Spiricon®
OPHIR Photonics
A Newport Company

BeamWatch®
User Guide

For Windows 7® and Windows 10®

Version 2.x

For Sales, Service, or Technical Support

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Dear Ophir-Spiricon Customer,

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

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

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

Sincerely,

Ophir-Spiricon, LLC

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

TABLE OF CONTENTS

Safety

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

Optical Radiation Hazards

BeamWatch is designed for use with high power lasers and therefore safety precautions must be taken. The user must be protected against accidental exposure. Exposure to personnel other than the user must also be considered. Hazards include direct beam exposure and reflected radiation. Protective eye shields and clothing must be worn.

Electrical Hazards

BeamWatch utilizes only low voltages, derived from the Ethernet and camera power supplies. Thus there is little risk of electrical shock presented to the user.

When installing or removing any hardware from 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.

How to Use This User Guide

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

Chapter 1 Introduction– An introduction to BeamWatch.

Chapter 2 Hardware Configuration – Provides getting started information and instruction on how to setup the BeamWatch hardware system.

Chapter 3 Software Setup – Provides software instruction on how to get started and install the BeamWatch software.

Chapter 4 BeamWatch Operating Controls – Describes all the various controls and functions within the BeamWatch software.

Chapter 5 Displays – Explains the functionality of all the various display components.

Chapter 6 Improving Results Accuracy – Gives detailed ways on how to improve the SNR and Caustic Fit.

Chapter 7 Automation Interface – Presents instructions on how to use the BeamWatch Automation Server.

CHAPTER 1 Introduction

BeamWatch is the laser industry's first beam monitoring system that is completely non-interfering; i.e. there is no contact with the laser beam. The measurement is made by imaging the Rayleigh scatter of the beam from the side using conventional cameras. Since nothing is inserted or scanned through the beam, it is ideal for measurement of high power lasers in the multi-kilowatt regime.

BeamWatch provides simultaneous measurement of multiple profiles along the beam caustic in the camera field-of-view (FOV). Operating at video rates, the speed of measurement allows for real-time determination of waist (focus spot) width and location, focal shift, centroid, M^2 or K, divergence, Beam Parameter Product, Rayleigh length, and relative power. The real-time performance also allows for measurement of dynamic focal shift during laser startup.

The technique is based on Rayleigh scattering of laser light by oxygen and nitrogen molecules in the air as the beam propagates. Measurement of this scattered light provides an equivalent slit scan of the laser beam in the direction of the view observed. The scattered light is measured using conventional CCDs and image capture systems.

The BeamWatch has GigE connectivity to standard personal computers for data acquisition, analysis, and display. The BeamWatch graphical user interface is based on the Windows Ribbon framework. Multiple panes display: the camera image, Beam Parameters with statistics, and scanning slit equivalent profiles at user selectable locations. Notes for test descriptions and user comments can also be enabled.

Your BeamWatch system includes:

- Spiricon BeamWatch software
- BeamWatch camera system with an Ethernet cable and power supply
- BeamWatch mounting plate
- USB 3.0 to Gigabit adaptor
- Alignment Tool (for use with alignment beams only)
- A hose and regulator valve for use with dry gas
- A quick start note card

Optional equipment

We recommend one or more of these additional products.

- BeamWatch rotation mount (SP90346)
- Locking Ethernet cable (SP90394)
- 10kW water cooled power meter
- 30kW water cooled power meter
- 100kW water circulated power meter
- Juno PC interface
- Vega power meter

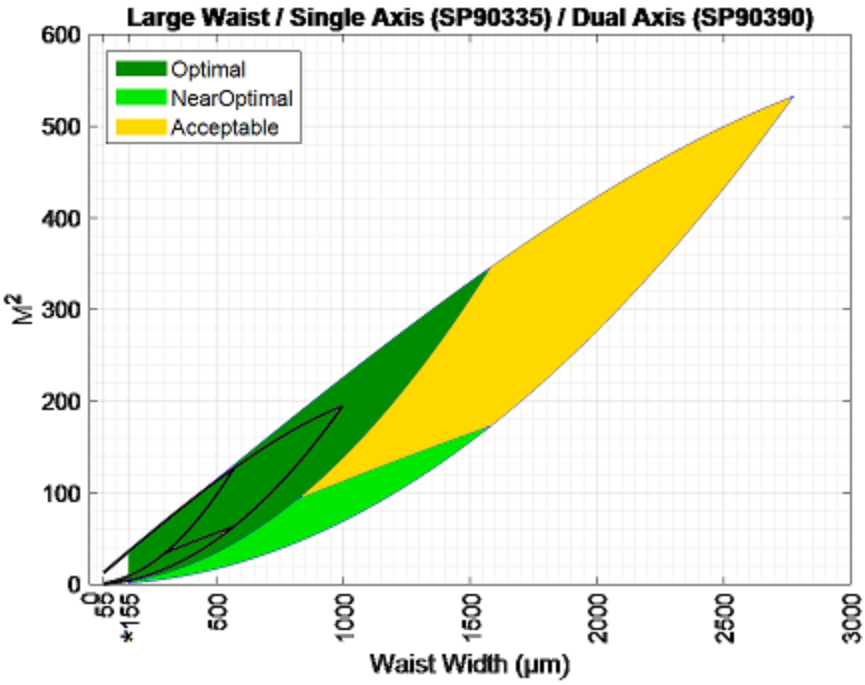
Consult your Ophir-Spiricon Representative or call Ophir-Spiricon’s Sales Department for ordering information.

1.1 Specifications

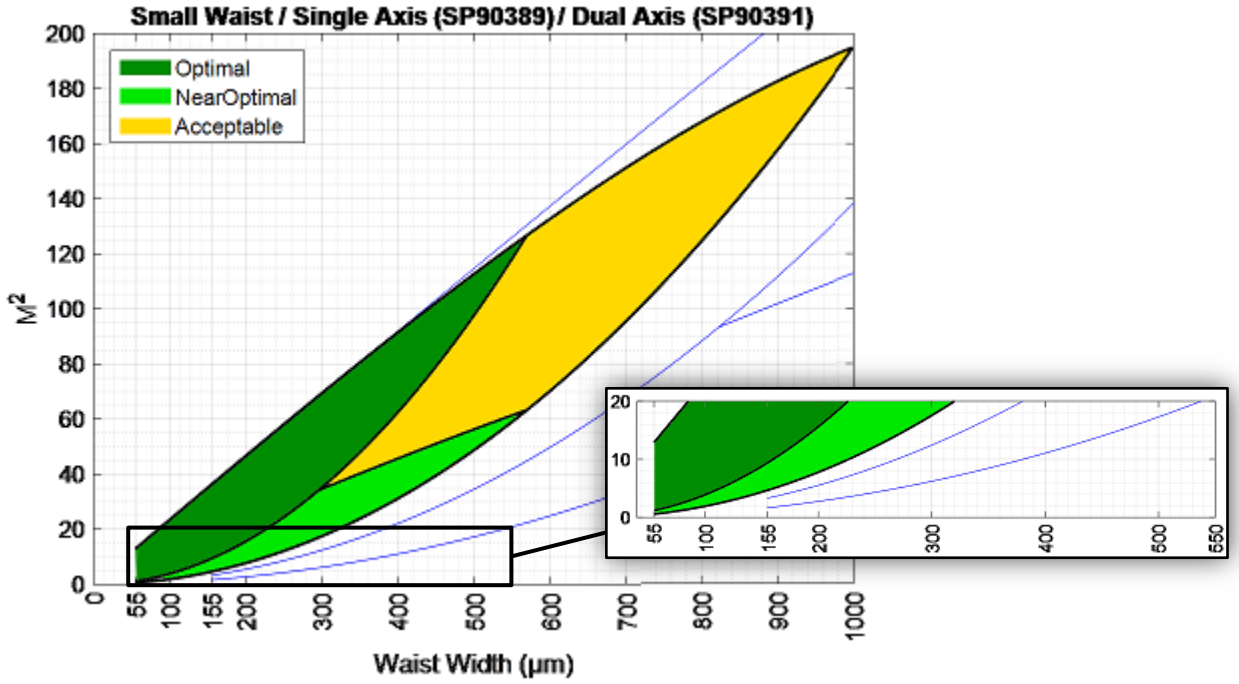
Wavelength	980 – 1080 nanometers
Minimum Power density	~2 Megawatts/cm^2
Minimum Focus Spot **SP90335/SP90390** **SP90389/SP90391**	 155 microns 55 microns
Camera Field of View inside the BeamWatch unit **SP90335 (Single axis)** **SP90389 (Single axis)** **SP90390 (Dual axis)** **SP90391 (Dual axis)**	 32.17mm x 17.09mm 11.26mm x 5.98mm 32.17mm x 8.55mm 11.26mm x 2.99mm
Maximum Beam diameter at entrance/exit	12.5 millimeters
Communication to PC	GigE Ethernet
Power	12 Volts DC, 1.67 Amps max
Particulate Purge	Clean Dry Gas (Air, Nitrogen, or Argon), approximately 10 LPM

The plots below are intended to give a visual indication of the recommended operating space for BeamWatch. If BeamWatch is operated outside of this space, it may be more difficult to see the curvature of the caustic or the beam may be large enough at the edges of the image that it is out of focus.

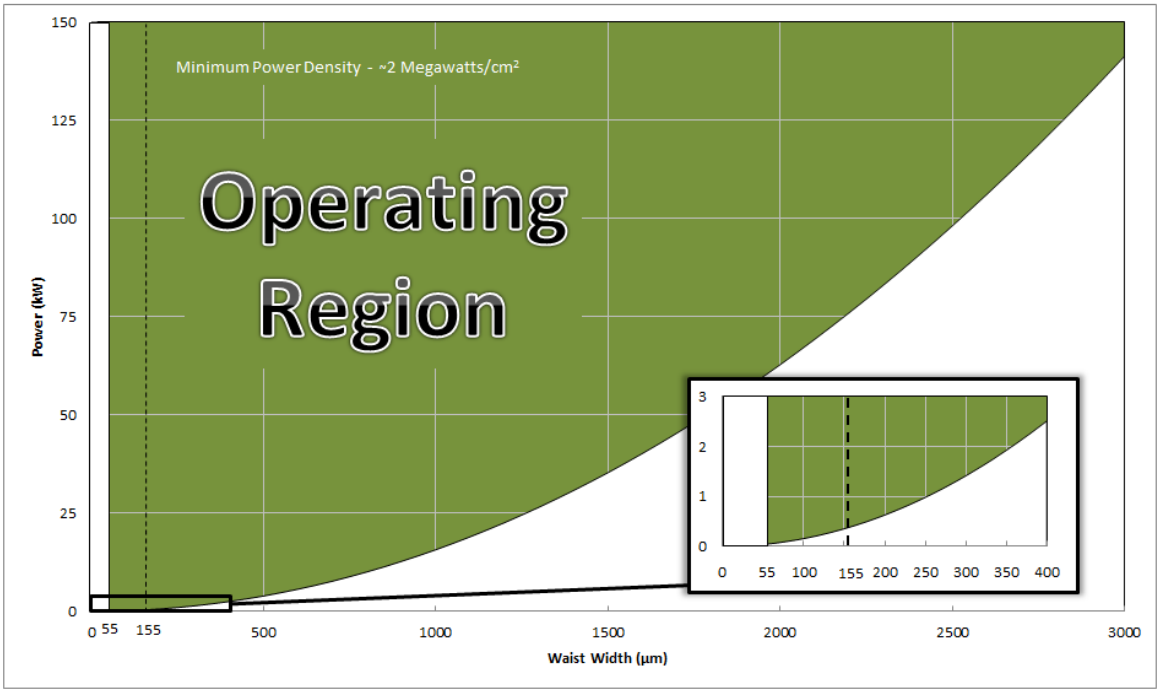
- Optimal has at least 3 Rayleigh lengths on both sides of the waist, with the waist at the center of the image
- Near Optimal has at least 3 Rayleigh lengths on one side of the waist, with the waist at the end of the image
- Acceptable has at least 1.5 Rayleigh lengths on both sides of the waist, with the waist at the center of the image



*** Below 155µm, see chart for Small Waist (SP90389 and SP90391)**



The power density also plays a role in the operating space. The chart below shows the required power vs. focus spot size for a top hat beam.



The equation to estimate the maximum spot size is derived from the power density equation.

$$Power\ Density = \frac{P_{ave}}{A_{1/e^2}} \geq 2 \times 10^6 \frac{W}{cm^2}$$

Where P_{ave} is the average beam power and A_{1/e^2} is the area of the beam at the $1/e^2$ location.

1.2 Computational Accuracy

Accuracy Specifications

- Waist Width (Spot Size) ±5%
- Waist Location ±125 microns within the BeamWatch window
- Focal Shift ±50 microns
- Beam Parameter Product ±3.5% RMS
- Divergence ±3.5% RMS
- M^2 ±3.5% RMS

BeamWatch is a revolutionary product with unique measurement abilities.

The focus spot size is calculated in milliseconds without contacting the beam. Compared to products that also measure spot size, BeamWatch produces accurate results to within ±5%.

BeamWatch is the first product capable of measuring dynamic focal point shift. This focus position is measured in two dimensions; along the caustic and orthogonal to the camera viewing direction. Measurement of these at the BeamWatch video frame rate of ~6Hz provides dynamic measurement of the focal shift in near real-time. This is useful to find the

behavior of the focal spot during critical startup moments and how it may vary after running for long periods of time. Within the BeamWatch measurement window, the accuracy of the focal point location is ±125µm.

CHAPTER 2 Hardware Configuration

This chapter will walk you through how to setup and start using your BeamWatch including:

- Camera setup
- Aligning your beam with BeamWatch

Dimensions of the BeamWatch and the mounting plate are shown in APPENDIX A.

Important: *Two plugs are provided to keep dust out of the BeamWatch system. Make sure* ***both*** *of these plugs are removed before use with a laser.*

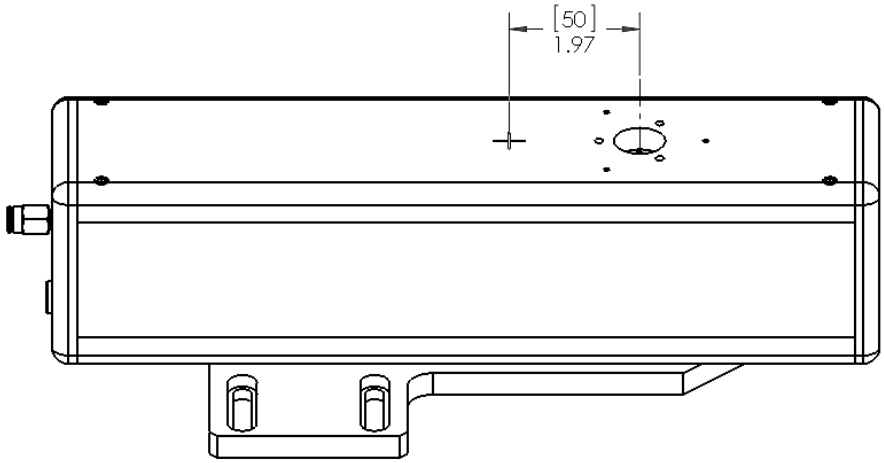
2.1 Camera Mounting

The BeamWatch unit must be mounted to a stable surface. A slotted mounting plate is provided with the system. Once in the desired location, secure the unit with four ¼-20 or M6 screws in the slots. If not mounted in a fixed position, measurement error or damage to the unit may occur.

2.2 Camera Positioning

Position the BeamWatch unit in the path of the laser beam with the top of the unit facing the laser delivery head. The center of the entrance aperture is located 50mm from the crosshair marked on the top of the camera (see image below). Make sure the beam is passing unobstructed through the entrance and exit apertures.

Note: *An alignment tool is provided for use with low power alignment beams only. Do not use with high power beams. This device is described in a user note supplied with the unit.*



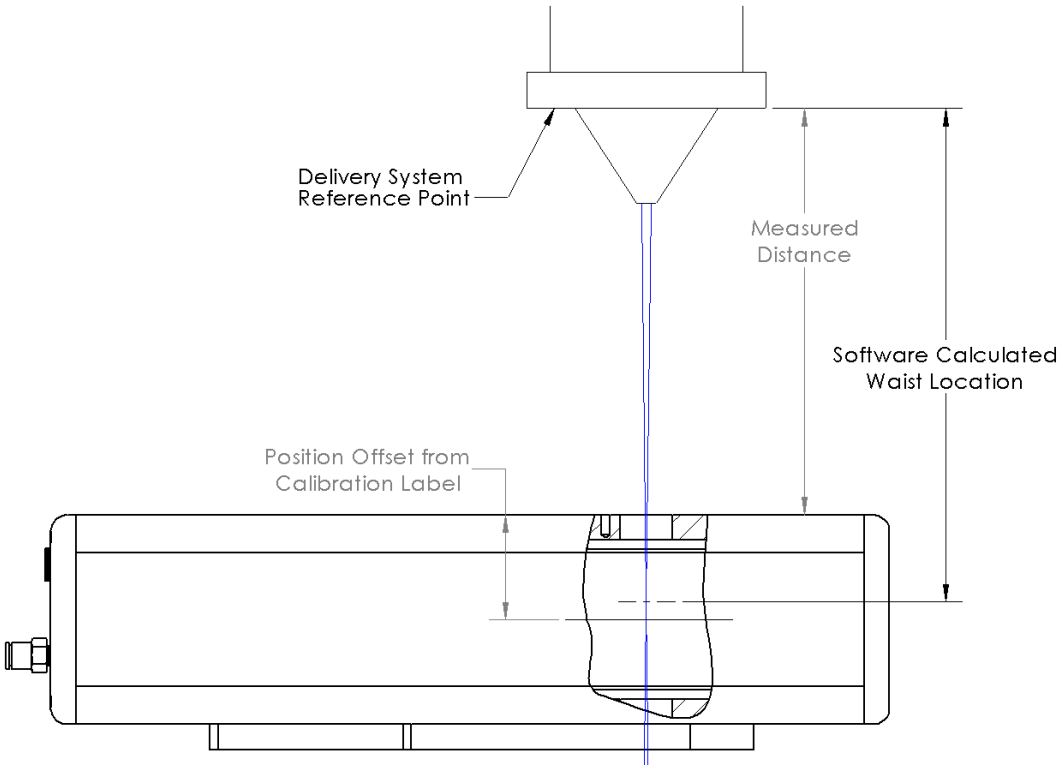
Along the laser axis, position the BeamWatch unit at the nominal focus position. (Refer to APPENDIX A for axis identification.) To obtain results within ±5% accuracy, the camera must be aligned perpendicular to the beam with minimal tilt (<5°) in all directions and the beam

must lie in the plane of the camera focus. Use either a translation stage or the laser robotics to facilitate the positioning of the beam in the camera focus plane.

Position the BeamWatch unit so the beam waist is approximately in the center of the unit. The scribe mark on the side of the camera is a reference to this position. The calibrated distance from the top of the BeamWatch to the center of the detector array can be found on the calibration sticker.

There is no automated method for finding the major and minor axes of elliptical beam. The BeamWatch unit must be manually rotated to find these axes. A rotation mount (SP90346) is offered as an accessory to assist in this alignment. After the software is installed and the beam is centered in the BeamWatch unit, rotate the unit around the beam while viewing the Waist Width result in the software until max/min values are found. For best measurements with dual axis BeamWatch units, rotate the BeamWatch until the major and minor axes of the beam are aligned with the X and Y axes of the software. It is irrelevant which of the BeamWatch axes views the major or minor axes of the beam.

After the BeamWatch is positioned, measure the distance from any desired reference point on the laser delivery head to the top face of the camera. This value is the **Distance** of the laser and must be entered into the software during setup (see section 4.4.3). The software automatically adds the calibrated distance from the top of the unit to the center of the camera imager. This value is used to calculate the Waist Location result as the total distance between the laser source and the focus spot. The image below shows where each measurement point is located.



2.3 Beam Dump

A suitable beam dump, such as a power meter, must be provided. To obtain accurate results, the beam dump must have minimal backscatter, such as a cone type or black absorber power meter. We recommend an Ophir Power Meter rated for your laser power. Contact your Ophir-Spiricon representative for additional information.

2.4 Particulate Removal

The industrial laser environment has high levels of particulates that must be removed from the camera FOV to obtain accurate results. With BeamWatch, this is accomplished by generating a laminar flow region at the camera FOV using a clean, dry gas source. We recommend Air, Nitrogen, or Argon. Connect the provided hose to the gas source. Adjust either the flow regulator on the BeamWatch unit or the gas source until a steady flow is achieved, approximately 10 LPM. A weak flow will not be effective, and a flow that is too strong will become turbulent.

Once the software is installed and a high-power laser is being viewed, it may become apparent that the flow needs to be adjusted. When a particulate contacts the beam, it appears as a streak of high intensity light in the software, often saturating the beam image. Adjust the flow until a minimum amount of particulates are seen.

2.5 Camera Electrical

Using the provided power cord, connect the 12 VDC connector to the camera. Plug the other end into a surge protected 100-240 VAC outlet.

Connect one end of the supplied Ethernet cable to the camera. Refer to APPENDIX A for connector locations. Connect the free end of the Ethernet cable to an available Ethernet port on your computer. Alternatively, if there are no available Ethernet ports, connect the Ethernet cable to the provided USB 3.0 to Gigabit adaptor and connect the free end to an available USB 3.0 port on your computer.

This completes the hardware setup of your system.

Important: *Two plugs are provided to keep dust out of the BeamWatch system. Make sure* ***both*** *of these plugs are removed before use with a laser.*

CHAPTER 3 Software Setup

This chapter will walk you through how to setup and start using your BeamWatch including:

- Installing BeamWatch software
- Launching BeamWatch

BeamWatch is designed for use on a personal computer running Windows 7 or Windows 10 64 bit operating systems. For best performance, it is recommended that your system also includes:

- Advanced Graphics chip set with 1GB of dedicated graphics memory
- At least 4GB of main memory (8GB is preferred)
- At least 50GB of hard disk space available, much more (>100GB) to log large data files
- A high-resolution color monitor, 1440x900 minimum recommended
- A CD-ROM Drive

3.1 BeamWatch Software Installation

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

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

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

After the program is installed, the BeamWatch icon 

will appear on your desktop. This completes the installation process.

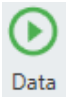
The latest version of the software can be found on the Spiricon website at www.ophiropt.com.

3.2 Launch BeamWatch

To start the BeamWatch software, double click the desktop icon or go to the Windows taskbar and select **Start** > **All Programs** > **Spiricon** > **BeamWatch** > **BeamWatch**

Enter the laser wavelength and the distance from the delivery head reference point to the top of the BeamWatch unit in the **Laser** panel. You are now ready to start taking measurements.

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

With the camera plugged into the PC, when BeamWatch opens it will automatically connect to the camera. The default configuration is loaded. Displays will initially appear blank. Click on the Data  /  button to start and stop data collection.

CHAPTER 4 BeamWatch Operating Controls

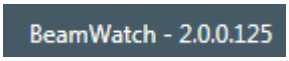
This chapter describes the various screen and display features as well as the controls provided both within the Ribbon bars and inside the various display windows.

BeamWatch was designed to have a minimal amount of controls to make the application simple and intuitive to use. This allows for quick and accurate measurements to be made without spending a lot of time on configuring and learning the software.

4.1 Title Bar Features

Ophir-Spiricon, LLC's (Spiricon) BeamWatch employs the Windows ribbon control motif which provides intuitive access to control functions as well as the ability to hide the controls for better screen utilization. This chapter describes the various control features available in BeamWatch beginning with the terminology used to identify the basic control forms.

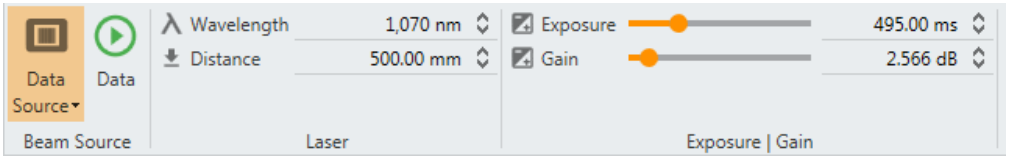
Title Bar The upper bar on the application contains, from left to right, the

- System Menu button 
- Quick Access Toolbar 
  - The button shown here is Start/Pause data collection
- Application name and version number 

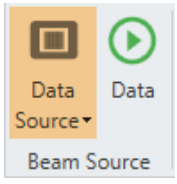
- Standard Windows Minimize, Maximize, and Close buttons 

Ribbon Tab 

This bar looks like the traditional menu bar but is now used to define the current ribbon control being accessed. Double click on any tab heading to open and close the entire ribbon bar display area. If the ribbon bar is closed, a single click will temporarily open the selected tab just long enough to modify a single entry item. Double clicking on a blank space in this bar will maximize the entire display.

Ribbon Bar 

This area displays the current set of panel control options available within a selected ribbon tab. These panels contain all of the common control items.

Panel 

Panels contain buttons, dropdown lists, edit controls, etc. Tool tips are available on most all controls. Hover the mouse over a control to view these tips.

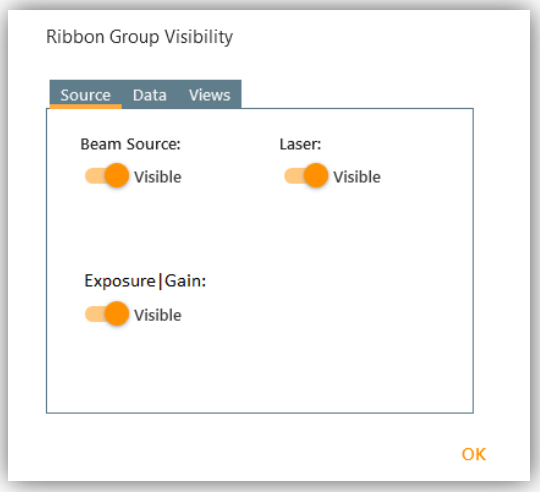
Display Area The display area, the area below the ribbon bar, consists of the calculated results, the 2D beam image, the beam profile display at the cursor location, the 3D beam

image (in dual axis systems only), and time charts,. Each of these displays can be disabled, resized, docked, or floated to any location on the screen. The content of the display area is explained in chapter 5.

Status Bar The bottom line of the BeamWatch application contains information about the current operating condition. The content of this bar is explained in section 5.4.

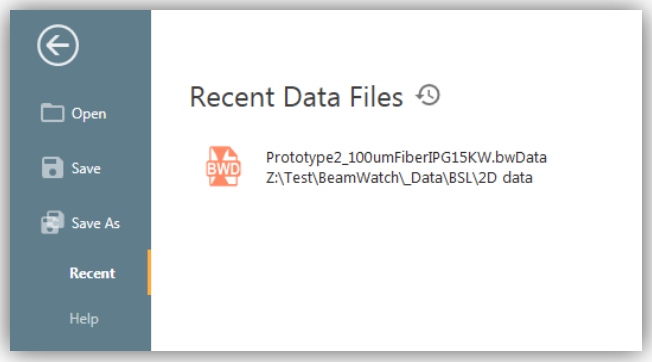
4.2 Ribbon Group Visibility

Located below the Close button is the **Ribbon Group Visibility** configuration . This opens a dialog box that allows turning on or off ribbon panels. Select which ribbon to view and click the slider to turn the panel on or off.



4.3 Backstage View

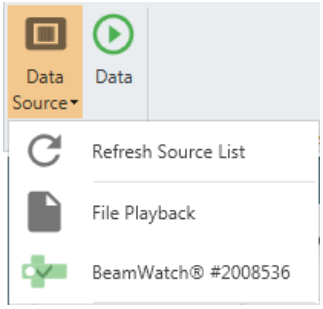
Data files are saved and loaded via the Backstage view. Below is an example. The files listed on the right are recently saved or opened files. To perform a quick reload from the list, click once on the desired file name. The **Help** option provides a link to this user guide and displays the current software version and copyright information.



4.4 Source Ribbon

The **Source** ribbon contains controls that may vary between cameras or beams.

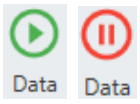
4.4.1 Data Source



Click this control to display a dropdown list of connected BeamWatch units sorted by serial number. Select the unit to connect to the application. When launching BeamWatch, this list will populate with all available cameras and automatically connect to the first camera found. The source list will not update again unless **Refresh Source List** is clicked, even if additional units were connected or disconnected.

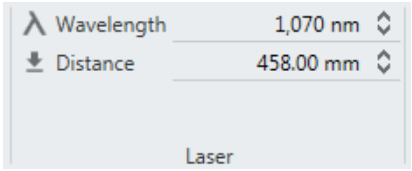
File Playback is used to load saved files into the frame buffer for review. Selecting this option will open the standard Windows navigation window to browse and select a saved *.bwData file.

4.4.2 Data



This control provides the only manual means of starting and pausing the data collection process of BeamWatch. Their operation should be instantly recognizable because of their familiar design. This control is repeated in the Quick Access Toolbar and with the keyboard shortcut **Ctrl**+**Spacebar**.

4.4.3 Laser



Use this panel to enter information about the laser. This information is used in the calculation of results.

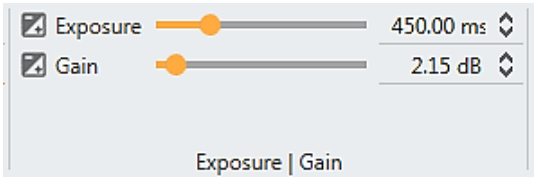
Wavelength Enter the wavelength of the beam in nm. This value is used when calculating the Beam Quality results such as M^2 and Divergence.

Distance Enter the measured distance from any desired reference point on the laser delivery head to the top face of the unit in mm.

The distance from the top of the BeamWatch unit to the center of the camera sensor array is calibrated at the factory. For reference, this position offset can be found on the calibration label supplied with the unit. The software automatically adds this value to the user-entered

distance to get the total distance from the delivery head reference point to the center of the camera. The total distance is used when calculating the Waist Location result and when determining the current cursor location.

4.4.4 Exposure|Gain

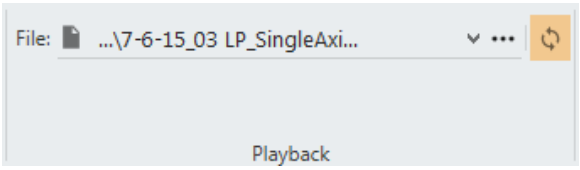


This control is only available when a BeamWatch unit is connected to the software. Use the slider or the text box to enter the **Gain** and **Exposure** for the camera. These options determine the intensity and quality of the output image.

Increasing the **Exposure** time is the desired method for obtaining a higher SNR and a brighter image. This control sets the amount of time the camera looks at the beam before reporting a frame.

The **Gain** setting is used less often. A higher Gain value will improve the quality of the image, but this method should be used sparingly. A value set too high will begin to overcorrect and make the image worse.

4.4.5 File Playback



When loading a data file, file playback is enabled. This allows the user to review and play thru a selected data file that contains multiple frame records. The frames are loaded into the frame buffer and can be scrolled thru manually with the frame buffer, or automatically by clicking the button.

Data files can store a maximum of 999 frames using the Frame Buffer. They also store the existing BeamWatch settings including wavelength, distance, summing, averaging, and notes.

Note: *All existing settings will be overwritten whenever a data file is loaded. If the current settings are important, a data file should be saved before any other data file is loaded.*

To exit File Playback and collect live data again, click **Data Source** and reselect your camera.

Note: *Files saved in BeamWatch v1.x have a* ****.lbd*** *extension and can be loaded into the current software version. These files will be automatically converted and a new file will be saved with a* ****.bwData*** *extension.*

File This field displays the name and location of the file currently being viewed. Clicking on the file name will open a list of recent files.

File Browse This button opens the standard Windows Explorer dialog box. Navigate to and select the data file to be reviewed. Data files can also be loaded using the Backstage

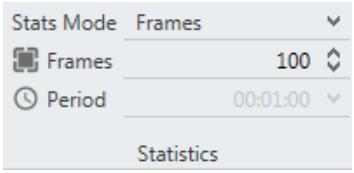
view, by dragging and dropping a file into the BeamWatch window, or by selecting **File Playback** in the **Data Source** dropdown.

Loop Playback  When this button is enabled, the playback will loop continuously thru the frame buffer.

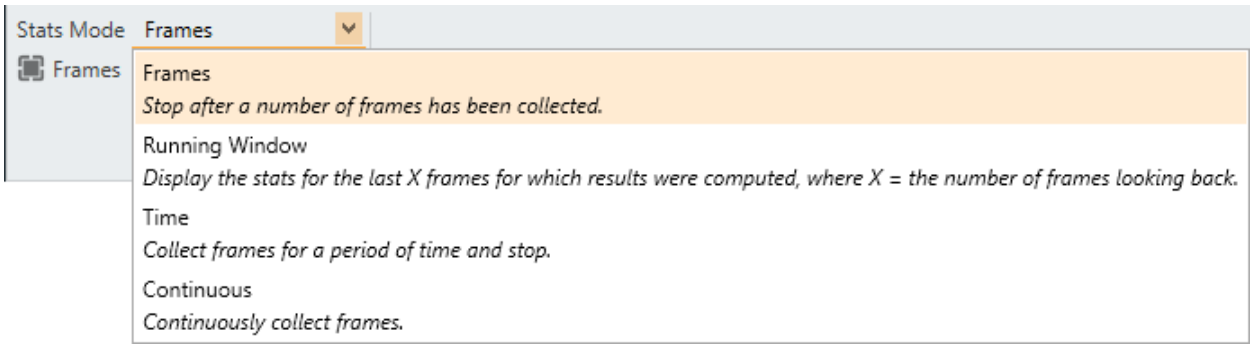
4.5 Data Ribbon

The **Data** Ribbon provides many of the standard controls for managing how the image data is captured and processed.

4.5.1 Statistics



This panel sets the number of samples to use in computing the statistical results values.



There are four different running modes for collecting statistics.

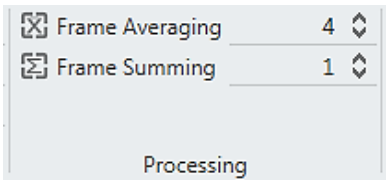
Frames One of the most common and simplest methods for collecting statistics is to set the number of frames to collect and report the results on. Statistics will stop calculating after the set number of frames are collected. The maximum number of frames is 9,999.

Running Window This method allows statistics to be recomputed continuously but only the values from the last number of specified frames will be used. The maximum number of frames is 9,999.

Time Set the period of time over which statistics will be collected in HH:MM:SS. Statistics will stop calculating after the set time has passed. The maximum time is 23:59:59.

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

4.5.2 Processing



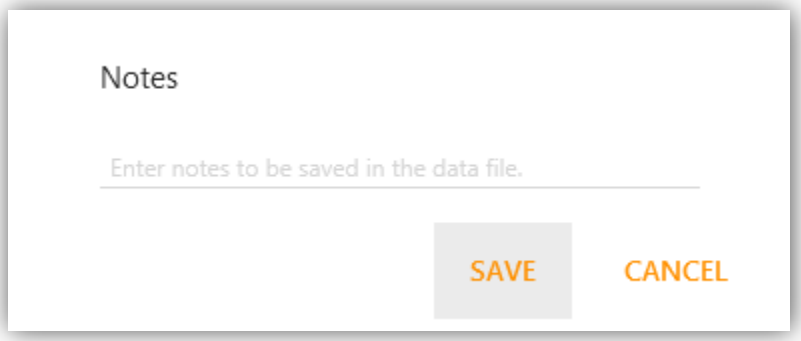
This panel allows for various types of image processing which is applied as frames of data are collected. These controls are described below.

Frame Averaging Enter the number of frames to be averaged while collecting data. The averaging result is added to the frame buffer and used in calculations. In this example, four frames are averaged and the resulting single frame is added to the frame buffer and used in calculations. Frame averaging is a convenient method that can improve the signal-to-noise ratio (SNR) when observing low signals where noise is a significant problem. The SNR is improved by the square root of the number of frames averaged.

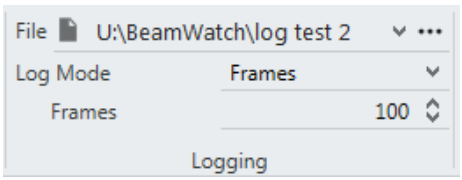
Frame Summing Enter the number of frames to be summed. The summing result is added to the frame buffer and used in calculations. In this example, frame summing is set to one, which disables summing. Frame summing is a technique to increase the amplitude of weak signals, especially for beams rated <5kW. Be cautious, the displayed signal may become saturated and the calculated results will become invalid if too many frames are summed.

4.5.3 Notes

Select this button to open a separate **Notes** window for user text entries. This window will automatically resize to fit the text that is entered. Add notes at any time. To close the window, click **Save** or **Cancel**. Cancelling will revert to the previously saved state. Notes are saved in the *.bwData file and loaded when reviewing data.



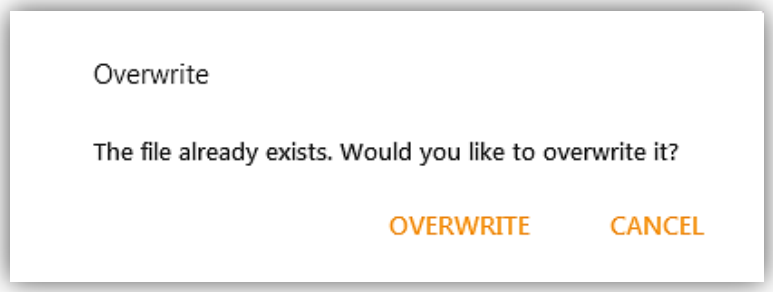
4.5.4 Logging Controls



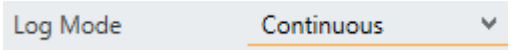
Logging is used to record data files for results. Each logging file contains a time stamp and only the results and statistics that are enabled. Logs are saved as *.csv files and can be imported into Excel or similar programs for further analysis. Changes in this panel cannot be made while data acquisition is running.

All log file entries that pertain to one frame of data 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.

File This field displays the name of the file and the save location where the current logging operation will save. Clicking on the file name opens a list of recent files and locations. If the specified file already exists when logging is started, a dialog appears asking to overwrite or cancel the logging operation.



File Browse This button opens the standard Windows Explorer dialog box. Navigate to save location and enter the Log File Name in the **File Name** field, then click **Open**.

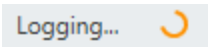
Log Mode 

This control enables logging and sets the logging method. Log files can be set to capture a specified number of frames, run for a certain period of time, or log continuously until data acquisition is stopped.

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

If the **Log Mode** is set to **Frames** or **Time**, data acquisition will automatically stop when the log file is complete. Whenever logging is stopped, no matter by what means, the **Log Mode** is automatically set to **Disabled**. To begin a new logging cycle the logging method must be re-selected. This is to prevent accidentally filling the hard drive.

When time or frame logging is in process, a progress meter 

will appear in the status bar. When logging continuously, a processing icon 

will appear in the status bar. This gives a visual reminder that the log is running.

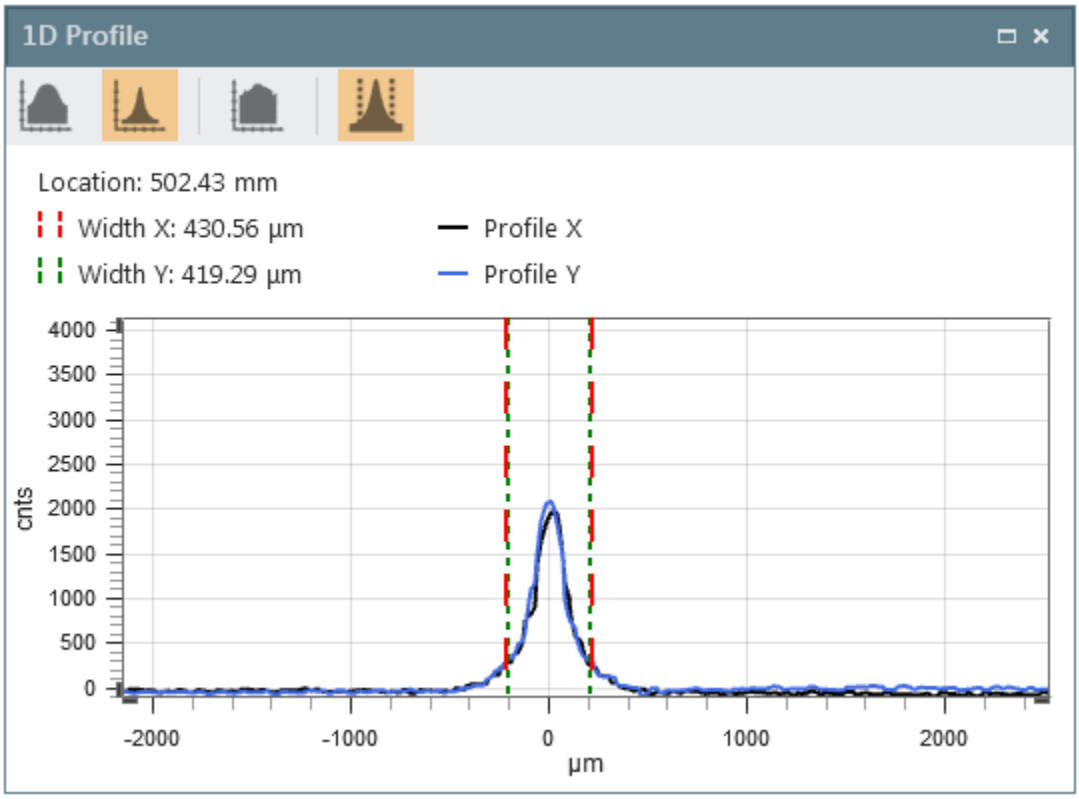
4.6 Views Ribbon

This ribbon provides a way to open and close different windows in the display area. If a window is closed, this ribbon provides the only means of restoring the display.

4.6.1 1D Profile

This display shows the scanning slit equivalent profile at the cursor location. Drag and drop the dotted line (cursor) in the **2D Beam Display** window to the desired position along the beam to see the profile at that location. The location of the cursor and the beam width at that position are shown at the top of the display.

When viewing two axes of the beam, the profiles are overlapped in the **1D Profile** display with the centroids aligned. This can help visually determine if there is astigmatism in the beam.



The horizontal axis is the width of the ROI with zero at the center of the beam(s). The vertical axis is the raw pixel counts of the data. The scale can be changed with the **1D Profile** controls.

This display can zoom in and out using the mouse wheel and can be panned by clicking and dragging the mouse inside the chart area.

4.6.1.1 1D Profile Controls 

These controls are specific to the **1D Profile** display. They control the vertical axis of the display and enable the beam width markers.

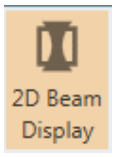
Logarithmic Scale  Set the vertical scale to logarithmic. This is helpful to enhance and view the noise on the sides of the beam.

Linear Scale  Set the vertical scale to linear.

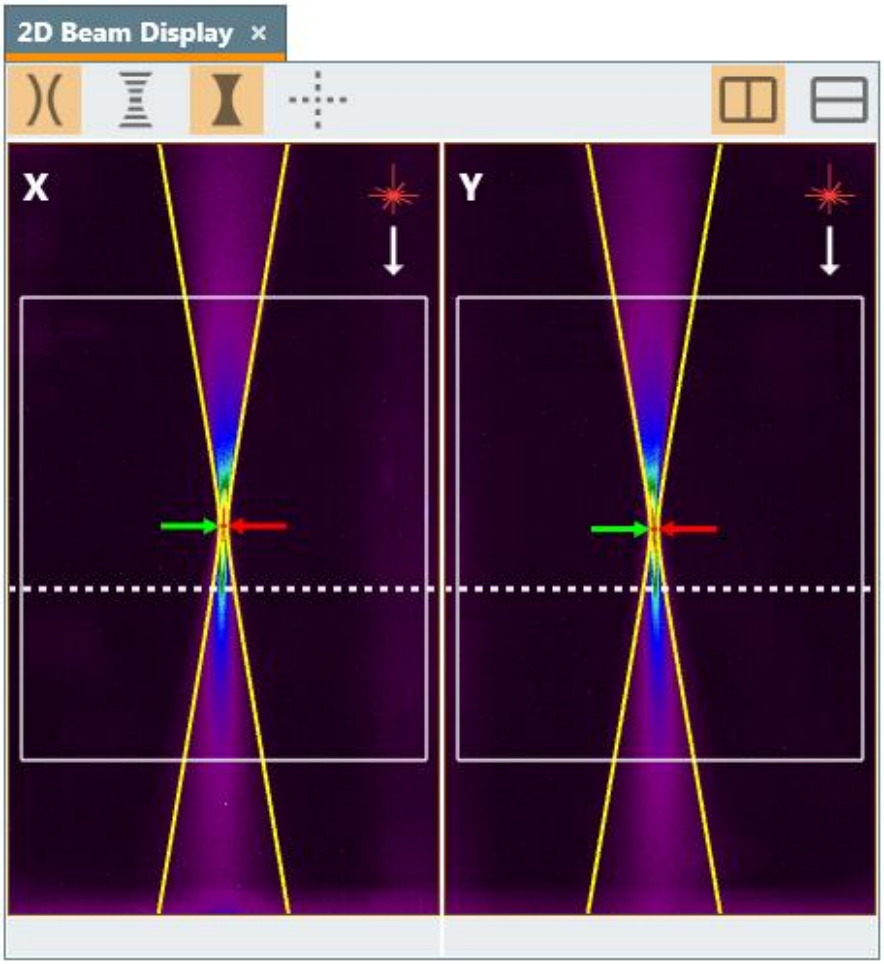
Auto Scale  Enable/Disable the auto scaling option for the 1D profile when viewing a linear scale.

Beam Width Markers  Enable/Disable the calculated beam widths at the cursor location.

4.6.2 2D Beam Display



The **2D Beam Display** window is shown below. In the image, the fitted caustic and the beam image are both enabled.



The white border is the region of interest (ROI) for calculating results. This region is always rectangular and is drawn automatically around the beam. This allows for the most accurate results calculations.

The white dotted line across the ROI is the cursor location. The **1D Profile** display shows the scanning slit equivalent profile at the cursor position. Click and drag the cursor to any location along the beam to view the profile at that location. The **Width at Cursor** result will report the beam width at the location of the cursor using the 13.5% of Peak method.

The red line is the waist location reference point. This line is drawn at the first calculated beam width position after starting data collection. Reset this position to the next valid beam width location by selecting **Reset** in the **Results** window. The red arrow to the right of the caustic always points to the waist location reference point and shows the location more clearly.

The green line is the current waist location. This line will drift as the waist location of the beam changes. The green arrow to the left of the caustic always points to the current waist location and shows the location more clearly.

4.6.2.1 2D Beam Display Controls 

These controls are specific to the **2D Beam Display** window. They control the display layers as well as the display orientation of the beam.

Beam Fit  Enable/Disable the yellow fitted beam width. Turning this off will also remove the ROI and waist location markers. When disabled, there is a better view of the beam edges.

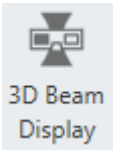
Raw Beam  Enable/Disable the red raw (measured) beam width data points. This may be beneficial to view the actual measured widths if unexpected results are being obtained.

Beam Image  Enable/Disable the 2D beam display image. Turn this off to see a clearer view of the caustic or raw data.

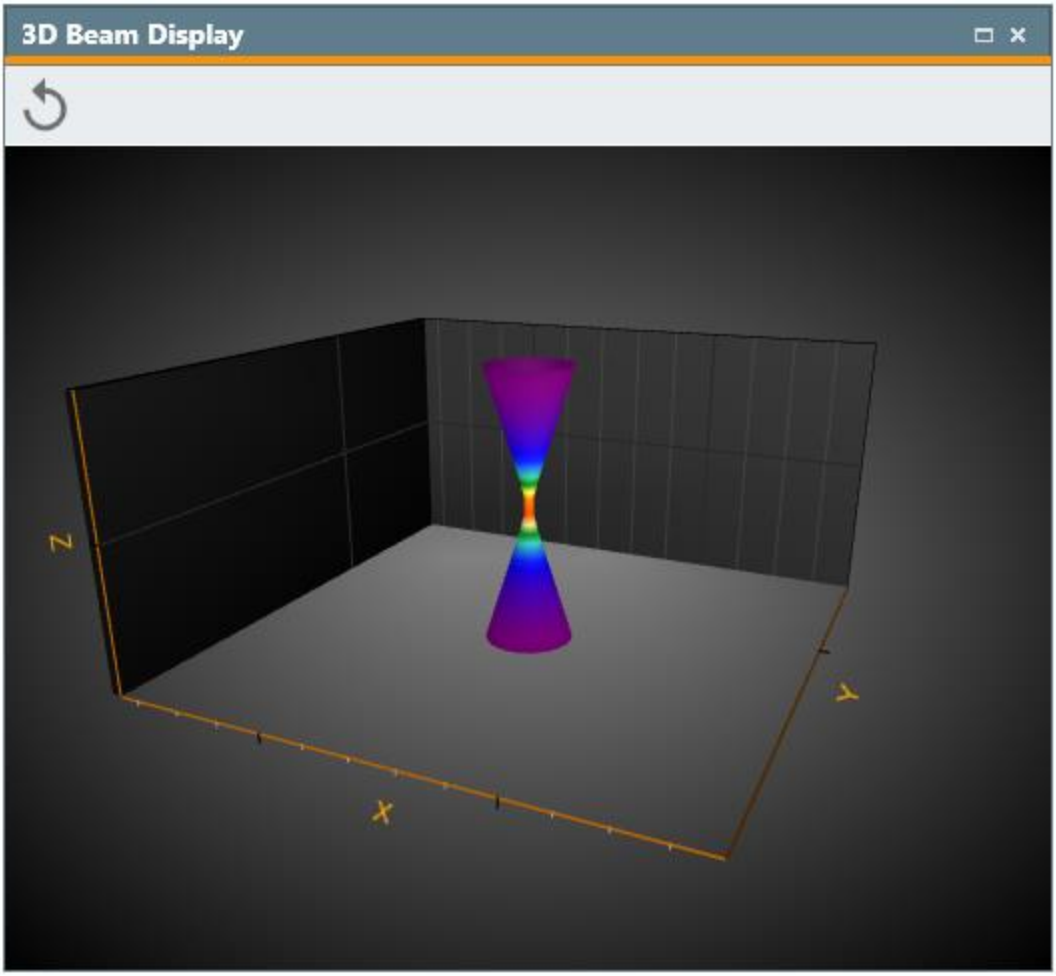
Alignment Crosshair  When enabled, a crosshair is overlaid in the **2D Beam Display** window at the center of the detector array. When viewing two axes of the beam, two crosshairs will appear marking the center of each area. The beam is aligned and the best results are obtained when the beam waist is centered on these crosshairs.

Vertical Display  Display the beam in a vertical direction in the application.

Horizontal Display  Display the beam in the horizontal direction in the application.

4.6.3 3D Beam Display 

Only available in dual axis units, the **3D Beam Display** window shows an interpolated reconstruction of the beam. This display can be rotated, panned, and zoomed using the mouse as described below.



Rotate - Position the cursor over the image, depress the left mouse button, and drag the mouse to obtain the desired orientation.

Pan - Position the cursor over the image, depress the right mouse button, and drag the mouse to move the image to the desired location.

Zoom - Zoom in and out by placing the cursor over the display and scroll with the mouse wheel.

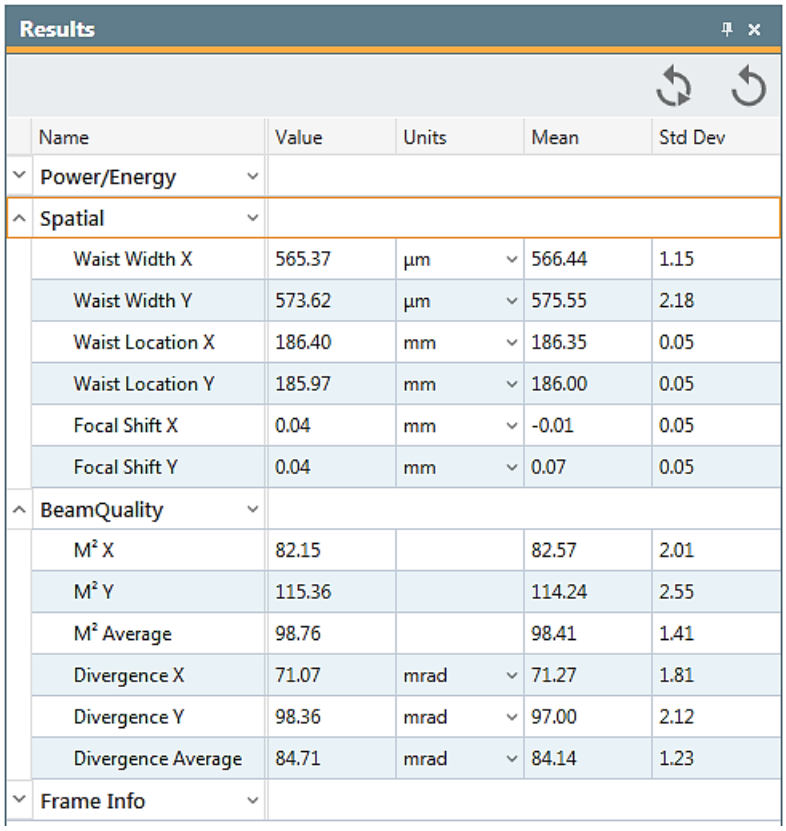
Reset  Click this button to reset the position of the 3D display to the default state.

4.6.4 Results Display 

Results groups have dropdown controls that select which results items are enabled as well as other related features such as:

- Collapse/expand a group
- Enable Statistical results for a group

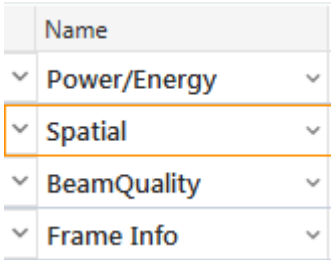
Relative Power is the average number of counts in each slice of the beam. **Centroid** is measured from the center of the display window. A negative **Focal Shift** indicates an upward drift in the focus spot location as shown on the BeamWatch 2D display.



Name	Value	Units	Mean	Std Dev
Power/Energy				
Spatial				
Waist Width X	565.37	µm	566.44	1.15
Waist Width Y	573.62	µm	575.55	2.18
Waist Location X	186.40	mm	186.35	0.05
Waist Location Y	185.97	mm	186.00	0.05
Focal Shift X	0.04	mm	-0.01	0.05
Focal Shift Y	0.04	mm	0.07	0.05
BeamQuality				
M^2 X	82.15		82.57	2.01
M^2 Y	115.36		114.24	2.55
M^2 Average	98.76		98.41	1.41
Divergence X	71.07	mrad	71.27	1.81
Divergence Y	98.36	mrad	97.00	2.12
Divergence Average	84.71	mrad	84.14	1.23
Frame Info				

Reset on Start  When enabled, this control will cause all statistics to Reset when data acquisition is started. This is a good way to ensure all statistics stay in sync. This also resets the red focal point reference position in the **2D Beam Display** window and all open charts.

Reset  Click on this momentary button to reset all statistics at any time. This also resets the red focal point reference position in the **2D Beam Display** window and all open charts. Results will also reset if the **Reset** button in the **Charts** window is clicked.

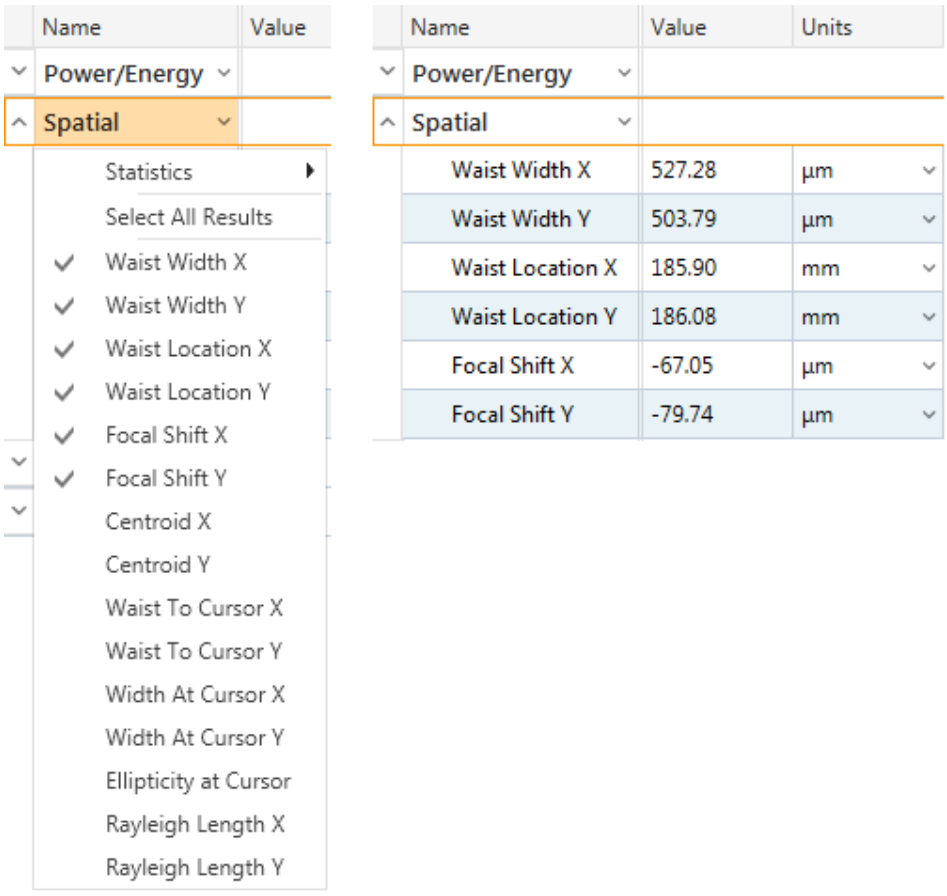


The Results items are grouped into logical divisions. The names are self-descriptive and will lead you to where to look for a specific type of result.

Click on the group name to open a dropdown selector of the results within the group. The ⌄ control to the left of the result group name will expand the group and show the enabled result items.

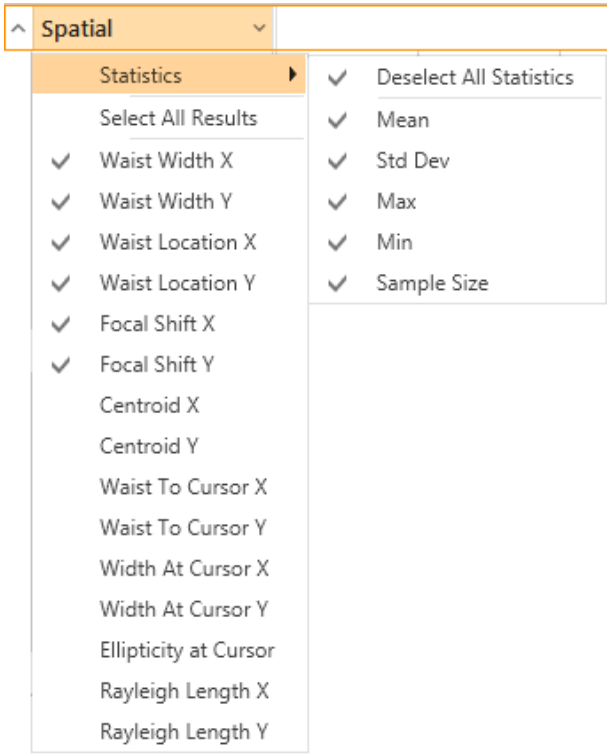
When connected to a dual axis BeamWatch, the **Spatial** group will contain the results items shown below. When connected to a single axis BeamWatch, the results are condensed, showing a single result without indication to X or Y.

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



4.6.4.1 Group Statistics

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

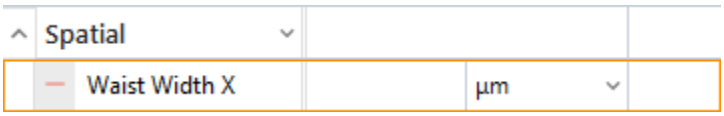


The figure below shows how a full set of statistics will appear.

Name	Value	Units	Mean	Std Dev	Max	Min	Sample Size
Power/Energy							
Spatial							
Waist Width X	29.76	µm	31.44	2.27	40.53	29.11	32
Waist Width Y	29.75	µm	31.18	1.56	33.12	29.11	32
Waist Location X	502.75	mm	502.77	0.06	502.81	502.48	32
Waist Location Y	502.76	mm	502.78	0.03	502.81	502.72	32
Focal Shift X	-0.02	mm	-0.01	0.06	0.04	-0.29	32
Focal Shift Y	-0.02	mm	0.00	0.03	0.04	-0.05	32
BeamQuality							
M^2 X	2.11		2.09	0.18	2.62	1.29	32
M^2 Y	2.11		2.11	0.10	2.62	1.96	32
M^2 Average	2.11		2.11	0.10	2.62	1.96	32
Divergence X	96.79	mrad	91.14	11.50	120.96	43.21	32
Divergence Y	96.73	mrad	92.55	7.51	120.96	85.06	32
Divergence Average	96.76	mrad	92.54	7.51	120.96	85.06	32

4.6.4.2 Close

To remove a results item from the **Results** display, place your mouse on the title of the result item and click on the close icon that appears next to it. Observe that if the result item has been dragged and dropped in another window, closing it in the results window will also remove it from all other windows.

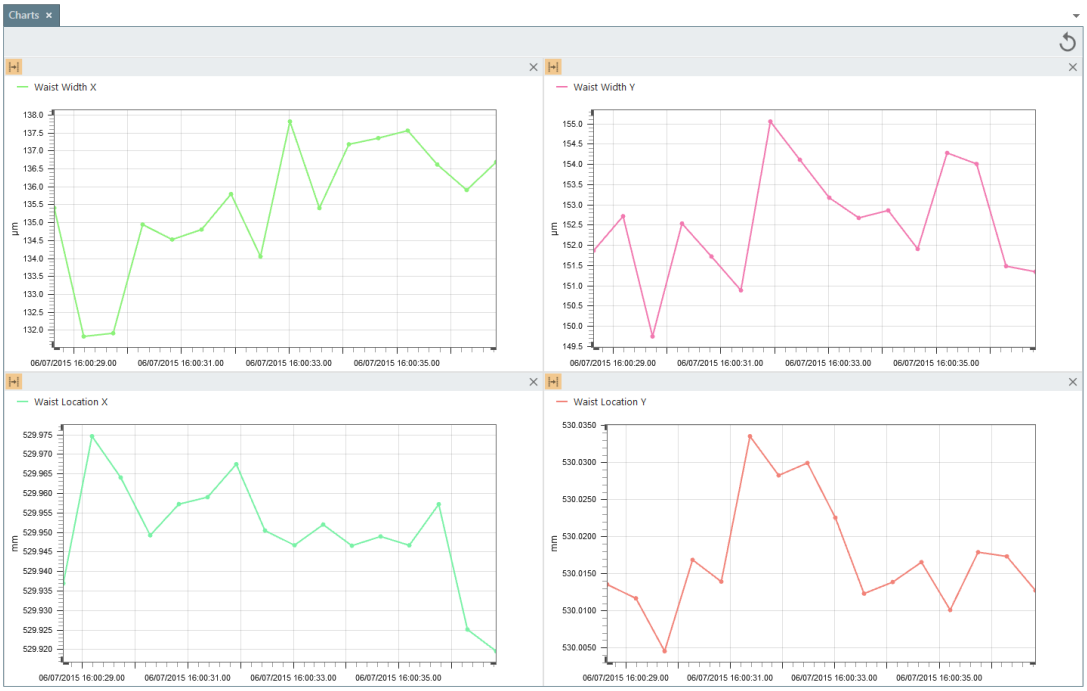


4.6.4.3 Create Chart

Left click on a result name and select **Create Chart** to open a new time chart for that result. Time charts are plots of selected result items as they change over time. When charting, the **Charts** window will open and all enabled time charts will be added.

4.6.5 Charts

Charts are opened by left-clicking on a result in the **Results** window and then clicking **Create Chart**. The **Charts** window will open, if it is not already, and the new chart will be added to it. As more charts are opened, they create a tile pattern in this window. In the image shown below, four charts have been created.



Each result can be charted. If a chart is closed, the data is deleted. When loading a saved file, the chart data is not automatically restored, but can be recreated by playing thru the frame buffer.

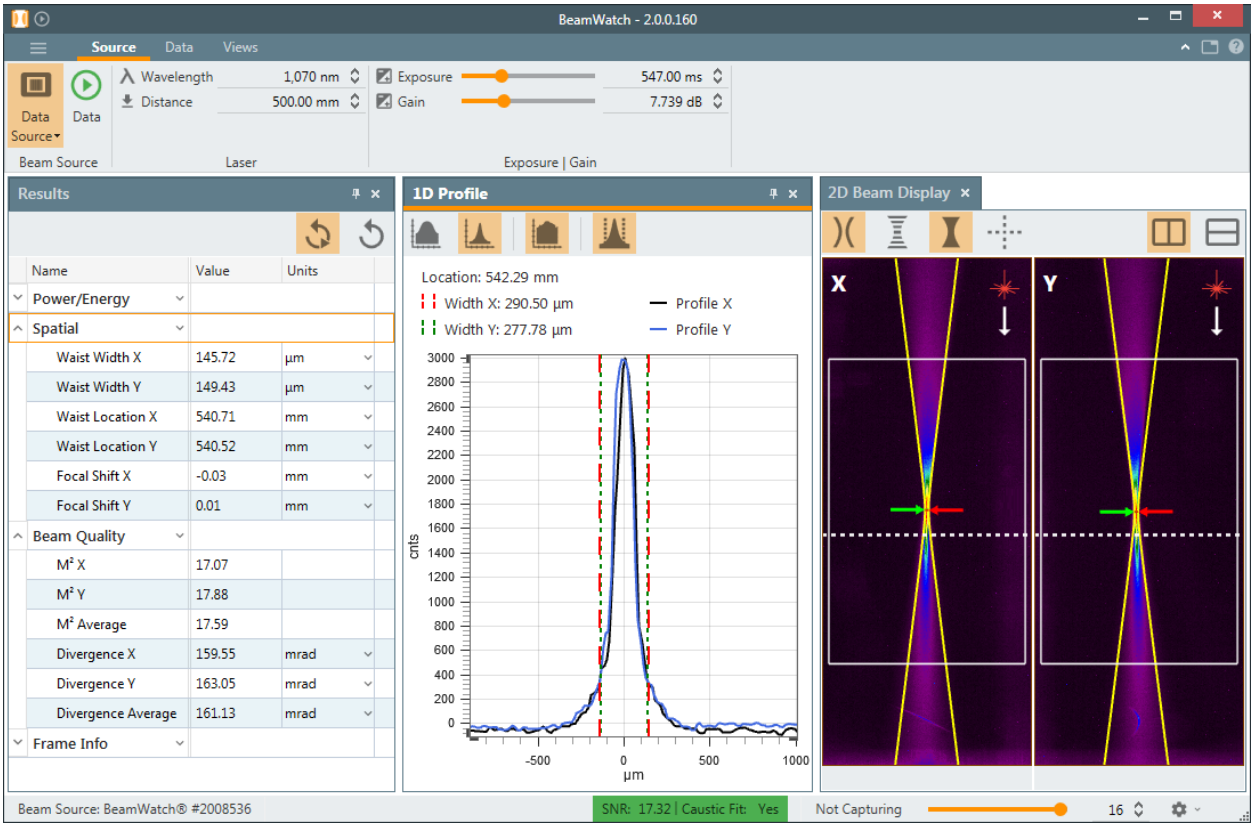
Reset  Click on this momentary button to reset all charts at any time. This also resets the red focal point reference position in the **2D Beam Display** window and all results. Charts will also reset if the **Reset** button in the **Results** window is clicked.

Auto Adjust Range  When this button is enabled, the chart automatically adjusts to fit all data points. When disabled, click and drag in the chart area to pan along the time axis. Auto Adjust can be enabled/disabled for each chart individually.

CHAPTER 5 Displays

BeamWatch has the ability to create flexible display environments to meet the user's specific needs. All windows have the option to hide, float, and reposition on the screen.

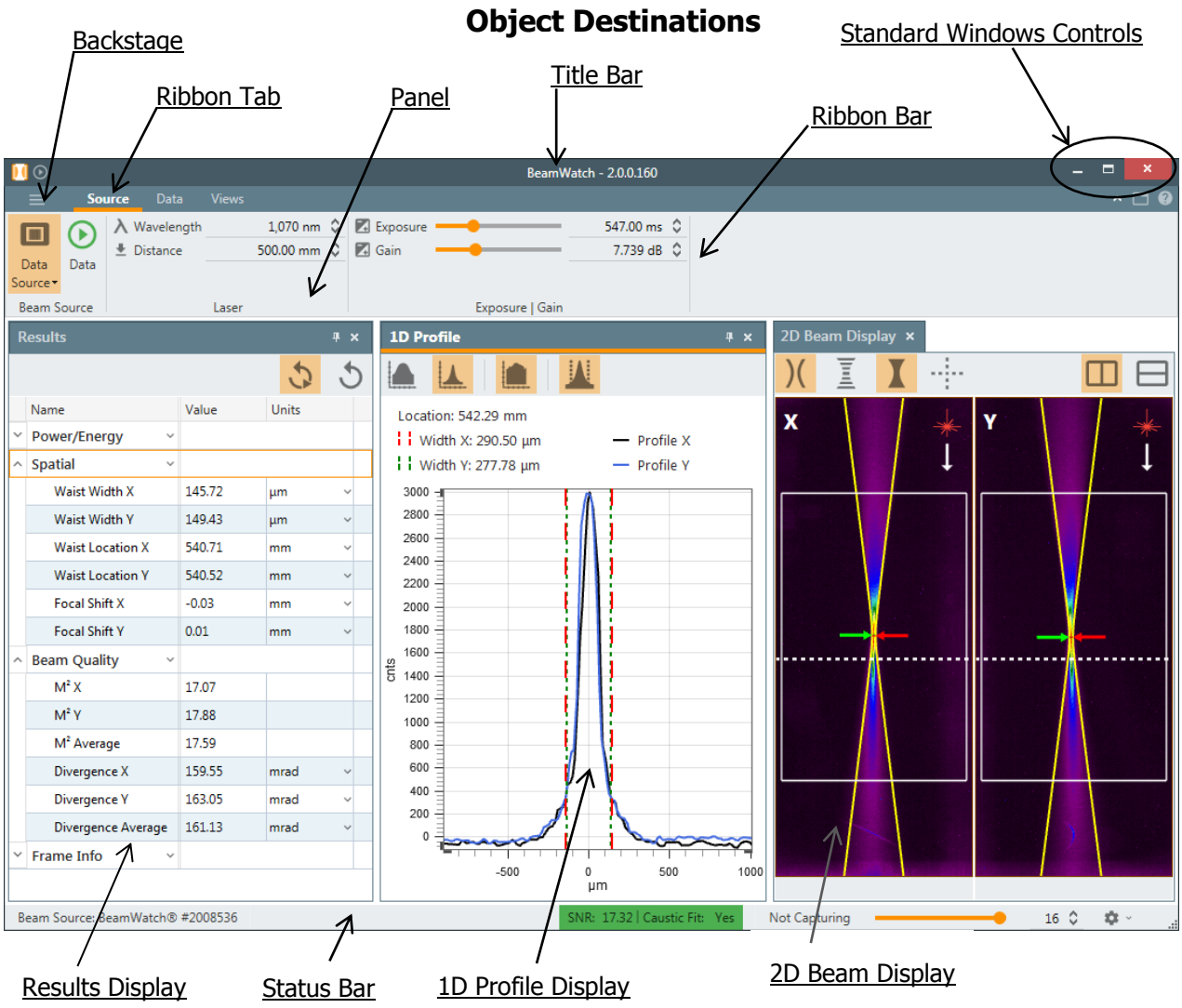
In this chapter, the tools that control the screen layout will be described. Below is how BeamWatch appears in the default state.



5.1 Display Terminology

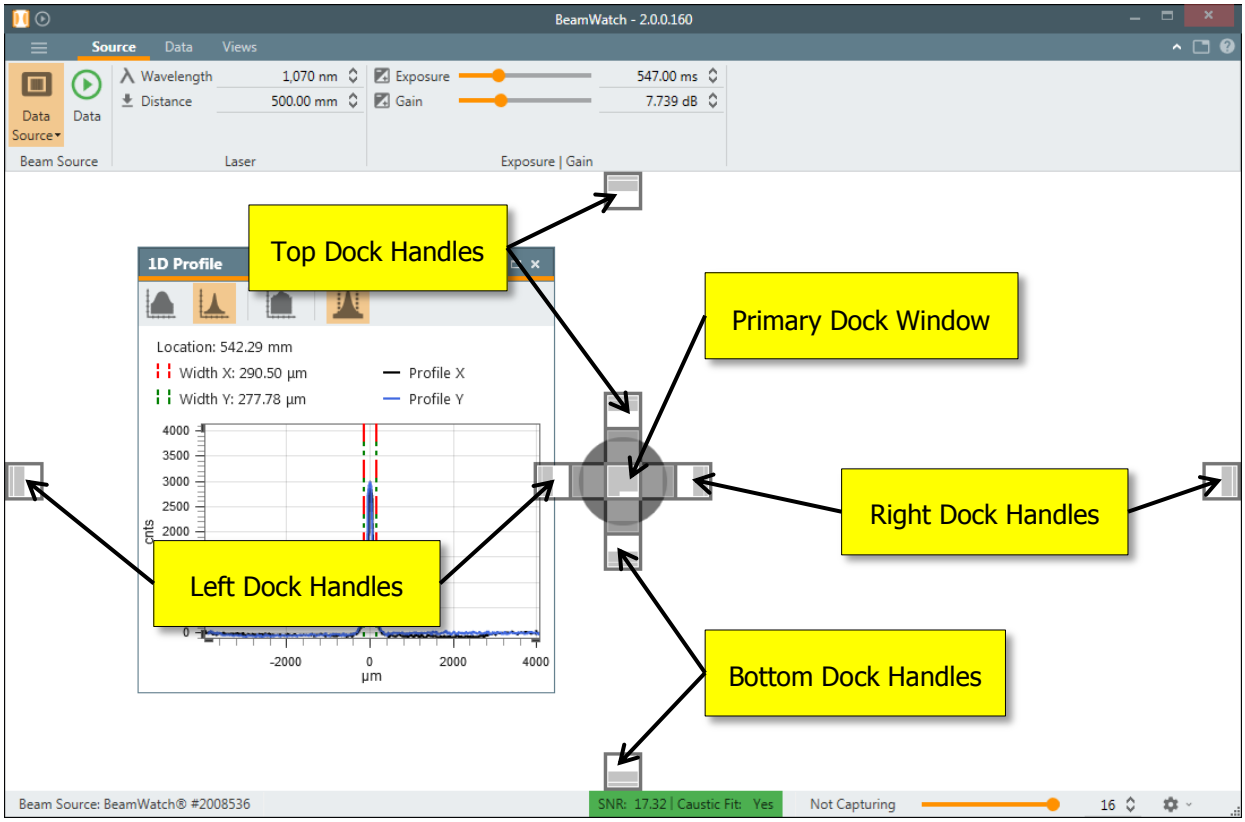
The BeamWatch layout employs terminology that may be new to some Microsoft users. This section will provide a graphical glossary of the terminology used.

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



5.2 Docking Handles

The application will start in the default window layout. To undock a window, grab the tab with the mouse and drag down into the window area. When dislocated from a docked position, a set of docking handles will appear as shown below. In this example, the **1D Profile** window is being dragged.



Drag the display over one of the dock handles and release to place the window in that position. If the window is not released on one of the dock handles, it will be set to floating. All windows can be dragged and docked to any of the display handles or left to float anywhere on the screen.

Each docked window will have its own set of dock handles, thus more child windows can be docked within each new window. This permits placing windows side by side, and over and under each other.

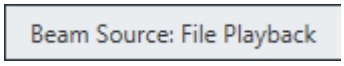
A floating window can be re-docked into the main application by dragging its title bar into the main display window and dropping on a dock handle.

5.3 Auto Hide

The Auto Hide feature allows hiding a display within the margins of the application. The hidden windows can be opened temporarily by hovering over or clicking on the window's tab. To hide a window, click the pin icon shown in the title bar of the display. Unpin by clicking this icon again and the window will be restored to its previously docked position.

5.4 Status Bar

The status bar contains useful information about the camera information, results accuracy, and frame buffer size. Each section is described below.

Beam Source 

The camera model and serial number are displayed here when a camera is connected. When viewing a loaded file, **File Playback** is displayed.

Annunciator 

This section will change color depending on the accuracy of the calculated results. If all of the values are good, the annunciator will be green. If any single value could yield results with a lower accuracy, the annunciator will turn yellow. Colors are set so they can be easily viewed through laser protective eyewear. An explanation of this annunciator and how to improve the results accuracy is described in chapter 6.

Capture Rate 

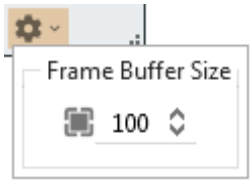
The frame rate is calculated and updated as data frames are received from the camera in real time. When stopped, **Not Capturing** is displayed.

5.5 Frame Buffer

The frame buffer is a temporary data storage space. The frame size and current frame position is indicated in the buffer controls in the status bar. Once the frame buffer is full, data acquisition will continue, but the frames will be overwritten in a "first in, first out" fashion. The data of the deleted frames is lost. The result statistics are not affected by the frame buffer size.

Frame Buffer Position 

The slider edit control indicates the current displayed frame buffer location. To navigate in the frame buffer, either edit the frame number or run the slider to the desired location.

Frame Buffer Size 

The size of the frame buffer is set using this control. Specify the number of frames you want the buffer to hold. Maximum setting is 999.

Note: *When saving data files, all frames in the frame buffer will be saved. The larger the frame buffer size, the larger the data file. Always use the smallest buffer size that will accomplish the required tasks.*

When loading saved data files, the frame buffer will fill with all the saved frames. The frames can be scrolled thru manually or automatically using the File Playback.

CHAPTER 6 Improving Results Accuracy

When the SNR and Caustic Fit are both good, the annunciator in the Status bar will turn green and the results are within the ±5% accuracy specification. If one of the values is questionable, the annunciator will turn yellow and the results accuracy could be ±20%. As long as the Caustic Fit is able to draw, the Spatial results will still be in the ±5% accuracy region, even if the SNR is low. The table below shows how each of these values affects the outcome of the results.

SNR	Caustic Fit	Spatial Results	All Other Results
High	Yes		
Low	Yes		
Low	No		

Ways to improve the accuracy of each measurement are described below.

6.1 SNR

The Signal-to-Noise Ratio (SNR) is a ratio of the desired signal to the level of background noise. A value of 10 or higher is generally considered good. A higher SNR is obtained by reducing noise or by increasing the signal. The four main ways to do this are described here.

Increasing the **Exposure** time is the desired method. This setting determines the amount of time the camera looks at the beam before reporting a frame. Longer exposure times increase the intensity of the beam on the camera imager and therefore increases the SNR.

The SNR can also be increased by using **Frame Averaging**. 5-10 frames is usually enough to improve this value. The noise is decreased by the square root of the number of frames averaged.

Another way to improve the SNR is by using **Frame Summing**. This method will increase the intensity of the beam for each reported frame. However, summing too many frames may make the signal become saturated, so use this method wisely.

A less used technique is to increase the **Gain** setting. A higher Gain value will improve the quality of the image, but this method should be used sparingly. A value set too high will begin to overcorrect and make the SNR worse.

6.2 Caustic Fit

The **Caustic Fit** can be seen in the **2D Beam Display** window by enabling **Fit** at the top of the display. If the Caustic Fit is unable to draw, the signal is usually weak (<5kW) and/or there is a lot of background noise. Follow the above stated solutions to improve the SNR and the Caustic Fit will also improve.

A large amount of particulates in the beam path will cause the Caustic Fit to be unstable. If this occurs, the purging gas will need to be altered. Adjust either the flow regulator on the BeamWatch unit or the gas source until a minimum number of particulates are observed.

CHAPTER 7 Automation Interface

BeamWatch provides an automation interface via .NET components to allow customers the ability to build custom applications that incorporate the laser beam analysis and processing power of BeamWatch. The BeamWatch automation interface allows developers control of BeamWatch programmatically. The automation interface was developed to provide the ability to base control decisions for a second application on results and behaviors recognized by BeamWatch. With this ability, users can quickly and efficiently meet manufacturing and analysis goals with minimum human interaction.

7.1 Automation Design Skill Set

Over the years, Spiricon has learned that to design a proper automation client for products similar to BeamWatch requires a skill level comparable to that of a degreed and experienced computer programmer. Even with this background, a learning curve is necessary to achieve an acceptable level of competency. To assist your company in choosing a good employee fit for this type of work, we offer the following guidelines for the minimal skill sets needed.

To interface with LabVIEW you need:

- An understanding of .NET programming methods.
- Prior, and recent, experience designing and deploying National Instruments LabVIEW VI's in an automation environment.
- Review Spiricon's **Automation Documentation** (see 7.4 below).

To interface with a program written in Visual Basic (VB), C++, or C# you need:

- A minimum BS degree in Computer Science or Computer Engineering, or equivalent.
- Three or more years of software design experience using Microsoft Visual Studio design and debugging tools.
- Demonstrated proficiency in writing programs in Microsoft Visual Basic, C++, or C#
- A background in .NET programming methods
- Review Spiricon's **Automation Documentation** (see 7.4 below).

7.2 New BeamWatch Automation

BeamWatch v1.x used ActiveX to provide the automation interface. With the release of v2.0, Spiricon decided to upgrade to the newer .Net technology which provides more functionality. Because of this change, any automation interface that was built for 1.x will no longer function. We apologize for any inconveniences.

7.3 Introduction

The BeamWatch automation interface was designed to achieve two main goals. First, to allow the user to programmatically do what they could otherwise do via the graphical user interface (GUI). Second, to expose stable interfaces to the user that will not change, causing breaks to their dependent code, with the exception of upgrading from 1.x to 2.0. In order to facilitate

these goals, it is important that the user be given stable abstractions to program against. It is likewise important to allow BeamWatch to evolve as new features are added. Spiricon is dedicated to protect users from changes in underlying implementation as BeamWatch evolves. To this end, the automation interface is presented as a set of interfaces that collectively expose the functionality of the application. Access to these various interfaces is provided by creating one concrete class known as AutomatedBeamWatch. Interfaces needed to create, control, extract results and destroy an instance of the BeamWatch application are accessed via properties found in the AutomatedBeamWatch class.

7.4 Documentation

The Automation API reference is presented via html. The html reference provides cross-referenced access to all interfaces and functionality provided for automation application development. The **BeamWatch Automation API** may be accessed via the following link:

Automation Documentation

-or-

Via the start menu shortcut as shown below:

Start -> All Programs -> Spiricon -> BeamWatch -> Documentation -> Automation Interface

7.5 Examples

An example of a simple automation application in C# is provided. For a step-by-step walkthrough click on following link:

Automation Example

-or-

Navigate to the file located at:

C: -> Program Files -> Spiricon -> BeamWatch -> Automation -> Documentation -> csharp_example.html

APPENDIX A Mechanical Dimensions