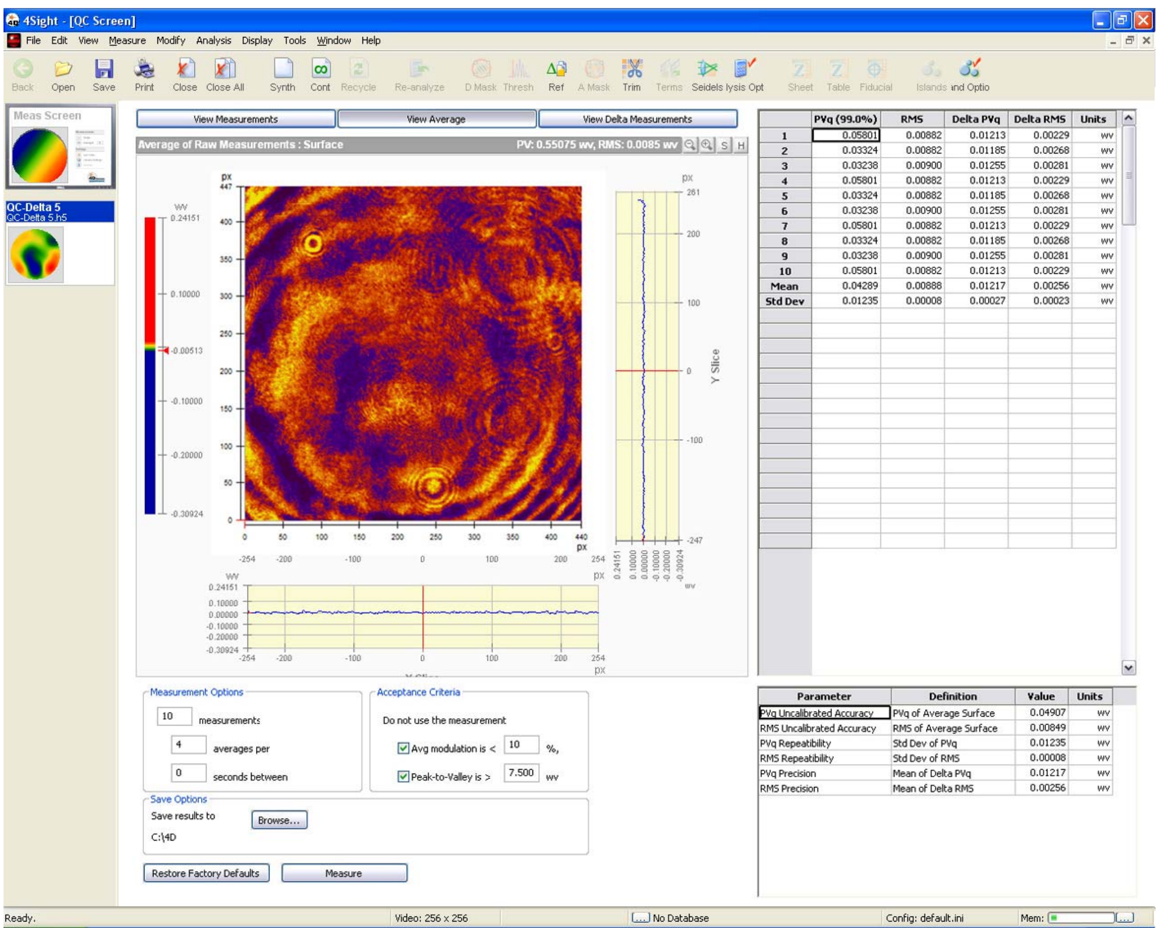


Figure 137: QC Screen after a measurement run.

On the lower right of the screen you can determine how many measurements will be acquired:

Measurements The number of measurements to complete.

Averages per The number of runs to average for each measurement. In most cases 8-10 measurements and 16 averages per measurement yields useful results.

Seconds Between The time delay between measurements.

Save Results To The disk location to which the measurements will be saved.

You can also specify Acceptance Criteria for individual measurements acquired during the run. If a single measurement fails to meet all the acceptance criteria, for example because of vibration or air turbulence, then the measurement will be repeated.

Avg Modulation is < Check the box and enter a percentage to ignore measurements with insufficient average modulation.

Peak-to-Valley is > Check the box and enter a height to ignore any measurements with excessive peak-to-valley variation.

When you click **Measure**, 4Sight will begin acquiring all of the measurements, repeating any measurements that do not meet the Acceptance Criteria. All valid measurements will automatically be saved to disk.

Note: Any measurements already in the destination folder will be deleted and replaced with the new measurement set.

Once the measurement is complete you can click the buttons above the contour plot to view the individual **Measurements,** the **Average** of all measurements or the **Delta** (differences) between each individual measurement and the average.

Use the **Movie** toolbar buttons  to step through the measurements or deltas.

For each measurement the following statistics are displayed in the upper right of the screen:

PVq (XX%) The peak-to-valley height, discarding the highest and lowest percentage of pixels. The percentage is defined under **Analysis Options > Statistics.**

RMS The root-mean-square roughness.

Delta PVq The peak-to-valley height calculated for each delta (rather than each measurement).

Delta RMS The root-mean-square roughness calculated for each delta (rather than each measurement).

Units The units for each measurement.

Right click in the table to copy cells, or the entire table, to the clipboard. Right click and choose **Save** to save the entire table as a comma-separated (csv) or tab-separated (tsv) file.

The QC Screen also calculates the following statistics. “Average surface” refers to the average of all measurements, as seen by clicking the **View Average** button:

PVq Uncalibrated Accuracy. The two-point peak-to-valley height for the average surface.

RMS Uncalibrated Accuracy The root-mean-square roughness for the average surface.

PVq Repeatability The standard deviation of the peak-to-valleys of the individual averaged measurements.

RMS Repeatability The standard deviation of the RMS of the individual averaged measurements.

PVq Precision The mean of the peak-to-valleys of the delta measurements.

RMS Precision The mean of the RMS of the delta measurements.

Spot Analysis

The Spot Analysis reports the intensity distribution of a focused beam, calculated based upon the measured far-field intensity and phase. The analysis can be used to determine, for example, the focused beam intensity distribution of a DVD or Blue-ray diode laser pickup head.

Spot Analysis is similar to the Point Spread Function (*PSF*) but in addition to using the wavefront phase, it also accounts for the non-uniform intensity distribution of the beam via the *Apodization Reference*. This is typically done by blocking the reference beam and taking a measurement. If no Apodization Reference is specified, a uniform far-field intensity distribution is assumed. Spot Analysis also relies on the user specified values contained under the Optical Parameters to scale the lateral or spatial units. The Encircled Energy diagram plots the total percentage of laser energy contained within a given radius.

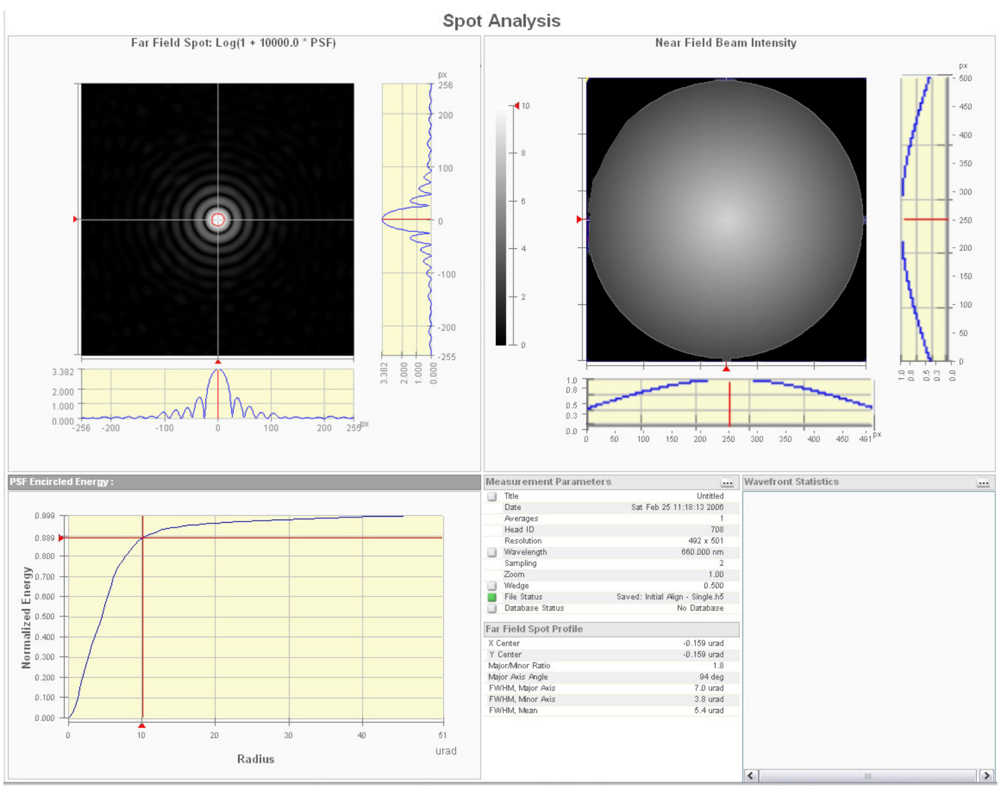


Figure 138: Spot Analysis.

The top two main plots are *Contour Plots*, and as such all display and right-click options apply. The Normalized Energy plot has the same features as an *XY Slice* plot, so all display features and cursor controls apply.

Absolute Calibration (3-Flat Test)

Absolute flatness testing obtains the surface shape of flats independent of the shape of the reference and optical system used in the test. This measurement is specific to Fizeau type interferometers. To run the analysis you will make four measurements using three flats in different pairings and orientations. First, mark the back and right side of each flat. Next, complete the four required measurements per the diagrams below. An underline represents the back of the flat, “X” represents the right side, and “180” indicates that the flat is rotated 180 degrees about the optical axis. Note that flats A and B must be transparent while C can be reflective.

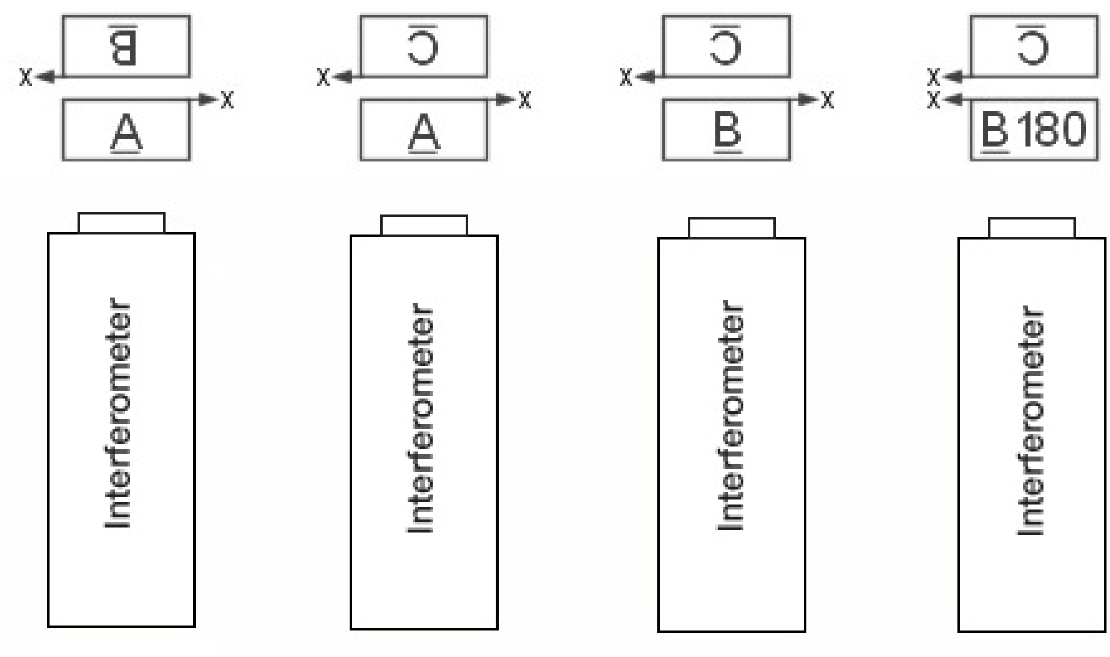


Figure 139: Orientations for the 3-flat measurements.

Now choose **Analysis > Absolute Calibration (3-Flat Test)**. Drag each of the measurements from the Measurement Stack into the correct locations in the analysis screen. When all four have been entered the analysis will calculate the surface of each of the three flats.

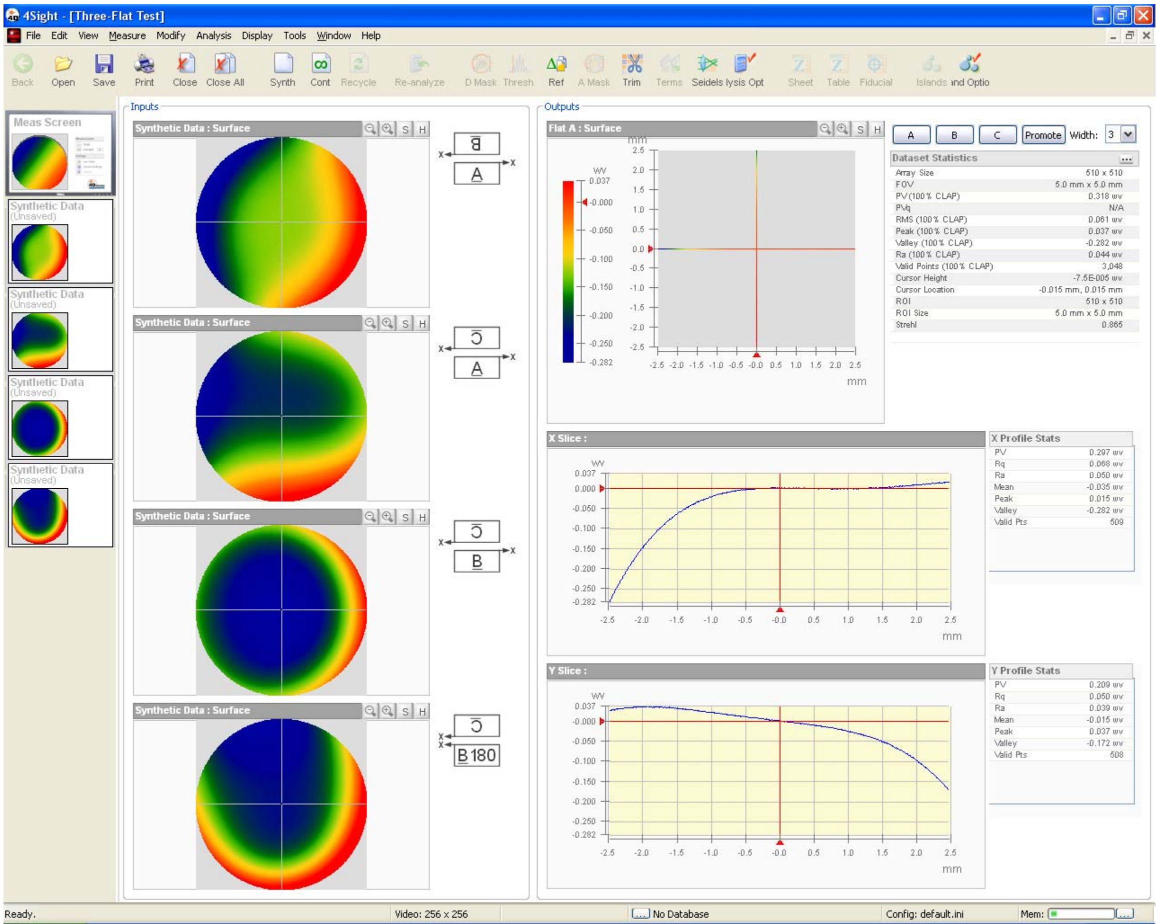


Figure 140: Orientations for the 3-flat measurements.

The 3-flat test determines the shape of the component flats along the X and Y axes only—these will appear as narrow strips in the plot in the upper right of the screen. The *XY Slice* plots show the heights along these traces in the X and Y directions. Click the **A, B** and C buttons to view the surface plots for each of the three flats. Click **Promote** to add the currently viewed surface to the Measurement Stack.

Absolute Calibration (3-Sphere Test)

As with the 3-Flat test described above, the 3-sphere test uses multiple measurements to extract the surface of a spherical mirror and eliminate the contribution of the interferometer and lens. To use the analysis you will first measure a sphere in three configurations: right side up, rotated 180 degrees about its axis, and at the cat's eye position. Once the measurements are complete and open on the Measurement Stack, choose **Analysis > Absolute Calibration (3-Sphere Test)**.

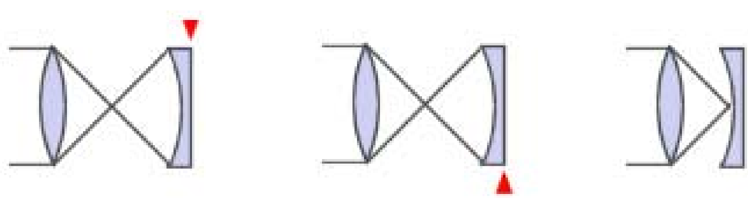


Figure 141: 3-sphere measurement positions and orientations.

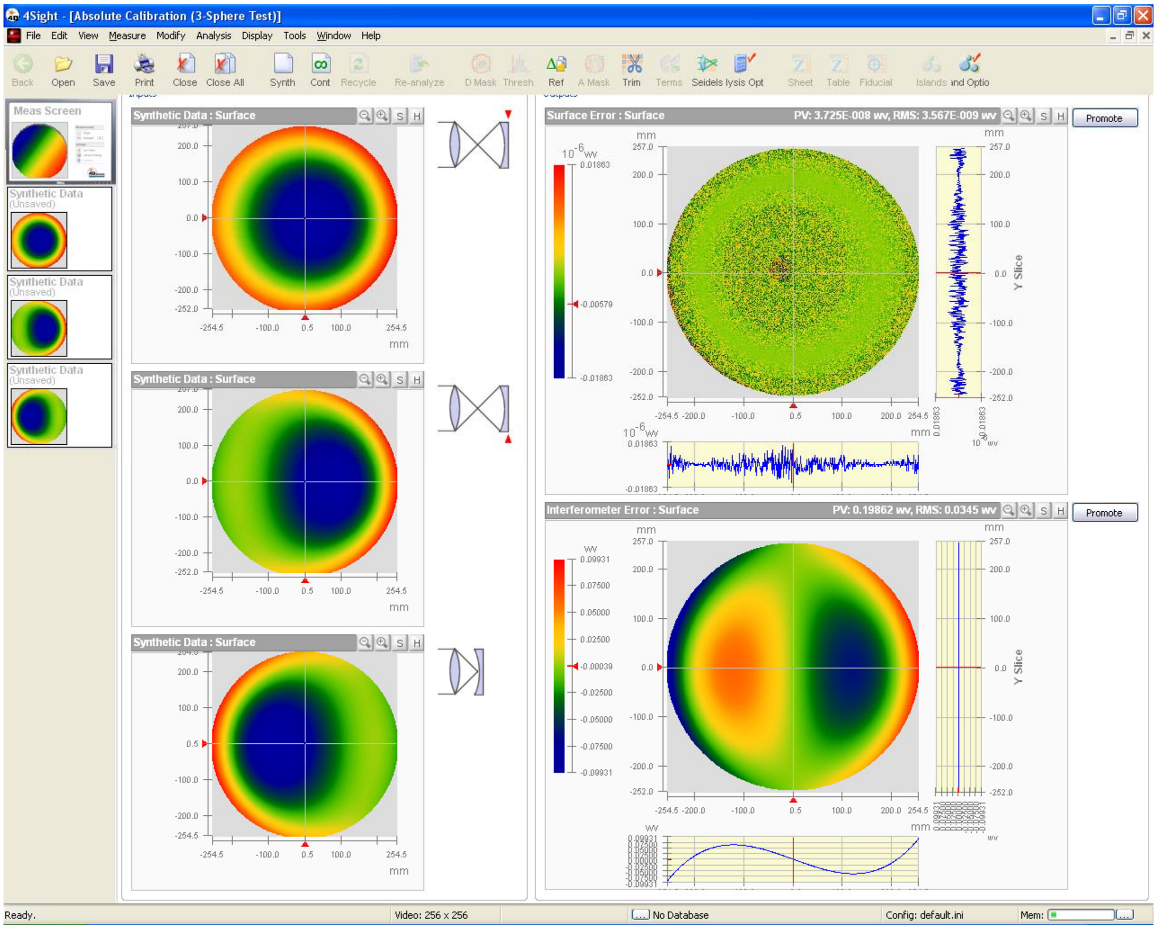


Figure 142: Absolute Calibration (3-Sphere) Analysis.

The analysis will calculate the absolute shape of the spherical surface and the shape induced by the interferometer itself. These two contour plots will be displayed on the right side of the screen.

Optical Thickness Analysis

The Optical Thickness Analysis is an option for use with 4D interferometers with short coherence length laser sources. The short coherence source enables "direct cavity" measurements, in which the front surface of a test sample serves as the reference while the back surface is measured. The Thickness analysis reports the pixel-by-pixel optical path difference between the front and back surfaces.

To run the analysis:

1. Click the **Thickness** button on the Measurement Screen to open the **Optical Thickness Preferences** dialog box (*Figure 143*).

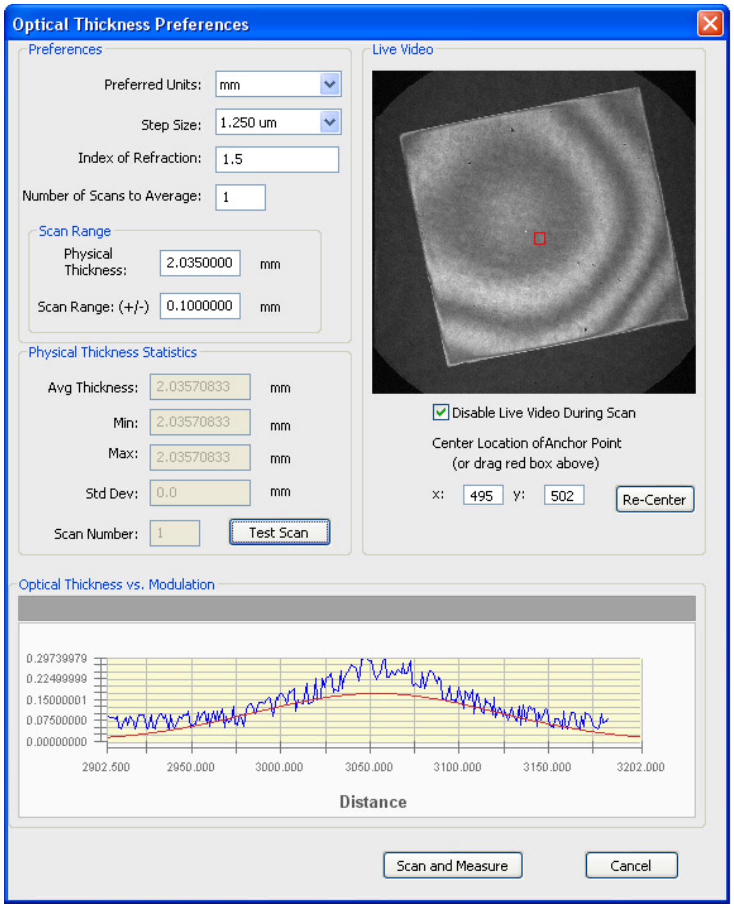


Figure 143: Optical Thickness Options Dialog Box.

2. Enter the **Preferred Units** in which to report the thickness statistics.

3. Enter the **Step Size**, the increment by which the motor will move during the scan. A smaller step size gives better resolution but will also increase scan time.

4. Enter the **Index of Refraction** for the sample part.

5. Enter the **Physical Thickness** of the sample and the **Scan Range**.

6. Click **Test Scan** to verify that the Scan Range and other properties are correct before making the actual measurement. The system will move the path match motor through the selected Scan Range, in the increments selected under Step Size. The average modulation of all pixels in the field of view will be plotted after each step. When the scan is complete the **Physical Thickness Statistics** will be reported.

7. Enter the **Number of Scans to Average**. A higher number of scans will improve accuracy but will also increase measurement time.

8. Click **Scan and Measure**. The system will move the path match motor through the selected Scan Range the number of times selected under Number of Scans to Average. A contour plot showing the thickness at each pixel will be displayed, along with the **Mean** thickness and other statistics.

Disk Analysis

4Sight includes a suite of analyses for measuring the surface shape of optical and magnetic disks. These analyses simulate the contribution of disk shape to the path of the recording head flying above the disk. You can analyze the disk surface along up to five circular slices of user-specified radii.

The following analyses are available for disk testing:

- Runout
- Velocity
- Acceleration
- Radial Slope
- Tangential Slope
- Radial Curvature
- Tangential Curvature.

These analyses are grouped into a single screen for easy access and comparison. *Microwaviness* analysis is also available on a separate screen. Each analysis is described below.

Disk Analysis Options

The disk analyses require you to define several parameters regarding the size and simulated motion of the disk. Some parameters affect all analyses, while others affect only certain calculations. To set the Disk Options, choose **Analysis** > **Disk** > **Options**.

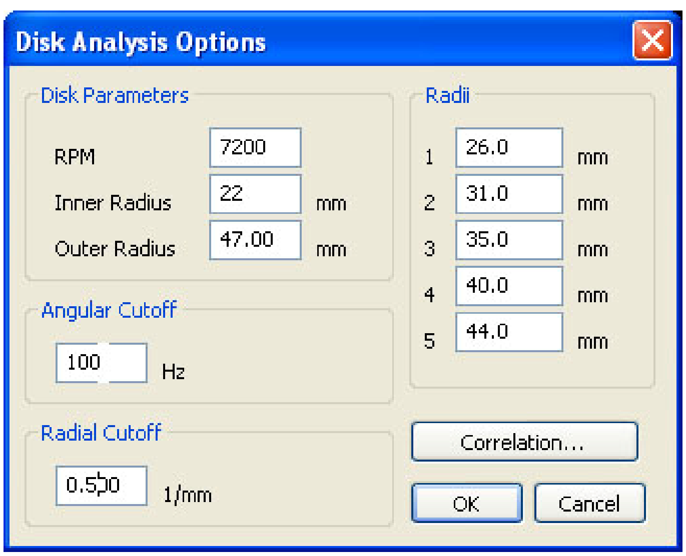


Figure 144: Disk Analyses Screen.

Set the following parameters:

RPM	The speed at which the disk is spinning, in RPM (Revolutions Per Minute).
Inner Radius	The inner radius of the disk. All pixels inside this radius will be masked.

Outer Radius The outer radius of the disk. All pixels outside this radius will be masked.

Radii The radii of the five cursors along which statistics will be gathered for each disk analysis.

Angular Cutoff The highest frequency of features tangential to the disk radius that will be included in the calculations. It is specified by the number of times a feature occurs per revolution of the disk. For example, a feature appearing every 45 degrees occurs 8 times/revolution; entering an Angular Cutoff of 8 would therefore mask all features smaller than (occurring more frequently than) 8 times per revolution.

The Angular Cutoff is also shown in Hz for comparison to other analysis software. This calculation is also affected by the RPM setting.

Radial Cutoff The highest frequency of features along the disk radius that will be included in the calculations. For example, a Radial Cutoff of 2 would mask features smaller than 0.5 mm in length (occurring more than 2 times per mm).

Note: All 4Sight disk analyses are calculated using Cartesian coordinates. The units will be based upon those selected under **Edit** > **Units**.

Correlation Enter values to correlate individual parameters to those of other systems or metrology methods (See *Correlation Coefficients* below).

Disk Analysis Screen

To calculate the disk analyses choose **Analysis** > **Disk** > **Disk Analysis**. The Disk Analysis screen will open.

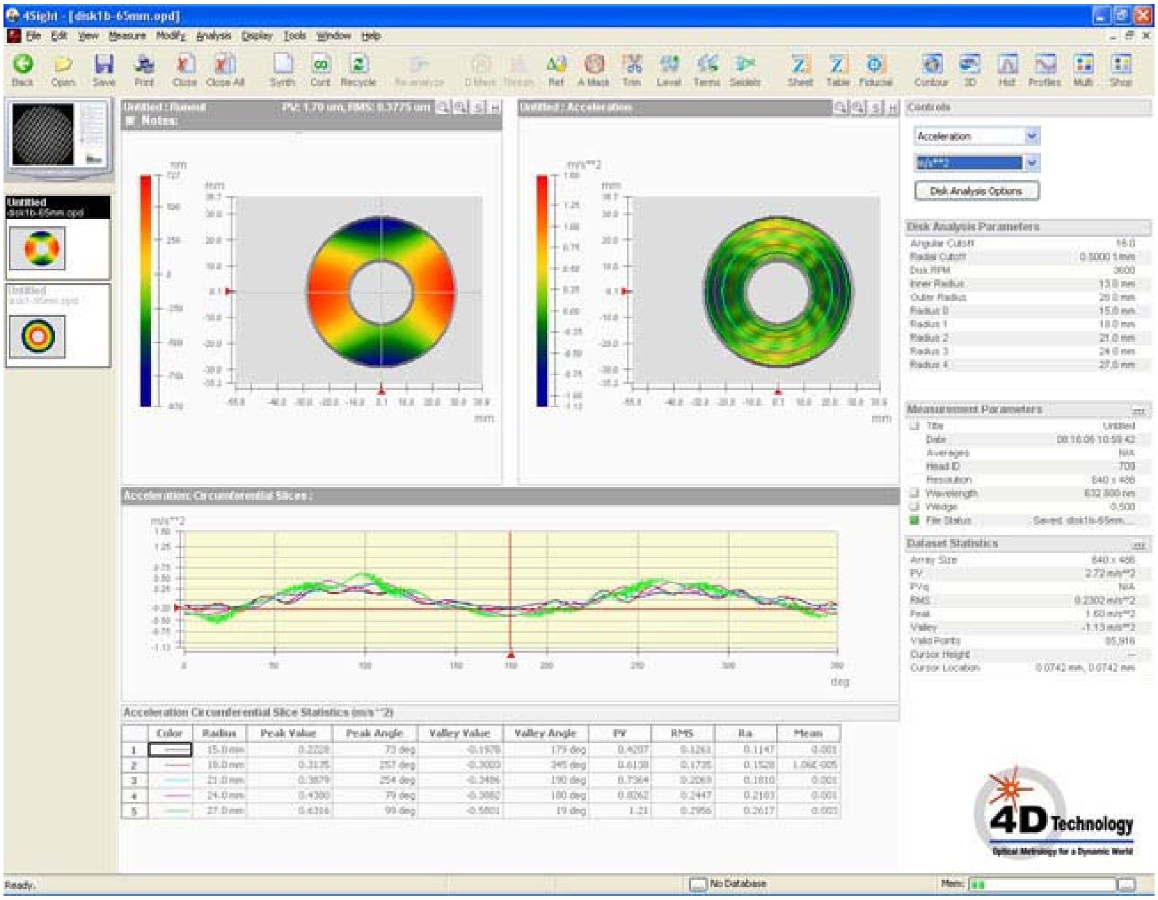


Figure 145: Disk Analyses Screen.

Choose the disk analysis to view from the **Controls** list in the upper right of the screen.

The Disk Analysis screen is divided into five main areas:

1. The upper left plot shows disk Runout, equivalent to a surface height map of the disk. All *Contour Plot* viewing and right click options apply.

2. The upper right plot shows the results for the analysis you select from the **Controls** list (in the upper right of the screen). All *Contour Plot* viewing and right click options apply.

Note: Both contour plots share the same *Palette* and Max Contrast settings. Changing them for one plot will also change them for the other.

3. The Circumferential Slices plot shows statistics along five circular cursors, with their radii determined in the Disk Options dialog box. The plot will change based upon the analysis selected from the Controls list. The traces are color-coordinated to match the upper right plot. All XY Slice options (cursors, selecting and exporting trace data, etc) apply.

4. The table at the bottom of the screen shows statistics for the selected analysis along each of the five circular cursors. The statistics and units will change based upon the analysis you select from the Controls list.

Radius The radius at which the statistics are measured.

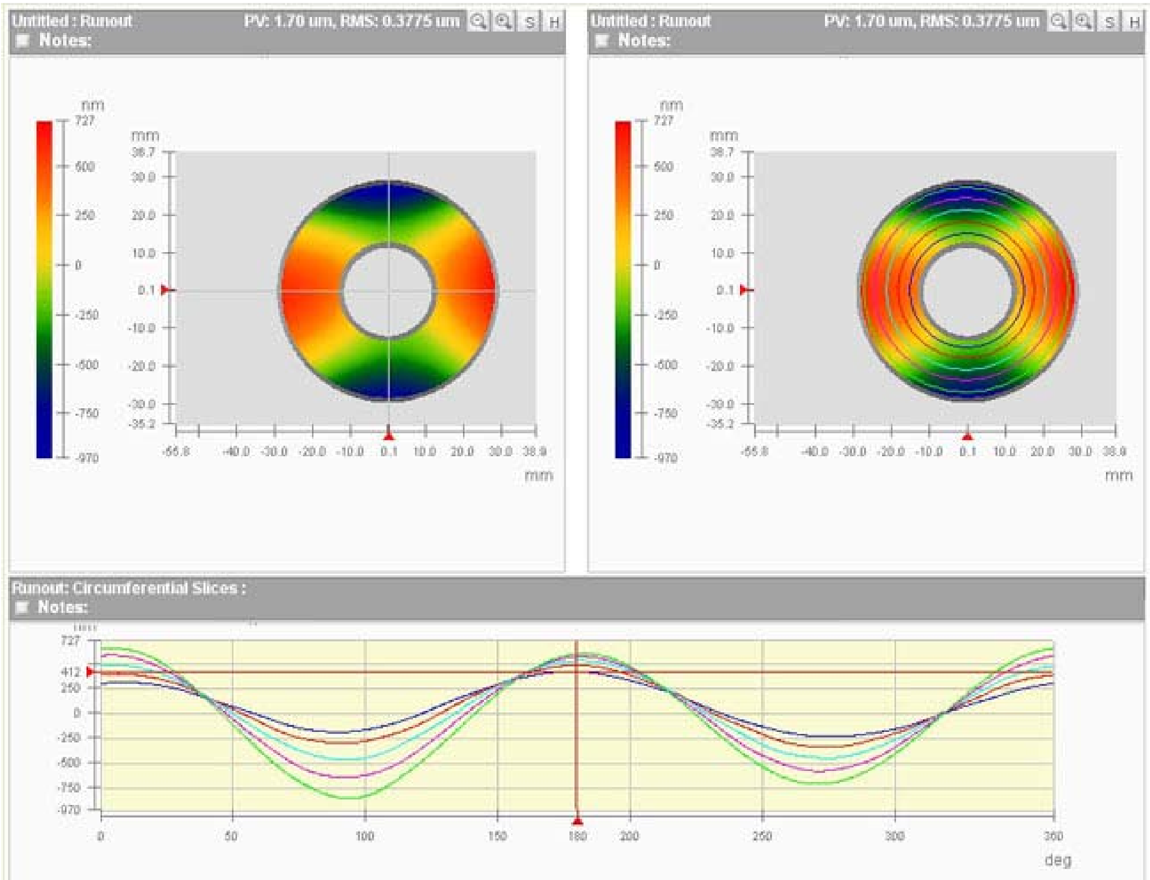
Peak Value	The maximum value for the analysis at that radius.
Peak Angle	The rotational angle at which the peak value occurs. 0 degrees is the "3:00" position; the angle is measured counter-clockwise from 0.
Valley Value	The minimum value for the analysis at the given radius.
Valley Angle	The rotational angle at which the peak value occurs. 0 degrees is the "3:00" position; the angle is measured counter-clockwise from 0.
PV	The peak-to-valley difference for the analysis at the given radius.
RMS	The root-mean-square value of the analysis at the given radius.
Ra	The average deviation from the mean of the analysis along the given radius.
Mean	The mean value of the analysis at the given radius.

The data can be copied and pasted into other programs for further analysis.

5. The right side of the screen shows the settings from the Disk Options screen, as well as standard 4Sight *Measurement Parameters* and *Dataset Statistics*.

Runout

This analysis maps the surface height of the disk, with the inside diameter and outside diameter masked per the settings on the Disk Options screen.



Runout Circumferential Slice Statistics (nm)

	Color	Radius	Peak Value	Peak Angle	Valley Value	Valley Angle	PV	RMS	Ra	Mean
1		15.0 mm	413	177 deg	-240	275 deg	653	208	185	72.4
2		18.0 mm	477	179 deg	-342	275 deg	819	270	242	56.5
3		21.0 mm	523	181 deg	-472	93 deg	995	341	307	22.5
4		24.0 mm	577	4 deg	-644	92 deg	1222	419	377	-22.7
5		27.0 mm	648	3 deg	-858	94 deg	1506	497	446	-72.1

Figure 146: Runout.

The Runout contour plot is always present as the upper left plot; however, choosing Runout as the viewed analysis also lets you calculate Runout statistics along the five circular cursors.

Velocity

Velocity is the first circumferential or rotational derivative of runout. It corresponds to the z-velocity of the disk head, assuming that the head maintains a perfect spacing above the disk, and the disk rotates at constant angular velocity. Velocity is defined as:

$$V_z = \varpi\left(x\left(\frac{\partial z}{\partial y}\right) - y\left(\frac{\partial z}{\partial x}\right)\right)$$

where z = height and ω = angular velocity $\left(\frac{d\theta}{dt}\right)$.

Velocity is affected by the RPM and Angular Cutoff settings on the Disk Options screen. To show greater detail increase the angular cutoff.

Acceleration

Acceleration is the second circumferential or rotational derivative of runout. It corresponds to the z-acceleration of the disk head, assuming that the head maintains a perfect spacing above the disk, and the disk rotates at constant angular velocity. Acceleration is defined as:

$$a_z = \varpi^2\left(-x\left(\frac{\partial z}{\partial x}\right) - y\left(\frac{\partial z}{\partial y}\right) + x^2\left(\frac{\partial^2 z}{\partial y^2}\right) + y^2\left(\frac{\partial^2 z}{\partial x^2}\right) - 2xy\left(\frac{\partial^2 z}{\partial x \partial y}\right)\right)$$

where z = height and ω = angular velocity $\left(\frac{d\theta}{dt}\right)$.

Acceleration is affected by the RPM and Angular Cutoff settings on the Disk Options screen. To show greater detail increase the angular cutoff.

Radial Slope

Radial slope is the slope along the radius ,

$$\frac{dz}{dr} = \left(\frac{x}{r}\right)\frac{\partial z}{\partial x} + \left(\frac{y}{r}\right)\frac{\partial z}{\partial y}$$

where z = height and r = radius. Slope units are dimensionless.

Radial slope is affected by the Radial Cutoff setting on the Disk Options screen. To show greater detail increase the Radial Cutoff.

Tangential Slope

tangential slope is the slope of the disk in the direction tangent to the radius. It is defined as:

$$\frac{dz}{ds} = \left(\frac{x}{r}\right)\frac{\partial z}{\partial y} - \left(\frac{y}{r}\right)\frac{\partial z}{\partial x}$$

where z = height, r = radius and s = rθ. Slope units are dimensionless.

Tangential slope is affected by the Angular Cutoff setting on the Disk Options screen. To show greater detail increase the Angular Cutoff.

Radial Curvature

Radial curvature is the local curvature of the disk along the radius. It is defined as:

$$\frac{d^2 z}{dr^2} = \left(\frac{x}{r}\right)^2 \frac{\partial^2 z}{\partial x^2} + \left(\frac{y}{r}\right)^2 \frac{\partial^2 z}{\partial y^2}$$

where z = height and r = radius.

Radial curvature is affected by the Radial Cutoff setting on the Disk Options screen. To show greater curvature detail increase the Radial Cutoff.

Tangential Curvature

Tangential curvature is the local curvature of the disk in the direction tangent to the radius. It is defined by:

$$\frac{d^2 z}{ds^2} = \left(\frac{x}{r}\right)^2 \frac{\partial^2 z}{\partial y^2} + \left(\frac{y}{r}\right)^2 \frac{\partial^2 z}{\partial x^2} - \frac{\partial^2 z}{\partial x^2} - 2\frac{xy}{r}\frac{\partial^2 z}{\partial x \partial y}$$

where z = height, r = radius and s=rθ.

Tangential curvature is affected by the Angular Cutoff setting on the Disk Options screen. To show greater curvature detail increase the Angular Cutoff.

Microwaviness

The Microwaviness Analysis defines disk features within a certain size range, typically those on the same order of size as the recording head. The analysis applies a band pass Fourier filter to the frequencies occurring tangential to the radius of the disk.

Microwaviness Options

To run the analysis you must first define several parameters by choosing **Analysis** > **Microwaviness** > **Options**:

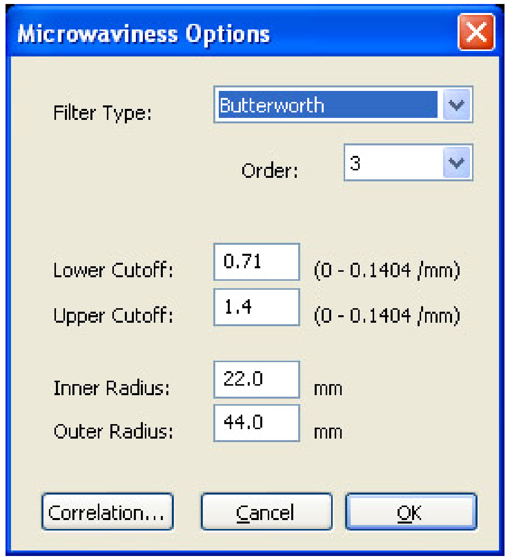


Figure 147: Microwaviness Options Dialog Box.

Filter Type Select the type of band pass *Filters* to apply: **Rectangular** or **Butterworth**.

The difference in filter types affects the transition near the cutoff frequency. The rectangular filter simply passes or blocks frequencies right up to the cutoff, which may produce "ringing" when the data is transformed back to the spatial domain. The Butterworth filter applies a more gradual transition near the cutoff frequency to reduce ringing.

Order Determines the steepness of the Butterworth filter roll-off near the transition frequency. The higher the order, the more closely the filter approximates the Rectangular filter.

Low Cutoff Frequency Features occurring at frequencies below this cutoff will be excluded from analysis. The allowable values as dictated by the Nyquist limit (i.e., sampling rate) is shown.

High Cutoff Frequency Features occurring at frequencies above this cutoff will be excluded from analysis. The allowable values as dictated by the Nyquist limit (i.e., sampling rate) is shown.

Inner Mask Radius The inner radius of the disk. Pixels within this radius will be masked.

Outer Mask Radius The outer radius of the disk. Pixels outside this radius will be masked.

Correlation Enter values to correlation individual parameters to those of other systems or metrology methods (See *Correlation Coefficients* below).

Microwaviness Analysis Screen

To run the analysis choose **Analysis** > **Microwaviness** > **Microwaviness Analysis.** The Microwaviness Analysis screen will open.

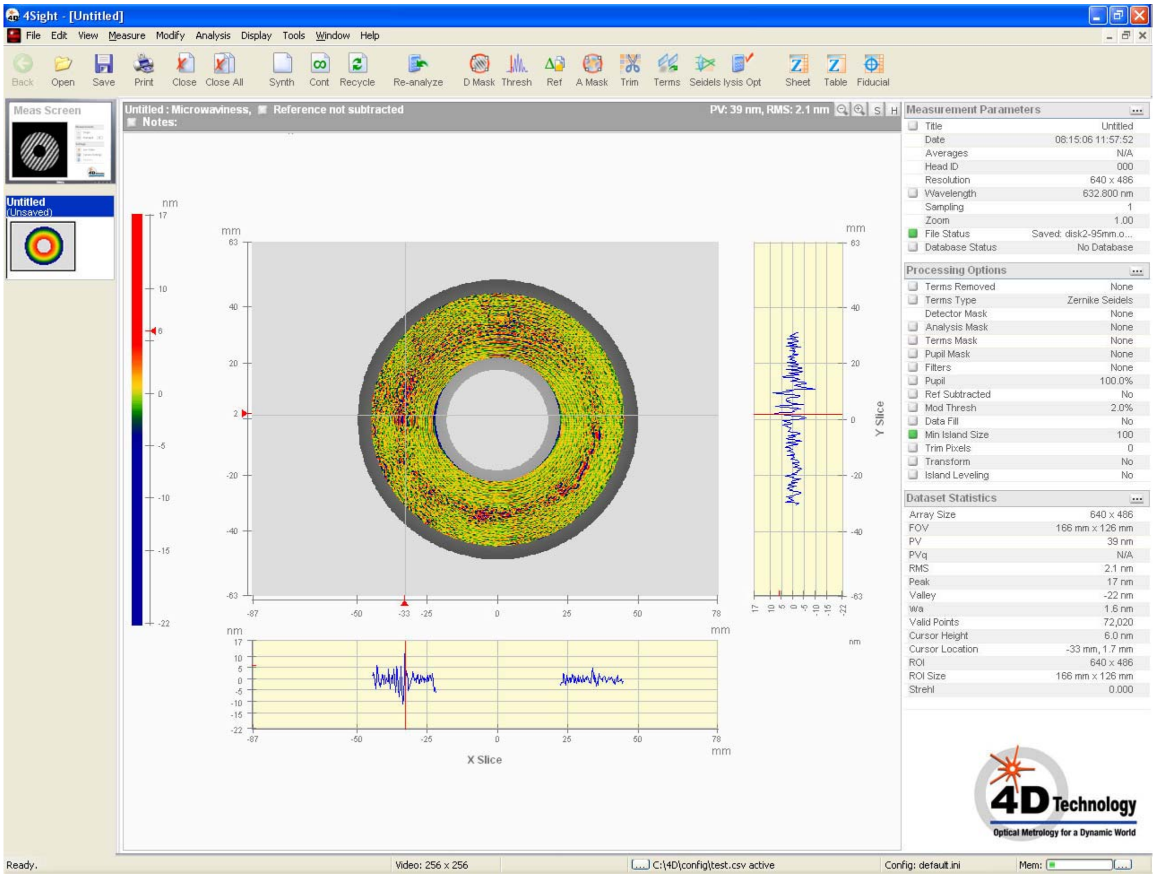


Figure 148: Microwaviness Analysis Screen.

The Microwaviness screen shows a *Contour Plot* of the data. All contour plot viewing and right-click options apply. Statistics, including peak-to-valley height (PV) and average roughness (Wa) are shown at the right.

To view the data in 3D, right click in the data and choose **3D Plot**.

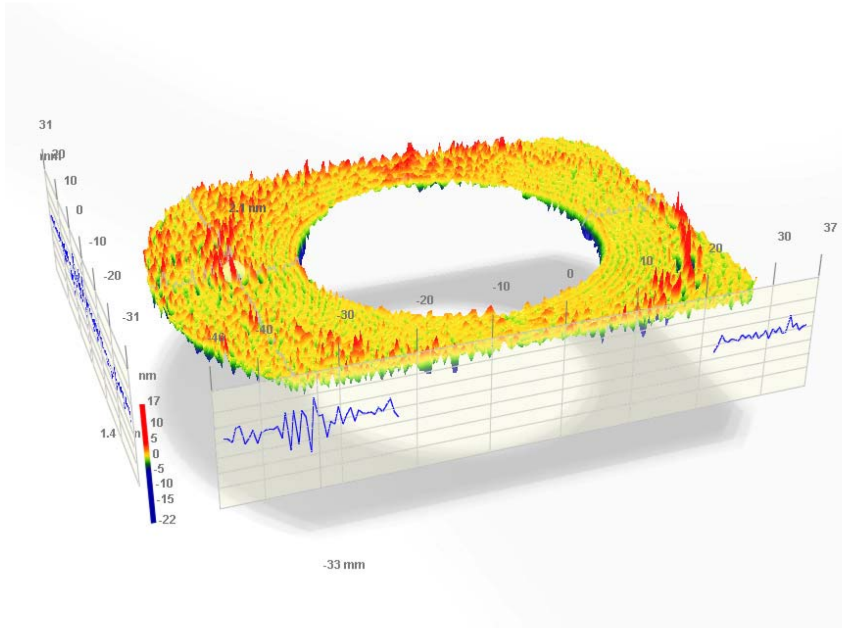


Figure 149: Microwaviness Analysis 3D Plot.

Correlation Coefficients

4Sight's Disk Analysis and Microwaviness analysis data can be easily correlated to the results from other systems or metrology methods. To enter correlation values, click **Correlation** in the Disk Analysis Options or Microwaviness Options dialog boxes. You will be prompted to enter a password, since changing the correlation values will alter all subsequent data.

Note: Only the correlated values are stored in 4Sight's database—raw measurement data is *not* stored. Be certain to record changes to the correlation values in order to maintain data integrity.

In the correlation table, enter the correlation coefficients (i.e., the coefficients for the correlation equation ax^2 + bx +c) for as many parameters as necessary. The default values are 0, 1 and 0—you only need to enter values that differ from these defaults. To reset all values to the defaults, click **Clear All**.

Check the **Apply** box to use the new correlation coefficients with subsequent data. Click **Change Password** to alter the password required to change correlation values.

Click the **Save** button to store your changes.

Figure 150: Correlation coefficients.

Tip: In the Measurement Parameters area, the **Correlation Parameters** box will be green when parameters are applied. It will be gray otherwise.

Multiple Measurement Mode

Multiple Measurement Mode is an option on some systems which lets you switch between Spatial (dynamic) and Temporal (traditional temporal interferometry) measurements using the same interferometer. If your system is enabled to make such measurements you will see an additional **Phase-Shifting Mode** option on the **Measure** menu. Select either **Spatial** or **Temporal** to switch between modes. When you do so, a dialog will appear instructing you to realign the transmission flat.

Spatial measurement mode, in which all interferograms are obtained simultaneously, is described in Chapters 2 and 3 of this manual. In temporal measurements, piezo-driven mechanism (PZT) alters the phase between the test and reference beams. Interferograms are obtained at specific phases over an interval of time.

For temporal measurements it is necessary to calibrate the PZT. To do so, choose **Measure > Calibration >Phase Shifter Calibration** (*Figure 151*). Click the **Test PZT Calibration** button to open the Phase Shift Calibration window. Click the **Test** button to verify the PZT calibration. If the calibration is correct, the histogram in the right of the window should show a strong peak at 90 degrees (this is true even if you are using a 60 degree phase shifting algorithm). If the calibration is incorrect, click the **Auto-Calibrate** button to update it.

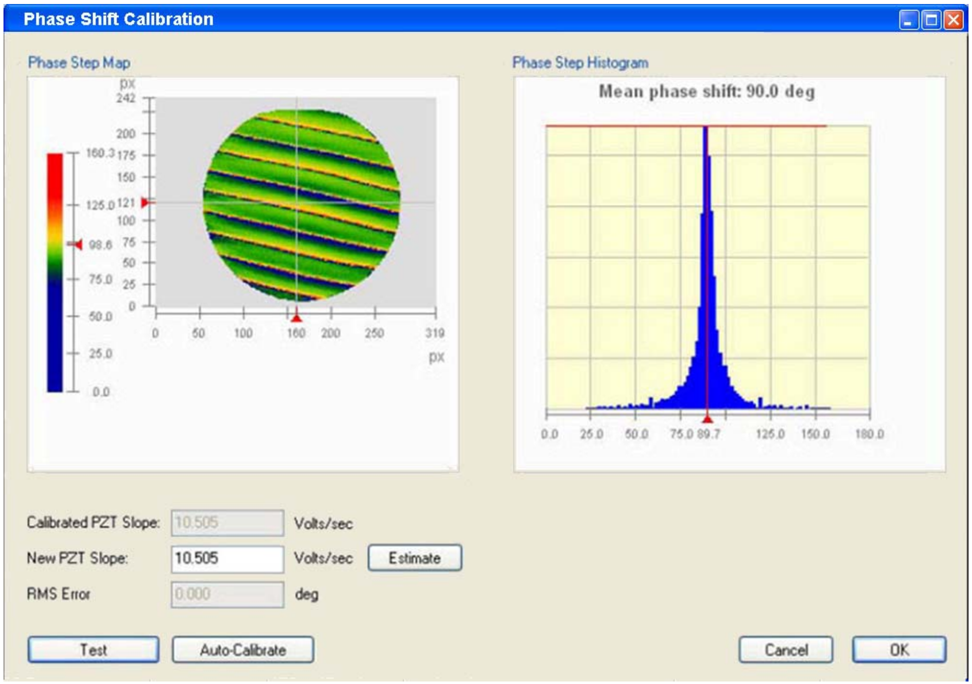


Figure 151: PZT Calibration.

Several functions under **Measure > Measurement Options > PSI** (*Figure 152*) also control how temporal measurements will be made:

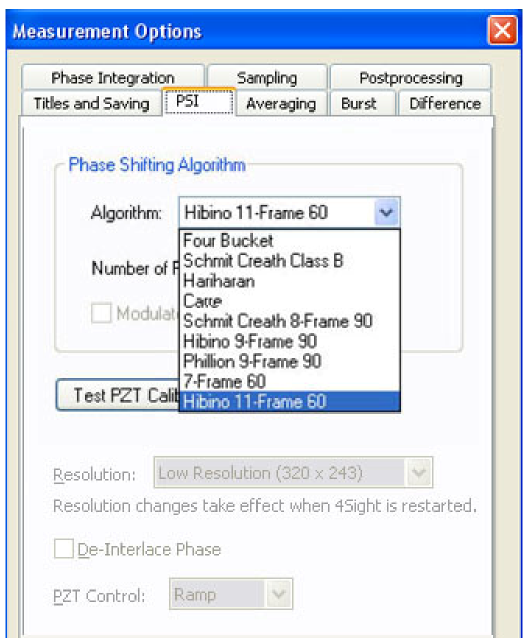


Figure 152: PSI Measurement Options for temporal measurements.

Algorithm	The phase shifting algorithm. Choose from several 90-degree and 60-degree options (see below for more details).
Number of Frames	The number of interferograms to record. 4D recommends that you select at least 5 frames for the best results.

Modulate Starting Phase *Averaging* measurements can help remove the effect of noise and artifacts from a measurement. In temporal measurements, however, if the first measurement is taken at the same phase each, the averaged measurement might still retain some artifacts. Choosing this option can improve averaged measurements by changing the starting phase for the individual measurements.

Resolution For Wyko interferometers you can select Low Resolution (320 x 243) or High Resolution (640 x 486). Low resolution provides less spatial resolution (i.e., fewer pixels) but eliminates interline, or odd/even artifacts associated with the camera at higher resolution. Low Resolution is recommend unless the higher spatial resolution is absolutely necessary.

De-Interlace Phase This option offers another approach to fixing the odd/even artifacts for Wyko interferometers in high resolution mode. This feature calculates the average height (phase) in each of the odd and even fields, then offsets them so they match.

PZT Control This option determines how the PZT moves while the frames are acquired. In **Ramp** mode the PZT moves at a constant velocity, acquires all frames, then stops. In **Step** mode the PZT locates, acquires one frame, and repeats this process for each frame. Step mode can introduce transients and can take longer, leaving more opportunity for vibration and test part to drift. For this reason, Ramp mode is recommended.

PSI Algorithms

4Sight includes several phase-shifting algorithms for temporal PSI measurements. The algorithms have different error signatures and characteristics. In general, a larger number of frames results in smaller error. The primary tradeoff is:

- simplicity and small amounts of data, versus
- better error suppression, more data and longer acquisition time.

A good rule of thumb is to use the simplest algorithm that produces the desired result. At least 3 frames are necessary for a calculation when the phase shift is known.

4-frame algorithms: 4-Bucket, Carre and Schmit Creath Class B (see [1, 5]). The 4-Bucket algorithm is the standard in 4D dynamic interferometers and assumes 90 degree phase shifts. It is sensitive to phase shift errors, but not to second-order detector nonlinearities. The Schmit-Creath Class B was designed with 90 degree phase shifts to reduce sensitivity to phase shift errors, but this trades off an increased sensitivity to detector nonlinearities. The Carre assumes equal phase shifts with unknown value and is good for multiple-wavelength measurements where you don't want to recalibrate the phase shifter between wavelengths.

5-frame algorithms: Hariharan (see [5, 6]; also noted as 5A method in ref [5]). Adding a fifth frame with a standard 90 degree phase shift can reduce sensitivity to many errors. The Hariharan is much less sensitive to phase shift calibration error (about equal to the Schmit-Creath Class B) and insensitive to 2nd order detector nonlinearities.

7-Frame algorithms: 7-frame 60 (see [7]). This algorithm has 7-frames with 60 degree phase shifts covering a total of 360 degrees. It was developed as a means of reducing errors due to fringe nonlinearities with a phase shifter that was linear over one fringe of shift. By having more frames it has less sensitivity to nonlinearities and gain variations between frames.

8- and 9-Frame algorithms: Schmit-Creath 8-Frame 90 (see [5, 8]), Hibino 9-frame 90 (see [9]), Phillion 9-frame 90 (see [10]). The Schmit-Creath 8-frame 90 was designed by tailoring the sampling window function to suppress harmonics. The Hibino and Phillion methods are examples of algorithms designed to suppress nonlinearities and random errors.

11-frame algorithm: Hibino 11-frame 60 (see [12]). Like the 7-frame 60 this was designed to suppress errors due to nonsinusoidal fringes. The extra frames help suppress higher orders of errors at the expense of a longer acquisition time.

The following references provide additional information on the various algorithms. Overviews of the algorithms and methods can be found in references [1-4].

1. K. Creath, "Phase-measurement interferometry techniques," in *Progress in Optics*, E. Wolf, ed. Elsevier Science Publishers, Amsterdam, 349-393 (1988).
2. K. Creath, and J. Schmit, *Phase measurement interferometry*, Elsevier (2004).
3. J. E. Greivenkamp, and J. H. Bruning, "Phase shifting interferometry," in *Optical Shop Testing*, D. Malacara, ed. John Wiley & Sons, New York, 501-598 (1992).
4. H. Schreiber, and J. H. Bruning, "Chapter 14: Phase Shifting Interferometry," in *Optical Shop Testing, 3rd Edition*, D. Malacara, ed. Wiley, Hoboken, NJ, 667-755 (2007).
5. J. Schmit, and K. Creath, "Extended Averaging Technique For Derivation Of Error-Compensating Algorithms In Phase-Shifting Interferometry," Applied Optics **34**(19), 3610-3619 (1995).
6. P. Hariharan, B. F. Oreb, and T. Eiju, "Digital phase-shifting interferometry: a simple error-compensating phase calculation algorithm," Applied Optics **26**(3), 2504-2505 (1987).
7. K. G. Larkin, and B. F. Oreb, "A new seven-sample symmetrical phase-shifting algorithms," Interferometry: Techniques and Analysis, Proc. SPIE **1755**, (1992).
8. J. Schmit, and K. Creath, "Window function influence on phase error in phase-shifting algorithms," Applied Optics **35**(28), 5642-5649 (1996).
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10. D. W. Phillion, "General methods for generating phase-shifting interferometry algorithms," Applied Optics **36**(31), 8098-8115 (1997).
11. Y. Surrel, "Design of phase-detection algorithms insensitive to bias modulation," Applied Optics **36**(4), 805-807 (1997).
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13.

Chapter

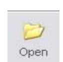
17

Scripting

4Sight™ includes extensive scripting features that allow you to automate repetitive tasks. Almost anything that can be done manually within 4Sight can also be done with a script. For example, you might develop a script to take a measurement, wait 5 seconds, take another measurement, then save the resulting difference to a file.

Scripts are written in the Python® programming language and executed from within 4Sight. A number of samples are included with 4Sight under (by default) C:\Program Files\4Sight\Scripting Samples. These samples, starting with Demos 1-4, provide a good starting point for scripting within 4Sight.

Note: If you are new to scripting with Python there are many helpful sites (in particular, http://www.python.org/) and hundreds of freely-distributed, general-purpose Python libraries available on-line.

To open an existing script click the **Open** 

toolbar button, or choose **File** > **Open.** Under **Files of Type** choose **Python Scripts**, then locate and select the desired script. Python scripts will have .py extensions. When you click **Open** the steps in the script will appear in the 4Sight scripting interface shown below.

The left pane of the Scripting Screen displays the steps in the script for viewing or editing. The right hand pane lists the available 4Sight functions which can be added to the script. Click on the general categories to display or hide each group of functions. Click on an individual function to view its description at the lower right . Double-click a function to add it to the script at the current cursor location.

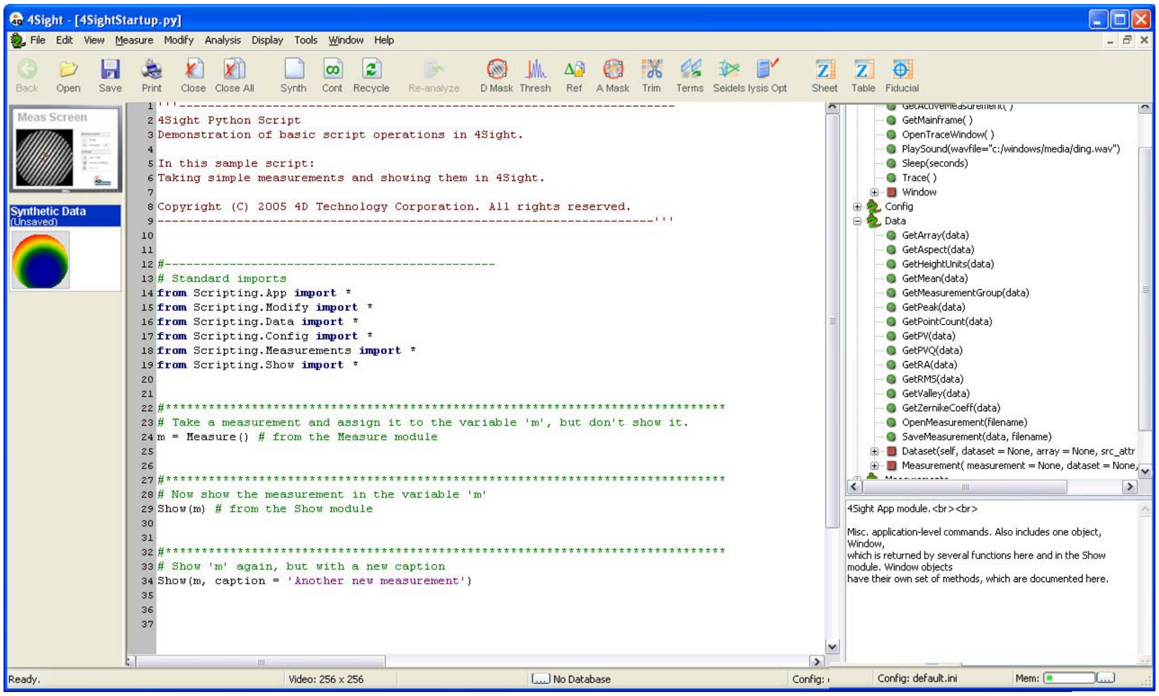
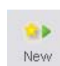


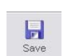
Figure 153: Scripting Screen.

Appendix *A4* contains a complete list of the functions and objects available within 4Sight's scripting interface.

To create a new script press the **New Script** 

toolbar button, or choose **File > New > Python Script**. Use the items at the right to build up the new script.

Note: More than one script can be open at any time, allowing you to compare scripts, or to cut and paste content.

To save a script click the **Save** 

toolbar button or choose **File > Save**. Provide a file name and location for the script file.

To execute a script, first open it within the Scripting Screen. Click the **Current** toolbar button 

, choose **Tools > Run Current Script**, or press **Ctrl-R** to execute it.

You can designate a **Default** script as part of the measurement configuration as well. To do so, choose **Tools > Select Default Script**, then locate and select the desired script. Now, click the **Default** toolbar button 

or choose **Tools > Run Default Script** to execute that default script, regardless of whether any other script screens are open. Choose **File > Save Config As Default** to use the script as the default in subsequent 4Sight sessions as well.

Chapter

18

Troubleshooting

This section provides miscellaneous suggestions to assist if you are experiencing difficulties with 4Sight™ software.

Common Problems

Live Video is Blank

- Check power to the interferometer and/or camera.
- Check the camera and framegrabber cable connections. If the system has been moved, the framegrabber card might need to be re-seated.
- Check for mechanical obstructions including any of the interferometer's own beam blocks.
- If the video is still not showing, determine whether 4Sight is acquiring frames from the camera. To do this, check the current frame rate, displayed on 4Sight's status bar. If a frame rate is displayed (e.g, "25 FPS) this indicates 4Sight is actually acquiring frames from the camera (although they may be very dark frames). Another check is to open the Camera Settings dialog box from the Measurement Screen and check the Show Intensity Histogram box. If the mean value and/or histogram is changing, then 4Sight is acquiring frames from the camera.
- If 4Sight is acquiring frames but they're all black, increase the camera exposure time and/or gain from the Camera Settings dialog box.
- If 4Sight is not acquiring frames (that is, the FPS is not displayed and the histogram does not update), it may be waiting for an external trigger. From the Measurement Screen choose Camera Settings > External Trigger and set it to None.
- The 4Sight hardware configuration files may have been altered or deleted. The hardware configuration is stored in text files (4Sight.ini and xxx.ini where xxx usually refers to the serial number of your interferometer). Typically the hardware configuration files are stored in "C:\4D\System". If that directory does not exist, it may be stored in your 4Sight folder, typically "C:\Program Files\4Sight\System." If these files have been deleted or moved, restore them or contact 4D Technology for assistance.
- Consult your hardware manual for more.

Live Video is Slow

4Sight allows you to view not only the live video, but also live profile plots of the video, a live intensity histogram, and a live modulation histogram. These displays update with each video frame, so they can slow down the video rate. To achieve fastest video rates, close any of the "live" displays that you're not using. Or, check the **Fast** box on the Measurement Screen to close all "live" displays.

3D Display is Slow

You can rotate or scale 3D plots in 4Sight by dragging them with the mouse. Under normal conditions the display should update quickly and smoothly, as you move the plot. If the 3D plots update slowly, you might need to look at your graphics hardware or settings.

4Sight uses a technology called OpenGL to display 3D graphics. OpenGL is supported to some degree on all Windows systems, but it works much faster if you have a reasonably good video adapter. (A "video adapter" is also called a "video board" or "graphics card"). If you're using the video output from the computer's motherboard, you can greatly increase the 3D performance by installing a video adapter. Virtually any video adapter of recent vintage will provide good performance with 4Sight.

If you already have a video adapter installed but the performance is still slow, make sure the drivers are installed properly, or update the drivers.

Overall System Performance is Slow

Each measurement on the *Measurement Stack* uses computer resources, including memory. If too many measurements are on the Stack, your system might slow down noticeably. There is no precise limit on the number of measurements you can have open, but a good guideline is to close measurements when the Measurement Stack begins to scroll. It's also a good practice to close measurements that you are not actively using.

4Sight Does Not Remember my Settings

See *Managing Configurations* for information about saving your settings.

Cannot Save the Configuration File (or Measurement File)

You might not have the correct privileges, or the disk might be full. See your administrator.

Modulation Threshold Cannot be Changed

Modulation data is not stored with averaged measurements or promoted datasets. Therefore, the modulation threshold cannot be updated unless modulation data is present.

Measurement is Missing Some or All Data

1. View the individual interferograms and verify that they appear as expected. (There are several ways to view the interferograms. You can click the **Interferograms** button at the bottom of the Measurement Screen, or if you've already promoted the measurement, select **View** > **Interferograms** > **1…n**.).

2. If the interferograms are too dark, raise the camera exposure to an appropriate level and re-measure. (See *Camera Settings* for details.)
3. The lighter fringes are "saturated" (over-exposed, or clipped), lower the camera exposure such that the live video contains no red pixels, then re-measure. (See *Camera Settings* for details.)
4. The interferograms should have good contrast. Ideally, the black fringes should be nearly black, and white fringes should be nearly white. If the entire image has low contrast, you might need to balance the reflection from the part with the reflection from the reference mirror. Consult your hardware manual for details.
5. The black and white fringes should be wide enough that each fringe is clearly visible. If the fringes run together, 4Sight cannot resolve them. Try realigning your sample to remove tilt. The sample may also have too much shape to allow measurement.
6. If a *Detector Mask* is applied, verify that it is not obscuring the data.
7. If an *Analysis Mask* is applied, verify that it is not obscuring the data.
8. Make sure the following Trimming options are not set too high: Minimum Island Size, Trim Pixels, Intensity Threshold, Modulation Threshold.
9. If a reference is subtracted the resulting measurement will have valid data only where both the measurement and the reference have valid data. Make sure the reference is appropriate for the measurement. See *Subtracting a Reference.*
10. If you are masking outside the *Unit Circle*, consider disabling this option, or increasing the Percent Clear Aperture.
11. If your interferometer is not vibration-insensitive, any vibration or turbulence can cause problems.

If none of these suggestions help, read on.

Measurement Doesn't Appear as Expected

The best way to analyze a measurement is to start at the beginning of the measurement flow and work your way downstream. Select **View > Measurement Flow**, then follow these steps to isolate the problem using the *Measurement Flow* screen:

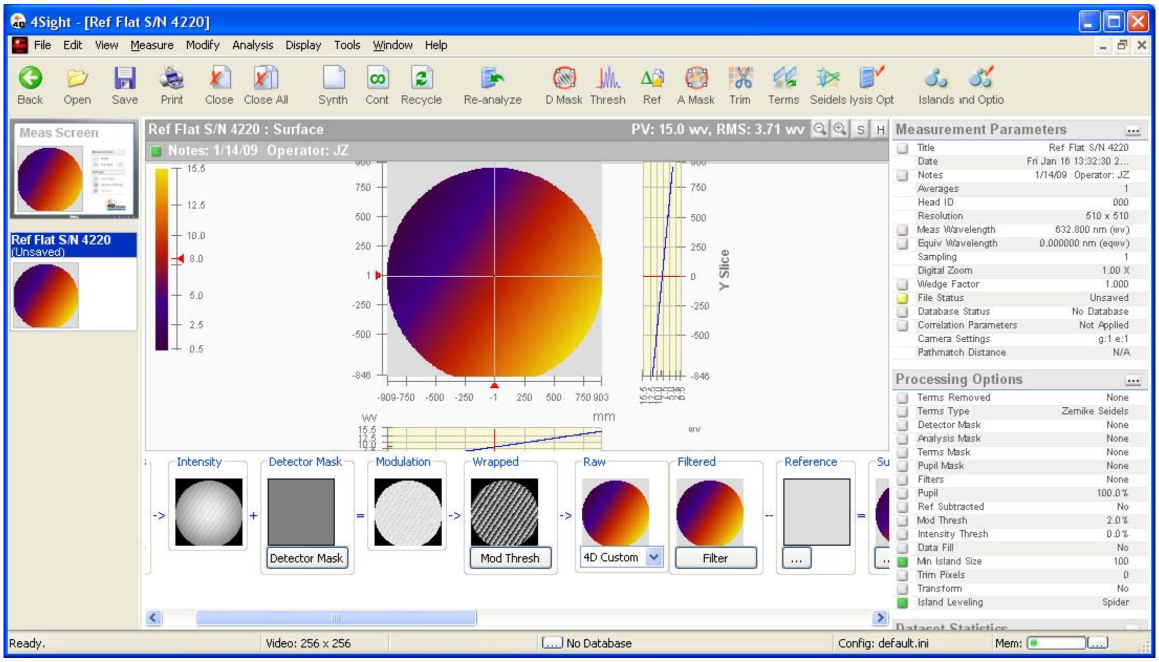


Figure 154: Measurement Flow screen.

1. Click on the **Interferograms** thumbnail at the bottom of the screen. Use the arrow buttons under the thumbnail to view each interferogram. Each interferogram should look very similar to the others. The only significant difference should be “phase-shifting” as the fringes slide laterally from one interferogram to the next. Verify that the light level is producing adequate intensity and contrast.

2. Click on the **Intensity** thumbnail. The intensity data should be relatively uniform across the entire plot. Slight ripples and slightly lower intensity near the edges are both normal. Large local fluctuations in the intensity, however, might indicate a problem with the phase shifter or calibration.

3. Click on the **Detector Mask**. A thumbnail of the mask is shown. If the thumbnail is all light-gray, there is no detector mask applied. Click the button under the thumbnail to change the detector mask.

4. Click on the **Modulation** thumbnail. The modulation should be relatively uniform, and should look very similar to the intensity dataset (except perhaps using a different color palette). The values of modulation vary widely, depending on the part and test setup, but in general values approaching 1.0 are excellent, while much lower values may be problematic.

5. Click on the **Wrapped** thumbnail. If there is missing data, you need to change the modulation threshold. Click on the button below the thumbnail to open the modulation threshold settings.

6. Click on the **Raw** thumbnail. If there are steps, or discontinuities, in the raw data, you can try a different phase unwrapper from the choices below the thumbnail. If that doesn’t help, you may need to define a detector mask that excludes edges and other problematic areas.

7. Follow the measurement through the remainder of the flow. Click the button below any problematic step to access the options to remedy the trouble.

Diagnostic Tools

4Sight includes several advanced tools to help diagnose any system or measurement problems. These tools are primarily for use by trained personnel only and are described only briefly here. To access these options choose **Tools** > **Debug**, then select one of the following:

Scripting Console Opens a new window in which a technician can type commands to explore the state of the program.

Start Debug Console Opens a new window where diagnostic messages are printed. The diagnostic information in this window contains status information as well as any error messages.

Show Hardware Config Opens the hardware configuration file in a text editor. This file should not be changed unless authorized by 4D Technology.

Appendix A1

Zernike Polynomials

The Zernike polynomials fit by 4Sight™ are shown in the table below. For a detailed discussion of Zernike polynomials and their use in optical metrology, consult Vol XI of *Applied Optics and Optical Engineering*.

$z0 = 1;$	Piston or Bias
$z1 = \rho \operatorname{Cos}[\theta];$	Tilt x
$z2 = \rho \operatorname{Sin}[\theta];$	Tilt y
$z3 = -1 + 2\rho^2;$	Power
$z4 = \rho^2 \operatorname{Cos}[2\theta];$	Astig x
$z5 = \rho^2 \operatorname{Sin}[2\theta];$	Astig y
$z6 = \rho\ (-2 + 3\rho^2) \operatorname{Cos}[\theta];$	Coma x
$z7 = \rho\ (-2 + 3\rho^2) \operatorname{Sin}[\theta];$	Coma y
$z8 = 1 - 6\rho^2 + 6\rho^4;$	Primary Spherical
$z9 = \rho^3 \operatorname{Cos}[3\theta];$	Trefoil x
$z10 = \rho^3 \operatorname{Sin}[3\theta];$	Trefoil y
$z11 = \rho^2\ (-3 + 4\rho^2) \operatorname{Cos}[2\theta];$	Secondary Astigmatism x
$z12 = \rho^2\ (-3 + 4\rho^2) \operatorname{Sin}[2\theta];$	Secondary Astigmatism y
$z13 = \rho\ (3 - 12\rho^2 + 10\rho^4) \operatorname{Cos}[\theta];$	Secondary Coma x
$z14 = \rho\ (3 - 12\rho^2 + 10\rho^4) \operatorname{Sin}[\theta];$	Secondary Coma y
$z15 = -1 + 12\rho^2 - 30\rho^4 + 20\rho^6;$	Secondary Spherical
$z16 = \rho^4 \operatorname{Cos}[4\theta];$	Tetrafoil x
$z17 = \rho^4 \operatorname{Sin}[4\theta];$	Tetrafoil y
$z18 = \rho^3\ (-4 + 5\rho^2) \operatorname{Cos}[3\theta];$	Secondary Trefoil x
$z19 = \rho^3\ (-4 + 5\rho^2) \operatorname{Sin}[3\theta];$	Secondary Trefoil y
$z20 = \rho^2\ (6 - 20\rho^2 + 15\rho^4) \operatorname{Cos}[2\theta];$	Tertiary Astigmatism x
$z21 = \rho^2\ (6 - 20\rho^2 + 15\rho^4) \operatorname{Sin}[2\theta];$	Tertiary Astigmatism y
$z22 = \rho\ (-4 + 30\rho^2 - 60\rho^4 + 35\rho^6) \operatorname{Cos}[\theta];$	Tertiary Coma x
$z23 = \rho\ (-4 + 30\rho^2 - 60\rho^4 + 35\rho^6) \operatorname{Sin}[\theta];$	Tertiary Coma y
$z24 = 1 - 20\rho^2 + 90\rho^4 - 140\rho^6 + 70\rho^8;$	Tertiary Spherical
$z25 = \rho^5 \operatorname{Cos}[5\theta];$	Pentafoil x
$z26 = \rho^5 \operatorname{Sin}[5\theta];$	Pentafoil y
$z27 = \rho^4\ (-5 + 6\rho^2) \operatorname{Cos}[4\theta];$	Secondary Tetrafoil x
$z28 = \rho^4\ (-5 + 6\rho^2) \operatorname{Sin}[4\theta];$	Secondary Tetrafoil y
$z29 = \rho^3\ (10 - 30\rho^2 + 21\rho^4) \operatorname{Cos}[3\theta];$	Tertiary Trefoil x
$z30 = \rho^3\ (10 - 30\rho^2 + 21\rho^4) \operatorname{Sin}[3\theta];$	Tertiary Trefoil y
$z31 = \rho^2\ (-10 + 60\rho^2 - 105\rho^4 + 56\rho^6) \operatorname{Cos}[2\theta];$	Quatenary Astigmatism x
$z32 = \rho^2\ (-10 + 60\rho^2 - 105\rho^4 + 56\rho^6) \operatorname{Sin}[2\theta];$	Quatenary Astigmatism y
$z33 = \rho\ (5 - 60\rho^2 + 210\rho^4 - 280\rho^6 + 126\rho^8) \operatorname{Cos}[\theta];$	Quatenary Coma x
$z34 = \rho\ (5 - 60\rho^2 + 210\rho^4 - 280\rho^6 + 126\rho^8) \operatorname{Sin}[\theta];$	Quatenary Coma y
$z35 = -1 + 30\rho^2 - 210\rho^4 + 560\rho^6 - 630\rho^8 + 252\rho^{10};$	Quaternary Spherical

Appendix

A2

Measurement Flowchart

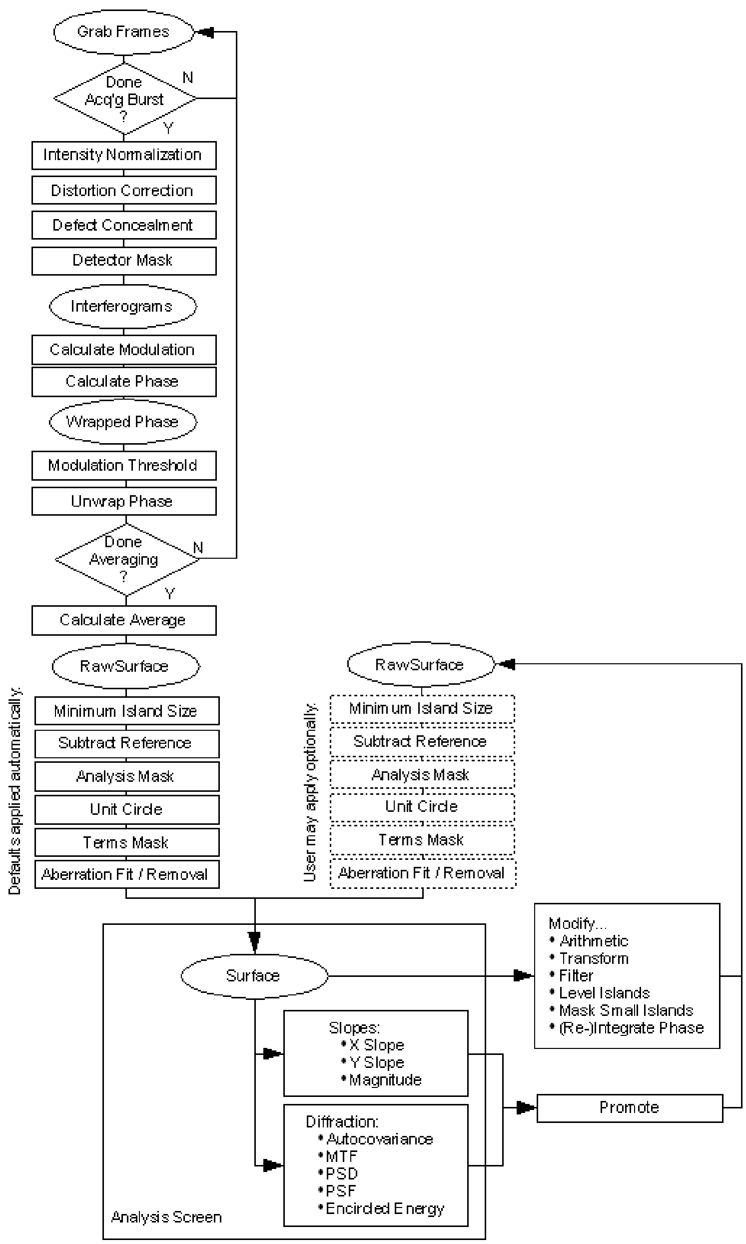


Figure 155: 4Sight Measurement Flow.

Appendix

A3

HDF5 File Format

The following table describes the contents of 4Sight's HDF5 file format. You can view the contents of an HDF5 file using the *HDF Explorer* application.

4D	The version of 4Sight used to make the measurement, date the measurement was taken, etc.
Measurement [X]	A *Grouped Measurement* may contain multiple measurements. Each measurement will have a section in the file, with X as the number of the measurement number, starting at 0. The *Camera Settings*, *Sampling* rate and other general parameters are in this level.
Analyzed	The analyzed data array and parameters: Reference subtraction parameters (See *Subtracting a Reference*) *Optical Parameters* *Trim Pixels* *Analysis Options* *Island Options* *Filters* *Data Modification* *Masking* settings.
Refdata	The *Optical Reference* measurement data array and parameters.
Aprefdata	The *Apodization Reference* measurement data array and parameters.
Intrefdata	The *Interferogram Reference* measurement data array and parameters.
Fiducials	The *Fiducials* for rigid body transformations.
Frames	The individual frames of interference data.
Frame[X]	Each frame, where X is the number of the frame.
Frame_full	All interference data, from which the individual frames are extracted.
Opts	The *Averaging* options, measurement mode (dynamic vs temporal), and other general acquisition parameters.
Genraw	The phase unwrapped data array and parameters.
Maskshapes	The shapes comprising the detector, analysis, terms and pupil masks.
Roi_rect	The dimensions and location of the current region of interest. See *Digital Zoom*.
Rubber_band_1,2	The location of the targets used when *Setting Lateral Scaling*.

Appendix

A4

Scripting Commands

Virtually any command that you can complete in 4Sight™ can also be automated using Python scripts (see *Scripting* for details). The following is a list of objects and functions available through the scripting interface. There are only a few objects, notably the Dataset and Measurement objects, both found in the Data section.

App

These are miscellaneous, application-level commands. The Window object, which is returned by several functions here and in the Show module, is included here as well.

ClearWebServiceErrorLog	Clears the Web Service error log (the error log for the optional Web Services feature is appended if an error is encountered)
ExecuteMenuOption(option, sep = '|')	Parses the given string into a menu option, and executes the option. String together the menu names (sans special characters) such as "File|Open".
ExecuteScript(fullpath)	Executes the given file as a Python script. Example: ExecuteScript('c:/4d/scripts/script0.py')
GetAcquireOptionsFrame( )	Returns the frame containing the measurement buttons (located in the Measurement Screen).
GetActiveChildWindow( )	Returns the active child window, as a Window object, or None.
GetActiveMeasurement( )	Returns the active measurement as a Measurement object.
GetCameraOptionsFrame	Returns the frame representing the Camera Options dialog box

GetCameraTemperature	Returns the operating temperature of the camera in degrees Celsius, or None if the camera does not report a temperature.
GetErrorLog	Returns a log of errors reported by 4Sight, buffered in a file and returned as one concatenated string. When this call is made, the error log file is cleared. Duplicate errors are not appended, but instead incremented and the total number of duplicate errors are displayed in parentheses next to the specific error.
GetLastMeasurement	Returns the last used measurement as a Measurement object.
GetMainframe( )	Returns the 4Sight main window as a Window object.
OpenTraceWindow( )	Opens the 4Sight debug window, a Screen to which print statements can be written. Subsequent output from the Trace function will go to this window. No return.
PlaySound(fullpath)	Plays a .wav file. If no file is specified, attempts to play a ding from Windows' default location. Example: PlaySound(wavfile="c:/windows/media/ding.wav")
Sleep(seconds)	Delays for a specified number of seconds.
Trace(string)	Sends the string to the 4Sight debug window. Open the window first using OpenTraceWindow().
ScriptingError	Generic exception handler for the script editor.
Window	Encapsulates an MDI child window, for example the default screen with a contour plot and statistics. Objects of this type are returned by several functions in the App and Show modules.
Window > Activate( )	Attempts to bring the window to the top.
Window > SetTitle(title)	Sets the window title.

Window > GetMeasurement( )	Returns the Measurement object shown in this window
Window > Close( )	Closes the window.

Config

This module provides an interface for getting and setting configuration parameters, including Measurement Options, Analysis Options, and various toolbox options such as Modulation Threshold and Subtract Reference. When parameters are changed using the set methods, the change will affect subsequent measurements only. The get methods return the parameters that will be applied to future measurements.

ClearApodizationReference( )	Disables apodization reference. No return.
ClearInterferogramReferenceSubtraction( )	Disables interferogram reference subtraction. No return.
ClearOpticalReferenceSubtraction( )	Disables optical reference subtraction. No return.
GetAutoLocateUnitCircleCenter( )	Returns True if the unit circle center location is automatic, False if located from the pupil.
GetAutoPromote( )	Returns True if new measurements are automatically promoted.
GetAutoSave( )	Returns True if new measurements are automatically saved.
GetAutoSaveFolder( )	Returns the name of the folder used for auto-saving new measurements.
GetAverageGoodPixels( )	Returns the minimum number of good pixels used in Smart Averaging.
GetAverageTermsRemoved( )	Returns the terms removed when using Smart Averaging for new measurements.
GetAveragingEqualizeIslandsEnabled( )	Returns True if Equalize Islands option of smart averaging is enabled.
GetCoordinateOrigin( )	Returns the coordinate system origin as 'center' or 'lower left' .

GetDataFillEnabled( )	Returns True if Data Fill is enabled.
GetDataFillIterations( )	Returns the number of iterations used in Data Fill.
GetIntegrationMethod( )	Returns the integration method, either 'Flood Fill' or '4D Custom' .
GetIntensityThreshold( )	Returns the current Intensity Threshold as a percentage (0-100), where 100 represents the saturation point of the camera.
GetMaskOutsideUnitCircle( )	Returns True if masking outside the unit circle is enabled.
GetMinIslandSize( )	Returns the current value of minimum island size in pixels.
GetModulationThreshold( )	Returns the current value of the modulation threshold as a percentage (0-100).
GetNewMeasurementStackPos( )	Returns where on the stack new measurements are placed: either 'Top' or 'Bottom' .
GetPercentClearAperture( )	Returns the Percent Clear Aperture as a percent of the pupil diameter.
GetPistonFitMethod( )	Returns the piston removal method, either 'average' or 'minimum height'.
GetPostProcFilter( )	Returns current post-process filter: one of 'none','lowpass','highpass','smoothing','median' or 'sigma'.
GetPostProcFilterFrequency( )	Returns the cut-off frequency used in the post-processing filter of new measurements. Applies only if PostProcFilter is lowpass or highpass.
GetPostProcFilterSigma( )	Returns the sigma width, as a number of standard deviations, used in the post-processing filter of new measurements if PostProcFilter is sigma.
GetPostProcFilterWindow( )	Returns the window size, in pixels, used in the post-processing filter of new measurements. Applies only if PostProcFilter is smooth, sigma, or median.
GetPSIAlgorithm( )	Returns the PSI algorithm, one of 'Basic','Schmit-Creath','Hariharan','Carre'.

GetPSIFrameCount( )	Returns number of frames used in phase-shifting. There is no corresponding set method, since the number of frames is determined by the PSI algorithm.
GetPVQEnabled( )	Returns True if PVq calculation is enabled.
GetPVQPercentage( )	Returns the percentage used in PVq calculation (0-100).
GetRemoveAstig( )	Returns whether astig aberration removal is enabled.
GetRemoveComa( )	Returns whether coma aberration removal is enabled.
GetRemovePiston( )	Returns whether piston aberration removal is enabled.
GetRemovePower( )	Returns whether power aberration removal is enabled.
GetRemoveSpherical( )	Returns whether spherical aberration removal is enabled.
GetRemoveTilt( )	Returns whether both x- and y-tilt aberration removal are enabled.
GetRemoveXTilt( )	Returns whether x-tilt aberration removal is enabled.
GetRemoveYTilt( )	Returns whether y-tilt aberration removal is enabled.
GetSampling( )	Returns sub-sampling factor for new measurements: 1, 2, 3, or 4 .
GetSmartAveragingEnabled( )	Returns True if Smart Averaging of new measurements is enabled.
GetTitleTemplate( )	Returns the title template for new measurements.
GetTrimPixels( )	Returns the current number of pixels to be trimmed.
OpenConfigFile(filename)	Reads the 4Sight configuration from the specified file, for example 'c:/4d/config/default.ini'. Returns True on success, else False.
PopConfig( )	Restores the most recently PushConfig-ed config. Must be preceded by a call to PushConfig() or will give an error.

PushConfig( )	Saves the current 4Sight configuration on the config stack. Use PopConfig() to restore it. Returns True on success.
SaveConfigFile(filename = None)	Saves the current configuration to the specified file, for example 'c:/4d/config/myconfig.ini', or to the default 4Sight configuration if filename is None. Returns True if the file was saved.
SetApodizationReference(data)	Enables the apodization reference and establishes the reference data. Data is a Measurement. If data is None, apodization reference subtraction is disabled. No return.
SetAutoLocateUnitCircleCenter(auto = True)	Enables automatic location of the unit circle center. If disabled, the pupil is used. No return.
SetAutoPromote(promote)	Sets whether new measurements are automatically put on the stack. 0 or 1. No return.
SetAutoSave(save)	Sets whether new measurements are automatically saved to a file. No return.
SetAutoSaveFolder(folder)	Sets the folder for auto-saving new measurements. folder is a string, for example 'c:/data/new' No return.
SetAverageGoodPixels(enabled = True)	Returns the minimum number of good pixels used in Smart Averaging.
SetAverageTermsRemoved(terms)	Sets the terms to remove when smart-averaging new measurements. Terms must be 'Tilt' or 'Tilt+Curv'. No return.
SetAveragingEqualizeIslandsEnabled(enabled = True)	Enables or disables the Equalize Islands option of smart averaging. No return.
SetCoordinateOrigin(origin)	Sets the coordinate origin to one of: 'center' or 'lower left'. No return.
SetDataFillEnabled(enabled = True)	Enables or disables Data Fill. No return.
SetDataFillIterations(iterations)	Sets the number of iterations used in Data Fill. No return.
SetIntegrationMethod(method)	Sets the phase integration method. Method is either 'Flood Fill' or '4D Custom'. No return.

SetIntensityThreshold(pixels)	Sets the Intensity Threshold percentage to a value 0-100 where 100 represents the saturation point of the camera. No return.
SetInterferogramReferenceSubtraction (refMeasurement, window = 1)	Enables interferogram reference subtraction and establishes the reference data. refMeasurement is a measurement, and window is the window size in pixels. If refMeasurement is None, interferogram reference subtraction is disabled. No return.
SetMask(string maskType, string fileName)	Sets the mask defined in the specified file as the specified mask type. maskType can be 'Analysis', 'Detector', 'Pupil' or 'Term'. If fileName is blank, the specified mask will be cleared. If maskType is also empty, all masks will be cleared. Example: SetMask('Detector', 'c:\4d\masks\detector.mask')
SetMaskOutsideUnitCircle(mask = True)	Enables automatic location of the unit circle center. If disabled, the pupil is used. No return.
SetMinIslandSize(pixels)	Sets the minimum island size in pixels. No return.
SetMeasurementModulationThreshold(float threshold, string averageOnly, int retries)	Sets the minimum acceptable modulation percentage(0 - 100) for a measurement. A threshold value of 0 disables modulation validation. averageOnly specifies whether modulation validation should occur only for average measurements. retries specifies the number of attempts to meet or exceed the threshold.
SetMeasurementPVqThreshold (float threshold)	Sets the maximum acceptable PVq value (in nm) for a measurement. The threshold is applied before aberrations are removed. A value of 0 disables PVq validation.
SetModulationThreshold(threshold)	Sets the modulation threshold to a value 0-100. No return.
SetNewMeasurementStackPos(pos)	Sets the stack position for new measurements to 'Top' or 'Bottom'. No return.
SetOpticalReferenceSubtraction(data)	Enables optical reference subtraction and establishes the reference data. Data is a Measurement or Dataset. If data is None, optical reference subtraction is disabled. No return.
SetPercentClearAperture(percent)	Sets the Percent Clear Aperture analysis option, as a percent of

	the pupil diameter. No return.
SetPistonFitMethod(method)	Sets the piston removal method to one of: 'average' or 'minimum height'. No return.
SetPostProcFilter(method)	Sets the post-process filter to one of 'none', 'lowpass', 'highpass', 'smoothing', 'median' or 'sigma'. No return.
SetPostProcFilterFrequency(frequency)	Sets frequency, used in the post-processing filter of new measurements if PostProcFilter is lowpass or highpass. Frequency is a floating-point number. No return.
SetPostProcFilterSigma(sigma)	Sets sigma width, a number of standard deviations, used in the post-processing filter of new measurements if PostProcFilter is sigma. No return.
SetPostProcFilterWindow(window)	Sets window size, in x and y pixels, used in the post-processing filter of new measurements if PostProcFilter is smooth, sigma, or median. Window must be 3, 5, 7 or 9. No return.
SetPSIAlgorithm(algorithm)	Sets the PSI algorithm. Alorithm is a string, one of 'Basic', 'Schmit-Creath','Hariharan', or 'Carre'. No return.
SetPVQEnabled(enabled = True)	Enables or disables PVq calculation. No return.
SetPVQPercentage(percentage)	Sets the percentage used in PVq calculation (0-100). No return.
SetRemoveAllAberrations(remove = True)	Enables or disables all aberration removal. No return.
SetRemoveAstig(remove = True)	Enables or disables astig aberration removal. No return.
SetRemoveComa(remove = True)	Enables or disables coma aberration removal. No return.
SetRemovePiston(remove = True)	Enables or disables Piston aberration removal. No return.
SetRemovePower(remove = True)	Enables or disables power aberration removal. No return.
SetRemoveSpherical(remove = True)	Enables or disables spherical aberration removal. No return.
SetRemoveTilt(remove = True)	Enables or disables x- and t-tilt aberration removal. No return.

SetRemoveXTilt(remove = True)	Enables or disables x-tilt aberration removal. No return.
SetRemoveYTilt(remove = True)	Enables or disables y-tilt aberration removal. No return.
SetSampling(sample)	Sets sub-sampling factor for new measurements to one of 1, 2, 3 or 4. No return.
SetSmartAveragingEnabled(enabled = True)	Enables or disables smart averaging of new measurements. No return.
SetTitleTemplate(template)	Sets the title template for new measurements. Template is a string, for example 'Mirror %N %x'. No return.
SetTrimPixels(pixels)	Sets the number of pixels to be trimmed. No return.

Data

These functions define the objects Dataset and Measurement, and provides support functions for data access. Remember that a "dataset" is a 2-dimensional array, and a "measurement" is a collection of datasets and options that specify how to process them.

In some cases the Dataset and Measurement objects hide some implementation details. For example, the 2-dimensional array encapsulated by the Dataset object might have associated pixel spacing information. The Dataset object currently does not expose this property. But if you are programming in Python, you can access this and many other properties by using the GetInternalData() method of Measurement and Dataset. If you need to do this, please contact 4D Technology for help.

GetArray(data)	Returns the underlying array of the given Dataset or a Measurement.
GetAspect(data)	Returns the aspect of the given Dataset or a Measurement.
GetHeightUnits(data)	Returns the height units of the given Dataset or a Measurement.
GetMean(data)	Returns the mean pixel value of the given Dataset or a Measurement.

GetMeasurementDate(data)	Returns the date of the given measurement.
GetMeasurementGroup(data)	Returns a list of Measurements in the same group as the specified data. Groups are created by Burst measurements and certain other operations.
GetMeasurementNumAverages(data)	Returns the number of averages in the given measurement.
GetMeasurementSampling(data)	Returns the sampling of the given measurement.
GetMeasurementTitle(data)	Returns the title of the given measurement.
GetMeasurementZoom(data)	Returns the digital zoom value of the given measurement.
GetPeak(data)	Returns the Peak statistic of the given Dataset or a Measurement.
GetPeakwithUnits(data)	Returns the Peak statistic of the given Dataset or a Measurement.
GetPointCount(data)	Returns the point count of the given Dataset or a Measurement.
GetPV(data)	Returns the PV statistic of the given Dataset or a Measurement.
GetPVwithUnits(data, analysis=None)	Returns the PV statistic of the given Dataset or a Measurement, with the units appended to the string.
GetPVQ(data)	Returns the PVQ statistic of the given Dataset or a Measurement.
GetPVQwithUnits(data)	Returns the PVQ statistic of the given Dataset or a Measurement, with the units appended to the string.
GetRA(data)	Returns the RA statistic of the given Dataset or a Measurement.

GetRAwithUnits(data)	Returns the RA statistic of the given Dataset or a Measurement, with the units appended to the string.
GetResolution(data)	Returns the resolution of the given measurement, as a string.
GetRMS(data)	Returns the RMS statistic of the given Dataset or a Measurement.
GetRMSwithUnits(data)	Returns the RMS statistic of the given Dataset or a Measurement, with the units appended to the string.
GetValidPointswithUnits(data)	Returns the point count of the given Dataset or a Measurement, with the units appended to the string.
GetValley(data)	Returns the Valley statistic of the given Dataset or a Measurement.
GetValleywithUnits(data)	Returns the Valley statistic of the given Dataset or a Measurement.
GetWavelength(data)	Returns the wavelength of the given measurement.
GetWedgeFactor(data)	Returns the wedge factor of the given measurement.
GetZernikeCoeff(data)	Returns the array of zernike coefficients of the given Dataset or a Measurement.
OpenMeasurement(filename)	Creates a Measurement object from a file. Returns the new Measurement object, or None.
SaveMeasurement(data, filename)	Saves the Dataset or Measurement to the given file name. Returns True if the file was saved.
Dataset(self, dataset = None, array = None, src_attr = None, label='')	Provides a scripting interface to an encapsulated Dataset object.
Dataset > ConvertToMeasurement(mblock =	Converts this Dataset into a scripting

None)	Measurement object. This conversion is performed automatically by most functions that can take either a Measurement or Dataset, so you should typically not need to call this.
Dataset > Copy( )	Returns a clone of this object
Dataset > GetArray( )	Returns the array object owned by the Dataset object. The array is either a Python Numeric or masked array. Its type can be found by inspecting the returned array, typically short integer for interferograms and single- precision float for phase, analyzed, and other array.
Dataset > GetInternalData( )	Returns the contained dataset object. This allows access to lower-level properties and methods, which are not documented here. Please see comments at the top of the Data module.
Measurement(measurement = None, dataset = None, mblock = None)	Provides a scripting interface to an encapsulated Measurement object.
Members of Measurement:	
Measurement >GetAnalyzedDataset( )	Returns the analyzed Dataset object. Same as GetDataset('analyzed', 'dataset')
Measurement >GetAverageModulation( )	Returns the average modulation from the most recent measurement.
Measurement >GetDataset(name = 'analyzed', subresult = None)	Returns a Dataset object. A Measurement contains a collection of Datasets. The mblock and result parameters specify which of the Datasets to return. Valid pairs of (mblock, result) include: 'frames', 'frame1' (interferogram 1) 'frames', 'frame2' 'frames', 'frame3' 'frames', 'frame4' 'frames', 'full' (hardware-dependent; typically a nearly-raw camera frame) 'intensity', 'dataset' (average of the interferograms, simulates blocked reference beam)

	'genraw', 'modulation' (modulation map) 'genraw', 'dataset' (raw phase) 'analyzed', 'dataset' (processed phase) Typically the mblocks listed above are calculated automatically when you take a measurement or open a file, so GetDataset('analyzed', 'dataset') requires no calculations. Additionally you may specify mblocks downstream of 'analyzed'. For example, on a call to GetDataset('psf', 'dataset'), 4Sight performs the Point Spread Function analysis (if it has not already been performed) and returns the resulting PSF dataset. Valid pairs of (mblock, result) downstream of 'analyzed' include: 'slopes', 'xslope' 'slopes', 'yslope' 'slopes', 'dataset' (magnitude slope), 'zernikes', 'surface' (input to zernike analysis) 'zernikes', 'fit' (best-fit dataset) 'zernikes', 'residual' (fit minus surface) 'psf', 'dataset' (Point Spread Function) 'psfee', 'dataset' (PSF Encircled Energy) 'psfqe', 'dataset' (PSF Ensquared Energy) 'geoee', 'dataset' (Geometric Encircled Energy) 'geoqe', 'dataset' (geometric ensquared energy) 'psd', 'dataset' (power spectral density) 'mtf', (modulation transfer function) 'autocovariance', 'dataset' (autocovariance) 'stepheight', 'dataset' (leveled to largest island) 'prism', 'dataset' (2 or 6 largest islands) Note you can also get a Dataset using the more general GetResult. GetDataset ensures that the returned value is indeed a Dataset, whereas GetResult returns a datatype dependent on the mblock and result requested.
Measurement >GetInternalData( )	Returns the contained measurement object. This allows access to lower-level properties and methods, which are not documented here. Please see comments at the top of the Data module.
Measurement >GetRawDataset( )	Returns the raw phase Dataset object. Same as GetDataset('genraw', 'dataset')

Measurement >Save(filename)	Saves to the given file name using the HDF5 file format. Filename should include the h5 extension ('c:/myfile.h5'). Returns True if the file was saved.
Measurement>Update( )	Ensures that the specified analysis block is up-to-date. Name can be 'frames', 'genraw', or 'analyzed'.

Hardware

These functions retrieve information from, or send instructions to, an interferometer attached to the 4Sight host computer.

AdjustFocus	Adjusts the measurement area focus by the specified number of steps. Steps can be a positive or negative value. Zero is not allowed. Returns: string (focus position or error message). *Example: AdjustFocus(-10)*
GetCameraExposure()	Returns the current exposure time of the camera in milliseconds.
GetCameraGain()	Returns the current camera gain setting.
GetFocusPosition( )	Returns the current focus position.
GetPathMatchPeakPosition( )	For systems with short coherence laser sources, returns the last found path match peak position.
PathMatch(string pathMatchFile, string fineScanOnly, string autoFineTune)	For systems with short coherence laser sources, performs a path match scan. pathMatchFile is the name of a path match settings file. If fineScanOnly is “True”, a coarse scan will not be performed. If autoFineTune is “True” a fine scan will be performed in addition to the coarse scan. Example: PathMatch('Path Match Settings',’False’, 'True')

RecalibratePathMatch(string pathMatchFile)	Homes the instrument stage and finds zero OPD, reporting the modulation percentage value at zero OPD. Returns: string (modulation or error message). pathMatchFile is the name of a path match settings file. Example: RecalibratePathMatch('Path Match Settings')

Measurements

These functions take measurements from the script, returning a Measurement object. Some functions take an "mblk" parameter which specifies how far the measurement and analysis flow should proceed. The options are 'frames' (acquire interferograms), 'genraw' (phase map processed from the interferograms), and 'analyzed' (the phase map after subtracting reference, removing aberrations, etc.). For most application, use 'analyzed'.

Acquire_frames()	Acquires the specified number of frames. Returns an int containing the number of frames acquired; a value of -1 indicates that an error occurred. **Note**: the sequence "acquire_frames(), calibrate_raw_frames(), analyze_calibrated_frames()" is equal to the Burst button on the Measurement Screen.
Analyze_calibrated_frames()	Converts calibrated camera frames to measurements. Returns an int containing the number of frames analyzed (excluding the average if calculated); a value of -1 indicates that an error occurred.
Average_frames()	Averages the specified measurements. Returns an int containing the number of frames averaged; a value of -1 indicates that an error occurred.
AverageMeasure(frameCount = 7, mblk='analyzed')	Completes an Average measurement using the specified number of measurements (frameCount). mblk must be 'raw' or 'analyzed'.

BurstMeasure(frameCount, delayms = 0.0, calcAverage = False, Manage = False)	Returns a Measurement object generated from a burst of frameCount measurements. delayms is the period to wait between measurements, in ms; calcAverage is whether to calculate the average across the burst; Manage is whether to place the measurement on the Measurement Stack.
Calibrate_and_analyze_frames()	Applies calibration to frames and convert to measurements. Returns an int containing the number of frames calibrated and analyzed (excluding the average if calculated); a value of -1 indicates that an error occurred.
Calibrate_raw_frames()	Applies calibration to frames. Returns an int containing the number of frames calibrated; a value of -1 indicates that an error occurred.
DifferenceMeasure(delay1 = 0.0, prompt1 = False, delay2 = 0.0, prompt2 = False, savesources = True)	Returns a Measurement object generated from a difference measurement. delay1 is the delay in seconds (may be fractional) before the first measurement is acquired, and prompt1 is whether to prompt the user before acquiring the first measurement. delay2 and prompt2 are similar for the second measurement. If savesources is True, the two source measurements are promoted to the stack as a burst of two, but a reference to them is currently not returned by this function.
Measure(mblk='analyzed')	Returns a new Measurement object generated from a single measurement.

Modify

These functions relate to modifying Datasets and Measurements.

Some functions take 'data' as parameters. The data parameters may be either Measurement objects or a Dataset objects. If a Measurement is passed as the data parameter, the modification is performed on the final, analyzed surface contained in that measurement, or, if there is no analyzed surface, then modification is performed on the raw phase contained in the measurement.

The parameter names indicate the type of data allowed. If the parameter name contains the word 'dataset', it must be a Dataset; if it contains measurement, it must be a Measurement, and if the parameter name is simply 'data', it may be a Measurement or Dataset.

Add(data1, data2)	Returns the sum of data1 + data2. The data items can be Datasets or Measurements.
ApplyMatrix(data, args)	Applies a transform matrix. The data can be a Dataset or Measurement. Returns a new Dataset.
AutoLocateUnitCircleCenter(measurement, auto = True)	Enables automatic location of the unit circle center. If disabled, the pupil is used. Operates in-place, no return.
Average(dataList)	Returns a new Dataset which is the average of the Datasets or Measurements in the list.
Combine(dataList)	Combines the input Datasets or Measurements such that the result at each pixel is the corresponding good pixel in any of the datasets. If more than one are good, take their average. Returns a new Dataset. Data in list is left unchanged.
CoordinateOrigin(measurement, origin)	Sets the coordinate origin to one of: 'center' or 'lower left' Operates in-place, no return.
DataFillEnabled(measurement, enabled = True)	Enables or disable Data Fill Operates in-place, no return.
DataFillIterations(measurement,iterations)	Sets the number of iterations used in Data Fill Operates in-place, no return.
DeinterlaceFilter(data)	Equalizes average values of odd and even lines, removing interlace effects. Returns a new Dataset. Data is left unchanged.
Divide(data1, data2)	Returns the quotient of data1 / data2. The data items can be Datasets or Measurements.
FlipX(data)	Flips the data 180 about the Y-axis. The data can be a Dataset or Measurement. Returns a new Dataset.

FlipY(data)	Flips the data 180 about the X-axis. The data can be a Dataset or Measurement. Returns a new Dataset.
FlipZ(data)	Inverts the data's Z coordinate. The data can be a Dataset or Measurement. Returns a new Dataset.
FourierBandpass(data, cutoff)	Applies a Fourier bandpass filter with specified cutoffs. Returns a new dataset. Data is left unchanged.
FourierHighpass(data, cutoff)	Applies a Fourier highpass filter with specified cutoff. Returns a new Dataset. Data is left unchanged.
FourierLowpass(data, cutoff)	Applies a Fourier lowpass filter with specified cutoff. Returns a new Dataset. Data is left unchanged.
Integrate(data, method=None)	Removes any two-pi errors in the phase map. Returns a new Dataset. Data is left unchanged.
IntensityThreshold(data, threshold)	Sets the Intensity Threshold, as a percent of the camera's saturation value, for the given Measurement. Operates in-place. No return.
LevelIslands(data, method=LEVEL_TILT, dbgbin=None)	Levels islands in data. Method must currently be 0. The leveled data is returned, and data is left unchanged.
MaskAbove(data, t)	Masks pixels in data with values greater than t. Returns a new Dataset. Data is left unchanged.
MaskBelow(data, t)	Masks pixels in data with values less than t. Returns a new Dataset. Data is left unchanged.
MaskInside(data, t0, t1)	Masks pixels in data with values greater than t0 and less than t1. Returns a new Dataset. Data is left unchanged.

MaskIslands(data, min_size=None)	Masks islands with area smaller than min_size pixels. Returns a new Dataset, and data is left unchanged.
MaskOutside(data, t0, t1)	Masks pixels in data with values less than t0 or greater than t1. Returns a new Dataset. Data is left unchanged.
MaskOutsideUnitCircle(measurement, mask = True)	Enables masking outside of the unit circle center. Operates in-place, no return.
MedianFilter(data, windowsize)	Applies a Median filter with specified window size in pixels. Returns a new Dataset. Data is left unchanged.
MinIslandSize(data, pixels)	Applies the specified minimum island size, in pixels, to the data, in-place. Islands with area less than min_island_size pixels will be masked. No return.
ModulationThreshold(data, threshold)	Sets the Modulation Threshold, as a percent, for the given Measurement. Operates in-place. No return.
Multiply(data1, data2)	Returns the product of data1 * data2. The data items can be Datasets or Measurements.
PercentClearAperture(measurement, percent)	Sets the Percent Clear Aperture analysis option Operates in-place, no return.
PistonFitMethod(measurement, method)	Sets the piston removal method to one of: 'average' or 'minimum height' Operates in-place, no return.
PVQEnabled(measurement, enabled = True)	Enables or disable Q Peak-Valley calculation Operates in-place, no return.
PVQPercentage(measurement, percentage)	Sets the percentage used in Q Peak-Valley calculation. Operates in-place, no return.
RemoveAberrationTerm(data, term, remove = True)	Removes one aberration term from the data. The data can be a Dataset or Measurement. Generally you should not call this, instead

	call RemoveTilt, etc.
RemoveAstig(data, remove = True)	Removes astig aberration from the measurement in-place. No return.
RemoveComa(data, remove = True)	Removes coma aberration from the measurement in-place. No return.
RemovePiston(data, remove = True)	Removes piston from the measurement in-place. No return.
RemovePower(data, remove = True)	Removes power from the measurement in-place. No return.
RemoveSpherical(data, remove = True)	Removes sperical aberration from the measurement in-place. No return.
RemoveTilt(data, remove = True)	Removes X & Y tilt from the measurement in-place. No return.
RemoveXTilt(data, remove = True)	Removes X tilt from the measurement in-place. No return.
RemoveYTilt(data, remove = True)	Removes Y tilt from the measurement in-place. No return.
Resize(data, scale)	Resizes dataset laterally, both x and y, by scale (1.0 retains same size) and return a new Dataset. Anisotropic resizing is not supported by this function. Data is left unchanged.
Rotate180(data)	Rotates the data about Z by 180 degrees. The data can be a Dataset or Measurement. Returns a new Dataset.
RotateCCW90(data)	Rotates the data about Z by 90 degrees counter-clockwise. The data can be a Dataset or Measurement. Returns a new Dataset.
RotateCW90(data)	Rotates the data about Z by 90 degrees clockwise. The data can be a Dataset or Measurement. Returns a new Dataset.

Scale(data, factor)	Returns a new Dataset scaled by factor. Data is left unchanged.
SeparateIslands(meas)	Separates a Measurement containing multiple islands into a grouped measurement containing one island each. (4D Todo: this should be able to take a Dataset also.)
SigmaFilter(data, sigma_width, window_size)	Applies a Sigma filter with specified sigma_width as a number of standard deviations, and specified window size in pixels. Returns a new Dataset. Data is left unchanged.
SmoothingFilter(data, windowsize)	Applies a Smoothing filter with specified window size in pixels. Returns a new Dataset. Data is left unchanged.
Subtract(data1, data2)	Returns the difference of data1 - data2. Data items can be Datasets or Measurements.
SubtractApodizationReference(measurement, referenceData)	Subtracts the apodization reference data from the given measurement. If 'referenceData' is None then the subtraction is disabled.
SubtractInterferogramReference(measurement, reference)	Subtracts the interferogram reference data from the given measurement. If 'referenceData' is None then the subtraction is disabled. Modifies the measurement in-place. No return.
SubtractOpticalReference(measurement, referenceData)	Subtracts the optical reference data from the given Measurement. If 'referenceData' is None then the subtraction is disabled.
Transform(data, dict)	Applies a transform. The data can be a Dataset or Measurement. Returns a new Dataset. dict is a dictionary with the following keys: 'flipped': 0 or 1, defaults to 0 'pre_translate_x': defaults to 0.0 'pre_translate_y': defaults to 0.0 'scale_x': defaults to 1.0

	'scale_y': defaults to 1.0 'rotate_deg': defaults to 0.0 'post_translate_x': defaults to 0.0 'post_translate_y': defaults to 0.0 'interpolate': defaults to "None", other options are: "linear","spline" or "catmull"
TrimPixels(data, pixels)	Sets the number of pixels to erode from the data. The number of pixels does not accumulate across subsequent calls. Operates in-place. No return.

Show

These functions are for showing Measurements and Datasets. The Show(...) function is the most commonly used function in this module. It displays the data in the default window, with specified title. This module also includes some basic message boxes.

CreateProgressWindow(title=’Running 4Sight Script’, message=’Performing Step 1’, Max=100	Returns a new Progress Window. Title is displayed in the window's title bar. Message is displayed inside the window. Maximum is the number of steps. Note you MUST call the window's Close() method when finished.
MessageBox(text, caption = '4Sight')	Displays a message box with an OK button. No return value.
MessageBoxOK(text, caption = '4Sight')	Displays a message box with an OK button. No return value.
MessageBoxOKCancel(text, caption = '4Sight')	Displays a message box with OK and Cancel buttons. Returns True if the user clicks OK.
MessageBoxYesNo(text, caption = '4Sight')	Displays a message box with Yes and No buttons. Returns True if the user clicks Yes.
MultipleChoice(text, caption = ‘4Sight’)	Displays a list of choices and return the selected strings as a tuple. Choice is a list of strings.
SaveJPEG(data,filename, mblock=’analyzed’, result=’dataset’)	Saves a Measurement, Dataset, array or file as a JPEG using the default display, typically the contour plot. Typically the

	default values of mblock and result are what you want, however you may specify them as follows: If data is a Measurement, mblock specifies which Dataset to show, and may be 'frames', 'genraw', or 'analyzed'. If mblock is 'frames', result may be 'frame1', 'frame2'...; if mblock is 'genraw', result may be 'moduation' or 'dataset'; and if mblock is 'analyzed'; 'result' must be 'dataset'. If data is a Dataset, mblock must be 'analyzed' and result must be 'dataset'. Finally, regardless of whether data is a Measurement or a Dataset, you may specify mblocks beyond 'analyzed', for example 'psf' to show a point spread function, although the ShowPSF and related functions provide a simpler way to do this. Title is displayed on the titlebar of the window. Returns True (if successful) or False.
Show(data, mblock='analyzed', result='dataset', title='')	Displays a Measurement, Dataset, array or file using the default display, typically the contour plot. Typically the default values of mblock and result are what you want, however you may specify them as follows: If data is a Measurement, mblock specifies which Dataset to show, and may be 'frames', 'genraw', or 'analyzed'. If mblock is 'frames', result may be 'frame1', 'frame2'...; if mblock is 'genraw', result may be 'moduation' or 'dataset'; and if mblock is 'analyzed'; 'result' must be 'dataset'. If data is a Dataset, mblock must be 'analyzed' and result must be 'dataset'. Finally, regardless of whether data is a Measurement or a Dataset, you may specify mblocks beyond 'analyzed', for example 'psf' to show a point spread function, although the ShowPSF and related functions provide a simpler way to do this. Title is displayed on the title bar of the window, and caption is displayed smaller

	somewhere in the window. Returns a new Window object.
Show3FlatTest( )	Absolute flat test (3-flat test). No return value.
Show3SphereTest( )	Absolute calibration (3-sphere test). No return value.
ShowAutoCovariance(data=None)	Autocovariance analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowCubeAnalysis(data=None)	Corner cube prism analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowDirectCavityAnalysis(data=None)	Direct Cavity analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowDiskAnalysis(data=None)	Disk analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowEncircledEnergy(data=None)	Diffraction encircled energy analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowEnhancedSegmentResolution(data=None)	Show Enhanced segment resolution of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowEnsquaredEnergy(data=None)	Diffraction ensquared energy analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowFiducial(data=None)	Fiducial transform of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowGaussianAnalysis(data=None)	Gaussian distribution analysis of the given Dataset or Measurement, or of the active Measurement. No return value.

ShowGeometricEncircledEnergy(data=None)	Geometric encircled energy of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowGeometricEnsquaredEnergy(data=None)	Geometric ensquared energy of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowGeometricSpotDiagram(data=None)	Geometric spot diagram of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowGlassDefectAnalysis(data=None)	Gaussian distribution analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowHist(data, mblock='analyzed', result='dataset', title='')	Displays a measurement, dataset, or or filename using the histogram display. See Show() for explanation of parameters. Returns a new Window object.
ShowIntensity(data=None)	Displays Intensity dataset of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowIntensityDistAnalysis(data=None)	Intensity distribution analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowIslandAnalysis(data=None)	Island analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowMeasurementFlow(data=None)	Displays Measurement Flow screen of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowMicrowavinessAnalysis(data=None)	Disk analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowMTF(data=None)	MTF analysis of the given Dataset or Measurement, or of the active Measurement. No return value.

ShowNewMeasurement(title = '')	Acquires a new measurement and show it in a contour view window. Returns a new Window object, or None.
ShowPrismAnalysis(data=None)	Right Angle Prism analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowPSD(data=None)	Diffraction PSD analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowPSF(data=None)	Diffraction PSF analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowQCFrame( )	Displays QC screen. No return value.
ShowShopScreen(data=None)	Displays Shop Screen of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowSlopeAll(data=None)	All-slope analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowSlopeMagnitudes(data=None)	Slope magnitude analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowSlopeX(data=None)	X-slope analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowSlopeY(data=None)	Y-slope analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowStepAnalysis(data=None)	Step analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowThicknessAnalysis(data=None)	Thickness analysis of the given Dataset or Measurement, or of the active Measurement.

	No return value.
ShowWaveCamSpotAnalysis(data=None)	WaveCam spot analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowZernikeTable(data=None)	Zernike table analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
ShowZernikeWorksheet(data=None)	Zernike Worksheet Analysis of the given Dataset or Measurement, or of the active Measurement. No return value.
TextBox(text, caption = '4Sight')	Displays a scrollable text message box with an OK button. Suitable for long text messages. Supports copy to clipboard. No return value.
ProgressWindow	A progress window with a cancel button. This is useful for long processes.Use CreateProgressWindow to create an object of this type. Note you MUST call the window's Close() method when finished.
ProgressWindow > Close()	Dismisses the window. (This will happen automatically if the user cancels.)
ProgressWindow . Update(value=-1, new_message=")	Updates the progress with a new value and new message. Returns False if the user has pressed the cancel button, True otherwise.

QC

These functions are available in 4Sight's QC mode only.

CalibrateIntensity( )	Production | Calibrate Intensity
GetDistortionCorrection( )	Returns True if distortion correction is enabled.
GetDistortionCorrectionAvailable( )	Returns True if Distortion Correction is an

	available option.
GetFactoryRectReduction( )	Returns True if factory rect reduction is enabled.
GetFactoryRectReductionAvailable( )	Returns True if Factory Rect Reduction is an available option.
GetIntensityCorrectionMethod( )	Returns the string representing the intensity correction method.
ImportRawPhase(filename)	Creates a measurement from raw phase data in the specified file.
SetDistortionCorrection(enabled)	Enables or disables distortion correction.
SetFactoryRectReduction(enabled)	Enables or disabled factory rect reduction.
SetIntensityCorrectionMethod(method)	Sets the Experimental Intesity Calibration method to one of 'None', 'Quadrant', or 'Pixel'.
ShowFourierWorksheet(data=None)	Fourier worksheet analysis.
ShowFringeFit(data=None)	Measure | Production | Diagnostics |Fringe Fits.
ShowIntensityAverages(data = None)	Displays QC intensity averages.
ShowIntensityCorrections( )	Measure | Production | Calibrate Intensity | Experimental... | View Current...
ShowLissajous(data=None)	Measure | Production | Diagnostics | Lissajous Figure.
ShowPhaseStep(data = None)	Displays phase step dataset.
ShowPixelatedPhaseError(data=None)	Measure | Production | Diagnostics | Pixelated Phase Error.

Appendix

A5

Mask Format

The following information provides the format of 4Sight masks such that you can design and use masks created out side of 4Sight.

4Sight mask files have file extension ".mask" and are in configuration file (.ini) format. Each mask shape is defined by a row in the file. The basic format is as follows:

[Mask]

Shape0=type|coordinates|mask-mode|id|creation-rect

Shape1=type|coordinates|mask-mode|id|creation-rect

Shape2=type|coordinates|mask-mode|id|creation-rect

…

Rect=(0, 0, 510, 510)

where

Type = the type of shape:

- circle (defined as a square ellipse)
- c3 (circle defined by 3 arc points)
- rect (rectangle)
- ellipse
- polygon (polygon or n-gon)
- cube (corner cube)
- prism (right angle prism)
- spider.

Coordinates = location of the points required to define each shape. All coordinates are in pixels, and all rotation and angle values are in degrees:

- circle: left, top, width and height of a rectangle enclosing the circle
- c3: point1, point2, point3, aspect ratio

- rect: x and y location of the four corners, followed by rotation
- ellipse: left, top, width and height of rectangle enclosing the ellipse
- polygon: (x and y location of each vertex)
- prism: (x and y location of the outer corner of the shape, followed by points defining the inner edges of both rectangles)
- cube: left, top, width and height of a rectangle enclosing the shape, followed by the rotation and the width between the faces
- spider: left, top, width and height of a rectangle enclosing the shape, followed by rotation, spacing between the legs, number of legs, and angle of each leg.

Mask-mode = "Mask Outside", "Mask Inside", or "Pass Inside"

ID: default is zero

Creation-rect: The array size when the shape was created. The default values are 0, 0, width of array, height of array. It is not modified after creation.

Rect - (left, top, width and height of the rectangle bounding the entire mask.

For example, the file below is a mask consisting of four shapes:

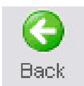
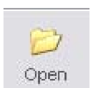
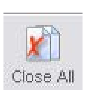
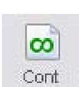
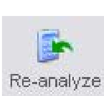
```
[Mask]
Shape0=circle|12.1439848148, 15.6709557692, 492.765972279,
492.765972279|Mask Outside|0|0.0,0.0,510.0,510.0
Shape1=c3|127.5,63.5,63.5,127.5,133.496932515,122.503067485,1.000000|Ma
sk Outside|0|0.0,0.0,256.0,256.0
Shape2=rect|(124.22801635991821,
117.9458077709611),(191.50000000000003,117.94580777096112),(191.5000000
0000009, 191.5),(124.22801635991823, 191.49999999999997),|Mask
Inside|0|0.0,0.0,256.0,256.0
Shape3=polygon|(239.0, 228.0),(184.0, 60.0),(129.0, 87.0),|Mask
Inside|0|0.0,0.0,256.0,256.0
Rect=(0, 0, 510, 510)
```

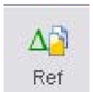
Appendix

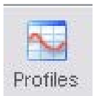
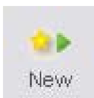
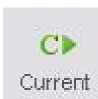
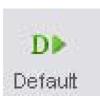
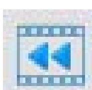
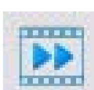
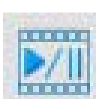
A6

Toolbar Buttons

The following buttons are available as part of the 4Sight™ toolbar. Note that some buttons may be disabled or hidden, depending upon your preferences and the current software state. See *Toolbar* for more details.

	**Back** returns you to the analysis screen you last viewed.
	**Open File** lets you open a stored file from disk.
	**Save File** lets you store a file to disk.
	**Print** sends the current screen content to the printer.
	**Close** closes the currently active measurement.
	**Close All** closes all open measurements.
	**Synth** lets you generate a synthetic data.
 	**Cont** initiates a *Continuous Measurement*. **Stop** ends the measurement.
	***Recycle*** takes a new measurement and displays it in the current analysis window.
	***Reanalyze*** opens the current measurement in the Measurement Screen.

	**DMask** opens the Edit Mask dialog box for editing the *Detector Mask*.
	**Thresh** opens the Signal Thresholds dialog box where you can adjust the Modulation and Intensity thresholds (See *Trimming* for details).
	**Ref** opens the Reference Subtraction dialog box where you can specify reference measurements and options (See *Subtracting a Reference*).
	**A Mask** opens the Edit Mask dialog box for editing an *Analysis Mask.*
	**Trim** opens the *Trim Pixels* dialog box where you can choose to erode less reliable pixels from the edges of data.
	**Terms** opens the Edit Mask dialog box for editing an *Terms .*
	**Seidels** opens the *Aberrations Removal* dialog box, where you can specify which combination of Seidel aberrations can be subtracted.
	**A Opts** opens the *Analysis Options* dialog box
	**Sheet** opens the *Zernike Worksheet*.
	**Table** opens the *Zernike Table*.
	**Fiducial** opens the *Fiducial Worksheet.*
	**Islands** performs an *Island Analysis* on the current measurement.
	**Isl Opts** opens the *Island Options* dialog box.
	**Contour** displays the current measurement as a *Contour Plot.*
	**3D** displays the current measurement as a *3D Plot..*

	**Hist** displays the current measurement as a *Histogram Plot.*.
	**Profiles** displays the current measurement as an *XY Slice.*
	**Multi** displays the current measurement as a *Multi-plot.*
	**Shop** displays the current measurement in the *Shop Screen.*
	**New Script** opens the Scripting Screen where you can develop a new automation script. See *Scripting* for details.
	**Current** runs the currently selected automation script. See *Scripting* for details.
	**Default** runs the designated "Default" script. See *Scripting* for details.
	**Save** creates a .avi movie file from a *Grouped Measurement* and saves it to disk.
	**Previous** moves to the prior measurement in a *Grouped Measurement*.
	**Next** moves to the subsequent measurement in a *Grouped Measurement*.
	**Play/Pause** starts and stops the animated playback of a *Grouped Measurement*.

Appendix

A7

Warranty

The following sections provide the standard 4D Technology warranty policy.

Warranty on New Systems and Accessories

Seller warrants to the original Buyer that new equipment will be free of defects in material and workmanship for a period of one year commencing at acceptance or 60 days from shipment, whichever comes first. This warranty covers parts and labor, including field service and travel if applicable.

Seller does not warrant that any equipment or system can be used for any particular purpose other than that covered by the applicable published specifications. Seller warrants to the original Buyer that the software will perform in substantial compliance with the written materials accompanying the software. Seller does not warrant uninterrupted or error-free operation.

Seller's obligation under these warranties is limited to repairing or replacing, at Seller's option, defective, non-expendable parts or software. Seller warrants to the original Buyer that replacement parts will be new or of equal functional quality and warranted for the remaining portion of the original warranty. These services will be performed at Seller's option at either the Seller's facility or Buyer's location. Buyer must contact Seller in advance for authorization to return defective material and follow Seller's shipping instructions. Freight charges to Seller's facility are Buyer's responsibility. Seller will return material to Buyer's location at Seller's expense.

The warranty obligation of Seller shall not extend to defects that do not impair service or to provide warranty service beyond normal business hours, Monday through Friday excluding Seller holidays. Buyer must alert Seller within 30 days of the discovery of a defect.

Seller assumes no liability under the above warranties for equipment failures resulting from abuse, misuse, modification, or mishandling, damage due to external forces, acts of God, flooding, power surges, power failures, defective electrical work, improper operation or maintenance or failure to perform preventive maintenance.

Warranty on Replacement Parts

Seller warrants all purchased replacement parts will be free from defect in materials and workmanship for a period of 90 days from date received by Buyer. Seller will repair or replace at its discretion such parts when returned to Seller.

Warranty on Used Equipment

Unless otherwise noted on quotation or invoice, all used parts or systems sold by Seller are sold AS IS without warranty of any kind.

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Scheduling Repair or Service

If you have a problem and need assistance, please contact us at the 4D Technology Corporation main office in Tucson, Arizona at (520) 294-5600 during normal business hours. Be sure to have the model number, serial number, nature of problem, date of original shipment and/or your purchase order number available. We will determine if you need to return a part or your instrument to 4D for service and will provide you with a return authorization number (RA number.) This number must be displayed on the shipping container. Equipment returned to 4D without authorization will be returned. If a service visit is required we will make the necessary arrangements and contact you to schedule the visit.

Appendix

A8

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Glossary

Aberration	Deviation of a wavefront (or surface) from an ideal wavefront, which may be flat or may have a certain shape by design.
Analyzed Data	The raw data after performing any user-specified processing, including masking, aberrations removal, island removal, reference subtraction, etc.
Dataset	A 2-dimensional data array, along with scaling factors and other auxiliary information. Examples of datasets include Interferograms, Unwrapped Data, and Surface Data. See also: Measurement.
Frame	A single image acquired from the camera or other source. For many applications each camera frame represents one interferogram, so the two terms are often used synonymously.
Fringe	A single white or black band in an interferogram, corresponding to maximum constructive or destructive interference respectively.
Grouped Measurement	A series of measurements with a defined order, such that they can be played like a movie. A burst measurement is an example of a grouped measurement.
Integration	Same as Unwrapping.
Integration Error	Same as Unwrapping Error.
Intensity Data	The average of the interferograms. Intensity data is an artificial dataset that approximates what the part would look like under “normal” lighting, without interference, since averaging the phase-shifted interferograms tends to cancel the fringes.
Interference	An interaction between two beams of light, wherein the beams add constructively (sum) at some points and add destructively (cancel) at other points.
Interferogram	An image having black and white bands (fringes) caused by interference between two beams of light.
Measurement	A collection of (a.) datasets, including interferograms and other datasets calculated from the interferograms, (b.) analysis options which define how to process the datasets, and (c.) auxiliary information including the date and time,

title, masks, and fiducials.

Modulation	The degree to which a pixel changes intensity across interferograms as the phase is shifted. The ideal modulation is 1.0, although much lower signals can be measured with satisfactory results.
OPD	Optical Path Difference. Same as wavefront. Refers to the fact that an interferometer measures the difference between the lengths of the optical paths traveled by a reference beam and by a test beam.
Phase	The difference between the phases of the two interfering beams. When the two beams are “in phase” with each other and add constructively, the phase is said to be zero; when the two beams are “out of phase” with each other and add destructively, the phase is said to be pi, or 180 degrees.
Phase Shifting	It is possible to estimate a wavefront from a single interferogram. However, much more accurate results can be achieved by acquiring multiple (typically 4 or 5) interferograms while successively shifting the phase of one of the beams by a known amount between each interferogram. This process is called phase-shifting interferometry.
Raw Data	Same as Unwrapped Data.
Reference Data	A dataset, usually representing systemic aberration or shape, which is to be subtracted from a measurement, leaving only the shape of interest.
Seidel Polynomials	A set of polynomials often used in optical design.
Surface Data	Same as Analyzed Data. Implies the measurement was made using a beam reflected off a surface, as opposed to a transmitted wavefront.
Unwrapped Data	Wrapped data after unwrapping.
Unwrapping	The process of resolving two-pi ambiguities in the phase data. Unwrapping transforms the sawtooth-shaped wrapped data into smooth unwrapped data.
Unwrapping Error	Errors in the unwrapping process, resulting in a two-pi discontinuity even in the unwrapped data. Often the discontinuity propagates from a noisy edge or spike; eliminating the noisy area with a detector mask often fixes the error.
Wavefront	A surface joining all points at which a propagating beam of light has equal phase. If a part is being measured by reflecting the beam off the part, then wavefront is synonymous with surface.
Wavelength	The wavelength of the laser used in the interferometer. Wavelength, along with wedge, is needed to convert phase into real-world units.

Wedge	The number of waves of light represented by each fringe. Wedge, along with wavelength, is needed to convert phase into real-world units.
Wrapped Data	A dataset of the phase. Since phase varies from zero to two-pi and then wraps back to zero, the wrapped data has a sawtooth shape.
Zernike Polynomials	A set of orthogonal polynomials with certain characteristics that make them especially useful for characterizing optical wavefronts.
Zoom	Various features that increase the size of a particular region of interest. Optical zoom increases the actual magnification of the interferometer. Digital zoom enlarges a small region to fill the window.

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