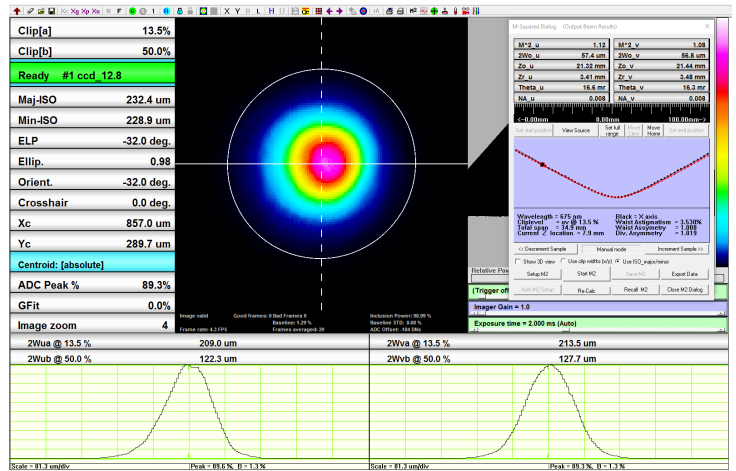


M-Squared Measurement Systems

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.

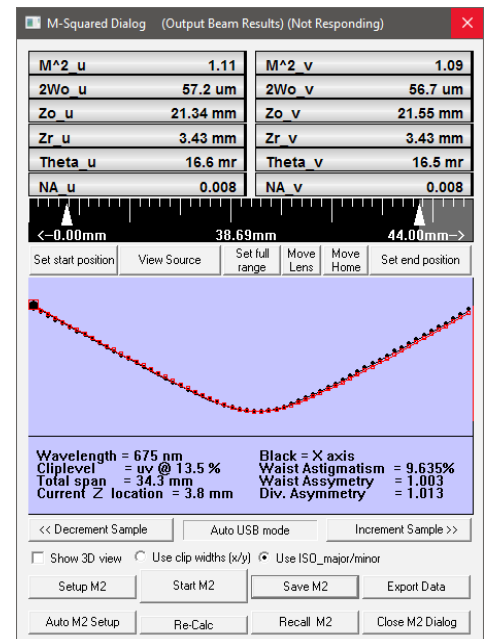
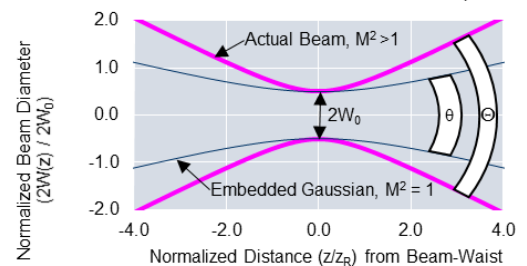
At its simplest M^2 may be defined as: *The ratio of the divergence of the actual beam, to that of a theoretical, diffraction-limited beam with the same waist diameter.*

$M^2 = (\Theta/\theta)$ where Θ is the measured, far-field, full-angle divergence of the actual beam, and θ 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, Raleigh range, etc.

- BeamR²** 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.

M^2 : The 'Embedded Gaussian' Concept



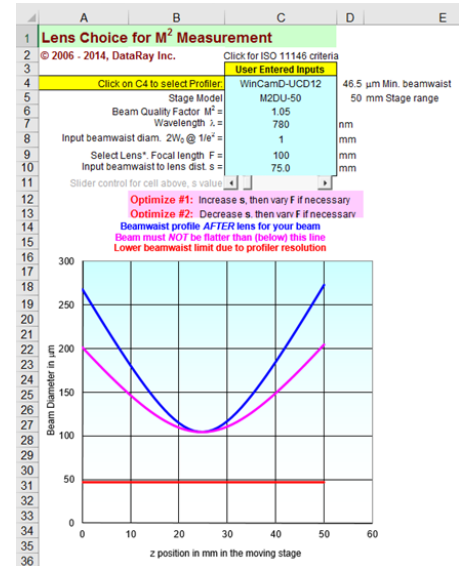
ISO 11146 Compliant, Single Plane Measurement Systems on a Moving Stage

The ISO 11146 standard requires measurement of the second moment beam diameter in multiple planes (≥ 5) about the beam waist and multiple planes (≥ 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

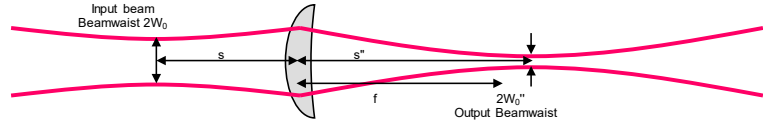
WinCamD™ cameras offers the most flexible imaging system & can measure a very wide range of M^2 on pulsed & CW beams. Wavelengths from 190 nm to 1350 nm, with sensor sizes to 11.3 x 11.3 mm, & pixel sizes down to 3.2 μm .



WinCamD-LCM4



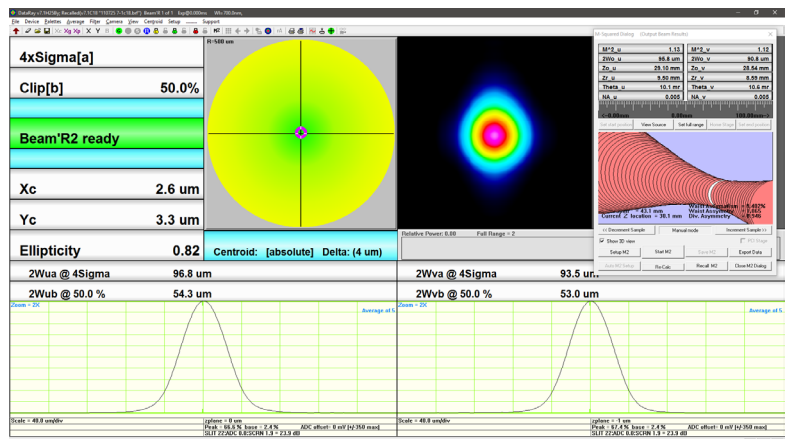
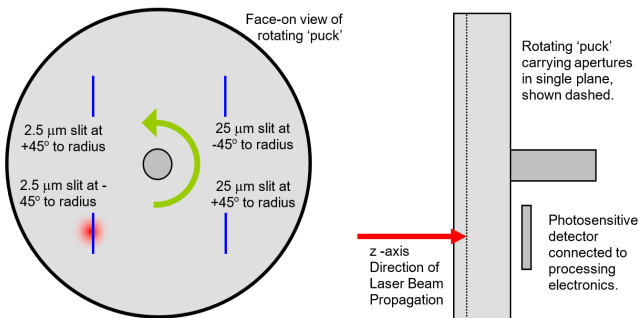
WinCamD-UCD12,15, 23, -UHR, -XHR



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



Beam'R2 Slit Scan Sequence Schematic & Detail



M2DU-50 and -200 Stages

- Resolution < 1 μm
- DataRay software controlled
- RoHS and CE compliant



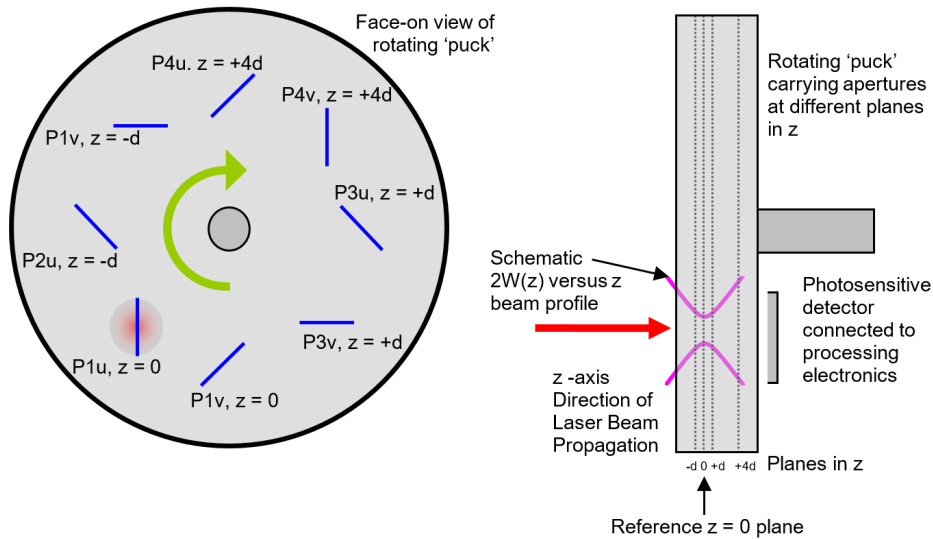
Real-time M²

The **BeamMap2™** is a high resolution (0.1 μm) patented, multiple z plane XYZΘθ measurement system that gives **real-time** measurement of M², 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.

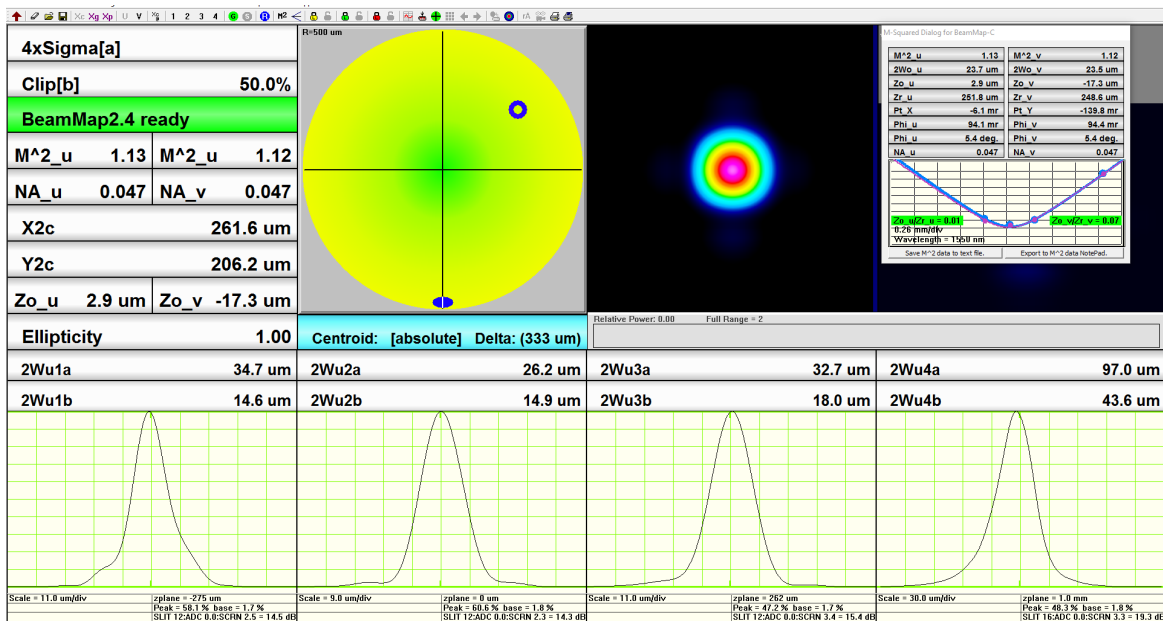
See the White Paper for more information on this unique system: http://www.dataray.com/assets/pdf/DataRay_BM2_whitepaper.pdf

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 M², divergence

M² 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	Multiplane Real-time M ²	Model ¹
190-800			√	BR2-Si	√	BMS2-Si-XXX
800-1800			√	BR2-IGA	√	BMS2-IGA-XXX
800-2500			√	BR2-IGA2.5	√	BMS2-IGA-2.5-XXX ¹

¹ 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

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 ¹	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
Cameras	
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
Stages	
M2DU-WCD-50	M ² linear stage, 2.5 μm step, 50 mm travel, for cameras
M2DU-WCD-200	M ² linear stage, 2.5 μm step, 200 mm travel for cameras
Slit Scanning System	
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
Stage	
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