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Technical Note

Measured and Predicted Beam Widths are Different

> *"When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, what ever the matter may be."*
>
> *Lord Kelvin*

Possible Reasons Measured and Predicted Beam Widths Do Not Match

Photon Inc. has been supplying highly accurate instruments[1] for more than a decade. Facing many challenges on accuracy, we have often seen the difference explained by one of the following:

Mathematical Model for Spot Size

- Model uses beam radius, instrument measures beam width.
- Model predicts beam width by one method (pin hole, slit, encircled energy, moment method), instrument measures by another.
- Beam is gaussian, model is for geometrical beam size prediction.[2]
- Beam is truncated entering focusing lens; model does not assume truncation.
- Predicted and measured beam width clip levels are different ($1/e^2$ vs. FWHM).

Beyond Instrument Capability

- Slit too large for measured beam (spot should be at least 3-4 times larger than slit width).
- Too few pixels or data points under the measured beam (need 12-20 pixels under the profile.
- Power too high, instrument saturated (flat top profile).
- Instrument is for CW source; laser is a pulsed source or on a low duty cycle.
- Beam light level is too low.
- Slit profiler with silicon detector should be used at λ<950 nm.

Experimental

- Laser not what you believe. Is it operating multi-mode? Data sheet wrong? M^2>1.0
- Instrument axis not aligned to beam major or minor axis; especially important with extremely elliptic beams.
- Laser beam is on top of a pump beam light; i.e. both are being measured (pedestal).
- Lenses or other optics are not sufficient quality; spots smaller than 15 µm usually require much better optics (typical R.M.S wavefront better than 1/10th wave).
- Optical system is poorly aligned. Lenses/mirrors of extremely high quality do not perform well when mis-aligned.
- Lens not designed for use at wavelength being used (visible microscope objective used in the infrared).
- Lens focal length quoted at different wavelength than that being used.
- Lens focal length not what is marked on the package.
- Attenuators[3] are thermal lensing—translate filter, if spot size changes (possible thermal lensing).

- Finding the exact spot where a beam smaller than 7 µm is focused requires an extremely high quality focus mechanism as well as a high quality mechanical stage. Routine lab stages are seldom capable of positioning to better than ±25 µm. A 5 µm spot has a depth of focus (spot grow to 1.4 times the minimum waist) of 25 µm.
- Instrument not calibrated (if this is an option).
- Instrument damaged; slit punctured, CCD burned; micrometer causing focus does not have resolution.
- Instrument not at smallest waist.
- System vibrates (a vibrating beam can be measured larger than it really is).
- If the system requires a collimated source, the degree of collimation becomes very important for spots less than 8 mm. [4]

General Comments

It is our experience that unless you can use the source shape as it arrives (a collimated LD or HeNe laser), it's important to develop a good understanding of gaussian optics. We suggest you read Professor O'Shea's book[2] and consider the purchase of Photon's Model LAB-EXP[5], which is a set of experiments written by Professor O'Shea for Photon. Call, email, or visit our website for a data sheet.

References

[1]T.F. Johnston, Jr., and John M. Fleischer, *Applied Optics,* Vol. 35, No. 10, pp. 1719-34 (April 1, 1994)

[2] D.C. O'Shea, *Elements of Modern Optical Design,* John Wiley & Sons (1985)

[3] J.M. Fleischer, ATP; *Continuously Variable Attenuator for True Laser Profiles,* Proceedings SPIE Reprint Vol. 1834, pp. 33-40, Laser Energy Distribution Profiles (1992)

[4] Photon inc. Application Note #220, Measure Divergence and Collimate Lasers

[5] Photon inc. Data Sheet, *Model LAB-EXP Guide to Understanding Gaussian Laser Optics*