Laser Power & Energy Measurement Laser Beam Analysis

2018

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Ophir Power and Energy Meters – Versatility for Every Application

Ophir sensor, power meter and computer interface system means that virtually any sensor can work "plug and play" with any power meter or computer interface. Ophir has the widest range of sensors on the market with the highest performance so almost any measurement need can be accommodated. The measurement results can also be used in many ways - on the power meter screen, stored on board, sent to PC with results presented in many ways and on several platforms.

Pyroelectric Sensors
Energies pJ to Joules
Rep rates to 25kHz
(page 85)

Thermal Sensors
Powers mW to kW and
single shot energy
(page 38)

Photodiode Sensors
Powers pW to Watts
(page 24)

Computer Interfaces
with USB/Bluetooth/Ethernet

EA-1
Ethernet

Pulsar
1 ,2 ,4 channels

Power Meters
with USB/RS232

StarBright
added features

Vega
color

Nova II
general

Quasar
wireless

Juno
compact

StarLite
basic

Nova
rugged

Laser Star
2 channel

Software Solutions
StarLab, LabVIEW, StarCom &
COM Object

Calibration Capability at Ophir

Calibration is perhaps the most important of our products. In order to ensure the best possible calibration of your instruments, Ophir takes a number of extra steps not taken by other vendors.

Laser absorption varies with wavelength, so it is not enough to calibrate at one wavelength. If the variation is small, then the sensors are calibrated at several laser wavelengths and each laser covers a range of wavelengths. If the absorption variation with wavelength is considerable, the sensor is provided with an absorption correction curve activated by the wavelength of use. Going one step further, Ophir checks the curve at a number of NIST and PTB traceable wavelengths and corrects it if necessary. To do this, we have a complete line of calibration lasers so that we can always calibrate at or near the customer's wavelength. These lasers include powers up to 1000W and both CW and pulsed lasers. We also have a number of sensors calibrated at NIST and PTB used as calibration standards. Below is a list of the calibration wavelengths used at Ophir in calibrating our standard catalog sensors.

In addition to calibration variation with wavelength, there are other possible sources of calibration error such as nonlinearity, variation with position on the surface and for pyroelectric sensors, pulse frequency. All of these factors are taken into consideration in the calibration and accounted for. For a complete analysis of Ophir calibration accuracy and error budget, please see our website at:
www.ophiropt.com/calibration-procedure/tutorial

Special Calibration

In addition to standard calibration wavelengths shown below, customers can have their Ophir sensor calibrated at additional wavelengths for more accuracy. Please consult your Ophir agent for special requests.

Wavelengths of Calibration per Sensor Type

Wavelength	193	248	254	266	355	365	410	436	488	532	577	633	675	750	755	808	905	980	1014	1046	1064	1070	1310	1550	2100	2940	10600	Spectral Curve
Pulsed/Continuous	P	P	C	P	P	C	C	C	C	P,C	C	C	C	C	P	C	P	C	C	C	P,C	C	C	P,C	P	P	C	
Photodiode sensors																												
PD300						●		●	●		●	●							●	●								●
PD300-UV			●			●		●	●		●	●							●	●								●
PD300-IR																●		●						●				●
PD300-3W						●		●	●		●	●								●								●
PD300-IRG																●		●		●			●	●				●
IS-1, IS-1-2W						●		●			●									●								●
IS-6			●			●		●			●									●								●
3A-IS								●				●	●							●								●
Thermal sensors																												
Standard Broadband<1000W										●											●						●	
Standard Broadband 1-15kW																●						●					●	
Helios																						●						
30K-W																						●						
120K-W																						●						
LP1 type										●						●		●								●		●
LP2 type																						●						
Comet 10K																						●					●	
Comet 1K										●												●					●	
P type										●											●							
PF type		●								●											●						●	
PF with diffuser				●	●					●											●				●			
HE type										●											●				●	●		
HE with diffuser		●			●					●											●							
EX type		●								●																		
SV type	●																				●						●	
Pyroelectric sensors																												
PD10-C, PD10-pJ-C	●	●					●										●											●
PD10-IR-pJ-C, PD10-IR-C											●						●							●				
PE9-C	●				●																●			●				
PE9-ES-C					●																●			●				
PE10-C					●																●							
BB type																					●							
BF type	●	●			●					●											●					●		●
BF with diffuser		●			●					●											●				●	●		●
Metallic (standard)		●			●																●					●		●
PE50BB-DIF-C										●											●				●			
PE50-DIF-ER-C										●											●				●	●		
PE50-DIF-C	●	●								●											●				●	●		
PE100BF-DIF-C										●											●			●				

Sensors

Laser Beam Analysis

3.1 Choosing a Beam Profiler

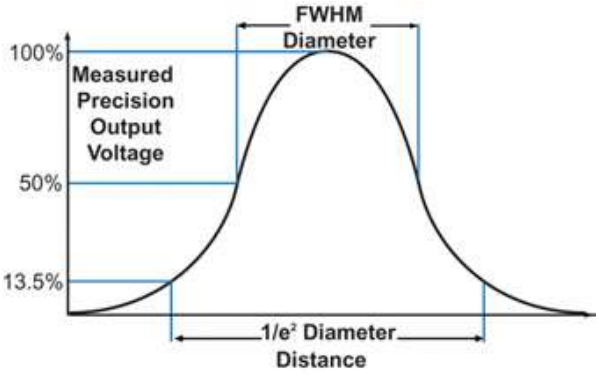
A laser beam profiler will increase your chance of success anytime you wish to design or apply a laser or when you find your laser system is no longer meeting specifications. You would never think of trying to build a mechanical part without a micrometer. So why attempt to build lasers or laser systems with only a power meter? You will produce the desired results more quickly if you can measure basic things like beam width or size, beam profile and power.

We believe as Lord Kelvin said: "You cannot improve it if you cannot measure it".

3.1.1 Four Basic Questions

When choosing a laser beam profiler there are a plethora of choices to do the job, including CCD and CMOS cameras, scanning slit sensors, InGaAs and pyroelectric cameras, pinhole, and knife edge sensors to mention some. How does one decide which is the proper solution for one's application and from which company to obtain the profiler system? When making the selection there are four basic questions about the laser application that one must answer.

Wavelength?



The first question is: *What wavelength(s) do you intend to measure?* The answer to this question determines the type of detector needed, and what the most cost effective approach may be. For the UV and visible wavelength range from <193nm up to the very near infrared at around 1300nm, silicon detectors have the response to make these measurements. The largest number of cost effective solutions exist for these wavelengths including CCD cameras and silicon detector-equipped scanning aperture systems. Which of these is the best will be determined by the answers to the other three questions.
For the near infrared, from 800 to 1700nm, the choices become less abundant. In the lower end of this range from 800–1300nm the CCD cameras may still work, but InGaAs arrays become necessary above 1300nm. These are more expensive; four to five times the cost of the silicon CCDs. Scanning slit systems equipped with germanium detectors are still quite reasonably priced, within a few hundred dollars of their silicon-equipped cousins. At the mid and far infrared wavelengths the pyroelectric cameras and scanning slits sensors with pyroelectric detectors provide viable alternatives, again the best approach being determined by the answers to the subsequent questions.

Beam Size?

The second question is: *What beam width or spot size do you wish to measure?* This question can also impact the profiler type choices. Arrays are limited by the size of their pixels. At the current state-of-the-art pixels are at best around 4µm for silicon arrays, and considerably larger, 30um to 80um with InGaAs and pyroelectric cameras. This means that a UV-NIR beam should be larger than 50µm or roughly 10 pixels in diameter to ensure that enough pixels are utilized to make an accurate measurement. Beams with spot sizes smaller than 50um can be optically magnified or expanded to be measured with a camera. InGaAs camera pixels are around 30µm, limiting the minimum measurable beam size to 300µm; pyroelectric array pixels are even larger at 80µm, meaning the beams need to be at least 0.8mm to yield accurate results. Scanning slit profilers can measure with better than 3% accuracy beams that are four times the slit width or larger, putting the minimum beam sizes at around 8µm without magnification. Those investigators who want to measure their beams directly without additional optics could find this to be an advantage.

Power?

The third question is: *What is the power of the beam?* This determines the need for attenuation, and/or beam splitting, as well as the detector type. Array detectors, such as silicon CCD, CMOS, InGaAs and Pyroelectric cameras will usually need attenuation when measuring lasers. Scanning slit type profilers can measure many beams directly without any attenuation, due to the natural attenuation of the slit itself. Detector arrays and knife-edge profilers, by their nature, will allow the entire beam to impact the detector at some point in the measurement, leading to detector saturation unless the beam is appropriately attenuated. Lasers of any wavelength with CW powers above 100mW can be measured with the pyroelectric detector-equipped scanning slit profiler, making it the easiest profiler for many applications. Scanning slit profilers can directly measure up to kilowatts of laser power, depending on the spot size or power density.

CW or Pulsed?

The final question is: *Is the laser continuous wave (CW) or pulsed?* Lasers that operate pulsed at repetition rates less than ~10 kHz are best profiled with an array. Scanning apertures cannot measure many beam sizes at this repetition rate effectively in real time . CW and pulsed beams with repetition rates above ~10 kHz can be measured with scanning slits if the combination of the repetition rate and the beam size are sufficient to have enough laser pulses during the transit time of the slits through the beam to obtain a good profile. Knife-edge profilers are only able to measure CW beams. Pulsed beams have other considerations when selecting a beam profiling instrument, particularly pulse-to-pulse repeatability, and pulse-energy damage thresholds of the slit material or in the case of array detectors, beam sampling optics.

3.1.2 One More Question

Besides these four questions about the physical nature of the laser to be measured, there is one more that needs to be asked: How accurate does the measurement need to be? Not all profilers or profiler companies are equal in this regard. Properly designed, maintained and calibrated camera and slit - based profilers can provide sub-micron precision for both beam width and beam position (centroid) measurements.

A state-of-the-art CCD array with 4µm pixels can provide ±2% beam width accuracy for beams larger than 50µm. Accuracy for smaller beams may be worse due to the effects of insufficient resolution or pixilation. In addition, the effects of attenuation optics, noise and proper baseline zeroing or offset compensation can have dramatic impact on the accuracy of the measurement. Cameras that are not designed specifically for profiling may be much worse due to the presence of a cover glass and/or IR cut-off filter covering the array. These optical elements must be removed for laser profiling to prevent interference fringes or distortion of the beam being tested. Camera arrays provide a true two-dimensional picture of the beam and will show fine structure and hot and cold spots, which a slit will integrate out. Some applications do not require a map of the laser power distribution within the spot: spot size and spot location are sufficient. Other applications require that a careful mapping of the complete mode structure is made. These applications require 2D, array based sensors. The accuracy requirement is a question of what the data is to be used for. Accurate collimation or focus control requires the highest beam size accuracy. Checking the laser for hot spots, uniformity or beam shape dictates that the 2D sensor is employed and is as important as absolute size measurement accuracy.

How and where a profiler is to be used is also an important consideration in the equation. Profilers used by research and development scientists are often specialized. Ease-of-use and high throughput may be of no consequence if the purpose is to characterize specific optical systems that are well understood by the investigator. On the other hand, when a profiler needs to be used on the factory floor for quality assurance of the manufacturing process, ease-of-use, high throughput, and reproducibility become paramount. In this case the profiler requiring the least "fiddling" is generally the best fit. Here there is a competition between the intuitive and the ease-of-use. Some people find the 2-dimensional camera array to be the most intuitive, because they can relate to the idea of "taking a picture" of the laser beam; X-Y scanning slits may seem less intuitive. For any process that uses or works with CW or high frequency pulsed lasers the scanning slit will have the advantage of measuring the beam directly, possibly even at its focus point, without additional attenuation optics. The dynamic range of these systems is also broad enough to measure both the focused and the unfocused beam without changing the level of attenuation. Camera arrays, on the other hand will require attenuation adjustment.

Conversely, if the important aspect of the measurement is the two-dimensional image of the beam, or if the laser is pulsed at a low repetition rate, the array will be the solution; even if it means attenuation optics.

Also, many factory applications may want to 'embed' the beam profiler into a manufacturing cell or a piece of automation so the measurements and possibly pass/fail results are completed automatically. If so, look for a system that has this ability. Automation capability typically means the laser beam profile system communicates to other applications through LabView, Excel or .NET.

Whether choosing a camera or scanning slit system the user must first determine the laser beam measurement environment and what measurements are the most important to the success of the application. Ease of use and absolute spot size favors the scanning slit system while knowing about the hot and cold spots or the image of the beam under test, or any low repetition pulsed laser, requires a camera based beam profiling system. The assistance of knowledgeable product specialists is required to provide analysis of the measurement requirements of your laser application as well as to describe the features and benefits of available products.

Slit-based Beam Profiler Camera-based Beam Profiler

3.1.3 User Guide for Choosing the Optimum Beam Profiling System

Laser Wavelength	Power			Minimum Beam Size				
	<100mW	100mW-100W	>100W	<20µm	>20 <50µm	>50µm	>500µm	>1mm
UV-Vis	NS-Si	NS-Pyro		NS-Si/3.5/1.8	NS-Si/9/5	NS-Si/9/5	NS-Si /9/5	NS-Si /9/5
	SP928	SP928	NS-Pyro		NS-Pyro/9/5	NS-Pyro/9/5	NS-Pyro/9/5	NS-Pyro/9/5
	LT665	LT665	SP928			SP928	SP928	SP928
			LT665			LT665	LT665	LT665
NIR 1000-1100nm	NS-Ge	NS-Pyro		NS-Ge/3.5/1.8	NS-Ge/9/5	NS-Ge/9/5	NS-Ge/9/5	NS-Ge/9/5
	SP928	SP928	NS-Pyro		NS-Pyro/9/5	NS-Pyro/9/5	NS-Pyro/9/5	NS-Pyro/9/5
	LT665	LT665	SP928			SP928	SP928/SP907	
Industrial & Additive								
Fiber	BC	BC	BC, BW		BC	BC, BW	BC, BW	BC
CO2	Pyrocam	Pyrocam	MC					Pyrocam, MC
Telecom and Eye-Safe 1100-1800nm	NS-Ge	NS-Pyro		NS-Ge/3.5/1.8	NS-Ge/9/5	NS-Ge/9/5	NS-Ge/9/5	NS-Ge/9/5
			NS-Pyro		NS-Pyro/9/5	NS-Pyro/9/5	NS-Pyro/9/5	NS-Pyro/9/5
						XEVA	XEVA	XEVA
	Pyrocam	Pyrocam	Pyrocam				Pyrocam	Pyrocam
1500-1600nm	NS-Ge	NS-Ge	NS-Ge	NS-Ge/3.5/1.8	NS-Ge/9/5	NS-Ge/9/5	Pyrocam	NS-Ge/9/5
	SP928-1550	SP928-1550	SP928-1550			SP928-1550	XEVA	SP928-1550
	LT665-1550	LT665-1550	LT665-1550			LT665-1550	SP928-1550	XEVA
							LT665-1550	LT665-1550
MIR & FIR	Pyrocam	NS-Pyro		Pyrocam w/ Beam Expansion	NS-Pyro/9/5	NS-Pyro/9/5	NS-Pyro/9/5	NS-Pyro/9/5
		Pyrocam	NS-Pyro				Pyrocam	Pyrocam
			Pyrocam					
			ModeCheck					

Abbreviations:

FIR	Far Infrared	**NIR**	Near Infrared	**BC**	BeamCheck
Ge	Germanium	**Si**	Silicon	**BW**	BeamWatch
HP	High Power	**SP**	Indicates camera profiler	**MC**	ModeCheck
MIR	Mid-Infrared	**NS**	NanoScan		
UV-Vis	Ultraviolet - Visible				

Laser Wavelength	Minimum Beam Size		CW or Pulsed			Customer Priority				
	>5mm	>10mm	CW	Pulsed <1kHz	Pulsed >1kHz	Price	2D/3D	No optics	Speed	Ease of use
UV-Vis	Pyrocam	NS-Pyro		Pyrocam w/ Beam Expansion	NS-Pyro/9/5	NS-Pyro/9/5	NS-Pyro/9/5	NS-Pyro/9/5	NS	NS
		Pyrocam	NS-Pyro				Pyrocam	Pyrocam		
			Pyrocam							
NIR 1000-1100nm	NS-Ge/12/25		NS	SP928	SP928	SP928	SP928	NS	NS	NS
	NS-Pyro/20/25	NS-Pyro/20/25	SP928	LT665	NS		LT665			
	LT665	L11059	LT665		LT665					
		LT665								
Industrial & Additive										
Fiber	Pyrocam	Pyrocam	Pyrocam	Pyrocam	Pyrocam	NS/Pyrocam	Pyrocam	NS/Pyrocam	Pyrocam	Pyrocam
CO2	MC	MC	MC	MC	MC	MC	MC	NS/Pyrocam	MC	MC
Telecom and Eye-Safe 1100-1800nm	NS-Ge/12/25		NS	XEVA	XEVA	NS	XEVA	NS	NS	NS
	NS-Pyro/20/25	NS-Pyro/20/25			NS		Pyrocam			
	Pyrocam									
1500-1600nm	NS-Ge/12/25	NS-Pyro/20/25			NS					
	SP928-1550	LT665-1550	XEVA	XEVA	XEVA	SP928-1550	SP928-1550	NS	NS	NS
	LT665-1550			LT665-1550	LT665-1550		LT665-1550			
MIR & FIR	NS-Pyro/20/25	NS-Pyro/20/25	NS	Pyrocam	NS	NS	Pyrocam	NS	NS	NS
	Pyrocam		Pyrocam		Pyrocam					

Abbreviations:

FIR	Far Infrared
Ge	Germanium
HP	High Power
MIR	Mid-Infrared
UV-Vis	Ultraviolet - Visible
NIR	Near Infrared
Si	Silicon
SP	Indicates camera profiler
NS	NanoScan
BC	BeamCheck
BW	BeamWatch
MC	ModeCheck

3.2 Benefits of Beam Profiling

You can get more out of your laser

- Figure 1 shows an industrial Nd: YAG laser, near Gaussian beam, with 100 Watts output power and 1.5kW/cm^2 power density. Figure 2 is the same Nd: YAG beam at greater power, 170 Watts, but it split into 2 peaks producing only 1.3kW/cm^2 power density. The power density of the beam decreased 13% instead of increasing by the 70% expected. Without measuring the beam profile and beam width, you would not know what happened to your power density, and why the performance did not improve.

Laser cavities become misaligned

- Figures 3 & 4 are beam profiles of CO_2 lasers used for ceramic wafer scribing in the same shop. The second laser with the highly structured beam produced mostly scrap parts, until the laser cavity was aligned.

Off axis delivery optics

- Figures 5 & 6 show an industrial Nd:YAG laser with misaligned turning mirror, before and after adjustment.

Alignment of devices to lenses

- Figures 7 & 8 show beam profiles during alignment of a collimating lens to a laser diode. The first profile shows poor alignment of the lens to the diode, which can easily be improved when seeing the profile in real time.

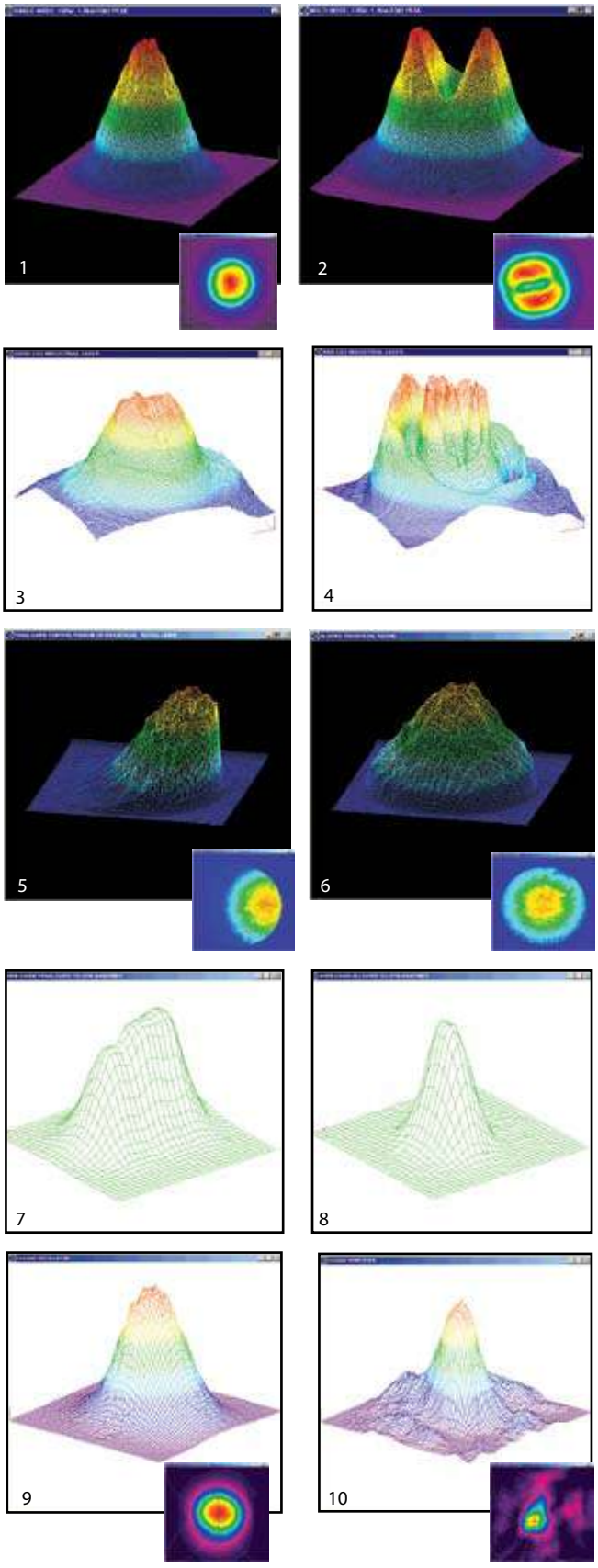
Laser amplifier tuning

- Figures 9 & 10 show a Cr:LiSAF femtosecond laser oscillator beam with a near Gaussian output, and what happens to the oscillator beam with poor input alignment

All these examples illustrate the need for beam monitoring

- If the beam has problems, you must (or should) measure the beam and you must (or should) see the profile of the beam to make corrections.
- Most laser processes can be improved
- Scientific experiments can be more accurate
- Commercial instruments can be better aligned
- Military devices can have greater effectiveness
- Industrial processing produces less scrap
- Medical applications are more precise

Just knowing the beam profile can make the difference between success and failure of a process.



3.3 Introduction to Camera-Based Profilers

Beam Attenuating Accessories

A camera-based beam profiler system consists of a camera, profiler software and a beam attenuation accessory. Spiricon offers the broadest range of cameras in the market to cope with wavelengths from 13nm, extreme UV, to 3000 µm, in the long infrared. Both USB and FireWire interfaces are available for most wavelength ranges providing flexibility for either laptop or desktop computers.

BeamGage®, the profiling software, comes in two versions: Standard and Professional. Each builds off of the next adding additional capability and flexibility needed for adapting to almost any configuration requirement.
Spiricon also has the most extensive array of accessories for beam profiling. There are components for attenuating, filtering, beam splitting, magnifying, reducing and wavelength conversion. There are components for wavelengths from the deep UV to CO2 wavelengths. Most of the components are modular so they can be mixed and matched with each other to solve almost any beam profiling requirement needed.

Acquisition and Analysis Software

The BeamGage software is written specifically for Microsoft Windows operating systems and takes full advantage of the ribbon-base, multi-window environment. The software performs rigorous data analyses on the same parameters, in accordance with the ISO standards, providing quantitative measurement of numerous beam spatial characteristics. Pass/Fail limit analysis for each of these parameters can be also applied.

- ISO Standard Beam Parameters
- Dslit, Denergy, D4σ
- Centroid and Peak location
- Major and Minor Axis
- Ellipticity, Eccentricity
- Beam Rotation
- Gaussian Fit
- Flat-top analysis / Uniformity
- Divergence
- Pointing stability

For data display and visualization, the user can arrange and size multiple windows as required. These may contain, for example, live video, 2D Topographic and 3D views, calculated beam parameters and summary statistics in tabular form with Pass/Fail limit analysis, and graphical strip chart time displays with summary statistics and overlays. Custom configured instrument screens with multiple views can be saved as configuration files for repeated use. Data can be exported to spreadsheets, math, process/ instrumentation and statistical analysis programs, and control programs by logging to files or COM ports, or by sharing using LabView or ActiveX Automation.

- Video Dual Aperture Profiles
- Beam Statistics
- 3D Profile View
- 2D Topographic View
- Time Statistics Charts
- Pointing / Targeting
- Hide measurements and features not in use for user simplicity
- Notes

3.3.1 BeamGage

See your beam as never before

3.3.1.1 BeamGage®-Standard Version

- Extensive set of ISO quantitative measurements
- Patented Ultracal™ algorithm for highest accuracy measurements in the industry
- Customizable user interface for 'ease of use'
- Auto-setup and Auto-exposure capabilities for fast set-up and optimized accuracy
- Statistical analysis on all calculated results displayed in real time
- New BeamMaker® beam simulator for algorithm self-validation

The performance of today's laser systems can strongly affect the success of demanding, modern laser applications.

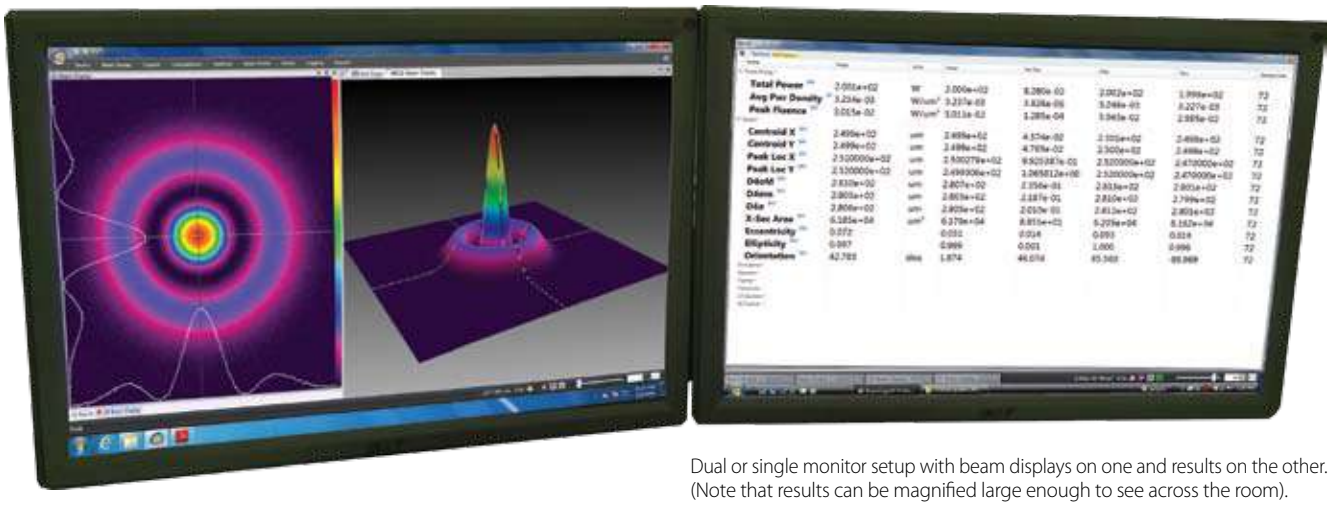
The beam's size, shape, uniformity or approximation to the expected power distribution, as well as its divergence and mode content can make or break an application. Accurate knowledge of these parameters is essential to the success of any laser-based endeavor. As laser applications push the boundaries of laser performance it is becoming more critical to understand the operating criteria.

For over thirty years Ophir-Spiricon has developed instruments to accurately measure critical laser parameters. Our LBA and BeamStar software have led the way.
Now with the introduction of BeamGage, Ophir-Spiricon offers the first "new from the ground up" beam profile analysis instrument the industry has experienced in over 10 years.

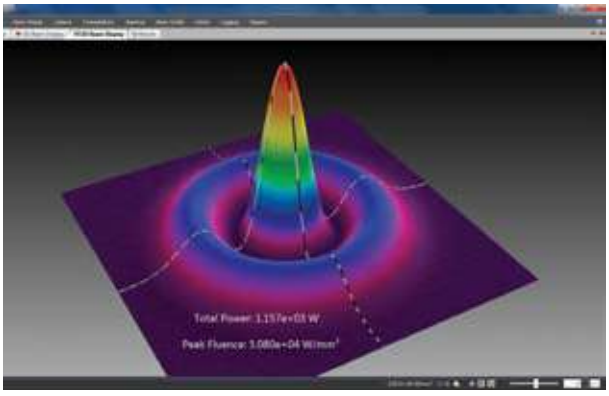
BeamGage includes all of the accuracy and ISO approved quantitative results that made our LBA software so successful. BeamGage also brings the ease-of-use that has made our BeamStar software so popular. Our patented UltraCal algorithm, guarantees the data baseline or "zero-reference point" is accurate to 1/10 of a digital count on a pixel-by-pixel basis. ISO 11146 requires that a baseline correction algorithm be used to improve the accuracy of beam width measurements. UltraCal has been enhanced in BeamGage to assure that accurate spatial measurements are now more quickly available.

See Your Beam As Never Before:

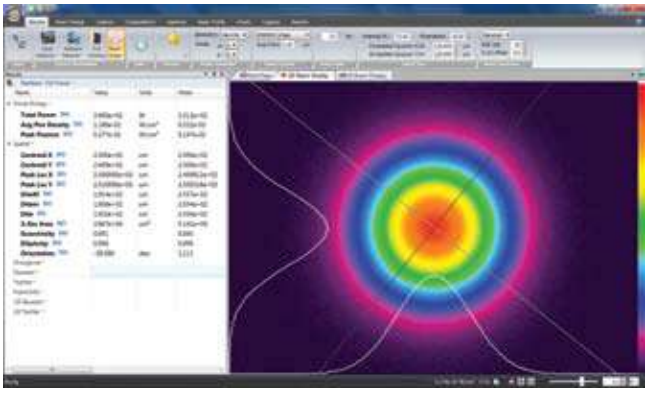
The Graphical User Interface (GUI) of BeamGage is new. Dockable and floatable windows plus concealable ribbon tool bars empowers the BeamGage user to make the most of a small laptop display or a large, multi-monitor desktop PC.



Dual or single monitor setup with beam displays on one and results on the other. (Note that results can be magnified large enough to see across the room).

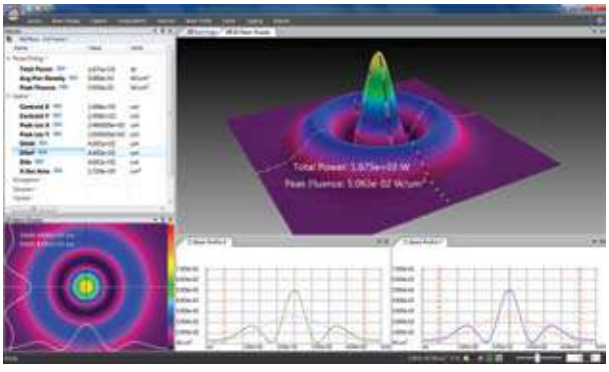


Beam only (Note results overlaid on beam profile).



Beam plus results

- 3D displays Rotate & Tilt. All displays Pan, Zoom, Translate & Z axis Zoom



Multiple beam and results windows.
(Note quantified profile results on 3D display & quantified 2D slices).

Measure Your Beam As Never Before:

Ultracal: Essential, or no big deal?

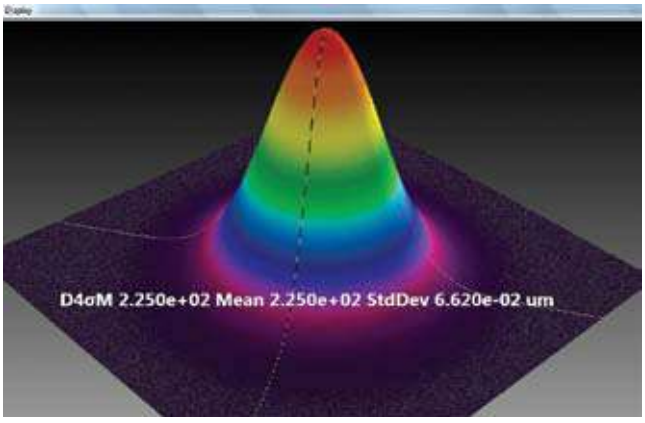
If you want accurate beam measurements, you want Ultracal.

What is Ultracal?

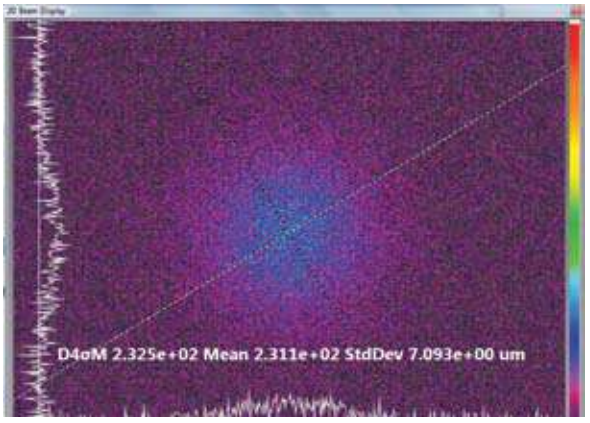
Our patented, baseline correction algorithm helped establish the ISO 11146-3 standard for beam measurement accuracy. The problems with cameras used in beam profile measurements are: a) The baseline, or zero, of the cameras will drift with time and temperature changes, and b) include random noise. Ultracal is the only beam profiler algorithm that sets the baseline to "zero", and, in the center of the noise. (Competitive products use other less sophisticated algorithms that perform a baseline subtraction, but truncate the noise below the "zero" of the baseline. This leaves only a "positive" component, which adds a net value to all beam measurements).

Try the following on any other beam profiler product to see the inherent error if you don't use Ultracal.

1. Measure a beam with full intensity on the profiler camera.
2. Insert a ND2 filter (100X attenuation) into the beam and measure it again.
3. Compare the results.
4. The Standard Deviation below is about 3%, which is phenomenal compared to the 100% or more of any beam profiler without Ultracal.



Beam at full intensity, Width 225µm, Std Dev 0.06µm



Beam attenuated 100X (displayed here in 2D at 16X magnitude zoom), Width 231µm, Std Dev 7µm

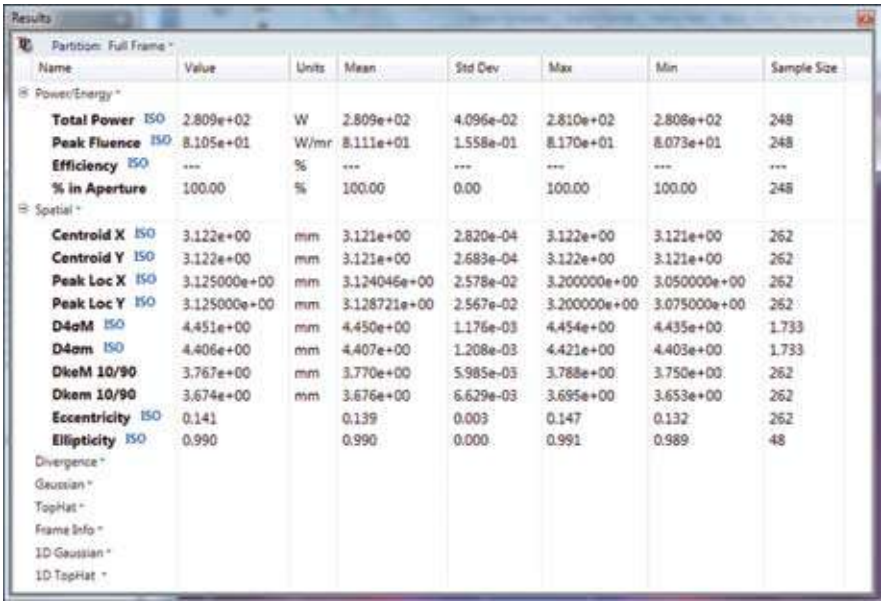
Adding the use of Automatic Aperture improves the accuracy to 1%. (The conditions of this measurement is a camera with a 50dB SNR).

5. You normally don't make measurements at such a low intensity. But occasionally you may have a drop in intensity of your beam and don't want to have to adjust the attenuation. Or, you may occasionally have a very small beam of only a few tens of pixels. In both of these cases, Ultracal becomes essential in obtaining accurate measurements.

Beam Measurements and Statistics

BeamGage allows you to configure as many measurements as needed to support your work, and comes standard with over 55 separate measurement choices. To distinguish between calculations that are based on ISO standards and those that are not, a graphical ISO logo is displayed next to appropriate measurements. You can also choose to perform statistical calculations on any parameter in the list.

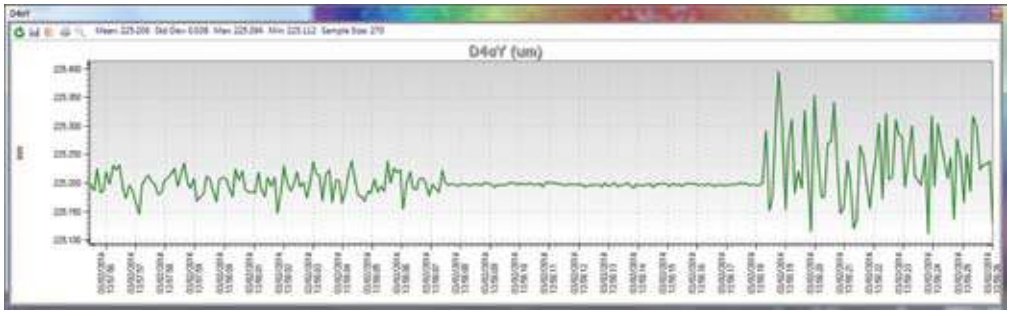
Small sample of possible measurements out of a list of 55



Sample of calculation results with statistics applied

Multiple Charting Options

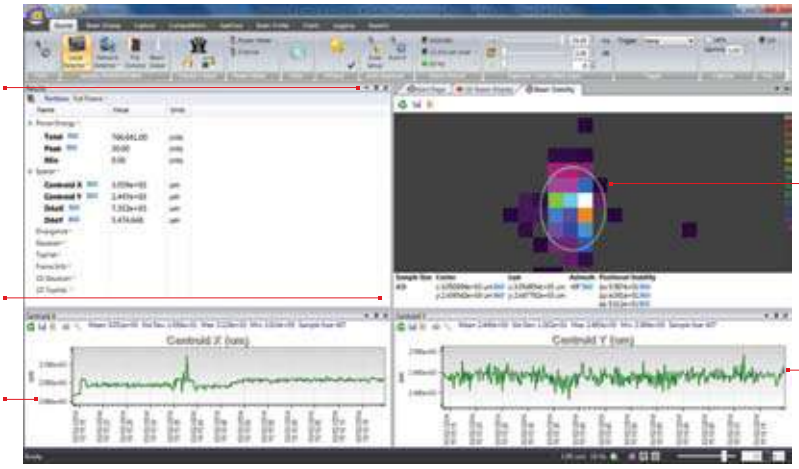
You can create strip charts for stability observations on practically any of the calculations options available. Charts enable tracking of short or long term stability of your laser.



Strip chart of beam D4sigma width. Note how changing conditions affects the width repeatability.
Beam intensity changed over 10db, making noise a significant factor in measurement stability.

Beam Pointing Stability

Open the Pointing Stability Window to collect centroid and peak data from the core system and display it graphically. View a chart recorder and statistical functions in one interface:



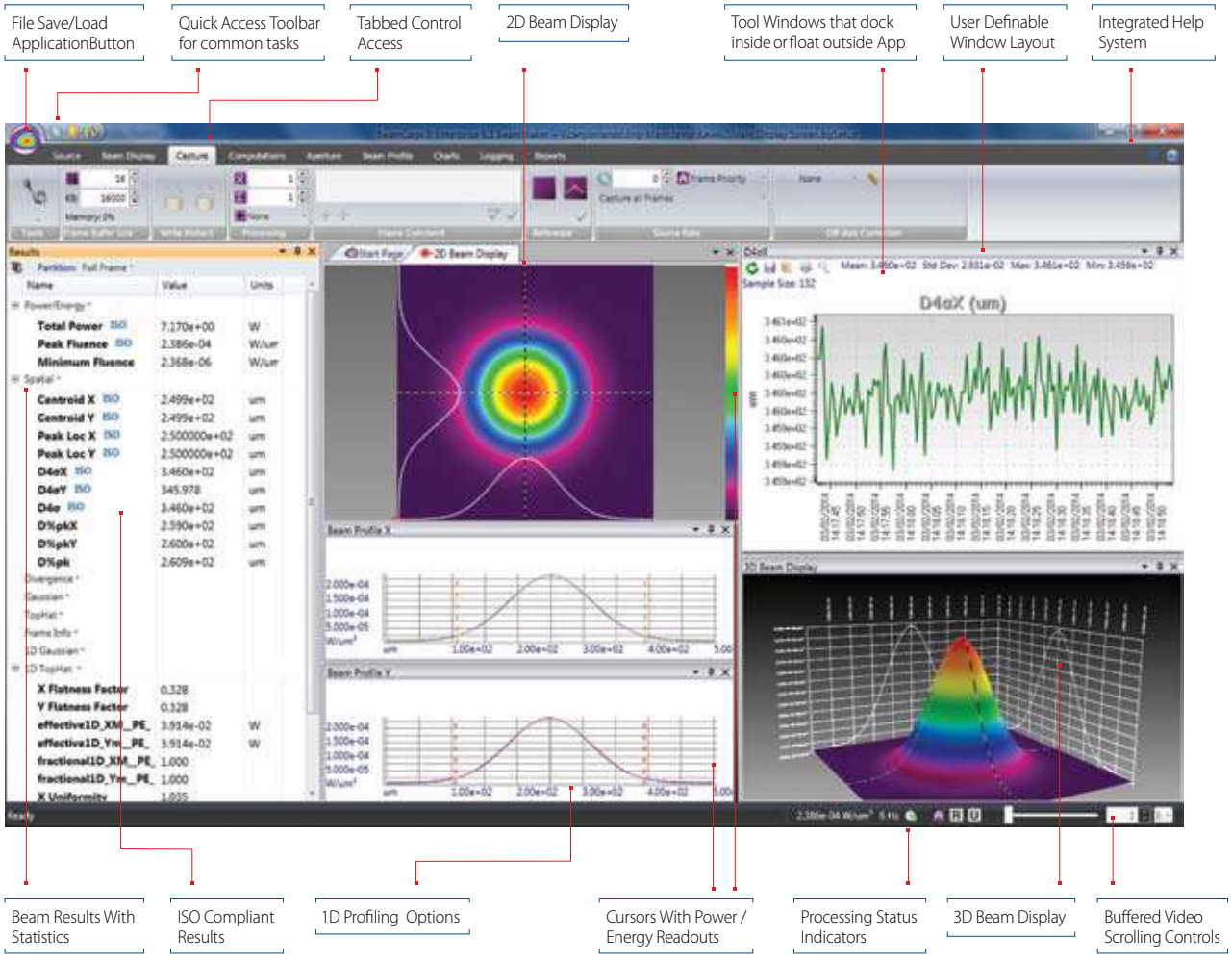
Easy to Use and Powerful

BeamGage is the only beam profiler on the market using modern Windows 7 navigation tools. The menu system of BeamGage is easy to learn and easy to use with most controls only one mouse click away. Some ribbon toolbar examples:

Some of the Beam Display options (Display access options under the Tools tab on the left).

Some of the Beam Capture options.

BeamGage Main Display Screen



Pass / Fail with Password Protection for Production Testing

BeamGage allows the user to configure the displayed calculations; set-up the screen layout and password protect the configuration from any changes. This permits secure product testing as well as data collection for Statistical Process Control (SPC), all while assuring the validity of the data.

Name	Value	Mean	Std Dev	Max	Min	Units
Power/Energy *						
Spatial *						
Centroid X ISO	7.831e+01	7.831e+01	2.849e-03	7.832e+01	7.830e+01	um
Centroid Y ISO	7.965e+01	7.965e+01	3.047e-03	7.966e+01	7.964e+01	um
Peak Loc X ISO	7.000000e+01	7.073199e+01	1.340173e+0	7.500000e+01	6.700000e+01	um
Peak Loc Y ISO	7.100000e+01	7.183659e+01	1.333245e+0	7.500000e+01	6.800000e+01	um
D4σX ISO	1.238e+02	1.238e+02	8.334e-03	1.239e+02	1.238e+02	um
D4σY ISO	124.041	124.053	0.008	124.079	124.027	um
D4σ ISO	1.239e+02	1.239e+02	6.395e-03	1.240e+02	1.239e+02	um

Failures (or successes) can be the impetus for additional actions including a TTL output signal or PC beep and the termination of further data acquisition.

Camera Compatibility

For lasers between 190-1100nm wavelengths, BeamGage interfaces to silicon CCD USB cameras. For applications between 1440-1605nm, BeamGage supports cost effective phosphor coated CCD cameras. For demanding applications between 900-1700nm, BeamGage supports an InGaAs camera. And for applications in the ultraviolet, 13-355nm, or far infrared or Terahertz range, 1.06-3000nm, BeamGage supports Spiricon's Pyrocam, pyroelectric array cameras.

190-1100nm*



Model	SP907	SP928	SP300
Spectral Response nm	190 - 1100nm*	190 - 1100nm*	190 - 1100nm*
Application	1/1.8" format, slim profile, wide dynamic range, CW & pulsed lasers, adjustable ROI	1/1.8" format, high resolution, wide dynamic range, CW & pulsed lasers, adjustable ROI	1/1.8" format, high resolution, high speed, CW & pulsed lasers, adjustable ROI
Number of Elements	964 x 724	1928 x 1448	1928 x 1448
Interface Style	USB 3.0	USB 3.0	USB 3.0
Windows OS support	Windows 7 (64) and Windows 10		

190-1100nm*


Model	LT665	L11059
Spectral Response nm	190 - 1100nm*	190 - 1100nm*
Application	12.5mm x 10mm, 1" format for large beams, CW & pulsed lasers, adjustable ROI	36mm x 24mm, 35mm format for large beams, CW & pulsed lasers, adjustable ROI
Number of Elements	2752 x 2192	4008 x 2672
Interface Style	USB 3.0	USB 2.0
Windows OS support	Windows 7 (64) and Windows 10	

* Although our silicon cameras have shown response out to 1320nm it can cause significant blooming which could lead to significant errors of beam width measurements. We would suggest our XC13 InGaAs camera for these wavelengths to give you the best measurements.

1440-1605nm



Model	SP907-1550	SP928-1550	LT665-1550
Spectral Response nm	1440 - 1605nm	1440 - 1605nm	1440 - 1605nm
Application	NIR wavelengths, 1/1.8" format, low resolution, adjustable ROI and binning	NIR wavelengths, 1/1.8" format, adjustable ROI and binning	12.5mm x 10mm, 1" format for large beams, CW & pulsed lasers, adjustable ROI
Number of Elements	964 x 724	1928 x 1448	2752 x 2195
Interface Style	USB 3.0	USB 3.0	USB 3.0
Windows OS support	Windows 7 (64) and Windows 10		

900-1700nm

Model	XEVA 100Hz
Spectral Response nm	900 - 1700nm
Application	High resolution InGaAS performance, NIR wavelengths
Number of Elements	320 x 256
Interface Style	USB 2.0
Windows OS support	Windows 7 (64) and Windows 10

13-355nm & 1.06-3000µm

Model	Pyrocam IIIHR	Pyrocam IV
Spectral Response nm	13-355nm & 1.06-3000µm	13-355nm & 1.06-3000µm
Application	UV & Far IR Only commercial array to view Terahertz	UV & Far IR Only commercial array to view Terahertz
Number of Elements	160 x 160	320 x 320
Interface Style	GigE	GigE
Windows OS support	Windows 7 (64) and Windows 10	

Unique Features of BeamGage - Standard

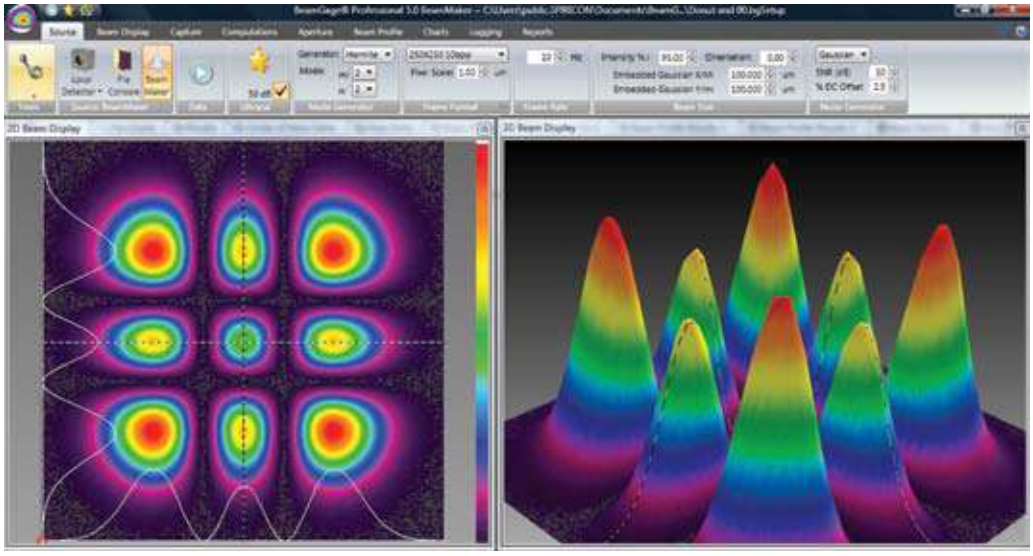
Power/Energy Calibration

Using the USB output from select Ophir power/energy meters, the BeamGage application will display measured power/energy values from the full range of Ophir thermopile, photodiode and pyroelectric sensors. Pulsed lasers can be synced up to 100Hz, or the frame rate of the triggered camera, whichever is less. This is the first time in the industry a laser power meter has been married to a laser beam profile system.

BeamGage is the only product to integrate profiling and power meter measurements

BeamMaker®; Numerical Beam Profile Generator

BeamGage contains a utility, BeamMaker, that can synthetically generate beam profile data by modeling either Laguerre, Hermite or donut laser beams in various modal configurations. BeamMaker permits the user to model a beam profile by specifying the mode, size, width, height, intensity, angle, and noise content. Once generated the user can then compare the theoretically derived measurements to measurements including experimental inaccuracies produced by the various measurement instruments and environmental test conditions. Users can now analyze expected results and confirm if measurement algorithms will accurately measure the beam even before the experiment is constructed. BeamMaker can help laser engineers, technicians and researchers understand a beam's modal content by calculating results on modeled beams for a better understanding of real laser beam profiles. BeamMaker is to laser beam analysis as a function generator is to an oscilloscope.



BeamMaker producing a synthetically generated Hermite TEM_{22} beam and displayed in both 2D and 3D

Integrated automatic Help linked into the Users Guide

Touch sensitive Tool tips are available on most all controls, and "What's This" help can provide additional details. Confused about what something is or forgot how it works, just go to the top right corner and touch the "What's This" help icon, then click on the control or menu item that you want more info about and you are taken to the explanation within the BeamGage Users Guide.

Multilingual

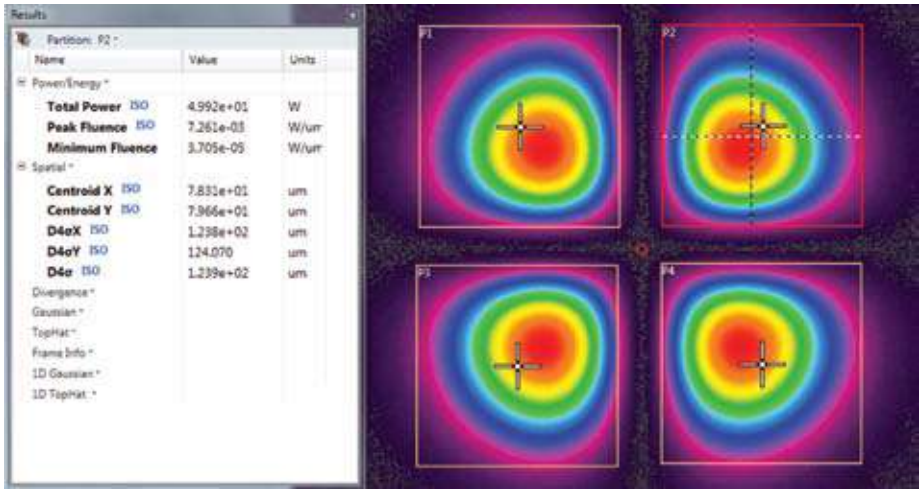
BeamGage comes with both Japanese and Chinese user interface. Country specific manuals can be downloaded from the ophiropt.com/photonics web site.

3.3.1.2 BeamGage®-Professional Version

Professional is an upgrade version of BeamGage-Standard that has all of the BeamGage-Standard features plus additional functionality.

Image Partitioning

Partitioning allows the user to subdivide the camera image into separate regions, called partitions, and compute separate beam results within each partition. When using partitioning special results items can be displayed that relate to delta values between the computed centroids or peaks of each partition. Partitioning is useful to enable separate analysis of individual beams when multiple beams impinge on the camera simultaneously. This feature is particularly useful when analyzing multiple fibers in a single bundle.



Shown is an example of the results for partition P2 and its related display frame. Observe that the selected partition is highlighted in RED. The crosshair in each partition is user controlled. The crosshair can be moved to a new position with the mouse or can be numerically positioned using the expanded controls that appear when a partition is created.

Automation Interface

BeamGage Professional provides an automation interface via .NET components to allow customers the ability to build custom applications' that incorporate the laser beam analysis and processing power of BeamGage. The BeamGage automation interface allows developers to control BeamGage programmatically via a set of "puppet strings" known as the automation interface. The automation interface was developed to provide the ability to base control decisions for a second application on results and behaviors recognized by BeamGage. With this ability users can quickly and efficiently meet their manufacturing/analysis goals with minimum human interaction.

The automation interface was designed to achieve two main goals. First, to allow the BeamGage user to programmatically do what they could otherwise do via the graphical user interface (GUI). Second, to expose stable interfaces to the user that will not change, causing breaks to their dependent code. Interface examples for LabVIEW, Excel and .NET VB are included.

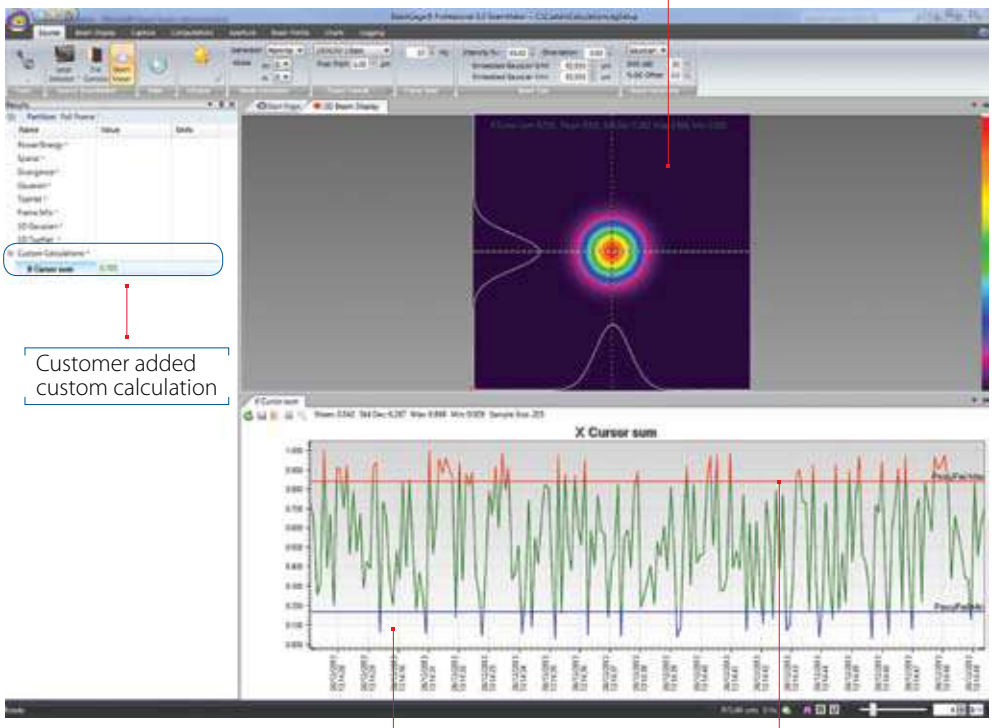
Custom Calculations

If BeamGage-Standard does not have the measurement you need the Professional and Enterprise versions permit the user to program-in their own set of calculations. User defined computations are treated the same as other BeamGage standard calculations.

These custom results are displayed on the monitor, logged with results, and included on hard copy print-outs as if they were part of the original application.

An example of a customer generated custom equation.

$$S = \frac{1}{\pi^2}\left|\int_0^{2\pi}\int_0^1 \exp(2\pi i \Delta W(\rho,\theta))\,\rho d\rho d\theta\right|^2$$


Custom results with statistics
Customer added custom calculation
X Cursor sum
Custom results being plotted
Custom results with pass/fail turned on

3.3.1.3 Software Comparison Chart

Features	BeamGage® Standard	Upgrade to BeamGage® Professional to include: (all features in Standard plus)
Features Overview	User selectable for either best "accuracy" or "ease of use"	
	Supports our patented Ultracal algorithm plus Auto-setup and Auto-exposure capabilities	
	Extensive set of ISO quantitative measurements	
	Support for USB, GigE and Pyrocam IIIHR and Pyrocam IV cameras	Supports InGaAs and large format L11059 cameras
	New Beam Maker® beam simulator for algorithm self validation. See below for more detailed description	
	Simultaneous 2D and 3D displays	
	Multi-instance, multi-camera use	
	Results synchronized to select models of Ophir power/energy meters. Supported products include: Vega, Nova II, Pulsar, USBI and Juno, in both 32 and 64bit OS. (Quasar is not supported)	
	Supports Satellite windows on multiple monitors	
	Continuous zoom scaling in both 2D and 3D	
		Window partitioning to allow analysis of multiple beams from a single camera image
	Camera ROI support on USB and Firewire cameras	
	Manual and Auto-aperturing to reduce background effects	
	Pass/Fail on all results items, w/multiple alarm options	
	Beam Pointing Stability scatter plot and stripchart results	
	Full featured logging capabilities in a reloadable industry standard data file format	
	Configurable Report Generator that allows cut and paste of results, images and settings	
		NET Automation interface that allows for remote control. Examples in LabView, Excel and .Net VB
	Supports English, German, Japanese and Chinese Windows 7 (64) and Windows 10	
	Multilingual GUI in English, Japanese and Chinese	
	Administrator can lock software options for non-administrators	
Quantitative Calculations; Basic Results	(per ISO 11145, 11146-1/-3, and 13694)	
Power/Energy Results	Total power or energy (Can be calibrated or sync'd to an external Ophir power/energy meter)	
	Peak power/energy density	
	Min. Fluence	
	Average pulse power	
	Peak pulse power	
	Device efficiency	
	% in Aperture	
Spatial Results	Peak and Centroid locations	
	Beam width	
	▪ Second Moment (D4s)	
	▪ Knife Edge 90/10	
	▪ Knife Edge (User selectable level)	
	▪ Percent of Peak (User selectable)	
	▪ Percent of Total Energy (User selectable)	
	▪ Encircled power smallest slit @ 95.4	
	▪ Moving slit (User selectable)	
	Beam diameter	
	▪ Average diameter (based on x/y widths)	
	▪ Second Moment (D4s)	
	▪ Encircled power smallest aperature 86.5	
	▪ Encircled power smallest aperture (User selectable level)	

Features	BeamGage® Standard	Upgrade to BeamGage® Professional to include: (all features in Standard plus)
	Elliptical Results	
	▪ Elliptical orientation	
	▪ Ellipticity	
	▪ Eccentricity	
	Distance Measurement	
	▪ Cursor to Crosshair	
	▪ Centroid to Crosshair	
	Area Results	
	Beam cross-sectional area	
Divergence	Focal Length method	
	Far-field two-point method	
	Far-field Wide Angle method	
Gaussian Fit	2D whole beam fits	
	1D line fits	
	Height	
	Width X/Y	
	Centroid	
	Goodness of fit	
	Roughness of fit	
Tophat Results	2D and 1D	
	Flatness	
	Effective Area	
	Effective Power/Energy	
	Fractional Effective Power/Energy	
	Effective Average Fluence	
	Uniformity	
	Plateau Uniformity	
	Edge Steepness	
	1D or 2D surface inclination	
Other Quantitative Items	Frame Averaging	
	Frame Summing	
	Frame Reference Subtraction	
	Image Convolution	
	Camera signal/noise calculator	
	Row and Column summing with results loggable	
		Scalable Intensity Histogram, exportable
		X or Y axial off axis image correction
Beam Stability Displays and Results	(per ISO 11670)	
	Pointing Stabilty of Centroid	
	▪ Scatter Plot display w/histogram	
	▪ Mean Centroid	
	▪ Azimuth angle of the scatter	
	▪ Stability (M'/m'/S)	
	▪ Max Radius	
	▪ X/Y centroid/peak Strip chart plots	
	▪ Sample/Time controlled	
	▪ Pass/Fail limits	
	▪ Auto scaling	
	▪ Beam Width/Diameter Strip Charts with Results	
	▪ X/Y M/m beam widths plots	
	▪ Beam Diameter plot	
	▪ Mean/Std Dev/Min/Max results displayed	
	▪ Power/Energy Strip Charts	
	▪ Total Power/Energy plot	
	▪ Peak fluence plot	
	▪ Avg Power plot	
	▪ Elliptical Results Strip Chart	
	▪ Elliptical orientation plot	
	▪ Ellipticity plot	
	▪ Eccentricity plot	
	▪ Mean/Std Dev/Min/Max results displayed	
Custom Calculations		User can program-in own set of calculations
Beam Profile Display Options	Utilizes advanced hardware accelerated graphics engines. All display windows can be satellited to utilize multiple display monitors.	
	Can open one each simultaneous 2D and 3D beam display windows	
	Common color palette for 2D and 3D displays	
	Can open X and/or Y 1D beam slice profiles overlaid onto the 2D or 3D displays or in separate windows	

Features	BeamGage® Standard	Upgrade to BeamGage® Professional to include: (all features in Standard plus)
	Continuous software zooming in both 1D, 2D and 3D displays	
	Pan to any detector location	
	Continuous Z axis display magnitude scaling	
	Multiple 128 color palettes user selectable	
	Results items can be pasted into 2D, 3D, 1D, Pointing stability or Chart display windows.	
		Able to partition the camera imager into multiple regions with separate results.
1D Features	Available overlaid with 2D and 3D or in separate windows	
	X any Y plots on separate or combined displays	
	1D displays with basic results and column row summing option	
	Tophat 1D displays with Tophat results	
	Gaussian 1D displays with Gaussian fit results	
	1D Profile display of the Gauss fit results on 1D, 2D and 3D displays	
2D Features	Continuously zoomable and resizable displays in satellitable window	
	Continuous Z axis display magnitude scaling	
	Zoomable to subpixel resolution for origin and cursor placements	
	Pixel boundaries delinated at higher zoom magnifications	
	Adjustable Cursors that can track peak or centroid	
	Adjustable Crosshairs that can track peak or centroid	
	Adjustable manual apertures	
	Viewable Auto-aperture placement	
	Displayed beam width marker	
	Integrated Mouse actuated pan/zoom controls	
	Separate 2D pan/zoom window to show current view in 2D beam display	
	Manual or fixed origin placement	
		Ability to create partitions using the manual aperture controls
3D Features	3D graphics utilize solid surface construction with lighting and shading effects	
	Integrated Mouse actuated pan/zoom/tilt/rotate controls	
	Selectable Mesh for drawing speed vs resolution control	
	Continuously zoomable and resizable displays in satellitable window	
	Continuous Z axis display magnitude scaling	
	User enabled backplanes with cursor projections	
Partitioning		Users can subdivide the imager into separate beam measurement regions. All enabled results are computed inside of each partition
		The manual aperture is used to define and create rectangular partition
		When partitioning is enabled some new results items will be enabled
		Centroid measurements between beams in each partition can be performed
		Partitioned imagers must have a single origin common to all partitions. All coordinate results are globally referenced to this single origin
Statistical Analysis	Performed on all measurement functions with on-screen display	
	▪ Choices of intervals	
	▪ Manual start/stop	
	▪ Time from 1 second to 1000 hours	
	▪ Frames from 2 to 99,999 Measurements reported	
	▪ Current frame data, Mean, Standard Deviation, Minimum, Maximum of each calculation performed	
	Controls integrated with beam stability results, scatter and strip chart plots	

Features	BeamGage® Standard	Upgrade to BeamGage® Professional to include: (all features in Standard plus)
File types	Industry Standard HDF5 data and setup file format which are compatible in third party applications such as MatLab and Mathmatica	
	Math program and Excel compatible ASCII-csv results files	
	Graphics in jpg file format	
	Legacy file Compatibility with LBA formats	
	A user defined single file output that can contain settings, beam displays, beam profiles, charts, results, etc. in either .pdf or .xps file formats	
Printing	Images, reports, results, graphs, charts, statistics and setup information	
	Option to print many frames in a single operation	
	WYSIWYG images	
Pass/Fail	Set Maximum/Minimum limits on all calculations and statistics	
	Red/Green font color indication on result items	
	Multiple choices for indication of failed parameters, including TTL pulse for external alarm	
	Master pass/fail which triggers alarm on any failure	
	USB signal, beep, stop, and log alarm options	
Logging	Video Data Logging Formats: HDF5, ASCII-csv	
	Results in ASCII-csv	
	Pictures 2D and 3D in jpg, gif, tiff, bmp, png file formats	
	Charts in ASCII-csv	
	Cursor Data in ASCII-csv	
	Row/Column summed in ASCII-csv	
	Continuous Logging	
	Time Interval Logging	
	Frame Count Logging	
	Periodic Sampling	
	Pass/Fail Sampling	
	Burst Sampling, after a user specified time interval, sample a user specified number of frames	
Exporting	Convert frame buffer data to third party format	
	Export a user specified number of frames from the buffer	
	Export Image Data: ASCII-cvs	
	Export Results: ASCII-csv	
	Export Picture: jpg, gif, tiff, bmp, png file formats supported	
	Export Cursor Data: ASCII-cvs	
	Export Row/Column summed: ASCII-cvs	
	Export Image Data in Aperture	
Automation Interface (.NET)		Automation Interface with examples in LabVIEW, Excel and Net VB
		Automate launch and termination of the application
		Automate start, stop, Ultracal, Auto-X and Auto Setup
		Automate the loading of application setups
		Automate control of most camera settings
		Automate a subset of the application features and controls
		Automate the capture of Binary Video Data
		Automate the acquisition of application results
		Automate the acquisition of application Images
Integrated Help	PDF Operators Manual	
	Context Sensitive (Whats this?) Help	
	Context Sensitive Hints	
Signal Conditioning for Enhanced Accuracy	Spiricon's patented Ultracal enables more accurate beam measurement and display. Ultracal takes a multi- frame average of the baseline offset of each individual pixel to obtain a baseline accurate to approximately 1/8 of a digital count. This baseline offset is subtracted from each frame, pixel by pixel, to obtain a baseline correction accurate to 1/8 digital count. Spiricon's Ultracal method retains numbers	

Features	BeamGage® Standard	Upgrade to BeamGage® Professional to include: (all features in Standard plus)
	less than zero that result from noise when the baseline is subtracted. Retaining fractional and negative numbers in the processed signal can increase the beam width measurement accuracy by up to 10X over conventional baseline subtraction and clip level methods. Spiricon's Ultracal conforms to the best method described in ISO 11146-3:2004	
Frame Averaging	Up to 256 frames can be averaged for a signal-to-noise ratio, S/N, improvement of up to 16X (Noise is averaged up to 1/256th [8 fractional bits]). Data is processed and stored in a 32bit format	
Frame Summing	Up to 256 frames can be summed to pull very weak signals out of the noise	
	Due to the precise nature of Ultracal baseline setting, (i.e., a retention of both positive and negative noise components) summing of frames can be performed without generating a large offset in the baseline	
Convolution (Adjacent Pixel Averaging)	Choice of 5 convolution algorithms for spatial filtering for both display and calculations. Spatial filtering improves the visual S/N	
Beam Maker®	Beam Maker is a new feature that allows the user to model both Laguerre-Gaussian and Hermite-Gaussian laser beams in various modal configurations. With these models you have verification and validation tools that allows not only OSI but also the end user to verify BeamGage's basic beam width measurement algorithms. It can also be used to model laser beams with special input conditions such as signal-to-noise, background offset, and bits per pixel resolution. This allows the user to better understand the accuracy of measurements made under both optimum and adverse conditions. This tool provides the user with a method to validate algorithms against current ISO standards and methods. It can also be used to validate third party algorithms by making the output data available for use in third party applications	
Camera Features	Camera features are governed by the capabilities of the various cameras that will interface with these software products, and second by which of these camera features are implemented in the software. This section will describe typical camera features supported in the application	
	Black Level Control (used by Ultracal and Auto-X and Auto-setup)	
	Gain Control (used by Auto-X and Auto-setup)	
	Exposure Control (used by Auto-X and Auto-setup)	
	User Programmable ROI	
	Pixel Binning	
	Pixel Sampling	
	Bits per pixel setting	
	External Trigger Input	
	Trigger Delay	
	Strobe Output	
	Strobe Delay	
	External Trigger Probe	
	Internal Trigger Probe	
Camera related features in the applications	These are features related to but not generally dependent upon the camera design	
	Gamma Correction	
	Gain Correction	
	Bad Pixel Correction	
	Lens Applied Option	
	Pixel scale settings	
	Magnification settings	
	Frame buffer settings	
	Ultracal	
	Enable Auto-X (auto exposure control)	
	Perform an Auto-Setup	
	8/10/12/14/16 bits per pixel	
	Select Format or ROI	
	Measure S/N ratio	
Trigger, Capture and Synchronization Methods	Capture methods are features related to the application while Synchronization methods relate more to the abilities of the specific camera. NOTE: Frame capture rates are determined by many factors and are not guaranteed for any specific operating configuration	

Features	BeamGage® Standard	Upgrade to BeamGage® Professional to include: (all features in Standard plus)
	Trigger modes	
	▪ CW - captures continuously, see Capture Options below	
	▪ Trigger-In from laser: Trigger pulses supplied to the camera	
	▪ Strobe-Out to laser: Strobe pulses output from the camera	
	▪ Video Trigger: Frame captured and displayed only when the camera sees a signal greater than a user set level	
	Capture options	
	▪ Capture options are redefined and are approached in a different manner than older products. The items listed below will allow for all of the previous methods but with more flexibility than ever before	
	▪ Results Priority: Results priority will slow the capture rate to be in sync with the computational results and display updates	
	▪ Frame Priority: Frame priority will slow results and display updating to insure that frames are collected and stored in the frame buffer as fast as possible (replaces block mode)	
	▪ Stop After: Will collect a set number of frames and then stop (replaces Single-Shot mode)	
	▪ Periodic: Will collect frame at a programmed periodic rate	
	▪ Periodic Burst: Will collect frames in a Burst at programmed periodic rates	
	Post processing is still available but is done via a different mechanism and is limited to only data file sources	
Video Playback	Video playback, post processing and post analysis	
	User customizable playback rates	
	Video file quick pan/search controls	
	Whole video file playback looping with sub-selection looping	
	Playback Video produced by logging	
	Almost all measurements can be performed on video files	
System Requirements	PC computer running Windows 7 (64) and Windows 10 Laptop or Desktop	
	Not all cameras run in all Microsoft OS versions, see camera section for specifics	
	GHz Pentium style processor, dual core recommended	
	Minimum 2GB RAM (4GB required for L11059 camera)	Minimum 3-4GB RAM
	Accelerated Graphics Processor	
	Hard drive space suitable to hold the amount of video data you expect to store (50-100 GB recommended)	

3.3.1.4 Ordering Information

Item	Description	P/N
190 - 1100nm BeamGage **Standard**: Beam Profiler Systems (camera and software)		
BGS-USB-SP907-OSI	BeamGage Standard software, software license, 1/1.8" format 964x724 pixel camera with 17.5mm C mount CCD recess. Comes with USB cable and 3 ND filters	SP90417
BGS-USB-SP928-OSI	BeamGage Standard software, software license, 1/1.8" format 1928x1448 pixel camera with 17.5mm C mount CCD recess. Comes with USB cable and 3 ND filters	SP90421
BGS-USB3-SP300	BeamGage Standard software, software license, 1/1.8" format 1928x1448 pixel camera with 17.5mm C mount CCD recess. Comes with USB 3.0 cable and 3 ND filters	SP90375
BGS-USB3-LT665	BeamGage Standard Edition software, software license, 1 inch format 2752x2192 pixel camera with 17.5mm C mount CCD recess. Comes with USB 3.0 cable and 3 ND filters	SP90377
190 - 1100nm BeamGage **Professional** Beam Profiler Systems (camera and software)		
BGP-USB-SP907-OSI	BeamGage Professional software, software license, 1/1.8" format 964x724 pixel camera with 17.5mm C mount CCD recess. Comes with USB cable and 3 ND filters	SP90418
BGP-USB-SP928-OSI	BeamGage Professional software, software license, 1/1.8" format 1928x1448 pixel camera with 17.5mm C mount CCD recess. Comes with USB cable and 3 ND filters	SP90422
BGP-USB3-SP300	BeamGage Professional software, software license, 1/1.8" format 1928x1448 pixel camera with 17.5mm C mount CCD recess. Comes with USB 3.0 cable and 3 ND filters	SP90376
BGP-USB3-LT665	BeamGage Professional Edition software, software license, 1 inch format 2752x2192 pixel camera with 17.5mm C mount CCD recess. Comes with USB 3.0 cable and 3 ND filters	SP90378
BGP-USB-L11059	BeamGage Professional software, software license, 35mm format 4008x2672 pixel camera. Comes with universal power supply, 5 meter USB A-B cable and 3 ND filters (1.0, 2.0 & 3.0, optimized for use in the region of 400-700nm; ND 3.0 filter is installed in the input aperture of the camera)	SP90320
1440 - 1605nm BeamGage **Standard**: Beam Profiler Systems (camera and software)		
BGS-USB-SP907-1550-OSI	BeamGage Standard software, software license, 1/1.8" format 964x724 pixel camera with 17.5mm C mount CCD recess. Phosphor coated to 1550 nm. Comes with USB cable and 3 ND filters	SP90419
BGS-USB-SP928-1550-OSI	BeamGage Standard software, software license, 1/1.8" format 1928x1448 pixel camera with 17.5mm C mount CCD recess. Phosphor coated to 1550 nm. Comes with USB cable and 3 ND filters	SP90423
BGS-USB3-LT665-1550	BeamGage Standard Edition software, software license, 1 inch format 2752x2192 pixel camera with 17.5mm C mount CCD recess. Phosphor coated 1550nm sensor. Comes with USB 3.0 cable and 3 ND filters	SP90384
1440 - 1605nm BeamGage **Professional** Beam Profiler Systems (camera and software)		
BGP-USB-SP907-1550-OSI	BeamGage Professional software, software license, 1/1.8" format 964x724 pixel camera with 17.5mm C mount CCD recess. Phosphor coated to 1550 nm. Comes with USB cable and 3 ND filters	SP90420
BGP-USB-SP928-1550-OSI	BeamGage Professional software, software license, 1/1.8" format 1928x1448 pixel camera with 17.5mm C mount CCD recess. Phosphor coated to 1550 nm. Comes with USB cable and 3 ND filters	SP90424
BGP-USB3-LT665-1550	BeamGage Professional Edition software, software license, 1 inch format 2752x2192 pixel camera with 17.5mm C mount CCD recess. Phosphor coated 1550nm sensor. Comes with USB 3.0 cable and 3 ND filters	SP90385
900 - 1700nm BeamGage **Professional** Beam Profiler Systems (camera and software)		
BGP-USB-XC130	BeamGage Professional software, software license, 320x256 pixel InGaAs camera with C mount recess. 9 to 1.7um spectral band. Comes with universal power supply, USB cable, external trigger cable and 3 ND filters (consult factory for other camera options)	SP90241

Ordering Information

Item	Description	P/N
13 - 355nm & 1.06 - 3000µm BeamGage **Professional** and windowless bezel comes with the unit, other windows available for purchase		
PY-III-HR-C-A-PRO	Pyroelectric array detector, chopped, Grade A, one Gigabit Ethernet port, BeamGage Professional GigE to USB3 adaptor, hard shipping case, 3 meter GigE cable, and power supply w/locking connector included.	SP90405
Windows for Pyrocam IIIHR		
PY-III-HR-W-BK7-1.064	Pyrocam III-HR window assembly, BK7, A/R coated for 1.064µm	SP90365
PY-III-HR-W-SI-1.05-2.5	Pyrocam III-HR window assembly, Si, A/R coated for 1.05 to 2.5µm	SP90366
PY-III-HR-W-SI-2.5-4	Pyrocam III-HR window assembly, Si, A/R coated for 2.5 to 4µm	SP90367
PY-III-HR-W-GE-3-5.5	Pyrocam III-HR window assembly, Ge, A/R coated for 3 to 5.5µm	SP90368
PY-III-HR-W-GE-10.6	Pyrocam III-HR window assembly, Ge, A/R coated for 10.6µm	SP90369
PY-III-HR-W-GE-8-12	Pyrocam III-HR window assembly, Ge, A/R coated for 8 to 12µm	SP90370
PY-III-HR-W-ZNSE-10.6	Pyrocam III-HR window assembly, ZnSe, A/R coated for 10.6µm	SP90371
PY-III-HR-W-ZNSE-2-5	Pyrocam III-HR window assembly, ZnSe, A/R coated for 2 to 5µm	SP90372
PY-III-HR-W-BaF2-Uncoated	Pyrocam III-HR window assembly,BaF2 uncoated for 193 to 10µm	SP90373
PY-III-HR-W-POLY-THZ	Pyrocam III-HR window assembly, LDPE, uncoated for Terahertz wavelengths	SP90374
PY-IV-C-A-PRO	Pyroelectric array detector, chopped, Grade A, one Gigabit Ethernet port, BeamGage Professional GigE to USB3 adaptor, hard shipping case, 3 meter GigE cable, and power supply w/locking connector included.	SP90404
PY-IV-C-MIR PRO	Pyroelectric array detector, chopped, Grade A, one Gigabit Ethernet port, BeamGage Professional GigE to USB3 adaptor, hard shipping case, 3 meter GigE cable, and power supply w/locking connector included.	SP90414
Windows for Pyrocam IV		
PY-IV-W-BK7-1.064	Pyrocam IV window assembly, BK7, A/R coated for 1.064µm	SP90301
PY-IV-W-SI-1.05-2.5	Pyrocam IV window assembly, Si, A/R coated for 1.05 to 2.5µm	SP90302
PY-IV-W-SI-2.5-4	Pyrocam IV window assembly, Si, A/R coated for 2.5 to 4µm	SP90303
PY-IV-W-GE-3-5.5	Pyrocam IV window assembly, Ge, A/R coated for 3 to 5.5µm	SP90304
PY-IV-W-GE-10.6	Pyrocam IV window assembly, Ge, A/R coated for 10.6µm	SP90305
PY-IV-W-GE-8-12	Pyrocam IV window assembly, Ge, A/R coated for 8 to 12µm	SP90306
PY-IV-W-ZNSE-10.6	Pyrocam IV window assembly, ZnSe, A/R coated for 10.6µm	SP90307
PY-IV-W-ZNSE-2-5	Pyrocam IV window assembly, ZnSe, A/R coated for 2 to 5µm	SP90308
PY-IV-W-ZNSE-UNCOATED	Pyrocam IV window assembly, ZnSe, uncoated	SP90336
PY-IV-W-POLY-THZ	Pyrocam IV window assembly, LDPE, uncoated for Terahertz wavelengths	SP90309
Software Upgrades		
BGS TO BGP UPGRADE	Upgrade BeamGage Standard Edition to Professional Edition. Requires a new camera key to activate	SP90233
Camera Accessories		
USB-Pass/Fail Cable	Output Pass/Fail signals when BeamGage is in output mode	SP90060
1100 Photodiode Trigger, Si	Optical trigger assembly which can be mounted on camera or separately to sense laser pulses and synchronize camera with pulses	SP90408
1800 Photodiode Trigger, InGaAs	Optical trigger assembly which can be mounted on camera or separately to sense laser pulses and synchronize camera with pulses	SP90409
Training		
Training	BeamGage training DVD	SP90429

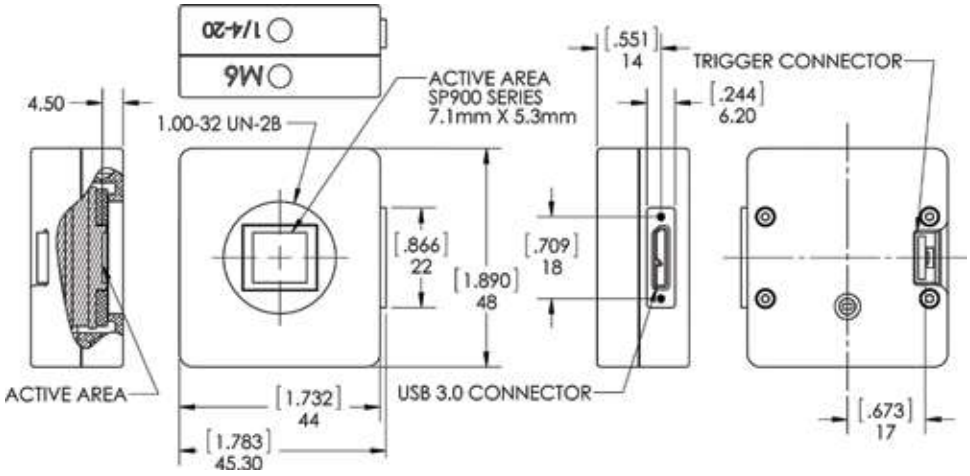
3.3.1.5 Cameras for BeamGage®

3.3.1.5.1 190-1100nm USB Silicon CCD Cameras

SP907 low resolution and SP928 high resolution

Features

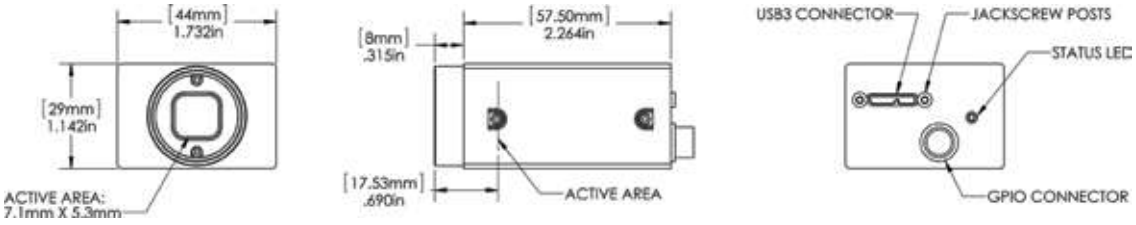
- 1/1.8 imager format
- Small camera size
- 56dB true dynamic resolution



SP300 High resolution, high speed

Features

- 1/1.8 imager format
- High resolution
- High speed
- 56dB true dynamic resolution



Item	Specification		
Model	**SP907**	**SP928**	**SP300**
Application	1/1.8" format	1/1.8" format	1/1.8" format
Spectral Response	190 - 1100nm (2)	190 - 1100nm (2)	190 - 1100nm (2)
Active Area	7.1mm x 5.3mm	7.1mm x 5.3mm	7.1mm x 5.3mm
Pixel spacing	7.38µm	3.69µm	3.69µm
Number of effective pixels	964 x 724	1928 x 1448	1928 x 1448
Minimum system dynamic range	56 dB	56 dB	56 dB
Linearity with Power	±1%	±1%	±1%
Accuracy of beam width	±2%	±2%	±2%
Frame rates in 12 bit mode (4)	23 fps at full resolution	13 fps at full resolution	26 fps at full resolution
Shutter duration	30µs to multiple frames	30µs to multiple frames	30µs to multiple frames
Gain control	0 dB to 24 dB	0 dB to 24 dB	0 dB to 24 dB
Trigger	Hardware/Software trigger & strobe out	Hardware/Software trigger & strobe out	Hardware/Software trigger & strobe out
Photodiode trigger	Si response: SP90408	Si response: SP90408	Si response: SP90408
Saturation intensity (1)	0.97µW/cm²	0.97µW/cm²	0.97µW/cm²
Lowest measurable signal (1)	1.2nW/cm²	1.2nW/cm²	1.2nW/cm²
Damage threshold	50W/cm² / 0.1J/cm² with all filters installed for < 100ns pulse width(3)		
Dimensions	48 mm x 44 mm x 20.2 mm	48 mm x 44 mm x 20.2 mm	44 mm x 29 mm x 58 mm
CCD recess	4.5 mm	4.5 mm	17.5 mm
Image quality at 1064nm	Pulsed with trigger sync - excellent Pulsed with video trigger - good CW - good	Pulsed with trigger sync - excellent Pulsed with video trigger - good CW - good	Pulsed with trigger sync - excellent Pulsed with video trigger - good CW - good
Operation mode	Interline transfer CCD	Interline transfer CCD	Double tap interline transfer CCD
Software supported	BeamGage STD or PRO	BeamGage STD or PRO	BeamGage STD or PRO
PC interface	USB 3.0	USB 3.0	USB 3.0
OS Supported	Windows 7 (64) and Windows 10		

Notes:

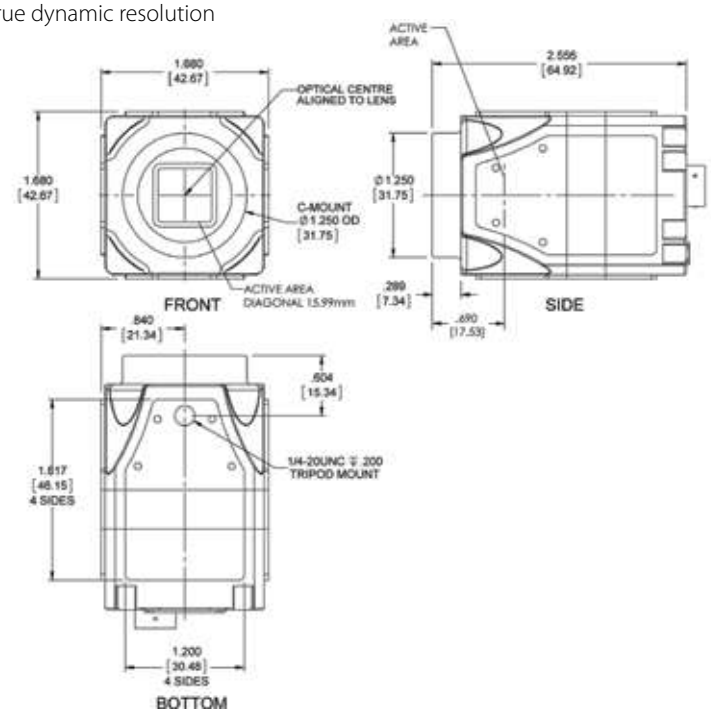
(1) Camera set to full resolution at maximum frame rate and exposure times, running CW at 632.8nm wavelength. Camera set to minimum useful gain for saturation test and maximum useful gain for lowest signal test.
(2) Camera may be useable for wavelengths below 350nm but sensitivity is low and detector deterioration may occur. Therefore UV image converter is recommended. Although our silicon cameras have shown response out to 1320nm it can cause significant blooming which could lead to significant errors of beam width measurement. We would suggest our XC130 InGaAs camera for these wavelengths to give the best measurements.
(3) This is the damage threshold of the filter glass of the filters. Assuming all filters mounted with ND1 (red housing) filter in the front. Distortion of the beam may occur with average power densities as low as 5W/cm².
(4) Highly dependent on PC processor and graphics adapter performance.

3.3.1.5.2 Large Format 190-1100nm USB Silicon CCD Cameras

LT665

Features

- Large 1" imager format
- High resolution
- High speed
- 54dB true dynamic resolution

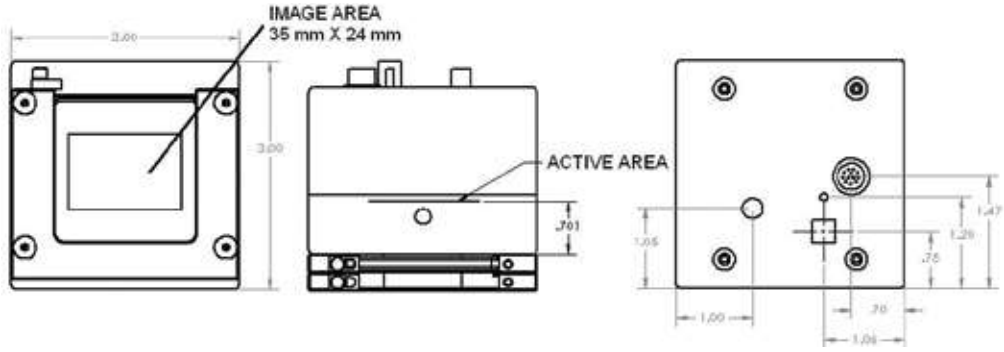


L11059

Features

- 35mm x 24mm imager format
- Highest resolution
- Programmable high speed electronic shutter
- 59bB true dynamic resolution

Comes with 3 ND filters (ND1, ND2, ND3) ND3 mounted in camera



Item	Specification	
Model	**LT665**	**L11059**
Application	1" format	35mm format
Spectral Response	190 - 1100nm (2)	190 - 1100nm (2)
Active Area	12.5mm x 10mm	35mm x 24mm
Pixel spacing	4.54µm x 4.54µm	9.0µm x 9.0µm
Number of effective pixels	2752 x 2192	4008 x 2672
Minimum system dynamic range	54 dB	59 dB
Linearity with Power	±1%	±1%
Accuracy of beam width	±2%	±2%
Frame rates in 12 bit mode (4)	27 fps at full resolution	3.1 fps at full resolution
Shutter duration	31µs to multiple frames	10µs to multiple frame
Gain control	0.8 dB to 56 dB	0.8 dB to 56 dB
Trigger	Hardware/Software trigger & strobe out	Supports both trigger & strobe out
Photodiode trigger	Si response: SP90408	Si response: SP90408
Saturation intensity (1)	1.3µW/cm²	0.15µW/cm²
Lowest measurable signal (1)	0.3nW/cm²	0.17nW/cm²
Damage threshold	50W/cm² / 0.1J/cm² with all filters installed for < 100ns pulse width(3)	0.15mW/cm²
Dimensions	43 mm x 43 mm x 65 mm	83 mm x 76 mm x 128 mm
CCD recess	17.5mm	18.8mm
Image quality at 1064nm	Pulsed with trigger sync - excellent Pulsed with video trigger - good CW - good	Pulsed with trigger sync - excellent Pulsed with video trigger - good CW - good
Operation mode	Quad Tap interline transfer CCD	
Software supported	BeamGage STD and PRO	BeamGage PRO
PC interface	USB 3.0	USB 2.0
OS Supported	Windows 7 (64) and Windows 10	

Notes:

(1) Camera set to full resolution at maximum frame rate and exposure times, running CW at 632.8nm wavelength. Camera set to minimum useful gain for saturation test and maximum useful gain for lowest signal test.

(2) Camera may be useable for wavelengths below 350nm but sensitivity is low and detector deterioration may occur. Therefore UV image converter is recommended. Although our silicon cameras have shown response out to 1320nm it can cause significant blooming which could lead to significant errors of beam width measurement. We would suggest our XC130 InGaAs camera for these wavelengths to give the best measurements.

(3) This is the damage threshold of the filter glass of the filters. Assuming all filters mounted with ND1 (red housing) filter in the front. Distortion of the beam may occur with average power densities as low as 5W/cm².

(4) Highly dependent on PC processor and graphics adapter performance.

3.3.1.5.3 1440-1605nm Phosphor Coated CCD Cameras For NIR Response

Features

- 1440-1605nm Wavelengths
- NIR Telecom mode field analysis
- NIR Laser beam analysis

Available Models

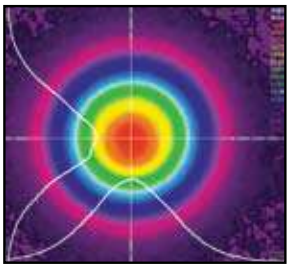
- USB models: SP907-1550
  SP928-1550
- Large Format: LT665-1550

SP907-1550
SP928-1550

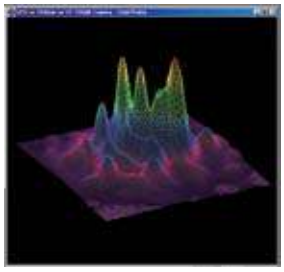
LT665-1550

Phosphor Coating Technology

The up-conversion from NIR to visible light in the 1550 series cameras is nonlinear. The anti-Stokes phosphor coating produces visible photons at a rate roughly the square of the input signal. This is shown dramatically where the camera total output increases dramatically faster than a linear output shown in the bottom line. The CCD camera saturation in the center of a beam, the up-converted visible signal drops as the square of the input signal. Thus the lower signal wings of a beam are suppressed, resulting in the appearance and measurement of a beam width much smaller than actual.

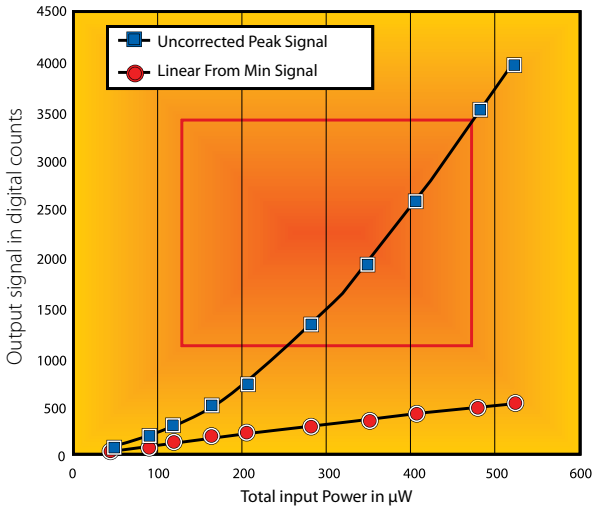


1550nm Fiber Output

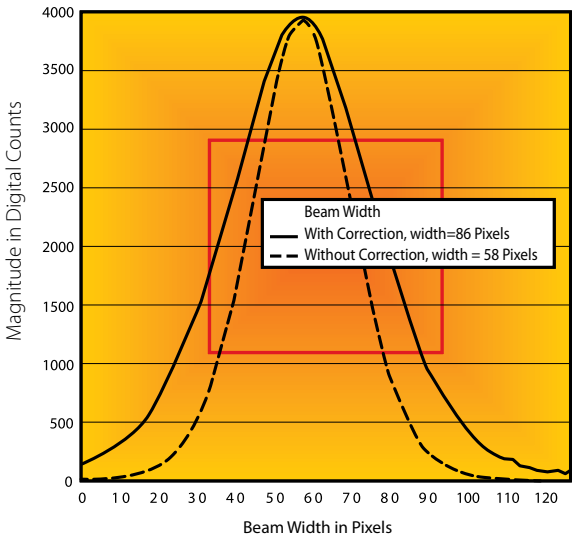


1610nm OPO Output

This illustration is a comparison of the cross-section of a beam with and without correction. As seen, the real width of the beam is much greater than would be observed without correction.



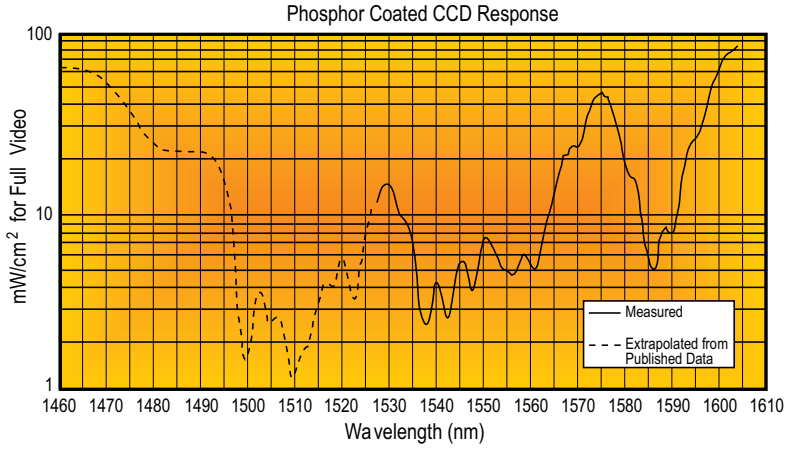
Non-Linearity of SP-1550M Camera at 1550nm



SP-1550M Camera: Comparison of Beam Shape with and without Correction Factor

Wavelength Response

The anti-Stokes up-conversion efficiency is very wavelength dependent. This graph shows the typical spectral response curve of a new, high response coating. As seen, we have calibrated the response from 1527nm to 1605nm. We have extrapolated the shorter wavelength region by comparing our measured response to data published over the entire range.

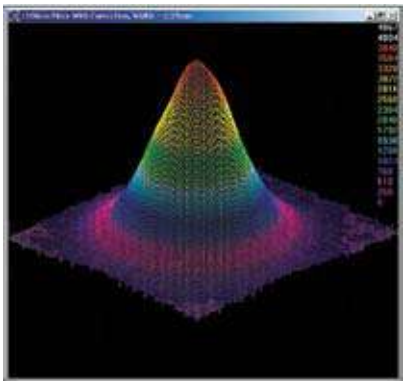


Signal required versus wavelength to achieve camera full signal illumination by anti-Stokes up conversion material.

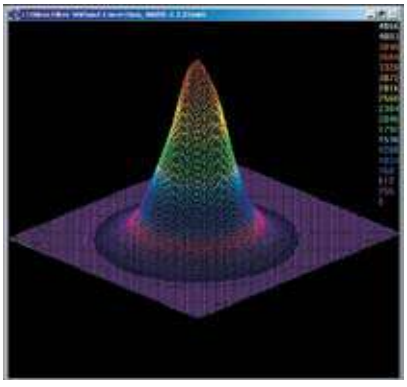
Phosphor Coated Cameras with Spiricon's BeamGage software

Spiricon's engineers have carefully measured the non-linearity of the signal generated by the Phosphor Coated series cameras. The software in the BeamGage incorporates an algorithm to correct for the non-linearity. This illustration shows the linearity obtained, showing in the top line that the low level signals drop linearly, rather than at the square of the input, seen in the lower line.

The two photos show the uncorrected and corrected camera beam shape in 3D. See the BeamGage section for additional information on the beam analyzer.



Beam profile of a fiber beam with non-linearity correction.



Beam profile of a fiber beam without non-linearity correction.

Specifications: Phosphor Coated For NIR Response

Item	Specification		
Model	**SP907-1550**	**SP928-1550**	**LT665-1550**
Application	NIR wavelengths, 1/1.8" format, low resolution	NIR wavelengths, 1/1.8" format, low resolution	NIR wavelengths, 1" format, higher resolution
Spectral Response	1440 - 1605nm	1440 - 1605nm	1440 - 1605nm
Active Area	7.1mm x 5.3mm	7.1mm x 5.3mm	12.5mm x 10mm
Pixel spacing (1)	7.38µm x 7.38µm	3.69µm x 3.69µm	4.54µm x 4.54µm
Number of effective pixels	964 x 724	1928 x 1448	2752 x 2192
Minimum system dynamic range (2)	~30 dB	~30 dB	~30 dB
Linearity with Power	±5%	±5%	±5%
Accuracy of beam width	±5%	±5%	±5%
Frame rates in 12 bit mode (3) (5)	23 fps at full resolution	13 fps at full resolution	27 fps at full resolution
Shutter duration	30µs to multiple frames	30µs to multiple frames	31µs to multiple frames
Gain control	0 dB to 24 dB	0 dB to 24 dB	0.8 dB to 56 dB
Trigger	Supports both trigger and strobe out	Supports both trigger and strobe out	Supports both trigger and strobe out
Photodiode trigger	InGaAs response: SP90409	InGaAs response: SP90409	InGaAs response: SP90409
Saturation intensity (1)	7mW/cm^2 at 1550nm		
Lowest measurable signal (1)	50µW/cm^2		
Damage threshold	50W/cm^2 / 0.1J/cm^2 with all filters installed for < 100ns pulse width (4)		
Dimensions	48mm x 44mm x 20.2mm	48mm x 44mm x 20.2mm	43mm x 43mm x 65mm
CCD recess	4.5mm	4.5mm	17.5mm
Operation mode	Interline transfer CCD	Interline transfer CCD	Quad Tap interline transfer CCD
Software supported	BeamGage STD and PRO	BeamGage STD and PRO	BeamGage STD and PRO
PC interface	USB 3.0	USB 3.0	USB 3.0

Notes:

(1) Despite the small pixel size, the spatial resolution will not exceed 50µm due to diffusion of the light by the phosphor coating.
(2) Signal to noise ratio is degraded due to the gamma of the phosphor's response. Averaging or summing of up to 256 frames improves dynamic range by up to 16x = +24 dB.
(3) In normal (non-shuttered) camera operation, the frame rate is the fastest rate at which the laser may pulse and the camera can still separate one pulse from the next. With electronic shutter operation, higher rate laser pulses can be split out by matching the laser repetition to the shutter speed.
(4) This is the damage threshold of the filter glass of the filters. Assuming all filters mounted with ND1 (red housing) filter in the front. Distortion of the beam may occur with average power densities as low as 5W/cm^2.
(5) Highly dependent on PC processor and graphics adapter performance.

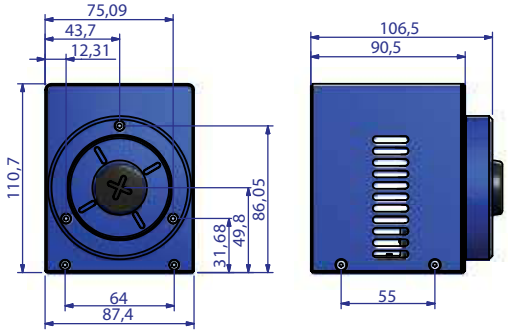
3.3.1.5.4 900-1700nm - InGaAs NIR Cameras

Models XC-130 100Hz

Features

- NIR performance at room temperature
- High resolution InGaAs array: 320x256
- 60dB true system dynamic range
- Exclusive Ultracal for ISO conforming accuracy
- Available with BeamGage software

XEVA 100Hz



USB Cameras for use with Laptop or Desktop PC

Model XEVA XC-130	Description
Application	NIR wavelengths, high resolution, ROI and binning
Spectral response	900-1700nm (consult factory for other options)
Element pitch	30µm square
Number or elements	320 x 256
Area	9.6 x 7.6mm
Lens	C-mount, (Optional)
Minimum system dynamic range	low gain 68dB, high gain 60dB
Saturation intensity	1.3 uW/cm^2 at 1550 nm
Frame rate (2)	100 Hz (1)
Non-uniformity correction	2-Point correction plus bad pixel correction, NUC files provided
Snap-shot mode	Via external TTL trigger, cable provided
Trigger	Supports both trigger and strobe out
Photodiode trigger	InGaAs response: SP90409
Exposure control	1us to 400 sec in Low Gain mode
Imager Cooling	Thermoelectric cooler plus forced convection
Ambient operating temperature	0 - 50° C
Dimensions, mm, HxWxD	111 x 87 x 107 mm
Weight, camera head	approx. 1.8 kg
Software supported	BeamGage PRO
PC interface	USB 2.0, special cable provided
Notes:	(1) The uncorrected rate, final corrected rate will be less. (2) Highly dependent on PC processor and graphics adapter performance.

3.3.1.5.5 13-355nm and 1.06-3000µm - Pyroelectric Array Camera

Pyrocam™ IIIHR & Pyrocam IV Series

Features

- Spectral ranges available from 13 to 355nm and 1.06 to >3000µm
- Image CO_2 lasers, telecom NIR lasers, THz sources and other infrared sources out to Far IR
- Solid state array camera with 1000:1 linear dynamic range for accurate profiling
- Integrated chopper for CW beams and thermal imaging
- Interchangeable windows available for a variety of applications
- Includes BeamGage® Laser Beam Analysis Software for quantitative analysis and image display

Pyrocam IIIHR

Pyrocam IIIHR Plus

Pyrocam IV

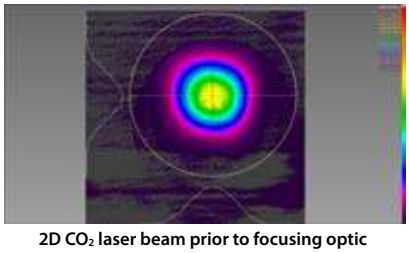
Spiricon has been the world leader in the manufacture of pyroelectric solid-state detector arrays and cameras. For over 25 years the Pyrocam has been the overwhelming camera of choice for Laser Beam Diagnostics of IR and UV lasers and high temperature thermal imaging. Precision, stability, reliability, and versatility have become its proud heritage.

The Pyrocam IIIHR offers a 1/2X1/2 inch detector array with easy Windows® camera setup and quantitative image display through the BeamGage software, 16 bit digitizer, versatile Gigabit Ethernet PC interface, and an integral chopper for CW beams and thermal imaging.

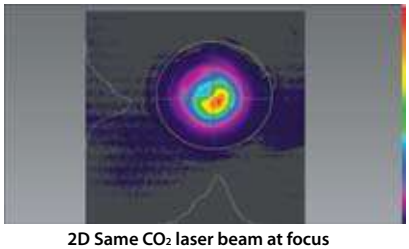
The Pyrocam IV offers a 1X1 inch detector array with easy Windows® camera setup and quantitative image display through the BeamGage software, 16 bit digitizer, with a high-speed Gigabit Ethernet PC interface, and an integral chopper for CW beams and thermal imaging.

See Your Beam As Never Before

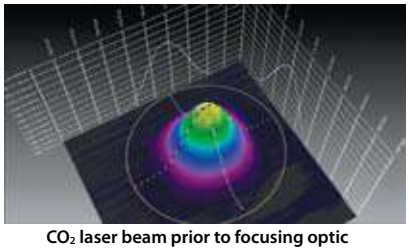
Both Pyrocam cameras create clear and illuminating images of your laser beam profile. Displayed in 2D or 3D views, you can immediately recognize beam characteristics that affect laser performance and operation. This instantly alerts you to detrimental laser variations. Instantaneous feedback enables timely correction and real-time tuning of laser parameters. For example, when an industrial shop foreman saw the CO_2 laser beam profile in Figure 1 he knew immediately why that laser was not processing materials the same as the other shop lasers, that had similar profiles shown in Figure 2.



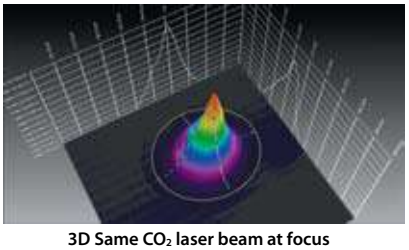
2D CO_2 laser beam prior to focusing optic



2D Same CO_2 laser beam at focus



CO_2 laser beam prior to focusing optic



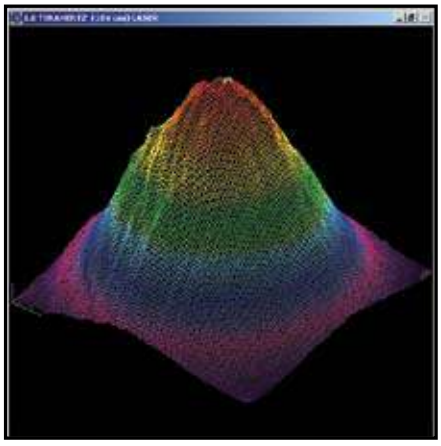
3D Same CO_2 laser beam at focus

Pulsed and CW Lasers

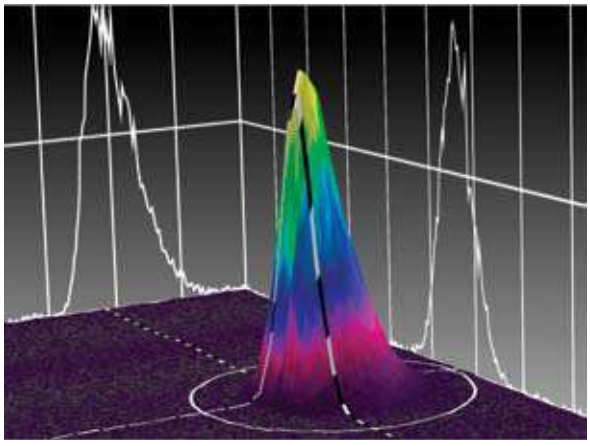
The Pyrocams measure the beam profile of both pulsed and CW lasers. Since the pyroelectric crystal is an integrating sensor, pulses from femtosecond to 12.8ms can be measured. The pyroelectric crystal only measures changes in intensity, and so is relatively immune to ambient temperature changes. Because CW laser beams must be chopped to create a changing signal, the Pyrocam contains an integral chopper.

Measuring Terahertz Beam Profiles

Spiricon's Pyrocam pyroelectric cameras are an excellent tool for measuring THz lasers and sources. The coating of the crystal absorbs all wavelengths including 1µm to over 3000µm (0.1THz to 300THz). For THz sources the sensitivity of the Pyrocam is relatively low, at about 1.5mW/cm^2 at full output. With a S/N of 1000, beams of 30mW/cm^2 are easily visible.
In addition, with Spiricon's patented Ultracal baseline setting, multiple frames can be summed to "pull" a signal out of the noise. Summing 256 frames enables viewing of beams as low as 0.5-1.0mW/cm^2.



Pyrocam III imaging THz laser beam at 0.2THz (1.55mm) 3mW input power; 19 frames summed



Pyrocam IV imaging THZ laser beam 0.5 THz (5mm) 5mW input power; single frame

Broad Wavelength Response

The Pyrocam detector array has a very broadband coating which enables operation at essentially all IR and UV laser wavelengths. The curve ends at 100nm in the UV, but X-ray operation has been observed. Likewise the curve ends at 100µm in the far IR, but the camera has been used at >3000µm.

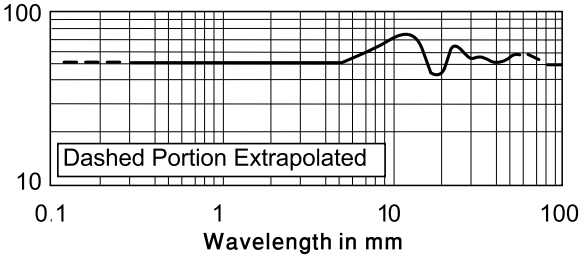
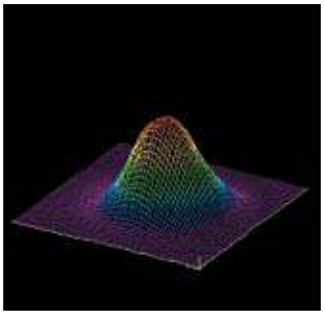
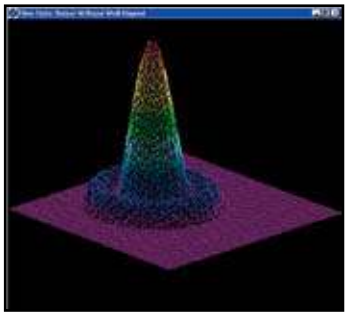


Fig. 6. Spectral response of Pyrocam™ III detector array without window.

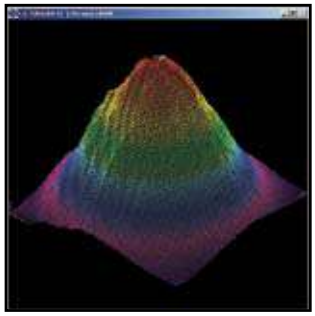
Thus you can use the Pyrocam in the near IR for Nd:YAG lasers at 1.06µm, and for infrared fiber optics at 1.3µm and 1.55µm. Use the Pyrocam for HF/DF lasers near 4µm and for Optical Parametric Oscillators from 1 µm to 10µm. It measures Free Electron Lasers between 193µm and 3000µm.



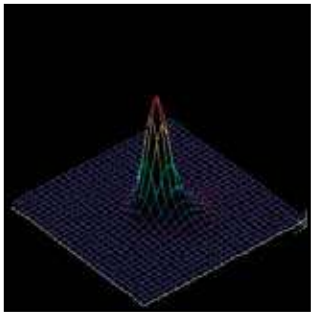
Er:YAG laser at 2.9µm.



Output of infrared fiber optic.



THz laser beam at 1.6THz (184µm).



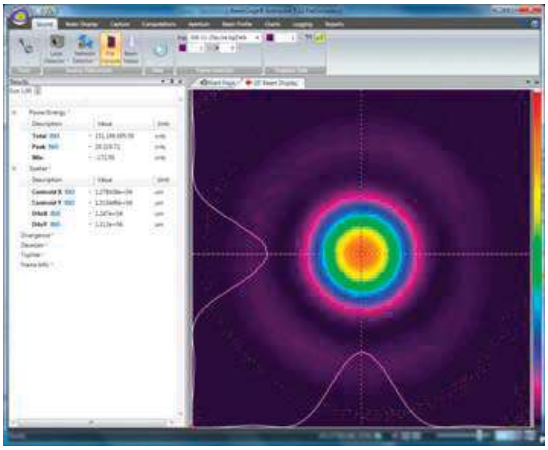
Free Electron laser at 100µm.

The Pyrocam is extremely useful in the UV from 13nm to 355nm for Excimer lasers and for tripled or quadrupled Nd:YAG lasers. The detector is stable under UV illumination, without the deterioration experienced by CCD cameras. (The pyroelectric detector operates in the visible spectrum, and can see the alignment HeNe used with CO_2 lasers. However, spurious response from the underlying silicon multiplexer creates undesirable performance, and the camera is not recommended for quantitative visible measurements).

BeamGage Image Analysis Software

Both Pyrocams come bundled with BeamGage, the state-of-the-art beam profiling system that performs rigorous data acquisition and analysis of laser beam parameters, such as beam size, shape, uniformity, divergence, mode content, and expected power distribution. Once the Pyrocam is connected to the PC and BeamGage is running, the software automatically detects the camera presence and is immediately ready to start taking images and displaying them on the monitor.

BeamGage is the industry's first beam profiling software to be newly designed, from scratch, using the most advanced tools and technologies. BeamGage is based on UltraCal™, Spiricon's patented baseline correction algorithm that helped establish the ISO 11146-3 standard for beam measurement accuracy.
BeamGage provides high accuracy results, guaranteeing the data baseline (zero-point reference) is accurate to 1/8th of a digital count on a pixel-by-pixel basis.

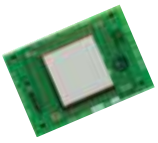


BeamGage recognizes the Pyrocam IIIHR & IV and allows you to quickly start analyzing your laser beam

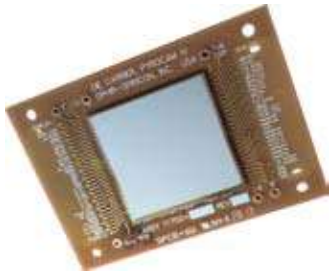
BeamGage permits the user to employ custom calculations for best fit to an individual application. These user-defined computations are treated like the standard calculations. They can be displayed on the monitor, logged with results, and included in hard-copy reports.
The system also allows the user to configure the displayed calculations, set-up the screen layout, and password-protect the configuration. This permits secure product testing, ensures security in production environments where plant floor personnel interface with the system, and assures the validity of the data for Statistical Process Control (SPC).

Hybrid Integrated Circuit Sensor

The Pyrocam consists of a $LiTa0_3$ pyroelectric crystal mounted with indium bumps to a solid-state readout multiplexer. This sensor, developed as the Company's core technology for the Pyrocam I, has proven to be the most rugged, stable, and precise IR detector array available. Light impinging on the pyroelectric crystal is absorbed and converted to heat, which creates charge on the surface. The multiplexer then reads out this charge. For use with short laser pulses, the firmware in the camera creates a very short electronic shutter to accurately capture the thermally generated signal.



Pyrocam™ IIIHR 12.8X12.8mm array



Pyrocam IV 25mm X 25mm array

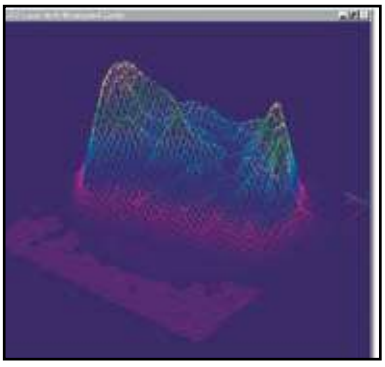
State-Of-The-Art Electronics

The camera features a high resolution A/D converter which digitizes deep into the camera noise. This enables reliable measurement and analysis of both large signals and low level signals in the wings of the laser beam. High resolution digitizing also enables accurate signal summing and averaging to pull weak signals out of noise. This is especially useful with fiber optics at 1.3µm and 1.55µm, and in thermal imaging.

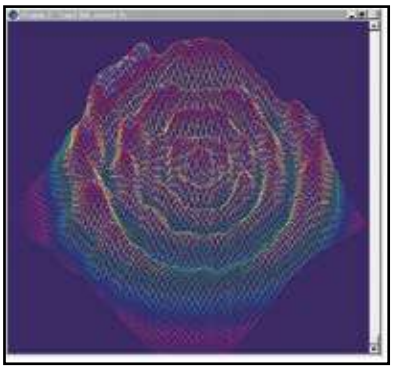
Applications Of The Pyrocam™ IIIHR

The Pyrocam is an ideal camera for use in scientific laboratory investigation of laser beams. This includes physics, chemistry, and electronic system designs. As an example, the photos below show a research CO_2 laser and a research Nd:YAG laser, both with cavity misalignment. The camera is also useful in product engineering of CO_2 and other infrared lasers. The Pyrocam is an integral part of the assembly lines of many CO_2 laser manufacturers. Integrators of systems are using the Pyrocam sensor to make sure that optical systems are aligned and operating properly.

There are many medical applications of the Pyrocam, such as the analysis of excimer lasers used for eye surgery. In many cases these lasers need alignment to ensure that the eye surgery is performed as expected. Other medical IR lasers perform dermatology, for which the uniformity of the beam profile must be assured.



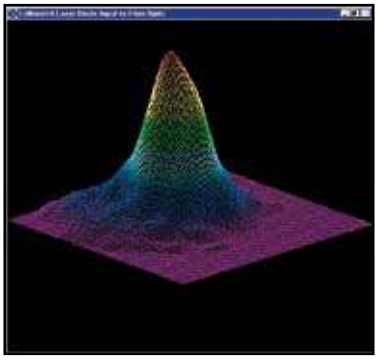
CO_2 laser with cavity misalignment.



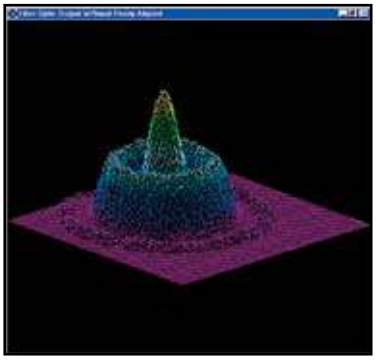
Nd:YAG laser with cavity misalignment.

Fiber optic communications, at 1.3µm and 1.55µm make significant use of the Pyrocam for analyzing the beams being emitted, as well as analyzing properties of the beams before launching them into fibers. The greater stability of the Pyrocam make it a good choice over other cameras operating at telecommunication wavelengths.

The Pyrocam is becoming an essential tool in the maintenance of industrial infrared lasers, especially CO_2. The Pyrocam replaces non-electronic mode burns and acrylic blocks by providing higher definition electronic recording of data, and analysis of short term fluctuations. The Pyrocam is superior to other electronic methods of measuring CO_2 lasers because the entire beam can be measured in a single pulse, and additional measurements made in real-time. This ensures that the beam did not change during the measurement.



CO_2 laser with cavity misalignment.



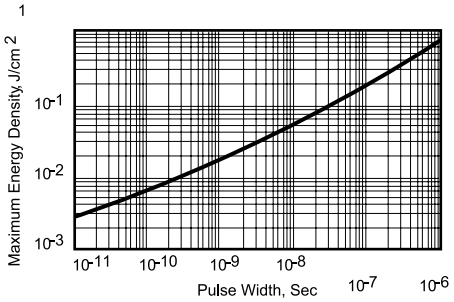
Nd:YAG laser with cavity misalignment.

Detector Damage Threshold

The Pyrocam sensor is capable of operation with intensities about 100 times greater than CCD cameras. This makes the camera ideal for use with high power lasers, as less attenuation is required. Nevertheless, pulsed lasers with fluence too high can evaporate the absorbing front electrode.

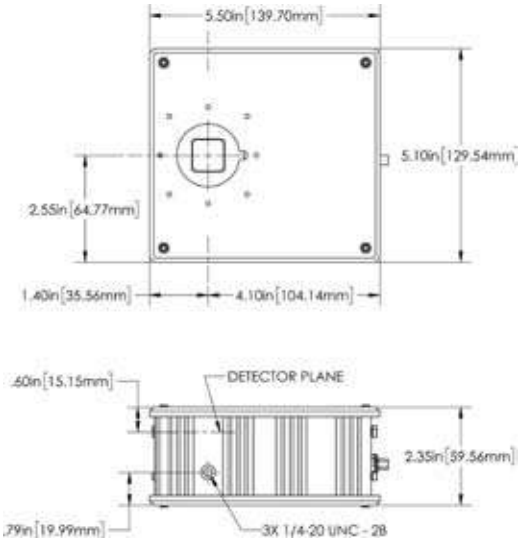
As shown the damage threshold increases with pulse width. With nanosecond and longer pulses, detector saturation occurs before damage.
With shorter pulses it helps to increase the camera amplifier gain so that electronic saturation occurs before damage.

The sensor can be damaged by excessive CW power, which causes crystal cracking. Very few Pyrocam detectors have been damaged by CW power, but some have been ablated by high peak pulse energy.

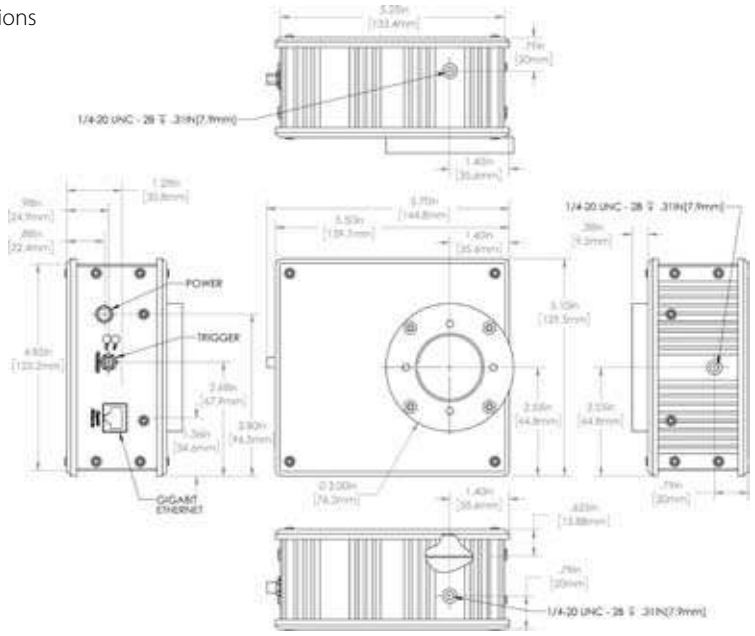


Pulsed damage threshold of pyroelectric detector coating.

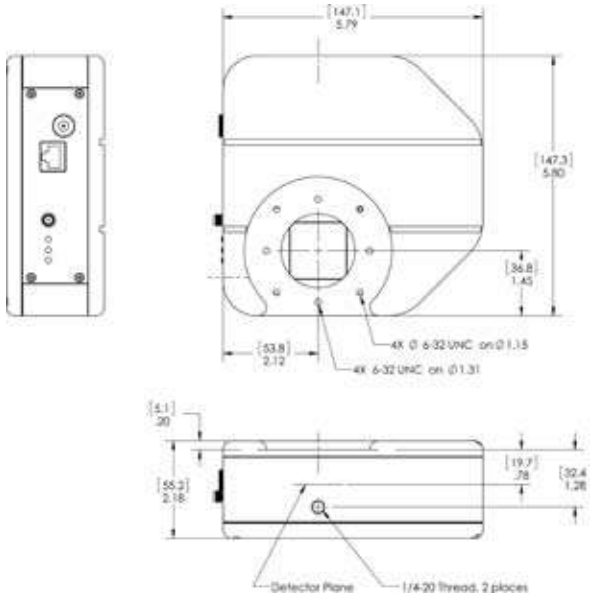
Pyrocam IIIHR Dimensions



Pyrocam IIIHR Plus Dimensions



Pyrocam IV Dimensions



Specifications

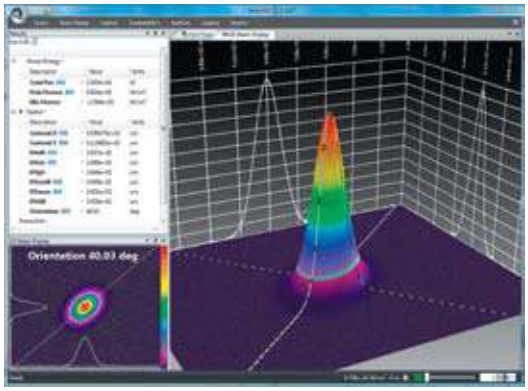
	Pyrocam IIIHR		Pyrocam IIIHR Plus	Pyrocam IV	
Application	UV and IR	MIR [1]	UV and IR	UV and IR	MIR [1]
Spectral response	13 - 355nm	3 - 5µm	13 - 355nm	13 - 355nm	3 - 5µm
	1.06 - 3000µm		1.06 - 3000µm	1.06 - 3000µm	
Interchangeable windows	See selection in Ordering section		See selection in Ordering section	See selection in Ordering section	
Detector array details					
Active area	12.8mm x 12.8mm		12.8mm x 12.8mm	25.6mm x 25.6mm	
Element spacing	80µm x 80µm		80µm x 80µm	80µm x 80µm	
Number of elements	160 x 160		160 x 160	320 x 320	
Pixel size	75µm x 75µm		75µm x 75µm	75µm x 75µm	
CHOPPED CW OPERATION					
Chopping frequencies	25Hz, 50Hz		25Hz, 50Hz	25Hz, 50Hz	
Sensitivity (RMS noise limit)	64nW/pixel (25Hz)		64nW/pixel (25Hz)	64nW/pixel (25Hz)	
	96nW/pixel (50Hz)		96nW/pixel (50Hz)	96nW/pixel (50Hz)	
	1.0mW/cm^2 (25Hz)		1.0mW/cm^2 (25Hz)	1.0mW/cm^2 (25Hz)	
	1.5mW/cm^2 (50Hz)		1.5mW/cm^2 (50Hz)	1.5mW/cm^2 (50Hz)	
Noise equivalent power (NEP)	13nW/Hz$^{1/2}$/pixel (1Hz)		13nW/Hz$^{1/2}$/pixel (1Hz)	13nW/Hz$^{1/2}$/pixel (1Hz)	
Saturation power	3.0W/cm^2(25Hz)		3.0W/cm^2(25Hz)	3.0W/cm^2(25Hz)	
	4.5W/cm^2 (50Hz)		4.5W/cm^2 (50Hz)	4.5W/cm^2 (50Hz)	
Damage threshold power					
Over entire array	2W		2W	2W	
Peak Power Density	8W/CM^2 (Chopped mode)		8W/CM^2 (Chopped mode)	8W/CM^2 (Chopped mode)	
	4W/CM^2 (CW in pulsed mode)		4W/CM^2 (CW in pulsed mode)	4W/CM^2 (CW in pulsed mode)	
PULSED OPERATION					
Laser pulse rate	Single-shot to 1000Hz		Single-shot to 1000Hz	Single-shot to 1000Hz	
Pulse width	1fs - 12.8ms		1fs - 12.8ms	1fs - 12.8ms	
Sensitivity (peak noise limit)	0.5nJ/pixel		0.5nJ/pixel	0.5nJ/pixel	
	8µJ/cm^2		8µJ/cm^2	8µJ/cm^2	
Saturation energy	15mJ/cm^2		15mJ/cm^2	15mJ/cm^2	
Damage threshold	20mJ/cm^2 (1ns pulse)		20mJ/cm^2 (1ns pulse)	20mJ/cm^2 (1ns pulse)	
	600mJ/cm^2 (1 ms pulse)		600mJ/cm^2 (1 ms pulse)	600mJ/cm^2 (1 ms pulse)	
Trigger input					
High logic level	3.5 - 6.0V DC		3.5 - 6.0V DC	3.5 - 6.0V DC	
Low logic level	0 - 0.8V DC		0 - 0.8V DC	0 - 0.8V DC	
Pulse width	4µs min		4µs min	4µs min	
Trigger	Supports both trigger and strobe out		Supports both trigger and strobe out	Supports both trigger and strobe out	
Photodiode trigger	InGaAs response: SP90409		InGaAs response: SP90409	InGaAs response: SP90409	
OPERATING CONNECTIONS AND CONDITIONS					
Power	12VDC		12VDC	12VDC	
Line frequency	60/50Hz External Supply		60/50Hz External Supply	60/50Hz External Supply	
Power consumption	12W		12W	12W	
Operating temperature	5°C to 50°C		5°C to 50°C	5°C to 50°C	
PHYSICAL					
Case Dimensions	140mm H X 130mm W X 60mm D		140mm H X 130mm W X 70mm D	147.3mm H X 147.1mm W X 55.2mm D	
Detector Position	Centered in width 35.6mm from bottom 15.43 ± .75mm behind front cover (without included C-mount attached) Tilt <2°		Centered in width 35.6mm from bottom 15.43 ± .75mm behind front cover (without included telescope attachment) Tilt <2°	53.8mm from bottom left 36.8mm from bottom 19.7 ± .75mm behind front cover Tilt <2°	
Weight	0.85Kg (1.83lbs); not including power supply		0.85Kg (1.83lbs); not including power supply	1.2kg (2.65lbs); not including power supply	
PC interface	Gigabit Ethernet (IEEE 802.3ab), GigE Vision compliant		Gigabit Ethernet (IEEE 802.3ab), GigE Vision compliant	Gigabit Ethernet (IEEE 802.3ab), GigE Vision compliant	
MEASUREMENTS PERFORMED					
Comes with BeamGage PRO	Extensive set of quantitative and image display capabilities. See BeamGage data sheet.		Extensive set of quantitative and image display capabilities. See BeamGage data sheet.	Extensive set of quantitative and image display capabilities. See BeamGage data sheet.	
Array Quality					
	Grade A <50 bad pixels, all correctable No uncorrectable clusters		Grade A <50 bad pixels, all correctable No uncorrectable clusters	Grade A <300 bad pixels, all correctable No uncorrectable clusters	

[1] The MIR (Mid-IR) versions on the Pyrocam IIIHR and IV are designed specifically for Mid-IR lasers in the spectral range 3 to 5µm.
The MIR versions feature specifically designed sensors that maximize the optical signal for high fidelity spatial profile measurements of laser beam in the 3 to 5µm spectral range.

Ordering Information

Item	Description	P/N
13 - 355nm & 1.06 - 3000µm BeamGage **Professional** a windowless bezel comes with the unit, other windows available for purchase		
PY-III-HR-C-A-PRO	Pyroelectric array detector, chopped, Grade A, one Gigabit Ethernet port, BeamGage Professional, GigE to USB3 adaptor, hard shipping case, 3 meter GigE cable, and power supply w/locking connector included.	SP90405
PY-III-HR-C-MIR-PRO	Pyroelectric array detector, chopped, Grade A, one Gigabit Ethernet port, BeamGage Professional, GigE to USB3 adaptor, hard shipping case, 3 meter GigE cable, and power supply w/locking connector included.	SP90415
PY-III-HR-C-A-PLUS	Pyroelectric array detector, chopped, Grade A, one Gigabit Ethernet port, BeamGage Professional, GigE to USB3 adaptor, hard shipping case, 3 meter GigE cable, and power supply w/locking connector included. Comes with telescopic adaptor mounted to front case.	SP90448
Optional windows for Pyrocam IIIHR		
PY-III-HR-W-BK7-1.064	Pyrocam III-HR window assembly, BK7, A/R coated for 1.064µm	SP90365
PY-III-HR-W-SI-1.05-2.5	Pyrocam III-HR window assembly, Si, A/R coated for 1.05 to 2.5µm	SP90366
PY-III-HR-W-SI-2.5-4	Pyrocam III-HR window assembly, Si, A/R coated for 2.5 to 4µm	SP90367
PY-III-HR-W-GE-3-5.5	Pyrocam III-HR window assembly, Ge, A/R coated for 3 to 5.5µm	SP90368
PY-III-HR-W-GE-10.6	Pyrocam III-HR window assembly, Ge, A/R coated for 10.6µm	SP90369
PY-III-HR-W-GE-8-12	Pyrocam III-HR window assembly, Ge, A/R coated for 8 to 12µm	SP90370
PY-III-HR-W-ZNSE-10.6	Pyrocam III-HR window assembly, ZnSe, A/R coated for 10.6µm	SP90371
PY-III-HR-W-ZNSE-10.2µm & 10.6µm	Pyrocam III-HR window assembly, ZnSe, A/R coated for 10.2µm & 10.6µm	SP90412
PY-III-HR-W-ZNSE-2-5	Pyrocam III-HR window assembly, ZnSe, A/R coated for 2 to 5µm	SP90372
PY-III-HR-W-BaF2-Uncoated	Pyrocam III-HR window assembly,BaF2 uncoated for 193 to 10µm	SP90373
PY-III-HR-W-POLY-THZ	Pyrocam III-HR window assembly, LDPE, uncoated for Terahertz wavelengths	SP90374
PY-IV-C-A-PRO	Pyroelectric array detector, chopped, Grade A, one Gigabit Ethernet port, BeamGage Professional, GigE to USB3 adaptor, hard shipping case, 3 meter GigE cable, and power supply w/locking connector included.	SP90404
PY-IV-C-MIR-PRO	Pyroelectric array detector, chopped, Grade A, one Gigabit Ethernet port, BeamGage Professional, GigE to USB3 adaptor, hard shipping case, 3 meter GigE cable, and power supply w/locking connector included.	SP90414
Optional windows for Pyrocam IV		
PY-IV-W-BK7-1.064	Pyrocam IV window assembly, BK7, A/R coated for 1.064µm	SP90301
PY-IV-W-SI-1.05-2.5	Pyrocam IV window assembly, Si, A/R coated for 1.05 to 2.5µm	SP90302
PY-IV-W-SI-2.5-4	Pyrocam IV window assembly, Si, A/R coated for 2.5 to 4µm	SP90303
PY-IV-W-GE-3-5.5	Pyrocam IV window assembly, Ge, A/R coated for 3 to 5.5µm	SP90304
PY-IV-W-GE-10.6	Pyrocam IV window assembly, Ge, A/R coated for 10.6µm	SP90305
PY-IV-W-GE-8-12	Pyrocam IV window assembly, Ge, A/R coated for 8 to 12µm	SP90306
PY-IV-W-ZNSE-10.6	Pyrocam IV window assembly, ZnSe, A/R coated for 10.6µm	SP90307
PY-IV-W -ZNSE-2-5	Pyrocam IV window assembly, ZnSe, A/R coated for 2 to 5µm	SP90308
PY-IV-W-ZNSE-UNCOATED	Pyrocam IV window assembly, ZnSe, uncoated	SP90336
PY-IV-W-POLY-THZ	Pyrocam IV window assembly, LDPE, uncoated for Terahertz wavelengths	SP90309
Options		
BSQ-PY-M	Pyrocam license for Manual BeamSquared	SP90410

3.3.2 BeamMic™ – Basic Laser Beam Analyzer System

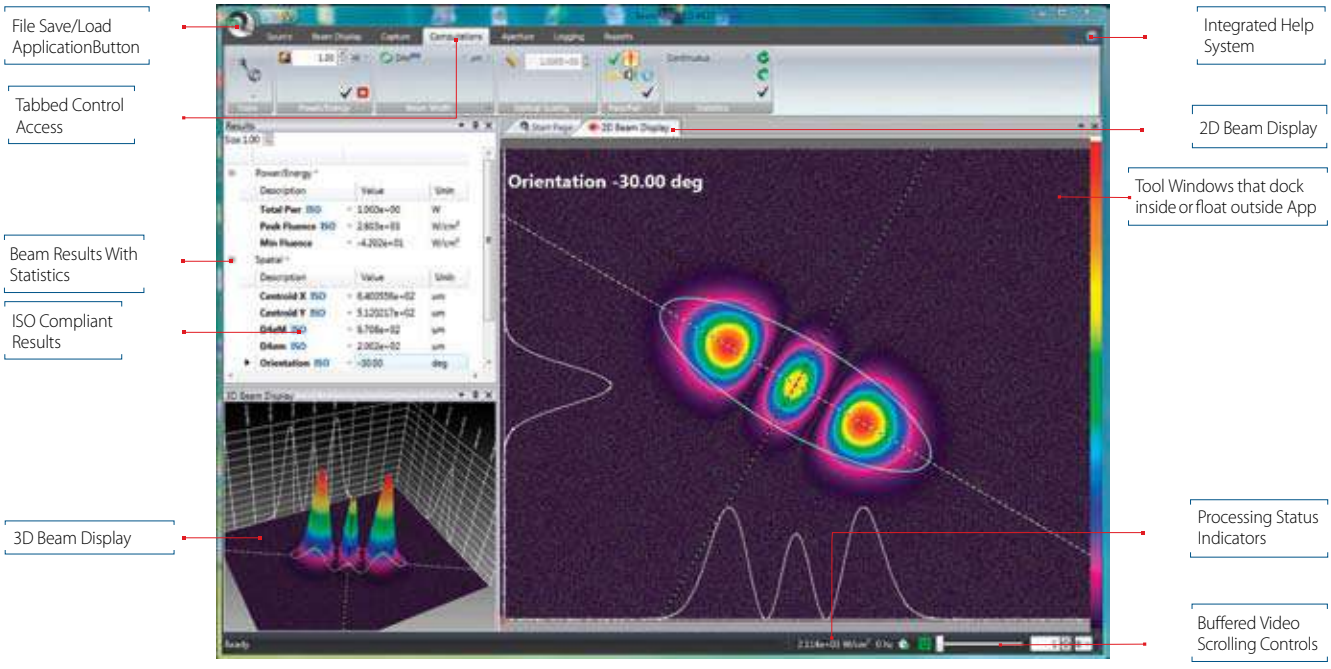


- High-speed false color beam intensity profile displays in both 2D and 3D
- Operates in Windows 7 and Windows 10
- Numerical beam profile analysis employs patented advanced calibration algorithms
- Extensive set of ISO quantitative measurements
- ISO beam width and diameter methods
- Enhanced window layout tools to get the most out of the desktopdisplay area
- Pass/fail testing available on most all measured parameters
- Support for USB SPxxx series cameras
- Supports satellite windows on multiple monitors
- Continuous zoom scaling in both 2D and 3D
- Results logging capabilities exportable to Excel
- Industry std data file formats, HDF5 and CSV
- Configurable Report Generator that allows cut and paste of results, images and settings from .PDF and .XPS file types
- Statistical Analysis of all measured parameters
- Both Drawn and Auto Aperture for isolating beam data
- Integrated automatic Help linked into this .pdf Users Guide
- Automation interface via .NET components

BeamMic is an introductory product for those that do not need all of the features in our award winning beam profiling product, BeamGage. BeamMic includes a simplified set of measurements allowing for basic beam characterization to help improve your system performance without going to a full-featured SPC type system. This is perfect for the operator to do a quick check on the laser system prior to starting their process. BeamMic meets many of our industrial customer's basic needs at a cost effective price.

The beam's size, shape, uniformity or approximation to the expected power distribution, can make or break an application. Accurate knowledge of these parameters is essential to the accuracy of any laser-based application. As laser applications push the boundaries of laser performance it is becoming more critical to understand the operating criteria.

BeamMic Main Display Screen



Camera Compatibility

For lasers between 190-1100nm wavelengths, BeamMic interfaces to silicon CCD USB cameras. For applications between 1440-1605nm, BeamMic supports cost effective phosphor coated CCD cameras.

190-1100nm

Model	SP907	SP928
Spectral Response nm	190 - 1100nm*	190 - 1100nm*
Application	1/1.8" format, slim profile, wide dynamic range, CW & pulsed lasers, adjustable ROI	1/1.8" format, high resolution, wide dynamic range, CW & pulsed lasers, adjustable ROI
Number of Elements	964 x 724	1928 x 1448
Interface Style	USB 3.0	USB 3.0
Windows OS Support	Windows 7 and Windows 10	

* May be useable for wavelengths below 350nm but sensitivity is low and detector deterioration may occur. Therefore UV image converter is recommended. Although our silicon cameras have shown response out to 1320nm it can cause significant blooming which could lead to errors of beam width measurement. We would suggest our XC130 InGaAs camera and BeamGage for these wavelengths to give you the best measurements.

1440-1605nm

Model	SP907-1550	SP928-1550
Spectral Response nm	1440 - 1605nm	1440 - 1605nm
Application	NIR wavelengths, 1/1.8" format, low resolution, adjustable ROI and binning	NIR wavelengths, 1/1.8" format, low resolution, adjustable ROI and binning
Number of Elements	964 x 724	1928 x 1448
Interface Style	USB 3.0	USB 3.0
Windows OS Support	Windows 7 and Windows 10	

** Despite the small pixel size, the spatial resolution will not exceed 50µm due to diversion of the light by the phosphor coating.

3.3.2.1 Software Specifications

Features	BeamMic - Laser Beam Analyzer Software
Features Overview	Designed for entry level or basic profiling needs
	Supports our patented Ultracal algorithm plus Auto-setup and Auto-exposure capabilities
	Extensive set of ISO quantitative measurements
	Support for high and low resolution USB cameras
	Simultaneous 2D and 3D displays
	Multi-instance, multi-camera use
	Supports Satellite windows on multiple monitors
	Continuous zoom scaling in both 2D and 3D
	Camera ROI support
	Manual and Auto-aperturing to reduce background effects
	Pass/Fail on all results items, w/multiple alarm options
	Results logging capabilities in a reloadable
	Industry standard data file format
	Configurable Report Generator that allows cut and paste of results, images and settings.
	Supports English, German, Japanese and Chinese Windows OS in 64bit . Multilingual GUI in English, Japanese and Chinese.
Quantitative Calculations; Basic Results	(per ISO 11145, 11146-1/-3, and 13694)
Power/Energy Results	Total power or energy
	Peak power/energy density
	Min. Fluence
Spatial Results	Peak and Centroid locations
	Beam width
	▪ Second Moment (D4s)
	▪ Knife Edge 90/10
	▪ Knife Edge (User selectable level)
	▪ Percent of Peak (User selectable)
	▪ Percent of Total Energy (User selectable)
	▪ Encircled power smallest slit @ 95.4
	▪ Moving Slit (User Selectable)
	Beam diameter
	▪ Average diameter (based on x/y widths)
	▪ Second Moment (D4s)
	Elliptical Results
	▪ Elliptical orientation
	▪ Ellipticity
	▪ Eccentricity
2D Features	Continuously zoomable and resizable displays in satellitable window
	Continuous Z axis display magnitude scaling
	Zoomable to subpixel resolution for origin and cursor placements
	Pixel boundaries delinated at higher zoom magnifications
	Adjustable Cursors that can track peak or centroid
	Adjustable manual apertures
	Viewable Auto-aperture placement
	Displayed beam width marker
	Integrated Mouse actuated pan/zoom controls
	Manual or fixed origin placement
3D Features	3D graphics utilize solid surface construction with lighting and shading effects
	Integrated Mouse actuated pan/zoom/tilt/rotate controls
	Selectable Mesh for drawing speed vs resolution control
	Continuously zoomable and resizable displays in satellitable window
	Continuous Z axis display magnitude scaling
	User enabled backplanes with cursor projections
Statistical Analysis	Performed on all measurement functions with on-screen display
	▪ Choices of intervals
	▪ Manual start/stop
	▪ Time from 1 second to 1000 hours
	▪ Frames from 2 to 99,999
	Measurements reported
	▪ Current frame data, Mean, Standard Deviation, Minimum, Maximum of each calculation performed

Features	BeamMic - Laser Beam Analyzer Software
File types	Industry Standard HDF5 data and setup file format which are compatible in third party applications such as MatLab and Mathmatica
	Math program and Excel compatible ASCII-csv results files
	Graphics in jpg file format
	A user defined single file output that can contain settings, beam displays, beam profiles, results in either .pdf or .xps file formats
Printing	Images, reports, results, statistics and setup information
	Option to print many frames in a single operation
	WYSIWYG images
Pass/Fail	Set Maximum/Minimum limits on all calculations and statistics
	Red/Green font color indication on result items
	Multiple choices for indication of failed parameters, including TTL pulse for external alarm
	Master pass/fail which triggers alarm on any failure
	USB signal, beep, stop, and log alarm options
Logging	
	Results in ASCII-csv
	Continuous Logging
	Time Interval Logging
	Frame Count Logging
	Pass/Fail Sampling
Exporting	Convert frame buffer data to third party format
	Export a user specified number of frames from the buffer
	Export Image Data: ASCII-cvs
	Export Results: ASCII-csv
	Export Picture: jpg, gif, tiff, bmp, png file formats supported
	Export Image Data in Aperture
Integrated Help	PDF Operators Manual
	Context Sensitive (Whats this?) Help
	Context Sensitive Hints
Signal Conditioning for Enhanced Accuracy	Spiricon's patented Ultracal enables more accurate beam measurement and display. Ultracal takes a multi- frame average of the baseline offset of each individual pixel to obtain a baseline accurate to approximately 1/8 of a digital count. This baseline offset is subtracted from each frame, pixel by pixel, to obtain a baseline correction accurate to 1/8 digital count. Spiricon's Ultracal method retains numbers less than zero that result from noise when the baseline is subtracted. Retaining fractional and negative numbers in the processed signal can increase the beam width measurement accuracy by up to 10X over conventional baseline subtraction and clip level methods. Spiricon's Ultracal conforms to the best method described in ISO 11146-3:2004
Frame Averaging	Up to 256 frames can be averaged for a signal-to-noise ratio, S/N, improvement of up to 16X (Noise is averaged up to 1/256th [8 fractional bits]). Data is processed and stored in a 32bit format
Frame Summing	Up to 256 frames can be summed to pull very weak signals out of the noise. Due to the precise nature of Ultracal baseline setting, (i.e., a retention of both positive and negative noise components) summing of frames can be performed without generating a large offset in the baseline
Convolution (Adjacent Pixel Averaging)	Choice of 5 convolution algorithms for spatial filtering for both display and calculations. Spatial filtering improves the visual S/N
Camera Features	Camera features are governed by the capabilities of the various cameras that will interface with these software products, and second by which of these camera features are implimented in the software. This section will describe typical camera features supported in the application
	Black Level Control (used by Ultracal and Auto-X and Auto-setup)
	Gain Control (used by Auto-X and Auto-setup)
	Exposure Control (used by Auto-X and Auto-setup)
	Pixel Sampling
	Bits per pixel setting
	External Trigger Input
	Trigger Delay
	Strobe Output
	Strobe Delay
	External Trigger Probe
	Internal Trigger Probe
Camera related features in the applications	These are features related to but not generally dependent upon the camera design
	Gamma Correction
	Gain Correction
	Bad Pixel Correction
	Lens Applied Option
	Pixel scale settings
	Magnification settings
	Frame buffer settings
	Ultracal
	Enable Auto-X (auto exposure control)
	Perform an Auto-Setup
	8 & 12 bits per pixel
	Select Format
	Measure S/N ratio

Features	BeamMic - Laser Beam Analyzer Software
Trigger, Capture and Synchronization Methods	Capture methods are features related to the application while Synchronization methods relate more to the abilities of the specific camera. NOTE: Frame capture rates are determined by many factors and are not guaranteed for any specific operating configuration.
	Trigger modes
	▪ CW - captures continuously, see Capture Options below
	▪ Trigger-In from laser: Trigger pulses supplied to the camera
	▪ Strobe-Out to laser: Strobe pulses output from the camera
	▪ Video Trigger: Frame captured and displayed only when the camera sees a signal greater than a user set level
	Capture options
	▪ Capture options are redefined and are approached in a different manner than older products. The items listed below will allow for all of the previous methods but with more flexibility than ever before
	▪ Results Priority: Results priority will slow the capture rate to be in sync with the computational results and display updates
	▪ Frame Priority: Frame priority will slow results and display updating to insure that frames are collected and stored in the frame buffer as fast as possible (replaces block mode)
	▪ Stop After: Will collect a set number of frames and then stop (replaces Single-Shot mode)
	▪ Periodic: Will collect frame at a programmed periodic rate
	▪ Periodic Burst: Will collect frames in a Burst at programmed periodic rates
	Post processing is still available but is done via a different mechanism and is limited to only data file sources
Automation Interface (.NET)	Automation Interface with examples in LabVIEW, Excel and Net VB
	Automate launch and termination of the application
	Automate start, stop, Ultracal, Auto-X and Auto Setup
	Automate the loading of application setups
	Automate control of most camera settings
	Automate a subset of the application features and controls
	Automate the capture of Binary Video Data
	Automate the acquisition of application results
	Automate the acquisition of application Images
System Requirements	PC computer running Windows 7 and Windows 10 Laptop or Desktop.
	GHz Pentium style processor, dual core recommended
	Minimum 2GB RAM
	Accelerated Graphics Processor Hard drive space suitable to hold the amount of video data you expect to store (50-100 GB recommended)
	Windows 7 (64) and Windows 10

3.3.2.2 Ordering Information

Item	Description	P/N
BeamMic USB2 Beam Analyzer Systems (camera and software)		
BM-USB-SP907-OSI	BeamMic software, software license, 1/1.8" format 964X724 pixel camera with 4.5mm CCD recess. Comes with USB cable and 3 ND filters	SP90425
BM-USB-SP907-1550-OSI	BeamMic software, software license, 1/1.8" format 964X724 pixel camera with 4.5mm CCD recess. Phosphor coated to 1550 nm. Comes with USB cable and 3 ND filters	SP90426
BM-USB-SP928-OSI	BeamMic software, software license, 1/1.8" format 1928X1448 pixel camera with 4.5mm CCD recess. Comes with USB and cable and 3 ND filters	SP90427
BM-USB-SP928-1550-OSI	BeamMic software, software license, 1/1.8" format 1928X1448 pixel camera with 4.5mm CCD recess. Phosphor coated to 1550 nm. Comes with USB and cable, 3 ND filters	SP90428
Software Upgrades		
BeamMic to BGS Upgrade	Upgrade BeamMic to BeamGage Standard Edition. Requires a camera key to activate. (SP cameras may require a firmware upgrade to enable ROI features)	SP90219
BeamMic to BGP Upgrade	Upgrade BeamMic to BeamGage Professional Edition. Requires a camera key to activate (SP cameras may require a firmware upgrade to enable ROI features)	SP90229
Optical Synch for Pulsed Lasers		
Photodiode Trigger, Si, 1100	Optical trigger assembly which can be mounted on camera or separately to sense laser pulses and synchronize SP cameras with pulses. See optical trigger data sheet	SP90408
Recommended Optional		
LBS-300s-BB	Dual beam splitters and configurable 9 ND filters for 190-1550nm; screws onto front of camera	SP90467

3.3.3 Focal Spot Analyzer

Measure how focal distance shifts with power

- Image focal spots down to 25µm in size
- For laser powers up to 400W (additional external ND filters required)
- Can measure systems with focal length as short as 73mm (exact path length distance within the assembly will be NIST calibrated and includes a calibration certificate +/-50µm)
- Produces undistorted sample of laser under test
- Adjustable attenuation maximizes system dynamic range
- Up to 1 x 10^{-10} attenuation available (without external filters)
- Analyzer includes camera, attenuation, BeamGage software and calibration certificate

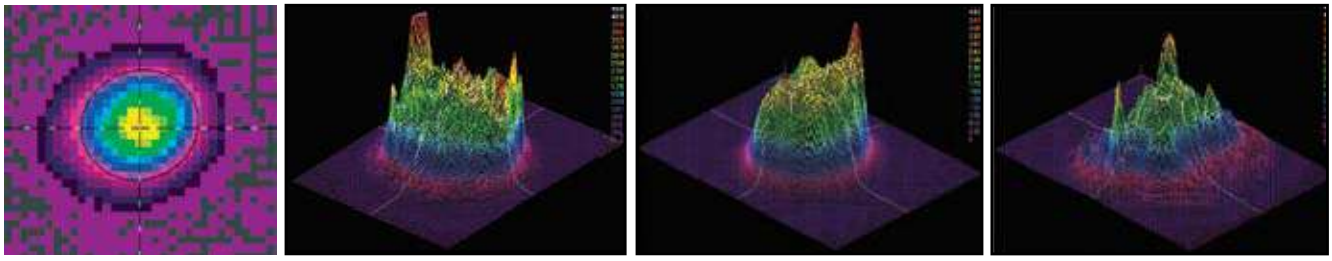
Measure your laser beam power distribution and focal spot size of wavelengths from 266 – 1100nm. The average power can be from <1 to 400 Watts and the focal spot can be as small as 25µm. The FSA can also be used to measure how the focal spot shifts with power during its critical start-up phase.

The FSA includes; choice of high resolution camera, 2 beam splitters, a removable beam block on the 2nd splitter, and user selectable attenuation filters prior to the beam entering the camera.

Operation

The assembly is placed below the final focusing lens of the laser at a distance equal to the expected focal length. The focal spot is found by moving the assembly closer and farther from the beam until the smallest spot size is seen. The distance between the focusing lens and the datum point on the FSA assembly is added to the distance from the datum to the camera array (each FSA assembly will be factory calibrated to within +/- 50 µm). These two measurements will give you the exact distance of your lasers focal spot.

Examples of Usage



65µm diameter focal spot

Focal spot spatial power density changing with laser power level

Specifications

Model	SP928	LT665
Application	1/1.8" format	1" format
Spectral Response	190 - 1100nm (2)	190 - 1100nm (2)
Active Area	7.1mm x 5.3mm	12.5mm x 10mm
Pixel spacing	3.69µm	4.54µm x 4.54µm
Number of effective pixels	1928 x 1448	2752 x 2192
Minimum system dynamic range	56 dB	54 dB
Linearity with Power	±1%	±1%
Accuracy of beam width	±2%	±2%
Frame rates in 12 bit mode (4)	13 fps at full resolution	27 fps at full resolution
Shutter duration	30µs to multiple frames	31µs to multiple frames
Gain control	0 dB to 24 dB	0.8 dB to 56 dB
Trigger	Hardware/Software trigger & strobe out	Hardware/Software trigger & strobe out
Photodiode trigger	N/A	Si response: SP90408
Saturation intensity (1)	0.97µW/cm^2	1.3µW/cm^2
Lowest measurable signal (1)	1.2nW/cm^2	0.3nW/cm^2
Damage threshold	50W/cm^2 / 0.1J/cm^2 with all filters installed for < 100ns pulse width(3)	50W/cm^2 / 0.1J/cm^2 with all filters installed for < 100ns pulse width(3)
Dimensions	48 mm x 44 mm x 20.2 mm	43 mm x 43 mm x 65 mm
CCD recess	4.5 mm	17.5mm
Image quality at 1064nm	Pulsed with trigger sync - excellent Pulsed with video trigger - good CW - good	Pulsed with trigger sync - excellent Pulsed with video trigger - good CW - good
Operation mode	Interline transfer CCD	Quad Tap interline transfer CCD
Software supported	BeamGage STD or PRO	BeamGage STD and PRO
PC interface	USB 3.0	USB 3.0
OS Supported	Windows 7 (64) and Windows 10	Windows 7 (64) and Windows 10

Notes:

(1) Camera set to full resolution at maximum frame rate and exposure times, running CW at 632.8nm wavelength. Camera set to minimum useful gain for saturation test and maximum useful gain for lowest signal test.
(2) Camera may be useable for wavelengths below 350nm but sensitivity is low and detector deterioration may occur. Therefore UV image converter is recommended. Although our silicon cameras have shown response out to 1320nm it can cause significant blooming which could lead to significant errors of beam width measurement. We would suggest our XC130 InGaAs camera for these wavelengths to give the best measurements.
(3) This is the damage threshold of the filter glass of the filters. Assuming all filters mounted with ND1 (red housing) filter in the front. Distortion of the beam may occur with average power densities as low as 5W/cm^2.
(4) Highly dependent on PC processor and graphics adapter performance.

Ordering Information

Model	LBS-300s-UV	LBS-300s-VIS	LBS-300s-NIR	LBS-300s-BB
Wavelength	266-355nm	400-700nm	1064nm	190-1550nm
Wedge Material	UVFS	UVFS	UVFS	UVFS
Wedge Coating	A/R ≤1%	AR ≤1%	AR ≤1%	No coating, 4% reflection
Clear aperture	17.5mm	17.5mm	17.5mm	17.5mm
Reflection	0.01%	0.01%	0.01%	0.16%
Wedge ND value, each	ND ≥2	ND ≥2	ND ≥2	ND ~1.3
ND Filters	Inconel	Bulk ND	Bulk ND	One each of the UV, VIS & NIR sets
ND Values, nominal	0.3, 0.7, 1.0, 2.0, 3.0, 4.0 (Blu holders)	0.3, 0.7, 1.0, 2.0, 3.0, 4.0 (Grn holders)	0.3, 0.7, 1.0, 2.0, 3.0, 4.0 (Red holders)	See UV, VIS and NIR descriptions
Filter Slides	3	3	3	9
Maximum allowable input to filter (1)	100 W/cm^2 CW 20mJ/cm^2, 10ns pulse	50 W/cm^2 1J/cm^2, 10ns pulse	50 W/cm^2 1J/cm^2, 10ns pulse	See adjacent specifications

Note: (1) ND bulk absorbing filters damage threshold is 50W/cm^2 but should be used at <5W/cm^2 to avoid thermal lensing effects.

Ordering Information

Item	Description	P/N
BGS-LBS-300s-UV-CAL	LBS-300s-UV beam splitter & neutral density filters combo + BeamGage Standard software, software license, 1/1.8" format 1928X1448 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90456
BGS-LBS-300s-UV-CAL-Lt665	LBS-300s-UV beam splitter & neutral density filters combo + BeamGage Standard software, software license, 1" format 2752X2192 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90477
BGS-LBS-300s-VIS-CAL	LBS-300s-VIS beam splitter & neutral density filters combo + BeamGage Standard software, software license, 1/1.8" format 1928X1448 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90457
BGS-LBS-300s-VIS-CAL-Lt665	LBS-300s-VIS beam splitter & neutral density filters combo + BeamGage Standard software, software license, 1" format 2752X2192 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90478
BGS-LBS-300s-NIR-CAL	LBS-300s-NIR beam splitter & neutral density filters combo + BeamGage Standard software, software license, 1/1.8" format 1928X1448 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90458
BGS-LBS-300s-NIR-CAL-Lt665	LBS-300s-NIR beam splitter & neutral density filters combo + BeamGage Standard software, software license, 1" format 2752X2192 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90479
BGS-LBS-300s-BB-CAL	LBS-300s-BB beam splitter & neutral density filters combo + BeamGage Standard software, software license, 1/1.8" format 1928X1448 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90459
BGS-LBS-300s-BB-CAL-Lt665	LBS-300s-BB beam splitter & neutral density filters combo + BeamGage Standard software, software license, 1" format 2752X2192 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90480
BGP-LBS-300s-UV-CAL	LBS-300s-UV beam splitter & neutral density filters combo + BeamGage Professional software, software license, 1/1.8" format 1928X1448 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90460
BGP-LBS-300s-UV-CAL-Lt665	LBS-300s-UV beam splitter & neutral density filters combo + BeamGage Professional software, software license, 1" format 2752X2192 pixel camera pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90481
BGP-LBS-300s-VIS-CAL	LBS-300s-VIS beam splitter & neutral density filters combo + BeamGage Professional software, software license, 1/1.8" format 1928X1448 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90461
BGP-LBS-300s-VIS-CAL-Lt665	LBS-300s-VIS beam splitter & neutral density filters combo + BeamGage Professional software, software license, 1" format 2752X2192 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90482
BGP-LBS-300s-NIR-CAL	LBS-300s-NIR beam splitter & neutral density filters combo + BeamGage Professional software, software license, 1/1.8" format 1928X1448 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90462
BGP-LBS-300s-NIR-CAL-Lt665	LBS-300s-NIR beam splitter & neutral density filters combo + BeamGage Professional software, software license, 1" format 2752X2192 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90483
BGP-LBS-300s-BB-CAL	LBS-300s-BB beam splitter & neutral density filters combo + BeamGage Professional software, software license, 1/1.8" format 1928X1448 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90463
BGP-LBS-300s-BB-CAL-Lt665	LBS-300s-BB beam splitter & neutral density filters combo + BeamGage Professional software, software license, 1" format 2752X2192 pixel camera + NIST traceable calibrated path length from top of unit to CCD array. Comes with USB cable and 3 ND filters.	SP90484

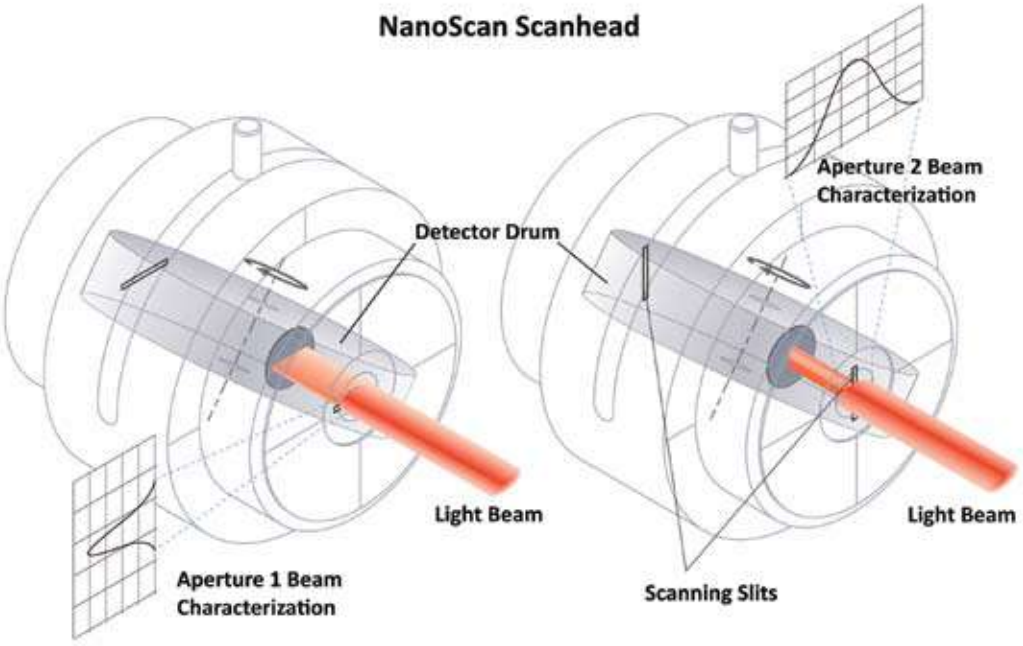
3.4 Introduction to Scanning-Slit Profilers

The scanning slit beam profiler moves two narrow orthogonal slits in front of a linear photo-detector through the beam under analysis. Light passing through the slit induces a current in the detector. Thus, as the slit scans through the beam, the detector signal is linearly proportional to the spatial beam irradiance profile integrated along the slit. A digital encoder provides accurate slit position. The photo-induced current signal is digitized and analyzed to obtain the beam profile in both X and Y from the two orthogonal slits.

The slit apertures act as physical attenuators, preventing detector saturation for most beam applications. High dynamic range amplification allows operation over many orders of magnitude in beam power.

From these profiles, important spatial information such as beam width, beam position, beam quality, and other characteristics are determined. This technique can accommodate a wide variety of test conditions. Because slit scanners measure beams at high powers with little or no attenuation, they are ideal to profile beams used in material processing.

Carbon dioxide (CO_2) lasers are widely used in materials processing, and have a 10.6 micron wavelength that cannot be profiled with most cameras. Slit scanners, therefore, provide an convenient means of measuring high-resolution CO_2 lasers with powers up to and exceeding 1000 watts.



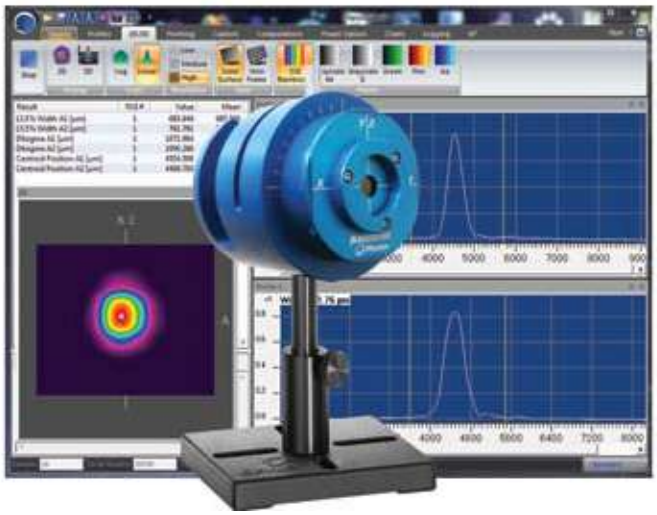
3.4.1 NanoScan 2s

3.4.1.1 NanoScan 2s – Standard Version

Scanning Slit Beam Profiler For High Accuracy Dimensional Measurement

NanoScan 2s combines the convenience and portability of direct USB connectivity with the speed, accuracy, and dynamic range that users have come to expect from the Photon NanoScan slit based profilers. The NanoScan 2s is available with a silicon, germanium or pyroelectric detector, which allows it to profile lasers of any wavelength from UV to far infrared, out to 100µm and beyond. With the new NanoScan 2s software package, the user can configure the display interface however it is desired; displaying those results of most interest on one easy-to-read screen, or on multiple screens.

The NanoScan slit profiler is the most versatile laser beam profiling instrument available today: providing instantaneous feedback of beam parameters for CW and kilohertz pulsed lasers, with measurement update rates to 20Hz. The natural attenuation provided by the slit allows the measurement of many beams with little or no additional attenuation. The high dynamic range makes it possible to measure beams while adjustments to focus are made without having to adjust the profiler. Just aim the laser into the aperture and the system does the rest!



Capabilities

NanoScan 2s is a PC-based instrument for the measurement and analysis of laser beam spatial irradiance profiles in accordance with the ISO standard 11146. The scan heads also measure power in accordance with ISO 13694.

NanoScan uses the scanning slit, one of the ISO Standard scanning aperture techniques. It can measure beam sizes from microns to centimeters at beam powers from microwatts to over kilowatts, often without attenuation. Detector options allow measurement at wavelengths from the ultraviolet to the infrared.

The NanoScan 2s digital controller has 16-bit digitization of the signal for enhanced dynamic range up to 35dB power optical. With the accuracy and stability of the beam profile measurement you can measure beam size and beam pointing with a 3-sigma precision of several hundred nanometers. The software controllable scan speed and a "peak-connect" algorithm allows the measurement of pulsed and pulse width modulated lasers with frequencies of 10kHz and higher*. The NanoScan is also able to measure up to 16 beams, or regions of interest, in the aperture simultaneously.

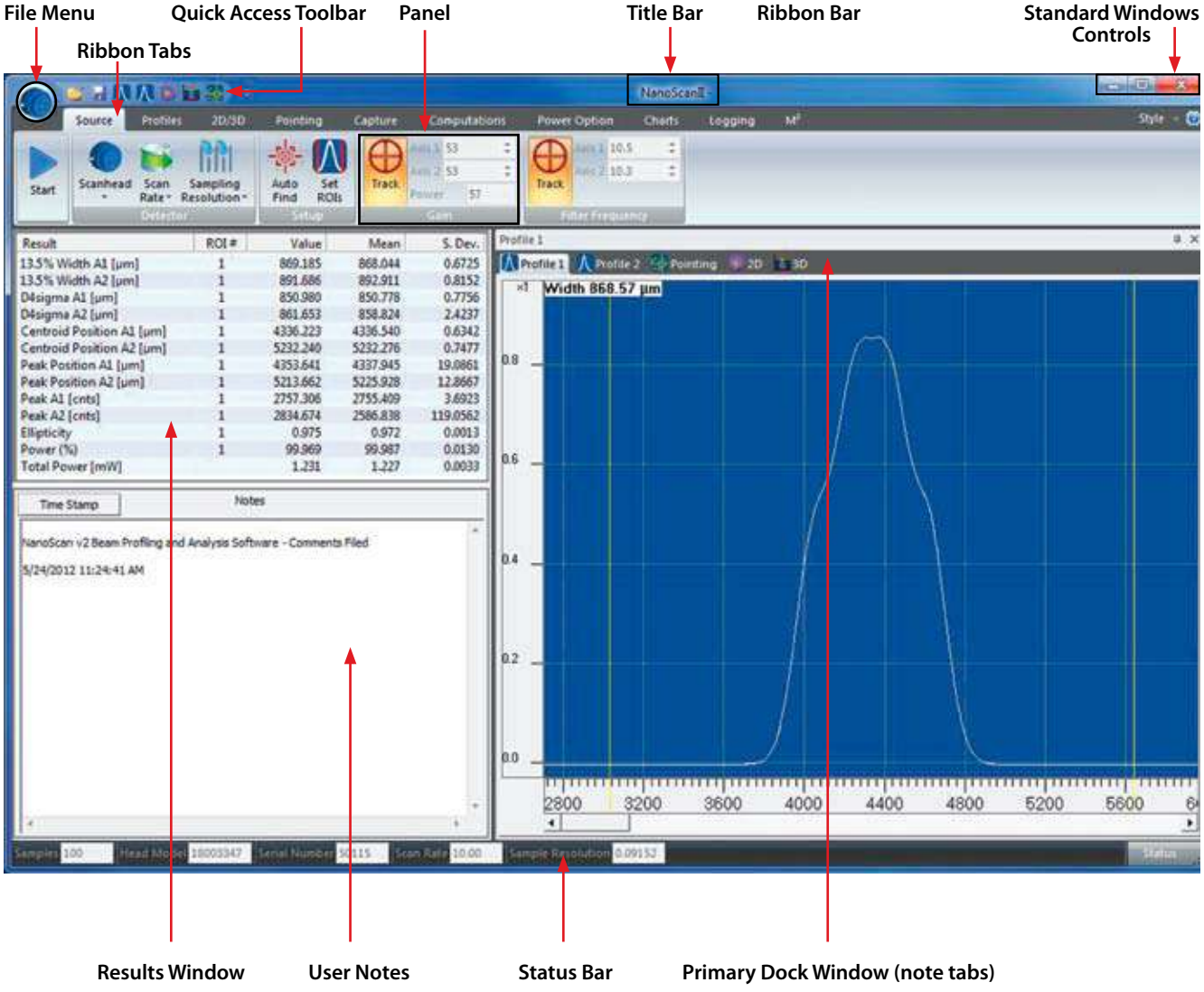
Benefits

- Measure any wavelength from UV to very far infrared (190nm to >100µm)
- Instantaneous real time display of results; beam found in less than 300ms and updated at up to 20Hz
- Waist location can be determined to within ±25µm due to the well-defined Z-axis datum plane of the NanoScan
- Measure pulsed and CW lasers
- For pulsed beams the pulse rate is measured and reported
- From as small as 7µm beams, can be measured directly with guaranteed accuracy and precision
- Additional high signal to noise ratio can be achieved with averaging
- Z-axis caustic measurements are available with built-in mechanical linear stage control
- M2 propagation ratio values available with simple M^2 Wizard included with the software.
- Any beam result can be charted and monitored over time
- Power levels can be monitored along with spatial measurements to determine if losses are introduced by beam adjustments
- Log results to text files for independent analysis
- Automate the system using optional ActiveX Automation commands, available with the PRO version software and scan heads Samples of automation programs included for Excel, VBA, LabView and Visual Basic.net

* The minimum frequency is a function of the beam size and the scan speed. This is a simple arithmetic relationship; there must be a sufficient number of pulses during the time that the slits sweep through the beam to generate a meaningful profile. Please refer to Photon's Application Note, Measuring Pulsed Beams with a Slit-Based Profiler.

NanoScan 2s Configurable User Interface

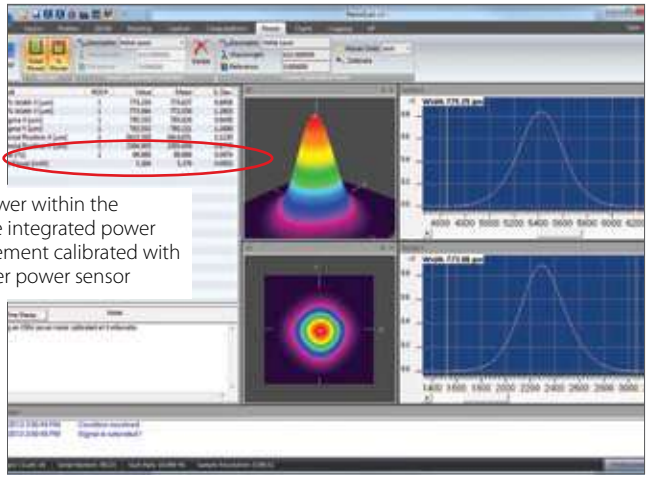
In addition to new hardware, the NanoScan 2s has an updated integrated software package for the Microsoft Windows Platform, which allows the user to display any of the results windows on one screen. The NanoScan 2s software comes in two versions, STD and PRO. The NanoScan 2s Pro version includes ActiveX automation for users who want to integrate the NanoScan into OEM systems or create their own user interface screens with C++, LabView, Excel or other OEM software packages.



Example of display configuration window

Integrated Power Meter

The silicon and germanium detector equipped NanoScan 2s systems include an integrated 200mW power meter. The scanhead comes with a quartz attenuator window that provides a uniform response across a broad wavelength range.
This is a relative power meter that has better than 1.5% correspondence when calibrated with a user-supplied power meter and used in the same configuration as calibrated.
The power meter screen in the software shows both the total power and the individual power in each of the beams being measured.



% of power within the aperture integrated power measurement calibrated with customer power sensor

Available Detectors

The NanoScan 2s is available with silicon, germanium or pyroelectric detectors to cover the light spectrum from UV to very far infrared.

Apertures and Slits

The NanoScan 2s is available with a variety of apertures and slit sizes to allow for the accurate measurement of varying beam sizes. The slit width defines the minimum beam width that can be measured; due to convolution error, the slit should be no larger than ¼ the beam diameter to provide a ±3% accurate measurement. For this reason the minimum beam diameter measureable with the standard 5µm slit is 20µm. To measure beams smaller than 20µm it is necessary to use the small aperture 1.8µm slit instrument, providing a minimum beam diameter of ~8µm. Because these slits are so narrow, the maximum length limits the aperture to 3.5mm. Contrary to many people's beliefs, these smaller slits do not improve the resolution of the measurement, only the minimum size of the beam. Therefore, unless it is necessary to measure beams less than 20µm, one would be advised to stick with the 9mm/5µm configurations.
For very large beams, NanoScan is available with a large 20 or 25mm aperture with 25µm slits. These sensor are larger than the standard scan heads (100mm diameter)

NanoScan 2s Scanhead Model	Si/3.5/1.8µm	Si/9/5µm	Si/9/25µm
Wavelength	190nm - 950nm	190nm - 950nm	190nm - 950nm
Slit Size	1.8µm	5µm	25µm
Aperture Size	3.5mm	9mm	9mm
1/e² Beam Diameter Range	7µm-~2.3mm	20µm-~6mm	100µm-~6mm
Spatial Sampling Resolution	5.3nm-18.3µm		
Profile Digitization	16-bit		
Scan frequency	1.25, 2.5, 5, 10, 20Hz		
Power Reading	User calibrated		
Power Aperture Window	Metalized Quartz (200mW upper limit)		
Laser Type	CW or Pulsed		
Operating Range	See Operating Space Charts		
Damage threshold	See Operating Space Charts		
Rotation Mount	Standard		
Scanhead Dimension	63.4mm diameter x76.8mm long See Mechanical Drawing for details		

NanoScan 2s Scanhead Model	Ge/3.5/1.8µm	Ge/9/5µm	Ge/9/25µm
Wavelength	700nm - 1800nm	700nm - 1800nm	700nm - 1800nm
Slit Size	1.8µm	5µm	25µm
Aperture Size	3.5mm	9mm	9mm
1/e² Beam Diameter Range	7µm-~2.3mm	20µm-~6mm	100µm-~6mm
Spatial Sampling Resolution	5.3nm – 18.3µm		
Profile Digitization	16 bit		
Scan Frequency	1.25, 2.5, 5, 10, 20Hz		
Power Reading	User calibrated		
Power Aperture Window	Metalized Quartz (200mW upper limit)		
Laser Type	CW or Pulsed		
Operating Range	See Operating Space Chart		
Damage Threshold	See Operating Space Chart		
Rotation Mount	Standard		
Scanhead Dimension	63.4mm diameter x 76.8mm long See Mechanical Drawing for details		

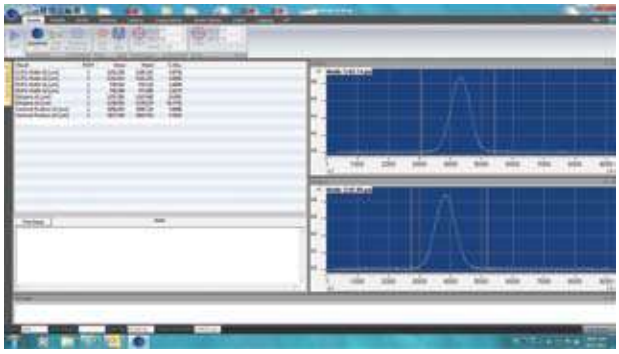
NanoScan 2s Scanhead Model	Pyro/9/5µm	Pyro/9/25µm
Wavelength	190nm->100µm	190nm->100µm
Slit Size	5µm	25µm
Aperture Size	9mm	9mm
1/e² Beam Diameter Range	20µm-~6mm	100µm-~6mm
Spatial Sampling Resolution	5.3nm-18.3 µm	
Profile Digitization	16-bit	
Scan Frequency	1.25, 2.5,5,10,20Hz	
Power Reading	Not available	
Power Aperture Window	N A	
Laser Type	CW or Pulsed	
Operating Range	See Operating Space Chart	
Damage Threshold	See Operating Space Chart	
Rotation Mount	Standard	
Scanhead Dimension	63.4 mm diameter x 76.8mm long See Mechanical Drawing for details	

The Most Versatile and Flexible Beam Profiling System Available

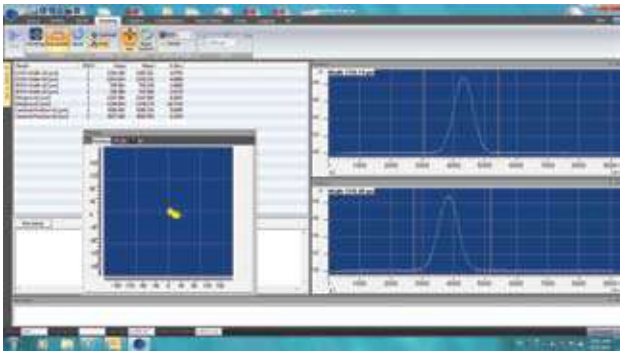
With the available range of detectors, slit sizes and apertures the NanoScan 2s provides the maximum versatility in laser beam profiling. NanoScan 2s adds the convenience and portability of direct USB connectivity: no external controllers or power supplies required to operate the profiler. In addition the rotation mount has been redesigned to provide a stand for vertical operation, if desired. The mount can be positioned in one of two places. If vertical operation is desired the mount is positioned toward the back of the scanhead to expose the stand, which can be affixed to the optical table or stage. If standard horizontal operation is desired, then the rotation mount can be positioned in the forward configuration, maintaining the original length and size of the scanhead.

See Your Beam As Never Before

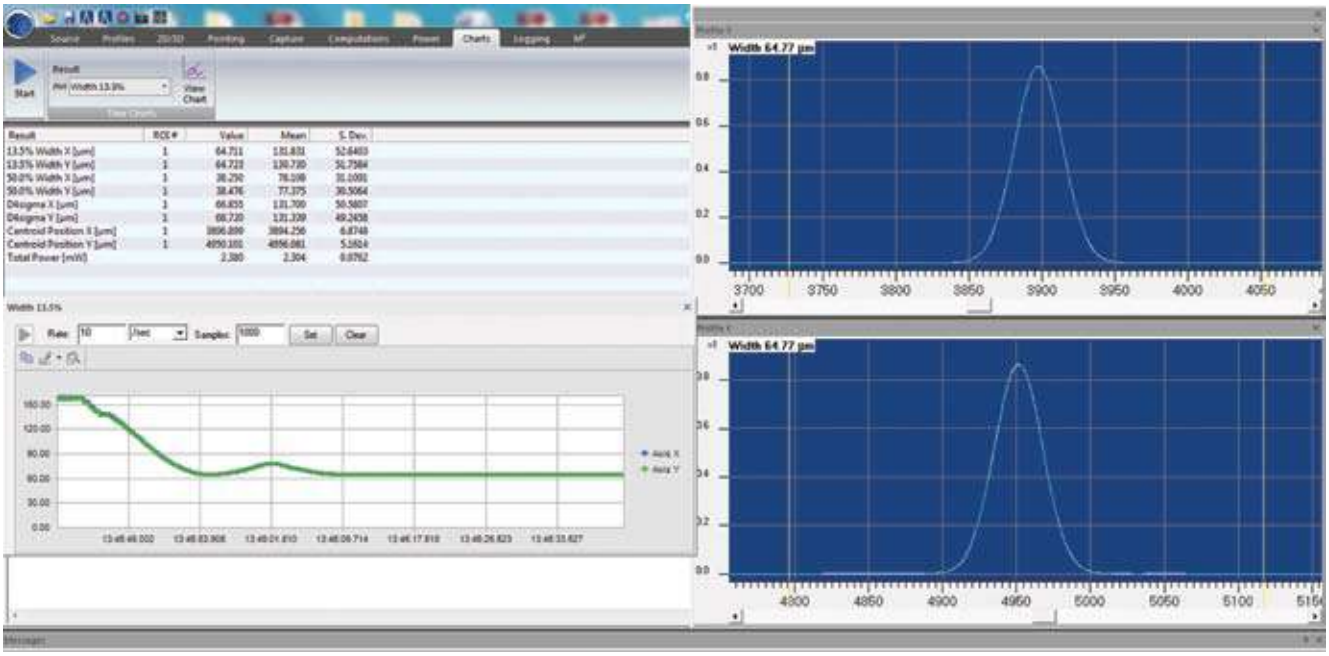
The new NanoScan 2s graphical user interface (GUI) allows the user to set the display screens to any appropriate configuration, displaying those that are of interest and hiding what is not. This means that you can have the information that you want to see, uncluttered by extraneous output, and you can have all the features you need, visible at once. The screens can be docked or floating with ribbon bars for the controls that can be visible or hidden as desired. This allows you to take advantage of a large, multi-monitor desk top or maximize the useful information on a small laptop display.



Simple docked view of profiles and numerical results



Both docked and undocked windows: profiles, results, and pointing



Example of time charts used to monitor focusing process

Measured Beam Results

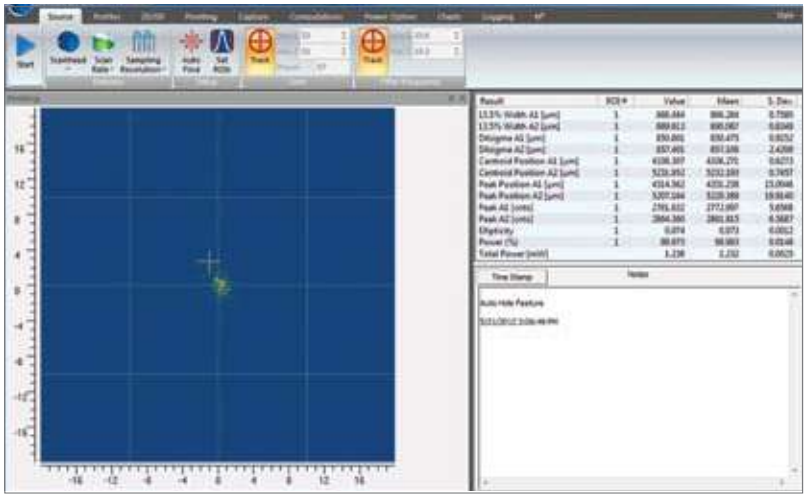
From 1989 through 1996, John Fleischer, founder and past President of Photon Inc., chaired the working laser beam width ISO/DIN committee that resulted in the ISO/DIN 11146 standard. The final approved standard, available in 13 languages. The standard governs profile measurements and analysis using scanning apertures, variable apertures, area sensors and detector arrays. NanoScan 2s measures spatial beam irradiance profiles using scanning slit techniques.

Results measured include:

- Beam Width at standard and user-definable clip levels, including $1/e^2$ and 4σ
- Centroid Position
- Peak Position
- Ellipticity
- Gaussian Fit
- Beam Divergence
- Beam Separation
- Pointing Stability
- ROI Power
- Total Power
- Pulsed Laser Repetition Rate

Result	ROI #	Value	Mean	S. Dev.
13.5% Width A1 [µm]	1	863.328	864.612	0.7082
13.5% Width A2 [µm]	1	876.317	875.622	0.9432
D4sigma A1 [µm]	1	849.062	849.700	1.5084
D4sigma A2 [µm]	1	842.054	840.924	2.3751
Centroid Position A1 [µm]	1	1.111	-0.133	0.5622
Centroid Position A2 [µm]	1	-1.730	0.275	1.2221
Peak Position A1 [µm]	1	-11.521	-19.890	5.6014
Peak Position A2 [µm]	1	4.156	8.732	6.9860
Peak A1 [cnts]	1	2812.438	2810.688	4.0486
Peak A2 [cnts]	1	2687.898	2678.320	5.5879
Ellipticity	1	0.806	0.807	0.0023
Power [%]	1	99.994	99.979	0.0273
Total Power [mW]		1.202	1.203	0.0002

Example of the many measurements that can be made and the precision you can expect



Knowing pointing stability is a critical factor in laser performance

M^2 Wizard

M-squared (M^2) software Wizard is an interactive program for determining the "times diffraction limit" factor M^2 by the Rayleigh Method. The M^2 Wizard prompts and guides the user through a series of manual measurements and data entries required for calculating M^2. Used with a user-provided translation stage focusing lens and the M^2 Wizard in the NanoScan Analysis Software, the user can quickly and easily determine the times-diffraction propagation factor (M^2) of a laser. For automated and automatic M^2 measurements the NanoModeScan option is required.

Pulsed Laser Beam Profiling

In addition to profiling CW laser beams, NanoScan can also profile pulsed laser beams with repetition rate in the 10kHz range and above. To enable the measurement of these pulsed lasers, the NanoScan profiler incorporates a "peak connect" algorithm and software-controlled variable scan speed on all scanheads. The accuracy of the measurement generally depends on the laser beam spot size and the pulse-to-pulse repeatability of the laser. The NanoScan is ideal for measuring Q-switched lasers and lasers operating with pulse width modulation power (PWM) control. In the past few years, lasers with pico- and femtosecond pulse durations have begun to be used in many applications. Although these lasers add some additional complication to the measurement techniques, the NanoScan can also measure this class of laser.

3.4.1.2 NanoScan 2s – Professional Version

Automation Interface

For customer who want to incorporate the NanoScan 2s into an automated procedure or to create a customized user interface, the PRO version scanheads include an ActiveX Automation Server that can be used by an Automation Client written in Visual Basic for Applications (VBA), C/C++ or by an application which supports ActiveX Automation, such as Microsoft Excel, Microsoft Word or National Instruments' LabVIEW. The software package include example of programs written in Excel and LabVIEW in the automation folder.

3.4.1.3 NanoScan 2s Acquisition and Analysis Software

Use the Software specification from the existing NanoScan 2s data sheet

*Feature		NanoScan Standard	NanoScan Professional (all features in Standard plus)
Controls			
Source	ScanHead Select, Gain, Filter, Sampling Resolution, AutoFind, Rotation Frequency, Record Mode	●	
Capture	Averaging, Rotation, Magnification, CW or Pulse Modes, Divergence, Gaussian Fit, Reference Position, Recompute	●	
Regions of Interest (ROI)	Single or Multiple, Automatic or Manual, Colors	●	
Profiles	Vertical Scale (1´, 10´, 100´), Logarithmic Scale, Z & PAN (Automatic or Manual)	●	
Computation: ISO 13694, ISO 11146	D_{slit}, (13.5%, 50% 2 User Selectable Clip Levels), $D_{4\sigma}$, Width ratios, Centroid Position, Peak Position, Centroid Separation, Peak Separation, Irradiance, Gaussian Fit, Ellipticity, Divergence, Total Power, Pulse Frequency, % power	●	
	Continuous, Rolling, Finite	●	
Pointing	Centroid or Peak, Accumulate Mode, Beam Indicator, Graph Center, Colors	●	
2D/3D	2D or 3D Mode, Linear or Logarithmic Scale, Resolution, Fill Contours, Solid Surface, or Wireframe, Clip Level Colors	●	
Charts	Chart Select, Parameter Select, Aperture Select, Update Rate, Start and Clear	●	
Logging	File Path/Name, Delimiter, Update Rate	●	
M^2	Rail Setup: Com Port and Length, Connect/Disconnect, Rail Control	●	
Views			
Profiles	Displays Beam Profiles for each axis, with optional Gaussian Overlays	●	
Results	Displays Values and Statistics for Selected results	●	
Pointing	Displays the XY position of the Centroid or Peak for each ROI , with optional overlays and Accumulate Mode	●	
Charts	Displays Time Charts for User-selected results	●	
2D/3D	Displays pseudo 2D/3D Beam Profile	●	
M^2 Wizard	An interactive procedure for measuring M^2 by the Rayleigh Method	●	
File Saving			
NanoScan Data Files		●	
Text Files		●	
Data Logging			
Log to File		●	
Reports			
NanoScan Report		●	
Automation Interface			
ActiveX Automation Server			●
Minimum System Requirements			
PC computer running windows 7 (32/64) Laptop or Desktop[1]			
A dual core processor CPU, 2GHz or better			
2GB of RAM[2]			
1-USB 2.0 port available			
At least 250MB of free HDD space			
1400 x 900 display resolution or better			
Graphics card w/hardware accelerator			
DVD-ROM drive			
Microsoft compatible pointing devices(e.g., mouse, trackball, etc)			

*Download the NanoScan Acquisition and Analysis Software Manual for a complete description of all Software Features

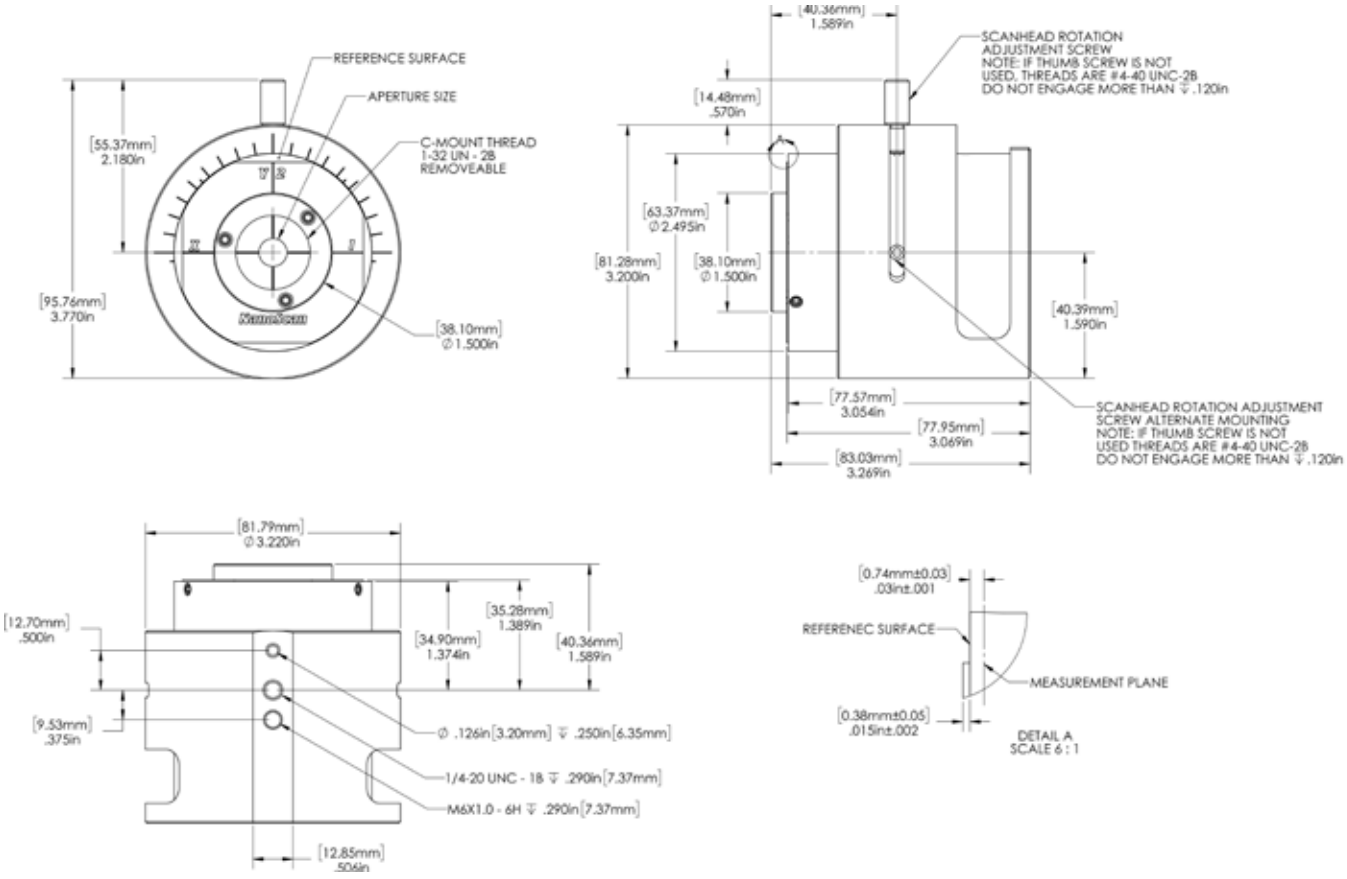
1. A business/professional version of windows is recommended. The NanoScan v2 software has not been tested with home versions of Windows. Both 64-bit and 32-bit versions of Windows 7 are supported. NanoScan v2 is no longer tested on Windows XP 32-bit operating systems.
2. The computer memory (RAM) will affect the performance of the software in the Data Recorder.

3.4.1.4 Specifications

Model	General Specification
Bus interface	USB 2.0
Signal digitization	16bit
Maximum digitization clock	21.4MHz
Maximum update rate	20Hz
Data transfer	Bulk Transfer Mode
On-board memory	64MB mDDR SDRAM
Weight	434g (15.3 ounces)
Operating temperature	0-50°C
Humidity	90%, non-condensing
Scanhead Dimensions	3.03"(7.68cm) L X 2.5"(6.35cm) Ø
Power	USB 2.0 Bus Powered
CPU Clock	300MHz
Memory Clock	264MHz
Scanning Motor	Brushed DC, 4W max

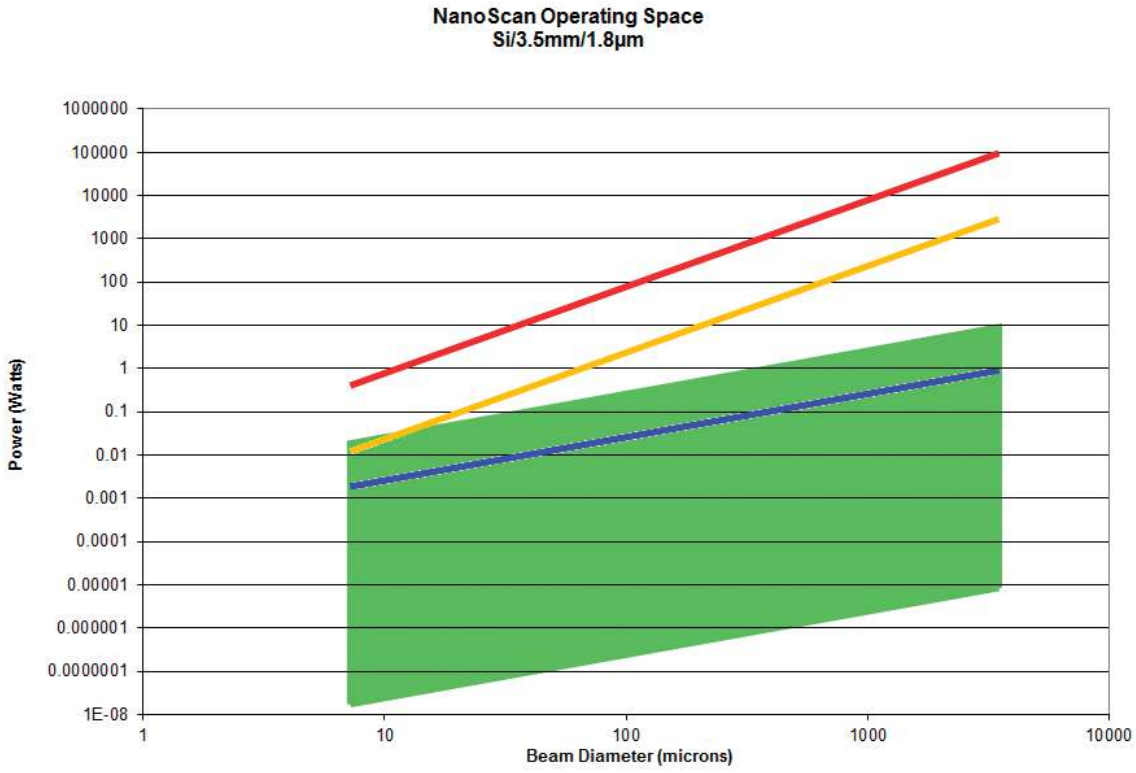
Mechanical Dimensions

NanoScan 2s Standard Scanhead: NS2s-Si, NS2s-Ge and NS2s-Pyro



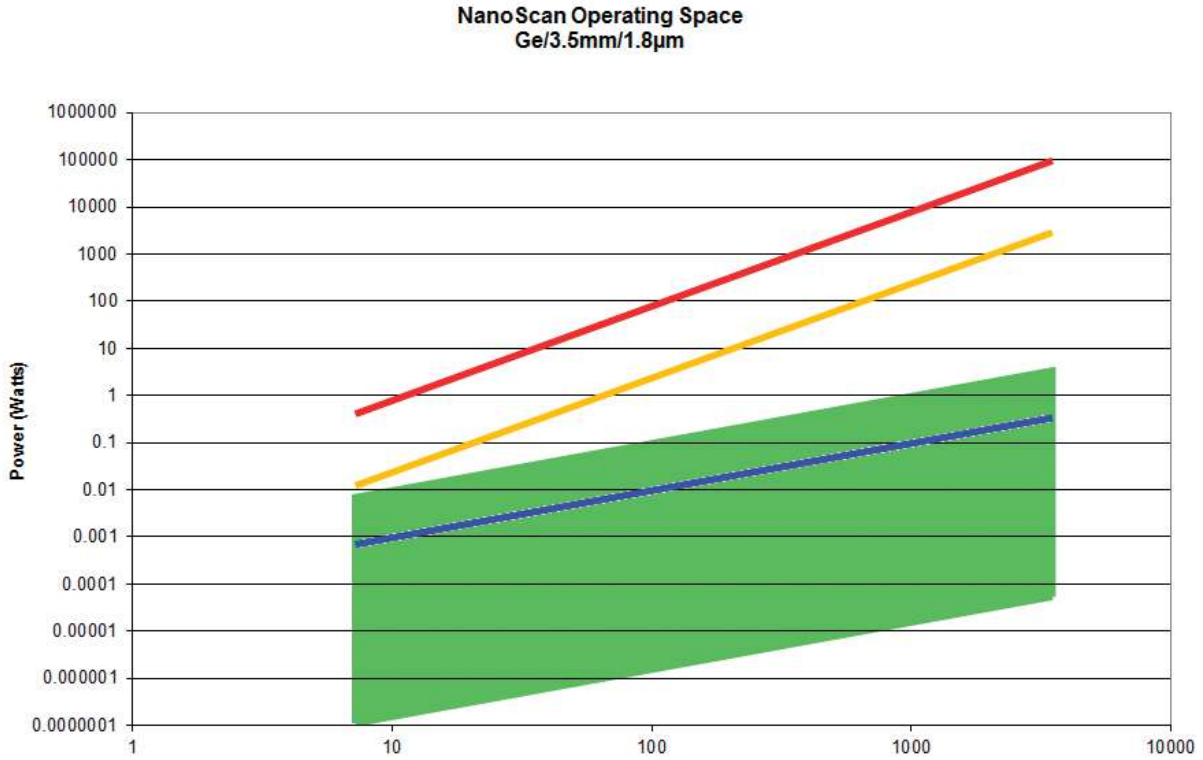
Typical NanoScan Operating Space Charts

Operating range is at peak sensitivity of detector. Operating space is NOT absolute.
THESE CHARTS TO BE USED AS A GUIDE ONLY.



Silicon Detector

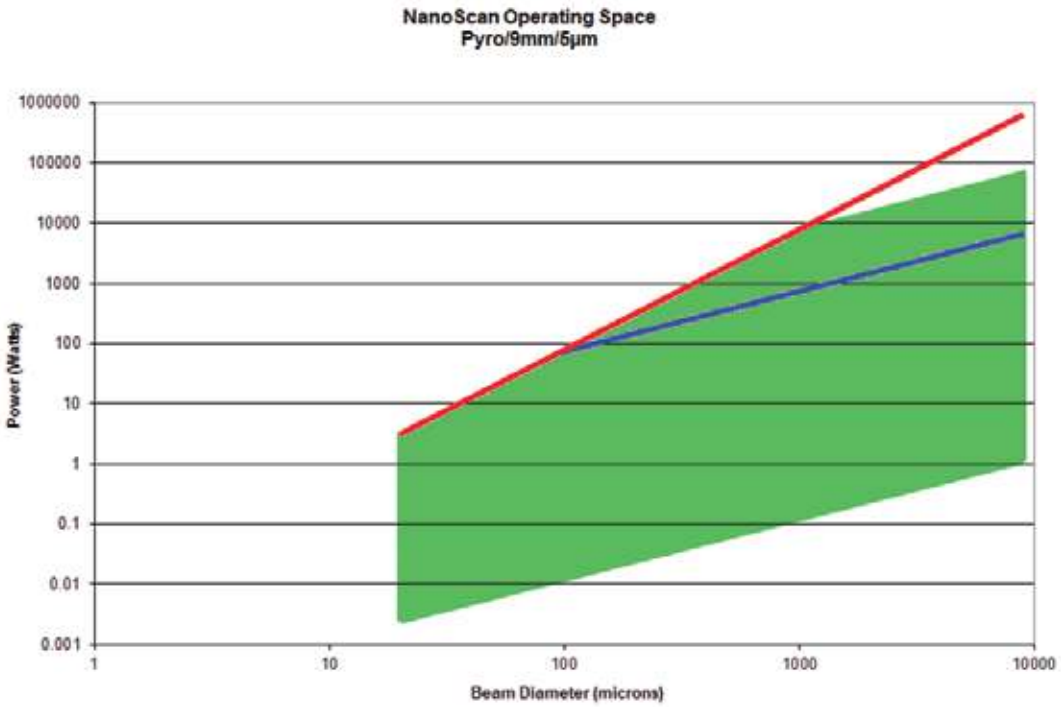
Silicon Detector: Responsivity varies with wavelength. Detects between 400-1100nm. Peak responsivity is 0.7 amps/watt at 980nm. Detector to detector responsivity variation can be as great as ±20%.
Power: Average power in the laser beam.
Beam Diameter: Assumes a round beam. The operating point for an elliptic beam can be approximated by using the average diameter. For extremely elliptic beams (ratio >4:1), contact Spiricon.
Pulsed Operation (**):** Upper limit of the operating space for pulsed laser measurements.
Black Coating Removed (**):** Slits are blackened to reduce back reflections; blackening begins to vaporize near this line. Slits in pyro detectors are not blackened.
Slit Damage (**):** Power density (watts/cm^2) where one can begin to ablate and cut the slits.
Refer to Spiricon's *Damage Threshold with High Power Laser Measurements* document.
Left Boundary: The left boundary is 4 times the slit width, where slit convolution error becomes significant to the 5% level for reported 1/e^2 diameter of a TEM$_{00}$ Gaussian beam.
Right Boundary: The right boundary is the instrument entrance aperture diameter, which determines the largest beam profile and diameter that can be measured. For a TEM$_{00}$ Gaussian beam the 1/e^2 diameter needs to be ≤1/2 the aperture diameter to measure and see the entire profile out to the tails. Similarly for a Flat-top distribution the 1/e^2 diameter needs to be ≤~95% of the aperture diameter.
To obtain any given clip level diameter for any beam (but not the full profile) ~95% of the aperture is useable.



Germanium Detector

Responsivity: Detector converts constant, incident photons to a current.

Germanium Detector: Responsivity varies with wavelength. Detects between 800-1800nm. Peak responsivity is 1.05 amps/watt at 1550nm. Detector to detector responsivity variation can be as great as ±20%.
Power: Average power in the laser beam.
Beam Diameter: Assumes a round beam. The operating point for an elliptic beam can be approximated by using the average diameter. For extremely elliptic beams (ratio >4:1), contact Spiricon.
Pulsed Operation (——— **):** Upper limit of the operating space for pulsed laser measurements.
Black Coating Removed (——— **):** Slits are blackened to reduce back reflections; blackening begins to vaporize near this line. Slits in pyro detectors are not blackened.
Slit Damage (——— **):** Power density (watts/cm^2) where one can begin to ablate and cut the slits. Refer to Spiricon's *Damage Threshold with High Power Laser Measurements* document.
Left Boundary: The left boundary is 4 times the slit width, where slit convolution error becomes significant to the 5% level for reported 1/e^2 diameter of a TEM$_{00}$ Gaussian beam.
Right Boundary: The right boundary is the instrument entrance aperture diameter, which determines the largest beam profile and diameter that can be measured. For a TEM$_{00}$ Gaussian beam the 1/e^2 diameter needs to be ≤1/2 the aperture diameter to measure and see the entire profile out to the tails. Similarly for a Flat-top distribution the 1/e^2 diameter needs to be ≤~95% of the aperture diameter. To obtain any given clip level diameter for any beam (but not the full profile) ~95% of the aperture is useable.



Pyroelectric Detector

Pyroelectric Detector: Uniform in response between 0.2 and 20 microns wavelength.
Power: Average power in the laser beam.
Beam Diameter: Assumes a round beam. The operating point for an elliptic beam can be approximated by using the average diameter. For extremely elliptic beams (ratio >4:1), contact Spiricon.
Pulsed Operation (———): Upper limit of the operating space for pulsed laser measurements.
Slit Damage (———): Power density (watts/cm^2) where one can begin to ablate and cut the slits. Refer to Spiricon's *Damage Threshold with High Power Laser Measurements* document.
Left Boundary: The left boundary is 4 times the slit width, where slit convolution error becomes significant to the 5% level for reported 1/e^2 diameter of a TEM_{00} Gaussian beam.
Right Boundary: The right boundary is the instrument entrance aperture diameter, which determines the largest beam profile and diameter that can be measured. For a TEM_{00} Gaussian beam the1/e^2 diameter needs to be ≤1/2 the aperture diameter to measure and see the entire profile out to the tails. Similarly for a Flat-top distribution the 1/e^2 diameter needs to be ≤~95% of the aperture diameter. To obtain any given clip level diameter for any beam (but not the full profile) ~95% of the aperture is useable.

3.4.1.5 Ordering Information

Item	Description	P/N
NS2s-SI/3.5/1.8-STD	NanoScan 2s Silicon Detector 3.5mm aperture 1.8µm slits. High-resolution head featuring Silicon detector, 63.5mm diameter head with rotation mount, 3.5mm entrance aperture, and matched pair of 1.8µm wide slits. Use from 190nm to wavelengths <1µm. Not for 1.06µm wavelength	PH00456
NS2s-SI/9/5-STD	NanoScan 2s Si Detector 9mm aperture 5µm slits. High-resolution head featuring Si detector, 63.5mm diameter head with rotation mount, 9mm entrance aperture, and matched pair of 5µm wide slits. Use from 190nm to wavelengths <1µm. Not for 1.06µm wavelength	PH00457
NS2s-SI/9/25-STD	NanoScan 2s Si Detector 9mm aperture 25µm slits. High-resolution head featuring Si detector, 63.5mm diameter head with rotation mount, 9mm entrance aperture, and matched pair of 25µm wide slits. Use from 190nm to wavelengths <1µm. Not for 1.06µm wavelength	PH00458
NS2s-Ge/3.5/1.8-STD	NanoScan 2s Ge Detector 3.5mm aperture 1.8µm slits. High-resolution head featuring Germanium detector, 63.5mm diameter head with rotation mount, 3.5mm entrance aperture, and matched pair of 1.8µm wide slits. Use from 700nm to 1.8µm wavelength	PH00459
NS2s-Ge/9/5-STD	NanoScan 2s Ge Detector 9mm Aperture 5µm slits. High-resolution head featuring Germanium detector, 63.5mm diameter head with rotation mount, 9mm entrance aperture, and matched pair of 5µm wide slits. Use from 700nm to 1.8µm wavelength	PH00460
NS2s-Ge/9/25-STD	NanoScan 2s Ge Detector 9mm Aperture 25µm slits. High-resolution head featuring Germanium detector, 63.5mm diameter head with rotation mount, 9mm entrance aperture, and matched pair of 25µm wide slits. Use from 700nm to 1.8µm wavelength	PH00461
NS2s-PYRO/9/5-STD	NanoScan 2s Pyro Detector 9mm Aperture 5.0µm slits. High-resolution head featuring pyroelectric detector, 63.5mm diameter head with rotation mount, 9mm entrance aperture, and matched pair of 5µm wide slits. Use from 190nm to >100µm wavelength	PH00462
NS2s-PYRO/9/25-STD	NanoScan 2s Pyro Detector 9mm Aperture 25.0µm slits. High-resolution head featuring pyroelectric detector, 63.5mm diameter head with rotation mount, 9mm entrance aperture, and matched pair of 5µm wide slits. Use from 190nm to >100µm wavelength	PH00463
NS2s-Si/3.5/1.8-PRO	NanoScan 2s Silicon Detector 3.5mm aperture 1.8µm slits. High-resolution head featuring Silicon detector, 63.5mm diameter head with rotation mount, 3.5mm entrance aperture, and matched pair of 1.8µm wide slits. Use from 190nm to wavelengths <1µm. Not for 1.06µm wavelength Software includes ActiveX automation feature	PH00464
NS2s-Si/9/5-PRO	NanoScan 2s Si Detector 9mm aperture 5µm slits. High-resolution head featuring Si detector, 63.5mm diameter head with rotation mount, 9mm entrance aperture, and matched pair of 5 µm wide slits. Use from 190nm to wavelengths <1µm. Not for 1.06µm wavelength Software includes ActiveX automation feature	PH00465
NS2s-Si/9/25-PRO	NanoScan 2s Si Detector 9mm aperture 25µm slits. High-resolution head featuring Si detector, 63.5mm diameter head with rotation mount, 9mm entrance aperture, and matched pair of 25µm wide slits. Use from 190nm to wavelengths <1µm. Not for 1.06µm wavelength Software includes ActiveX automation feature	PH00466
NS2s-Ge/3.5/1.8-PRO	NanoScan 2s Ge Detector 3.5mm aperture 1.8µm slits. High-resolution head featuring Germanium detector, 63.5mm diameter head with rotation mount, 3.5mm entrance aperture, and matched pair of 1.8µm wide slits. Use from 700nm to 1.8µm wavelength Software includes ActiveX automation feature	PH00467
NS2s-Ge/9/5-PRO	NanoScan 2s Ge Detector 9mm Aperture 5µm slits. High-resolution head featuring Germanium detector, 63.5mm diameter head with rotation mount, 9mm entrance aperture, and matched pair of 5µm wide slits. Use from 700nm to 1.8µm wavelength Software includes ActiveX automation feature	PH00468
NS2s-Ge/9/25-PRO	NanoScan 2s Ge Detector 9mm Aperture 25µm slits. High-resolution head featuring Germanium detector, 63.5mm diameter head with rotation mount, 9mm entrance aperture, and matched pair of 25µm wide slits. Use from 700nm to 1.8µm wavelength Software includes ActiveX automation feature	PH00469
NS2s-Pyro/9/5-PRO	NanoScan 2s Pyro Detector 9mm Aperture 5.0µm slits. High-resolution head featuring pyroelectric detector, 63.5mm diameter head with rotation mount, 9mm entrance aperture, and matched pair of 5µm wide slits. Use from 190nm to >100µm wavelength Software includes ActiveX automation feature	PH00470
NS2s-Pyro/9/25-PRO	NanoScan 2s Pyro Detector 9mm Aperture 25.0µm slits. High-resolution head featuring pyroelectric detector, 63.5mm diameter head with rotation mount, 9mm entrance aperture, and matched pair of 5µm wide slits. Use from 190nm to >100µm wavelength Software includes ActiveX automation feature	PH00471
Software Upgrades		
NSv2 STD to NSv2 PRO Upgrade	Upgrade NanoScan v2 Standard version software to the PRO version. This upgrade opens the NanoScan automation feature for those users wanting to integrate or develop their own interface using Visual Basic for Applications to embed into such applications as LabView. Return scanhead to factory	PH00417

3.5 Accessories for Beam Profiling

Introduction

Spiricon has the most extensive array of accessories for beam profiling existing. There are components for attenuating, filtering, beam splitting, magnifying, reducing and wavelength conversion. There are components for wavelengths from the deep UV to CO_2 wavelengths. Most of the components are modular so they can be mixed and matched with each other to solve almost any beam profiling requirement needed.

3.5.1 Neutral Density Attenuators/Filters

For almost all applications, the laser beam intensity is too high for the operating range of the CCD. Therefore ND glass attenuator filters are available to reduce the intensity to the proper level at the CCD. These filters are carefully designed not to affect beam quality or cause interference effects. One stackable ND1 filter and 2 ND2 filters are supplied standard with each c-mount camera.

Model	Stackable ND Filters ND1 / ND2 / ND3	ATP-K Variable Attenuator	UV ND Filters	Specialty Filter for 355nm
Nominal ND value	1, 2, 3	ND=1.7-4.6 Max. ND: 7.4 (with fixed 2.8 gray-glass attenuator)	0.3, 0.7, 1.0, 1.3, 1.7, 2.0, 2.3, 2.7, 3.0, 3.3, 3.7, 4.0, 4.3, 4.7, 5.0, 6.0	Pass 355nm, blocks 532nm & 1064nm
Clear aperture	Ø19mm	Ø15mm	Ø20mm	Ø19mm
Damage threshold	5W/cm² no distortion	100mW/mm no thermal lensing	100W/cm² CW, 10ns pulses, no distortion	5W/cm² no distortion
Mounting	C-Mount Threads	C-Mount Threads	C-Mount Threads	C-Mount Threads

Stackable ND filters

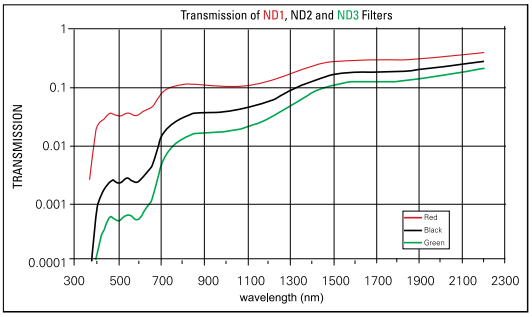
The individual filters come in three versions, the ND1 filter in the red housing with ~10% transmission in the visible, the ND2 filter in the black housing with ~1% transmission and the ND3 filter in the green housing with ~0.1% transmission. The individual filters can be screwed on top of each other and thus stacked.
They are set at a small wedge angle in the housing so as not to cause interference effects.

ND1, ND2 and ND3 stackable filters

Stackable filter showing wedge

Transmission vs. Wavelength

These bulk-absorbing "neutral density" or ND filters do not have a flat response in attenuation vs. wavelength. See the graph for typical transmission vs. wavelength characteristics.



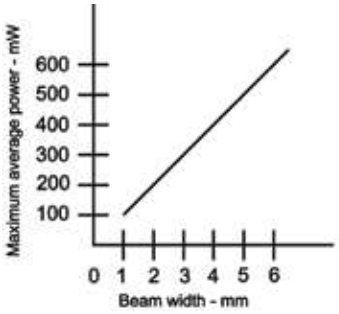
Specifications	
Item	**ND1 / ND2 / ND3**
Nominal ND (vis)	1, 2, 3
Clear Aperture	Ø19mm
Damage threshold	5W/cm², 1J/cm² for ns pulses

ATP-K Variable Attenuator

This option makes beam profiling easy. The ATP-K attenuates your laser without ghost reflections or fringes and has a knob-operated variable wedge attenuator of ND 1.7–4.6, and comes with a fixed gray-glass attenuator with ND 2.8.
The ATP-K is also designed to be used with the HP-XXX high power attenuators and beam splitters. Both types of attenuators attach directly to the ATP-K via C-mount. The ATP-K has simple reproducible attenuation settings, and has a wavelength range of 360 to 2500+ nm.

Figure 1 below shows the safe average power for negligible beam distortion from thermal lensing. Absorptive filters, such as used in the ATP-K have an upper power limit of approximately 100mW per mm beam diameter. For pulsed beams, Figure 2 shows the damage threshold for energy where breakage of the glass wedge may occur. This is approximately 5J per mm beam diameter. For lasers with power or energy levels above this the first stage of attenuation will need to come from our line of high power reflective attenuators.

Figure 1 – Safe average power for negligible beam distortion



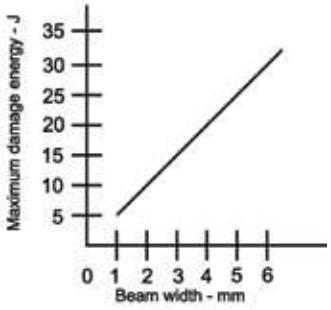


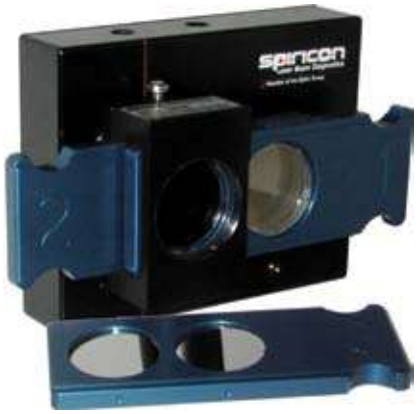
Figure 2 – Point at which damage will occur with pulsed energy

ATP-K Specifications	
Maximum Power/Energy Handling	100 mW/mm beam diameter 100 mJ total avg. energy Damage threshold: 5J
Note: Powerful laser sources may require additional attenuation prior to the beam's exposure to Model ATP-K. Additional attenuation usually is achieved by use of high-power laser mirror attenuators or clean, high-quality quartz plates (recommended with slight wedge angles).	
Wavelength Range	360-2500+ nm Near flat response out to 1500nm
Attenuation Range	Variable filters: ND = 1.7 to 4.6 Maximum ND 7.4 (with fixed 2.8 gray-glass attenuator)
Note: ND (optical density) = log (1/T) or T=10^(-ND) where T is the fraction of light transmitted. For example, an ND of 5 transmits 0.00001 or 0.001%.	
Clear Aperture	15mm diameter
Dimensions	94 (W) x 28 (H) x 43 (D) mm
Thickness Tolerance	±0.25mm
Mounting	C-mount
Base Mount	¼-20

UV ND Filters

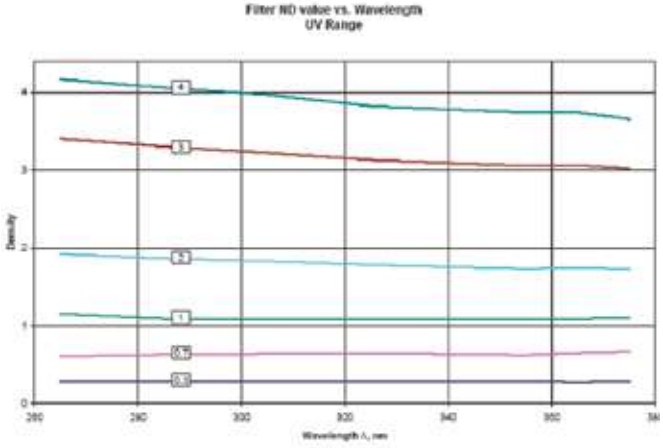
This accessory can be used with any camera fitted with C- mount threads. Simply thread the attenuator assembly into the front of the camera and then slide the ND filter arrays to get the desired amount of attenuation. This device can be used with laser outputs from microwatts to Watts. Three filter holders are provided with two filters in each holder. Each filter in the holder provides for a different value of attenuation. To use, slide the desired holder into the housing slot. A click is felt when the filter is properly aligned with the beam. The holders provided will allow for attenuation of up to ND 6.

C-mount interface for universal application to our CCD and Pyroelectric cameras 190-380nm
attenuation covers Excimer, Helium Cadmium, and the Nd:YAG UV harmonic laser wavelengths.
Attenuation with these ND filters permits the best use of the dynamic range of a beam profiling camera.
Attenuation range of 0.3 to 6.0 optical densities (ND).
Set consists of three slides with two filters in each slide.
The Six Filters include 0.3, 0.7, 1.0, 2.0, 3.0 and 4.0 optical densities.
Two filters can be employed at one time for 0.3 – 6.0 optical attenuation in 0.3 or 0.4 ND steps.
20mm clear aperture will not vignette any of our applicable camera sensors.
Damage threshold = 100W/cm^2 for CW lasers and 20mJ/cm^2 for nano-second pulse width lasers.
Additional Beam Splitters can be added for attenuation of high power UV lasers.
UV attenuation system uses high quality optics from the leader in laser beam diagnostics.



Specifications

Item	UV ND Filters
Nominal ND (UV)	0.3, 0.7, 1.0, 1.3 ,1.7, 2.0, 2.3, 2.7, 3.0, 3.3, 3.7, 4.0, 4.3, 4.7, 5.0, 6.0
Aperture	Ø20mm
Damage threshold	100W/cm^2 CW, 10ns pulses, no distortion



Specialized Filters

There are also specialized filters available to eliminate extraneous wavelengths when measuring very short or very long wavelengths where the CCD cameras are not sensitive and the desired signal can get swamped by extraneous light of other wavelengths.
These filters are as follows:

1. The 355nm filter for monitoring the 3rd harmonic of YAG. This filter transmits 355nm but blocks 532nm and 1064nm.

Transmission	~ 60 at 355mn, zero at 532nm, and 5E-6 at 1064nm
Filter Thickness	4mm
Filter Spacing	8mm
Flatness	2 waves in the visible
Laser damage Threshold	0.6J/cm^2 and 50W/cm^2

This filter has the same standard thread so it can be mixed with all the other components.
See ordering information for more details.

Ordering Information

Item	Description	P/N
ND1 stackable filter (red housing)	4mm spacing screw on filter for camera with transmission of between 20% and 5% depending on spectral range. Can be stacked and combined with other filters and beam splitters.. One filter is included with Spiricon cameras	SPZ08234
ND2 stackable filter (black housing)	4mm spacing screw on filter for camera with transmission of between 7% and 0.5% depending on spectral range. Can be stacked and combined with other filters and beam splitters. Two filters are included with Spiricon cameras	SPZ08235
ND3 stackable filter (green housing)	4mm spacing screw on filter for camera with transmission of between 2% and 0.05% depending on spectral range. Can be stacked and combined with other filters and beam splitters	SPZ08253
ATP-K	Variable Attenuator Package provides smooth knob operated variable wedges with attenuation of optical density (ND) 1.7–4.6 for a total attenuation capability of ND 7.4. Specially designed to eliminate ghost reflections, fringes, and light leaks. Small compact module including C-mount adapter to attach to camera, and C-mount receptacle to easily attach additional HP-series attenuators	PH00128
UV ND Filters	3 Filters holders each with 2 inconel UV ND. Filters for attenuation up to ND 6	SP90228
Filter for 355nm-V2; give an undistorted image of the 355nm light	Silicon cameras can see the 355nm 3rd harmonic radiation of YAG. The YAG however usually emits some light at 532nm and 1064nm as well. This filter filters out the other 2 wavelengths to give undistorted image of the 355nm light	SPZ08246

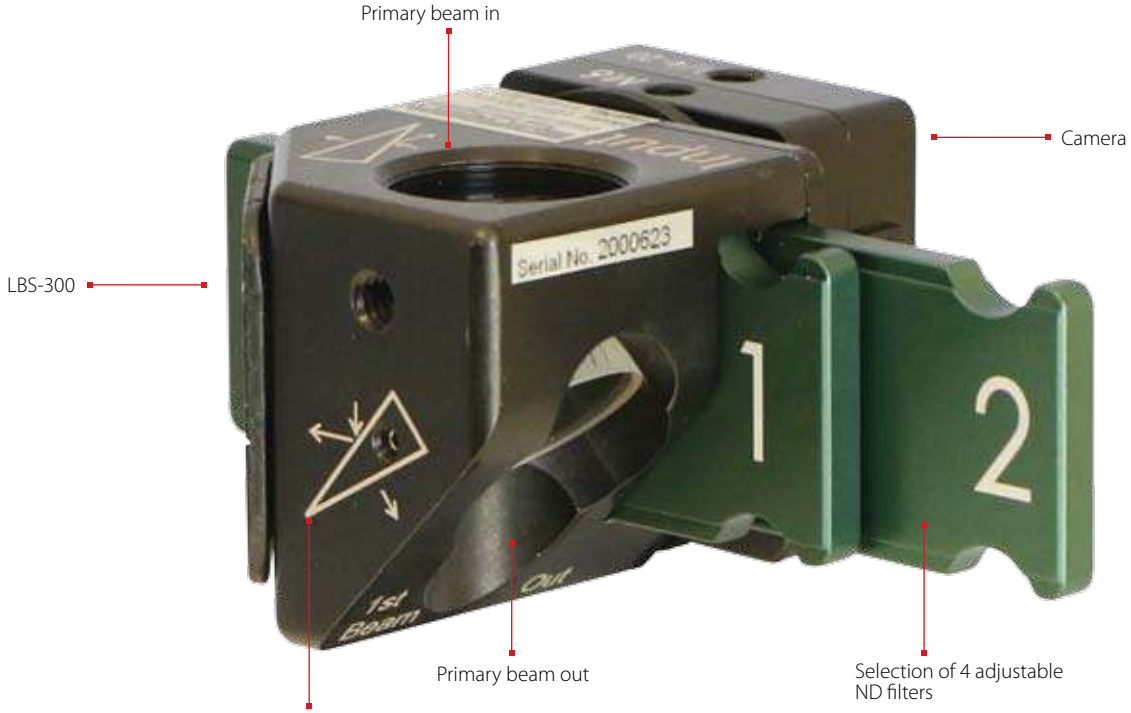
3.5.2 Beam Splitter + Neutral Density Filters Combo

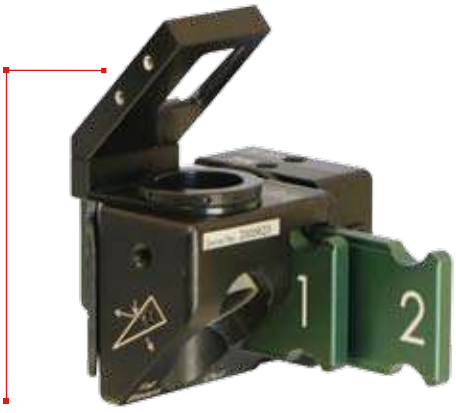
The attenuators described before can provide a high degree of attenuation however, these neutral density attenuators cannot dissipate more than 5W or so. Therefore we often place beam splitters in front of the attenuators to reduce the intensity before the ND filters. These beam splitters are made of UV grade fused silica for use from 190 to 2000nm. Since they do not absorb light, they have a much higher power handling capacity than the ND attenuator/filters.

Model	LBS-300s	LBS -400	LBS-100
Wavelength	multiple versions from 190 to 1550nm	UV or 10.6µm	multiple versions; 400-700nm, 1064nm, 10.6µm
Reflection	0.01% of incident beam	0.01%	4% @ 400-900nm, 1% @1064nm, 0.5% or 5% @10.6µm
Nominal ND value (vis)	0.3, 0.7, 1, 2, 3, 4	0.5, 1.0 in both filters	0.3, 0.7, 1, 2, 3, 4 for 300-700nm & 1064nm 30% & 60% for 10.6µm
Clear Aperture	Ø17.5mm	Ø31.75mm	Ø19mm
Damage threshold	see spec sheet	See spec sheet	5W/cm^2 no distortion
Mounting	CS-mount or Ophir mount	Custom thread	C-Mount and Lab post mounted

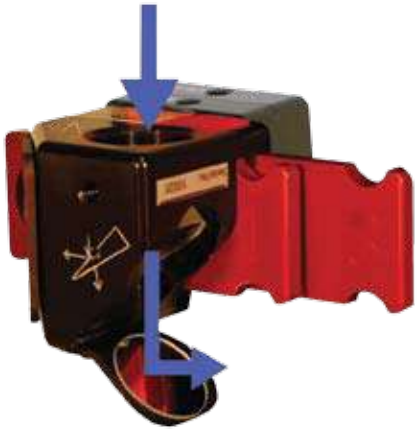
LBS-300s Beam Splitters

The LBS-300s beam splitter attachment for C-mount, CS-mount, or Ophir mount cameras allow you to measure laser beams with diameters up to 15mm and powers ranging from 10 mWatts to ~400 Watts. The beam sampler is designed so that the preferential polarization selection effect of a single wedge is cancelled out and the resulting beam image is polarization corrected to restore the polarization components of the original beam. The beam sampler operates by reflecting the incoming beam from the front surfaces of a pair of wedges through 90 degrees into the camera. Approximately 99% of the beam is transmitted through the beam sampler with 0.01% passed on to the camera. A set of adjustable ND filters are provided to make final intensity adjustments to the beam before it reaches the camera imager. If additional attenuation is needed, an external wedge may be mounted at the input port, however this 3rd wedge will cause polarization selectivity when the beam is significantly polarized different in the S and P planes. A 1.035-40 thread is provided behind each wedge along the axis of the output beam that can be used to directly mount accessories with 1" lens tubes such as beam dumps or even power and energy sensors to the LBS-300s.

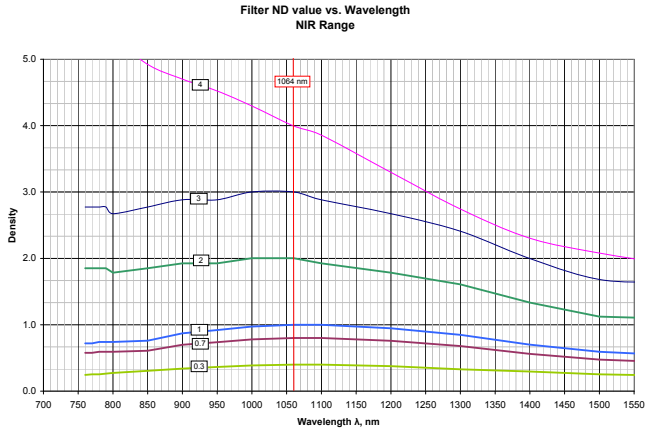




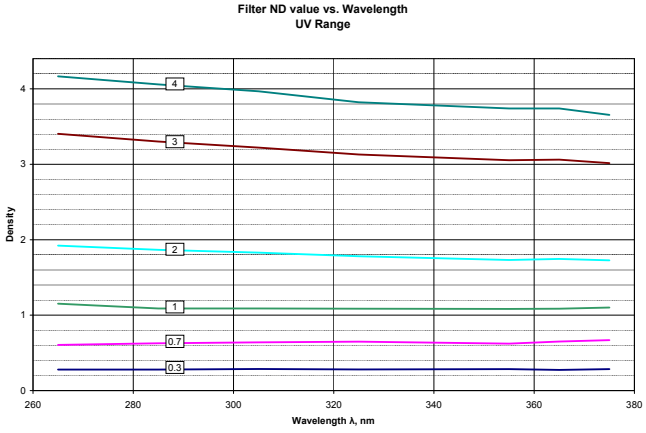
Optional SP90273 Large C-mount Wedge Splitter



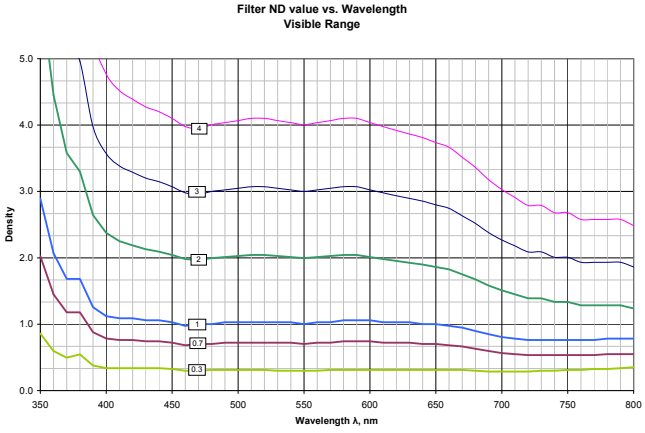
Optional SP90263 Beam Deflector



NIR filter set (Red Holders) – SP90185



UV filter set (Blue Holders) – SP90183



VIS filter set (Green Holder) – SP90184

Ordering Information

Model	LBS-300s-UV	LBS-300s-VIS	LBS-300s-NIR	LBS-300s-BB
Part No.	**SP90464**	**SP90465**	**SP90466**	**SP90467**
Wavelength	266-355nm	400-700nm	1064nm	190-1550nm
Wedge Material	UVFS	UVFS	UVFS	UVFS
Wedge Coating	A/R ≤1%	AR ≤1%	AR ≤1%	No coating, 4% reflection
Clear aperture	17.5mm	17.5mm	17.5mm	17.5mm
Reflection	0.01%	0.01%	0.01%	0.16%
Wedge ND value, each	ND ≥2	ND ≥2	ND ≥2	ND ~1.3
ND Filters	Inconel	Bulk ND	Bulk ND	One each of the UV, VIS & NIR sets
ND Values, nominal	0.3, 0.7, 1.0, 1.5, 2.0, 3.0 (Blu holders)	0.3, 0.7, 1.0, 2.0, 3.0, 4.0 (Grn holders)	0.4, 0.8, 1.0, 2.0, 3.0, 4.0 (Red holders)	See UV, VIS and NIR descriptions
Filter Slides	3	3	3	9
Maximum allowable input to filter (1)	100 W/cm² CW 20mJ/cm², 10ns pulse	50 W/cm² 1J/cm², 10ns pulse	50 W/cm² 1J/cm², 10ns pulse	See adjacent specifications
Accessories				
Beam Dumps	BD-040-A, 40 Watts Max Power, Air Cooled			SP90192
	BD-500-W, 500 Watts Max Power, Water Cooled			SP90193
Large C-mount Wedge Splitter	For additional attenuation add this to the front end of the LBS-300. Good for 350-2000nm			SP90273
Beam Deflector Assembly	for 350-1200 nm only			SP90263
Beam Deflector Assembly	For 266 nm, high damage threshold			SP90287
Beam Deflector Assembly	For 355 nm, high damage threshold			SP90286
Beam Deflector Assembly	For 532 nm, high damage threshold			SP90285
Beam Deflector Assembly	For 1064 nm, high damage threshold			SP90284
Note: (1)	ND bulk absorbing filters damage threshold is 50W/cm² but should be used at <5W/cm² to avoid thermal lensing effects.			

LBS-400 Beam Splitters

The LBS-400 beam sampler attachment for Pyrocam cameras allow you to measure UV, NIR or IR wavelength laser beams with diameters up to 1 inch (25.4mm) and powers ranging from 10mW to ~500W. The beam sampler is designed so that the preferential polarization selection effect of a single wedge is cancelled out and the resulting beam image is polarization corrected to restore the polarization components of the original beam.

The beam sampler operates by reflecting the incoming beam from the front surfaces of a pair of wedges through 90 degrees into the camera. Approximately 99% of the beam is transmitted through each beam sampler with 0.01% passed on to the camera. A set of adjustable filters are provided to make final intensity adjustments to the beam before it reaches the camera imager.

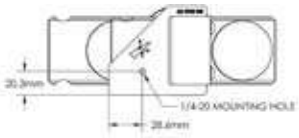
Model	**LBS-400-UV**	**LBS-400-NIR**	**LBS-400-IR**
Part No.	**SP90351**	**SP90354**	**SP90349**
Wavelength	193-355nm	1064nm	10.6µm
Wedge Material	UVFS	BK7	ZnSe
Wedge Coating	A/R ≤1.5%	A/R ≤1%	A/R ≤1%
Clear Aperture	1.25 inch (31.75mm)	1.25 inch (31.75mm)	1.25 inch (31.75mm)
Reflection	0.01%	0.01%	0.01%
Wedge ND value (each)	ND ≥2	ND ≥2	ND ≥2
Filter Material	Inconel	Bulk ND	CaF2
Filter ND Values nominal	0.5, 1.0 in both filters	0.5, 1.0 in both filters	0.5, 1.0 in both filters
Adjustable Filter Slides	2	2	2
Filter Damage [1]	100 W/cm^2 20mJ/cm^2, 10ns pulse	50 W/cm^2 1J/cm^2, 10ns pulse	5W/cm^2 300 J/cm^2, 1ms pulse

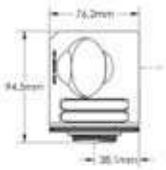
[1] ND bulk absorbing filters damage threshold is 50W/cm^2 but should be used at <5W/cm^2 to avoid thermal lensing effects.

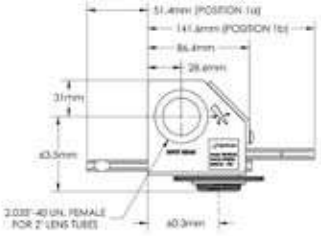
Accessories

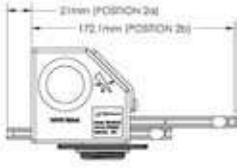
LBS-400 to L11059 adapter	SP90439	Adapter plate to mount L11059 to LBS-400
Beam Dumps	BD-040-A, SP90192 BD-500-W, SP90193	40 Watts Max Power, Air Cooled 500 Watts Max Power, Water Cooled

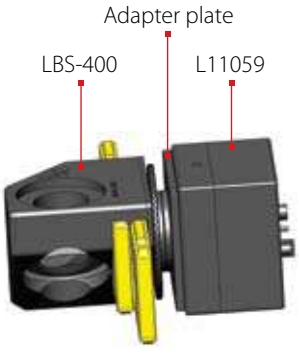
LBS- 400



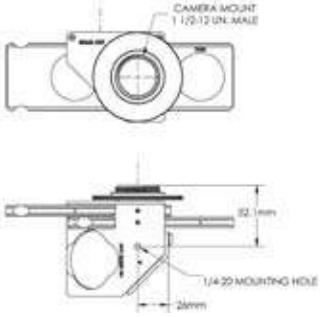








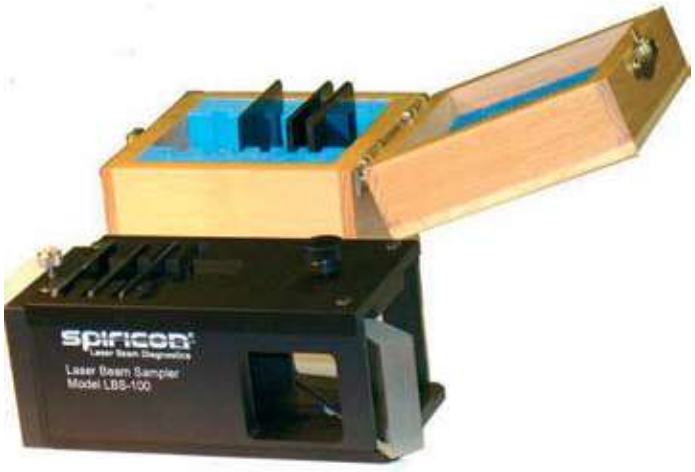
Accessory adapter plate

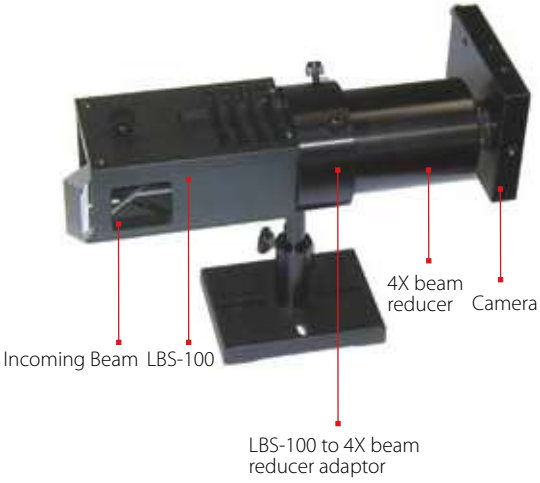


LBS-100 Attenuator

The LBS-100 system that is not as compact as the LBS-300 above but has larger aperture, and has versions for longer wavelengths. The system contains the mounting frame, 1 wedge beam splitter and several attenuators. The exit end of the LBS-100 is standard C mount thread so all our cameras can be mounted to the frame. The wedge angle is 6.5 degrees to insure that the reflection from the rear side will not enter the camera. The optical elements are flat to 1/4 wave in the visible to ensure no distortion of the beam.

LBS-100 System





The LBS beam splitter/attenuator system can be combined with the 4X beam reducer, as shown above, to attenuate and view large beams.

Ordering Information

Item	Wavelength range	Absorber material	Neutral Densities or transmission	Wedge material and reflection	Max power density on ND filters	Clear aperture	Dimensions	P/N
LBS-100	400 - 700nm recommended, functional to 2600nm	Neutral density glass	0.3, 0.7, 1.0, 2.0, 3.0, 4.0 ND at 632nm	Fused Silica 4% in wavelength range 400 - 900nm	5W/cm² for no distortion, 50W/cm² damage	19mm	65mm W x 55mm H x 140mm D	SP90061
LBS-100 YAG	1064nm	Same	Same	1% at 1064nm	Same	Same	Same	SP90057
LBS-100 IR 0.5	10.6µm	CaF2 flats,3 -3mm and 1-1mm	30% T for 3mm flat, 60% T for 1mm flat at 10.6µm	ZnSe 0.5% at 10.6µm	Same	Same	Same	SP90058
LBS-100 IR 5.0	10.6µm	Same	Same	ZnSe 5% at 10.6µm	Same	Same	Same	SP90059
Accessories								
LBS-100 filter set	Replacement filter set							SP90141
LBS-100 -YAG filter set	Replacement filter set							SP90142
LBS-100 to L11058/L11059 adaptor	Mount L11058/L11059 camera to LBS-100 attenuator							SP90196
LBS-100 to 4X beam reducer adapter	This adapter enables mounting of the LBS-100 beam splitter/attenuator assembly in front of the 4X beam reducer. The combined assembly can image large high power beams in one unit.							SPZ17029

3.5.3 Beam Splitter




Model	Beam Tap I & II	Beam Tap I & II YAG	Stackable Beam Splitter	Single & Dual Front-Surface Beam Samplers
Wavelength	400-700nm	1064nm	190-2000nm	200nm-2.5µm
Reflection	4% & 0.16% of incident beam	0.5% & 0.0025% of incident beam	5% & 0.25% of incident beam	0.057% @ 532nm
Clear aperture	Ø17.5mm	Ø17.5mm	Ø15mm	14mm x 14mm
Damage threshold	1MW/cm^2 CW, or 1MJ/cm^2 pulsed	1MW/cm^2 CW, or 1MJ/cm^2 pulsed	>5J/cm^2	100MW/cm^2
Mounting	C-Mount Threads	C-Mount Threads	C-Mount Threads	C-Mount Threads

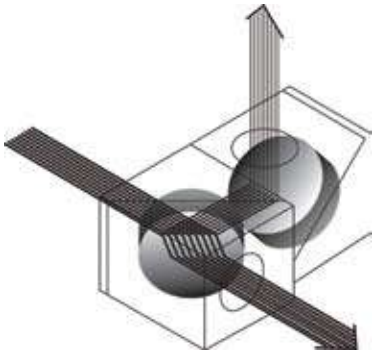
Beam Tap I & II

- Dual surface reflector for equalizing S & P polarization
- The two planes of reflection are orthogonal

Single Surface Polarization Problems

A single surface reflection at 45° is often used to sample a laser beam for profile measurements or for monitoring power or energy. However, as shown on page 191, at 45° a single surface reflects the S polarization component at more than 10 times the reflection of the P component. Depending on the laser polarization content, or stability, this sampling can provide very misleading and unreliable measurements. (The BT-I-YAG has both surfaces A/R coated for 1064nm so the reflection for both polarizations is equal at 0.5%. At other wavelengths far from 1064nm the above discussion applies).

Equalizing S & P reflected polarization

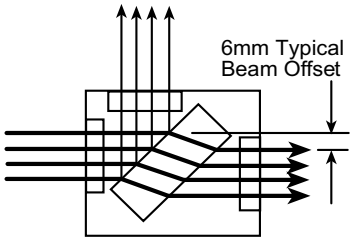


Any arbitrary polarization component can be broken into equivalent S & P components. With complimentary sampling surfaces any given component gets reflected once as the S polarization, and the second time as the P polarization. Thus using 2 surfaces, the total reflected energy for all polarization components is the sum of the **S** reflectance and the **P** reflectance. This causes the sampled beam to have **S & P** components that are identical to the original beam.

Beam path through beam tap

The Beam Tap II uses two reflecting surfaces such that the two planes of reflection are orthogonal. The standard Beam Tap I rear surface is AR coated from 400-700nm.

This diagram shows the 6mm offset of the through beam that is created by the reflecting optic. The deflection angle of the output beam is less than 0.007 degrees. The rear surface of the flat is AR coated to maximize the throughput of the main beam. The standard Beam Tap II rear surface is AR coated for 400nm-700nm. The YAG version is AR coated for 1064nm on both surfaces.



Beam tap reflection vs wavelength

Shown is the Beam Tap II final sampled reflection vs. wavelength.
As shown both the S & P reflection are nearly constant at 0.05% from the UV to the infrared.
(See figure 7 in the Beam Tap manual in our website)

Ordering Information

Model	Surface	Wavelength range	Optical Material	Reflection	P/N
BT-I	Single surface, 1 cube	400-700nm	UVFS	4% Ravg	SP90135
BT-II	Dual surface, 2 cubes	400-700nm	UVFS	0.16% Ravg	SP90133
BT-I-YAG	Single surface, 1 cube	1064nm	BK7	0.5% Ravg	SP90173
BT-II-YAG	Dual surface, 2 cubes	1064nm	BK7	0.0025% Ravg	SP90172

Stackable Beam Splitters

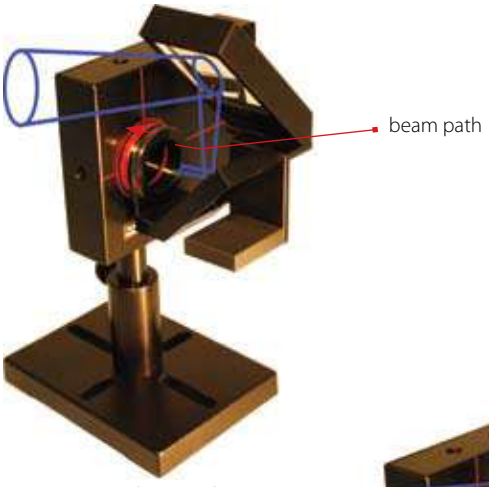
The stackable beam splitters are designed for maximum modularity and shortest beam path. They are compatible with almost all of our cameras having the standard C mount thread and can mount either to other attenuators or to the camera itself. Each beam splitter reflects ≤6% of the incoming beam and allows approximately ≥94% of the beam to pass directly through. By stacking 2 splitters ≤6% of ≤6% or 0.36% of the original beam intensity is directed into the camera. The beam splitters are mounted over the fixed or variable attenuators with a simple fastening ring and can be oriented in any direction with the beam coming from right, left, up, down, or front. The Beam Splitters will operate for wavelengths from 193nm - 2500nm. Damage threshold is >5J/cm2 for 10ns pulses.

An optional Ø30mm clear aperture splitter allows for larger diameter incoming beams. Caution: Beam convergence and power density must be known at the imager so you don't overflow the imager size and maximum power density at the imager.

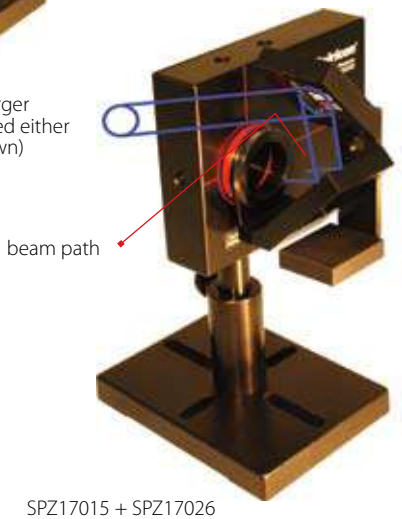
A different set of stackable beam splitters are specifically coated for optimization at 1064nm. Each beam splitter reduces the intensity to 1% of the input Beam. 2 stacked splitters will produce a sampling Beam with 0.01% intensity of the original beam.

The wedge angle of 10 degrees insures that only the reflection from the front surface will appear on the camera with no double images. The user must insure that there are beam stops for the transmitted and reflected beams.

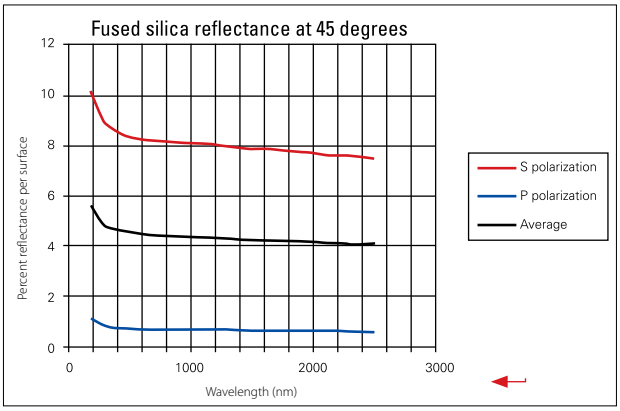
Note that if possible, the user should use an even number of beam splitters so as to cancel any possible polarization effects.



For converging beams a larger aperture splitter can be used either by itself or stacked (as shown)



SPZ17015 + SPZ17026
(used either singularly or stacked)



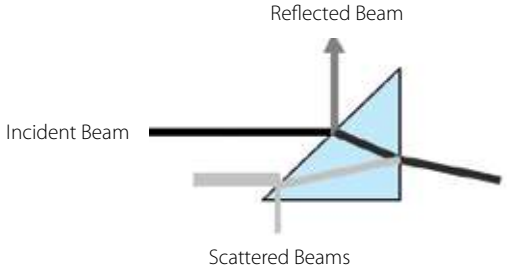
Ordering Information

Item	Description	Clear Aperture	Material	Wavelength	Reflectance	Path length to CCD with 3 screw-on ND filters	P/N
1st Wedge Beam Splitter	45 degree wedged beam splitter	Ø15mm	UVFS	193-2500nm	≤6%	60mm	SPZ17015
2nd Wedge Beam Splitter	Additional 45 degree wedged beam splitter to mount to 1st wedge beam splitter		UVFS	193-2500nm	≤6%	93mm	SPZ17026
Large Aperture Wedge Beam Splitter	For converging beams a larger aperture wedge beam splitter	Ø30mm	UVFS	193-2500nm	≤6%	60mm	SPZ17025
1st Wedge Beam Splitter	45 degree wedged beam splitter	Ø15mm	UVFS coated 1064nm	1064nm	≤1%	60mm	SPZ17031
2nd Wedge Beam Splitter	Additional 45 degree wedged beam splitter to mount to 1st wedge beam splitter		UVFS coated 1064nm	1064nm	≤1%	93mm	SPZ17032

Single and Dual Prism Front-Surface Beam Samplers

The Prism Front-Surface Beam Sampler (PFSA) is a C-mount fixture housing a UV-Grade Fused Silica right angle prism, used for sampling the front surface reflection for high power/energy beam-profiling applications. Reflection at nominal incidence of 45°is polarization and wavelength dependent, with 532nm s-polarization reflected at 8.27%, and p-polarization at 0.68%.

The system is available as either a single prism (PFSA) or dual orthogonal prism (DPFSA) unit. The dual orthogonal prism configuration results in polarization independent reflection of 0.057% at 532nm. Other filters and attenuators can be attached using the C-mount female threads at the input end. The use of a right-angle prism to sample the incident beam guarantees that any scattered secondary beams do not interfere with measurement, as shown in the sketch.



Dual Prism Front Surface Sampler

Prism Front Surface Attenuator Specifications

Wavelength of use	200nm to ~2.5um	
Optical Material	UV-Grade Fused Silica	
Surface Quality	20-10	
Surface Accuracy	λ/10	
Angle of Incidence	45°	
Clear Aperture	14mm x 14mm	
Reflection	Polarization	
λ (nm)	P	S
248.3	0.88%	9.40%
351.1	0.75%	8.65%
532	0.68%	8.27%
1064	0.64%	8.01%
Laser Damage Threshold	CW> 100MW/cm^2	
Dimensions(PFSA)	38.1mm x 32.3mm x 29.5mm	
Dimensions (DPFSA)	44.5mm x 40mm x 32.5mm	
Output Mounting with Brass Lock Ring	C-Mount Male (1"-32 Thread Male)	
Input Mounting	C-Mount Female (1"-32 Thread Female)	

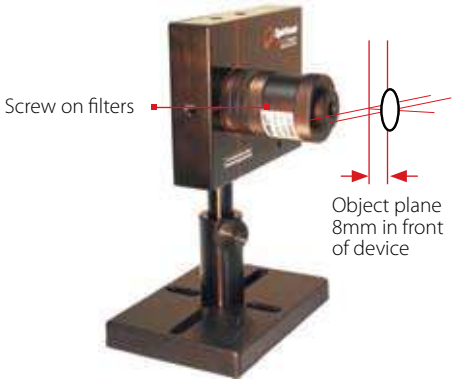
Two Single Prism Front Surface Samplers mounted on a ATP-K Attenuator

Ordering Information

Model	Surface	P/N
PFSA	Single Prism Front Surface Sampler	PH00052
DPFSA	Dual Prism Front Surface Sampler	PH00053

3.5.4 Beam Expanders Microscope Objectives

Model	Beam Expander	4X Beam Expander with UV Converter
Wavelength	400-1800nm	193nm-360nm
Beam Size Change	4X, 6X, 12X, 22X	4X Expansion
Clear aperture	1/4 the size of the CCD imager	
Mounting	C or CS Mount Threads	



Camera with 4X beam Expander (SPZ12022)

Beam expanders are designed to work with C-mount threaded cameras that have 4.5mm imager back focal spacing or with CS (12.5mm) back focal spacing. The 4X beam expander is an expanding telescope that images the beam as it looks at 8mm from the end of the expander onto the CCD while enlarging the image 4X. In addition to the 4X beam expander, other microscope objectives are available for expanding the beam even more. There are objectives for 6X, 12X, and 22X expansion. The various expanders allow the use of our 2% and 10% filters as well as the variable attenuator so as to accommodate the camera to a wide range of source intensities.

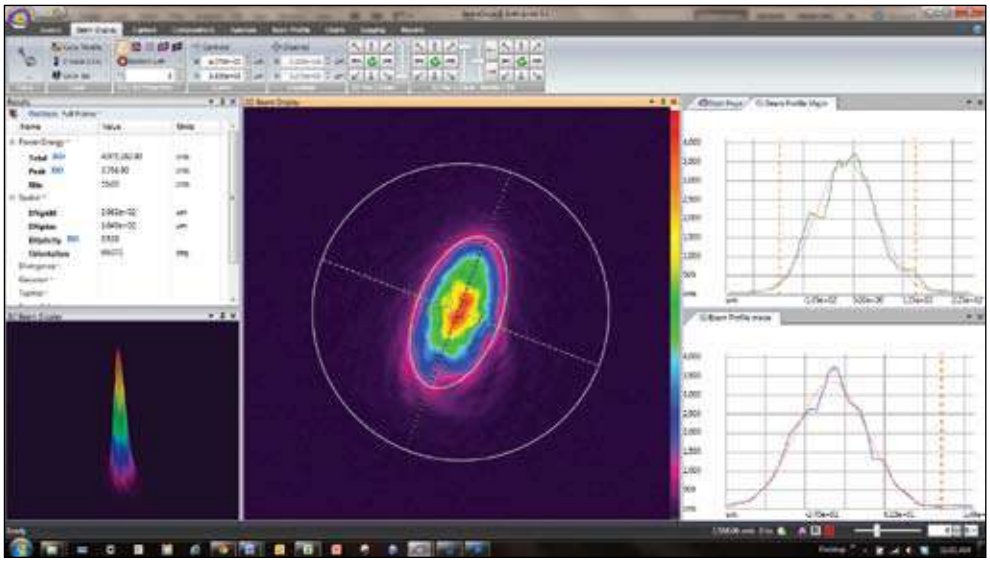
With a camera having 4.4µm pixel spacing using the beam expander, the effective resolution can be as good as 0.5µm. The object plane that is imaged onto the CCD is located several mm in front of the assembly so even hard to get to focal spots and other small images are easy to image. The beam expanders are designed to accommodate up to 3 screw on filters or a variable attenuator behind them so a wide range of intensities can be accommodated.

For intensities too large to be accommodated by just filters, beam splitters are available to reduce the intensity before the beam expander. The beam expander is primarily intended for nonparallel beams such as focal spots and fiber tips. If small parallel beams are imaged, interference effects may occur.

The 4X Beam expander can also be fitted with a UV converter plate at its object plane so that you can look at small beams in the spectral range 193-360nm and expand them 4X.
See ordering information for further details.

Camera with 12X Expanding Microscope Objective (SPZ08259)

Camera with 4X Beam Expander (SPZ17022) and SPZ17027 Beam Splitter



Shown is an image of the tip of a single mode fiber measuring 16µm by 30µm in the two axes. The beam width as measured on the profiles shows 4X the actual size so we can measure to a resolution of ~2µm.

Approximate expansion ratio	Spectral range	Distance from lens barrel to focus	Distance from focus to 1st beam splitter	Distance of closest approach to focus with 1 beam splitter	Total length of assembly
4X	400 - 1800nm	8mm	18mm	32mm	50mm
6X	600 - 1064nm	16mm	10mm past 1st surface	4.5mm	107mm
12X	600 - 1064nm	6mm	6mm	20mm	101mm
22X	600 - 1064nm	2.4mm	8mm	22mm	102mm

The UV converter is a UV sensitive plate that can be mounted over the 4X Beam Expander.
The UV sensitive plate is positioned at the object plane of the 4X beam expander, 8 mm in front of the unit. When UV radiation hits the fluorescent plate, it absorbs the UV radiation and re-emits visible light proportionate to the incident UV light. This light pattern is then expanded 4 times and imaged onto the imager of a C-mount camera.

Specifications	4X Beam Expander with UV converter
Beam Reduction	4X expansion ±2% with included correction factor
Spectral range	193 - 360nm
Resolution	15µm x 15µm;
Minimum signal	~50µJ/cm^2
Saturation intensity	~30mJ/ cm^2 at 193nm, ~15mJ/cm^2 at 248nm 20 times greater with optional beam splitter
Effective Aperture	1/4 the size of the CCD dimensions
Damage threshold	0.1J/cm^2 w/o beam splitter, 2J/cm^2 w/ beam splitter
Dimensions	Ø31mm dia x 120mm length

Camera with 4X Beam Expander and UV Image Converter

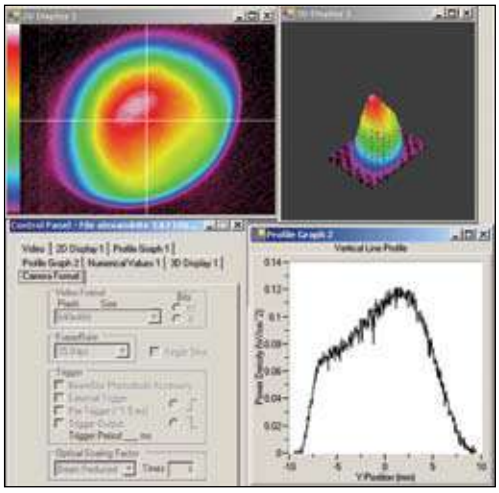
Ordering Information

Item	Description	P/N
4X reimaging beam expander	Screw optical assembly that images the plane 8 mm in front of the expander onto the CCD while enlarging it 4X. Fits 4.5mm recess and CS mount cameras	SPZ17022
UV converter assembly for 4X beam expander	Screw on assembly which has UV plate that converts 193 - 360nm radiation to visible. This plate is at the object plane of the 4X expander so it produces a 4X enlarged image on the CCD	SPZ17019
6X expanding microscope objective	Screw optical assembly that images the plane 16mm in front of the lens onto the CCD while enlarging it ~6X. Fits 4.5mm recess and CS mount cameras. Needs spacer assembly SPZ08261	SPZ08257
12X expanding microscope objective	Screw optical assembly that images the plane 6mm in front of the lens onto the CCD while enlarging it ~12X. Fits 4.5mm recess and CS mount cameras. Needs spacer assembly SPZ08261	SPZ08259
22X expanding microscope objective	Screw optical assembly that images the plane 2.6mm in front of the lens onto the CCD while enlarging it ~22X. Fits 4.5mm recess and CS mount cameras. Needs spacer assembly SPZ08261	SPZ08260
Spacer assembly for objectives	Spacer assembly for above. One only needed for all expanders above	SPZ08261
Beam splitter for expanders above	45 degree angle wedge beam splitter which mounts onto beam expander. Reduces beam intensity by ~20 times. For spectral range 190 – 2500nm. Introduces 35mm extra beam path to object plane	SPZ17027
Additional beam splitter for above	Additional beam splitter to mount to 1st beam splitter	SPZ17026

3.5.5 Beam Reducers

4X Reimaging Beam Reducer

The 4X Beam Reducer is an imaging system that images the plane 30cm in front of the reducer onto the camera CCD sensor while reducing the size 4 times and inverting it. The beam reducer uses the 3 screw on attenuators provided with the camera. Since the intensity of a beam after reduction will be increased by 4x4=16 times, it is advisable to attenuate the beam more than you would without beam reduction. This can be done with additional external beam splitters and attenuators which are available (see ordering information).
Note that the custom designed beam reducer gives better image quality than tapered fibers since it does not introduce graininess or uneven pixel response. Also the image distortion of ~1% is considerably lower than with most tapered fibers. The beam reducer is not compatible with CS mount cameras.



Shown is an image of an Alexandrite laser with beam diameter of 18mm. As can be seen, it is easily seen with the SP 620 camera with the 4X beam reducer.

4X beam reducer (SPZ17017)

Optional large wedge beam splitter (SPZ17018)

LBS-100 (SPZ17029) + LBS-100 combined with 4X beam reducer (SP90061+SPZ17017)

The 4X beam reducer can be combined with the LBS-100 beam splitter/attenuator system to attenuate higher power beams before reducing them in size

Specifications of 4X beam reducer

Spectral Range	360nm to 1100nm
Antireflection Coating	Antireflection coating optimized for 1064nm and 532nm
Beam reduction Accuracy	± 3%
Size	Ø60 mm dia x 94mm length
Aperture	50mm
Maximum Beam Size	SP 503: 25x19mm, SP 620 or GRAS20: 28x21.2mm
Distortion of Beam	Less than 1% over 80% of diameter
Damage Threshold	30mJ per pulse for nanosecond pulses

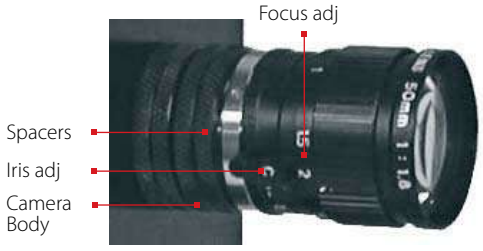
Ordering Information

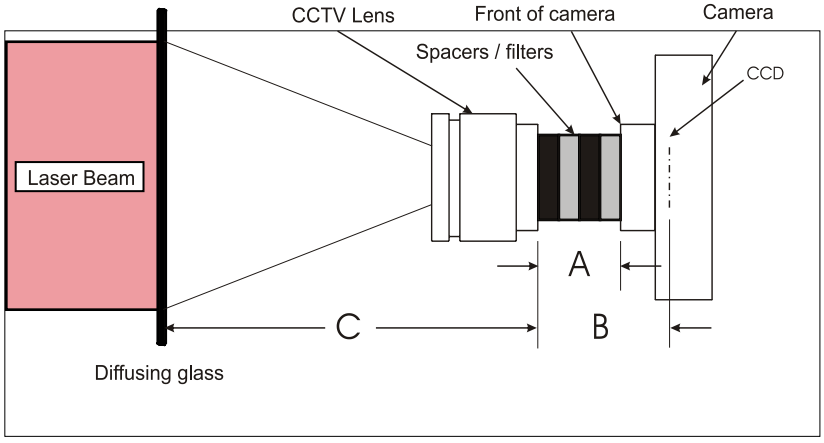
4X Imaging Beam Reducer

Item	Description	P/N
4X reimaging beam reducer	Screw on beam reducer for beams in the wavelength region 360 – 1100nm that reimages the beam 30cm in front of the unit onto the CCD while reducing the beam size 4X. Entrance aperture is 50mm. Fits 4.5mm recess cameras only	SPZ17017
Accessories		
LBS-100 to 4X beam reducer adapter	This adapter enables mounting of the LBS-100 beam splitter / attenuator assembly in front of the 4X beam reducer. The combined assembly can image large high power beams in one unit	SPZ17029
Beam splitter large wedge	Wedge, UVFS, 44X32 mm, uncoated wedge housing mounts to 1/4" thread, 1/2" diameter laboratory rod (not included)	SPZ17018

3.5.6 CCTV lens for front imaging through glass or reflected surface

When direct imaging in front of the camera, for example, an image projected onto a diffusing surface, such as a ground glass plate, it is necessary to reduce the image so that it completely fits onto the CCD chip surface. The 25mm and 50mm CCTV lenses image an object from a given plane in front of the lens onto the CCD while reducing the size. The lens can image such objects at distances from about 10cm in front of the lens (20cm for the 50mm lens) to 1 meter or more depending on the distance from the lens to the camera. The distance from lens to camera depends on the camera type and spacers placed between the lens and the camera.

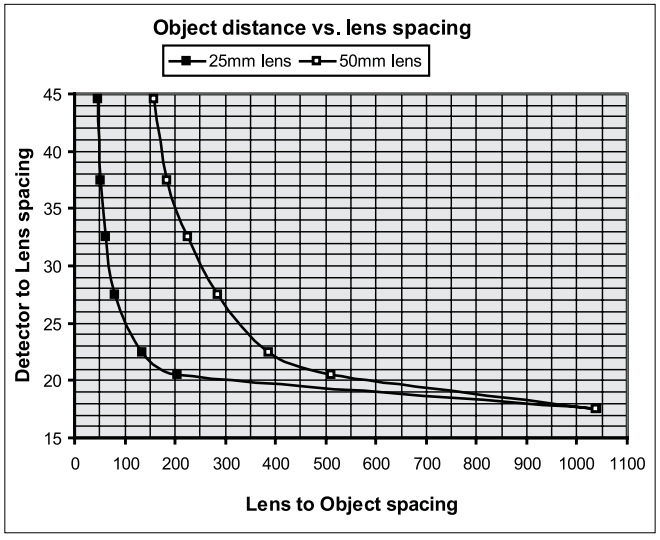


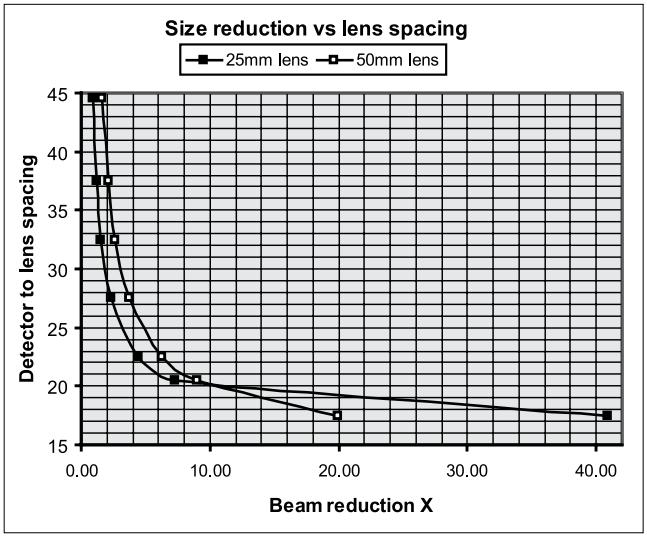


A. - Total length of spacers added to system
B. - Detector to Lens spacing. Distance 'A' plus the CCD inset for the camera type
C. - Lens to Object spacing

CCD inset for Camera Types

C mount (Camera front to CCD = 17.5mm) for nominal lens magnification, use without spacers.
CS mount (Camera front to CCD = 12.5mm) for nominal lens magnification, use 5mm spacer.
SP mount (SP cameras. Camera front to CCD = 4.5mm) for nominal lens magnification, use with 13mm spacers.





Ordering Information

Item	Description	P/N
25mm focal length CCTV lens kit	25mm focal length lens assembly with locking iris and focus adjustment. Includes 1 ea - 8mm spacer and 2 ea - 5mm spacers	SP90085
50mm focal length CCTV lens kit	Same as above except 50mm focal length lens	SP90038
4mm spacer	Screw on spacer to add 4mm spacing to optical system	SPG01698
5mm spacer	Screw on spacer to add 5mm spacing to optical system	SPG02106
8mm spacer	Screw on spacer to add 8mm spacing to optical system	SPG02067

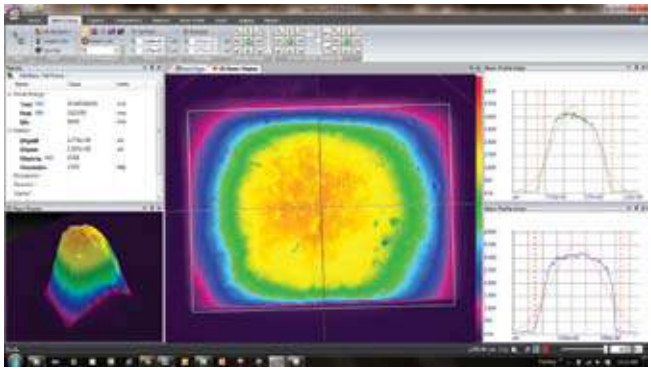
3.5.7 Imaging UV lasers

Integral Reimaging UV Image Converters

The UV image converters are fluorescent plates that convert UV radiation that is poorly imaged by silicon cameras into visible light that is then imaged onto the CCD of the camera. These fluorescent plates are specially designed for UV conversion and have a high light output, wide linear dynamic range and high damage threshold. There are 3 versions available:

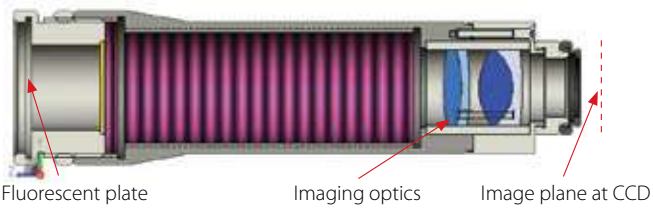
1. The 4X UV image converter for large beams converts to visible and then images onto the CCD while reducing the beam size 4X.
2. The 1:1 UV image converter converts to visible and images the beam onto the CCD without changing the size.
3. The 4X expander with UV converter converts to visible and images a beam enlarged 4X onto the CCD.

All of the above imagers allow a beam splitter to be mounted at 45 deg angle in front of the imager so as to allow imaging of higher power/energy beams.



Shown here is a profile of a 355nm UV laser. The beam is converted to a visible wavelength, reduced in size and imaged by the beam profiling camera

Cross section of 4X reducing UV image Converter



4X beam reducing UV Image Converter as mounted on camera (SPZ17024)

1X UV Image Converter with Optional Beam Splitter (SPZ17023 + SPZ17015)

4X beam expander with UV converter (SPZ17019+SPZ17022)

Specifications	4X UV Image Reducing Converter	1X UV Image Converter	4X Beam Expander with UV converter
Beam Reduction	4X reduction ±2% with included correction factor	1:1 imaging ±2% with included correction factor	4X expansion ±2% with included correction factor
Resolution	50µm x 50µm	35µm x 35µm	15µm x 15µm
Spectral range	193 to 360nm		
Minimum signal	~1µJ/cm² with blank filter		
Saturation intensity	~30mJ/cm² at 193nm, ~15mJ/cm² at 248nm with included filter 20 times above values with optional beam splitter	~15mJ/cm² at 193nm, ~20mJ/cm² at 248nm with included filter, 20 times greater with optional beam splitter	~30mJ/cm² at 193nm, ~15mJ/cm² at 248nm 20 times above values with optional beam splitter
Effective Aperture	Ø30mm but effective beam size is limited to 4X CCD dimensions	Ø18mm but effective beam size is limited to CCD dimensions	1/4 the size of the CCD dimensions
Damage threshold	100W/cm² or 2J/cm² with beam splitter		
Dimensions	Ø50mm dia x 185mm length	Ø31mm dia x 120mm length	Ø29mm dia x 69mm length

Ordering Information

Item	Description	P/N
1X UV image converter	Screw on imaging telescope that converts UV image to visible and images same size on CCD. For beam intensities from 50µJ/cm² to 15mJ/cm². Fits 4.5mm recess and CS mount cameras.	SPZ17023
Beam splitter for above	45 degree wedged beam splitter to reduce intensities on image converter by ~20X. For beam intensities of up to 300mJ/cm² at 193nm.	SPZ17015
4X reducing UV image converter	Screw on imaging telescope that converts UV image to visible reduces the size 4X and images on CCD. For beam intensities from 1µJ/cm² to 15mJ/cm².	SPZ17024
Beam splitter for above	45 degree wedged beam splitter to reduce intensities by ~20X. For beam intensities of up to 300mJ/cm² at 193nm.	SPZ17007
UV converter assembly for 4X beam expander	Screw on assembly which has UV plate to convert 193 - 360nm radiation to visible. The plate is at the object plane of the 4X expander (P/N SPZ17022) and produces a 4X enlarged image on the CCD. Requires separate purchase of 4X reimaging beam expander SPZ17022	SPZ17019
20mm diameter UV imaging plate	Ø20mm diameter UV image conversion plate only. For customers that have own imaging system. Converts UV image to visible. For beam intensities 50µJ/cm² to 10mJ/cm².	SPF01177
30mm diameter UV imaging plate	Ø30mm diameter UV image conversion plate only. For customers that have own imaging system. Converts UV image to visible. For beam intensities 50µJ/cm² to 10mJ/cm².	SPF01150
50mm X 50mm UV imaging plate	50X50mm diameter UV image conversion plate only. For customers that have own imaging system. Converts UV image to visible. For beam intensities 1mJ/cm² to 20mJ/cm². Not suitable for 193nm.	SP90082

Optical Camera Trigger

The Optical Camera Trigger is an optical sensor that detects pulsed light sources and generates outputs to trigger a camera. The front aperture of the Optical Trigger must be directed at a light source that provides the necessary properties for trigger activation. (e.g. a laser flash lamp, a pick-off source from the main laser beam, or similar). The light source may be a direct or indirect pulsed waveform.

The Optical Trigger system is supplied with a C-Mount adapter, a ¼-20 adapter, M6-1.0 adapter, Through-Hole adapter, or Velcro Strap options which allows attachment of the Optical Triger in a multitude of mounting configurations. One trigger cable and one mount option comes with the photodiode trigger. Specify one of each at time of order. See user guide for camera specific mounting options.

Specifications

Model	1100	1800
Detector	Si	Si/InGaAs
Mininum pulse width	1µs	1µs
Optical Threshold Wavelength		
200nm	10.0 1µJ	N/A
633nm	3.5 1µJ	4 1µJ
1064nm	5 1µJ	10.0 1µJ
1550nm	N/A	4 1µJ

Mounting Options

SP90437 C-Mount Mounting Plate & Locking Ring

SP90436 Through Hole Mounting Plate

SP90434 ¼-20 Hole Mounting Plate

SP90435 M6 X 1.0 Hole Mounting Plate

SP90438 Velcro Mounting System

Example of mounting options

Ordering Information

Item	Description	P/N
1100	Photodiode Trigger, Si	SP90408
1800	Photodiode Trigger, InGaAs	SP90409
	With either trigger above you must specify 1 cable and 1 mount at time of order	
Cable	Photodiode Trigger Cable for GRAS3, GRAS20, SP300, 6ft	SP90430
Cable	Photodiode Trigger Cable for SP907, SP928, 6ft	SP90431
Cable	Photodiode Trigger Cable to SMA for LT665, Pyrocam IIIHR & IV, 6ft	SP90432
Cable	Photodiode Trigger Cable to BNC for Gevicam, L11059, Xeva, Pyrocam III, 6ft	SP90433
Mount	1/4-20 Mount, Photodiode Trigger	SP90434
Mount	M6 X 1.0 Mount, Photodiode Trigger	SP90435
Mount	Thru Hole Mount, Photodiode Trigger	SP90436
Mount	C-Mount, Photodiode Trigger	SP90437
Mount	Velcro Strap Mount, Photodiode Trigger	SP90438

3.6 Near Field Profilers

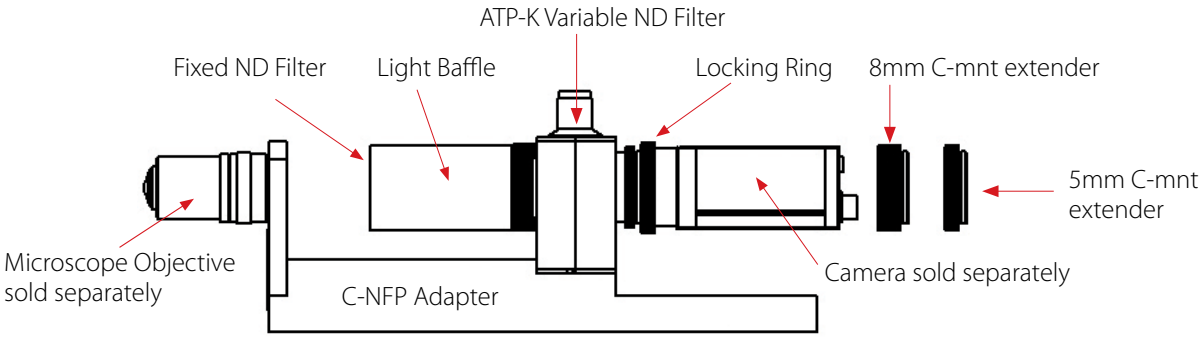
3.6.1 Camera Based Near-Field Profiler

- Allows measurement of beams normally too small for camera profiler
- Expands beam to reduce power/energy density
- Provides near-field profile of fibers, LD junctions, and other small sources
- Can be used to measure tightly focused beam with camera and attenuation
- Nominal 10X, 20X, 40X, 60X Beam expansion available
- Easily calibrated to provide absolute measurement values
- Built-in continuously variable attenuation
- C-mount for attachment to any silicon CCD camera profiler
- Camera and BeamGage software purchased separately

Near field profiling can also be used with camera profilers to analyze small beams, and involves a microscope objective lens to image the beam onto a camera detector array. This technique expands the measurement range of the camera to include smaller beams, which could not be ordinarily measured due to the pixel size of the detector array. Near field profiling is performed in fiber and waveguide analysis, lens characterization, and other applications where beams 50 microns or smaller are analyzed. While there are more accurate techniques to measure these beam sizes, the camera provides two-dimensional information that cannot always be obtained through knife-edge or scanning slit methods. This camera accessory includes base plate for mounting camera and Microscope Objective, ATP-K variable attenuator, 50mm C-Mount and an 8mm and 5mm spacer. User selectable magnification lenses, camera and BeamGage must be purchased separately.

The near field of the test beam or sample is imaged with the microscope objective lens and relayed to the camera. The bracket mounting fixture holds both the lens and camera, which itself can be mounting on a positioner or optical rail. This complete system provides everything necessary to perform near-field measurements right out of the box.

C-mount NFP Adapter Assembly



Ordering Information

Item	Description	P/N
C-NFP Assy	Includes base plate for mounting camera and Microscope Objective, ATP-K variable attenuator, 50mm C-Mount and an 8mm and 5mm spacer	SP90291
60X	60X, Microscope objective	SP90292
40X	40X, Microscope objective	SP90293
20X	20X, Microscope objective	SP90294
10x	10X, Microscope objective	SP90295

3.7 What is M^2 ?

M^2 or Beam Propagation Ratio, is a value that indicates how close a laser is to being a single mode TEM_{00} beam, which in turn determines how small a beam waist can be focused. For the perfect Gaussian TEM_{00} condition the M^2 equals 1.

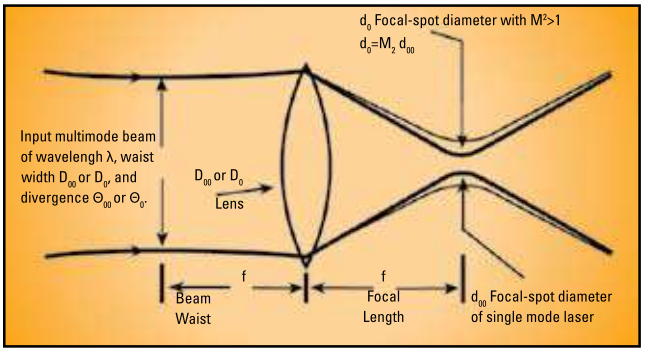
For a laser beam propagating through space, the equation for the divergence, θ, of an unfocused beam is given by:

$$\theta_0 = M^2 4\lambda/\pi D_0$$

For a pure Gaussian TEM_{00} beam M^2 equals 1, and thus has no impact on the calculation. The calculation of the minimal beam spot is then:

$$d_0 = 4\lambda/\pi\theta$$

Again with M^2 equal to 1, the focused spot is diffraction limited. For real beams, M^2 will be greater than 1, and thus the minimum beam waist will be larger by the M^2 factor.



Characteristics of a laser beam as it passes through a focusing lens.

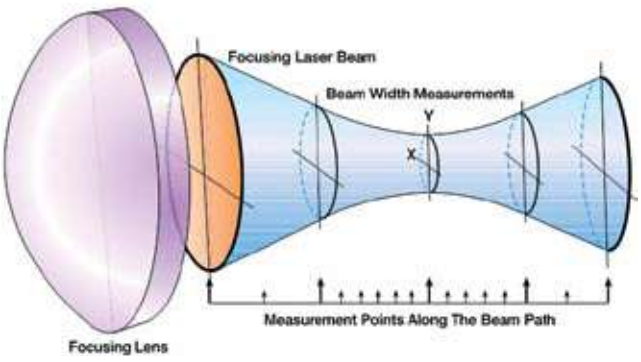
How is M^2 measured?

M^2 cannot be determined from a single beam profile measurement. The ISO/DIS 11146 requires that M^2 be calculated from a series of measurements as shown in the figure above. M^2 is measured on real beams by focusing the beam with a fixed position lens of known focal length, and then measuring the characteristics of the artificially created beam waist and divergence.

To provide an accurate calculation of M^2, it is essential to make at least 5 measurements in the focused beam waist region, and at least 5 measurements in the far field, two Rayleigh ranges away from the waist area. The multiple measurements ensure that the minimum beam width is found. In addition, the multiple measurements enable a "curve fit" that improves the accuracy of the calculation by minimizing measurement error at any single point. An accurate calculation of M^2 is made by using the data from the multiple beam width measurements at known distances from a lens, coupled with the known characteristics of the focusing lens.

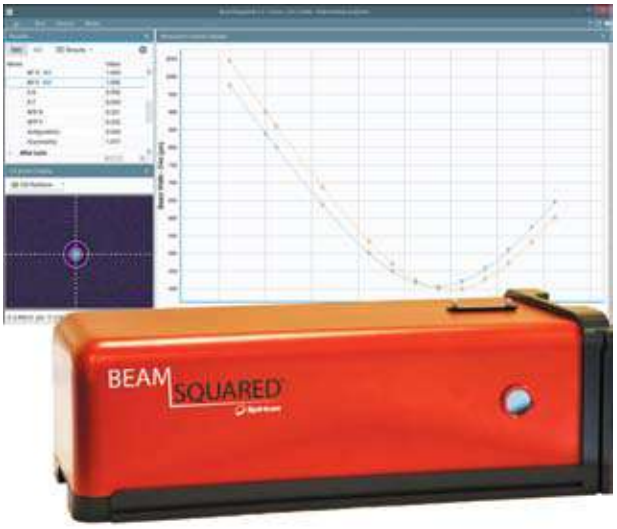
M^2 Measurement Solutions

Ophir-Spiricon and Photon have a number of solutions for the measurement of M^2 ranging from simple manual processes to fully automated dedicated instruments, depending on the frequency of the need to measure M^2 of lasers and laser systems. We have a system that will meet most needs, whether for research and development of new laser systems, manufacturing quality assurance, or maintenance and service of existing systems.



3.7.1 Camera Based Beam Propagation Analyzer: M^2

3.7.1.1 BEAM SQUARED

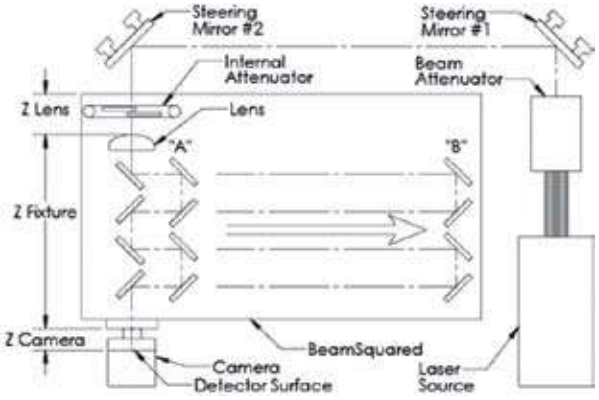


- ISO compliant
- Automatically measure your beam quality in under 1 minutes
- Tune your laser for best operation
- Specifically developed for continuous usage
- Unequaled accuracy using patented Ultracal™ Calibration
- Long optical train & automatic attenuation adjustment
- Flexible mounting configurations, 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 CO2 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 UltracalTM 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.

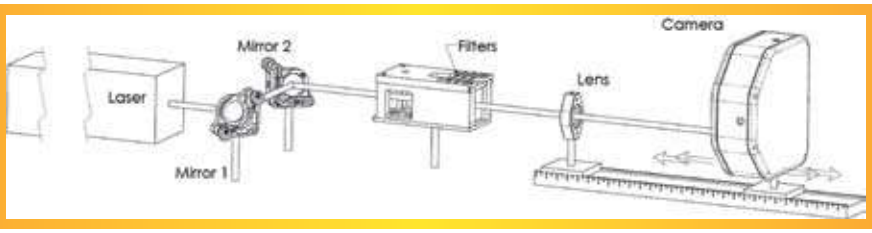
Automatic M^2 - at Production Speeds

The Beam Squared 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.



Features

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

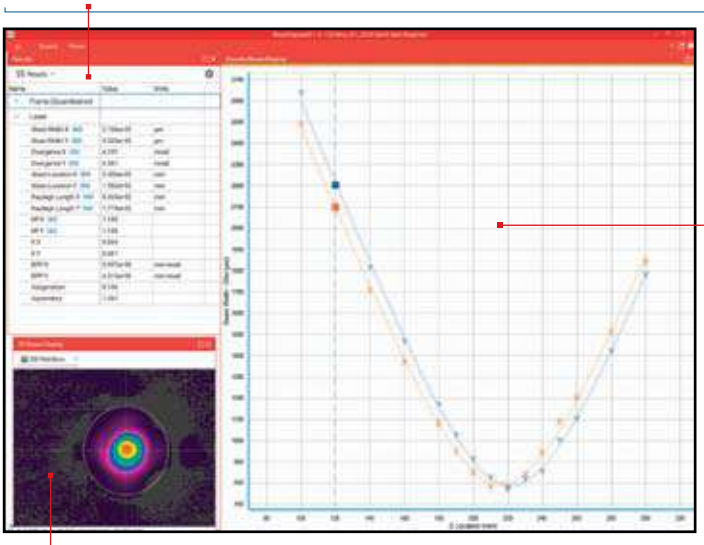
BeamSquared measures propagation characteristics in both the X and Y axes and displays the following parameters:

- 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^2-200s 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.

3.7.1.1.1 Specifications

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		
General			
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		
Standard Optics			
	Different lenses are required for different wavelength regions, spot sizes and divergences. Four lenses are included with the SP920 systems and two lenses with the XC-130 system. See below, for nominal focal lengths. Additional lenses must be ordered separately.		
Lenses	BSQ-SP920 266-440nm UV 500mm FL (included) 430-700nm VIS 500 FL (included) 430-700nm VIS 400 FL (included) 650-1000nm NIR 400 FL (included) 1000-1700nm Extended NIR 400 FL (included)	BSQ-XC-130-A 1000-1700nm Extended NIR 400 FL (included)	BSQ-A Lens kits – optional
Attenuation Range			
	Nominally from ND 1.0 to ND 4.8. Actual values vary with wavelength.		
Damage Limits [1]			
For the SP920	.15 mW/cm2 CW mode 1.0 µJ/cm² pulse mode for a 10mm Both of the above for an M²=1 @ 1064nm		
[1] **CCD cameras can be damaged by power in excess of 0.1 mW/cm² or energy in excess of 1 mJ/cm². 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.**			
For the XC-130 and Pyrocam IIHR and Pyrocam IV	See individual camera data sheets		
Optical Limits			
Wavelength Range	266 -1700nm limited by Camera The CCD camera is operational from 266 to 1100nm. InGaAs camera operates from 900 to 1700nm. Pyrocam from 1.06 to 3000µm		
Beam Size	BeamSquared Auto Mode 1mm – 10mm BeamSquared Manual Mode 0.8mm – 10mm maximum for Pyrocam IIIHR and 0.8mm – 20mm maximum for Pyrocam IV Varies with wavelength, waist size, location, and M²		
Minimum Beam Width	SP920 XC-130 Pyrocam IIIHR or IV (manual & w/o optical train only)	36.9µm 300µm 800µm	
Environmental			
Storage Temperature	-30° C to 65° C		
Storage Humidity	95% maximum (non-condensing)		
Operating Temperature	10° C to 40° C		
Operating Humidity	95% maximum (non-condensing)		
Power Requirements[2]			
Input Voltage	90 – 264 V AC		
AC Line Current	1.6 A		
Line Frequency	47Hz to 63Hz		
[2] For the optical train only. The PC computer supplies the power for the system components, such as the CCD camera.			
Physical			
Weight	26 lbs. w/o camera		
Dimensions	See manual or web site		

3.7.1.1.2 Ordering Information

Item	Description	P/N
BSQ-SP920	BeamSquared software, software license, SP300 USB 3.0 camera, optical train, automatic and manual operation, recommended for 266nm - 1100nm wavelengths.	SP90502
BSQ-XC-130-A	BeamSquared software, software license, XC-130 USB 2.0 camera, optical train, automatic and manual operation, recommended for 900nm - 1700nm wavelengths.	SP90444
BSQ-A	BeamSquared software, software license, and optical train no camera included. For use with compatible cameras purchased. Compatible camera must be return to factory for upgrade at no additional charge. If, upon inspection the camera does not meet specifications, a repair change will be applicable.	SP90445
BSQ-PY-M	BeamSquared software and software license for manual M^2 measurement using a Pyrocam camera (optical train and Pyrocam camera not included).	SP90410
Options		
BSQ-Lens Kit 266-1000		SP90449
BSQ-Lens Kit 650-1700		SP90450
BSQ-Lens Kit UV 500mm		SP90451
BSQ-Lens Kit VIS 500mm		SP90452
BSQ-Lens Kit VIS 400mm		SP90453
BSQ-Lens Kit NIR 400mm		SP90454
BSQ-Lens Kit Extended NIR 400mm		SP90455

3.7.2 Slit - Based Beam Propagation Analyzer: M^2

3.7.2.1 NanoModeScan

The NanoModeScan combines the flexibility and speed of the NanoScan with dedicated M^2 measurement hardware and software. The NanoModeScan provides an automated measurement of M^2 using either the ISO 11146 or the Rayleigh method.

The ISO Method software and hardware report the ISO 11146 parameters:

- Times diffraction limit: M^2
- Beam propagation factor: K
- Beam waist size: d_0
- Beam waist location: Z_0
- Divergence: θ
- Rayleigh range: Z_r

NanoModeScan

By adding the capabilities of the NanoScan to the ModeScan, the range of possible measurable lasers is greatly expanded and the speed of the measurements dramatically improved. The NanoScan's software controlled variable scan speed allows the measurement of both CW and kHz pulsed lasers with any NanoScan scan head, covering the entire wavelength range from UV to FIR.
The NanoScan's rapid beam finding and autoranging speed up the total M^2 measurement to ~20 seconds for CW lasers. NanoModeScan comes with two user selectable lenses to generate the proper artificial waist for the laser source under test. For ease of alignment, there is an entrance iris on the optical axis of the NanoModeScan and a precision alignment stage for horizontal and vertical positioning.

The ISO 11146 Method

The ISO 11146 method for measuring the propagation of a laser source calls for the measurement of the beam diameter for at least 10 positions through the waist created by a test lens inserted in the beam path. Five locations should be within ±1 Rayleigh range of the artificial waist and at least five more points beyond two Rayleigh ranges from this waist. These measurements are then used to compute the laser propagation parameters. Once points are selected properly, the ISO Method is the fastest measurement method and best for volume testing of lasers.

The Rayleigh Method

The ISO method requires the user to manually select the measurement points, and changing one or two of the selected points can yield different M^2 values. The Rayleigh method is completely automated, selecting its own measurement points based on mapping the Rayleigh range of the beam waist. This method is fully discussed in the user manual. In addition, the Rayleigh method can yield more consistent results for M^2 values for lasers that are not exactly like those for which the ISO standard was written, such as fiber lasers, lensed diode lasers, and VCSELs.

The NanoScan Difference

With the NanoScan-equipped NanoModeScan, all scan heads can measure pulsed beams with repetition frequencies down to 10kHz. The silicon and germanium detectors will measure less than a milliwatt of power. The pyroelectric detector-equipped NanoScan head can analyze higher power lasers at all wavelengths. The increased dynamic range of the NanoScan enhances the signal to noise ratio of the system and allows a much broader range of laser powers to be analyzed with one instrument setup.

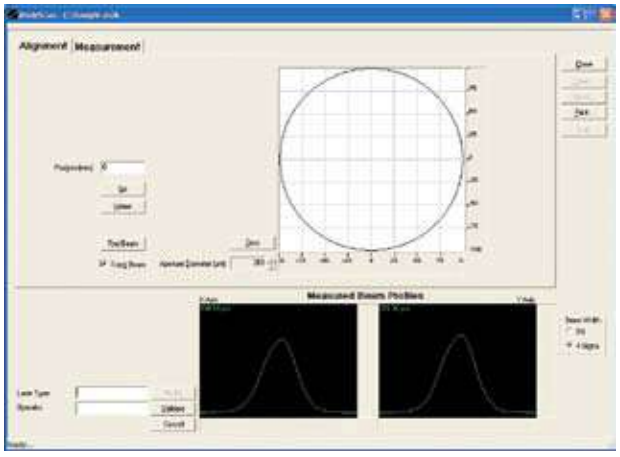
Real-Time Divergence Measurement

By monitoring the divergence angle θ, it is possible to make a measurement that will be directly proportional to M^2. This enables the adjustment of the laser performance in real time at the NanoScan's rapid update rate (up to 20Hz). To use this feature, the scan head is moved to a position one geometric focal length from the test lens. Divergence is the beam diameter divided by the focal length, and the measured divergence is equal to M times the embedded divergence.

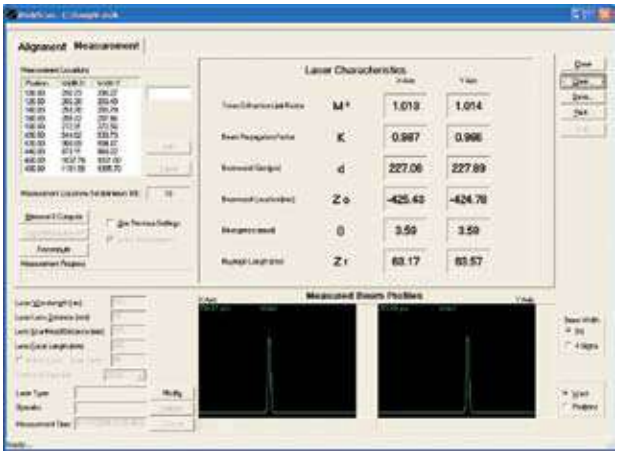
Therefore when the beam diameter at this location is minimized, the divergence is at its minimum and the M^2 of the laser should then be optimized. After this real-time adjustment, the full M^2 measurement can be done to generate the required parameter values. This method makes the NanoModeScan an even more valuable tool for the final setup of lasers on the manufacturing floor by decreasing the time it takes both to adjust the laser system and to make the measurements required for quality control documentation.

3.7.2.1.1 NanoModeScan Specifications

Sensor/Detector	
Scan head Travel	500mm
Optical Axis Height	140-170mm
Lens	See ordering chart
Minimum Spot Size	See scan head specifications
Computer/Electrical	
Source Power	See scan head specifications
File Saving and Data Logging	Data files, ASCII Files
AC Power	110V, 60Hz standard 220V, 50Hz optional
Communication	RS-232 Interface or USB to RS-232 adapter provided
Mechanical (Dimensions in mm)	
NanoModeScan Linear Stage	812 × 102 × 78
Photon Motion Controller	273 × 89 × 57
Weight	
NanoModeScan Linear Stage	8.4kg
Photon Motion Controller	1.5kg



Alignment screen in ModeScan software



Measurement results screen in ModeScan software

3.7.2.1.2 Ordering Information - NanoModeScan M^2 Systems

All NanoModeScan Systems include (unless otherwise noted):

- High-resolution scanhead with rotation mount
- Two user selectable lenses come with the NanoModeScan
  - 200 mm focal length VIS coated for 430–700nm (not for use with Germanium detector)
  - 400 mm focal length VIS coated for 430–700nm (not for use with Germanium detector)
  - NIR Near IR: 650–1000nm
  - LIR Long IR: 1000–1550nm (not for use with Silicon detector)
  - VLIR: Very long infrared >1550nm. (for use with NMS-NS2s-Pyro/9/5 only)
  - UV: 200 mm focal length lens coated for UV wavelength

Item	Description	P/N
NanoModeScan M^2 Systems		
NMS-NS2s-Si/9/5	Model 1740 ModeScan with NanoScan 2s Silicon (Si) Detector 9mm aperture 5µm slits Si detector, 63.5mm diameter head, 9mm entrance aperture, and matched pair of 5.0µm wide slits. Use from 190 to 1000nm wavelengths.	PH00477
NMS-NS2s-GE/9/5	Model 1740 ModeScan with NanoScan 2s Germanium (GE) Detector 9mm aperture 5.0µm slits. Germanium detector, 63.5mm diameter head, 9mm entrance aperture, and matched pair of 5.0µm wide slits. Use from 700nm to 1.8µm wavelength.	PH00478
NMS-NS2s-Pyro/9/5	Model 1740 ModeScan with NanoScan 2s Pyroelectric Detector 9.0mm aperture 5µm slits. Pyroelectric detector, 63.5mm diameter head, 9mm entrance aperture, and matched pair of 5µm wide slits.	PH00479
NanoModeScan Accessories		
NanoModeScan comes with two user selectable, must specify at time of order		
LENS 200mm VIS	200mm focal length lens for use 400-700nm wavelength	PH00237
LENS 400mm VIS	400mm focal length lens for use 400-700nm wavelength	PH00238
LENS 100 VIS	100 mm focal length lens for use 400–700nm wavelength	PH00093
LENS 100 NIR	100 mm focal length lens for use 650–1000 nm wavelength	PH00094
LENS 200mm NIR	200mm focal length lens for use 650-1000nm wavelength	PH00239
LENS 400mm NIR	400mm focal length lens for use at 650-1000nm wavelength	PH00240
LENS 100 LIR	100 mm focal length lens for use 1000–1550nm wavelength	PH00095
LENS 200mm LIR	200mm focal length lens for use at 1000-1550nm wavelength	PH00241
LENS 400mm LIR	400mm focal length lens for use at 1000-1550nm wavelength	PH00242
LENS 400 2um	400mm focal length lens for use at @2µm wavelength	PH00224
LENS 190 10.6	7.5-inch focal length lens for use at 10.6µm wavelength	PH00092
LENS 200 UV-XXX	200mm quartz lens for use between 190–400nm wavelengths. Specify use wavelenght in the XXX item description.	PH00090
LENS 400 UV-XXX	Optional 400mm quartz lens for use between 190–400nm wavelengths. Specify use wavelenght in the XXX item description.	PH00091
1740 LENS MNT	Lens mount for users wanting to use their own 25mm diameter lens	PH00075
Model 1740 ModeScan	Rail w/o scan head, small scan head	PH00447
1740 LENS PREP	ModeScan custom lens	PH00076

BEAMWATCH®
U.S. PATENT 8,988,673

3.8 BeamWatch® Non-contact, Focus Spot Size and Position monitor for high power YAG, Diode and Fiber lasers

- Instantly measure focus spot size
- Dynamically measure focal plane location during start-up
- From 400W and up – no upper limit (So far we have measured up to 100kW)
- Non-contact, laser beam is completely pass-through
- Automation Control Interface for System Integration
- GigE camera interface for local network installation
- Patented

BeamWatch utilizes disruptive technology to measure laser beam characteristics of very high power lasers. By not intercepting the beam and yet providing instantaneous measurements, you can now monitor the beam at frequent intervals without having to shut down the process or remove tooling and fixtures to get access. In addition, you can now measure focal spot location at several times per second and know if there is any focal spot shift during those critical start-up moments.

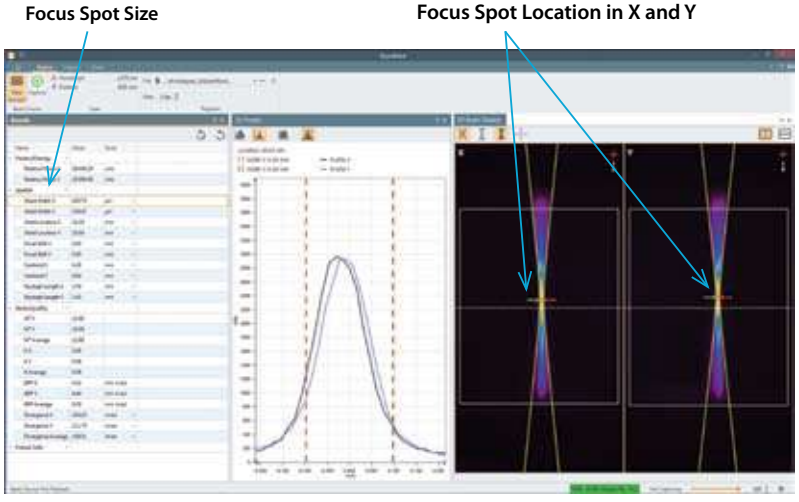
Disruptive Technology

BeamWatch is the first device to measure a laser without coming in contact with its beam which allows it to be the first laser quality measurement product in history to have no upper limit on the lasers which it can measure. BeamWatch provides high-power industrial laser users with data never before seen such as the dynamic measurement of focus shift caused by thermal effects on the laser system. BeamWatch also provides the industrial laser user with measurement of other key laser operating parameters in real-time.

The system measures the signal generated from Rayleigh scattering around the laser's beam waist, where the power density is the highest. Rayleigh scattering is a physical property of light caused by light scattering off of air molecules. Unlike traditional beam measurement systems, the beam passes directly through BeamWatch and is not disrupted, mechanically or optically. In addition, BeamWatch has no moving parts so there is no need for cooling of any components. Specialized system software dynamically measures the signal multiple times per second, allowing the laser user to key in on critical operational laser attributes, such as beam waist size and position with respect to the material being processed.

BeamWatch User Interface

The user has access to those tools needed for start-up and advanced beam diagnostics.



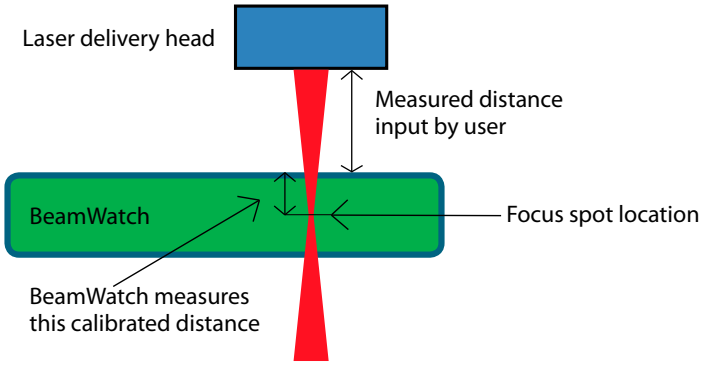
User interface for dual axis set-up and beam diagnostics

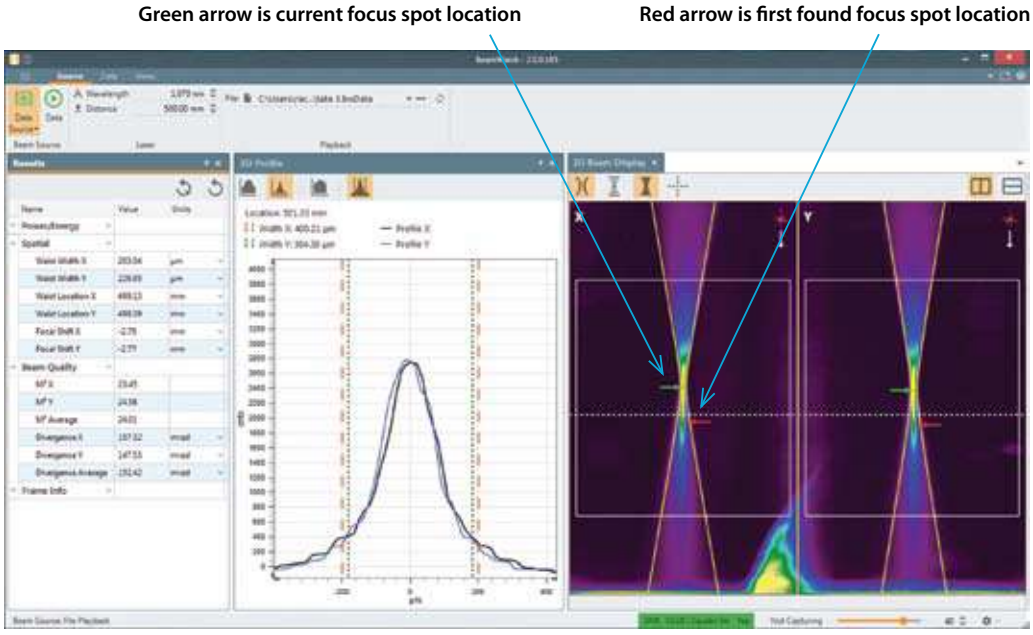
Focus Spot Size (Waist Width)

BeamWatch images the full beam caustic measuring the waist at its smallest point, many times per second.

Focus Spot Location

Now you can precisely know the dynamic behavior of focal spot shift throughout the laser duty cycle. By inputting the known distance from the laser delivery head to a precise datum on BeamWatch the focal spot distance is constantly measured and tracked with millisecond updates.





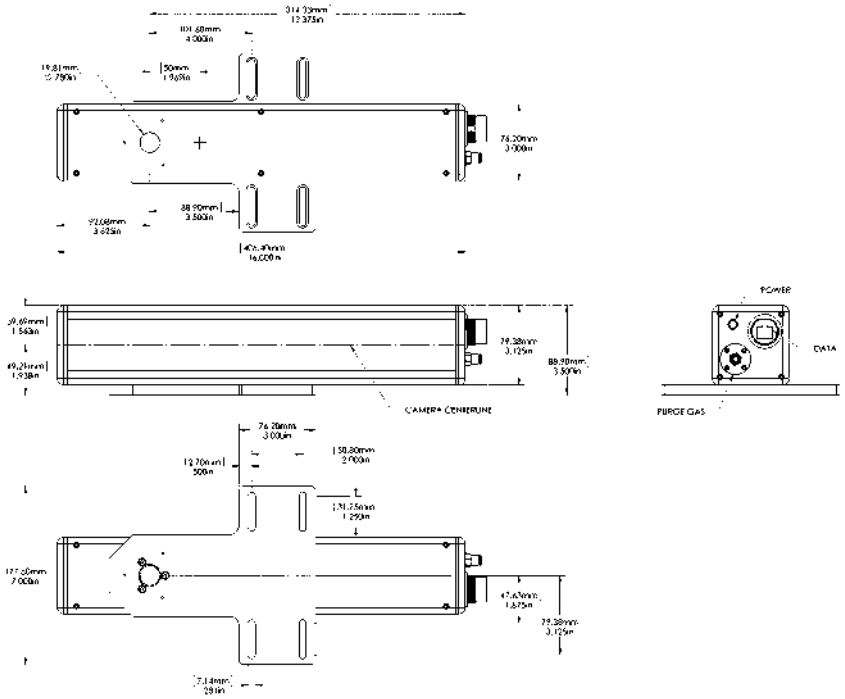
Assured Process Consistency

Measure as often as needed to assure repeatable and consistent process uniformity. Mount BeamWatch into the process or manually insert BeamWatch and make periodic measurements.
You can also automatically compare to initial process validation measurements and utilize automated pass/fail.

Automation Interface

BeamWatch includes the tools to support Automation Clients written in Visual Basic for Applications (VBA), C++ CLI, or any .Net compliant environment, such as Microsoft Excel or National Instruments' LabVIEW.

Periodically measure and compare



3.8.1 Product Specifications

Model	BeamWatch
Wavelength	980-1080nm
Minimum Power density	2 Megawatts/cm^2
Minimum Spot Size	
SP90390 Dual axis	155 microns
SP90391 Dual axis	55 microns
Maximum Beam diameter at entrance/exit	12.5mm
Communication to PC	GigE Ethernet
Power	110 – 220 Volts AC
Particulate Purge	Clean Dry Gas, approximately 10 LPM
Accuracy	
Waist Width (Spot Size)	±5%
Waist Location	±125 micrometers within the BeamWatch window
Focal Shift	±50 microns
Beam Parameter Product	±3.5% RMS
Divergence	±3.5% RMS
M^2	±3.5% RMS

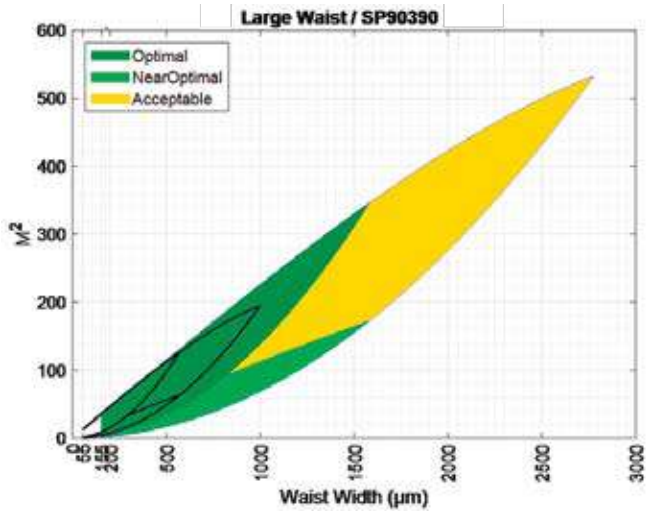
Specification subject to change

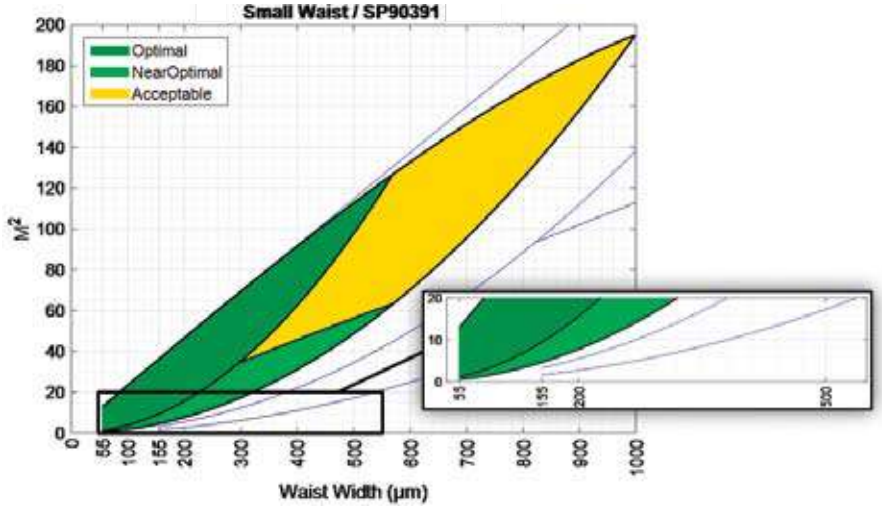
Operating Space Charts

The plots are intended to give a visual indication of the recommended operating space for BeamWatch. If BeamWatch is operated outside of this space, it may be more difficult to see the curvature of the caustic or the beam may be large enough at the edges of the image that it is out of focus.
The maximum waist is dependent on the power density and M^2 of the beam. Specified is a minimum power density of 2 megawatts/cm^2 and the M^2 vs waist width is shown in the corn-looking graphs. Following these charts also covers the 12.5mm max beam size as it enters and exits the unit.

The 12.5mm maximum beam size at entrance and exit is the physical clear aperture of unit, and is the same for all models.

- Optimal has at least 3 Rayleigh lengths on both sides of the waist, with the waist at the center of the image
- Near Optimal has at least 3 Rayleigh lengths on 1 side of the waist, with the waist at the end of the image
- Acceptable has at least 1.5 Rayleigh lengths on both sides of the waist, with the waist at the center of the image



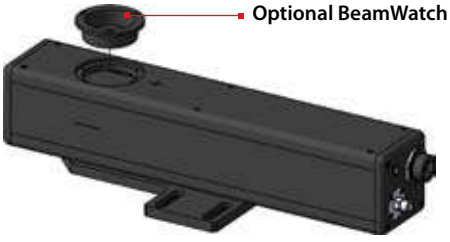


3.8.1.1 Software Features

Software Features	Dual Axis
Results - Power/Energy	Relative Power
Results - Spatial	Waist Width X & Y
	Waist Location X & Y
	Focal Shift X & Y
	Centroid X & Y
	Width at Cursor X & Y
	Ellipticity at Cursor
	Rayleigh Length X & Y
	Waist to Cursor X & Y
Results - Beam Quality	M^2 X & Y
	M^2 Average
	K X & Y
	K Average
	BPP X & Y
	BPP Average
	Divergence X & Y
	Divergence Average
Results	All results can be shown/hidden.
Frame Info	Frame ID
	Timestamp
1D Profile	Logarithmic or Linear
	Control to enable/disable the beam width markers
	Profiles are drawn at the cursor location. Cursor is controlled in the 2D display
	Display shows current cursor location and width at cursor results
	The X and Y profiles are overlapped in a single display
2D Beam Display	Overlays that can be enabled/disabled
	Fitted caustic and drawn beam area
	Raw data points
	Beam Image
	Alignment Crosshair – Marks the center of the display for each axis
	Beam can be displayed vertically or horizontally on the screen
	Labels indicate X and Y axis and the direction of beam propagation
	Cursor can be moved to any point along the beam
	Focal point indicators – one shows current waist position, another shows first found waist position
Statistics	Mean, Std Dev, Max, Min, and Sample Size
System Requirements	PC computer running Windows 7 (64) and Windows 10 Laptop or Desktop:
	GHz Pentium style processor, dual core recommended
	Minimum 2GB RAM
	Accelerated Graphics Processor
	Hard drive space suitable to hold the amount of video data you expect to store (50-100 GB recommended)

Option

For those applications where the laser delivery nozzle cannot be positioned close enough to the measurement centerline, the cup aperture replaces the flat aperture.



3.8.1.2 Ordering

Item	Description	P/N
BW-NIR-2-155	Dual axis - BeamWatch non-contact, focus spot size and position monitor for focus spots from 155µm and larger (see operating space charts)	SP90390
BW-NIR-2-55	Dual axis - BeamWatch non-contact, focus spot size and position monitor for focus spots from 55µm and larger (see operating space charts)	SP90391
Options		
Cup aperture	For those applications where the standard flat aperture does not position the delivery head close enough to the measurement centerline. Includes alignment tool SP90475	SP90476
Suggested Add-Ons		
Rotation Mount	Add-on 180° manual rotation mount to bottom of BeamWatch	SP90346
Locking Ethernet Cable	Replace standard Ethernet cable with one that locks into place, IP67 rated	SP90394
5000W-BB-50	5kW water cooled power sensor	7Z02754
10K-W-BB-43	10kW water cooled power sensor	7Z02756
30K-W-BB-74	30kW water cooled power sensor	7Z02757
120K-W	100kW water circulated power sensor for laser with an approximately Gaussian beam and fiber output	7702691
Juno	Compact module to operate one Ophir sensor from your PC USB port	7Z01250
Vega	Hand held color universal power meter	7Z01560

3.8.2 BeamCheck™ - Beam profiling system for Additive Manufacturing

- Beam check measures:
  - Focal spot size at the build plane
  - Laser power at the build plane
  - Laser power density at the build plane
  - Changes in spot size & power density over time
- 0.1 to 600 Watt integrated power sensor
- For fiber lasers; 1060 to 1080nm Wavelength
- Power densities to >3MW/cm^2
- Spot sizes – 37um to 3.5mm
- Frame rate – multiple frames per second
- Additive manufacturing system focal length 200mm – >400mm

Additive manufacturing has restructured how prototype, developmental and advanced design mechanical components are made. Direct Laser Melting, Selective Laser Sintering or 3D metal Printing is quickly becoming the standard for designs that could not be fabricated with traditional metal removing techniques.

To create consistent, strong structures using laser-based additive manufacturing processes that meet flyable DOD standards or FDA requirements, the metallurgy must be consistent, and a laser beam of known dimension, power density and focal spot location is required.

Quality 3D laser printed processes require a laser delivering the correct amount of power, distributed correctly and focused at the correct location. To insure consistent and structurally sound parts these parameters should be directly measured before and after any critical part is made.

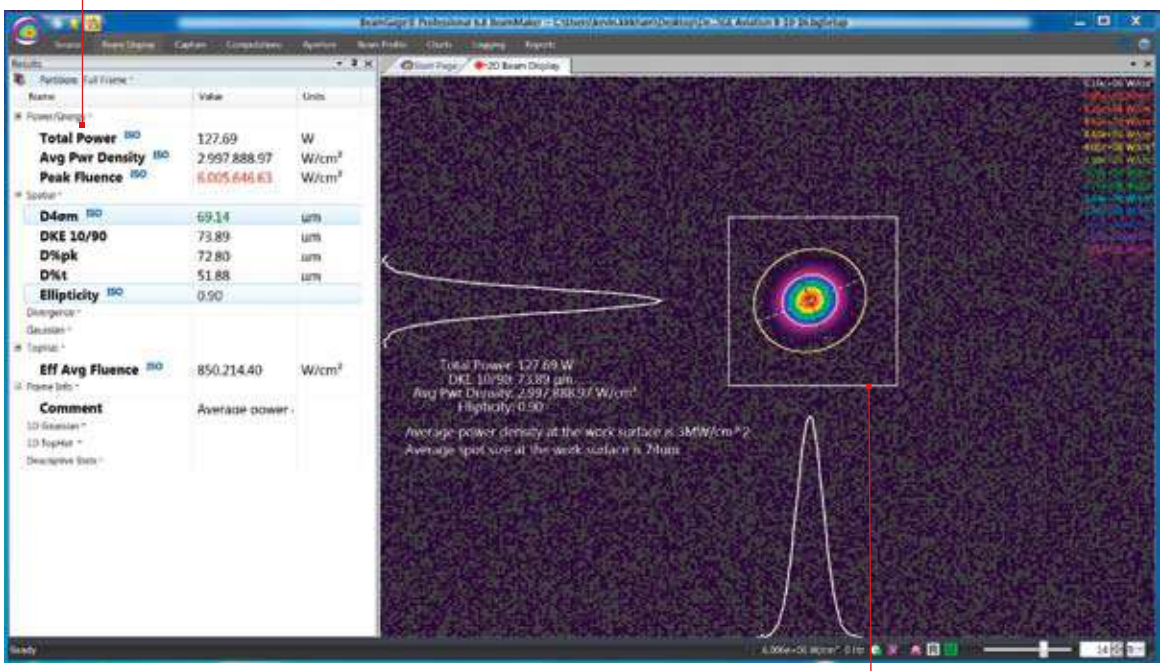
BeamCheck is an integrated laser measurement system designed to measure critical laser beam parameters for laser-based additive manufacturing systems BeamCheck includes a CCD camera for spatial measurements and a NIST-traceable power sensor that will provide a complete analysis of the laser power density profile.

The camera is precisely located at the build plane so that an accurate power density model of the working laser beam can be made. A beam splitter directs a small percentage of the beam to the camera, while the majority of the beam is directed to the integrated power sensor. From these measurements an accurate beam spot size and power density can be derived.

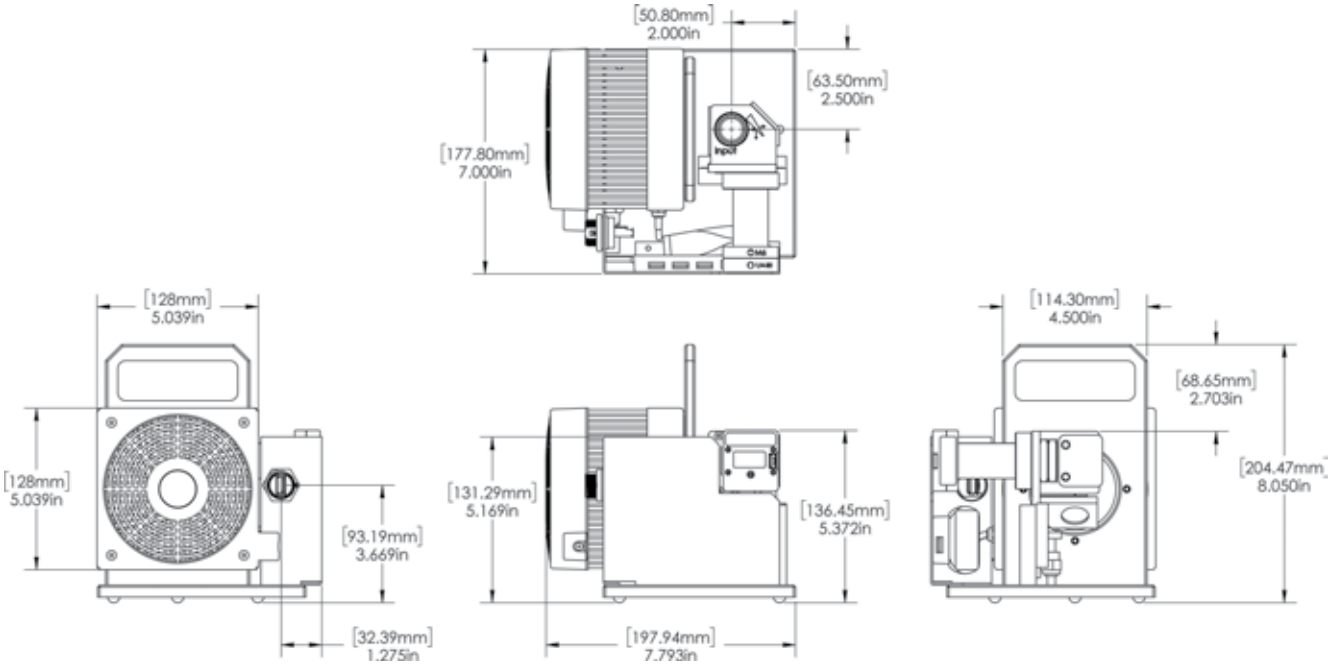
BeamCheck Includes

Beam Profiling	
	SP928 high resolution CCD camera
	▪ 3.69um square pixel, USB 3.0, multiple frames per second
	CCD is positioned within +/- 50µm of the same distance as the work surface
	LBS-300-NIR laser beam splitter / attenuator
	▪ Directs the beam to both the camera and power sensor
Power Measurement	
	FL600-LP1-65 laser power sensor
	▪ NIST traceable, 600 Watts, fan cooled
	JUNO Smart Sensor to USB Adapter
Software	
	BeamGage Professional Software to run on user supplied PC
	StarLab software to interface power sensor to BeamGage
Data is saved in ASCII and HDF5 formats	
Custom print-out includes;	
	2D False Color Power Density Map
	Total Power
	▪ NIST Traceable certificate
	Beam Diameter (D4sigma, 90/10 Knife Edge, Power-in-a-Bucket)
	Peak Power Density
Calibration Certificates for;	
	FL600-LP1-65 Power Sensor
	JUNO USB Converter
	SP928 CCD Camera
	Calibration of build plate distance to camera array location

Industry standard ISO measurements



1D and 2D representation of spatial distribution of the power within the beam



Ordering Information

Item	Description	P/N
BeamCheck	Beam profiling system for Additive Manufacturing Systems	SP90411

3.8.3 BeamWatch® AM - Beam profiling system for Additive Manufacturing Systems

BeamWatch AM provides simultaneous measurements of multiple profiles along the beam caustic in the camera field-of-view (FOV). Real-time measurements are performed at video rates. They include:

- Waist (focus spot) width and location
- Focal shift
- Centroid
- M2 or K
- Divergence
- Beam Parameter Product
- Rayleigh length
- Absolute power
- Tilt angle

Real-time performance also allows for measurement of dynamic focal shift during laser startup.

Additive manufacturing has restructured how prototype, developmental and advanced design mechanical components are made. Direct Laser Melting, Selective Laser Sintering or 3D Metal Printing is quickly becoming the standard for designs that could not be fabricated with traditional metal removing techniques.

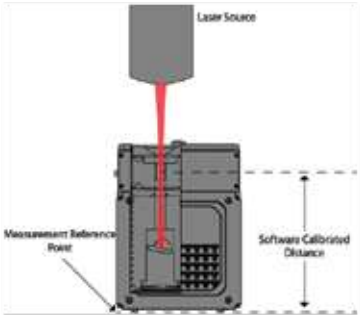
To create consistent, strong structures using laser-based additive manufacturing processes that meet flyable DOD standards or medical device FDA requirements, the metallurgy must be consistent, and a laser beam of known dimension, power density and focal spot location is required.

Quality 3D laser printed processes require a laser delivering the correct amount of power, distributed correctly and focused at the correct location. To insure consistent and structurally sound parts these parameters should be directly measured before and after any critical part is made.

BeamWatch AM measurement technique is based on Rayleigh scattering of laser light by oxygen and nitrogen molecules in the air as the beam propagates through the medium. Measurement of this scattered light provides an equivalent slit-scan of the laser beam in the direction of the observed view. The scattered light is measured using a conventional camera and image capture systems. BeamWatch AM includes a camera for spatial measurements and a NIST-traceable power sensor that will provide a complete analysis of the laser power density profile.

The camera is simultaneously, and real-time, viewing the beam caustic including the near/focus/and far field of the beam. This measurement technique includes Propagation and M2 measurements adhering to the ISO 11146 standards. In addition, and because all measurements are made in real-time, any focal shift occurring during the critical start up seconds is measured and reported.

BeamWatch AM has USB connectivity to Windows personal computers for data acquisition, analysis, and display.

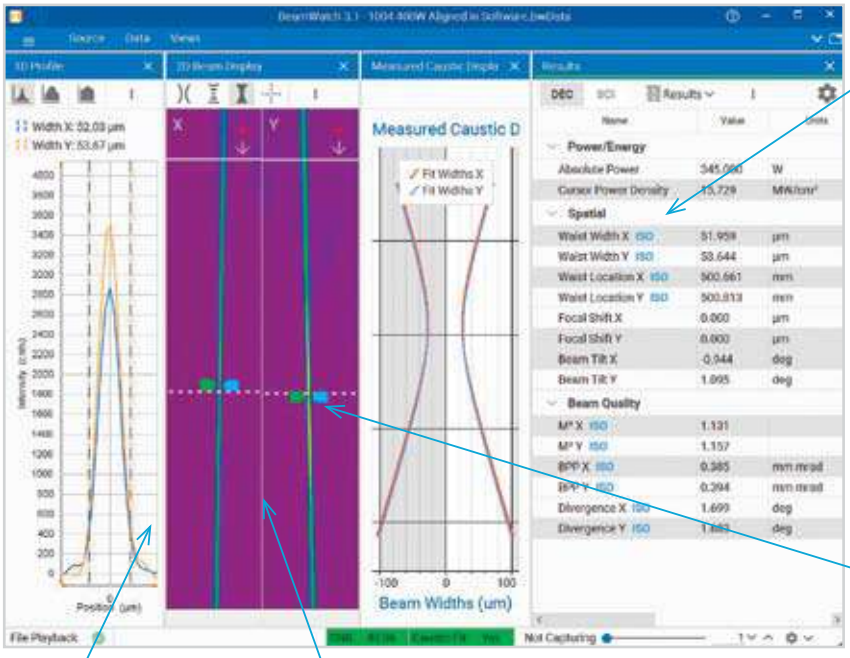


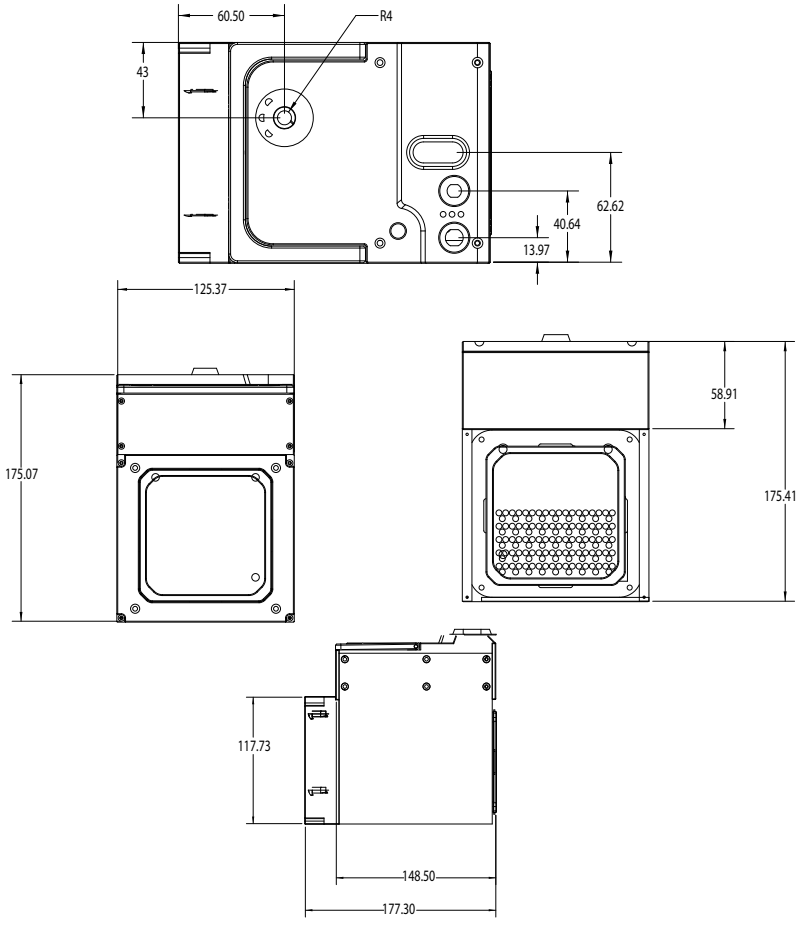
Calibrated beam path for precise focus spot location

Specifications

Beam Profiling	
Wavelength	1060-1080 nm
Minimum Power density	1.5 Megawatts/cm2 (50µm spot at 30 W)
Minimum Focus Spot	50 microns
Maximum Beam diameter at entrance/exit	6 mm (4.5 mm using the Halo Aperture)
ISO 11146 measurements	Self monitoring; will display ISO next to the measurement
Power Meter/Beam Dump	
Measured Power	30 W to 1000 W
Maximum Power Exposure	1000 W for 2 minutes
Precision	NIST traceable calibration, ±3%
Cool-down Time	20 minutes with fan cooling if used to maximum exposure
Software	
BeamWatch AM software	To run on user supplied PC
	Data is saved in ASCII and HDF5 formats
	Print-out of critical measurements and graphics

Calibration Certificates	
Power Sensor	NIST traceable
JUNO USB Converter	NIST traceable
Camera	Certification
Distance from bottom of unit to focus location	NIST traceable
General	
Communication to PC	USB 2.0 & USB 3.0
Power	110 - 220 Volts AC 50/60Hz
Particulate Purge	Clean dry gas
Weight	17 lbs
Dimensions	7.03in x 4.96in x 7.16in
	178.57mm x 126mm x 181.92mm





Ordering Information

Item	Description	P/N
BW-NIR-2-50-AM	Beam profiling system for Additive Manufacturing Systems	SP90470

3.9 A New Method to Assure the Performance of High Power CO_2 Lasers

3.9.1 ModeCheck®

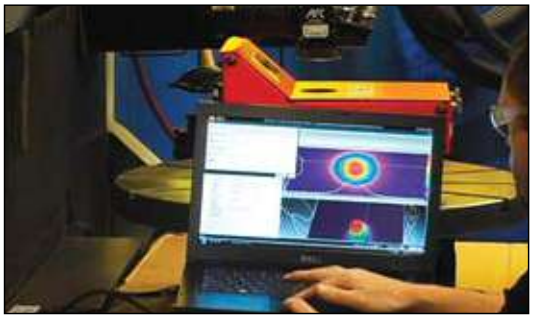
- Beam Profiler for collimated CO_2, 10.6um wavelength, beam width up to 30mm
- Quality Cutting, Marking, Drilling & Ablating Require More Than Consistent Laser Power
- Instantaneously "see" and measure the beam - reduce set-up time between jobs
- Real-time "mode burns" - eliminate hazardous acrylic vapors
- Optimize laser efficiency - reduce cost per part
- Predict laser preventative maintenance - increase manufacturing efficiency

ModeCheck is designed for the industrial parts manufacturer to reduce the time it takes to change over between different jobs. The user can quickly place the ModeCheck in front of the laser and see and measure, in real-time, the laser beam profile to confirm optimal laser performance. In addition, and when used periodically, the user can compare measurement changes from the same set-up and make necessary laser adjustments, keeping the laser output constant for the same job from day-to-day. Over time the user will be able to see and measure laser degradation to predict and advance schedule down-time needed for periodic maintenance.

ModeCheck eliminates operator exposure to acrylic mode burn hazards while improving product quality and manufacturing efficiency.

Measurements:
In addition to both 2D and 3D graphical image display and save, the following measurements are made from each image:

- Beam Widths and Diameters
- Beam Position Stability
- Power Density Peak
- Beam Centroid Location
- Elliptical Analysis with Major Axis Orientation



It's just this easy.

1. Remove Focusing optic or attach the optional MLA
2. Locate the beam center with pointing beam or similar device
3. Place ModeCheck in beam center
4. Turn on Laser
5. Instantly see, measure and electronically store the beam characteristics

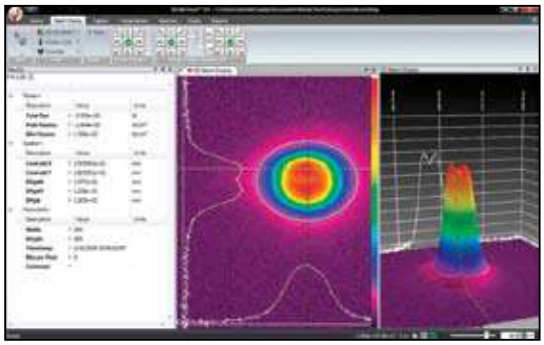
Optional Accessories

One must manage the pass-through laser beam by collecting the beam using either a power meter or beam dump. We recommend using a power meter as the additional measurement information will assist in managing laser optimization. Note that any beam dump or power meter large enough to handle 5-10kW will require water cooling. There are holes on the bottom of ModeCheck for mounting the Power Meter Head or Beam Dump.

A ruggedized storage/carrying case is highly recommended for safe and efficient handling.

The ModeCheck Lens Adapter (MLA) is an option that will enable a ModeCheck to recollimate a focused CO2 laser beam. The advantage of using this adapter is that the focusing head of the machine does not have to be removed, which is the normal case for a ModeCheck without this adapter. The disadvantage is that the ModeCheck must be positioned further from the output head in order to properly recreate the collimated beam profile. The re-collimating lens must be supplied by the user and must be the same lens that is used on the lasers cutting head. (See application note: SP90329).

A PC is required to run the ModeCheck imaging software. The camera is powered over the USB cable that connects the computer to ModeCheck.



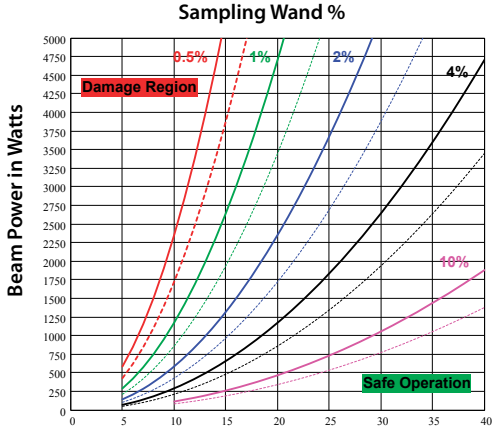
ModeCheck makes instantaneous beam measurements along with graphically displaying both the 2D and 3D power density distribution

ModeCheck with optional MLA, profiling a CO_2 cutting laser with its processing head installed

3.9.1.1 Specifications Model

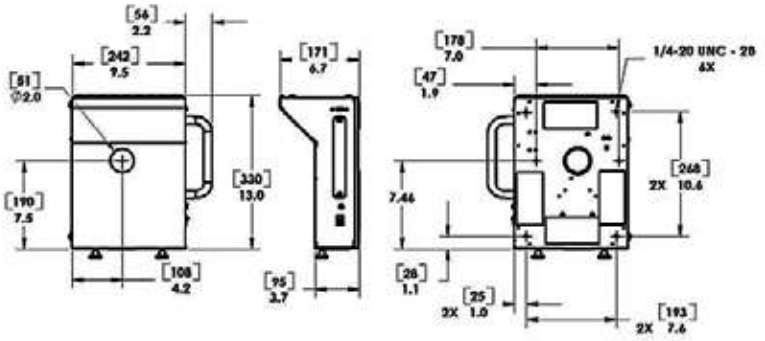
Specifications Model	ModeCheck
Laser Input Power	100-5000 Watts (or more depending on Beam size)
Input Clear Aperture	50mm (~2")
Laser Type	CW, Pulsed >100 KHz
Beam Width	5mm - 30mm
Pick-off Percent	0.5%, 1%, 2%, 4%, 10% sampling wands; user replaceable
Damage Threshold	27 - 36 W/cm^2; See graph
Camera	1/3" format CMOS, 480x480, 6µm pixel, 8bit, CS-mount, USB2
Lens	12mm C-mount
Cooling	Built in Fan (water required for the optional beam dump or optional power meter sensor)
UV Light Source	LED array
Software	ModeCheck
Power Requirements	Input: 100-240 Vac, 50-60Hz, 1.5A Output: 12Vdc, 5.0A, w/power jack, UL listed and CE compliant universal power supply included Camera is powered over the USB port
Dimensions	9.5"x 13"x 6.7" 242mm x 330mm x 171mm Not including handle and cabling or any options
Weight	~8 lbs 3.6kg
Beam Dump (optional)	Water cooled and rated for 5kW total power
Power Meter (optional)	5000W-SH; up to 5kW total power 10kW-SH-V2; up to 10kW total power
Laptop Computer	Provided by user; Windows 7 (32/64)
Compliance	Unit meets CE and RoHS requirements

The optional rugged case is recommended for safe storage in an industrial facility



Damage and Saturation Power vs Beam Dia

Safe Operation is to the Right of the Solid line. Image Saturation is approximately the Dashed line. Chose a sampling Wand that contains your beams maximum power and minimum diameter to be near but below the dashed line for safe and best beam viewing.



MODECHECK DIMENSIONS W/O BEAM DUMP

3.9.1.2 Ordering Information

Item	Description	P/N
MODECHECK CO_2-5kW	ModeCheck, CO_2 sampler for 10.6µm beams up to 5kW, beam width up to 30mm; includes 2 user selectable wands from selection below	SP90211
0.5% wand	0.5% beam wand sampler, see damage and saturation chart	SP90324
1% wand	1% beam wand sampler, see damage and saturation chart	SP90325
2% wand	2% beam wand sampler, see damage and saturation chart	SP90326
4% wand	4% beam wand sampler, see damage and saturation chart	SP90327
10% wand	10% beam wand sampler, see damage and saturation chart	SP90283
Beam Dump; 5kW	Beam dump for up to 5kW continuous, includes mounting bracket, requires continuous water flow.	SP90224
5000W-BB-50	Power sensor, measure CO_2 power up to 5000W; water cooling needed	7Z02754
Mounting Hardware, 5000W detector	Mounting hardware for 5kW power sensor. Required when ordering the 5000W-SH sensor	SP90212
10kW-BB-45	Power sensor, measure CO_2 power up to 10,000W; water cooling needed	7Z02756
Mounting Hardware, 10,000W detector	Mounting hardware for 10KW power sensor. Required when ordering the 10kW-SH-V2 sensor	SP90213
ModeCheck storage/carrying case	Ruggedized ModeCheck storage/carrying case	SP90227
Collimating 2" Lens Adapter	ModeCheck Lens Adapter (MLA) enables a ModeCheck to recollimate a focused CO2 laser beam. MLA should be ordered with the ModeCheck so that it can be factory installed.	SP90329