# WinCamD Use with Beam Reducers

## Introduction

DataRay offers a wide range of beam profiling devices to characterize an ever-expanding list of beams. Our cameras can measure a minimum beam size down to 32 microns, and our scanning slit devices can measure even smaller beams down to 2 microns in diameter using knife-edge mode. The size of the detection area determines how large of a beam we can measure directly, which varies from a few millimeters on our scanning slit devices up to 15 x 20 mm on our TaperCamD-UCD23. For beam sizes that are too large or too small to be measured directly, we still offer several options to provide useful measurements. One option for large collimated beams is to use a beam reducer to change the size of the input beam; this blog post will discuss the theory and usage of a beam reducer for beam profiling.


Figure 1: BR-VIS-2 Beam Reducer

## Background: Gaussian Beams

The diameter of a laser as it propagates is well-approximated by a Gaussian beam since Gaussian beams are solutions to the wave equation for an electromagnetic field in free space. In fact, the beam quality measurement known as $M^2$ measures how close a laser resembles a fundamental mode Gaussian beam.

For any given wavelength, the entire beam caustic of a perfect Gaussian beam can be completely derived from any one of the following properties: beam waist, Rayleigh range, or far-field divergence. The beam waist, Rayleigh range and far-field divergence are relevant beam parameters because beam reducers are intended to accept a relatively large beam waist with a long Rayleigh range and low far-field divergence—also known as a collimated beam.

## Afocal Systems

An afocal imaging system is a lens system where the input and output are both approximately collimated. The output does not converge or diverge the input beam, so there is no defined focus on either side. Such a system can be created using two lenses with separation equal to the sum of their focal lengths. The simplest afocal systems are the Galilean telescope and Keplerian telescope.

## Keplerian Telescope Design

The Keplerian telescope consists of two positive focal length lenses separated by the sum of their focal lengths. With a collimated input, the first lens creates a focus at a distance equal to its focal length. The second lens is placed a distance equal to its focal length away from that focus to re-collimate the beam. The choice of focal lengths determines the ratio of the input and output beam diameters. The image is inverted and reverted, but this can be corrected in software. For lasers of higher power, the increased irradiance at the focus between lenses can heat up the air and affect performance. Keplerian telescopes are not typically used as laser beam reducers for this reason.

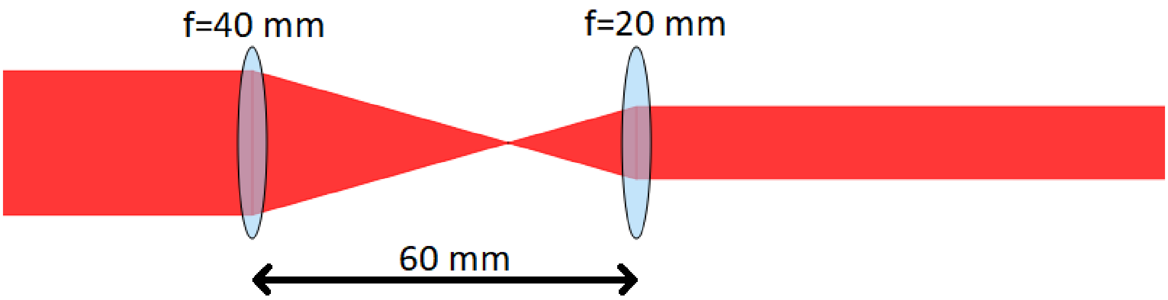


Figure 2: Keplerian beam reducer with magnification of -(20/40)=-1/2

## Galilean Telescope Design

The Galilean telescope design is very similar to the Keplerian design, but one of the lenses has a negative focal length. The lenses are still separated by the sum of their focal lengths, but now there is no intermediary focus and the tube length is shorter than the Keplerian design. For these reasons, the Galilean telescope is the better design for laser beam reducers. All standard beam reducers offered by DataRay are Galilean beam reducers.

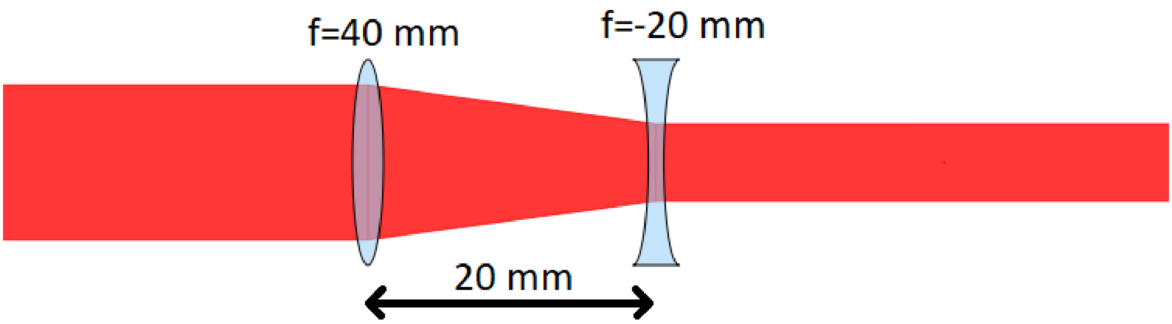


Figure 3: Galilean beam reducer with magnification of -(-20/40)=1/2

## Calibration

Since the focal length of the lenses depend on the wavelength of the laser, the necessary distance between the two lenses will vary slightly with wavelength. DataRay will choose a collimated beam with the closest available wavelength for your application and adjust the lens distance to provide an approximately collimated output with beam waist 6 meters away. This may or may not be the correct setting for your laser measurement setup.

## Magnification

The magnification is determined by the ratio of lens focal lengths. DataRay offers beam reducers with magnifications of 1/2, 1/5, 1/10, and 1/15. The magnification specification assumes far-field distances from the input and output beam waists to the beam reducer, defined as $> 2$ Rayleigh lengths away. Since this isn't always true, it is best to measure the practical magnification by moving either the input source or camera+lens laterally and measuring how much the beam centroid moves. The ratio will provide the actual magnification, which can then be input in the software's capture setup dialog as the PMF (Pixel Multiplication Factor) value. The displayed on-screen measurements will then be compensated in accordance with the entered PMF value.

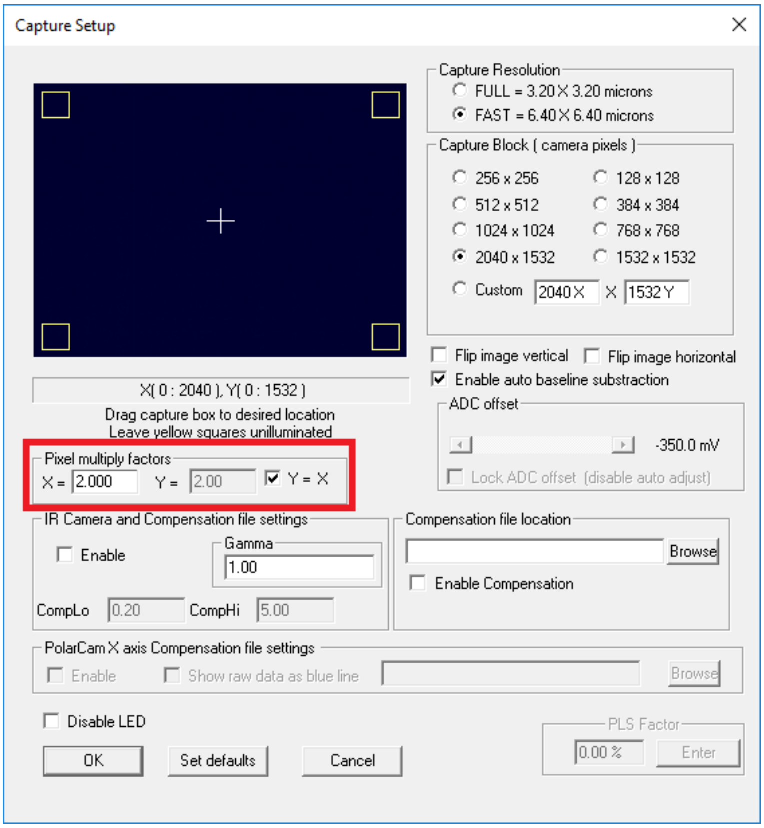


Figure 4: The Capture Setup dialog is opened from the Setup menu bar option, or by pressing ALT+S. For a 1/2 beam reducer, the PMF will be set to 2

## Specifications

DataRay offers beam reducers with three different coating options: VIS, NIR, and TEL anti-reflection coatings. The magnifications for each model are shown in Table 1, which also lists the maximum

| Model | Wavelength Range | Magnification | Max Input Beam Diameter | Diffraction-Limited Input Beam Diameter |
|---|---|---|---|---|
| **BR-VIS-2** | 400-650 nm | 1/2 | 19.4 mm | 17.0 mm |
| **BR-VIS-5** | | 1/5 | 35.0 mm | 25.0 mm |
| **BR-VIS-10** | | 1/10 | 35.0 mm | 30.0 mm |
| **BR-VIS-15** | | 1/15 | 43.5 mm | 37.5 mm |
| **BR-NIR-2** | 650-1050 nm | 1/2 | 19.4 mm | 17.0 mm |
| **BR-NIR-5** | | 1/5 | 35.0 mm | 25.0 mm |
| **BR-NIR-10** | | 1/10 | 35.0 mm | 30.0 mm |
| **BR-NIR-15** | | 1/15 | 43.5 mm | 37.5 mm |
| **BR-TEL-2** | 1050-1620 nm | 1/2 | 19.4 mm | 17.0 mm |
| **BR-TEL-5** | | 1/5 | 35.0 mm | 25.0 mm |
| **BR-TEL-10** | | 1/10 | 35.0 mm | 30.0 mm |
| **BR-TEL-15** | | 1/15 | 43.5 mm | 37.5 mm |

Table 1: Beam Reducer Specifications

input beam diameters. The diffraction-limited input beam diameter will be smaller than the maximum input diameter, and defines the input beam size that will result in a wavefront error of less than $\lambda/4$.

## Conclusion

Beam reducers are used to reduce the diameter of collimated input beams, to output a collimated beam with a smaller diameter. They are useful for measuring large collimated beams that are too large to be measured directly. DataRay's beam reducers are compatible with any of our standard C-mount beam profiling cameras. Please feel free to contact support@dataray.com to discuss your specific application and choose the best method of measurement.