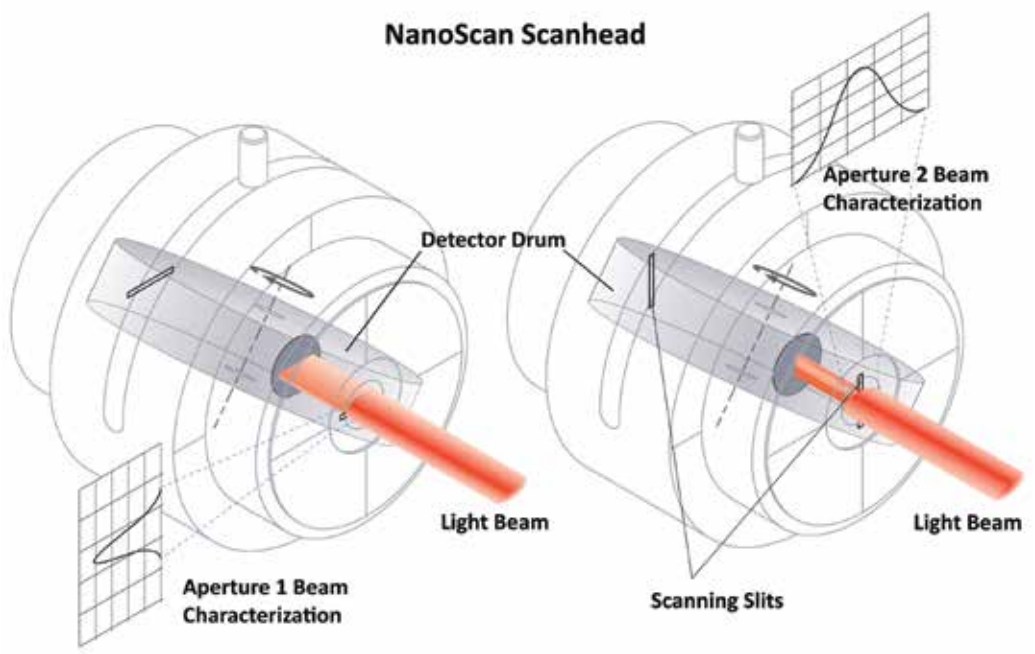
3.4 Introduction to Scanning-Slit Profilers

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 a convenient means of measuring high-resolution CO_2 lasers with powers up to and exceeding 1000 watts.

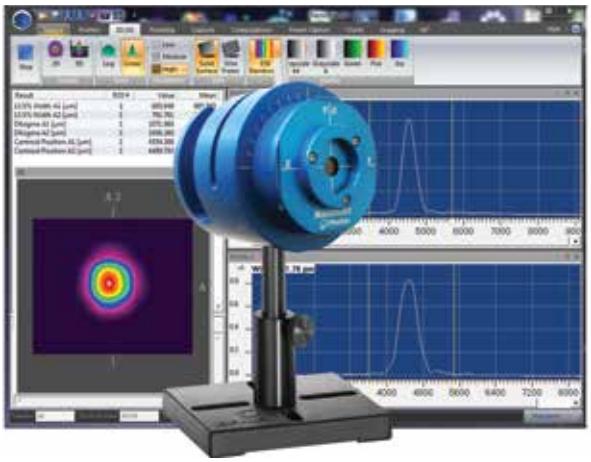


3.4.1 NanoScan 2s

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.

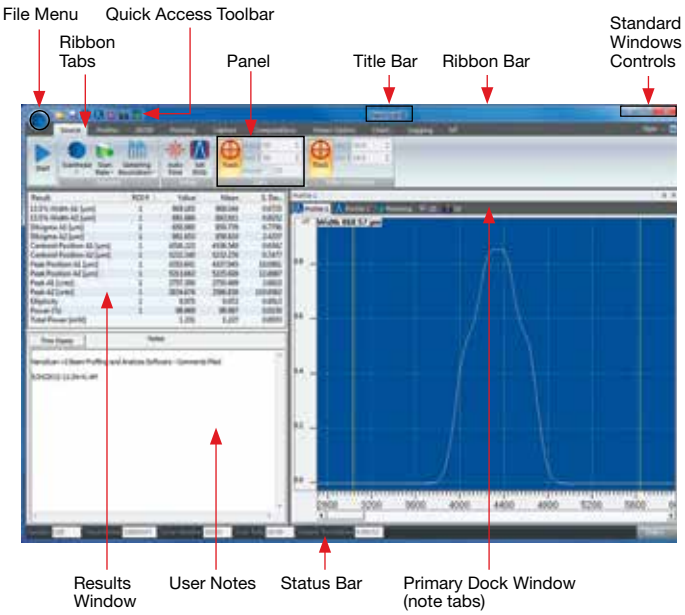
Benefits

- 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
- M^2 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.

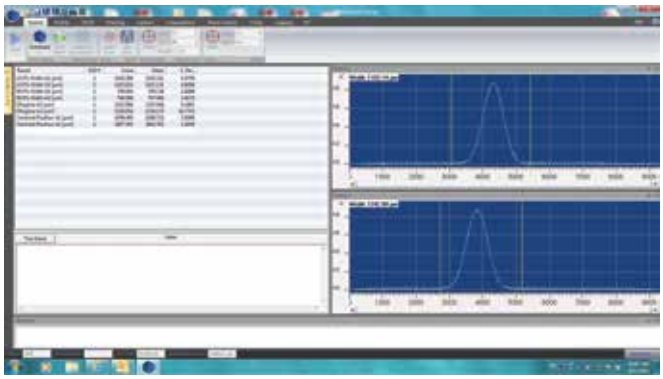
NanoScan 2s Configurable User Interface

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.

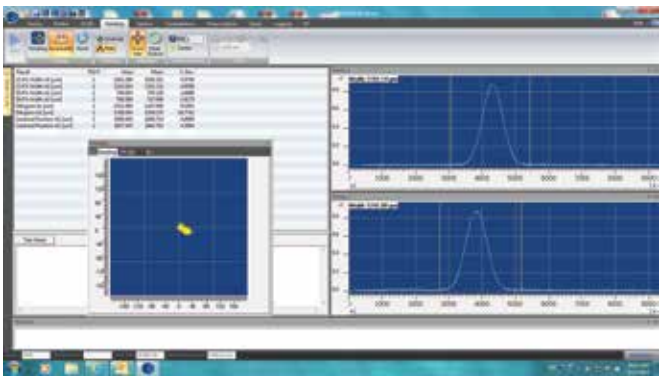


See Your Beam As Never Before

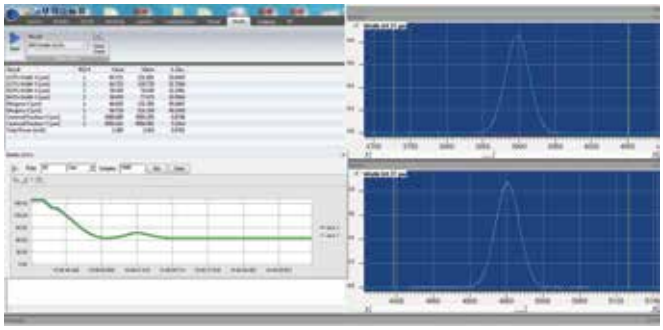
The new NanoScan 2s graphical user interface (GUI) allows the user to set the display screens to any appropriate configuration, displaying those that are of interest and hiding what is not. This means that you can have the information that you want to see, uncluttered by extraneous output, and you can 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



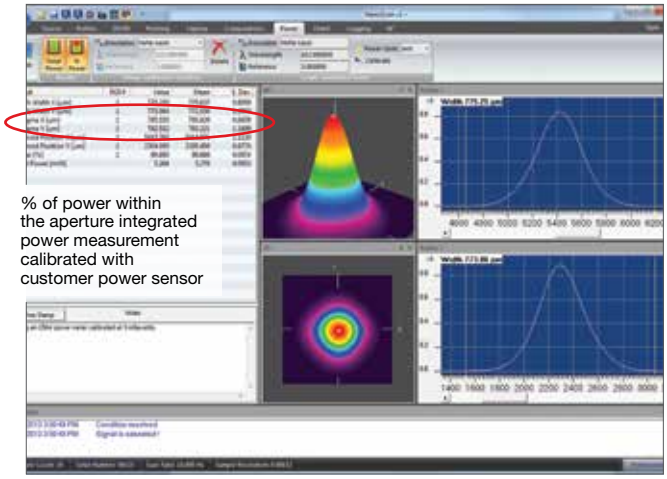
Both docked and undocked windows: profiles, results, and pointing



Example of time charts used to monitor focusing process

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 measurable 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.

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.

For Higher Powers, Teams up the NanoScan with the LBS-300s

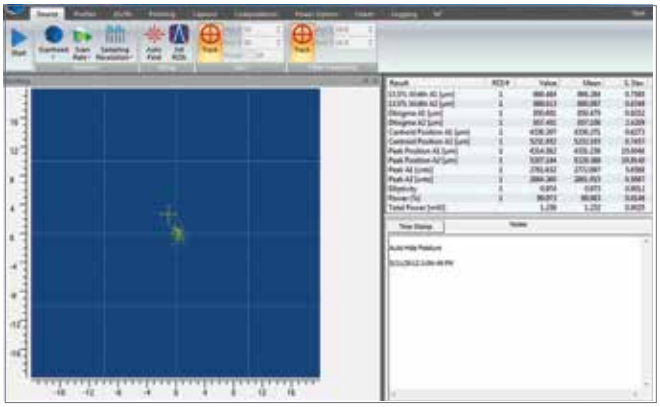
In order to measure powers and energies above the limits of the NanoScan, an LBS-300s of the appropriate wavelength rang can be attached to the front of the NanoScan and measure powers up to 1000W and more.
The C mount thread of the LBS-300s mates with the C mount thread of the NanoScan. There are various models of the LBS-300s ranging in wavelength from 190nm up to 1550nm and beyond. Alternatively, the Stackable Beam Splitters can be attached to the NanoScan and used to attenuate high power beams.

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



Knowing pointing stability is a critical factor in laser performance

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

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.

3.4.1.1 Software Comparison Chart

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

*Feature		NanoScan Standard	NanoScan Professional
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			
A dual core processor CPU, 2GHz or better			
2GB of RAM			
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

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.

Specifications

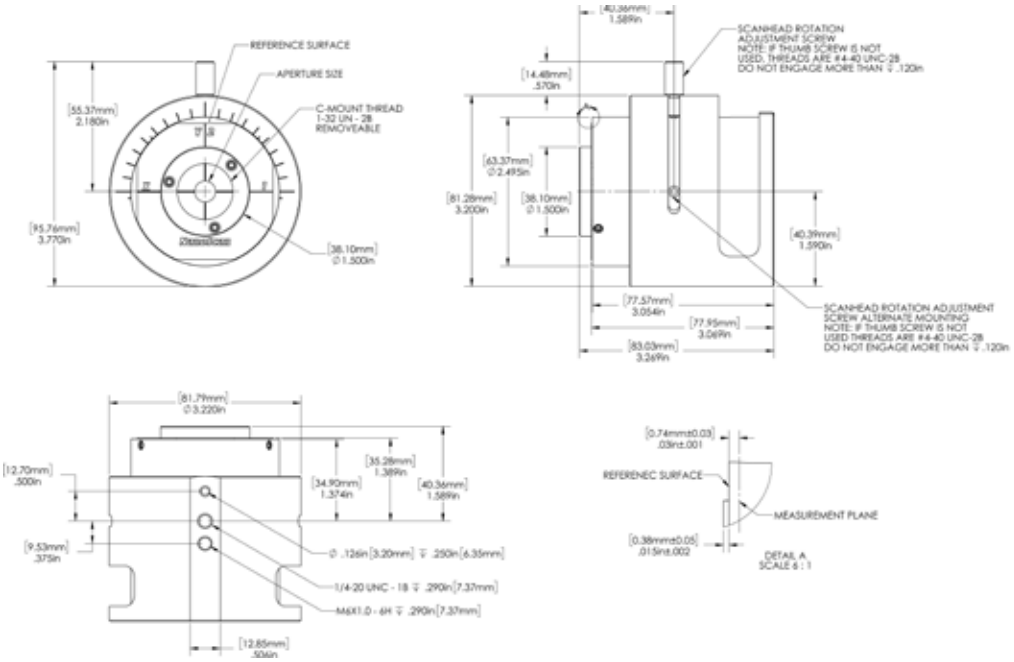
Model	Si/3.5/1.8µm	Si/9/5µm	Ge/3.5/1.8µm	Ge/9/5µm	Pyro/9/5µm
Wavelengths	190-1100nm (1)	190-1100nm (1)	700-1800nm	700-1800nm	190-100µm
Slit size	1.8µm	5µm	1.8µm	5µm	5µm
Aperture size	3.5mm	9mm	3.5mm	9mm	9mm
$1/e^2$ Beam diameter range	7µm-~3mm	20µm-~6mm	7µm-~2.3mm	20µm-~6mm	20µm-~6mm
Spatial sampling resolution	5.3nm-18.3µm				
Scan frequency	1.25, 2.5, 5, 10, 20Hz				
Power reading	User calibrated				
Power aperture window	Metalized Quartz (200mW upper limit)				N/A
Laser type	CW or Pulsed				
Operating range	See Operating Space Charts				
Damage threshold	See Operating Space Charts				
Rotation mount	Standard				
Bus interface	USB 2.0				
OS supported	Windows 7 (64) and Windows 10				
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	76.8mm L x 63.5mm Ø				
Power	USB 2.0 Bus Powered				
CPU clock	300MHz				
Memory clock	264MHz				
Scanning motor	Brushed DC, 4W max				
Compliance	CE, UKCA, China RoHS				

Note: (1) Between 950nm and 1100nm, there might be a degradation of system performance

Ordering Information

Supported software	**NanoScan Professional (1)**		**NanoScan Standard**	
Model	**Item**	**P/N**	**Item**	**P/N**
Si/3.5/1.8µm	NS2s-Si/3.5/1.8-PRO	**PH00464**	NS2s-SI/3.5/1.8-STD	**PH00456**
Si/9/5µm	NS2s-Si/9/5-PRO	**PH00465**	NS2s-SI/9/5-STD	**PH00457**
Ge/3.5/1.8µm	NS2s-Ge/3.5/1.8-PRO	**PH00467**	NS2s-Ge/3.5/1.8-STD	**PH00459**
Ge/9/5µm	NS2s-Ge/9/5-PRO	**PH00468**	NS2s-Ge/9/5-STD	**PH00460**
Pyro/9/5µm	NS2s-Pyro/9/5-PRO	**PH00470**	NS2s-Pyro/9/5-STD	**PH00462**
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**

Note: (1) Software includes ActiveX automation feature



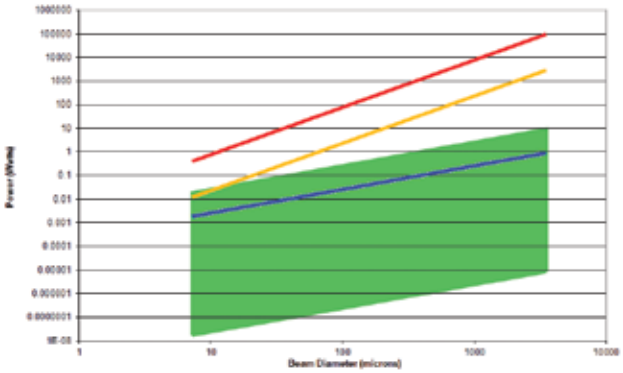
Typical NanoScan Operating Space Charts

Operating range is at peak sensitivity of detector.

Operating space is NOT absolute.

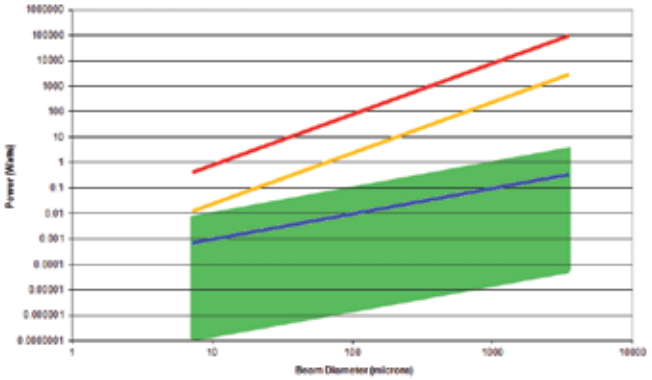
THESE CHARTS TO BE USED AS A GUIDE ONLY.

NanoScan Operating Space
Si/3.5mm/1.8µm



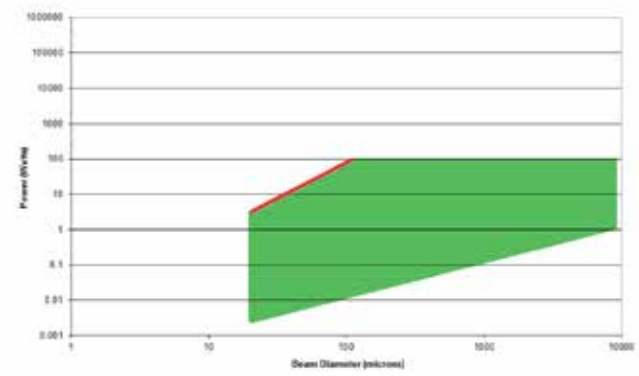
Silicon Detector: Responsivity varies with wavelength. Detects between 400-1100nm. Peak responsivity is 0.7 amps/watt at 980nm. Detector to detector responsivity variation can be as great as ±20%.

NanoScan Operating Space
Ge/3.5mm/1.8µm



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%.

NanoScan Operating Space
Pyro/9mm/5µm



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.

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.