USER MANUAL

Beamage Series | USB 3.0 Beam Profiling Cameras

gentec-eo
PARTNERS for ACCURACY

121-103680

WARRANTY

First Year Warranty

The Gentec-EO Beamage series beam profiler carries a one-year warranty (from date of shipment) against material and/or workmanship defects, when used under normal operating conditions. The warranty does not cover damages related to battery leakage or misuse.

Gentec-EO Inc. will repair or replace, at Gentec-EO Inc.'s option, any Beamage that proves to be defective during the warranty period, except in the case of product misuse.

Any attempt by an unauthorized person to alter or repair the product voids the warranty.

The manufacturer is not liable for consequential damages of any kind.

Contacting Gentec Electro-Optics Inc.

In case of malfunction, contact your local Gentec-EO distributor or nearest Gentec-EO Inc. office to obtain a return authorization number. The material should be returned to:

Gentec Electro-Optics, Inc.
445, St-Jean-Baptiste, Suite 160
Québec, QC
Canada, G2E 5N7

Tel: (418) 651-8003
Fax: (418) 651-1174
E-mail: service@gentec-eo.com
Website: gentec-eo.com

CLAIMS

To obtain warranty service, contact your nearest Gentec-EO agent or send the product, with a description of the problem, and prepaid transportation and insurance, to the nearest Gentec-EO agent. Gentec-EO Inc. assumes no risk for damage during transit. Gentec-EO Inc. will, at its option, repair or replace the defective product free of charge or refund your purchase price. However, if Gentec-EO Inc. determines that the failure is caused by misuse, alterations, accident or abnormal conditions of operation or handling, it would therefore not be covered by the warranty.

SAFETY INFORMATION

Do not use a Beamage if the device or the detector looks damaged, or if you suspect that a Beamage is not operating properly.

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy. If not installed and used in accordance with the instructions, it may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, try to correct the interference by taking one or more of the following steps:

- Reorient or relocate the receiving antenna.
- Increase the distance between the equipment and receiver.
- Connect the equipment to an outlet that is on a different circuit than the receiver.
- Consult the dealer or an experienced radio/TV technician for help.

Caution: Changes or modifications not expressly approved in writing by Gentec-EO Inc. may void the user's authority to operate this equipment.

SYMBOLS

The following international symbols are used in this manual:

Refer to the manual for specific Warning or Caution information to avoid any damage to the product.

DC, Direct Current

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1. BEAMAGE SERIES – USB 3.0 BEAM PROFILING CAMERAS

1.1. INTRODUCTION

Gentec-EO introduces the Beamage beam profiler series. Its sleek and thin design allows the Beamage to fit between tight optical components. Its USB 3.0 connection and improved algorithm allows very fast frame rates. The Beamage-3.0 2.2 MPixel CMOS sensor has a large ⅔” optical format with a small 5.5 µm pixel pitch allowing high resolution on large beams. For larger beams, the Beamage-4M impressive 4.2 MPixel CMOS sensor and its very large 1’’ optical formal is the ideal solution. Both beam profilers are available in the IR version allowing measurements between 1495 and 1595 nm. The newest member of this series is the Beamage-4M-FOCUS, specifically designed for extra large beams. Its bounded fiber optic taper extends the sensor surface to 20.5 x 20.5 mm effective size. Most importantly the innovative and improved PC-Beamage software is simple and intuitive to any new or expert beam profiling user.

All screenshots in this manual with the words "Beamage-3.0" can be interpreted as "Beamage-4M".

1.2. SPECIFICATIONS

The following specifications are based on a one-year calibration cycle, an operating temperature of 18 to 28°C (64 to 82 F) and a relative humidity not exceeding 80%.

	Beamage-3.0	Beamage-3.0-IR	Beamage-4M	Beamage-4M-IR	Beamage-4M-FOCUS
	Sensor				
Sensor Technology	CMOS without coverglass				
Sensor Size	11.3 x 6.0 mm		11.3 x 11.3 mm		20.5 x 20.5 mm effective size[1]
Sensor Area	0.67 cm^2		1.28 cm^2		4.2 cm^2 effective optical aperture
Pixel Count	2.2 MPixels		4.2 MPixels		
Pixel H x V	2048 x 1088		2048 x 2048		
Optical Format	⅔”		1”		
Pixel Dimension	5.5 µm				12 µm effective size
Shutter Type	Global				
Wavelength Range	350 - 1150 nm	1495 - 1595 nm	350 - 1150 nm	1495 - 1595 nm	350 - 1150 nm

[1] With Pixel Multiplication Factor 1.8

Minimum Measurable Beam	55 µm	70 µm[1]	55 µm	70 µm[1]	120 µm
ADC	12 bit (default) or 10 bit				
Frame Rate	11 fps (2.2 MPixel Full Frame) 20 fps (1.1 MPixel Active Area 2048 x544) 32 fps (0.066 MPixel Active Area 256 x 256)		6.2 fps (4.2 MPixel Full Frame) 11.4 fps (2.1 MPixel Active Area 2048 x 1024) 18.6 fps (1.1 MPixel Active Area 2048 x 544) 32 fps (0.066 MPixel Active Area 256 x 256)		
RMS noise	1000:1 (60 dB)				
Minimum and Maximum Exposure Times	0.06 to 200 ms				
External Trigger	SMA connector 1.1 volts to 24 volts, the rise edge response time is 300 ns Trigger signal pulse width: min: 300 ns Optional SMA to BNC adaptor (202273)				

	Damage Thresholds
Maximum Average Power	1 W with ND filter
Maximum Power Density (1064 nm, CW)	10 W/cm^2 with ND4.0 filter
Maximum Energy Density (1064 nm, Pulsed)	300 $\mu J/cm^2$ with ND4.0 filter

	Physical Characteristics	
Dimensions	61 H x 81.1W x 19.7D mm	61 H x 81.1W x 46.5D mm
Weight	138 g	235 g
Distance from front of case to sensor	7.8 mm	
Default Attenuation	ND 4.0	

[1] Minimum measurable beam is larger because of the Point Spread Function (PSF) of the Phosphor Coating

	Measured and Displayed Parameters
Displays	3D, 2D, XY (crosshair), Beam Tracking, M^2 Curves
Beam Diameter Definition	4 Sigma (ISO) - ISO-11146-1:2005 FWHM along crosshair (50%) $1/e^2$ along crosshair (13.5%) 86% effective diameter (D86) Custom along crosshair (%)
Beam Center Definition	Centroid - ISO-11146-1:2005 First Encountered Peak
Displayed Measurements	Major Axis Minor Axis Effective Diameter Ellipticity Orientation Centroid X and Y Peak X and Y Peak Saturation Level Peak to Average Ratio X and Y Divergence Fitted Gaussian equations Roughness fit along crosshairs Gaussian fit along crosshairs Mean Centroid Position Azimuth Beam Position Stability M^2 Quality Measurement
Setup Options	Exposure Time (auto or manual) Image Orientation (rotation and flip) Image Averaging (temporal filter) Active Area Pixel Addressing Gain ADC Level Magnifying Lens
Processing Option	Background Subtraction Area Filters (triangular and flat spatial filters) Normalized Display Trigger
Buffer	Buffer size from 1 to 128 frames Possibility to animate stored frames
File options	Save 1 or all images in buffer Save in native format, text format, or binary format Load native format files Default and custom print report Save 3D or 2D image in bitmap format Save crosshairs in text format Data Acquisition of measurements in text format and in native format

	PC Requirements
USB Port	USB 3.0 port for optimal performance USB 2.0 port
Operating System Compatibility	Windows 10 Windows 8 (for optimal performance) Windows 7 (for optimal performance) Windows Vista
Average RAM Allocation	500 MB Up to 1250 MB for128 images in buffer
Recommended Requirement	4 Gb RAM minimum 8Gb RAM for optimal performance Intel i series processors (i3, i5, i7) or equivalent for optimal performance, other processors will have lower specifications. i7 for optimal performance Beamage-3.0 is a new and a high end product. It needs an equally recent high end computer to work. Computer hardware must be from 2010 or after. No computer or parts bought before 2010 will be supported
For Optimal Performance	Close all programs except the PC-Beamage; Keep a minimum of 1 GB RAM free when running the PC-Beamage; Keep a minimum of 50% of free CPU power when running the PC-Beamage Use an Image Buffer of 1
Multi Camera Recommendation	When working with more than one camera, we strongly recommend using one USB3.0 port per camera and a recent high end computer for optimal performance
Internet Upgrades	Downloadable at www.gentec-eo.com/downloads

1.3. MECHANICAL DESCRIPTION

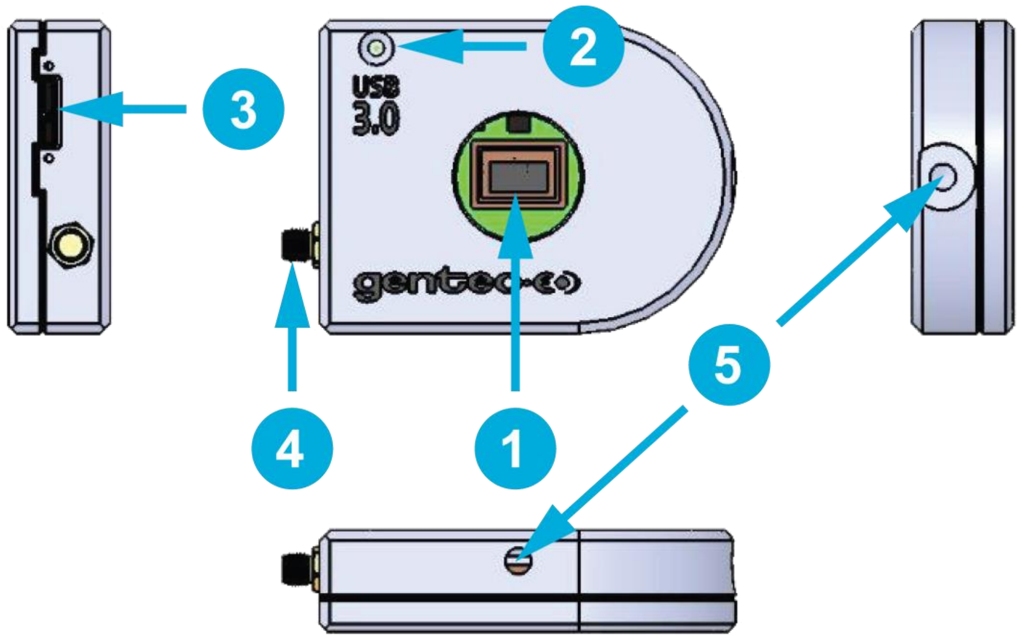


Figure 1-1 Beamage Series Front and Side Views

1 **Aperture**
The aperture of the Beamage and the screw threads are C-MOUNT, allowing easy connectivity with optical accessories such as attenuation filters, UV converters or lenses. The sensor is centered with the aperture's center.

2 **LED Indicator**
The LED indicates if the Beamage has been detected by the computer and if it is currently streaming.

3 **USB 3.0 Connector**
The USB 3.0 connector is now more rugged with its threaded holes. Please note that only USB 3.0 compliant cables can be used with the Beamage. USB 2.0 ports can be used, but it will lower the Beamage speed performances.

4 **SMA Connector**
The SMA connector is used to externally trigger the Beamage. A SMA to BNC adaptor is available.

5 **Fixation Holes**
¼"-20 holes are aligned with the sensor's center allowing easy optical alignment.

1.4. SPECTRAL CURVES

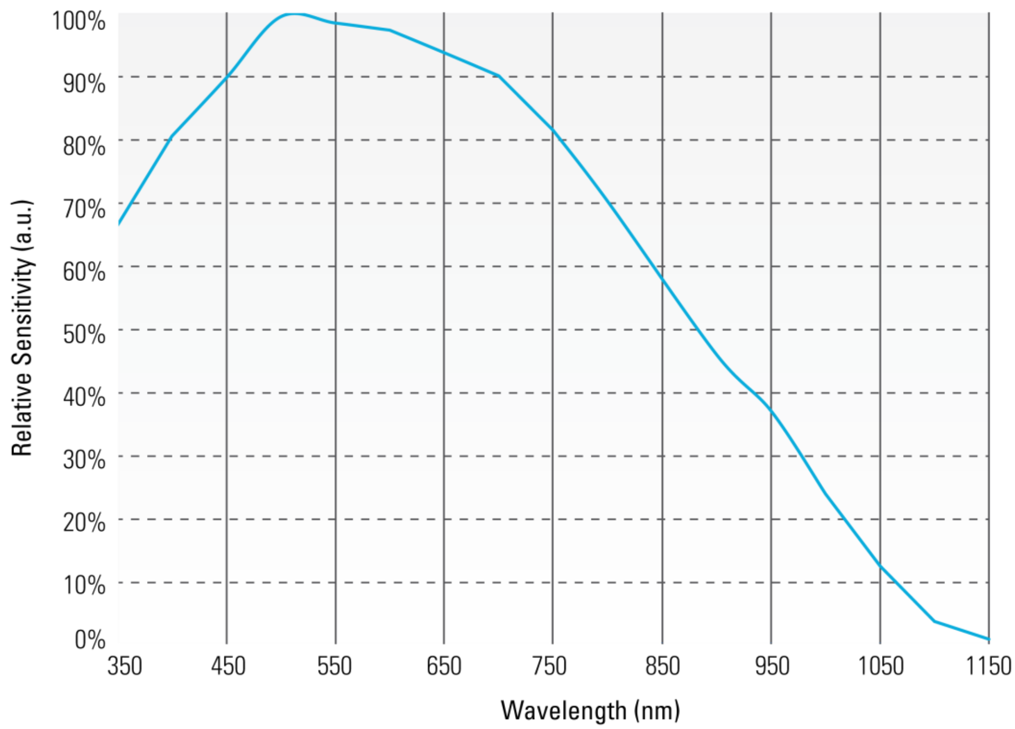


Figure 1-2 Spectral Response of the Sensor

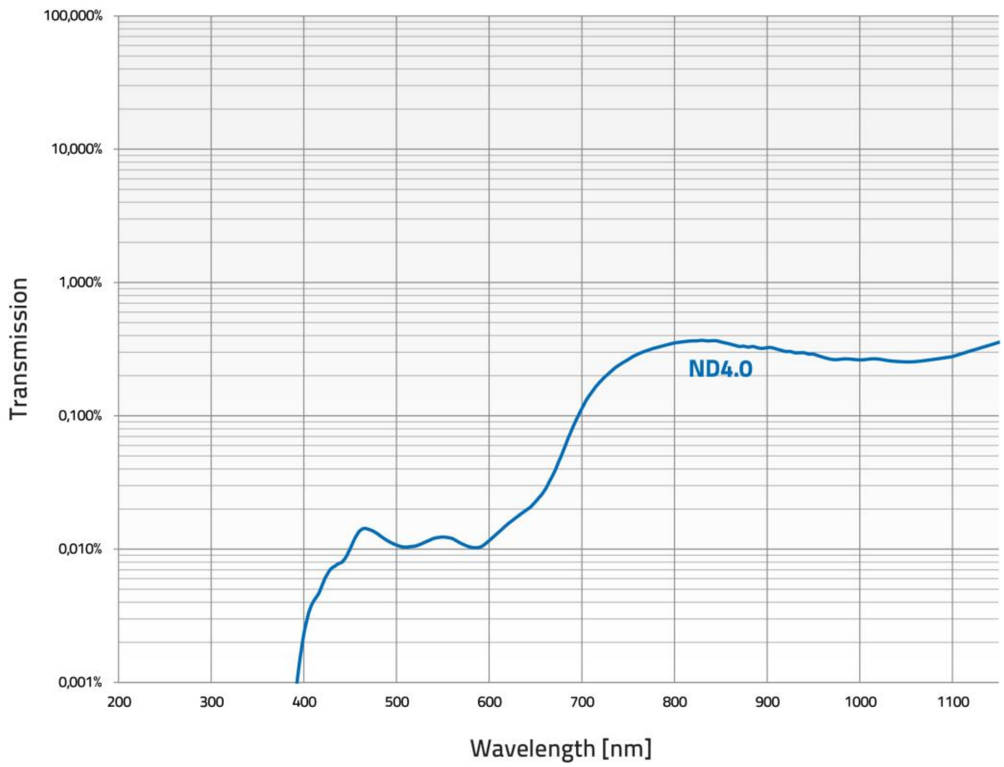


Figure 1-3 Transmission of the ND4.0 Filter

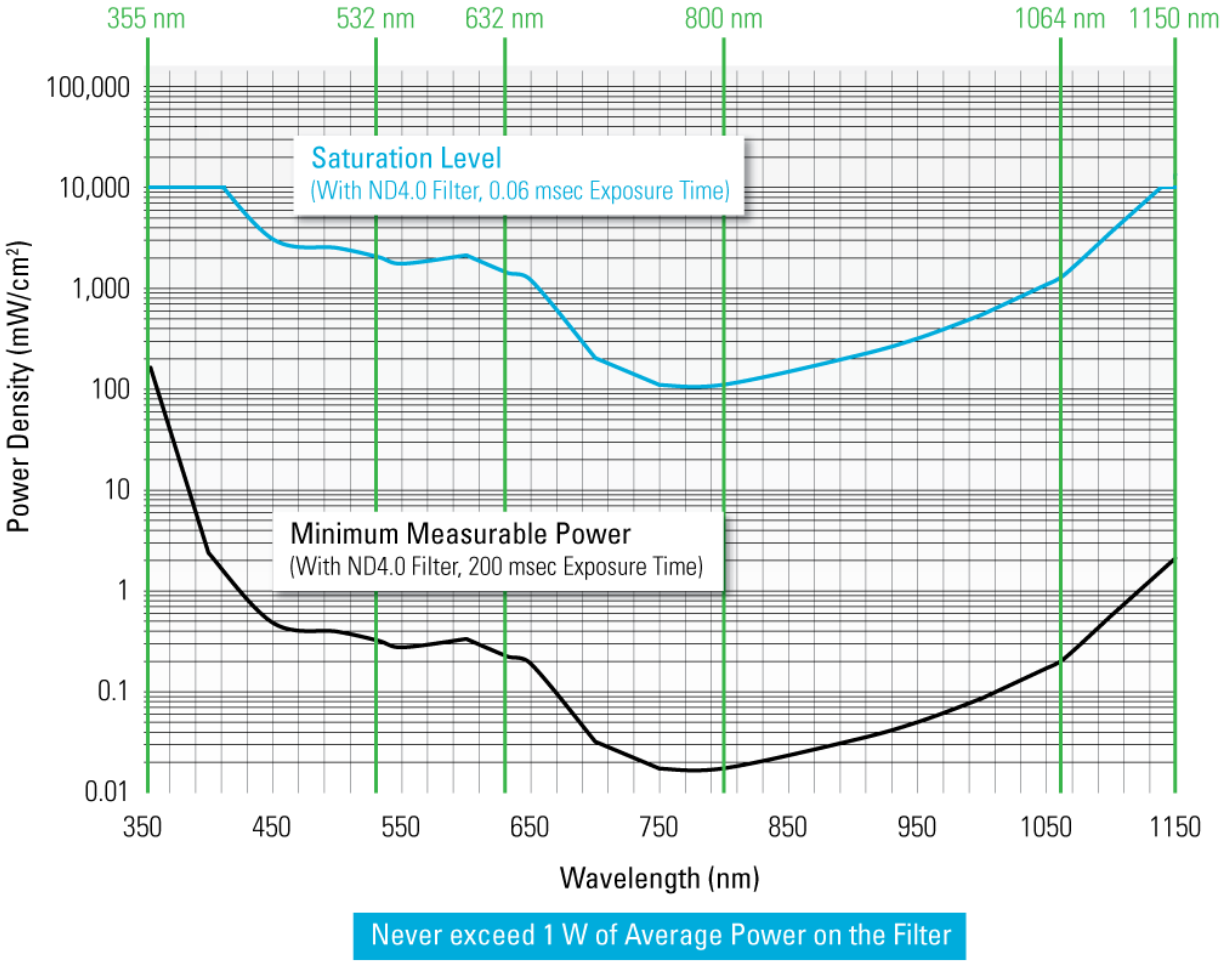


Figure 1-4 Minimum Measurable Power and Saturation Power Level

Wavelength	UG11-UV		ND 0.5		ND 4.0		ND5.0		IR Filter	
	Minimum (mW/cm^2)	Saturation (mW/cm^2)	Minimum (mW/cm^2)	Saturation (mW/cm^2)	Minimum (mW/cm^2)	Saturation (mW/cm^2)	Minimum (mW/cm^2)	Saturation (mW/cm^2)	Minimum (mW/cm^2)	Saturation (mW/cm^2)
300 nm	0.0001	0.54								
355 nm			0.00053	3.4	160		240			
532 nm			0.00007	0.47	0.32	2000	4.2			
632 nm			0.00008	0.49	0.22	1400	2.6	16000		
800 nm			0.00008	0.51	0.017	110	0.092	590		
1064 nm			0.00075	4.8	0.22	1400	1.3	8100		
1150 nm			0.0094	61	2.1	13000	12			
1310 nm									0.55	6900
1550 nm**			0.12	1.70	0.005	3.80	0.002	0.0293		

- Minimum power is measured at an exposure time of 200 ms
- Saturation level is measured at an exposure time of 0.06 ms
- Do not exceed 1 W on the ND filter
- For higher densities please refer to the Beamage Accessories User Manual to correctly attenuate your laser
- **Valid for Beamage-3.0-IR and Beamage-4M-IR

.

2. QUICK START PROCEDURE

1. Install the PC-Gentec-EO Software.

2. Install the USB Drivers. Make sure to follow the installation instructions (refer to Appendix B).

   NOTE: The drivers must be reinstalled with each new software installation. If necessary, update the firmware using the BeamageUpdater file (Refer to Appendix C).

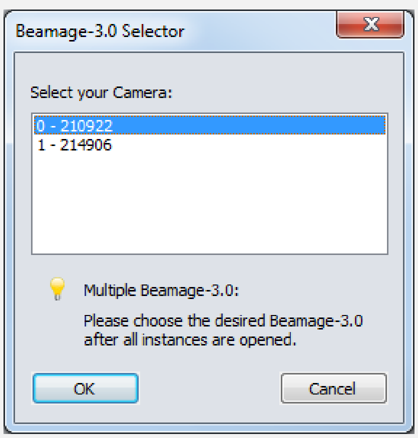
3. Connect the Beamage to a USB3.0 or USB2.0 port.

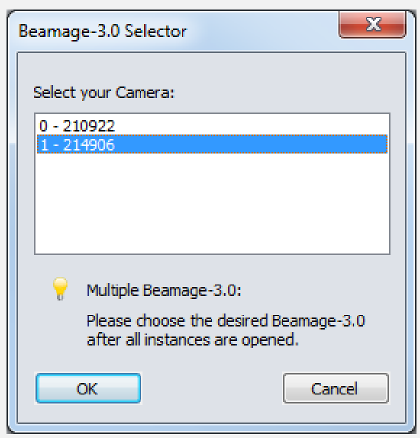
   NOTE: Make sure to secure the USB connector on the Beamage using the set screws. This will ensure a stable communication.

4. Start your laser and align the beam in the aperture of the camera.

5. Start the PC-Beamage software. Select the camera from the list. The green LED button in the **Main Controls** indicates that communication has been established.

   NOTE: When using multiple cameras, you need to start multiple instances of the software one by one and then select the desired camera in each. For example, if you have 2 cameras, first open an instance of PC-Beamage and wait for the Beamage Selector dialog. Then, open another instance of PC-Beamage and wait for the Beamage Selector dialog. Then, go back to the first instance and select the appropriate serial number. Finally, go to the second instance and select the remaining camera.





6. Press **Start Capture**.

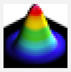
7. Let the **Auto Exposure** algorithm find the correct exposure time. This should take a few seconds. If the exposure time is 200 ms and your beam is underexposed, you need to remove some attenuation. If the exposure time is 0.06 ms and the beam is saturated, you need to add attenuation.

8. Remove the background radiation:

   a) Click on **Subtract Background**.
   b) A message box will appear. Once this message appears, block your laser beam and click **OK**
   c) Once the “Please wait” message disappears, you can unblock your laser beam.

9. The measurements appear in the **Home** tab on the right-hand side.

10. Choose the appropriate graphic for your measurement mode on the bottom left hand-side:

    a.  3D display;

    b.  2D display;

    c.  XY display;

    d.  Beam tracking display.

3. USER INTERFACE

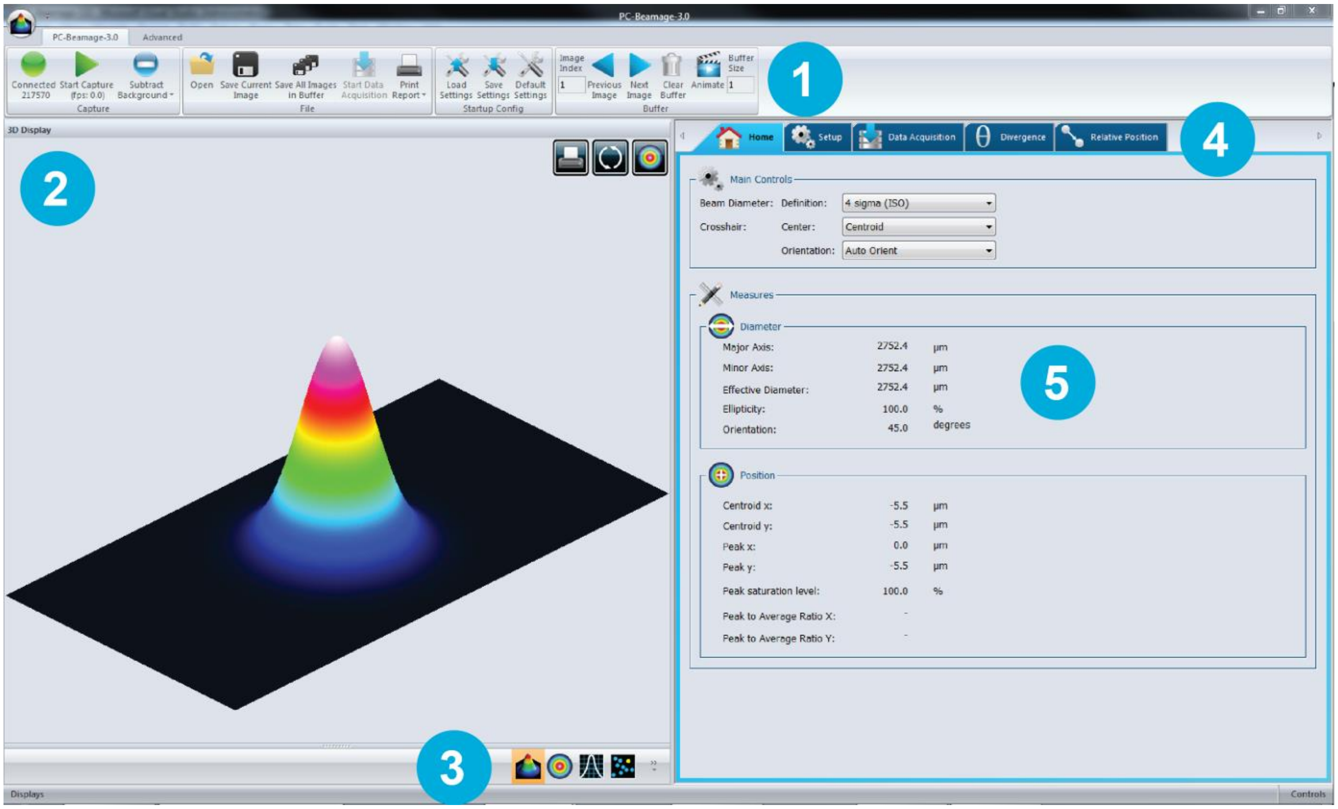


Figure 3-1 PC-Beamage User Interface

1

Main Controls
The top portion of the software is in a ribbon format and includes all the main controls. These are grouped by family, including Capture controls, File controls, Startup Config controls, Buffer controls, Data Computation controls (which include a very useful spatial filter and a normalizing function), M2 controls and Information controls.

2

Display Panel
The left-hand side of the software is the display panel. Three displays are available: 3D, 2D, and XY (cross-sectional graphs along the crosshairs).

3

Change Display
At any time, it is possible to change the type of display by selecting the desired graphic.

4

Analysis Panel - Tab Selector
Choose between the Home, Setup or Data Acquisition panel tab.

5

Analysis Panel – Controls
The right-hand side of the software contains the Home, Setup and Data Acquisition tabs. The first tab (Home) allows the user to select the type of measurements to be performed, it also shows the resulting measures of the beam. The second tab (Setup) contains all the measurement parameters, such as the Exposure Time, Image Orientation, Averaging, Active Area, and more. The third tab (Data Acquisition) lets the user specify the desired acquisition parameters.

3.1. MAIN CONTROLS

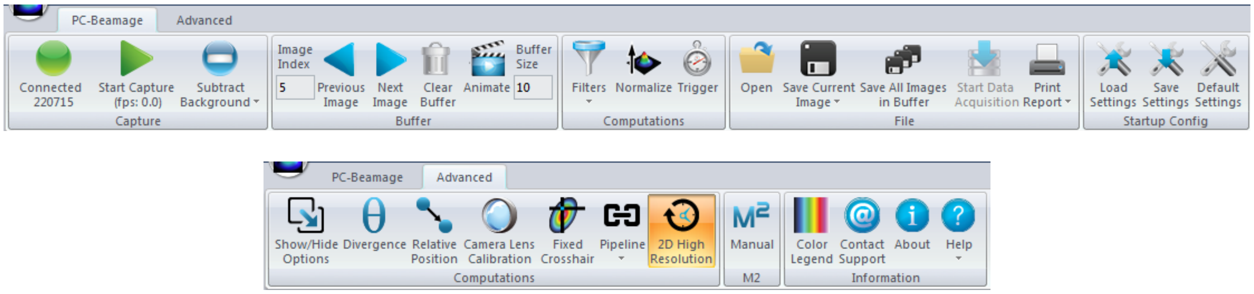


Figure 3-2 Main Controls

To give more room to the graphical display and less to the ribbon, you can minimize the ribbon by right-clicking on it and choosing “Minimize the ribbon”. You can retrieve the ribbon at any time by right-clicking on the upper portion of the window and unchecking “Minimize the ribbon”.

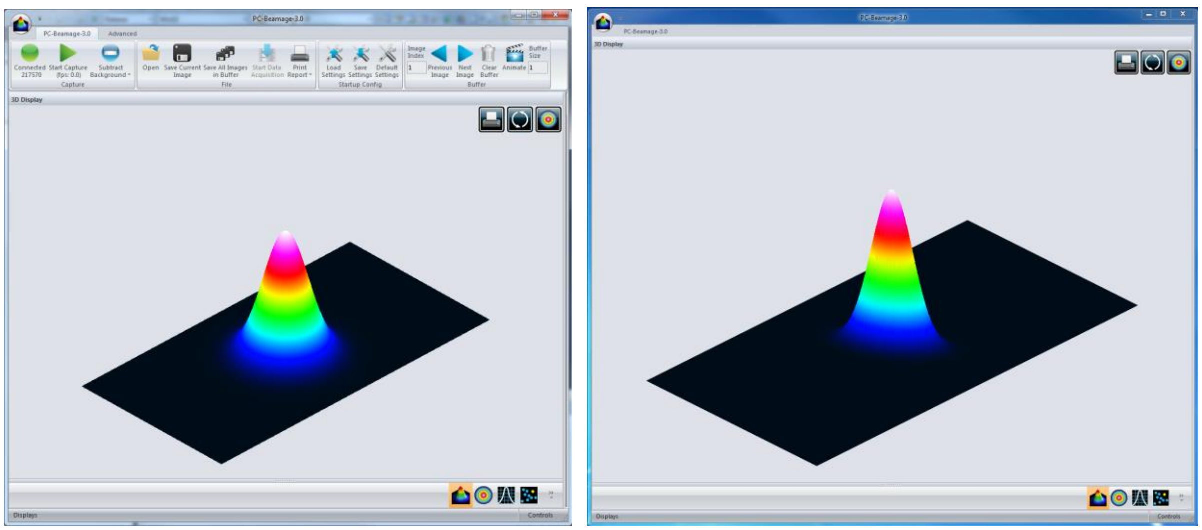


Figure 3-3 The PC-Beamage Interface With and Without the Main Controls Ribbon

3.2. MULTIPLE BEAMAGE MODE

It is possible to connect multiple Beamage units to a single computer. When you start the PC-Beamage, the following window showing all the serial numbers of the connected cameras will appear. If numerous Beamage are connected to the computer, please select the desired camera. To connect to another Beamage simultaneously, you must first start all desired PC-Beamage instances one by one before selecting the desired serial number for each instance. For example, if you have 2 cameras, first open an instance of PC-Beamage and wait for the Beamage Selector dialog. Then, open another instance of PC-Beamage and wait for the Beamage Selector dialog. Then, go back to the first instance and select the appropriate serial number. Then, go back to the second instance and do the same. You can start streaming after all the desired Beamage units have been connected to a PC-Beamage instance.

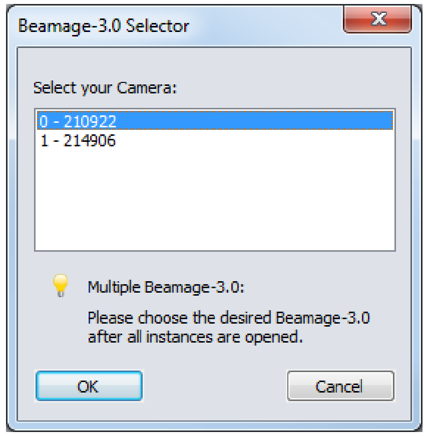


Figure 3-4 Beamage Selector for Numerous Connected Beamage

Warning

Multiple Beamage beam profilers can be connected to a single computer. However, PC-Beamage is not a multiple device software so you need to open a new instance of the program for each camera that is connected to your computer.

3.3. CAPTURE CONTROLS

The *"Capture Menu"* displays the Beamage current status, controls the capture, and captures an *average detector background map.*

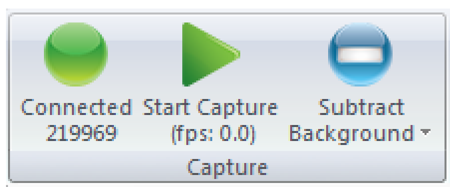


Figure 3-5 Capture Controls

3.3.1. Camera Status

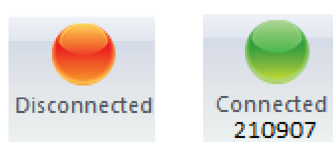


Figure 3-6 Camera Status

The software will automatically detect when a Beamage is connected to the computer and it will be indicated in the *Camera Status* with a green button, while a red button indicates that there is no Beamage connected. When the PC-Beamage is capturing an image, the status green button will flash as well as the LED on the Beamage. Each time the pixels are capturing an image, the LED will be off to avoid parasitic lighting from the LED. Note that clicking on this button will not do anything since it is not a control button, but rather a status indicator. It also indicates the serial number of the connected Beamage 3.0.

3.3.2.Capture

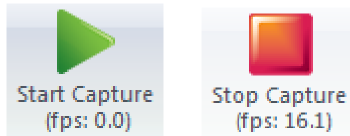


Figure 3-7 Capture Button

To start capturing images with the Beamage, click on the *"Start Capture"*. If no Beamage is connected to the computer or if the *"Animate"* mode (refer to section 3.4.4) is on, this button will not be available. Once the Beamage starts streaming, the frame rate will be displayed below the button in frames per second (fps). This measure includes the acquisition and computation time.

3.3.3.Subtract Background

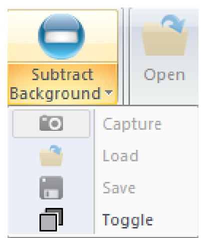


Figure 3-8 Subtract Background Button

The *"Subtract Background"* button includes a drop down menu in its lower part. The list contains a *"Capture"* button, a *"Load"* button, a *"Save"* button and a *"Toggle"* button.

Warning

To abide by ISO-11146-3:2004 (Section 3) and have an accurate measurement, a background subtraction must be done.

Once you have clicked the upper part of the *"Subtract Background"* button or the *"Capture"* button in the drop down menu, the following message box will appear:

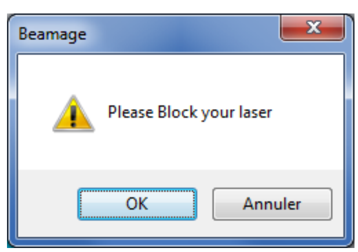


Figure 3-9 Subtract Background Message Box

Once this message box appears, block the beam and click on *"OK"*. The software will capture 10 images and average pixel by pixel to compute the *average detector background map.* A *"Please Wait"* message box will appear while the software is capturing the *background map.* The detector background map will be subtracted from all the images that will follow. Note that once the background subtraction has been done, the exposure time will no longer be in *"Auto"* mode and set to the current exposure time.

To load a background map (*.BMG file) that already exists on your computer, simply click the *“Load”* button in the drop down menu and browse the file on your computer. To save your background map (*.BMG file) on your computer, simply click the *“Save”* button in the drop down menu.

It is possible to toggle ON or OFF the background subtraction at any moment by simply clicking the *“Toggle”* button in the drop down menu.

It is also possible to see the background. To see it, stop the capture and simply click the “Open File Button” (section 3.6.1). The background has the same format (*.BMG file) as all Beamage images.

Tip

If the *Exposure Time* is set to “Auto”, be sure to block your beam only when the Message Box appears and not before.

3.4. BUFFER CONTROLS

The PC-Beamage software saves the last 128 frames in the buffer. This buffer is circular, the first stored frame is replaced by the last taken image. The buffer can store from 1 to 128 frames. By default, the buffer size is 10.

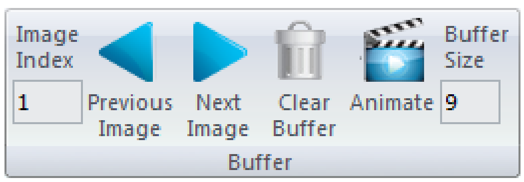


Figure 3-10 Buffer Controls

Warning

Note that all images are stored in the RAM memory of your computer, which could limit the number of images in the buffer.

3.4.1. Image Index

Figure 3-11 Image Index

The *“Image Index”* edit box displays the current image index. When the Beamage is not streaming, it is possible to access different frames by typing the desired image index.

3.4.2. Previous and Next Image

Figure 3-12 Previous and Next Image Buttons

The *"Next Image"* and *"Previous Image"* buttons access the next and previous image in the buffer.

3.4.3. Clear Buffer

Figure 3-13 Clear Buffer Button

The "*Clear Buffer*" button clears the entire buffer. The captured frames will no longer be available, any measures and graphical displays will also be erased.

3.4.4. Animate

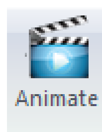


Figure 3-14 Animate Button

Once the Beamage has captured frames in its buffer, it is possible to stream them in a playback manner. With as much as 128 frames temporarily saved in the buffer, simply clicking the animation button will create an animation with any display (2D, 3D, and XY). This allows to visualize the beam while working offline and to have a recalculation process if the beam diameter definition or crosshair parameters are changed.

3.4.5. Buffer Size

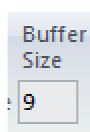


Figure 3-15 Buffer Size

The *"Buffer Size"* edit box displays the number of images stored in the buffer. It is possible to change the buffer size from 1 to 128 images.

3.5. DATA COMPUTATIONS

The *"Data Computations"* menu filters and normalizes the current frame and enables the Beamage's trigger and divergence options.

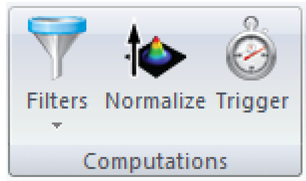


Figure 3-16 Data Computations

3.5.1.Filters

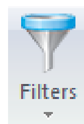


Figure 3-17 Filters Button

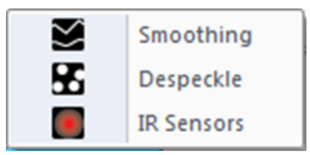


Figure 3-18 Available Filters

The "*Filters"* button opens a drop-down menu. Two spatial filters are available: "*Smoothing"* and "*Despeckle"*. These tools are great with low quality laser or low level signals. Note that the "*Despeckle*" filter is more "aggressive" than the *"Smoothing"* filter, which makes it ideal for very poor quality beams.

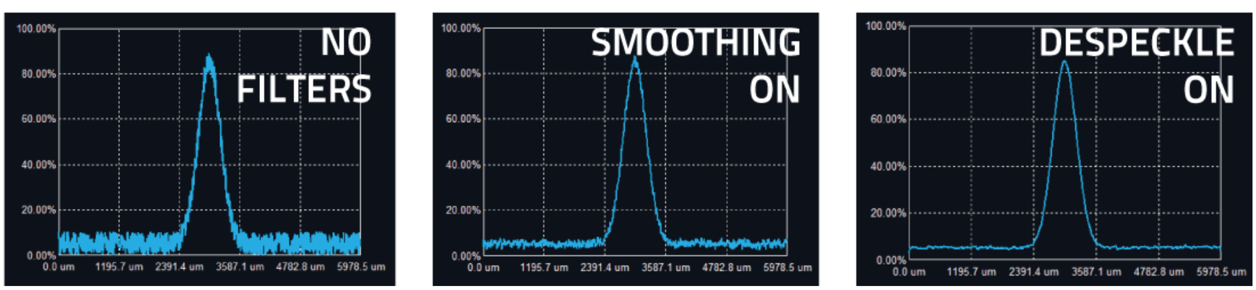


Figure 3-19 Spatial Filter Example

Warning

If an image is saved while it is in "*Filter*" mode, the resulting filtered image will be saved

Smoothing Filter

The *"Smoothing"* filter performs a 3x3 mask triangular filter. The center pixel has a higher weight (3/11) than the surrounding pixels (1/11). If the filtered pixel is on the edge, it will set the surrounding pixels outside the image to 0.

Despeckle Filter

The *"Despeckle"* filter uses a 9x9 mask flat filter to perform a simple averaging of the central pixel. All pixels have the same weight (1/81). If the filtered image is on the edge, the surrounding pixels outside the image will be set to 0.

IR Sensors Filter

The "*Filters"* button also contains the "*IR Sensors*" correction factor. With a Beamage-3.0-IR camera, this filter must be activated. Then, a correction factor is applied to the intensity of each pixel, according to the following correction formula:

$$IR\ Pixel\ Intensity = Pixel\ Intensity^{\frac{1}{Correction\ Factor}} * \frac{Max\ Intensity}{Max\ Intensity^{\frac{1}{Corretion\ Factor}}}$$

3.5.2.Normalize

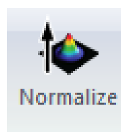


Figure 3-20 Normalize Button

The *"Normalize"* button will spread the graph's (3D, 2D, and XY) intensity over the full range (0% to 100%). Note that only the displays are normalized, the normalization does not affect the centroid and diameter computations.

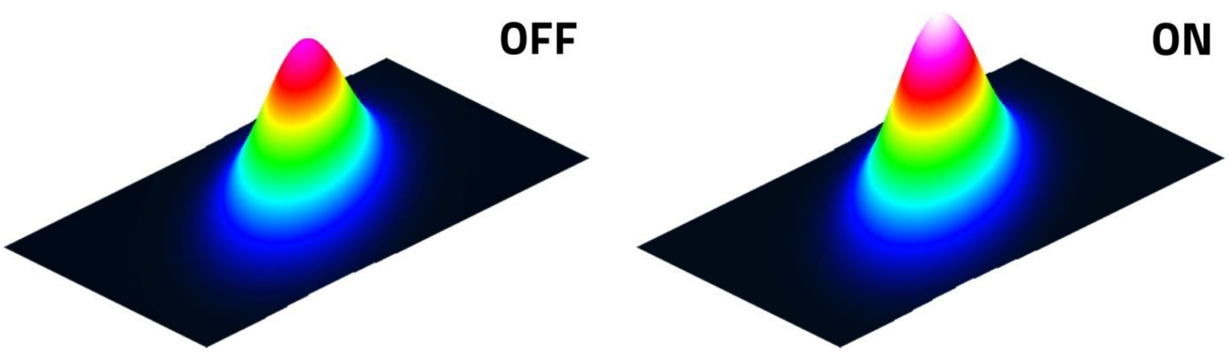


Figure 3-21 Normalization Example

3.5.3.Trigger

Figure 3-22 Trigger Button

The *“Trigger”* button enables the camera to capture images only when an electric signal is sent to the Beamage via the SMA connector. This can synchronize the system’s capture rate with a pulsed laser source. A SMA to BNC adaptor is provided (202273). The input trigger signal can be from 1.1 volts to 24 volts. The rise edge response time is 300 ns. The pulse width of the trigger signal must be between 300 ns and 230 ms.

SMA Connector

Figure 3-23 SMA Connector for Trigger Input

3.6. FILE CONTROLS

The *“File Menu”* opens and saves frames captured with the Beamage, and also prints a complete report. These controls are not available while capturing images, except for “*Start Data Acquisition*” function, which is only available while the camera is streaming.

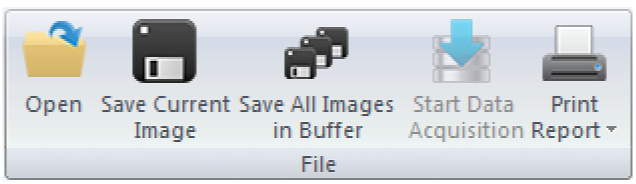


Figure 3-24 File Controls

3.6.1. Open

Figure 3-25 Open File Button

Click on the *“Open”* file button to retrieve previously saved data. The PC-Beamage software will only open native *.BMG files. The files can contain between 1 and 128 frames, depending on how the file was created (refer to section 3.6.2 and 3.6.3). If the file was saved with multiple frames, it will be possible to access all of them with the *Buffer Control* (refer to section 3.7).

3.6.2. Save Current Image

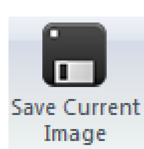


Figure 3-26 Save Current Image Button

Click on the *"Save Current Image"* button to save the currently displayed image. This option will only save 1 frame. Data can be saved in native *.BMG format, in text *.TXT format or in binary *.BIN format. Note that only the *.BMG format can be re-opened with the PC-Beamage software.

The *.TXT and the *.BIN files must be used with a compatible software. The *.TXT file saves a header containing the measurements settings followed by the sensor's output matrix. Every pixel output is separated by a semicolon. The *.BIN file only saves the data and does not contain a header. The *.BIN file saves data on signed 32 bit integers.

3.6.3.Save All Images in Buffer

Figure 3-27 Save All Images in Buffer Button

Click on the *"Save All Images in Buffer"* button to save all the frames stored in the buffer. Data can be saved in native *.BMG format, in text *.TXT format or in binary *.BIN format. Note that only the *.BMG format can be re-opened with the PC-Beamage software. When opening the *.BMG file, all the stored images will be accessible via the *Buffer Controls* menu including all the calculated measurement values (refer to section 3.7).

When saving in *.TXT or *.BIN file, a series of files will be saved and identified with their respective buffer index number. The *.TXT and the *.BIN files must be used with a compatible software. The *.TXT file saves a header containing the measurements settings followed by the sensor's output matrix. Every pixel output is separated by a coma. The *.BIN file only saves the data and does not contain a header. The *.BIN file saves data on signed 32 bit integers.

3.6.4.Start Data Acquisition

Figure 3-28 Start Data Acquisition Button

Click on the *"Start Data Acquisition"* button to start the data logging of all the measurements displayed in the "*Home"* tab. This function is only available while the camera is streaming. The acquisition parameters can be modified in the "*Data Acquisition"* tab on the right-hand side of the user interface (refer to section 4.3).

It is only possible to save the beam profiling results shown in the "*Home*" tab (refer to section 4.3) in a *TXT file. The *TXT file includes a header, containing the acquisition settings, followed by the data. Each line corresponds to a single frame and all the measurements are separated by a tab. This file can be opened in a spreadsheet software, such as Microsoft Excel.

It is also possible to save the images associated with the measurements saved in the *.TXT logging file. Each image will be individually saved in a native *.BMG file. Each file will have the same filename as the *.TXT file, followed by the corresponding increment.

Warning

Each *.BMG file can take up to 8.50 MB on the hard drive. Acquiring multiple frames can quickly sum up to multiple GigaBytes.

Fast acquisition should only be done on the computer's hard drive and cannot be done on an external drive or on a server hard drive.

3.6.5. Print Report

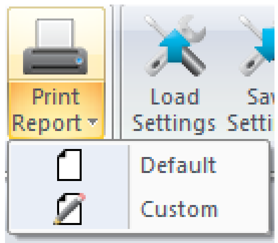


Figure 3-29 Print Report Button

Click on the *"Print Report"* button and choose the *Default* option to print a complete report of the current measurement. To print only specific information from the current measurement, choose the Custom option and a dialog box will show up. Check every measurement wanted in the report and uncheck every measurement not wanted in the report.

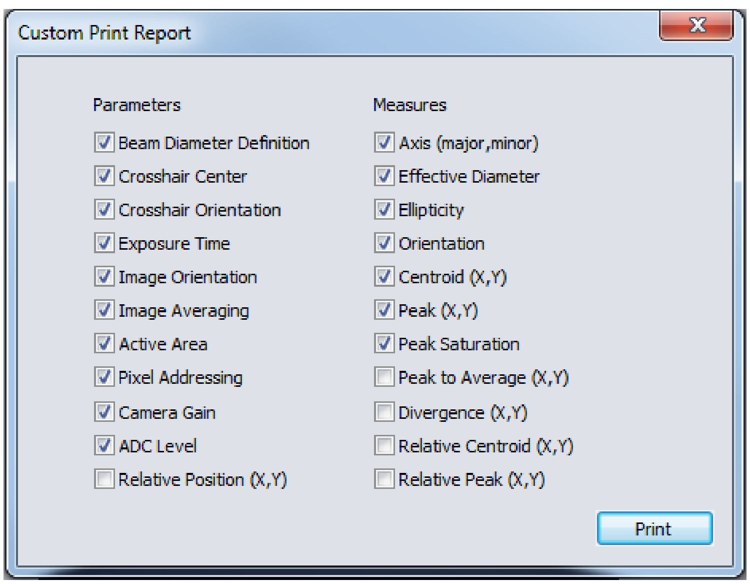


Figure 3-30 Custom Print Report dialog

After choosing the default or the custom report, a print preview will appear in the PC-Beamage software. To print the report, click "Print". To exit without printing, click "Exit". These buttons are located on the right-hand side.

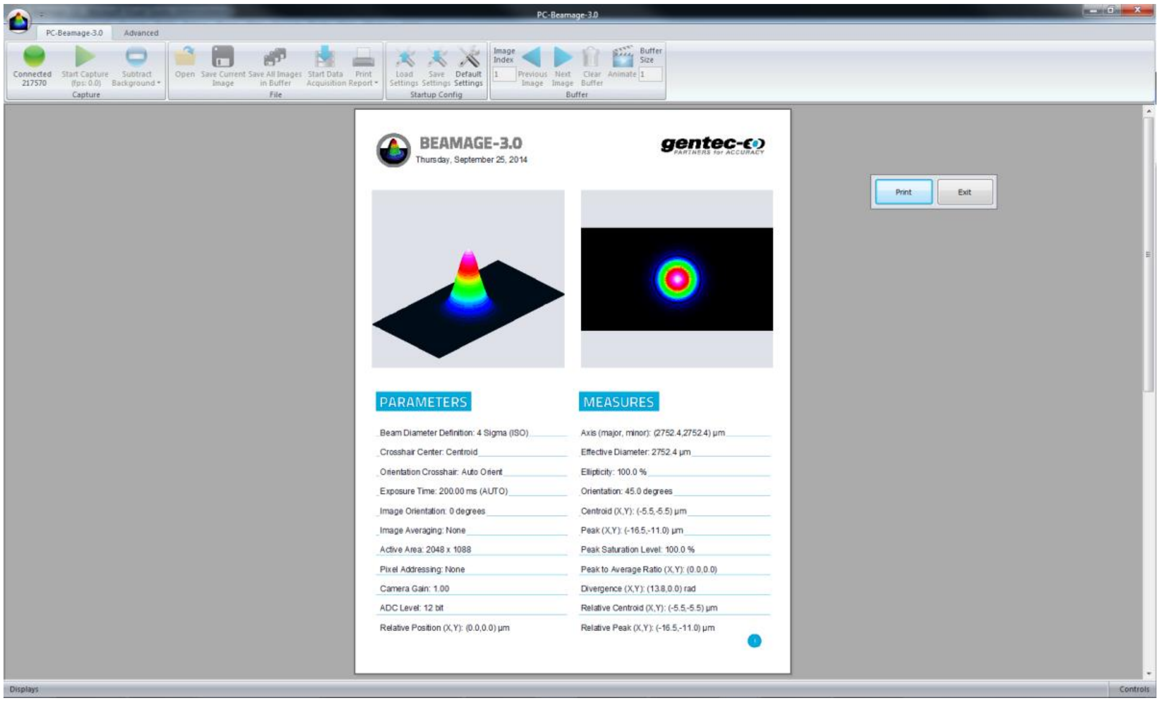
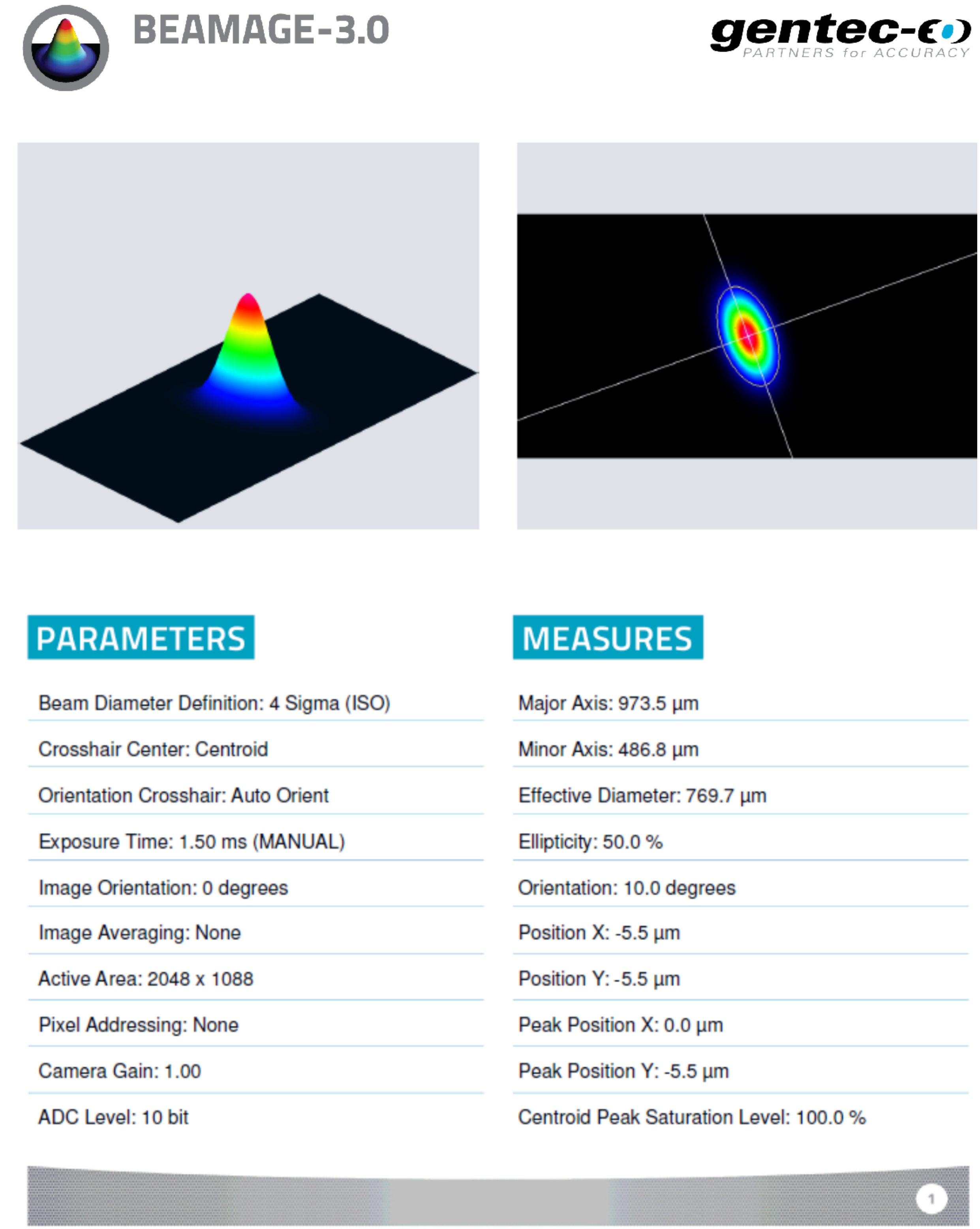


Figure 3-31 Print Report Preview

The report fits on 2 pages. The first page presents the 3D and 2D images, measurement results, and the Beamage settings.



BEAMAGE-3.0

gentec-eo
PARTNERS for ACCURACY

PARAMETERS

Beam Diameter Definition: 4 Sigma (ISO)

Crosshair Center: Centroid

Orientation Crosshair: Auto Orient

Exposure Time: 1.50 ms (MANUAL)

Image Orientation: 0 degrees

Image Averaging: None

Active Area: 2048 x 1088

Pixel Addressing: None

Camera Gain: 1.00

ADC Level: 10 bit

MEASURES

Major Axis: 973.5 µm

Minor Axis: 486.8 µm

Effective Diameter: 769.7 µm

Ellipticity: 50.0 %

Orientation: 10.0 degrees

Position X: -5.5 µm

Position Y: -5.5 µm

Peak Position X: 0.0 µm

Peak Position Y: -5.5 µm

Centroid Peak Saturation Level: 100.0 %

1

Figure 3-32 Default Print Report Page 1

The second page prints the cross-sectional XY graphs along the crosshairs. If the *"Cursor"*, the "*Gaussian Fit", "FWHM", or the "1/e^2"* options are selected (refer to section 0), they will also appear in the report.

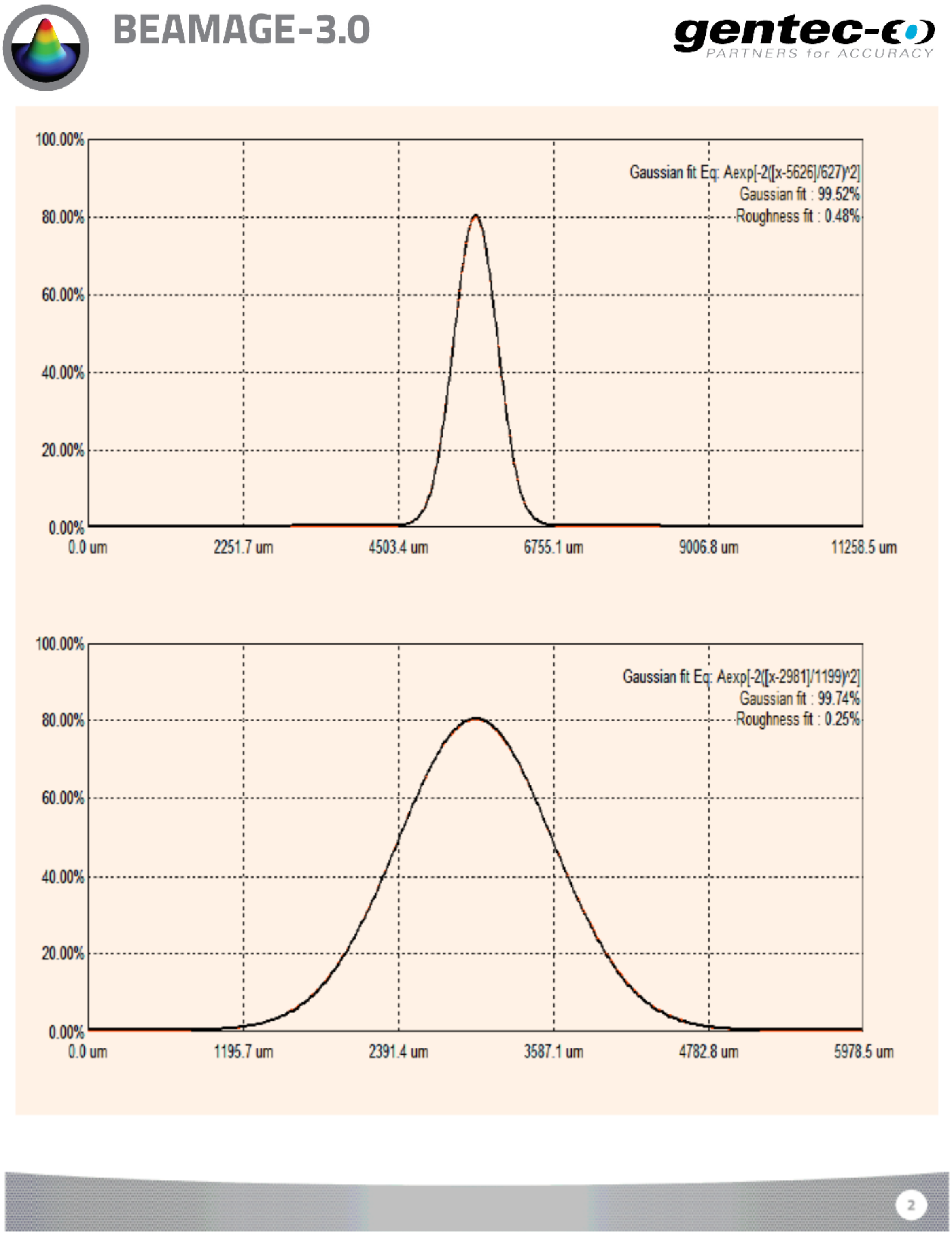


Figure 3-33 Default Print Report Page 2

3.7. STARTUP CONFIG CONTROLS

The PC-Beamage software can load, save and reset to the default factory state the software settings. The file extension is *.geo.

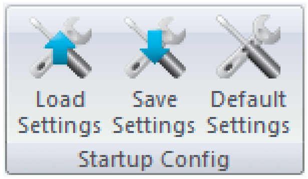


Figure 3-34-Startup Config Controls

Tip

When closing the PC-Beamage, all current settings will be saved and will automatically be loaded next time the PC-Beamage is opened.

The complete list of settings saved could be finding in the annex section.

3.8. ADVANCED COMPUTATIONS

The PC-Beamage software offers advanced computation features for specific applications. These options can be hidden or shown depending on your needs. These controls can be found in the *Advanced* ribbon tab.

Figure 3-35-Startup Config Controls

3.8.1. Show/Hide Options

Figure 3-36 Show/Hide Options Button

The "*Show/Hide Options*" button will show or hide the "*Divergence*", the "*Relative Position*", "*Camera Lens Calibration*" and "*Fixed Crosshair*" panels beside the "*Data Acquisition*" tab. By clicking on "*Show All' or "Hide All"*, one can show or hide both tabs at the same time. The "*Start LabVIEW Pipeline*" button will open the communication channel between the PC-Beamage and the LabVIEW driver. Please refer to section 7 for more information about this function.

3.8.2. Divergence

Figure 3-37 Divergence Button

The "*Divergence*" button activates a new tab on the right-hand side of the user interface. It contains all the settings and results relative to the beam divergence (refer to section 0). To compute the divergence and abide by the ISO-11146-1:2005 standard, the first step is to place an aberration-free lens between the Beamage and the laser. The lens should be placed in the far-field of the laser beam while the Beamage should be at the focal point of the lens. The second step is to enter the focal length of the lens in the software. Since the focal length is wavelength dependent, make sure to use the correct value for your laser in the settings. The divergence in both main axes (x and y) are computed as defined by the ISO-11146-1:2005 and ISO-11146-2:2005 standards and displayed at the bottom of the "*Divergence"* tab.

Warning

The Beamage sensor must be placed precisely at the focal point, not at the beam waist.

3.8.3. Relative Position

Figure 3-38 Relative Position Panel

The "*Relative Position*" panel activates a new tab on the right-hand side of the user interface. It contains all the settings and results relative to the origin position. This tool allows you to easily align a laser to any desired position. Please refer to section 4.5 for more information about this functionality.

3.8.4. Camera Lens Calibration

Figure 3-39 Camera Lens Calibration Panel

The "Camera Lens Calibration" panel activates a new tab on the right-hand side of the user interface. It contains the procedure relative to the camera lens calibration. This tool allows you to easily calibrate a system that contains a magnifying lens. Please refer to section 4.6 for more information about this function.

3.8.5.Fixed Crosshair

Figure 3-40 Fixed Crosshair Panel

The “Fixed Crosshair Panel” panel activates a new tab on the right-hand side of the user interface. It contains the settings relative to the fixed crosshair. This tool allows you to easily fix and see the crosshair at a precise position on the sensor, and also to adjust the crosshair’s orientation. Please refer to section 4.7 for more information about this function.

3.8.6.Pipeline

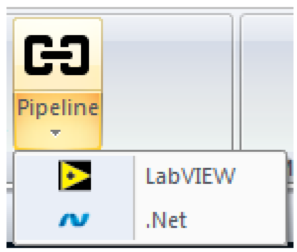


Figure 3-41 Third Party Pipeline

The measures computed by PC-Beamage can be sent to a third party application written in LabVIEW or in any .Net language. To do so, you must activate the pipeline to open the communication between the two software applications. Please refer to section 7 for more information.

3.8.7.2D High Resolution

Figure 3-42 2D High Resolution

The PC-Beamage offers the possibility to lower the 2D resolution, only showing 1/16 pixels, offering a higher frame rate. By default, the PC-Beamage is always in 2D high resolution. This feature is especially useful when viewing a large beam and when high speed is a priority.

3.9. BEAMAGE-M2 MODE

Figure 3-43 Show/Hide M2 Mode Button

The M2 mode activates the M^2 measurement functions of PC-Beamage software. The M^2 factor can be considered as a quantitative indicator of laser beam quality. In terms of propagation, it is an indicator of closeness to an ideal Gaussian beam at the same wavelength. For more information on how to use this mode, please refer to section 6.

3.10. SOFTWARE INFO

The "*Information Menu"* displays important and useful information about the Beamage and provides help.

Figure 3-44 Software Info

3.10.1. Color Legend

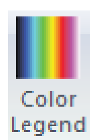


Figure 3-45 Color Legend Button

The *"Color Legend"* button shows the colors corresponding to the 3D and 2D display intensity levels.

Figure 3-46 Color Legend

3.10.2. Contact Support

Figure 3-47 Contact Support Button

If you need support or help with your PC-Beamage software you can contact a Gentec-EO representative by clicking on the *Contact Support* button. By clicking on this button, a *Contact Support* panel will appear and will prompt you to fill in the required information.

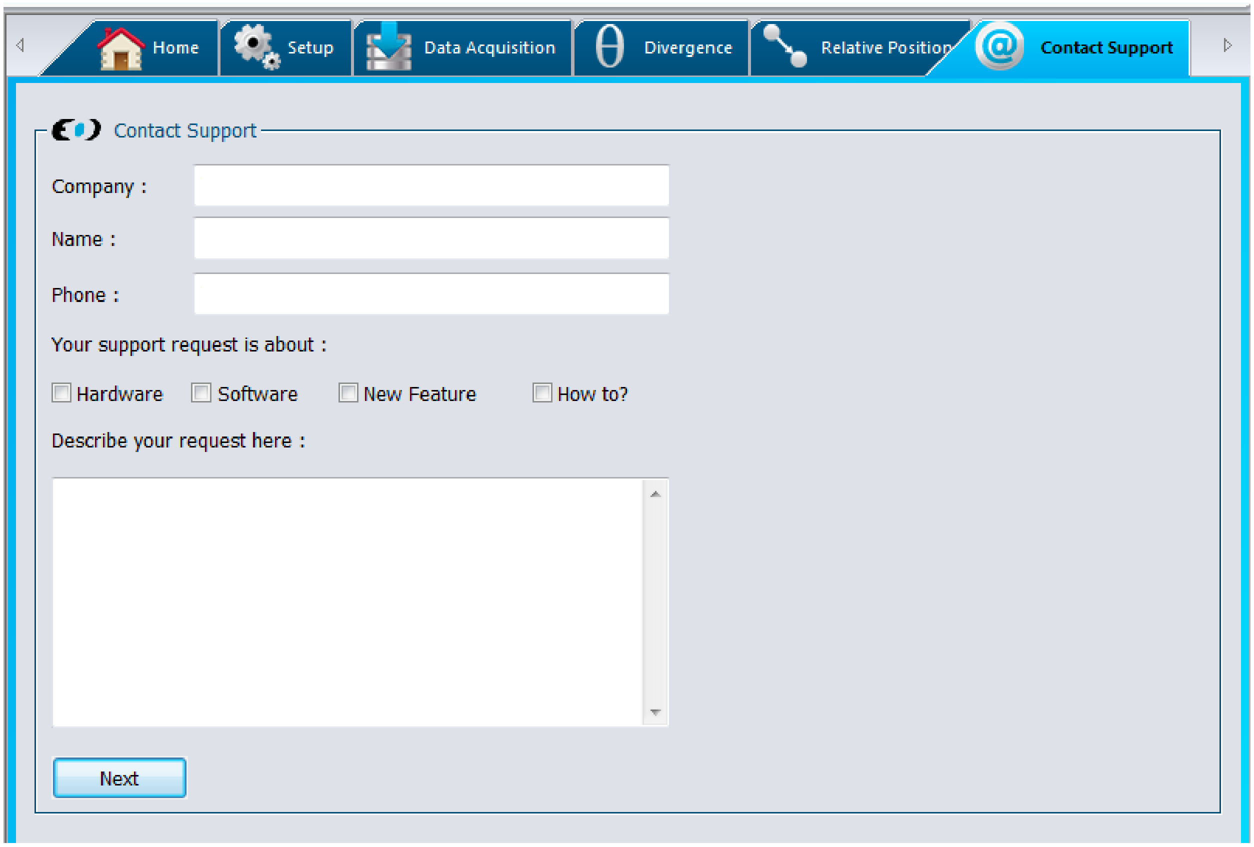


Figure 3-48 Contact Support Button

Once you click *Next*, an automatically generated email will appear containing information about your PC-Beamage setup and your beam profiler. You can also attach any files, images, or documents concerning your issue to this email.

3.10.3. About

Figure 3-49 About Button

To learn more about the PC-Beamage software, camera and sensor, click the "*About"* Button.

Tip

You can also obtain the latest PC-Beamage software version on our website at www.gentec-eo.com/downloads

3.10.4. Help

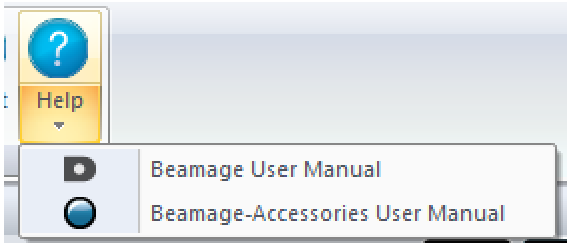


Figure 3-50 Help Button

The *"Help"* button opens the Beamage Series user manual. All information, tips, warnings and troubleshooting about the software are in this manual. It is also possible to open both the Beamage user manual and the Beamage accessories user manual.

Warning

The help file is in PDF format. A PDF reader needs to be installed on your computer to open the file.

4. HOME AND SETUP PANELS

The PC-Beamage offers different panels to view the measures and set different options for the Beamage.

Home: Controls the computation parameters and displays the beam's diameter and centroid information.

Setup: Controls the Beamage parameters.

Data Acquisition: Controls the acquisition parameters

Divergence: Controls the divergence parameters and displays the results. This tab is available when the *Divergence* button is activated in the *Main Controls* (refer to section 3.8.1).

Relative Position: Sets the origin position (0,0) to a user-defined value. This tab is available when the *Relative Position* button is activated in the *Main Controls* (refer to section 3.8.1).

Camera Lens: Calibrates the *Pixel Multiplication Factor* when using a Camera Lens. This tab is available when the *Camera Lens* button is activated in the *Main Controls* (refer to section 3.8.1).

Fixed Crosshair: Set the crosshair origin position (0,0) and orientation to a user-defined value. This tab is available when the *Fixed Crosshair* button is activated in the *Main Controls* (refer to section 3.8.1).

M2: Turns the PC-Beamage software into M2 mode to measure the Beamage Propagation M2 factor (refer to section 6)

To choose the desired display mode, click on the corresponding tab above the Controls and Measure panel

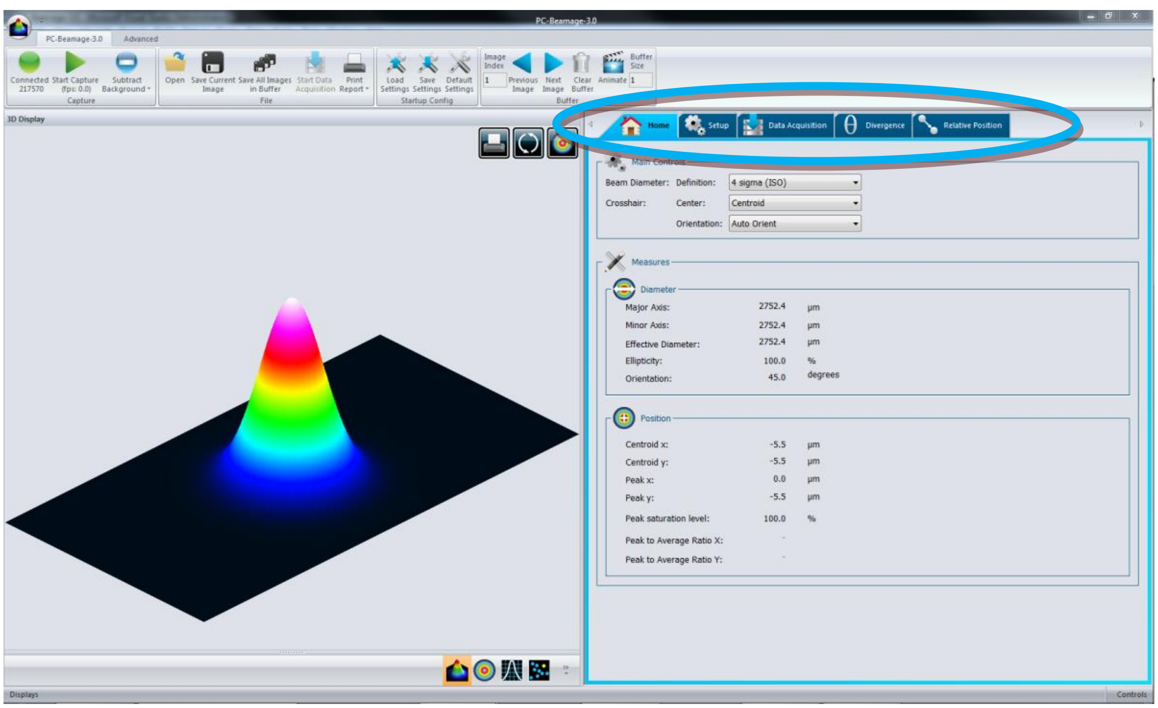


Figure 4-1 Graphic Display

4.1. HOME

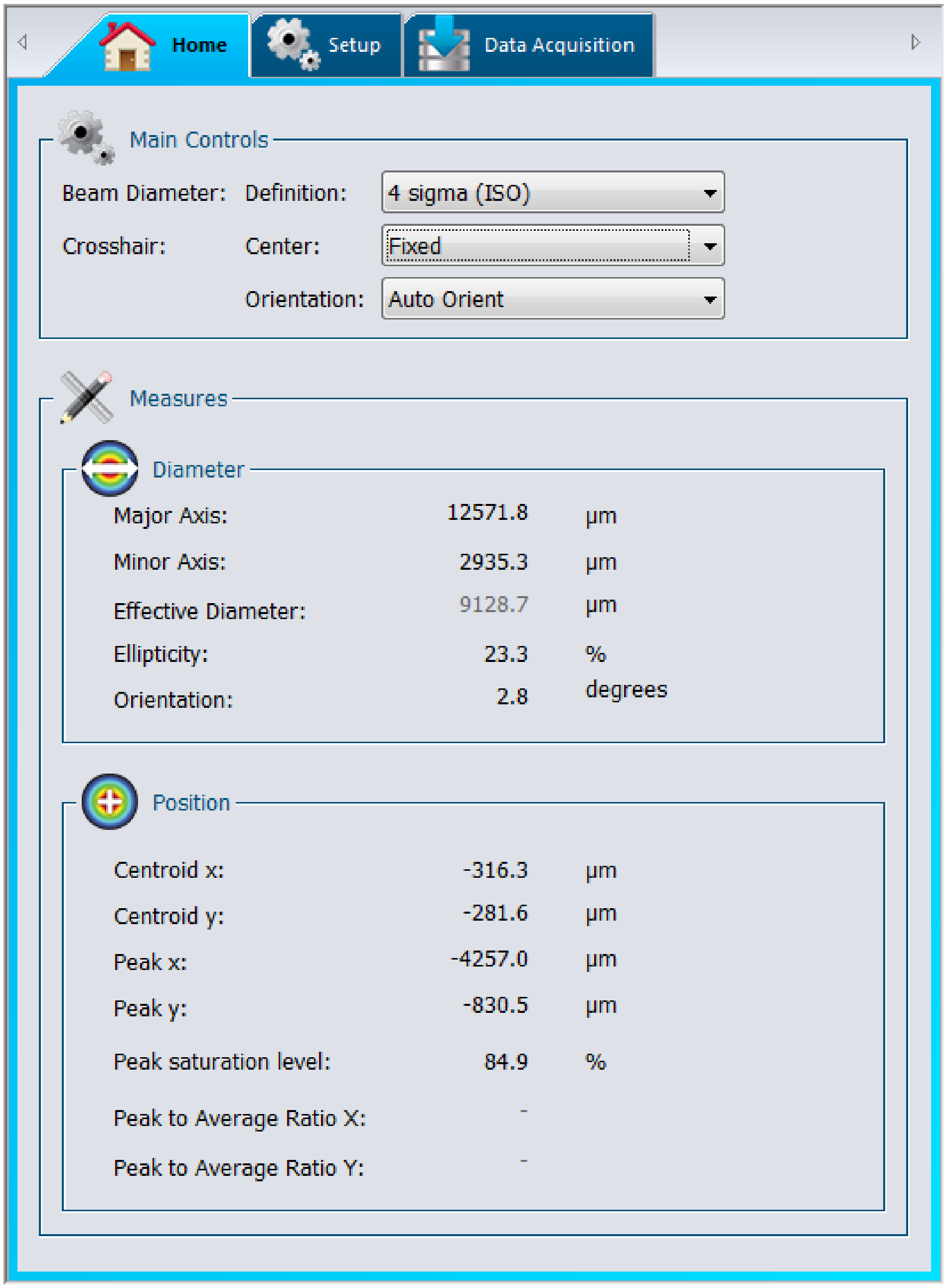


Figure 4-2 Home Tab

Main Controls: Defines the beam width definition and crosshair position.

Diameter: Displays the beam diameter computation results.

Centroid: Displays the beam's centroid and peak coordinates.

4.1.1.Main Controls

The "*Main Controls*" section allows the user to set the desired beam diameter definition and crosshair position. Use the drop-down menu to select the desired settings.

4.1.1.1. Beam Diameter Definition

By default, the beam width definition is set to "*4 sigma (ISO)*" which respects the ISO-11146-1:2005 and ISO11146-2:2005 standards (refer to Appendix A. ISO11146 and ISO11670 Definitions). This definition takes the entire image to compute the beam parameters, which slows the computation time and reduces the frame rate.

The *"FWHM along crosshairs (50%)"* finds the crosshair's Full Width Half Maximum (FWHM). The algorithm will return the width corresponding to the curve's first half maximum and the curve's last half maximum. Because the beam definition only takes into account a slice of the beam, the computation time is much faster and higher frame rates can be achieved.

The *"1/e2 along crosshairs (13.5%)"* finds the crosshair's width corresponding to $1/e^2$ (about 13.5%) of its maximum. As with the FWHM, this beam definition will increase the frame rate.

The *"86% effective diameter (D86)"* computes the circular beam containing 86% of the total intensity. This definition assumes the beam is circular.

4.1.1.2. Crosshair Definition

The crosshair is defined by its center (intersection of the 2 crosshairs) and its orientation. The crosshair center can be set to the beam's centroid as defined by the ISO-11146-1:2005 and ISO-11146-2:2005 standards, the beam's peak position or at a user-defined fixed position. If many pixels correspond to the peak value, the crosshair's center will be set to the first peak.

The crosshair's orientation is set to *"Auto Orient"* by default, which aligns it to the beam's orientation as defined by the ISO-11146-1:2005 and ISO-11146-2:2005 standards. It can also be set to a fixed 45° or 0° angle, or at a user-defined fixed angle.

Warning

The crosshair definition will affect the XY Display (refer to section 00) and the beam width if it is defined by the FWHM or $1/e^2$ along crosshair

4.1.2.Measures

The *"Measures"* section presents the beam's diameter and centroid information according to the selected beam definition (refer to section 4.1.1.1).

The computation algorithm first determines an approximate beam diameter (13.5% clip level). The algorithm will consider that all pixels outside 2 times the approximate beam diameter are the *outside area*. The *outside area's* average will become the *baseline*, which will be subtracted from the *area containing the beam*. Only the *area containing the beam* will be used to compute the diameter. This means that a smaller beam will have a smaller area which will decrease the computation time and increase the frame rate. If the beam is larger and all pixels contain the *area containing the beam*, there will be no *baseline* subtraction and the frame rate will be slower.

4.1.2.1. Diameter

The *"Major Axis"* is the beam maximum width whereas the "Minor Axis" is the minimum beam width.
The "Effective Diameter" is the beam's diameter considering it is circular.
The effective diameter is only valid if the ellipticity is greater than 87%. If the beam's ellipticity is lower than 95%, the effective diameter will by grayed-out, indicating it is not valid.
The *"Ellipticity"* is the ratio between the minor axis and the major axis. For a perfect round Gaussian beam, the ellipticity would be equal to 100%.
The *"Orientation"* is defined as the "angle between the *x-axis* […] and that of the principal axis of the power density distribution which is closer to the *x-axis."* [1]. From this definition, the angle is comprised between -45° and 45°.

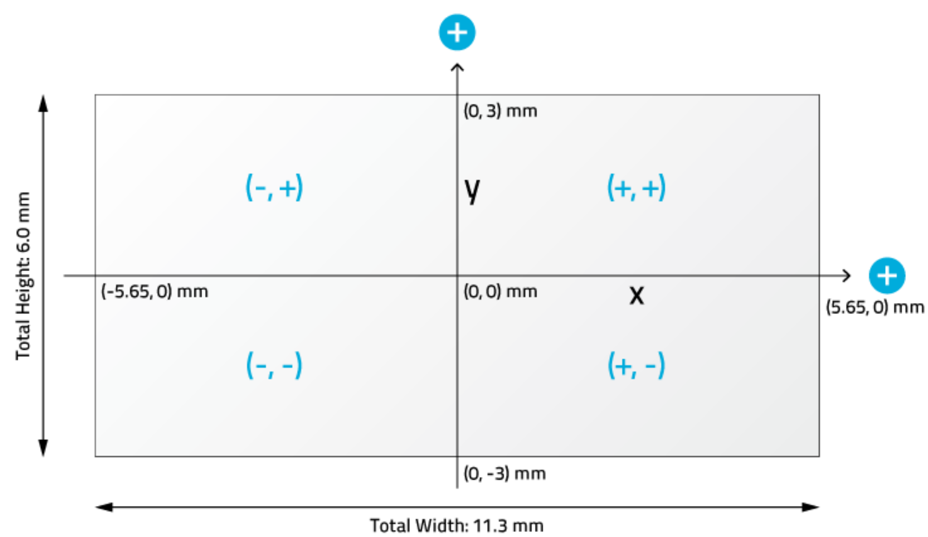
For more information on beam diameter computations as defined by the ISO-11146-1:2005 and ISO-11146-2:2005 standards, please refer to Appendix A. ISO11146 and ISO11670 Definitions)

Warning

According to the beam definition, the displayed measures will vary. For example, for "*86% effective diameter (D86)*", only the effective diameter will be displayed, as the major, minor axis, and orientation are not relevant in a perfectly circular beam.

4.1.2.2. Centroid

All positions are relative to the image center which is (0,0). The horizontal axis increases toward the right-hand side and the vertical axis increases toward the top.



[1] International Organization for Standardization, *ISO 11146 :2005 Laser and laser-related equipment – Test methods for laser beam widths, divergence angles and beam propagation ratios, 2005, Geneva*

Figure 4-3 Fixed Coordinates System for the Sensor

The beam *"Centroid"* corresponds to the beam's first order distribution as defined by the ISO-11146-1:2005 and ISO-11146-2:2005 standards (refer to Appendix A)

The beam's *"Peak"* position corresponds to the pixel's peak value position. If many pixels correspond to the peak value, the crosshair will be centered on the first peak.

The beam *"Peak to Average Ratio"* corresponds to the ratio between the actual beam peak value and the height of an equivalent simulated flat-top beam. The simulated beam's width is the $1/e^2$ diameter of the actual beam and has the same area (same energy). The software computes the ratios for both the X and Y axes.

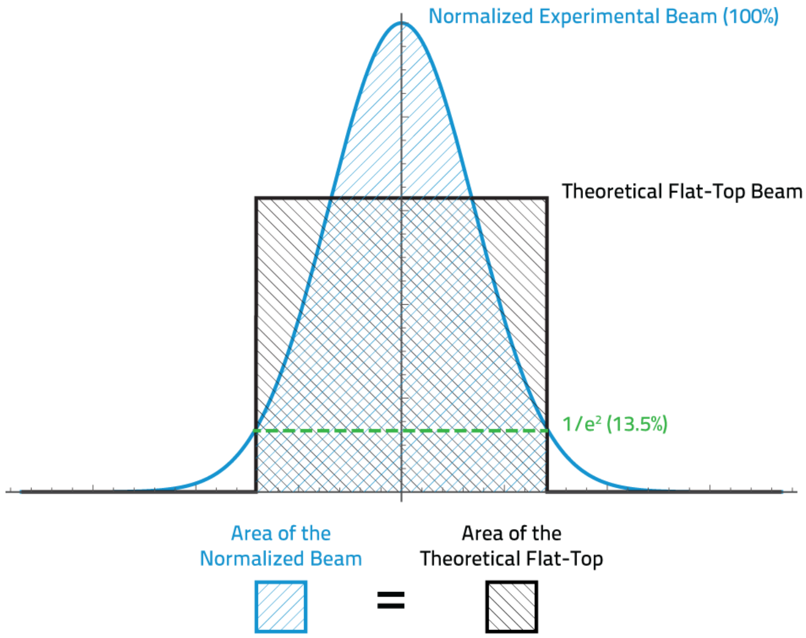


Figure 4-4 Peak to Average

These results are only available when the *"1/e2 along crosshairs (13.5%)"* beam diameter definition is selected. If any other definition is used, the *"Peak to Average Ratios"* are not computed and dashes are displayed. When the crosshair center is set to *"Centroid"* instead of *"Peak"*, results are grayed out to remind the user that the values do not correspond to the *"Peak to Average Ratios"*.

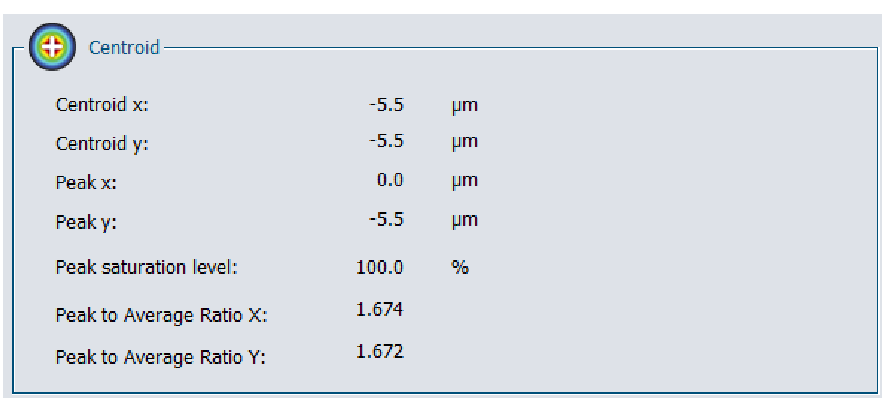


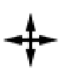
Figure 4-5 Peak to Average Ratio Example

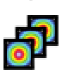
4.2. SETUP

The *"Setup"* tab allows the user to set the Beamage parameters.

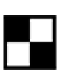
Figure 4-6 Setup Tab

 **Exposure time:** Controls the Beamage sensor's exposure time.

 **Image orientation:** Rotates or flips the captured image.

 **Image Averaging:** Applies a temporal filter by averaging multiple frames

 **Active Area:** Selects the region of interest.

 **Pixel Addressing:** Reduces the spatial resolution by averaging or decimating pixels.

Gain: Adds numerical gain to captured image.

 **ADC Level:** Selects the BEAMAGE's ADC level for each pixel

 **Pixel Multiplication Factor:** Adjusts the pixel multiplication factor when using optical components

4.2.1.Exposure Time

The *“Exposure Time”* controls the Beamage’s exposure time settings. It can be set from 0.06 ms to 200 ms. The *“Auto”* option will automatically set the exposure time in order to have the maximum beam intensity at 85% of the sensor’s saturation level. The exposure time can also be set manually by clicking on the corresponding radio button and changing the value in ms.

Tip

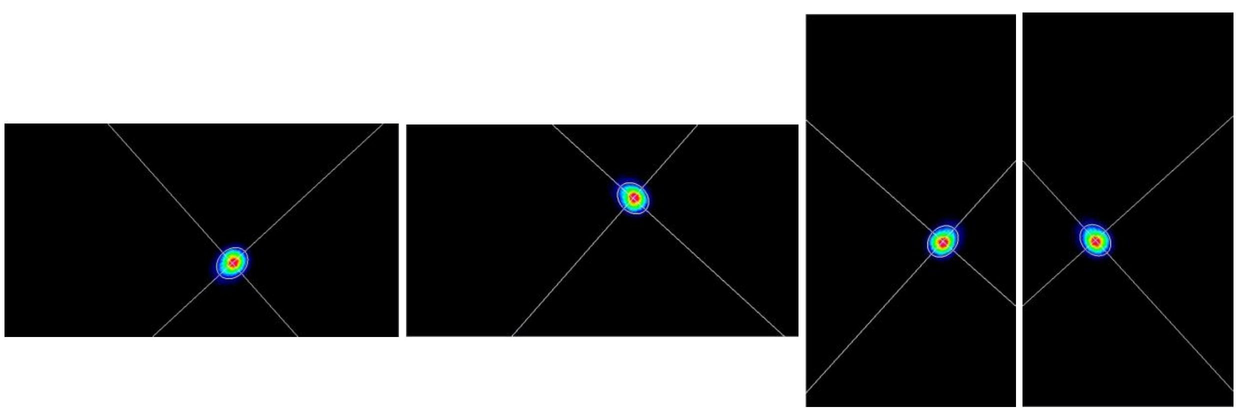
> If the beam is still saturated at a 0.06 ms exposure time, please increase the attenuation in front of the Beamage. If the beam intensity is too low at 200 ms exposure time, please lower the attenuation in front of the Beamage.

4.2.2.Image Orientation

The *“Image Orientation”* controls rotate or flip the captured frame. The captured frame can be rotated to 90º, 180º, or 270º. All angles rotate clockwise. The captured frame can also be flipped horizontally or vertically. If a frame is saved with a rotation and/or a flip, it will keep these orientation settings. Note that the reference axis for the centroid is neither flipped nor rotated. All positions are always relative to the image’s center which is (0,0) and the horizontal axis always increases towards the right-hand side and the vertical axis always increases towards the top.

Warning

> When the Beamage is not capturing images and is in *“Animate”* mode or buffer viewing mode, it will neither flip nor rotate the current image, as it has already been captured.



Initial image (no rotation, no flip) Flip horizontal 90° rotation Flip & rotation

Figure 4-7 Image Orientation Examples

4.2.3. Image Averaging

The *"Image Averaging"* function is a temporal filter that captures a specified number of frames (2, 5, or 10) and averages the frames pixel by pixel to create a single time-averaged image. This lowers the total frame rate because multiple frames need to be captured for one computation.

Tip

> Image Averaging will smooth the beam fluctuations that can occur over time. It is very useful when working with unstable laser sources.

4.2.4. Active Area

The *"Active Area"* function allows the user to select a region of interest (ROI) on the sensor. This will increase the frame rate, as fewer pixels need to be transferred from the Beamage. This can only be done on small beam sizes, since a cropped beam would invalidate the beam width measurements. Furthermore, to have an accurate measurement, the active area must be at least 2 times the beam size.

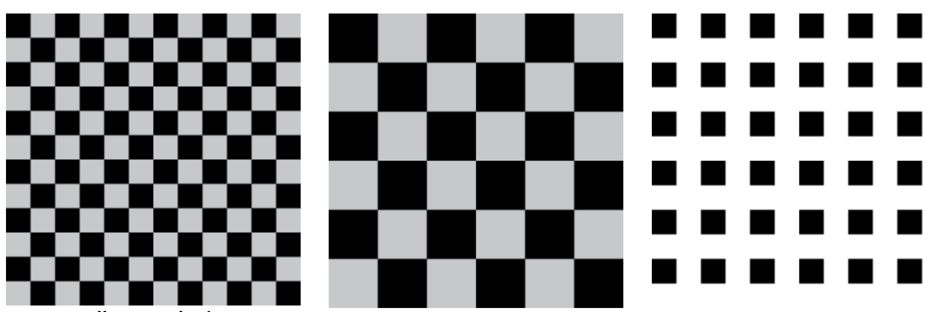
The user can select the desired area from a preset selection or enter a custom size. By default, the area will be placed at the sensor's upper left corner pixel (0, 0). This position can be changed by entering the active area's upper left position. Checking the "*Center"* check box will center the active area to the sensor's center.

Tip

> **When working with small beams,** optimize the speed of the data transfer and still maintain accurate results, by using an *Active Area* that is twice the size of your beam.

4.2.5. Pixel Addressing

The *"Pixel Addressing"* mode allows the user to downsample the captured image. The *"Average 2x2"* will take a 2x2 pixel cluster and return its average as one larger pixel. The "Average 2x2" function is only available in the 12-bit ADC mode. The *"Decimate 2x2"* will only return 1 out of the 4 pixels. Because the pixel area is doubled with this mode, it can be used with large beams, where the spatial resolution is not crucial. It will increase the frame rate because fewer pixels are transferred from the Beamage.



Full Resolution Average 2x2 Decimate 2x2

Figure 4-8 Pixel Addressing Mode

Tip

<u>When working with large beams,</u> optimize the speed of the data transfer by reducing the spatial resolution using the *Pixel Addressing* function.

4.2.6. Gain

The *"Gain"* setting allows the user to set a numerical gain on the captured image. The gain must be between 1 and 10. If the pixel value is over the maximum ADC level (For 12-bit → 2^{12} = 4096), the pixel value will be topped at the maximum ADC level.

4.2.7. ADC Level

The ADC level is the pixel's depth which can be set to 12 or 10 bit. In the 12-bit mode, each pixel value is on 2^{12} = 4096 levels while the 10-bit mode is on 2^{10} = 1024 levels. The 12-bit mode has a slower frame rate.

Warning

If the Beamage is set in 12-bit mode, it will slow the frame rate.

4.2.8. Pixel Multiplication Factor (PMF)

If the Beamage camera is operated with an optical component that has magnification properties (such as a magnifying lens, a UV Converter or an IR Adaptor), the Pixel Multiplication Factor must be adjusted in order to have the exact beam dimensions. The *"Pixel Multiplication Factor"* section can be found at the bottom of the *"Setup" tab.*

Tip

The default value for the *Pixel Multiplication Factor* is 1.

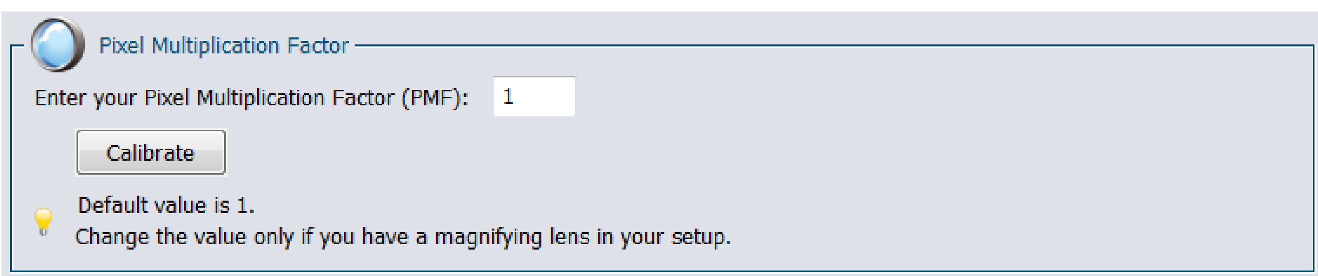


Figure 4-9 Pixel Multiplication Factor

It is possible to manually set a value for the PMF. Simply enter the desired value in the white box and press enter. The beam dimensions will be adjusted accordingly. If a camera lens is used with the Beamage camera, it is possible to follow the camera lens calibration steps by clicking on the *"Calibrate"* button. This will open the *"Camera Lens"* tab. Refer to section 4.6 for more information about the camera lens calibration

4.3. DATA ACQUISITION

The *"Data Acquisition"* tab allows the user to set the acquisition parameters. It is possible to save the beam profiling results shown in the "*Measures*" tab (refer to section 4.1.2) in a *TXT file. The *TXT file includes a header, containing the acquisition settings, followed by the data. Each line corresponds to a single frame and all the measurements are separated by a tab. This file can be opened in a spreadsheet software, such as Microsoft Excel. It is also possible to save the images associated with the measurements saved in the *.TXT logging file. Each image will be individually saved in a native *.BMG file.

Camera Name: PC-Beamage-3.0
Serial Number: 208111
Firmware: 1.7
Description: PC-Beamage-3.0
Sample Rate: 1 / 1 pulse(s)
Total Duration: 0:0:0:15 (DD:HH:MM:SS)

Date	Ellapsed time(sec)	Major Axis(um)	Minor Axis(um)	Effective Diameter(um)	Ellipticity(%)	Orientation(degrees)	Centroid X(um)	Centroid y(um)	Peak X(um)	Peak Y(um)	Peak Saturation	Peak to Average Ratio X	Peak to Average Ratio Y
09:43:39, Thursday, June 13, 2013	0.421	2666.7	1281.5	2092.1	48.1	29.5	-141.2	977.1	-159.5	858	93.9	2.8	2.4
09:43:39, Thursday, June 13, 2013	0.874	2666.6	1281.5	2092	48.1	29.5	-141.9	977.1	-462	880	89.7	2.8	2.4
09:43:40, Thursday, June 13, 2013	1.466	2667	1282.6	2092.6	48.1	29.5	-141.2	978	-462	880	90.5	2.8	2.4
09:43:40, Thursday, June 13, 2013	1.919	2666.4	1282.2	2092.1	48.1	29.5	-141.8	976.9	-170.5	858	92.4	2.8	2.4
09:43:41, Thursday, June 13, 2013	2.371	2666.1	1281.2	2091.6	48.1	29.5	-141.3	976.1	-456.5	880	95.1	2.8	2.4
09:43:41, Thursday, June 13, 2013	2.808	2669.3	1285.3	2094.9	48.2	29.6	-140.2	978.9	-198	858	93	2.8	2.4
09:43:42, Thursday, June 13, 2013	3.26	2668.2	1284.6	2094	48.1	29.4	-140.6	977.7	-462	880	95.8	2.8	2.4
09:43:42, Thursday, June 13, 2013	3.713	2667.3	1282.5	2092.8	48.1	29.4	-141.8	976.7	-165	858	91.3	2.8	2.4
09:43:43, Thursday, June 13, 2013	4.165	2667.6	1283.3	2093.2	48.1	29.4	-141.9	976.9	-198	858	91.7	2.8	2.4
09:43:43, Thursday, June 13, 2013	4.618	2668	1283.8	2093.6	48.1	29.5	-141.3	977.1	-170.5	869	93.4	2.8	2.4
09:43:44, Thursday, June 13, 2013	5.07	2669.2	1287.1	2095.4	48.2	29.4	-141.1	977.5	-170.5	858	92.5	2.8	2.4
09:43:44, Thursday, June 13, 2013	5.522	2667.7	1283.3	2093.3	48.1	29.4	-141.4	976.7	-170.5	858	94.3	2.8	2.4
09:43:45, Thursday, June 13, 2013	5.975	2668.7	1285.5	2094.5	48.2	29.5	-141.6	977.3	-159.5	869	92.9	2.8	2.4
09:43:45, Thursday, June 13, 2013	6.443	2670	1286.4	2095.6	48.2	29.4	-140.6	978	-462	880	92.7	2.8	2.4

Figure 4-10 Example File of a Measurement Acquisition

To start the acquisition, click on the "Start Data Acquisition" button in the "Main Controls" (refer to section 3.6.4).

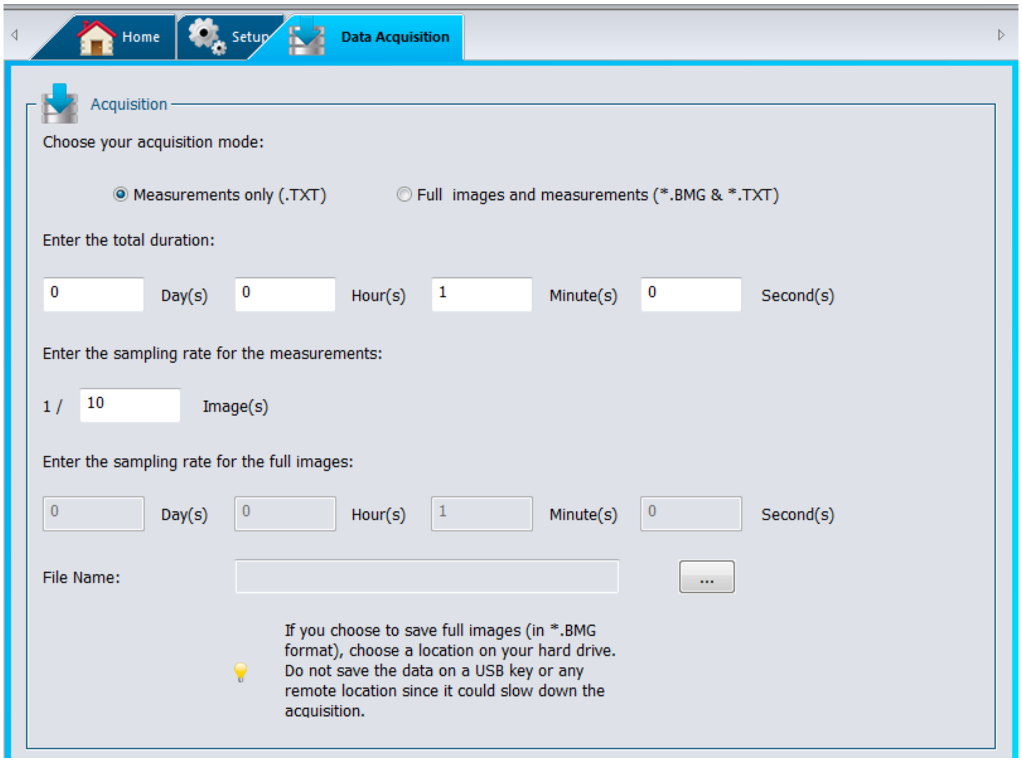


Figure 4-11 Data Acquisition Tab

The *“Duration”* defines the time for which the acquisition will keep running. The countdown starts as soon as the user presses the *“Start Data Acquisition”* button located in the *“Main Controls”*. The user can select the number of days, hours, minutes and seconds.

The *“File Name”* allows the user to specify a name and a path for his file. A filename must be defined to start an acquisition. If the *“Full images and measurements*” is selected, then a series of “.BMG” files with the same filename concatenated with its corresponding increment will be saved.

The *“Sample Rate”* defines the rate at which the samples are saved. When choosing the *“Measurements only”* acquisition mode, the sample rate is defined as 1/X images. To save every frame computed, enter the value “1” in the box. To keep track of only a small amount of frames, enter a higher value. When choosing the *‘Full images and measurements”* acquisition mode, the sample rate is defined temporally. The fastest rate is limited to 1 per second.

Warning

Each *.BMG file can take up to 8.50 MB on the hard drive. Acquiring multiple frames can quickly sum up to multiple Gigabytes. If the total acquisition if over 1 GB, a warning message will appear. If there is only 10 GB left on the hard drive, a warning message will appear and the acquisition will be stopped. Fast acquisition should be done on the computer’s hard drive and cannot be done on an external drive or on a server hard drive since it could slow down the acquisition.

4.4. DIVERGENCE

The divergence tab opens when the divergence button is clicked in the Main Controls (refer to section 3.8.1).
To compute the divergence and abide by the ISO-11146-1:2005 standard, the first step is to place an aberration-free lens between the Beamage and the laser. The lens should be placed in the far-field of the laser beam while the Beamage is at the lens’ focal point. The second step is to enter the lens’ focal length in the software. Since the focal length is wavelength dependent, make sure to use the correct value for your laser in the prior settings. The divergence in both main axes (x and y) are computed as defined by the ISO-11146-1:2005 and ISO-11146-2:2005 standards and displayed at the bottom of the “*Divergence”* tab (refer to Appendix A).

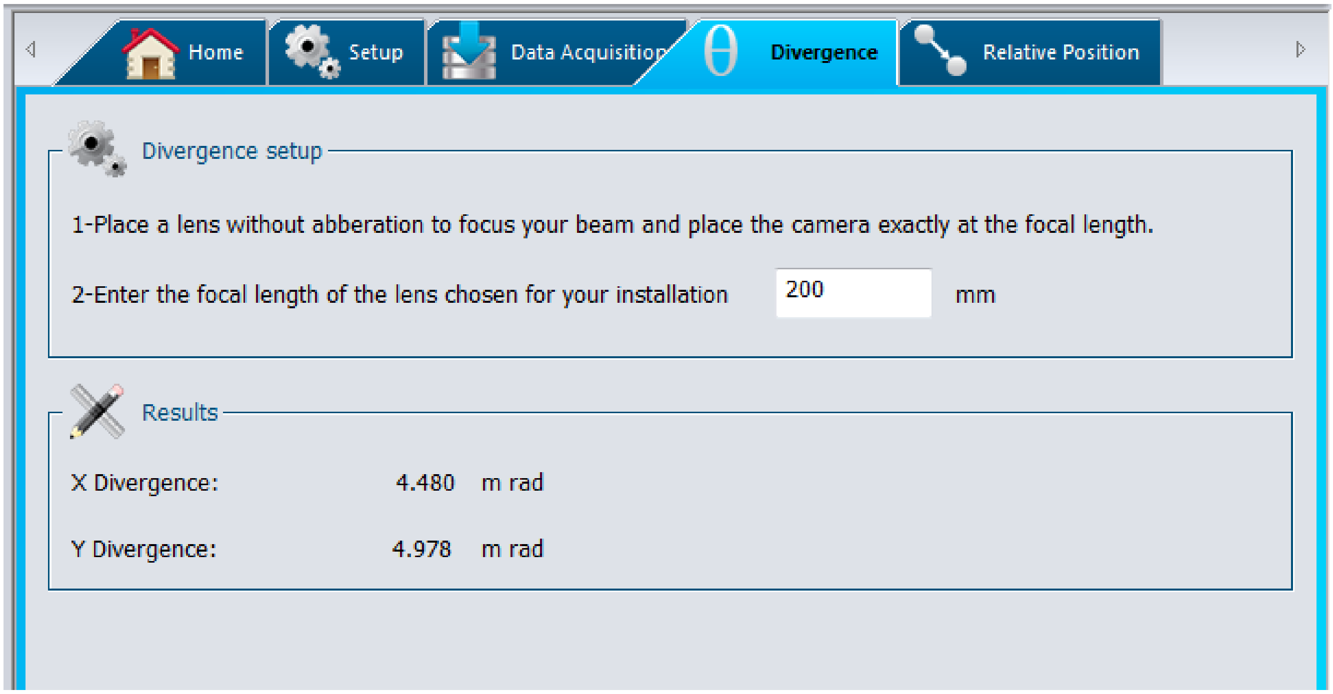


Figure 4-12 Divergence Tab

Warning

The Beamage sensor must be placed precisely at the focal point, not at the beam waist.

4.5. RELATIVE POSITION

4.5.1. Setup

The “*Setup*” section, which displays the coordinate system of the Beamage sensor on the right side, allows the user to select the parameter that will be considered as the origin position (0,0) by the software.

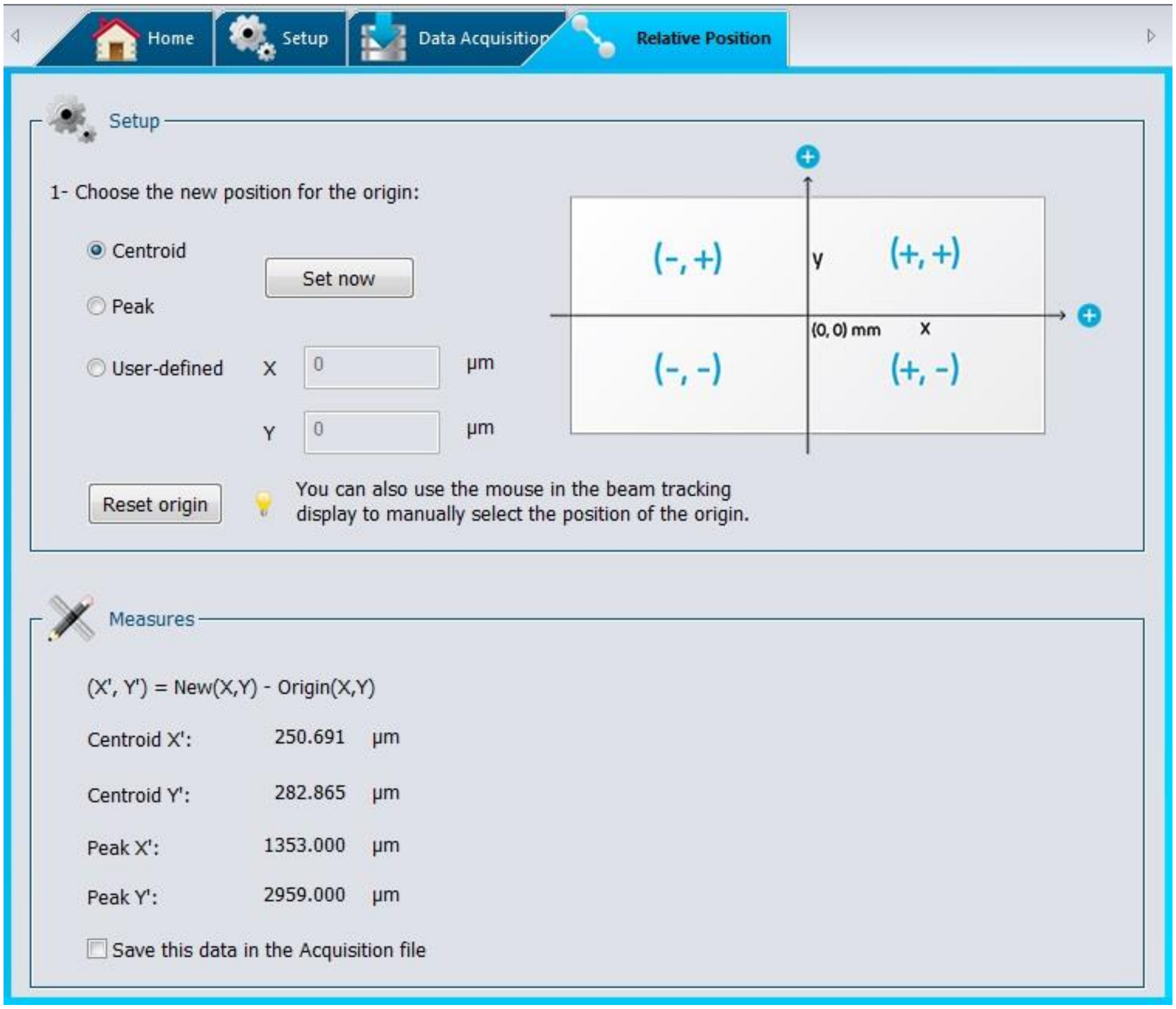


Figure 4-13 Relative Position Tab

By selecting “*Centroid*” and clicking “*Set now*”, the user chooses to position the origin at the computed centroid (center of energy). By selecting “*Peak*” and clicking “*Set now*”, the user chooses to position the origin at the computed energy peak (highest measured value). The option “*User-defined*”, allows the user to manually enter origin position values for both the X and Y axes.

It is also possible to position the origin by simply clicking with the mouse in the display. This can be done in the Beam Tracking Display, which shows the coordinate system of the Beamage sensor (refer to section 6.4). First, click on the “*Beam Tracking Display*” button at the bottom of the display screen to open the Beam Tracking window. Then, activate the pointer button at the top of the display ,and click where you want to position the new origin of the coordinate system. Once you have clicked on the desired point, the coordinate values for both X and Y axes will automatically be set beside “*User-defined*” in the “*Relative Position*” tab.

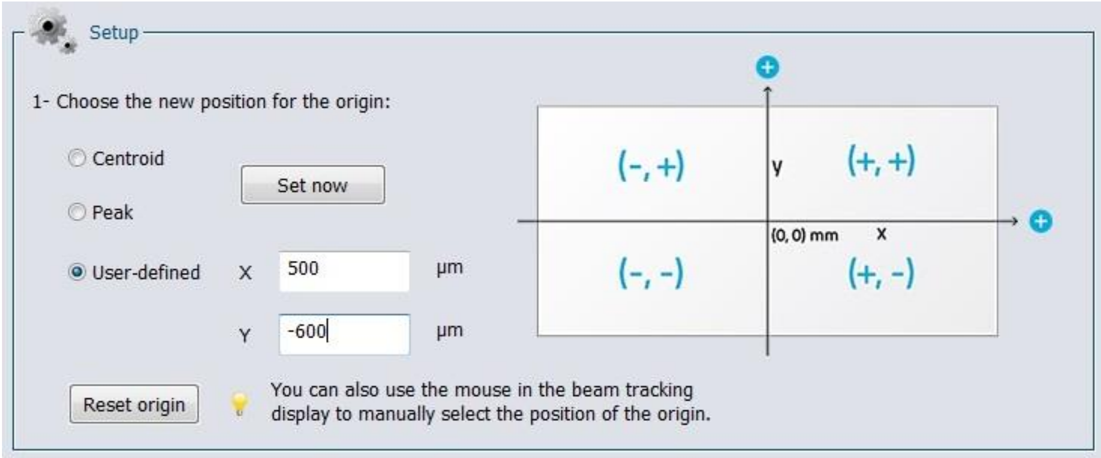


Figure 4-14 Coordinates Defined by User

To set the origin back to its default position (0,0), click on the "*Reset origin*" button below "*User-defined*". This will also automatically select the default option "*Centroid*" for the origin position.

4.5.2.Measures

Once the origin position is determined by the user, the software will calculate the difference between the coordinates of this new position and the latest computed centroid or peak coordinates. The results are displayed in the "*Measures*" section of the "*Relative Position*" tab.

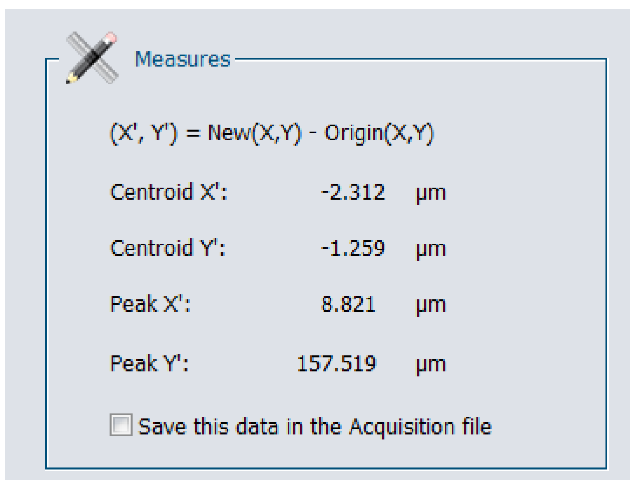


Figure 4-15 Measures Section

It is possible to save the data in the Acquisition file. To do so, select the "*Save this data in the Acquisition file*" option at the bottom of the "*Measures*" section.

4.6. CAMERA LENS

Prior to profiling a beam with a camera lens, one must adjust the *Pixel Multiplication Factor* of the lens (see section 5.2.8).

The "*Camera lens calibration*" section allows the user to calibrate the PC-Beamage software when a camera lens is used with the Beamage. This panel is accessible by clicking "*Calibrate*" in the "*Pixel Multiplication Factor"* section in the "*Setup"* panel or in the "*Show/Hide Options*" in the Ribbon.

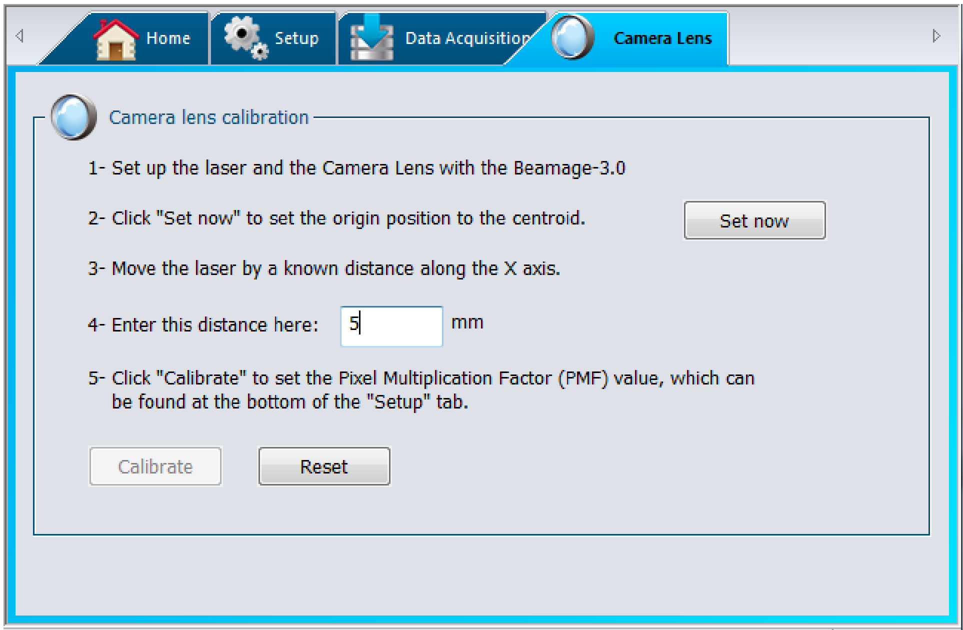


Figure 4-16 Camera Lens Calibration Section

1. Set up the laser and the camera lens with the Beamage.
2. Click on "*Set now*" to set the centroid to the current position
3. Then, move the laser source (or the Beamage camera) by a known distance along the X axis, parallel to the diffuser.

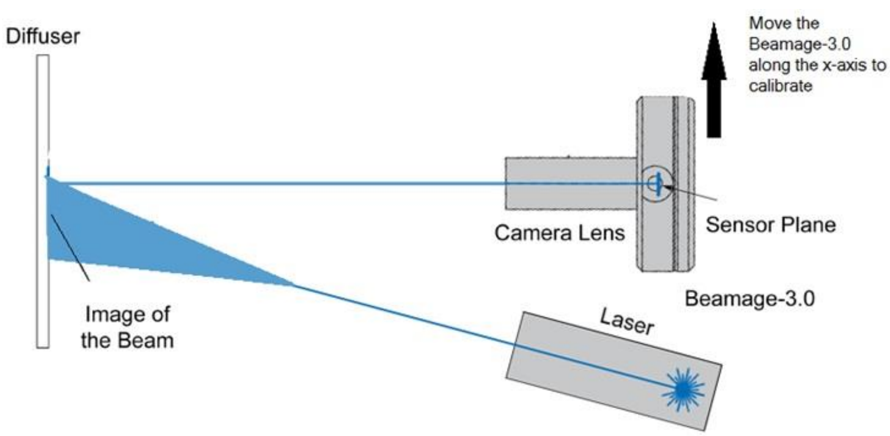


Figure 4-17 Camera Lens Calibration Moving Direction

4. Enter this distance (in mm) in the appropriate box and press enter.
5. Finally, click on the "Calibrate" button to automatically set the *Pixel Multiplication Factor (PMF)* value found in the bottom of the "*Setup*" tab. Once the PMF is set, the beam dimensions will be adjusted to compensate for the magnification of the camera lens (Beam Tracking Display).

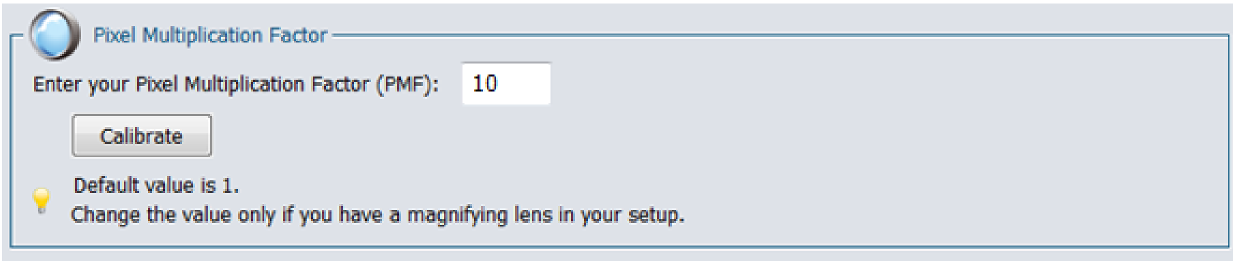


Figure 4-18 Pixel Multiplication Factor Section

6. To return to original values for the *Pixel Multiplication Factor*, click on "*Reset*"

4.7. FIXED CROSSHAIR

4.7.1. Center Setup

To activate the fixed crosshair center option, go to the "*Home*" panel, in the "*Main Controls*" section and choose the *Fixed* option for the crosshair center. This will automatically open the "*Fixed Crosshair"* panel.

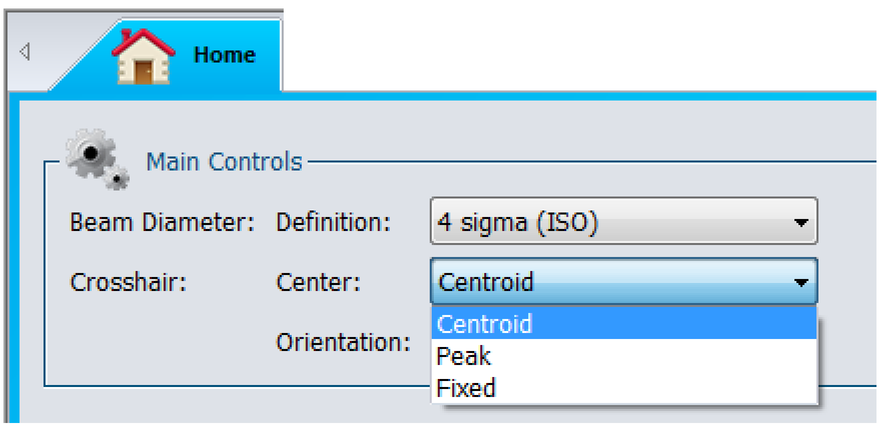


Figure 4-19 Fixed Crosshair Center Section

The "*Center Setup*" section, which displays the coordinate system of the sensor on the right side, allows the user to select the parameter that will be considered as the origin of the crosshairs (0,0).

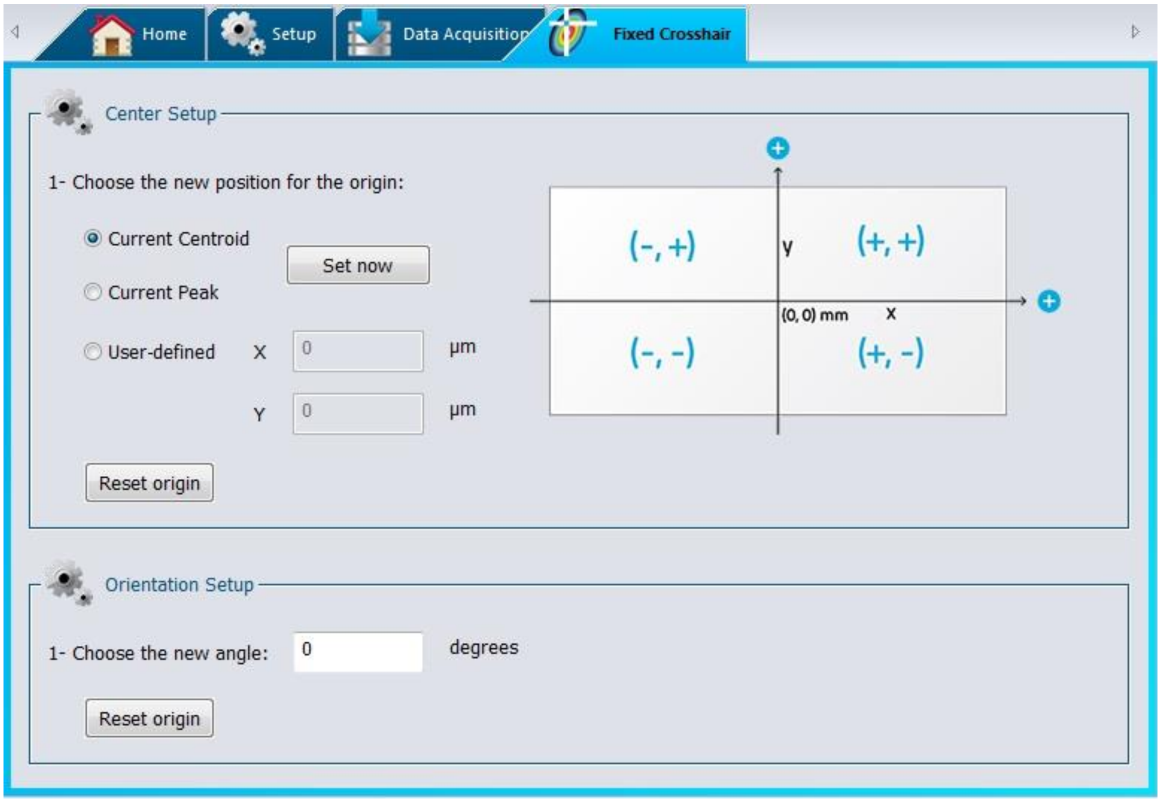


Figure 4-20 Fixed Crosshair Section

By selecting "*Centroid*" and clicking "*Set now*", the user chooses to position the origin of the crosshairs at the calculated centroid position (center of energy). By selecting "*Peak*" and clicking "*Set now*", the user chooses to position the origin of the crosshairs at the calculated peak energy position (highest measured value). The option "*User-defined*", allows the user to manually enter the origin of the crosshairs at a defined position in both the X and Y axes.

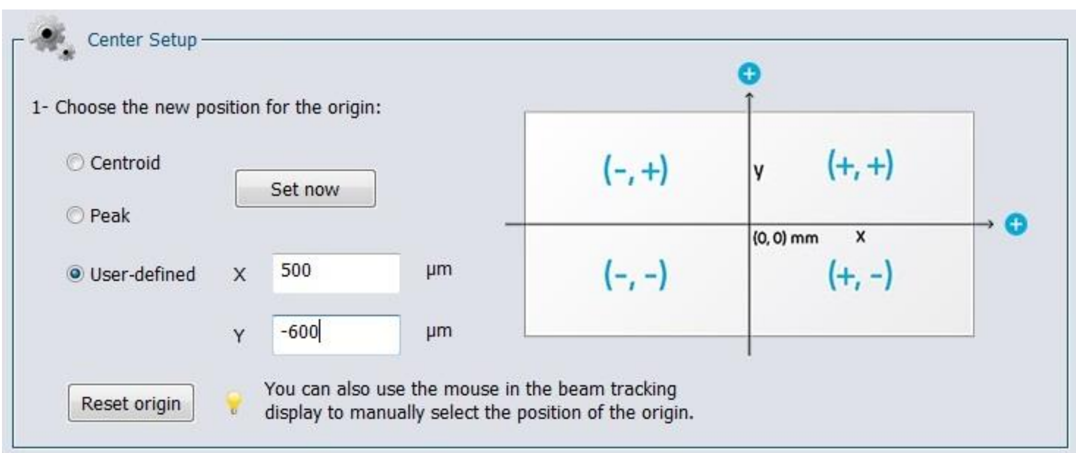


Figure 4-21 User-Defined Origin

Once the origin of the crosshairs is determined by the user, the software will be able to see the crosshairs from this particular origin in the 2D Display.

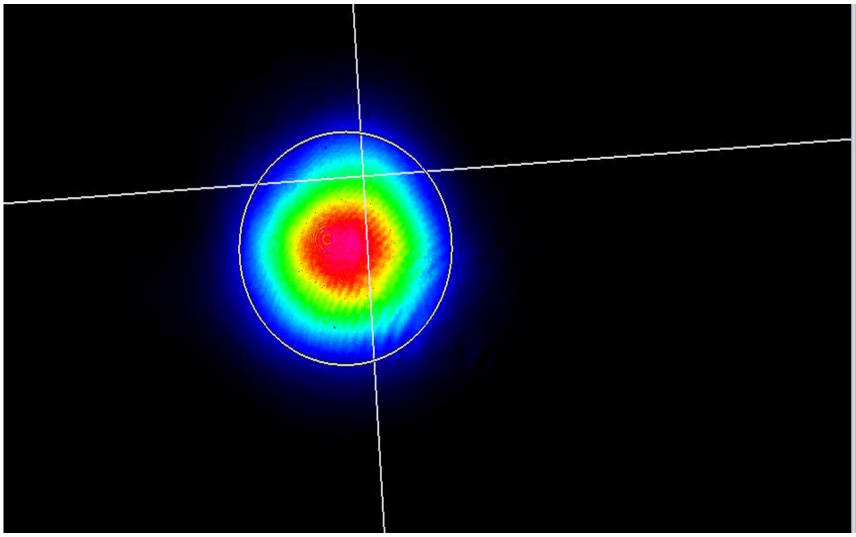


Figure 4-22 Fixed Crosshairs at Peak Position in the 2D Display

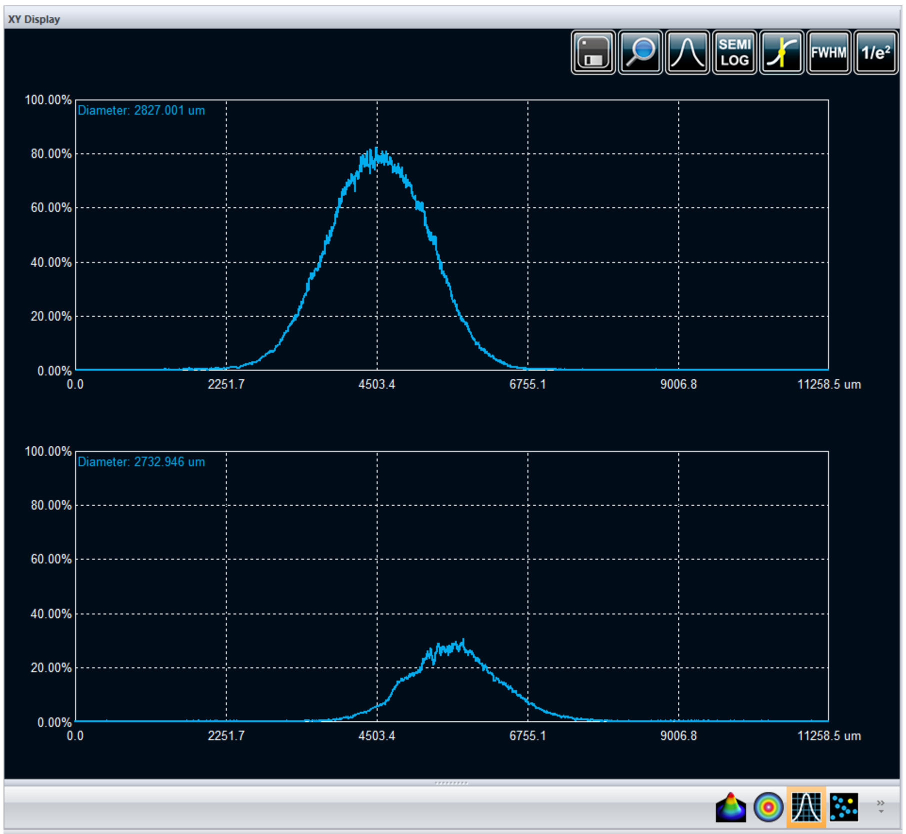


Figure 4-23 Fixed Crosshairs at Peak Position in the XY Display

It is also possible to set the origin in the 2D display. When the *Fixed* option is active in the "*Home"* panel, the picker tool will be activated in the 2D Display. To use it and set the origin of the fixed crosshair center, click on the toolbar button and then, click on the position into the image.

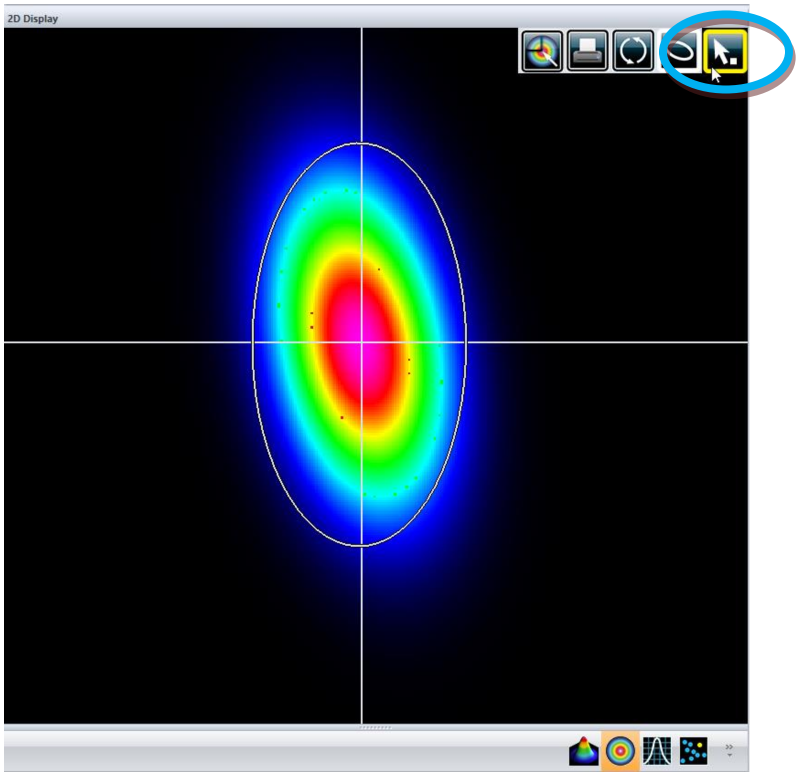


Figure 4-24 Fixed Crosshairs picker tool in the 2D Display

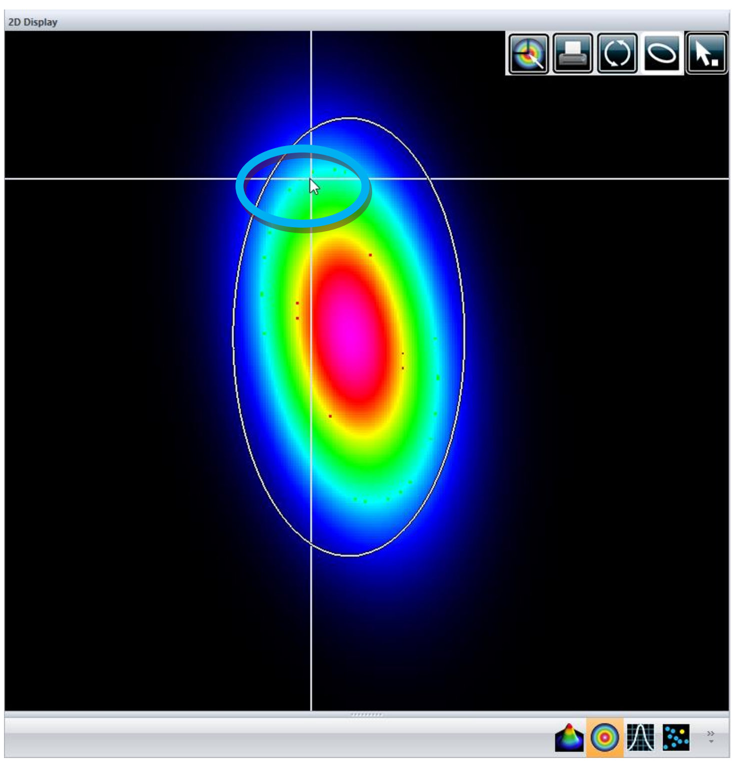


Figure 4-25 Fixed Crosshairs picking position in the 2D Display

4.7.2.Orientation Setup

To activate the fixed crosshair orientation option, go to the "*Home*" panel, in the "*Main Controls*" section and choose the *Fixed* option for the crosshair orientation. This will automatically open the "*Fixed Crosshair"* panel.

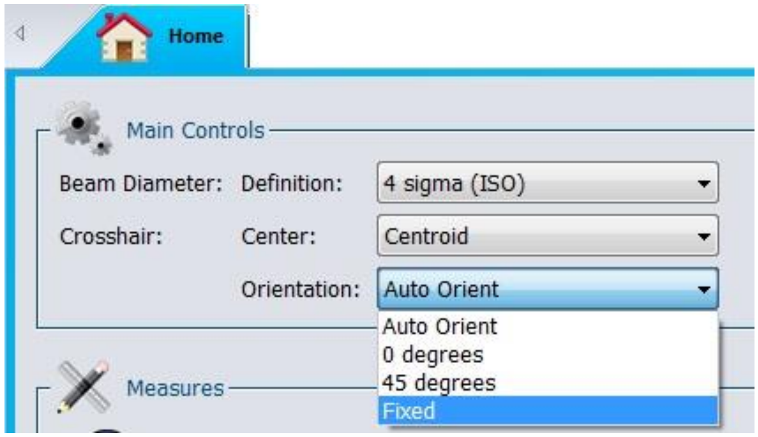


Figure 4-26 Fixed Crosshair Orientation Section

The "*Orientation Setup*" section allows the user to set the crosshair orientation. Once the orientation of the crosshairs is determined by the user, the software will be able to see the crosshairs at this particular angle with respect to the sensor's main axes.

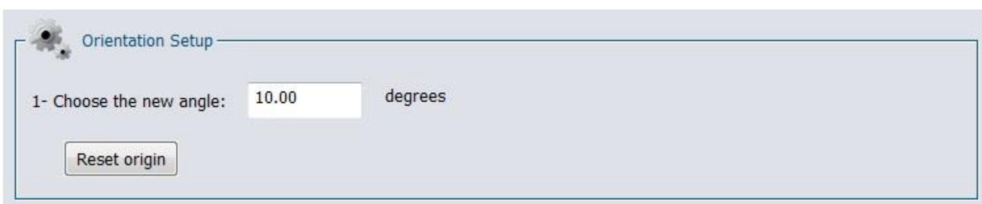
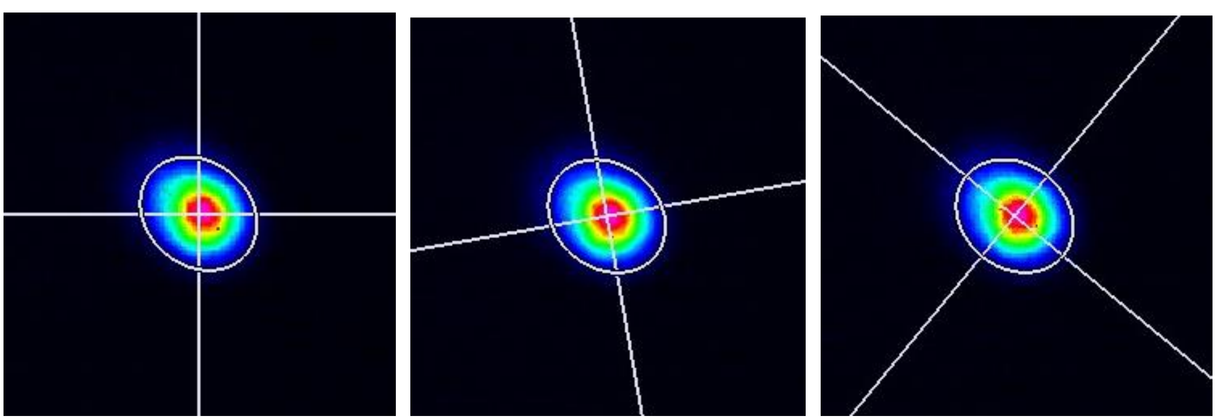


Figure 4-27 User-Defined Crosshair Orientation

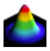


0.00 degrees 10.00 degrees Auto Orient

Figure 4-28 Different Crosshair Orientations for the Same Beam

5. DISPLAY PANEL

The PC-Beamage offers four different graphical displays to view and analyze the laser beam.

 **3D Display:** A real time display of the beam intensity in a 3D representation.

 **2D Display:** A real time display of the beam intensity in a 2D representation.

 **XY Display:** A real time display of the beam's XY cross-sectional graphs along the crosshairs.

 **Beam Tracking Display:** A real time display of the beam's position stability

To choose the desired display mode, click on the corresponding icon in the lower control bar under the display panel.

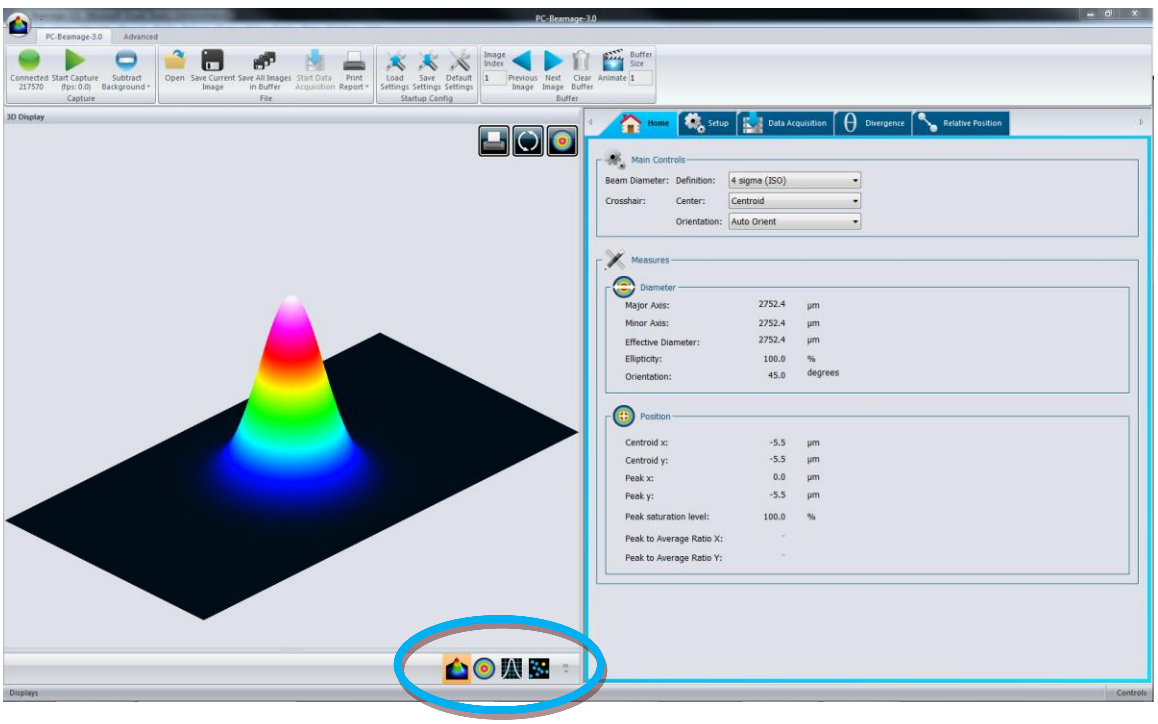


Figure 5-1 Display Panel

5.1. 3D DISPLAY

The 3D Display represents the beam's intensity in three dimensions. False coloring is added to increase the contrast. The color legend used for the various intensity levels is available in the "*Main Controls*" ribbon (refer to section 3.10.1).

To rotate the image, hold down the left button on the mouse and move the mouse. The scroll button on the mouse zooms the image in or out. It is also possible to zoom in the image by pressing the "+" key on the keyboard and similarly, it is possible to zoom out the image by pressing the "-" key on the keyboard. Pressing the Ctrl button while holding down the left mouse button will pan the 3D image along its Y axis. Doing the same procedure with the Shift button pans the 3D image along its X axis.

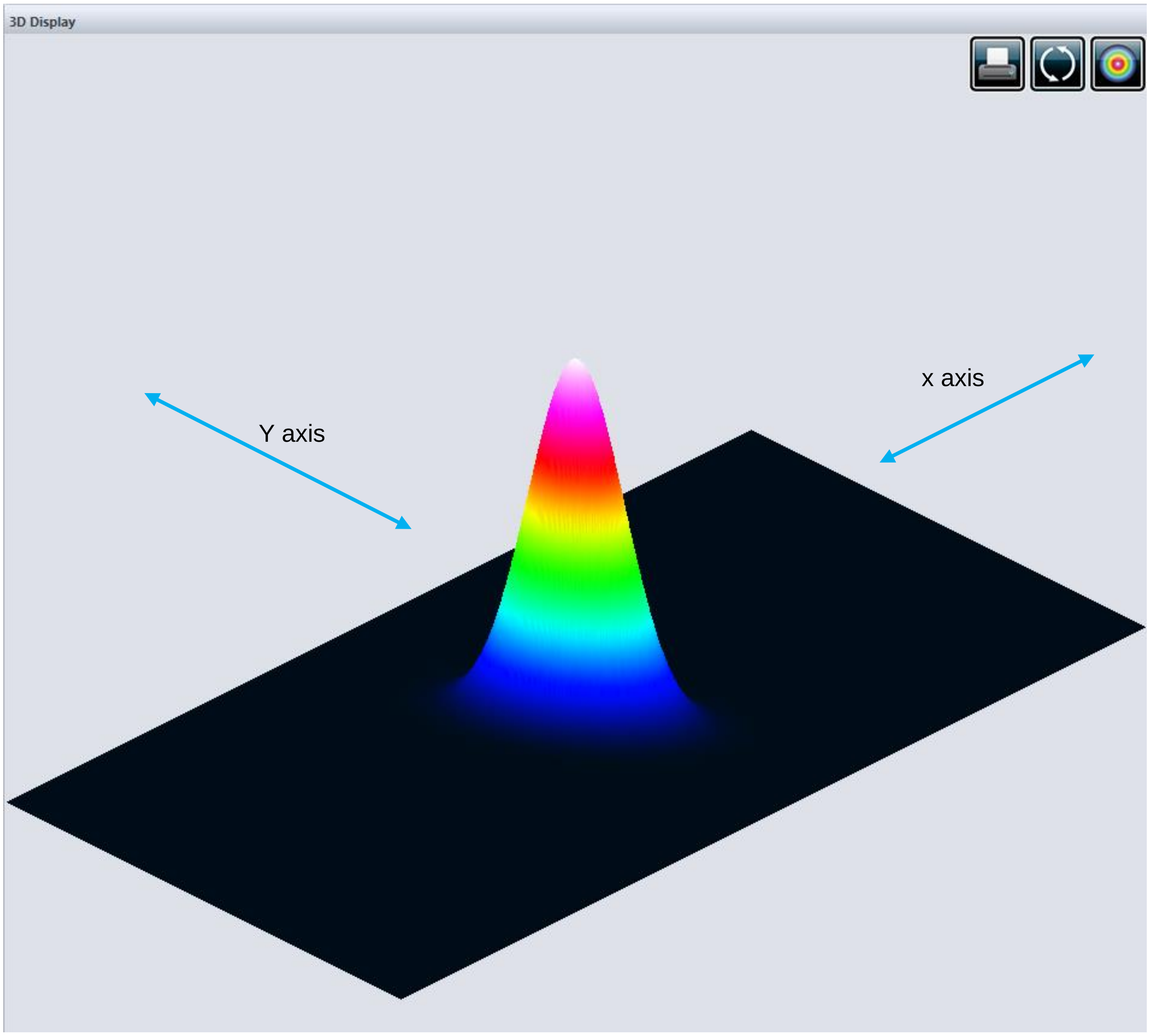


Figure 5-2 3D Display

5.1.1.3D Display: Controls

The toolbar buttons on the upper right corner control the 3D image.

Print Screen: Saves a *.BMP image of the current 3D display.

Reset View: Resets the display to its original parameters.

Top View: Views the 3D image from the top, creating a top-view projection.

5.2. 2D DISPLAY

The 2D Display represents the beam's intensity in two dimensions. False coloring is added to increase the contrast. The color legend used for the various intensity levels is available in the "*Main Controls*" ribbon (refer to section 3.10.1). The 2D display also features the crosshairs (set to the major and minor axis or along specified angles).

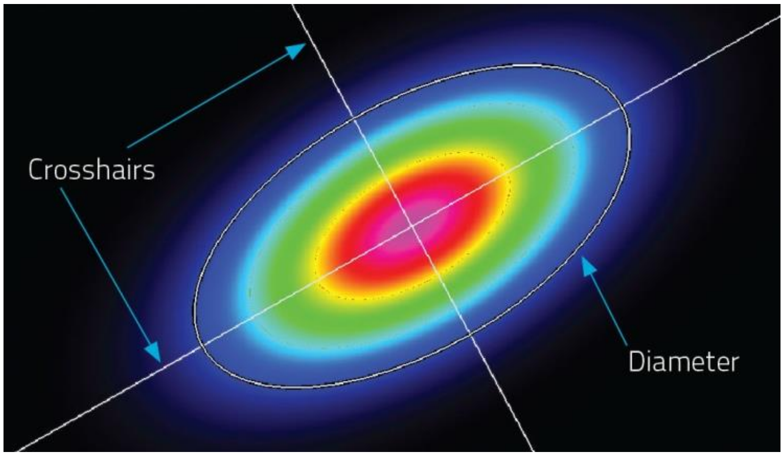


Figure 5-3 2D Display Showing Crosshairs and Diameter Positions

To optimize the software's performance, the resolution of the 2D image is downsampled when the Beamage is streaming. Nonetheless, the computation is done on all transferred pixels. For images larger than 1000x1000 only 1/16 pixels are displayed, for images larger than 500x500 only 1/4 pixels are displayed and for smaller images all pixels are displayed. When the Beamage is stopped or in the animate mode, all pixels are always displayed regardless of the image size.

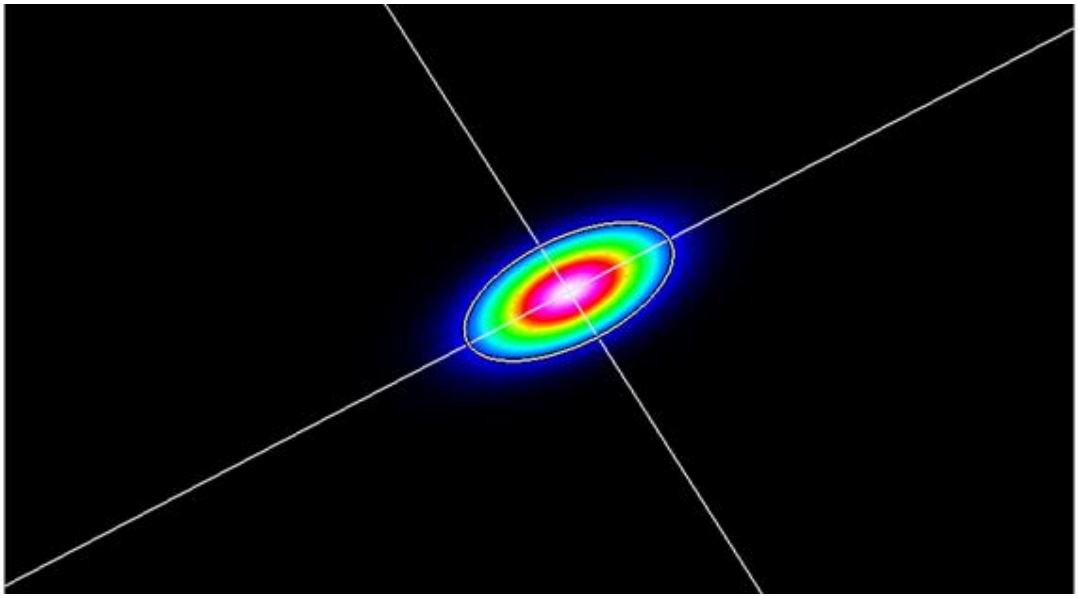


Figure 5-4 2D Display

To translate the image, hold down the left button on the mouse and move the mouse. The "up arrow", "down arrow", "left arrow" and "right arrow" will also move the image accordingly. The scroll button on the mouse zooms the image in or out. It is also possible to zoom in the image by pressing the "+" key on the keyboard and similarly, it is possible to zoom out the image by pressing the “-“ key on the keyboard.

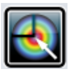
5.2.1.2D Display: Controls

The toolbar buttons on the upper right corner control the 2D image.

Print Screen: Saves a *.BMP image of the current 2D display.

Reset View: Resets the view settings to its original parameters.

Show/Hide Diameter: Displays the ellipse corresponding to the beam diameter (refer to section 4.1.1.1).



Select Active Area: Selects with cursor an active area.

Set Fixed Crosshair Origin: Sets the fixed crosshair origin, please refer to section 4.7.1

5.3. XY DISPLAY

The “*XY display*” plots cross-sectional graphs of the beam along the crosshairs. The crosshairs position and orientation are defined in the “*Home”* tab (refer to section 4.1.1.2)

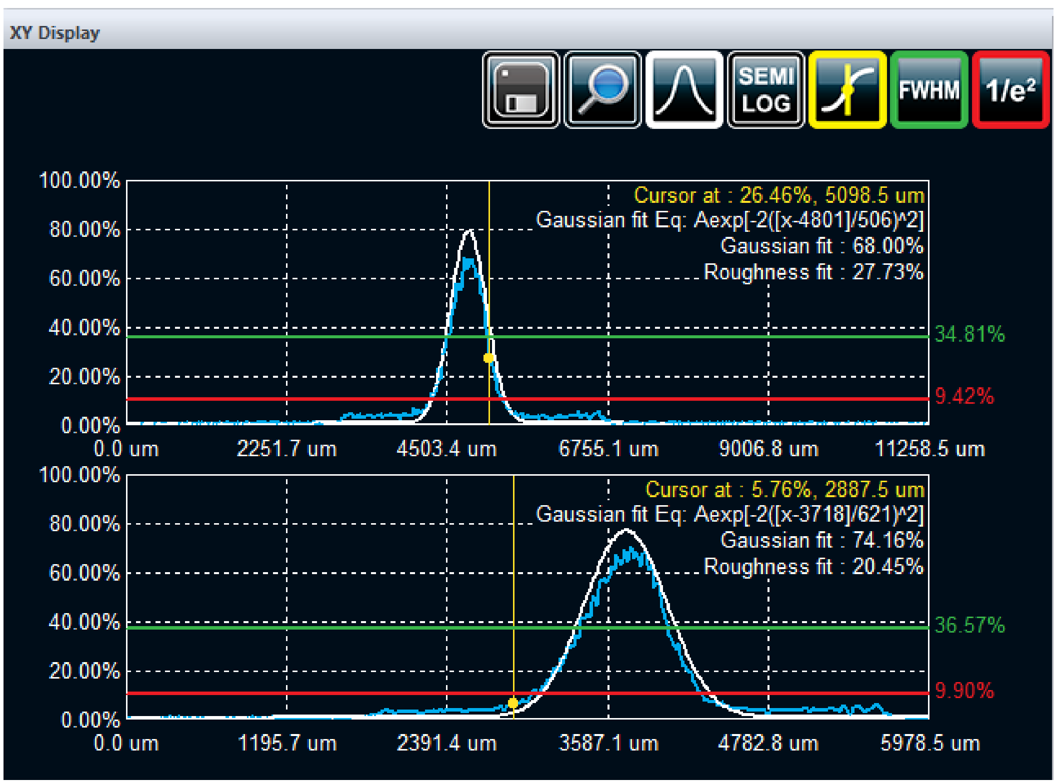


Figure 5-5 XY Display

5.3.1.XY Display: Controls

The toolbar buttons on the upper right corner control the XY graphics.

Save: Saves the crosshair information in a *.TXT file. If the *"Gaussian Fit"* was activated, the crosshair information of the Gaussian fit will also be saved in the file.

Zoom: Activates the zoom for both graphics individually. Zooming can be done by selecting an area with the left mouse button. Double-clicking the image returns it to the original state.

Gaussian Fit: Shows/Hides the best fitted Gaussian along the experimental curve. Refer to section 3.4.2 for more information.

Semi-Log: Transforms the linear graphics to semi-logarithmic graphs to enhance the details in the low intensity parts of the beam.

Cursor Position: Shows/Hides a cursor on each graph with their intensity and position value in the graph's upper right corner. The cursors are positioned by clicking on the desired spots with the left mouse button.

FWHM: Shows/Hides the level corresponding to the half maximum value.

$1/e^2$: Shows/Hides the level corresponding to the $1/e^2$ value.

5.3.2.Gaussian Fit

The *"Gaussian Fit"* function fits the best Gaussian curve on the experimental data. When the "*Gaussian Fit"* is activated, it displays three information on the graphic's upper right corner.

5.3.2.1. The Gaussian equation

The first information to be displayed is the equation of the fitted Gaussian. The Gaussian equation is defined by:

$$f(x) = Ae^{\left[-2\left(\frac{x-c}{w}\right)^2\right]}$$

where w is the beam's radius, c its centroid.

5.3.2.2. The Gaussian Fit factor

The Gaussian Fit factor is defined as:

$$Gaussian\ fit\ (\%) = \left[1 - \frac{\sum |E_i - E_i^a|}{\sum E_i^a}\right] \times 100\%$$

where E is the experimental curve and E^a is the theoretical Gaussian curve.

The closer to 100%, the better the Gaussian fit.

5.3.2.3. The Roughness Fit factor

The Roughness Fit factor is the maximum deviation between the theoretical Gaussian curve and the measured curve, as defined by ISO13694:2000[1]:

$$Roughness\ fit\ (\%) = \left[\frac{|E_i - E_i^a|_{max}}{E_{max}}\right] \times 100\%$$

where E is the experimental curve and E^a is the theoretical Gaussian curve.

The closer to 0%, the better the Gaussian fit.

[1] International Organization for Standardization, *ISO 13694 :2000 Laser and laser-related equipment – Test methods for laser beam power (energy) density distribution, Geneva*

5.4. BEAM TRACKING DISPLAY

The “*Beam Tracking Display*” shows the variation of the position of the centroid on the sensor. The yellow cross represents the last calculated centroid position while the blue dots represent the previous ones. A dot is added to the chart at each computation. The buffer can memorize as many as 2000 calculations. The buffer is circular, which means that once it is full, it replaces the oldest value in memory by a new one. The mean position of all the centroid positions is represented by a red cross and the origin position is represented by a large white cross with a green center.

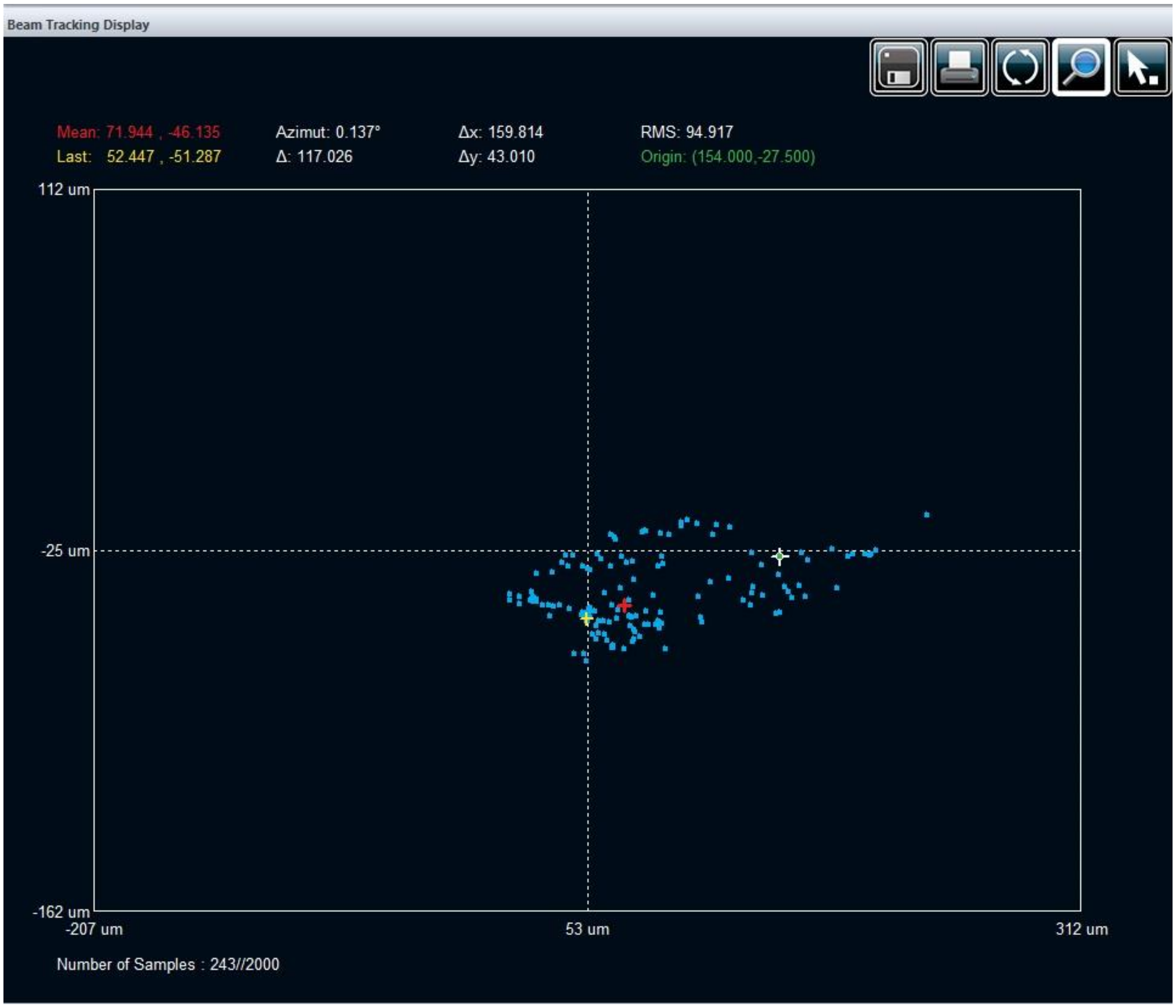


Figure 5-6 Beam Tracking Display

Useful ISO 11670 compliant values appear above the chart. They give an indication on how much the beam drifts from its mean position.

- *Mean*: Coordinates of the mean position of the centroid.
- *Last*: Coordinates of the last calculated position of the centroid.
- *Azimuth*: Orientation for which the drift is maximal.
- *Δ*: Overall beam positional stability
- *Δx*: Beam positional stability in the azimuth direction.
- *Δy*: Beam positional stability perpendicularly to the azimuth.
- *RMS*: RMS standard deviation value of the centroid’s position (not ISO measurement)

- *Origin*: Relative position of the centroid

The beam positional stability values are based on the standard deviation concept[1]. Small values represent small deviations and a good stability.

Please refer to Appendix A for ISO mathematical definitions of the quantities listed above.

5.4.1. Beam Tracking Display: Controls

The toolbar buttons on the upper right corner control the beam tracking plot.

Save: Saves all the centroid coordinates available in the buffer in a *.TXT file.

Print Screen: Saves a *.BMP image of the current beam tracking display.

Reset Buffer: Erases all the data from the buffer and clears the chart.

Zoom: Activates the zoom. Zooming can be done by selecting an area with the left mouse button and de-zooming can be done by double-clicking the image.

Set Origin Point: Sets the origin point (0, 0) of the sensor for the relative positioning, please refer to section 3.8.3.

---

[1] International Organization for Standardization, *ISO 11670:2003 Laser and laser-related equipment – Test methods for laser beam parameters – Beam positional Stability, Geneva*

6. M2 MODE

6.1. INTRODUCTION

The M^2 factor can be considered as a quantitative indicator of laser beam quality. In terms of propagation, it is an indicator of closeness to an ideal Gaussian beam at the same wavelength. Please refer to Appendix B for the theory about M^2 quality factor.

Using a minimalist setup, it is now possible to use a Beamage camera and readily available tools to perform manual M^2 calculations. Using a lens and moving the camera along the z-axis, you can use the M2 Manual routine if the Beamage software to obtain ISO 11146 M2 measurements.

6.2. M2 MANUAL METHOD

The Manual M^2 method is the simplest and most accurate M^2 measurement method and it is ideal for stable laser beams. To manually measure the M^2 factor of your laser, you will need an imaging lens and a system to measure the distance between the lens and the sensor plane of the camera. Ideally, you should use a graduated optical rail system to get the most accurate measurement, but a simple ruler or a caliper can be used.
The optical setup of the Manual M^2 method reimages the laser beam waist and captures different slices of the laser beam's propagation *within at least 3 Rayleigh lengths*. Here is a simplified setup to measure the M^2 factor. Please make sure you properly attenuate the laser beam before the lens, as the beam power density will be higher at the waist position after the lens.

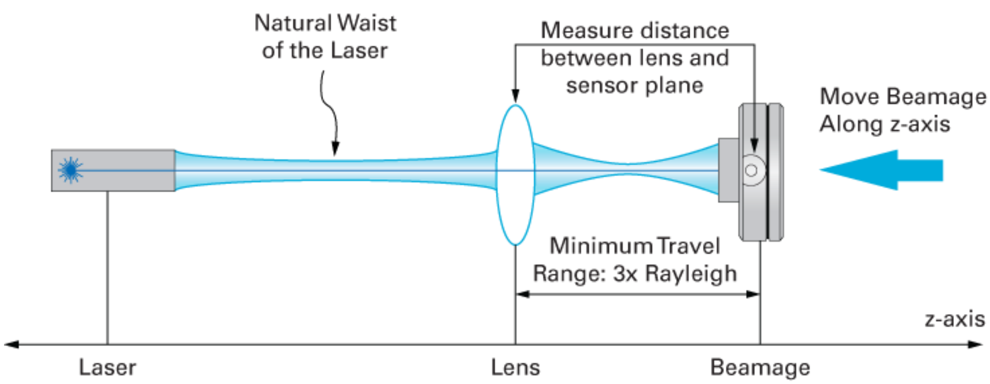


Figure 6-1 Optical Setup for the M2 measurement

Tips

- Make sure you place a lens after the waist in order to be able to reimage it
- Choose a lens which will allow you to have a travel distance that is within your workable space
- You can use laser viewing cards along the z-axis to make sure you have an appropriate waist and to have a rough idea of its position
- Align the Beamage and the z-axis to make sure the laser beam is stays within the sensor for the entire travel range. Due to minimal misalignment, the beam might not always be centered. Although not ideal, this is not an issue, as long as the beam is within the sensor.

6.3. PROCEDURE

1) Start the image capture.

2) Ensure that the following conditions are met to maximize the accuracy of the M^2 measurement:
   a. Set the Beam Diameter Definition at **1/e2 along crosshairs (13.5%)**
   b. Set the Crosshair position at:
      i. Center: **Centroid**
      ii. Orientation: **0 degrees**
   c. Make a **Subtract Background** to minimize the noise[1]
   d. Set Exposure Time at **Auto** to optimize the intensity of your beam

3) Click the **M^2 Manual** button in the main menu. Note that the Beamage must have been streamed at least once or a file must have been opened to access the **M^2 Manual** button.

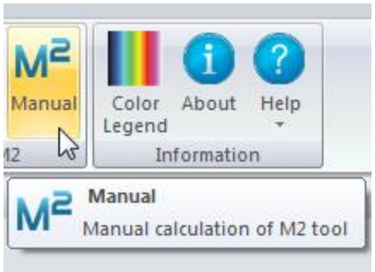


Figure 6-2 M^2 Manual Button

4) Go to the **M^2 Manual** panel and enter the information about your setup:
   a. Enter the laser wavelength
   b. Enter the focal length of the lens chosen for the installation

[1] Note that, in theory, the background subtraction is only valid for one exposure time. For rigorous measurements, the subtraction should be done for every measurement as they will be made at different exposure times. However, making a background subtraction at the highest exposure time and then using the *Auto Exposure* will greatly minimize the error and is thus a very acceptable method in standard environments.

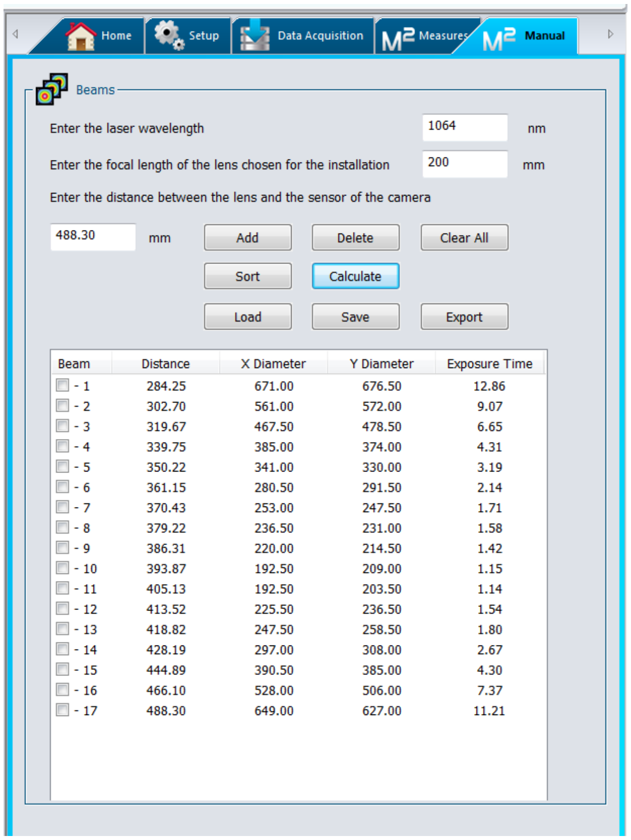


Figure 6-3 M^2 Input panel

5) Measure the distance between the lens and the sensor of the Beamage. The sensor is located 7.8 mm from the front of the casing. Enter the distance in the appropriate box.

6) Click on the **Add** button. The measured X and Y diameters and the exposure time will automatically be saved.

7) Move the Beamage and repeat actions **5** and **6** as you go along the z-axis. You will notice that, as you get closer to the waist, the diameters and exposure times will decrease.

8) To make an accurate M^2 measurement, you must add images of the beam in the Far Field (beyond 2 Rayleigh lengths) and from either side of the waist in the Near Field (within 1 Rayleigh length) . Please refer to ISO-11146 for more information.

9) Below are all the available functions:
   a. **Distance**: Distance between the lens and the camera sensor.
   b. **Add**: Add the current beam diameter to the list.
   c. **Delete**: Remove the selected row from the list. The row must be selected before deleting it.
   d. **Clear All**: Remove all the data from the list.
   e. **Sort**: All beams will be sorted by distance.
   f. **Calculate**: M^2 measurements will be done with the current data.
   g. **Load**: Add saved beams from a *.m2man file.
   h. **Save**: Save all beams from the list to a *.m2man file.
   i. **Export**: Export all the data to an Excel compatible *.txt file.

10) When a minimum of 5 beams have been entered, use the **Calculate** function. A curve fit will then be available in the **M^2 Curve Display** and all M^2 measurements will be available in the **M^2 Measures** tab panel. All results are given for the before and after the lens. Results are shown as follow:
    a. **z0**: Beam waist position from lens in mm
    b. **do**: Beam waist diameter in um
    c. **Zr**: Rayleigh distance in mm
    d. **Div**: Divergence in mrad
    e. **M2**: M^2
    f. **BPP**: Beam Parameter Product in mrad*mm
    g. **Delta Z**: Difference between z0 in x and z0 in y
    h. **Astig**: Astigmatism in %

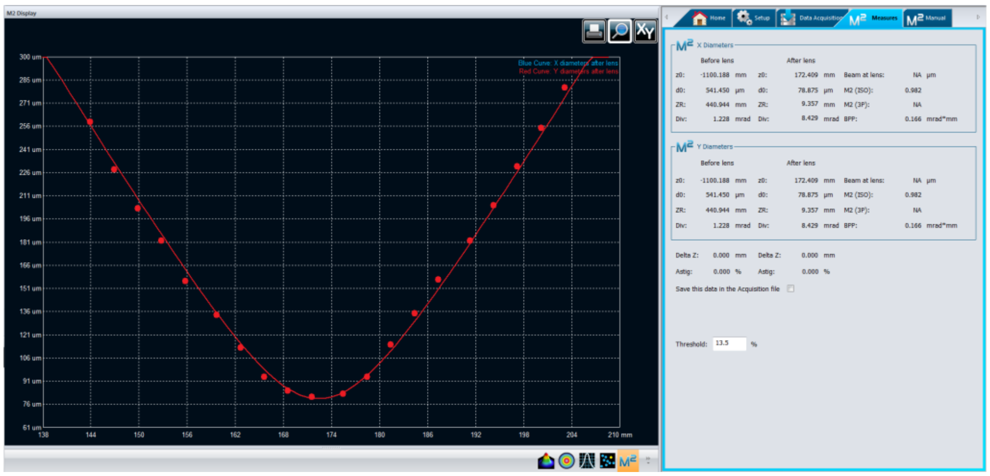


Figure 6-4 M^2 Measurement Panel and Display

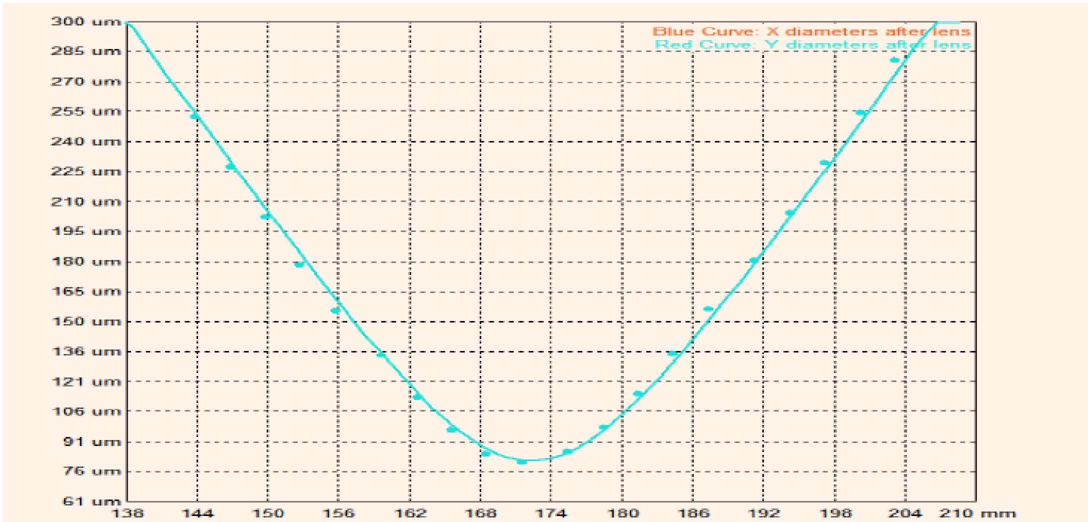
11) At any time during the process:
    a. More beams can be added to the list by using the **Add** button. When using this function, all previously added beams will be kept.
    b. A beam can be deleted by using the **Delete** button. The corresponding beam row must be selected before using this function.
    c. New M^2 calculations can be done by using the **Calculate** button. If a new beam has been added or deleted, the **Calculate** button must be used to know the new result of the M^2 measurements

12) A customized print report has been made for the **M^2 manual** mode. To use the Print Report function, press the **Print Report** button in the main menu

BEAMAGE-3.0 M2

Tuesday, December 02, 2014

gentec-eo PARTNERS for ACCURACY



X DIAMETERS		Y DIAMETERS	
Before Lens	After Lens	Before Lens	After Lens
z0: 1000.222 mm	z0: 172.272 mm	z0: 850.222 mm	z0: 172.272 mm
d0: 498.359 µm	d0: 80.659 µm	d0: 498.359 µm	d0: 80.659 µm
ZR: 368.872 mm	ZR: 9.663 mm	ZR: 368.872 mm	ZR: 9.663 mm
Div: 1.351 mrad	Div: 8.348 mrad	Div: 1.351 mrad	Div: 8.348 mrad
BPP: 0.168 mrad*mm	M2 (ISO/3P): 0.994/NA	BPP: 0.168 mrad*mm	M2 (ISO/3P): 0.994/NA

Delta Z (before lens): 150.000 mm	Delta Z (after lens): 0.000 mm
Astigmatism (before lens): 100.000 %	Astigmatism (after lens): 0.000 %
Wavelength: 532 nm	Focal Length: 150.0 mm
Sensor Distance: 0.000 mm	

Figure 6-5 M^2 Print Report

13) To retrieve previously saved data, click on the *Load* button. Note that the wavelength and the focal lens are not saved. You must enter them again. Click on *Calculate* to see the M^2 results in the *M2 Curve Display* and *M2 Measures* panel.

7. THIRD PARTY COMMANDS

7.1. PC-BEAMAGE LABVIEW VIS AND .NET COMMANDS

The PC-Beamage Software can be controlled from LabVIEW using the VI Library supplied by Gentec-EO. They are individual VIs to implement each of the supported control and measurement functions. It is also possible to create more Labview VIs using the LabVIEW commands.

Gentec-EO also offers .Net named pipes commands to allow you to create your own C++, C# or Visual Basic application. Named pipes can be used to provide communication between processes on the same computer or between processes on different computers across a network.

A VI example that demonstrates how to use the individual VIs to build a standalone LabVIEW application is available. Likewise, a C++ solution example program is available to demonstrate how to use the individual commands and build a standalone C++ application.

Before using the VIs or the commands, the PC-Beamage Software must be running, and the LabVIEW or .Net Pipeline must be opened (refer to section 3.8.6).

The Vis and commands can be grouped into 6 basic categories.

1. Connection Commands
2. Control Commands
3. Measurement Commands
4. Display Commands
5. Activation Commands
6. Miscellaneous Commands

Description	Available VI samples	Available commands for LabVIEW and .Net
Connection Commands		
Checks to ensure the required DLL file is present in the directory in which the LabVIEW VIs are located.	Verify DLL	
Connects to the LabVIEW pipeline opened by the PC-Beamage software.	Connect to PC Beamage	
Disconnects from the LabVIEW pipeline opened by the PC-Beamage software	Disconnect from PC Beamage	
Control Commands		
Stops the capture from the PC-Beamage software and the Beamage USB Camera. This is the same as pressing the Stop Capture button in the software.	Control Stop Capture.	*CTLSTOP
Starts the capture from the PC-Beamage software and the Beamage USB Camera. This is the same as pressing the Start Capture button in the software.	Control Start Capture.	*CTLSTART
Sets the Beam Diameter Definition Control in the PC-Beamage Software. This is the same as pressing the selecting the 4 Sigma (ISO) control in the software.	Control 4 Sigma.	*CTL4SIG
Sets the Beam Diameter Definition Control in the PC-Beamage Software. This is the same as pressing the selecting the FWHM control in the software.	Control FWHM.	*CTLFWHM

Sets the Beam Diameter Definition Control in the PC-Beamage Software. This is the same as pressing the selecting the $1/e^2$ along crosshairs (13.5%) control in the software	Control 1OVRe^2.	*CTL1OVRE
Sets the Beam Diameter Definition Control in the PC-Beamage Software. This is the same as pressing the selecting the 86% effective diameter (D86) control in the software.	Control 86%.	*CTL86
Sets the Crosshair Center Control in the PC-Beamage Software. This is the same as pressing the selecting the Centroid control in the software	Control Centroid.	*CTLCENT
Sets the Crosshair Orientation Control in the PC-Beamage Software. This is the same as pressing the selecting the Auto Orient control in the software	Control Peak.	*CTLPEAK
Sets the Crosshair Orientation Control in the PC-Beamage Software. This is the same as pressing the selecting the Auto Orient control in the software.	Control Auto.	*CTLAUTO
Sets the Crosshair Orientation Control in the PC-Beamage Software. This is the same as pressing the selecting the 0 degrees control in the software.	Control Zero.	*CTLZERO
Sets the Crosshair Orientation Control in the PC-Beamage Software. This is the same as pressing the selecting the 45 degrees control in the software	Control 45.	*CTL45
Sets the Exposure Time Control in the PC-Beamage Software. This is the same as pressing the selecting the Auto exposure time control in the software.		*CTLETAUTO
Sets the Exposure Time Control in the PC-Beamage Software. This is the same as pressing the selecting the Manual exposure time control in the software.		*CTLETMANU
Sets the Save Current Image Control in the PC-Beamage Software. This is the same as pressing Save Current Image control in the software. Image format will be *.BMG.		*CTLIMGSAVE
Sets the Save Current Image Control in the PC-Beamage Software. This is the same as pressing Save As Current Image control in the software. Image format will be *.TXT.		*CTLTXTSAVE
Save the current 2D display image into MyDocuments/Gentec-eo/beamage.bmp.		*CTLBMPSAVE
Measurement Commands The measurement for the Diameter and Position. Running the selected commands returns the reading from the software.		
Returns the beam's effective diameter measurement	Measure Effective Diameter	*MEAEFFDIA
Returns the beam's ellipticity measurement	Measure Ellipticity	*MEAELLIP
Returns the beam's orientation measurement	Measure Orientation	*MEAORIEN
Returns the beam's peak saturation level measurement	Measure Peak Saturation	*MEAPKSAT
Returns the beam's major axis measurement	Measure Major Axis	*MEAMAJAX
Returns the beam's minor axis measurement	Measure Minor Axis	*MEAMINAX
Position Commands Position commands have separate VIs for the X and Y measurements. Running the selected command returns the reading from the software.		
Returns the beam's X centroid measurement and	Measure X Centroid and	*MEACENTX and

returns the beam's Y centroid measurement	Measure Y Centroid	*MEACENTY

Returns the beam's X FWHM measurement and returns the beam's Y FWHM measurement	Measure X FWHM and Measure Y FWHM	*MEAFWHMX and *MEAFWHMY
Returns the beam X 1/e^2 diameter measurement and returns the beam Y 1/e^2 diameter measurement	Measure X 1OVRE^2 Measure Y 1OVRE^2	*MEA1OVREX and *MEA1OVERY
Returns the beam's X Gaussian Equation and returns the beam's Y Gaussian Equation	Measure X Gaussian Equation and Measure Y Gaussian Equation	*MEAEQUX and *MEAEQUY
Returns the beam's X Gaussian Fit and returns the beam's Y Gaussian Fit	Measure X Gaussian Fit % and Measure Y Gaussian Fit %	*MEAGFITX and *MEAGFITY
Returns the X peak to average measurement and returns the X peak to average measurement	Measure X Peak to Average and Measure Y Peak to Average	*MEAPKRAX and *MEAPKRAY
Returns the X peak measurement and returns the Y peak measurement	Measure X Peak and Measure Y Peak	*MEAPEAKX *MEAPEAKY
Returns the X roughness fit measurement and returns the Y roughness fit measurement	Measure X Roughness Fit and Measure Y Roughness Fit	*MEARFITX and *MEARFITY
Returns the X or Y graph's intensity level at cursor position in %		*MEAPERX and *MEAPERY -
Returns the X or Y graph's cursor position		*MEAPOSX and *MEAPOSY
Track Display Measurement Commands These measurements are on the TRACK Display. Use the Display commands to choose the TRACK Display before requesting measurement data from the software.		
Returns the X coordinate of the last measured centroid and returns the Y coordinate of the last measured centroid	Measure X Last and Measure Y Last	*MEALASTX and *MEALASTY
Returns the X coordinate of the mean position of all measured centroids and Returns the Y coordinate of the mean position of all measured centroids	Measure X Mean and Measure Y Mean	*MEABEAMX and *MEABEAMY
Returns the beam's X positional stability in the azimuth direction and returns the beam's Y positional stability perpendicularly to the azimuth direction	Measure X Delta and Measure Y Delta	*MEADELTX and *MEADELTY

Returns the oorientation for which the drift is maximal.	Measure Azimuth	*MEAAZMTH

Returns the overall beam positional stability	Measure Delta	*MEADELTA
Returns the number of samples in the Track Display buffer	Measure Number of Samples	*MEANSMPL
Returns the RMS standard deviation value of the centroid's position (not ISO measurement)	Measure RMS	*MEARMS
Display Commands These VIs decide which display the PC-Beamage software will use. Using them is the same as pressing one of the four display buttons on the bottom of the software screen.		
Switches to the 2 D display screen	Display 2D.	*DIS2D
Switches to the 3 D display screen.	Display 3D	*DIS3D
Switches to the XY display screen	Display XY.	*DISXY
Switches to the Beam Track display screen.	Display TRACK.	*DISTRACK
Activate Commands. These commands select which measurement the PC-Beamage software will use. Using them is the same as pressing one of the four buttons on the top of the XY Display software screen. For LabVIEW users, the Cursor Control Button is not implemented in this release of LabVIEW VIs. You must run each of these VIs at least one time before requesting the respective measurement.		
Running this has the same effect as pressing the Gaussian button in the XY Display.	Activate Gaussian	*ACTXYGAUSS
Running this has the same effect as pressing the SEMI LOG button in the XY Display.	Activate LOG.	*ACTXYLOG
Running this has the same effect as releasing the SEMI LOG button in the XY Display	Activate LIN.	*ACTXYLIN
Running this has the same effect as pressing the FWHM button in the XY Display.	Activate FWHM.	*ACTXYFWHM -
Running this has the same effect as pressing the 1/e2 button in the XY Display.	Activate 1OVRE.	*ACTXYE2
Running this has the same effect as pressing the Subtract background in the ribbon.		*ACTBACK
Running this has the same effect as pressing the Subtract background in the ribbon		*DACTBACK
Miscellaneous VIs		
Returns the PC-Beamage software version.	Query PC Beamage Version	*VER
Returns the serial number of the camera that is currently connected to the software	Query Serial Number.	*MEASNM
Use this command to send the desired manual time. Ex: To set the exposure time to 12.34 ms, send *SNDMAN1234		*SNDMAN
Interfaces with the DLL file to read data from the software.	Read PC Beamage	
Interfaces with the DLL file to write data to the software.	Write PC Beamage.	
This VI is used to determine the behavior of the example application when it exits. If the example is being run in the LabVIEW Development environment, it will stay in memory and stay loaded on exit. If it is being run as an executable file, it will unload and clean memory when it exits.	Stay or Go.	

7.2. LABVIEW EXAMPLE

The VIs have all been used to create an example software. The front panel of this example is shown below.

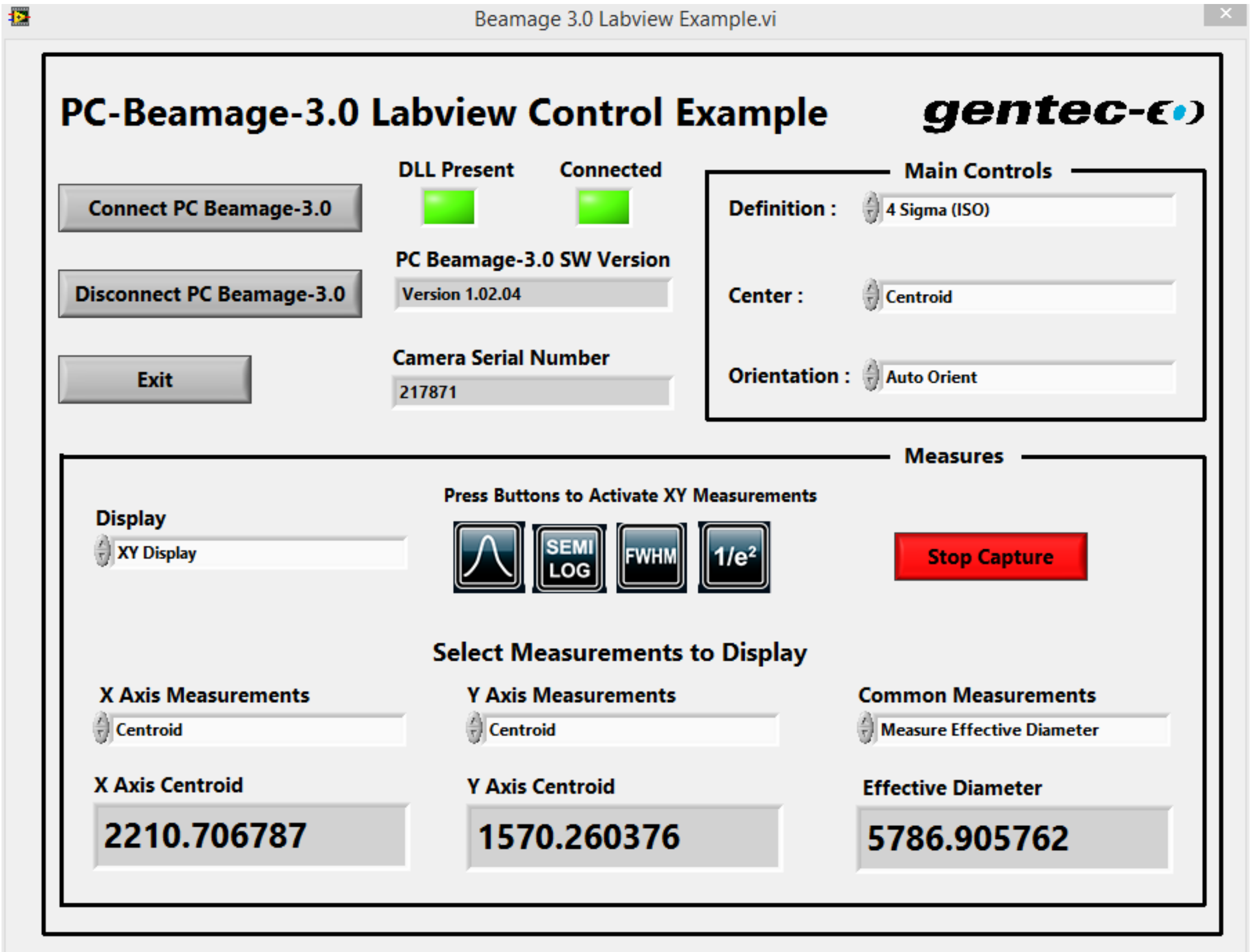


Figure 7-1 Beamage LabVIEW Example

The example is written to be easy to use and understand so as to aid in the development of custom LabVIEW software. It uses an event structure to show the various controls. To use the example:

1. Copy the VIs into the folder of your choice, along with the supplied DLL file.

2. Start LabVIEW and run the example VI.

3. The VI will check to ensure the DLL is present. A warning will be issued if it cannot be located, and the required location will be displayed. Place the DLL in that location.

4. Plug a Beamage Camera into a USB port on the PC in use. Start PC-Beamage and let it connect to the camera.

5. Under the Show/Hide Options menu item, select Start LabVIEW Pipeline. The PC-Beamage software will verify the connection. You may now minimize the PC-Beamage software as LabVIEW can now control the functions (refer to section 3.8.6).

6. Press the Connect PC Beamage button on the LabVIEW software. The Connected LED will turn on. The VI will ask the PC-Beamage for some information, and the software Version and Serial Number indicators will appear.

7. Press the Start Capture button. The Selected measurements will activate. Use the Main, Display, Activate buttons, and Measurements controls to select the desired measurements. The Activate buttons are only visible when the XY Display is selected.

8. Pressing Disconnect or Exit will automatically stop all measurements and close the LabVIEW pipeline.

7.3. .NET EXAMPLE

The NamedPipeClient.sln solution is a C++ standalone application to show how to use the PC-Beamage's .Net commands supplied by Gentec-EO.

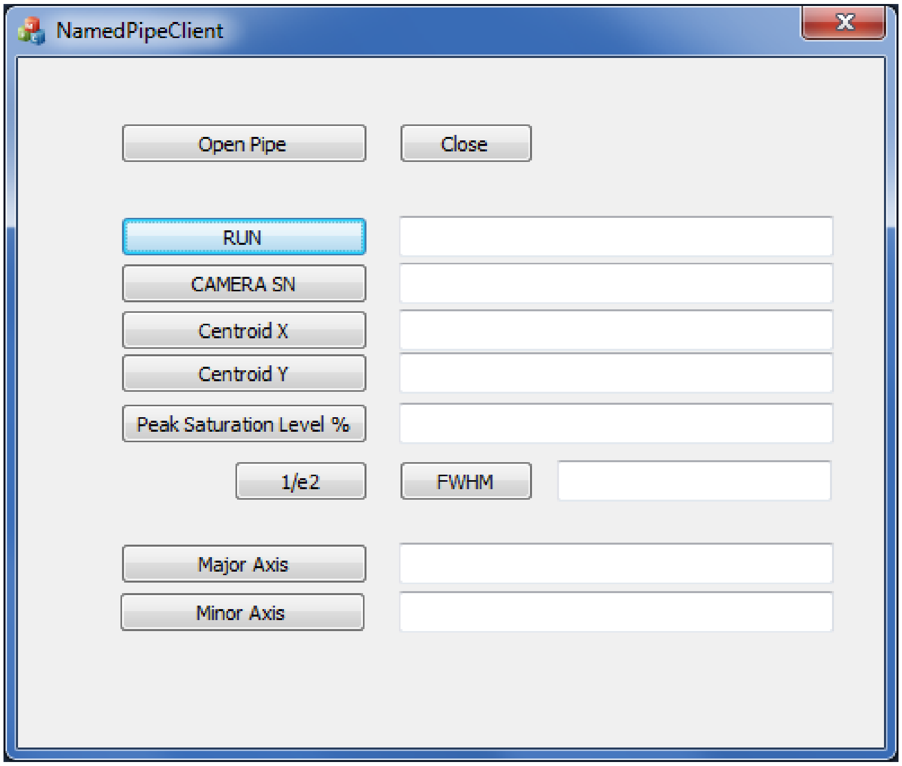


Figure 7-2 Beamage C++ Standalone Example

The example is written to be easy to use and understand so as to aid in the development of custom C++software. It uses an event structure to show the various controls. To use the example:

1. Compile and run the NamedPipeClient.sln.

2. Plug a Beamage Camera into a USB port on the PC in use. Start PC-Beamage and let it connect to the camera.

3. Under the Show/Hide Options menu item, select Start .Net Pipeline. The PC-Beamage software will verify the connection. You may now minimize the PC-Beamage software as LabVIEW can now control the functions (refer to section 3.8.6).

4. Click the *Open Pipe* to start the communication between the application and the PC-Beamage software.

5. Click on the different buttons to try the different commands.

6. You will find all the example code in the NamedPipeClientDlg.cpp file.

7. End by clicking Close.

8. TROUBLESHOOTING AND TIPS

1) While trying to install PC-Beamage, the following message appears: The program can't start because msvcr100.dll is missing […]

You must download the missing dll from Microsoft software and install it on your computer:
32 bit: http://www.microsoft.com/download/en/details.aspx?id=5555
64 bit: http://www.microsoft.com/download/en/details.aspx?id=14632

2) Beamage is not detected

Make sure the Beamage is connected to a USB 3.0 Super Speed port. The Beamage will work if plugged directly in a USB 2.0 port at a slower transfer rate.

Close the software application, disconnect and reconnect the USB 3.0 to the Beamage and open the software application. The LED indicator on the Beamage should blink in green and then in red before turning on green. If the LED does not turn on at the software's startup or if it does not turn on completely, please contact your Gentec-EO representative or contact us at service@gentec-eo.com.

3) The display area is completely white

Press the "*Refresh*" button and the display should come back.

4) Changing the optics in front of the Beamage

Because the Beamage's sensor does not have a cover glass, it is very sensitive to dust. Change the optics in a clean environment and put the Beamage's aperture facing down to minimize the dust.

5) Small black spots appear on the image

If these small black spots do not change place even if you rotate the attenuation filter, it is probably dust on the sensor. **DO NOT TOUCH** the surface of the chip to remove the dust as this will damage the sensor. **AT YOUR OWN RISK**, you can use an oil-free air jet to blow the dust away or contact your Gentec-EO representative.

6) It is not possible to start an acquisition. It keeps opening a warning message indicating that 0 GB is available on hard drive

This is probably due to the fact the path in/ which the PC-Beamage was not installed in the default C:\Program Files\GENTEC-EO\PC-Beamage directory.

7) There is no serial number displayed in the camera

- Please close the PC-Beamage software program, wait a couple of seconds and open the PC-Beamage again.
- If the problem persists, please verify in Window's Task Manager if there is only one PC-Beamage.exe instance running. If more than one are running, end all processes and open PC-Beamage again.
- If the problem persists, please disconnect the Beamage and connect it again.
- If the problem persists, please contact your Gentec-EO representative or contact us at service@gentec-eo.com.

8) The detected serial number is 000000

This happens when you connect a Beamage for the first time in a new USB port. The drivers need to be installed each time a new Beamage is plugged for the first time in a new USB port. When this happens, the PC-Beamage software often opens before the drivers are installed, indicating a 000000 serial number. Close the PC-Beamage software and restart the application.

9) The 10 bit adc level is not available even when the Beamage is connected to a usb 3.0 port

The 10-bit ADC level is only available when using a USB 3.0 port. If it is not available even when connected on a USB 3.0 port, reboot the computer. If it is still not available, please contact your Gentec-EO representative or contact us at service@gentec-eo.com.

10) Do not disconnect the Beamage while it is streaming

The Beamage must not be disconnected when it is streaming.

11) Tips to increase the frame rate

The Beamage's frame rate greatly depends on the computer's performances. Here are a few tips to increase the frame rate:

- Use a USB-3.0 port;
- Use a computer with high performances (refer to PC Requirements section 1.2);
- Use Windows 7 or Windows 8;
- Follow the PC operating state for optimal conditions (refer to section 1.2)
- Do not use Filters (refer to 3.5.1);
- Do not use Image Averaging (refer to 4.2.3);
- For a large beam, use Pixel Addressing (refer to 4.2.5);
- For a small beam, use an Active Area (refer to 4.2.4);
- Make sure you have a short exposure time;
- Do not stream multiple Beamage units simultaneously.

9. DECLARATION OF CONFORMITY

Application of Council Directive(s):	2004/108/EC The EMC Directive
Manufacturer's Name:	Gentec Electro Optics, Inc.
Manufacturer's Address:	445 St-Jean Baptiste, suite 160 (Québec), Canada G2E 5N7
European Representative's Name:	Laser Components S.A.S.
Representative's Address:	45 bis Route des Gardes 92190 Meudon (France)
Type of Equipment:	Laser Beam Diagnostic Equipment.
Model No.:	Beamage
Year of test & manufacture:	2012

Standard(s) to which Conformity is declared:
EN 61326 :2005/EN 61326 : 2006/ Emission generic standard

Standard	Description	Performance Criteria
CISPR 11 :2009 +A1 2010	Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement	Class A
EN 61326 :2005/EN 61326 : 2006	Limits and methods of measurement of radio interference characteristics of information technology equipment. Testing and measurements of radiated emission	Class A
IEC 61000-4-2:2001	Electromagnetic compatibility (EMC) – Part 4: Testing and measurements techniques- Section 2: Electrostatic discharge.	Class B
IEC 61000-4-3:2002	Electromagnetic compatibility (EMC) – Part 4: Testing and measurements techniques- Section 3: Radiated, Radio Frequency immunity.	Class A

I, the undersigned, hereby declare that the equipment specified above
conforms to the above Directive(s) and Standard(s).

Place: Québec (Québec)

Date : 11 September, 2013

(President)

APPENDIX A. ISO11146 AND ISO11670 DEFINITIONS

The beam centroid coordinates are given by:

$$\bar{x}(z) = \frac{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x,y,z)x dxdy}{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x,y,z)dxdy}$$

$$\bar{y}(z) = \frac{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x,y,z)y dxdy}{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x,y,z)dxdy}$$

The beam widths are defined as an *"extent of a power density distribution in a cross section of beam based on the centered second order moments of the power density distribution."*

The second order moments of power density distribution are given by:

$$\sigma_x^2(z) = \frac{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x,y,z)(x-\bar{x})^2 dxdy}{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x,y,z)dxdy}$$

$$\sigma_y^2(z) = \frac{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x,y,z)(y-\bar{y})^2 dxdy}{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x,y,z)dxdy}$$

$$\sigma_{xy}^2(z) = \frac{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x,y,z)(x-\bar{x})(y-\bar{y}) dxdy}{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x,y,z)dxdy}$$

The beam widths are given by:

$$d_{\sigma_x} = 2\sqrt{2}\left\{\left(\sigma_x^2+\sigma_y^2\right)+\gamma\left[\left(\sigma_x^2-\sigma_y^2\right)^2+4\left(\sigma_{xy}^2\right)^2\right]^{\frac{1}{2}}\right\}^{\frac{1}{2}}$$

$$d_{\sigma_y} = 2\sqrt{2}\left\{\left(\sigma_x^2+\sigma_y^2\right)-\gamma\left[\left(\sigma_x^2-\sigma_y^2\right)^2+4\left(\sigma_{xy}^2\right)^2\right]^{\frac{1}{2}}\right\}^{\frac{1}{2}}$$

where:

$$\gamma = \frac{\sigma_x^2-\sigma_y^2}{\left|\sigma_x^2-\sigma_y^2\right|}$$

The major axis is the width's maximum whereas the minor axis is the width's minimum.

The effective diameter of the beam is an *"extent of a circular power density having an ellipticity greater than 0.87. […] If the ellipticity is larger than 0.87, the beam profile may be considered to be of circular symmetry at that measuring location and the beam diameter can be obtained from:"*

$$d_\sigma = 2\sqrt{2}\left(\sigma_x^2+\sigma_y^2\right)^{1/2}$$

The beam ellipticity is the *"ratio between the minimum and maximum widths"*

The beam orientation is the "*angle between the x-axis […] and that or the principal axis of the power density distribution which is closer to the x-axis."* From this definition, the angle is comprised between 45° and -45°.

$$\varphi(z) = \frac{1}{2}\arctan\left(\frac{2\sigma_{xy}^2}{\sigma_x^2-\sigma_y^2}\right)$$

The beam's divergences transformed by an aberration-free focusing element of focal length *f* are given by the following equations:

$$\theta_x = \frac{d_{\sigma_x}}{f}$$
$$\theta_y = \frac{d_{\sigma_y}}{f}$$
$$\theta_\sigma = \frac{d_\sigma}{f}$$

In the laboratory or usual system of coordinates (X',Y',Z'), the coordinates of the latest calculated position of the centroid for both X' and Y' axes are given by the following equations:

$$\bar{x'}(z) = \frac{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x',y',z')x'dx'dy'}{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x',y',z')dx'dy'}$$
$$\bar{y'}(z) = \frac{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x',y',z')y'dx'dy'}{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x',y',z')dx'dy'}$$

The coordinates of the mean position of all computed centroids for both X' and Y' axes are thus defined by the following equations, which are simple arithmetic means,

$$\bar{x}'_M = \frac{\sum_i \bar{x}'_i}{n}$$
$$\bar{y}'_M = \frac{\sum_i \bar{y}'_i}{n}$$

Where $\bar{x'}_i(z)$ and $\bar{y}'_i(z)$ are the centroid coordinates for X' and Y' axes already saved in the buffer, and *n* the number of computed centroid positions saved in the buffer.

The azimuth angle, which is the angle between the usual X' axis and all computed centroids, is given by the following equation:

$$\psi = \frac{1}{2} arctan\left(\frac{2s_{\bar{x}\bar{y}}{}^2}{s_{\bar{x}}{}^2 - s_{\bar{y}}{}^2}\right)$$

where we have the following definitions:

$$s_x = \sqrt{\frac{\sum_i \bar{x}_i{}^2}{n-1}}$$
$$s_{\bar{y}}{}^2 = \frac{\sum_i(\bar{y}'_i - \bar{y}'_M)^2}{n-1}$$
$$s_{\bar{x}\bar{y}}{}^2 = \frac{\sum_i(\bar{x}'_i - \bar{x}'_M)(\bar{y}'_i - \bar{y}'_M)}{n-1}$$

In the beam axis coordinate system (X,Y,Z), the beam positional stability values in the azimuth direction (X) and perpendicularly to the azimuth direction (Y), which are 4 times the standard deviations of all computed centroid values, are given by the following equations:

$\Delta_x(z) = 4s_x$
$\Delta_y(z) = 4s_x$

The overall positional stability is given by:
$\Delta(z) = 2\sqrt{2}s$

In the previous 3 equations, the standard deviations are defined by the following equations:

$$s_x = \sqrt{\frac{\sum_i \bar{x}_i^{\,2}}{n-1}}$$
$$s_y = \sqrt{\frac{\sum_i \bar{y}_i^{\,2}}{n-1}}$$
$$s = \sqrt{\frac{\sum_i \bar{x}_i^{\,2} + \bar{y}_i^{\,2}}{n-1}}$$

$\bar{x}_i^{\,2}$ and $\bar{y}_i^{\,2}$ are derived from $\overline{x'}_i^{\,2}$ and $\overline{y'}_i^{\,2}$ by transformation of coordinates. (X',Y',Z') is the usual or laboratory coordinate system and (X,Y,Z) is the beam axis coordinate system.

The RMS standard deviation value of the centroid position, which is not an ISO standard, is given by the following equation:

$$RMS = \sqrt{\left(\frac{\sum_i x_r^2 + y_r^2}{n}\right)}$$

where x_r^2 *and* y_r^2 are relative values.

APPENDIX B. M^2 QUALITY FACTOR THEORY

Understanding the M^2 Factor

The M^2 factor, which is unitless, can be considered as a quantitative indicator of laser beam quality. It indicates the deviation of the measured beam from a theoretical Gaussian beam of the same wavelength. It can mathematically be defined as the ratio between the Beam Parameter Product (BPP = beam waist radius (w_0) multiplied by divergence half-angle (θ)) of the measured beam with the theoretical Gaussian beam. Thus, for a single mode ideal TEM_{00} theoretical Gaussian beam, the M^2 factor is exactly 1. Also, the beam parameter product (BPP) of the laser beam, represented by the product of a laser beam's divergence angle (half-angle) and the radius of the beam at its narrowest point (the beam waist), is always equal or greater to the ideal beam parameter product. An M^2 value very close to 1 indicates an excellent beam quality. This is associated with a low divergence and a good ability to focus. Multimode lasers have higher M^2 factors.

Propagation Parameters

In the following equations, ''th'' refers to theoretical values and ''exp'' to experimental or real values.

The beam waist is defined as the location along the beam propagation axis where the beam radius reaches its minimum value (see the Beam Propagation Diagram below). For a theoretical Gaussian beam, the beam radius $w_{th}(z)$ at any z position along the beam axis is given by the following equation:

$$w_{th}(z) = w_{oth}\sqrt{1+\left(\frac{\lambda z}{\pi w_{oth}^2}\right)^2}$$

Where λ is the laser wavelength and w_{0th} the theoretical beam waist radius.

As depicted in the figure below, the theoretical Rayleigh length Z_{Rth} is the distance (along the propagation axis) between the beam waist and the position where the beam radius is $\sqrt{2}$ times larger than the beam waist (doubled cross-section).

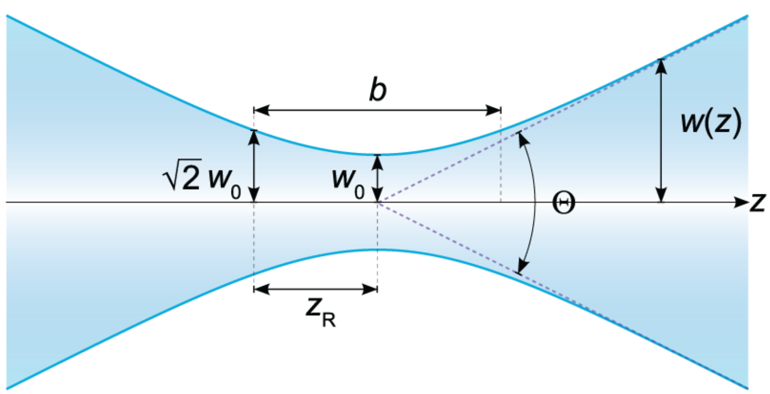


Figure B-1 Beam Propagation Diagram

Mathematically, it is given by the following equation:

$$z_{R\,th} = \frac{\pi\left(w_{0_{th}}\right)^2}{\lambda}$$

Far from the beam waist, the beam expansion becomes linear and the theoretical divergence half-angle ϑ_{th} (half of the angle shown in the Beam Propagation Diagram) can be obtained by evaluating the limit of the beam radius' first derivative as the position tends towards infinity and with the small angle approximation:

$$\tan\theta_{th} \approx \theta_{th} = \lim_{z\to\infty}\frac{dw_{th}(z)}{dz} = \lim_{z\to\infty}\frac{d}{dz}w_{0_{th}}\sqrt{1+\left(\frac{\lambda z}{\pi\left(w_{0_{th}}\right)^2}\right)^2} = \frac{\lambda}{\pi w_{0_{th}}}$$

For a laser beam that passes through a focusing lens of focal length *f*, the theoretical radius of the beam w_{fth} at the focal spot of the lens can be obtained by multiplying the beam divergence half-angle with the focal length *f*:

$$w_{f_{th}} = f\theta_{th} = \frac{f\lambda}{\pi w_{0_{th}}}$$

As mentioned, all of the equations above describe theoretical ideal Gaussian beams. However, they can describe the propagation of real laser beams if we slightly modify them using the M^2 factor, which can be mathematically defined by the following equations:

$$M^2 = \frac{\pi\theta_{exp}w_{0_{exp}}}{\lambda} = \frac{\theta_{exp}w_{0_{exp}}}{\theta_{th}\,w_{0_{th}}} > 1 \quad because \quad \theta_{exp}w_{0_{exp}} > \frac{\lambda}{\pi} = \theta_{th}w_{0_{th}}$$

It is possible to see here why small M^2 values correspond to low experimental divergences and small experimental beam waist radiuses.

Using the M^2 factor, the experimental beam waist radius $w_{exp}(z)$ is therefore given by the following equation:

$$w_{exp}(z) = w_{0_{exp}}\sqrt{1+z^2/Z_{R_{exp}}^2}$$

The M^2 factor affects both beam waist radius and Rayleigh length, according to the following equations :

$$z_{R_{exp}} = \frac{\pi w_{0_{th}}^2}{M^2\lambda}$$

$$w_{0_{exp}} = M^2 w_{0_{th}}$$

The experimental half-angle divergence ϑ_{exp} and the experimental beam radius at the focal spot of the lens w_{fexp} are given by the following equations:

$$\theta_{exp} = \frac{M^2\lambda}{\pi w_{0_{exp}}}$$

$$w_{f\,exp} = f\theta_{exp} = \frac{fM^2\lambda}{\pi w_{0_{exp}}}$$

We can now easily understand why small M^2 values correspond to low divergence beams with small focus spots.

Practical Measurement

In order to measure the M^2 factor, multiple slices of the beam within and beyond one Rayleigh length along the propagation axis must be considered. For each one, the beam radius *w(z)* is measured. A hyperbola, which recalls the beam radius equation, is then fitted with the results. The M^2 value is derived from that fit.

Since the distance range within which the measures must be taken is too large (could be several meters), the use of a focusing lens is mandatory. It is also mandatory to comply with ISO standard. It helps to compress the slices of interest around the focal spot of the lens.

APPENDIX C. BEAMAGE-3.0 DRIVER INSTALLATION QUICK GUIDE

1) Do not connect the USB cable to your computer before installing the appropriate software and drivers. The camera will not be recognized if so.

2) The latest available version of *PC-Beamage* must be installed before setting the drivers. It can be downloaded from the *Downloads* tab in the bottom of the following web page: https://gentec-eo.com/products/beam-diagnostics/Beamage-3.0.

3) If the software is already installed on your computer, please make sure it is the latest available version of *PC-Beamage*. To do so, open the *PC-Beamage* software and click on *About*. Another window will appear and you will be able to *Update* the software.

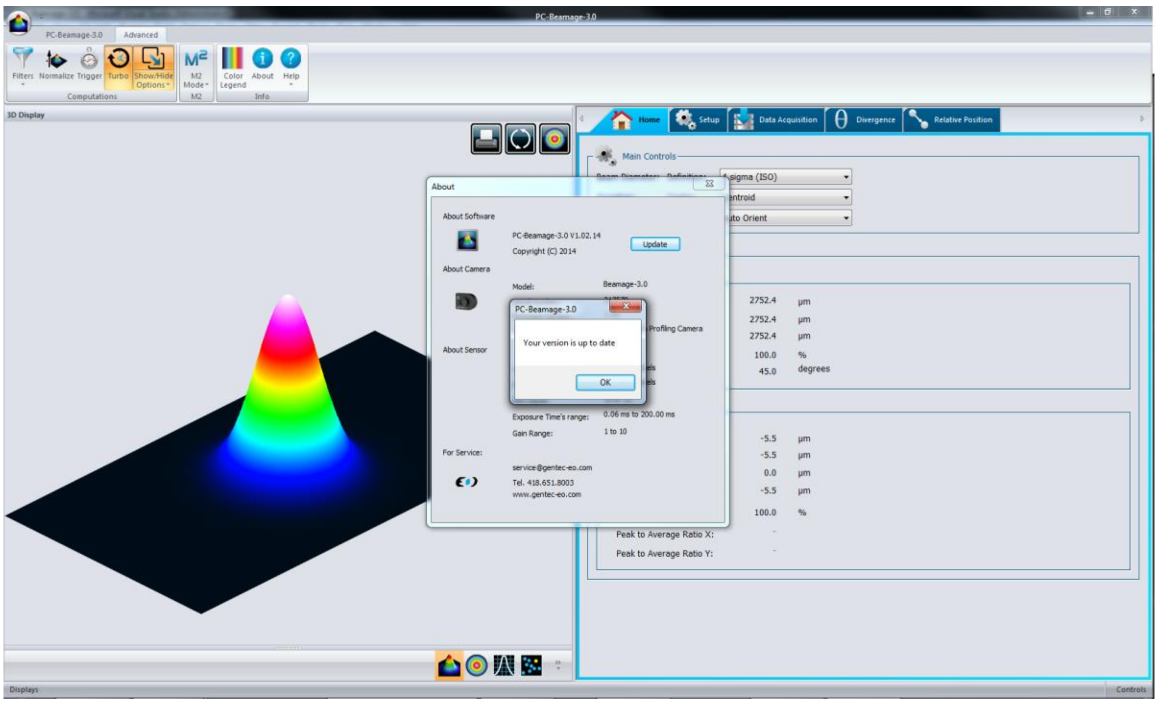


Figure B-2 PC-Beamage

4) You can now open the *Drivers Installer*. The latest version can be downloaded from the *Downloads* tab at the bottom of the following web page: https://gentec-eo.com/products/beam-diagnostics/Beamage-3.0. Once the file is opened, a security warning should appear. Click on *Run.*

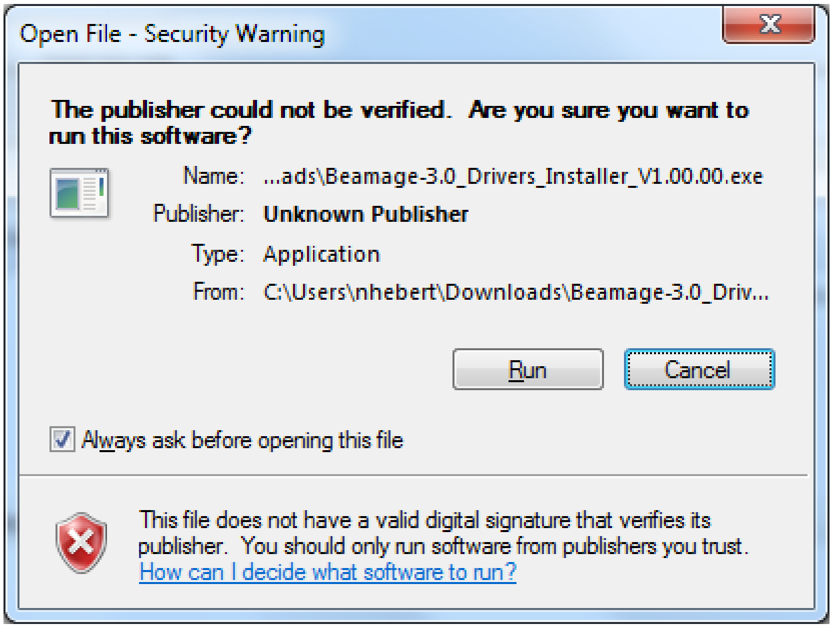


Figure B-3 Security Warning

5) Choose the option that corresponds to your operating system. Please note that Windows XP is not officially supported and thus Gentec-EO does not provide assistance if this OS is used.

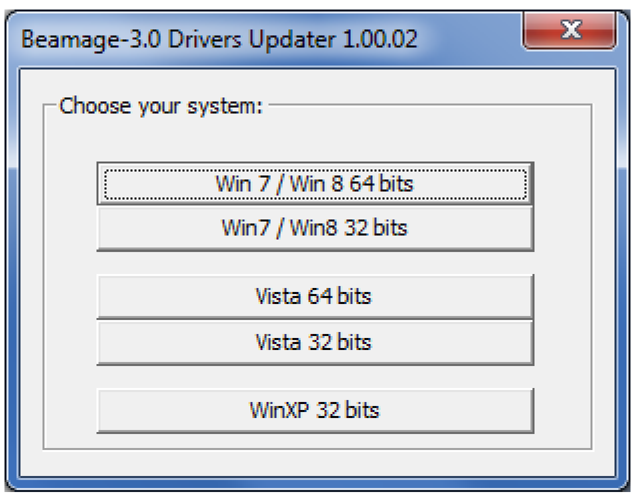


Figure B-4 Choose your system

To find out what is your operating system, click on the *Start* (Windows home screen) button and type in *System* in the search field. Click on *System* under *Control Panel*. A window will appear, indicating which operating system is used. The x64 choices are applicable to 64-bit systems while the x86 choices are applicable to 32-bit systems.

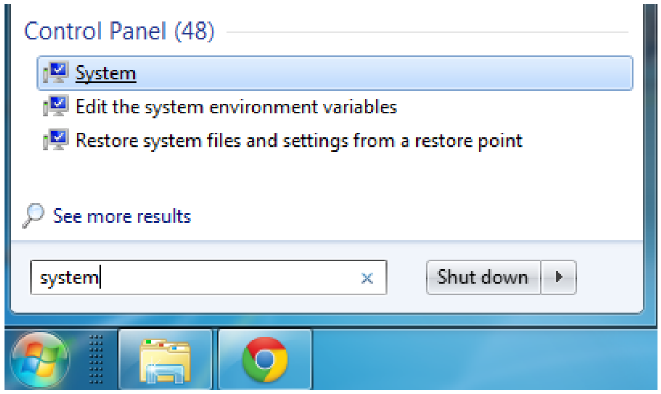


Figure B-5 Search for “System”

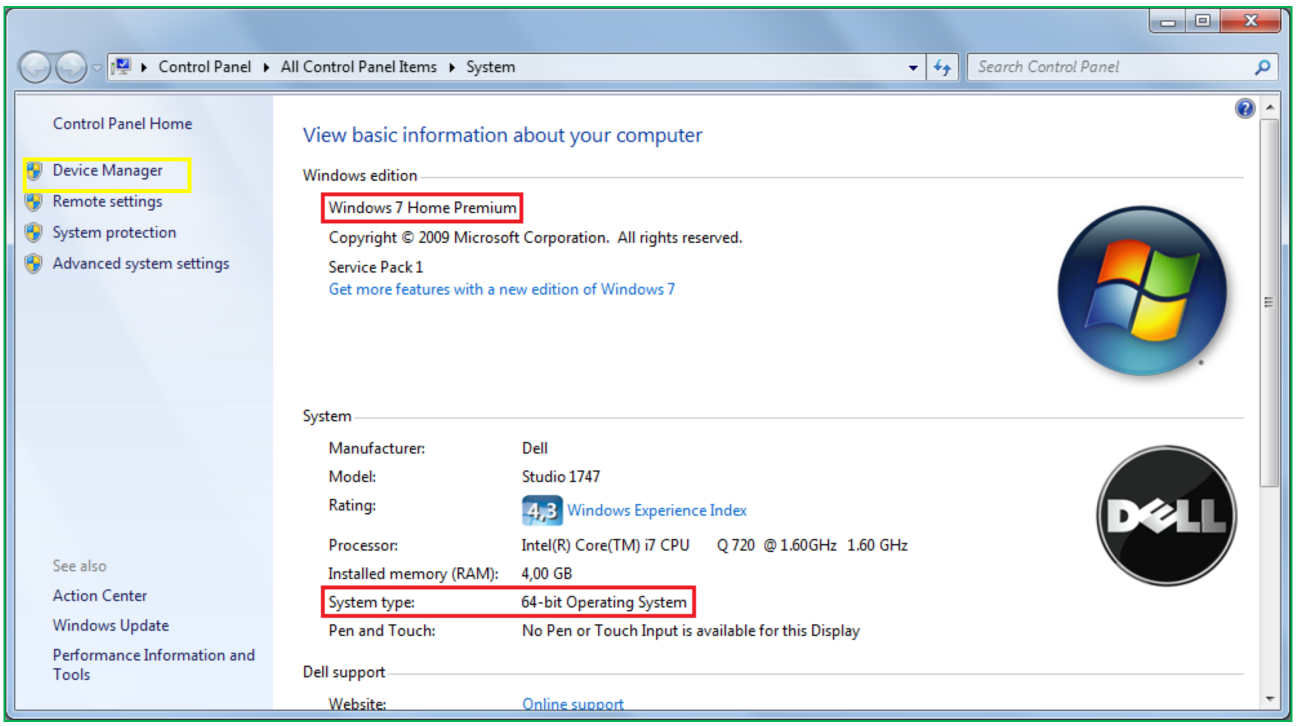


Figure B-6 System information

6) After choosing the operating system, you will be asked to unplug the camera. If you followed the former steps, the camera should already be unplugged. Click on *OK*.

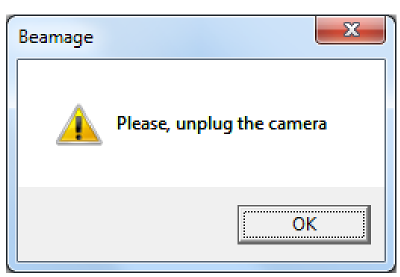


Figure B-7 Unplug the camera

7) You will be asked if you want to allow the program to make changes to your computer. Click on *Yes*.

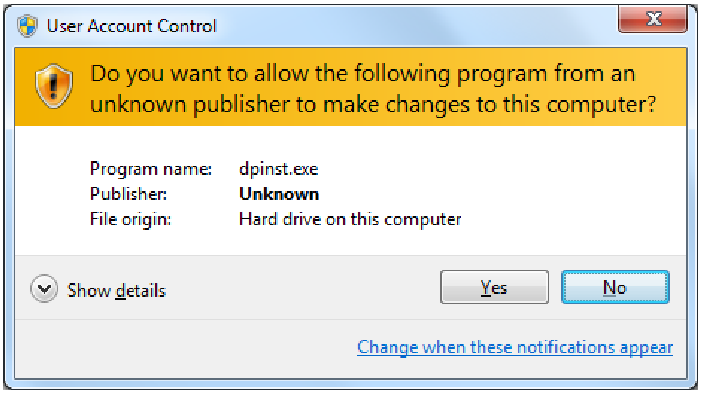


Figure B-8 User Account Control

8) The driver installation wizard will appear. Click on *Next*.

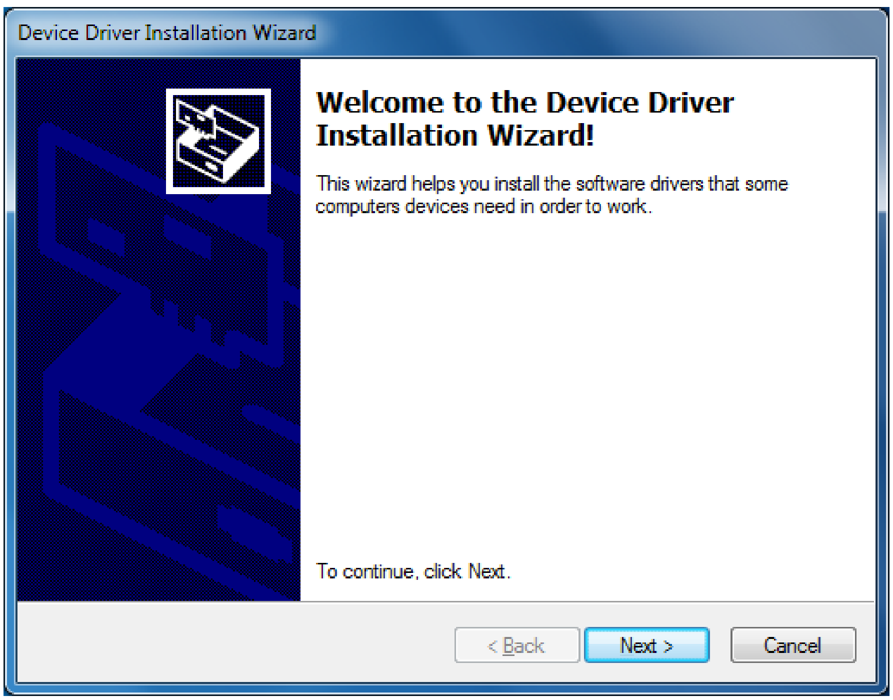


Figure B-9 Device Driver Installation Wizard

9) To confirm that you want to install the device software, click on *Install*.

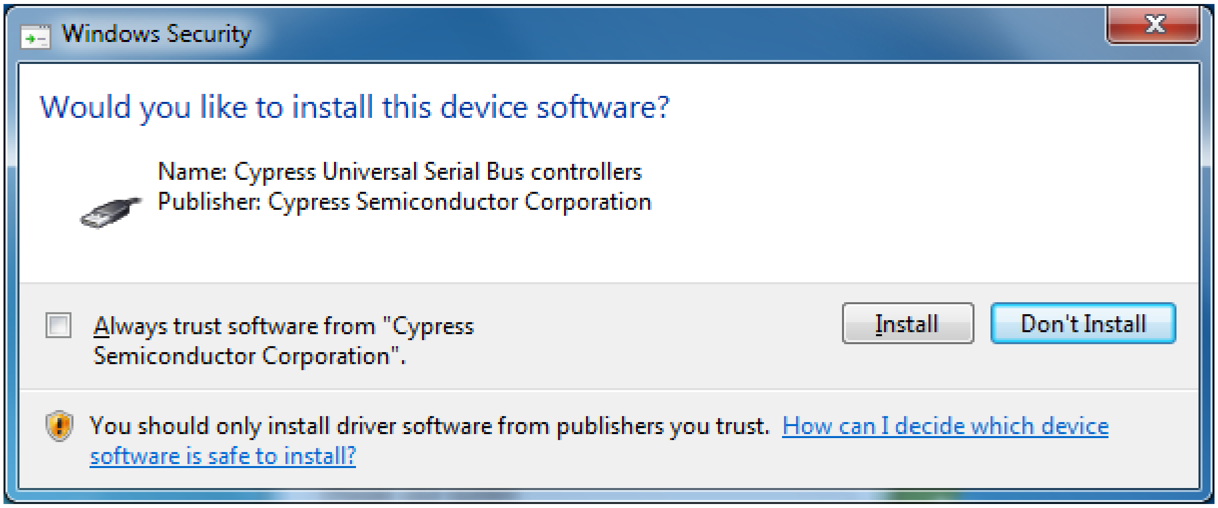


Figure B-10 Confirmation Window

10) Once the installation is completed, click on *Finish*.

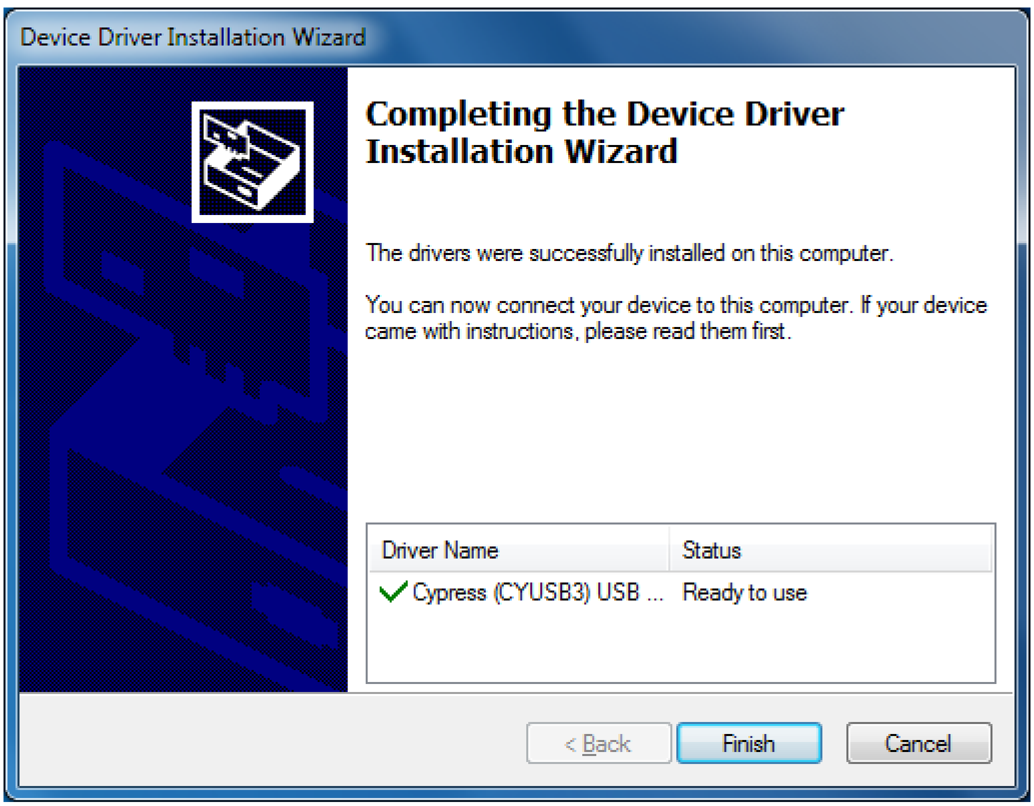


Figure B-11 Installation Completed

11) You will be prompted to connect the camera. Connect it through your USB port, but **DO NOT CLICK ON *OK* RIGHT AWAY**. Wait for the following message to appear at the bottom right of your screen before clicking on *OK*.

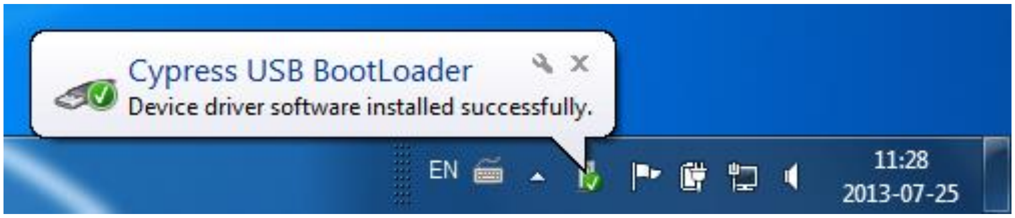


Figure B-12 Driver installed successfully (1)

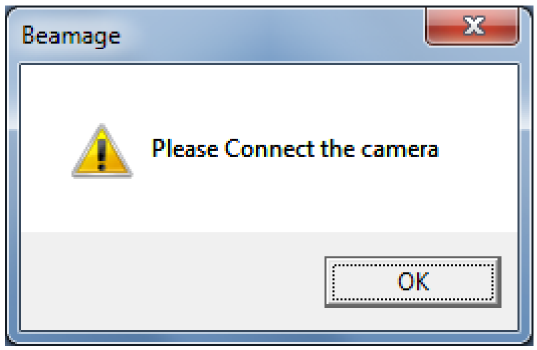


Figure B-13 Connect the camera

12) Another window will inform you that you can now use PC-Beamage. Click on OK.

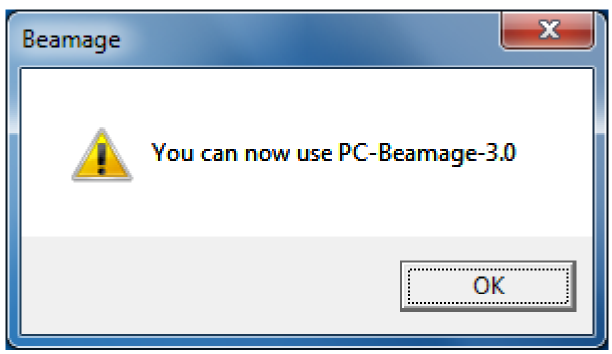


Figure B-14 You can now use PC-Beamage

13) To allow the device to be recognized by your computer, unplug and plug back the USB cable.

14) Start the PC-Beamage application. A camera selector will appear, with a series of zero as the single option. Meanwhile, the last driver will be installed. Wait for the following message to appear at the bottom right of your screen. Click on *OK* in and close the application.

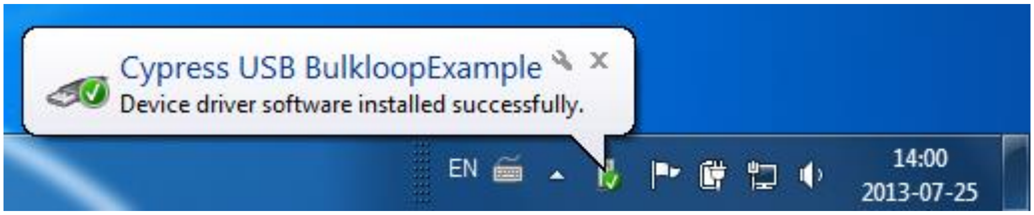


Figure B-15 Driver installed successfully (2)

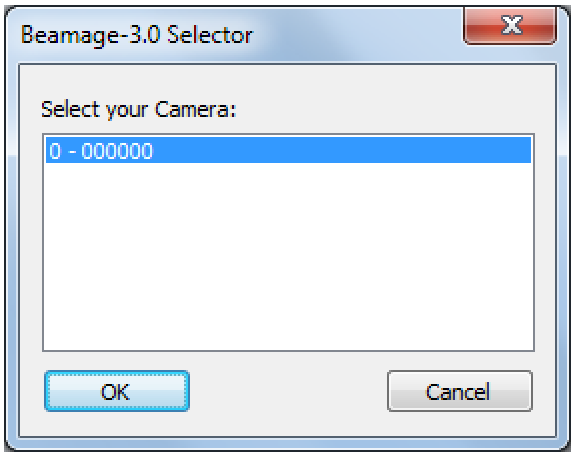


Figure B-16 Camera Selector (1)

15) Restart the PC-Beamage application. Select your camera and click on *OK*. The 6 digits following the dash correspond to the serial number of your device. You are now ready to use your Beamage.

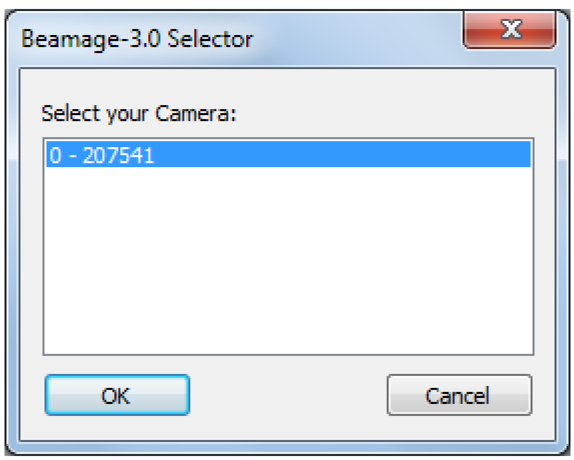


Figure B-17 Camera Selector (2)

Verify that the driver has been correctly installed

It is not necessary to follow these steps to install the USB drivers. They are verification steps only.

1) Open your Device Manager. To open the *Device Manager*, click on the *Start* (Windows home screen) and type in *Device Manager* in the search field. Click on *Device Manager* under *Control Panel*. Be careful not to click on *Devices and Printers* instead of *Device Manager*.

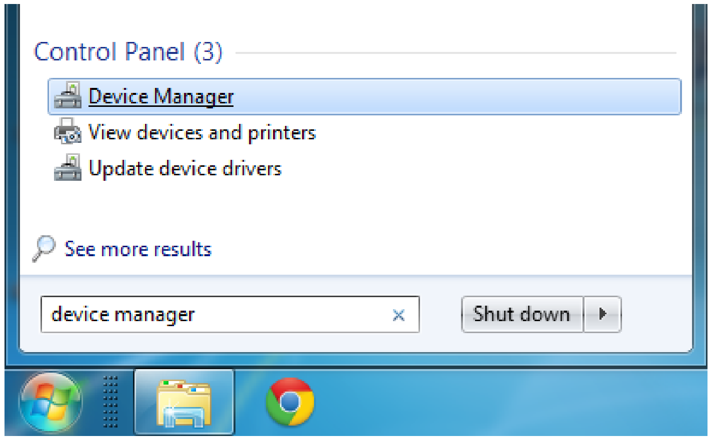


Figure B-18 Search for “Device Manager”

You can also open the Device Manager through the System Window

2) Close the PC-Beamage application (if it is already opened). Connect the Beamage camera to your computer. If everything went well until now, the device *Cypress USB BootLoader* should be marked by a yellow warning in the *Device Manager*. It should be located under *Universal Serial Bus controllers*.

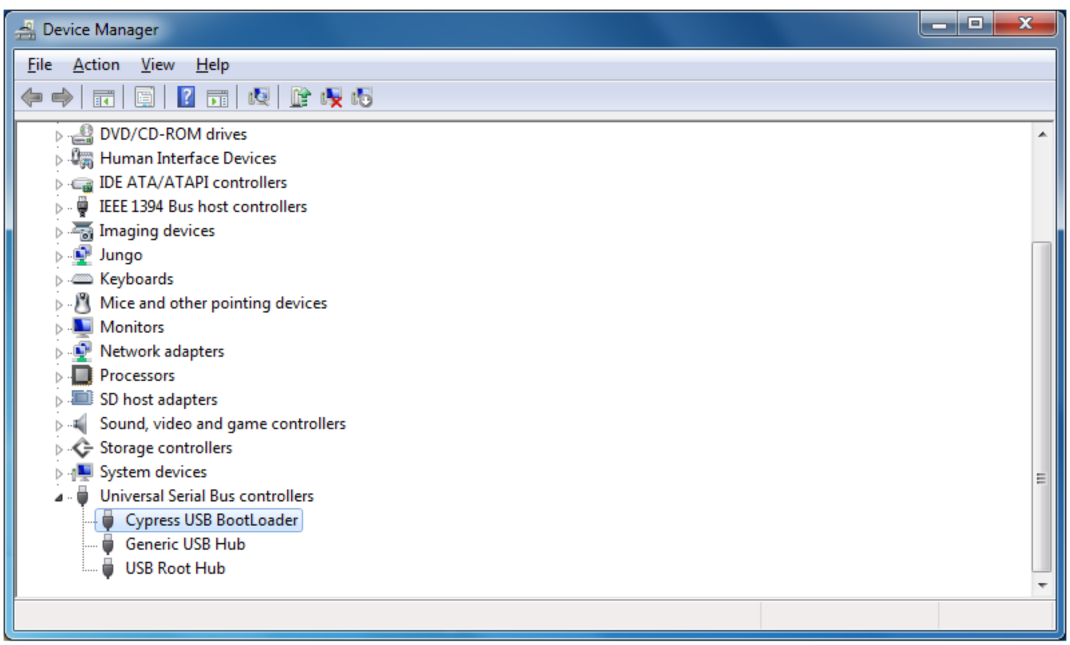


Figure B-19 Cypress USB BootLoader

3) Open PC-Beamage and make sure *Cypress USB BootLoader* has been replaced by *Cypress USB BulkloopExample*.

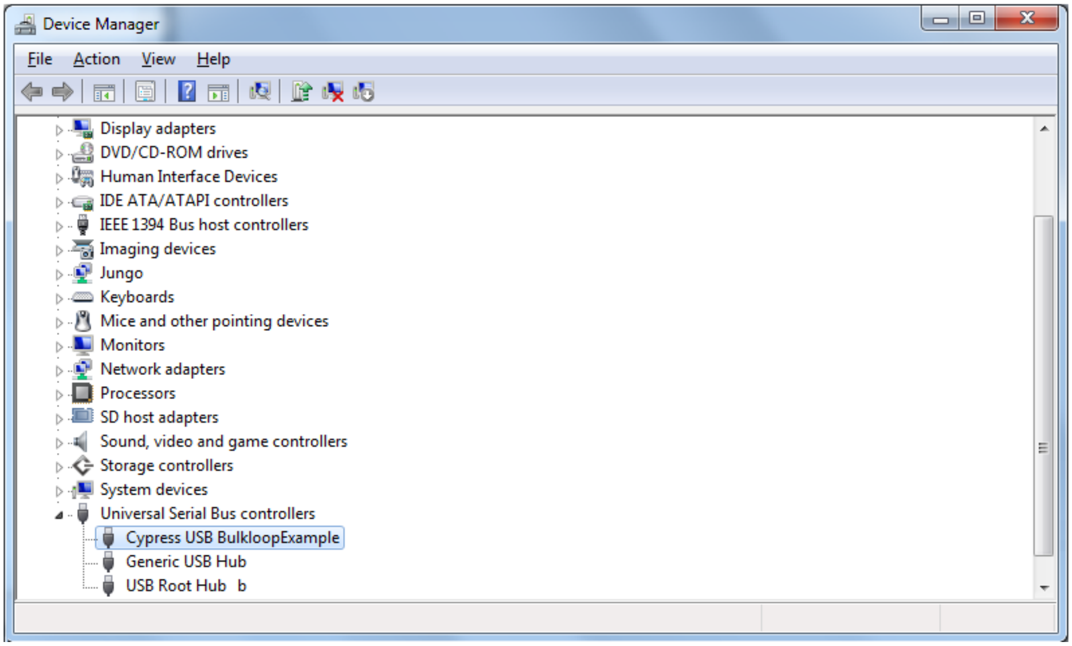


Figure B-20 Cypress USB BulkloopExample

APPENDIX D. BEAMAGE FIRMWARE INSTALLATION QUICK GUIDE

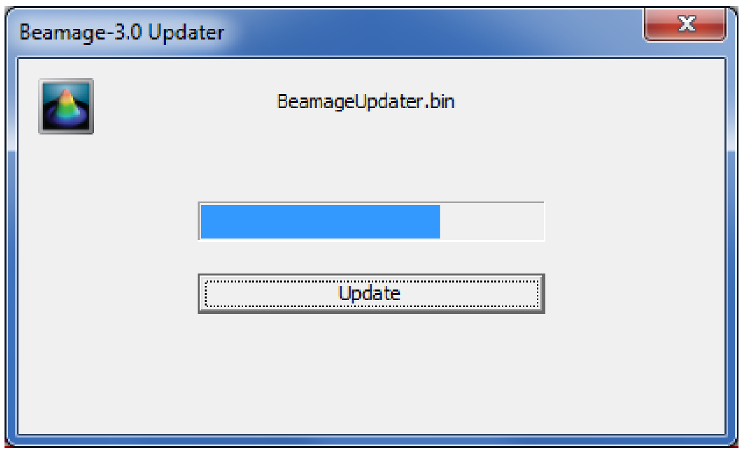
1) If the software version of the PC-Beamage is not compatible with the Beamage's firmware version, an error message will appear. ***If so, it is important to update the firmware version and to reinstall the drivers in order to use the PC-Beamage's new functions***.

2) First, download the latest BeamageUpdater available on Gentec-EO's website at www.gentec-eo.com/downloads.

3) Connect the Beamage to your computer. If the Beamage is already connected, please disconnect and reconnect it.

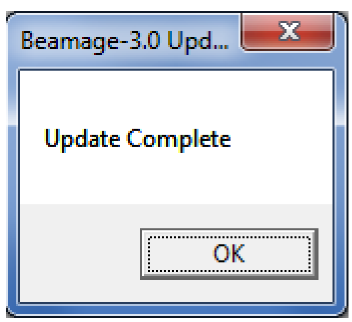
4) Run the Beamage-3.0 Updater.

5) Click on "Update".



The Beamage-3.0 Updater might ask you to reset the Beamage. If so, please disconnect and reconnect the Beamage and click on "Update" again.

6) Once this is done, a message box will appear. Click on *OK*.



7) Once the firmware is up to date, update the drivers by following the steps described in Appendix B. Please note that even if the drivers were previously installed, the new software and firmware versions need a new driver installation.

APPENDIX E. RECYCLING AND SEPARATION PROCEDURE FOR WEEE

This section is used by the recycling center when the Beamage reaches its end of line. Breaking the calibration seal or opening the Beamage's case will void the warranty

The complete Beamage contains:

1 Beamage
1 USB 3.0 cable with screw locks
1 BNC to SMA connector
1 Software CD-ROM

SEPARATION

Plastic: Aperture cap, SMA cap.
Metal: Beamage case, screws, SMA connector, BNC to SMA connector, ND filter holder.
Wires: USB cable.
Printed circuit board: inside the Beamage.
Glass: ND filter.
CD: CD-ROM.

DISMANTLING PROCEDURE

Remove the 3 screws on the BEAMAGE's back cover with an Allen key.
Remove the 1 screw holding the PCB's with a flat screw driver.
Cut the wire between the PCB and the SMA connector.
Remove the ND filter and remove the glass with a spanner wrench.

APPENDIX F. COMPLETE LIST OF SAVED SETTINGS

- Image buffer size
- Smoothing filter activated
- Despeckle filter activated
- IR filter activated
- Normalize option activated
- Trigger option activated
- Turbo option activated
- Divergence tab is activated
- Relative position tab is activated
- Camera lens calibration tab is activated
- Fixed crosshair tab is activated
- XY display options:
  - Gaussian activated
  - Semilog activated
  - Data cursor activated
  - FWHM activated
  - 1/e2 activated
- Measure tab options:
  - Beam diameter definition
  - Crosshair center choice
  - Crosshair orientation choice
- Setup tab options:
  - Is auto exposure time activated
  - Exposure time
  - Image rotation
  - Image flip vertical
  - Image flip horizontal
  - Image buffer averaging
  - Active area:
    - Choice
    - Left
    - Top
    - Center activated
    - Width
    - Height
  - Pixel addressing mode
  - Camera numerical gain
  - Camera bit depth
  - Magnification factor
- Acquisition tab options:
  - Acquisition mode
  - Duration:
    - Days
    - Hours
    - Minutes
    - Seconds
  - Sample rate images
  - Sample rate:
    - Days
    - Hours
    - Minutes
    - Seconds
  - Acquisition filename
- Divergence tab options:
  - Focal distance
- Relative position tab options:
  - Relative position mode
  - X baseline position
  - Y baseline position
  - Save to log activated
- Camera lens calibration tab options:
  - X baseline position
  - Moving distance in X
  - Is calibrated activated
- Fixed crosshair tab options:
  - Fixed crosshair mode
  - X crosshair baseline position
  - Y crosshair baseline position

Crosshair angle

APPENDIX G SATURATION LIMIT FOR BEAMAGE WITH ND4.0 FILTER

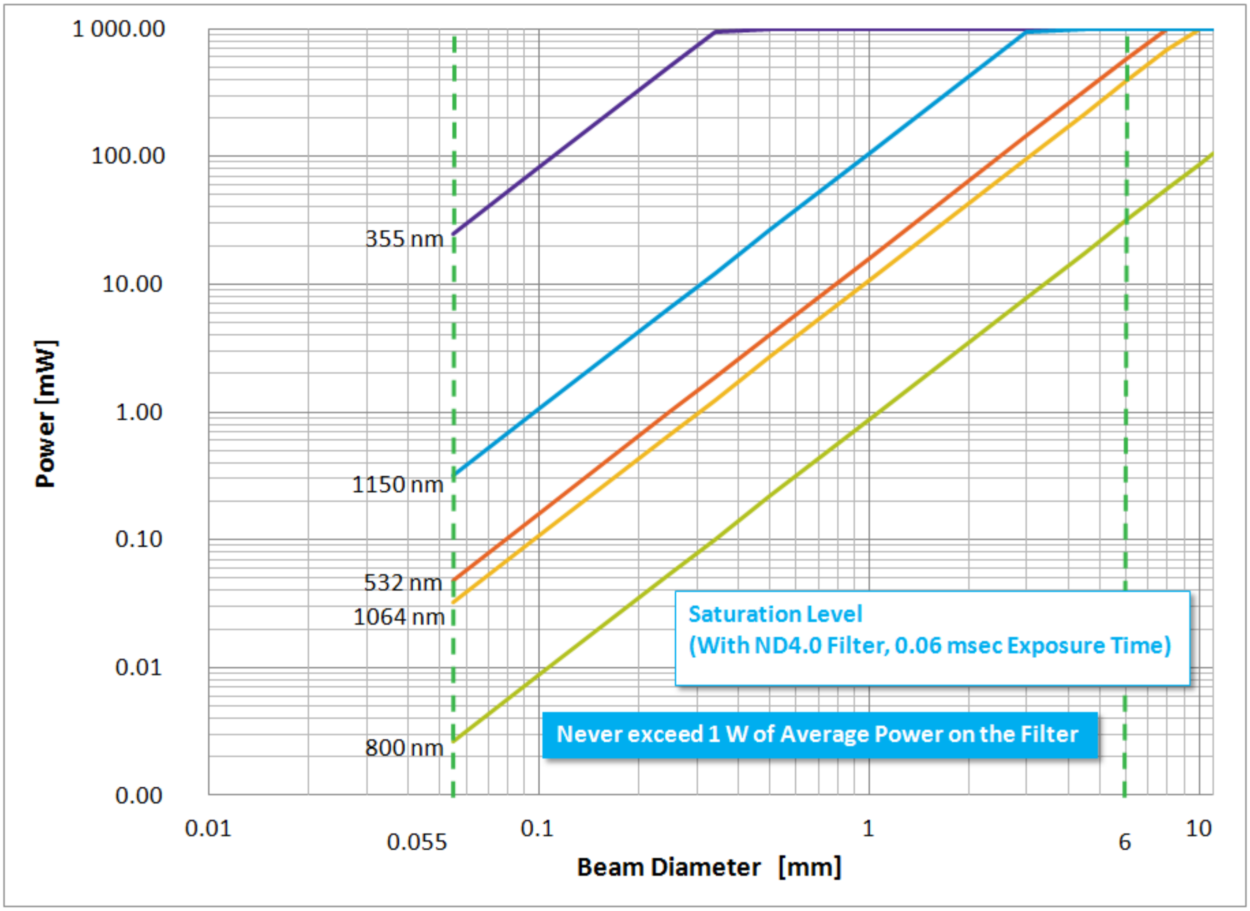


Figure F-1 Saturation Limit for Beamage with ND4.0 Filter and 0.06 msec Exposure Time

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