DataRay Inc.

WinCamD use with Beam Expanders

Beam Profiling … Engineered as a system
… Delivered as a Solution

Applies to:

- WinCamD series products with beam expanders attached.
- Versions 6.00L and higher of **iDataRay.exe** software.

A. Alternatives

For direct measurement of large beams, DataRay offers TaperCam cameras with a 14 x 10 mm input aperture and TaperCamD20-15 cameras with a 20 x 15 mm input aperture. For beams which are within these input aperture sizes, this is the preferred approach. For larger beams, beam expanders are required.

B. Saturation Power Calculation

Saturation power values will be **reduced by the square of the actual magnification**.

C. Mechanics

– Remove the dust cap from the ND4 filter.

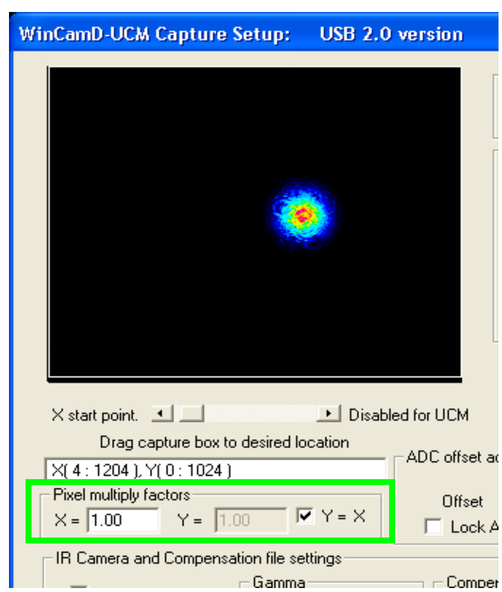
– C-mount beam expanders screw directly to the ND4 filter. (e.g. Melles Griot, Edmund)

– Thor Labs beam expanders require a Thor Labs SM1A9 adaptor, provided with the telescope if supplied by DataRay.

– Protect the telescope input with a dust cover when not in use.

– Focusable telescopes supplied by DataRay are pre-focused to give a minimum spot size at a range of 6 m when attached to a HeNe laser. This may or may not be the correct setting for your laser measurement setup.

D. What's the big deal on magnification?



I attached a x5 beam expander to the camera. Surely I simply enter a PMF (Pixel Multiply Factor) of 5 in the Setup dialog in the software and the beam diameters will be correct?

Superficially it is as simple as this … ***but only for input and exit beamwaists in the far field***.

Consider an incoherent beam going into a x5 telescope. For a collimated input beam, the output beam is x5 larger, ***but only if the object plane is at several times the focal length of the input lens***.

Similarly, with a coherent beam, the Beam Expander (actually a Beam Reducer as used), the output beam is x(1/5) smaller, ***but only if the input beamwaist and the camera sensor are at several times the Rayleigh Range from the lens***. Strictly speaking this Far-field is at >2.Zr from the beamwaist.

E. What's Rayleigh Range? How large is it?

For a 632.8 nm HeNe laser with M^2 =1.1, beamwaist = 1 mm, the Rayleigh Range is 1.13 m.

For a 1064 nm Nd:Yag laser with M^2 =1.1, beamwaist = 10 mm, the Rayleigh Range is 67 m.

As you can see, in most situations that require a telescope, getting a high multiple of Zr from the beamwaist is very difficult. In addition, whilst in many cases the beamwaist is at the exit aperture of the laser, this is not universally true so you may not know where it is.

In Section G, we show how to calculate some of these things, if you care to spend time on this.

F. Practical Magnification Measurement.

Measure the actual magnification by moving the source or the WinCamD + telescope.

- Where Z is the propagation direction, mount the source or the camera + telescope on an XY translation stage with micrometers. Approximately center the beam. Take up any backlash on the translation stage.
- Press **z** on the keyboard to set the relative **Xc**, **Yc** centroid to **0**,**0**.
- Move the source or the camera on its translation stage by a known amount, say **Δx**.
- Note the centroid change, **ΔXc** in this example.
- Calculate the **PMF** = **Δx/ΔXc**
- Go to the **Setup** pull-down menu and select **Capture setup dialog**.
- Enter the **PMF** value in the Pixel multiply factor box (shown on page 1).
- Note the value down somewhere, e.g. in a notebook and/or the **Other:** box on the camera rear label. E.g.: **PMF = x.x with x5 on Nd;Yag 1**
- The displayed on-screen values will now be compensated
- **IMPORTANT**: If you **Load defaults** you will have to reenter the PMF value.

G. Rayleigh Range detail

The Rayleigh Range, Zr, is defined as the distance for the beamwaist at which the second moment beam diameter has increased by a factor of $2^{0.5}$. It is calculated as:

$$z_R = \frac{2W_0}{\Theta} = \frac{\pi . W_0^2}{M^2 . \lambda} \qquad M^2 = \frac{\Theta}{\theta}$$

Where:

Θ is The measured, far-field, full-angle divergence of the actual beam

θ is The theoretical far-field divergence of a *'perfect'* TEM_{00} Gaussian beam which *has the same waist diameter as the measured beam.*

$$\theta = \frac{2\lambda}{\pi W_0}$$

$2W_0$ is The second moment beam waist diameter.

M^2 is the 'M-squared' or Quality Factor of the beam. M^2 =1 for a TEM_{00} Gaussian.

If you know the details of the lenses in your beam expander, the M^2 of the laser and the position of the laser beamwaist with respect to the lenses in the beam expander, you can in theory calculate the magnification, This is beyond the scope of this Application Note.

Melles Griot catalogs have a helpful reference section on Gaussian Beam Optics if you have the time.