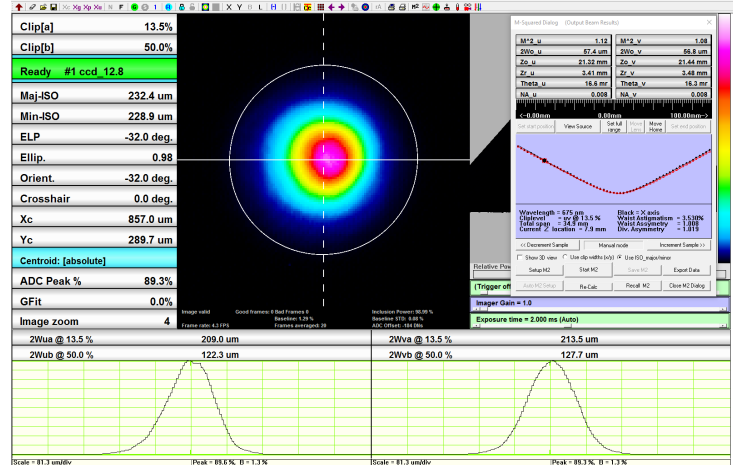


# M-Squared Measurement Systems

## Why care about M-Squared?

- It is the QA delivery or acceptance criterion on a laser or laser system.
- You need to understand why a 'focused' laser spot diameter is larger than calculation predicted.
- You are tasked with measuring  $M^2$ , and/or somebody gave you a copy of the ISO 11146 standard.
- Because  $M^2$  is an invariant property of a laser beam propagating through a perfect\* optical system.  $M^2$  may therefore be used to describe the beam at any point in that optical system. (\*The optical system neither distorts nor truncates the beam.)



$M^2$  or **Beam Quality factor** is a dimensionless parameter that characterizes the degree of *imperfection* of a real-world laser beam. The lower the value of  $M^2$ , the more tightly the beam can be focused to a small spot. A perfect  $TEM_{00}$  beam has  $M^2 = 1$ .

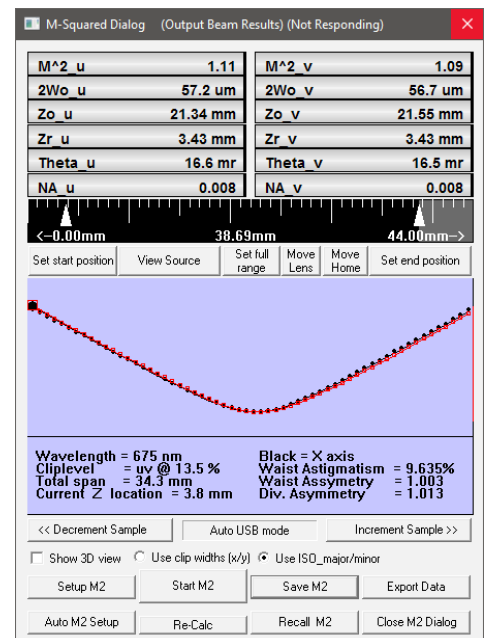
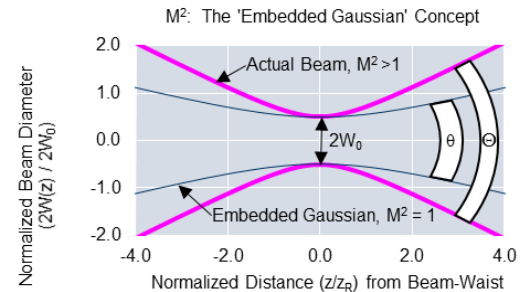
No laser beams are 'perfect'. Limitations of the laser cavity, the lasing medium, and/or the output/ancillary optics, means that most beams are not the diffraction-limited, Gaussian profile, pure  $TEM_{00}$  mode described in textbooks. Complex beams contain multiple mode contributions that increase  $M^2$ . Even a 'good' laboratory HeNe laser has an  $M^2$  of around 1.05 to 1.2, rather than the 1.0 of a 'perfect'  $TEM_{00}$  beam.

At its simplest  $M^2$  may be defined as: *The ratio of the divergence of the actual beam, to that of a theoretical, diffraction-limited beam with the same waist diameter.*

$M^2 = (\Theta/\theta)$  where  $\Theta$  is the measured, far-field, full-angle divergence of the actual beam, and  $\theta$  is the theoretical far-field divergence of a 'perfect'  $TEM_{00}$  Gaussian beam which *has the same waist diameter as the measured beam.*

DataRay offers both imaging camera and slit scanning systems to measure  $M^2$ , divergence, beam profile, beam position, Rayleigh range, etc.

- BeamR<sup>2</sup>** and **WinCamD** profiling cameras on linear stages move through the beamwaist to perform ISO 11146 compliant measurements
- BeamMap2** gives *real-time*  $M^2$  using a patented multi-planed scanning system.



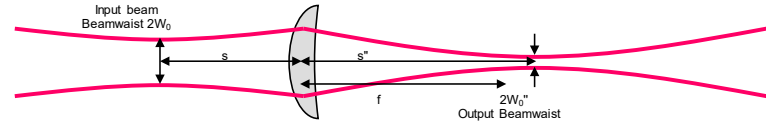
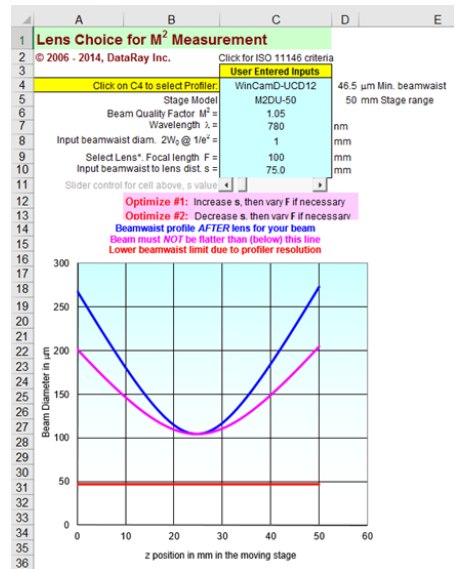
# ISO 11146 Compliant, Single Plane Measurement Systems on a Moving Stage

The ISO 11146 standard requires measurement of the second moment beam diameter in multiple planes ( $\geq 5$ ) about the beam waist and multiple planes ( $\geq 5$ ) in the far field. In most circumstances this requires a single plane beam profiler moved along the propagation axis by a z stage.

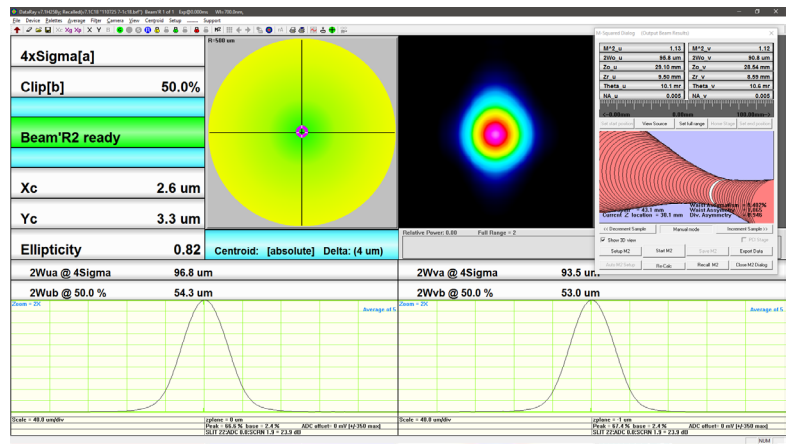
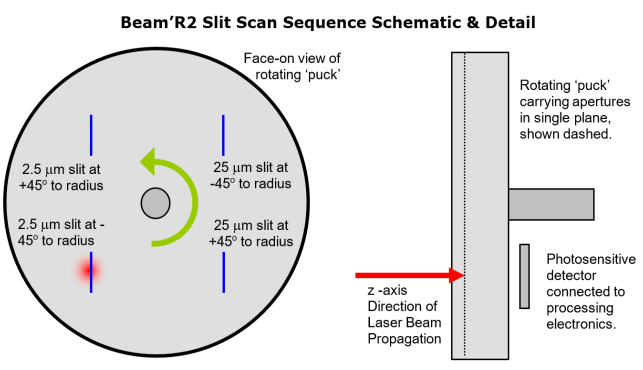
DataRay's modular based systems offers users the ultimate flexibility in  $M^2$  measurement. A spreadsheet supports selection of the optimal  $M^2$  measurement configuration: Camera based or slit scan based system, lens selection, 50 or 200 mm long translation stage:

[http://www.dataray.com/assets/xls/Lens\\_choice\\_for\\_M2\\_measurement2.xlsm](http://www.dataray.com/assets/xls/Lens_choice_for_M2_measurement2.xlsm)

**WinCamD™** cameras offers the most flexible imaging system & can measure a very wide range of  $M^2$  on pulsed & CW beams. Wavelengths from 190 nm to 1350 nm, with sensor sizes to 11.3 x 11.3 mm, & pixel sizes down to 3.2  $\mu\text{m}$ .



**Beam'R2™** is a high resolution (0.1  $\mu\text{m}$ ) single plane scanning system, with a wide range of wavelength options from 190 nm to 2.5  $\mu\text{m}$  and configuration options to measure  $M^2$ , divergence, Rayleigh range etc.



## M2DU-50 and -200 Stages

- Resolution < 1  $\mu\text{m}$
- DataRay software controlled
- RoHS and CE compliant



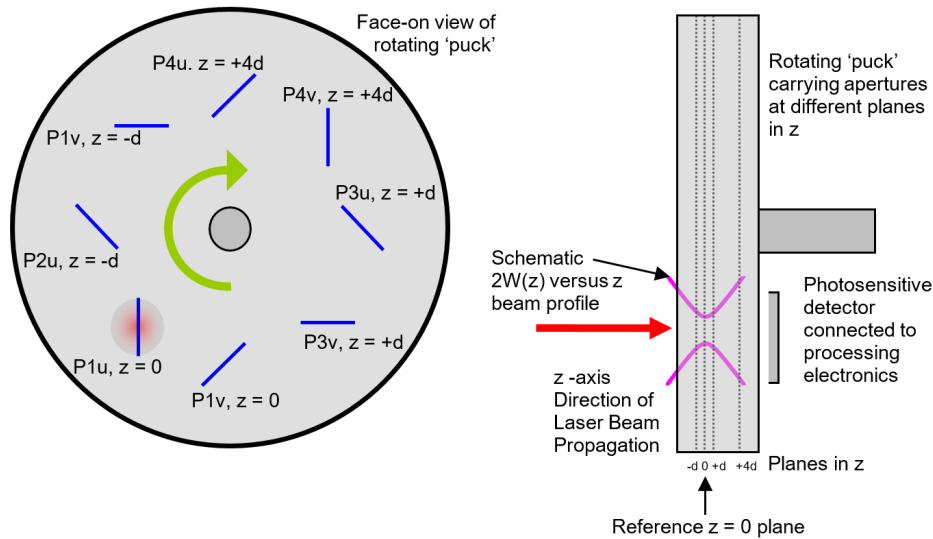
## Real-time M<sup>2</sup>

The **BeamMap2™** is a high resolution (0.1 μm) patented, multiple z plane XYZΘ measurement system that gives **real-time** measurement of M<sup>2</sup>, alignment, divergence, and beamwaist position and dimensions. BeamMap2 has two versions covers focused beams with slit plane separation **d** options of 50, 100, 250, 500 or 750 μm. The Collimate™ version covers close-to-collimated beams and has a plane spacing of 5 mm.

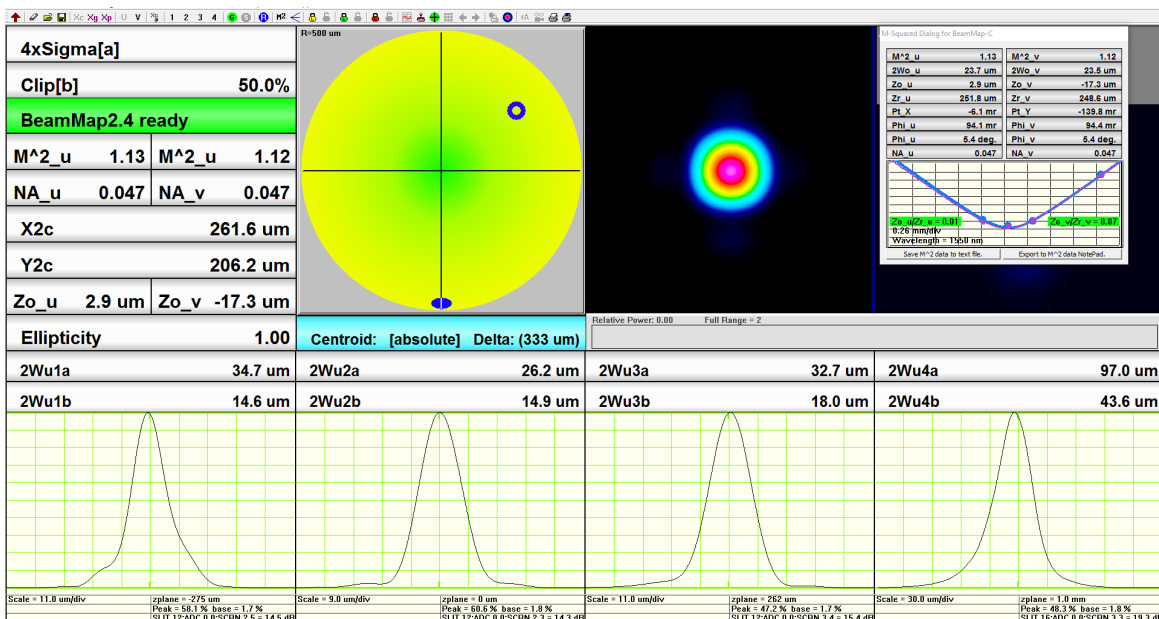
See the White Paper for more information on this unique system: [http://www.dataray.com/assets/pdf/DataRay\\_BM2\\_whitepaper.pdf](http://www.dataray.com/assets/pdf/DataRay_BM2_whitepaper.pdf)

### BeamMap2 Principal of Operation

- A disk ['puck'] carrying multiple XY slit pairs rotates about an axis parallel to the z-axis, this satisfies the orthogonal linear scan requirements of the ISO 11146 standard.
- The slits are precisely calibrated in multiple planes separated in z in the focal region.
- Slits are placed at ±45° to the local radial direction. Effective slit width is 2x greater than actual slit width.



BeamMap2 schematic puck configuration



Screen image showing profiles in the 4 planes along with M<sup>2</sup>, divergence

## M<sup>2</sup> Measuring Systems



### Wavelength Range

Camera Systems	WinCamD-LCM4	WinCamD-UCD series	Beam'R2™		BeamMap2™	
190-355	√	√				
355-1100	√	√				
355-1350	√	√				
Scanning Systems			Single Plane	Model	Multipane Real-time M <sup>2</sup>	Model <sup>1</sup>
190-800			√	BR2-Si	√	BMS2-Si-XXX
800-1800			√	BR2-IGA	√	BMS2-IGA-XXX
800-2500			√	BR2-IGA2.5	√	BMS2-IGA-2.5-XXX <sup>1</sup>

<sup>1</sup> Multiple model numbers are possible for the different slit/plane configurations. Please consult the factory or the selection spread available on our website: [http://www.dataray.com/assets/xls/DataRay\\_BeamMap2\\_Series\\_Choice.xls](http://www.dataray.com/assets/xls/DataRay_BeamMap2_Series_Choice.xls)

## Ordering Information

### Lens Selection

Model	Description
LNZ-UV-Focal Length 190-380 nm	Focal lengths available- 50,75,100,150, 200,250,500 mm, diameters 25 or 50 mm, with mount and spacers
LNZ-VIS-Focal Length 400-800 nm	Focal lengths available- 50,75,100,150, 200,250,500 mm, diameters 25 or 50 mm, with mount and spacers
LNZ-NIR- Focal Length 650-1050 nm	Focal lengths available- 50,75,100,150, 200,250,500,750,1000 mm, diameters 25 or 50 mm, with mount and spacers
LNZ-TEL- Focal Length 1050-1620 nm <sup>1</sup>	Focal lengths available- 50,75,100,150, 200,250,500,750,1000 mm, diameters 25 or 50 mm, with mount and spacers

## Camera/Scanning System

Model	Description
<b>Cameras</b>	
S-WCD-LCM4	Complete global CMOS beam profiling camera and accessories USB 3.0, 1" sensor, 5.5 μm pixels
S-WCD-UCD23	Complete global CCD series beam profiling camera and accessories USB 2.1, 2/3" sensor, 6.5 μm pixels
S-WCD-UCD15	Complete global CCD series beam profiling camera and accessories USB 2.1, 1/1.8" sensor, 4.4 μm pixels
S-WCD-UCD12	Complete global CCD beam profiling camera and accessories USB 2.1, 1/2" sensor, 4.65 μm pixels
S-WCD-UHR	Complete CMOS beam profiling camera and accessories USB 2.1, 1/2" sensor, 5.2 μm pixels
S-WCD-XHR	Complete CMOS beam profiling camera and accessories USB 2.1, 1/2" sensor, 3.2 μm pixels
<b>Stages</b>	
M2DU-WCD-50	M <sup>2</sup> linear stage, 2.5 μm step, 50 mm travel, for cameras
M2DU-WCD-200	M <sup>2</sup> linear stage, 2.5 μm step, 200 mm travel for cameras
<b>Slit Scanning System</b>	
S-BR2-	Beam'R2 scanning system- select Si, IGA, or IGA2300
S-BMS2	Complete BeamMap2 system- select Si, IGA, or Ext IGA2300 No stage required
<b>Stage</b>	
M2DU-BR2	Linear Stage for BR2 scanning systems

## Accessories

IC	Instrument case. Foam cells for custom configuration
ND Filters	Full range of ND filters including our new MagND filters for quick change 0.5, 1.0, 2.0, 3.0, 4.0, 5.0