LBP2 Series

Laser Beam Profiler User Guide for v3.x

Laser Beam Analyzer

For Windows 7® and Windows 10®

Newport®
Experience | Solutions

Warranty

Newport Corporation warrants that this product will be free from defects in material and workmanship and will comply with Newport's published specifications at the time of sale for a period of one year from date of shipment. If found to be defective during the warranty period, the product will either be repaired or replaced at Newport's option.

To exercise this warranty, write or call your local Newport office or representative, or contact Newport headquarters in Irvine, California. You will be given prompt assistance and return instructions. Send the product, freight prepaid, to the indicated service facility. Repairs will be made and the instrument returned freight prepaid. Repaired products are warranted for the remainder of the original warranty period or 90 days, whichever first occurs.

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The above warranties do not apply to products which have been repaired or modified without Newport's written approval, or products subjected to unusual physical, thermal or electrical stress, improper installation, misuse, abuse, accident or negligence in use, storage, transportation or handling. This warranty also does not apply to fuses, batteries, or damage from battery leakage.

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Newport Corporation Calling Procedure

If there are any defects in material or workmanship or a failure to meet specifications, promptly notify Newport's Returns Department by calling 1-800-222-6440 or by visiting our website at www.newport.com/returns within the warranty period to obtain a **Return Material Authorization Number (RMA#)**. Return the product to Newport Corporation, freight prepaid, clearly marked with the RMA# and we will either repair or replace it at our discretion. Newport is not responsible for damage occurring in transit and is not obligated to accept products returned without an RMA#.

E-mail: rma.service@newport.com

When calling Newport Corporation, please provide the customer care representative with the following information:

- Your Contact Information
- Serial number or original order number
- Description of problem (i.e., hardware or software)

To help our Technical Support Representatives diagnose your problem, please note the following conditions:

- Is the system used for manufacturing or research and development?
- What was the state of the system right before the problem?
- Have you seen this problem before? If so, how often?
- Can the system continue to operate with this problem? Or is the system non-operational?
- Can you identify anything that was different before this problem occurred?

Notice

The Ultracal processing feature is protected under United States Patent Nos. 5,418,562 and 5,440,338.

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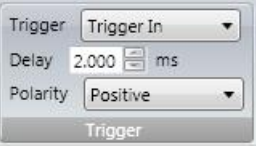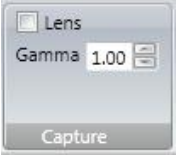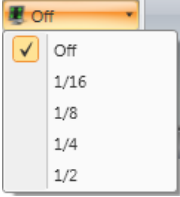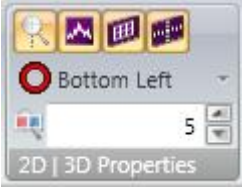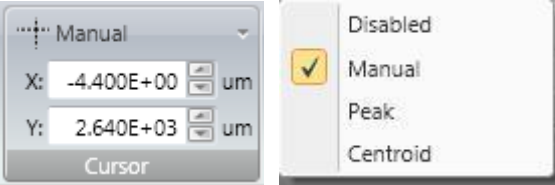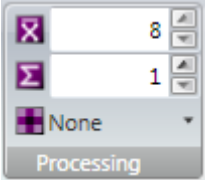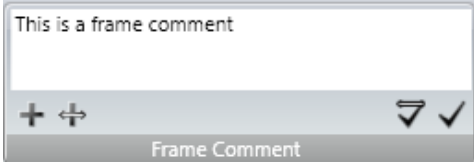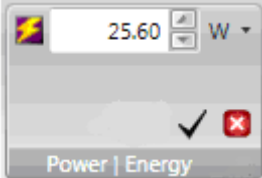While every precaution has been taken in the preparation of this guide, the publisher and author assume no responsibility for errors, omissions, or any loss of data because of said errors or omissions.
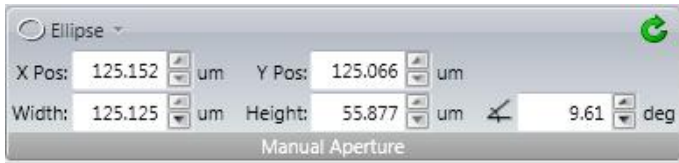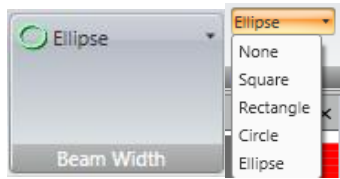
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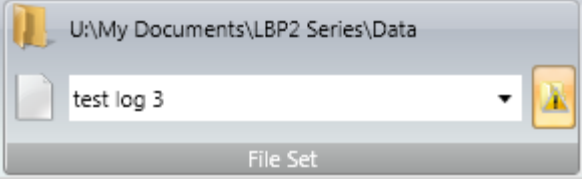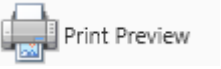
Obtain the latest version of this user guide at the product page in www.newport.com

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Safety

While LBP2 itself does not present the user with any safety hazards, this instrument however 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 LBP2, 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

LBP2 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 any 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 LBP2

Introduction to LBP2

The Newport Corporation Laser Beam Analyzer, LBP2, 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
- Numerical beam profile analysis employing advanced patented calibration algorithms
- Extensive set of ISO quantitative measurements
- All ISO beam width and diameter methods supported
- 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 SPxxx series cameras
- Supports satellite windows on multiple monitors
- Continuous zoom scaling in both 2D and 3D
- Results logging capabilities exportable to Excel
- Industry standard data file formats, HDF5 and CSV
- Configurable Report Generator that allows cut and paste of results, images and settings from .PDF file types
- Statistical Analysis of all measured parameters
- Both Manual and Auto Aperture for isolating beam data
- Integrated automatic Help linked into this .pdf Users Guide

A complete LBP2 system consists of the following equipment:

- Newport LBP2 software
- USB3 camera with interconnect cables, an External Trigger cable.
- A multi-core Pentium (2.00 GHz or better) style or equivalent PC with Windows 7 or Windows 10 operating system
  - Advanced Graphics chip set w/256MB of dedicated graphics memory
  - At least 4 GB RAM
  - At least 100 MB 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:

- A printer with appropriate Windows compatible drivers
- LBP2 Beam Sampler 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. Newport offers optional equipment for beam attenuation. Information for the LBP2 Beam Sampler series is shown below. Consult your Newport Representative or call Newport's Sales Department for further information.

Part Number	Description
LBP2-SAM-NIR	LBP2 BEAM SAMPLER, NIR
LBP2-SAM-VIS	LBP2 BEAM SAMPLER, VIS
LBP2-SAM-UV	LBP2 BEAM SAMPLER, UV
LBP2-SAM-BB	LBP2 BEAM SAMPLER, BROADBAND

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 LBP2. Install all updates before installing LBP2.

How to Use This User Guide

Read this user guide before setting up your LBP2 system. Become familiar with the laser beam analysis theory and acquire a basic understanding of how LBP2 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 LBP2 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 LBP2 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.

CHAPTER 1 Equipment Setup

Read the previous <u>Introduction to LBP2</u> section to learn what type of computer is needed to best operate with the advanced windowing features design into LBP2.

- Install the LBP2 application
- Connect the camera
- Launch LBP2
- Configure LBP2 for your camera
- Collect data

1.1 LBP2 Software Installation

Important: *Do not connect the camera to the computer until after the LBP2 software is installed.*

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

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 **Newport 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 Newport CD. Click on the **Autoplay** option. This will open the **Newport 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

With the included USB cable, connect the provided camera to the PC's USB3 port. Connect only one camera at this time.

Important: *For a camera to be able to operate with LBP2, the camera must be licensed to do so. Cameras sold with Newport products are already licensed to operate with LBP2.*

1.3 Launch LBP2 Software

To start the LBP2 application, go to the Windows taskbar and select **Start** > **All Programs** > **LBP2 Series**

Important: *Review the remaining chapters of this user guide and become familiar with the operation and capabilities of the LBP2 system before performing any laser measurements. This user guide may also be found on the installation disk in PDF format and on the Newport web site at www.newport.com. Simply follow the LBP2 Series product links*

1.4 Setup the Camera

With the camera plugged into the PC, the first time LBP2 software is opened it will automatically connect 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 Newport 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 LBP2 its model and serial number will appear in a dropdown list. Click on the camera to connect it to the LBP2 application. The camera controls will appear in the ribbon bar and the camera will begin collecting data.

Note: If a camera is plugged in that LBP2 recognizes, but is not licensed, then the camera controls will not appear; rather a license entry box will open in the ribbon.

This may be a good point in time to 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 LBP2 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.

When LBP2 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 <user_name>\My Documents\LBP2 Series\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 LBP2 are write protected files. These file names begin with a tilde (~).

The setup file will open and LBP2 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 Newport 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 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 LBP2 on a simple, user friendly, HeNe style laser.

For a first time user, beginning with a low cost HeNe or diode laser pointer is a good type of beam to practice with.

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, LBP2 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. The Ophir SP cameras used with LBP2 all support

electronic triggering via the SMA Cable supplied with the camera. 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.

Caution: ***Never apply voltages greater than 5VDC to the input triggers of 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 LBP2 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 LBP2 is closed and the application has detected a setup change, it will prompt to save the new setup.

When installed, LBP2 creates two folders in the installers user account:
>   **C:\Users\<user_name>\My Documents\LBP2 Series\Data**
>   **C:\Users\<user_name>\My Documents\LBP2 Series\Setups**

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

CHAPTER 2   LBP2 Operating Controls

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

2.1   Title Bar Features

Newport Corporation's LBP2 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 LBP2 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 LBP2 Series 1.0

- Selected input source, Model and Serial number SP620U #553589
- Name of the setup file last loaded or saved
  C:\Users\Public\Documents\Power Total Pk and Min.lbp2Setup
- Standard Windows Minimize, Maximize and Close buttons

Ribbon Tab | Source | Beam Display | Capture | Computations | Aperture | Logging | Reports |
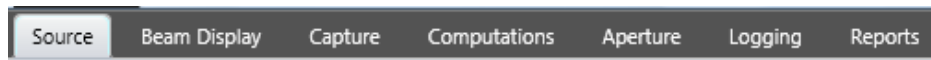
This bar looks like the traditional menu bar but is now used to define the current ribbon control being accessed. <u>Double clicking on any Menu item can open and close the entire ribbon bar display area.</u> A single click will temporarily open a closed ribbon bar just long enough to modify a single entry item.

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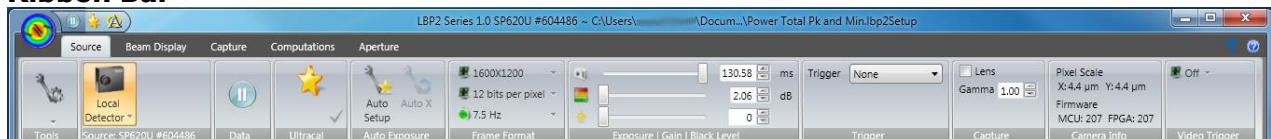
This area displays the current set of control panel options available within a selected menu item. These panels contain most of the common control items.

Panels Panels contain traditional Windows buttons, dropdown lists, edit controls, etc. Touch sensitive Tool tips are available on most all controls and Results items. Some

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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.

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 LBP2 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 LBP2 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 a later section of this chapter.

What's This [?] help can provide additional details. Click on the **What's This** [?] button, then click on any featured item in LBP2. 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 **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**

Choose the programs that Windows uses by default

Set your default programs
Make a program the default for all file types and protocols it can open.

Associate a file type or protocol with a program
Make a file type or protocol (such as .mp3 or http://) always open in a specific program.

Change AutoPlay settings
Play CDs or other media automatically

Set program access and computer defaults
Control access to certain programs and set defaults for this computer.

2. Find and select the line that has the **.pdf** extension.
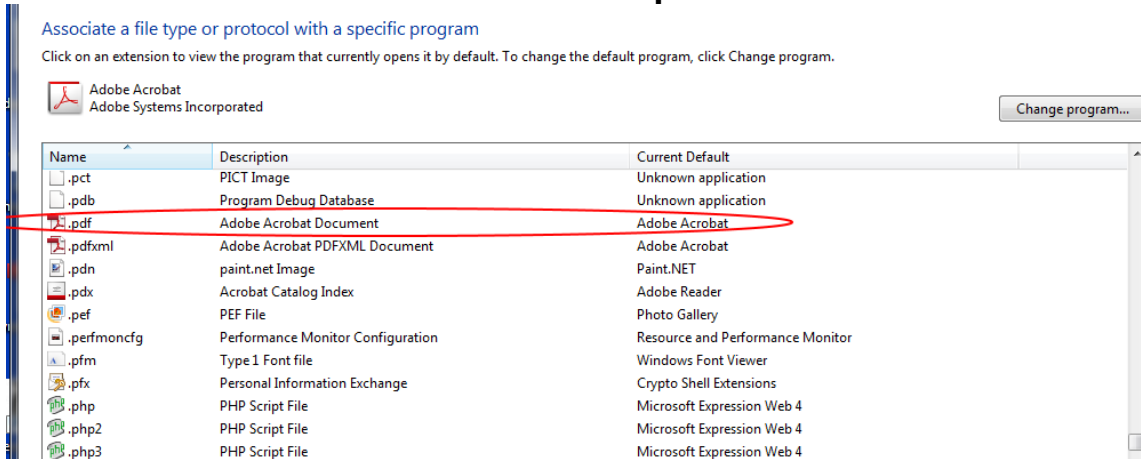
3. Click on the **Change program...** button.
4. Select **Adobe Reader** and click **OK**.
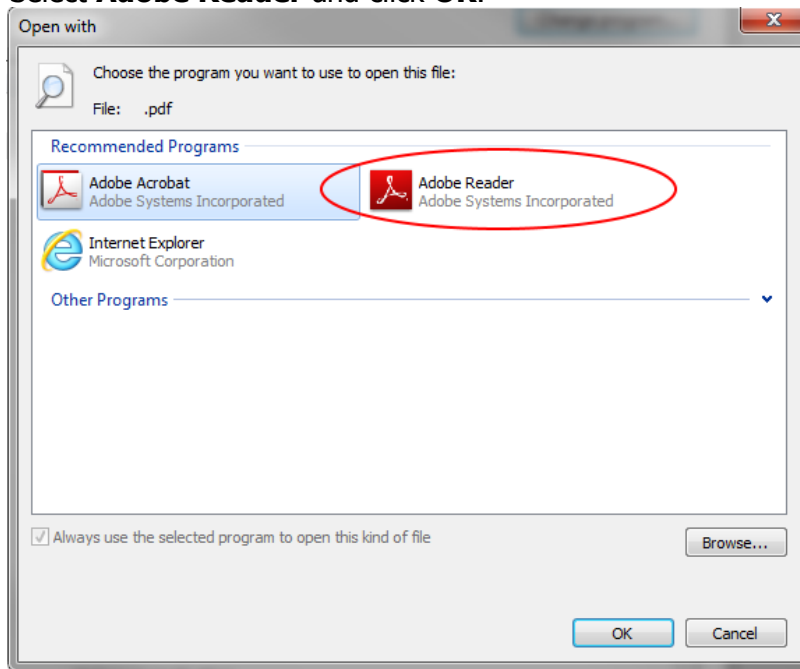
2.1.2   Adobe Reader XI Problem

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 camera is assigned to run in the currently open application. After making a camera selection, this ribbon will reconfigure itself such that it provides the controls that apply to the selected camera.

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 panel, will be visible or hidden from view.

Local Detector Clicking on this item will drop a list of supported and available Cameras. Only devices that are plugged into a suitable interface on the current platform PC will be listed.

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 LBP2 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 LBP2 will open in an off-line state with no source selected.

Once a camera 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 LBP2 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 variety

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of unique features it will not be possible to describe every type of control that may get incorporated in LBP2. The most often encountered controls will be described in this section.

2.2.2.1   Data

This control, also repeated in the Quick Access Toolbar, provides the only manual means of **Starting** and **Pausing** the data collection process of LBP2. This operation should be instantly recognizable because of their familiar design.

2.2.2.2   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 [U] 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 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 then 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 a 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 (EGB) 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 beam's 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.*

2.2.2.3   Frame Format

This control is used to select the formatting of the camera data frames. Various cameras have greater or lesser features in this area. The cameras that Newport uses with LBP2 have some degree of format control. The types of controls appearing here are as follows:
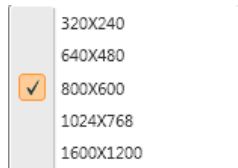
Frame Format This dropdown control will reveal a list of camera preset ROI (Region of Interest) and Binning formats that the user can select from. These formats are normally centered in the camera imager's window and allow for quick modification of the camera settings. Some formats may employ pixel binning that can speed up the camera imager frame rate but preserve the field of view of the imager. Small ROI's usually result in higher camera frame rates.
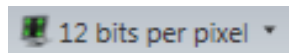
Bits Per Pixel This control sets the camera output format in number of bits per pixel. The lowest setting is 8, and the highest is 16. The available settings are camera dependent.
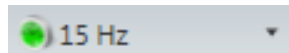
Frame Rate in Hz   Use this control to select one of the currently available default camera frame rates. The available rates will change based on the selected Frame Format.

2.2.2.4   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

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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.
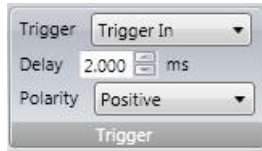
2.2.2.5   Trigger

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.

- o **None** The camera is operating in CW mode and will output frames continuously.

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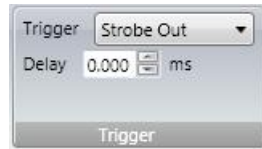
- o **Strobe Out** The camera will run in CW mode but issue a Strobe output pulse at the start of each frame exposure time. Some cameras also offer a Strobe Delay and a Strobe Pulse Width setting feature.

- o **On-Board Photodiode** The SP620 and SP503 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 calibrate 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

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depending upon the duration of the laser pulse. If the pulse is short, <100us, 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.
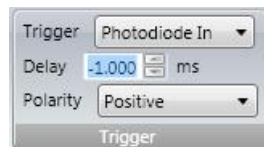
Photodiode In The SP620 and SP503 cameras can be operated with an external photodiode trigger probe. The delay for these cameras can be either positive or negative depending upon the duration of the laser pulse. If the pulse is short, <100us, set a negative delay of at least -1.0ms, and a camera exposure 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.
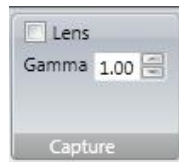
2.2.2.6   Capture

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 LBP2 application.

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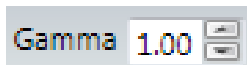
Gamma Correction If the camera employs a solid state CCD style detector, then its detector responds linearly to monochromatic light. For linearly responding cameras the Gamma setting should be set to 1.

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.

2.2.2.7　Camera/Firmware Info

This panel provides 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.
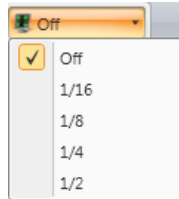
2.2.2.8　Video Trigger

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.

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** and **3D** display windows. The Tools panel allows the user to display and hide the following items:
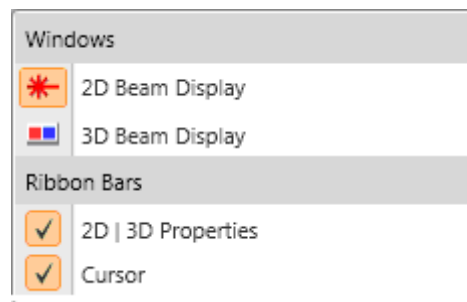
2.3.1　2D|3D Properties

This panel controls a number of display features in the 2D and/or 3D Beam Display Windows.   The top four 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 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.

Note: Different beam profiles are shown in the following depictions.
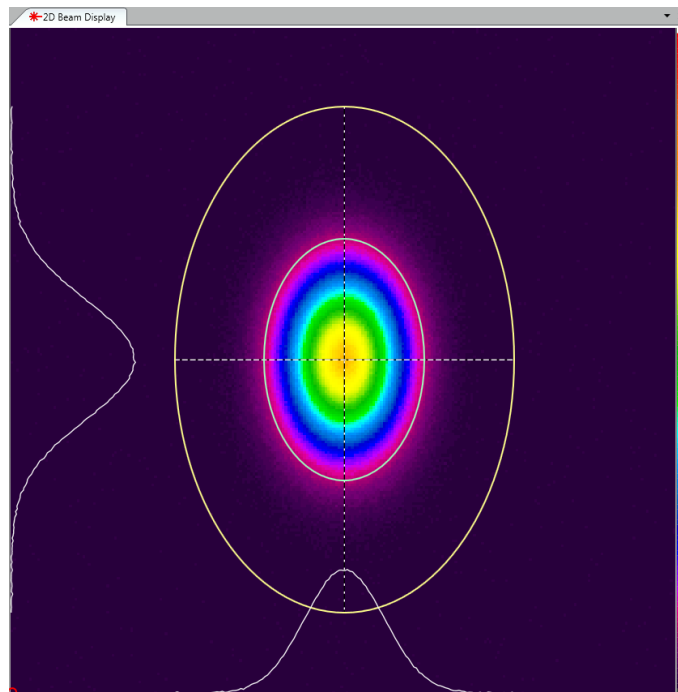
2.3.2   2D Beam Display Window

Auto-aperture (Lt Yellow), displayed Beam Width (Lt Green). The beam slice profile is drawn in White. 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 or in the **Center** of the display window.
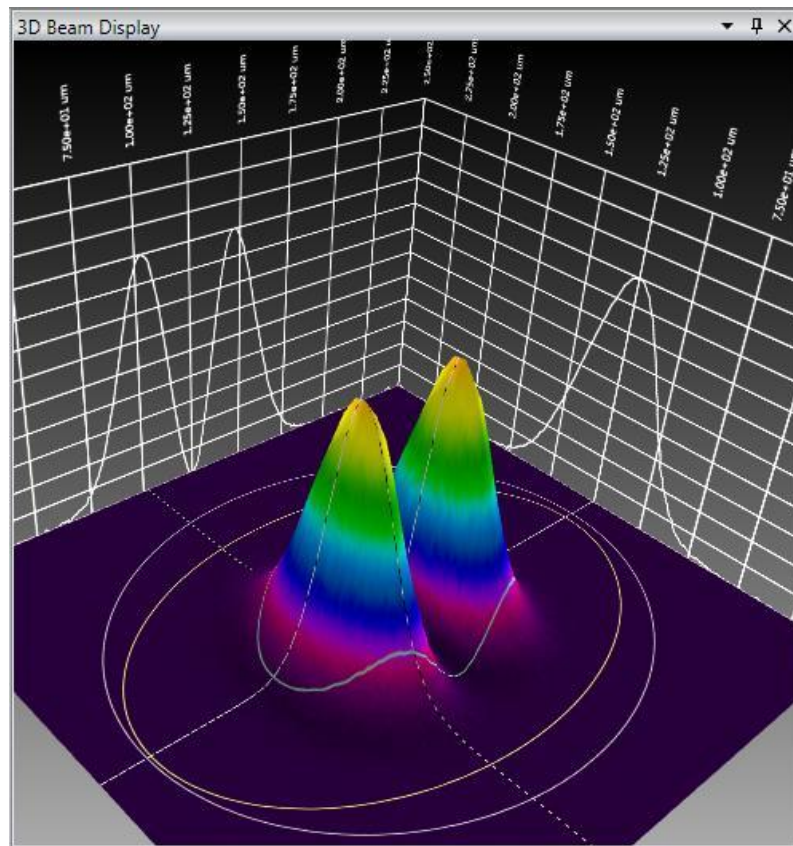
2.3.3   3D Beam Display Window

The projected apertures: Manually Drawn Aperture (Lt Grey), Auto-aperture (Lt Yellow), and Beam Width (Lt Green). The beam slice profiles are traced in White and projected onto the visible **Backplanes**.
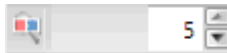
The **3D Resolution** edit control determines the amount of detail that will be rendered in the 3D beam profile. A number **1** is finest resolution and will cause the data frames to update at a slower rate.   The max value is **10** and will result in a more grainy looking display but the update rate 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.*
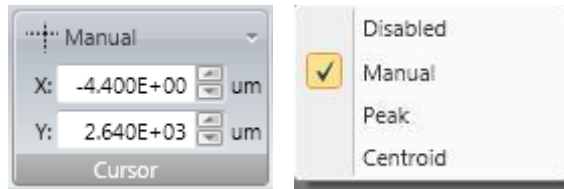
2.3.4   Cursor

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 Cursor 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.

2.4 Capture Ribbon and Controls

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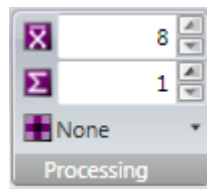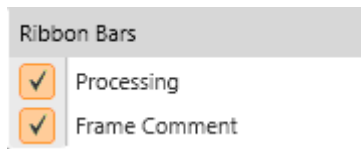
2.4.1   Processing

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 placed into the frame buffer. Frame Averaging is a convenient method that can improve the signal to noise ratio when observing low signals where noise is a significant problem. The signal to noise ratio is improved by the square root of the number of frames averaged.

Σ 1 ⬍ **Frame Summing** Enter the number of frames that are to be summed and the summed results will be saved in the frame buffer. In this example, frame summing is set to 1, disabling 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 that a positive baseline offset doesn't blow up the resulting data frame.
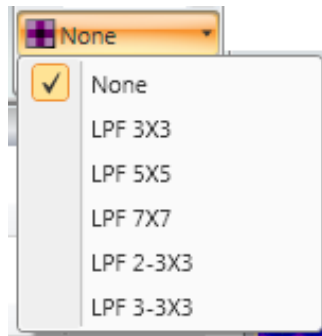
Convolution

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.
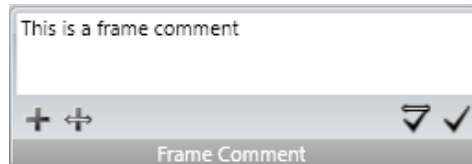
2.4.2   Frame Comment

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 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 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 in the buffer.

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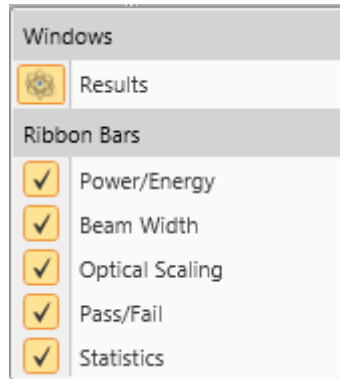
Note: The Results button in the above Tools menu opens/closes the Results display window. The remainder of this section will describe only the panel controls. The following section will describe the Results display window which contains its own set of controls.
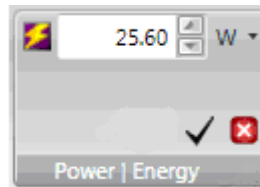
2.5.1   Power /Energy

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.

✓ **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.

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 in covered in more detail in CHAPTER 5.

2.5.2   Beam Width Basis

The Beam Width Basis selects which method will be 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 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.
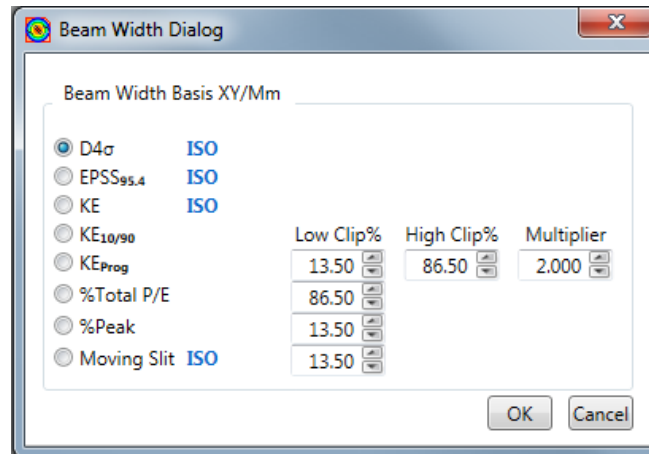
Note: A computational description of these Beam Width and Diameter setting notations is contained in CHAPTER 5.

2.5.2.1   Programmable Knife Edge

KEProg   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 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%.
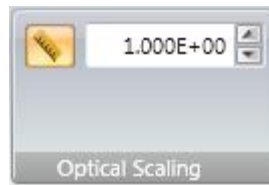
2.5.3   Optical Scaling

> 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.
>
> 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 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 apply an action on: on Pass, on Fail, 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.

2.5.5 Statistics

This panel contains the master control for the Results windows 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 a Reset of the stats can be forced 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	3.997e+00	W	3.998e+00	1.015e-03	4.000e+00	3.996e+00	32
Peak Fluence ISO	1.903e-03	W/um²	1.896e-03	5.208e-06	1.909e-03	1.889e-03	32
Minimum Fluence	-2.548e-05	W/um²	-2.810e-05	2.908e-06	-2.384e-05	-3.364e-05	32
⊟ Spatial ▾							
Centroid X ISO	1.250021e+02	um	1.249977e+02	8.333e-03	1.250158e+02	1.249803e+02	32
Centroid Y ISO	1.250107e+02	um	1.250033e+02	1.162e-02	1.250236e+02	1.249794e+02	32
D%pkX	5.900e+01	um	5.972e+01	7.289e-01	6.100e+01	5.900e+01	32
D%pkY	9.000e+01	um	8.994e+01	7.594e-01	9.100e+01	8.900e+01	32
D%pk	7.328e+01	um	7.344e+01	6.783e-02	7.358e+01	7.328e+01	32

All of the available statistical measurement types: Mean, Std Dev, Max, and Min are shown in the above example.
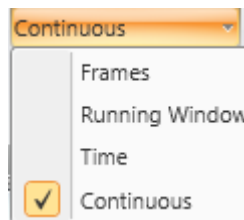
There are four different running modes for collecting Statistics. After setting up one of these modes, make sure the Capture setup is compatible with the objectives of the statistical mode setup.
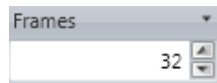
Frames One of the most common and simplest method for collecting statistics is to just set the number of frames to collect and report the results on. Data collection will stop after the set number of frames are collected.
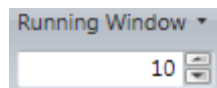
Running Window This method allows statistics to be recomputed continuously but only the stats for the last number of specified frames will be displayed.
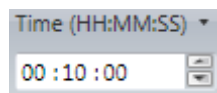
Time Set the period of time over which the stats will be collected in HH:MM:SS. This clock will count down while collecting data and stop data collection when the time is up. With this approach, the number of frames that will end up in the final count is determined by the other factors, such as the **Frame Rate**.
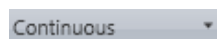
Continuous Statistics will be computed continuously until manually stopped or reset.

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 insure all stats stay in sync.

Reset Click on this momentary button to reset all statistics.

Important: *When collecting stats 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 to another display window
- Configure the Pass/Fail limits for a selected results item
- Set the font size and color for the results items

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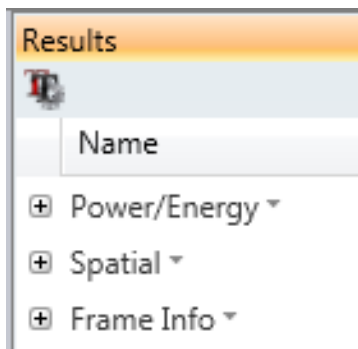
The Results Items are grouped into logical divisions. The names are self-descriptive and will lead you to where to look for a specific type of result.

Click on the group name to open a dropdown selector of the results within 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 in the example shown 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 compute 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	3.997e+00	W	3.998e+00	1.015e-03	4.000e+00	3.996e+00	32
Peak Fluence ISO	1.903e-03	W/um²	1.896e-03	5.208e-06	1.909e-03	1.889e-03	32
Minimum Fluence	-2.548e-05	W/um²	-2.810e-05	2.908e-06	-2.384e-05	-3.364e-05	32

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

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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.
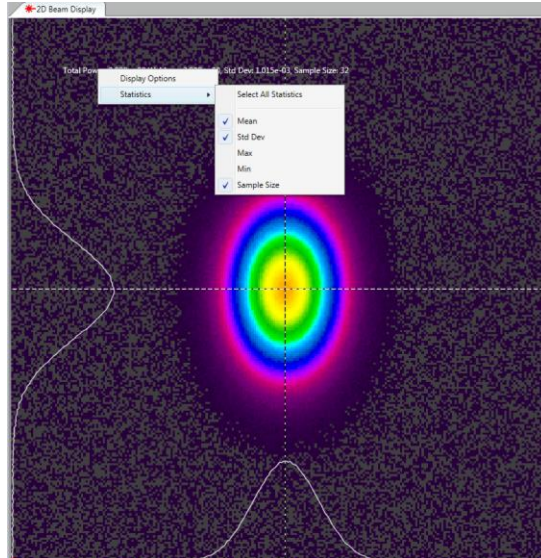
The results item will float in the designated display window with a transparent background. To reposition the location of the item, use the mouse to drag and drop it to a new location. To delete the floating item, place the mouse over the item and click the cancel box that appears. Observe that if the 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 Peak Fluence results overlaid in the 2D Beam Display window.
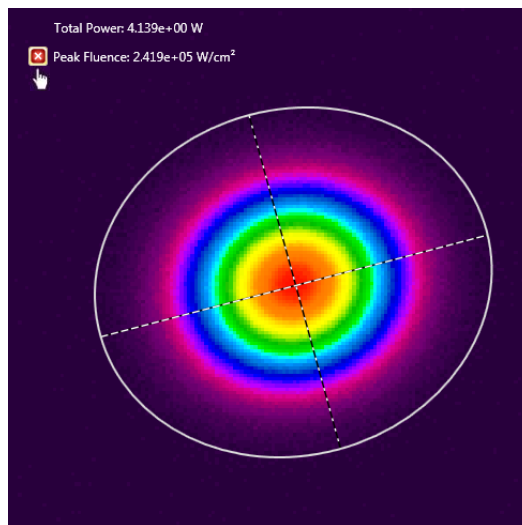
2.6.3   Results Options

Each results item has its own dropdown list of results options as well as the drag and drop feature. The **Edit Pass/Fail** 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 [icon] at the top of the Results window.
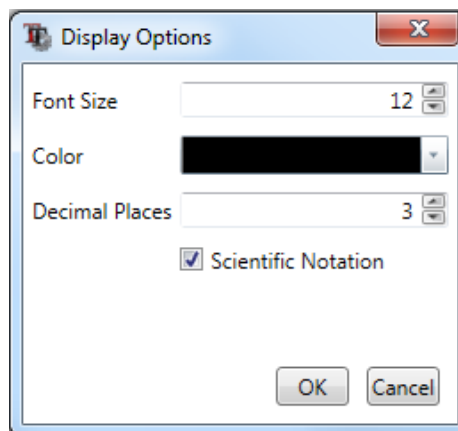
Set the font size, color, and the number of decimal places to be displayed for the selected result. Scientific notation for the result can also be enabled/disabled.

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   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.

2.6.3.3 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 value that defines 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**.

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

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

2.6.3.4 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.
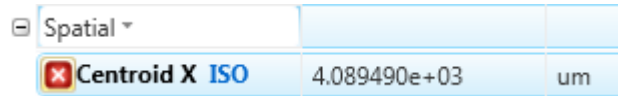
2.7 Aperture Ribbon and Controls

LBP2 can display three types of apertures: a manually drawn, an Auto Aperture, and a Beam Width aperture.

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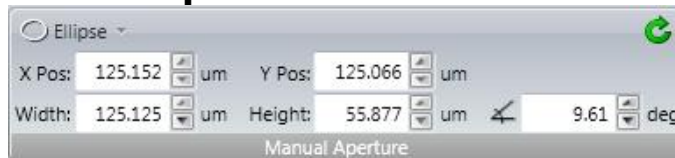
The Manual Aperture (displayed in Lt Grey) can be drawn in one of four user selectable shapes: Circle, Ellipse, Square, or Rectangle. The aperture size, position, and orientation can be controlled by entering numerical values in the above edit boxes, or it can be manipulated by the mouse.

To manipulate the aperture begin by clicking somewhere on its perimeter. This will open a set of handles that provide grab point for moving, sizing and reorientation.
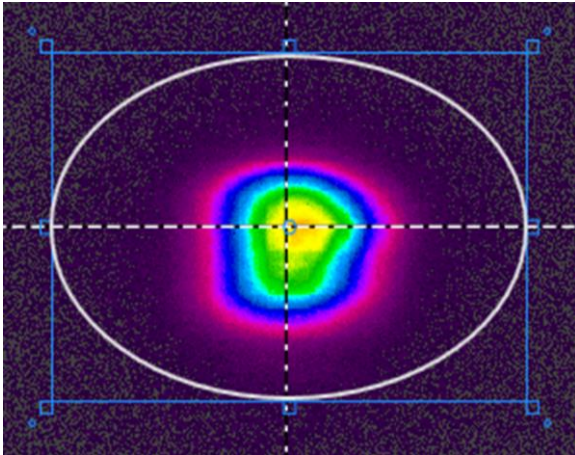
Click on the inside of the blue box to drag and drop the location of the aperture.

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.
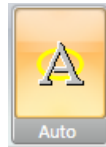
2.7.2   Auto Aperture

The Auto Aperture (displayed in Lt Yellow) is one of the most important computational aids, and should be used whenever possible. This feature is so important that it is provided in the upper left quick launch area of the title bar right next to the start/pause control.

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 will be included in the results calculations. Note how it isolates the noise in the outlying area from being included in the calculations.
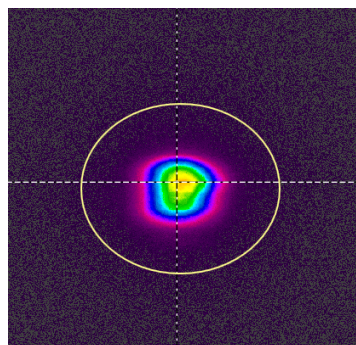
The auto aperture is always drawn as an ellipse and will orient off axis when one of the off-axis results (Orientation, Ellipticity, or Eccentricity) is enabled.

Important: *Because both the Manual and the Auto aperture isolate regions of the display for computational purposes, a precedent is established on the order in which they are applied. The Manual Aperture is applied first and can affect the outcome of the Auto Aperture's location, size and shape. Once the Auto-Aperture is established then 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.*
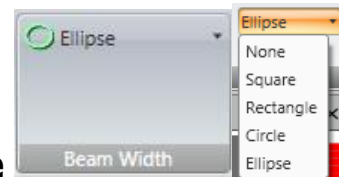
2.7.3   Beam Width Displayed Aperture

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.
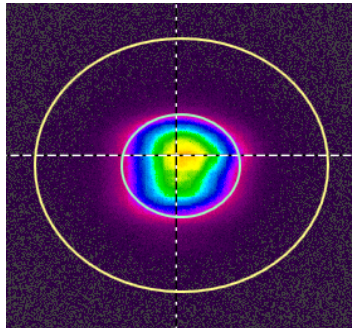
2.8   Logging Ribbon

Logging can be used to record computational results into ASCII 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 results items being logged.

For the purpose of clarity, all log file entries that pertain to one frame of 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.
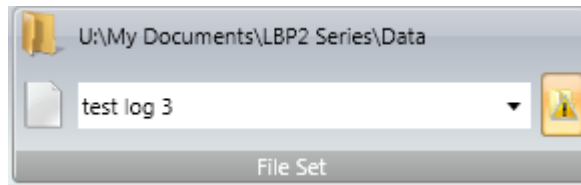
2.8.1   File Set

To begin the process a file path and name must be entered in the File Set panel.
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.
Results log files will have a .csv file extension.
   .csv, for LBP2 ASCII comma delimited log files

When installed, LBP2 creates two folders in the installers user account:
   C:\Users\<user_name>\Documents\LBP2 Series\Data
   C:\Users\<user_name>\Documents\LBP2 Series\Setup
The default location for results log files is in the ..\Data folder.

  The button in the corner enables the file Overwrite warning. Leave this on so as to avoid accidentally overwriting a log file with the same name.
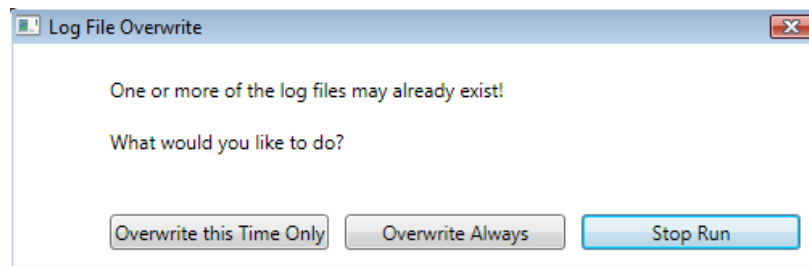
Important: *Use care when setting up logging scenarios. A poorly configured Logging operation left unattended may fill the hard drive.*

2.8.2   Logging Results

  To enable log results logging operation the above button must be enabled. These files contain the results per frame with a time stamp. Each file can contain multiple record entries.

After enabling the results, click **Start** to begin collecting and logging results.
To stop the logging process, click **Pause** .

Whenever the logging process is stopped, no matter by what means, the above logging results button is automatically disabled. To begin a new Logging cycle the selection must be re-enabled.

2.8.3 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.
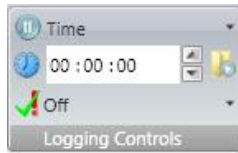
 The logging duration can also be set to terminate after a certain time period has elapsed.

 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 results 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.

2.9 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 LBP2. 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.
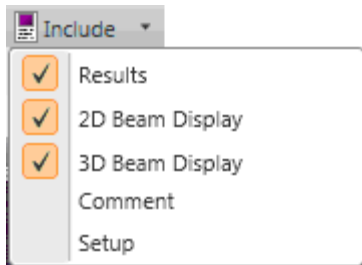
Include Options   Use the Reports Include dropdown to enable the items that are to appear in a report. The window must be opened somewhere on the screen to be able to print it.

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 check this and each printed item will be printed on separate sheets of paper.
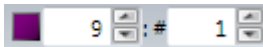
The **From:** value is the current frame buffer display location and indicates at which frame the report process will start. To print more than one frame, enter the number to report in the **#** of frames to report on in this edit box. The number of frames always counts up in the frame buffer and the 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 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 to insure that a lot of paper doesn't get wasted.*

CHAPTER 3 Displays

3.1 Displays

LBP2 has the ability to create a flexible display environment to meet the user's specific needs.   In this chapter the tools that control the screen layouts will be described.

Below is an example of LBP2 in a minimalist form.
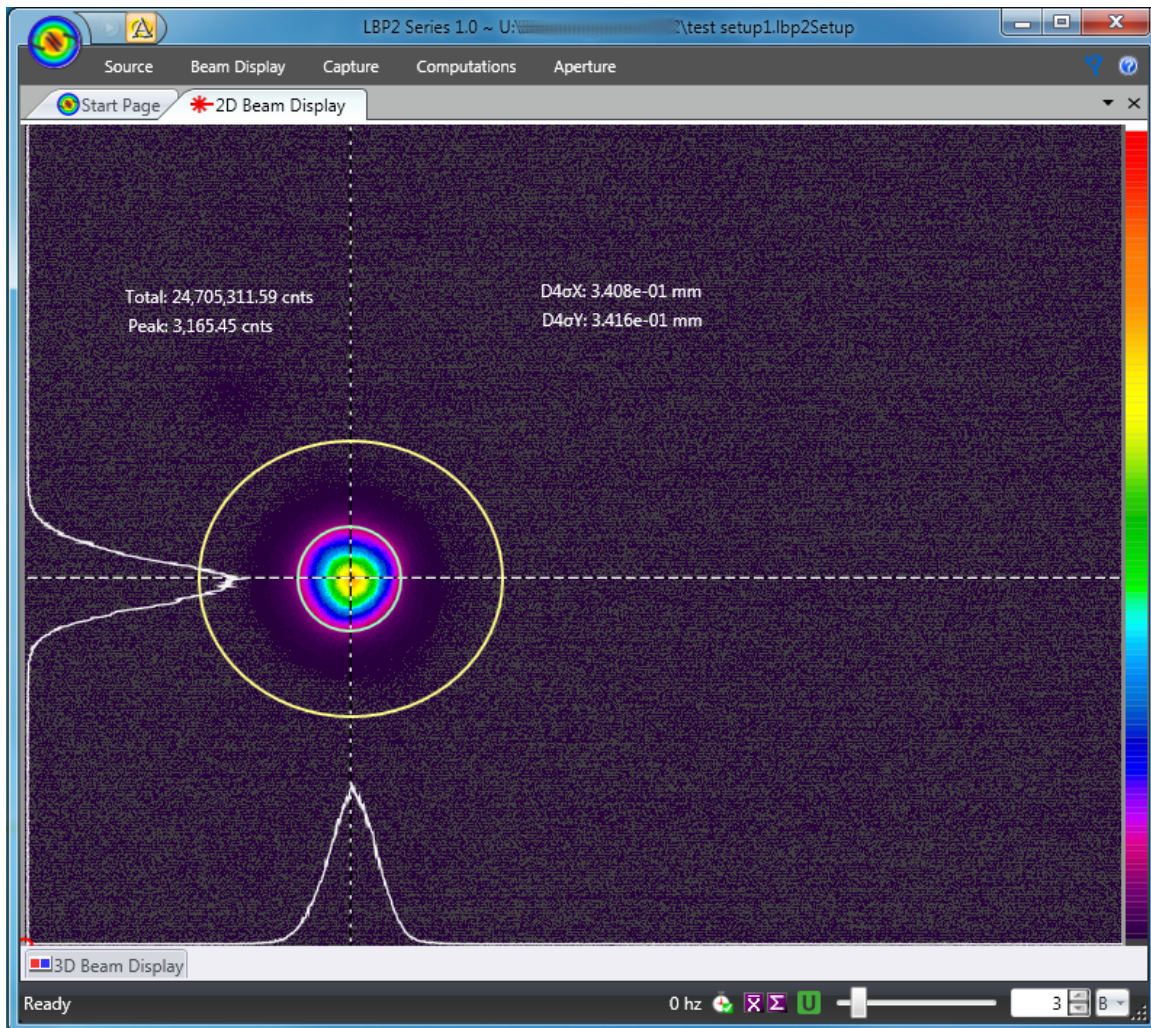
Here is an example with all the display windows operating.
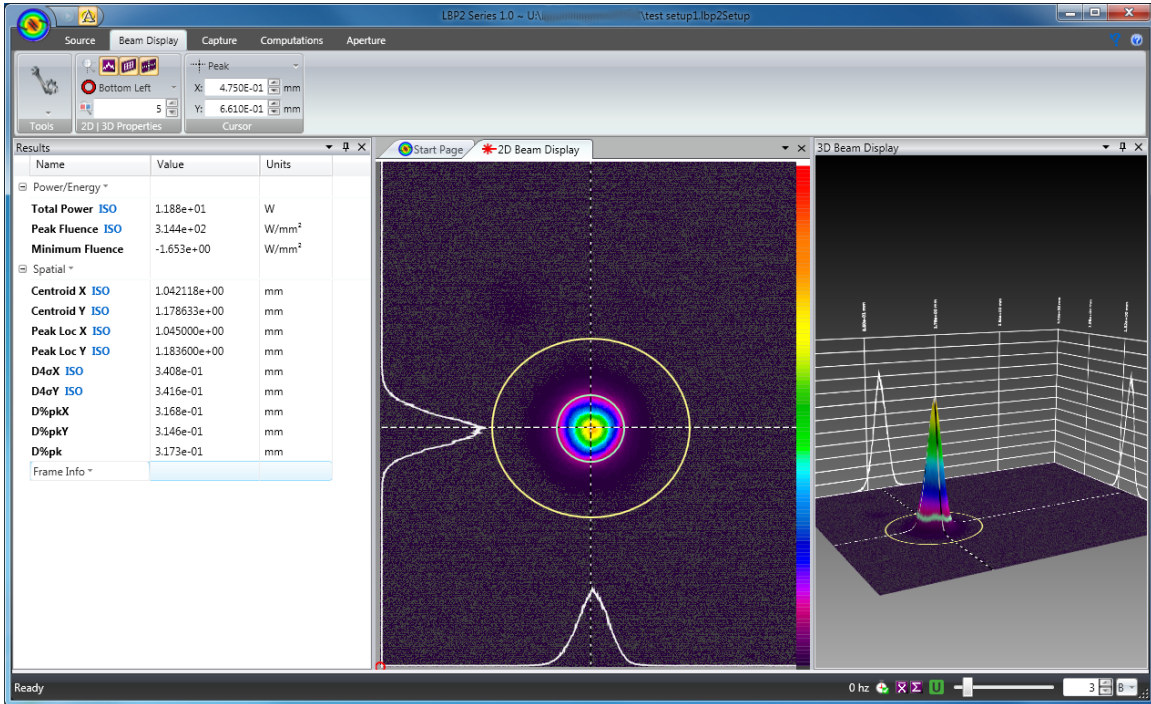
3.2 Display Terminology

The tools that control the 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 LBP2. The ones we have chosen here, if not chosen by consensus, are at least consistent and logical.

Object Designations

File Access button

Quick Launch buttons

Ribbon tabs

Title bar

Standard Windows controls

Ribbon bar and Panels

Bottom Docked and Pinned window expansion tabs / Status bar

Results window left docked in the Main application window

Primary Dock window of the 2D display, note the tab
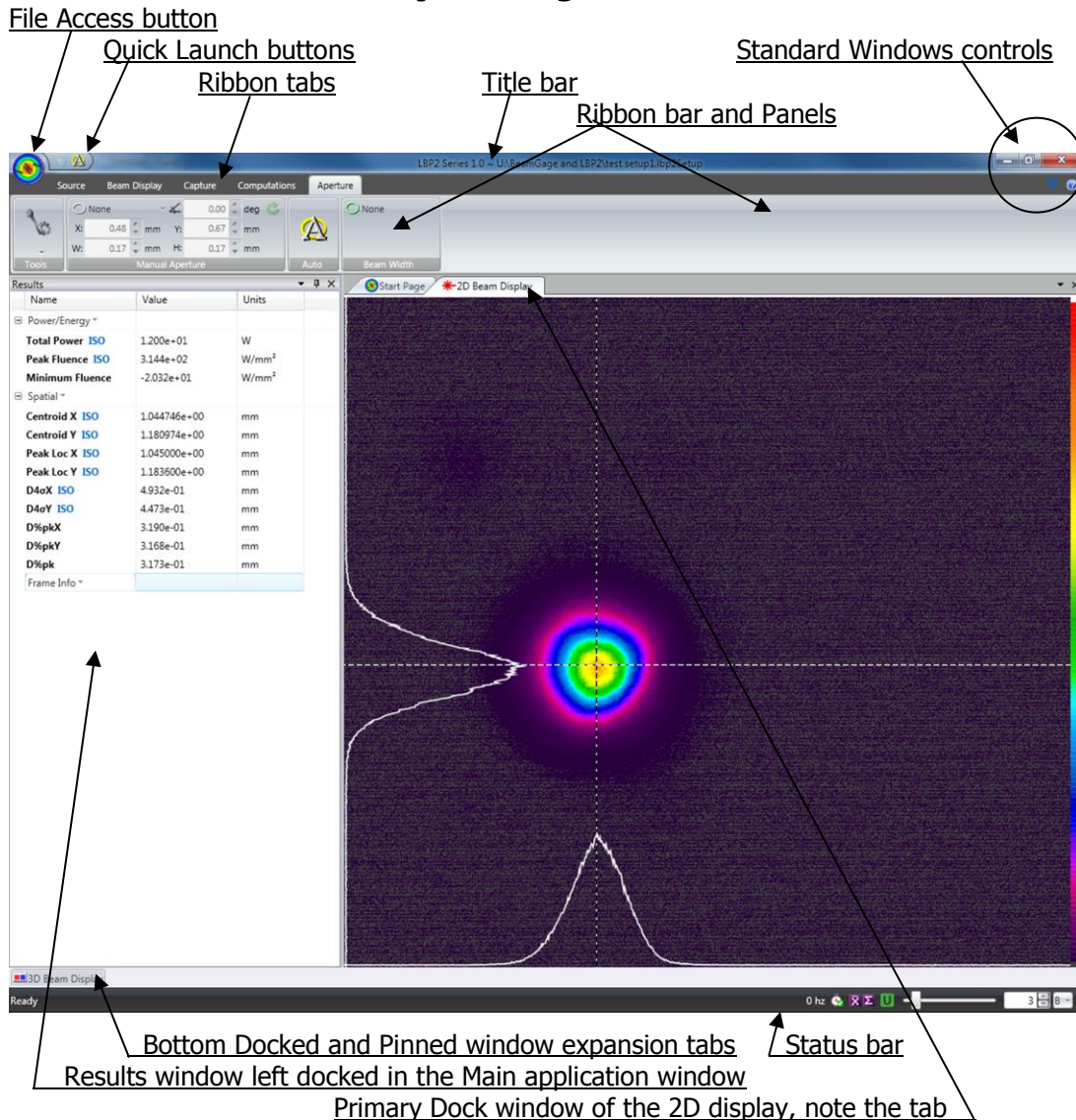
3.2.1 The Primary Dock Window and Dock Handles

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. When 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 affords a limited view of each window. Note: 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.
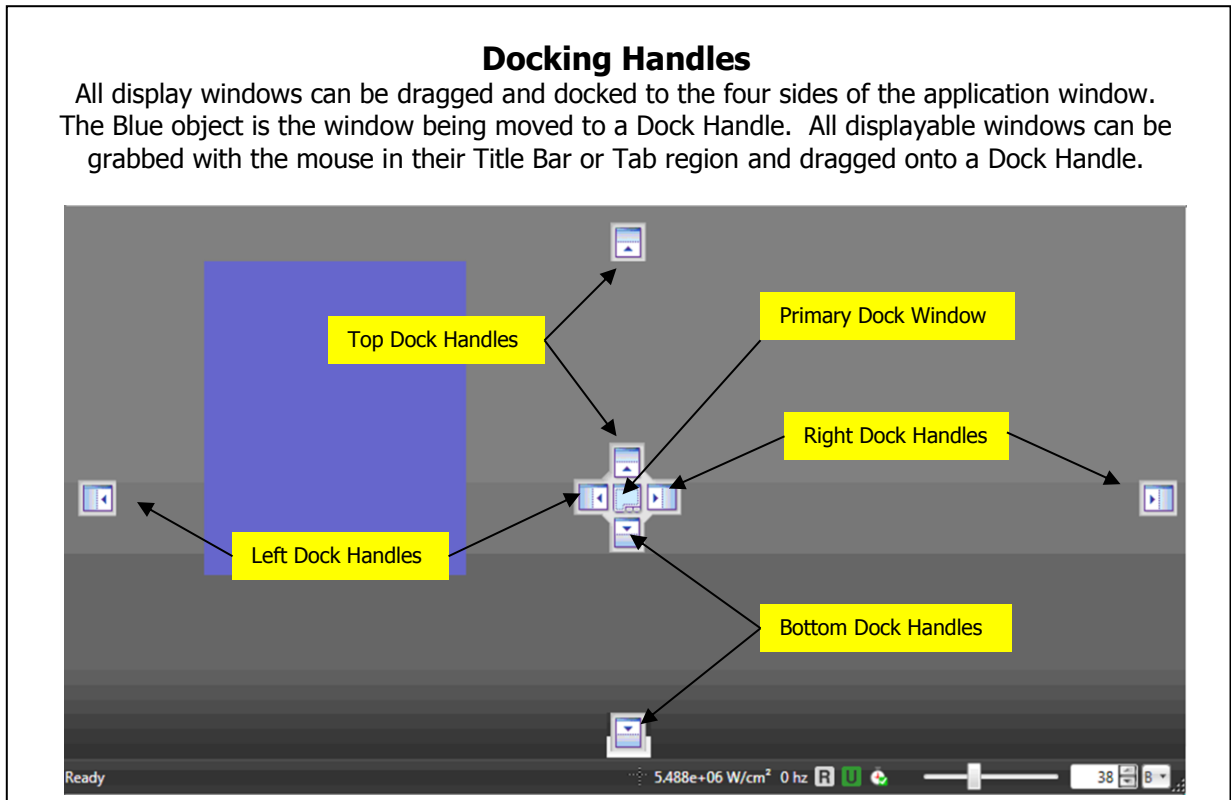
For example, click on the **Beam Display** tab and then in the **Tools** panel click on the **3D Beam Display** item. This will open the 3D display in the primary dock window. Using the left mouse button click on and drag the 3D Beam Display tab and drag it into the bottom of the Results window. The docking handles will appear as in the image below.
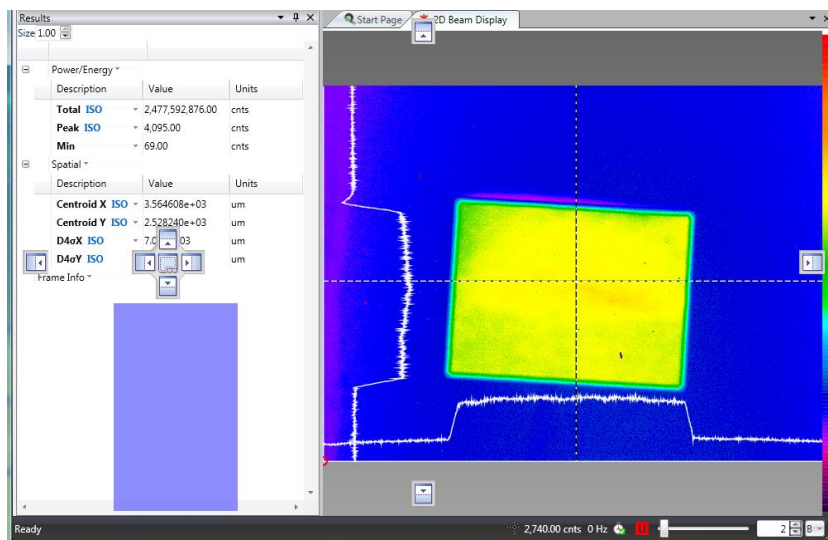
Now drag the mouse cursor to touch the center-bottom docking handle and release the mouse button. The 3D display is now docked into the results window as shown below right.

3D Beam Display in Primary Dock window before relocating	And after relocating to the Lower Results Dock Handle
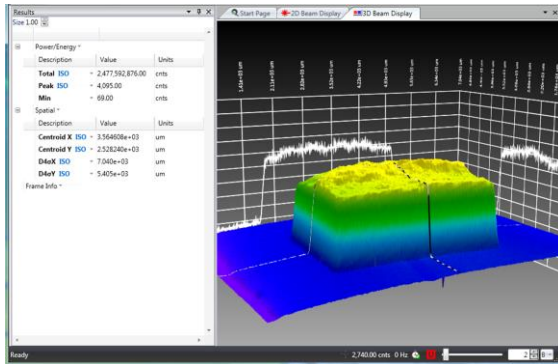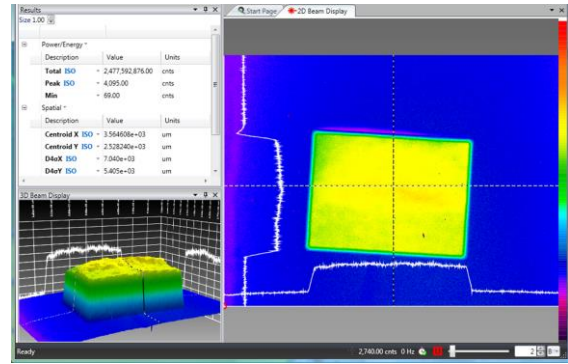
Note: Once a window has been repositioned, LBP2 will remember the placement so that when the window is reopened it will appear in the last docked location, not in the Primary Dock Window.

Important: *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

LBP2 has 3 display windows that can be positioned by the user in a number of different ways. Each time a window is docked it will clone its own set of Dock Handles. This permits placing windows side by side, and over and under each other.

Exception: 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 three windows two docked and one floating outside of the main LBP2 application.   The best way to learn how to manipulate the windows and use the docking handles is to experiment.
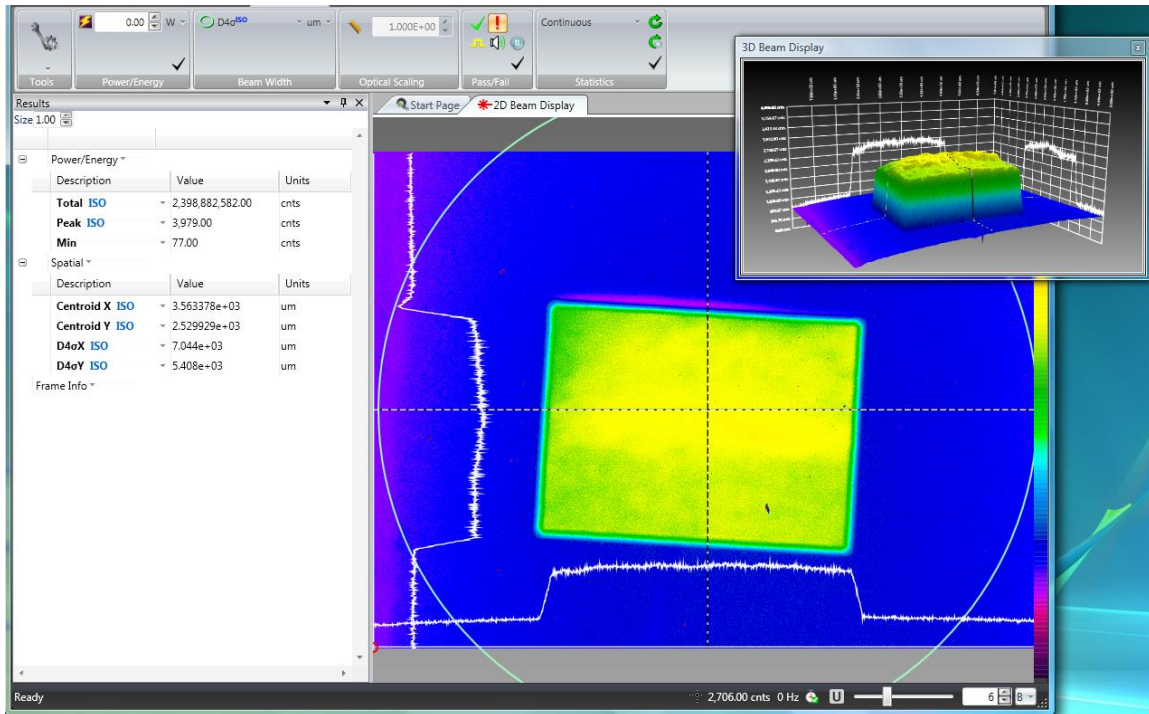
3.2.3   Pin

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 tag. Clicking on the windows Pin control feature will cause a window to collapse into the dock frame. The figure below shows two separate windows pinned to left side of LBP2's main window.
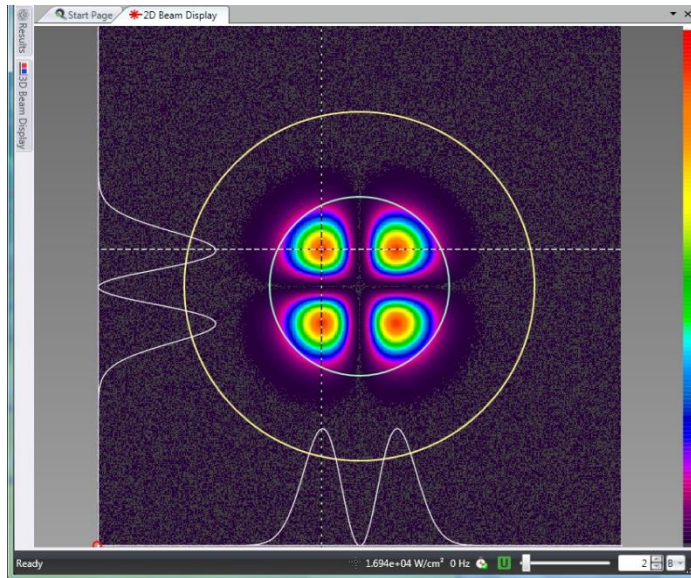
Hovering or clicking on one of the pinned tabs will cause the collapsed item to pop out from the edge for viewing, as shown below.
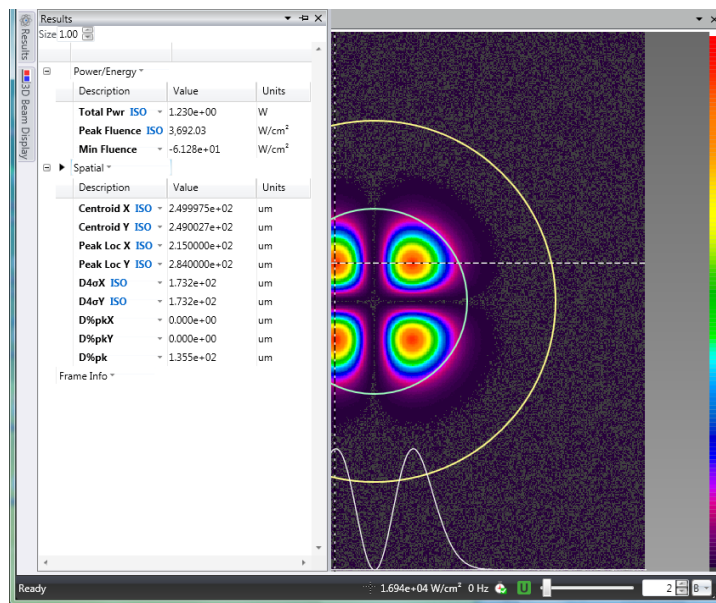
Clicking on it a second time will re-collapse the window.   This feature allows for better use of available desktop space.

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

3.3 Status Bar
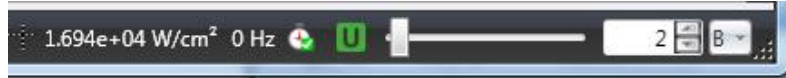
The right most section of the Status bar contains the most commonly visible elements. Each is described below.
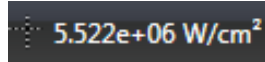
Cursor Fluence This value is the measured beam fluence at the position of the Cursor. When not calibrated, the units are in raw or processed counts (cnts).

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 LBP2 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.

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 become 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 a **U** will display the current Ultracal frame.

CHAPTER 4 Files and Formats

4.1 LBP2 File Types

As of this writing, LBP2 produces four different types of files. All use industry standard formats, but not all are meaningfully useable by a LBP2 user. The list of file types and their naming extensions are as follows:

Extension label	LBP2 Application	Format
.lbp2Setup	Setup file type	HDF5, proprietary content
.lbp2Data	Data Files that are reloadable and	HDF5, compatibility w/ Matlab and many other 3rd party applications
.csv	Results Log files	Comma delimited ASCII
.pdf	Report file format	Adobe compatible

4.2 Setup Files, .lbp2Setup, HDF5

The Setup files are used to define the configuration states of LBP2. The user can configure LBP2 into many different 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 three 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. **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.

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

4.3 Data Files, .lbp2Data, 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 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.
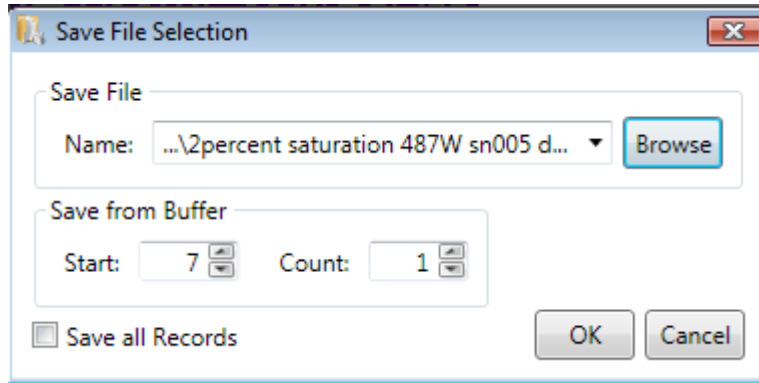
2) **Load Data…** Will open a specialized Windows file load dialog box (see below) directed at the folder where the data files are saved. Specify which frames in the data file to load by entering the **Load from File: Start** frame and frame **Count** and where in the **Write to Buffer: Start** to begin depositing the data. 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. **Save all Records** will be unchecked
    e. **Restore Original Settings** checkbox 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.
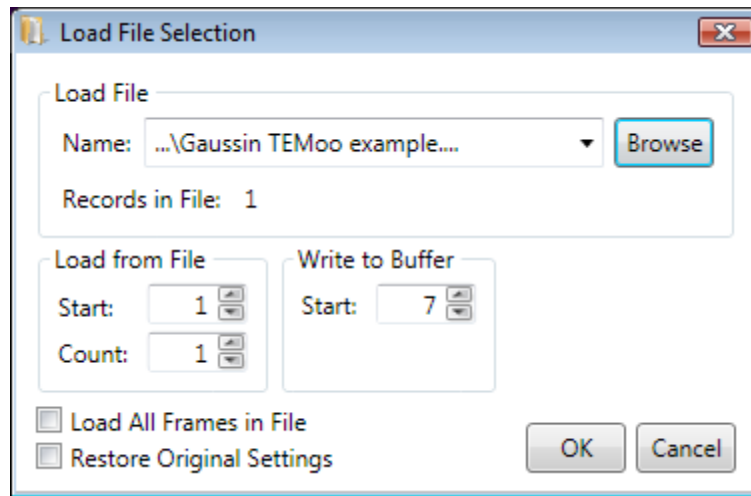
Important: *Loading a data file that is larger than the frame buffer size will cause the data to wrap and overwrite the frame buffer with the last frames loaded remaining in the buffer. LBP2 has a fixed 16 frame buffer size.*

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 .lbp2Data file format contains the processed image output from LBP2. 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\LBP2 Series\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. LBP2 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

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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** .
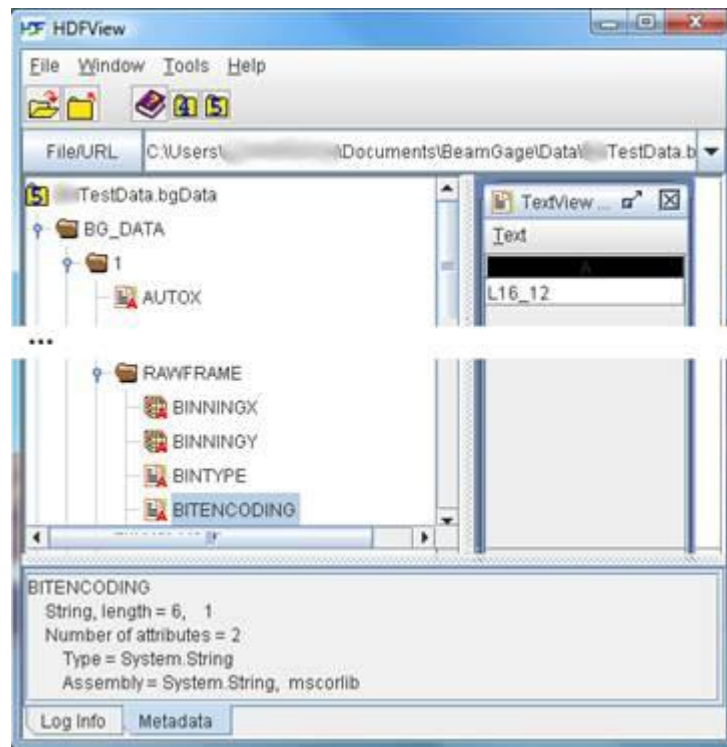
This means that the original or raw data format was from a **12** bit camera and was shipped left justified in a **16** bit word. The **L**, **R** or **S** tells us if the data was left or right justified within the word sized (pixel) packet or if it was a signed format. All signed formats are left bit justified with the sign bit in the left most position. LBP2 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 LBP2 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

LBP2 always stores pixel data in the above S32 signed binary fixed point format. If the frame 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, 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, .csv, ASCII

Log results files are ASCII comma delimited text files that contain entries for Date, Time, and each enabled computed 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.

	A	B	C	D	E	F	G	H	I
			Total Pwr	Peak Fluence	Min Fluence	Centroid X	Centroid Y		
1	Date	Time	W	W/cm²	W/cm²	um	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									

4.6 Report Files, .pdf

Reports can be configured to contain the various results and displays that are part of LBP2. A report can either be a printed document, or can be saved in an Adobe .PDF file format.
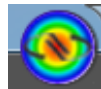
4.7 File Access Window

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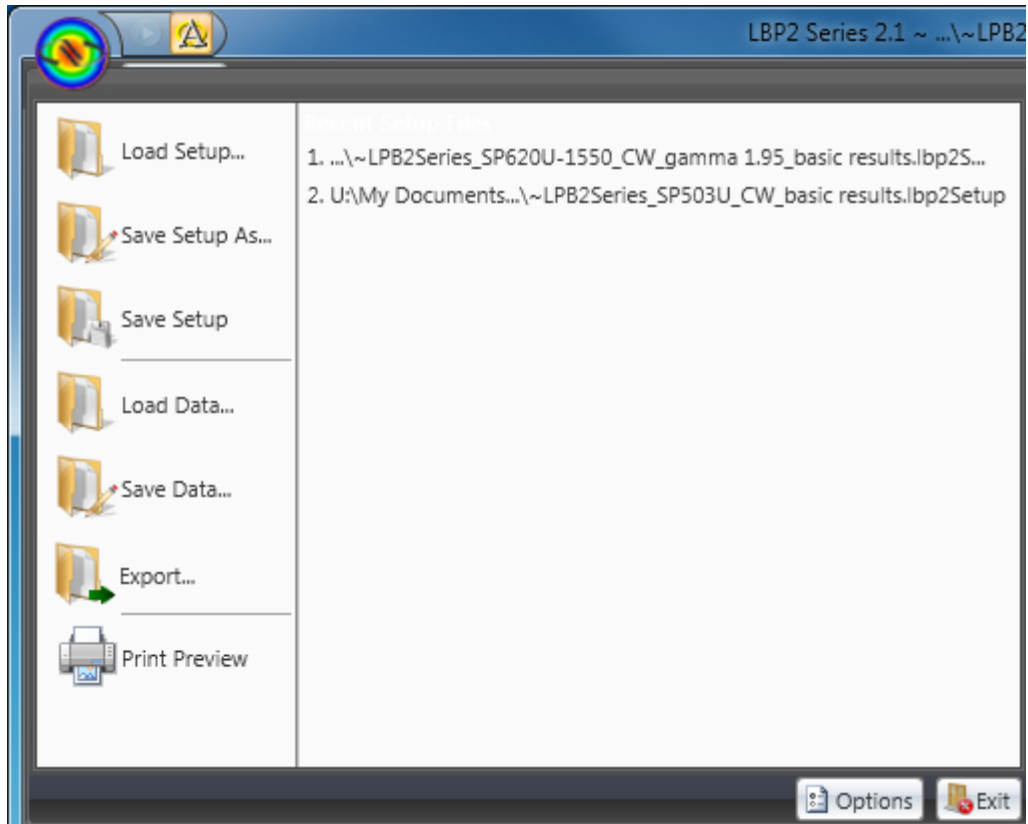
4.7.1   Print Preview
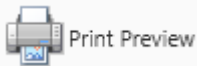
Use the Print Preview button to produce a printed report without having to access the **Reports** ribbon. The settings in the Reports ribbon will be applied as preconfigured. A temporary PDF file will be created which can be printed or saved using the Adobe controls. Once the PDF is closed, the temporary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

4.7.2   Export

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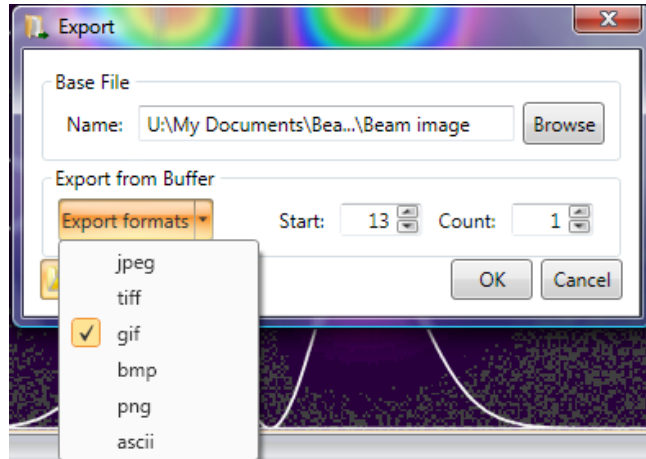
Select which type of image format to create, more than one type can be created at a time. Enter at what buffer location to start and how many frames to export. Enter a file name or click Browse. Then click OK.

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 <u>exactly</u> 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 will 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 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.

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.

LBP2 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 and the camera must be returned for repair.

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's recommend performing 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 upon 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 LBP2 has both Manual Aperture and an Auto Aperture capabilities. Newport 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

The current versions of the International Organization for Standardization (ISO) that pertains to the measurements of laser beam characteristics have been incorporated into LBP2. At the same time, other legacy measurement techniques that have found general favor in the industry have been preserved. 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 LBP2'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 non-ISO beam width basis, such as a 50% of Peak, then it is likely that another result 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 the 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.

See Appendix A for a table of ISO computational definitions with 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:

	Low Clip%	High Clip%	Multiplier
KE$_{10/90}$			
KE$_{Prog}$	13.50	86.50	2.000
%Total P/E	86.50		
%Peak	13.50		
Moving Slit ISO	13.50		

- Elliptical beam Orientation

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

- With the **Percent of Power/Energy** method, LBP2 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, LBP2 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 Centroid and Orientation of elliptical beams. These are shown in the table below.

Beam Width Basis	Clip Level used for Orientation and Centroid
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
Total P/E

The cameras used with LBP2 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: An Auto Aperture takes precedence over a Manual Aperture.

5.6 Peak and Min
Peak, 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
Peak Loc X, Peak Loc Y

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, and 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
Centroid X, Centroid Y

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 then 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. LBP2 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/e² 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 notions **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 exceed 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 4-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.

$$\textbf{D4}\pmb{\sigma}\textbf{X:} \quad d_{\sigma x} = 4 \cdot \sigma_x$$

$$\textbf{D4}\pmb{\sigma}\textbf{Y:} \quad d_{\sigma y} = 4 \cdot \sigma_y$$

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 root of the variance. 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

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

For the second moment diameter of a circular beam:

$$\textbf{D4σ:} \quad d_\sigma(z) = 2\sqrt{2\sigma(z)}$$

Where :

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

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

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

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

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, then drawing an 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 LBP2 borrow from two sources:

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

2) LBP2 also employs a 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 upon 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. To use this option successfully requires advanced knowledge of the beams modal content.

All Knife Edge Diameters 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

LBP2 measures the lengths of two orthogonal lines that pass through the beam centroid. The beam widths are determined by separately looking out along each line and count 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.

The Diameter percent of total 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 default clip level is 86.5% which will yield an accurate second moment beam width for a TEM_{00} beam.

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.

5.9.4　　Percent of Peak Method
D%pkX/M, D%pkY/m, D%pk

LBP2 analyzes two orthogonal lines of pixels that pass through the beam centroid. The beam widths are determined by separately looking out along each line 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 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.

The Diameter percent of total 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 above clip level is also applied and if set to 13.5% will yield an accurate second moment beam width for a TEM_{00} beam.

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.

5.9.5　　Moving Slit Percent of Peak Method
D%msX/M, D%msY/m

LBP2 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 not very accurate.

5.9.6   Encircled Power Methods
Depss(X/M) 95.4, Depss(Y/m) 95.4

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

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 not very accurate.

5.10 Rotated Beams
Orientation, Ellipticity, Eccentricity

LBP2 can compute and display the Orientation, Ellipticity and Eccentricity of beams rotated with respect to the normal X and Y axis. 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 Prog	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.

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

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

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

5.11 Gamma Correction `Gamma 1.00`

If the camera has a gamma value less than or greater than 1, LBP2 can be set to correct for the camera's non-linear response. Enter the gamma of the camera in the Gamma field 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 LBP2.

5.12 Convolution

Convolution algorithms in LBP2 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 is 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 determine the type of area transform that will be applied to the image data.

The figure below shows a 3x3 neighborhood and convolution kernel.

Input Image

Convolution Processing

P_1	P_2	P_3
P_4	P_5	P_6
P_7	P_8	P_9

X

K_1	K_2	K_3
K_4	K_5	K_6
K_7	K_8	K_9

3x3 Pixel Neighborhood
P_5 is the pixel being replaced.

3x3 Convolution Kernal

Weighted Sum Calculation

$$P_5' = \sum_{n=1}^{9}(K_n \times P_n)$$

New value for each pixel is placed into the output image.

Output Image
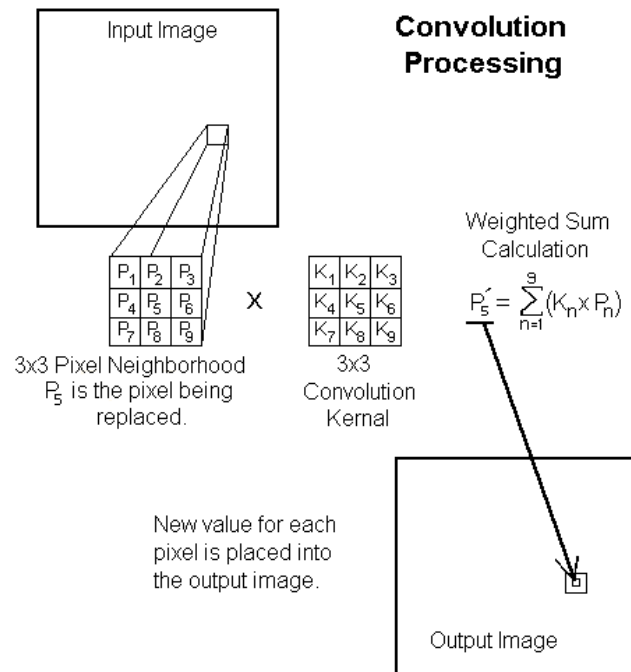
The tables below give the convolution coefficients (K values) for some of the included low-pass spatial filters.

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

CHAPTER 6 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 LBP2 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 LBP2 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 LBP2 products and install the latest version.
Error Message: "Data Source Unavailable"	If received when selecting a data source, LBP2 was unable to connect to the camera.	Please contact 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 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.

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 it will be updated 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 LBP2. These notations may be slightly modified for the purpose of maintaining consistency in labeling within LBP2 and standard industry and legacy usage. Not all listed results are currently provided in LBP2.*

( ) 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 mean 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 moment diameter of a

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[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 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 11146-1 sec 7.2.

[2] The Knife Edge measurement technique is mentioned in 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.

				1				3.3	circular beam.
									beam diameter (second moment)
									$$d_\sigma(z) = 2\sqrt{2\sigma(z)}$$
									where :
									$$\sigma^2 = \frac{\iint r^2 \cdot E(r,\varphi,z) \cdot r \cdot dr d\varphi}{\iint E(r,\varphi,z) \cdot r \cdot dr d\varphi}$$
									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
									$$\bar{x} = \frac{\iint x E(x,y,z) dx dy}{\iint E(x,y,z) dx dy}$$
									$$\bar{y} = \frac{\iint y E(x,y,z) dx dy}{\iint E(x,y,z) dx dy}$$

3	$w_{()}$	beam radius	x					3.4.1 3.4.2	Half a beam diameter. See above.
4	$d_{\sigma x}$ $d_{\sigma y}$	beam widths… second moment	x					3.5.2 3.5.1	Second moment, knife edge, or smallest slit methods
	$d_{x,k}$ $d_{y,k}$	knife edge		1				3.2	beam widths (second moment) $$d_{\sigma x}(z) = 4\sigma_x(z)$$
	$d_{x,u}$ $d_{y,u}$	smallest aperture				x		3.2.4	$$d_{\sigma y}(z) = 4\sigma_y(z)$$ knife edge, 90/10% method smallest slit method
5	M^2	beam propagation ratio	x					3.7	Measure of how close the beam is to the diffraction limit of a perfect Gaussian beam.
				1				3.4	$$M^2 = \frac{\pi d_{\sigma 0} \Theta_\sigma}{4\lambda}$$
6	$d_{0,u}$ $d_{\sigma 0}$	beam waist diameter	x					3.11.1	Beam diameter measurements performed at the waist.

No.	Symbol	Name						Ref	Description
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	pulse energy	x					3.21	Energy in one pulse…
	Q(z)					x		3.1.4 9.2.2	at location z. Joules $$Q(z) = \iint H(x,y,z)dxdy$$
12	H(x,y)	energy density	x					3.22	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)					x		3.1.2	$$H(x,y,z) = \int E(x,y,z)dt$$
13	$E_{()}$	average power density	x					3.43	Total power of a beam divided by its cross sectional area.
14	P	CW power	x					3.44	Power output of a CW laser…
	P(z)					x		3.1.3 9.2.2	at location z. Watts $$P(z) = \iint E(x,y,z)dxdy$$
15	E(x,y)	power density	x					3.45	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
	E(x,y,z)					x		3.1.1	

											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 $1/10^{th}$ 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: $$z_R = \pi \frac{d_{\sigma 0}^2}{4\lambda}$$ 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	angular			x				3.1	Angular movement of the

					X					Description
	α_y	movement								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.
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. $$\Delta(z) = \sqrt{2}s$$ $$\Delta_x(z) = 2s_x$$ $$\Delta_y(z) = 2s_y$$ 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

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[3] The asymmetric beam axis distribution should not be confused with the asymmetric beam power/energy distribution function.

#	Symbol	Name						Section	Description
									(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: $$E_{\eta T}(z) = \eta E_{max}(z)$$ for pulsed beams: $$H_{\eta T}(z) = \eta H_{max}(z)$$ where: $\quad \mathbf{O} \leq \eta \langle \mathbf{1}$
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: $\quad 0 \leq f_\eta(z) \leq 1$
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 density				x		3.2.8	Spatially averaged power/energy density of the distribution at location z, defined as the weighted mean. effective average power: $$E_\eta(z) = \frac{P_\eta}{A^i_\eta}$$ effective average energy: $$H_\eta(z) = \frac{Q_\eta}{A^i_\eta}$$
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: $\qquad 0 < F_\eta \le 1$
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: $$U_\eta = \frac{1}{E_\eta}\sqrt{\frac{1}{A^i_\eta}\iint \left[E(x,y) - E_\eta\right]^2 dxdy}$$ 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_η=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-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: $0 \leq R \leq 1$, 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. 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

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 Camera Specifications

Item	Specification	
Model	SP907	SP928
Application	1/1.8" Format	1/1.8" Format
Spectral Response	190 - 1100nm (2)	190 - 1100nm (2)
Active Area	7.1mm X 5.3mm	7.1mm X 5.3mm
Pixel Spacing	7.38µm x 7.38µm	3.69µm x 3.69µm
Number of Effective Pixels	964 x 724	1928 x 1448
Minimum System Dynamic Range	56 dB	56 dB
Linearity with Power	±1%	±1%
Accuracy of Beam With	±2%	±2%
Frame Rates in 12 bit Mode	23 fps at Full Resolution	13 fps at Full Resolution
Shutter Duration	30µs to Multiple Frames	30µs to Multiple Frames
Gain Control	0 dB to 24 dB	0 dB to 24 dB
Trigger	Hardware/Software Trigger & Strobe Out	
Photodiode Trigger	N/A	N/A
Saturation Intensity (1)	0.97µw/cm2	0.97µw/cm2
Lowest Measurable Signal (1)	1.2nW/cm2	1.2nW/cm2
Damage Threshold	50W/cm2 / 0.1J/cm2 with all filters installed for < 100ns pulse width(3)	
Dimensions	44mm x 35mm x 19.5mm	44mm x 35mm x 19.5mm
CCD Recess	12.5mm	12.5mm
Image Quality at 1064nm	Pulsed with trigger sync - excellent Pulsed with video trigger - good CW - good	
Operation Mode	Interline Transfer CCD	Interline Transfer CCD
PC Interface	USB 3.0	USB 3.0
OS Supported	Windows 7 (32/64) Windows 10 (32/64)	Windows 7 (32/64) Windows 10 (32/64)

Notes:

(1) Camera set to full resolution at maximum frame rate and exposure times, running CW at 632.8nm wavelength. Camera set to minimum useful gain for saturation test and maximum useful gain for lowest signal test.

(2) Camera may be useable for wavelengths below 350nm but sensitivity is low and detector deterioration may occur. Therefore UV image converter is recommended. Although our silicon cameras have shown response out to 1320nm it can cause significant blooming which could lead to significant errors of beam width measurement. We would suggest our XC130 InGaAs camera for these wavelengths to give the best measurements.

(3) This is the damage threshold of the filter glass of the filters. Assuming all filters mounted with ND1 (red housing) filter in the front. Distortion of the beam may occur with average power densities as low as 5W/cm2.

Note: All USB3 cameras supported by LBP2 will operate in either 32 bit or 64 bit Windows Operating Systems (OS). Newport recommends Windows 7 with at least 4GB of RAM memory and an add-in graphics card.
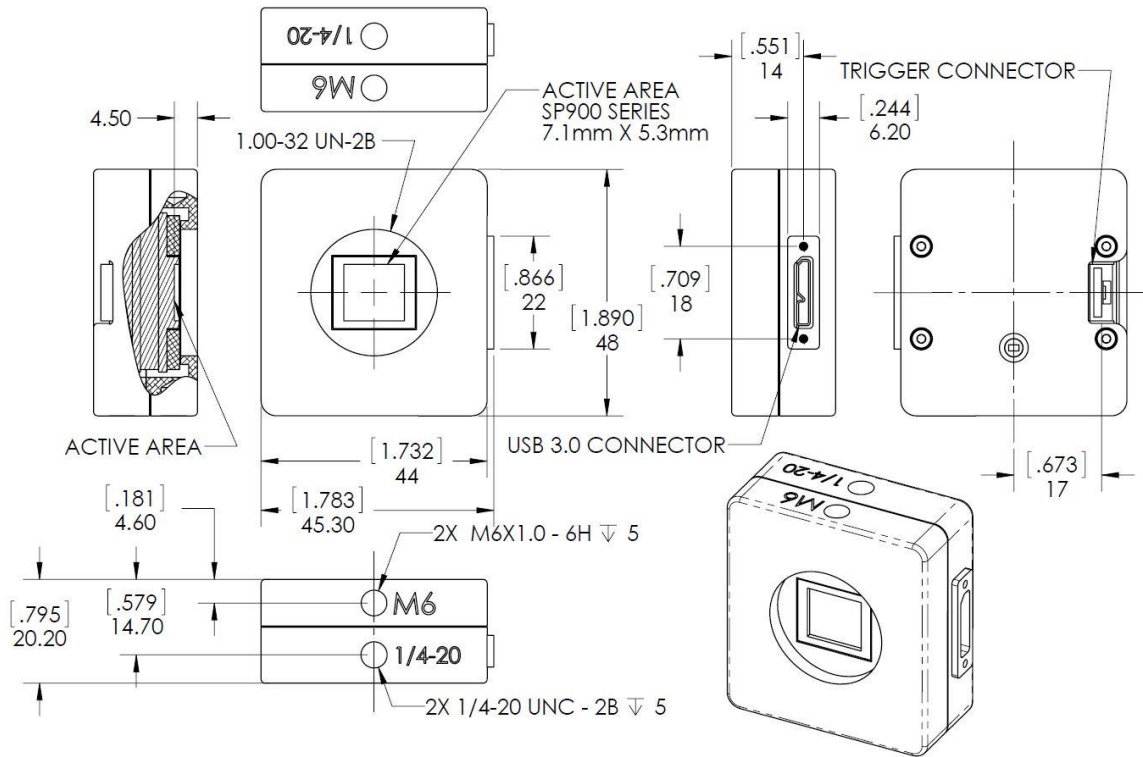
LBP2 v2 Series Camera

APPENDIX C -1550 Phosphor Coated Cameras

Item	Specification	
Model	SP907-1550	SP928-1550
Application	NIR wavelength , 1/1.8" Format, low resolution	NIR wavelength , 1/1.8" Format, high resolution
Spectral Response	1440 - 1605nm	1440 - 1605nm
Active Area	7.1mm X 5.3mm	7.1mm X 5.3mm
Pixel Spacing (1)	7.38µm x 7.38µm	3.69µm x 3.69µm
Number of Effective Pixels	964 x 724	1928 x 1448
Minimum System Dynamic Range (2)	56 dB	56 dB
Linearity with Power	±5%	±5%
Accuracy of Beam With	±5%	±5%
Frame Rates in 12 bit Mode (3)	23 fps at Full Resolution	13 fps at Full Resolution
Shutter Duration	30µs to Multiple Frames	30µs to Multiple Frames
Gain Control	0 dB to 24 dB	0 dB to 24 dB
Trigger	Hardware/Software Trigger & Strobe Out	
Photodiode Trigger	N/A	N/A
Saturation Intensity (1)	7mW/cm2 at 1550nm	7mW/cm2 at 1550nm
Lowest Measurable Signal (1)	50µW/cm2	50µW/cm2
Damage Threshold	50W/cm2 / 0.1J/cm2 with all filters installed for < 100ns pulse width(4)	
Dimensions	44mm x 35mm x 19.5mm	44mm x 35mm x 19.5mm
CCD Recess	17.5mm	17.5mm
Image Quality at 1064nm	Pulsed with trigger sync - excellent Pulsed with video trigger - good CW - good	
Operation Mode	Interline Transfer CCD	Interline Transfer CCD
PC Interface	USB 3.0	USB 3.0
OS Supported	Windows 7 (32/64) Windows 10 (32/64)	Windows 7 (32/64) Windows 10 (32/64)

Notes:

(1) Despite the small pixel size, the spatial will not exceed 50µm due to diffusion of the light by the phosphor coating.

(2) Signal to noise ratio is degraded due to the gamma of the phosphor's response. Averaging or summing of up to 256 frames improves dynamic range by up to 16x = +24 dB.

(3) In normal (non-shuttered) camera operation, the frame rate is the fastest rate at which the laser may pulse and the camera can still separate one pulse from the next. With electronic shutter operation, higher rate laser pulses can be split out by matching the laser repetion to the shutter speed.

(4) This is the damage threshold of the filter glass of the filters. Assuming all filters mounted with ND1 (red housing) filter in the front. Distortion of the beam may occur with average power densities as low as 5W/cm2.
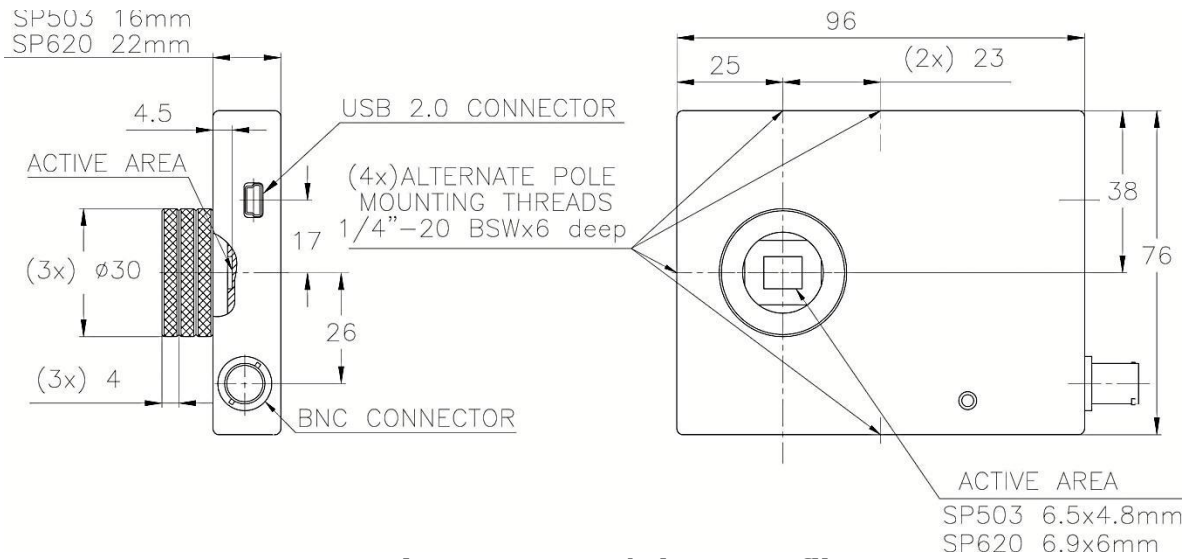
APPENDIX D Legacy Camera Specifications

Item	Specification	
Model	**SP503U**	**SP620U**
Application	½" format, slim profile, wide dynamic range, CW & pulsed lasers, adjustable ROI	1/1.8" format, high resolution, wide dynamic range, pulsed lasers, CW, YAG, adjustable ROI
Spectral Response	190 - 1100nm [2]	190 - 1100nm [2]
Active Area	6.3mm W x 4.7mm H	7.1mm W x 5.4mm H
Pixel spacing	9.9µm x 9.9µm	4.40µm x 4.40µm
Number of effective pixels	640 x 480	1600 x 1200
Minimum system dynamic range	64 dB	62 dB
Linearity with Power	±1%	±1%
Accuracy of beam width	±2%	
Frame rates: In 12 bit mode	30 fps at full resolution 60 fps at 320 x 240	7.5 fps at full resolution 28 fps at 640 x 480 44 fps at 320 x 240
Shutter duration	30µs to multiple frame times	
Gain control	43:1 automatic or manual control	29:1 automatic or manual control
Trigger	1. BNC connector accepts positive or negative trigger. LED on camera indicates triggering. Will synchronize with laser repetition rates up to 1kHz. Built in pre-trigger allows synchronization to even sub-nanosecond pulses 2. Same connector can provide trigger out to sync laser. Supports programmable delay on Strobe Out 3. Same connector accepts photodiode trigger (see below)	
Photodiode trigger	Optional photodiode trigger available	
Saturation intensity [1]	1.3µW/cm² 2.2µW/cm²	2.2µW/cm²
Lowest measureable signal [1]	0.5nW/cm²	2.5nW/cm²
Damage threshold	50W/cm² / 0.1J/cm² with all filters installed for <100ns pulse width [3]	
Dimensions and CCD recess	96mm x 76mm x 16mm CCD recess: 4.5mm below surface	96mm x 76mm x 23mm CCD recess: 4.5mm below surface
Image quality at 1064nm	Pulse with trigger sync - excellent Pulsed with video trigger - good CW - poor	Pulse with trigger sync - excellent Pulsed with video trigger - good CW - good
Operation mode	Interline transfer progressive scan CCD	
Software supported	LBP2 Series	
PC interface	USB 2.0	

Notes:

(1) Camera set to full resolution at maximum frame rate and exposure times, running CW at 632.8nm wavelength. Camera set to minimum useful gain for saturation test and maximum useful gain for lowest signal test.

(2) May be useable for wavelengths below 350nm but sensitivity is low and detector distortion may occur. Therefore UV image converter is recommended. Although our silicon cameras have shown response out to 1320nm it can cause significant blooming which could lead to significant errors of beam width measurement.

(3) This is the damage threshold of the filter glass of the filters. Assuming all filters are mounted with ND1 (red housing) filter in the front. Distortion of the beam may occur with average power densities as low as 5W/cm²

Note: All USB2 cameras supported by LBP2 will operate in either 32 bit or 64 bit Windows Operating Systems (OS). Newport recommends Windows 7 with at least 4GB of RAM memory and an add-in graphics card.

LBP2 Series Camera w/ three ND filters.

APPENDIX E Legacy -1550 Phosphor Coated Cameras

Item	Specification	
Camera	SP503U-1550	SP620U-1550
Application	NIR wavelengths, ½" format, low resolution	NIR wavelengths, 1/1.8" format, low resolution, adjustable ROI and binning
Spectral Response	1440 - 1605nm	1440 - 1605nm
Maximum beam size	6.3mm W x 4.7mm H	7.1mm W x 5.4mm H
Pixel spacing[1]	9.9µm x 9.9µm	4.4µm x 4.4µm
Number of effective pixels	640 x 480	1600 x 1200
Minimum system dynamic range[2]	~30 dB	~30 dB
Linearity with Power	±5%	±5%
Spatial Uniformity	±5%	±5%
Accuracy of beam width	±5% for beams larger than 0.6mm	
Frame rates[3]	30 fps at full resolution 60 fps at 320 x 240	8 fps at full resolution 28 fps at 640 x 480 44 fps at 320 x 240
Shutter duration	30µs to multiple frame times	
Gain control	43:1 manual	29:1 manual
Trigger	Supports both Trigger In and Strobe Out	
Photodiode trigger	Consult Factory	
Saturation intensity	7mW/cm² at 1550nm	
Lowest measureable signal	~ 50µW/cm²	
Damage threshold	50W/cm² / 0.1J/cm² with all filters installed for <100ns pulse width[4]	
Dimensions and CCD recess	96mm x 76mm x 16mm; 4.5mm below surface	96mm x 76mm x 28mm; 4.5mm below surface
Operation mode	Interline transfer progressive scan CCD	
Software supported	LBP2 Series	
PC interface	USB 2.0	
Minimum host system requirements	Pentium IV 1GHz (Dual-core & >2GHz for best performance), 1GB Memory, USB2, Operating system: Windows 7	

Notes:

(1) Despite the small pixel size, the spatial resolution will not exceed 50µm due to diffusion of the light by the phosphor coating.

(2) Signal to noise ratio is degraded due to the gamma of the phosphor's response. Averaging or summing of up to 256 frames improves dynamic range by up to 16x = +24dB

(3) In normal (non-shuttered) camera operation, the frame rate is the fastest rate at which the laser may pulse and the camera can still separate one pulse from the next. With electronic shutter operation, higher rate laser pulses can be split out by matching the laser repetition to the shutter speed.

(4) This is the damage threshold of the filter glass of the filters. Assuming all filters are mounted with ND1 (red housing) filter in the front. Distortion of the beam may occur with average power densities as low as 5W/cm²

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