

## 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 horizontally or vertically
- Pulsed and CW for most beam diameters and powers
- Compact and portable
- Detectors from 266nm to 10.6µm

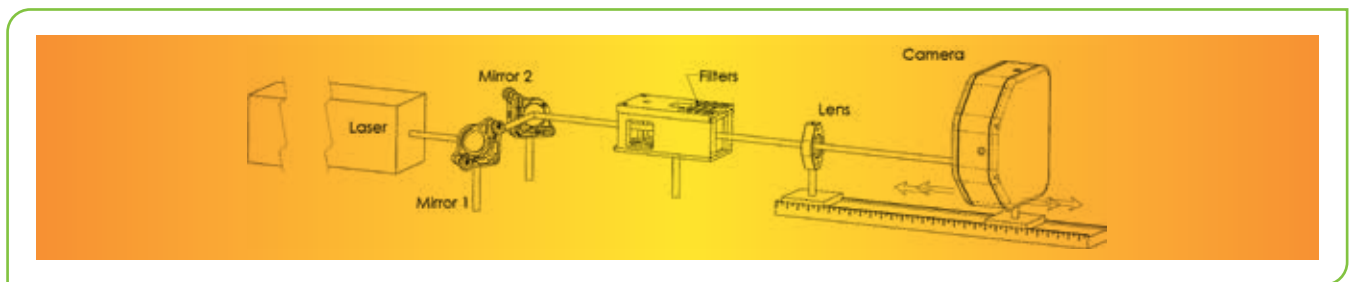
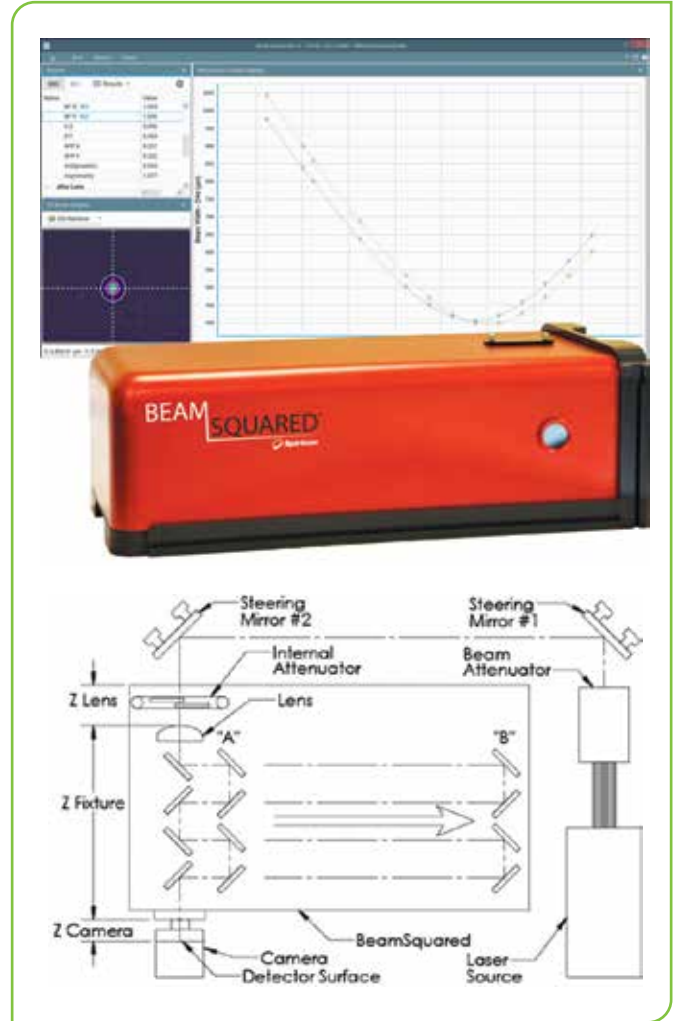
The BeamSquared® system is a compact and fully automated tool for measuring the propagation characteristics of CW and pulsed laser systems from the UV to NIR to Telecom wavelengths. Users can also measure wavelengths above 1.8 microns, including CO<sub>2</sub> and terahertz in manual mode (a bench set-up; 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<br>Width at waist Wx, Wy<br>Divergence angle Qx, Qy<br>Waist location Zx, Zy<br>Rayleigh X, Y<br>Astigmatism<br>Asymmetry ratio<br>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<br>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> Shutter only open when in live mode<br>Table and attenuator calibration at startup (homing before each run)   |
| Supports hardware Trigger  |  |
| Faster run times than M2-200s  |  |
| New Interface  | Selectable theme colors<br>Splash screen with progress bar   |
| 2D display   | Selectable Color Palette<br>Manual Cursor when not running (Cursor at centroid otherwise)  |
| Caustic Display  | Selecting individual frames<br>Auto Aperture<br>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)<br>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)<br>Laser Results (Waist Width, Divergence, Waist Location Rayleigh Length, M2, K, BPP, Astigmatism, Asymmetry)<br>After Lens Results (Waist Width, Divergence, Waist Location Rayleigh Length, Astigmatism, Asymmetry)<br>Effective Focal Length of lens<br>Fitted/Measured Divergence<br>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> |
| Multiple Runs  | Result statistics<br>Progress Indicator  |
| Single Page Report   | Setup information<br>Results<br>Statistics<br>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:

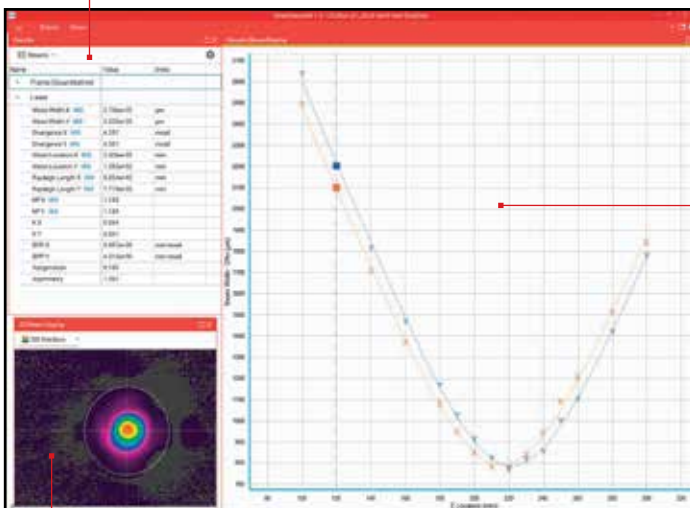
- Waist diameters
- Full angle Divergences
- Waist locations
- Rayleigh lengths
- M<sup>2</sup> or K and BPP factors
- Astigmatism
- Asymmetry



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<sup>2</sup> 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<sup>2</sup> 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>General</b>                           |  |   |  |   |
| Camera model                             | SP920  | XC130   | BeamSquared® software, software license, and optical train, no camera included   | Pyrocam™ IIIHR or Pyrocam™ IV Software only, camera and optical train not included. See individual camera data sheets |
| Sensor type                              | Silicon CCD  | InGaAs CCD  |  |   |
| Wavelengths                              | 266 – 1100nm   | 900 – 1700nm <sup>(1)</sup>                                   |  |   |
| 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   |   |  |   |
| Resolution                               | 0.05mm   |   |  |   |
| Compliance                               | CE, China RoHS   |   |  |   |
| <b>Standard optics</b>                   |  |   |  |   |
| Lenses included <sup>(2)</sup>           | 266-440nm UV 500mm FL<br>430-700nm VIS 500mm FL<br>430-700nm VIS 400mm FL<br>650-1000nm NIR 400mm FL<br>1000-1700nm Extended NIR<br>400mm FL   | 1000-1700nm Extended NIR<br>400mm FL<br>650-1000nm NIR 400 FL | 266-440nm UV 500mm FL<br>430-700nm VIS 500mm FL<br>430-700nm VIS 400mm FL<br>650-1000nm NIR 400mm FL<br>1000-1700nm Extended NIR<br>400mm 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>(3)</sup></b>      |  |   |  |   |
|  | 0.15 mW/cm <sup>2</sup> CW mode<br>1.0 µJ/cm <sup>2</sup> pulse mode<br>Both of the above for an M <sup>2</sup> =1 @<br>1064nm   | 100 mW/cm <sup>2</sup>  | Depends on type of the camera  | See camera data sheets  |
| <b>Optical limits</b>                    |  |   |  |   |
| Wavelength range                         | 266 to 1100nm  | 900 to 1700nm   | Depends on type of the camera  | 1.06 to 3000µm  |
| Beam size                                | BeamSquared Auto Mode 1mm – 10mm<br>Varies with wavelength, waist size, location, and M <sup>2</sup>   |   |  | Pyrocam IIIHR 0.8mm – 10mm max<br>Pyrocam IV 0.8mm – 20mm max<br>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>Environmental</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>(4)</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   |
| <b>Physical</b>                          |  |   |  |   |
| Weight                                   | 26 lbs. w/o camera   |   |  | N/A   |
| Dimensions                               | 217.2mm X 459.5mm X 156.3mm  |   |  | N/A   |
| <b>Ordering information</b>              |  |   |  |   |
| Part Number                              | SP90502  | SP90444 <sup>(5)</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) 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>(4) For the optical train only. The PC computer supplies the power for the system components, such as the CCD camera.</p> <p>(5) 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 245-440nm                                 | 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 245-440nm                                | SP90558 |
| BSQ-Lens UV 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 |

