

## 3.7.1 Camera Based Beam Near-Field Propagation Analyzer: M<sup>2</sup>

### 3.7.1.1 BeamSquared®

- ISO compliant
- Automatically measure your beam quality in under 1 minutes
- Tune your laser for best operation
- Specifically developed for continuous usage
- Unequaled accuracy using patented Ultracal™ Calibration
- Long optical train & automatic attenuation adjustment
- Flexible mounting configurations, install horizontal or vertically
- Pulsed and CW for most beam diameters and powers
- Compact and portable
- Detectors from 266nm to 10.6μm

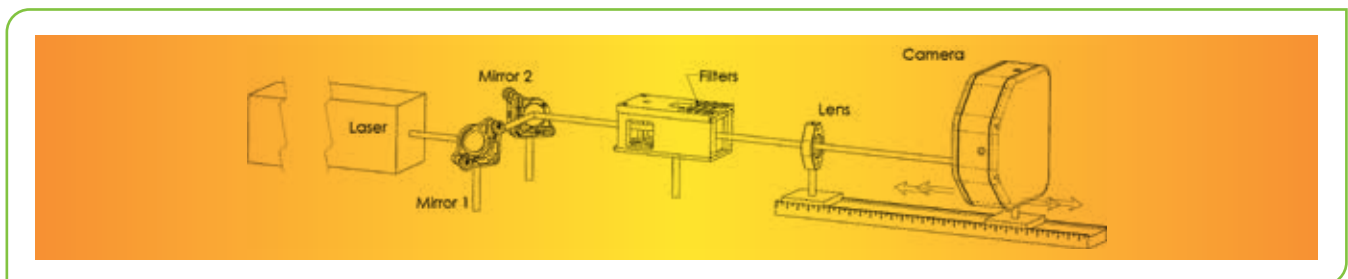
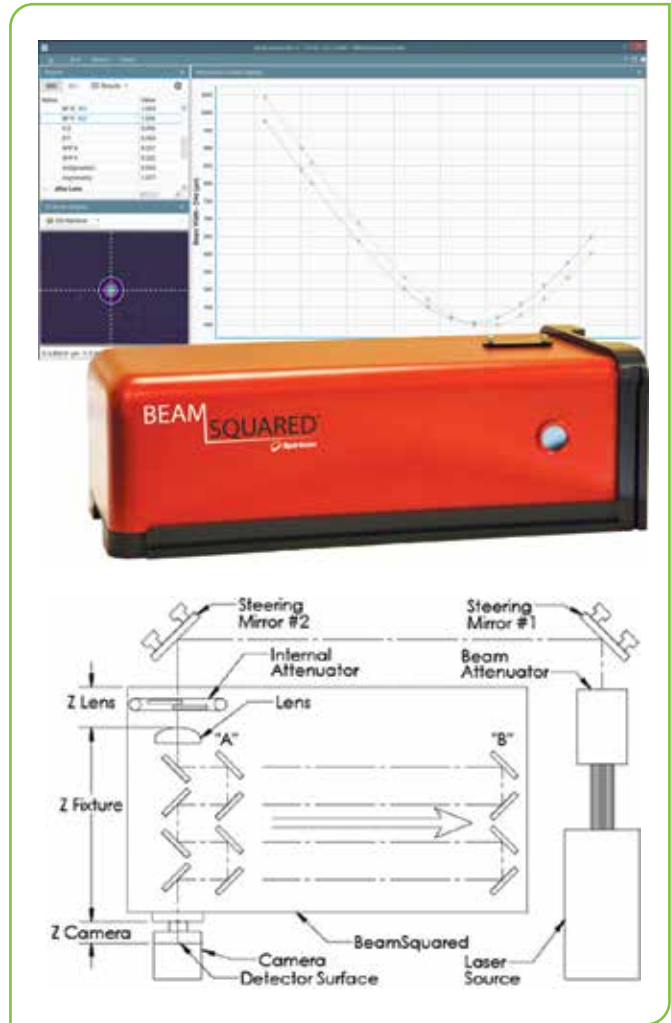
The BeamSquared® system is a compact and fully automated tool for measuring the propagation characteristics of CW and pulsed laser systems from the UV to NIR to Telecom wavelengths. Users can also measure wavelengths above 1.8 microns, including CO<sub>2</sub> and terahertz in manual mode (a bench set-up; without the automated optical train) with a Pyrocam™ IV or IIIHR. Our longer optical train and patented Ultracal™ Calibration makes BeamSquared the most accurate product on the market and is ISO 11146 compliant. Its operational robustness and reliability ensures continuous use applications in industry, science, research and development.

#### Automatic M<sup>2</sup> - at Production Speeds

The BeamSquared optical train uses a fixed position lens with movable mirrors and camera. The mirrors that direct the focused beam into the camera are moved to precise locations, translating the beam through the near field, the waist, and the far field regions. All these measurements and translations, as well as incremental beam attenuation, are automatically controlled by the BeamSquared software. Design improvements in the BeamSquared system have decreased the measurement reporting time by 2-3 times, making it possible to report M<sup>2</sup> in under a minute.

#### Manual M<sup>2</sup>

Manual mode is available for wavelengths greater than NIR, particularly Terahertz and above, and for beams that are too large or too small for the BeamSquared optical system. Users are required to provide a manual translation/attenuation apparatus.



## Software Features

### Features

#### Measurements

M2x, M2y, Kx, Ky, BPPx, BPPy  
 Width at waist Wx, Wy  
 Divergence angle Qx, Qy  
 Waist location Zx, Zy  
 Rayleigh X, Y  
 Astigmatism  
 Asymmetry ratio  
 Statistical results are available on all measurements

Supports both automated and manual runs

#### New Hardware

Camera Options include: SP920, Xeva, Pyrocam™ III HR or IV  
 RF Lens Reader  

- Lens must be present for operation
- Lens configuration data stored with lens (Focal length, calibration wavelength, material, etc.)

 Shutter only open when in live mode  
 Table and attenuator calibration at startup (homing before each run)

Supports hardware Trigger

Faster run times than M2-200s

#### New Interface

Selectable theme colors  
 Splash screen with progress bar

#### 2D display

Selectable Color Palette  
 Manual Cursor when not running (Cursor at centroid otherwise)

#### Caustic Display

Selecting individual frames  
 Auto Aperture  
 Exclude points from run

#### Run Info Display

Displays Caution Notice when beams are non-conforming: (too dark, too bright, misaligned, too large or too small)  
 Option to ignore misaligned beams

Editable Settings (Wavelength, Laser to box distance, Laser to lens and focal length in manual mode)

#### Calculations

Frame Results (Total, Min, Peak, % in Aperture, Avg Pwr Density, Beam Width, Centroid, Peak, Cross Sectional Area)  
 Laser Results (Waist Width, Divergence, Waist Location Rayleigh Length, M2, K, BPP, Astigmatism, Asymmetry)  
 After Lens Results (Waist Width, Divergence, Waist Location Rayleigh Length, Astigmatism, Asymmetry)  
 Effective Focal Length of lens  
 Fitted/Measured Divergence  
 Supported Beam Width calculations  

- D4 Sigma
- Knife Edge 10/90 and Programmable
- EPSA - Encircled Power Smallest Aperture (power in a bucket)

#### Multiple Runs

Result statistics  
 Progress Indicator

#### Single Page Report

Setup information  
 Results  
 Statistics  
 Caustic chart

#### Logging/Export data

.CVS File

## Accuracy by Design

Spiricon products are known for accuracy. Using our patented Ultracal calibration method, auto aperturing to exclude noise beyond the wings of the laser beam, and long optical path, assures the user of the most accurate measurements in the industry.

## Designed by Our Customers

Guided by customer input from our widely deployed previous generation M2-200s system, Spiricon redesigned the BeamSquared® to meet the challenging demands of the laser industry. The new BeamSquared system has significantly higher durability and operational robustness for continuous use in a three shifts a day, seven days a week environment. The rigid baseplate and internal optics greatly simplifies and reduces the time for initial set-up and alignment. The lens configuration data is now stored using an RF ID chip embedded in the lens holder which is uploaded automatically by the BeamSquared system when the lens cartridge is inserted in the system, eliminating the need for our customers to keep track of configuration file. Both novice and seasoned users will appreciate these new features along with the time-tested excellence that Spiricon has provided over the years.

## Measurements

BeamSquared measures propagation characteristics in both the X and Y axes and displays the following parameters:

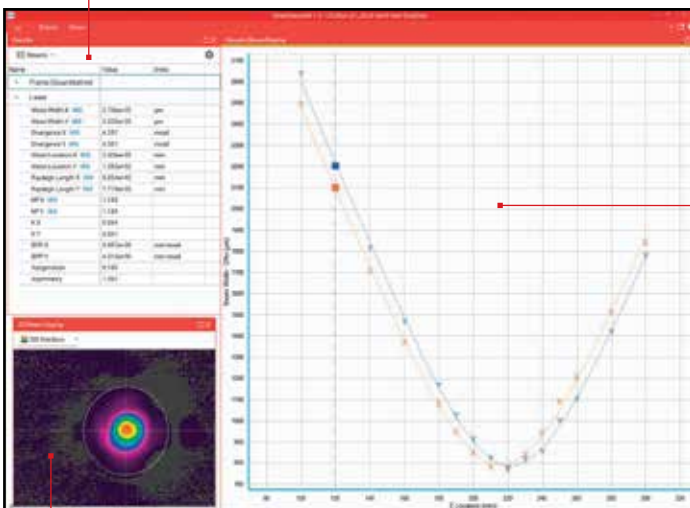
- Waist diameters
- Full angle Divergences
- Waist locations
- Rayleigh lengths
- $M^2$  or K and BPP factors
- Astigmatism
- Asymmetry



To optimize bench space, BeamSquared can be mounted either horizontally or vertically. Laser beam input port is the same dimension with either mounting method, X = Y, and the same as the M<sup>2</sup>-200s that it is replacing.

## Main Screen Functions

This window displays quantitative measurements of the laser parameters. These include the X and Y beam widths,  $M^2$  or K, the divergence angles, the Rayleigh range, and other parameters shown.



This window presents measurements of beam width vs. position for a given run. After measuring a few points, the software extrapolates a curve fit. The Xs and Ys represent individual measurement points. The solid lines present the best fit hyperbola of the beam propagation equation to the measured points. The  $M^2$  and other laser parameters are computed from the best fit hyperbola since it provides a smoothing of the data points.

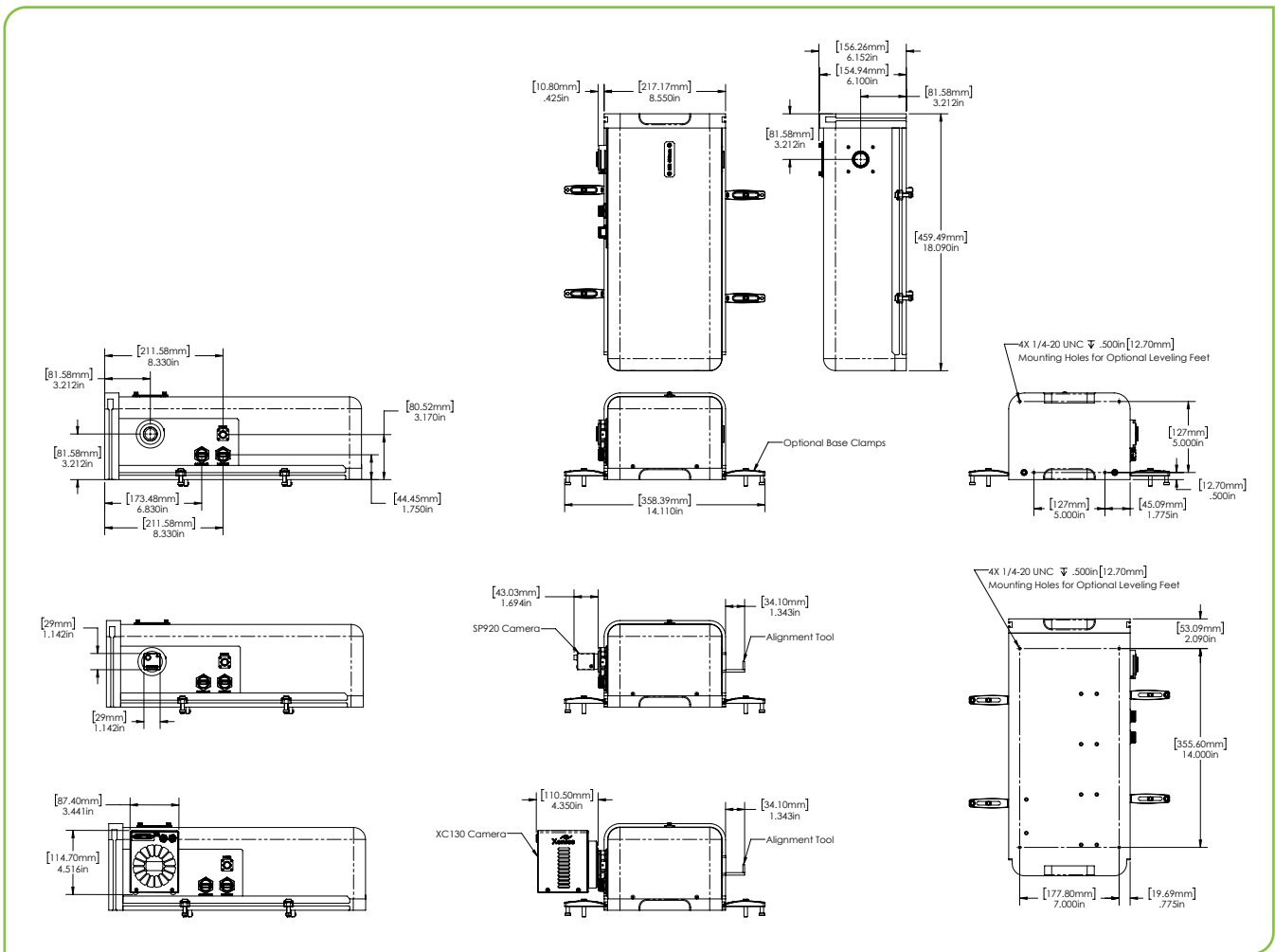
This window displays the 2D or 3D beam profile of the currently measured point in the beam propagation curve. This image enables visual intuitive verification of the beam profile behavior through focus. After each run the user can click any individual measured point and observe the beam profile. Outlying or anomalous points can be automatically or manually excluded from the curve fit calculations for more accurate results.

## Specifications

Model	BSQ-SP920	BSQ-XC130	BSQ-A	BSQ-PY-M
<b>Beam Profiling</b>				
Camera model	SP920	XC130	BeamSquared® software, software license, and optical train, no camera included	Pyrocam™ IIIHR or Pyrocam™ IV
Sensor type	Silicon CCD	InGaAs CCD		Software only, camera and optical train not included.
Wavelengths	266 – 1100nm	900 – 1700nm <sup>(1)</sup>		See individual camera data sheets
Active area	7.1mm x 5.3mm	9.6mm x 7.6mm		
Elements	1624 x 1224	320 x 256		
Effective pixel	4.4µm x 4.4µm	30µm x 30µm		
Dynamic range	60dB	68dB		
Frame rate	15 fps	100 fps		
Interface	USB 2.0 and 3.0			
Accuracy	±5% typical, ±10% waist location and Rayleigh length typical			
Measurement cycle time	<1 minute typical, depending on setup conditions and operating mode			
Camera attachment	Standard C-mount, 90° camera on axis rotation			
Translation system	Step-motor driven ball screw			
Translation stage resolution	0.05mm			
<b>Standard optics</b>				
Lenses included <sup>(2)</sup>	266-440nm UV 500mm FL 430-700nm VIS 500mm FL 430-700nm VIS 400mm FL 650-1000nm NIR 400mm FL 1000-1700nm Extended NIR 400mm FL	1000-1700nm Extended NIR 400mm FL 650-1000nm NIR 400 FL	266-440nm UV 500mm FL 430-700nm VIS 500mm FL 430-700nm VIS 400mm FL 650-1000nm NIR 400mm FL 1000-1700nm Extended NIR 400mm FL	N/A
Optional lenses <sup>(3) (4)</sup> *Not part of the standard BSQ kit	266-440nm UV 750mm FL 266-440nm UV 1000mm FL 430-700nm VIS 750mm FL 430-700nm VIS 1000mm FL 650-1000nm NIR 750mm FL 1000-1550nm Extended NIR 750mm FL	650-1000nm NIR 750mm FL 1000-1550nm Extended NIR 750mm FL	266-440nm UV 750mm FL 266-440nm UV 1000mm FL 430-700nm VIS 750mm FL 430-700nm VIS 1000mm FL 650-1000nm NIR 750mm FL 1000-1550nm Extended NIR 750mm FL	N/A
<b>Attenuation range</b>				
	Nominally from ND 1.0 to ND 4.8. Actual values vary with wavelength.			N/A
<b>Damage limits <sup>(5)</sup></b>				
	0.15 mW/cm <sup>2</sup> CW mode 1.0 µJ/cm <sup>2</sup> pulse mode Both of the above for an M <sup>2</sup> =1 @ 1064nm	100 mW/cm <sup>2</sup>	Depends on type of the camera	See camera data sheets
<b>Optical limits</b>				
Wavelengths <sup>(6)</sup>	266 - 1100nm	900 - 1700nm	Depends on type of the camera	1.06 - 3000µm
Beam size	BeamSquared Auto Mode 1mm – 10mm Varies with wavelength, waist size, location, and M <sup>2</sup>			Pyrocam IIIHR 0.8mm – 10mm max Pyrocam IV 0.8mm – 20mm max Depends on customer mechanics and lens
Minimum beam width	44µm	300µm	N/A	800µm
<b>Software</b>				
BeamSquared Software	Fast scan method (1 minute) for automatic (ISO) and manual M2 measurement			
<b>General</b>				
Storage temperature	-30° C to 65° C			N/A
Storage humidity	95% maximum (non-condensing)			N/A
Operating temperature	10° C to 40° C			N/A
Operating humidity	95% maximum (non-condensing)			N/A
<b>Power requirements <sup>(7)</sup></b>				
Input voltage	90 – 264 V AC			N/A
AC Line current	1.6 A			N/A
Line frequency	47Hz to 63Hz			N/A
Weight	26 lbs. w/o camera			N/A
Dimensions	217.2mm X 459.5mm X 156.3mm			N/A
Compliance	CE, UKCA, China RoHS			
<b>Ordering information</b>				
Part Number	SP90502	SP90444 <sup>(8)</sup>	SP90445	SP90410
Notes:	<p>(1) For wavelengths between 1300-1400nm inner reflections have been observed that may impact beam measurement</p> <p>(2) Different lenses are required for different wavelength regions, spot sizes and divergences, Additional lenses must be ordered separately.</p> <p>(3) For selection of optimal BeamSquared lens, use Beam Profiler Finder.</p> <p>(4) These lenses have been calibrated for measurement of lasers with Rayleigh length up to 20 meters, for longer Rayleigh lengths, please use Beam Profiler Finder.</p> <p>(5) CCD cameras can be damaged by power in excess of 0.15 mW/cm<sup>2</sup> or energy in excess of 1 µJ/cm<sup>2</sup>. BeamSquared employs a focusing optic. While it may be that the laser input power or energy measures well below this damage threshold, it can easily exceed these levels when focused onto the camera sensor. Use caution and error on the side of safety. CCD cameras can be costly to repair or replace.</p> <p>(6) For UV lasers 245-440nm, it is recommended to use the UV reflective ND2 filter P/N SP90568</p> <p>(7) For the optical train only. The PC computer supplies the power for the system components, such as the CCD camera.</p> <p>(8) P/N for USA only, for any other country please consult Ophir representative</p>			

## Accessories Ordering Information

Item	Description	P/N
BSQ-SP920-A	An SP920 camera licensed for BeamSquared®. Sold as an accessory for those also purchasing a BSQ-XC130	SP90521
BSQ-Lens Kit 266-1550	Lens kit that includes 5 BeamSquared lenses: 500mm UV, 500mm VIS, 400mm VIS, 400mm NIR, 400mm XNIR	SP90449
BSQ-Lens Kit 650-1700	Lens kit that includes 2 BeamSquared lenses: 400mm NIR, and 400mm XNIR.	SP90450
BSQ-Lens UV 500mm	Single BeamSquared lens, 500mm focal length, A/R coated for 266-440nm	SP90451
BSQ-Lens VIS 500mm	Single BeamSquared lens, 500mm focal length, A/R coated for 430-700nm	SP90452
BSQ-Lens VIS 400mm	Single BeamSquared lens, 400mm focal length, A/R coated for 430-700nm	SP90453
BSQ-Lens NIR 400mm	Single BeamSquared lens, 400mm focal length, A/R coated for 650-1000nm	SP90454
BSQ-Lens XNIR 400mm	Single BeamSquared lens, 400mm focal length, A/R coated for 1000-1550nm	SP90455
BSQ-Lens XNIR 600mm	Single BeamSquared lens, 600mm focal length, A/R coated for 1000-1550nm	SP90485
BSQ-Lens UV 750mm	Single BeamSquared lens, 750mm focal length, A/R coated for 266-440nm	SP90554
BSQ-Lens VIS 750mm	Single BeamSquared lens, 750mm focal length, A/R coated for 430-700nm	SP90555
BSQ-Lens NIR 750mm	Single BeamSquared lens, 750mm focal length, A/R coated for 650-1000nm	SP90556
BSQ-Lens XNIR 750mm	Single BeamSquared lens, 750mm focal length, A/R coated for 1000-1550nm	SP90557
BSQ-Lens UV 1000mm	Single BeamSquared lens, 1000mm focal length, A/R coated for 266-440nm	SP90558
BSQ-Lens VIS 1000mm	Single BeamSquared lens, 1000mm focal length, A/R coated for 430-700nm	SP90559
BSQ SP300 to SP920 upgrade	Camera upgrade	SP90511
BGS license for BSQ-SP920	Includes BeamGage Standard software license in addition to BeamSquared software license	SP90214
BGP license for BSQ-SP920	Includes BeamGage Professional software license in addition to BeamSquared software license	SP90244
BGP license for BSQ-XC130	Includes BeamGage Professional software license in addition to BeamSquared software license	SP90508
BSQ-XC130-KEY	Includes BeamSquared software license for XC-130 camera	SP90503
BSQ - UV Reflective Filter	BeamSquared reflective ND2 filter, UV Grade Fused Silica, Inconel coating for 245-440nm	SP90568



Beam Analysis

3.7.1.1