

Gaussian Beam Divergence Measurement

Theory

Gaussian beams do not follow the same rules as incoherent beams described by geometric optics. For a Gaussian beam, it may be shown that:

- When a Gaussian beam passes through a lens, the far field divergence of the input beam may be determined by measuring the beam diameter **at the back focal distance from the lens**.
 - Note that this is **not** the position of the beam waist formed after the lens.
 - This is true **irrespective** of the distance of the source from the lens.
 - This assumes that the lens does not introduce additional aberrations, normally achieved by using a long focal length achromat coated for the wavelength(s) of interest.

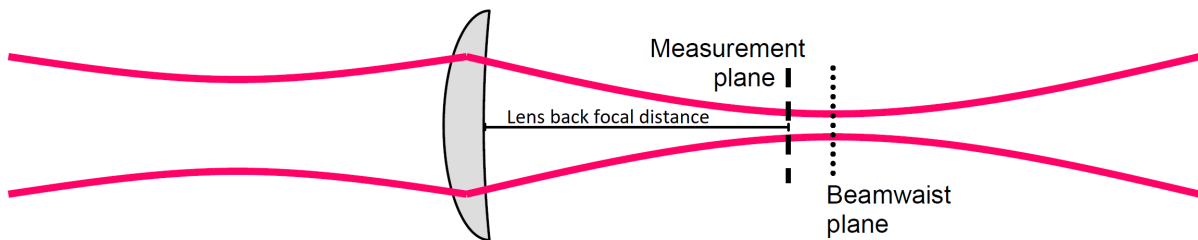


Figure 1: The measurement plane coincides with the back focal plane of the lens. This is not necessarily where the beam will focus.

The far field full divergence angle of the input beam, Θ mrad, is calculated as: $\Theta = 2W/F$ mrad in accordance with ISO 11146.

- $2W$ μm is the measured Second moment (4σ) beam diameter in the Measurement plane
- F mm is the focal length of the lens at the wavelength of interest.

Modeling

The [Gaussian Beam Divergence Measurement worksheet](#) available on the DataRay website models the measurement and estimates the accuracy. The steps below outline how to use the worksheet.

1. Enter the lens focal length, the input beam's estimated M^2 value, wavelength, waist diameter, and waist to lens distance.
2. Check that the calculated **beam diameter at measurement plane** is within the measurement limits of your beam profiler. For a camera, the beam diameter should be at least 10X the pixel size. For a scanning slit beam profiler, it should be at least $2 \mu\text{m}$.
 - If the beam size is too small, try a longer focal length lens.

3. Use the right chart to check whether the divergence error is within your requirements. The error depends on how close the measurement plane is to the actual back focal plane of the lens for your specific wavelength. DataRay's calibration is easily within +/- 5 mm, and usually within +/- 1 mm. If your divergence measurement is very sensitive, please contact DataRay Support with your measurement parameters and requirements.

Application

This technique requires an appropriate lens and a beam diameter measurement instrument.

- The instrument may be a WinCamD series camera or a BeamR2/BeamMap2 scanning slit XY profiler.
- The lens must have a known focal length, be coated for the wavelength(s) of interest, and have a diameter at least 1.5 times, and preferably 2 times the $1/e^2$ (13.5%) beam diameter at the lens.
- Errors in the lens focal length value or positioning of the instrument with respect to the back focal length will lead to errors in the divergence measurement. The spreadsheet models these errors.
- The beam must be centered on the lens.
- The beam centroid in the measurement plane does not reflect the input beam pointing.

The lens and instrument may be supplied by DataRay as a pre-aligned system, or may be mounted on an optical bench or table. Use the spreadsheet & contact DataRay for details and lens suggestions for your beam.

DataRay Software Setup & Measurement

DataRay software version 8.0C94 and higher supports real-time divergence calculations for beam profiling cameras with a calibrated lens accessory.

1. Install DataRay software version 8.0C94 or higher. This software supports all of our current beam profiling cameras.
2. Attach the calibrated lens accessory to your device. The calibration is valid for a specific device S/N and should not be adjusted.
3. Connect the device to the computer and start the DataRay software.
4. Open the Clip Level Dialog by clicking in the Clip[a] or Clip[b] button area.
5. Choose the **Enable Ancillary Lens Divergence** option. We suggest using the 4σ width calculation method because it is most robust, but you can choose to use a clip level if desired.
6. Enter the lens focal length value in the relevant field.
7. Press **OK** to confirm the settings and close the dialog.
8. Press **Go** to start taking measurements. The Major/Minor far-field full divergence value is shown in real-time above each of the 1D profile plots.

Accuracy

Typically an accuracy of 0.1 to 0.05 mrad divergence measurement should be achievable, but this is largely beam/lens dependent. To simply adjust an input beam assembly for best collimation, minimize the value of **2W** in the measurement plane by adjusting for a minimum focus size. Contact support@dataray.com for help with accuracy and misalignment sensitivity calculations for your beam.

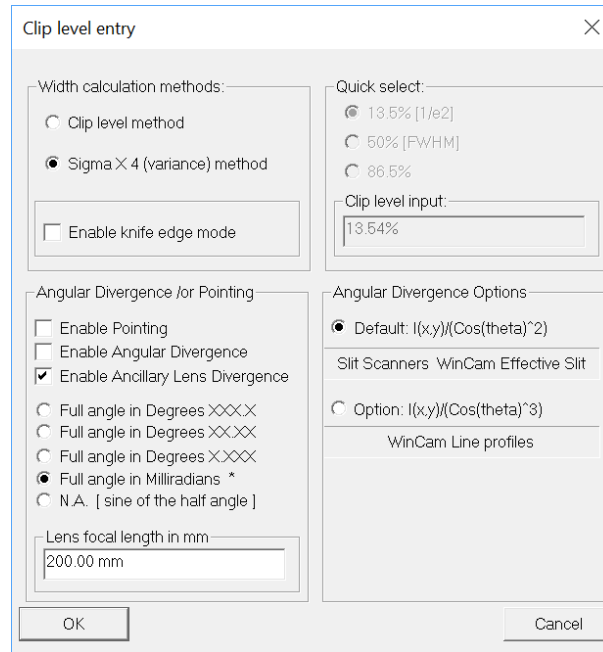


Figure 2: Clip Level Dialog.

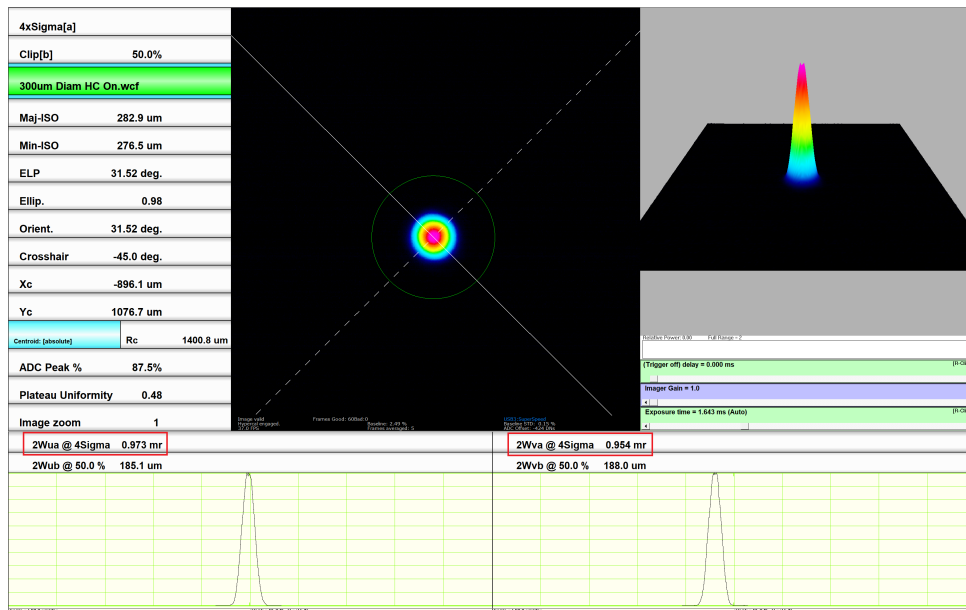


Figure 3: Divergence Measurement