

## 3.7.1 Camera Based Beam Near-Field Propagation Analyzer: $M^2$

### 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

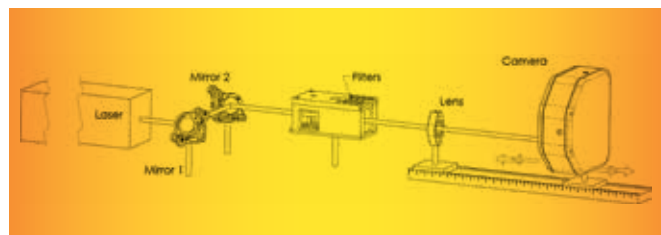
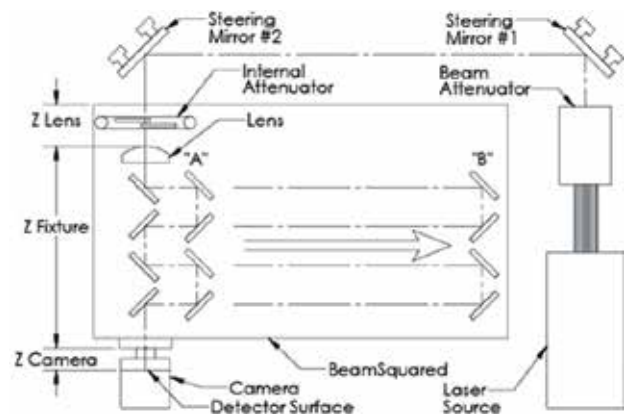
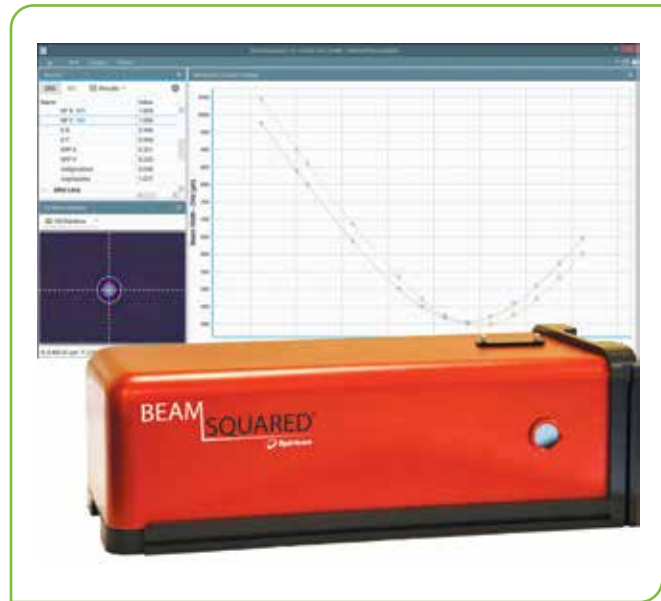
The BeamSquared® system is a compact and fully automated tool for measuring the propagation characteristics of CW and pulsed laser systems from the UV to NIR to Telecom wavelengths. Users can also measure wavelengths above 1.8 microns, including CO<sub>2</sub> and terahertz in manual mode (a bench set-up; 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 $M^2$ - 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  $M^2$  in under a minute.

#### Manual $M^2$

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	<ul style="list-style-type: none"> <li><math>M^2_x</math>, <math>M^2_y</math>, Kx, Ky, BPPx, BPPy</li> <li>Width at waist Wx, Wy</li> <li>Divergence angle Qx, Qy</li> <li>Waist location Zx, Zy</li> <li>Rayleigh X, Y</li> <li>Astigmatism</li> <li>Asymmetry ratio</li> <li>Statistical results are available on all measurements</li> </ul>
Supports both automated and manual runs	
New Hardware	<ul style="list-style-type: none"> <li>Allows standalone computer control of BeamSquared motion system</li> <li>Camera Options include: SP920, SP204S, Xeva, Pyrocam™ III HR or IV</li> <li>RF Lens Reader               <ul style="list-style-type: none"> <li>• Lens must be present for operation</li> <li>• Lens configuration data stored with lens (Focal length, calibration wavelength, material, etc.)</li> </ul> </li> <li>Shutter only open when in live mode</li> <li>Table and attenuator calibration at startup (homing before each run)</li> </ul>
Supports hardware Trigger	
Faster run times than M <sup>2</sup> -200s	
New Interface	<ul style="list-style-type: none"> <li>Selectable theme colors</li> <li>Splash screen with progress bar</li> </ul>
2D display	<ul style="list-style-type: none"> <li>Selectable Color Palette</li> <li>Manual Cursor when not running (Cursor at centroid otherwise)</li> </ul>
Caustic Display	<ul style="list-style-type: none"> <li>Selecting individual frames</li> <li>Auto Aperture</li> <li>Exclude points from run</li> </ul>
Run Info Display	<ul style="list-style-type: none"> <li>Displays Caution Notice when beams are non-conforming: (too dark, too bright, misaligned, too large or too small)</li> <li>Option to ignore misaligned beams</li> </ul>
Editable Settings (Wavelength, Laser to box distance, Laser to lens and focal length in manual mode)	
Calculations	<ul style="list-style-type: none"> <li>Frame Results (Total, Min, Peak, % in Aperture, Avg Pwr Density, Beam Width, Centroid, Peak, Cross Sectional Area)</li> <li>Laser Results (Waist Width, Divergence, Waist Location Rayleigh Length, <math>M^2</math>, K, BPP, Astigmatism, Asymmetry)</li> <li>After Lens Results (Waist Width, Divergence, Waist Location Rayleigh Length, Astigmatism, Asymmetry)</li> <li>Effective Focal Length of lens</li> <li>Fitted/Measured Divergence</li> <li>Supported Beam Width calculations               <ul style="list-style-type: none"> <li>• D4 Sigma</li> <li>• Knife Edge 10/90 and Programmable</li> <li>• EPSA - Encircled Power Smallest Aperture (power in a bucket)</li> </ul> </li> </ul>
Multiple Runs	<ul style="list-style-type: none"> <li>Result statistics</li> <li>Progress Indicator</li> </ul>
Single Page Report	<ul style="list-style-type: none"> <li>Setup information</li> <li>Results</li> <li>Statistics</li> <li>Caustic chart</li> </ul>
Logging/Export data	.CVS File
BeamSquared motion utility which allows standalone computer control of BeamSquared motion system	

## Accuracy by Design

Ophir products are known for accuracy. Using our patented Ultracal calibration method, auto aperture 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.

BeamSquared SP204S Pro with superior optical components, a state-of-the-art calibration process, and stringent quality control protocols, ensuring superior precision in measuring laser beam parameters across a wide range of applications requiring large beam diameters and large Rayleigh ranges.

## Designed by Our Customers

Driven by a commitment to continuous innovation and a customer-centric approach, Ophir has evolved the BeamSquared® to meet the ever-changing demands of the laser industry, delivering precision and reliability tailored to user needs. 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:

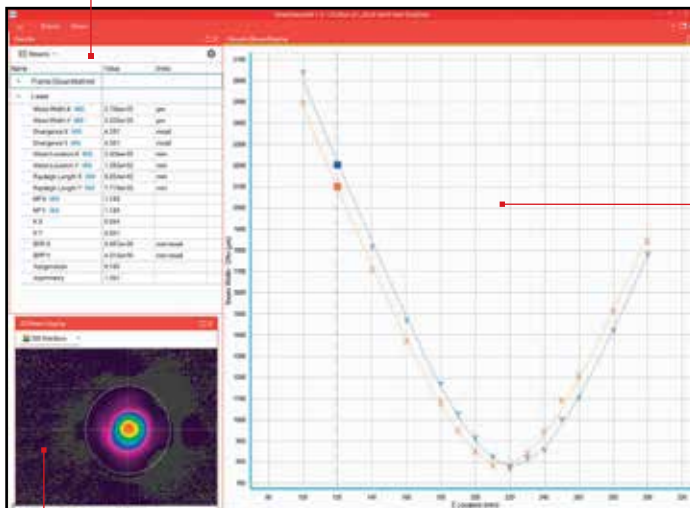
- Waist diameters
- Full angle Divergences
- Waist locations
- Rayleigh lengths
- $M^2$  or K and BPP factors
- Astigmatism
- Asymmetry

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-SP204S-Pro	BSQ-SP204S	BSQ-SP1203 <sup>(12)</sup>	BSQ-PY-M
<b>Beam Profiling</b>				
Camera model	SP204S	SP204S	SP1203	Pyrocam™ IIIHR or Pyrocam™ IV
Sensor type	Silicon CMOS	Silicon CMOS	InGaAs	Software only, camera and optical train not included.
Wavelengths	266 – 1100nm <sup>(1)</sup>	266 – 1100nm <sup>(1)</sup>	900 – 1700nm <sup>(2)</sup>	See individual camera data sheets
Active area	6.7mm x 5.6mm	6.7mm x 5.6mm	9.6mm x 7.6mm	
Elements	2472 x 2064	2472 x 2064	640 x 512	
Effective pixel	2.74µm x 2.74µm	2.74µm x 2.74µm	15µm x 15µm	
Dynamic range	67 dB	67 dB	68dB	
Frame rate	37 fps	37 fps	60 fps	
Interface	USB 3.0	USB 3.0		
<b>Accuracy <sup>(3)</sup></b>				
Waist location	±6%	±10%	±10%	
Astigmatism	±3%	N/A	N/A	
Rayleigh Length	±6%	±10%	±10%	
Rest of the beam parameters	±5%	±5%	±5%	
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>(4)</sup>	266-440nm UV 750mm FL 430-700nm UV 1000mm FL 430-700nm VIS 500mm FL 1000-1700nm Extended NIR 600mm FL <sup>(5)</sup>	266-440nm UV 500mm FL 430-700nm VIS 500mm FL 650-1000nm NIR 400mm FL 1000-1700nm Extended NIR 600mm FL	1000-1700nm Extended NIR 400mm FL 650-1000nm NIR 400 FL	N/A
Optional lenses <sup>(6) (7) (8)</sup> *Not part of the standard BSQ kit	Additional lenses can be added on request	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	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>(9)</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>	See camera data sheets
<b>Optical limits</b>				
Wavelengths <sup>(10)</sup>	266 - 1100nm		900 - 1700nm	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	27µm		150µm	800µm
<b>Software</b>				
BeamSquared Software	Fast scan method (1 minute) for automatic (ISO) and manual M <sup>2</sup> measurement, Windows 11 (64)			
<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>(11)</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	SP90649	SP90630	SP90644 <sup>(12)</sup> : BSQ-A-SP1203 SP90524 <sup>(12)</sup> : SP1203 Camera SP90645 <sup>(12)</sup> : BSQ SP1203 License Kit	SP90410

- Notes:
- (1) If device is used below 300 nm, measurement accuracy may degrade and long-term intensive irradiation at UV wavelengths may cause permanent damage to the imager.
  - (2) For wavelengths between 1300-1400nm inner reflections have been observed that may impact beam measurement
  - (3) Accuracy of All Beamsquared SP204S types are based on VIS & NIR 1mm beam. Additionally, Beamsquared SP204S Pro is based on UV & VIS at 4mm beam diameter laser.
  - (4) Different lenses are required for different wavelength regions, spot sizes and divergences. Additional lenses must be ordered separately.
  - (5) All Beamsquared- SP204S Pro lenses has specially calibrated optimized for improved accuracy from UV-NIR lasers with large beam diameters.
  - (6) For selection of optimal Beamsquared lens, use Beam Profiler Finder.
  - (7) 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.
  - (8) Optional lenses without additional calibration will work with Beamsquared SP204S Pro but the device will have performance same as standard Beamsquared.
  - (9) Damage threshold listed is based on products with similar design. Silicon 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. Cameras can be costly to repair or replace.
  - (10) For UV lasers 245-440nm, it is recommended to use the UV reflective ND2 filter P/N SP90568
  - (11) For the optical train only. The PC computer supplies the power for the system components, such as the USB3 camera.
  - (12) For the **BSQ-SP1203** you need to order the 3 P/Ns above

## Accessories Ordering Information

Item	Description	P/N
BSQ-SP204S-A	An SP204S camera licensed for BeamSquared®. Sold as an accessory for those also purchasing a BSQ-XC130	SP90631
BSQ-A	BeamSquared® software, software license, and optical train, no camera included	SP90445
BSQ-Lens Kit UV-XNIR	Lens kit that includes 4 BeamSquared lenses: 500mm UV, 500mm VIS, 400mm NIR, 600mm XNIR	SP98009
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 or SP920 to SP204S Upgrade	Camera upgrade	SP90632
BGS license for BSQ-SP204S	Includes BeamGage Standard software license in addition to BeamSquared software license	SP90633
BGP license for BSQ-SP204S	Includes BeamGage Professional software license in addition to BeamSquared software license	SP90634
BGP license for BSQ-XC130	Includes BeamGage Professional software license in addition to BeamSquared software license	SP90508
BGP license for BSQ-SP1203	Includes BeamGage Professional software license in addition to BeamSquared software license	SP90646
BSQ - UV Reflective Filter	BeamSquared reflective ND2 filter, UV Grade Fused Silica, Inconel coating for 245-440nm	SP90568

