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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1.0 INTRODUCTION ........................................................................................................ 0
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 format 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%.

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Beamage-3.0</th>
<th>Beamage-3.0-IR</th>
<th>Beamage-4M</th>
<th>Beamage-4M-IR</th>
<th>Beamage-4M-FOCUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor Technology</td>
<td>CMOS without coverglass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensor Size</td>
<td>11.3 x 6.0 mm</td>
<td>11.3 x 11.3 mm</td>
<td></td>
<td>20.5 x 20.5 mm effective size¹</td>
<td></td>
</tr>
<tr>
<td>Sensor Area</td>
<td>0.67 cm²</td>
<td>1.28 cm²</td>
<td></td>
<td>4.2 cm² effective optical aperture</td>
<td></td>
</tr>
<tr>
<td>Pixel Count</td>
<td>2.2 MPixels</td>
<td></td>
<td>4.2 MPixels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pixel H x V</td>
<td>2048 x 1088</td>
<td></td>
<td>2048 x 2048</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optical Format</td>
<td>⅔”</td>
<td></td>
<td>1”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pixel Pitch of Sensor² (Pixel Size)</td>
<td>5.5 µm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shutter Type</td>
<td>Global</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wavelength Range</td>
<td>350 - 1150 nm</td>
<td>1495 - 1595 nm</td>
<td>350 - 1150 nm</td>
<td>1495 - 1595 nm</td>
<td>350 - 1150 nm</td>
</tr>
</tbody>
</table>

¹ With Pixel Multiplication Factor 1.8
² For –IR models, optical resolution is larger (7 µm) because of the Point Spread Function (PSF) of the Phosphor Coating. For the –FOCUS model, optical resolution is larger (12 µm) because of the Pixel Multiplication Factor (PMF) and of the Point Spread Function (PSF) of the bound fiber optic bundle.
<table>
<thead>
<tr>
<th>Minimum Measurable Beam (ISO)</th>
<th>55 µm</th>
<th>70 µm&lt;sup&gt;1&lt;/sup&gt;</th>
<th>55 µm</th>
<th>70 µm&lt;sup&gt;1&lt;/sup&gt;</th>
<th>120 µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12 bit (default) or 10 bit</td>
</tr>
<tr>
<td>Frame Rate</td>
<td>11 fps (2.2 MPixel Full Frame)</td>
<td></td>
<td>6.2 fps (4.2 MPixel Full Frame)</td>
<td>20 fps (1.1 MPixel Active Area 2048 x 544)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>32 fps (0.066 MPixel Active Area 256 x 256)</td>
<td></td>
<td>18.6 fps (1.1 MPixel Active Area 2048 x 544)</td>
<td></td>
<td>32 fps (0.066 MPixel Active Area 256 x 256)</td>
</tr>
<tr>
<td>RMS noise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1000:1 (60 dB)</td>
</tr>
<tr>
<td>Minimum and Maximum Exposure Times</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.06 to 200 ms</td>
</tr>
<tr>
<td>External Trigger</td>
<td></td>
<td>SMA connector</td>
<td></td>
<td></td>
<td>1.1 volts to 24 volts, the rise edge response time is 300 ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trigger signal pulse width: min: 300 ns</td>
<td></td>
<td></td>
<td>Optional SMA to BNC adaptor (202273)</td>
</tr>
</tbody>
</table>

### Damage Thresholds

<table>
<thead>
<tr>
<th>Maximum Average Power</th>
<th>1 W with ND filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Power Density</td>
<td>10 W/cm² with ND4.0 filter</td>
</tr>
<tr>
<td>(1064 nm, CW)</td>
<td></td>
</tr>
<tr>
<td>Maximum Energy Density</td>
<td>0.1 J/cm² for ND4.0 filter only</td>
</tr>
<tr>
<td>(1064 nm, 10 ns Pulsed)</td>
<td>(30 µJ/cm² on sensor)</td>
</tr>
</tbody>
</table>

### Physical Characteristics

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>61 H x 81.1W x 19.7D mm</th>
<th>61 H x 81.1W x 46.5D mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>138 g</td>
<td>235 g</td>
</tr>
<tr>
<td>Distance from front of case to sensor</td>
<td>7.8 mm</td>
<td></td>
</tr>
<tr>
<td>Default Attenuation</td>
<td>ND 4.0</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> Minimum measurable beam is larger because of the Point Spread Function (PSF) of the Phosphor Coating (for the –IR models) and of the bound fiber optic bundle (for the –FOCUS model)
<table>
<thead>
<tr>
<th><strong>Measured and Displayed Parameters</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Displays</strong></td>
</tr>
<tr>
<td>3D, 2D, XY (crosshair), Beam Tracking, M² Curves</td>
</tr>
<tr>
<td><strong>Beam Diameter Definition</strong></td>
</tr>
<tr>
<td>Displays 3D, 2D, XY (crosshair), Beam Tracking, M² Curves</td>
</tr>
<tr>
<td><strong>Beam Center Definition</strong></td>
</tr>
<tr>
<td>Displays 3D, 2D, XY (crosshair), Beam Tracking, M² Curves</td>
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<td><strong>Displayed Measurements</strong></td>
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<td>Displays 3D, 2D, XY (crosshair), Beam Tracking, M² Curves</td>
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<td><strong>Setup Options</strong></td>
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<td>Displays 3D, 2D, XY (crosshair), Beam Tracking, M² Curves</td>
</tr>
<tr>
<td><strong>Processing Option</strong></td>
</tr>
<tr>
<td>Displays 3D, 2D, XY (crosshair), Beam Tracking, M² Curves</td>
</tr>
<tr>
<td><strong>Buffer</strong></td>
</tr>
<tr>
<td>Displays 3D, 2D, XY (crosshair), Beam Tracking, M² Curves</td>
</tr>
<tr>
<td><strong>File options</strong></td>
</tr>
<tr>
<td>Displays 3D, 2D, XY (crosshair), Beam Tracking, M² Curves</td>
</tr>
<tr>
<td>PC Requirements</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td><strong>USB Port</strong></td>
</tr>
<tr>
<td><strong>Operating System Compatibility</strong></td>
</tr>
<tr>
<td><strong>Average RAM Allocation</strong></td>
</tr>
<tr>
<td><strong>Recommended Requirements</strong></td>
</tr>
<tr>
<td><strong>For Optimal Performance</strong></td>
</tr>
<tr>
<td><strong>For Faster Frame Rate</strong></td>
</tr>
<tr>
<td><strong>Multi Camera Recommendation</strong></td>
</tr>
<tr>
<td><strong>Internet Upgrades</strong></td>
</tr>
</tbody>
</table>
1.3. MECHANICAL DESCRIPTION

![Figure 1-1 Beamage Series Front and Side Views](image)

**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.

Add or remove accessories in a clean room or very clean environment, and position the front cover of the camera downwards when doing so.

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

**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. Do not use at any time low-cost USB-3.0 cables. USB 2.0 ports can be used, but it will lower the Beamage speed performance.

In order to ensure reliable and stable communication with a Beamage, precautions must be taken when handling the USB cable and its connector:
- Connector screws: Screw until it is tight, but be careful not to screw too tight. This could potentially damage the connector.
- Do not apply pressure on the connector or pull the cable when it is connected.
- We strongly recommended using the cable provided with the Beamage.
- The maximum length for a USB-3.0 cable is 3 meters (9 feet and 10 inches). For a longer distance, a good quality repeater is mandatory.
- Avoid using low-cost USB-3.0 computer expansion card.
- For optimal performance and stability, do not use any other USB device that communicates intensive data and uses high power current on your USB port when using the Beamage.
- Disable any power saving settings on your computer. It could reduce the power attribution on the USB port and the Beamage camera needs all the power from the USB-3.0 port to provide a stable communication.
- For a laptop computer, always power the computer when using the Beamage camera.

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

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

![Figure 1-2 Beamage-4M-FOCUS Front and Side Views](image)

**Aperture**
The optical aperture of the Beamage-4M-FOCUS is centered with the T-Mount threads on the front casing. These threads and the included T-Mount to SM2 adaptor allow easy connectivity with optical accessories such as attenuation filters.

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

**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. Do not use at any time low-cost USB-3.0 cables. USB 2.0 ports can be used, but it will lower the Beamage speed performance.

In order to ensure reliable and stable communication with a Beamage, precautions must be taken when handling the USB cable and its connector:
- Connector screws: Screw until it is tight, but be careful not to screw too tight. This could potentially damage the connector.
- Do not shake the cable when the Beamage is connected.
- Do not apply pressure on the connector when it is connected to a Beamage.
- We strongly recommend using the cable provided with the Beamage.
- The maximum length for a USB-3.0 cable is 3 meters (9 feet and 10 inches). For a longer distance, a repeater is mandatory.
- Avoid using low-cost USB-3.0 computer expansion card.
- For optimal performance and stability, use only the Beamage and do not use any other USB device that communicates intensive data and use high power current on your computer.
- Disable any power saving settings on your computer, it could reduce the power attribution on the USB port and the Beamage camera needs all the power from the USB-3.0 port to provide a stable communication.
- For a laptop computer, always power the computer when using the Beamage camera.

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

**Fixation Holes**
¼”-20 holes are aligned with the sensor’s center allowing easy optical alignment.
1.4. SPECTRAL CURVES

**Figure 1-3** Spectral Response of the Sensor

**Figure 1-4** Transmission of the ND4.0 Filter
Figure 1-5 Minimum Measurable Power and Saturation Power Level

Never exceed 1 W of average power on the filter.
<table>
<thead>
<tr>
<th>Wavelength</th>
<th>UG11-UV</th>
<th>ND 0.5</th>
<th>ND 4.0</th>
<th>ND5.0</th>
<th>IR Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum (mW/cm²) Saturation (mW/cm²)</td>
<td>Minimum (mW/cm²) Saturation (mW/cm²)</td>
<td>Minimum (mW/cm²) Saturation (mW/cm²)</td>
<td>Minimum (mW/cm²) Saturation (mW/cm²)</td>
<td>Minimum (mW/cm²) Saturation (mW/cm²)</td>
</tr>
<tr>
<td>300 nm</td>
<td>0.0001</td>
<td>0.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>355 nm</td>
<td>0.00024</td>
<td>3.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>532 nm</td>
<td>0.000034</td>
<td>0.47</td>
<td>0.15</td>
<td>2000</td>
<td>1.9</td>
</tr>
<tr>
<td>632 nm</td>
<td>0.000035</td>
<td>0.49</td>
<td>0.10</td>
<td>1400</td>
<td>1.2</td>
</tr>
<tr>
<td>800 nm</td>
<td>0.000037</td>
<td>0.51</td>
<td>0.0080</td>
<td>110</td>
<td>0.042</td>
</tr>
<tr>
<td>1064 nm</td>
<td>0.00035</td>
<td>4.8</td>
<td>0.099</td>
<td>1400</td>
<td>0.59</td>
</tr>
<tr>
<td>1150 nm</td>
<td>0.0043</td>
<td>61</td>
<td>0.97</td>
<td>13000</td>
<td>5.7</td>
</tr>
<tr>
<td>1310 nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Beamage-3.0-IR and Beamage-4M-IR**

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>UG11-UV</th>
<th>ND 0.5</th>
<th>ND 4.0</th>
<th>ND5.0</th>
<th>IR Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1550 nm</td>
<td>0.12</td>
<td>1.70</td>
<td>0.005</td>
<td>3.80</td>
<td>0.002</td>
</tr>
</tbody>
</table>

**Beamage-4M-FOCUS**

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>UG11-UV</th>
<th>ND 0.5</th>
<th>ND 4.0</th>
<th>ND5.0</th>
<th>IR Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>355 nm</td>
<td>0.33</td>
<td>4700</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>532 nm</td>
<td>0.000039</td>
<td>0.55</td>
<td>0.17</td>
<td>2400</td>
<td>2.2</td>
</tr>
<tr>
<td>632 nm</td>
<td>0.000029</td>
<td>0.41</td>
<td>0.086</td>
<td>1200</td>
<td>0.99</td>
</tr>
<tr>
<td>800 nm</td>
<td>0.000026</td>
<td>0.36</td>
<td>0.0056</td>
<td>78</td>
<td>0.030</td>
</tr>
<tr>
<td>1064 nm</td>
<td>0.0013</td>
<td>18</td>
<td>0.37</td>
<td>5200</td>
<td>2.2</td>
</tr>
<tr>
<td>1150 nm</td>
<td>0.013</td>
<td>175</td>
<td>2.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 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
2. QUICK START PROCEDURE

1. Install the PC-Beamage 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. For a Beamage-4M-FOCUS, enter the Pixel Multiplication Factor (PMF) at the bottom of the Settings tab. You must enter the PMF for every computer on which the Beamage-4M-FOCUS is used.

7. Press Start Capture.
8. 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.

9. 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.

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

11. Choose the appropriate graphic for your measurement mode on the bottom left hand-side:
   a. ![3D display](image)
   b. ![2D display](image)
   c. ![Crosshair Display](image)
   d. ![Beam tracking display](image)
3. USER INTERFACE

**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.

**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).

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

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

**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.

*Figure 3-1 PC-Beamage User Interface*
3.1. MAIN CONTROLS

![Figure 3-2 Main Controls](image)

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](image)

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.
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.

3.3.1. 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

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 3.4.5) 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.

If you use a laptop which battery is not charging and you start a capture, a pop-up will appear stating that your computer is not connected. See Figure 3-8.

![Figure 3-7 Capture Button](image)

Your laptop needs to be plugged in because the PC-Beamage Software prevents that the computer goes into sleep mode while the application is active, so if your laptop is not plugged in while you are using the PC-Beamage Software, your computer will shut down and you will lose all the information that has not been saved.
3.3.3. Subtract Background

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.

![Subtract Background Button](image)

**Figure 3-9 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:

![Subtract Background Message Box](image)

**Figure 3-10 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 3-11 Buffer Controls](image)

**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 3-12 Image Index](image)

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. Exposure Time

The Exposure time can be set to a certain value between 0.06 ms and 200 ms by typing the desired value in the “Exposure time” box. Click the “Auto” checkbox to let the camera set itself to a suitable exposure time. Drag the slider to adjust the exposure time using the mouse cursor; slide to the right to increase the value.

3.4.3. Previous and Next Image

The “Next Image” and “Previous Image” buttons access the next and previous image in the buffer.

3.4.4. Clear Buffer

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.

3.4.5. Animate

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.
3.4.6. 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.

![Data Computations Menu](image)

**Figure 3-17** Data Computations

3.5.1. Filters

![Filters Button](image)

**Figure 3-18** Filters Button

![Available Filters](image)

**Figure 3-19** 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.

![Spatial Filter Example](image)

**Figure 3-20** 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:

\[
IR\ Pixel\ Intensity = Pixel\ Intensity \times \frac{1}{Correction\ Factor} \times \frac{Max\ Intensity}{Max\ Intensity^{Correction\ Factor}}
\]

### 3.5.2. Normalize

**Figure 3-21** 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 3-22** Normalization Example

### 3.5.3. Trigger

**Figure 3-23** 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](image)

**Figure 3-24 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.

![File Controls](image)

**Figure 3-25 File Controls**

#### 3.6.1. Open

![Open File Button](image)

**Figure 3-26 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

![Save Current Image Button](image)

**Figure 3-27 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

![Save All Images in Buffer](image)

Figure 3-28 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

![Start Data Acquisition](image)

Figure 3-29 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 format *.JPG, *.BMP and 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, each *.JPG file can take up to 200KB and each *.BMP file can take up to 1.2 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

![Print Report Button](image)

Figure 3-30 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.

![Custom Print Report dialog](image)

Figure 3-31 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 3-32 Print Report Preview

The report fits on 2 pages. The first page presents the 3D and 2D images, measurement results, and the Beamage settings.
Figure 3-33 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/e²” options are selected (refer to section 0), they will also appear in the report.

Figure 3-34 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 3-35-Startup Config Controls](image)

**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 3-36-Startup Config Controls](image)

3.8.1. Show/Hide Options

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

![Divergence Button](Image)

**Figure 3-38 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 4.4). 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](Image)

**Warning**

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

3.8.3. Relative Position

![Relative Position Panel](Image)

**Figure 3-39 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

![Camera Lens Calibration Panel](Image)

**Figure 3-40 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

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

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

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

![Image of M2 Mode Tabs]

**Figure 3-44 Show/Hide M2 Mode Tabs**

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 the Beamage-M2 user manual.

3.10. M2 FILE

![Image of M2 File Management]

The M2 data and files can be managed via this set of buttons. More info about these can be found in the Beamage-M2 user manual.

3.11. SOFTWARE INFO

The “Information Menu” displays important and useful information about the Beamage and provides help.

![Image of Information Menu]

**Figure 3-45 Software Info**

3.11.1. Color Legend

![Image of Color Legend]

**Figure 3-46 Color Legend Button**
The “Color Legend” button shows the colors corresponding to the 3D and 2D display intensity levels.

![Color Legend](image)

**Figure 3-47** Color Legend

### 3.11.2. Contact Support

![Contact Support](image)

**Figure 3-48** 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.
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.

3.11.3. About

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

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

![Help Button](image)

**Figure 3-51 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 the Beamage-M2 user manual).

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

![Figure 4-1 Graphic Display](image-url)
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/e² (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 Crosshair Display (refer to section 5.3) and the beam width if it is defined by the FWHM or 1/e² 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 beam diameter “dox” and “doy” refers to the beam width closest to the x horizontal axis and y vertical axis as defined by the ISO-11146-1:2005 and ISO11146-2:2005 standards. If the Beam Diameter Definition is set to “FWHM along crosshair” or “1/e² along crosshair” and the crosshair orientation is set to 0° angle, “dox” and “doy” will refer to x as the horizontal axis and y the vertical axis.

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 “dox” and “doy” diameters, 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.

![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/e² diameter of the actual beam and has the same area (same energy). The software computes the ratios for both the X and Y axes.

![Diagram](image)

**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”.

![Table]

**Figure 4-5 Peak to Average Ratio Example**
4.2. SETUP

The “Setup” tab allows the user to set the Beamage parameters.

![Setup Tab Diagram]

**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 90°, 180°, or 270°. 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.

**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.

Figure 4-8 Pixel Addressing Mode
Tip

When working with large beams, 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 $\rightarrow 2^{12} = 4096$), 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.

To obtain accurate value with a Beamage-4M-FOCUS, you must enter the PMF that is written on the instrument’s certificate.

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 format *.JPG, *.BMP or a native *.BMG file.

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).
Choose your acquisition mode:
- Measurements only (*.TXT)
- Full images and measurements (*.BMG & *.TXT)
- Full images and measurements (*.JPG & *.TXT)
- Full images and measurements (*.BMP & *.TXT)

Enter the total duration:

0 Day(s) 0 Hour(s) 1 Min(s) 0 Sec(s)

Enter the sampling rate for the measurements:

1/10 Image(s)

Enter the sampling rate for the full images:

0 Day(s) 0 Hour(s) 1 Min(s) 0 Sec(s)

File Name: ...

If you choose to save full images (in *.BMG, *.JPG or *.BMP format), choose a location on your hard drive. Do not save the data on a USB key or any remote location since it could slow down the acquisition.

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 (*.BMG & *.TXT)” is selected, then a series of “.BMG” files with the same filename concatenated with its corresponding increment will be saved (is the same process for “Full images and measurements (*.JPG & *.TXT)” and “Full images and measurements (*.BMP & *.TXT).”

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, each *.JPG file can take up to 200 KB and each *.BMP file can take up to 1.20 MB on the hard drive. Acquiring multiple frames can quickly sum up to multiple Gigabytes. If the total acquisition is 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](image)

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.
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.

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.

Figure 4-14 Coordinates Defined by User

Figure 4-15 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.

![Camera Lens Calibration Section](image)

**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.

![Camera Lens Calibration Moving Direction](image)

**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).

![Pixel Multiplication Factor](image)

*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.

![Home Panel](image)

*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).
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.

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.
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.

![Fixed Crosshair Orientation Section](image)

**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.

![User-Defined Crosshair Orientation](image)

**Figure 4-27** User-Defined Crosshair Orientation

![Different Crosshair Orientations for the Same Beam](image)

**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.
- **Crosshair Display**: A real time display of the beam’s shape 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 3.11.1).

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.
5.1.1. 3D Display: Controls

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

- **Print Screen**: Saves a *.BMP or *.JPG 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 3.11.1). The 2D display also features the crosshairs (set to the major and minor axis or along specified angles).

![2D Display Showing Crosshairs and Diameter Positions](image)

**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.

![2D Display](image)

**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 or *.JPG 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. CROSSHAIR DISPLAY

The “Crosshair 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)

![Crosshair Display](image)

*Figure 5-5 Crosshair Display*
5.3.1. Crosshair Display: Controls

The toolbar buttons on the upper right corner control the crosshair graphs.

- **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 informations 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:

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

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:

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

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:

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

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

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

---

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.

![Beam Tracking Display](image)

**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 origin
The beam positional stability values are based on the standard deviation concept\(^1\). Small values represent small deviations and a good stability.

For tracking more than 2000 points, please refer and use the acquisition feature : 3.6.4 Start Data Acquisition. 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 or *.JPG 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.

---

6. M² MODE

The M² 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 M² quality factor.

Using a minimalist setup, it is possible to use a Beamage camera and readily available tools to perform manual M² calculations. Using a lens and moving the camera along the z-axis, you can use the M² Manual routine in the Beamage software to obtain ISO 11146 M² measurements. See the Beamage-M2 user manual for details on how to proceed for a manual measurement.

Automated M² measurements can be performed on the Beamage-M2 system. See the Beamage-M2 User Manual under the Help menu for more information.

Note that all the information about M² measurement using a Beamage camera or a Beamage-M2 device is presented in the Beamage-M2 User Manual.
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

<table>
<thead>
<tr>
<th>Description</th>
<th>Available VI samples</th>
<th>Available commands for LabVIEW and .Net</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Connection Commands</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Checks to ensure the required DLL file is present in the directory in which the LabVIEW VIs are located.</td>
<td>Verify DLL</td>
<td></td>
</tr>
<tr>
<td>Connects to the LabVIEW pipeline opened by the PC-Beamage software.</td>
<td>Connect to PC Beamage</td>
<td></td>
</tr>
<tr>
<td>Disconnects from the LabVIEW pipeline opened by the PC-Beamage software</td>
<td>Disconnect from PC Beamage</td>
<td></td>
</tr>
<tr>
<td><strong>Control Commands</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td>Control Stop Capture.</td>
<td>*CTLSTOP</td>
</tr>
<tr>
<td>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.</td>
<td>Control Start Capture.</td>
<td>*CTLSTART</td>
</tr>
<tr>
<td>Save the beam raw data information in the beamage.txt file.</td>
<td>Control Data Save</td>
<td>*CTLDATSAVE</td>
</tr>
<tr>
<td>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.</td>
<td>Control 4 Sigma.</td>
<td>*CTL4SIG</td>
</tr>
<tr>
<td>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.</td>
<td>Control FWHM.</td>
<td>*CTLFWHM</td>
</tr>
<tr>
<td>Command</td>
<td>Description</td>
<td>Key</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td>-----</td>
</tr>
<tr>
<td>*CTL1OVRE</td>
<td>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</td>
<td>Control $1OVRe^2$.</td>
</tr>
<tr>
<td>*CTL86</td>
<td>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.</td>
<td>Control 86%.</td>
</tr>
<tr>
<td>*CTLCENT</td>
<td>Sets the Crosshair Center Control in the PC-Beamage Software. This is the same as pressing the selecting the Centroid control in the software</td>
<td>Control Centroid.</td>
</tr>
<tr>
<td>*CTLPEAK</td>
<td>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</td>
<td>Control Peak.</td>
</tr>
<tr>
<td>*CTLAUTO</td>
<td>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.</td>
<td>Control Auto.</td>
</tr>
<tr>
<td>*CTLZERO</td>
<td>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.</td>
<td>Control Zero.</td>
</tr>
<tr>
<td>*CTL45</td>
<td>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.</td>
<td>Control 45.</td>
</tr>
</tbody>
</table>
| *CTLETAUTO | 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. | *
| *CTLETMANU | 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. | *
| *CTLIMGSAVE | 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. | *
| *CTLTXTSAVE | 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. | *
| *CTLBMPSAVE | Save the current 2D display image into MyDocuments/Gentec-eo/beamage.bmp. | *

**Measurement Commands**

The measurement for the Diameter and Position. Running the selected commands returns the reading from the software.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>*MEAEFFDIA</td>
<td>Returns the beam’s effective diameter measurement</td>
<td>Measure Effective Diameter</td>
</tr>
<tr>
<td>*MEAELLIP</td>
<td>Returns the beam’s ellipticity measurement</td>
<td>Measure Ellipticity</td>
</tr>
<tr>
<td>*MEAOrien</td>
<td>Returns the beam’s orientation measurement</td>
<td>Measure Orientation</td>
</tr>
<tr>
<td>*MEAPKSAT</td>
<td>Returns the beam’s peak saturation level measurement</td>
<td>Measure Peak Saturation</td>
</tr>
</tbody>
</table>
| *MEASIGX | Returns the beam’s diameter closest to the X axis | *
| *MEASIGY | Returns the beam’s diameter closest to the Y axis | *
| *MEAMAJAX | Returns the beam’s major axis measurement | Measure Major Axis |
| *MEAMINAX | Returns the beam’s minor axis measurement | Measure Minor Axis |
| *MEAXDIV | Returns the X divergence measurement | Measure X Divergence |
| *MEAYDIV | Returns the Y divergence measurement | Measure Y Divergence |
### Position Commands
Position commands have separate VIs for the X and Y measurements. Running the selected command returns the reading from the software.

<table>
<thead>
<tr>
<th>Command Description</th>
<th>Measure Description</th>
<th>VIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Returns the beam’s X centroid measurement and returns the beam’s Y centroid measurement</td>
<td>Measure X Centroid and Measure Y Centroid</td>
<td>*MEACENTX and *MEACENTY</td>
</tr>
<tr>
<td>Returns the beam’s X FWHM clip level measurement and returns the beam’s Y FWHM clip level measurement</td>
<td>Measure X FWHM and Measure Y FWHM</td>
<td>*MEAFWHMX and *MEAFWHMY</td>
</tr>
<tr>
<td>Returns the beam X 1/e^2 diameter measurement and returns the beam Y 1/e^2 diameter measurement</td>
<td>Measure X 1OVRE^2 and Measure Y 1OVRE^2</td>
<td>*MEA1OVREX and *MEA1OVERY</td>
</tr>
<tr>
<td>Returns the beam’s X Gaussian Equation and returns the beam’s Y Gaussian Equation</td>
<td>Measure X Gaussian Equation and Measure Y Gaussian Equation</td>
<td>*MEAEQUX and *MEAEQUY</td>
</tr>
<tr>
<td>Returns the beam’s X Gaussian Fit and returns the beam’s Y Gaussian Fit</td>
<td>Measure X Gaussian Fit % and Measure Y Gaussian Fit %</td>
<td>*MEAFITX and *MEAFITY</td>
</tr>
<tr>
<td>Returns the X peak to average measurement and returns the X peak to average measurement</td>
<td>Measure X Peak to Average and Measure Y Peak to Average</td>
<td>*MEAPKRAX and *MEAPKRAY</td>
</tr>
<tr>
<td>Returns the X peak measurement and returns the Y peak measurement</td>
<td>Measure X Peak and Measure Y Peak</td>
<td>*MEAPEAKX and *MEAPEAKY</td>
</tr>
<tr>
<td>Returns the X roughness fit measurement and returns the Y roughness fit measurement</td>
<td>Measure X Roughness Fit and Measure Y Roughness Fit</td>
<td>*MEARFITX and *MEARFITY</td>
</tr>
<tr>
<td>Returns the X or Y graph’s intensity level at cursor position in %</td>
<td></td>
<td>*MEAPERX and *MEAPER -</td>
</tr>
<tr>
<td>Returns the X or Y graph’s cursor position</td>
<td></td>
<td>*MEAPOSX and *MEAPOSY</td>
</tr>
</tbody>
</table>

### 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.

<table>
<thead>
<tr>
<th>Command Description</th>
<th>Measure Description</th>
<th>VIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Returns the X coordinate of the last measured centroid and returns the Y coordinate of the last measured centroid</td>
<td>Measure X Last and Measure Y Last</td>
<td>*MEALASTX and *MEALASTY</td>
</tr>
<tr>
<td>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</td>
<td>Measure X Mean and Measure Y Mean</td>
<td>*MEABEAMX and *MEABEAMY</td>
</tr>
<tr>
<td>Returns the beam’s X positional stability in the azimuth direction and</td>
<td>Measure X Delta and Measure Y Delta</td>
<td>*MEADELTX and *MEADELTY</td>
</tr>
<tr>
<td><strong>Returns the beam’s Y positional stability perpendicularly to the azimuth direction</strong></td>
<td>Measure Azimuth</td>
<td>*MEAAZMTH</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>Returns the orientation for which the drift is maximal.</strong></td>
<td>Measure Delta</td>
<td>*MEADELTA</td>
</tr>
<tr>
<td><strong>Returns the overall beam positional stability</strong></td>
<td>Measure Number of Samples</td>
<td>*MEANSMPL</td>
</tr>
<tr>
<td><strong>Returns the RMS standard deviation value of the centroid's position (not ISO measurement)</strong></td>
<td>Measure RMS</td>
<td>*MEARMS</td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th><strong>Switches to the 2 D display screen</strong></th>
<th>Display 2D.</th>
<th>*DIS2D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Switches to the 3 D display screen.</strong></td>
<td>Display 3D</td>
<td>*DIS3D</td>
</tr>
<tr>
<td><strong>Switches to the Crosshair Display screen</strong></td>
<td>Display XY.</td>
<td>*DISXY</td>
</tr>
<tr>
<td><strong>Switches to the Beam Track display screen.</strong></td>
<td>Display TRACK.</td>
<td>*DISTRACK</td>
</tr>
</tbody>
</table>

**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 Crosshair 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.

<table>
<thead>
<tr>
<th><strong>Running this has the same effect as pressing the Gaussian button in the Crosshair Display.</strong></th>
<th>Activate Gaussian</th>
<th>*ACTXYGAUSS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Running this has the same effect as pressing the SEMI LOG button in the Crosshair Display.</strong></td>
<td>Activate LOG.</td>
<td>*ACTXYLOG</td>
</tr>
<tr>
<td><strong>Running this has the same effect as releasing the SEMI LOG button in the Crosshair Display</strong></td>
<td>Activate LIN.</td>
<td>*ACTXYLIN</td>
</tr>
<tr>
<td><strong>Running this has the same effect as pressing the FWHM button in the Crosshair Display.</strong></td>
<td>Activate FWHM.</td>
<td>*ACTXYFWHM</td>
</tr>
<tr>
<td><strong>Running this has the same effect as pressing the 1/e2 button in the Crosshair Display.</strong></td>
<td>Activate 1OVRE.</td>
<td>*ACTXYE2</td>
</tr>
<tr>
<td><strong>Running this has the same effect as pressing the Subtract background in the ribbon.</strong></td>
<td></td>
<td>*ACTBACK</td>
</tr>
<tr>
<td><strong>Running this has the same effect as pressing the Subtract background in the ribbon</strong></td>
<td></td>
<td>*DACBACK</td>
</tr>
<tr>
<td><strong>Running this has the same effect as pressing the Trigger button in the ribbon</strong></td>
<td>Activate Trigger</td>
<td>*ACTTRIG</td>
</tr>
<tr>
<td><strong>Running this has the same effect as pressing the Trigger button in the ribbon</strong></td>
<td>Deactivate Trigger</td>
<td>*DACTTRIG</td>
</tr>
<tr>
<td><strong>Running this has the same effect as pressing the Divergence button in the ribbon</strong></td>
<td>Activate Divergence</td>
<td>*ACTDIVER</td>
</tr>
</tbody>
</table>

**Miscellaneous VIs**

<table>
<thead>
<tr>
<th><strong>Returns the PC-Beamage software version.</strong></th>
<th>Query PC-Beamage Version</th>
<th>*VER</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Returns the serial number of the camera that is currently connected to the software.</strong></td>
<td>Query Serial Number.</td>
<td>*MEASNM</td>
</tr>
<tr>
<td><strong>Use this command to send the desired manual time. Ex: To set the exposure time to 12.34 ms, send “SNDMAN1234”</strong></td>
<td></td>
<td>*SNDMAN</td>
</tr>
<tr>
<td><strong>Send the focal length value for divergence calculation towards PC-Beamage software</strong></td>
<td>Focal Length Divergence</td>
<td>*SNDFLDIVER</td>
</tr>
<tr>
<td><strong>Interfaces with the DLL file to read data from the software.</strong></td>
<td>Read PC Beamage</td>
<td></td>
</tr>
</tbody>
</table>
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 Crosshair 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.

![NamedPipeClient Diagram]

*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.

### 7.4. BEAMAGE SDK

Gentec-EO’s *Beamage SDK* has been designed to help clients develop their own software user interface, make their own image analysis, and integrate the Beamage camera to their system without using Gentec-EO’s *PC-Beamage* software. This is for experienced programmers only.

Gentec-EO’s *Beamage SDK* is a *dll* (Dynamic Link Library) that communicates with the camera drivers. It provides our customers with specific software functions to control the Beamage camera and retrieve images from it, in order to build custom Windows applications.
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:

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 Windows' 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, it is very likely that the USB-3.0 is damaged and unusable. In that case, we strongly recommend not using this USB-3.0 with the Beamage camera, it could have a negative impact on the communication stability.

For more information, 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 10;
- 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 as small as possible (3 times the beam diameter, refer to 4.2.4);
- Make sure you have a short and a manual exposure time;
- Do not stream multiple Beamage units simultaneously.
- Close any other software on your computer.
- Make a background subtraction;
- Use 1/e2 beam diameter definition with 0 degree orientation;
- Deactivate 2D High Resolution (Advanced tab);
- Have a minimum of 30% of hard drive space available;
- Unplug any other peripheral device on your computer
- Disable any power saving settings on your computer.
9. DECLARATION OF CONFORMITY


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

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

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

Place: Québec (Québec)
Date: July 14, 2016

(President)
APPENDIX A. ISO11146 AND ISO11670 DEFINITIONS

The beam centroid coordinates are given by:

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

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

The 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:

\[ \sigma_x^2(z) = \frac{\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} E(x, y, z) (x - \bar{x})^2 \, dx \, dy}{\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} E(x, y, z) \, dx \, dy} \]

\[ \sigma_y^2(z) = \frac{\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} E(x, y, z) (y - \bar{y})^2 \, dx \, dy}{\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} E(x, y, z) \, dx \, dy} \]

\[ \sigma_{xy}(z) = \frac{\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} E(x, y, z) (x - \bar{x})(y - \bar{y}) \, dx \, dy}{\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} E(x, y, z) \, dx \, dy} \]

The beam widths are given by:

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

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

where:

\[ \gamma = \frac{\sigma_x^2 - \sigma_y^2}{|\sigma_x^2 - \sigma_y^2|} \]

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°.

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

The beam’s divergences transformed by an aberration-free focusing element of focal length \( f \) are given by the following equations:

\[ \theta_x = \frac{d_{\sigma_x}}{f} \]
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:

\[
\begin{align*}
\bar{x}'(z) &= \frac{\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} E(x',y',z')x'dx'dy'}{\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} E(x',y',z')dx'dy'} \\
\bar{y}'(z) &= \frac{\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} E(x',y',z')y'dx'dy'}{\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} E(x',y',z')dx'dy'}
\end{align*}
\]

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,

\[
\begin{align*}
\bar{x}_M &= \frac{\sum_i \bar{x}_i'}{n} \\
\bar{y}_M &= \frac{\sum_i \bar{y}_i'}{n}
\end{align*}
\]

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:

\[
\psi = \frac{1}{2} \arctan \left( \frac{2s_{xy}}{s_x^2 - s_y^2} \right)
\]

where we have the following definitions:

\[
\begin{align*}
s_x &= \sqrt{\frac{\sum_i \bar{x}_i'^2}{n-1}} \\
s_y &= \frac{\sum_i (\bar{y}_i' - \bar{y}_M')^2}{n-1} \\
s_{xy} &= \frac{\sum_i (\bar{x}_i' - \bar{x}_M)(\bar{y}_i' - \bar{y}_M)}{n-1}
\end{align*}
\]

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:

\[ s_x = \frac{\sum \bar{x}_i^2}{\sqrt{n - 1}} \]
\[ s_y = \frac{\sum \bar{y}_i^2}{\sqrt{n - 1}} \]
\[ s = \sqrt{\frac{\sum \bar{x}_i^2 + \bar{y}_i^2}{n - 1}} \]

\( \bar{x}_i^2 \) and \( \bar{y}_i^2 \) are derived from \( \bar{x'}_i^2 \) and \( \bar{y'}_i^2 \) 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:

\[ RMS = \sqrt{\left( \frac{\sum x_i^2 + y_i^2}{n} \right)} \]

where \( x_i^2 \) and \( y_i^2 \) 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 \( \theta \)) 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 \( \lambda \) is the laser wavelength and \( w_{oth} \) 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).

![Beam Propagation Diagram](image)

Figure B-1 Beam Propagation Diagram
Mathematically, it is given by the following equation:

\[ Z_{Rth} = \frac{\pi (w_{0th})^2}{\lambda} \]

Far from the beam waist, the beam expansion becomes linear and the theoretical divergence half-angle \( \theta_{th} \) (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:

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

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

\[ w_{fth} = f \theta_{th} = \frac{f \lambda}{\pi w_{0th}} \]

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:

\[ M^2 = \frac{\pi \theta_{exp} w_{0exp}}{\lambda} = \frac{\theta_{exp} w_{0exp}}{\theta_{th} w_{0th}} > 1 \quad \text{because} \quad \theta_{exp} w_{0exp} > \theta_{th} w_{0th} = \frac{\lambda}{\pi} \]

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

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

\[ w_{exp}(z) = w_{0exp} \sqrt{1 + \frac{z^2}{Z_{Rexp}^2}} \]

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

\[ Z_{Rexp} = \frac{\pi w_{0th}^2}{M^2 \lambda} \]

\[ w_{0exp} = M^2 w_{0th} \]
The experimental half-angle divergence $\theta_{\text{exp}}$ and the experimental beam radius at the focal spot of the lens $w_{f\text{exp}}$ are given by the following equations:

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

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

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. THE PC-BEAMAGE SOFTWARE AND THE SOLID PDF CREATOR SOFTWARE INSTALLATION

1) Download and run the Beamage Installer. The latest version can be downloaded from the Downloads tab at the bottom of the following web page: https://www.gentec-eo.com/resources/download-center.

2) Use the installer to install the PC-Beamage Software, see Figure C-1.

3) When the PC-Beamage Software is installed, you can install the Solid PDF Creator, which is a free software that allows you to create the various reports with the PC-Beamage software. It remains an optional installation because you can use the software of your choice to generate your documents in PDF format, See Figure C-2.
4) Select *Standard Installation* and check "I have read and agree to the terms and conditions of the license Agreement" to agree the license and click Next to start installing the *Solid PDF Creator*. See Figure C-3

![Solid PDF Creator Setup](image)

**Figure C-3** Solid PDF Creator Setup

5) Click *Finish* to finish installing the Solid PDF Creator. See Figure C-4

![Solid PDF Creator Setup](image)

**Figure C-4** Solid PDF Creator Setup
Tip

For a first installation with the M² system, you can click on the “Install All” button. This button installs the PC-Beamage software, the Beamage camera drivers, and the driver for the translation stage, see Figure C-5.

Figure C-5 Install All Button.
APPENDIX D. 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 following web page: https://www.gentec-eo.com/resources/download-center

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 know the software version.

![Figure D-2 PC-Beamage](image-url)
4) Download and run the Beamage Installer. The latest version can be downloaded from the following web page: https://www.gentec-eo.com/resources/download-center. See Figure D-3.

![Beamage Installer (Beamage-3.0 Driver)](image1.png)

**Figure D-3** Beamage Installer (Beamage-3.0 Driver)

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.

![Choose your system](image2.png)

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

Figure D-8 User Account Control

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

Figure D-9 Device Driver Installation Wizard
9) To confirm that you want to install the device software, click on *Install*.

![Figure D-10 Confirmation Window](image)

**Figure D-10** Confirmation Window

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

![Figure D-11 Installation Completed](image)

**Figure D-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 D-12 Driver installed successfully (1)](image)

**Figure D-12** Driver installed successfully (1)

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

![Figure D-13 Connect the camera](image)

**Figure D-13** Connect the camera

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

![Figure D-14 You can now use PC-Beamage](image)

**Figure D-14** You can now use PC-Beamage
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.

![Driver installed successfully](image)

**Figure D-15 Driver installed successfully (2)**

![Camera Selector](image)

**Figure D-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.

![Camera Selector](image)

**Figure D-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 D-18 Search for “Device Manager”](image)

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 D-19 Cypress USB BootLoader](image)
3) Open PC-Beamage and make sure *Cypress USB BootLoader* has been replaced by *Cypress USB BulkloopExample*.

![Device Manager](image)

**Figure D-20** Cypress USB BulkloopExample
APPENDIX E. 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 Beamage Installer available on Gentec-EO’s website at https://www.gentec-eo.com/resources/download-center.

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

4) Click on the “Camera Firmware” button, see Figure E-1.

5) Click on “Update”.

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 F. 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 G. 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
- Crosshair 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 H. SATURATION LIMIT FOR BEAMAGE WITH ND4.0 FILTER

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