BeamGage®

User Guide

Laser Beam Analyzer

For Windows 7® and Windows 10®

BeamGage Standard Edition Version 6.x

BeamGage Professional Edition Version 6.x

Notice for Adobe Reader XI Users

If the BeamGage "What's This" help feature only opens this User Guide at this page, see section 2.1.2 for instructions on how to configure Adobe Reader XI to correct this problem.

For Sales, Service or Technical Support

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Ophir-Spiricon, LLC
3050 North 300 West
N. Logan, Utah 84341

Dear Ophir-Spiricon Customer,

Please accept our sincerest appreciation for the recent purchase of your new BeamGage system! It is truly our pleasure to serve you.

Here at Ophir-Spiricon we strive to provide the highest level of leading edge photonic measurement technology and service. We know that your experience with us will be a pleasant one and the relationship we build will serve your photonic measurement needs for years to come. As a valued customer, your comments and opinions are very important to us. If you have any questions, comments, or concerns please feel free to contact our service department. We are eager to help with everything from basic setup, to finding solutions for the most complex photonics measurement needs.

Thank you for your business. We look forward to serving you.

Sincerely,

Ophir-Spiricon, LLC

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Obtain the latest version of this user guide at http://www.ophiropt.com/laser-measurement-instruments/beam-profilers/services/manuals.

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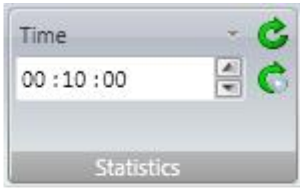
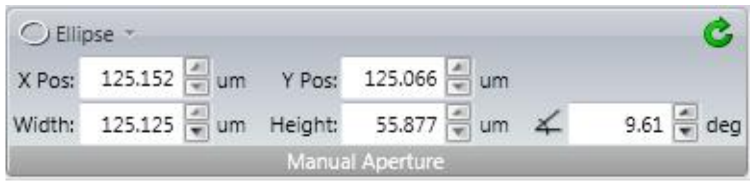
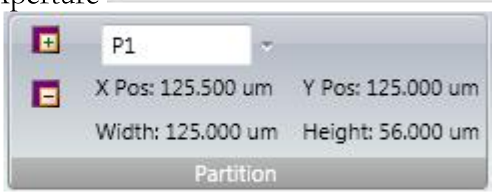
Pass/Fail

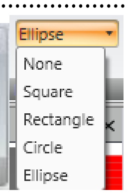

Time
00 :10 :00
Statistics


Ellipse
X Pos: 125.152 um
Y Pos: 125.066 um
Width: 125.125 um
Height: 55.877 um
9.61 deg
Manual Aperture


P1
X Pos: 125.500 um
Y Pos: 125.000 um
Width: 125.000 um
Height: 56.000 um
Partition


Auto


Ellipse
Beam Width


Ellipse
None
Square
Rectangle
Circle
Ellipse


Beam Profile X
Beam Profile Y

Safety

While BeamGage itself does not present the user with any safety hazards, this instrument is intended for use with laser systems. Therefore, the user should be protected from any hazards that the laser system may present. The greatest hazards associated with laser systems are damage to the eyes and skin due to laser radiation.

Optical Radiation Hazards

With almost any camera used with the BeamGage, the optical radiation at the camera sensor is low enough to be considered relatively harmless. Nevertheless, use of this instrument may require the user to work within the optical path of lasers. Exposure to radiation from these lasers may be sufficient to warrant the use of protective equipment.

Unless the laser's optical path is enclosed, the user should be protected against accidental exposure. Exposure to personnel other than the user must also be considered. Hazards include direct beam exposure and reflected radiation.

When working with an unenclosed beam path, it is advisable to do so while the laser is powered down or at reduced power levels. Whenever there is a risk for dangerous exposure, protective eye shields and clothing should be worn.

Electrical Hazards

BeamGage utilizes only low voltages, derived from the IEEE-1394 bus, USB bus, and camera power supplies. Thus there is little risk of electrical shock presented to the user.

When installing or removing hardware form a PC, the power to the computer should always be disconnected.

The computer should always be operated with its covers in place and in accordance with its manufacture's recommendations.

The computer should always be operated with a properly grounded AC power cord.

General Information about BeamGage

Introduction to BeamGage

The Ophir-Spiricon Laser Beam Analyzer, BeamGage, is a low cost, PC-based product for use in modern multi core advanced Pentium-generation personal computers running the Windows 7 or later operating systems. Some of these features include:

- High-speed high-resolution false color beam intensity profile displays in both 2D and 3D
- Operates in Windows 7 (32/64) and later MS operating systems (not all cameras supported in 64bit versions)
- Numerical beam profile analysis employing advanced patented calibration algorithms
- Extensive set of ISO quantitative measurements
- Three Divergence measurement techniques, one ISO method
- Full ISO TopHat results
- All ISO beam width and diameter methods supported
- ISO plus expanded Gauss fit capabilities for both 1D and 2D
- Enhanced window layout tools to get the most out of the desktop display area
- Pass/fail testing available on most all measured parameters
- Support for USB, FireWire, Gig-E, and Pyrocam
- New **BeamMaker** beam simulator for algorithm self-validation. BeamMaker is a trademark of Ophir-Spiricon, LLC.
- Results synchronized to select models of Ophir power/energy meters
- Supports satellite windows on multiple monitors
- Continuous zoom scaling in both 2D and 3D
- Camera ROI support on USB, FireWire, and Gig-E cameras
- Expanded beam stability results in the form of strip chart and scatter plots
- Industry standard data file formats, HDF5 and CSV
- Video Playback console for review and post processing
- Configurable Report Generator that allows cut and paste of results, images, and settings from .PDF file types
- .NET Automation interface that allows for third party remote control
- Statistical Analysis of all measured parameters
- The ability to program Custom Calculations results
- Histogram display and results
- Both Manual and Auto Aperture for isolating beam data
- Off axis aspect ratio image correction
- Both Results and Data logging capabilities with multiple logging methods
- Integrated automatic Help linked into this .PDF Users Guide

A complete BeamGage system consists of the following equipment:

- Spiricon BeamGage software
- FireWire, USB, or Gig-E camera with interconnect cables, an External Trigger cable, and external power supply, when applicable
- A multi-core Pentium (2.00 GHz or better) style or equivalent PC with Windows 7 (32/64) or Windows 10 (32/64) operating system
  - IEEE-1394a/b (FireWire) bus interface, either built into the computer, motherboard, or installed via PCI card
  - Advanced Graphics chip set w/256MB of dedicated graphics memory
  - At least 2 GB of main memory, 4 GB is better
  - At least 50 GB of hard disk space available
  - A high-resolution color monitor, 1440x900 minimum recommended.
  - A CD-ROM Drive

The following Windows Experience Index values are recommended:

Component	Desktop	Laptop
Processor	4.4	4.7
Memory (RAM)	4.5	4.8
Graphics	3.5	3.4
Gaming graphics	3.0	3.8
Primary hard disk	5.0	4.0

Optional equipment:

- IEEE-1394 hub for connecting multiple cameras to one IEEE-1394 bus
- A printer with appropriate Windows compatible drivers
- LBS-300, LBS-100, or other Laser Beam Attenuator
- USB-TTL Pass/Fail signaling option, order SP90060

Most laser beams require significant amounts of attenuation before application to the camera sensor. Attenuation requirements vary greatly depending upon application. Spiricon offers optional equipment for beam attenuation. Consult your Ophir-Spiricon Representative or call Ophir-Spiricon's Sales Department for further information.

Camera specification:

See appropriate Appendix for information regarding camera specifications.

Important: ***Your Windows PC must have all of the latest Microsoft updates and service packs installed to insure successful operation with BeamGage. Install all updates before installing BeamGage.***

How to Use This User Guide

Read this user guide before setting up your BeamGage system. Become familiar with the laser beam analysis theory and acquire a basic understanding of how BeamGage operates. Insights gained through this review will facilitate achieving a correct system setup, and help with interpreting results.

Chapter 1 Equipment Setup Provides getting started instructions, and describes how to utilize some pre-canned setups that can speed up collecting useful beam data for the first time user.

Chapter 2 BeamGage Operating Controls Describes all the various displays, control panels, menus, and dialog boxes in detail, along with configuration considerations and optimization techniques.

Chapter 3 Displays Explains how to employ the many display controls that are used to launch, dock, float, pin, and hide the various display components.

Chapter 4 Files, Formats and Privileges Describes the types of file formats generated by BeamGage and some of the things that can be done with them. Also how to lockout controls for restricted users.

Chapter 5 Computations Presents background information on the theory behind the laser beam measurements and the ISO measurement methods, as well as the new BeamMaker modeling feature.

Chapter 6 Partitioning Presents instructions on how to use the BeamGage Partitioning feature available only in Professional edition.

Chapter 7 Custom Calculations Presents instructions on how to use the BeamGage Custom Calculations Server available only in Professional edition.

Chapter 8 Automation Interface Presents instructions on how to use the BeamGage Automation Server available only in Professional edition.

CHAPTER 1 Equipment Setup

Read the previous Introduction to BeamGage section to learn what type of computer is needed to best operate with the advanced windowing features design into BeamGage. This chapter will instruct how to:

- Install the BeamGage application
- Connect the camera
- Launch BeamGage
- Configure BeamGage for your camera
- Collect data

1.1 BeamGage Software Installation

Important: ***Do not connect the camera to the computer until after the BeamGage software is installed.***

To Install the Spiricon Software Application:
There are two ways to install the software from the Spiricon provided CD. This procedure will work as described on Windows 7 operating systems. All installations must be performed with Administrator privileges.

Note: Spiricon no longer verifies or certifies operation with Windows XP or Vista.

1. If the computer is setup to Auto Play CD's do the following:
    a. Insert the supplied CD into the CD-ROM drive and wait for the **Spiricon Software Auto Install** screen to appear.
    b. Click on the **Software Install** button.
    c. Follow the directions that appear on the screen.

2. If the computer does not have the Auto Play feature enabled:
    a. Insert the supplied CD into the CD-ROM drive and open **Windows Explorer**.
    b. Select **My Computer** and right-click on the CD-ROM drive that contains the Spiricon CD. Click on the **Autoplay** option. This will open the **Spiricon Software Auto Install** screen.
    c. Click on the **Software Install** button.
    d. Follow the directions that appear on the screen.

1.2 Connect the Camera

Important: ***Some supplied cameras are more complicated to connect than others. When such cameras are purchased with BeamGage a special User Note document is included and packed with the camera. When such documents are provided be sure to follow them precisely as written.***

With the included FireWire, USB, or Cat6 cable, connect the provided camera to the PC's FireWire, USB, or Gig-E Ethernet port. Connect only one camera at this time.

Note that some cameras, such as the Pyrocam, Xeva, Gig-E or the L11059, will require an external power supply. Be sure to connect the camera to its provided power supply and connect it to a compatible AC power source as applicable.

Important: ***For a camera to be able to operate with BeamGage the camera must be licensed to do so. Only cameras sold with Spiricon products can be licensed to operate with BeamGage. Many older Spiricon supplied FireWire and USB cameras can be licensed to work with BeamGage. Frame Grabber cameras are not compatible with BeamGage.***

1.3 Launch BeamGage

To start the BeamGage application, go to the Windows taskbar and select **Start -> All Programs -> BeamGage (edition)**

Important: ***Review the remaining chapters of this user guide and become familiar with the operation and capabilities of the BeamGage system before performing any laser measurements. This user guide may also be found on the installation disk in PDF format and on the Spiricon web site at www.ophiropt.com. Simply follow the BeamGage product links.***

1.4 Setup the Camera

With the camera plugged into the PC, the first time BeamGage opens, it will automatically attach to the camera it finds, and start running. The default configuration will be loaded and camera imager data output will appear in the 2D display window.

This default setup will assume a CW laser application and it is only useful as an initial starting point that will indicate that the camera is connected to the application and it is collecting data. As the camera is exposed to room light, the 2D image will indicate the presence of light striking the camera imager.

Click on the Source ribbon tab and observe the controls for the camera.

Click on the Pause and Start button to stop and start data collection.

If you did not have a Spiricon supplied and licensed camera connected at the time of launch, plug it in now per 1.2 above and select it by clicking on the **Local Detector** button. If the camera is licensed for use with BeamGage its model and serial number will appear in a dropdown list. Click on the camera to connect it to the BeamGage application. The camera controls will appear in the ribbon bar and the camera will begin collecting data.

Note: If a camera that BeamGage recognizes is plugged in, but is not licensed, then the camera controls will not appear; rather a license entry box will open in the ribbon. When upgrading from LBA, BeamStar, or BeamMic software, a license key will be provided that will license the older camera to operate with BeamGage. Enter it in the license key panel and then follow the instructions that appear on the screen.

Become familiar with the camera controls and features associated with the attached camera. Many cameras will have common features and some will have unique capabilities depending upon the make and model.

1.5 Collect Data

The BeamGage application is shipped with a number of pre-canned setup files that can be used to help get started collecting meaningful data from the camera-laser system. These setup files are divided into three complexity groups. The three groups are labeled as follows:

1. **Novice…** for the beginner. Many of BeamGage's operating features are hidden with only the most commonly used features visible in the ribbon bars. Get up and running quickly without having to make too many decisions.
2. **Intermediate…** more complexity revealed. For the somewhat more knowledgeable user who needs to perform more advanced operations such as image processing.
3. **Advanced…** everything available. For the most sophisticated user who may want to explore all of BeamGage's features.

When BeamGage was installed it created a number of folders in the current users **Documents** folder. To load one of these canned setup files do the following:

1. Click on the File Access button 
2. Click on Load Setup
3. The canned setup files should appear in the Documents\BeamGage\Setups\ folder.
4. Select the setup file that seems to be a best fit for the desired type of operation.

Note: All of the pre-canned setup files provided with BeamGage are write protected files. These file names begin with a tilde (~).

The setup file will open and BeamGage will begin collecting data from the camera.

To begin collecting data with the camera, insert the necessary amount of beam attenuation devices between the camera input and the laser beam output and then align the camera with the laser beam.

Most Spiricon supplied cameras are supplied with a basic set of ND filters that can attenuate lasers up to about 5 Watts. At power levels greater than this the user should add in additional beam attenuating devices such that the power delivered to the camera imager is low enough to prevent damage.

Warning: Camera imagers are easily damaged by laser power and energy levels from lasers that are considered to be of relatively low output power. Be sure to read the damage specifications of the supplied camera (see the appendixes) and do not exceed them. Replacing these special camera imagers is time consuming and costly.

1.5.1 CW Laser Setup

For a CW laser choose a **...CW...** style canned setup file. This is the most basic type of setup and works best to become familiar with BeamGage on a simple, user friendly, low power, HeNe style laser.

If the laser has a high rep rate pulsed output (pulsing much faster than the camera frame rate) then to the camera it may appear more like a CW output. If this is the case, applying a CW setup on this type of laser may be successful.

If the pulsed laser has a low rep rate, or there is a need to split out single laser pulses, then choose a Pulsed setup as described below.

1.5.2 Pulsed Laser Setup

If working with a pulsed laser choose a **...Pulsed...** style pre-canned setup file. All of the pulsed setup files employ the **Video Trigger** capture mode. This is a simple method to automatically sync the input with the pulse rate of the laser. In this mode BeamGage will buffer a data frame every time the camera outputs a frame of data that contains a laser pulse.

Video Trigger mode will not produce the best image quality, especially if the pulse width is large in proportion to the frame exposure time. Occasionally frames will be distorted or of lower than normal amplitude. This type of frame should be ignored when using Video Trigger mode.

To improve the data collection reliability, change from the Video Trigger mode to the Camera Trigger mode. Most cameras used with BeamGage support electronic triggering of the camera. Spiricon supplies camera trigger cables with all cameras that support the external trigger feature. The Trigger panel in the Source ribbon contains the controls for setting up the trigger mode on the camera. All cameras can be triggered with low voltage TTL or CMOS input signals.

Warning: Never apply voltages greater than 5Vdc to the input triggers of FireWire and USB style cameras. Voltages greater than 5 Volts may damage the camera.

1.6 Saving The Setup

To save a setup so that it can be reused at a later time, click on the **File Access** button and then the **Save Setup As...** item. Enter a new name for the setup file and click **Save**.

The last saved or opened setup will be remembered by the application and will be the new default setup the next time BeamGage is launched. This "last used" "last saved" feature is also user specific; meaning that the last used or last saved file by user johndoe will apply to that user but other default files will apply to different users.

Note: Each time BeamGage is closed and the application has detected a setup change, it will prompt to save the new setup.

When installed, BeamGage creates two folders in the installers user account:

C:\Users\<user_name>\Documents\BeamGage\Data
C:\Users\<user_name>\Documents\BeamGage\Setup

The default location for data, log files, and reports is the …\Data folder.
The default location for setup files is the …\Setup folder.

CHAPTER 2 BeamGage Operating Controls

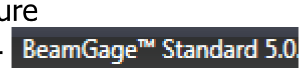
This chapter will describe the various screen and window features as well as the controls provided both within the Ribbon panels and inside the various display windows.

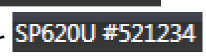
2.1 Title Bar Features

Ophir-Spiricon, LLC's (Spiricon's) BeamGage employs the latest ribbon control motif introduced by Microsoft in the 2007 Office suite. This new format was created in order to provide more intuitive access to control functions as well as the ability to hide the controls for better screen utilization. This chapter will describe the various control features available in BeamGage, beginning with the new terminology used to identify the basic control forms.

Title Bar This upper bar on the application contains, from left to right, the

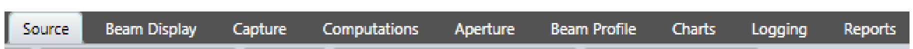
- File Access button 
- Quick Access Toolbar 

  The three buttons shown here are, from left to right:
  - Start/Pause data collection or replay control
  - Perform an Ultracal
  - Enable/Disable Auto Aperture
- Application name and version number 

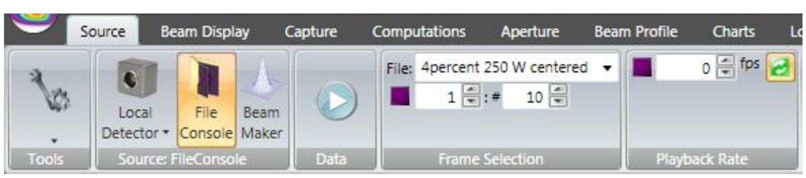
- Selected input source, Model, and Serial number 

- Name of the setup file last loaded or saved
  

- Standard Windows Minimize, Maximize, and Close buttons

Ribbon Tab 

This bar looks like the traditional menu bar but is now used to define the current ribbon control being accessed. Double-clicking on any Menu item can open and close the entire ribbon bar display area. A single click will temporarily open a closed ribbon bar long enough to modify a single entry item.

Ribbon Bar 

This area displays the current set of control panel options available within a selected menu item. These panels contain most of the common control items.

Panels Panels contain traditional Windows buttons, dropdown lists, edit controls, etc. Some panels have a small expansion button located in the lower right corner of the panel. Clicking on this button will reveal additional, less frequently accessed controls that fall under the function title of the panel. Touch sensitive Tool tips are available on most all controls and Results items.

Display Area The display window can be formatted to display any of the various child windows that can be docked within the applications main window area. The child windows can be docked in a large number of user specifiable formats. Child windows can also be removed from the main window and floated anywhere on the available desktop. Floating windows will always appear on top of the BeamGage application that owns it, but can be hidden under other open applications.

Important: ***Floating child windows do not appear as separate items in the Windows task bar and can be inadvertently lost in a busy desktop with many open applications. Use them prudently.***

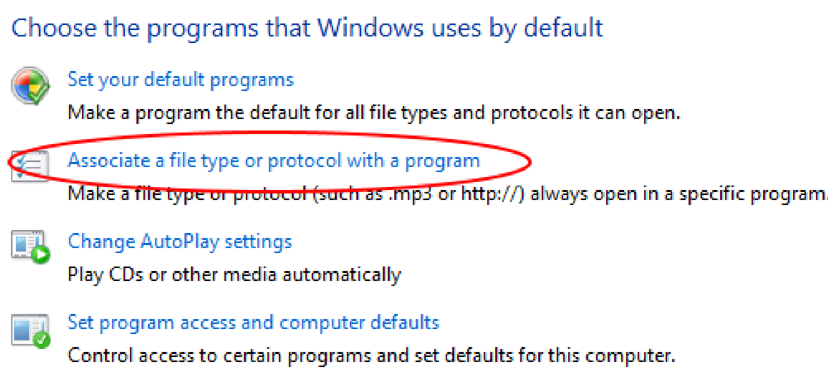
Status Bar The bottom line of the BeamGage application contains a number of display items that will convey a variety of current operating conditions and states. The content of this bar will be explained in section 3.3.

What's This help can provide additional details. Click on the **What's This** button, then click on any featured item in BeamGage. The User Guide will open, or if already open, go to the section in the guide that describes the selected feature or result.

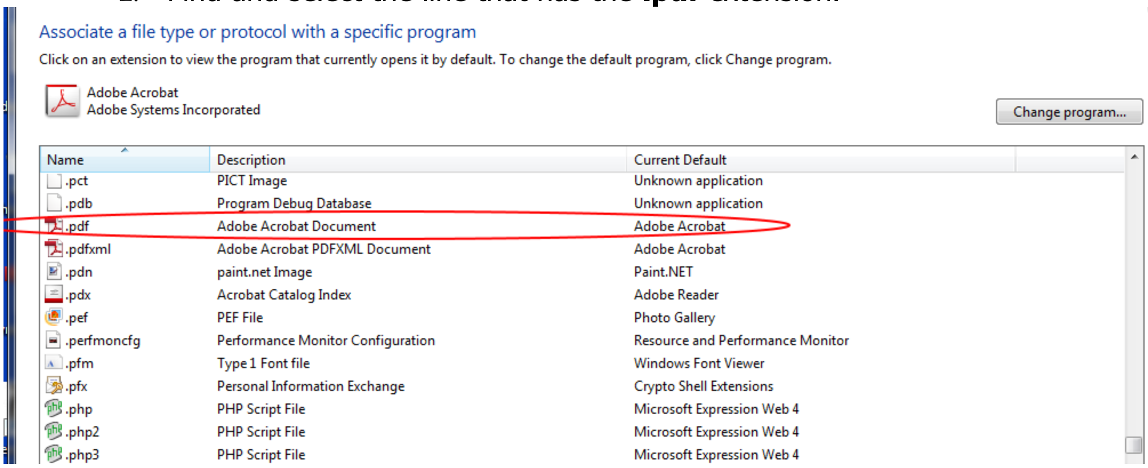
2.1.1 Default PDF Viewer

There are many different programs that allow viewing a PDF. Adobe itself has several of these products (Adobe Reader, Adobe Acrobat, etc.). The BeamGage **What's This** links work best if Adobe Reader is your default PDF viewer. If Adobe Reader is not your default viewer, follow these steps to change it.

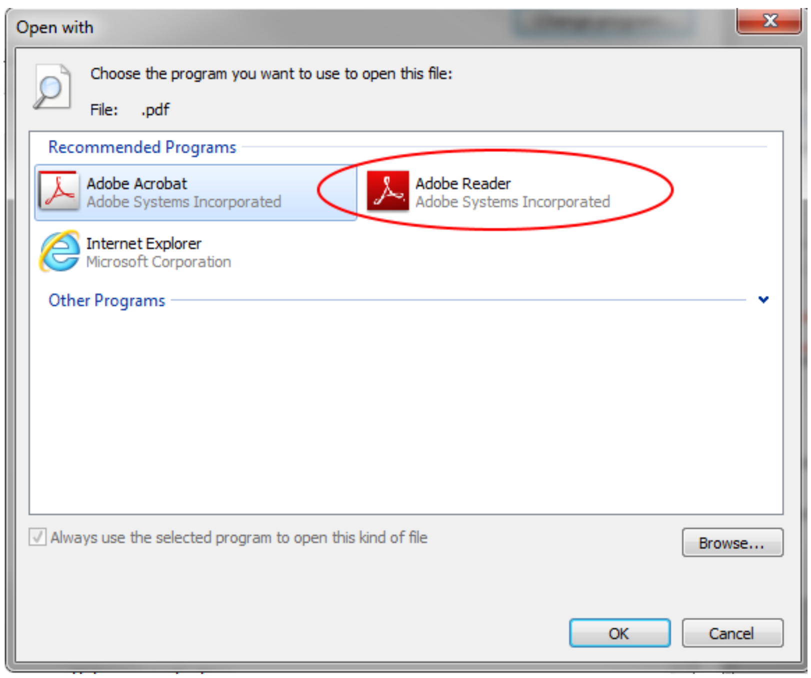
1. Navigate to **Start -> Default Programs -> Associate a file type or protocol with a program**



2. Find and select the line that has the **.pdf** extension.



3. Click on the **Change program…** button.
4. Select **Adobe Reader** and click **OK**.



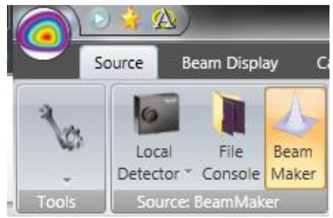
2.1.2 Adobe Reader XI Problem

It has been observed that the **What's This** feature may not work reliably with the newest release of Adobe Reader XI. This is caused by a security feature that is included in Adobe Reader XI, and probably to future releases of Adobe Reader. To enable **What's This** help to operate correctly, make the following change to the Properties section in Adobe Reader XI:

1. Open Adobe Reader XI
2. On the Menu bar click **Edit**
3. Click on **Preferences…**
4. In the Categories list click on **Security (Enhanced)**
5. Uncheck the **Enable Protected Mode at startup** item, and answer **Yes**
6. Click **OK**

2.2 Source Ribbon and Panel Options

The Source panel controls which type of input is assigned to run in the currently open application. There are four standard input choices, but not all are available in all versions of BeamGage. After making a Source selection, this panel will reconfigure itself such that it provides the controls that apply to the selected source.



Tools This Panel is common to all Ribbons. Within it are the controls that determine which Window and Panel items, under the control of the ribbon, will be visible or hidden from view.

Local Detector Clicking on this item will drop a list of supported and available local input devices such as a USB Camera, FireWire Camera, Gig-E Camera, or Pyrocam. Only devices that are plugged into a suitable interface on the current platform PC will be listed. This option is available in all versions of BeamGage.

File Console Data files of saved frames can be replayed via this input selection. Specify the source file and the number of frames that can be replayed. New processing functions can be applied to the played back data, such as frame averaging, convolution, etc. This option is available in most versions of BeamGage.

BeamMaker® This is a synthetic source that allows the user to define an input beam consisting of user defined modalities. This new feature can be used to model beams and verify BeamGage's numerical algorithms or user supplied algorithms including Custom Calculations.
Effects of baseline offset, signal to noise, aperture placement, modal mix, etc. can be modeled in order to provide the user with ISO validation of numerous measurement techniques. This option is available in most versions of BeamGage.

2.2.1 Local Detector

Click on this control to see a list of available local input cameras plugged into this PC. Available devices are listed by model and serial number. Click on the device to connect to the application. Upon launching BeamGage it will attempt to connect cameras in the following order:

1. The camera model and serial number specified in the currently applicable setup file.
2. If the above camera is not found, then it will connect to a similar model of camera that is available.

3. If multiple similar cameras are plugged in, then a list will appear prompting a selection of one of the available cameras.
4. If no camera is available BeamGage will open in an off-line state with no source selected.

Once a camera type is selected the region to the right of the **Source** panel will be replaced with the controls that are applicable to the chosen camera model. This will also include common controls that affect how BeamGage will collect data.

The next sections describe the operation of both common and camera related controls.

2.2.2 Camera Source and Operating Controls

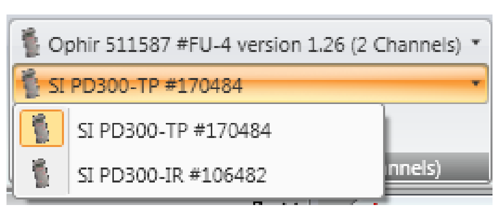
This section will describe the operation of controls most often present when a camera is selected as the Source. Because different cameras can provide a wide variety of unique features, it will not be possible to describe every type of control that may get incorporated in BeamGage. The most often encountered controls will be described in this section.

Note: For specialized camera controls see the appropriate camera Appendix located at the end of this users guide.

2.2.2.1 Power Meter 

A new feature, introduced for the first time in BeamGage, is the ability to interface select Ophir power/energy meters directly into a laser beam analyzer application. This feature will collect in *real-time* power/energy results that are readable over the Ophir meter USB port and integrate those reading into the BeamGage's power/energy display results items. This allows the power/energy results to be as accurate as a NIST referenced power or energy head. This feature eliminates the need to manually calibrate BeamGage based on ever changing setup conditions.

When a USB input from one or more Ophir power meters is connected to the local machine, the Power Meter drop down control will display the ID of the connected meter as shown below. Click on the Ophir product that is to be connected to BeamGage.

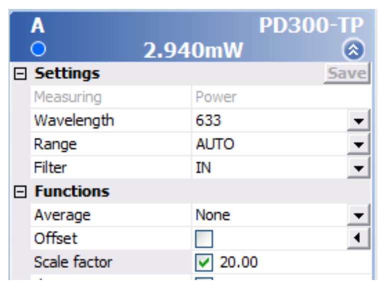


If the meter has a multiple head feature (such as the Pulsar product line) then the Channel drop down control will become active and the output from one of the available heads can be selected.

Whenever an Ophir power/energy meter is selected in this panel, the power readings in BeamGage will reflect, in real-time, both the value and the units of the input readings from the meter. These inputs will override any manually calibrated settings during the time when data frames are being collected.

The value from the Ophir meter device may not be scaled correctly if a beam sampler/attenuator is in the meter's head path. In order to have BeamGage scale the results to correctly reflect true laser power/energy you may enter a scaling factor or a beam sample percentage using this control. To enter a **Scale Factor**, use the right-hand edit control; or to enter a **Beam Sample Percentage** use the left-hand edit control. The scale factor has a range from 1000.000 to 1.0000. The beam sample percentage has a range from 0.1% to 100%. The scale factor method follows the approach used in Ophir's StarLab 2.01, see below. The beam sample percentage method follows the approach used in the Ophir Nova II and Vega.
For example: If entering a 5% beam sample in a Nova II, enter 5% in the beam sample percentage edit control. If entering a scale factor of 20 in StarLab enter a scale factor of 20.000 in BeamGage.

BeamGage



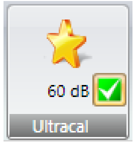
StarLab 2.0x

2.2.2.2 Data 

This control, also repeated in the Quick Access Toolbar, provides the only manual means of **Starting** and **Pausing** the data collection process of BeamGage. Their operation should be instantly recognizable because of their familiar design.

2.2.2.3 Ultracal and Auto Exposure 

These three tools are used to calibrate the camera and produce good baseline calibrations so that accurate beam width calculations can be achieved. The operation of each will be discussed below and their interactions explained.



Ultracal After manually setting up the camera and the laser input with the appropriate amount of beam attenuation, block the beam from the camera and click on **Ultracal**. This will cause an accurate baseline calibration of the camera to be performed. **Ultracal** will preserve both the positive and negative noise floor and, when utilized in conjunction with Auto Aperture, will result in the most accurate beam width calculations possible with camera based technology.

Upon completing the baseline correction cycle, the Ultracal checkbox will turn ON, a measured signal-to-noise ratio of the camera in RMS dB will be computed and displayed, and a Green  will illuminate in the status bar. To turn off the Ultracal processing, click off the checkbox button.

Note: The "U" indicator will turn Red, and Ultracal processing will be suspended when a camera setting changes that can compromise the setup. Hover over this indicator for an explanation of what changed that caused the suspension.


Auto Setup With this control, the requirement to setup the camera-laser system quite as meticulously as in the above Ultracal case is not needed. Instead, merely get a close beam intensity setup onto the camera and then click the Auto Setup button. This feature will automatically adjust the camera Exposure and Gain, and then automatically start an Ultracal cycle, prompting when to block the beam. When finished the laser beam should appear scaled in the beam display window and an accurate baseline computed and applied to the processed image.

The same Ultracal settings will be enabled as in the previous Ultracal cycle. The accuracy and stability of the resulting setup will depend on how close to a good setup things were before starting the cycle. The displayed signal to noise ratio is a good indicator of how well things turned out. The closer this value is to the published s/n ratio of the camera the more optimized is the setup.

The final settings of the Exposure and Gain controls are also a good indicator. Too much increase in Gain will raise the camera noise and contribute rapidly to a reduced s/n ratio. By the same token, too much reduction in the Exposure setting can introduce blooming in some cameras at certain wavelengths.

After performing one Auto Setup cycle it is likely that only periodic additional Ultracal cycles are needed to insure a good return to baseline tracking if the baseline should drift.

 **Auto X** Clicking on this button will enter an Auto-Xposure mode and make the Exposure, Gain, and Black Level controls switch into an auto tracking mode. Previous Ultracal processing will be disabled and a new automatic baseline subtraction method will take effect. This mode will track the changes of the laser beams intensity and do its best to display the beam over a wide range of changing input conditions. Baseline correction is still occurring but the precision and amount is constantly changing as input conditions change.

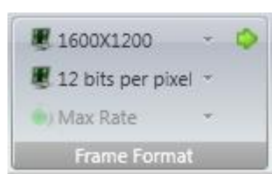
The beam width results obtained in this mode can be almost as accurate as those obtained from an Ultracal'd setup when best input conditions prevail. As more Gain is applied the results will degrade and become noisier and less accurate. By observing the settings of the Exposure, and especially the Gain control sliders, one can see when things degrade. Adjusting the input attenuation to minimize the Gain setting will almost always result in improved accuracy.

The best performance will always be achieved by performing the most precise setup of the system and using the Ultracal baseline processing. The Auto methods provide convenience with a possible reduction in accuracy. The user must decide on which tradeoff is appropriate to their application.

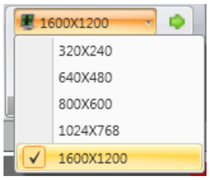
Limitations

There are some limitations on the auto features when operating with a pulse laser and with camera or Video Triggering enabled. With slow rep-rate pulsed lasers, the exposure control is only usable to split out single laser pulses. As a result, the automatic control of the Exposure feature is not useful as a traditional intensity change device. Thus, in triggered modes, the only effective automatic control is the Gain control. The drawbacks of using this control have already been pointed out. Thus the benefits of the Auto features in single pulse exposure triggered modes are somewhat limited.

Important: ***The Auto X mode will not adjust for a manual power/energy calibration and thus cannot be relied upon to accurately track beam power/energy changes. This mode is best used with an external power/energy meter source.***

2.2.2.4 Frame Format 

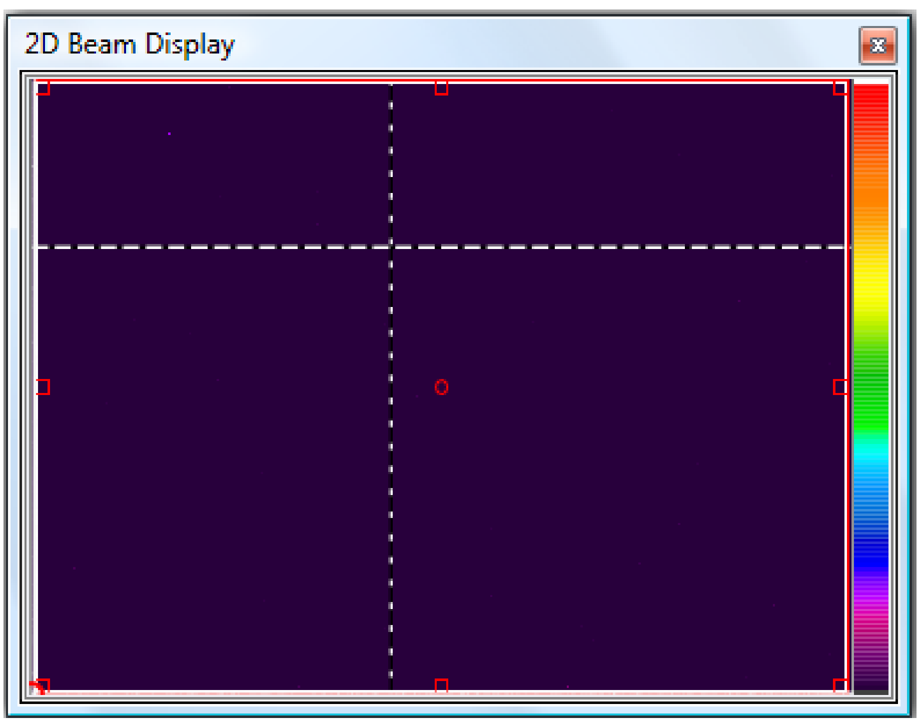
This control is used to select the formatting of the camera data frames. Various cameras will have greater or lesser features in this area. Most of the cameras that Spiricon uses with BeamGage have some degree of format control. The types of controls appearing here are as follows:



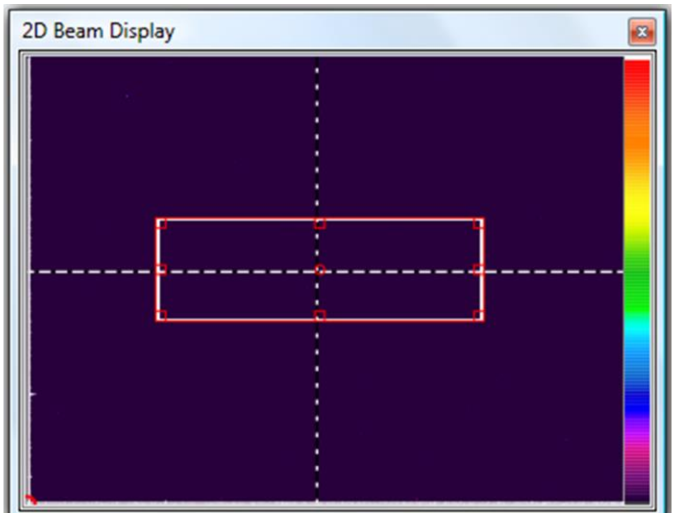
Frame Format This dropdown control will reveal a selection of camera preset ROI (Region of Interest) and Binning formats for the connected camera. These formats are normally centered in the camera imager's window and allow for quick modification of the camera settings. Some formats may employ pixel binning that can speed up the camera frame rate but preserve the field of view of the imager. Smaller ROI's usually result in higher camera frame rates.

The **Custom ROI** expansion button will appear if the camera has programmable ROI capability. Click on the expansion button to reveal the custom ROI controls. The custom ROI controls will appear as shown below.

When the ROI controls are activated, the captured image will become full frame and a White aperture window will appear in the 2D display. Click on this aperture to highlight its RED control handles as shown below.



This special ROI aperture can be used to define the new region of interest that the camera will output.



The handles can be used to resize and position the aperture into the shape and location of the desired ROI as shown here.

The edit controls will indicate the pixel **X** and **Y Offset** of the upper left corner and the pixel **Width** and **Height** of the image. The ROI can also be adjusted by using these edit controls.

Two controls are provided that can force the ROI to be centered within the horizontal and/or vertical width/height of the imager.

 Enabling the **Horizontal Centering** control will cause the ROI to only be translatable vertically while held centered horizontally.

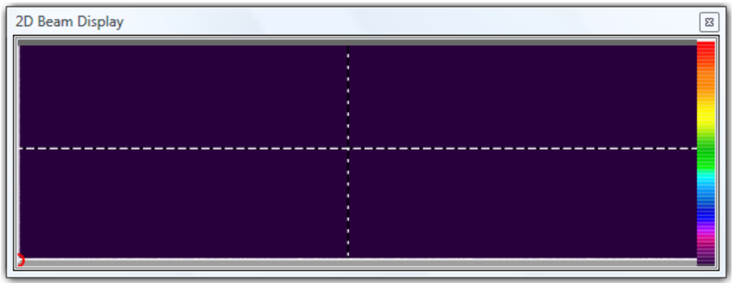
 Enabling the **Vertical Centering** control will cause the ROI to only be translatable horizontally while held centered vertically.

Enabling both the **Horizontal** and **Vertical Centering** control will cause the ROI to lock into the center of the imager.

Binning can be applied to speed up the capture rate but still cover the same area on the detector as indicated by the ROI window. Note that when binning is enabled most cameras will disable bad pixel correction. This condition may not be acceptable for some applications.

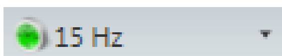
Select a **Bits Per Pixel** value. Some cameras will run faster with lower bits per pixel settings while some will not. Using too few bits may compromise accuracy with cameras with lower s/n ratios.

Once the ROI setting is configured click on the **Set** button to apply it. The 2D window will then change to the size set by the custom ROI controls. In the above example, the new 2D display will look something like this:



Only one custom ROI setup is available at any one time. The panel's **Bits per Pixel** and **Frame Rate** dropdown edit controls may be disabled when an ROI is enabled. This can vary depending upon the camera type. For some cameras the frame rate is forced to its max value.

Bits Per Pixel This control sets the camera output format in number of bits per pixel. The lowest setting is 8, and the highest is 16. The available settings are camera dependent.



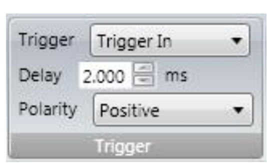
Frame Rate in Hz Use this control to select one of the currently available default camera frame rates. The available rates will change based on the selected Frame Format.

2.2.2.4.1 Special L11059 Operation

The Lumenera L11059 model cameras will respond differently with and without the application of the **Horizontal Centering** feature. The advantage of the horizontally centered ROI is that the camera can run faster than if the ROI is horizontally decentered. There is no impact caused by the use of Vertical Centering.

2.2.2.5 Exposure|Gain|Black Level

These slider edit controls permit manual adjustment of the camera settings that determine the intensity and quality of the output image. In Auto modes, these controls will automatically adjust themselves to the input beam intensity conditions. The **Ultracal** operation will only adjust the **Black Level** while the **Auto Setup** and **Auto X** operations can modify all of them.

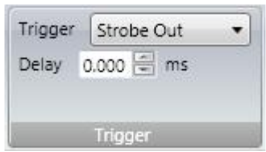


2.2.2.6 Trigger

This panel only affects the electronic trigger features in the selected camera. The camera must be provided with a low voltage TTL/CMOS input trigger pulse to activate the external trigger feature. The Strobe Out is a low voltage TTL/CMOS output signal that can be used to trigger a laser. Trigger options are described below.

- **None** – The camera will operate in CW mode and will output frames continuously.

- **Trigger In** – The camera will only start to expose and transmit a frame of data when a trigger pulse is sent to the camera. If a delay in the start of exposure time is needed enter the delay time in the adjacent edit box. Delay time is programmable in milliseconds.

- 

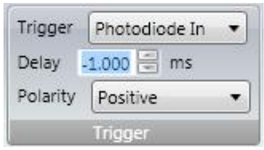
Strobe Out – The camera will run in CW mode but issue a Strobe output pulse at the start of each frame exposure time. Some cameras also offer a Strobe Delay and a Strobe Pulse Width setting feature.

- 

On-Board Photodiode – The legacy SP503U and SP620U cameras have a built-in photodiode detector that can be used to sync pulsed lasers without providing an external signal to the camera. When this device is selected the camera will start a calibration cycle setting the photodiode detector to the room ambient lighting conditions. During this calibration cycle the laser must not be firing. When the cycle completes the camera should be able to detect the laser flash and trigger in sync with the laser pulses. If the room lighting conditions change and the camera stops triggering reliably, then this calibration cycle should be repeated by cycling back to **Trigger-None** and then reselecting **On-Board Photodiode**.

The delay for these cameras can be either positive or negative depending upon the duration of the laser pulse. If the pulse is short, <100µs, set a negative delay of at least -1.0ms, and a camera exposure time of at least 2ms. If the laser pulse width is long, set a delay of 0ms and the exposure time to be just slightly longer than the pulse width.

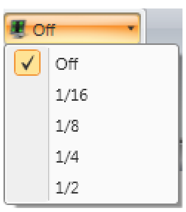
Because the location of the on-board detector is fixed on the front of the camera, it may not always be able to detect the laser pulse under all operating conditions. If it fails to perform reliably then you should purchase the remote photodiode detector option (see below), or connect a trigger cable to the camera from the laser.

- 

Photodiode In – Some cameras can be operated with an external photodiode trigger probe. These are the legacy SP503 and SP620 cameras. The delay for these cameras can be either positive or negative depending upon the duration of the laser pulse. If the pulse is short, <100µs, set a negative delay of at least -1.0ms, and a camera exposure time of at least 2ms. If the laser pulse width is long, set a delay of 0ms and the exposure time to be just slightly longer than the pulse width.

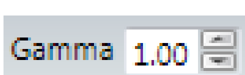
2.2.2.7 Capture 

This panel provides some image processing features. None of these are controls that affect the camera electronically but do setup image processing options with the BeamGage application.



Video Trigger This dropdown control will enable and set the threshold for the Video Trigger. This feature permits only those frames of data that contain a laser pulse to be captured. The setting value will set the sensitivity of the trigger based on the cameras number of bits per pixel. For example: A camera set to 12 bits per pixel, 4095 counts full scale, and a threshold of ¼, will trigger on a beam that has a peak amplitude >1023 counts.

Lens Check this box if the camera is fitted with an inverting lens. When enabled, the 2D image orientation is adjusted to depict the image as if the observer is standing and viewing the scene from behind the camera. When disabled, the 2D image is oriented as if the observer is standing in front of the camera looking at the surface of the detector.



Gamma Correction If the camera employs a solid state CCD or MOS style detector, then its detector responds linearly to monochromatic light. For linearly responding cameras the Gamma setting should be set to 1.

For cameras that employ phosphors or other exotic wavelength conversion materials the gamma of the phosphor should be entered here to convert the nonlinear response back to a linear one.

2.2.2.8 Camera/Firmware Info

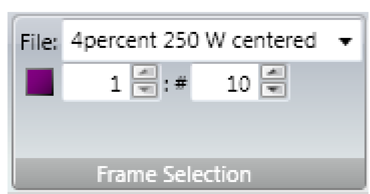
These panels provide some basic information about the camera source. Various kinds of information may appear. In the above example the native camera pixel scale (pixel pitch) in the X and Y axes is shown, as well as the firmware versions running in the camera.

2.2.3 File Console

This source selection is the File Playback Console. With this selection, a BeamGage Data File becomes the Source material. This feature allows the user to playback a selected data file that contains multiple frame records. Various processing features can be applied to the input data with the re-played frames being processed into the frame buffer.

Important: ***The File Console playback concept will treat the input data file as if it is being seen for the first time, just like new input from a camera. All results obtained will depend on the current settings, not on the settings that were in place when the data was originally captured. Therefore the results that will appear will depend on what constraints are currently being applied.***

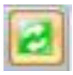
2.2.4 Frame Selection



The most common use for the File Console selection is to simply playback some data frames previously recorded. Before data can be played, the **Frame Selection** panel must point to the file that will be played. Click on the Browse button to locate the file to play. The start frame and number (#) of frames will fill with a **1** and the number of frames in the selected file, respectively. To playback a limited section of the file's frames, adjust these values accordingly.

2.2.5 Playback Rate

The specified playback file will normally playback as fast as possible (when set to zero), but can be throttled slower by setting a playback rate value greater than zero. The set rate is in frames per second.

 For the playback to loop continuously, click on this icon.

Important: ***When running at full playback speed it is possible that a frame could be skipped if the files load faster than they can be processed. Reduce the playback rate to insure all frames get loaded and processed.***

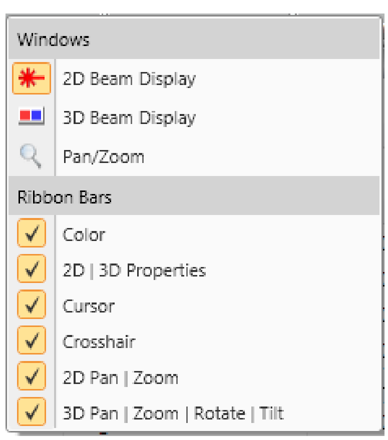
2.2.6 BeamMaker®

BeamMaker is an innovative new feature available for the first time in a laser beam analyzer. This new tool will allow the user to create synthetic laser beams in user defined modes and under a range of programmable conditions. With these synthetic beams it becomes possible to perform validation of Spiricon ISO compliant algorithms as well as test the results of your own application specific algorithms.

CHAPTER 5 will discuss the uses and features of BeamMaker and offer some examples to help the user learn how to apply it in common situations.

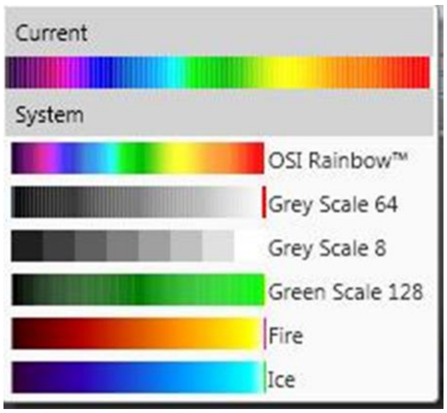
2.3 Beam Display Ribbon and Panel Controls

The Beam Display Ribbon provides all of the standard controls for managing the presence and content of the **2D**, **3D**, and **Pan/Zoom** display windows. The Tools panel allows the user to display and hide the following items:

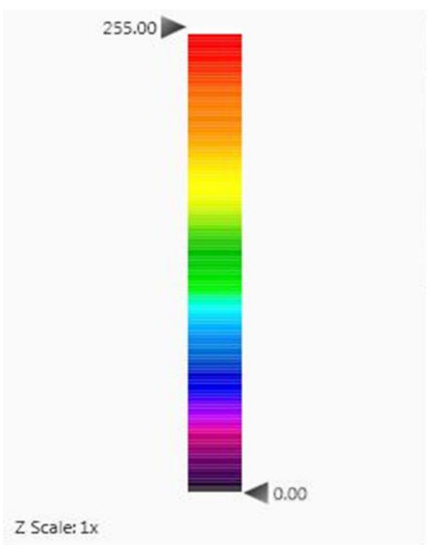


2.3.1 Color

These controls select the color display options that are common to the 2D, 3D, and Pan/Zoom windows.



The **Color Palette** dropdown selector displays a set of color palettes than can be applied to the beam intensity profiles. Click on the desired display palette.



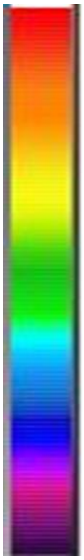
The **Z Scale** opens a vertical palette with dual slider controls that allows the user to scale the colors into a smaller region of the Z axis beam intensity profile. This is most useful when trying to resolve the lowest intensity features often present in the wings of the beam.

Grab the top arrow and slide it downwards and observe the false color detail expand at the bottom of the beam profile displays.

Grab the center and slide the entire palette up and down inside of the beam profile.

The numerical values indicate the location of the palette boundaries and the actual amount of Z Scaling zoom factor that is enlarging the beam profile in the intensity or Z axis.

The **Color Bar** dropdown selector turns on or off the presence of a color bar display in the 2D beam display window.

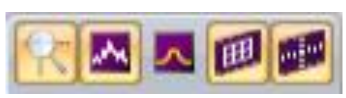


<The **Color Bar** display can be either a solid vertical bar that displays the distribution of the colors from the lowest to the highest beam intensity. Or…

…numerically coded **Color Levels** that **>** translate the colors into non-calibrated pixel counts or calibrated pixel Fluence values.

2.3.2 2D|3D Properties

This panel controls a number of display features in the 2D and/or 3D Beam Display Windows. The top five buttons toggle on/off the following features, from left to right:



- **Enable/Disable Zoom to Cursor** If the Cursors are present and this button is ON, zooming in the 2D display windows will be to the point of the Cursor intercepts. When OFF or when the cursors are not present, the zooming action will be to the center of the **2D Beam Display** window.

- **Enable/Disable Beam Profiles** When the **Cursors** are present they define a 1D slice thru the beam intensity profile. When ON, this control will project the slice profiles along the bottom and left side of the **2D Beam Display** window.

- **Enable/Disable Reference Profiles** When the **Cursors** are present and data is stored in the **Reference Frame**, the Cursors define a 1D Slice thru the Reference Frame's intensity profile. When ON, this control will project the **Reference Frame** slice profiles along the bottom and left side of the **2D Beam Display**. This option is disabled until a **Reference**

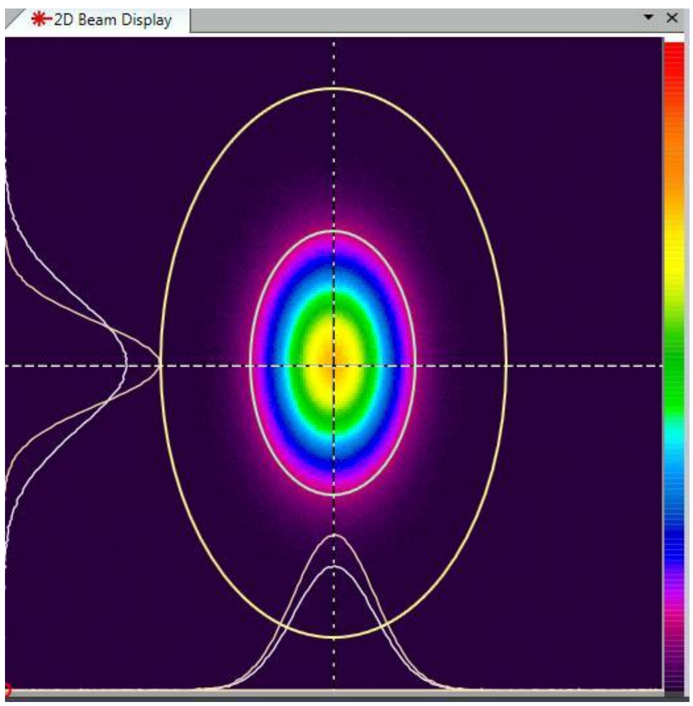
Frame has been selected. See section 2.4.5 for information on Reference Frames.

- **Enable/Disable 3D Backplanes** Turns ON/OFF the 3D backplanes. These planes can be useful when viewing the slice profiles in the **3D Beam Display** window.

- **Enable/Disable 2D Elements in 3D** Turns ON/OFF projections of the Manual, Auto, and Beam Width Apertures onto the surface of the 3D beam profile.

The following figures depict the views of the 2D and 3D Beam Profile windows with all of the above properties enabled with both Cursor and Reference Frame slice profiles.

The beam profiles in each of the following depictions are different.



2.3.3 2D Beam Display Window

In the image above, the Auto Aperture (Yellow), displayed Beam Width (Lt Green), and Color Bar are enabled. The beam slice profile is drawn in White; the Reference Frame profile in Lt Yellow. The 2D Beam Display is shown in the Primary Dock Window indicated by the presence of the upper identifying tab. Manual Aperture is not enabled.

The small red circle, just visible in the lower left corner indicates the **Origin** position.

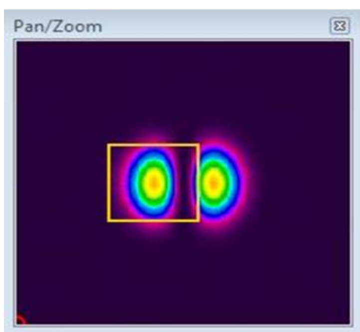
The **Origin** can be placed at the data display's **Bottom Left** corner, to the **Center**, or it can be manually snapped to the location of the **Crosshair**.

See the **Crosshair** control panel in section 2.3.8 for information on how to position it.

2.3.4 2D Pan|Zoom

2D Panning and Zooming in the 2D Beam Display window can be accomplished either with the above control device or with the mouse. The Arrows Pan the beam while the slider is a Zoom control. The center button will re-center and resize the beam to fit the window.

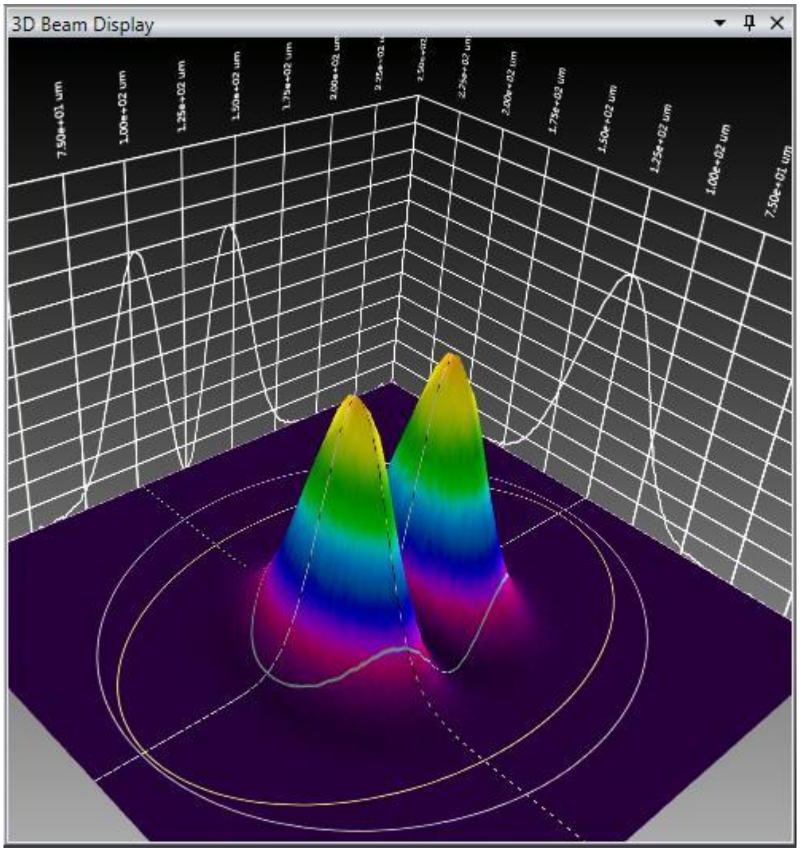
The simplest way to Pan and Zoom the 2D Beam Display is to position the mouse pointer into the window, then Pan by holding down the left button and dragging the display to its final destination and Zoom by using the mouse wheel control.



The **Pan/Zoom Window** can be used to indicate where within the beam data the 2D image is originating from. Enable this window in the **Tools** panel.

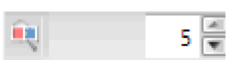
The Yellow box indicates the region of the imager that is panned and zoomed into.

Note: The Pan/Zoom window indicator has no relationship with the ROI setting in the camera or with the regions defined by the apertures. It is only a display tool.



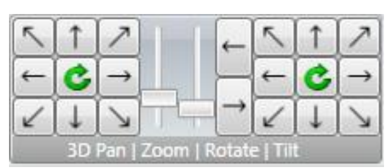
2.3.5 3D Beam Display Window

The image above displays a typical 3D view. The projected apertures: Manually Drawn Aperture (Lt Grey), Auto-aperture (Yellow), and Beam Width (Lt Green) are shown. The beam slice profiles are traced in White and projected onto the visible **Backplanes**.



The **3D Resolution** edit control determines the amount of detail that will be rendered in the 3D beam profile. A number **1** is finest resolution and will cause the data frames to update at a slower rate. The max value is **10** and will result in a more grainy looking display but the update rate will be faster.

Important: ***The 3D display utilizes the maximum amount of graphics drawing resources that the PC and Graphics card can provide. As a result the 3D display will always cause the acquisition rates to run significantly slower, especially noticeable with higher resolution cameras.***



2.3.6 3D Pan|Zoom|Rotate|Tilt

Pan, Zoom, Rotate, and Tilt in the 3D Beam Display window can be accomplished either with the above control device or with the mouse. The left set of arrows Pans the 3D beam view while the two sliders Zoom In and Zoom Out respectively. Click on the center button to re-center and resize the beam to fit the window.

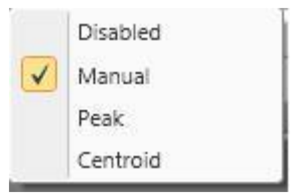
The next two controls will cause the 3D display to rotate about its central axis.

The right set of arrows will tilt the display along two orthogonal axes, front to back and clockwise/counterclockwise. Click on the center button to restore the tilt positions to normal views.

The same 3D Pan, Zoom, Rotate, and Tilt operations can be performed with the mouse controls. With the cursor placed onto the 3D beam image, the mouse buttons and mouse motion perform the following tasks:

- To Pan the display: hold the left button down.
- To Rotate the display: hold the right button down.
- To Tilt the display: hold both buttons down.
- To Zoom in and out: roll the wheel.

2.3.7 Cursor



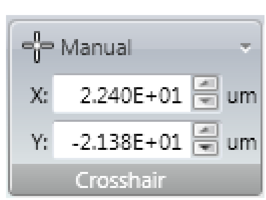
This panel controls the presence and operating mode of Cursors in the 2D and 3D Beam Display windows. They also dictate the location of the data plotted in the Beam Profile display windows. The Cursors can be set to operate in three modes:

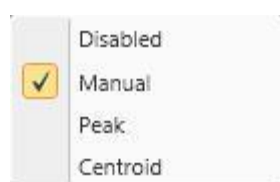
- **Manual** Position the Cursors anywhere within the 2D Beam Display Window either by dragging and dropping with the mouse (grab at the intersection), or most accurately by typing in the exact **X** and **Y** coordinates in the provided edit controls.

- **Peak** The Cursors will automatically track the Peak fluence of the input beam. If two identical peaks are present the one closest to the top left corner will be indicated.

- **Centroid** The Cursor will automatically track the location of the computed beam Centroid.

2.3.8 Crosshair





This panel controls the presence and operating mode of Crosshair in the 2D Beam Display window. It is not visible in the 3D Display. The Crosshair can be set to operate in three modes:

- **Manual** Position the Crosshair anywhere within the 2D Beam Display window either by dragging and dropping with the mouse (grab at the intersection), or most accurately by typing in the exact **X** and **Y** coordinates in the provided edit controls.

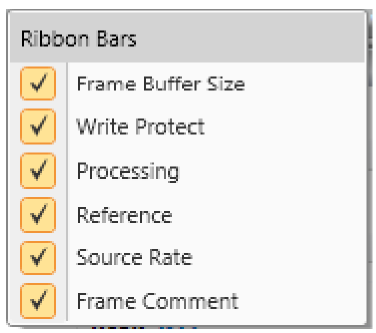
- **Peak** The Crosshair will automatically track the Peak fluence of the input beam. If two identical peaks are present, the one closest to the top left corner will be indicated.

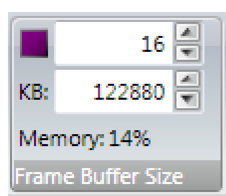
- **Centroid** The Crosshair will automatically track the location of the computed beam Centroid.

The displayed spatial units will follow the units setting in the **Computations** ribbon.

2.4 Capture Ribbon and Controls

The Capture Ribbon provides many of the standard controls for managing the various ways that the image data can be captured and processed. The Tools panel allows the user to display and hide the following control items:

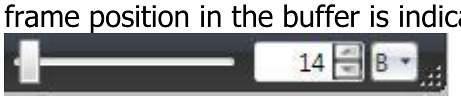




2.4.1 Frame Buffer Size

The size of the image capture buffer can be set in this panel. Set the number of Frames it can hold and the software will report how much memory is needed and what percent of the available memory is consumed.

The Frame Buffer is a round-robin temporary data storage space. The current frame position in the buffer is indicated in the buffer control area on the status bar.



Use the slider bar, the edit control, or spin arrows to move around the buffer.

The amount of memory assigned per frame depends on the frame size of the camera. Larger imagers will require more memory space per frame than a smaller format. The camera ROI feature can be used to reduce memory demands.

BeamGage employs a dynamic memory allocation algorithm that will automatically decrease the size of the frame buffer as total system memory demand increases. What this means is that the set frame buffer size might shrink if other applications are opened that place a demand on the available memory space greater than the amount of total memory available. Normally with today's PCs that have 2 or more GB of RAM memory installed, this will not be a common occurrence. However, if additional applications are opened, such as large CAD or document files, you may notice that the frame buffer has reduced in size to allow these other applications to be accommodated.

Hint: Always use the smallest buffer size that will accomplish the required tasks.

2.4.2 Write Protect

The Write Protect controls allow protecting buffered data frames from being overwritten by new data. Toggle the frame protection state of a single frame or of the entire contents of the frame buffer. When a displayed frame is locked, a small closed padlock will appear in the status bar.

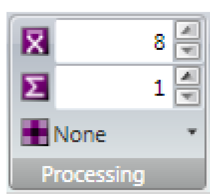
 Click to Write Protect the current frame.

Click to Unprotect the current frame. 

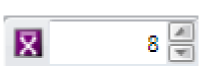
 Click to Write Protect the entire frame buffer.

Click to Unprotect the entire frame buffer. 

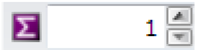
2.4.3 Processing



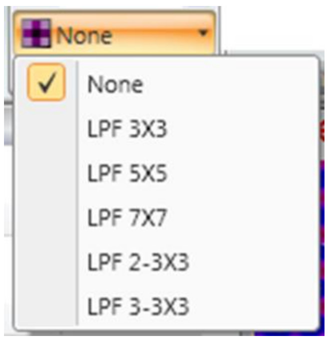
Various types of image processing can be applied to collected frames of data. Three of these are controlled here.



Frame Averaging Enter the number of frames that are to be averaged while collecting data. In this example, 8 frames will be averaged and the resulting single frame will be placed into the frame buffer. Frame Averaging is a convenient method that can improve the s/n ratio when observing low signals where noise is a significant problem. The s/n ratio is improved by the square root of the number of frames averaged.



Frame Summing Enter the number of frames that are to be summed. The summed results will be saved in the frame buffer. In this example, frame summing is set to 1, which disables summing. Frame Summing is a technique that can be used to increase the amplitude of weak signals. To use summing successfully, always have **Ultracal** processing enabled so a positive baseline offset doesn't blow up the resulting data frame.



Convolution

This control can be used to smooth the image noise using various Low Pass Filter (LPF) Convolution algorithms.

Convolution can help turn a very noisy beam into a smooth work of art if the beam has a lot of spatial noise.

2.4.4 Frame Comment

Use this area to enter comments that are to be attached to frames of data. Saved comments are shown in this panel, under the Frame Info section in the **Results** window, and at the top of a **Report** that contains a frame with a comment attached. Comments cannot be applied to write protected frames. Comments can be attached four different ways:

 **Comment current**

Attach the comment to only the currently displayed frame. It is recommended that these comments be saved to a data file as they will be lost once the frame is overwritten in the frame buffer.

 **Comment all**

Attach the comment to all previous non-write protected frames in the frame buffer. It is recommended that these comments be saved to a data file as they will be lost once the frame buffer is overwritten.

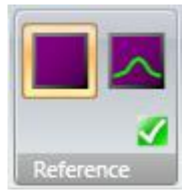
 **Comment new**

Attach the comment to the current and all future collected frames. To stop commenting on future frames, click this icon again.

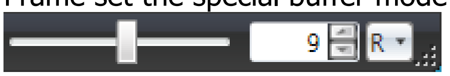
 **Comment all and new**

Attach the comment to all previous non-write protected frames and all future collected frames. To stop commenting on future frames, click this icon again.

Note: Adding a comment to all frames will overwrite any existing comments.

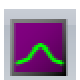
2.4.5 Reference Subtraction 

This is a special data processing mode. It will store a Reference Frame to a special frame buffer location and then subtract it from the incoming data frames. Only one reference frame can be saved at a time. To view the currently saved Reference Frame set the special buffer mode control to "R" as shown below.



 **Save Current Frame to Reference**

Click on this button to store the currently displayed frame into the reference frame buffer.

 **Save the Gauss Fit of Current Frame to Reference**

Click on this button to store a Gaussian fit of the currently displayed frame into the reference frame buffer.

 **Enable/Disable Reference Subtraction**

Toggle **ON** or **OFF** Reference Subtraction processing. When enabled, newly acquired frames of data will have the reference frame subtracted and the results stored in the Frame Buffer and a Green  will illuminate in the status bar.

Note: The "R" indicator will turn Red and Reference Subtraction processing will be suspended when a camera setting changes that can compromise the setup. Hover over this indicator for an explanation of what changed that caused the suspension.

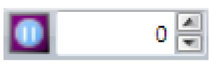
Important: Reference Subtraction can only be enabled when a data frame of the same format as the incoming data format has been stored into the reference frame buffer.

2.4.6 Source Rate Control

This panel controls the manner in which data frames are collected. When set as shown above, data frames will be collected continuously until stopped by the operator or by other stop conditions set elsewhere in the application. Data can be collected in either of two priority modes: **Frame Priority** or **Results Priority**.

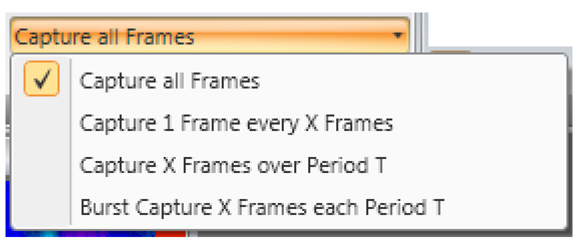
Frame Priority will attempt to capture data frames and store them into the frame buffer as quickly as possible. Results will be computed and posted as the remaining bandwidth will allow, but results posting will skip frames if it cannot keep up with the rate at which data is streaming in. Even in this mode, it may be possible that the camera will output frames faster than BeamGage can keep up.

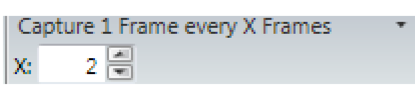
Results Priority will make the computing and posting of results more important than how fast frames get placed into the frame buffer. If observing the results is the main focus of operation then use this mode.



The **Stop After** control will permit collecting a programmed number of data frames and then acquisition will stop when the set number is reached. Clicking the Start button will begin a new cycle. When set to Zero this feature is disabled and frame collection is not affected by this control.

The lower dropdown control will reconfigure the data collection into a number of more complex data acquisition modes. Its settings can work in parallel with the previous settings. When many of these types of controls are enabled at the same time, some unanticipated results can occur, so apply them carefully. Each of the three bottom settings will be discussed separately below.



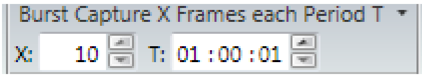


Periodic Frame Sampling

The value set into the X edit control determines what the periodic sample rate will be. In the above example, the capture rate will be 1 frame out of every 2 frames transmitted by the input device.

Timed Periodic Frame Sampling

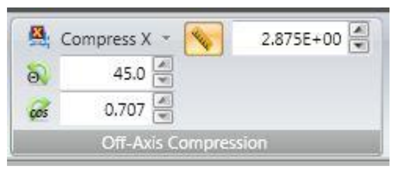
Collect an average of X frames every T seconds. In the above example, 2 frames will be collected every 1 second, for a capture frame rate of 2Hz.



Burst Periodic Sampling

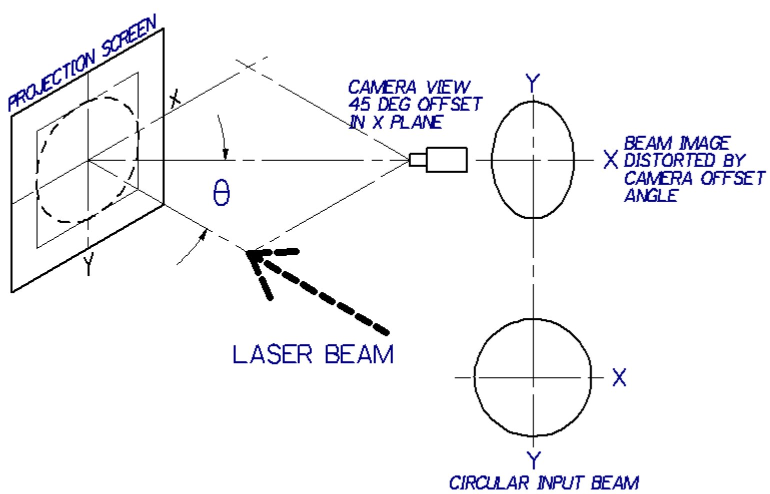
This mode will acquire X number of frames each time the Period–T elapses. Enter the time in HH:MM:SS. In the above example, 10 frames will be collected as quickly as possible every 1 hour and 1 second of elapsed time.

All of the above a sampling sessions begin by clicking the Start button. Clicking Pause will end the previous cycle. Clicking the Start button again will begin a new cycle. The acquisitions will run until stopped by the operator or by some other setting.

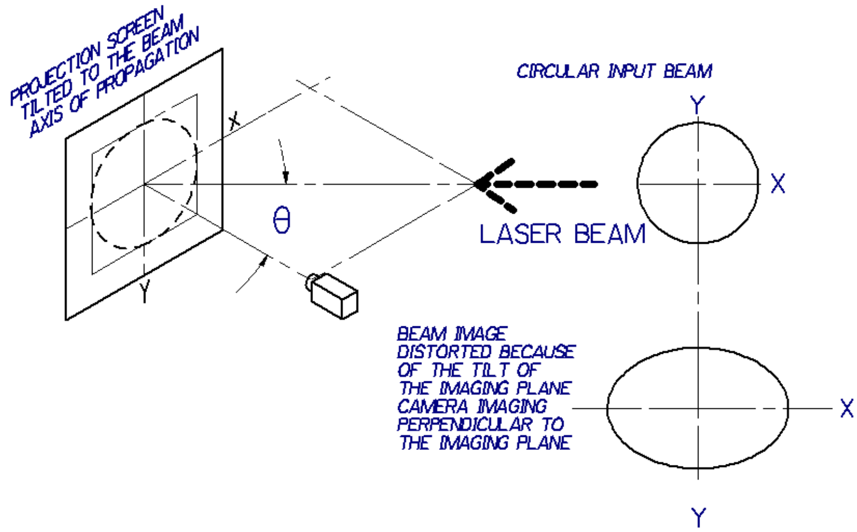


2.4.7 Off Axis Correction

Off Axis Correction is available only in BeamGage Professional edition. It will allow the user to correct for beam image aspect ratio distortion by compressing it in one axial direction. This correction is limited to distortion in either the X or Y plane, but not in both planes at the same time. Off-Axis Correction can be employed either when the camera is off axis to the imaging plane or when the laser is off axis to the imaging plane, so long as at least one of the two is located orthogonal to the imaging plane. The two figures below illustrate two possible applications where the camera or the laser is off axis in the systems X axial plane. A similar set of figures can be drawn with the camera and laser offset in the Y axial plane.



Camera off axis



Laser off axis

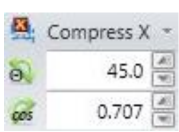
The above input beam is circular in both examples, but the beam imaged by the camera will appear either compressed or stretched in the X axis depending upon which is off axis to the imaging plane, the camera or the laser. Beam compression in one axis can be employed to restore the beam's aspect ratio.

BeamGage employs a Bresenham smooth scaling image compression algorithm. In the top figure the beam aspect ratio can be restored by compressing the data in the Y axial direction. In the bottom figure compressing in the X axial direction will restore the aspect ratio.

Note: BeamGage cannot perform image expansion, only image compression.

2.4.7.1 Correction in Two Steps

When working with an off axis imaging system, as in the above examples, the user can correct the beam image and results by following the two step process described in the following sections.



Step 1, Correct the Image

To enable image compression, select which axis needs to be compressed. If the Y axis appears stretched relative to the X, select **Compress Y**. If the X axis appears stretched relative to the Y, select **Compress X**. To turn image correction off, select **None**. Enter the off-axis angle that the camera or laser makes with respect to the Z axis of the image plane into the **Θ** edit control. Alternately enter the **cosΘ** value. These are linked edit boxes where one will display the equivalent of the other. **Θ** is limited to a maximum of 45.0°, **cosΘ** to a minimum of 0.707.

Step 2, Scale the Image

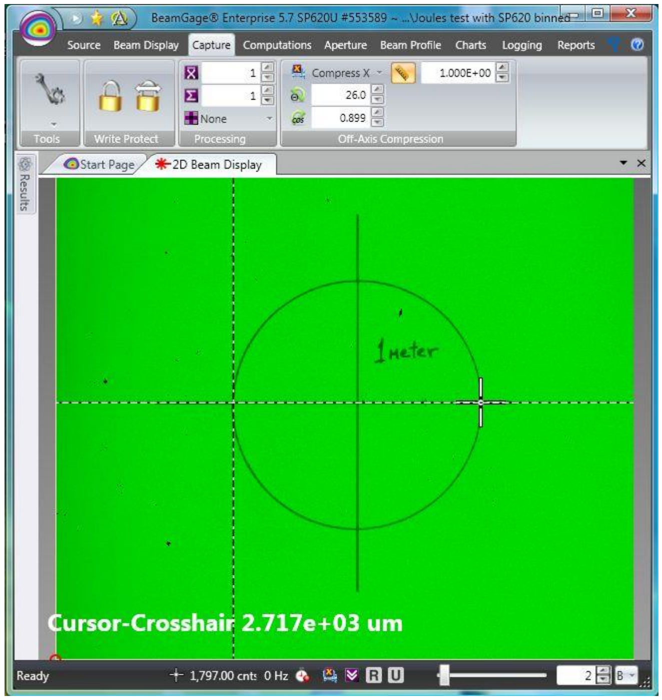
After the image has been corrected it will need to be accurately scaled. The **Optical Scale** edit control is described in section 2.5.3. The **Optical Scale** factor control is replicated here so that all of the needed inputs for correcting and scaling the image are available in this one location. Click on the ruler button to activate scaling and enter the scaling factor in the edit control.

2.4.7.1.1 Correction Example

The following example describes a common application of off-axis image correction.
In this example the camera is placed low in the Y axis of the target. A temporary 1 meter diameter circle with a crosshair is placed in the image plane. It will be used to align, correct, and scale the final image. The original image, shown below, is what the target looks like before correction. Note that the BeamGage display is reduced to just a few windows for simplicity.

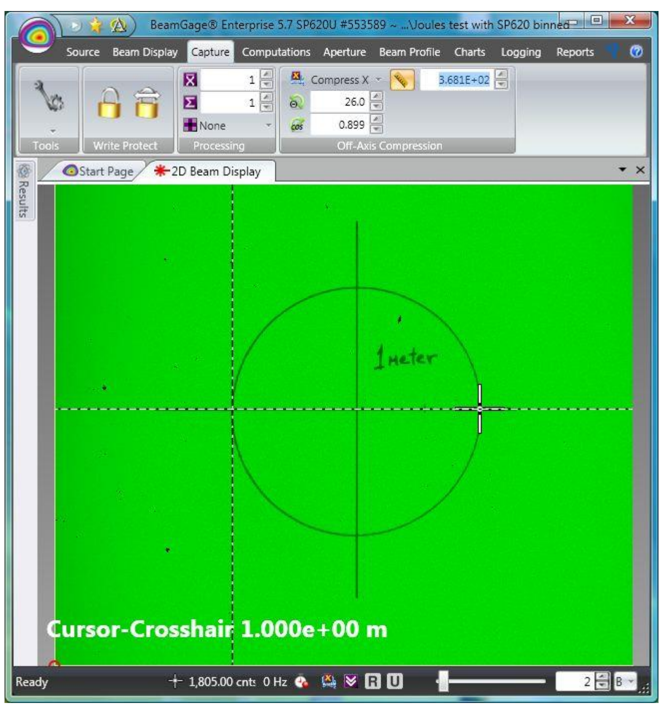
The camera is focused on the target and the Cursor and Crosshair are enabled. The Cursor-Crosshair distance results have been overlaid onto the 2D display. Observe that the target circle is flattened as a result of the off axis view of the camera. The current scale factor is 1x so the distances are based on the pixel pitch of the camera.

The first step in correcting the above image is to apply image compression in the X axis. After adjusting **Θ**, the X axis is compressed and the target restored to a circular shape as shown below.



It was determined in this example, by trial and error, that the camera's angle in the Y axis was 26.0 degrees. At this compression setting the image was measured using the Cursor-Crosshair distances in both the X and Y axes and found to be the same.

The final step is to set the scaling factor so that the resulting circle measures 1 meter. The image below shows the scaling factor modified to a value of 368.1, resulting in a Cursor-Crosshair distance of 1.000+00 m.



This would be an appropriate time to save the setup if it may be needed again in the future.

2.4.7.2 Correction Induced Errors

The Bresenham compression algorithm is designed for speed at the expense of accuracy. One consequence is that small compressed images may experience some amount of image distortion. To keep the measurement errors low, the user should make the imaged beam fill as much of the camera's imager as possible, but without overfilling the frame. Since most cameras have wider X axis, it is beneficial to orient the camera with the elongated image axis aligned with the cameras X axis and the narrower image in the Y axis. This will require compression in the X axis resulting in a more squared off final image aspect ratio.

Note: To prevent overfilling the imager the beam area should under fill the imager. A good rule of thumb is that the beam width should be no greater than half the imager in height and width.

The table below indicates the typical degree of induced second moment beam width error as the original imaged beam is compressed in size for various offset angles. Pixels and beam widths are normalized to unit pixel values. BeamMaker was employed to create an elongated Gaussian beam, and then the compression feature was used to correct it. The user may employ BeamMaker to replicate their beam size and measurement method to determine error based on a specific measurement scenario.

Beam Size in Pixels vs. Θ	**10°**	**20°**	**30°**	**45°**
10	+1.5%	+4.3%	+1.1%	+1.0%
15	+1.6%	-0.3%	-0.3%	+0.5%
30	+1.5%	-0.4%	0%	0%
60	-0.2%	+0.1%	0%	0%
100	-.4%	0%	0%	0%

Typical Second Moment Beam Width Compression Measurement Error, Corrected Beam Width vs. Offset Angle

As illustrated above, beam widths > 60 pixels will suffer little error effects due to the compression algorithm. Error effects only become significant if the beam approaches 10 pixels, which is the recommended minimum spot size for beams even without applying compression.

2.4.7.3 Correction Alters the Image Data Format

When image compression is applied the resulting image data format will be permanently modified from the original format generated by the camera. This modified data format can be processed, saved, and reloaded just as if it originated from a camera with the same horizontal and vertical format that resulted from the compression process. In other words, this new image is forever linked to this resulting image size.

The pixel scaling is made permanent for these data sets and will be reapplied if the data is later viewed. Frames that have been compressed cannot be uncompressed at a later time.

In order to process this image against another, such as in the case of image reference subtraction, both the source and the reference images must be in exactly matching formats.

2.4.7.4 Optical Considerations

In all instances it is assumed and required that the user is applying a properly designed optical imaging system. The system must take into account the depth of field of the lens as applied. Beams imaged off-axis may also experience additional distortion if the beam is not collimated (i.e. rapidly diverging or converging) and the projection plane is tilted to the beam axis. Control of background light, scatter, diffusion in the projection plane, and wavelength filters are also things that might need to be taken into account.

Rear Surface Projections

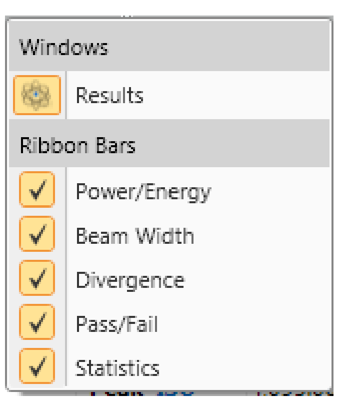
The projection plane can also be made of a diffuse material that allows the image to be viewed on its rear surface. Rear surface imaging is often performed off-axis. All of the above scenarios that apply to front surface distortion can also apply to rear surface imaging.

Projection Directly on the Camera Imager

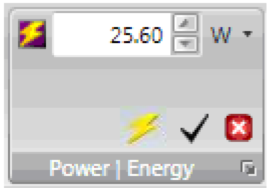
It should be noted that the above figure titled **Laser off axis** can also be applied if the camera imager is substituted for the projection plane. While this is a less common application, its solution is exactly as described above.

2.5 Computations Ribbon and Controls

The Computations Ribbon provides many of the basic setup controls for the computed values that can be enabled in the Results Window as well as other display windows that depict numerical values either directly or in graphical form. The Results window and panels are enabled in the Tools panel:



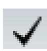
Note: The Results button in the above Tools menu opens/closes the Results display window. The remainder of this section will describe only the panel controls. The following section will describe the Results display window which contains its own set of controls.



2.5.1 Power /Energy

This panel is used to manually calibrate the beam power/energy based on a measurement from an external power/energy meter. When set to Zero, the results are un-calibrated and the beam intensity is reported in counts.

Important: ***When an external Ophir meter is connected to the local PC and has been selected as a calibration source, the values entered here have no effect.***

 **Apply Calibration** To calibrate the beam, enter the Power/Energy value in the edit control, select the appropriate units, and click Apply. The frame currently being displayed will be assigned this calibration value. If the calibration value has been changed but not applied, the value will turn Red.

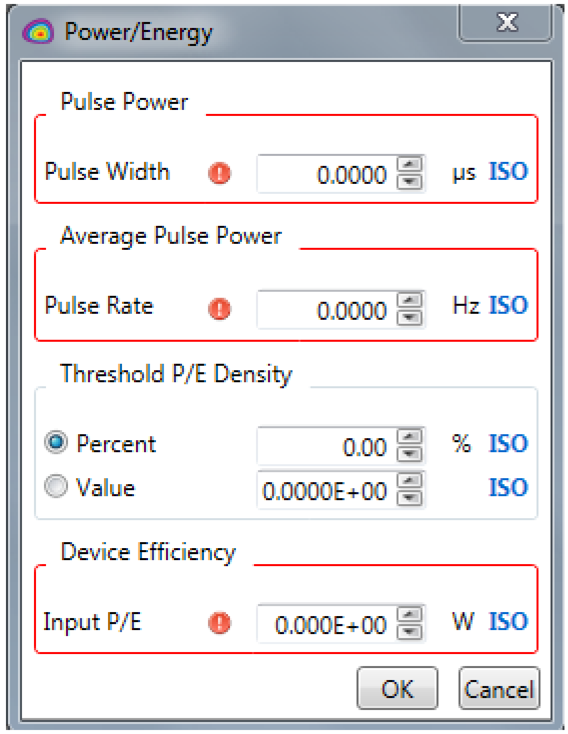
 **Clear Calibration** To cancel the calibration, click on this button. The last entered calibration value will remain but the calculated units will revert to processed digitized counts (cnts) and will be dimensionless.

 When this icon appears it indicates that the power/energy results are coming from a connected Ophir power/energy meter and the values entered here are being ignored.

Note: Once a calibration has been made, if the units are changed the results will automatically update. However, the units cannot be changed from Power to Energy or vice versa. In order to make this change, the calibration must first be cleared and then recalibrated with the correct units.

The button in the lower right corner will open an expanded **Power/Energy** dialog box. These additional entries are needed to compute additional power/energy results items. These are described below and reviewed mathematically in CHAPTER 5.

Note: If an entry is not applicable with the current calibration, an error will appear around the option. Place your cursor over the warning sign for an explanation as to why the option is not applicable.



The blue letters **ISO** indicates that the result is computed using an ISO defined method. However, if other settings are inappropriately configured, the ISO result may not be achieved. This topic is covered in more detail in CHAPTER 5.

2.5.1.1 Pulse Power

The Peak Pulse Power of a single laser pulse can be computed by entering the laser's pulse width in the associated edit control.

2.5.1.2 Average Pulse Power

The Average Pulse Power of a pulsed laser can be computed by entering the pulse repetition rate in the associated edit control.

2.5.1.3 Threshold P/E Density

The TopHat Threshold Power/Energy Density can be computed by entering the known threshold effective fluence value needed to perform the work of the TopHat beam. This result can also be computed based on a **% of Peak** setting.

2.5.1.4 Device Efficiency

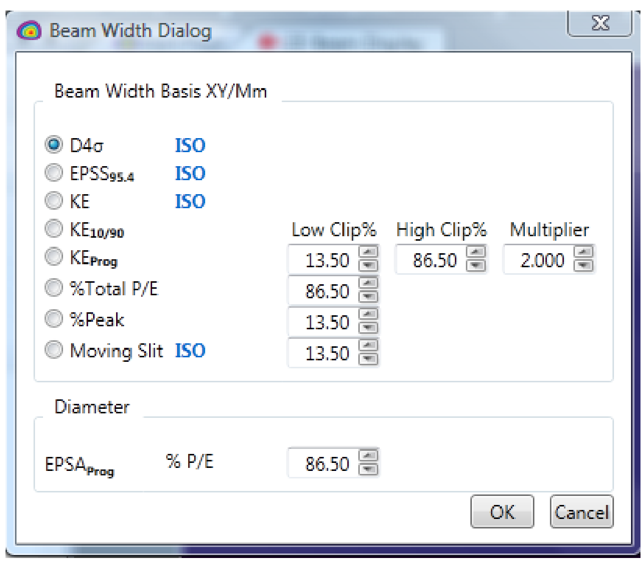
Enter the input power or energy of the laser to compute the laser's overall Device Efficiency. Enter the laser's input power/energy in the same units that are being used to measure the output power/energy, i.e. Watt units or Joule units for the input and output.

2.5.2 Beam Width Basis

The Beam Width Basis is one of the most important settings with regards to obtaining accurate ISO results in many areas. The choice made here defines the beam width basis that will be used in computing all other results items that require and rely on the **Beam Width** or **Diameter** as an input. For example, an **ISO Divergence** calculation needs a reasonably accurate second moment beam width input to yield correct divergence results. In fact, many of the ISO results rely heavily on the use of the second moment beam width or diameter definition as an input. The Beam Width Basis also selects which method is used to draw the Beam Width aperture in both the 2D and 3D displays. It also impacts which clip level method is employed when computing a beam's rotational orientation.

Use the dropdown edit control and select the Beam Width Basis. Choose the primary spatial display units in the right-hand dropdown control.
The **D4σ** choice is the preferred Second Moment calculation method.

The button in the lower right corner will open an expanded Beam Width Basis dialog box, shown below. Some of the Beam Width results item choices require additional input parameters in order for them to be correctly and meaningfully applied. The required input parameters can be entered here. The factory default settings are shown below.



If the camera is using an imaging optic, such as a beam expander/reducer, this dialog box contains the entry to apply a pixel scaling factor in order to correct for optical expansion or reduction effects.

Note: A description of these Beam Width and Diameter setting notations is contained in CHAPTER 5.

2.5.2.1 Programmable Knife Edge, KE_{Prog} , KE Clip%

These are the settings for the user programmable Knife Edge Clip level entries. Specify a **Low** and a **High** % of power clip level and a **Multiplier** correction factor. 13.5% and 86.5% with a 2x multiplier is the default setting and represents the second moment settings for a TEM_{00} Gaussian beam.

2.5.2.2 Programmable % of Total Power/Energy, %P/E , Clip%

Enter the percent of power/energy contained to set the clip level for computing the beam widths and diameters using this method. 86.5% is the default setting and represents the second moment setting for a TEM_{00} Gaussian beam.

2.5.2.3 Programmable % of Peak, %Peak , Clip%

The Spiricon Legacy version of this result is based on a 1D analysis of the data lying along the X/Y or M/m axis running through the centroid of the beam. Enter the percent of the beam's peak fluence that will define the clip level for computing the beam widths and diameters using this method. 13.5% is the default setting and represents the second moment setting for a TEM_{00} Gaussian beam. To obtain a **FWHM** (Full Width Half Max) result set this value to 50%.

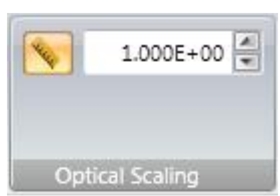
2.5.2.4 Programmable Moving Slit % of Peak , D%ms , Clip%

This result mimics the moving slit method as defined by **ISO 11146-3**. Enter the percent of the beam's peak fluence that will define the clip level for computing the beam widths and diameters using this method. 13.5% is the default setting and represents the second moment setting for a TEM_{00} Gaussian beam. This method assumes the beam is TEM_{00} ($M^2=1$). To obtain a **FWHM** (Full Width Half Max) result set this value to 50%.

2.5.2.5 Diameter EPSA % of Power/Energy

This is the Diameter Encircled Power Smallest Aperture method, also commonly called the encircled power or power in a bucket method. Enter the percent of the total power for the reported beam diameter to encircle. 86.5% is the default setting and represents the second moment setting for a TEM_{00} Gaussian beam.

2.5.3 Optical Scaling



If the camera is using an imaging optic, such as a beam expander or reducer, this dialog box contains the entry to apply a pixel scaling factor in order to correct for optical expansion or reduction effects.

Click on the ruler button to activate the optical scaling feature. When OFF, no scaling will be applied. When enabled, enter a scaling Expansion or Reduction factor in the edit control to compensate for an enlarged or reduced beam.

Values >1 indicate a larger field of view projected onto the imager. Examples would be a beam reducer or a standard C-mount lens.

Values <1 indicate a smaller field of view projected onto the imager. Examples would be a beam expander or a microscope objective.

2.5.4 Divergence

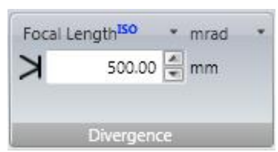
BeamGage supports three different methods for measuring Divergence.

1. The ISO Focal Length method
2. The Far-Field 2 point method
3. The Point Source Far-Field Wide Angle method

Each will be described in more detail in CHAPTER 5.

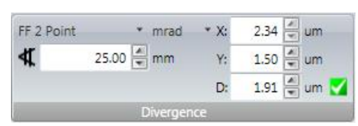
A simple controls oriented description will be provided here.

2.5.4.1 Focal Length Method



The Focal Length divergence method provides a means for finding the far-field beam divergence at any point in the beam propagation path. This method is for small divergence angles and is best displayed using the **mrad** units. Enter the **focal length**, in mm, of the plano-convex lens being employed.

2.5.4.2 Far-Field Two Point Method

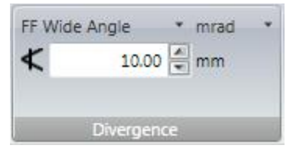


This method can only be accurate when the measurements are made in the far-field of a small diameter laser beam. Use it for small divergences with the units best suited for **mrad** dimensions. This method requires that the beam be measured twice at two places distant from each other but both in the far-field of the caustic. The first measurement should be the smaller beam width. After collecting and Pausing on this result, click the  button to transfer the beam widths into the X:, Y:, and D: edit controls. Or enter these values manually. Note the position of the camera imager.

Move the camera imager to the second more distant location and enter the delta Separation Distance from the first sample location in mm.

Click Start. The Divergence results will be computed based on the angle subtended by the two beam widths.

For most accurate results use a second moment beam width basis and be sure to **Ultracal** before making each measurement.



2.5.4.3 Far-Field Wide Angle Method

This method assumes that the laser beam emanates from a point source. This is a good approximation for measuring the divergence of a laser diode in **degrees**. Set the camera imager at a position in the beam far-field that can still contain the entire laser beam profile. This is usually quite close to the laser source. This distance must be determined with reasonably good accuracy. Enter this Detector Distance in the edit control.

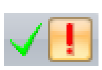
As the resulting beam widths are measured, the corresponding divergence angles will be computed.

2.5.5 Pass/Fail

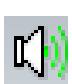
This panel contains the master Pass/Fail controls. Pass/Fail boundary conditions are set in the various Results display windows. The controls that enable the Pass/Fail indicators and the consequences of a Pass or a Fail event are determined here.

Note: When a Pass/Fail item is enabled anywhere in the results, the Enabled box will automatically be checked.

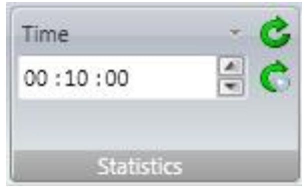
 **Master Pass/Fail Enable/Disable** Toggle ON to allow Pass/Fail limits to be applied to bounded results items. Pass/Fail testing is disabled when OFF.

 **Pass/Fail Action** Select which pass/fail condition to perform an action on: Pass, Fail, or no Action. Above indicates to take action on Fail. The possible actions are:

 **TTL Pulse** output from a USB adapter on each actionable event. Order this adapter as an option. Order Part Number SP90060.

 **Beep**, the PC's Beep tone will sound when an actionable event occurs.

 **Stop** running when an actionable event occurs.



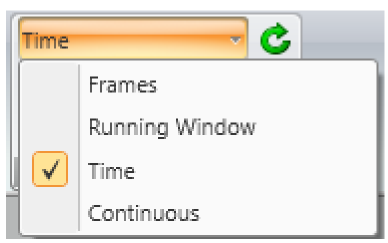
2.5.6 Statistics

This panel contains the master control for the Results window Statistical calculations. This also sets the number of samples to use in computing the statistical results values. The stats can be set to Reset each time data collection is started or they can be manually Reset at any time, even when running.

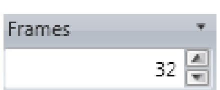
A typical stats display will look something like the results display shown below.

Name	Value	Units	Mean	Std Dev	Max	Min	Sample Size
Power/Energy							
Total Power ISO	3.749e+02	W	3.749e+02	7.493e-02	3.751e+02	3.748e+02	100
Avg Pwr Density ISO	3.486e+06	W/cm^2	3.488e+06	3.341e+03	3.496e+06	3.482e+06	100
Peak Fluence ISO	1.299e+07	W/cm^2	1.300e+07	2.729e+04	1.307e+07	1.294e+07	100
Spatial							
Centroid X ISO	1.249938e+02	pixels	1.249868e+02	1.437e-02	1.250306e+02	1.249492e+02	100
Centroid Y ISO	1.250022e+02	pixels	1.249855e+02	1.350e-02	1.250190e+02	1.249567e+02	100
D%pkX	0.000e+00	pixels	0.000e+00	0.000e+00	0.000e+00	0.000e+00	100
D%pkY	0.000e+00	pixels	0.000e+00	0.000e+00	0.000e+00	0.000e+00	100
D%pk	1.990e+01	pixels	1.993e+01	1.859e-01	2.037e+01	1.951e+01	100

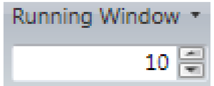
All of the available statistical measurement types: Mean, Std Dev, Max, Min, and Sample Size are shown in the above example.



There are four different running modes for collecting Statistics. The mode selected here will also interact with the **Source Rate** settings in the **Capture** ribbon. After setting up one of these modes, make sure the Capture setup is compatible with the objectives of the statistical mode setup.



Frames One of the most common and simplest methods for collecting statistics is to set the number of frames to collect and report the results on. Data collection will stop after the set numbers of frames are collected.

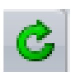


Running Window This method allows statistics to be recomputed continuously but only the stats for the last number of specified frames will be displayed.

Time Set the period of time over which the stats will be collected in HH:MM:SS. This clock will count down while collecting data and stop data collection when the time is up. With this approach, the number of frames that will end up in the final count is determined by other factors such as the **Capture Source Rate**.

Continuous Statistics will be computed continuously until manually stopped or reset.


Reset on Start When enabled, this control will cause all statistics to Reset when the Start button is clicked. This is a good way to ensure all stats stay in sync.


Reset Click on this momentary button to reset all statistics.

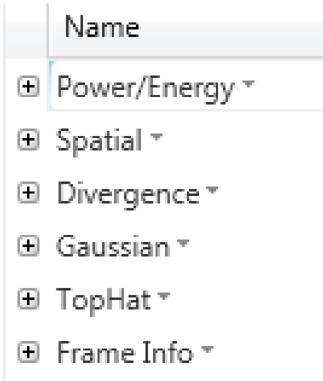
Important: ***When collecting statistics over an extended period of time, the camera baseline may drift due to changes in the camera's temperature. For best results allow the camera to reach thermal equilibrium, and then try to maintain the temperature as stable as possible while collecting data frames.***

2.6 Results Display Controls

The Results display window is the only window with a great number of embedded controls. Results groups as well as the individual Results items have dropdown controls that select which results items are to be enabled/computed as well as other related features such as:

- Collapse/expand a group
- Enable Statistical results, applied to groups or to individual items
- Drag and Drop a result item in another display window
- Configure the Pass/Fail limits for a selected results item
- Open a Strip chart on a selected results item
- Set the font size and color for a selected results item

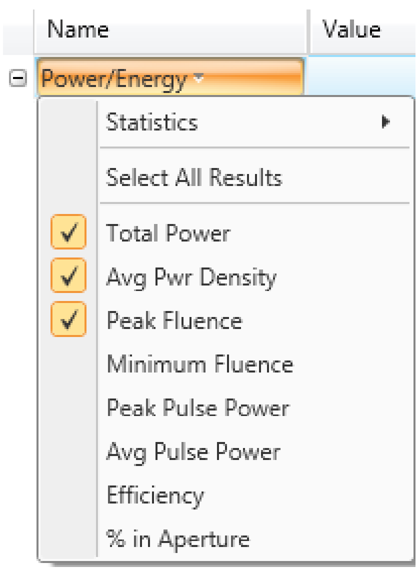
Note: Only enabled results are computed.

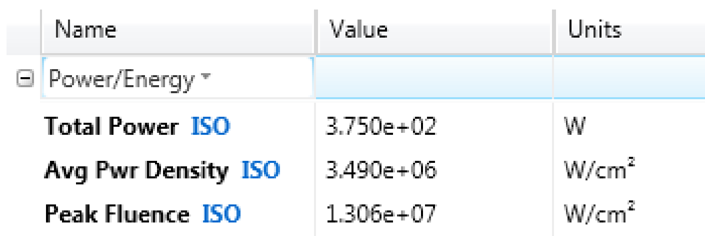


The Results Items are grouped into logical divisions. The names are self-descriptive and will lead you to where to look for a specific type of result.

Click on the group name to open a dropdown selector of the results with the group. The **+** control will expand the group and show the enabled results items.

The **Power/Energy** group contains the results items shown below.

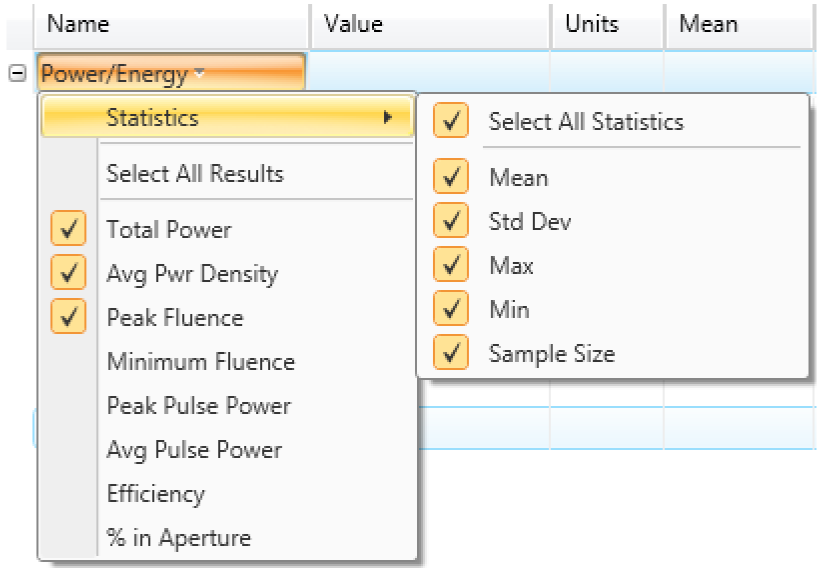




The items checked in the group will appear in the expanded results as shown in the example above.

2.6.1 Group Statistics

To enable the statistics within a group click on the Statistics dropdown option as shown below. This reveals the basic statistical choices. Check on the statistical item(s) that are to be computed and displayed.



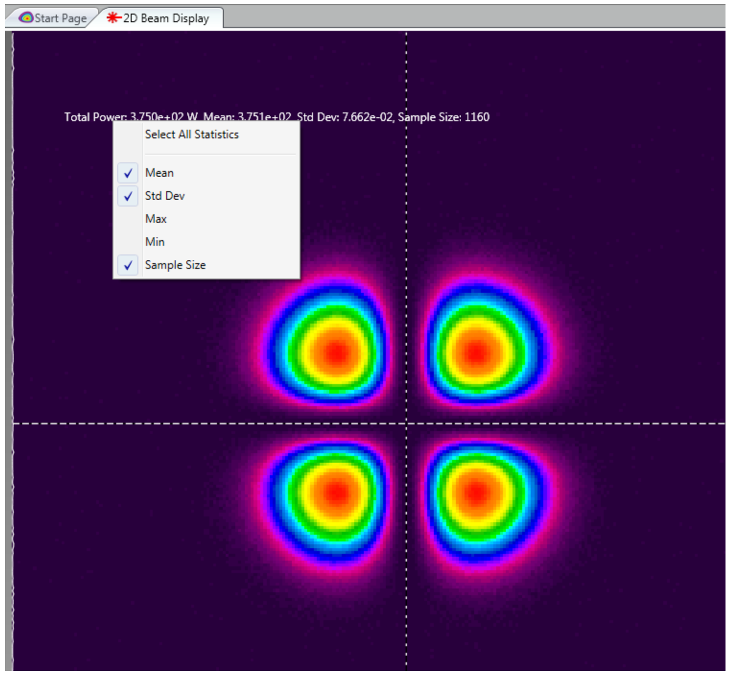
Observe that the Sample Size must be enabled for each item. When each item is enabled, the sample size for that item resets. The easiest way to get all results in sync is to enable the desired results and then reset all statistics in the **Computations** ribbon.

The figure below shows how a full set of statistics will appear.

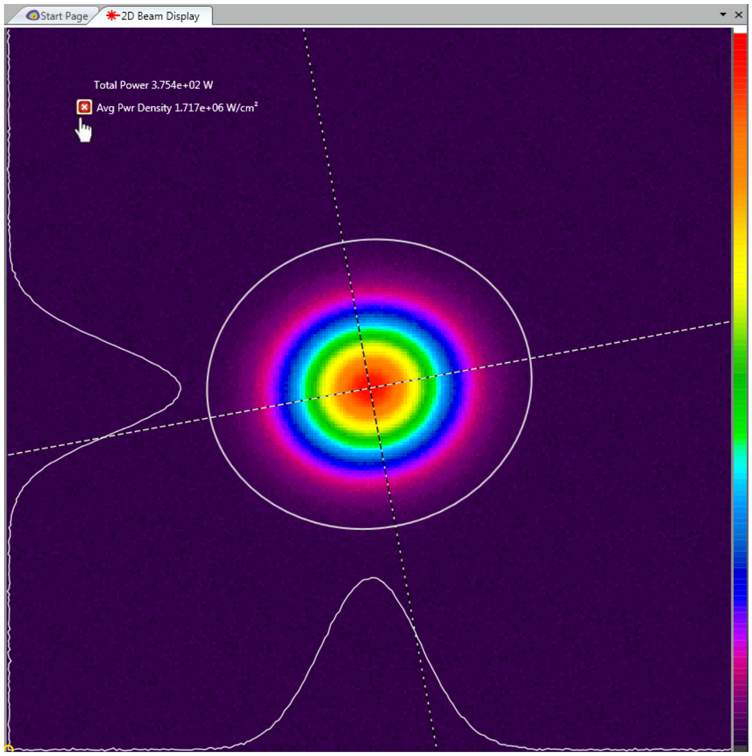
Name	Value	Units	Mean	Std Dev	Max	Min	Sample Size
⊟ Power/Energy							
Total Power ISO	3.749e+02	W	3.749e+02	7.493e-02	3.751e+02	3.748e+02	100
Avg Pwr Density ISO	3.486e+06	W/cm²	3.488e+06	3.341e+03	3.496e+06	3.482e+06	100
Peak Fluence ISO	1.299e+07	W/cm²	1.300e+07	2.729e+04	1.307e+07	1.294e+07	100
⊟ Spatial							
Centroid X ISO	1.249938e+02	pixels	1.249868e+02	1.437e-02	1.250306e+02	1.249492e+02	100
Centroid Y ISO	1.250022e+02	pixels	1.249855e+02	1.350e-02	1.250190e+02	1.249567e+02	100
D%pkX	0.000e+00	pixels	0.000e+00	0.000e+00	0.000e+00	0.000e+00	100
D%pkY	0.000e+00	pixels	0.000e+00	0.000e+00	0.000e+00	0.000e+00	100
D%pk	1.990e+01	pixels	1.993e+01	1.859e-01	2.037e+01	1.951e+01	100

2.6.2 Drag and Drop

As shown below, the Drag and Drop feature will allow selected results to float into any display window. This provides the ability to strip off only the results items that are needed to be seen and overlay them inside of another display window. If statistics values are enabled when the result is dragged, they will appear in the display window once dropped. Statistics values can also be enabled/disabled for the selected result while it is in the display window.



The results item will float in the designated display window with a transparent background. To reposition the location of the item, use the mouse to drag and drop it to a new location. To delete the floating item, place the mouse over the item and click the cancel box that appears. Observe that if the result item is copied and displayed in another window, hiding it in the results window will not remove it from the display window. That removal must be performed separately. The example below shows the Total Power and Avg Pwr Density results overlaid in the 2D Beam Display window.

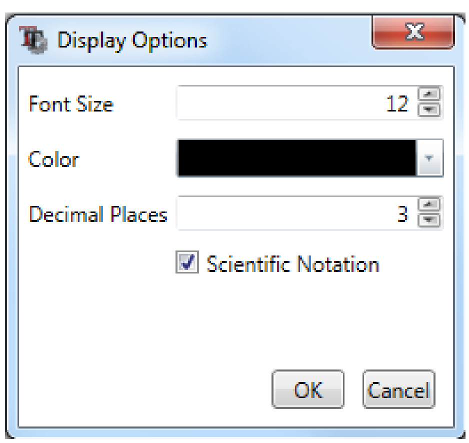


2.6.3 Results Options

Each result item has its own dropdown list of statistics and results options as well as a drag and drop feature. The **Edit Pass/Fail**, **Chart**, and **Display Options** will open another dialog box that contains additional choices. Only the **Display Options** and **Statistics** for an item that has been dropped in a separate display can be controlled separate from the **Results** window.

2.6.3.1 Display Options

The font size, color, and display notation for results can be changed using the **Display Options** dialog box. Right-click a results item and select Display Options to open the dialog box. The Display Options can be changed for all results at once by clicking  at the top of the Results window.



Set the font size, color, and the number of decimal places to be displayed for the selected result. Scientific notation for the result can also be enabled/disabled.

Note: If a pass/fail value is also enabled for the selected result item, the pass/fail colors will overwrite the color selected here.

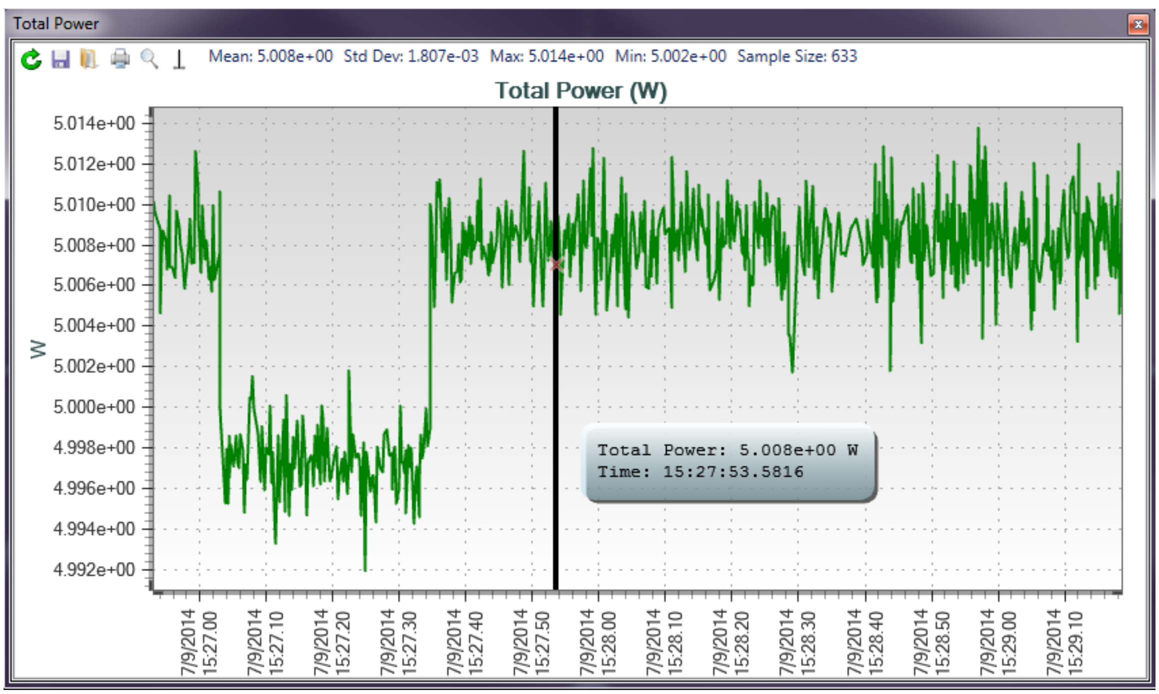
If an item has been dropped in a different display, the set display options are maintained. The display options can also be changed for the results after dropping it in a separate display area.

2.6.3.2 Chart

The Chart option will open a **Strip Chart** window that will plot the results item over time. The Charts ribbon and the Charts display contain important controls that may need to be modified so the charting operation will perform as expected.

The Chart window will open in a Primary Dock tab and will more than likely need to be repositioned.

The figure below shows a typical Strip Chart display window for Total Power.



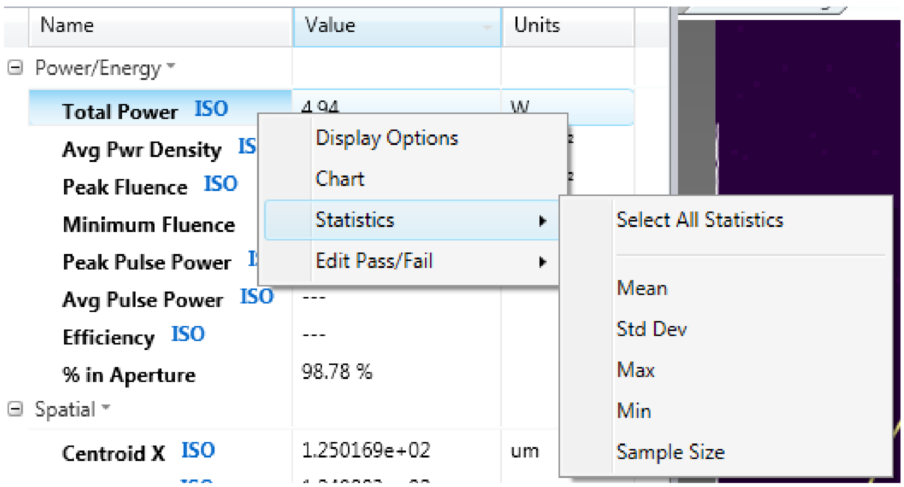
Observe that strip charts also contain the stats for the result item being plotted and the Sample Size in both the chart and the stats.

Within each chart are controls that allow the user to perform actions just on the individual chart. These are:

- **Reset** clear the chart data
- **Save** the chart to an ASCII .csv results file
- **Load** a chart from either a saved chart or log file
- **Print** the chart
- **Reset Pan/Zoom** to show all collected data points
- **Center Cursor** to position the cursor in the center of the chart

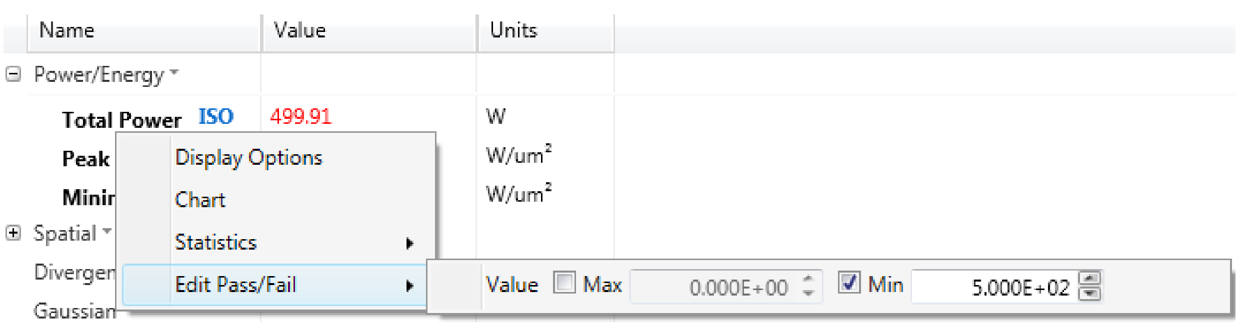
2.6.3.3 Individual Statistics

Statistics values can be enabled/disabled for each result individually. Right-click on the heading of a result to view the options and select the statistics values.



2.6.3.4 Edit Pass/Fail

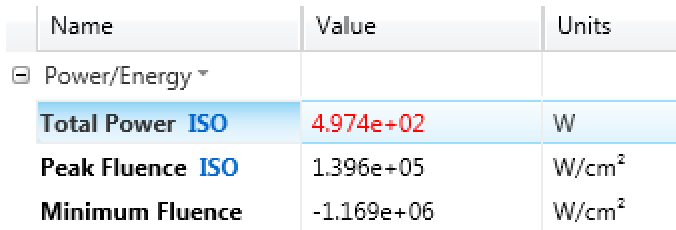
This is the control that enables and sets the Pass/Fail limits. Right-click a Results item, select Edit Pass/Fail, enable the pass/fail condition that is to be applied, and enter the limit values that define the boundary conditions.



In the above example, the Pass condition is that the Total Power must be greater than or equal to 500 Watts. Observe that the Units selected define the pass/fail units.

When the results fail the pass/fail criteria, the results value will appear in **Red**. If the result satisfies the pass/fail criteria, the results value will appear **Green**.

In the result display below is an example of the above Total Power setting failing.

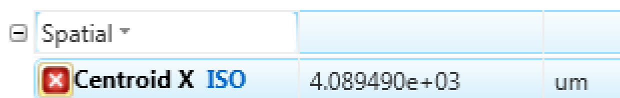


Name	Value	Units
Power/Energy		
Total Power ISO	4.974e+02	W
Peak Fluence ISO	1.396e+05	W/cm²
Minimum Fluence	-1.169e+06	W/cm²

Additional Pass/Fail settings may need to be set in the **Computations Pass/Fail** panel.

2.6.3.5 Hide

To remove a results item from the Results display, place your mouse on the title of the results item and click on the Hide icon that appears next to it. Observe that if the result item has been Dragged and Dropped in another window, hiding it in the results window does not remove it from that window. That removal must be performed separately.



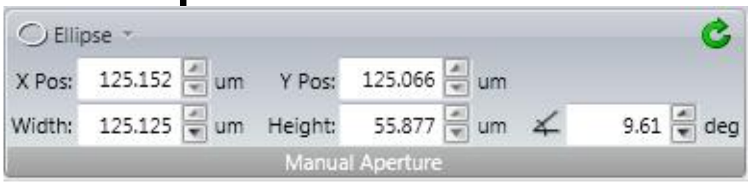
2.7 Aperture Ribbon and Controls

BeamGage can display three types of apertures: a manually drawn, an Auto Aperture, and a Beam Width aperture. BeamGage Professional edition also has the ability to create partitions within the 2D display.

The **Manual** and **Auto Aperture** limit the region where data is analyzed and the results computed.

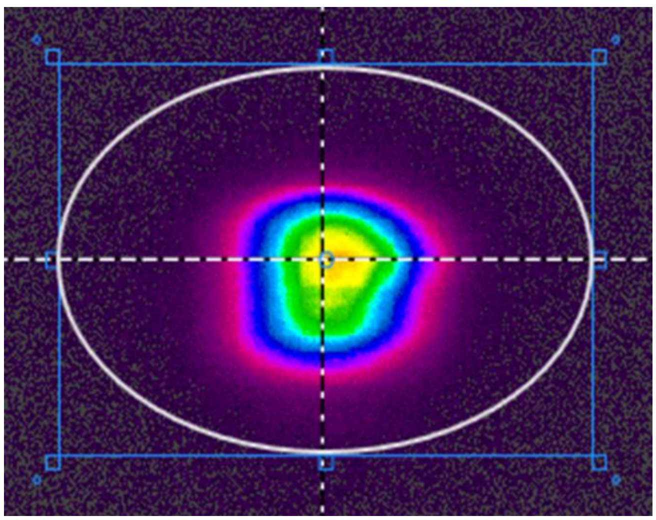
The **Beam Width** aperture is a display device that indicates the size and approximate location and orientation of the computed beam widths. The assigned Beam Width Basis is used to define the size of this aperture.

2.7.1 Manual Aperture



The Manual Aperture (displayed in Lt Grey) can be drawn in one of four user selectable shapes: Circle, Ellipse, Square, or Rectangle. The aperture size, position, and orientation can be controlled by entering numerical values in the above edit boxes, or it can be manipulated by the mouse.

To manipulate the aperture, begin by clicking somewhere on its perimeter. This will open a set of handles that provide grab points for moving, sizing, and reorientation.



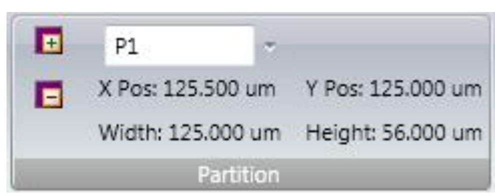
Click on the inside of the blue box to drag and drop the location of the aperture.

Click on one of the small blue boxes to resize.

Drag and drop one of the corner blue circles to change the orientation.

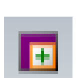
Click outside of the blue box to release and hide the handles.

Reset Aperture Will resize and position the aperture in the event that the ROI changes and the aperture is no longer in image space.

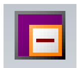


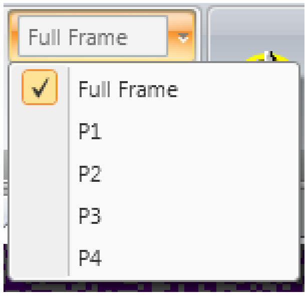
2.7.2 Partition

Partitions are available only in BeamGage Professional edition. This feature is complicated and is covered in more detail in CHAPTER 6.



Add Partition Creates a partition with the current size and location of the manual aperture. This option is only available when the manual aperture is enabled. Partitions are always square or rectangular and oriented on axis.

 **Remove** Removes the current partition selected from the **Name** dropdown list. This option is only available when a partition has been created.



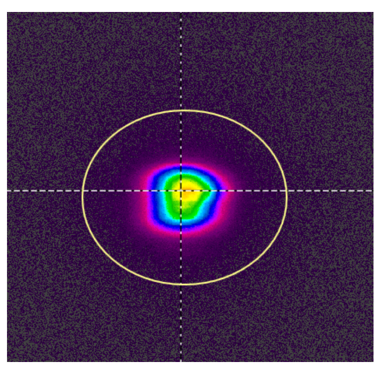
Name Dropdown list to select a partition. **Full Frame** selects the full detector area or the enabled manual or auto aperture.

2.7.3 Auto Aperture 

The Auto Aperture (displayed in Lt Yellow) is one of the most <u>important</u> computational aids, and should be used whenever possible. This feature is so important that it is provided in the Quick Access Toolbar.

The Auto Aperture is especially important to apply when making second moment measurements as it can aid in reducing the impact of noise in the wings of the beam. Wing noise can cause the computed second moment results to become very unstable. The smaller the beam relative to the display area, the more important it is to employ the Auto Aperture.

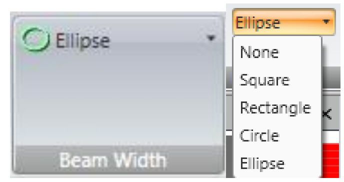
The figure below shows a beam with the resulting Auto Aperture surrounding the region of the beam that is included in the results calculations. Note how it isolates the noise in the outlying area from inclusion in the calculations.



The auto aperture is always drawn as an ellipse and will orient off axis when one of the off-axis results (Orientation, Ellipticity, or Eccentricity) is enabled.

Important: ***Because both the Manual and the Auto apertures isolate regions of the display for computational purposes, a precedent needs to be established on the order in which they are applied. If the Manual***

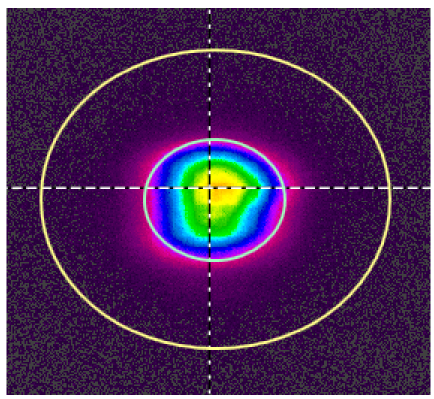
Aperture is applied first it can affect the outcome of the Auto Aperture's location, size, and shape. Once the Auto Aperture is established, only its boundary settings determine the outcome of the final results, i.e. an Auto Aperture takes precedence over a Manual Aperture when computing results.



2.7.4 Beam Width Displayed Aperture

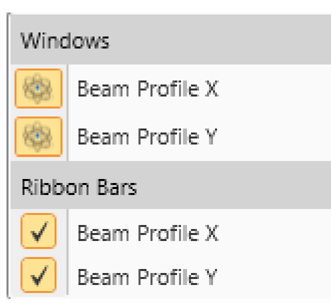
The displayed Beam Width Aperture (displayed in Lt Green) can be used to provide a view of the computed beam shape and orientation overlaid on top of the beam profile. This overlay can be drawn in both the 2D and the 3D Beam Displays. Select the shape that the displayed beam width needs to be displayed in.

The figure below shows both the Auto Aperture and the Beam Width drawn onto the 2D Beam Display.



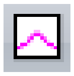
2.8 Beam Profile Ribbon

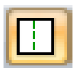
The Beam Profile ribbon provides two additional display windows that display 1D slice profiles of the beam at the cursor positions. The Beam Profile Tools are:

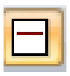


2.8.1 Beam Profile

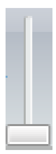
Because the X/Major and Y/minor profile sections are redundant, this discussion will proceed without reference to one or the other.

 Enable/Disable the display of the Gauss Fit profile.

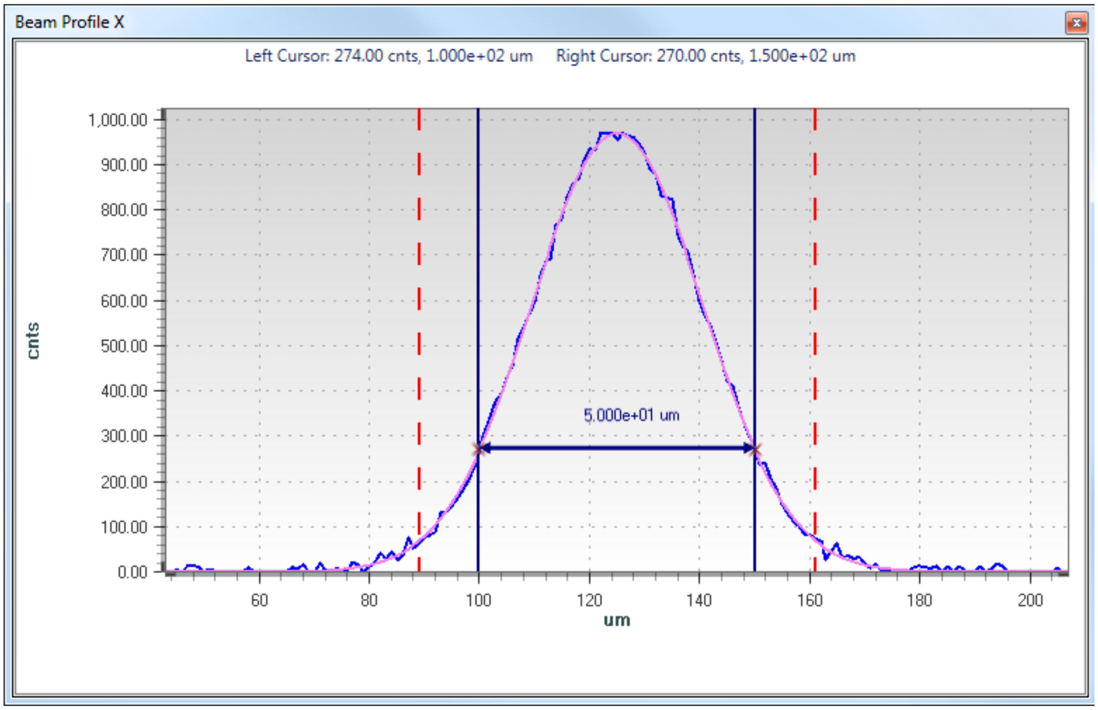
 Enable/Disable the display of the 1D Beam Width markers

 Show the TopHat Threshold marker.

 Enable/Disable the Caliper to display a second cursor.

  It is possible to Pan and Zoom in the 1D profiles using the Arrow and Slider controls in the panels, or by dragging the mouse in the display window and using the mouse wheel to zoom. The center button will reset the view to full width.

Beam Profile displays are similar to the embedded profiles drawn in the 2D and 3D display windows, except that they are drawn with scales and tools that provide them with more visual information. The figure below shows a typical 1D profile plot at one of the cursor locations.



Note: When the cursors are on axis the position locations are the same as in the X or Y positions relative to the 2D origin. When the cursors are off axis, the locations are specified as +/- distances from the Cursor intercepts.

Hint: It's a good idea to have the cursors track the centroid when off axis.

2.9 Charts Ribbon

BeamGage Standard edition can produce 2 different types of charts, **Beam Stability** and **Strip Charts**. The Beam Stability chart is enabled here in the Charts Tools. Strip Charts can be enabled via the individual result item that is to be graphed.

BeamGage Professional edition includes a **Histogram** charting feature. The histogram can be printed using the **Reports** feature. Histograms can also be saved into a *.csv comma delimited text file format.

The **Beam Stability** is a scatter plot depicting the movement of the laser beam's centroid location over time. The stability chart is a 2D histogram of the centroid position and does not include a time axis. The Beam Stability chart also includes a set of computed ISO results.

Centroid beam stability is often referred to as the beam's "Pointing Stability" as it indicates how the beam aim is drifting.

Strip Charts are plots of selected results items as they change over time. Charts will also display the four basic statistics as they apply to the region of the plot: Mean, Std Dev, Max, and Min.

Both the **Beam Stability** and **Strip Charts** will show a Sample Size value indicating how many frames were collected to yield the displayed results.

The **Histogram** charts the population distribution of a single data frame. The number of pixels included in the Histogram chart is defined by the aperture and follows the aperture priority rules.

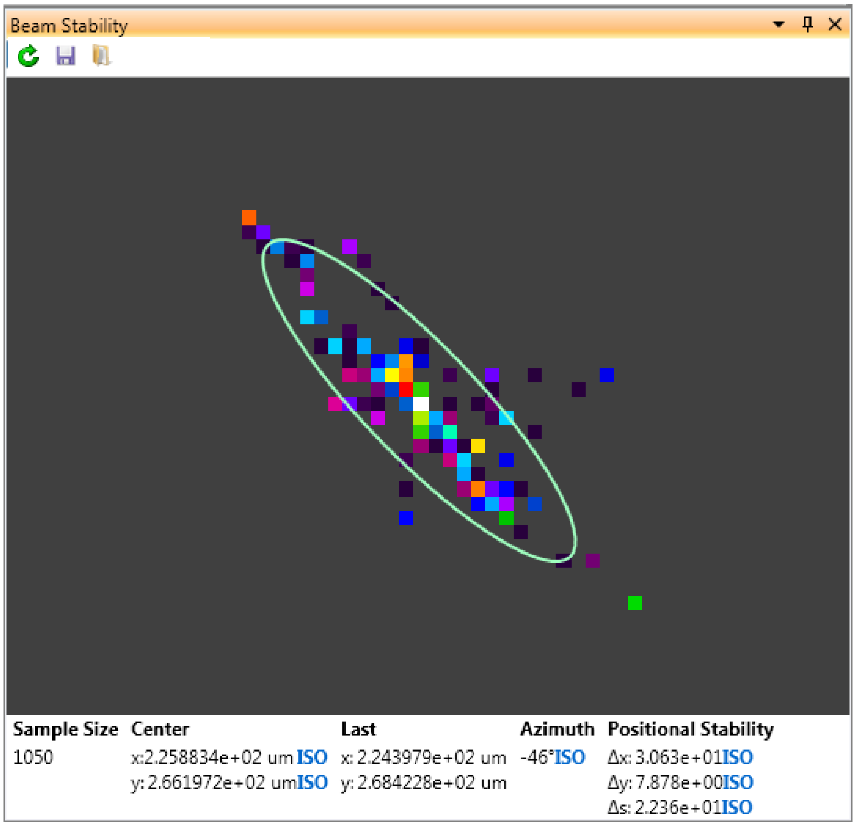
2.9.1 Beam Stability

Some laser beam centroids can drift over time. In some applications there is a need to know how much the beam drifts. The Beam Stability chart is a 2D histogram plot of the movement of the centroid location. This type of chart can convey the relative motion of the beam in space but not over time. The chart granularity, or bucket, is sized based on the dimensions of the camera pixel. The colors indicate the number of times (frequency) that the computed centroid falls inside the area of a pixel. The color palette is the same as the one chosen for the 2D beam intensity. However, the palette is automatically ranged such that the highest color intensity is always applied to the bucket with the greatest population (usually white) with lower valued populations proportionally spread across the lower colors.

The figure below shows the **Beam Stability** histogram motion for a beam that tends to wander up and to the right.

The Beam Stability window has a set of controls that operate only on the data located in this window. These are:

- **Reset** clear the chart and the results
- **Save** the chart to an ASCII *.csv results file
- **Load** a chart from a previously saved chart file



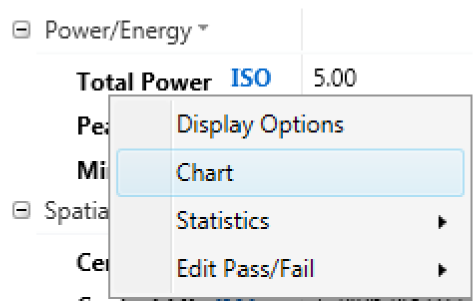
The above results tell the mathematical movements of the centroid histogram. These are ISO defined calculations and the above information is as follows:

- **Sample Size** Is the total number of data points in the histogram. A minimum of 1000 samples is required to satisfy the ISO requirement for the results items.
- **Center** Is the coordinate position of the centroid of the histogram.
- **Last** Is the coordinate of the last centroid plotted.
- **Azimuth Angle** Is the angular direction of movement.
- **Positional Stability** Is the computed 4σ of the displacement in the axis of the beam distribution Azimuth Angle where Δx, Δy, and Δs are the positional results along the direction the azimuth angle, orthogonal to the axis of the azimuth, and radially when the distribution of the motion is random and lacks a clearly definable Azimuth direction.
- The displayed aperture (Lt Green) is a graphical plot of the Azimuth, Δx, and Δy results plotted superimposed over the histogram distribution.

Note: The lower case x and y notations define the axis of the motion of the centroid per ISO 11670. The Laboratory system is always the upper case letters X and Y.

Beam Stability Pan|Zoom is a control that allows panning and zooming in the Beam Stabilities 2D plot window. This same control function can be performed with the mouse by dragging and dropping the view and by using the mouse wheel for zooming.

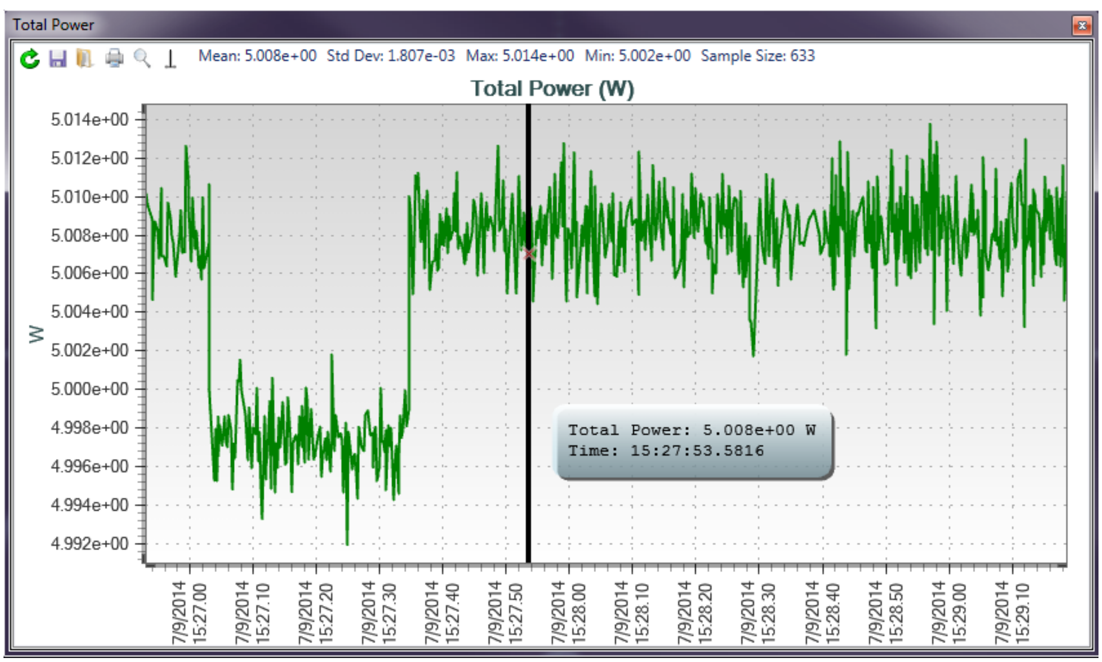
The  button enables automatic panning and zooming so that the plotted data is always best drawn to reveal the beam motion with the greatest clarity.



2.9.2 Strip Charts

Strip Charts are opened by right-clicking on a results item and then clicking **Chart**. This will cause a chart primary dock window to open. Each results item can be charted. In the example shown below, a **Total Power** chart has been launched. The plot of a manually started and stopped run is shown.

Note: It is possible that a particular calculation might produce a non-valid result; such as a power value less than zero. When this type of result occurs, it will not be plotted in a Strip chart.



In this example the vertical axis is displaying the beam power in Watts the horizontal axis is Time. A moveable cursor (vertical Black bar) can be moved to any location and the time and power can be seen in a readout box that follows the cursor. A Red X is shown at the point where the cursor and the data point intersect. When a chart is first opened or reset, this cursor is embedded in the left vertical axis. Click the **Center Cursor** button to bring the cursor to the center of the chart.

If the charted value has a Pass/Fail limit applied, a limit line will also be drawn in the strip chart. Pass/Fail values can be quickly changed by dragging the line in the chart.

Statistical results covering the data in the chart are displayed along the top edge of the window. These stats do not require that statistics to be enabled in the Results display window.

Panning and zooming into the data to reveal more detail can be accomplished by clicking and dragging the mouse and by using the mouse wheel to zoom. Zooming is centered on the mouse location. The axes can also be panned by clicking and dragging the tick marks of the axis.

Within the Strip Chart are **Save** and **Load** controls that allow a chart to be saved into and loaded from an ASCII log file. These files are formatted comma delimited and are compatible with Excel spreadsheets.

A separate **Print** button is provided so that any one chart can be easily printed.

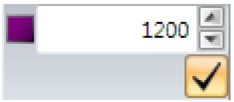
Charts can be individually **Reset**, separate from the ribbon panel reset which acts globally on all charts.

2.9.3 Chart Properties

The controls in this panel are common to both **Beam Stability** and **Strip Charts**. They set the running and reset properties of the charts.

Charts Reset Click on this momentary button to reset all open data charts. A chart does not have to be in view to be reset. Pinned charts are included.

Reset on Start When enabled, this control will cause all charts to Reset when the Start button is clicked. This is a good way to insure all charts stay in sync.



Sample Size The button and the edit control will cause the charting displays to be limited to a fixed running sample size. In this example, the charts will run until 1200 samples are plotted then the plot will operate in a last in first out mode maintaining the display of the last 1200 samples collected. The data of the deleted samples is lost. The displayed statistics will cover only the retained samples. The maximum sample size is 10,000.

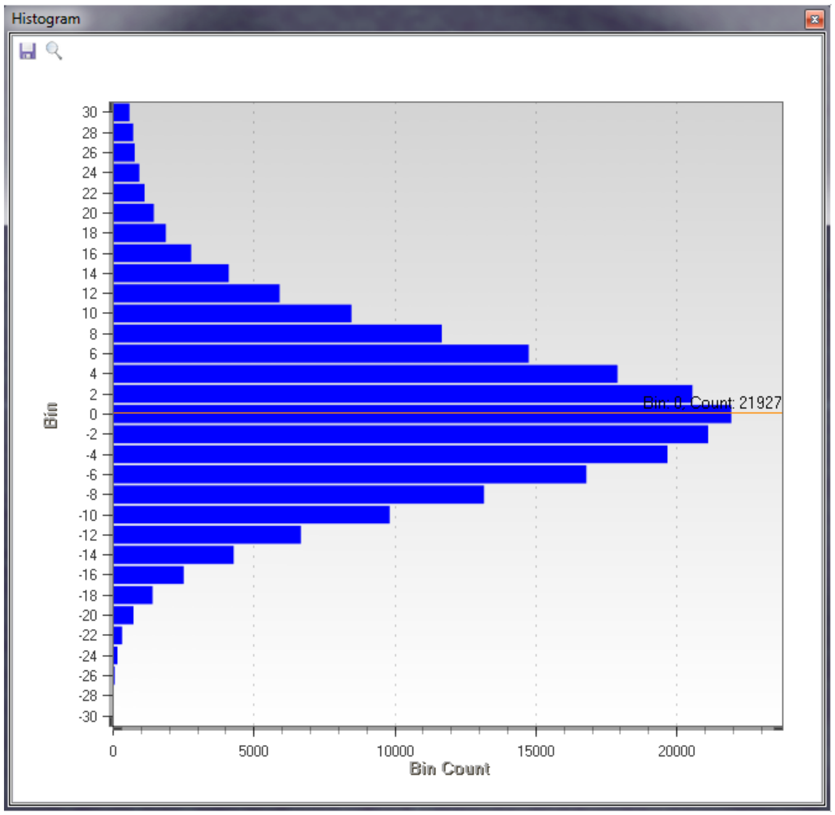
2.9.4 Histogram Chart

The Histogram charts the population distribution of a single captured data frame. The number of pixels included in the Histogram chart is defined by the aperture and follows the aperture priority rules. The histogram display ignores Partitions and only represents the full frame and the content of either a manual or auto aperture operating in the full frame.

The Histogram display will automatically scale to the range of pixel values observed in the data frame. The Histogram control panel, shown above, has specialized controls to allow the user to zoom and scroll thru the data and set the displayed binning size. The finest resolution for the bin is 1 pixel count. When operating in calibrated power/energy mode the displayed bin value is converted to the equivalent power/energy value. The values along the left side of the histogram display are the mean count/power/energy value for each bin.

The Orange cursor displays the current bin and the number of pixels observed in that bin. This cursor can be moved to any bin in this display.

The histogram plot shown below is what a typical Gaussian noise distribution looks like for a 12 bit camera with a signal-to-noise ratio of 55dB. The cursor is placed on the zero bin.



To save this data in a comma delimited .csv file, click on the **Save** button. A standard Windows file Save As dialog box will appear. Enter the file name and click Save. This type of file can be imported into Excel and many other types of mathematical analysis tools.

Note: The entire histogram data set gets saved at the set bin size.

2.9.5 Histogram Controls

The following is a description of the histogram display and viewing controls.

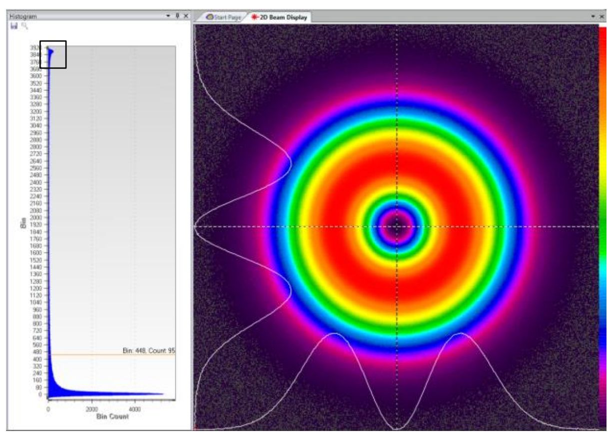
Bin Size Sets the binning population size in integer raw digitized counts. Values are assigned to the bins with their value rounded to the nearest bin integer. For example if the bin size is set to 2, a pixel with a count of 1.000 to 2.999 will be assigned to the #2 bin; while a pixel of a value +.999 to -1.000 will be assigned to the Zero (0) bin.

Histogram Panning When zoomed into the Histogram display the up/down arrows will scroll the histogram window either up or down. This operation can also be performed by placing the mouse cursor into the histogram window and sliding it up or down while holding down the left button. The mouse operation is limited to the current window display region and is best used for fine adjustments. Click on the Green arrow to reset the pan and zooming operations to the full histogram window.

 **Histogram Zooming** These two sliders, left and right, will zoom the vertical and horizontal histogram display, respectively. The numerical values will only become visible when the maximum vertical zoom level is reached. Vertical zooming will center upon the position of the violet cursor. Drag the cursor to the point of interest and then operate the zoom control. Vertical zooming can also be performed by placing the cursor inside the histogram window and then rolling the mouse wheel. Zooming is centered on the mouse location.

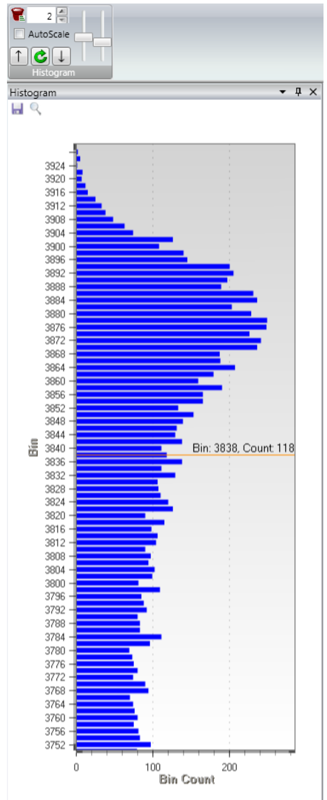
Histogram Scaling When enabled, the histogram max and min populated bins will be automatically sized to fit the current Histogram window. When disabled, the Histogram display will only follow the settings performed manually.

Example: Below is a histogram of the displayed donut beam. The bin size in this histogram is set to 2. The full histogram range is displayed in the first view. The power/energy is uncalibrated.



In order to view a specific region of the histogram in more detail, use the special histogram viewing controls. For example, to view the upper distribution indicted above in the black rectangle, use the controls as follows:

Disable **AutoScale** and place the mouse in the middle of the region to zoom into. Spin the mouse roller to zoom into the region of interest. Use the left slider to expand the distribution. After performing the above operations, the histogram display will look something like the image shown below.



2.10 Logging Ribbon

Logging can be used to record different types of data files onto the PC's hard drive. Logging performance is dependent upon the speed of the PC platform and on the type and number of items being logged.

Binary frame data files are usually large file types, often many megabytes per frame record. They also contain setup and additional display details, all of which take up space on a per frame basis. These files are saved in the industry standard HDF5 file format. These files can be reloaded into BeamGage and also displayed with the **Source**, **File Console** playback feature.

Numerical results logs are the fastest because they are essentially ASCII files with limited amounts of data in each record.

A special Column and Row summed log file allows for the exporting of the summing of all the rows and then all the columns into an ASCII file. This is a rather small file type and does not generally impact performance. Each record contains the results of the column summation and the results of the row summation, in that order.

The ASCII data file is an actual copy of the image's processed data, minus any graphical overlays. Thus this type of image will faithfully reproduce the processed pixel values. If the data is calibrated the ASCII with be in the calibrated power/energy value at each pixel. If uncalibrated, the data will be in counts. Ultracal'd data and Auto-X data will be processed and contain negative noise values as well as positive signal content. ASCII files can be quite large especially if the frame is large and the data is power/energy calibrated.

Unlike the previous data formats, the ASCII data will be the entire frame unless a manual or auto aperture is present. In this manner the amount of data can be reduced to just the region that is involved in results calculations. The X and Y extents of a drawn manual aperture will limit the image region logged into the ASCII file. If the aperture is not a rectangular shape drawn on axis, the pixels that lie outside of the aperture will be exported as empty values.

Note: A Manual aperture will also limit the area where data gets analyzed, not just the region copied into an ASCII image file. Use the manual aperture with this in mind.

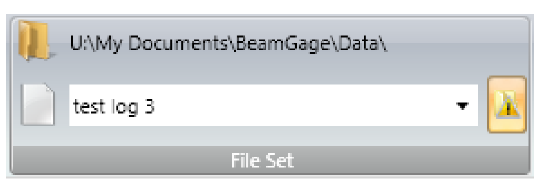
Hint: In order to keep the logged region stable, use the Manual aperture and turn off the Auto aperture.

For the purpose of clarity, all log file entries that pertain to one frame of data and/or results is called a record, and each record is time stamped. Log files are opened when they begin collecting records, and closed when the final record is entered and the logging process is terminated.

The act of opening a Log File requires a certain number of operator inputs. While closing a log file can occur much more easily. This "hard to start…easy to stop" philosophy is designed to prevent unintentional filling of a hard drive.

Image files are graphical file types. They can be used to create images that can be imported into third party document tools such as Adobe or MS Word. These files cannot be used to recreate the actual data of the frame and are mostly relegated to more artistic pursuits. You can create AVI or other types of video replay images with these.

See CHAPTER 4 for more details about the file formats created by BeamGage. This chapter also covers Exported image and ASCII data files which are the same as the file types logged in this section. Use the export feature to create single or small groups of image files when logging is not appropriate.



2.10.1 File Set

As described above, multiple types of log files can be generated simultaneously. To begin the process a file path and name must be entered in the File Set panel. This file name will be common to all of the resulting log files. Different file extensions will be added to the file name to designate the file type. The default file extensions are:

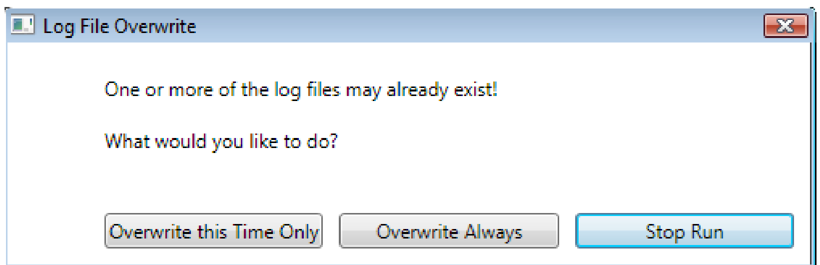
- **.bgData**, for BeamGage HDF5 data files.
- **.csv**, for BeamGage ASCII comma delimited log files

- **.bmp, .gif, .jpg, .png, .tif;** allowed image file formats

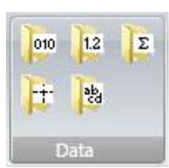
The upper line of text is the current path leading to the log file folder.
The second line is where the log file name is entered.

When installed, BeamGage creates two folders in the installers user account:
C:\Users\<user_name>\Documents\BeamGage\Data
C:\Users\<user_name>\Documents\BeamGage\Setup
The default location for data, log files, and reports is the ..\Data folder.

The  button in the corner enables the file Overwrite warning. Leave this on to avoid accidentally overwriting a log file with the same name.



Important: ***Use care when setting up logging scenarios. Logging operations can quickly fill the hard drive with many hundreds to thousands of data and/or image files. Be sure to tightly control all logging operations and do not log things that are not really needed. Avoid using Image logging since this data is not reloadable. ASCII data logging is primarily for export to third party applications. These files can be extremely large when saving power/energy calibrated frames.***

2.10.2 Logging Data 

The type(s) of data file(s) to log are controlled by these five buttons.

 Enable Frame data logging in HDF5 format. These binary data files can contain multiple records (frames) per file.

 Enable Results logging in ASCII format. Select the partition(s) and/or full frame to log. The full frame selection is governed by the manual or auto aperture if enabled. These files contain the results per frame with a time stamp. Each file can contain multiple record entries.

Enable Column/Row sum logging in ASCII format. These files contain the results per frame with a time stamp. Each file can contain multiple record entries.

Enable Cursor data logging in ASCII format. These files contain the results per frame with a time stamp. Each file can contain multiple record entries.

Enable Frame data logging in ASCII format, bounded by the aperture that is governing what data is used in the computed results. Each frame will be recorded into a separate file.

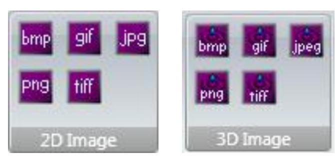
Note: Partitions frame data cannot be separately logged, only the full frame data will be logged. The partition apertures are ignored.

After enabling the required file types, begin logging by clicking **Start** .

To stop the logging process click **Pause** .

Whenever the logging process is stopped, no matter by what means, the above logging type buttons are automatically disabled. To begin a new Logging cycle the selection(s) must be re-enabled.

2.10.3 Logging 2D/3D Images



These controls select the type of image file type(s) to create a log file for. Each frame will be recorded into a separate file sharing a common name with a frame number and the appropriate file type extension.
To insure correct operation you must be in **Results Priority** capture mode or frame images may be skipped and the resulting number of frames may be less than the number specified.

bmp bmp Enable logging bmp image files.

gif gif Enable logging gif image files.

jpg jpeg Enable logging jpeg image files.

png png Enable logging png image files.

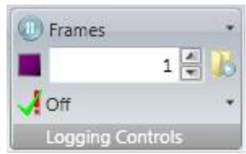
tiff tiff Enable logging tiff image files.

All logged images will contain the exact 2D or 3D display window in a What You See Is What You Get (WYSIWYG) form.

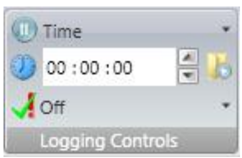
Important: ***Image files are not able to reproduce the numerical data used to create the viewed image. Use Data file types to extract real numerical information from the frame(s).***

Note: If, while logging a 2D or a 3D image window, you grab it to move or resize, the image will stop updating and logging will be suspended until you release the window.

2.10.4 Logging Controls



These controls allow automatic termination of the Logging cycle. The logging duration can be set to log a specified number of frames, as shown above.



The logging duration can also be set to terminate after a certain time period has elapsed.

Or it can be set to run continuously until  Pause is clicked.

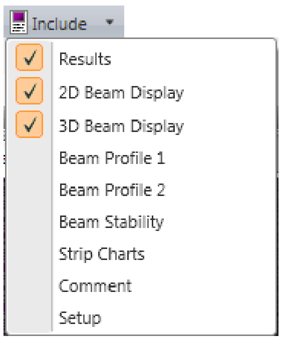
Warning: If not manually stopped the log will run until the hard drive is full.

Stop or Continue data capture When in a logging mode, the data will stop when the logging requirements of Time or Number of Frames is met. To continue capturing data frames after the logging process terminates, enable this control.

Log Pass/Fail The user can apply a Log Pass/Fail filter that determines which files get logged. If **Pass** is checked, then only the frames that pass the enabled Pass/Fail criteria will be logged. Similarly, if **Fail** it checked, only the failed frames will be logged.

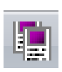
2.11 Reports Ribbon

Reports consist of user defined printouts or savable PDF files that can be created from the various display windows and results enabled in BeamGage. The basic rule is that items are printed in a "what you see is what you get" style. If certain displays are pinned, they will be automatically opened for the purpose of printing or saving to a PDF file.



Include Options Use the Reports Include dropdown to enable the items that are to appear in a report. The choices of what is available for printing extend into almost every item in the BeamGage application. The window must be opened somewhere on the screen to be able to print it.

Note: If Strip Charts is checked, all active charts, not just the ones currently visible, will be included in the report. To print a single chart, use the local Print button in the chart display window. Likewise, if Setup is checked, all of the panels with all of their settings will be added to the report.



Separate Pages To keep everything neatly sorted, enable this and each printed item will be printed on separate sheets of paper.

The **From:** value is the current frame buffer display location and indicates at which frame the report process will start. To print more than one frame, enter the number to report in the **#** of Frames to report on in this edit box. The number of frames always counts up in the frame buffer and the maximum number is the frame buffer size.

Click on the **Save** or **Print Preview** button to initiate the desired reporting operation. When **Save** is clicked, a PDF file format can be created. This will open a standard Windows **Save As** dialog. Enter a file name and click Save.

When **Print Preview** is clicked, a temporary PDF file will be created. This is a good way to verify what is being printed and how it will appear. The PDF can then be printed or saved using the Adobe controls. Once the PDF is closed, the temporary file will be deleted.

Important: ***If used carelessly, printed Reports have the ability to pump out a lot of paper on a printer. Whenever printing multiple numbers of frames, make it a habit to recheck the Options choices and view the generated PDF file to insure that a lot of paper doesn't get wasted.***

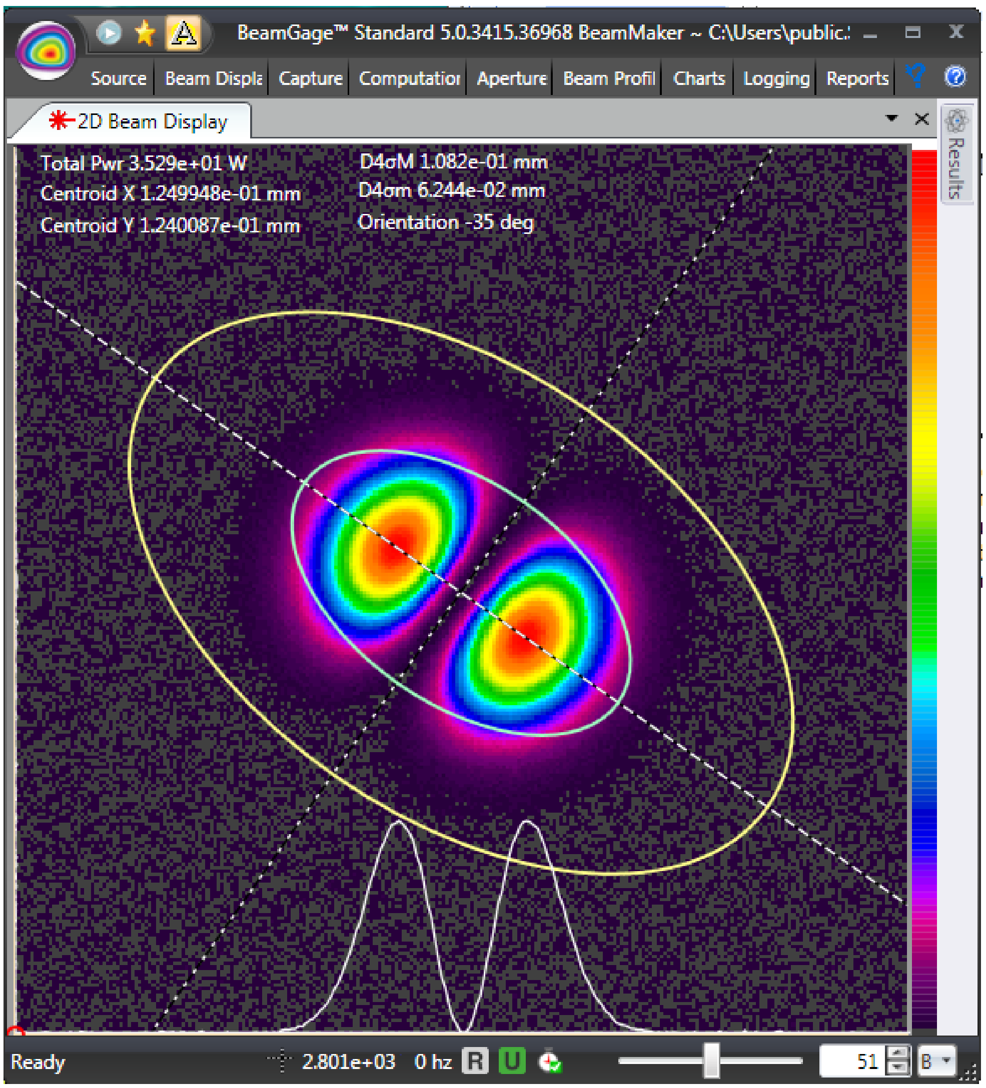
CHAPTER 3 Displays

3.1 Displays, Have Them Your Way

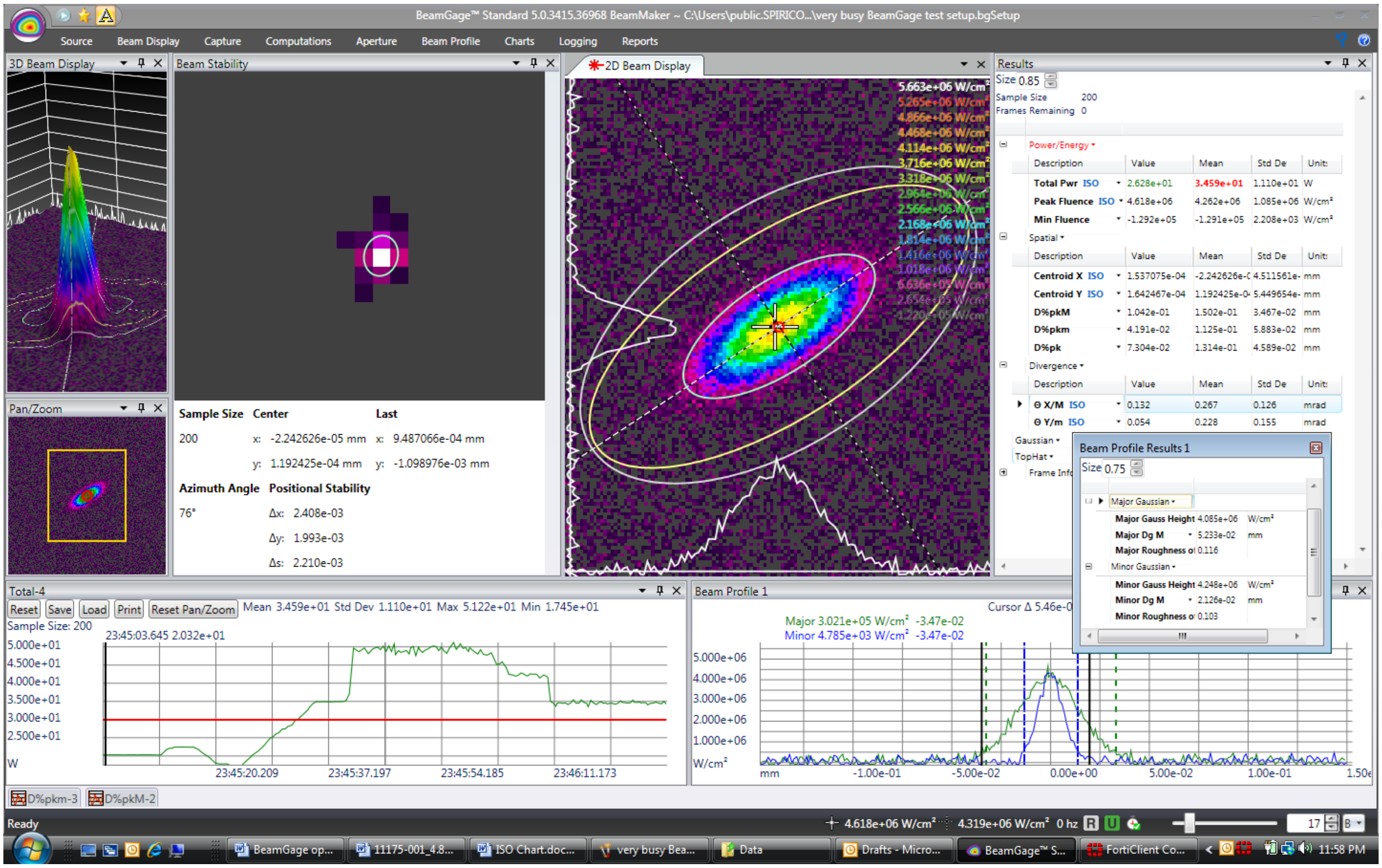
One of the neatest things about BeamGage is the ability to create a flexible display environment to meet the user's specific needs. From a very simple beam display window that shows just specific items; to a highly complex multi-tasking display with pop-out on demand display elements, floating desktop windows, and multiple display desktops. BeamGage can pretty much do it all.

In this chapter the tools that control the screen layouts will be described.

Below is an example of BeamGage in a minimalist form.



Here is an example of BeamGage where there's a lot going on. Some things are hidden from view but can be popped out by clicking on a pinned items tab handle.

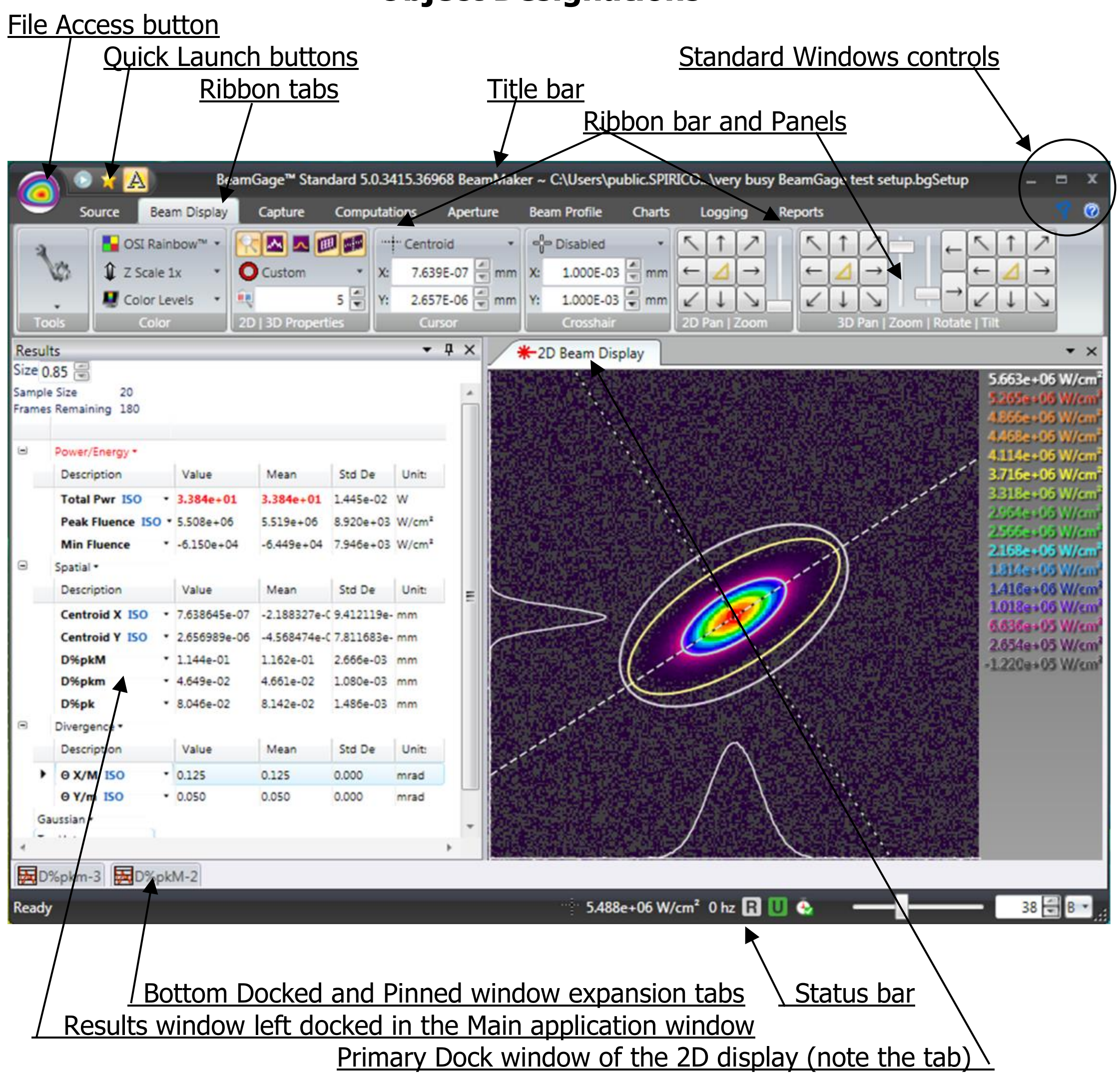


3.2 Display Terminology

The tools that permit making both the simple and complex screen layouts employ terminology that may be new to some Windows users. This section will provide a graphical glossary of terminology of things both old and new and hopefully useful.

Note: Within the industry there is some variation on the naming conventions in the ribbon motif that is employed in BeamGage. The ones we have chosen here, if not chosen by consensus, are at least consistent and logical.

Object Designations



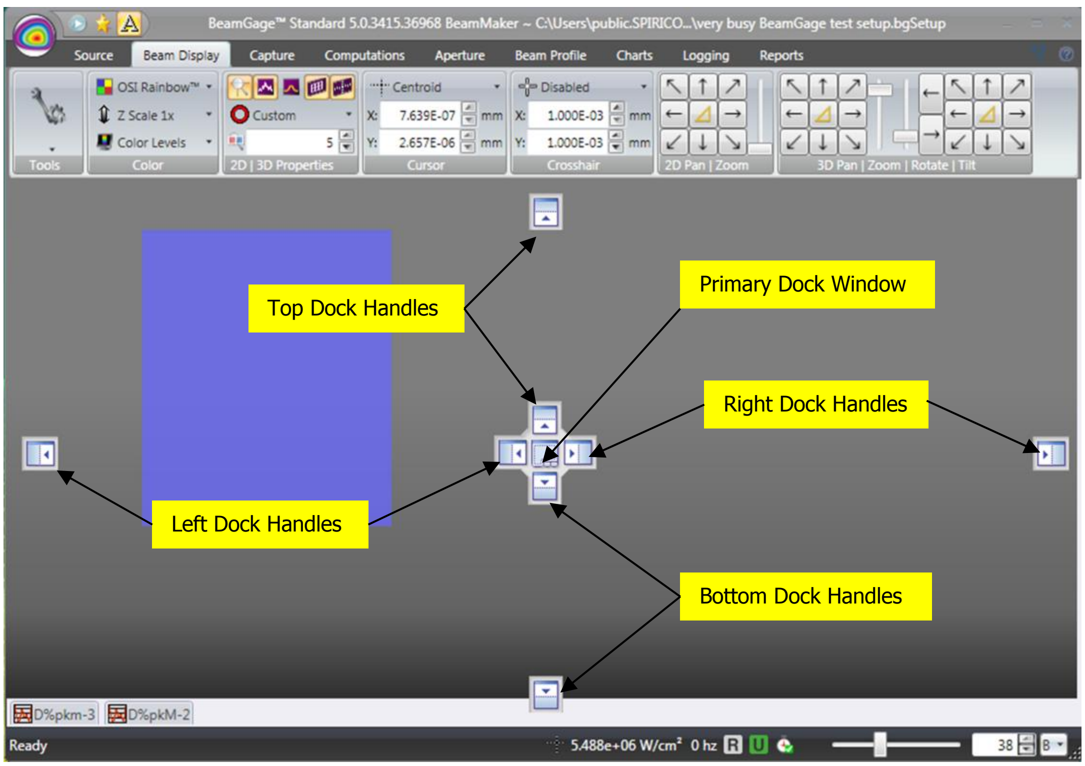
3.2.1 The Primary Dock Window and Dock Handles

The first time a window is opened it will appear as a primary dock window. This is a tabbed window located in the main display's application. See the **2D Beam Display** window in the above layout. Each time a new window is opened it will appear as another tab in the same space. Each new primary dock window will lie on top of the previous one. This stacked layout is one type of display option, but one that has a limited view of each stacked window. The Start Page tab is a permanent primary dock site object that cannot be removed.

To undock a primary dock window, grab the tab with the mouse and drag down into the application window area. When dislocated from a docked position the window will turn a Blue color and a set of docking handles will appear as shown below.

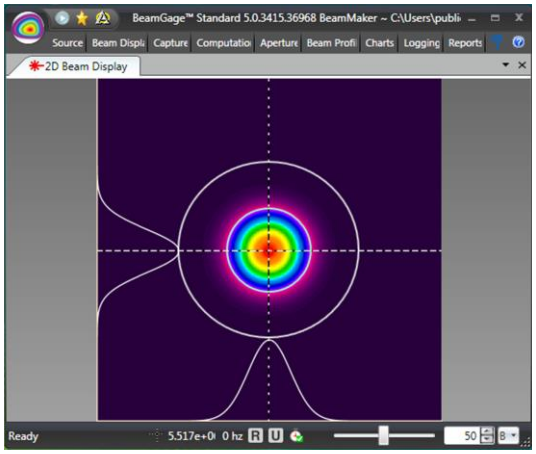
Docking Handles

All display windows can be dragged and docked to the four sides of the application window. The Blue object is the window being moved to a Dock Handle. All displayable windows can be grabbed with the mouse in their Title Bar or Tab region and dragged onto a Dock Handle.

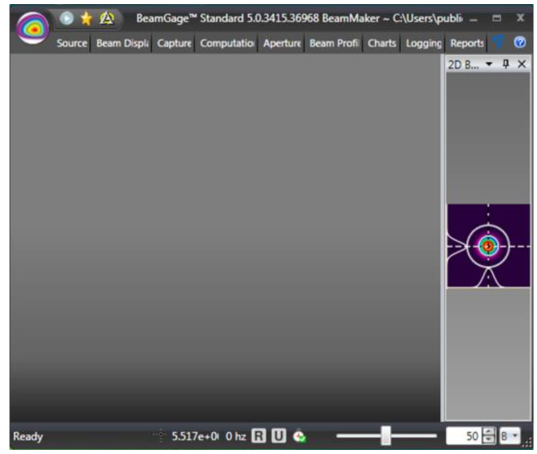


Now drag the mouse cursor to touch one of the perimeter docking handles and release the mouse button. The window will now be docked to one of the sides. If the window is not released on one of the docking handles, it will be set to floating and can be positioned anywhere on the screen.

2D Beam Display in Primary Dock window before relocating



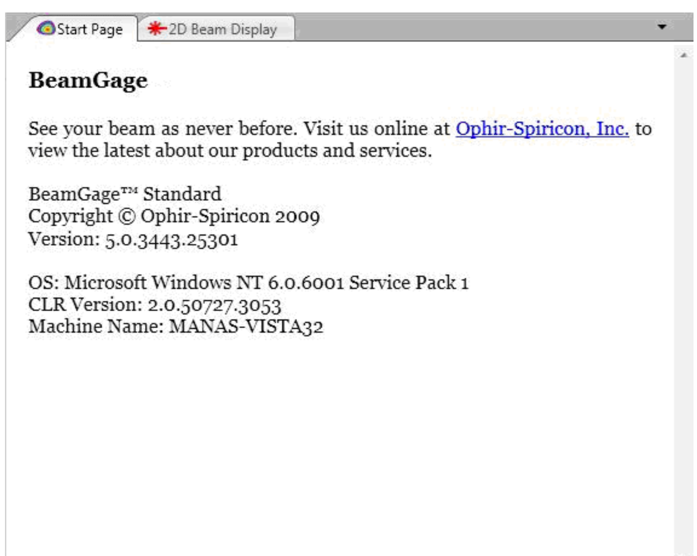
And after relocating to the Right Dock Handle



After positioning, resize the window into a more useful appearing display. To do this in the above example, simply grab the left edge and drag the window open.

Note: Once a window has been repositioned, BeamGage will remember the placement so that the next time the window is opened it will appear in the last docked location, not in the Primary Dock Window.

In order for this window docking scheme to operate correctly there must always be something in the Primary Dock window. This makes manipulating the other windows much easier as each child window's docking handles remain more accessible during the screen layout process. To insure the presence of the primary dock window, a permanent tab called the Start Page is always present. Usually this window is covered by another display window, like the 2D beam display shown above. The Start Page always contains the current version number and will look something like this:

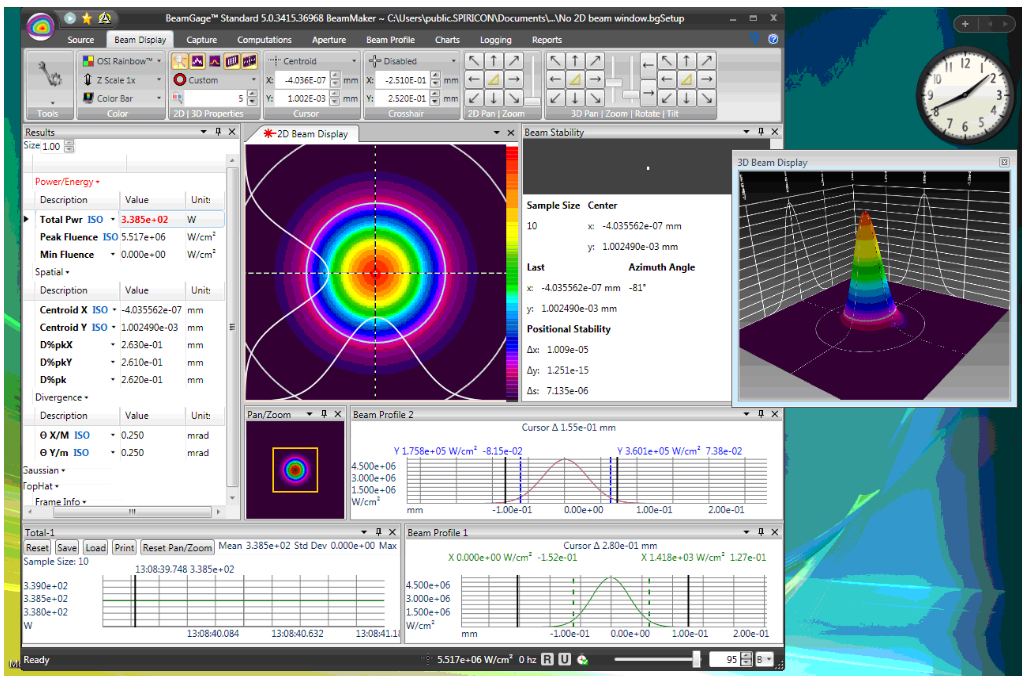


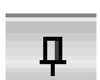
3.2.2 Dock Handle Cloning

Each child window will have its own set of Dock Handles, thus each time a window is docked it will clone its own set of handles. Thus more child windows can be docked within each new child, and so on, and so on…. This permits placing windows side by side, and over and under each other.

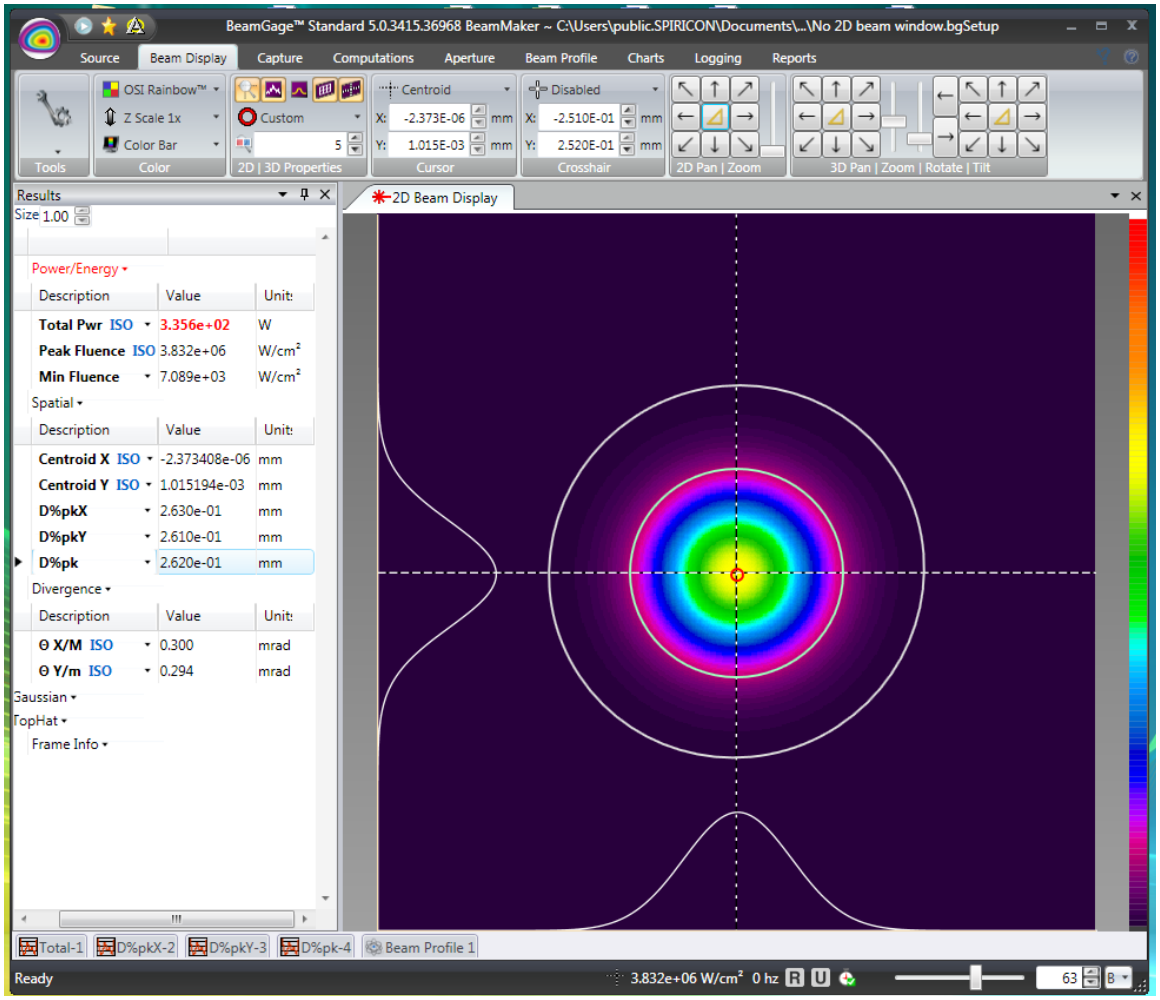
Note: Floating windows do not clone the docking handles. Thus they cannot be combined with other child windows. Floating windows are separated from the main application window and have no features beyond what appears in their window. A floating window can be re-docked into the main application by dragging its title bar back into the main display window and dropping on a dock handle.

Below is an example of many windows. Some docked inside of other docked windows and one floating outside of the main BeamGage application. The best way to learn how to manipulate the windows and use the docking handles is to experiment.

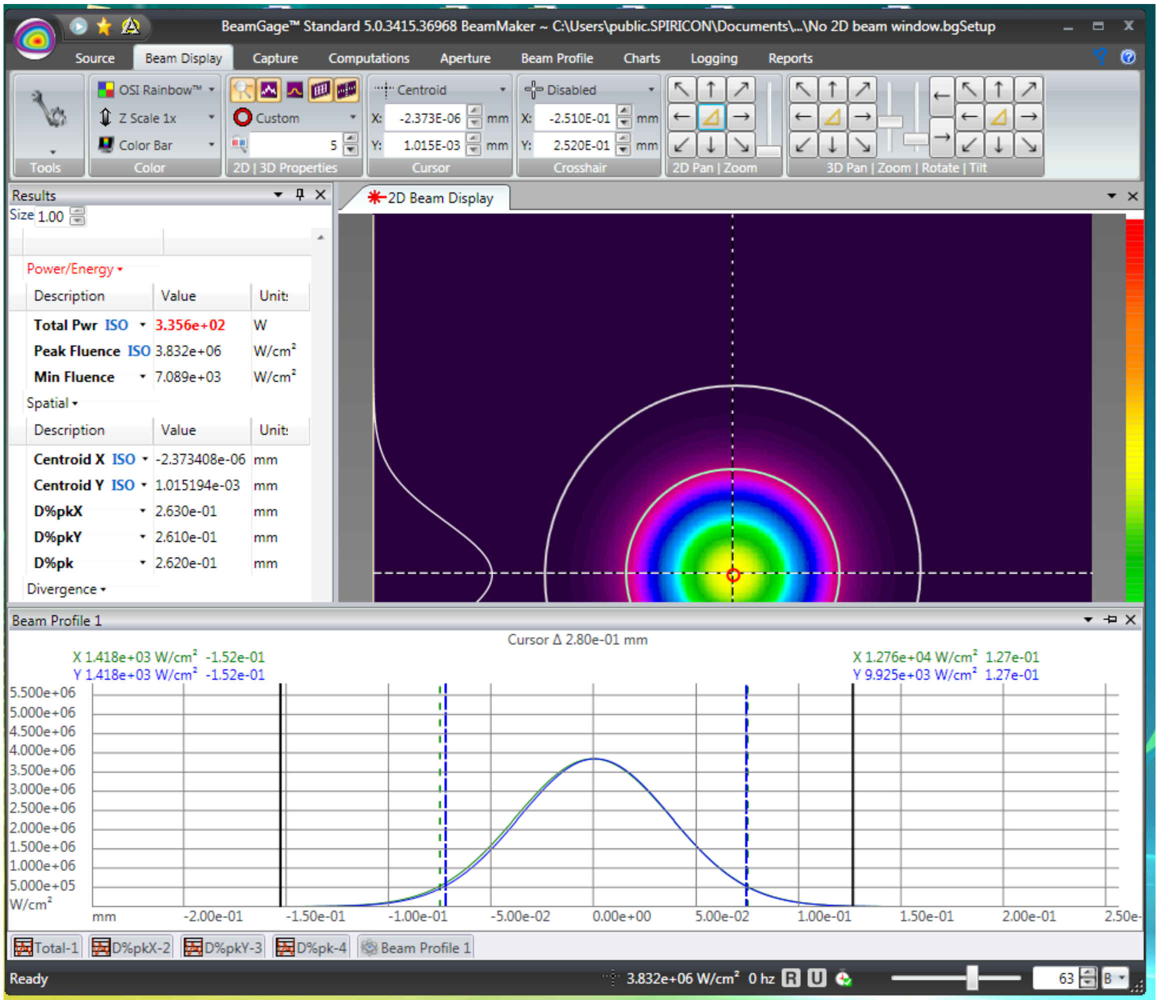


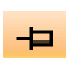
3.2.3 Pin 

The Pinning feature allows placement of many items into the space of a single dock site and then pop them open for viewing by hovering or clicking on the pinned window’s tab. Clicking on the windows Pin control feature, shown above, will cause a window to collapse into the dock frame. The figure below shows five separate windows pinned to the bottom of the BeamGage main window.



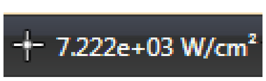
Hovering over or clicking on one of the pinned tabs will cause the collapsed item to pop out from the edge for viewing, see below. Clicking on it a second time will re-collapse the window.



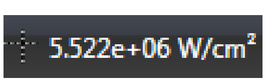
 **Un-pin** Click on the Un-pin tool to restore a pinned window to its former docked condition.

3.3 Status Bar 

The right most section of the Status bar contains the most commonly visible elements. Each is described below.



Crosshair Fluence This value is the measured beam fluence at the position of the Crosshair. When not calibrated, the units are in raw or processed counts (cnts).



Cursor Fluence This value is the measured beam fluence at the position of the Cursor. When not calibrated, the units are in raw or processed counts (cnts).

Frame Rate The frame rate is calculated and updated as data frames are received from the camera in real time. When stopped the rate displayed is 0Hz.


Dropped Frame The Dropped Frame indicator will have a **Green** checkmark when BeamGage is collecting frames at the camera output rate. If frames are being dropped the checkmark will turn or flicker **Red**. The input frame rate can be an important detail if attempting to collect laser pulses at a fixed and guaranteed rate. Adjust some display parameters to insure a high capture rate. See also **Frame Priority**.

Reference Subtraction This indicator will change color depending upon the current status of reference subtraction processing. The meanings are:

- **Grey**, Reference Subtraction disabled
- **Green**, Reference Subtraction enabled and active
- **Red**, Reference Subtraction has been disabled because of a change that may make it no longer reliable, such as the camera settings have changed

Ultracal This indicator will change color depending upon the current status of Ultracal processing. The meanings are:

- **Grey**, Ultracal disabled
- **Green**, Ultracal enabled and active
- **Red**, Ultracal processing has been disabled because of a change that may make it no longer reliable, such as the camera settings have changed

Auto-X When operating in auto exposure mode, the Ultracal indicator becomes the Auto-X indicator. When displaying **Green**, the collected data frame is expected to yield accurate results and should have a good baseline correction. When displaying **Red**, the results may be somewhat compromised or very poor.

Frame Buffer Indicator/Selector
The slider and edit control indicate the currently displayed frame buffer location. To navigate in the frame buffer, either edit the frame number or run the slider to the desired location. The letter edit control allows the user to view special frame buffer locations. When indicating a **B**, the display is following the buffer edit controls. Setting it to an **R** will force the display to show the currently saved Reference frame. Setting it to a **U** will display the current Ultracal frame.

CHAPTER 4 Files, Formats and Privileges

4.1 BeamGage File Types

As of this writing, BeamGage produces four different types of files. The list of file types and their naming extensions are as follows:

Extension label	BeamGage Application	Format
.bgSetup	Setup file type	HDF5, proprietary content
.bgData	Data Files that are loadable and playable by the File Console source	HDF5, compatibility w/ Matlab and many other 3rd party applications
.csv	Results, Log files, and Charts files	Comma delimited ASCII
.pdf	Report file format	Adobe compatible

4.2 Setup Files, .bgSetup, HDF5

The Setup files are used to define the configuration states of BeamGage. The user can configure BeamGage into an infinite number of setups and layouts to suit their application needs. To insure the precise return of the settings use the **Save Setup As…** file choice via the **File Access** button. There are five different setup file actions possible.

1. **Load Setup…** Will open the standard Windows file load dialog box directed at the folder where the setup files are saved. Select the file to be loaded and click OK. Note that the default folder will always be the last folder used.

2. **Load Setup BeamGage Only…** as in 1. above, but will only apply the settings not dealing with the Source selection. The Source settings will remain unmodified by this load operation.

3. **Load Setup Source Only…** as in 1. above, but will only load the Source selection and settings. The remaining settings will remain unmodified by this load operation.

4. **Save Setup As…** Will open the standard Windows file save dialog box directed at the folder where the setup files are saved. Enter the name of the new setup file and click Save. Note that the default folder will always be the last folder used.

5. **Save Setup** Will immediately overwrite the current setup with the current settings.

4.3 Data Files, .bgData, HDF5

Data files contain the processed beam data with setup information. Data files can contain one frame of data, or many frames of data. Each frame is called a record. Data records can be saved and loaded one record at a time or many records at a time. Data files can be saved from and loaded into the frame buffer.

Data files can be created using the Logging feature. A Logged data file is one that contains multiple records saved in real time.

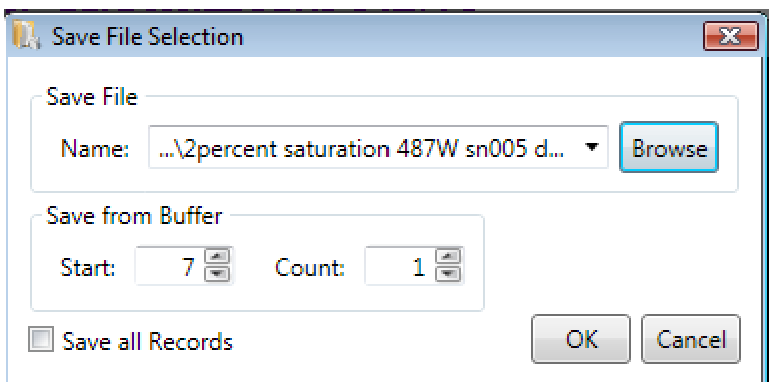
Data files can be played back and post-processed using the Source Playback Console.

Data files contain all the necessary information needed to reload and recreate the data in a manner that will replicate the conditions in place when the data was originally captured. They can also be loaded without restoring the setup conditions.

1. **Save Data…** Will open a specialized Windows file save dialog box (see below) directed at the folder where the data files are saved. Specify which frames in the frame buffer are to be saved by entering the **Start** frame and frame **Count** values, or by checking on the **Save all Records** checkbox.
    a. The default **Start** value will be the currently displayed frame
    b. The default **Count** will be 1
    c. **Save all Records** will be unchecked.

   Click on the **Browse** button and enter the name of the new file. Click **Save** and then click **OK** and the data file will be saved.

   Note that the default folder will always be the last folder used.



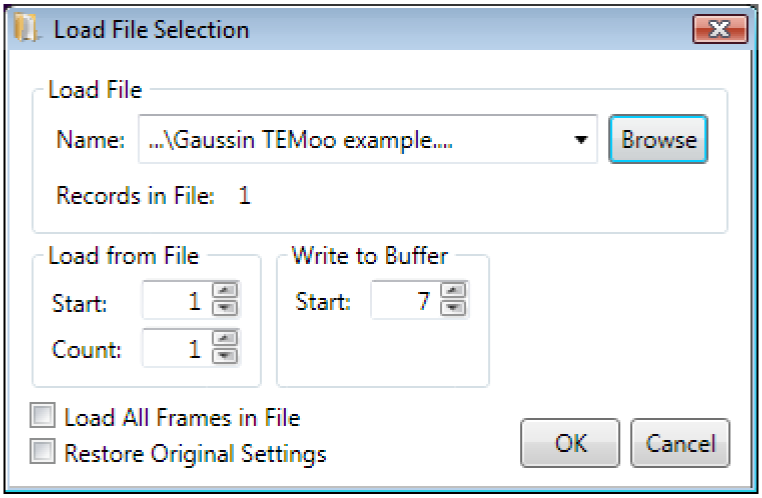
2. **Load Data…** Will open a specialized Windows file load dialog box (see below) directed at the folder where the data files are saved. Specify which frames in the data file to load by entering the **Load from File: Start** frame and frame **Count** and where to begin depositing the data in the **Write to Buffer: Start**. Or, by checking on the **Load All Frames in File** checkbox, the entire file and all its records will be loaded starting at the designated frame buffer position.

   To insure that the reloaded data will present in exactly the same manner as it was originally collected, check on the **Restore Original Settings** checkbox.
    a. The default **Start** value will be the 1st record in the file.
    b. The default **Count** will be 1
    c. The **Write to Buffer: Start** will be the current displayed location.

d. **Load All Frames in File** will be unchecked.
e. **Restore Original Settings** will be unchecked.

Click on the **Browse** button and enter the name of the new file. Click **Open** and then click **OK** and the data file's records will be loaded.

Note that the default folder will always be the last folder used.



Important: ***Loading a data file that is larger than the frame buffer size will cause the data to wrap and overwrite the frame buffer with the last frames loaded remaining in the buffer.***

4.4 HDF5 format

The HDF5 format is compatible with many third party applications, one of which is MATLAB. See the following web link to learn more about the HDF5 format. http://www.hdfgroup.org/HDF5/

The .bgData file format contains the processed image output from BeamGage. The HDF5 file contains a 2D array of the frame image that can be loaded into MATLAB so that third party computations can be performed on the data. The image and pixel data formatting is directly readable and follows standard HDF5 formatting rules.

An example that reads an HDF5 file into MATLAB is supplied and installed into the following folder location:

C:\Program Files\Spiricon\BeamGage <edition>\Examples\MatLab\...

4.4.1 Image Data Access

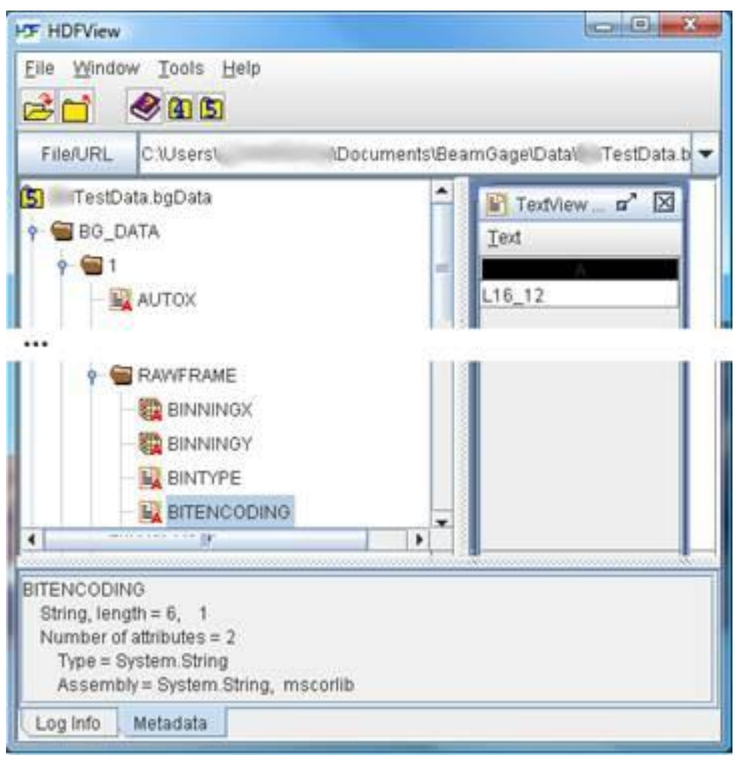
Pixel data is stored in the HDF5 file at folder node **1, DATA**. All pixel data is in an S32 bit signed binary fixed point format that is described below. Data is stored in packed 32 bit words loaded left to right, top to bottom, as it appears in the 2D display window. To determine the width and height of the date frame, access node **1, RAWFRAME, WIDTH** and **1, RAWFRAME, HEIGHT**.

4.4.2 Image Data Description

The input camera native source may be 8, 10, 12, 14, or 16 bits per pixel. BeamGage employs a normalized (signed 32-bit) fixed point format for storing pixel values in HDF5 data files. The acquired and processed camera pixel data is converted to a 32-bit signed value and stored. The most significant bit of the camera's native data is shifted to the bit position just behind the sign bit (assuming bit positions 0 [lsb] -31 [msb] this would be position 30). The empty bits below the native format are then available for additional precision and will be utilized via frame averaging, background subtraction, or other image processing activities.

This format has several advantages. One key advantage of this format is that frame averaging or baseline subtraction will allow the lower order bits to be populated with fractional values thus allowing greater precision.

In order to utilize the normalized data, the native format must be known or determined. The data format is stored in one of the HDF5 file's nodes. The window below shows an HDF viewer that is accessing the string that describes the native format of the data in the file. The string, see below, is found in a folder on node **1, RAWFRAME, BITENCODING** and is described as **L16_12**.



This means that the original or raw data format was from a **12** bit camera and was shipped left justified in a **16** bit word. The **L**, **R** or **S** tells us if the data was left or right justified within the word sized (pixel) packet or if it was a signed format. All signed formats are left bit justified with the sign bit in the left most position. BeamGage can support any one of the following native formats: (note that not all of these formats are in common use by camera manufacturers)

L8	x x x x x x x x	unsigned 8-bit
L16	x x x x x x x x x x x x x x x x	unsigned 16-bit
L16_8	x x x x x x x x _ _ _ _ _ _ _ _	
L16_10	x x x x x x x x x x _ _ _ _ _ _	
L16_12	x x x x x x x x x x x x _ _ _ _	
L16_14	x x x x x x x x x x x x x x _ _	
R16_8	_ _ _ _ _ _ _ _ x x x x x x x x	
R16_10	_ _ _ _ _ _ x x x x x x x x x x	
R16_12	_ _ _ _ x x x x x x x x x x x x	
R16_14	_ _ x x x x x x x x x x x x x x	
S16	s x x x x x x x x x x x x x x x	Note: Only 15 bits of precision
S16_13	s x x x x x x x x x x x x x _ _	
S16_14	s x x x x x x x x x x x x x x _	
S32	s x x x … … x x x	31 bits of precision*

s = signed bit; x = used bit; _ = unused bit

* All BeamGage data files are stored in S32 regardless of the native format. However you must know the native format in order to correctly position the decimal point.

To return to the original native pixel values you will need to divide by a normalization factor.

If the data is processed, as in the case of an Ultracal'd frame, you will not be able to recover the original raw camera data.

4.4.3 Calibrated Data Conversion

BeamGage always stores pixel data in the above S32 signed binary fixed point format. If the frames were saved as power/energy calibrated images, the HDF5 file will contain a power/energy conversion factor that can be used to convert each pixel value into power/energy units. To read the conversion factor, access the content of the string in the folder on node **1, RAWFRAME, ENERGY, POWER_CALIBRATION_MULTIPLIER**.

To determine what units to apply, access the folder on node **1, RAWFRAME, ENERGY BASE,** and **ENERGY QUANTIFIER**. The units will be whatever was in effect when the data was collected and calibrated. Examples are WATTS, MILLIWATTS, JOULES, MILLIJOULES, etc…

To determine the power or energy value of a given pixel, multiply the S32 binary value by the **POWER_CALIBRATION_MULTIPLIER** and assign the **ENERGYUNITS**.

4.5 Log Results and Chart Files, .csv, ASCII

Log results files are ASCII comma delimited text files that contain entries for Date, Time, and each enabled result item. These file types can be imported into MS Excel and other third party applications. The first row entry in a log file is a header describing the results items posted in the following entries. The logged items appear in the following rows, and the end entries contain the statistical results, if enabled. The example below shows what a log file looks like after importing the log data into an Excel spreadsheet.

Book1

	A	B	C	D	E	F	G	H	I
1	Date	Time	Total Pwr W	Peak Fluence W/cm²	Min Fluence W/cm²	Centroid X um	Centroid Y um	D4σX um	D4σY um
2	6/4/2009	15:30:11.621	2.00E+00	1.27E+04	-9.81E+02	2.50E+02	2.49E+02	1.76E+02	1.77E+02
3	6/4/2009	15:30:14.894	1.98E+00	1.26E+04	-1.07E+03	2.50E+02	2.49E+02	1.76E+02	1.75E+02
4	6/4/2009	15:30:15.027	1.98E+00	1.26E+04	-9.96E+02	2.50E+02	2.49E+02	1.76E+02	1.76E+02
5	6/4/2009	15:30:15.140	1.98E+00	1.28E+04	-1.03E+03	2.50E+02	2.49E+02	1.76E+02	1.76E+02
6	6/4/2009	15:30:15.344	1.98E+00	1.25E+04	-1.04E+03	2.50E+02	2.49E+02	1.77E+02	1.75E+02
7	6/4/2009	15:30:15.477	1.98E+00	1.27E+04	-1.00E+03	2.50E+02	2.49E+02	1.78E+02	1.77E+02
8	6/4/2009	15:30:15.679	1.98E+00	1.26E+04	-1.12E+03	2.50E+02	2.49E+02	1.76E+02	1.76E+02
9	6/4/2009	15:30:16.327	1.98E+00	1.28E+04	-9.87E+02	2.50E+02	2.49E+02	1.78E+02	1.77E+02
10	6/4/2009	15:30:16.546	1.98E+00	1.26E+04	-1.01E+03	2.50E+02	2.49E+02	1.76E+02	1.76E+02
11	6/4/2009	15:30:16.667	1.96E+00	1.24E+04	-1.01E+03	2.50E+02	2.49E+02	1.77E+02	1.76E+02
12	6/4/2009	15:30:16.984	1.96E+00	1.24E+04	-1.02E+03	2.50E+02	2.49E+02	1.75E+02	1.77E+02
13	6/4/2009	15:30:17.092	1.93E+00	1.22E+04	-1.02E+03	2.50E+02	2.49E+02	1.76E+02	1.77E+02
14	6/4/2009	15:30:17.419	1.93E+00	1.24E+04	-1.10E+03	2.50E+02	2.49E+02	1.77E+02	1.77E+02
15	6/4/2009	15:30:17.642	1.91E+00	1.22E+04	-9.77E+02	2.50E+02	2.49E+02	1.76E+02	1.76E+02
16	6/4/2009	15:30:17.861	1.91E+00	1.23E+04	-9.60E+02	2.50E+02	2.49E+02	1.79E+02	1.77E+02
17	6/4/2009	15:30:18.077	1.89E+00	1.20E+04	-1.06E+03	2.50E+02	2.49E+02	1.77E+02	1.78E+02
18	Name	Mean	StdDev	Max	Min				
19	Total Pwr	1.96E+00	3.34E-02	2.00E+00	1.89E+00				
20	Peak Fluence	1.25E+04	2.27E+02	1.28E+04	1.20E+04				
21	Min Fluence	-1.02E+03	4.48E+01	-9.60E+02	-1.12E+03				
22									

Strip charts in BeamGage can be saved into ASCII log files. The data in log files can also be loaded into appropriate BeamGage strip chart displays. To load a strip chart, the log file must contain the result item that the chart window is setup to plot, i.e. if the chart plots Total Power/Energy, the log file must contain a Total Power/Energy results column.

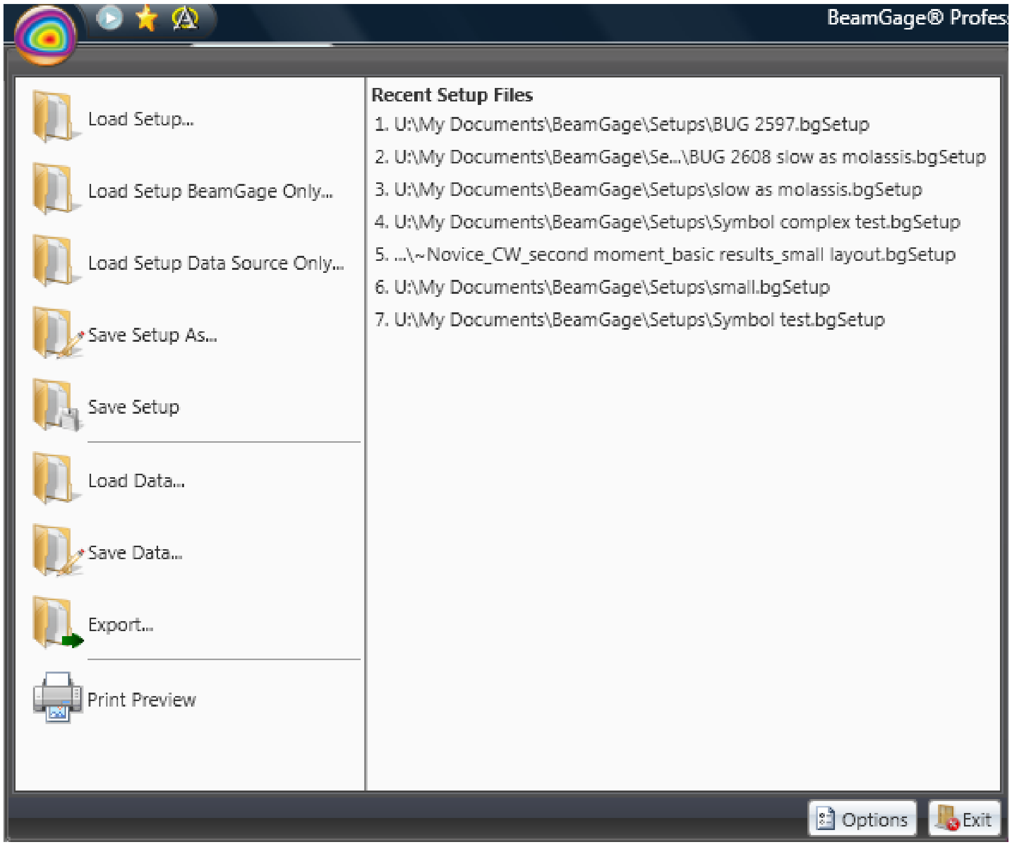
A Chart File is similar to a general purpose results log file except that the only results in the file are of the type plotted in the chart. For example, a Total Power strip chart plots Total Power vs. Time. Thus only the Date and Time stamp plus the Total Power will comprise entries in this chart file.

4.6 Report Files, .PDF

Reports can be configured to contain the various results and displays that are part of BeamGage. A report can either be a printed document, or can be saved into an Adobe .PDF file format.

4.7 File Access Window 

Data and Setup files are saved and loaded via the File Access button shown above. Below is an example of the File Access window. The files listed on the right are a list of the last saved or opened setup files. To perform a quick reload from the list, click once on the desired file name.

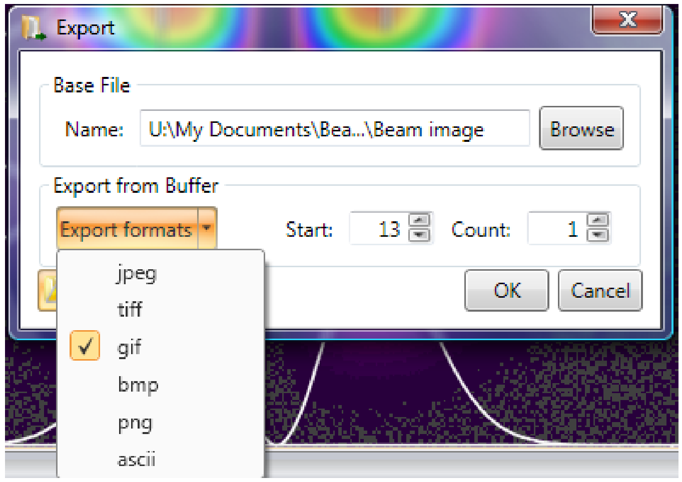


4.7.1 Print Preview 

Use the Print Preview button to produce a printed report without having to access the **Reports** ribbon. The settings in the Reports ribbon will be applied as preconfigured. A temporary PDF file will be created which can be printed or saved using the Adobe controls. Once the PDF is closed, the temporary file will be deleted.

4.7.2 Export Image 

To capture the 2D or 3D displayed image into an image file format, click on the **Export...** folder. This will open the **Export** dialog box shown below.



Select which type of image format to create. More than one type can be created at a time. Enter the buffer location to start and how many frames to export. Enter a file name or click Browse to select an existing file. Then click OK.

Important: ***Image exports of either 2D or 3D images need to be performed with the display fully visible. Closing the display or hiding it behind another displayed item will cause all overlays, such as results, apertures, profile slices, etc., to disappear from the exported file image.***

Important: ***Image files such as jpeg, tiff, gif, bmp, and png do not accurately preserve the data content of the source information. These files will contain an image exactly like the one currently being displayed.***

The ASCII file type is an actual copy of the image's processed data, minus any graphical overlays. Thus this type of image will faithfully reproduce the processed pixel values. If the data is calibrated, the ASCII with be in the calibrated power/energy value at each pixel. If uncalibrated, the data will be in counts. Ultracal'd data and Auto-X data will be processed and contain negative noise values as well as positive signal content. ASCII files can be quite large, especially if the frame is large and the data is power/energy calibrated.

Unlike the previous image formats, the ASCII data will be the entire frame unless a manual or auto aperture is present. In this manner, the amount of data can be reduced to just the region that is involved in results calculations. The X and Y limits of a drawn manual aperture will bind the image region exported into the ASCII file. If the aperture is not a rectangular shape drawn on axis, the pixels that lie outside of the aperture will be exported as empty values.

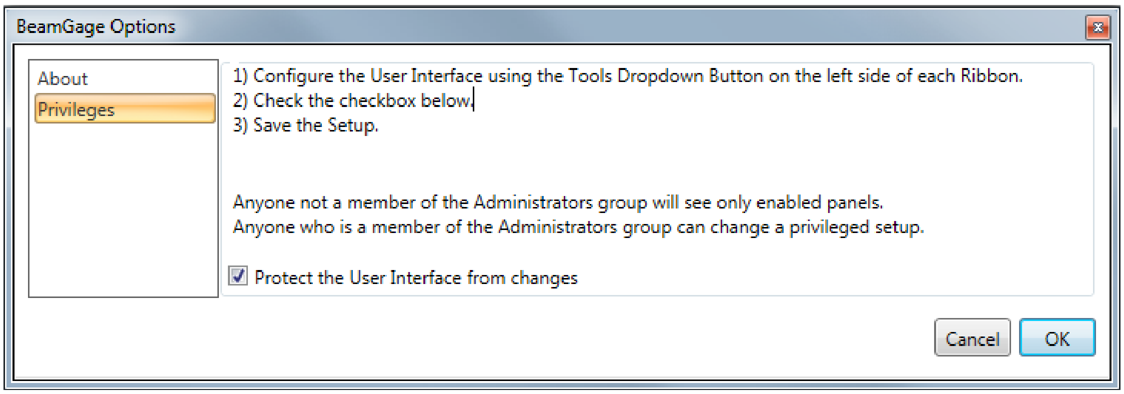
Note: A drawn manual aperture will also limit the area where data gets analyzed, not just the region copied into an ASCII image file. Use the manual aperture with this in mind.

Hint: In order to keep the ASCII export region stable, use the Manual aperture and turn off the Auto-aperture.

To export images in real time see section 2.10.3 on Logging 2D Images.

4.7.3 Options Privileges 

Click on the **Options** button and then the **Privileges** item and the following dialog box will open. In order to access this privilege control, the user must be assigned Administrator privileges on the local machine. This feature allows an administrator to **Protect** (lock) the controls and results such that a user cannot access certain controls or modify reported results.



The purpose of this feature is to restrict non-administrator users from accessing certain controls. For example, the user may want to setup BeamGage for a specific operator, and restrict that operator from changing the setup.

The instructions shown in this dialog box describe the basic procedure that is followed to hide features that a non-administrator will have access to.

After configuring BeamGage for its intended user/application, save a setup file and then copy that setup file into the target user's:
C:\Users\<user_name>\Documents\BeamGage\Setup file folder.
Be sure to set the **Attributes** of setup files to **Read Only** in order to insure that they cannot be deleted or overwritten.

This setup file, along with any other protected access setup files, will be the only setups that the restricted user will be able to load and run. The Administrator should logon as the target user and load the setup file the first time that BeamGage is launched under the users login account. After this initial setup load, the user will not be able to access or modify the concealed controls.

Note: This locking capability does not extend into every area in BeamGage. But it does cover the vast majority of operating controls.

The following feature items are blocked from the user when the protect box is checked:

1. The Panels enabled or hidden in the Tools panels are locked. Panels cannot be added or removed from view.

2. The Ribbon Bars sections of the Tools panels are disabled and not accessible.
3. Exposed results items cannot be deleted and new ones cannot be added. The results dropdown controls with their associated features are not accessible. Only those items enabled by the administrator are available.

The following items cannot be blocked from the user:

1. Displayed child windows can be opened/closed and repositioned on the desktop.
2. The BeamGage application window can be resized and positioned.
3. The Save and Load data file functions are accessible.
4. The Save and Load setup file functions are accessible.
5. The Run/Pause, Ultracal, and Auto Aperture buttons in the Quick Access Toolbar are always accessible.
6. The frame buffer position slider and edit controls are always active.
7. Ribbon tab open/close behavior is preserved.

CHAPTER 5 Computations

5.1 Computational Accuracy

The degree of accuracy of the computed results is based primarily on two factors. The first, and most significant, is the correct nulling of the camera background signal. The second deals with optimizing the presentation of the beam display within the detector and/or within a properly sized aperture.

The background nulling operation establishes the zero reference from which all computed results are based. Failure to correctly null and periodically monitor the background energy will yield inconsistent results. Excessive background energy levels will yield oversized beam diameters and reduced magnitudes when energy relationships are compared. The opposite effects will result if the background levels are excessively suppressed.

BeamGage is equipped with a patented auto calibration feature called Ultracal. Ultracal performs a nulling operation that is significantly more accurate than that which can be achieved manually. The Ultracal algorithm also compensates for background noise, imager point defects, and camera shading.

5.1.1 What is Ultracal?

The Ultracal processing feature should be used in the place of any manual energy nulling techniques. Ultracal employs a sophisticated proprietary algorithm that yields greatly improved accuracy over various operating conditions and signal dynamic range. In addition, it can quickly be rerun if changes in setup or conditions occur as required by modifications to experimental conditions.

Before performing an Ultracal it is recommended that the beam's presentation be optimized. Any changes to camera settings (Gain, Exposure, ROI, etc.) will invalidate the current Ultracal. Auto and Manual apertures are not locked by the calibration cycle and may be manipulated by the user at any time.

Ultracal will fail if there is excessive noise in the signal. This can be improved by decreasing the gain. If Ultracal continues to fail, there may be a "dark" pixel. If this is the case, a bad pixel correction will be needed. For a Pyrocam III or Pyrocam IV, see section H.1 or section I.1, respectively. All other cameras must be corrected at the Spiricon facility.

The Ultracal cycle can be run at any time. The beam must be blocked from the camera detector. After completion of the Ultracal cycle, the subsequent results remain accurate as long as the setup conditions remain the same and the camera black level, shading, and noise conditions do not change.

Since some cameras can drift with temperature, it is recommended to perform an Ultracal cycle every 10 to 15 minutes, or whenever the camera may have strayed. This drift can be observed as changes to the background noise image. Un-illuminated areas appear as gray and dark violet (almost black) random noise. If the background starts to look too gray, then the baseline is drifting negative; if too dark, then the baseline is drifting positive.

Note: These colors apply to the Continuous 128 color palette. The color shading changes depending on the palette selection, but the principle remains the same.

Important: ***Allow the camera to warm up and reach thermal equilibrium before performing calibrations. One hour is usually sufficient as a warm-up period. If the ambient air temperature is changing, then periodically recheck the background energy levels to make sure they haven't been significantly altered.***

5.2 Beam Presentation Affects Results

Effective beam presentation is essentially an attempt to improve accuracy by increasing the signal-to-noise property of the digitized data. Since the camera and the digitizing process primarily fix the noise level, most efforts concentrate on increasing the signal content.

Always try to optimize the beam's amplitude into the camera's dynamic operating range. Whenever possible, use external optical attenuation to bring the beam's peak signal levels into the upper half of the video signal's dynamic range. If optical attenuation results in low signal amplitude, use the camera's video gain control to restore some of the loss.

Important: ***Increasing gain also increases noise, so use it sparingly.***

To isolate the laser beam profile from unwanted background effects BeamGage has both Manual Aperture and an Auto Aperture capabilities. Spiricon recommends always using the Auto Aperture feature to insure elimination of background noise effects, which are detrimental when making second moment measurements.

If beam intensity is low and/or covers only a small fraction of the display window, use a manual aperture to eliminate the background energy noise in the wings. Use external optical magnification if the beam begins to approach only a few pixels in width. Widths of at least 10 pixels are required to obtain a reliable beam width measurement.

5.3 ISO Standards Compliance

Spiricon has adopted the current versions of the International Organization for Standardization (ISO) that pertains to the measurements of laser beam characteristics. At the same time, Spiricon has preserved other legacy measurement techniques that have found general favor in the industry. Some of these legacy techniques have been incorporated into ISO standards while others remain outside.

Computational methods that follow the ISO mathematical models are indicated in BeamGage's results and in other areas by having the suffix **ISO** as part of the results identifier. However, this marking does not mean that the computed result meets all the necessary ISO criteria. In particular, an ISO result may depend upon certain prerequisites. Such a prerequisite might be the need to utilize as an input the second moment beam width. If the user were to choose a different beam width basis, such as a 50% of Peak, then it is likely that the final results will not yield an ISO compliant answer.

Another area where one may fail to achieve a good ISO result could be in the application of proper baseline correction. While Spiricon's Ultracal technique is an ISO compliant method, it could be improperly applied or not monitored for thermal drift or ambient light effects. All of which could lead to an incorrect result, even though the computations themselves are performed according to ISO equations.

Important: ***The ISO standards referenced here are an ongoing work in progress. Spiricon will attempt to update BeamGage as they evolve. As of this writing, the definition of "Goodness of Fit" is being challenged and has been withdrawn from ISO 13694. The Goodness of Fit result that is currently reported is based on our current interpretation of this algorithm and is subject to change in the future.***

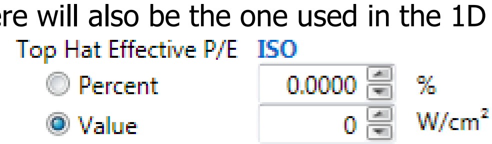
See APPENDIX A for a table of BeamGage supported ISO results and a reference to the applicable ISO standards.

5.4 Clip Level

The clip level is a processed power/energy pixel value. Various input dialog box entries apply to these results items. Only those pixel values that exceed the clip level are used in computing the following results:

- Certain Beam Width methods that have programmable clip levels, such as those shown below:

- TopHat results that rely on a programmable threshold. Enter the threshold clip level into the following dialog. Note that the value entered here will also be the one used in the 1D profile and results.



Depending on the Beam Width Method selected, the clip level value is determined as follows:

- With the **Percent of Power/Energy** method, BeamGage totals the pixel energy values in descending order until it finds the pixel that causes the sum to exceed the set Clip% of the total energy value. The energy value of this pixel becomes the clip level.

- With the **Percent of Peak** method, BeamGage sets the clip level to the value that is equal to the set Clip% of the current peak energy value.

The number of pixels with values above the clip level establishes the Effective Area of the beam. In some cases, the selected Beam Width Basis determines which Clip Level is used in the calculation of the Orientation of elliptical beams. These are shown in the table below.

Beam Width Basis	Clip Level used for Orientation
D4Sigma	None
Smallest Slit	None
Knife Edge 16/84	None
Knife Edge 10/90	Total Energy Clip
Knife Edge Prog	Total Energy Clip
% Energy	Total Energy Clip
% Peak	Peak Clip
Moving Slit	None

5.5 Total Power/Energy

The cameras used with BeamGage are not calibrated to directly provide the power/energy of a laser beam. The **Computations Power/Energy** panel allows the user to calibrate to the power/energy of the laser using an external measuring device. The value entered must be the total power/energy of the beam for the frame currently displayed. For accurate results, the beam must fit inside of the current ROI.

If a calibrated value of **zero** or a units setting of **counts** (cnts) is displayed, then all power/energy related results will be displayed as processed digitizer values. Any entry other than zero will immediately translate to the power/energy results items. The **Units** entry determines the energy units that appear to the right of various energy displays (i.e., W, J, mW/cm², etc.).

When using a Manual Aperture (without an Auto Aperture), the Total Power/Energy is the amount of power/energy inside the Manual Aperture.

When using an Auto Aperture (with or without a Manual Aperture), the Total Power/Energy is the amount of power/energy inside the Auto Aperture.
Thus: <u>An Auto Aperture takes precedence over a Manual Aperture.</u>

Note: When an Ophir power/energy meter is being used as the source for the Total results values, the above Power/Energy panel does not have an effect on the total results. See section 5.26.

5.6 Peak and Min

These are the Peak and Minimum power/energy density values in the displayed frame, or within the Manual or Auto Aperture if present. The Minimum value will most often

be negative, and is therefore not meaningful except as an indication of the amount of noise or baseline drift present in the video data.
An Auto Aperture takes precedence over a Manual Aperture.

5.7 Peak Location

This is the first location where the peak intensity value was found. The Peak Location is found by scanning the pixel data from left to right, top to bottom. If a Manual or Auto Aperture is present, then the scanning is confined to the pixels inside the aperture.
An Auto Aperture takes precedence over a Manual Aperture.

5.8 Centroid Location

The Centroid location is found by calculating the first moment (center of mass) of all the pixels that are selected to be analyzed. The selection process is controlled by the aperture settings. When no apertures are enabled the centroid is computed over the entire area of the imager. When a manual aperture is present, the centroid calculation only involves the data contained within the manual aperture. When Auto Aperture is enabled, it defines the region of the centroid calculation.
An Auto Aperture takes precedence over a Manual Aperture.

The following equations describe the X and Y centroid locations from the collection of data points that satisfy the above criteria:

$$x\ centroid = \frac{\sum(X \times z)}{\sum z}$$

$$y\ centroid = \frac{\sum(Y \times z)}{\sum z}$$

Where: X = x locations of selected pixels
Y = y locations of selected pixels
z = value of selected pixels

5.9 Beam Widths and Diameters

To some extent, beam width is a term that describes how the user has decided to measure the size of a laser beam. BeamGage is designed to provide a set of measurement tools that will allow the user to make this measurement as they see fit. The ISO standards have created a consensus regarding a standard definition of beam width. This definition has grown out of laser beam propagation theory and is called the Second Moment, or D4-Sigma beam width. (The "D" stands for Diameter but is also used to denote Beam Widths.) Sigma refers to the common notation for standard deviation. Thus an X-axis beam width is defined as 4 times the standard deviation of the spatial distribution of the beam's intensity profile evaluated in the X transverse direction. A measurement taken in the Y transverse direction will yield the Y-axis beam width.

Note: For a TEM_{00} (Gaussian) beam, 2-Sigma is the $1/e^2$ radius about the centroid.

The term **Diameter** implies that the beam is radially symmetric or circular in shape. The term **Width** implies that the beam is non-radially symmetric, but is however axially symmetric and characterized by two principal axes orthogonal to each other. Beams that are asymmetric, distorted, or irregularly shaped will fail to provide significantly meaningful or repeatable beam width results using any of the standard methods.

When measurements of the beam widths are performed on the cameras X and Y axes, results are denoted with the letters **X** and **Y**. When a rotated elliptical beam is being measured, the notations **X/Y** become **M/m** to denote the beam widths in the orthogonal **Major** and **minor** axes, respectively.

The absence of either the X/Y or M/m notation indicates when a **Diameter** result is being designated.

According to ISO, when the ratio of the Beam Widths exceeds 0.85, then the beam can be described as circular and the Diameter result is appropriate.

5.9.1 D4-Sigma Method

D4σX/M, D4σY/m, D4σ

Second moment method: ISO 11145, ISO 11146-1, and ISO 11146-3.
From laser beam propagation theory, the Second Moment, or D4-Sigma beam width definition is found to be of fundamental significance. It is defined as 4 times the standard deviation of the energy distribution evaluated separately in the X and Y transverse directions over the beam intensity profile.

$$\textbf{D4σX:}\quad d_{\sigma x} = 4 \cdot \sigma_x$$

$$\textbf{D4σY:}\quad d_{\sigma y} = 4 \cdot \sigma_y$$

Where: d_σ = The 4-Sigma beam width
σ = The standard deviation of the beam intensity

The standard deviations are derived from the distribution variances and are equal to the square roots of the variances. The variances are:

$$\sigma_x^2 = \frac{\sum_x \sum_y (x-\bar{x})^2 \cdot Z(x,y)}{\sum_x \sum_y Z(x,y)}$$

$$\sigma_y^2 = \frac{\sum_x \sum_y (y-\bar{y})^2 \cdot Z(x,y)}{\sum_x \sum_y Z(x,y)}$$

Where: Z = the intensity of the pixel at x,y

$\bar{x}$ and $\bar{y}$ are the coordinates of the centroid

For the second moment diameter of a circular beam:

$$\textbf{D4}\boldsymbol{\sigma}\textbf{:} \quad d_\sigma(z) = 2\sqrt{2\sigma(z)}$$

Where :

$$\sigma^2 = \frac{\iint r^2 \cdot E(r,\varphi,Z) \cdot r \cdot drd\varphi}{\iint E(r,\varphi,Z) \cdot r \cdot drd\varphi}$$

Where:

r is the distance from the centroid $(\bar{x},\bar{y})$

φ is the azimuth angle

the first moments give the coordinates of the centroid

$$\bar{x} = \frac{\iint xE(x,y,z)dxdy}{\iint E(x,y,z)dxdy}$$

$$\bar{y} = \frac{\iint yE(x,y,z)dxdy}{\iint E(x,y,z)dxdy}$$

Only beam propagation factors based on second moment beam widths/diameters, and divergence angles derived from the second moments of the energy density distribution function, will allow one to predict how a beam will propagate. Other definitions of the beam widths/diameters and divergence angles may be used, but they must be shown to be equivalent to the second moment definitions for computing the correct beam propagation.

To make an accurate measurement of the beam widths, establish an aperture for the beam inside a Manual or Auto Aperture. The aperture must be approximately 2x the size of the beam. The Auto Aperture feature will automatically provide such an aperture under most operating conditions. It can be used in combination with a Manual Aperture, if needed. If the beam size is already equal to about 1/2 the beam display window, a manual aperture may not be necessary. In such an event, be sure to center the beam in the window.

5.9.2 Knife Edge Method

DkeX/M 10/90, DkeY/m 10/90, DKE 10/90
DkeX/M 16/84, DkeY/m 16/84, DKE 16/84
DkeX/M prog, DkeY/m prog, DKE prog

Knife Edge beam widths are computed using special algorithms that simulate knife-edge techniques. The methods employed in BeamGage borrow from two sources:

1) ISO 13694 defines a method based on a 16/84 clip level method.

2) BeamGage also employs Spiricon's legacy 10/90 clip level method which we feel is superior to the ISO 16/84 technique. Reference: IEEE Journal of Quantum Electronics, Vol. 27, No. 4, April 1991 Choice of Clip Levels for Beam Width Measurements Using Knife-Edge Techniques by Siegman, Sasnett, and Johnston.

3) A user programmable method is also provided for users that wish to tune the process to best model their beam's mode content.

The ISO 16/84 method presets the Clip% values to 16% and 84%, respectively, and the Multiplier to 2.0. Best for beams that are mostly TEM_{00}.

The 10/90 method presets the Clip% values to 10% and 90%, respectively, and the Multiplier to 1.561. These are the recommended values based on the above Siegman, et al. paper, and are very compatible with CCD camera noise figures. These values are perfectly correct for computing an equivalent second moment width for TEM_{00} beams, and are a good approximation for many beams of mixed modes.

The third Knife Edge selection will allow programming the Clip% and Multiplier values. Use of this option successfully requires advanced knowledge of the beams modal content.

<u>All Knife Edge Diameters</u> are the computed average of the orthogonal beam widths.

When rotated beam results are disabled, the computed beam widths will be aligned with a pair of simulated knife-edges, cutting one in each of the X and Y directions. Hence, the displayed beam widths will be indicated in the results window as X and Y. If the laser beam is not radially symmetric but does contain two axes of symmetry, rotate the beam such that the beam's axes align with the X and Y axes of the display.

When rotated beam results are enabled, the computed beam widths will be aligned with a pair of simulated knife-edges, cutting one in each of the Major and Minor axial directions. Hence, the displayed beam widths will be indicated in the results window as **M**/Major and **m**/minor. The implication is that the displayed values represent the major and minor widths of an elliptically shaped laser beam.

Note: Rotated beam results are enabled whenever one of the following results items are enabled: Orientation, Ellipticity, Eccentricity.

5.9.3 Percent of Total Power/Energy Method

D%tX/M, D%tY/m, D%t

With the **Percent of Power/Energy** method, BeamGage totals the pixel energy values of all pixels in descending order until it finds the pixel that causes the sum to exceed the set Clip% of the total energy value. The energy value of this pixel becomes the clip level.

BeamGage determines the beam widths by separately looking out along the lengths of two orthogonal lines that pass through the beam centroid and counts all the pixels that are greater than the set clip level. The reported beam widths are the number of pixels greater than the clip level multiplied by the pixel pitch.

When rotated beam results are disabled, the computed beam widths are the measure of the pixels in the row and column that pass through the centroid. The beam widths in the results window are labeled **X** and **Y**.

When rotated beam results are enabled, the computed beam widths are the measure of the pixels along the Major and Minor axes that pass through the centroid. The beam widths in the results window are labeled **M**/Major and **m**/minor.

The Percent of Total diameter result is derived by taking the area of all pixels above the clip level, and computing the diameter of a circle that contains that amount of area. The Diameter beam width in the results window is labeled without axis labels.

5.9.4 Percent of Peak Method

D%pkX/M, D%pkY/m, D%pk

With the **Percent of Peak** method, BeamGage sets the clip level to the value that is equal to the set Clip% of the current peak energy value.

BeamGage determines the beam widths by separately looking out along the lengths of two orthogonal lines that pass through the beam centroid and counting all the pixels that are greater than the set clip level. The reported beam widths are the number of pixels greater than the clip level multiplied by the pixel pitch.

When rotated beam results are disabled, the computed beam widths are the measure of the pixels in the row and column that pass through the centroid. The beam widths in the results window are labeled **X** and **Y**.

When rotated beam results are enabled, the computed beam widths are the measure of the pixels along the Major and Minor axes that pass through the centroid. The beam widths in the results window are labeled **M**/Major and **m**/minor.

The Percent of Peak diameter result is derived by taking the area of all pixels above the clip level, and computing the diameter of a circle that contains that amount of area. The Diameter beam width in the results window is labeled without axis labels.

5.9.5 Moving Slit Percent of Peak Method

D%msX/M, D%msY/m

BeamGage emulates a moving slit by summing the rows and columns of data in either the X/Y or the M/m axial directions. The beam widths are determined by separately looking out along each line and counting all the sums that are greater than the set clip level of the peak sum. The reported beam widths are the number of sums greater than the clip level multiplied by the pixel pitch or the pixel pitch adjusted by the orientation angle. The default clip level is 13.5% which will yield an accurate second moment beam width for a TEM_{00} beam.

ISO 11146-3 section 10.4.3 describes this method. It is assumed that $M^2=1$ and thus the summed data is from a perfect TEM_{00} Gaussian distribution. As a result, the moving slit method will return an accurate second moment beam width for a TEM_{00} beam. For higher mode mixes, the accuracy will be at best a second moment approximation. In many cases this is not very accurate.

5.9.6 Encircled Power Methods

Depss(X/M) 95.4, Depss(Y/m) 95.4, Depsa86.5, Depsa-prog

The encircled power (ep) methods come in two versions, the smallest slit (ss) method for measuring beam widths, and the smallest aperture (sa) method for measuring beam diameters. The smallest aperture method is often referred to as a "power-in-a-bucket" method, where the size of the aperture is the bucket diameter.

For the epss method, a symmetrically adjustable slit centered at the beam centroid, and sized in both the X/Y or M/m axis, is found that contains 95.4% of the beam power/energy. The separation distance between the slit edges is the reported beam widths.

For the epsa method, a circular adjustable aperture is placed on the beam and centered on the beam centroid. The diameter is adjusted until it contains 86.5% of the beam power/energy. The epsa-prog method allows the percent of power in the aperture to be set by the user.

The above fixed percentages will return an accurate second moment beam width result for a TEM_{00} beam. For higher mode mixes, the accuracy will be at best a second moment approximation. In many cases this is not very accurate.

5.10 Rotated Beams

Orientation, Ellipticity, Eccentricity

BeamGage can compute and display the Orientation, Ellipticity, and Eccentricity of beams rotated with respect to the normal X and Y axes. This includes elliptical or rectangular shaped beams. When any one of the above results items is activated, the cursors will change to a rotated mode of operation. In this mode, the cursors will align to the orientation of the input beam.

If the beam is more circular than elliptical, the beam axes will gyrate uncontrollably indicating that the elliptical results items should probably be turned off.

The **Orientation** is defined as the angle formed between the Major axis and the horizontal, pointing to the right. If the Major axis points above the horizontal, the angle is positive (+); below the horizontal is negative (-). The Major and Minor axes are perpendicular to each other. The method for computing the orientation is effected by the chosen beam width basis. To achieve an ISO orientation result, one of the ISO indicated beam widths must be chosen as the beam width basis. Choosing a non-ISO (legacy) beam width as a basis will apply various clip level criteria for analysis of the orientation.

Beam Width Basis	Orientation Algorithm
D4Sigma	Azimuthal (ISO)
Smallest Slit	Azimuthal (ISO)
Knife Edge 16/84	Azimuthal (ISO)
Knife Edge 10/90	Legacy
Knife Edge Programmable	Legacy
% Energy	Legacy
% Peak	Legacy
Moving Slit	Azimuthal (ISO)

The **Ellipticity** result is the ratio of the computed beam widths. The Minor (smaller) beam width is always divided by the Major (larger) to produce a result less than or equal to one. Thus, beams with Ellipticity values close to 1.000 are nearly circular.

Ellipticity: $$\xi(z) = \frac{d_{\sigma m}}{d_{\sigma M}}$$

The **Eccentricity** result will approach Zero as the beam becomes more circular.

Eccentricity: $$e(z) = \frac{\sqrt{d^2_{\sigma M} - d^2_{\sigma m}}}{d_{\sigma M}}$$

5.11 Cross-Sectional Area

The cross-sectional area of the beam is the area contained by the computed beam width. The applicable beam width for this calculation is the one chosen as the Beam Width Basis. Note that in BeamGage, only beam widths, not beam diameters, can be used to compute the cross-sectional area result.

$$\textbf{X-Sec Area:} \quad A_\sigma = \pi \frac{d_{\sigma x} d_{\sigma y}}{4}$$

5.12 Crosshair Measurements

Cursor-Crosshair, Centroid-Crosshair

These two results are the straight line distances measured between the Crosshair and the Cursor or the Crosshair and the computed Centroid. For this result to operate correctly, the Crosshair must be enabled, and in the first case, the Cursor must also be enabled.

5.13 Average Power Density

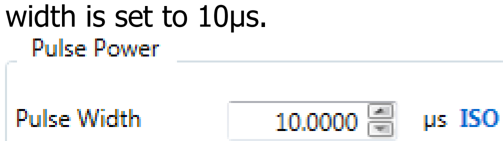
The average power density is the total power of the beam divided by its cross-sectional area.

5.14 Peak Pulse Power

In ISO this is simply called the Pulse Power, but common usage has added the term "peak" to denote the peak power present in a single pulse. Not to be confused with "peak power", this denotes the maximum of the power-time function.

This result is computed by dividing the energy of a single pulse by the pulse period. The pulse period is defined as the time interval between the half peak power points at the leading and trailing edges of the pulse.

To compute this result the input Total P/E units should be set to an energy value, such as Joules, and the pulse period must be entered into the Pulse Width edit control. This edit control is in the Computations Power/Energy expansion dialog box. In the example shown below, the pulse width is set to 10µs.

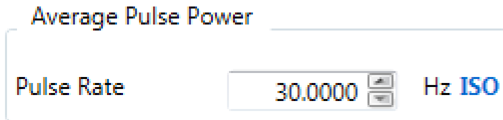


5.15 Average Pulse Power

The average pulse power is the time average power based on the pulse repetition rate in Hertz and the energy per pulse. This result is computed by multiplying the energy per pulse by the pulse rate in Hz.

To compute this result, the input Total P/E units should be set to an energy value, such as Joules, and the pulse rate must be entered into the Pulse Rate edit control.

This edit control is in the Computations Power/Energy expansion dialog box. In the example shown below, the pulse rate is set to 30Hz.

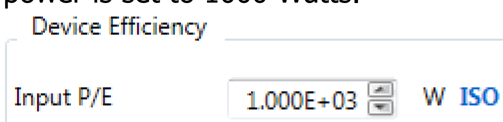


5.16 Device Efficiency

The efficiency result describes how well the laser converts input power/energy into output power/energy. The output value is divided by the input and multiplied by 100%.

In order to perform this calculation the input power/energy of the laser needs to be measured or known to some reasonable accuracy. Some laser manufactures provide input pump power/energy while others do not. If a mains power meter is available, this figure may be useful as the input power/energy value.

To compute this result the input and output P/E units must be the same. Manually enter the input power/energy value in the Device Efficiency Input P/E edit control. This edit control is in the Computations Power/Energy expansion dialog box. In the example shown below, the input power is set to 1000 Watts.



5.17 Percent in Aperture

When a Manual Aperture is placed onto the beam display, the percentage of the total energy of the frame that lies inside of the Manual Aperture is computed.

If an Auto Aperture is present, then the value represents the total energy contained within the Auto Aperture.

If no aperture is present, then this result displays 100%.

5.18 Divergence

Θ X/M, Θ Y/m, Θ

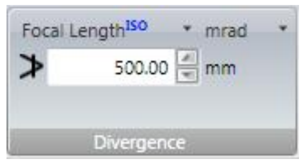
BeamGage supports three different methods for computing beam divergence. Each is useful under different operating conditions. Only the Focal Length method is recognized as ISO compliant. However, the other two methods should be just as accurate when properly applied. Only one method can be employed at a time.

Important: ***Divergence measurements that follow beam propagation theory are based on second moment beam width measurements. The beam widths used in these calculations are selected by the Beam Width Basis setting. If a basis other than second moment or a second***

moment approximation is chosen, then the divergence results will be affected accordingly.

5.18.1 Focal Length Method

This method is based upon the beam width of a focused beam's spot size and the focal length of the focusing optic. Divergence results will be computed in the X and Y aligned axes of the beam if off axis results are disabled, or for Major and Minor axes beam orientations if off axis is enabled. Enter the focal length of the optic into the divergence panel as shown below:



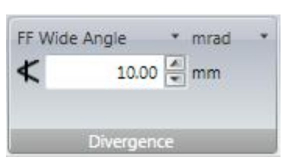
The Focal Length divergence method provides a means for finding the far-field beam divergence at any point in the beam propagation path. As shown below, the calculation performed by BeamGage is quite simple; however the optical setup must be done with great care. The user, to suit his particular application, must provide the optic. The focusing optic must be large enough to accommodate the input beam without introducing diffraction effects. Either a refracting or reflecting focusing optic can be used, but in either case the camera's detector must be placed at the exact focal length of the optical element. The Divergence result is based on the focused spot size as described in the equation below:

$$divergence = \tan^{-1}\left(\frac{W_f}{f}\right)$$

Where: W_f = The width of the focused spot at distance *f* from the optic
f = The focal length of the imaging optic at the wavelength of the laser

5.18.2 Far-Field Wide Angle Method

This method is designed to measure the divergence angles of devices, such as laser diodes, where the divergence angles tend to be large and are best measured in degrees rather than mrad. This method assumes that the laser output is essentially a point source. Enter the distance from the laser to the camera imager into the divergence panel as shown below:



Position the camera imager a known distance from the source and insure that the entire beam does not overfill the imager area. Because these sources are often diverging rapidly in one axis and slower in the other, it is recommended that the rapidly diverging axis be aligned with the wide axis of the camera imager.

The Divergence result is computed as follows:

$$divergence = 2 \cdot \tan^{-1}\left(\frac{W_C}{2 \cdot S}\right)$$

Where: W_C = The width of the beam at location S

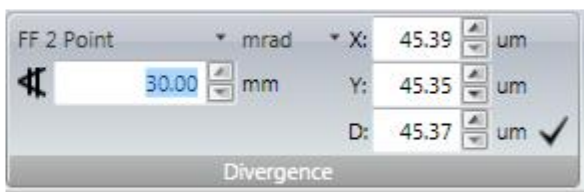
S = The distance from the beam source to the imager

5.18.3 Far-Field Two Point Method

This method is based upon the actual measured increase in laser beam width as it expands in the far-field region. Before using this method, be sure that the measurements will be made in the beam's far-field region, and that the size of the beam does not grow larger than the camera's ability to contain it. Divergence results will be computed in the X and Y aligned axes of the beam.

Note: We recommend to not use the off axis Elliptical mode when using the Far-Field method, but rather rotate the camera to bring the axes of the laser into X and Y alignment. This will eliminate any errors possibly caused by uncertainty in determining the orientation angles at the two measurement locations.

Position the camera in the beam path to acquire a first beam width sample. It is assumed that this first sample will be the one nearest the beam waist, but still in the far-field region, and thus the smaller sample size. With this measurement held in the results display, click on the checkmark to transfer this first sample results into the X, Y, and D beam width/diameter entries. See the example below:



These values can also be manually entered into the three edit boxes.

Next, move the camera a distance further from the beam waist. Enter the distance the camera has traveled as the Separation distance in the edit box. Now measure the beam widths at this new location and observe that the divergence results are being calculated based on the geometric expansion of the beam from the first and the second sample locations.

The Divergence result is computed as follows:

$$divergence = 2 \cdot \tan^{-1}\left(\frac{W_C - W_1}{2 \cdot S}\right)$$

Where: W_1 = The width of the beam at the first sample (nearer to the waist) location

W_C = The width of the beam at the Current (further from the waist) location

S = The separation distance between the two beam width sample locations

5.18.4 Far Field Radiant Intensity

When placed at the focal length of a lens, the intensity distribution on the imager is proportional to the angular distribution of the beam in the far field (at infinity).

The far field radiant intensity is the average power/energy per steradian (sr) contained within the propagating second moment beam width. This calculation is intended for use on a circular beam and will be computed using only the Θ divergence result. If the beam is not circular, the result will be an approximation of the mean or actual radial second moment calculation.

The expanding cone of laser power/energy, expressed in watts or joules per steradian, is independent of position. Once the far field divergence is known, independent of the method employed, it becomes possible to compute the Radiant Intensity.

$$J(\Theta) = \frac{P_\sigma}{2\pi[1 - \cos\left(\frac{\Theta}{2}\right)]}$$

Where: P_σ = The total second moment power/energy of the beam

Θ = The circular full angle divergence of the beam in rad

5.19 Gaussian Fit

BeamGage can perform a least squares bivariate normal equation (Gaussian equation) fit using all of the data when doing a 2D whole beam fit. Or it can perform two univariate normal equation fits using orthogonal lines of data defined at the Cursor location.

The whole beam fits are performed on the 2D beam profile and its results items are available in the main Results window. 2D fits can be performed either on or off axis.

The 1D fits are performed on the beam data plotted in the X/Y, M/m 1D beam profile displays. The results of the 1D fits are displayable in the Results window beneath the 1D Gaussian heading.

Of all the results items available from the fits, presently only one is an ISO defined item: **Roughness of Fit**. A results item called **Goodness of Fit** has been temporarily dropped from the ISO standard because of confusion in understanding how it is to be calculated. We have computed it based on our current interpretation of the method, however our results may change when ISO settles onto an agreed upon calculation.

The following table describes the available results items for both the 2D and 1D Gauss fits:

2D Whole Beam Fits	1D Line Fits are computed at Cursor Location

Gauss Height	X/M Gauss Height	Y/m Gauss Height
Gauss Width X/M	X/M Gauss Width X/M	Y/m Gauss Width Y/m
Gauss Width Y/m		
Gauss Centroid X	X/M Gauss Centroid X/M	Y/m Gauss Centroid Y/m
Gauss Centroid Y		
Goodness of fit*	X/M Goodness of fit*	Y/m Goodness of fit*
Roughness of fit	X/M Roughness of fit	Y/m Roughness of fit
Δ Centroid X		
Δ Centroid Y		
Δ Centroid	X/M Δ Centroid	Y/m Δ Centroid

*The **Goodness of Fit** results are based on our interpretation of the ISO method. Once the ISO definition becomes settled we will replace it with the agreed upon algorithm.

Note that all fits are least square fits, meaning that the algorithm minimizes the sum of the square of the differences between the data and the fitted surface or line, as described in the following equation.

$$A_{\min} = \sum_x \sum_y \left(Z_{xy} - S_{xy}\right)^2$$

Where: Z_{xy} = Amplitude of the pixel data at (x,y)

S_{xy} = Amplitude of fitted surface at (x,y)

5.19.1 Whole Beam Fit Equations

The bivariate normal equation is used to fit data in two locked directions, X and Y or Major and minor. The Whole Beam selection assumes the beam is circular or elliptical. The definition of the bivariate normal equation and the displayed results are as follows:

$$J = J_o e^{-2\left[\left(\frac{x-\bar{x}}{w_x/2}\right)^2 + \left(\frac{y-\bar{y}}{w_y/2}\right)^2\right]}$$

Where: J = Amplitude at the point (x,y)

J_o * = Amplitude at the Gaussian center

x = x location of pixel

$\bar{x}$ * = x location of the Gaussian center

w_x * = Horizontal width at $1/e^2$ of energy

y = y location of pixel

$\bar{y}$ * = y location of the Gaussian center

w_y * = Vertical width at $1/e^2$ of energy

Parameters marked with an asterisk (*) are the variables fitted.

5.19.2 X/Y or Major/Minor Line Fit Equations

The univariate normal equation is used to fit data in one direction. The definition of the equation and the displayed results are shown below.

For the X or Major cursor position:

$$J = J_M e^{-2\left(\frac{M-\overline{M}}{w_M/2}\right)^2}$$

Where:
J = Amplitude at the point M
J_M* = Amplitude at the Gaussian center
M = Location of pixel
$\overline{M}$ = Location of the Gaussian center
w_M* = Width at $1/e^2$ of energy

Parameters marked with an asterisk (*) are the variables fitted.

For the Y or Minor cursor position:

$$J = J_m e^{-2\left(\frac{m-\overline{m}}{w_m/2}\right)^2}$$

Where:
J = Amplitude at the point m
J_m* = Amplitude at the Gaussian center
m = Location of pixel
$\overline{m}$ = M location of the Gaussian center
w_m* = Width at $1/e^2$ of energy

Parameters marked with an asterisk (*) are the variables fitted.

5.19.3 2D Whole Beam Gauss Fit Results

The Gauss Fit results are defined as follows:

Gauss Height: the peak fluence of the Gauss fit result.

Gauss Width(s): The second moment width(s) of the Gauss fit, either X/Y or M/m.

Gauss Centroid: The X and Y coordinates of the fitted centroid.

Δ Centroid X/Y: The X and Y displacement of the fitted centroid from the X and Y coordinate values of the input beam centroid.

Δ Centroid: The straight line linear displacement of the fitted centroid to the centroid of the input beam.

Roughness of Fit: Maximum deviation of the theoretical fit to the measured distribution.

$$R = \frac{\left|E_{ij} - E_{ij}^{f}\right|_{\max}}{E_{\max}}$$

Where: E_{ij}^{f} = The fitted theoretical distribution

E_{ij} = The input beam distribution

Note: $0 \le R \le 1$, as $R \to 0$ the fit becomes better

5.19.4 1D Gauss Fit Results

The Gauss Fit results are defined as follows:

Gauss Height: the peak fluence of the Gauss fit result

Gauss Width: The second moment width of the Gauss fit on the cursor data

Gauss Centroid: The location of the fitted centroid on the cursor data

Δ Centroid: The displacement of the fitted centroid to the centroid of the input data on the cursor

Roughness of Fit: Maximum deviation of the theoretical fit to the measured distribution

$$R = \frac{\left|E_{i} - E_{i}^{f}\right|_{\max}}{E_{\max}}$$

Where: E_{i}^{f} = The fitted theoretical distribution

E_{i} = The input beam distribution

Note: $0 \le R \le 1$, as $R \to 0$ the fit becomes better

1D Gauss fits can be either X/Y aligned where the fits will be performed upon the cursor data in the X & Y directions, or the fits can be off axis Major/minor axes aligned with the fits performed upon the cursor data parallel with the Major and Minor axes passing through the Centroid.

When the off axis Major/minor mode is enabled the cursor intercepts become the origins for the 1D profile plots.

5.20 TopHat Results

ISO 13694 defines a large number of beam measurements that are typically applied to beams having what is called a TopHat profile. This 2D TopHat profile is characterized by beams that have a flat-topped energy distribution with steeply sloped sides. The 2D TopHat results are found in the main Results display window. These results are not confined to the TopHat shape, but because of their frequent association with this shape they are collectively referred to as TopHat results.

A subset of the TopHat results can be computed on the 1D beam profiles and these results items are located in the Beam Profile Results window.

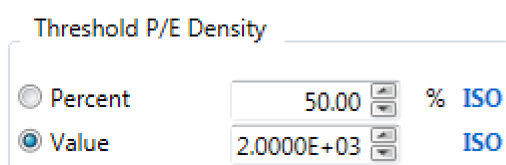
The TopHat results include the following set of computed items:

2D TopHat Results	*1D TopHat Results computed at Cursor Location	
Flatness	X/M Flatness	Y/m Flatness
Effective Area		
Effective Power	X/M Effective Power	Y/m Effective Power
Fractional Power	X/M Fractional Power	Y/m Fractional Power
Effective Avg Fluence		
Uniformity	X/M Uniformity	Y/m Uniformity
Plateau Uniformity	X/M Plateau Uniformity	Y/m Plateau Uniformity
Edge Steepness	X/M Edge Steepness	Y/m Edge Steepness

*The calculations applied to 1D results will have different meanings than those defined in ISO. It is up to the user to find utility in these results, and not to expect any special correlation between the 2D ISO values and the 1D values, even though they have similar names.

TopHat results introduce the concept of a threshold fluence value. Most appropriately this threshold value defines a minimum specification where the power/energy density of the beam is intense enough to do work; such as ablating a surface material, melting a target material, etc. Thus this threshold setting is used to define the effectiveness of the laser beam to perform a certain task.

The threshold value is programmed in the Computations Power/Energy expansion dialog box in the setting called Threshold P/E Density. This dialog is shown below.



In the above example the threshold fluence is set to 2000 W/cm². This value can also be programmed based on the percent of the peak fluence observed in the beam.

The threshold value is given the notation $E_{\eta \mathrm{T}}$

5.21 2D Whole Beam TopHat Calculations

The following sections will describe each of the TopHat results items as defined for 2D spatial analysis.

5.21.1 Effective Irradiation Area

$A_\eta^i(z)$ Irradiation area at location z for which the power/energy density exceeds the threshold density. This is the sum of all pixel areas that are equal to or greater than the threshold fluence.

5.21.2 Effective Average Power/Energy Density

Spatially averaged power/energy density of the distribution at location z, defined as the weighted mean.

$$E_\eta(z) = \frac{P_\eta}{A_\eta^i}$$

Where: P_η = The total power/energy above the threshold
A_η^i = The area containing the above power/energy

5.21.3 Flatness Factor

Flatness is defined as the ratio of the effective average power/energy density to the maximum power/energy density at location z.

$$F_\eta(z) = \frac{E_\eta}{E_{\max}}$$

Where: E_η = The effective average power/energy density
E_{max} = The peak power/energy density in the beam

5.21.4 Effective Power/Energy

$P_\eta(z)$ The Effective power/energy is the total power that is contained in the area above the threshold fluence.

Evaluated by summing only over locations (x,y) for which:

$$E(x, y) > E_{\eta_T}$$

5.21.5 Fractional Power/Energy

The fractional power/energy is the ratio of the power/energy above the threshold divided by the beam total power/energy.

$$f_\eta(z) = \frac{P_\eta(z)}{P(z)}$$

Where: $0 \leq f_\eta(z) \leq 1$

5.21.6 Beam Uniformity

The normalized RMS deviation of the power/energy density from its average value at location z.

$$U_\eta = \frac{1}{E_\eta}\sqrt{\frac{1}{A_\eta^i}\iint\left[E(x,y)-E_\eta\right]^2 dxdy}$$

Note: U_η = 0 for a perfect flat top beam with vertical edges

5.21.7 Plateau Uniformity

For distributions having a nearly flat-top profile.

$$U_P(z) = \frac{\Delta E_{FWHM}}{E_{\max}}$$

ΔE_{FWHM} is the full-width at half-maximum (FWHM) of the peak near E_{max} of the power/energy density histogram $N(E_i)$, i.e. the number of (x,y) locations at which a given power/energy density E_i is recorded.

Note: 0 < $U_P(z)$ < 1; $U_P(z)$ →0 as distributions become more flat-topped.

5.21.8 Edge Steepness

Normalized difference between effective irradiation areas of 10% and 90% of peak with power/energy density values of 10% of peak.

$$s(z) = \frac{A_{0.1}^i(z) - A_{0.9}^i(z)}{A_{0.1}^i(z)}$$

Note: 0 < $s(z)$ < 1; $s(z)$ →0 as the edges of the distribution become more vertical.

5.22 1D TopHat Calculations

The following sections will describe each of the TopHat results items as defined for 1D spatial analysis.

5.22.1 1D Flatness Factor

Flatness is defined as the ratio of the effective average power/energy density to the maximum power/energy density at location z.

$$F_{1\eta}(z) = \frac{\overline{E}_{1\eta}}{E_{1\max}}$$

Where: $E_{1\eta}$ = The average effective power/energy density above the threshold
E_{1max} = The peak power/energy density in the 1D beam profile

5.22.2 1D Effective Power/Energy

$P_{1\eta}(z)$ The Effective power/energy is the total power that is contained in the area above the threshold fluence.

Evaluated by summing only over locations (x) for which:

$$E(x) > E_{\eta T}$$

5.22.3 1D Fractional Power/Energy

The fractional power/energy is the ratio of the power/energy above the threshold divided by the beam total power/energy.

$$f_{1\eta}(z) = \frac{P_{1\eta}(z)}{P_1(z)}$$

Where: $0 \leq f_{1\eta}(z) \leq 1$

5.22.4 1D Beam Uniformity

Normalized RMS deviation of power/energy density from its average value at location z.

$$U_{1\eta} = \frac{1}{E_{1\eta}} \sqrt{\frac{\int [E_1(x) - E_{1\eta}]^2 dx}{d_{1\eta}^i}}$$

Note: $U_\eta = 0$ for a perfect flat top beam with vertical edges

5.22.5 1D Plateau Uniformity

For distributions having a nearly flat-top profile.

$$U_{1P}(z) = \frac{\Delta E_{1FWHM}}{E_{1\max}}$$

ΔE_{1FWHM} is the full-width at half-maximum (FWHM) of the profile peak near E_{1max} of the power/energy density histogram $N(E_i)$, i.e. the number of (x) locations at which a given power/energy density E_i is recorded.

Note: $0 < U_{1P}(z) < 1$; $U_{1P}(z) \rightarrow 0$ as distributions become more flat-topped.

5.22.6 1D Edge Steepness

Normalized difference between effective irradiation amplitudes of 10% and 90% of peak with power/energy density values of 10% of peak.

$$s_1(z) = \frac{d^i_{0.1} - d^i_{0.9}}{d^i_{0.1}}$$

Note: $0 < s_1(z) < 1$; $s_1(z) \rightarrow 0$ as the edges of the distribution become more vertical.

5.23 Beam Positional Stability

The beam stability results are defined in ISO 11670. The implementation performed in BeamGage assumes that the laser axis of propagation is parallel with the camera's Z axes and the measurement is made directly in the plane of the camera imager.

Note: BeamGage does not compute Beam Angular Stability.

To meet the ISO requirement for beam positional stability the laser beam must be sampled at least 1000 times during the measurement interval.

ISO also defines three stability recoding time periods as:

- Short-term, within a time period of 1 second
- Medium-term, within a time period of 1 minute
- Long-term, within a time period of 1 hour

With camera technology, the ability to capture 1000 frames in 1 second is not practical as the fastest cameras typically capture at rates of 60-100 fps. In addition, BeamGage would likely not be capable of computing the stability results at such high rates of speed. The ability to capture 1000 frames in about 1 minute may be possible under optimum conditions. Above 1 minute the possibility of satisfying the 1000 frame sample becomes more doable.

5.23.1 Mean Center

The X/Y Center results define the mean centroid position. This result is the same as the statistical Centroid X/Y Mean that is reported in the main Results display window. This is the mean of the centroid position over time and is the center of mass of the beam wander spatial histogram. This location shall be indicated by a crosshair drawn in the beam stability scatter plot.

5.23.2 Last Center

The X/Y Last result is the centroid of the last frame of data collected. It provides an indication of where the current beam centroid is located. This result is the same as the Centroid X/Y Values that are reported in the main Results display window.

5.23.3 Azimuth Angle

The angle that the major axis (x) of the asymmetric centroid histogram plot makes with respect to the laboratory (camera) axial system.

As the spatial histogram of the beam centroid motion is plotted, the movement will often take on an asymmetrical shape. Quite often this shape will point in a specific direction as the centroid wanders back and forth over time. The shape of this movement will often be rotated with respect to the camera's X/Y axes. The long axis of the motion is defined as a rotated coordinate system x/y with respect to the cameras coordinate system. The angle of the rotated x axis formed with the camera's X axis is call the Azimuth angle. Similar to the manner that an elliptical beam's orientation is calculated, the Azimuth is limited to a rotation of +90°/-89°.

5.23.4 Beam Positional Stability

Δx, Δy, Δs

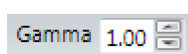
The positional stability of the beam in the x/y axial directions is four times the standard deviation of the distribution of the centroids histogram of movement.

The 2D histogram display uses a binning size equal to the current camera pixel scale. The center of the pixel defines the bin's absolute location and each centroid falling within the pixel is assigned to that pixels bin location. The positional standard deviations are computed based upon the bin coordinates, thus some rounding of the reported stability values does result.

The Δs standard deviation represents the radial beam stability value when the histogram plots a radially symmetric or random scatter plot having no meaningful azimuth angle.

In the beam stability scatter plot a displayed aperture will be drawn that indicates the position and size of the ellipse defined by the scatter histogram. The major axis of this ellipse will be aligned with the x axis or azimuth rotation. The minor axis of the ellipse will be aligned with the orthogonal y axis. The size of the ellipse will be based on the computed standard deviation of the histogram spatial distribution and is referred to as the beam positional stability.

5.24 Gamma Correction



If the camera has a gamma value less than or greater than 1, BeamGage can be set to correct for the camera's non-linear response. Enter the gamma of the camera in the Gamma field located in the Camera... dialog box. Each pixel of each new frame of data will be automatically corrected as defined in the equation shown below. An entry of "1.0" disables gamma correction.

$$z = \left(\frac{Z}{P}\right)^{1/g} \times P$$

Where: z = Gamma corrected pixel intensity

Z = Uncorrected pixel intensity value

g = Gamma

P = The maximum value for a pixel (255 for 8-bit cameras, 1023 for 10-bit cameras, and 4095 for 12-bit cameras, etc.)

Important: ***Be sure of the Gamma correction value. If necessary, run a response curve on the camera. Standard published gamma values are usually averages for particular camera types and may not always be adequate for obtaining the desired accuracy. Also, be wary of gamma values less than 1 published for CCD cameras. These values are usually approximations obtained by using two-piece linear fits to an exponential gamma curve. Whenever possible, use CCD cameras which allow for a gamma setting of 1.0 and do the gamma correction in BeamGage.***

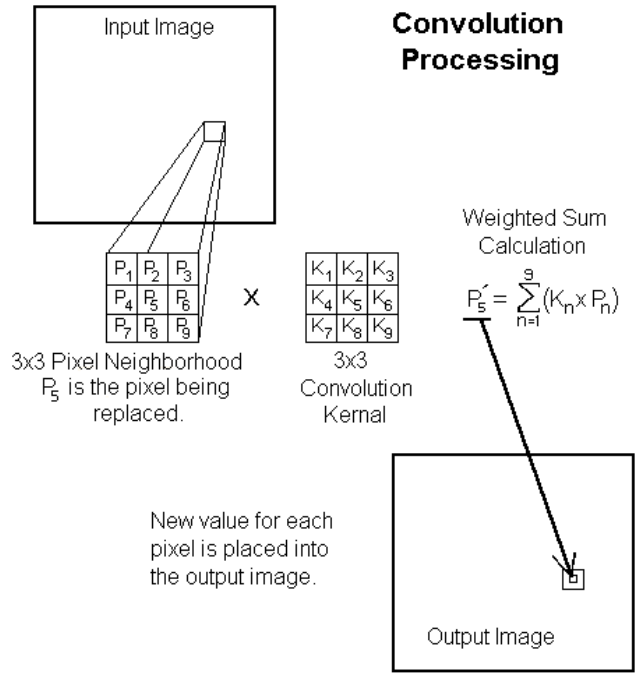
5.25 Convolution

Convolution algorithms in BeamGage may take on a number of forms. In the broadest sense, convolution refers to a general-purpose algorithm that can be used in performing a variety of area process transformations. One such general-purpose algorithm will be described here.

For the purpose of this description, the best way to understand a convolution is to think of it as a weighted summation process. Each pixel in an image becomes the center element in a neighborhood of pixels. A similarly dimensioned convolution kernel multiplies each pixel in the neighborhood. The sum of these products is then used to replace the center pixel.

Each element of the convolution kernel is a weighting factor called a convolution coefficient. The size and arrangement of the convolution coefficients in a convolution kernel determines the type of area transform that will be applied to the image data.

The figure below shows a 3x3 neighborhood and convolution kernel.



The tables below give the convolution coefficients (K values) for some of the included low-pass spatial filters.

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

LPF 1-3X3

1/10	1/10	1/10
1/10	1/5	1/10
1/10	1/10	1/10

LPF 2-3X3

1/16	1/8	1/16
1/8	1/4	1/8
1/16	1/8	1/16

LPF 3-3X3

1/25	1/25	1/25	1/25	1/25
1/25	1/25	1/25	1/25	1/25
1/25	1/25	1/25	1/25	1/25
1/25	1/25	1/25	1/25	1/25
1/25	1/25	1/25	1/25	1/25

LPF 1-5X5

1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49

LPF 1-7X7

5.26 Power/Energy Meter Calibration Methods

BeamGage has the ability to utilize an external Ophir power/energy meter for real-time reporting of the lasers total power/energy. Currently supported Ophir products are:

- USBI and Pulsar -1, -2, and -4 channel USB models
- Vega displays, via USB cable
- Nova II displays, via USB cable

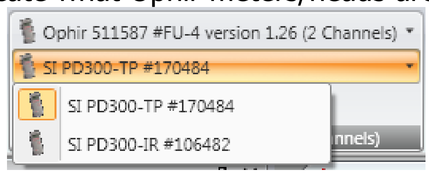
- Juno single channel USB model

The above Vega and Nova II displays must first be setup locally. The Pulsar and Juno models must be setup via StarLab2. At the present time StarLab2 does not support the Quasar Bluetooth product and as a result, neither does BeamGage.

Hint: You should save the setup into the head's flash memory for quicker restarts without having to make changes with the Display or StarLab application.

5.26.1 Selecting a Power/Energy Meter 

When BeamGage recognizes the presence of a useable power meter, the Power Meter dropdown will indicate what Ophir meters/heads are available.



The metered heads are selectable based on their model/serial number. If the meter supports multiple heads then the number of channels with a head plugged in will also be displayed. The channel dropdown can be used to select the desired head. Heads are denoted by model and serial number. If only one head is available, it will automatically be selected. To disconnect the meter from BeamGage, open the Power Meter dropdown and select **Disconnect**.

Important: ***Once a meter has been connected to BeamGage, StarLab will no longer be able to control or display output from that device. Thus it is important that the meter be properly configured for the desired mode of operation before making the connection to BeamGage. If it is necessary to readjust the meter, it must first be disconnected from BeamGage, reconnected to StarLab, and then reconnected to BeamGage. BeamGage will steal the meter away from StarLab, but StarLab cannot steal it from BeamGage.***

5.26.2 Power/Energy Meter Operation

With the meter connected, the Power/Energy manual calibration settings will no longer be in effect. An  icon will appear in the Power/Energy panel to indicate that a meter reading is being used for the power/energy results displays and related computations.

The reported meter values will be synchronized to the frame captures performed by BeamGage. However, it is important to understand that the values reported by the power meter and BeamGage may be asynchronous or synchronous depending upon the type of equipment in use and the way the equipment is configured. This means that the results assigned to each frame may or may not be temporally accurate. The next sections will describe how these various scenarios can affect the validity of the reported results versus the data image associated with the results.

5.26.3 Thermopile Head Operations

All of the Ophir high power heads are based on thermopile technology. One characteristic of the thermopile design is that they have relatively slow response times. In general the larger the total power capability of the head, the slower the response will be. Response times can vary from about a second to tens of seconds, depending upon the head.

Camera based beam profilers are generally faster in response, especially as the camera frame rate increases. As a result, the values reported by the meter will lag behind data collected by the camera. The faster and greater the magnitude of the power input change, the more noticeable the delay will be between the meter and the camera display. Once things have reached a steady state condition the head and the camera can be said to be in close agreement.

Ophir power meters employ speedup algorithms that improve this response time significantly. However, the lag will still be a factor under the best of conditions.

If attempting to have BeamGage report accurate real-time power fluctuations, it is better to use the meter to manually calibrate BeamGage and use a well Ultracal'd setup. This type of setup will remain quite accurate for power fluctuations in a range of about 50:1.

If a larger dynamic range is needed, and if the user can relax on the ability to show 1:1 correlation of the data frames vs. the power reading, the solution is to run BeamGage in Auto-X mode and do not try to infer a temporal match between the image results and the precise power results being reported.

5.26.4 Photodiode Head Operations

Photodiodes respond much quicker than thermopiles. As a purely electronic device, photodiodes can respond in near real time. Used in a power meter application they respond more slowly, as a tradeoff between speed and dynamic range. Photodiodes have a very large dynamic range, much greater than a CCD camera. As a result the rate at which data is output from a typical meter is about 15-16 Hz. Like a camera, running at about the same frame rate, the recorded power readings should be a pretty close temporal match.

5.26.5 Pyroelectric Head Operation

Joule meter heads operate on short pulse widths and can record pulse energies at very high rep-rates. An energy meter can significantly outperform a BeamGage camera system when it comes to collecting pulse to pulse energy readings.

The meter can be either self-triggered (by the head) or externally triggered.
The camera must be externally triggered to collect stable images and the exposure time must be long enough to contain the entire pulse width.

The ability for a camera to split out laser pulses and record them in real time is limited by the camera frame rate. Some of the fastest cameras run at 60-100 Hz frame rates. However, not all can be triggered this fast.

At pulse rates that exceed the camera frame rate, the exposure time can be set short enough so that only one pulse can be split out per captured frame. Of course this means that not all pulses are being collected.

The opposite choice is to allow the camera to collect multiple pulses per frame. This will have the effect of pulse summing a certain number of shots in the displayed frame. If the trigger rate is unstable, it could be possible that some frames may contain a different number of shots.

At the present time, BeamGage can precisely match the output from a Pulsar to the exact camera frame up to about 100 Hz, or the frame rate of the triggered camera, whichever is less.

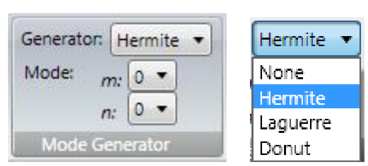
It cannot match rates from the Vega and Nova II if the pulse rates are much more than about 10 Hz. Even at these rates the synching is not always a perfect match.

At the time of this writing, the Juno is not available for testing but we are expecting it to perform about as well as the Pulsar.

5.27 BeamMaker™

BeamMaker is a proprietary embedded modeling tool that can be used to asses and validate Spiricon’s beam measurement algorithms, ISO algorithms, and specialized user algorithms. It also provides a convenient tool that can help model a particular measurement environment to determine what degree of accuracy is possible under a variety of conditions. This section will first describe how the controls operate, and then offer two examples that demonstrate how BeamMaker can be used.

5.27.1 Mode Generator



This control selects what type of beam mode is to be modeled and what mode is set. BeamGage supports only pure modes and one special mixed mode, the Donut (TEM_{01*}). Choose from either a Hermite, Laguerre, or the mixed Donut mode. The M² value of a modeled mode is defined as shown below:

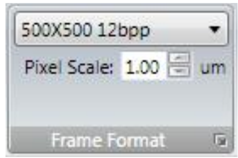
For the Hermite mode, program the TEM_{mn} m and n values, where:

$$M_x^2 = 2m + 1 \qquad M_y^2 = 2n + 1$$

For the Laguerre mode, program the TEM_{pl} p and l values, where:

$$M^2 = 2p + l + 1$$

The Donut mode, TEM_{01*}, consists of two superimposed Hermite TEM_{01} and TEM_{10} beams. This pure Donut mode has an M^2 value of 2.



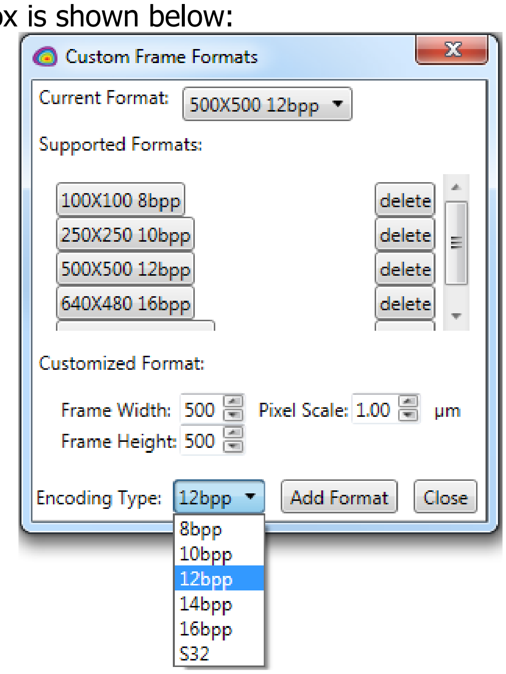
5.27.2 Frame Format

This panel defines the frame format in pixels, Width X Height, and the number of bits per pixel to use as the data format. BeamGage ships with a set of predefined formats that should satisfy most testing scenarios. Open the dropdown and select the format needed. In the above example, the frame format is set to 500 pixels wide, 500 pixels high, 12 bits per pixel data format, and 1.00µm square pixel pitch. (Pixels are always modeled square.)

If the predefined pixel scale setting is not what is needed, change the value using the **Pixel Scale** edit control. The pixel scale units are always microns, µm.

5.27.3 Custom Frame Format

If a new format is needed, first stop running, and then click on the dialog expansion button. This will access a system that allows the user to design a new format. This dialog box is shown below:

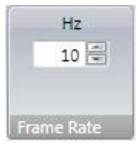


The currently available formats are shown in the **Supported Formats:** list. To delete a format click on the **delete** button adjacent to the format description. To add a format enter the new **Frame Width** and **Frame Height** sizes, the **Pixel Scale**, and select the bits per pixel **Encoding Type**; then click **Add Format**. Set the desired format into **Current Format**, and click **Close**.

The open beam display windows will resize into the new format design as soon as **Start** or **Ultracal** is clicked.

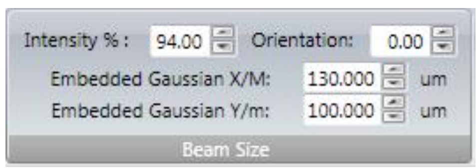
The **Encoding Type** defines the number of bits per pixel that will be used to model the beam. Spiricon currently ships cameras that support formats from **8bpp - 14bpp**. **16bpp** format cameras do exist but are very expensive and not very common. The **S32** format is a signed 32bit format. No known camera supports this large of a dynamic range. It is provided here only as an example to demonstrate how accurately a measurement could be made under nearly ideal input conditions.

5.27.4 Frame Rate

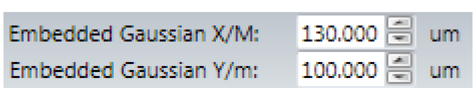


BeamMaker attempts to run at the frame rate set. The final speed will be dictated by the computations loading on the processor and by the Results/Frame Priority setting in the Capture ribbon. Larger frame sizes with larger beams will take longer to model. Adding noise will also take additional time.

5.27.5 Beam Size



Here is where the size, intensity, and orientation of modeled beams are defined. In all instances, what is being defined is the size of the embedded TEM_{00} Gaussian mode of the beam. This embedded mode will be transformed into the higher modes that may be specified in the previous Mode Generator panel. For example, an embedded TEM_{00} beam that has a 100µm beam width will result in a model beam that has a beam width M times larger than the embedded value. Thus, if the beam M² value is 2, the resulting modeled beam will have a beam width 1.414… times larger than the embedded size.



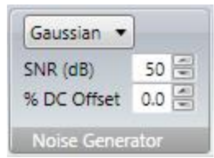
The embedded beam widths are set using these edit controls. The size is only programmable in microns, µm. The values set here will automatically scale up or down if the Pixel Scale setting in the Frame Format panel is modified.

Set the intensity of the modeled beam as a percentage of the model's full dynamic range. This setting should never be set to values near 100% when noise and Ultracal are being used as a part of the modeling process. The noise component is part of the model's dynamic range, just like it would be in a real camera. Thus, when a baseline is computed and subtracted from the model's dynamic range, the maximum beam intensity cannot be 100% of the original full scale counts, but is now a figure lowered by the mean baseline offset.

Typically values of 90-95% can be used to indicate full signal amplitude under most realistic noise scenarios. If the SNR is reduced to a level where noise constitutes a large percentage of the signal, this max setting may need to be set much lower.

If modeling an off axis elliptical beam, the user can set the orientation of the modeled beam with respect to the X axis. The orientation setting will agree with the Orientation results if the X/M major width is set as the larger of the two entered values. If the Y/m minor axis is set as the larger, then the reported orientation result will be 90° offset from the value entered here.

5.27.6 Noise Generator



This panel allows the user to add a **Gaussian** RMS signal to noise ratio (SNR) component to the modeled beam. The noise is specified in dB. If attempting to model a camera with a known SNR the camera noise value can be entered here. If no noise model is required select **None**.

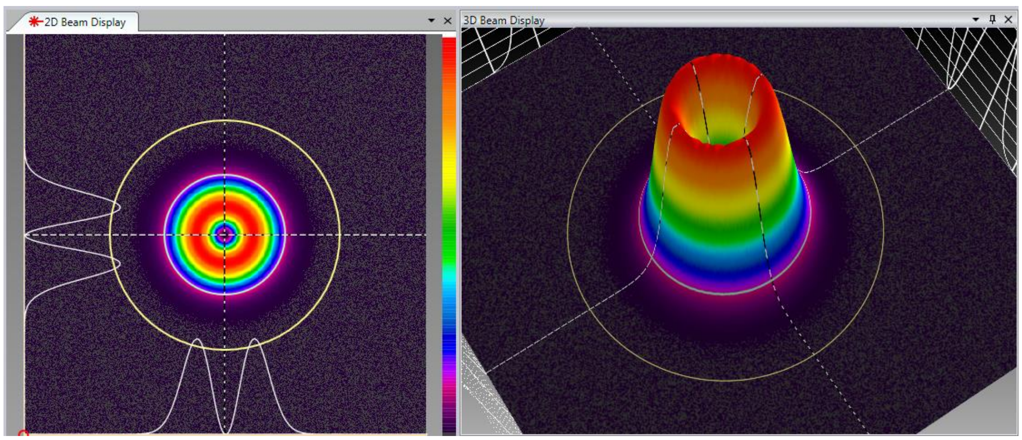
It is also possible to model the effects induced by a camera's DC offset bias. Enter the offset, positive or negative, as a % of the camera's full scale digitized output range. For example, a **% DC Offset =** -0.1, of a 12 bit (0-4095 counts) camera output range, will create an offset of -4 counts. This will offset (subtract) 4 counts from the input signal clipping at Zero. Conversely an increase in offset of 0.1% will add 4 counts to the input signal.

When used with BeamGage, a camera's black level is raised so as to preserve the full noise floor. This means that both the positive and negative noise can be used to compute a more accurate baseline. The user can program the offset higher or lower to simulate the effect on computed beam widths due to offset errors. Note that if no DC offset is applied, and noise is present, only the positive noise will be available when the beam widths are computed, having a net effect of increasing the measured beam size. Conversely, lowering the noise floor so as to suppress the baseline noise will lead to a reduced beam width measurement. The degree of the errors can be minor or significant depending on other conditions present; such as the use of an aperture, or the size of the beam relative to the imager if no aperture is used.

Important: ***Once a beam model is constructed, and the user wants to compute an accurate beam width, an Ultracal cycle <u>must</u> be performed. The Ultracal cycle will simulate the adjustment of the black level, treating the BeamMaker source as if it were a real camera. In effect, this will cancel the programmed % DC Offset since Ultracal is resetting the offset to achieve a best case baseline adjustment.***

5.28 BeamMaker™ Application

The following example demonstrates how a Donut TEM_{01*} beam profile produces different beam width results using the different methods available in BeamGage. In this model, the SNR is set to 60dB which is a value that matches most of the better cameras running with well optimized beam attenuation. Beam intensity is set to 95% and no offset is applied. The beam shown below has an embedded Gaussian set to 100µm in both the X and the Y axial directions. An Auto aperture is employed to reduce noise effects in the wings by limiting the calculations to only the area inside the aperture. The correct second moment beam width/diameter for this beam is thus 141.42um.



Only the X axis beam width, or the diameter, is shown in the following results.

Description	Value	Units
D4σX ISO	1.414e+02	um
DkeX 10/90	1.438e+02	um
DkeX 16/84 ISO	1.519e+02	um
DkeX prog	1.329e+02	um
D%pk	1.492e+02	um
D%t	1.314e+02	um
Depss(X) 95.4 ISO	1.294e+02	um
Depsa 86.5 ISO	1.325e+02	um

As seen in the above results, the second moment **D4σX** value is computing the second moment accurate to 4 significant digits. Some of the other methods are less accurate. Even those described as ISO methods can be seen to perform poorly. The **DkeX16/84** method measures the beam larger, while the **DepssX 95.4** and **Depsa 86.5** methods report smaller beam widths/diameters, respectively.

The **DkeX prog** result is yielding a very accurate result because the programmed settings for this have been set to 16/84 with a 1.86 multiplier, making it equivalent to the second moment for this pure donut mode input. Of course, a different setting would be optimum for a different mode or mode mix.

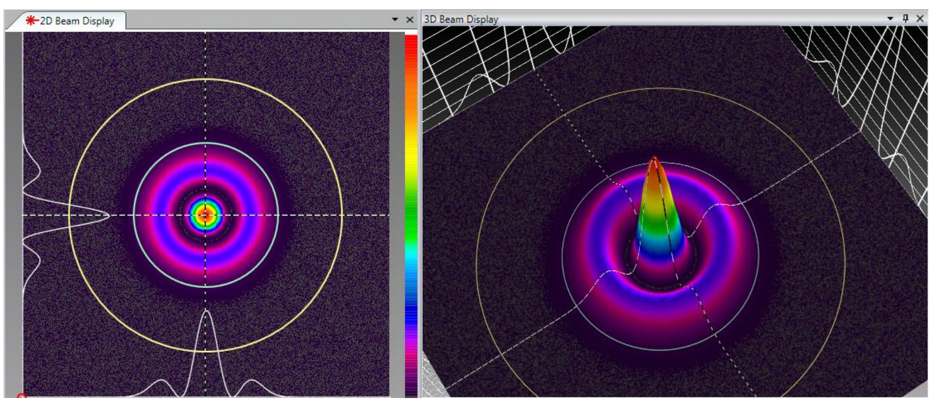
The accuracy of each of the above results is listed below as compared to the second moment. Observe that the Spiricon legacy 10/90 result is very close to the true second moment value, being high by about 1.7% in this example. This is why Spiricon has employed this method in the past as it works well for many mode mixes.

Method	Width/Dia.	% Error
D4σX ISO	141.4	---
DkeX10/90	143.8	1.7
DkeX16/84 ISO	151.9	7.4
DkeX prog	141.3	-.01
D%pk	149.2	5.5
D%t	131.4	-7.1
D%msX ISO	141.6	0.0
DepssX 95.4 ISO	129.4	-8.5
Depsa 86.5 ISO	132.5	-6.3

Donut Beam Results

Here's another example showing how results can vary based on the beam width method being employed. This beam model is of a Laguerre TEM_{10} mode. The basic settings are as in the previous example. The multiplier for the **DkeX prog** has been changed to 1.75 in order to compute an equivalent D4σ result.

The M^2 of this mode is 3, resulting in a beam width of 173.2μm (3^{-2} x 100μm). Observe the results shown below the beam profile.



Description	Value	Units
D4σX ISO	1.732e+02	um
DkeX 10/90	1.868e+02	um
DkeX 16/84 ISO	1.985e+02	um
DkeX prog	1.737e+02	um
D%pk	1.233e+02	um
D%t	1.543e+02	um
Depss(X) 95.4 ISO	1.592e+02	um
Depsa 86.5 ISO	1.645e+02	um

Method	Width/Dia.	% Error
D4σX ISO	173.2	---
DkeX10/90	186.8	7.9
DkeX16/84 ISO	198.5	14.6
DkeX prog	173.7	.28
D%pk	123.3	-28.8
D%t	154.3	-10.9
D%msX ISO	166.5	-3.9
DepssX 95.4 ISO	159.2	-8.1
Depsa 86.5 ISO	164.5	-5.0

Laguerre TEM_{10} Results

Note: All BeamMaker data frames can be saved as .bgData files in the HDF5 format. They can be power/energy calibrated and exported into 3rd party applications to be used to perform additional analysis. The data file can be modified and reloaded into BeamGage as long as critical header parameters are not destroyed in the process.

CHAPTER 6 Partitioning

The Partitioning feature is available only in BeamGage Professional edition. Partitioning allows the user to subdivide the camera imager into separate regions, called partitions, and compute separate beam results within each partition. When using partitioning, special results items can be displayed that relate to delta values between the computed centroids of each partition. When using partitions, some normally computed results may no longer have a useful meaning.

6.1 Partitioning Definitions and Rules

The full frame is the original input frame. Additional partitions can be created within the full frame. When partitions are created, special rules apply to both the content of each partition and to the full frame. The following apply when one or more partitions are created:

- The Origin location is set in the full frame and is global for all partitions.
- Partitions are always square or rectangular in shape and are always orientated on axis.
- Partitions appear as Orange apertures in the 2D display window.
- Partitions are not visible in the 3D display window or the 2D Pan/Zoom window.
- Partitions can overlap and be nested inside each other.
- The Results display window can only display the results of one partition at a time. The selected partition is highlighted in RED.
- Auto and Manual apertures are applied only to the full frame and have no effect on the results computed within the partitions.
- The Cursor and Crosshair operate in the selected partition.
- Power/Energy calibration values are always applied to the data in the full frame.
- Computed results items are enabled on a global basis, i.e. a result item enabled/disabled in any partition is enabled/disabled in all partitions.
- Statistical results can be computed in partitions.

6.2 Partitioning Features and Results

Results are individually computed for the content of each partition. Delta table results items are displacement measurements between either Centroids or Peaks located within each partition.

- Results from any partition can be dragged and dropped onto the display window.
- Individual Pass/Fail rules can be applied to partition results items.
- Linear Centroid to Centroid Deltas between partitions can be displayed in a Partition table.
- Linear Peak to Peak Deltas between partitions can be displayed in a Partition table.

Note: The number of partitions and the number of computations being performed within each partition will have a slowing effect on the overall performance. The

worst case scenario would occur if whole beam Gauss fits were being performed within each partition.

6.3 Partition Creation

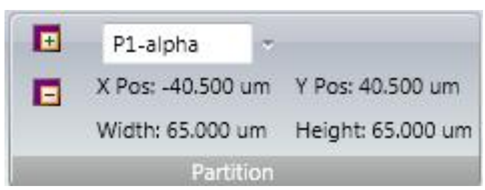
All partitions begin as a drawn manual aperture. Because partitions must be either square or rectangular in shape, you should always set the manual aperture shape to either Square or Rectangular. Also, since partitions must be drawn on axis, the rotation angle for the manual aperture should always be set to 0 degrees.

If the position of the aperture is important relative to a defined origin location, then be sure to set the Origin to the desired location. This can be changed later, but if you want to locate centroids relative to a fixed spatial position, it may be a good idea to fix this position at the start of the process.

To create a partition, begin by using the Manual Aperture Design tool. Create the aperture with the location and size required. For precise placement vs. a fixed origin position, use the numerical edit controls in the Manual Aperture panel.

Hint: For the most accurate beam width measurements, set the apertures to ~2x the expected beam width size.

Use the Partition panel to convert the manual aperture into a partition by clicking on the **Add Partition**  button.



An orange partition will be created with the same location and size as the manual aperture and a partition label will appear in its upper left-hand corner. The manual aperture will still be active and can be repositioned to create the next partition. Repeat the above process until all partitions have been created.

Partitions are assigned labels starting with P1, P2, P3 …etc. There is no limit to the maximum number of partitions that can be created.

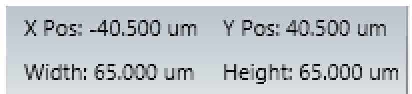
Partitions cannot be revised once created so it is important to use care and define them correctly. The only way to correct a partition is to delete it and recreate it. To delete a partition, select it and click on the **Remove Partition**  button.

The partition labels may be replaced with a user assigned alias. Select the partition that you wish to rename from the dropdown list. Click the partition name and type in the new name followed by the **Enter** key.

change to

The new partition name will appear as the partition label and at all locations where the partition is identified. Brevity in selection of the alias will be its own reward. Partitions cannot have the same name. The list will show the partitions in the order they were created.

The location and size of the selected partition will be displayed in the following form:



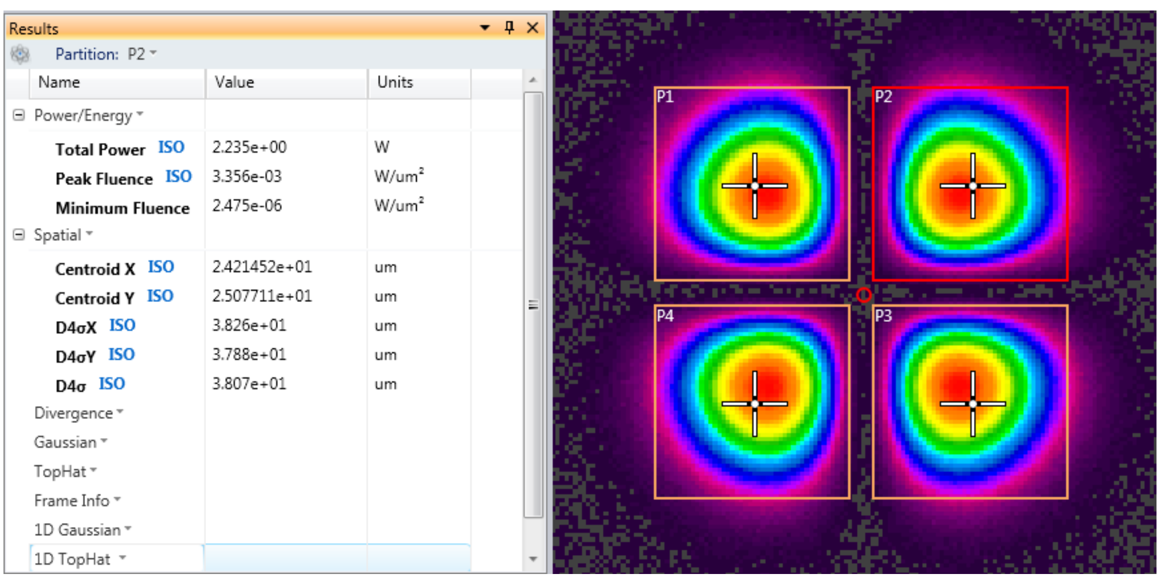
Where X Pos and Y Pos are the center coordinates of the partition.

Hint: To place the partition crosshair at the center of the partition, copy the X/Y values into the crosshair table explained in the following section.

6.4 Partition Results

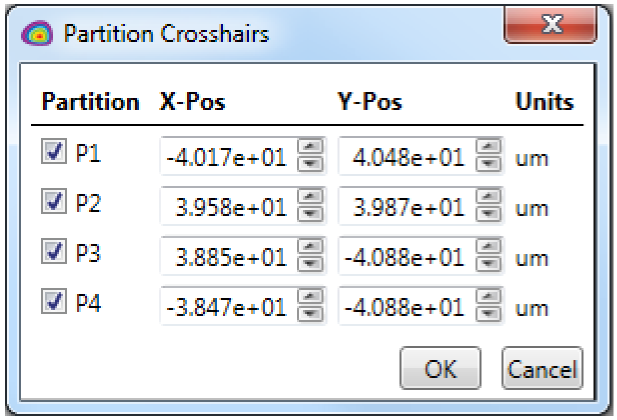
The results window can only display the computed results of one partition at a time. This constraint is due to space restrictions, especially if a large number of partitions are in use and more so when Statistics are being computed. Select which partition is displayed using the Partition panel.

Below is an example of the results for partition P2 and its related display frame.



Observe that the selected partition is highlighted in RED. The crosshair in each partition is user controlled. The crosshair can be moved to a new position with the mouse or can be numerically positioned using the expanded controls option that appears when a partition is created.

To numerically position the crosshair, click on the expand button. A coordinate table of the displayed Partition Crosshairs will appear as shown below. You can use the checkbox to turn the individual partition crosshairs ON or OFF, and manually enter the position that you want the crosshair to occupy.

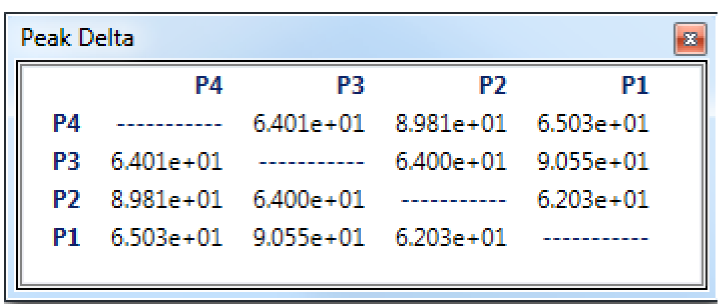


Note: A partition's crosshair cannot be located outside of the partition boundary.

6.5 Partition Delta Results

One of the most common applications for partitioning is to compare the alignment of multiple beam spots to a fixed set of spatial coordinates and/or to each other. This is usually done by checking the spacing between the partitioned spot centroids or peaks. To make this job easier, a new type of results window is provided. These are called Delta Centroid and Delta Peak tables and can be enabled using the **Tools** panel in the **Aperture** ribbon. They can display either straight line distance deltas or X/Y axis deltas. All values in the table are the results of subtracting the values found in each partition with the values in all the other partitions.

Below is an example of the linear distance displacements between the Peak values in each of the partitions depicted above in section 6.4.


Peak Delta

	P4	P3	P2	P1
P4	-----------	6.401e+01	8.981e+01	6.503e+01
P3	6.401e+01	-----------	6.400e+01	9.055e+01
P2	8.981e+01	6.400e+01	-----------	6.203e+01
P1	6.503e+01	9.055e+01	6.203e+01	-----------

Six possible variations can be computed and displayed based on the user's preference:

1. Straight line centroid to centroid delta values
2. X axial direction centroid to centroid delta values
3. Y axial direction centroid to centroid delta values
4. Straight line peak to peak delta values
5. X axial direction peak to peak delta values

6. Y axial direction peak to peak delta values

The number format of the values is the same as selected in the Display Options for the entire Results Window. See section 2.6.3.1 for more details.

Important: ***All X/Y Delta distances are computed on axis and are not compatible with using one of the off-axis features in BeamGage. To achieve stable and meaningful results, all of the off-axis results items, such as Orientation, Ellipticity, and Eccentricity, should remain disabled. Straight line delta distances are not affected if off-axis results are enabled.***

6.6 Partitions and Logging

When logging results with partitions, the results of each partition can be separately entered into its own log file.

Click on the Logging control panel's **Log Results** drop down to see a list of partitions to enable for logging. When statistics are enabled they will appear at the end of the log file in the normal fashion.

6.7 Partition's Adverse Effects

Because all the features are not cloned within partitions, some results items and displays may not work in as meaningful a manner as before. A few of these will be discussed in this section.

6.7.1 Partitioning and Cursor/Crosshair Operations

The 2D and/or 3D main display window cursors and crosshair will operate in the selected partition. If the mode of operation is to track the peak or centroid, it will do so within the boundary of the selected partition. If an Auto and/or Manual aperture is enabled, however, it will follow the normal aperture application rules for the full frame.

6.7.2 Partitioning with Beam Profiles

While the beam profile displays will continue to be available, there is only one set of common cursors for all the partitions. The beam profiles are created from the cursor and are restricted to the boundaries of the enabled partition. However, if partitions overlap, the usefulness of the beam profiles may be limited.

6.7.3 Partitioning with Beam Stability

The Beam Stability results are also available when partitioning. However, the stability plot and result will be performed on the content of the full frame and is not assignable to the content of any one partition.

You may apply a manual aperture onto one of the partitioned regions, and this will limit the stability results to just that one region. However, this will also reduce all of the full frame results to this one region, and that may complicate your ability to calibrate power/energy and monitor the entire frame.

6.7.4 Partitioning with Histogram

As in the preceding section, the Histogram display will operate only upon the content of the full frame. Adding a manual or auto aperture will further restrict the data content of the histogram, but this may adversely affect other full frame results calculations.

CHAPTER 7 Custom Calculations

BeamGage Professional provides a custom calculation ability which allows users to program their own set of calculations. Because of the high technological background required to successfully operate custom calculations, it is recommended that the user has the following minimum skill set:

* A minimum BS degree in Computer Science, Computer Engineering, or equivalent.
* Demonstrated proficiency in writing programs in Microsoft Visual Basic, and/or C++, and/or C#
* Review Spiricon's **Custom Calculations Documentation** (see 7.1 below). If you don't know immediately what this means and how to use it, you shouldn't be attempting to program your company's custom calculations.

7.1 Documentation

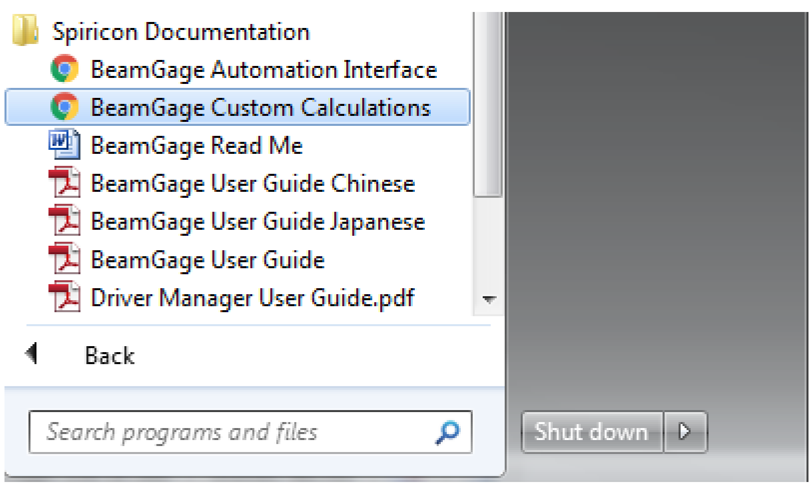
The custom calculations reference documentation is presented via html. The html provides cross-referenced access to all interfaces, functionality, and examples provided for custom calculation development and application. The **BeamGage Custom Calculations** may be accessed via the following link:

Custom Calculations Documentation

-or-

Via the start menu shortcut as shown below:

Start -> All Programs -> Spiricon Documentation -> BeamGage Custom Calculations



CHAPTER 8 Automation Interface

BeamGage Professional provides an automation interface via .NET components to allow customers the ability to build 'custom applications' that incorporate the laser beam analysis and processing power of BeamGage. The BeamGage automation interface allows developers to control BeamGage programmatically via a set of "puppet strings" known as the automation interface. The automation interface was developed to provide the ability to base control decisions for a second application on results and behaviors recognized by BeamGage. With this ability, users can quickly and efficiently meet their manufacturing/analysis goals with minimum human interaction.

8.1 Automation Design Skill Set

Over the years, Spiricon has learned that to design a proper automation client for products similar to BeamGage requires a skill level comparable to that of a degreed and experienced computer programmer. Even with this background, a learning curve is necessary to achieve an acceptable level of competency. Very often Spiricon's service and engineering departments are contacted by individuals that are assigned to design an automation interface, but lack a sufficient technical background. To assist your company in making a good employee fit for this type of work, we offer the following guidelines for the minimal skill sets needed.

To interface with LabVIEW you need:

- An understanding of .NET programming methods.
- Prior, and recent, experience designing and deploying National Instruments LabVIEW VI's in an automation environment.
- Review Spiricon's **Automation Documentation** (see 8.4 below). If you don't know immediately what this means and how to use it, you shouldn't be attempting to design your company's automation client.

To interface with a program written in Visual Basic (VB), C++, or C# you need:

- A minimum BS degree in Computer Science or Computer Engineering, or equivalent.
- Three (3) plus years of software design experience using Microsoft Visual Studio design and debugging tools.
- Demonstrated proficiency in writing programs in Microsoft Visual Basic, and/or C++, and/or C#
- A background in .NET programming methods
- Review Spiricon's **Automation Documentation** (see 8.4 below). If you don't know immediately what this means and how to use it, you shouldn't be attempting to design your company's automation client.

8.2 Evolution of Spiricon's Automation Interface

Spiricon's older products used COM and ActiveX to provide an automation interface. More recent technologies, like .NET, provide more fully featured functionality. Recent developments in remoting technologies allow nearly transparent interaction between machines on the same domain. This allows the user to leverage more than one machine while using BeamGage for analysis. COM remote operation is more difficult to use and setup when compared to its .NET counterpart. For this reason, BeamGage's automation interface was developed using Microsoft's .NET infrastructure. Any .NET application should easily integrate and be able to interact with the core functionalities provided by BeamGage.

8.3 Introduction

The BeamGage automation interface was designed to achieve two main goals. First, to allow the BeamGage user to programmatically do what they could otherwise do via the graphical user interface (GUI). Second, to expose stable interfaces to the user that will not change, causing breaks to their dependent code. In order to facilitate these goals, it is important that the user be given stable abstractions to program against. It is likewise important to allow BeamGage to evolve as new features are added. Spiricon is dedicated to protect users from changes in underlying implementation as BeamGage evolves. To this end, BeamGage's automation interface is presented as a set of interfaces that collectively expose the functionality of the application. Access to these various interfaces is provided by creating one concrete class known as BeamGageAutomation. From BeamGageAutomation, the user can create and destroy several instances of the BeamGage application.

BeamGageAutomation exposes a method (via the IV5AppServer interface it implements) called GetV5AppServer. This method will launch BeamGage instances and return a reference to an IAutomationCLT object (CLT stands for Core Logic Trunk). Each instance of BeamGage can be independently controlled via its respective core logic trunk. The number of active BeamGage applications available is controlled via BeamGageAutomation, while control of a single BeamGage instance is provided via its core logic trunk.

The IAutomationCLT exposes a method called GetInterfaceX. This method is used to access all API interfaces. Each interface is accessed via its name. Once the desired interface is acquired, the user can control its respective functionality for the given instance of BeamGage.

8.4 Documentation

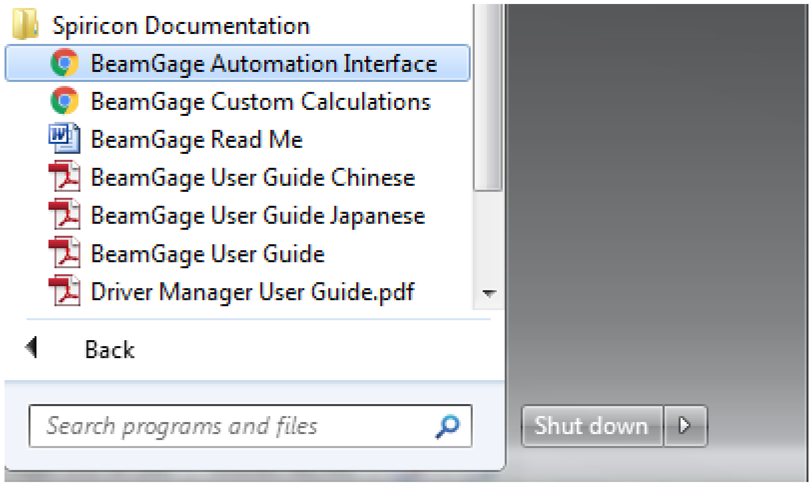
The Automation API reference is presented via html. The html reference provides cross-referenced access to all interfaces and functionality provided for automation application development. The **BeamGage Automation API** may be accessed via the following link:

Automation Documentation

-or-

Via the start menu shortcut as shown below:

Start -> All Programs -> Spiricon Documentation -> BeamGage Automation Interface



8.4.1 Examples

Examples of simple automation applications in LabVIEW and Visual Basic .NET are provided. For step-by-step walkthroughs click on the appropriate link:

Setup (LabVIEW)
Setup (VB)

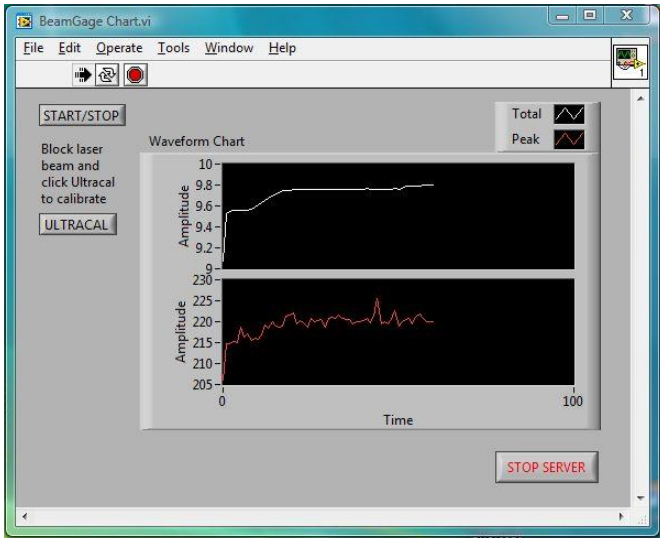
-or-

By navigating to the files located at:

C: -> Program Files -> Spiricon -> BeamGage Professional -> Automation -> Documentation

8.4.2 Operating the LabVIEW Example

The **TotalPeakExample** will open with the following LabVIEW VI:



… and it will open, connect to, and run BeamGage. When it opens BeamGage, BeamGage will start with the setup file last saved. If that setup connects to an available source, the Total Power and Peak Fluence values will plot in the displayed charts.

The **START/STOP** button will cause BeamGage to start and stop collecting data. The **ULTRACAL** button will cause BeamGage to perform an **Ultracal** cycle.

To close the above LabVIEW example and BeamGage you must, in the following order:

1. Click on the **Stop Server** button to close BeamGage.
2. Close the VI.

Important: ***BeamGage must be closed using the Stop Server button. It cannot be closed normally once this VI is closed. If you close the VI without first closing BeamGage with the Stop Server button, then the only way you will be able to close BeamGage will be by rebooting the PC.***

Important: ***When BeamGage is launched from an automation client, it can only be properly closed by that same client. Thus, it must be closed before the client is closed. Keep this in mind when designing your own client application.***

CHAPTER 9 Troubleshooting

System Troubleshooting		
Symptoms	**Cause**	**Resolution**
General Errors		
Error Message: "The Spiricon Console Service is unavailable on the computer."	The service is not running. Spiricon.ConsoleService.exe is a required service process for all BeamGage products.	If possible, restart the service with the Windows Service Manager, otherwise reboot the computer to restart the service.
	The console service communication ports are in-use or blocked.	Ensure that TCP ports 10100-11100 are available. If in use by another application, the port range may be customized by modifying PortFinder.config.xml (found in the BeamGage installation directory) and restarting the service.
	The environment required to run the service may be corrupt. In some cases this may happen due to a failed installation/upgrade of the software.	Uninstall all BeamGage products and install the latest version.
Error Message: "Data Source Unavailable"	If received when selecting a data source, BeamGage was unable to connect to the camera.	Please contact Spiricon Customer Service for assistance.
	If received after selecting a data source, e.g. during data acquisition or changing camera settings, then the data source process has or will likely crash.	Please contact Spiricon Customer Service with details of the behavior that caused the crash.
What's This Help doesn't open correct topic in Adobe Reader.	In Adobe Reader X and later, a security feature called "Protected Mode", can prevent an external application from accessing a PDF document's bookmarks correctly.	Disable Protected Mode in Adobe reader. For more details, go to http://www.ophiropt.com/laser-measurement-instruments/beam-profilers/knowledge-center/tech-tips/beamgage-adobe-reader If the behavior persists, try opening the User Guide separately and making the selection with the **What's This** cursor a second time.

System Troubleshooting

Symptoms	Cause	Resolution
SP Model Cameras		
CANNOT connect to an SP620U or SP503U camera, **CAN** connect to the BeamMaker or File Console data sources.	Camera may not be connected or USB cable is defective.	Verify cable connection between the camera and the computer. Verify that the device is recognized in Windows Device Manager.
	A powered USB 2.0 high speed port and cable may not be in-use.	Ensure camera is connected to a USB 2.0 high speed port, power savings modes are disabled, and the cable in use is certified for use with USB 2.0 high speed devices.
	A conflicting webcam may be installed.	Disable the webcam hardware in the system BIOS. If disabling the webcam hardware did not solve the problem on its own, locate and uninstall the preloaded software/drivers used to operate the webcam.
Pyrocam Model Cameras		
Cannot find the Pyrocam III in BeamGage using Windows 7.	The proper FireWire Bus Host Controller driver may not be installed.	The Pyrocam III camera driver requires the Windows 7 "1394 OHCI Compliant Host Controller (Legacy)" driver. If using the FireWire adapter card supplied with the camera system then this should be installed automatically by the Spiricon Camera Driver Manager found in the start menu. If using a FireWire adapter card other than what is supplied, please go to: http://www.ophiropt.com/laser-measurement-instruments/beam-profilers/knowledge-center/tech-tips/installing-the-pyrocam-iii

System Troubleshooting		
Symptoms	**Cause**	**Resolution**
Other Camera Models		
Cannot find the camera when selecting a Local Detector.	Camera may not be connected or USB cable is defective.	Verify cable connection between the camera and the computer. Verify that the device is recognized in Windows Device Manager.
	Ensure the proper drivers are installed for the camera you are using.	Locate the shortcut for the Spiricon Camera Driver Manager in the Windows Start Menu. Run the driver manager and follow the instructions to install the drivers for your camera.

APPENDIX A ISO Computations Table

This table of ISO computations follows the labeling and notions found in the ISO standards. Where differences exist within the standards, no particular preference is given to any one notation. The information contained here may not always agree with the latest releases of the individual standards; however Spiricon will update it from time to time as the ISO standards evolve. The Section numbers in the list may also break when ISO standards are reformatted. The ordering of the items follow no particular sequence and no importance should be attached to the item #.

Note: The symbols and names listed here may or may not agree with the notations used in BeamGage. These notations may be slightly modified for the purpose of maintaining consistency in labeling within BeamGage and standard industry and legacy usage. Not all listed results are currently provided in BeamGage.

( ) shall contain one of the following symbols[1]

u = a measurement based upon a percentage of power/energy, usually an encircled amount or contained by a smallest slit. The value u shall be replaced with an amount, such as 90 to represent 90%.

σ = a measurement based on second moment definitions

k = a measurement based on a Knife Edge measurement, usually a 10/90 percent of energy[2]

Item #	Symbol	Name	ISO 11145	ISO 11146	ISO 11670	ISO 13694	ISO 15367	Section	Definition
1	$A_{()}$ $A_\sigma(z)$	beam cross-sectional area	x			 x		3.2.1 3.2.2 3.2.6	Area bounded by the beam width definition ( ) for circular beams $A_\sigma = \pi \frac{d_\sigma^2}{4}$ for elliptical beams $A_\sigma = \pi \frac{d_{\sigma x} d_{\sigma y}}{4}$
2	$d_{()}$	beam diameter	x					3.3.1 3.3.2	Smallest aperture or second

[1] The ISO procedures typically refer to two types of beam diameter/width measurements; second moment, and encircled energy. When dealing with elliptical beams, the encircled energy method is modified to a minimum slit technique, where for a circular Gaussian distribution, 95.4% of the energy contained in a slit is equal to the second moment width. Also in dealing with elliptical beams, the direction of variable slit orientation is described as being in the "preferential directions"… see ISO 11145 sec 3.5.1. While the "preferential directions" are rather loosely defined, one can surmise that the later described azimuth directions can be used in its place… see ISO 11146-1 sec 7.2.

[2] The Knife Edge measurement technique is mentioned in ISO 13694 sec 3.2.4 d. It is not given much attention in the ISO documentation. However, it is a valuable measurement technique when correctly applied.

Item #	Symbol	Name	ISO 11145	ISO 11146	ISO 11670	ISO 13694	ISO 15367	Section	Definition
				1				3.3	moment diameter of a circular beam. beam diameter (second moment) $$d_\sigma(z) = 2\sqrt{2\sigma(z)}$$ where : $$\sigma^2 = \frac{\iint r^2 \cdot E(r,\varphi,z) \cdot r \cdot drd\varphi}{\iint E(r,\varphi,z) \cdot r \cdot drd\varphi}$$ where r is the distance from the centroid $(\bar{x}, \bar{y})$ φ is the azimuth angle and where the first moments give the coordinates of the centroid $$\bar{x} = \frac{\iint xE(x,y,z)dxdy}{\iint E(x,y,z)dxdy}$$ $$\bar{y} = \frac{\iint yE(x,y,z)dxdy}{\iint E(x,y,z)dxdy}$$
3	$w_{()}$	beam radius	x					3.4.1 3.4.2	Half a beam diameter. See above.
4	$d_{\sigma x}$ $d_{\sigma y}$ $d_{x,k}$ $d_{y,k}$ $d_{x,u}$ $d_{y,u}$	beam widths… second moment knife edge smallest aperture	x	 1		 x		3.5.2 3.5.1 3.2 3.2.4	Second moment, knife edge, or smallest slit methods beam widths (second moment) $$d_{\sigma x}(z) = 4\sigma_x(z)$$ $$d_{\sigma y}(z) = 4\sigma_y(z)$$ knife edge, 90/10% method smallest slit method
5	M²	beam propagation ratio	x	 1				3.7 3.4	Measure of how close the beam is to the diffraction limit of a perfect Gaussian beam.

Item #	Symbol	Name	ISO 11145	ISO 11146	ISO 11670	ISO 13694	ISO 15367	Section	Definition
									$M^2 = \frac{\pi d_{\sigma 0} \Theta_\sigma}{4\lambda}$
6	$d_{0,u}$ $d_{\sigma 0}$	beam waist diameter	x					3.11.1	Beam diameter measurements performed at the waist.
7	$d_{x0,k}$ $d_{y0,k}$ $d_{\sigma x0}$ $d_{\sigma y0}$	beam waist widths	x					3.13.1 3.13.2	Beam width measurements performed at the waist.
8	η_T	device efficiency	x					3.17	Ratio of the total power/energy in the beam to the total input power/energy.
9	$\Theta_{()}$ $\Theta_{x()}$ $\Theta_{y()}$	divergence angle	x	1				3.18 5.2	Full angle of the far-field envelope formed by the increasing beam diameter or widths. $\Theta_\sigma = \frac{d_{\sigma,fl}}{fl}$ Where *fl* is the focal length of a focusing optic and $d_{\sigma,fl}$ is the beam diameter at the focus.
10	$H_{()}$	average energy density	x					3.20	Total energy of a beam divided by its cross sectional area.
11	Q Q(z)	pulse energy	x			x		3.21 3.1.4 9.2.2	Energy in one pulse… at location z. Joules $Q(z) = \iint H(x, y, z) dxdy$
12	H(x,y) H(x,y,z)	energy density	x			x		3.22 3.1.2	Energy impinging on a specified area x,y at location z, divided by the area δA. Often referred to as fluence at a specific pixel location, and peak fluence. $H(x, y, z) = \int E(x, y, z) dt$

Item #	Symbol	Name	ISO 11145	ISO 11146	ISO 11670	ISO 13694	ISO 15367	Section	Definition
13	$E_{()}$	average power density	x					3.43	Total power of a beam divided by its cross sectional area.
14	P P(z)	CW power	x			x		3.44 3.1.3 9.2.2	Power output of a CW laser… at location z. Watts $P(z) = \iint E(x, y, z) dxdy$
15	E(x,y) E(x,y,z)	power density	x			x		3.45 3.1.1	Power impinging on a specified area x,y at location z, divided by the area δA. Often referred to as fluence at a specific pixel location, and peak fluence.
16	P_H	pulse power	x					3.46	Ratio of the pulse energy Q to the pulse duration τ_H.
17	P_{av}	average power	x					3.47	Product of the average pulse energy Q and the pulse repetition rate.
18	P_{pk}	peak power	x					3.48	Maximum of the power-time function.
19	τ_H	pulse duration	x					3.49	Time between the half peak power points at the leading and trailing edges of the pulse.
20	τ_{10}	10% pulse duration	x					3.50	Same as above except at the 1/10th of peak levels.
21	η_Q	quantum efficiency	x					3.52	Ratio of the energy of a single laser photon to the energy of a single pumping photon.
22	z_R , z_{Rx} z_{Ry}	Rayleigh length	x					3.53	Distance from the waist where the beam is √2 times larger than at the waist. for the Gaussian fundamental mode: $z_R = \pi \frac{d_{\sigma 0}^2}{4\lambda}$

Item #	Symbol	Name	ISO 11145	ISO 11146	ISO 11670	ISO 13694	ISO 15367	Section	Definition
									Generally the formula $$z_R = \frac{d_{\sigma 0}^2}{\Theta_\sigma}$$ is valid.
23	z_0 , z_{0x} z_{0y}	beam waist location		1				3.1	Position where beam widths reach their minimum values along the axis of prop.
24	M_{eff}^2	effective beam propagation ratio		1				3.5	For simple astigmatic beams $$M_{eff}^2 = \sqrt{M_x^2 M_y^2}$$
25	φ	azimuth angle		1 3				4.3 7.2 9.3	The angle that the beam's axis system (major axis) makes with respect to the laboratory (camera) axis system. (see equations in ISO reference sections)
26	α_x α_y	angular movement			x			3.1	Angular movement of the beam in the x-z and y-z planes. Requires a focusing element.
27	$\delta\alpha_x$ $\delta\alpha_y$	beam angular stability			x			3.2 8.2	Twice the standard deviation of the measured angular movement. $$\delta\alpha_x = \frac{2s_{\zeta x}}{fl}$$ $$\delta\alpha_y = \frac{2s_{\zeta y}}{fl}$$ $$\delta\alpha = \frac{\sqrt{2}s_{\zeta}}{fl}$$ Where *s* is the angular standard deviation of the energy/power distribution and *fl* is the focal length of the focusing optic.
28	a_x a_y	transverse displacement			x			3.4	Distance of transverse displacement of the beam in the x and y directions.

Item #	Symbol	Name	ISO 11145	ISO 11146	ISO 11670	ISO 13694	ISO 15367	Section	Definition
29	Ψ	azimuth angle[3]			x			4.2 8.1c	The angle that the major axis of the asymmetric centroid histogram plot makes with respect to the laboratory (camera) axial system. (see Figure 1 in the ISO reference)
30	$\Delta(z')$ $\Delta_x(z')$ $\Delta_y(z')$ $\Delta(z)$ $\Delta_x(z)$ $\Delta_y(z)$	beam positional stability			x			3.5 8.1	Maximum transverse displacement and/or angular movement of the beam away from an average, steady-state position. $\Delta(z) = 2\sqrt{2}s$ $\Delta_x(z) = 4s_x$ $\Delta_y(z) = 4s_y$ Where s is the standard deviation of the energy/power distribution.
31	$x'\ y'\ z'$	laboratory system			x			4.2	The orthogonal coordinate system of the laboratory (camera) system.
32	$x\ y\ z$	beam axis system			x			4.2	A second coordinate system that defines the axes of the laser beam.
33	$E_{max}(z)$ $H_{max}(z)$	maximum power/energy density				x		3.1.5	Maximum of the spatial power/energy density distribution function E(x,y,z) /H(x,y,z) at location z. Peak fluence.
34	(x_{max}, y_{max}, z)	location of the maximum				x		3.1.6	Location of $E_{max}(z)/H_{max}(z)$ in the x-y plane at z.
35	$E_{\eta T}(z)$ $H_{\eta T}(z)$	threshold power/energy density				x		3.1.7	A fraction η of the max power/energy density at location z. for CW-beams:

[3] The asymmetric beam axis distribution should not be confused with the asymmetric beam power/energy distribution function.

Item #	Symbol	Name	ISO 11145	ISO 11146	ISO 11670	ISO 13694	ISO 15367	Section	Definition
									$E_{\eta_T}(z) = \eta E_{max}(z)$ for pulsed beams: $H_{\eta_T}(z) = \eta H_{max}(z)$ where: $0 \leq \eta \langle 1$
36	$P_\eta(z)$ $Q_\eta(z)$	effective power/energy				x		3.2.1	Evaluated by summing only over locations (x,y) for which: $E(x,y) > E_{\eta_T}$ $H(x,y) > H_{\eta_T}$
37	$f_\eta(z)$	fractional power/energy				x		3.2.2	Fraction of the effective power/energy to the total power/energy at location z. $f_\eta(z) = \frac{P_\eta(z)}{P(z)}$ $f_\eta(z) = \frac{Q_\eta(z)}{Q(z)}$ where: $0 \leq f_\eta(z) \leq 1$
38	$\overline{(x,y)}$	centroid position				x		3.2.2	First linear moments at location z.
39	$\xi(z)$ $e(z)$	beam ellipticity/ eccentricity				x		3.2.5	Method for quantifying the circularity or squareness (aspect ratio) of a distribution at z. ellipticity: $\xi(z) = \frac{d_{\sigma y}}{d_{\sigma x}}$ eccentricity: $e(z) = \frac{\sqrt{d^2_{\sigma x} - d^2_{\sigma y}}}{d_{\sigma x}}$
40	$A^i_\eta(z)$	effective irradiation area				x		3.2.7	Irradiation area at location z for which the power/energy density exceeds the threshold density.
41	$E_\eta(z)$ $H_\eta(z)$	effective avg. power/energy				x		3.2.8	Spatially averaged power/energy density of the

Item #	Symbol	Name	ISO 11145	ISO 11146	ISO 11670	ISO 13694	ISO 15367	Section	Definition
		density							distribution at location z, defined as the weighted mean. effective average power: $$E_\eta(z) = \frac{P_\eta}{A_\eta^i}$$ effective average energy: $$H_\eta(z) = \frac{Q_\eta}{A_\eta^i}$$
42	$F_\eta(z)$	flatness factor				x		3.2.9	Ratio of the effective average power/energy density to the maximum power/energy density at location z. flatness factor: $$F_\eta(z) = \frac{E_\eta}{E_{\max}}$$ $$F_\eta(z) = \frac{H_\eta}{H_{\max}}$$ for: $0 < F_\eta \leq 1$
43	$U_\eta(z)$	beam uniformity				x		3.2.10	Normalized RMS deviation of power/energy density from its avg. value at location z. beam uniformity for CW-beams: $$U_\eta = \frac{1}{E_\eta}\sqrt{\frac{1}{A_\eta^i}\iint\left[E(x,y) - E_\eta\right]^2 dxdy}$$ beam uniformity for pulsed beams: $$U_\eta = \frac{1}{H_\eta}\sqrt{\frac{1}{A_\eta^i}\iint\left[H(x,y) - H_\eta\right]^2 dxdy}$$ Note: $U_\eta=0$ for a flat top beam.
44	$U_p(z)$	plateau uniformity				x		3.2.11	For distributions having a nearly flat-top profile. plateau uniformity for CW-

Item #	Symbol	Name	ISO 11145	ISO 11146	ISO 11670	ISO 13694	ISO 15367	Section	Definition
									beams $$U_p(z) = \frac{\Delta E_{FWHM}}{E_{\max}}$$ plateau uniformity for pulsed beams $$U_p(z) = \frac{\Delta H_{FWHM}}{H_{\max}}$$ Note: $0 < U_P(z) < 1$; $U_P(z) \rightarrow 0$ as distributions become more flat-topped.
45	s(z)	edge steepness				x		3.2.12	Normalized difference between effective irradiation areas of 10% and 90% of total and power/energy density values of 10% of peak. edge steepness $$s(z) = \frac{A_{0.1}^{i}(z) - A_{0.9}^{i}(z)}{A_{0.1}^{i}(z)}$$ Note: $0 < s(z) < 1$; $s(z) \rightarrow 0$ as the edges of the distribution become more vertical.
46	R	roughness of fit				x		3.3.1	Maximum deviation of the theoretical fit to the measure distribution. roughness of fit: $$R = \frac{\left\| E_{ij} - E_{ij}^{f} \right\|_{\max}}{E_{\max}}$$ where: E_{ij}^{f} is the fitted theoretical distribution. Note: $0 \le R \le 1$, as $R \rightarrow 0$ the fit becomes better.
47	G	goodness of fit				x		3.3.2	Parameter based upon Kolomogorov-Smirnov statistical test characterizing the fit between measured and theoretical distributions.

Item #	Symbol	Name	ISO 11145	ISO 11146	ISO 11670	ISO 13694	ISO 15367	Section	Definition
									goodness of fit: $$G = \frac{1}{1+\Delta\sqrt{N}}$$ where: N is the total number of data points in the measured distribution, Δ is the maximum deviation between measured and theoretical distributions of apertured powers/energies truncated at $n \geq 10$ random locations (x_i, y_j) in the distribution: $$\Delta = \frac{\left\|P_{ij} - P_{ij}^{f}\right\|_{\max}}{P}$$ Note: $0 \leq G \leq 1$, as $G \rightarrow 0$ the quality of the fit becomes better.
48	d_x , d_y	grid spacing					2	3.1	Partition of detector area into orthogonal grid of apertures.
49	A_{ij}	area of sub-aperture					2	3.2	Area of a sub-aperture may be either square or round.
50	L_H	focal length					2	3.3	Distance from the sub-aperture screen to the detector array.
51	d_p	pinhole diameter					2	3.5	Diameter of the holes in a Hartmann screen
52	N_{Fr}	Fresnel number					2	3.6	The ratio of the pinhole spacing to the radius of the projected spot on the detector. Fresnel number: $$N_{Fr} = \frac{d_x}{\rho_{ij}}$$ ρ_{ij} = radius of the projected spot

Item #	Symbol	Name	ISO 11145	ISO 11146	ISO 11670	ISO 13694	ISO 15367	Section	Definition
53	ρ_{ij}	spot radius					2	3.6	The spot radius is measured to the location of the first minimum in the point-spread function. for square pinholes: $\rho_{ij} = \frac{L_H \lambda}{d_x}$ for round pinholes: $\rho_{ij} = 1.22 \frac{L_H \lambda}{d_p}$
54	β_{max}	angular dynamic range					2	3.7	Maximum usable angular range of the Hartmann sensors.
55	$w_{s,rms}$	wavefront statistical uncertainty					2	3.8	Average uncertainty of estimating the wavefront over the entire aperture.
56	$w(x,y)$	wavefront shape					1	3.1.1	
57	$w_c(x,y)$	corrected wavefront shape					1	3.4.2	

APPENDIX B BeamGage Supported Cameras

BeamGage supports a variety of cameras to best suit your measurement application. We will add support for new cameras as technology continues to evolve. This table displays all the cameras that are supported in BeamGage. Click on the model name to access the camera specifications.

All of the cameras currently available have additional information provided in subsequent sections of this user guide. Please read over the information carefully before attempting to use the camera.

Model	BeamGage Standard	BeamGage Professional	Section
SP928	X	X	C.4
SP907	X	X	C.4
SP300	X	X	APPENDIX C
LT665	X	X	APPENDIX C
GeviCam	X	X	APPENDIX D, APPENDIX E
L11059		X	APPENDIX F
SP928-1550	X	X	C.4
SP907-1550	X	X	C.4
LT665-1550	X	X	APPENDIX C
Xeva XC-130		X	APPENDIX G
Pyrocam III	X	X	APPENDIX H
Pyrocam IIIHR	X	X	APPENDIX D, APPENDIX I
Pyrocam IV	X	X	APPENDIX D, APPENDIX I

Legacy Products			
SP620	X	X	
SP503	X	X	
Gras20	X	X	
SP620-1550	X	X	
SP503-1550	X	X	
Gras20-1550	X	X	

APPENDIX C USB 3.0 Cameras

C.1 Multi-tap Sensor Behavior

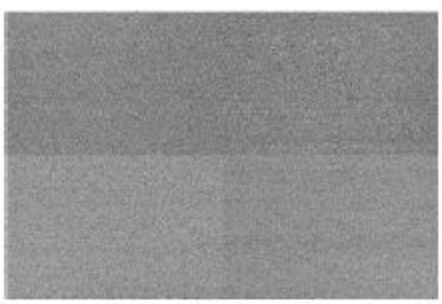
The Sony ICX694 sensor in the LT665 and the ICX687 in the SP300 utilizes EXview HAD II CCD Multi Tap sensor technology. There are some differences in behavior from traditional single tap sensors that are worth noting.

- Multi-tap sensors read out each tap individually and allow for faster frame rates in CCD sensors.
- Each tap has its own A/D converter and amplifier and thus must be factory matched.
- Factory matching ensures a uniform background response for a wide variety of conditions.
- A tap mismatch appears as a visible seam between taps.

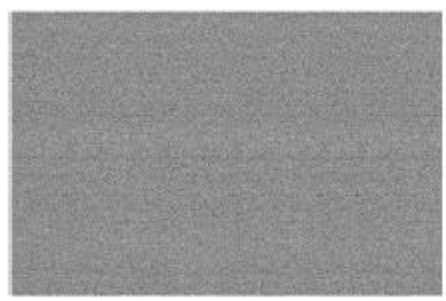
Slight mismatching is possible under some operational conditions but does not typically affect laser beam measurement.

The color palettes available in BeamGage are designed to maximize visibility across the dynamic range of the sensor and can greatly exaggerate tap mismatching to the human eye. The significance of a tap mismatch on a beam measurement is a function of the delta of the intensity across the mismatch and the peak intensity of the beam.

If conditions cannot be avoided that encourage a tap mismatch, then adjusting the peak intensity of the beam to 80-95% of saturation will ensure that the effect of the mismatch is statistically minimized.



Quad Tap Mismatch



Quad Tap Matched

This section contains reference material that has been reproduced with minor modification as it was provided in *The Benefits of Multi-tap Sensors* by Lumenera Corporation. No assumption of copyright is made on such material; all rights are retained by the original author.

C.2 LT665 Camera Specifications

C.2.1 Supplied Accessories

The LT665 is a quad-tap camera and is supplied with the following accessories:

- 5 volt AC power adapter, 2 Amp minimum, Center Positive
- Pre-wired 8-pin GPI/O cable (Hirose HR1824-ND adapter)
    - Pins 1 & 8 – External Power, DC Coaxial socket: 2.1mm (ID) x 5.5mm (OD)
    - Pins 6 & 7 – External Trigger, SMA Bulkhead, Female
    - Pins 2, 3, 4, 5 – Unused, Insulated, see reference table

C.2.2 External Trigger Control

The LT665 camera is supplied with an external trigger input cable. The input to this cable should be a standard TTL level positive going pulse. The camera will trigger, and begin integrating light on the rising edge. A trigger pulse should be at least 5μs in duration.
To operate in external trigger mode you must set this control to **Trigger In**. Select **None** when operating in CW mode.

C.2.3 GPI/O Connector Description[1]

For all non-isolated GPO/GPI pins, the voltage swing is as follows:

- For a LOW value: 0.0 to 0.1 V
- For a HIGH value: 3.0 to 3.3 V
- The typical forward current (I_f) is 20mA with maximum of 50mA.

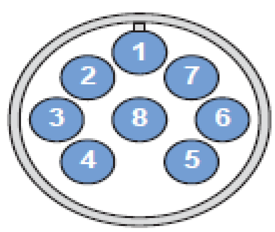


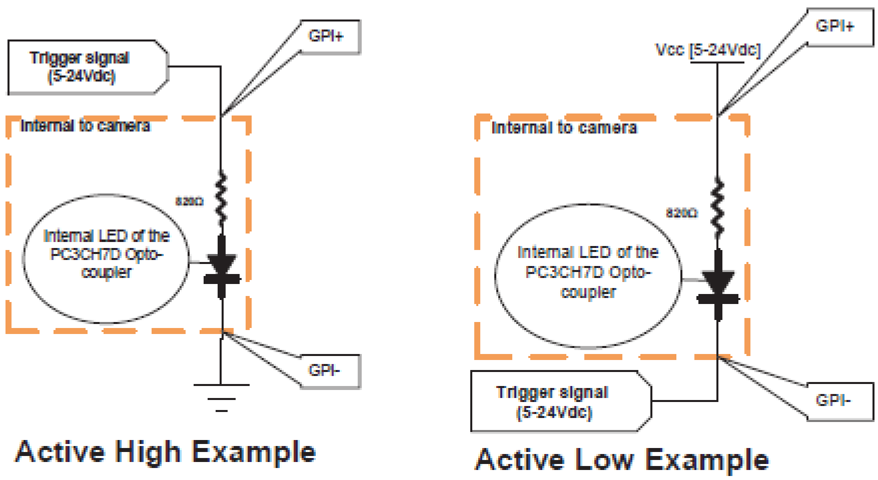
Figure 1: USB3.0 Camera front view of connector

Pin #	Function	Wire color	Description
1	V-External	RED	External power input terminal (+5Vdc)
2	GPO1+	GREEN	Optically isolated output positive terminal
3	GPO1-	ORANGE	Optically isolated output negative terminal
4	GPIO2	BLUE	Bi-directional general purpose I/O
5	GPIO3	BROWN	Bi-directional general purpose I/O
6	GPI1-	YELLOW	Optically isolated input negative terminal
7	GPI1+	GREY	Optically isolated input positive terminal
8	GND	BLACK	External power ground reference terminal

Figure 2: GPI/O cable wire color definition

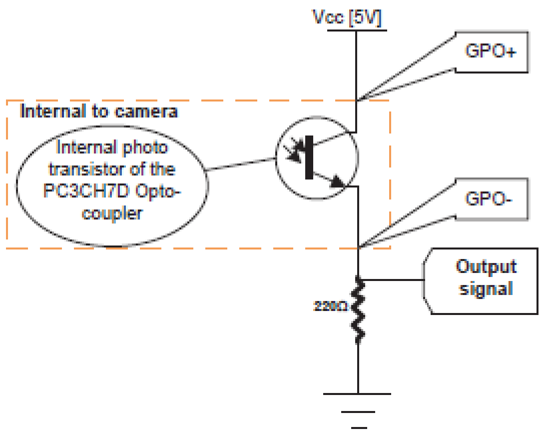
C.2.4 Optically Isolated Inputs[1]

The optically-isolated input pins are designed to operate from 5V to 24V at a typical current of 20mA and must not exceed 50mA. Greater input voltages are supported with use of an external resistor. When current flow from GPI1+ to GPI1- it will be seen as a level 1 from the camera otherwise the camera will see it as a level 0. A simple usage is to apply the signal (active high) on GPI1+ and then have GPI1- connect to the ground plane of the input signal (illustrated below). In some applications the trigger may need to be active low, and then Vcc (5-24V) from the trigger circuit should be applied at GPI1+ and the signal at GPI- as illustrated below. The internal resistor value on these pins is 820Ω. Therefore, Vinput = (0.02 A)*(820Ω + Rexternal).

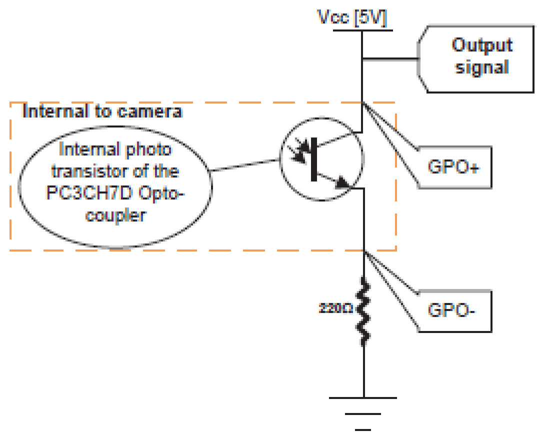


C.2.5 Optically Isolated Outputs[1]

The optically-isolated output requires an external resistor and biasing current. The current flow between collector and emitter should nominally be 20mA and must not exceed 50 mA. For example, for biasing with a 5V supply (output referenced to 5V), use a 220Ω series resistor. For a 12V supply, use 560Ω. There are 2 common configurations that can be used for outputs, active high or active low output signal. Active high output, will produce an output level to VCC when the LED in the opto-coupler is on, alternatively for active low output, configure the GPO1 to output 0 when the signal is active (illustrated below).



Active High output



Active Low Output

[1]Some sections above contain reference material that has been reproduced with minor modifications as it was provided in the *Lumenera Cameras User's Manual Release 6.5* by Lumenera Corporation. All information is assumed to be accurate at the time of writing. No assumption of copyright is made on such material, all rights are retained by the original author.

C.3 SP300 Camera Specifications

C.3.1 Supplied Accessories

The SP300 is a dual-tap camera and is supplied with the following accessories:

- USB3.0 Certified Standard-A to Micro-B cable
- Coax External Trigger Cable – Hirose HR25-7TP-8P(72) to BNC
    - Pins 1 & 5 – External Trigger, SMA Bulkhead, Female
    - Pins 2-4, & 6-8 – Not connected, see reference table

C.3.2 External Trigger Control

The SP300 camera is supplied with an external trigger input cable. The input to this cable should be a standard TTL level positive going pulse. The camera will trigger, and begin integrating light on the rising edge. A trigger pulse should be at least 5µs in duration.

To operate in external trigger mode you must set this control to **Trigger In**. Select **None** when operating in CW mode.

C.3.3 GPI/O Connector Description

The camera has an 8-pin GPIO connector on the back of the case; refer to the diagram below for wire color-coding. The connector is a Hirose HR25 8 pin connector with part number: HR25-7TR-8SA. The male connector is part number: HR25-7TP-8P(72). For all non-isolated GPO/GPI pins, the voltage swing is as follows:

- For a LOW value: 0.0 to 0.1 V
- For a HIGH value: 3.0 to 3.3 V
- The typical forward current (I_f) is 20mA with maximum of 25mA.

Table 6.1: GPIO pin assignments (as shown looking at rear of camera)

Diagram	Color	Pin	Function	Description
	Black	1	IO	Opto-isolated input (default Trigger in)
	White	2	O1	Opto-isolated output
	Red	3	IO2	Input/Output/serial transmit (TX)
	Green	4	IO3	Input/Output/serial receive (RX)
	Brown	5	GND	Ground for bi-directional IO, V_{EXT}, +3.3 V pins
	Blue	6	OPTO_GND	Ground for opto-isolated IO pins
	Orange	7	V_{EXT}	Allows the camera to be powered externally
	Yellow	8	+3.3 V	Power external circuitry up to 150 mA

Figure 3: SP300 front view of connector and Pin-out Definition

C.4 SP907 and SP928 Camera Specifications

C.4.1 Supplied Accessories

The SP907 and SP928 are single tap cameras and are supplied with the following accessories:

- USB3.0 Certified Standard-A to Micro-B cable
- Coax External Trigger Cable – JST BM09B-NSHSS-TBT to BNC
    - Pins 7 & 9 – External Trigger, SMA Bulkhead, Female
    - Pins 1-6 & 8 – Not connected, see reference table

C.4.2 External Trigger Control

The SP907 and SP928 cameras are supplied with an external trigger input cable. The input to this cable should be a standard TTL level positive going pulse. The camera will trigger, and begin integrating light on the rising edge. A trigger pulse should be at least 5µs in duration.

To operate in external trigger mode you must set this control to **Trigger In**. Select **None** when operating in CW mode.

C.4.3 GPI/O Connector Description

The camera has a 9-pin GPIO connector on the back of the case; refer to the diagram below for wire color-coding. The header connector is JST part number BM09B-NSHSS-TBT and the wire plug connector is JST part number NSHR-09V-S. The wire contacts are SSHL-003T-P0.2.

Table 6.1: GPIO pin assignments (as shown looking at rear of camera)

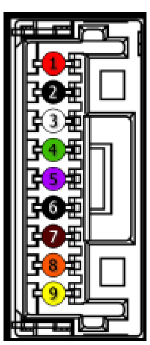
Diagram	Color	Pin	Function	Description
	Red	1	V_{EXT}	Allows the camera to be powered externally 5 - 24 VDC
	Black	2	GND	Ground for Input/Output, V_{EXT}, +3.3 V pins
	White	3	+3.3 V	Power external circuitry fused at 150 mA maximum
	Green	4	GPIO3 / Line3	Input/Output
	Purple	5	GPIO2 / Line2	Input/Output
	Black	6	GND	Ground for Input/Output, V_{EXT}, +3.3 V pins
	Brown	7	OPTO_GND	Ground for opto-isolated IO pins
	Orange	8	OPTO_OUT / Line1	Opto-isolated output
	Yellow	9	OPTO_IN / Line0	Opto-isolated input

Figure 4: SP907 and SP928 front view of connector and Pin-out Definition

APPENDIX D Gig-E Camera Specifications

D.1 Gig-E Camera Installation

Important: ***The Gig-E camera installation must be performed in the following order to insure a proper connection with BeamGage.***

The Gig-E camera is supplied with a USB 3.0 to Gigabit Ethernet adapter and a Cat6 Ethernet cable.

Most any commercially available Gig-E rated Ethernet card will work so long as it has Jumbo packet capability. In general, Ophir-Spiricon has found that Intel PRO/1000 series Ethernet PCI-Express cards and Realtek 8168/8111 chipsets in PCI-Express/34 cards, work trouble free. Only use a network interface card (NIC) that supports Jumbo packets.

It is recommended that one Gig-E rated Ethernet port on your computer be reserved for connection to the Gig-E camera. <u>BeamGage does not support a camera connected to your Local Area Network as a standalone device.</u>

D.2 Installing the Ethernet Adapter

Important: ***All of the following must be performed with Administrator privileges.***

The following steps will instruct how to install and configure the USB 3.0 to Gigabit Ethernet Adapter. However it may be possible to employ an unused Ethernet port already built-in or installed in your PC. The following instructions can be used for either case.

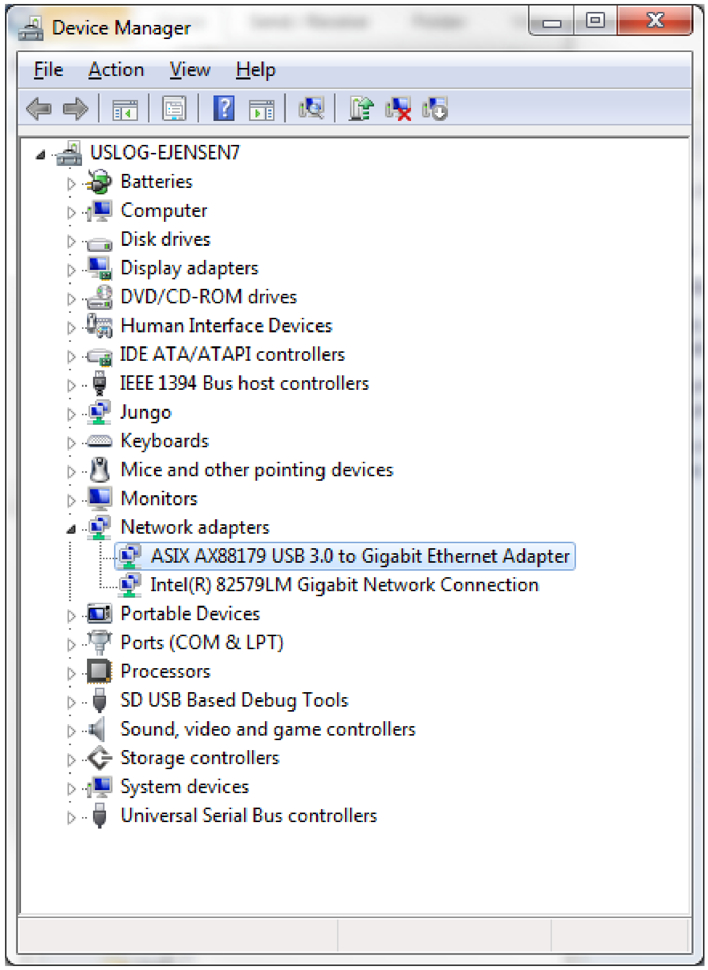
Important: ***Use of standard PCI style NIC cards is not recommended unless they are truly operating at 66MHz bus speed. Slower 33MHz cards will perform poorly, if at all.***

<u>**DO NOT POWER OR CONNECT THE CAMERA UNTIL DIRECTED TO DO SO.**</u>

1. Plug the USB connector into a USB 3.0 port. It is highly recommended that the adapter be plugged into a USB 3.0 port. When the adapter is plugged into a USB 2.0 port the camera may not work. At a minimum the image capture rate from the camera will be reduced.

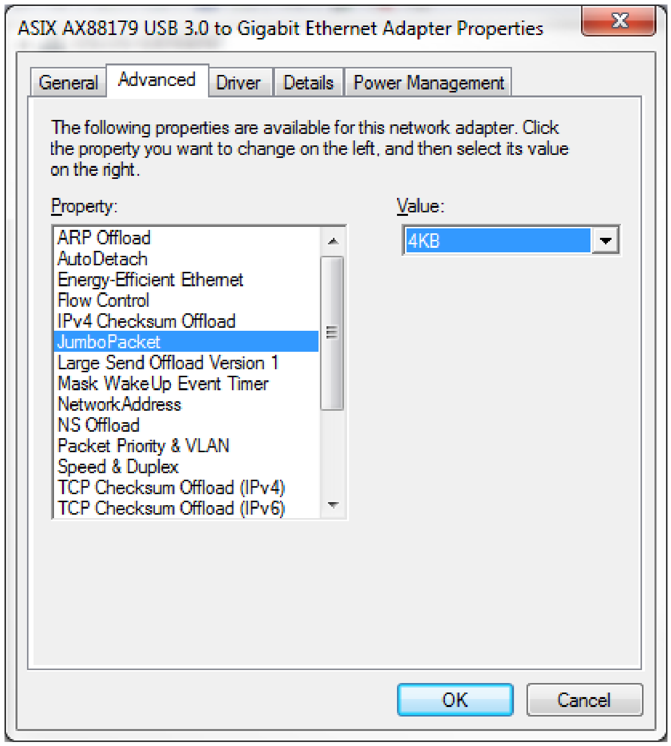
2. The plug and play feature of Windows will assign a driver to the newly found hardware.

3. Once the NIC and its driver are installed, open the Windows **Device Manager** and locate the new card in the **Network adapters** node. See the example of the ASIX AX88179 USB 3.0 to Gigabit Ethernet Adapter below. Be especially careful that you select the new card and not the NIC connected to your network. Changing the settings on your network card may cause you to be disconnected from your network.



4. Double click on the new adapter to open the properties window. Then click on the **Driver** tab. If needed use the **Update Driver** button to search for and install the latest driver.

5. Click on the **Advanced** tab. In the **Property** list locate and click on the item containing the word **Jumbo**. Set the value on this to the largest size available, see the example below.



Note: If your NIC doesn't support Jumbo packets it will not be suitable for operation with Gig-E cameras. Lack of Jumbo support may be an indication that the installed driver is old and a newer one may need to be installed.

6. Click OK.
7. This completes the NIC setup.

D.3 Connecting Gig-E to BeamGage

The Gig-E camera will now be connected to the PC and to BeamGage. The camera is pre-licensed for the edition of BeamGage supplied with the camera.

Important: ***The first time a Gig-E camera is connected to BeamGage with a newly installed NIC, you must do so with Administrator privileges. Thereafter it can be run with lower privileges.***

Do the following:

1. Locate the supplied BeamGage CD and run the BeamGage installation as directed on the CD jacket.

2. Connect the Cat6 cable between the camera and the NIC.

3. Connect the power supply to the camera then apply AC power to the power supply.

4. Launch BeamGage with **Administrator** privileges by right clicking on the application icon and selecting "Run as administrator".

5. In the Source tab click on **Local Detector**.

6. Observe that the camera appears for selection displayed as:
   (<IP address> / OSI_182000 #< serial number>)
   (<IP address> / Pyrocam_IV #<serial number>)

7. Click on the camera to select it. Note that a driver will be installed the first time the camera is selected. After a short delay the camera will connect and begin collecting data indicating that the installation was successful. Please be patient during this step. On some computers the delay may be as long as several minutes. If the camera does not begin collecting data within 15 minutes then you may need help from Ophir-Spiricon's Service Department.

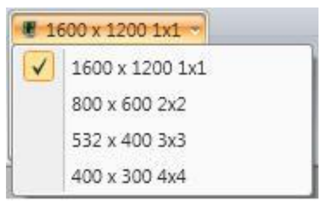
APPENDIX E GeviCam Camera Specifications

E.1 Gevicam Camera Operation

This section will describe the camera controls that are unique to the Gevicam camera. Common controls are covered in other sections of this manual. **What's this** help is available on all of the special Gevicam controls.

E.1.1 Frame Format

The Gevicam is supplied with a set of predefined formats with binning options. The image below indicates the available frame sizes and the associated binning level. Frame rates will increase as the level of binning increases. However, Bad Pixel correction does not operate when a binned format is selected.

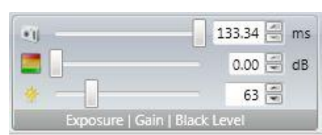


At the present time this camera does not support a user programmable ROI feature. If a demand for ROI control presents itself, it may be added in later camera updates.

Two (2) frame rates are offered with this camera. The 7.5Hz rate should always be employed when working with CW YAG lasers at 1064nm or for other CW wavelengths in this region. This will minimize any vertical blooming effects that are common to CCD cameras in the 900-1100nm region.

When using external triggering in pulse mode, this restriction is not an issue so long as trigger pulse timing meets the criteria set in E.1.3 below.

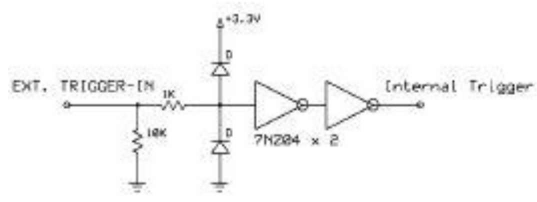
E.1.2 Exposure|Gain|Black Level



The Gevicam Exposure, Gain, and Black Level controls operate in the same as other CCD types of cameras. When operating in External Trigger mode, the exposure time should be set long enough to capture only one complete laser pulse.

E.1.3 External Trigger Control

The power supply connector to the camera has a Trigger Input BNC cable split out from the connector housing. You can supply a 5V TTL ≥ 2 µsec positive pulse to this connector for the purpose of externally triggering the camera.



Select the **Max Rate** frame rate when operating in pulsed mode with external triggers. The laser pulse should start no sooner than a few µsec after the rising edge of the trigger pulse. The exposure time should be set just long enough to contain the entire pulse width, and short enough to exclude pulses that may start before the imager has had time to be read out. This will prevent laser pulse doubling in the captured image.

E.1.4 Bad Pixel Correction

Bad Pixel correction is automatically enabled whenever the camera is operating in full resolution mode. Windowless imagers are more prone to developing bad pixels over time. If new bad pixels present a problem, you can send the camera back to Spiricon to be serviced as part of our camera recertification program. Part of that service will attempt to locate and add new bad pixels to the bad pixel correction map embedded in the camera.

APPENDIX F L11059 Camera Specifications

F.1 L11059 System Considerations

If using the L11059 camera at maximum full frame resolution, it is important that BeamGage be used in a Windows 7 or Windows 10, 64 bit OS, with at least 4GB of RAM memory. While it will operate in a 32 bit OS, performance will be significantly reduced and you must limit frame buffer size to only 2 – 4 frames. Frame acquisition rate and computational rates will also be slowed due to the large number of pixels that need to be processed.

If operating with small ROI settings or in one of the binning modes, the performance in a 32 bit OS will improve significantly as the number of pixels per frame becomes proportionally smaller. Even so, it's recommended that you have at least 3GB of RAM memory in a 32 bit OS.

F.2 Upgrading from LBA-USB to BeamGage

With the release of BeamGage v5.5, which includes the L11058 and L230 cameras, new Lumenera drivers will be deployed. These new drivers are not compatible with LBA-USB and will replace the older drivers that LBA-USB relies upon. As a result, LBA-USB will cease to operate with any of the Lumenera style cameras including the L11059. To maintain operation of LBA-USB, you must either relocate it to another PC or install BeamGage onto a different PC. Since BeamGage is designed around higher performance PC platforms, it is advised that it be installed on more modern equipment than LBA needed.

F.3 The L11059 first time connection

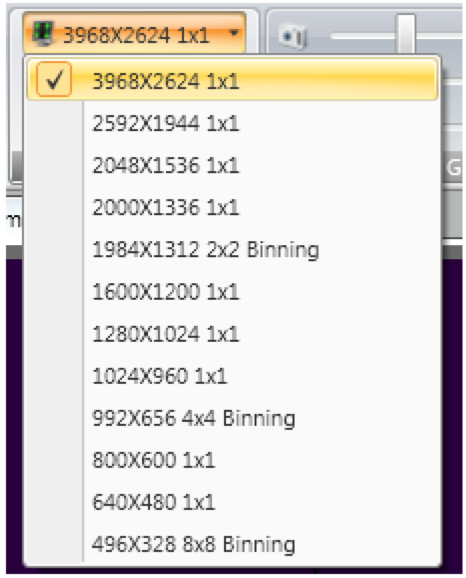
The first time an 11059 camera is connected to BeamGage the format will default into a full frame 4x4 binning mode. This is done in order to allow the camera to capture frames at a faster rate than if it started out in full 11 Mega-pixel format. Depending upon other settings in BeamGage, this camera may run very slowly when set into full resolution mode. This binned mode will give a better operating environment with which to setup and align your laser and prepare for final operation. Once things are configured, proceed to change the format to the one desired and make any last minute adjustments. Save the configuration.

F.4 The L11059 replaces the L11058

The 11058MB model is being dropped from the Spiricon catalog and replaced with the L11059M. For a short time it may still be possible to purchase the 11058MB. At least until Lumenera drops it from their product list. BeamGage supports both the original 11058M, 11058MB and 11059M versions of the Lumenera 35mm format camera. The 11059M is a reduced footprint version of the 11058MB model. The specifications of the 11059M are the same as the 11058MB.

F.5 L11059 BeamGage Operation

To see the features in BeamGage you will need to click on the **Source**, **Frame Format** panel. Click on the format (top) item to see the list of the provided preset formats.



The list (see above) is now quite extensive. In addition, there are full frame formats that utilize 2x2, 4x4, and 8x8 binning modes. These binning modes will allow for much higher full image format frame rates. In 8x8 bin mode, the camera can output full frames of data in excess of 20 fps. This is the fastest full image format possible with this model of camera. Of course, binning also reduces pixel to pixel resolution. So measuring small spots with high precision will suffer accordingly.

The latest version of BeamGage also offers user configurable ROI's. Consult the BeamGage User Guide on how to create your own ROI.

Something to be aware of when using the binning modes: Bad pixel correction is not supported when operating in binned modes. This is true for most all cameras. However, 11059 imagers often have a large number of bad pixels when compared to much smaller format imagers. The Ultracal operation will baseline correct most of the defects. However, unstable pixels, referred to as twinklers, may still randomly appear even after performing an Ultracal. The best method to eliminate their effects is by using a manual aperture to exclude them from the measurement region. Normally bad pixels do not significantly impact measurement results unless you are monitoring Peak level or Peak location and the twinkler rises above your signal peak.

Strobe Out is not supported in BeamGage.

F.6 External Triggering

The L11059 can be triggered from an external source. The cameras are supplied with an external trigger cable with BNC connectors. The drive for the trigger is positive TTL compatible 5VDC logic level pulses. The pulse should have a minimum pulse width of at least 5µs.

When operating in external trigger mode, the maximum frame rate will be ½ the CW rate. For example, if the selected camera format can collect 20fps in CW mode, it will only be able to collect 10fps when in external triggered mode.

Trigger mode is also equipped with a Delay feature that can be used to help isolate pulses that may occur within a burst of pulses.

APPENDIX G XenICs InGaAs Camera Specifications

G.1 XenICs XEVA Camera Installation

Important: ***To use a XenICs USB XEVA camera you will need to install the BeamGage software supplied on Spiricon's CD and the Xeneth software supplied on the XenICs CD. They can be installed in either order.***

You must run the XenICs CD and follow the directions for installing Xeneth. You will not be able to successfully use the XenICs camera in BeamGage unless the camera driver and calibration pack NUC files are available for BeamGage. The XEVA camera cannot be connected to both Xeneth and BeamGage at the same time.

Important: ***You must install the correct version of Xeneth for proper BeamGage operation. On the XenICs CD you will find a folder named Xeneth-Software containing four Xeneth EXE installation programs. For 32-bit operating systems you must install Xeneth-Setup-Advanced. For 64-bit operating systems you must install Xeneth-Setup-Advanced64. Xeneth-Api-Setup and Xeneth-Api-Setup64 are for those who wish to write their own software to control the camera and collect images.***

The operating controls for the XEVA model cameras have been simplified for use with BeamGage. This was necessary to keep the cameras operating under conditions that would yield best accuracy. Cameras with InGaAs imagers require a significant amount of image correction in order to make their output useful. XenICs cameras employ special NUC (non-uniformity correction) files that must be downloaded into the camera. These correction files are supplied by the manufacturer and are unique to each camera. NUC files provide gain, offset and bad pixel correction, as well as specific operating settings, such as exposure, gain, black level, imager temperature, etc. BeamGage provides a control panel that will allow the user to select the necessary NUC file.

There are two (2) types of NUC files, TrueNUC files and standard NUC files.

All types of NUC files can be used with Xeneth.

NUC files end with a file extension of .xca and are also referred to as "calibration packs" or "camera correction" files. XenICs provides a CD with each camera. This CD contains the factory generated NUC and TrueNUC files as well as a utility called **Xeneth** that allows the user to test the camera and make additional NUC files if necessary.

NUC and TrueNUC files fall into 2 general classes, High Gain (HG) and Low Gain (LG). For laser beam analysis the High Gain NUC files will be the ones most frequently employed. High Gain NUC files give exceptional response linearity. Low Gain NUC files will not produce good response linearity.

TrueNUC files can be used over a broad exposure range and will maintain good pixel correction. **The TrueNUC_HG file is recommended for use with BeamGage.**

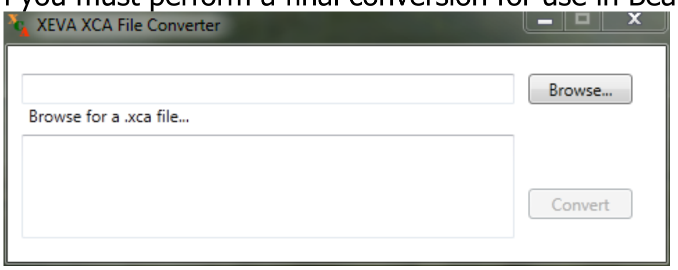
Regular NUC files are specified for operation at or very near the preset exposure that was in effect when the NUC file was created. Using them outside of their set value will degrade the cameras image correction performance.

G.1.1 Converting X-Control XCA files to Xeneth

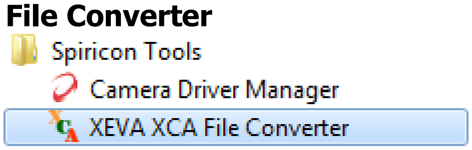
Important: ***X-Control NUC files are not compatible with BeamGage v6.0 and above.** You must convert NUC files supplied with cameras purchased prior to October 2013.*

Follow these instructions to convert X-Control XCA files for use with BeamGage v6.0 and above:

1. Copy the X-Control XCA files to the Xeneth calibration folder located at "C:\Program Files\Xeneth\Calibrations"
2. **Before** applying power to the camera, plug in the USB cable from the camera to the PC
3. Apply power to the camera
4. Start the Xeneth software
5. Select the camera and set "Calibration data" to "(none)"
6. In the File menu select "Settings"
7. Select the calibration file to convert
8. Click OK
9. In the Calibration menu select "Export calibration data".
10. Select a path. This can be any path, not necessarily the calibration folder.
11. Enter an appropriate file name by including Xeneth in the name
12. Click Save
13. Because of a bug in the Xeneth software, the converted calibration file will cause the camera background noise to be suppressed. This defeats the BeamGage Ultracal process and may cause inaccurate results. In order to correct for this problem you must perform a final conversion for use in BeamGage.



    a. Open the XEVA XCA File Converter utility installed with BeamGage.
        i. **Start Menu -> All Programs -> Spiricon Tools -> XEVA XCA File Converter**



b. Click the Browse button. A file selection dialog will open to the Xeneth\Calibrations directory from Step 1.
c. Select the NUC file that has been processed by the Xeneth software in the previous steps.
d. Click OK.
e. Click Convert.

14. Repeat steps 6-13 for each NUC file.

When loading a calibration pack in BeamGage be sure to specify the Xeneth converted NUC file. If you attempt to load an X-Control NUC file then BeamGage will display "Invalid Calibration!" in the Camera Correction File text box.

G.2 Getting Started with a XEVA camera

Once you have installed all of the above required software do the following:

1. **Before** applying power to the camera, plug in the USB cable from the camera to the PC
2. Apply power to the camera
3. Open **BeamGage**
4. Go to the **Source** panel and click on **Local Detector**, select the camera and you will be prompted to enter a Camera License Key. BeamGage may go there automatically.
   Note: If the camera was shipped from Ophir-Spiricon it may already have the license key loaded and steps 4 thru 6 can be skipped
5. Locate the camera license key supplied with the BeamGage CD or camera and enter this code. You must enter a license on each computer where the camera is used.
6. Cycle the **Source** selector to **File Console** and then back to **Local Detector**
7. It should startup running and collecting frames from the camera
8. In the **Source** ribbon click on the **Pause** button.
9. Go to the **Camera Correction File** panel and click on the drop down arrow
10. Select **Browse…**
11. Go to the folder: C:\Program files\X-Control\CalibrationPacks\
12. Click on an .xca file name that contains **TrueNUC_HG** and click **Open**
13. Click **Start** on the Source tab
14. The camera should now be collecting data frames with a well corrected image with a raised black level baseline.
15. The preset cooling temperature will normally be 17°C. Wait for the readout temperature to stabilize at this setting.
16. Once stabilized block the imager from stray radiation and perform an **Ultracal**
17. You are now ready to collect laser beam images in **CW** mode.
18. Attenuate the laser and adjust the **Exposure** time to an appropriate setting, you will need to re-Ultracal when the exposure time changes.

Important: To disconnect a XEVA camera always 1st remove power to the camera, then 2nd unplug the USB cable.

There is a known bug with the XEVA camera regarding unplugging the camera's USB cable with the camera under power. Doing so will crash the camera firmware. You must now power cycle the camera to restart it. When you re-plug the USB cable into the PC the camera will once again ask you to re-supply the Camera License Key in order to restore its operation with BeamGage. (XenICs has indicated that they are not going to fix this bug.)

Note: Custom NUC files created with Xeneth will operate correctly when used by BeamGage.

G.3 XenICs XEVA Camera Operation

This section will describe the camera controls that are unique to the XenICs XEVA camera. Common controls are covered in other sections of this manual. **What's this** help is available on all of the special XEVA controls.

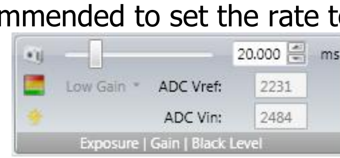
G.3.1 Frame Format

While displaying an apparent set of options there are few actual choices to be made. The XEVA camera does not support binning, and because the imager is a small 320X256 format the need for ROI adjustments are not in high demand. The first release of BeamGage with this camera will not support the ROI feature. If a demand for ROI control presents itself it may be added in later updates.

This camera only operates in 12 bits per pixel mode.

The XEVA camera model most commonly supplied or supported by BeamGage has a spec'd frame rate of 100Hz. With NUC the rate drops to about 90Hz. Unless there is a need for longer integration times it is recommended to set the rate to 90Hz.

G.3.2 Exposure|Gain|Black Level



The following settings are preset in the TrueNUC or NUC file to optimize the camera dynamic range for best beam measurement accuracy using BeamGage. Only the Exposure setting can be altered by the user. Only the Exposure setting can be saved into a BeamGage setup file.

The **Exposure** control operates much like any other type of camera. It sets the exposure duration in milliseconds. When operating in external trigger mode, the exposure time begins upon receipt of the electronic trigger pulse. When using a regular NUC file (not a TrueNUC) the exposure setting should not be changed.

The **Gain** indicator will follow the setting pre-programmed into the TrueNUC/NUC file. The setting can be either **High** or **Low**.

The **Black Level** indicator will also be preset to the value that corresponds to the TrueNUC/NUC file. In Xeneth, this setting is called ADC Vin. It is displayed here only for verification purposes.

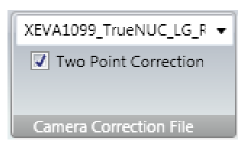
The **ADC Vref** indicator will also be preset to the value that corresponds to the TrueNUC/NUC file. It is displayed here only for verification purposes.

G.3.3 Cooling

The XEVA camera has a cooler that is used to stabilize the imager. The InGaAs type of imager is very sensitive to changes in temperature. To insure a stable baseline the temperature should be set to a value below the room temperature and below the detector's nominal operating temperature. Since 300° Kelvin is a nominal room temperature, and an operating camera will warm somewhat above this, all TrueNUC files will force a temperature value of 17°C. If the environment is naturally colder, say 12°C, then contact XenICs and order from them new TrueNUC/NUC files with a lower preset temperature value.

The camera has a cooler that can lower the imager temperature, but relies on normal heating of the camera to raise it. The readout from the camera will indicate that the cooler is functioning and tracking to the present value. There will be a nominal error between the set and the reported value from the camera. This error is compensated for in the TrueNUC/NUC file.

G.3.4 Camera Correction File



To successfully use an InGaAs camera, such as the XEVA, a camera correction file must be downloaded into the camera. The file must match how the camera is setup for use. When the Xeneth software that came with the camera was installed it copied the camera correction NUC files into a folder called:

C:\Program files\Xeneth\CalibrationPacks\...

This folder will contain 2 or more .xca NUC files specific to each camera's serial number. The name of the file will give details about when it should be applied. A file that contains the letters LG or HG are for low gain / high gain settings respectively.

To load a NUC file click on the dropdown arrow and browse to the folder shown above. Select the appropriate TrueNUC/NUC .xca file and click **Open**.

The **Two Point Correction** box should also always be checked as it doesn't make sense to try and operate these cameras without applying a NUC table. If you uncheck this item you can observe what the camera output looks like w/o NUC.

This file name will be saved in a setup file and automatically applied to the camera upon opening the setup if the camera is already attached. If the camera was not connected then you may need to manually restore it.

Note: Use of the NUC file will reduce the maximum frame rate of the camera by an amount corresponding to the impact of the NUC effort required. Typically this yields a 10-20% reduction in maximum frame rate.

G.3.5 External Trigger Control

The XEVA camera is supplied with an external trigger input cable. The input to this cable should be a standard TTL level positive going pulse. The camera will trigger, and begin integrating light on the rising edge. A trigger pulse should be at least 5μs in duration.

To operate in external trigger mode you must set this control to **Trigger In**. Select **None** when operating in CW mode.

APPENDIX H Pyrocam III Specifications

Note: With the release of BeamGage v5.5 the Pyrocam III can operate in both 32 bit and 64 bit Windows Operating Systems (OS). We recommend Windows 7 or Windows 10.

H.1 Pyrocam III Special Controls

The Spiricon Pyrocam III cameras do not operate like traditional CCD or CMOS devices and therefore require specially designed controls. Supplied with a Pyrocam III is a standalone Windows Console application. If you are only using the Pyrocam III for general imaging and basic results, this software will be all you need. The Pyrocam III Console application is installed automatically when the Pyrocam III software CD is run and the software, including BeamGage Standard edition, is installed.

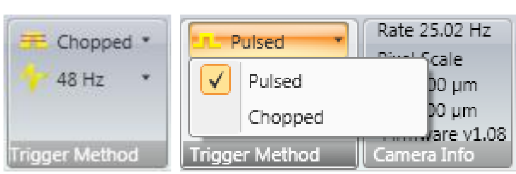
Important: ***Before attempting to use a Pyrocam III you should read and become familiar with the operating and setup requirements of the Pyrocam. Consult the supplied Pyrocam III Operator's Manual.***

The Pyrocam III Control Console application:

1. Can control all of the operating features of the Pyrocam III.
2. Can display the Pyrocam III images and provide basic beam calculations.
3. Contains special utilities that can be used to repair bad pixels and gain correct the Pyrocam III.
4. Is used to launch and connect the Pyrocam III to LBA-PC software.
5. Is used to launch and connect the Pyrocam III to M2-200 software.
6. Cannot be run at the same time as BeamGage.

The controls in the above console app are recreated and replaced in BeamGage, making the use of the console app only for the purpose of performing Pyrocam III maintenance operations such as bad pixel or gain correction.

The control panels for the Pyrocam III are shown below and its unique controls are explained. If you are already acquainted with the operation of the Pyrocam III using the above console, these controls will already seem familiar.



Chopped (CW) vs. Pulsed To operate in CW mode, the Pyrocam III employs a rotating chopper that can operate at one of two different chopping rates, 24.3Hz and 48.5Hz. We recommend that you always use the 48Hz rate in order to obtain good response linearity. The 24Hz rate should only be used in combination with maximum gain and frame averaging to extract the very weakest of images.

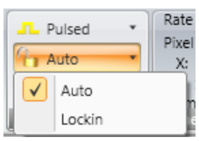
When operating in pulsed mode, the Pyrocam III must be externally triggered and the pulse width should be set to a value just slightly longer than the actual laser pulse.

The Rate display will indicate either the current chopper frequency or the input trigger pulse rate in Hz.

Exposure Control When operating in Pulsed mode, the Pyrocam must be externally triggered and the Exposure control must be set to a value slightly larger than the input pulse width. The exposure range is from 50 to 12,800µs.

Important: ***The Exposure control has no effect in chopped mode and there is no Auto setup or Auto-X features for the Pyrocam III.***

Hint: Always remember to re-Ultracal after changing the Exposure setting.

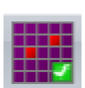


Auto/Lockin Rate The pulsed mode supports a lock-in trigger rate. This should only be used when a very stable trigger rate is present and it will not be changed. Using this feature can allow the Pyrocam III to acquire faster acquisition of a pulsed laser without the delay required to compute the trigger period. When you select Lockin, the current trigger rate will transfer into the Rate display below the Lockin control.

Hint: Use the Auto mode unless you have a specific reason to do otherwise.

Gain Control The Pyrocam III has a video gain control to help with viewing lower power lasers. The control will have different ranges in chopped and pulsed modes.

Hint: Always remember to re-Ultracal after changing the Gain setting.

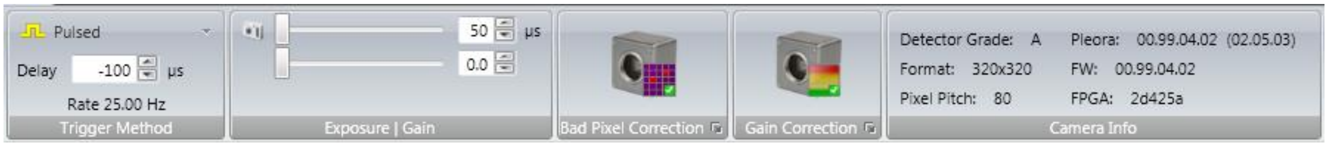

Bad Pixel Correction Click this control to enable/disable bad pixel correction in the Pyrocam III. Bad pixel correction will default in the ON state and should always be enabled except when performing Pyrocam III maintenance operations using the Control Console app. If this control is deactivated, it indicates that the Pyrocam III does not have a Bad Pixel map programmed. Note that the Pyrocam III has separate Bad Pixel Correction maps programmed for pulsed vs. chopped operation.

 **Gain Correction** Click this control to enable/disable gain correction in the Pyrocam III. Gain correction will default in the ON state and should always be enabled except when performing Pyrocam III maintenance operations using the Control Console app. If this control is deactivated, it indicates that the Pyrocam III does not have a gain correction table programmed. Note that the Pyrocam III has separate gain correction tables programmable for pulsed and chopped operation. Many of the Pyrocam III's will ship with a valid 48Hz chopped gain correction table installed at the factory. Pyrocam III's will almost never ship with a pulsed gain correction table.

APPENDIX I Pyrocam IV and IIIHR Specifications

I.1 Pyrocam IV and IIIHR Special Controls

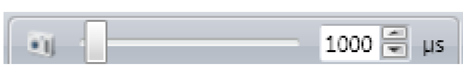
The Spiricon Pyrocam IV and IIIHR cameras do not operate like traditional CCD or CMOS devices and therefore require specially designed controls. Unlike the Pyrocam III, the Pyrocam IV and IIIHR do not come supplied with a separate Control Console Application. All of the features for the Pyrocam IV and IIIHR are found in the BeamGage software. The panels that are unique to the Pyrocam IV and IIIHR are shown and described below.



Chopped (CW) vs. Pulsed To operate in CW mode, the Pyrocam employs a rotating chopper that can operate at one of two different chopping rates, 25Hz and 50Hz. We recommend that you always use the 50Hz rate in order to obtain good response linearity. The 25Hz rate should only be used in combination with maximum gain and frame averaging to extract the very weakest of images.

When operating in pulsed mode, the Pyrocam must be externally triggered and the delay for the pulse width should be set to a value just slightly longer than the actual laser pulse.

The Rate value will indicate either the current chopper frequency or the input trigger pulse rate in Hz.



Exposure Control When operating in Pulsed mode, the Pyrocam must be externally triggered and the Exposure control must be set to a value slightly larger than the input pulse width. The exposure range is from 50 to 65,535µs.

Important: ***The Exposure control has no effect in chopped mode and there is no Auto setup or Auto-X features for the Pyrocam IV or IIIHR.***

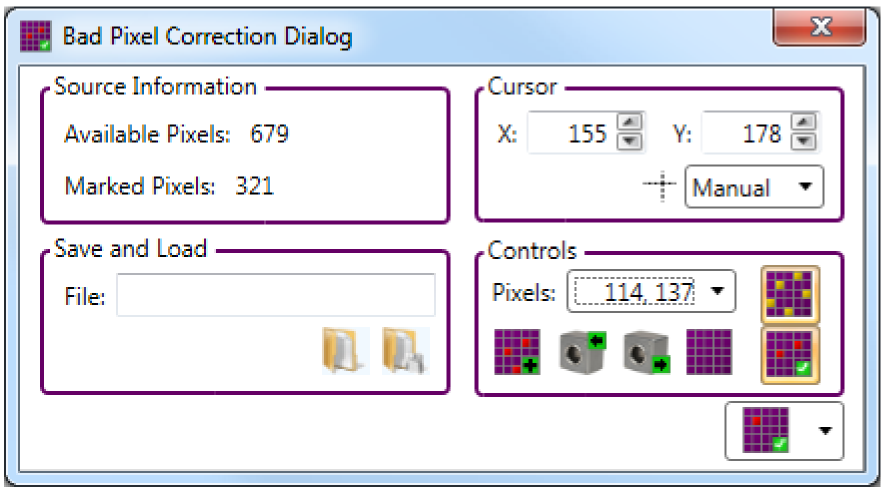
Hint: Always remember to re-Ultracal after changing the Exposure setting.

Gain Control The Pyrocam has a video gain control to help with viewing lower power lasers. The control will have different ranges in chopped and pulsed modes.

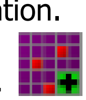
Hint: Always remember to re-Ultracal after changing the Gain setting.

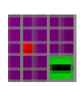
Bad Pixel Correction Click this control to enable/disable bad pixel correction in the Pyrocam. Bad pixel correction will default in the ON state and should always be enabled. If this control is deactivated, it indicates that the Pyrocam does not have a Bad Pixel map programmed. Note that the Pyrocam has separate Bad Pixel Correction maps programmed for pulsed vs. chopped operation.

Click on the expansion button to customize your own bad pixel correction map.



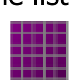
The **Source Information** group shows how many more pixels you can mark and how many pixels have already been marked. The **Save and Load** group allows you to save a different Bad Pixel maps for each Pyrocam. In the **Cursor** group, set the cursor to either **Manual** or **Peak** to locate the bad pixels. The X and Y values show the pixel value of the current cursor location.

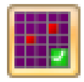
Add Pixel to List  Click to add the pixel at the current cursor location to the pixel correction list.

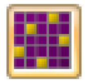
Remove Pixel from List  Click to remove the pixel selected from the **Pixels** dropdown from the pixel correction list.

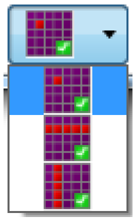
Write Pixel List  Click to write the current pixel list to the camera

Read Pixel List  Click to read the current pixel list from the camera. Note that this will replace the list currently displayed in BeamGage.

Clear Pixel List  Clears all marked pixels from the correction list

Software Bad Pixel Correction  Enable/Disable the bad pixel correction built into the BeamGage software.

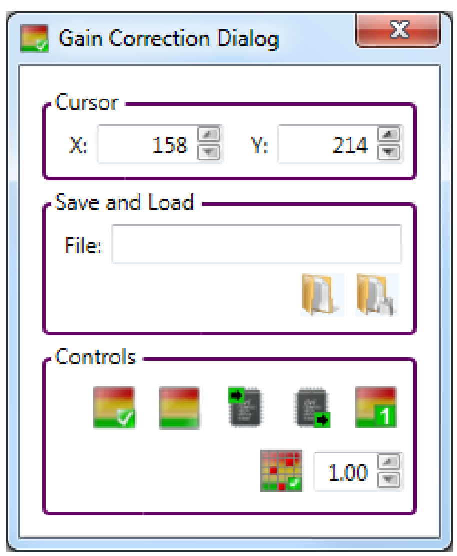
Bad Pixel Correction Map  Highlight the pixels currently in the correction list.

Pixel Selection Type  Select whether to affect a single pixel, row of pixels, or column of pixels when adding or removing pixels from the correction list.

Gain Correction

Click this control to enable/disable gain correction in the Pyrocam. Gain correction will default in the ON state and should always be enabled. If this control is deactivated, it indicates that the Pyrocam does not have a gain correction table programmed. Note that the Pyrocam has separate gain correction tables programmable for pulsed and chopped operation. Many Pyrocams will ship with a valid 50Hz chopped gain correction table installed at the factory. Pyrocams will almost never ship with a pulsed gain correction table.

Click on the expansion button to customize your own Gain Correction table.



The X and Y values show the current pixel location of the cursor. The **Save and Load** group allows you to save a different Gain Correction table for each setup of your Pyrocam.

Software Gain Correction Enable/disable the built in software gain correction

Create Gain Table Click to create the table of gain correction values

Write Flash Click to write the gain correction values to the camera

Read Flash Click to read the gain correction values from the flash

Set Gain Frame to Default Click to set the gain frame to the default value of 1.0 for each pixel

Pixel Gain Value 1.00 Select the gain value for the pixel at the current cursor position. Available options are between 0.50 and 2.00

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