NanoScan

Installation and Operation Manual

Model #________________________

Serial #________________________

Date ________________________

6878 Santa Teresa Blvd.

San Jose CA 95119

www.ophiropt.com

Photon
OPHIR Photonics Group

Copyright

NanoScan™ Analysis Software for Windows

Instruction Manual

Software License

The software provided is protected by the United States Copyright Law and International Treaty provisions. You are authorized to make one copy of the software for backup purposes only. You may only have one copy of the software in use at any given time.

This license is not transferable. Contact Photon Inc. if your unit was obtained as a resale.

The code and methods outlined are uniquely Photon's. Code found in another program that follows our outlined procedures could be in violation of the Photon Inc. copyright.

Trademarks

NanoScan and NanoScan Analysis Software are trademarks of Photon Inc. MS-DOS and Windows are registered trademarks of Microsoft Corporation. LabVIEW is a registered trademark of National Instruments.

WARRANTY POLICY

Photon's products are covered by limited warranty on parts and labor for 12 months from shipment date and 13 months if shipped to an authorized representative except as noted below. This warranty covers parts and labor to repair the equipment that fails to perform due to problems that are innate to the units and its components, but not due to neglect or misuse. Photon cannot be held liable for any damages beyond the original equipment cost.

Photon does not warrant incorrect use of instruments, such as but not limited to:

- Connecting or disconnecting a Photon sensor head or a plug-in card with the computer or Photon controller powered on.
- Plugging a Photon sensor head into a GAME PORT
- Plugging your Photon controller or your computer into a wall outlet without a surge protection strip.

Photon reserves the right to determine if the problem has been brought on by improper use.

Photon DOES NOT WARRANT DAMAGE TO APERTURES OR DETECTORS FOR ANY REASON. This includes but is not limited to the following: contamination, laser damage, puncture to apertures, melted apertures, cut apertures, melted or cut detectors, or slit or detector damage by intense laser beams for any reason.

The silicon array sensors shipped without a cover glass are not warranted for any reason. Sensors should never be cleaned.

Optical components such as the ATP series have a 15-day warranty on materials and workmanship. Photon does not warrant damage from shipping, mishandling or laser damage for any reason.

Whenever Photon sensors are ordered alone without a Photon control card or Photon software, the warranty is rendered void.

Warranty is not transferable except through resale of products by authorized agents of Photon inc. Unauthorized transfer of equipment and/or modifications to the equipment are grounds for voiding warranty coverage.

Photon reserves the **right to void** the warranty if the Buyer fails to meet the terms of purchase such as, but not limited to, a payment after the stated agreed invoice payment date or failure to pay for shipping charges as examples.

This is Photon's sole warranty with respect to its products. No statement, agreement or understanding, oral or written, made by an agent distributor, representative or employee of Photon, which is not contained in this warranty will be binding upon Photon, unless made in writing and executed by an officer. Photon makes no other warranty of any kind whatsoever, expressed or implied, and all implied warranties of merchantability and fitness for particular use which exceed the aforementioned obligation are hereby disclaimed by Photon and excluded from this agreement. Under no circumstances shall Photon be liable to Buyer in contract or in tort, for any special, indirect, incidental or consequential damages, expenses, losses or delays however caused.

Photon must be notified of the defect or nonconformity within the warranty period and the affected product returned to Photon's factory or an authorized service center within 30 days after the discovery of such defect or nonconformity. Shipment to Photon shall be made with an RMA# and prior authorization by Photon. Warranty repairs will be returned pre-paid lowest cost shipping method: ground shipment if within USA for example. If a faster return is desired the Buyer must pay the shipping charges

Software License Agreement

This legal document is an agreement between you, the end user, and Photon Inc. BY OPENING THE SEALED SOFTWARE PACKAGE, YOU ARE AGREEING TO BECOME BOUND BY THE TERMS OF THIS AGREEMENT, WHICH INCLUDES THE SOFTWARE DISCLAIMER OF WARRANTY (collectively the “Agreement”).

THIS AGREEMENT CONSTITUTES THE COMPLETE AGREEMENT BETWEEN YOU AND PHOTON INC. IF YOU DO NOT AGREE TO THE TERMS OF THIS AGREEMENT, DO NOT OPEN THIS PACKAGE. PROMPTLY RETURN THE UNOPENED PACKAGE AND THE OTHER ITEMS (INCLUDING WRITTEN MATERIALS AND BINDERS OR OTHER CONTAINERS) THAT ARE PART OF THIS PRODUCT, TO THE PLACE WHERE YOU OBTAINED THEM.

THIS AGREEMENT INCLUDES ALL MATERIALS PROVIDED IN THE SEALED SOFTWARE PACKAGE INCLUDING ALL MATERIALS PRODUCED, MANUFACTURED, DISTRIBUTED, PACKAGED, BUNDLED OR OTHERWISE INCLUDED BY PHOTON INC. IN THE SEALED SOFTWARE PACKAGE INCLUDING SOFTWARE FROM OTHER VENDORS, MANUFACTURERS, DEVELOPERS AND SUBCONTRACTORS.

Photon Inc. Software Site License

GRANT OF LICENSE. This product consists of software to be used with any Photon Inc. instrument product; e.g., NanoScan, ModeScan, USBeamPro, FireWire BeamPro, BeamScan, BeamPro$_{filer}$, Goniometric Radiometers. In consideration of payment of the license fee, which is part of the price you paid or agreed to pay upon receipt of the invoice from Photon Inc. for this product, Photon Inc., as LICENSOR, grants to you, as the LICENSEE, a personal, nonexclusive license to make and use copies of the applicable Photon Inc. instrument analysis software program (hereinafter, “PHOTON SOFTWARE”). You may install copies of PHOTON SOFTWARE on an unlimited number of computers at a single location, providing that only one individual at a time is using the PHOTON SOFTWARE. If you are an entity, Photon grants you the right to designate one individual within your organization to have the right to use the PHOTON SOFTWARE in the manner provided above. Photon Inc. reserves all rights not expressly granted to LICENSEE.

OWNERSHIP OF PHOTON SOFTWARE. As the LICENSEE, you own the magnetic or other physical media on which the PHOTON SOFTWARE is originally or subsequently recorded or fixed, but Photon Inc. retains title and ownership of the PHOTON SOFTWARE recorded on the original disk or tape and all subsequent copies of PHOTON SOFTWARE, regardless of the form or media in or on which the original and other copies may exist. This license is not a sale of the original PHOTON SOFTWARE or any copy.

COPY RESTRICTIONS. This PHOTON SOFTWARE and the accompanying written materials are copyrighted. Unauthorized copying of the PHOTON SOFTWARE is expressly forbidden. You may be held responsible for any copyright infringement that is caused or encouraged by your failure to abide by the terms of this License. Subject to these restrictions, and if the PHOTON SOFTWARE is not copy-protected, you may make up to three (3) copies of the PHOTON SOFTWARE solely for backup purposes. You must reproduce and include the copyright notice on the backup copy.

USE RESTRICTION. As the LICENSEE, you may physically transfer PHOTON SOFTWARE from one computer to another, provided that the PHOTON SOFTWARE is used by one individual at a time at one location.

TRANSFER RESTRICTIONS. This PHOTON SOFTWARE is licensed only to you, the LICENSEE, and may not be transferred to anyone without the prior written consent of Photon Inc. Any authorized transfer of the PHOTON SOFTWARE shall be bound by the terms and conditions of this Agreement. In no event may you transfer, assign, rent, lease, sell, or otherwise dispose of the PHOTON SOFTWARE on a temporary or permanent basis except as expressly provided herein.

TERMINATION. This license is effective until terminated. This license will terminate automatically without notice from Photon Inc. if you fail to comply with any provision of the License. Upon termination you shall destroy the written materials and all copies of the PHOTON SOFTWARE.

UPDATE POLICY. Photon Inc. may create, from time to time, updated versions of the PHOTON SOFTWARE. At its option, Photon Inc. will make such updates available to the LICENSEE.

MISCELLANEOUS. This agreement is governed by the laws of the State of California.

Disclaimer of Warranty and Limited Warranty

THE SOFTWARE AND ACCOMPANYING WRITTEN MATERIAL (INCLUDING INSTRUCTIONS FOR USE) ARE PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND. FURTHER, PHOTON INC. DOES NOT WARRANT, GUARANTEE, OR MAKE ANY REPRESENTATIONS REGARDING THE USE, OR THE RESULTS OF THE USE, OF THE SOFTWARE OR WRITTEN MATERIALS IN TERMS OF CORRECTNESS, ACCURACY, RELIABILITY, CURRENTNESS, OR OTHERWISE. THE ENTIRE RISK AS TO THE RESULTS AND PERFORMANCE OF THE SOFTWARE IS ASSUMED BY YOU. IF THE SOFTWARE OR WRITTEN MATERIALS ARE DEFECTIVE, YOU, AND NOT PHOTON INC. OR ITS DEALERS, DISTRIBUTORS, AGENTS, OR EMPLOYEES, ASSUME THE ENTIRE COST OF ALL NECESSARY SERVICING, REPAIR OR CORRECTION.

Photon Inc. warrants to the original LICENSEE that the medium on which the SOFTWARE is recorded is free from defects in materials and workmanship under normal use and service for a period of ninety (90) days from the date of delivery as evidenced by a copy of the receipt. If failure of the medium has resulted from accident, abuse, or misapplication, Photon Inc. shall have no responsibility to replace it or refund the purchase price. Any replacement disk or tape will be warranted for the remainder of the original warranty period or thirty (30) days, whichever is longer.

THE ABOVE ARE THE ONLY WARRANTIES OF ANY KIND, EITHER EXPESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, THAT ARE MADE BY PHOTON INC. ON THE PHOTON INC. PRODUCT. NO ORAL OR WRITTEN INFORMATION OR ADVICE GIVEN BY PHOTON INC., ITS DEALERS, DISTRIBUTORS, AGENTS, OR EMPLOYEES SHALL CREATE A WARRANTY OR IN ANY WAY INCREASE THE SCOPE OF THIS WARRANTY, AND YOU MAY NOT RELY ON ANY SUCH INFORMATION OR ADVICE. THIS WARRANTY GIVES YOU SPECIFIC LEGAL RIGHTS. YOU MAY HAVE OTHER RIGHTS, WHICH VARY FROM STATE TO STATE.

NEITHER PHOTON INC. OR ANYONE ELSE WHO HAS BEEN INVOLVED IN THE CREATION, PRODUCTION, OR DELIVERY OF THIS PRODUCT SHALL BE LIABLE FOR ANY DIRECT, INDIRECT, CONSEQUENTIAL, OR INCIDENTAL DAMAGES (INCLUDING DAMAGES FOR LOSS OF BUSINESS PROFITS, BUSINESS INTERRUPTION, LOSS OF BUSINESS INFORMATION, AND THE LIKE) ARISING OUT OF THE USE OF OR INABILITY TO USE SUCH PRODUCT EVEN IF PHOTON INC. HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. BECAUSE SOME STATES DO NOT ALLOW THE EXCLUSION OR LIMITATION OF LIABILITY FOR CONSEQUENTIAL OR INCIDENTAL DAMAGES, THE ABOVE LIMITATION MAY NOT APPLY TO YOU.

This Disclaimer of Warranty is governed by the laws of the State of California.

Table of Contents

IMPORTANT WARNING!

Do *not* expose a NanoScan to a laser beam if the drum is not spinning!

Scanhead damage thresholds are reduced below specifications when the drum is not spinning, increasing the possibility of damage to the scanhead.

ESPECIALLY IMPORTANT!

When measuring High Power CW or High Energy Pulsed lasers, do *not* expose a NanoScan to a laser beam if the drum is not spinning!

The NanoScan drum will not spin unless the power is ON and the software is launched. The laser beams incident on the aperture may cause damage to the slits/pinholes and detector when the drum is NOT spinning. The slits/pinhole substrates are thin membranes which can be damaged if stopped in the beam, and if this occurs, the detector may also be damaged. Use of a beam dump is recommended until the drum is spinning!

When running long-term tests with NanoScan, Configure the PC Power Management to NEVER go off, and to NOT ALLOW Automatic Updates. These cause the computer to reboot, closing the NanoScan program and stopping the NanoScan drum, potentially subjecting it to the same type of damage.

WARNING

Handle the NanoScan PCI card with care. The card has static sensitive components

Static electricity due to ESD (electrostatic discharge) can damage electronic circuits. Use standard laboratory safe ESD practices. Wear an ESD wrist strap and discharge yourself to a grounded surface before handling the card. Handle the card at the edges. Do not touch the components or the gold edge-connector leads on the PCI card.

Always plug your computer or your Photon controller into a power outlet strip with a surge protector. *Photon does not warrant damage due to power line surges.*

Always power-off the computer before installing or removing the card, cables or scanhead. Failure to do this can damage the integrated circuits.

1 Introduction

Congratulations on your purchase of the NanoScan Laser Beam Profiling System, the latest in the Photon Inc. line of scanning-slit beam-profiling instruments. Photon's philosophy is to produce instruments that both suppliers and original equipment manufacturers can depend on to provide the utmost accuracy and precision in beam profile measurement and characterization.

For over 20 years Photon's BeamScan has been the *de facto* industry standard for optical beam profiling, providing accurate and repeatable measures of beam width and beam position to the 1µm range. It has been recognized worldwide as the benchmark for all other beam profiling instruments. However, in recent years the measurement requirements of the photonics industry, particularly in the telecommunications and printing industries, have become even more demanding. It was clear the BeamScan technology had to change to meet these new industry needs. The result is the new NanoScan beam profiler.

NanoScan has the same outward appearance and functionality as its BeamScan predecessor, but is *very* different in performance. Improvements in scan motion control, detector signal amplification and conditioning, and data acquisition have yielded an order-of-magnitude increase in precision of beam size and position measurement to the 100nm level.

1.1 About This Manual

This manual will help you setup and operate your NanoScan system. This section includes a NanoScan system overview; a brief explanation of the NanoScan operation; an overview of the NanoScan Analysis Software; and some practical suggestions on proper care and regular calibration of your new instrument. Chapter 2 includes the system's packing list and unpacking and inspection instructions. Chapter 3 includes step-by-step system setup instructions for installing and configuring the hardware and software. The theory of operation of the NanoScan scanhead and principles of laser beam profiling measurement are discussed in Chapter 4. Descriptions of the features and operation of the NanoScan Analysis Software graphical user interface (GUI) and automation interfaces are provided in Chapter 5. Appendix A contains Scanhead Specifications; Appendix B shows the Mechanical Dimensions, and the operating charts of NanoScan models are shown in Appendix C.

1.2 Product Description

NanoScan is a PC-based instrument for the measurement and analysis of optical beam spatial profiles and power in accordance with ISO standards. Beam profiles are measured in accordance with the International Standard ISO 11146; power is measured in accordance with ISO 13694.

The system comprises a scanhead for sensing the laser beam and a PCI circuit card or USB2.0 controller, controlled through software, for scan control and data acquisition. System software includes a standalone user interface and an ActiveX Automation server.

NanoScan uses moving slits, one of the ISO Standard scanning aperture techniques. Measurement is possible for beam sizes from microns to centimeters at beam powers from microwatts to over kilowatts, without attenuation. Detector options—silicon, germanium, or pyroelectric—allow measurement at wavelengths from the ultraviolet to the far infrared. It can simultaneously measure multiple beams and offers a an optional power meter for scanheads with silicon and germanium detectors.

Profiles are acquired with 12-bit digitization, and analyzed for real-time updates up to the maximum scanhead rotation rate of 20Hz. Spatial sampling resolution can be as small as 5.7 nanometers. With NanoScan, beam profile measurement is extremely easy: simply position the scanhead in the beam path and within seconds the system does the rest.

Photon offers the standard NanoScan System with either a PCI or USB 2.0 bus interface to allow operation with industrial, desktop, and laptop PCs.

- **PCI System** for industrial and desktop PCs includes:
  - **NanoScan scanhead** with rotation mount and protective cap
  - **PCI Scan and Acquisition Card**
  - **NanoScan Beam Profiling and Analysis Software** for Microsoft Windows
  - **NanoScan Installation and Operation Manual**
- **USB 2.0 System** for industrial, desktop, and laptop PCs includes:
  - **NanoScan scanhead** with rotation mount and protective cap
  - **Model USB 2.0 Scan and Acquisition Controller**
  - **NanoScan Beam Profiling and Analysis Software** for Microsoft Windows
  - **Wall-Mount DC Power Supply and USB 2.0 Cable**
  - **NanoScan Installation and Operation Manual**

1.3 Operation and Use

The basic system operation is as follows: The scanhead detector “senses” incident laser beams directed into the scanhead entrance aperture. The detector analog output signal is proportional to the spatial beam profile and the total power in the beam. The PCI Scan and Acquisition Interface Card or the USB 2.0 Scan and Acquisition Controller controls the scanhead rotation rate, the analog signal amplification, signal filtering, the spatial sampling of the analog profile signal, and the 12-bit digital data acquisition. The acquired digital profile data is transferred into the computer memory for data analysis and display.

NanoScan is useful in any photonic application that requires precise and accurate measurement of beam size and position. The NanoScan can be operated either as a standalone instrument or integrated into automated test and measurement systems. As a standalone instrument, it is useful in research and development applications to configure, test, and verify designs, and also useful in manufacturing and production for real-time optical adjustments. As an automated system, it finds applications in tools for final test and quality assurance of optical systems. In either case, NanoScan provides considerable savings in time and improves productivity and throughput.

1.4 NanoScan Software Overview

1.4.1 NanoScan Beam Profiling GUI

The NanoScan Beam Profiling GUI is an easy-to-learn standalone user interface for operating the NanoScan system, providing scanhead control, profile acquisition, and data analysis. The software is written specifically for MS Windows platform, and is compatible with 2000 Professional, XP Professional, and Vista operating systems. This manual does not address the basics of MS Windows operations. It assumes that you know how to open and close programs; make selections and operate controls and dialogs; open, save, and close files; create directories; print, etc. For further assistance on MS Windows refer to MS Windows manuals, help files, and tutorials.

1.4.1.1 Scan Control and Profile Acquisition

The scan rotation rate, the spatial sampling interval, the signal amplifier gain, the filter settings, and the DC offset are set through software. The EEPROM in the scanhead contains critical information for operation. This information includes: head identification information, available rotation rates, amplifier gain tables, slit information, power window and calibration information, and acquisition channel definitions. There are also provisions for spatial and spectral calibration.

Scan rotation rates are typically 1.25, 2.5, 5, 10, and 20Hz. The spatial sampling interval is determined by the sampling clock (master local clock divided by the sampling clock divider), the scanhead drum rotation rate, and the drum radius. Spatial sampling can be set as low as 0.0458µm (at 10Hz rotation frequency) for typical 45° slit orientation. The available amplifier gains are scanhead dependent and are given in the gain table. Gain ranges on the order of >70dB are typical. The filter frequency can be adjusted over a range from 2kHz to 190kHz. The filter can be used to improve the signal-to-noise ratio in the acquired profile data within the limits of beam diameter measurement requirements, dependent on drum rotation rate. The spatial sampling interval, the gain, the filter setting, and the rotation rate can be set to optimize profile acquisition.

The acquired 12-bit profile data from each acquisition channel are temporarily saved in the board memory and then transferred in the host computer memory through a direct memory access (DMA) transfer with PCI systems, and through Bulk transfer mode with USB 2.0 systems.

1.4.1.2 Data Display and Visualization

There are data display screens that show X and Y profiles for up to 16 regions-of-interest (ROIs), the position plots of the beams, the total power and the percentage of power in each beam. Quantitative displays of user-selected parameters are constantly available on the right side of the screen.

1.4.1.3 Measured Beam Parameters

Parameters measured include:

- Beam Width at various clip levels
- Beam Width Ratios at various clip levels
- Centroid Position
- Peak Position
- Ellipticity
- 1D Gaussian Fit
- Beam Divergence
- Beam Separation
- Pointing Stability
- ROI Power
- Total Power
- Irradiance
- Pulsed Laser Repetition Frequency

1.4.1.4 Data Export

Data can be exported to spreadsheets, math and statistical analysis programs and process/instrumentation control programs. This is done by logging to files or COM ports, or shared using ActiveX Automation (OLE2).

1.4.2 ActiveX Automation Server

The Photon NanoScan Analysis Software includes an ActiveX Automation server interface for integrating the NanoScan system into custom automated test and measurement applications. Example applications with sample code for LabVIEW and MS Excel written in Visual Basic are provided on the software CD, in the Automation folder.

1.5 Protecting Your Investment

(See Warning on next page)

Always plug your PC computer into a **SURGE PROTECTION** outlet strip. It is recommended that the controller and all peripherals be powered from a single protected power strip. Be sure the electrical ground is carried through all connections. A power surge or electrical shock can cause serious damage to your NanoScan. This type of damage is not covered by warranty.

To provide accurate and precise measurements, the slits must be free of any debris. Operation in clean environments helps to ensure this. As an additional protective measure, it is also recommended to cover the aperture with the plastic cap when the scanhead is not in use.

The slits are thin fragile membranes that can be easily damaged by touch. Such damage can seriously compromise the measurement accuracy, and as such, NEVER touch the apertures!

Excessive beam power and power density from high power lasers and sharply focused beams may also damage the apertures. Refer to Scanhead Operating Space, Section 4.3.5, Aperture Damage Threshold, Section 4.4.15, and Appendix B, Operating Space Charts. Verify visually that the scanhead drum is spinning before you direct the laser beam into the scanhead.

Photon carries a limited warranty on parts and labor for 12 months. Photon does not warrant electrical damage caused by failing to safeguard the unit with a surge protector or for ESD related damage. Damage to slits or the detector is not warranted for any reason. Please refer to the Photon's Warranty Policy included with this manual for complete details.

Always protect your slits from dust and dirt by placing the plastic cap over the scanhead when not in use.

Photon strongly recommends an annual factory calibration and evaluation of the scanhead to maintain your investment and to ensure the product is measuring within specification. Photon offers several Calibration and Preventive Maintenance options. Regular calibration means:

- Measurement accuracy meets specifications
- Near 100% UP TIME
- Internal ISO requirements are met.

IMPORTANT WARNING!

Do *not* expose a NanoScan to a laser beam if the drum is not spinning!

Scanhead damage thresholds are reduced below specifications when the drum is not spinning, increasing the possibility of damage to the scanhead.

ESPECIALLY IMPORTANT

When measuring High Power CW or High Energy Pulsed lasers, do *not* expose a NanoScan to a laser beam if the drum is not spinning!

The NanoScan drum will not spin unless the power is ON and the software is launched. The laser beams incident on the aperture may cause damage to the slits/pinholes and detector when the drum is NOT spinning. The slits/pinhole substrates are thin membranes which can be damaged if stopped in the beam, and if this occurs, the detector may also be damaged. Use of a beam dump is recommended until the drum is spinning!

When running long-term tests with NanoScan, Configure the PC Power Management to NEVER go off, and to NOT ALLOW Automatic Updates. These cause the computer to reboot, closing the NanoScan program and stopping the NanoScan drum, potentially subjecting it to the same type of damage.

2 System Inspection

2.1 Inspection

Your NanoScan Laser Beam Profiling System has been tested extensively at Photon to ensure proper operation. All components were inspected and carefully packaged for shipment. Upon receipt of your NanoScan, please do the following:

- ✓ Check the contents of your shipment against the packing slip attached to the shipping box. Please note any discrepancy.
- ✓ Check the condition of the shipping container. Please note any damage to the container.
- ✓ If the container appears damaged, check the NanoScan System components for any signs of damage. If damage is observed, immediately report the damaged container to the shipping company. ***Photon does not warrant damage that occurs as a result of shipment.***

2.2 Packing Lists

2.2.1 NanoScan PCI Laser Beam Profiling System

1. NanoScan scanhead with protective cap
2. Rotation mount
3. NanoScan PCI Scan and Acquisition Card
4. NanoScan Acquisition and Analysis Software CD
5. NanoScan Installation and Operation Manual

2.2.2 NanoScan USB 2.0 Laser Beam Profiling System

1. NanoScan scanhead with protective cap
2. Rotation mount
3. NanoScan Model USB 2.0 Scan and Acquisition Controller
4. 5V DC 3.2A Power Supply with international plug kit
5. 2-meter USB 2.0A to USB 2.0B cable
6. NanoScan Acquisition and Analysis Software CD
7. NanoScan Installation and Operation Manual

3 NanoScan System Setup

Setup of the NanoScan system involves configuration of the system hardware and installation of the system software. For the PCI system, the PCI card must be installed in the host PC.

3.1 Recommended PC Requirements

To take full advantage of your NanoScan System capabilities, the following PC requirements are **recommended:**

- A processor equal or better than Pentium IV 2GHz
- Microsoft Windows 7, Windows Vista, Windows XP, or Windows 2000 Operating System[1]
- 1GB of RAM[2]
- 1 PCI slot or 1USB 2.0 port available, depending on controller version[3].
- At least 50MB of free space available on the hard disk
- SVGA or better (1280 x 1024 resolution)
- 24 bit color graphics card with hardware accelerator
- CD-ROM drive
- Microsoft compatible pointing device (e.g., mouse, trackball, etc.)

[1] *A business/professional version of windows is recommended, the NanoScan system has not been tested with home versions of windows.*

Note: Windows 2000 is only supported for the PCI Scan and Acquisition controller.

Note: For Microsoft Windows 2000 Professional operating system, the font selection must be set to "Normal".

[2] *The computer memory (RAM) will affect the performance of the software in Record Mode. Refer to Chapter 5, section 5.1.4 for more information on the Record Mode.*

[3] *Both 64-bit and 32-bit versions of windows are supported for the USB Scan and Acquisition controller; the PCI Scan and Acquisition controller is 32-bit only.*

3.2 NanoScan Installation

There are two steps to installing the NanoScan

- Installing the Software
- Installing the Hardware

The software should be installed before the hardware, otherwise you will have to dismiss many failed to install notifications.

3.2.1 Installing the Software as an Upgrade

In order to upgrade the NanoScan software you must first uninstall the current version of the software from the PC (Section 3.2.4) and then install the new software from the CD. (Section 3.2.2).

3.2.2 Software Installation

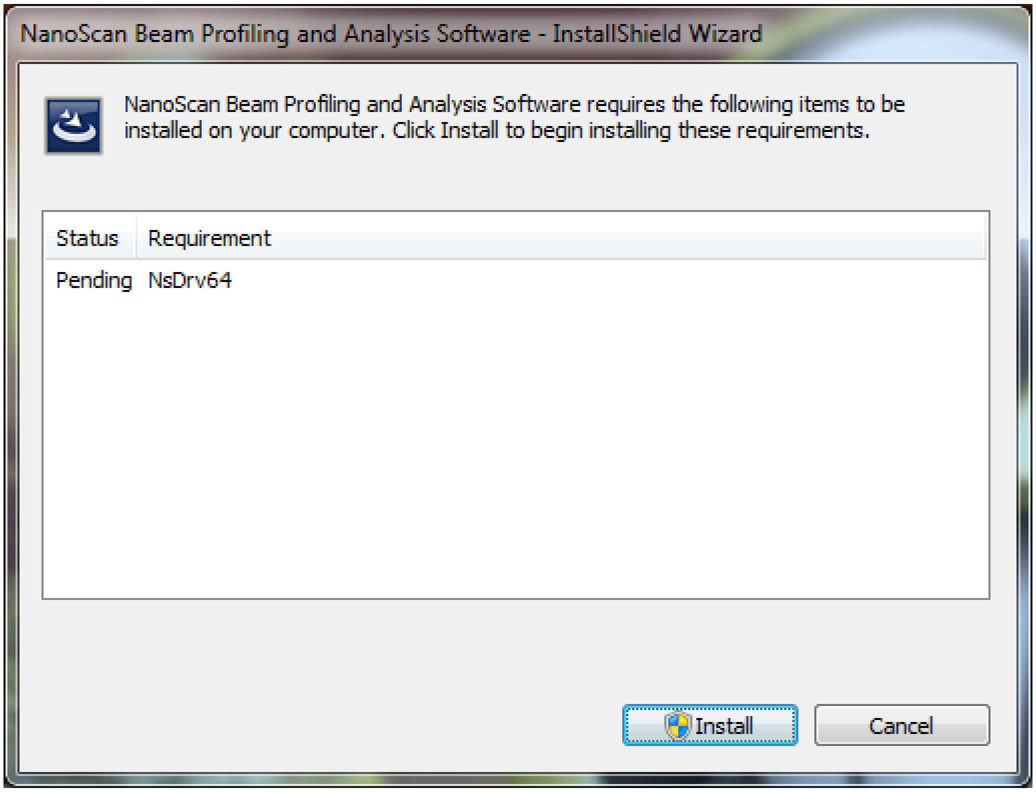
There may be minor differences to what is written here depending on what version of windows you are installing the NanoScan software on; ex. Windows XP will not have any UAC prompts.

Insert the CD; if the installer doesn't start automatically, navigate to the CD drive and open **Setup.exe**

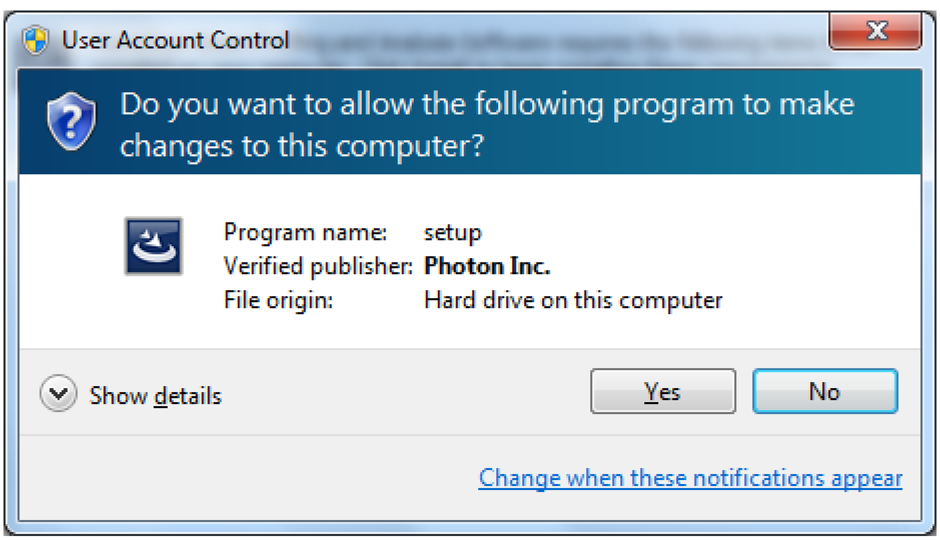
Depending on your system architecture, the installer will ask you to install the appropriate driver:

- NsDrv64 for 64-bit windows
- NsDrv32 for 32-bit windows

Choose **Install** to install the driver

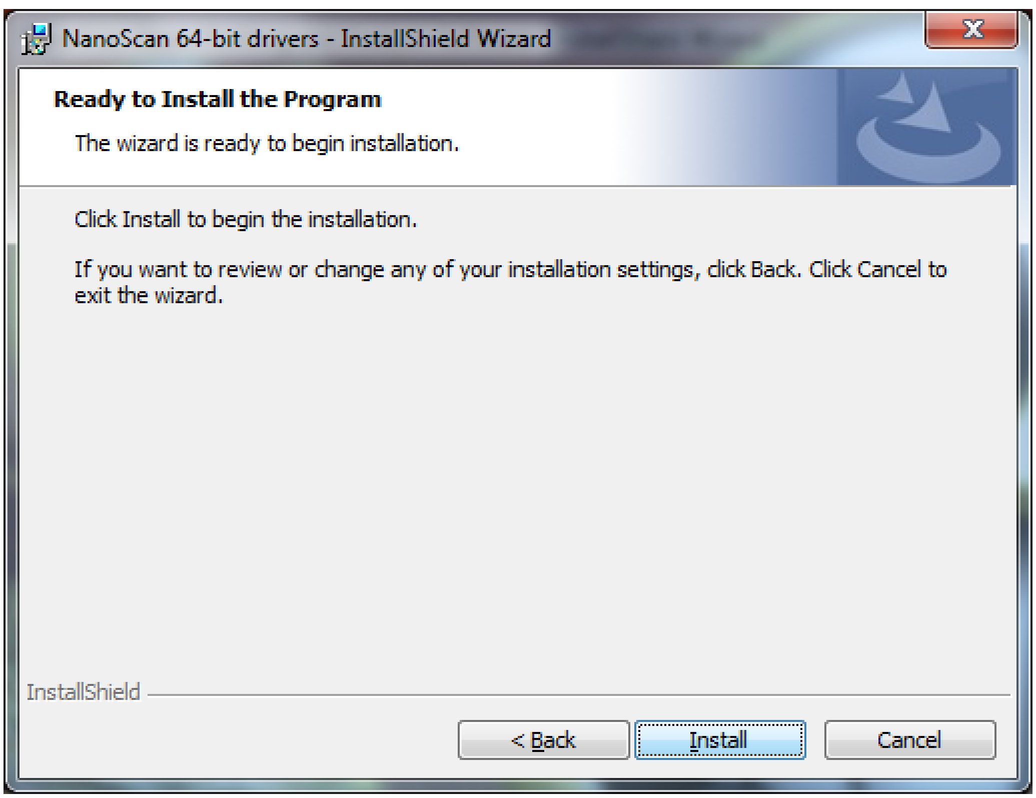


Choose **Yes** on any User Account Control (UAC) Prompts.

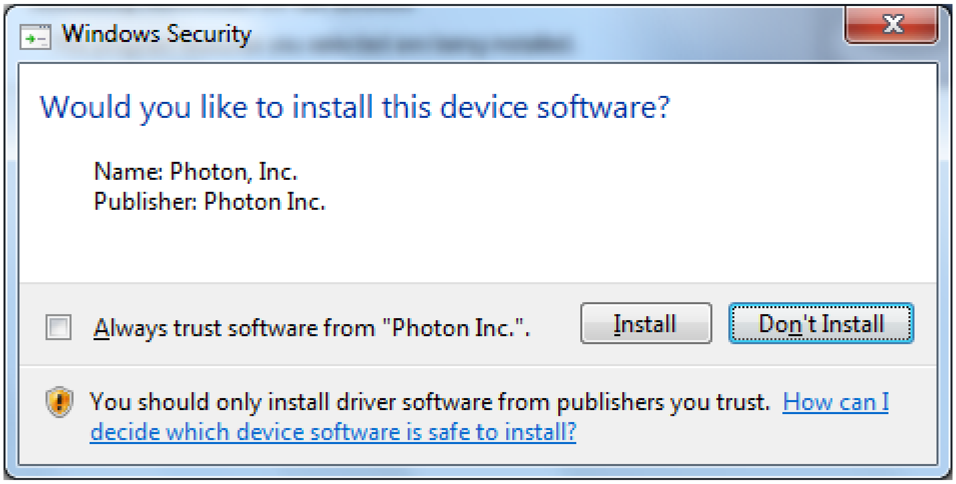


After the installer loads choose **Next**, then **Install**.

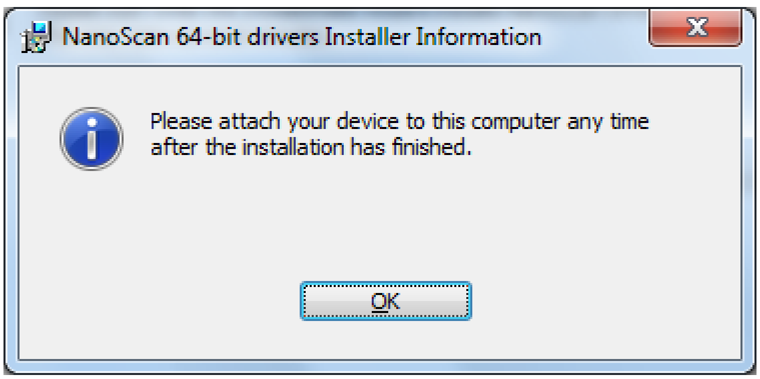

NanoScan 64-bit drivers - InstallShield Wizard
Welcome to the InstallShield Wizard for NanoScan 64-bit drivers
The InstallShield(R) Wizard will install NanoScan 64-bit drivers on your computer. To continue, click Next.
WARNING: This program is protected by copyright law and international treaties.
< Back
Next >
Cancel


NanoScan 64-bit drivers - InstallShield Wizard
Ready to Install the Program
The wizard is ready to begin installation.
Click Install to begin the installation.
If you want to review or change any of your installation settings, click Back. Click Cancel to exit the wizard.
InstallShield
< Back
Install
Cancel

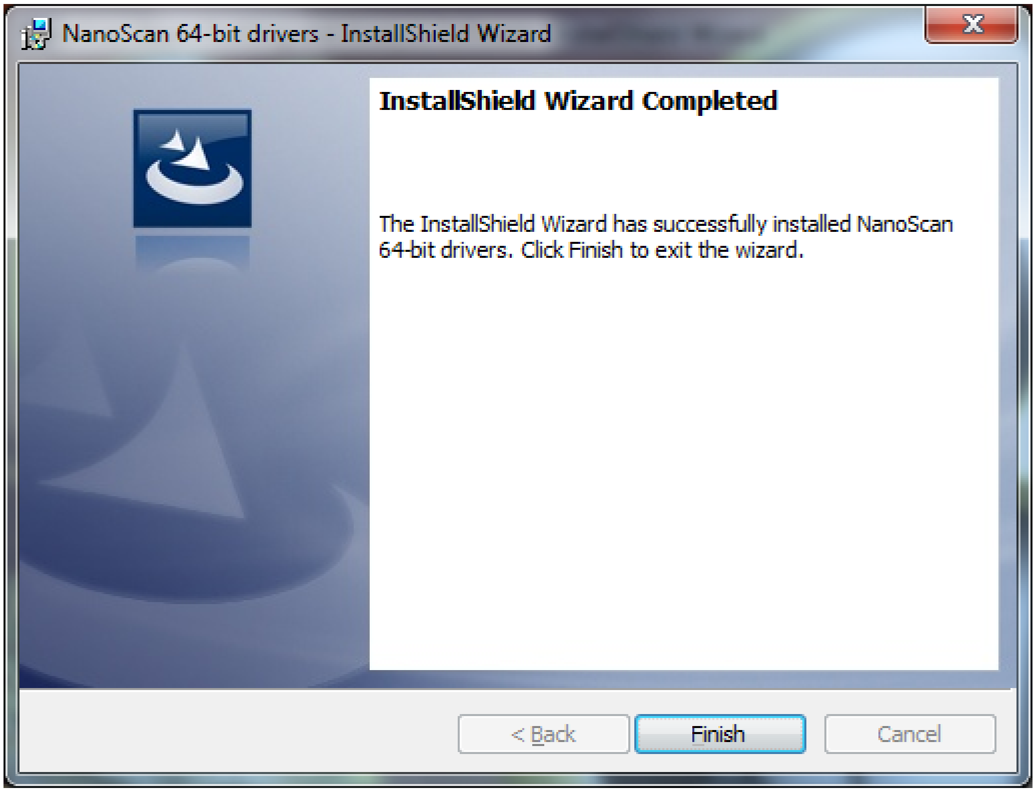
Choose **Install** at the windows security prompt. Optionally choose to **Always trust software from “Photon Inc.”** to never see this prompt again.



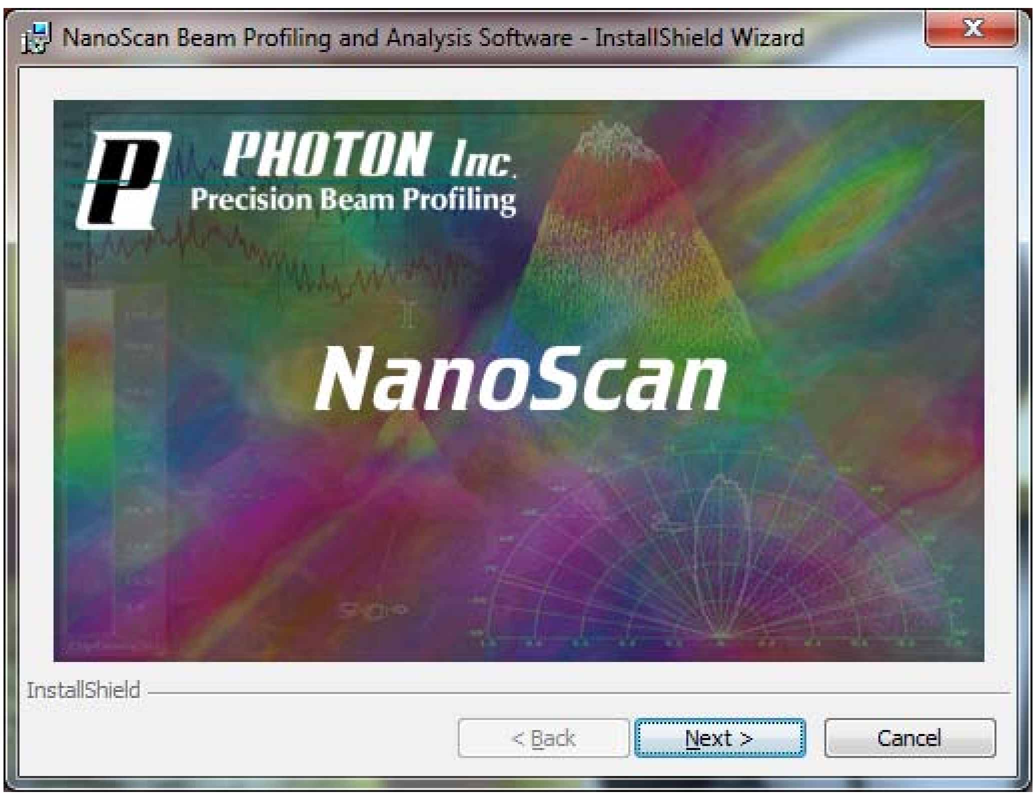
Choose **OK**.

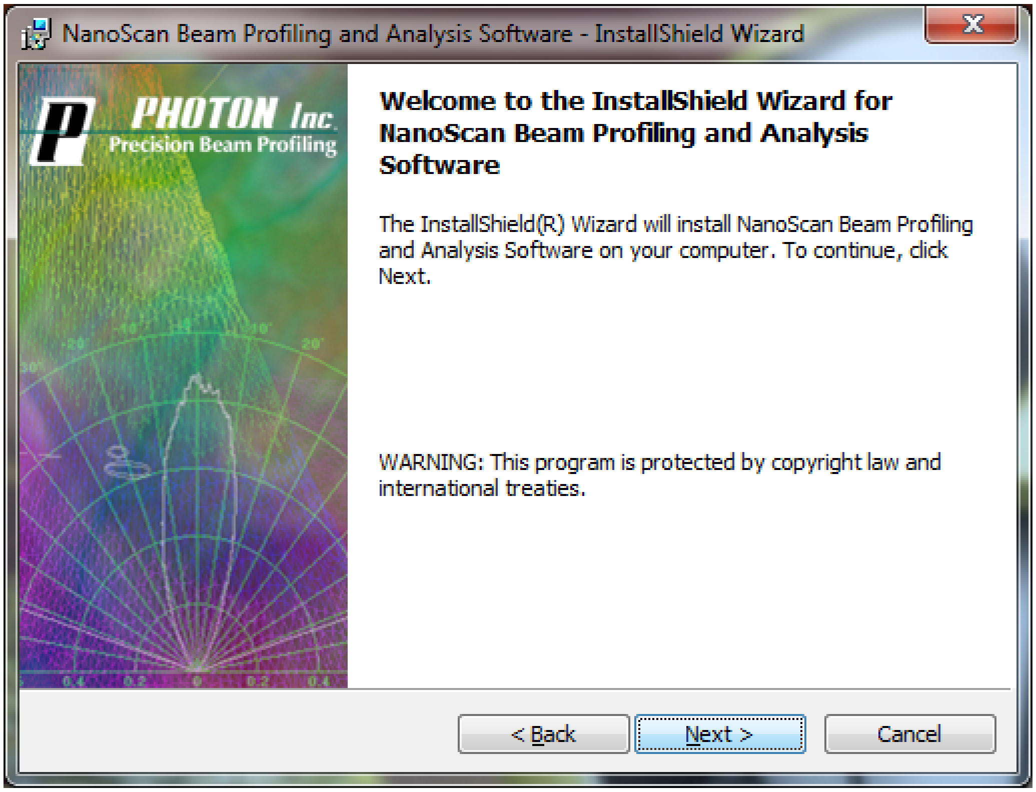


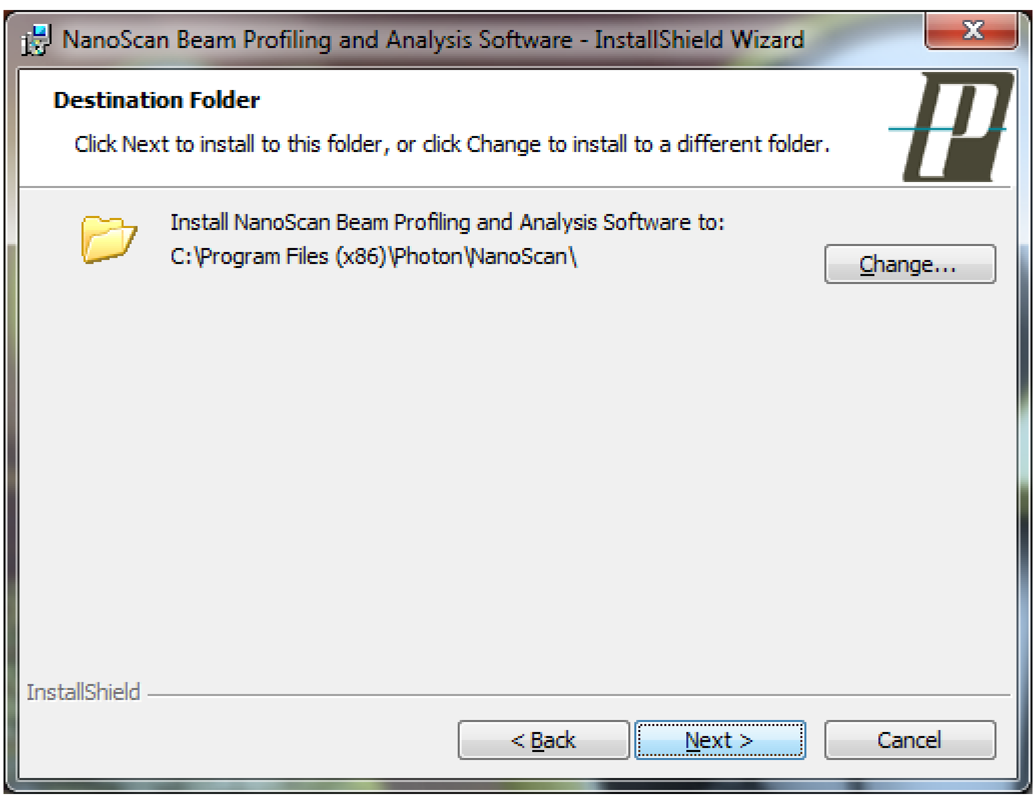
Choose **Finish**.



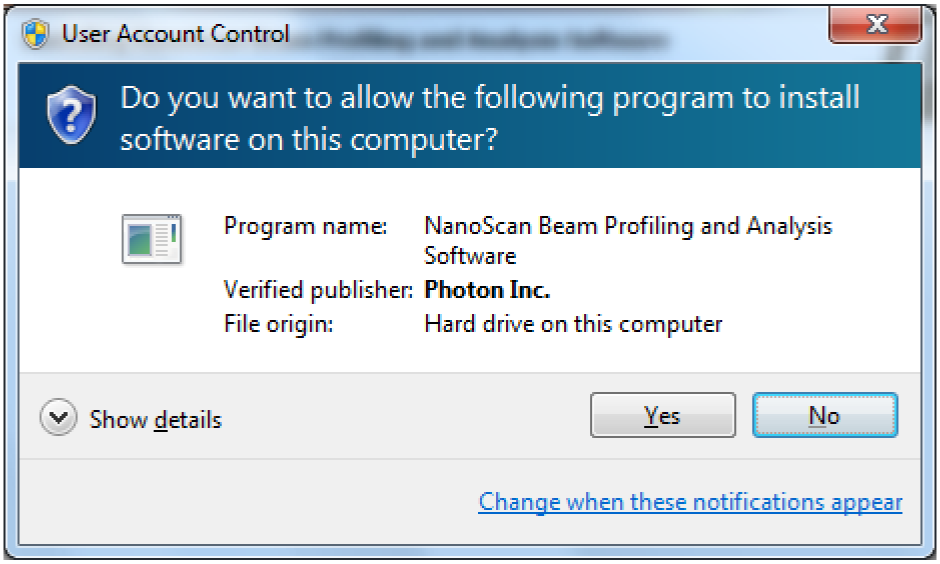
At this point the NanoScan Software will begin to install. Once the installer has finished loading completely choose **Next**, **Next**, **Next**.



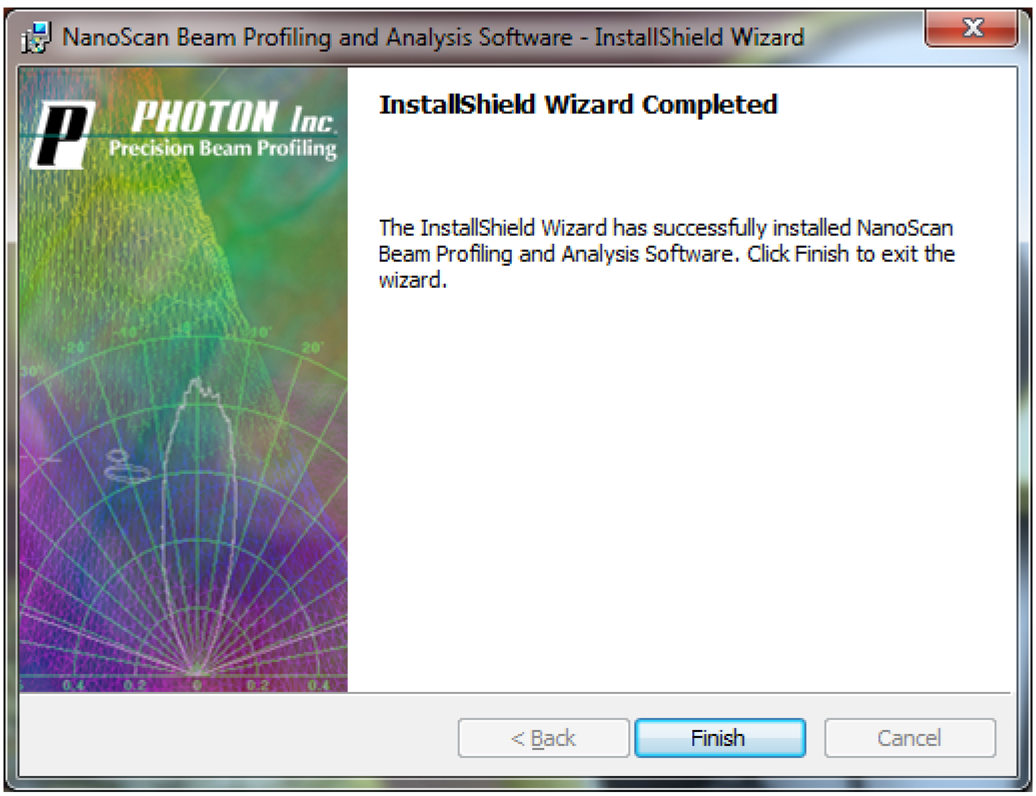

NanoScan Beam Profiling and Analysis Software - InstallShield Wizard
PHOTON Inc.
Precision Beam Profiling
Welcome to the InstallShield Wizard for NanoScan Beam Profiling and Analysis Software
The InstallShield(R) Wizard will install NanoScan Beam Profiling and Analysis Software on your computer. To continue, click Next.
WARNING: This program is protected by copyright law and international treaties.
< Back
Next >
Cancel


NanoScan Beam Profiling and Analysis Software - InstallShield Wizard
Destination Folder
Click Next to install to this folder, or click Change to install to a different folder.
Install NanoScan Beam Profiling and Analysis Software to:
C:\Program Files (x86)\Photon\NanoScan\
Change...
InstallShield
< Back
Next >
Cancel

Choose **Install** at the windows security prompt. Optionally choose to **Always trust software from “Photon Inc.”** to never see this prompt again.



Choose **Finish**



It is now time to install the hardware.

3.2.3 Hardware Installation

3.2.3.1 PCI Card Installation

Warning! Potential ESD Damage

The NanoScan PCI Card can be damaged by electrostatic discharge (ESD). To prevent ESD damage that can occur when handling electronic equipment, use a ground strap or similar device when performing this installation procedure, and handle the card without touching the gold fingers.

To install the NanoScan PCI Scan Control and Data Acquisition card in a PC compatible system:

1. Turn off your PC, unplug it and remove the cover.
2. Select one of the PCI slots available and remove the corresponding rear slot cover.
3. Install the NanoScan PCI Card into the selected PCI slot. Use the screw from the rear cover to secure the card.
4. Reinstall the computer cover.
5. Connect and secure the 26-pin high density D-subminiature connector of the Signal Cable (from the scanhead) to the PCI Card.
6. Plug in the PC and turn it on.

3.2.3.2 Model USB 2.0 Controller Installation

To install the Model USB 2.0 Controller in a PC compatible system:

1. Connect the NanoScan scanhead 26-pin high density D-subminiature connector to the Model USB 2.0 Controller
2. Connect the 5V DC Power Supply to the Model USB 2.0 Controller
3. Always plug the 5V DC Power Supply into a **SURGE PROTECTION** power strip.
4. Connect the USB 2.0 cable B connector to the Model USB 2.0 Controller
5. Connect the USB 2.0 cable A connector to the computer.

NOTE: USB 2.0 is *not* compatible with Windows 2000 Software

3.2.4 Uninstalling NanoScan Beam Profiling and Analysis Software

The process to uninstall the NanoScan software is similar to any other Windows compliant program.

1. Click the **Start** menu
2. Select **Control Panel**.
3. Under **Programs** select **Uninstall a Program.**
4. Select **NanoScan Beam Profiling and Analysis Software** from the software list.
5. Click **Uninstall** icon.
6. If a **User Account Control** dialog box appears stating that an unidentified program wants access to your computer, select **Allow** to continue uninstalling the software.
7. Repeat the Process for the **NanoScan 64-Bit Driver** or the **NanoScan 32-Bit Driver**.

IMPORTANT WARNING!

Do *not* expose a NanoScan to a laser beam if the drum is not spinning!

Scanhead damage thresholds are reduced below specifications when the drum is not spinning, increasing the possibility of damage to the scanhead.

ESPECIALLY IMPORTANT

When measuring High Power CW or High Energy Pulsed lasers, do *not* expose a NanoScan to a laser beam if the drum is not spinning!

The NanoScan drum will not spin unless the power is ON and the software is launched. The laser beams incident on the aperture may cause damage to the slits/pinholes and detector when the drum is NOT spinning. The slits/pinhole substrates are thin membranes which can be damaged if stopped in the beam, and if this occurs, the detector may also be damaged. Use of a beam dump is recommended until the drum is spinning!

When running long-term tests with NanoScan, Configure the PC Power Management to NEVER go off, and to NOT ALLOW Automatic Updates. These cause the computer to reboot, closing the NanoScan program and stopping the NanoScan drum, potentially subjecting it to the same type of damage.

4 Beam Profiling with NanoScan

NanoScan measures spatial beam irradiance profiles using scanning aperture techniques. The standard NanoScan uses the moving-slit method, approved by International Standard ISO/DIN 11146. Optionally, the NanoScan can be equipped with pinhole apertures to use the scanning pinhole method.

The profiles are analyzed to provide measures of beam width in accordance with the ISO/DIN standard. They are also analyzed to derive a number of other beam characterization parameters defined in ISO/DIN 13694, including beam centroid position, peak position, ellipticity, goodness of fit, roughness of fit, and more.

Profiles are acquired with 12-bit digitization and analyzed to provide real-time updates up to the maximum scan frequency of 20Hz. Spatial sampling resolution can be as small as 5.7 nanometers. With NanoScan, beam profile measurement is extremely easy—simply position the scanhead in the beam path and the system does the rest, providing results in less than 200ms.

Various scanhead designs accommodate measurement of beams over the wide range of beam size, beam power, and wavelength encountered in typical applications. Different detector types provide for measurement at wavelengths from the ultraviolet (UV) to the far infrared (FIR). Various detector sizes and slit widths allow for measurement of beam size from microns to centimeters at beam power from microwatts to kilowatts without attenuation. Consideration of the wavelength, beam size, and beam power ensure that a particular scanhead is appropriate for a given application.

For accurate beam profiling with NanoScan it is useful to understand the ISO/DIN standard and the measurement principles involved. Also, for any beam measurement, there are specific guidelines and restrictions that should be followed to obtain the most accurate and repeatable results.

4.1 International Standard ISO/DIN 11146

From 1989 through 1996, John Fleischer, 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, is a compromise based on many years of work by the committee. The standard governs profile measurements and analysis using scanning apertures, variable apertures, area sensors and detector arrays. Profiles obtained using these methods differ fundamentally, and each requires specific analyses to determine beam characterization parameters, most important of which is the beam width or diameter. Profile measurements using the various scanning aperture techniques were considered, including the moving-slit, moving knife-edge, variable-aperture, and scanning-pinhole methods. The committee eliminated one method from the list—the scanning pinhole. Although the committee agreed that the pinhole profile gives the highest spatial detail, it was dropped because of its sensitivity to small amounts of diffraction and the difficult requirement that the pinhole be scanned precisely through the maximum dimension of the beam in order to extract the correct width value. The committee also deemed the variable-aperture method as unsuitable for measurement of elliptical beams; therefore this method is limited to beams that are approximately circular.

4.1.1 Beam Width Analysis Methods

Four different methods of analysis for determination of beam width are allowed, including:

1. Moving-slit
2. Moving knife-edge
3. Variable aperture
4. Second-moment

The first three methods are appropriate for profiles as their names imply. The second-moment method, typically used for analysis of 2D profiles obtained with area profilers, is also applicable for moving-slit profiles.

In theory, the methods give exactly the same value for the $1/e^2$ width of perfect TEM_{oo} Gaussian beams. For all other beam profiles, different values will be obtained, although for typical beams the values are usually within less than 10% of each other.

Method 1 provides the best spatial detail. Method 2 gives little detail but is capable of measuring very small beams (if the edge quality is extremely high). Method 3 gives little spatial detail and has difficulty with elliptic beams. Method 4 obeys the propagation laws, but has difficulty with beams that have structure in the tails or noisy profile signals in general because these features are heavily weighted in the computation; i.e. by the square of the distance from the centroid. In practice, this method gives rise to poorer unit-to-unit repeatability with real laser beams.

The standard shows how to correlate beams measured by different methods if one has measured the propagation factor M^2. The standard also suggests that you state the measurement method when reporting a beam width, to keep confusion to a minimum.

4.1.1.1 Moving-Slit Analysis

Moving-slit beam width analysis, used by Photon Inc. since 1983, is illustrated in **Figure 4.1**. The observed peak is the 100% level, and the measurement baseline is the 0% level. The beam width per the ISO/DIN standards is defined as the spatial width at the 13.5% ($1/e^2$) level. It is also common in practice to use the beam size at other %-irradiance levels, or “clip” levels, such as, for example, the 50%, or full-width-half-max (FWHM) beam width, and is designated as d_{slit}.

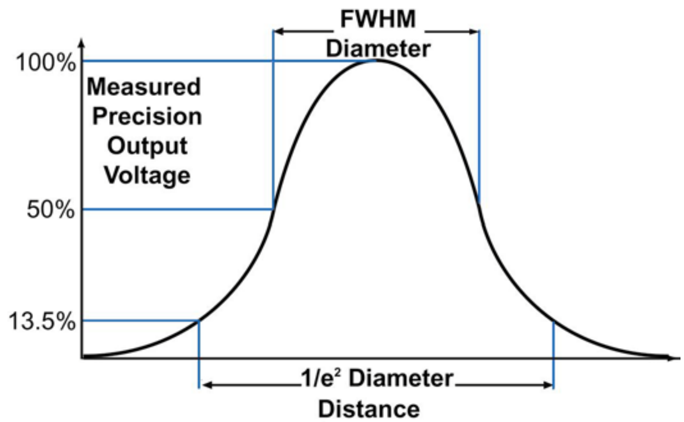


Figure 4.1 Clip-Level Beam Width Analysis

4.1.1.2 Moving Knife-Edge Analysis

Knife-edge profiles are one-dimensional cumulative spatial power distributions in the scan direction. The knife-edge width, designated d_{ke}, is defined as the distance between the 16% and 84% levels of the profile.

4.1.1.3 Moment Method Analysis

The moment method defines the beam width as four times the square root of the second moment of the beam spatial profile. This width, designated $d_{4\sigma}$, is equivalent to the $1/e^2$ slit and knife-edge method widths for a TEM_{00} Gaussian beam where $M^2=1$.

The second-moment integral for the x coordinate is:

$$\sigma_x^2(z) = \left\langle x^2 \right\rangle = \frac{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x,y,z)(x-\bar{x})^2 dxdy}{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} E(x,y,z) dxdy}$$

The corresponding beam diameter is $d_{4\sigma} = 4\sigma_x^2$

4.1.2 Comparison of Beam Profiling Methods

During the development of the draft laser standard, the committee compared what was measured by the different methods for several laser modes. The moment method was designated as the reference method because it provides the beam profile width that is always consistent with the laser propagation equation. Table 4.1 is a guide from the laser standard to illustrate how different each method can be. This is important if one writes a specification for a component and the vendor and the user want to correlate measurements obtained by different measurement methods. To avoid confusion, the standard suggests that the measurement method be stated along with the reported beam width. It is also recommended to report the standard deviation of the measurement.

Table 4.1 Comparison of Beam Width Measurement Methods

Method	Encircled Energy/ Variable Aperture	Moving Slit	Moving Knife-Edge	Moving Pinhole/ Detector 1D Array	Second Moment Moving Slit
Width Measured @ % PWR	86.5% Total	13.5% Highest Peak	10% to 90% Maximum Value	13.5% Outer Peak	Second Moment Calculation
Multiplier*	1.0	1.0	1.5606	1.0	4.0
What Measured	D at $1/e^2$	D at $1/e^2$	$\frac{D \text{ at } 1/e^2}{1.5606}$	D at $1/e^2$	$\frac{D \text{ at } 1/e^2}{4.0}$
Mode	% Beam Width Error	% Beam Width Error	% Beam Width Error	% Beam Width Error	% Beam Width Error
TEM_{00}	0	0	0	0	0
TEM_{01*}	-6.3	-0.7	-1.7	6.1	0
TEM_{10}	-5.6	-3.9	7.8	10.3	0
TEM_{11*}	-6.3	-1.0	9.3	8.5	0
TEM_{20}	-5.5	-3.9	11.5	8.6	0
TEM_{21*}	-6.0	-1.4	12.1	7.4	0
Uniform Density Circle	-7.5	-1.0	7.2	0	0
Uniform Density Square	-7.1	0	24.8	0	0

4.2 Principle of Measurement

4.2.1 Scanning Aperture Techniques

The scanning aperture technique with NanoScan is normally the moving-slit method; however, the scanning-pinhole method is an available option. These methods are illustrated in Figure 4.2. With all methods, the scanning aperture is interposed between the incident beam and a large-area detector. The detector output signal is proportional to the beam irradiance profile as the aperture scans through the beam. The scan can be made in discrete steps, or in a continuous fashion. With discrete steps, the spatial sampling interval is the step dimension, whereas with continuous scanning, the scan velocity and signal sampling determine the spatial sampling.

The profiles obtained using these methods differ fundamentally. The pinhole aperture provides a localized measurement through a particular segment of the beam, whereas the slit aperture integrates the beam along the slit direction, and the knife-edge integrates over the area of the beam. Thus, the profile information obtained using these techniques is dependent on the beam irradiance distribution.

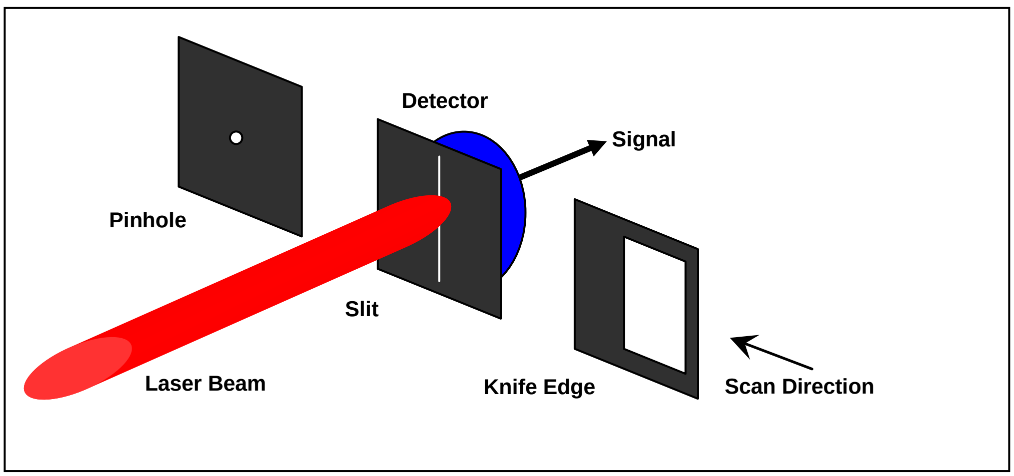


Figure 4.2 Illustration of scanning aperture beam profiling techniques

With the slit and knife-edge techniques, a measure of the width of the entire beam can be obtained in only one scan. However, for the pinhole technique, the scan must either be positioned properly in the beam or a full raster scan of the beam must be made to obtain the correct beam width value.

With slit and knife-edge apertures, the acquired profiles are along the apparent motion of the aperture, i.e., in the direction perpendicular to the aperture. Thus, by using multiple apertures oriented at different angles, profiles of the beam through different axes are obtained. Standard NanoScan configuration uses two slits oriented at 90° to each other, and two orthogonal profiles are measured for each scan. This technique is illustrated in Figure 4.3 below for the measurement of the major and minor axes of an elliptical beam using the moving-slit method.

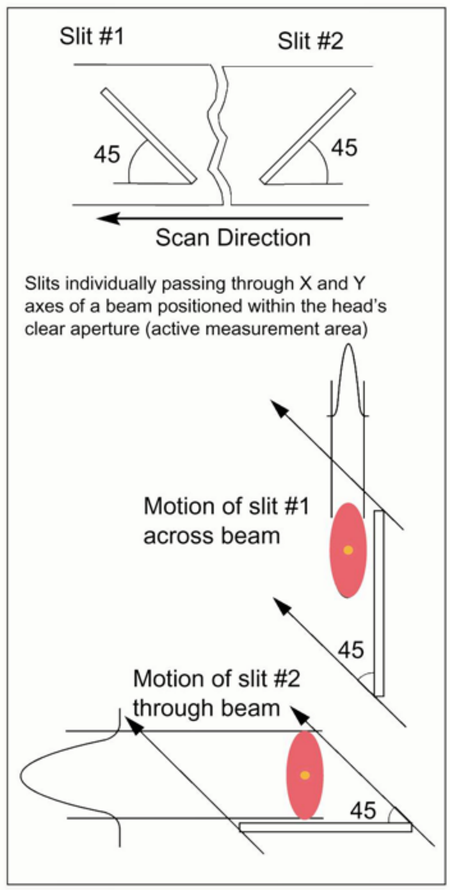


Figure 4.3 Measurement of the major and minor axes of an elliptical beam using the moving-slit method with 2 orthogonal slits.

If the apertures are mounted on a rotating drum to move the aperture through the beam, repetitive measurements of the beam profile are acquired at the scan rotation frequency. This arrangement, shown in Figure 4.4for a slit aperture, allows for real-time beam profiling. The measurement is not truly planar, because the aperture scan path is circular, but when the drum circumference is much larger than the beam dimensions, the errors introduced are negligible. To improve accuracy, mathematical corrections for the geometry can be made.

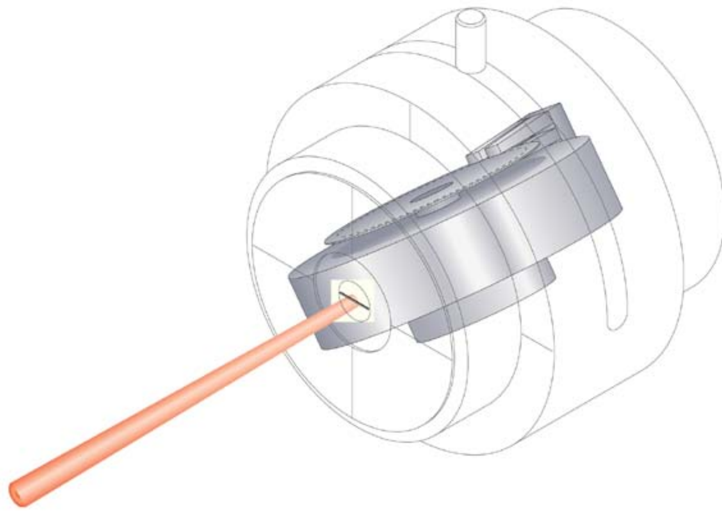


Figure 4.4 Scanning aperture instrument for laser beam profiling. A slit mounted to a motorized drum scans repetitively through the beam. An optical encoder provides motion control feedback and ensures accurate beam sampling.

4.2.2 NanoScan Dual-Axis Scanhead

In 1990, Photon Inc. became the first commercial supplier of profiling instruments to introduce multiple-aperture scanning. Specifically, the use of two slits oriented at ±45° with respect to the scan direction provides measures of the beam profile along orthogonal axes. This configuration is standard for NanoScan scanheads

Figure 4.5 below illustrates the operation of a dual-axis scanhead. The dual axis scanhead has two slits on a rotating drum. The slits are typically the same width and oriented at ±45° (90° to each other) with respect to the drum scan direction. In the figure, the drum is orientated at 45° to the incident beam, and consequently the apparent motions of the slits are in the horizontal and vertical directions respectively. In the illustration an elliptical beam, oriented with the major axis horizontal and the minor axis vertical, is incident on the scanhead. Slit aperture 1 scans along the vertical axis of the beam and slit aperture 2 scans along the horizontal axis. The measured beam profiles for each aperture are shown**.**

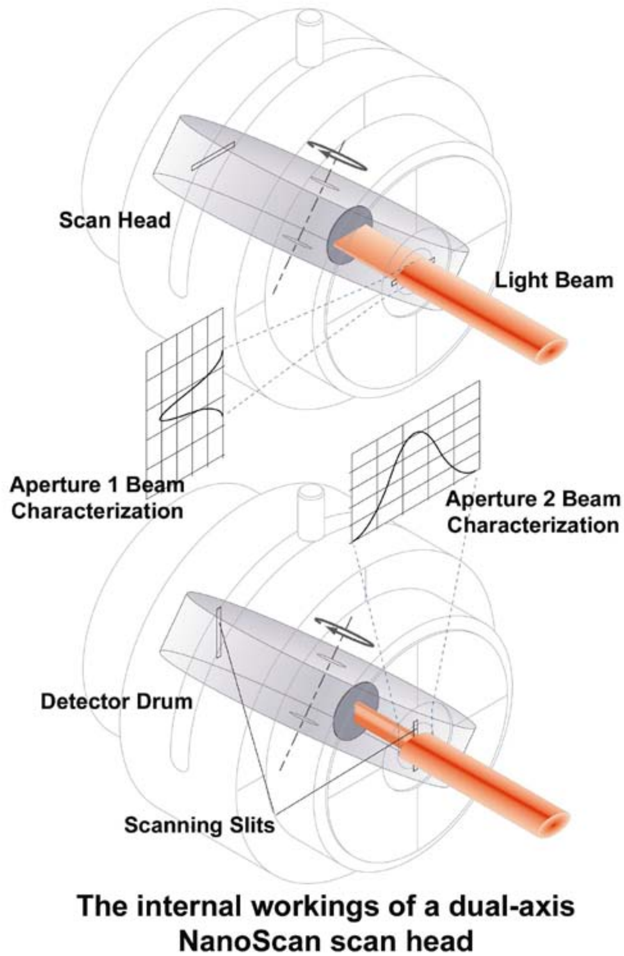


Figure 4.5 Illustration of NanoScan profiling with dual orthogonal slits

NanoScan comes with a rotation mount that allows easy adjustment for orientation through any azimuth of the incident beam. This is useful for measurement of elliptical beams with arbitrary orientation (see Section 4.4.12. for additional information).

4.2.3 NanoScan Power Measurement

For scanheads with a silicon or germanium detector, the NanoScan has a built-in power measurement capability as a standard feature. For power measurement, the scanhead drum has a large aperture that transmits the entire incident beam onto the detector. This allows the beam power level to be monitored simultaneously with the profile. The optional power meter (see Section 4.3.3.7) *must be* selected at the time of purchase of the NanoScan.

4.2.4 Pulsed Beam Profiling

In addition to profiling CW laser beams, NanoScan can also profile pulsed laser beams with repetition frequency in the 1kHz 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 is well suited to measure them, too. The measurement of all these types of pulsed lasers is discussed below.

When operating in Pulsed Mode, the peaks of the individual pulses in the profile are connected to form a smooth profile. All parameter computations are performed on the resulting smooth profile. Measurement accuracy depends on the Pulse-to-Pulse Repeatability, on the number of pulses in the profile during a single scan, which in turn depends on the laser repetition rate and beam diameter, and on Profile Averaging.

There are 2 modes of operation for pulsed lasers, depending on the pulse width. For pulse widths <~10ns, there is the Short Pulse mode; In this mode to provide the specified accuracy on the order of 2% the profile amplitude must be <256 counts to avoid amplifier nonlinearity. The Profile View Display automatically switches vertical scale to ×10. With Gain Tracking selected the amplitude will be limited to <256 counts. However, Gain can also be set manually. In this case, if the Gain is set so that the amplitude is greater than 256 counts, an information message will be displayed warning the user to decrease the gain.

For pulse widths >~10ns there is the Long Pulse mode. In this mode the Full-Scale amplitude is limited to 1500 counts above baseline to avoid amplifier nonlinearity and subsequent measurement error. Again, Gain can be set manually In this case if the Gain is set so that the amplitude is greater than 1500 counts an information message will be displayed warning the user to decrease the gain.

For CW beams the maximum amplitude is approximately 3000 counts. When operating in Short Pulsed Mode, the maximum profile amplitude is limited to 256 counts and in Long Pulse mode to 1500 counts. Hence for a given scanhead, this effectively reduces the upper boundary of the operating space for Short pulsed beam measurement by one decade from the corresponding operating space for CW beams, and by a factor of 2 for long pulsed beams.

4.2.4.1 Pulsed Mode: When to Use?

The pulsed mode of operation is recommended for all pulsed beams unless they fall into the category of "quasi-CW". Results can also vary dependent on Signal/Noise Ratio, and pulse-to-pulse repeatability. Use of Profile Averaging and Rolling Profile Averaging can improve measured pulsed beam profiles.

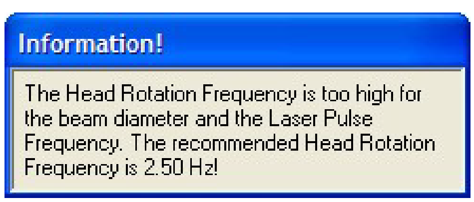
For quasi-CW pulsed beam profiles a better result may be obtained using the CW mode of operation. A quasi-CW beam is one that exhibits a profile with overlapped pulses. This occurs for larger spots at higher laser repetition frequency and longer pulse widths or duty cycle and slower scanhead rotation frequencies.

To make a visual determination if a beam profile is quasi-CW, turn off Filter Track and manually set the filter to 190kHz. Manually narrow the Region of Interest (ROI) to observe the individual pulses. If they overlap then the beam profile is quasi-CW. As an example, a 1mm $1/e^2$ diameter beam with pulse rate of 100kHz appears quasi CW at 10Hz scanhead rotation frequency.

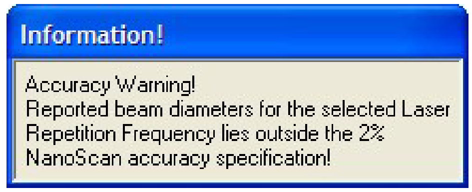
In these cases it is recommended to experiment a bit with the different measurement modes in order to obtain the most consistent results, and the final choice is up to the user.

4.2.4.2 Accuracy Requirement: minimum of 15 pulses per scan

As shown on page 4.12 in Table 4-2, a minimum of 15 pulses per single scan is required to obtain specified accuracy. This condition depends on the laser spot size and the scanhead rotation. If there are not enough pulses present in a single scan (<15), the software computes the corresponding head rotation frequency and displays an information message recommending a lower head speed.



If the computed head rotation frequency for the current conditions is below 1.25Hz, an information message will be displayed warning the user about operating the NanoScan system outside the NIST-Traceable ±2% accuracy specification.



4.2.4.2.1 Calculating the Minimum Beam Diameter per Laser Pulse Repetition Frequency

Table 4.2 on page 4.12 gives a list of calculated minimum beam diameters at a given pulse frequency for each of the drum sizes and for a desired number of pulses per profile. The more pulses per profile the more accurate the measurement is likely to be. The formula is fairly simple. Due to the 45^{o}angle of the slits to the direction of rotation, the actual speed of the slits is the drum speed divided by the square root of two.

$$\left(\frac{v/\sqrt{2}}{f} \right) N = D_{\min}$$

where:

v= drum velocity in µm per msec

f = pulse frequency in kHz

N = pulses per profile

D_{min}*= minimum beam diameter in µm*

The NanoScan pulsed operation can operate at any rotation rate, however it is recommended that the scan rate be 1.25 or 2.5Hz unless the laser repetition rate is above 50kHz. The larger drum used in the large aperture and High Power versions of the NanoScan cause the slits to move faster at any given rotation rate due to the larger circumference. For this reason the minimum beam sizes are larger for the large drum.

The peak connect algorithm finds the highest peak pulse, then using the frequency value entered by the operator it finds the other peaks and connects them to generate a smooth beam profile. It is important that the exact pulse frequency be entered into pulse acquisition parameters. The earlier BeamScan instruments only allowed the measurement of pulsed beams with the pyroelectric detector. NanoScan provides this capability with all scanheads and detectors. Beams with average powers that were too low to be measured with the pyroelectric detector can now be profiled using silicon or germanium scanheads.

At high laser repetition rates it may be better to operate the NanoScan in CW mode and let the auto-filter smooth the beam. When this is preferable is dependent on the individual laser's pulse performance. If inconsistent results are seen with a high rep rate laser (e.g., >80kHz), it would be advisable to try the measurement both ways.

Table 4.2 Minimum Beam Size Per Pulse Frequency

Minimum Beam Size per Pulse Frequency										
NanoScan	**Normal Drum**						**Large Drum (HP)**			
Rotation Rate (Hz)	1.25	2.50	5.00	10.00	20		1.25	2.50	5.00	10.00
slit speed (um/msec)	116.63	233.25	466.50	933.01	1866.01		233.25	466.50	933.01	1866.01
Data Points per Profile	15	15	15	15	15		15	15	15	15
Pulse Frequency (kHz)	**Minimum Beam diameter in µm**						**Minimum beam diameter in µm**			
0.5	3499	6998	N/A	N/A	N/A		6998	13995	N/A	N/A
1	1749	3499	6998	N/A	N/A		3499	6998	13995	N/A
2	875	1749	3499	6998	N/A		1749	3499	6998	13995
3	583	1166	2333	4665	N/A		1166	2333	4665	9330
4	437	875	1749	3499	6998		875	1749	3499	6998
5	350	700	1400	2799	5598		700	1400	2799	5598
6	292	583	1166	2333	4665		583	1166	2333	4665
7	250	500	1000	1999	3999		500	1000	1999	3999
8	219	437	875	1749	3499		437	875	1749	3499
9	194	389	778	1555	3110		389	778	1555	3110
10	175	350	700	1400	2799		350	700	1400	2799
11	159	318	636	1272	2545		318	636	1272	2545
12	146	292	583	1166	2333		292	583	1166	2333
13	135	269	538	1077	2153		269	538	1077	2153
14	125	250	500	1000	1999		250	500	1000	1999
15	117	233	467	933	1866		233	467	933	1866
16	109	219	437	875	1749		219	437	875	1749
17	103	206	412	823	1646		206	412	823	1646
18	97	194	389	778	1555		194	389	778	1555
19	92	184	368	737	1473		184	368	737	1473
20	87	175	350	700	1400		175	350	700	1400
21	83	167	333	666	1333		167	333	666	1333
22	80	159	318	636	1272		159	318	636	1272
23	76	152	304	608	1217		152	304	608	1217
24	73	146	292	583	1166		146	292	583	1166
25	70	140	280	560	1120		140	280	560	1120
50	35	70	140	280	560		70	140	280	560
100	17	35	70	140	280		35	70	140	280
150	12	23	47	93	187		23	47	93	187

4.2.4.3 Software Measurement of Laser Repetition Frequency

The software connects the pulse peaks based on the user input Laser Pulse Frequency. If the actual and input frequencies are significantly different the resulting profiles may be jagged (not smooth). When selected in software, the parameter Laser Pulse Frequency is measured and displayed as a check for possible incorrect entered Laser Pulse Frequency values. When jagged profiles appear, try using the measured frequency value and the beam profiles may become smoother.

The measured Laser Pulse Frequency current value, mean and standard deviation information could be important for your application.

4.2.4.4 Pulsed Laser Measurement Considerations

Pulse width modulated (PWM) sources will not increase the peak power density in your beam over (CW) continuous wave (100% on-time) operation values.

Q-Switched will increase peak irradiance above CW and may increase enough to damage slits and or detectors. Be sure to read these next two sections carefully to protect your investment and call or email if you have questions.

4.2.4.4.1 PWM Lasers

Many lasers, especially CO_2 lasers, use pulse width modulation (PWM) to control the average power level of the laser. Often, duty cycles are very high, sometimes >90%, for example. In this case, the beam operates as if it was CW, and many operators do not even realize that the laser is pulsing.

However, when attempting to measure a PWM laser with a scanning slit profiler, it usually must be treated as a pulsed laser source.

To use the pulsed mode of the NanoScan the laser's pulse frequency must be at least ~1 kHz, and the combination of the frequency and beam size must provide a sufficient number of pulses across the beam to generate a meaningful profile. Eight to ten pulses are a reasonable minimum, but 15 are preferred to get better accuracy. PWM lasers usually operate around 10kHz.

The relationship of the beam size and frequency is a fairly simple mathematical model. The NanoScan drum speed is software controlled from 1.25Hz to 20Hz. There are two available drum sizes for the NanoScan; the standard head has a drum diameter of 42mm and the large aperture and high power heads use a larger drum with 84mm diameter. On the 42mm drum at the 1.25Hz rotation rate the slits travel at around 116.6mm per second or 116.6µm per millisecond. At a 10kHz laser repetition rate, a 175µm beam would have 15 pulses during the time that the slit was traversing it. This would provide enough data to generate a meaningful profile. A smaller beam would require a faster pulse rate, a larger one could perhaps run at a lower repetition rate. For example, a 1.0mm beam could be measured with a pulse rate as low as 2kHz and still provide a profile.

Table 4.2 displays the minimum beam sizes and pulse frequencies for the large and small hubs and scan speeds printed in this chapter. It is recommended that the 1.25Hz scan speed be used for pulsed beams; however, if the beam sizes are large enough, or the pulse rates fast enough, the measurement can be sped up by increasing the scan speed to 2.5Hz or above. The NanoScan software will generate a warning if the scan rate is set too high for the pulse rate or beam size. This warning algorithm is based on having at least 15 pulses across the beam to provide a minimum of ±2% accuracy.

Use the CW Operating Space Chart (beam power versus beam diameter) for your scanhead when measuring PWM sources. Your maximum saturation power will still be the CW (100% on-time power) maximum for your laser even as the duty cycle decreases.

4.2.4.4.2 Q-Switched Lasers

Another type of pulsed laser, operating in the kHz pulse rate regime is the Q-Switched laser. These lasers use Q-switching to increase, rather than decrease, their effective power. By concentrating the laser power into a short pulse, the peak power of each pulse increases while maintaining a low average power. In order to measure these lasers the same mathematical relationship of pulse rate to beam diameter applies, but there is an additional complication; the peak power of the pulses may exceed the damage thresholds of the NanoScan even though the average power remains within the operating space. CW beams are measured as *power (P)* in watts; pulsed beams as *energy (E)* in joules. Therefore it is necessary to understand the beam's energy (E_{pulse}) to determine whether the unattenuated beam can be directly measured with the NanoScan.

$$E_{pulse} = \frac{P_{avg}}{f_{laser}}$$

Therefore a beam with an average power of 300 Watts with a pulse frequency of 8kHz will have energy as follows:

$$E_{pulse} = \frac{P_{avg}}{f_{laser}} = \frac{300\,\text{W}}{8\times10^{3}\,\text{Hz}} = 37.5\text{mJ}$$

The power density per pulse is also a function of the pulse duration τ. This is also important in understanding the potential damage to the profiler. Taking the above example, if the pulse duration is 1ms, then:

$$P_{pulse} = \frac{E_{pulse}}{\tau} \equiv \frac{37.5\text{mJ}}{1\times10^{-3}\,\text{s}} = 37.5\,\text{W}$$

4.2.4.4.3 Pico- and Femtosecond Lasers

When the pulse duration of the laser gets very short, such as with pico- and femtosecond lasers, the peak power of the pulses can become very large. This creates some added complications when determining the type of scanhead that can safely measure these beams. In addition to the average power of the beam, which is used to determine the proper operating space of a given scanhead, it is important to know the energy density of the pulses. The energy density must be below the damage threshold for the aperture material, and the average power must fall within the operating space of the scanhead for it to be possible to measure the beam without additional attenuation. To determine the energy density, first use the following formula for the E_{pulse}:

$$E_{pulse} = \frac{P_{avg}}{f_{laser}}$$

Most pico- and femtosecond lasers have both a high repetition rate and a fairly low average power. They use the short pulse duration to amplify the effective power of the laser beam. A typical laser that one might encounter would have an average power of 1.0 watt and a repetition rate of 80kHz. For this laser the E_{pulse} would be:

$$E_{pulse} = \frac{P_{avg}}{f_{laser}} = \frac{1\text{W}}{80000\,\text{sec}^{-1}} = 12.5\,\mu\text{J}$$

Using this value calculate the energy density for a given beam diameter by the following formula. Note that the energy density is presented as J/cm^2; therefore the beam area needs to be converted to cm in the formula. Unless the beam is wildly different from round, it is easiest to consider that the area will be that of a circle:

$$E_{density} = \frac{E_{pulse}}{\pi r^2}$$

For a 100µm beam at the 12.5µJ:

$$E_{density} = \frac{12.5\,\mu\text{J}}{\left(\frac{100\,\mu\text{m} \times 0.0001}{2}\right)^2 \pi} = 0.16\ \text{J}/\text{cm}^2 = 160\ \text{mJ}/\text{cm}^2$$

Once the energy density is calculated, it can be compared to the damage threshold for the aperture type and the wavelength range for the aperture material. The standard blackened slit material can only handle 10mJ/cm^2 before the blackening starts to ablate. For this reason, scanheads intended for use with these pico- and femtosecond lasers should have the reflective slits, regardless of the detector type or the average power of the lasers. The wavelength of the laser also influences the energy density that the aperture material can withstand. For the standard nickel alloy slits the maximum energy density is 600mJ/cm^2 for the range of 190nm to 400nm; for 400nm and above the value is 1.0J/cm^2. For the high power copper slits the values are 2.5J/cm^2 from 700nm to 3µm wavelength and 5J/cm^2 above 3µm. Copper slits are not recommended for use below 700nm, however in some experiments we have seen better performance in the UV (@355nm) from copper slits. This may be attributable to the better heat dissipation of the copper material or the fact that the copper aperture material is thicker than the nickel alloy.

Figure 4.6 below is a chart that can be used in lieu of the calculation to compare the energy per pulse at a given beam diameter with the appropriate threshold line for the aperture material and wavelength of use. For the above case the 12.5µJ energy at 100µm would be below the 600mJ damage line, but would certainly be well above the damage level for blackened apertures.

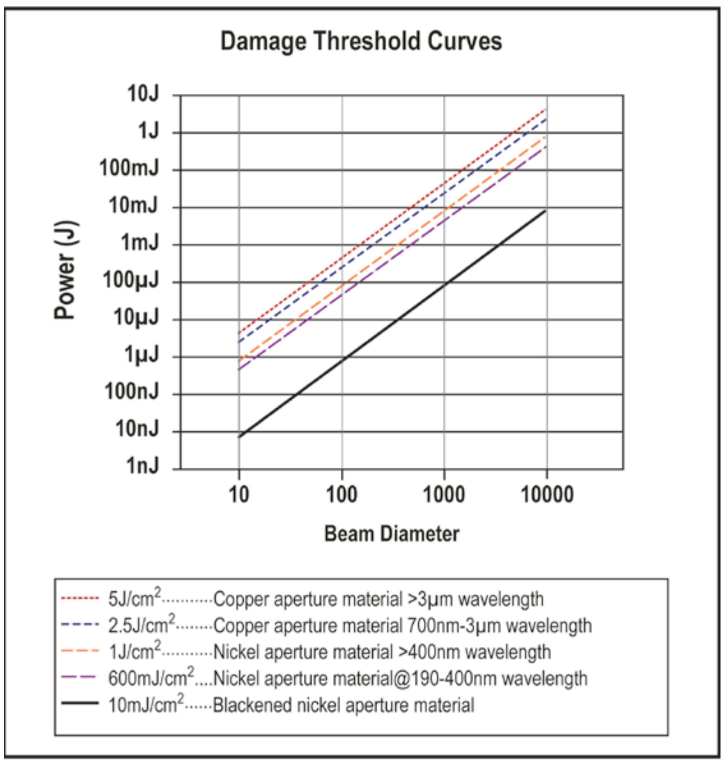


Figure 4.6 Damage Threshold Curves

These estimates of damage threshold are primarily based on the relative reflectivity of the slit material. There are many other factors that may influence interaction of the laser beam and the aperture. At some level of power and pulse duration this interaction may become non-linear. In addition surface finish, roughness, contamination, tarnish or oxidation can also affect the reflectivity of the materials. For this reason these damage threshold values can only serve as a guideline, not an absolute guarantee. Use caution when measuring any new or unfamiliar laser system.

4.3 NanoScan System Description

4.3.1 System Block Diagram

A block diagram showing the main components of the NanoScan is shown in Figure 4.7. The scanhead houses a motor with a rotating drum, a detector, signal conditioning amplifiers and filters, an EEPROM for storing critical scanhead information, and a communication interface. A signal/ communication cable connects the scanhead to the Scan Control and Data Acquisition PCI card. This card has a communication interface, signal conditioning filters, a 12-bit A/D converter, onboard memory, a system control unit, and either a PCI controller to interface to the computer's PCI bus, or a USB 2.0 Controller to interface to the USB 2.0 bus.

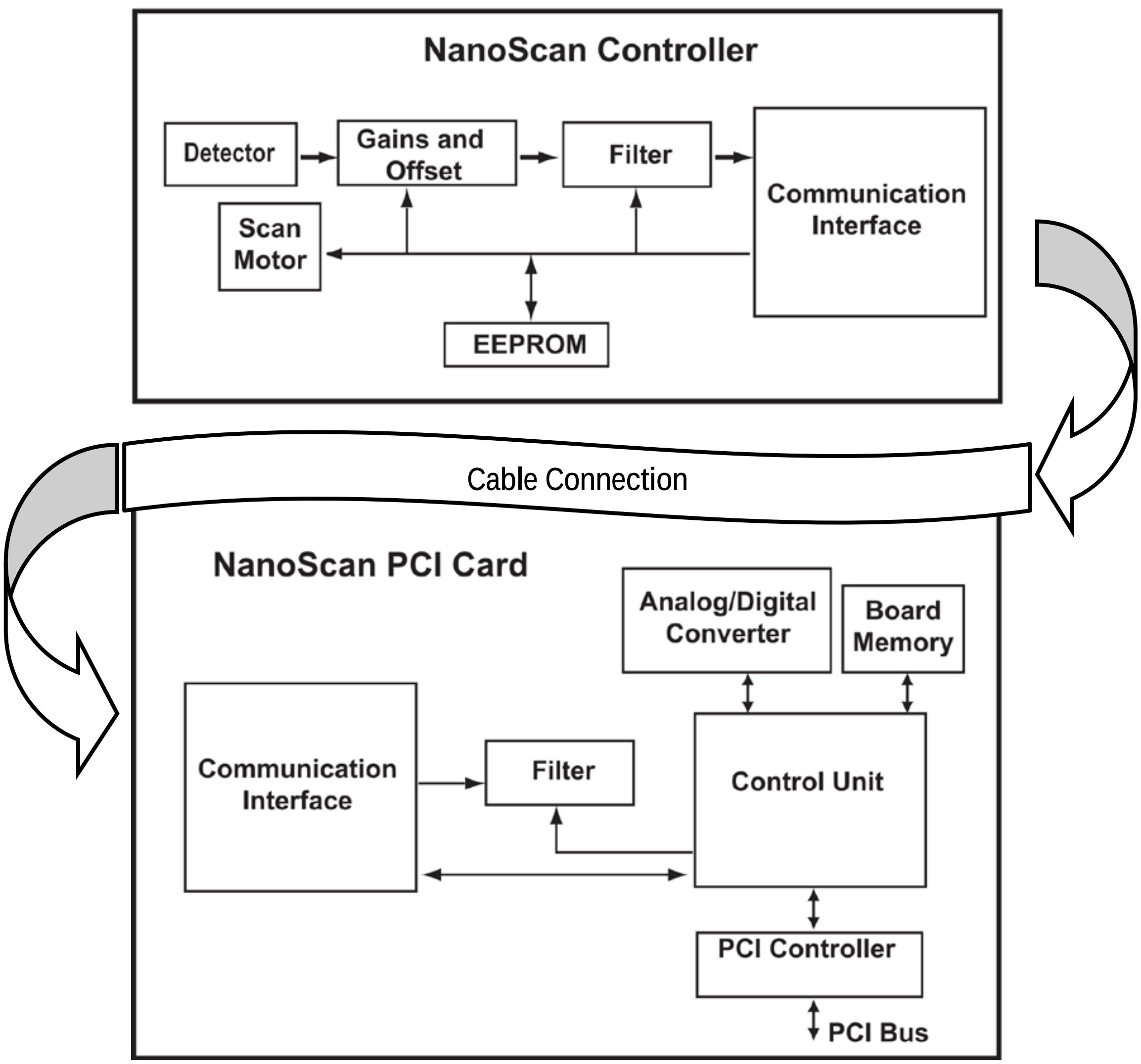


Figure 4.7 NanoScan System Block Diagram for PCI Controller

The basic system operation is as follows: The scanhead is positioned in the beam path at the desired measurement location. The scanhead detector “senses” the beam incident upon the scanhead entrance aperture. As the drum rotates and the slits traverse the detector, the detector analog output signal is proportional to the spatial beam profile. As the power window traverses the detector, the entire beam is incident upon the detector and the signal is proportional to the total beam power. The PCI Scan and Acquisition Card or the USB 2.0 Scan and Acquisition Controller controls scanhead rotation frequency, analog signal amplification, signal filtering, spatial sampling of the analog profile signal, and 12-bit digital data acquisition. The acquired digital profile data is transferred into the computer memory for data analysis and display.

The scan rotation frequency, spatial sampling interval, signal amplifier gain, filter settings, and DC offset are set through software. The EEPROM in the scanhead contains critical information for operation. This information includes: head identification information; available rotation rates, amplifier gain tables, slit information, power window and calibration information, acquisition channel definitions. There are also provisions for spatial and spectral calibration.

4.3.2 NanoScan Controller

Scan rotation rates are typically 1.25, 2.5, 5, 10, and 20Hz. The spatial sampling interval is determined by the sampling clock (master local clock divided by the sampling clock divider), the scanhead drum rotation frequency, and the drum radius. Spatial sampling can be set as low as 5.7nm for typical 45° slit orientation. The available amplifier gains are scanhead dependent and are given in the respective gain tables. Gain ranges on the order of >70dB are typical. The filter frequency can be adjusted over a range from 2kHz to 190kHz. The filter can be used to improve the signal-to-noise ratio in the acquired profile data within the limits of beam diameter measurement requirements, dependent on drum rotation frequency. The spatial sampling interval, the gain, the filter setting, and the rotation frequency can be set to optimize profile acquisition.

The acquired 12-bit profile data from each acquisition channel are temporarily saved in the board memory and then transferred in the host computer memory through a DMA transfer.

4.3.3 NanoScan Scanhead Components

The mechanical configuration of the main components of the scanhead is shown in Figure 4.8. These include the scan drum with optical position encoder and motor, slit, pinhole, or power apertures mounted on the drum (a slit is shown), the front cap with entrance aperture, and a stationary large-area photo detector that collects the transmitted light. The scanhead rotation mount allows for smooth and continuous adjustment of the scanhead angular orientation with respect to the beam axis. The knurled knob locking screw provides easy manipulation of the head and also secures it in the rotation mount. The scanhead electronics are not shown.

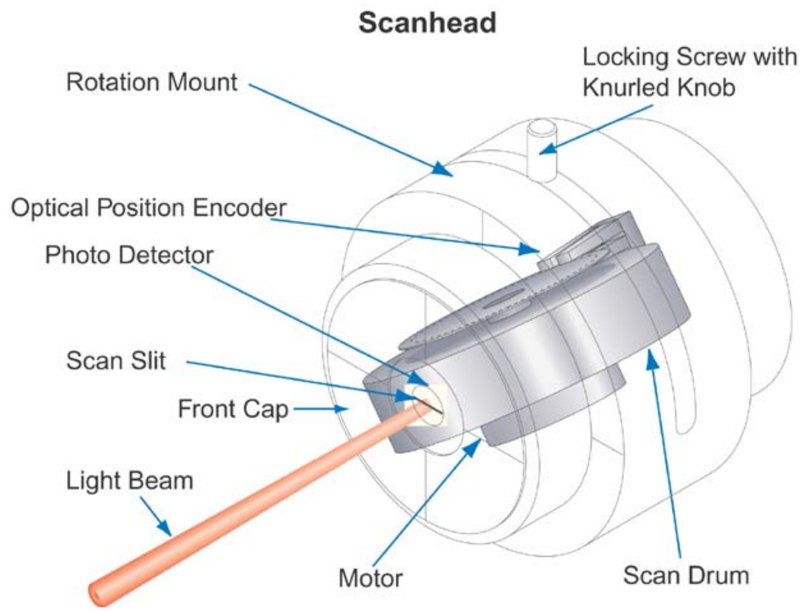


Figure 4.8 Scanhead Components

4.3.3.1 Scan Drum

The scan drum is manufactured to the most extreme mechanical precision necessary to achieve NanoScan's beam profiling accuracy. The apertures and the encoder are mounted on the drum, and the drum is mounted on the scan motor. The scan motor shaft is coupled to the drum at a hole at the drum axis.

The mechanical tolerances of the motor shaft hole relative to the drum determine the radial run-out of the drum surface and the angular "wobble" of the drum with respect to the motor shaft. These tolerances must be very small to allow the lowest possible instrument measurement astigmatism.

To accommodate the many different types of apertures that can be mounted to the drum, it is necessary to place openings in the drum surface at various positions along the drum. The material removal for these openings shifts the drum center-of-mass and creates a slight imbalance in the drum, which can affect the drum motion and introduce jitter. To minimize this effect, the drum is balanced to compensate for the change in the center-of-mass.

The optical position encoder mounts to a collar that is concentric with the motor-shaft mounting hole. The concentricity of these must be extremely precise in order for the encoder to provide accurate feedback to the motion controller.

4.3.3.2 DC Motor

The NanoScan uses DC motors to rotate the scan drum. The motors have very high quality bearings to minimize motor jitter. The motors are rated at 11,000rpm, but operate at 1200rpm or slower depending upon selected operating speed. The motor quality ensures years of trouble free operation. In nearly two decades Photon has never had to replace a motor due to bearing wear.

4.3.3.3 Optical Position Encoder

The optical position encoder tracks the position of the drum as it rotates. It provides position feedback in a proportional-integral control loop for control of the drum motion.

4.3.3.4 Front Cap with Entrance Aperture

The front cap of the scanhead has a circular entrance aperture that is slightly smaller in diameter than the photo detector. The entrance aperture dimension limits the size of the beam that can be measured. Standard NanoScan scanheads have nominal entrance aperture diameters of 3.5mm, 9mm, 21mm, and 25mm, depending on the detector type.

The front cap has scribe lines that define the 2 orthogonal scan axes. It also is the reference surface for the scanhead measurement datum plane.

4.3.3.5 Photo Detector

NanoScan scanheads come with silicon, germanium, or pyroelectric detectors. These detectors provide for measurement at wavelengths from the ultraviolet (UV) at 190nm to the far infrared (FIR) at 100µm.

The nominal wavelength responsivity curves for the silicon and germanium and pyroelectric detectors used in NanoScan are shown in Figure 4.9 below. The response for the pyroelectric detector is flat for wavelengths from 190nm to >20µm, with a nominal value of 3.8×10^{-7} A/W.

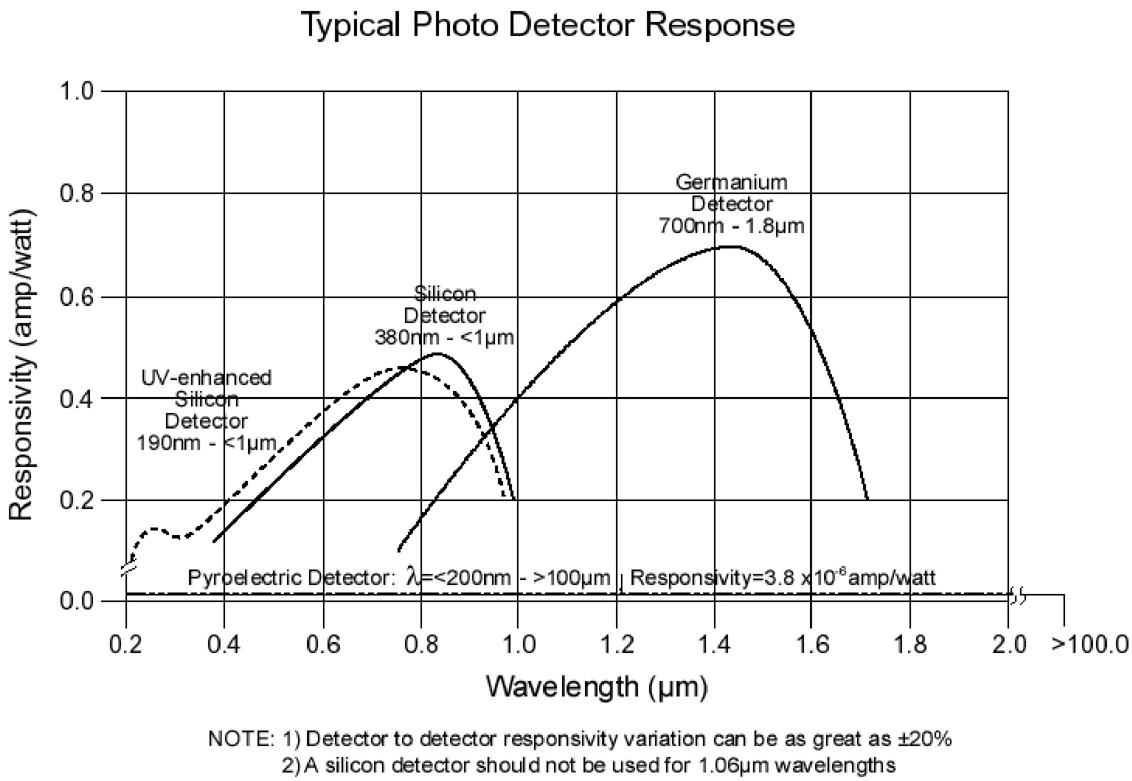
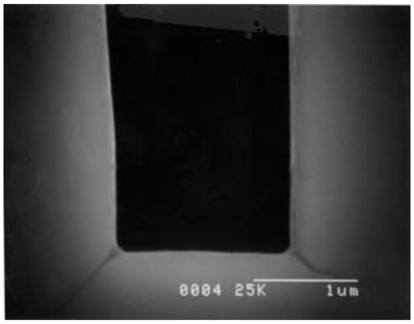


Figure 4.9 Typical Photo Detector Response for silicon, germanium, and pyroelectric detectors

4.3.3.6 Profile Apertures

NanoScan scanheads come standard with “air” slits—either 1µm, 1.8µm, 5µm or 25µm wide [10µm on High Power NanoScans]—in matched pairs. Air slits comprise a clear opening in a metallic substrate of membrane thickness proportions, nominally 15µm for the 1µm and 1.8µm slits, or 35µm for the 5µm and 25µm slits. This type of slit is free of multiple interference fringes, unlike slits made by depositing opaque materials onto a transparent substrate, such as chrome-on-glass slits, which can distort the beam profile. Scanheads with mixed pairs of slits or a single slit and a pinhole are available as options. The pinhole diameter can be as small as 2µm.

The edge quality of the slit apertures is important to obtain the most accurate profiles, especially for the measurements of very small beams in the range of tens of microns. An example of the edge quality of the slits used in NanoScan is shown in Figure 4.10. The figure shows photographs from a scanning electron microscope (SEM) for standard 1.8µm and 5µm slits. The observed quality of these slits in terms of the “straightness” of the edges is excellent.



a.

b.

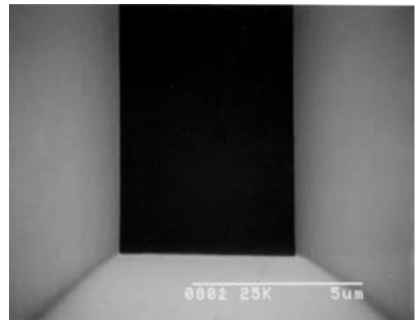


Figure 4.10 SEM images for a.) 1.8µm, and b.) 5µm slits.

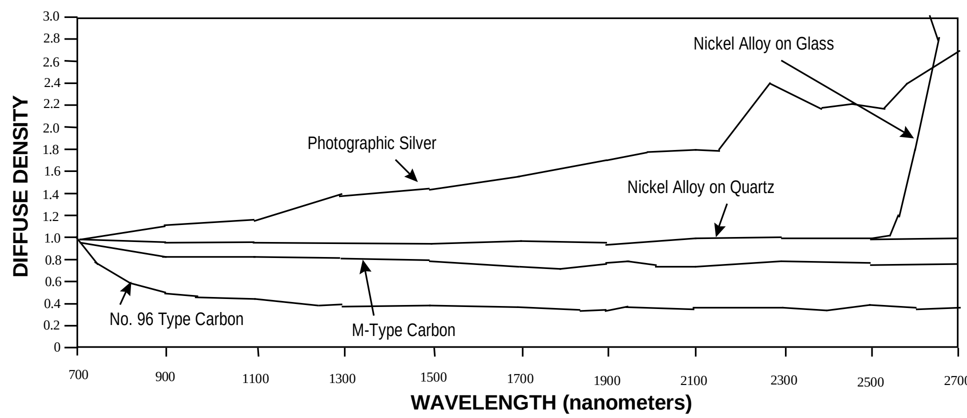
NanoScan scanheads with silicon or germanium detectors come standard with "blackened" apertures to greatly reduce light reflected back into the laser and thus prevent laser cavity oscillations. Blackening is achieved by chemical etching. As a result of the etching process, the slit edges become slightly roughened.

4.3.3.6.1 Option /HP-x-wavelength, High Incident Power Option (/HP)

Photon can install a Kodak Wratten attenuator (No. 96 Type Carbon) behind each slit to keep the photo detector within its linear operating range. The ND (neutral density) filter value of 1 or 2 is valid between 400 and 700nm.

The Wratten filter attenuation increases drastically below 400nm and decreases above 700nm (graph below starts from 700nm). The density is plotted against wavelength to help you understand why it may or may not operate at wavelengths away from the design point.

When ordering the /HP option, specify the attenuation required and the wavelength of operation. Photon will then provide the proper filter for the application.



Typical* Infrared transmittance density of KODAK Light Attenuator materials having a nominal visual density of 1.0.

*These curves indicate typical densities (for products having a *visual* density of 1.0) found over an expanded spectrum. They are not routinely-measured values by Kodak. Should these be of particular concern, the user should measure these densities on the specific sample involved. Also, those interested in work in the ultraviolet region should note that acetate materials tend to flouresce in this region.

Figure 4.11 Optical Density vs. Wavelength for Kodak Wratten No. 96 and for metallized quartz

4.3.3.7 Power Aperture

The power aperture provides for measurement of total beam power in NanoScan scanheads with either silicon or germanium detectors. A power meter is not available on scanheads with a pyroelectric detector. An attenuator placed behind the aperture reduces the incident beam power to avoid detector saturation. The attenuation depends on the desired power measurement range.

Power aperture attenuators are either a Kodak Wratten Neutral Density Filter No. 96, used for power levels up to 75mW, or a metallized quartz glass substrate, used for power levels up to 200mW.

A Kodak Wratten filter of specified neutral density is only “neutral” over the wavelength range from 400 to 700nm. Below 400nm the density increases as the wavelength moves to the UV domain and above 700nm the density decreases as the wavelength moves to the infrared. The density above 700nm for a nominal ND=1.0 filter is shown in Figure 4.11. The attenuation is specified at normal incidence, and will increase with increasing angle due to the increased path length. Kodak Wratten filters are completely free of pinholes and defects; thus they provide the most accurate power meter performance.

The metallized quartz glass filters have a very neutral response with wavelength, as shown in Figure 4.11. They can tolerate higher input laser power and also show less change of attenuation with angle near normal incidence because they operate by reflection. The metallized coatings on these filters may have tiny pinholes that give slightly less uniformity than the Kodak Wratten filter across the power aperture.

4.3.3.8 Rotation Mount

The Rotation Mount comes standard with all NanoScan scanheads. The rotation mount allows smooth continuous adjustment of angular position of the scanhead over a range of 190°. The rotation mount sleeve fits over the scanhead and permits attachment to a mount or positioning stage via a 1/4-20 thread (option M6) and/or a 0.125in. (3.2mm) diameter dowel pin receptor. After mounting, the scanhead can be rotated within the sleeve by loosening and sliding the retaining knurled knob.

4.3.3.9 Scanhead EEPROM

The EEPROM in the scanhead contains critical information used by the software for identification and operation. This information includes: head serial number, detector type, detector amplification gain tables, scan radius, available rotation rates, slit width and scan angle, pinhole diameter, nominal (0,0) position of the entrance aperture, power window filter density and calibration files.

4.3.4 Scan Motion Control

One of the most dramatic performance improvements that the NanoScan exhibits over the earlier generation of BeamScan products is position stability. Instrument induced "jitter" has been reduced significantly by the introduction of a new proportional-integral motion controller. NanoScan jitter should be less than 200nm, provided that the mounting of the source and the scanhead are optically isolated and stable. When using the NanoScan, any significant jitter probably indicates problems with the mechanical mounting of the device under test or the scanhead.

4.3.5 Scanhead Operating Space

The Operating Space Chart maps the useful measurement range for a given NanoScan scanhead, in terms of beam power and beam diameter for TEM_{00} Gaussian beams. The detector responsivity, the entrance aperture diameter, the slit width, and the amplifier gain and signal-to-noise performance determine the operating space.

A sample operating space for a NanoScan scanhead with a silicon detector and 1.8µm slits is shown in Figure 4.12. The abscissa of the chart is the $1/e^2$ beam diameter in microns and the ordinate is the incident beam power in watts. Operating Space Charts for standard scanheads are in Appendix C.

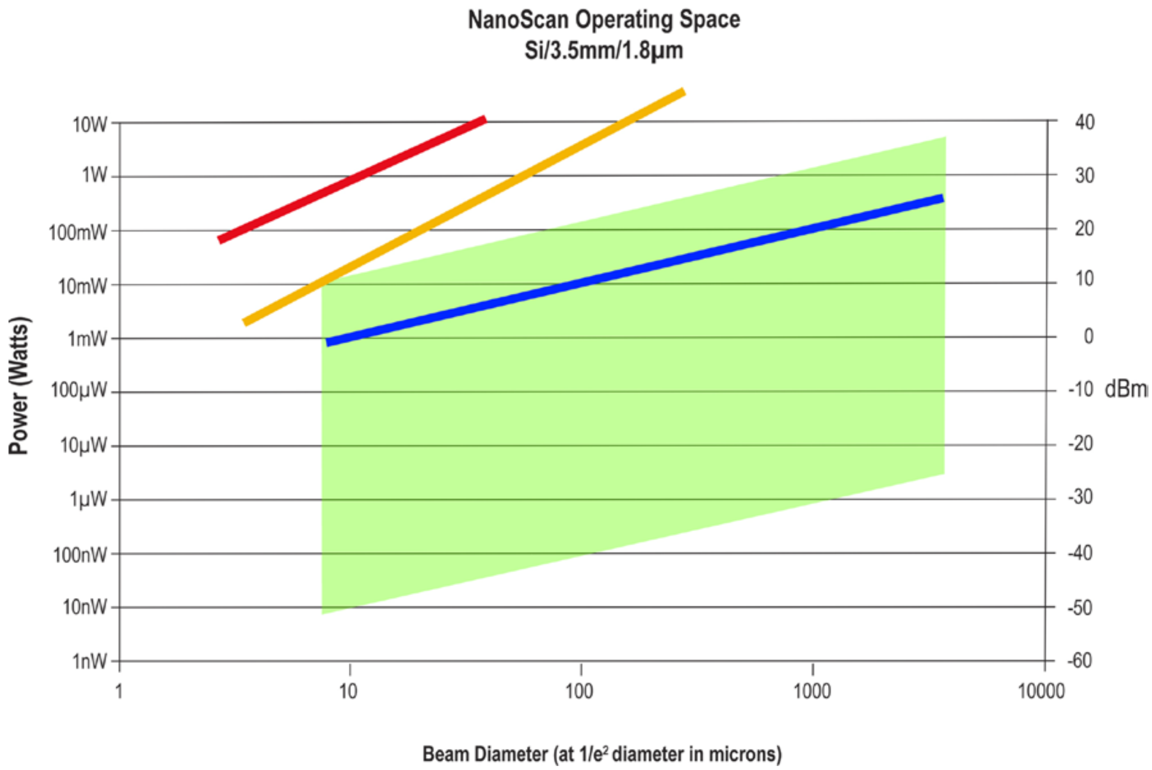


Figure 4.12 Operating Space for a NanoScan with silicon detector with aperture of 3.5mm and 1.8µm slits

The boundaries of the operating space define the power density of laser beams that can be measured directly with the NanoScan. The boundary at the left side is based on acceptable errors due to either slit convolution or electrical convolution from insufficient detection bandwidth. For convolution, the boundary is set at a beam diameter corresponding to four times the slit width, at which point a 5% systematic error in the raw profile is introduced. The limit for insufficient bandwidth is set at the beam diameter for which a 5% electrical convolution occurs. The lower boundary defines the lowest power density that can be detected and measured accurately with a minimum number of signal counts at a signal-to-noise ratio of 10. The upper boundary is the limit to beam power above which the detector will be saturated. The right boundary is defined by the dimension of the entrance aperture.

Note*:* The axes of the Operating Space Chart are logarithmic.

For pulsed operation in Short Pulse Mode, the signal amplitude is limited to ~10% of the maximum. This effectively sets a limit indicated in the operating space by a dashed line at one decade below the upper boundary.

Two other important lines on the chart are the damage thresholds. These are the lines on the upper left of the chart field. The lower line (dashed) of these describes the power density at which the blackening begins to be burned off the slits. The upper line (solid) describes the level at which the slits are physically damaged and burned. Operation above the lower line is not advised; operation above the upper line will result in immediate permanent damage to the NanoScan.

Due to the increased dynamic range of the NanoScan with the deep 12-bit digitization and variable scan speed, the operating space of any individual NanoScan scanhead is much larger than a corresponding BeamScan system.

Note: *Damage to scanheads from a high laser power is not covered by the Photon warranty.*

4.4 Measurement Considerations and Guidelines

In any beam profiling application, there are many things to consider, as well as guidelines and restrictions to be followed in order to obtain the most accurate and repeatable results.

4.4.1 Use the Appropriate Scanhead

The variety of standard NanoScan scanheads have different detectors and slit widths and are designed to cover the wide range of wavelength, beam size, and beam power typically encountered in profiling applications. In any particular application, the scanhead must have an operating space that is appropriate.

The operating space of a particular scanhead accommodates measurements without attenuation and without profile corrections over a range of nominally three decades in beam size and seven decades in beam power at a given wavelength. This space extends even further if profile corrections, profile averaging, or beam attenuation are allowed.

Due to the wide operating space of each scanhead, a single scanhead can often be used in a number of different applications: for example, characterizing different laser beams over the visible range to determine M^2 or the focused spot size through an optical system. However, sometimes the measurement requirements of the applications do not overlap, such as measurements of IR beams at 10.6µm and UV beams; such diverse applications may demand the use of different scanhead types.

4.4.2 Slit Width Selection Criteria

NanoScan scanheads are available standard with 1µm, 1.8µm, 5µm or 25µm wide matched slit pairs—or optionally with mixed pairs. The slit width determines the power measurement range and the diameter of the smallest spot that can be measured using the slit method without mathematical correction due to slit convolution. The practical lower limit for slit width dimension is 1µm.

The power measurement range is inversely proportional to the slit width; a wider slit transmits more power and allows measurements at lower power levels than a narrower slit. On the other hand, the limit for beam diameter is proportional to the slit width; thus, narrower slits are better for measurement of small spots. These two considerations must be balanced when selecting the measurement slit size, and sometimes a compromise is required.

Slit convolution introduces a systematic error in measured spatial beam widths that depends on the beam profile. This is discussed in detail in Section 4.4.10 for TEM_{00} Gaussian beams. For such beams, the systematic error in the measured beam diameter increases with the ratio of the slit width and the measured width. When this ratio exceeds approximately 0.4, the error becomes greater than 10%. It is also possible to deconvolve the slit width from the spatial profile mathematically, but many believe that this compromises accuracy too much.

As a guideline, it is recommended to use a slit width that is no larger than one-fourth the diameter of the smallest beam to be measured. In this case, the systematic error in the measured $1/e^2$ beam diameter is 5%, which in many cases is an acceptable error. Mathematical deconvolution to correct the error is only required if greater accuracy is needed. As an example, if the beam diameter is 4µm, and the slit width is 1µm, the measured value will be 4.2µm. If the beam is known to be Gaussian, then the actual value can be obtained by deconvolving the width of the slit.

If the power levels are very low and near the limits of operation, it may be necessary to use the widest slit available, regardless of the magnitude of the error introduced by the slit convolution effect.

4.4.3 Scanhead Positioning and Alignment

The NanoScan scanhead has features to aid in the positioning and alignments required for accurate beam measurements. These are illustrated in Figure 4.13. The measurement datum plane is precisely known and is mechanically referenced to the front cap. This measurement plane at the scanning aperture is located 1.1mm (±0.1mm) from the face of the front cap for most models. Refer to Scanhead Specifications, Appendix A, for specific model information. The front cap has scribe lines at the entrance aperture that represent the orthogonal scan axes. The rotation mount allows smooth continuous adjustment of angular position of the scanhead over a range of 190°. The rotation mount has scribe lines at 10° increments.

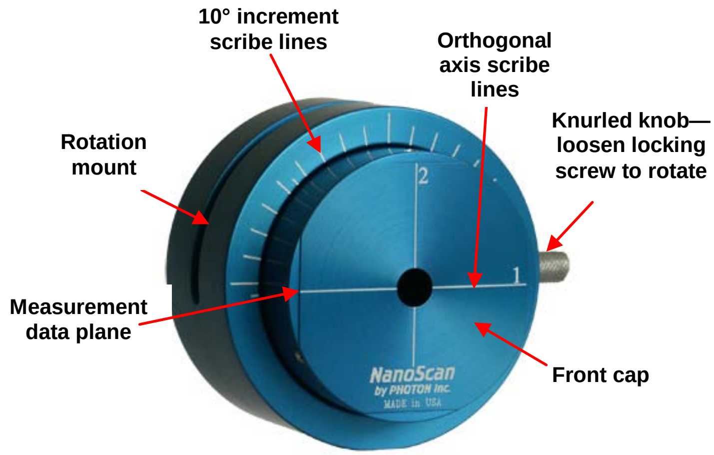


Figure 4.13 Features of the NanoScan Scanhead

4.4.3.1 The Measurement Plane

The measurement plane in the scanhead is the surface of the slit or pinhole apertures. The location of the measurement plane, measured from the edge of the tube, is nominally 0.74 ±0.025mm. Refer to Scanhead Mechanical Dimensions in Appendix C.

4.4.3.2 Working Distance

Working distance is the distance between the measurement plane and the most extreme mechanical surface (front cap). This distance is nominally 1.12mm for NanoScan. Refer to Scanhead Mechanical Dimensions in Appendix C.

4.4.3.3 Entrance Aperture Mechanical Center

The mechanical center of the entrance aperture [the (0,0) position] for each scanhead is determined at the factory during calibration and is assigned as the “default” center position. The accuracy of this alignment is specified at ±0.003” (.0762mm). This reference position is available through software.

4.4.3.4 User Defined (0,0) Position

It is also possible to redefine arbitrary center (0,0) positions for the scanhead entrance aperture in the software. There are several ways that this can be done. One method is to train the software with a good functional component or assembly. Make your setup; record the axis-1 and axis-2 coordinates. Load these co-ordinates as the 0,0 position numbers into the software. If you remove the head from your setup, it is unlikely you will maintain the (0,0) coordinates to a micron level and recalibration will be necessary.

Another method to establish a (0,0) position is to translate the scanhead across a focused beam and view the back reflection at the laser source. Do this for each orthogonal axis; record the two positions in the software as (0,0). Still another method is to translate the scanhead in the X and Y directions and observe the profiles as the beam hits the entrance aperture edges (you will see the beam clipped by the edge). Note the two edge position numbers for each X and Y; and use the midpoints for the (0,0) location.

4.4.3.5 Angular Alignment

The rotation mount in Figure 4.14 is used to align the direction of scan of the slits, as shown by the scribe marks on the front cap, with the major and minor axes of elliptical beams. This allows accurate measurement of elliptical beams. The rotation mount on the scanhead can maintain axial location to ±0.01mm when rotated if the following precautions are observed (If greater accuracy is required, the rotation sleeve should be replaced by a custom designed stage).

The scanhead axis-1 and axis-2 scans can be adjusted to change the scan azimuth (orientation) through the laser beam. The knurled knob locks the cylindrical scanhead in the rotation mount. By loosening the knurled knob, the scanhead can be rotated to align axis 1, for example, to the major axis of an elliptic beam. Retightening locks the position. The rotation mount allows 190 degrees of continuous adjustment.

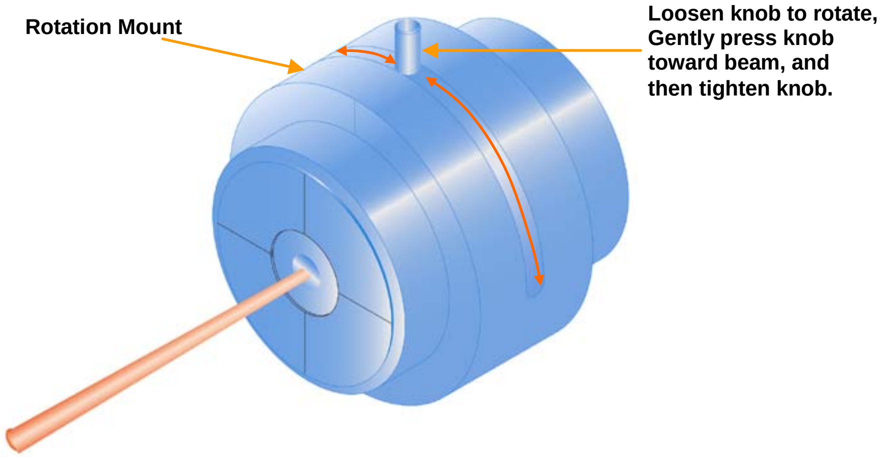


Figure 4.14 NanoScan Rotation Mount

Carefully align the scanhead and rotation mount so it is perpendicular to the beam axis.

Secure all mounting apparatus so all bolts or screws are very tight. Otherwise, it may move when you rotate the scanhead.

When rotating the scanhead, from 0° to 45° for example:

- Loosen the knurled knob locking screw.
- Put slight pressure on the side of the knurled knob in the direction of the focused beam to eliminate play in the slot while rotating the scanhead to maintain the position of the scan plane.
- Maintain the slight pressure against the knob while tightening it at the new scanhead position.

Repeatable axial results, at least ±100µm or better along the beam axis, have been produced using this technique.

For the most accurate alignment, it is best to rotate the scanhead while observing the **Dual Aperture Profile** screen in the software and looking for the point at which the minor axis is narrowest in one aperture and the major axis is widest in the other aperture.

4.4.4 Profile Acquisition

There are many factors that come into play in the acquisition of raw beam profiles to achieve high accuracy. These include the scan rotation frequency, the spatial sampling interval, the detector amplifier gain and bandwidth, and the signal filter. The acquisition parameters can be optimized for any given beam measurement, depending on the nominal width of the beam being measured.

4.4.4.1 Scanhead Rotation Frequency

The scanhead rotation frequency is the maximum update rate for profile acquisition and display of profiles and reported parameters. NanoScan operates at rotation rates of 1.25Hz, 2.5Hz, 5Hz, 10Hz, and 20Hz, which are selectable through the software. For each rotation frequency, there is a corresponding lower limit for width measurement due to the detector amplifier electrical bandwidth and rise time. This is because the rise time convolves with the profile. The scan jitter also depends on the rotation frequency, with the jitter decreasing at higher rates.

The lower two rates 1.25 and 2.5Hz should be used for pulsed beam operation. Refer to section 4.2.4 for an explanation of the pulsed operation and the effects of scan speed on this application.

4.4.4.2 Spatial Sampling

The spatial sampling interval is determined by the sampling clock, the scan frequency, the drum radius, and for slit apertures, the angle of the aperture with respect to the drum axis of rotation. The sampling clock is obtained from the master clock using various divide ratios covering a range of 1-200. As such, the sampling interval available with NanoScan covers a very wide range, from approximately 5.7nm at 1.25Hz rotation to 18.3µm at 20Hz rotation. Depending on the scanhead rotation frequency, the available sampling interval selections are shown below in Table 4.3 Spatial Sampling Intervals

Table 4.3 Spatial Sampling Intervals

1.25 Hz	2.5 Hz	5 Hz	10 Hz	20 Hz
0.0057	0.0114	0.0229	0.0458	0.0915
0.0086	0.0172	0.0343	0.0686	0.1373
0.0114	0.0229	0.0458	0.0915	0.1830
0.0229	0.0458	0.0915	0.1830	0.3661
0.0572	0.1144	0.2288	0.4576	0.9152
0.1144	0.2288	0.4576	0.9152	1.8304
0.2288	0.4576	0.9152	1.8304	3.6608
0.5720	1.1440	2.2880	4.5760	9.1521
1.1440	2.2880	4.5760	9.1521	18.3041

NanoScan is capable of acquiring and processing profiles across the entire entrance aperture at the minimum spatial sampling interval with tens to hundreds of thousands of points, depending on rotation frequency and sampling interval. However, to reduce the number of data points, such as for a custom automation interface, the spatial sampling interval can be increased. In this case, the maximum spatial sampling interval should be chosen to provide an adequate number of samples through the beam. As a general guideline, a minimum of 100 samples typically suffices for a smooth beam. If there is structure in the beam, then the sampling interval should be correspondingly smaller to resolve the fine structure.

The spatial sampling is along the curved trajectory of the slit as the drum rotates. Consequently, the use of a constant sampling interval is slightly in error due to the curvature. This leads to an accumulated error in position of approximately 1.5% at the edges of the entrance aperture window. This may be significant when measuring the positions of multiple beams, depending on position requirements. If so, a cosine correction can be applied to the sampling interval to compensate for the error. See Chapter 5.5.27 for a table of recommended sampling resolutions for specified drum rotation frequency.

4.4.4.3 Amplifier Gain

Amplifier gain, or “hardware” gain, is adjustable through software. The range of gain settings depends on the scanhead type. The gain steps are nominally 1dB increments, or a gain factor of 1.122. The gain should be set to maximize the peak of the profile.

4.4.4.4 Bandwidth

Bandwidth for a given rotation frequency affects both the signal-to-noise (S/N) ratio and the fidelity of measured profiles. The maximum bandwidth is 190kHz, and is adjustable through software down to 2kHz. Higher bandwidth is required for measurement of smaller beam diameters. Less bandwidth is required for lower scan rotation frequencies.

Undershoot observed in a profile, Figure 4.15 Profile Undershoot is an indication that the bandwidth is limited. Either increase the filter frequency or reduce the scan rotation frequency. Excessive noise in a profile indicates that the bandwidth should be reduced.

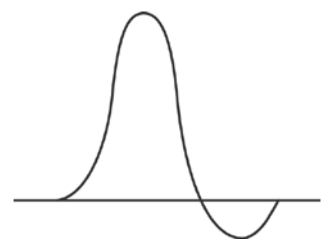


Figure 4.15 Profile Undershoot

4.4.4.5 Signal Filter

The signal filter is used to adjust the bandwidth at a given rotation frequency and amplifier gain to optimize the signal-noise ratio in the acquired profile. Strictly speaking laser beam profiles falls under the category of ‘transients” when it comes to data acquisition and signal analysis. The data acquisition system must have sufficient bandwidth to faithfully record all the signal components in the profile.

When setting the filter frequency Manually: as a general rule of thumb for Gaussian profiles a bandwidth of ~200kHz is required to faithfully measure a 10μm diameter beam at 10Hz scan frequency. At a 5Hz scan rate the required bandwidth is then 100kHz, or for a 5μm diameter beam it is again 200kHz, and so on.

The algorithm for Filter Auto Tracking computes a minimum Filter bandwidth based on 10× the minimum filter required for a “sinusoidal equivalent” beam diameter, or 12× the minimum filter for a “Gaussian equivalent” beam width. This is a conservative approximation intended to account for higher M^2 profiles including Flat Top.

4.4.4.6 Regions of Interest (ROIs)

Profile analysis is performed in defined Regions of Interest, or ROIs. ROIs can be set automatically or manually through the software. The maximum number of ROIs that can be defined is 16.

4.4.4.7 Profile Averaging

Profile averaging provides for improvement in Signal/Noise Ratio (SNR) with subsequent improvement in profile fidelity/accuracy and the precision of derived parameters. Two types of Profile Averaging are available: Profile Averaging and Rolling Profile Averaging. These can also be used in combination. Profile Averaging takes the average of N profiles before reporting a profile, and Rolling Profile Averaging uses the average of the last N profiles.

The specified lower boundary for NanoScan Operating Spaces corresponds to an SNR of 10. Averaging can be used to improve the SNR for such measurements, and also for power levels below the boundary where the profiles are effectively “buried” in noise. Thus profile averaging extends the measurement range of each NanoScan model to even lower power levels.

Averaging is also very effective at improving the measured Centroid (pointing) precision. Standard scanheads exhibit a 1σ standard deviation precision of approximately 0.2-0.4μm. Use of Rolling Average of 3 profiles reduces this to values <0.1μm. Further use of Profile Averages to the value of 100 and Rolling Profile Averages to the value of 16, for example, reduces this to levels as low as 0.010-0.020μm, or 10-20nm! This is far more accurate than any CCD, Quad Cell, or Position Sensitive Detector.

Averaging is also useful to “clean up” or smooth measured profiles when using the NanoScan Pulsed operation modes. This provides more accuracy and precision in measured parameters.

4.4.4.8 Coordinate System

The coordinate system orientation can be set through software. The default coordinate system is based on the scan axes. However, in some cases it is desirable to change the coordinate system using a rotation transformation. This is accomplished through the software.

4.4.5 Aperture Obliquity Correction

Aperture obliquity arises due to the curvature of the scan drum or due to beam incidence off the normal direction. This may be significant when measuring highly divergent beams, beams incident at large angles, or for multiple beams that fill the entrance aperture. When this is the case, corrections to the raw profile data can be made using a cosine correction factor.

4.4.6 Back Reflections and Laser Oscillation

When measuring laser beams, if the scanhead is positioned so that the incident beam is nearly perfectly normal to the scanning aperture on the drum, the reflection can propagate back into the laser cavity and cause oscillations in the laser power output. These oscillations are observed as a high frequency spatial pattern and/or moving ripples superimposed on the profile.

For low-power/power density measurements, reflections can be minimized using aperture materials with lower reflectivity at the wavelength of use, and also by blackening techniques. However, for very high-power/power density levels, it is often more important that the apertures reflect MORE of the incident beam in order to avoid damage to the apertures themselves.

If oscillations are seen when measuring raw laser beams, a simple solution is to observe the reflected beam spot back at the laser output and then slightly offset and or tilt the scanhead to steer the reflected beam off axis so that it misses the laser output mirror.

When measuring focused beams, a slight offset or tilt of the scanhead may not be sufficient because the focusing lens steers the reflected beam back to the source. In this case, use of an attenuator plate in the collimated beam path, tilted slightly so it doesn't cause feedback as shown in Figure 4.16, can solve the problem simply by reducing the incident beam, and hence the reflected beam, even if it is still feeding back into the cavity.

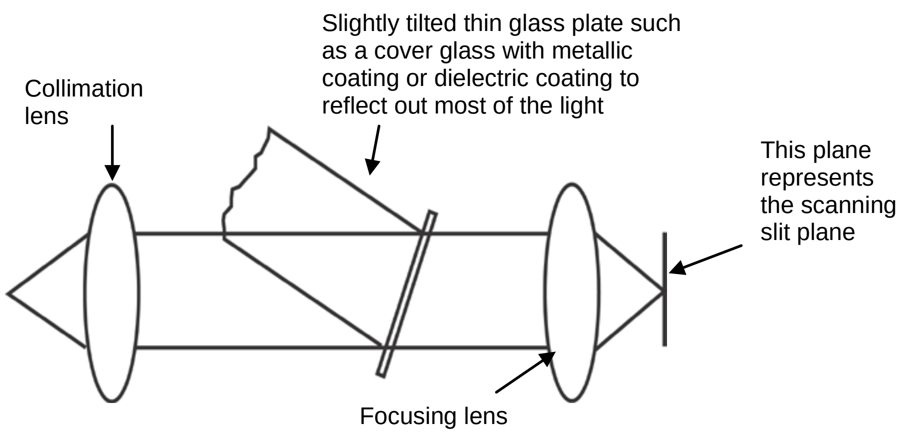


Figure 4.16 Use of an attenuator in the beam path to reduce back reflection—n.b., metallic filters are subject to thermal lensing, covered in Section 4.4.9.

4.4.7 Beam Divergence and Angle of Incidence

When considering the accuracy of raw profile measurement, two factors influence and limit the range of beam width—beam divergence and angle of incidence. These factors relate to the detector dimension, and the dimension and thickness of the aperture, and must be considered together with the nominal beam width and position in the entrance aperture.

The detector dimension and its position relative to the scan plane, and the entrance aperture diameter determine the ultimate limit of the beam divergence and/or angle of incidence for a given beam width. For divergence and incident angles above this limit, some or all of the light transmitted through the aperture misses the detector (located a few millimeters behind the slit plane). For a tightly focused beam incident near the center of the entrance aperture, the angular limit is nominally 40-45° for typical NanoScan scanheads. If the beam is incident near the edge of the aperture this angle is reduced. Also, for a larger beam the angular limit is less. A more stringent limit is due to the dimension and thickness of the apertures. As the divergence or angle of incidence increases, the slit vignettes and the transmitted light is reduced. For a particular aperture thickness, the vignetting decreases as the aperture dimension increases, allowing for larger divergence and incident angles.

In practice, NanoScan is ideally suited to the measurement of typical laser beams with low divergence in the milliradian range at angles of incidence up to approximately ±15°.

When measuring “point” sources with very high divergence, such as optical fibers, the angular limits are easily exceeded. However, in some cases it is possible to perform a mathematical correction to the raw profile data to obtain more accurate results.

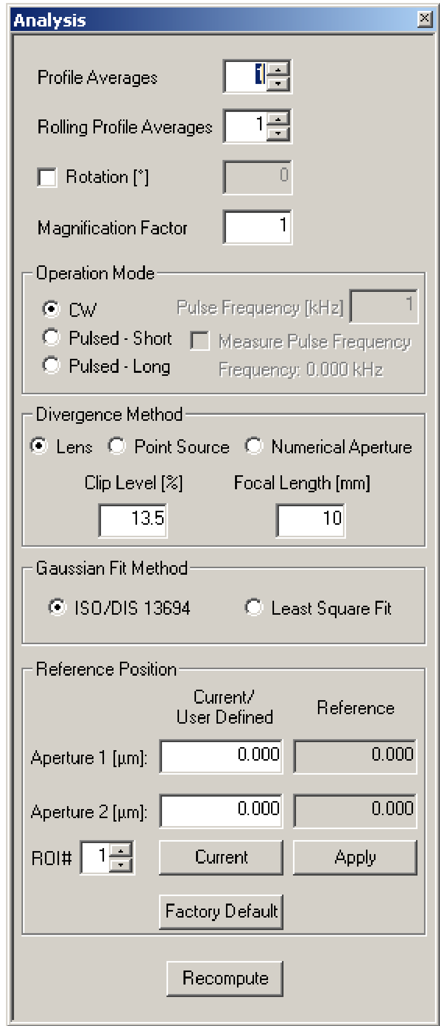
There are special calibrated fixture accessories for NanoScan, the Col-FXT series, for determining divergence of optical beams and setting collimation of optical assemblies. These fixtures incorporate various lenses and through a calibration procedure are positioned so the NanoScan scan plane is precisely at the geometric focus of the lens. In this case the following equation applies:

$$d = f\theta$$

Thus the measure of beam diameter at the geometric focus provides a direct measure of the divergence angle.

4.4.7.1 Divergence Measurement

NanoScan provides 3 methods for determining Divergence; the Lens method, the Point Source Method, and the Numerical Aperture method. Selection and configuration of the different methods is done through the Analysis ToolControl Dialog.



4.4.7.1.1 Lens Method

The Lens Method uses a lens of known focal length *f* and can help determine the divergence of the beam from a nearly collimated source. To measure the divergence, place a lens of known focal length *f* into the beam. To ensure aberration free measurement with a singlet, be sure that

$$\frac{f}{D_{input}} \geq 16$$

Place the NanoScan slit plane coincident with the plane containing the geometrical focus.

The beam diameter at the focal length is:

$$D_f = f \times \theta,$$

where:

D_f is the beam diameter at the geometrical focus of the lens (μm);

f is the focal length of the lens in microns;

θ is the divergence.

It is important to note that the geometrical focus and the waist usually do not coincide. The waist is usually beyond the geometrical focal plane. Typical *f* values range from 100mm to 500mm. The relationship applies for Gaussian (TEM_{00}) as well as any higher order or multi-mode sources (Figure 4.17).

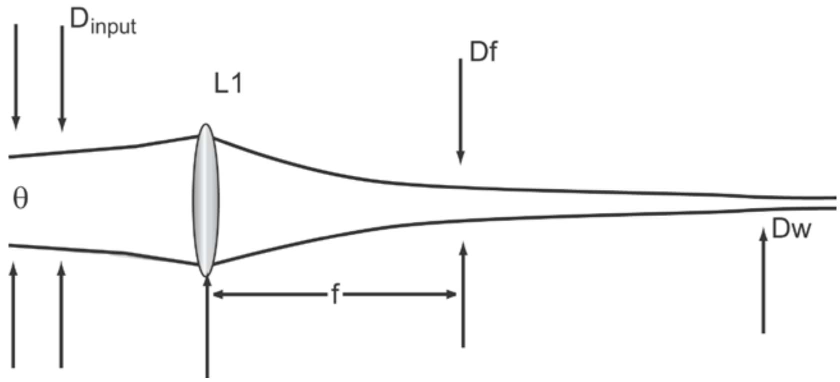


Figure 4.17 Measuring Divergence using the Lens Method

To use the lens method, select Lens under the Divergence Method group and enter the values for Clip Level (%) and Focal Length of the lens (mm) in the corresponding edit boxes. The beam divergence will be reported in milliradians.

4.4.7.1.2 Point Source Method,

The point source method requires that the beam diameter be measured in the far field. The distance L from the point source to the measurement plane must be known (Figure 4.18):

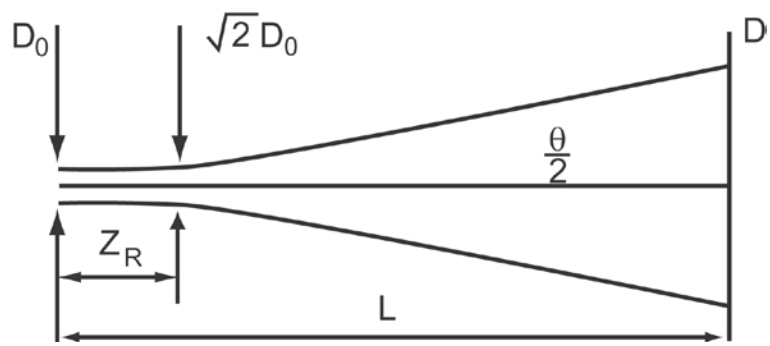


Figure 4.18 Measuring Divergence using the Point Source Method

Use the following equation to determine the far field measurement position:

$$L \gg \pi \cdot \frac{D_0^2}{\lambda},$$

where:
L is the distance from the point source;

D_0 is the source size;

λ is the beam's wavelength.

The divergence measured in the far field is:

$$\theta = 2\arctan\left(\frac{r}{L \cdot 10^3}\right),$$

where:
θ is the divergence (deg);
r is $d/2$, the beam radius (μm);
L is the distance from source (mm).
To use the Point Source method Point Source under the Divergence Method group and enter the values for Clip Level (%) and Distance from Point Source of the lens (in mm) in the corresponding edit boxes.

4.4.7.1.3 The Numerical Aperture Method

The Numerical Aperture (NA) is the sine of θ/2, the half-angle divergence. This method is typically used to characterize optical fiber. Be sure the beam width measure is made in the far field as discussed above.

$$NA = \sin\frac{\theta}{2}.$$

To use the Numerical Aperture method, select numerical Aperture under the Method group and enter the values for Clip Level (%) and Distance From Point Source of the lens (in mm) in the appropriate edit boxes.

Note: Fiber Numerical Aperture is often measured with a 5% clip level, as opposed to the more common 13.5% clip level used for the divergence of laser beams.

4.4.8 Stray Background Light

Stray light due to sources in the vicinity of the scanhead may affect the measurements. This is especially the case when measuring very low power sources in the visible range where the gain is very high, and room lights can cause significant stray background. The presence of stray light is usually observed as an unusual or unsuspected feature in a profile. It can be verified by turning off the source of the beam being measured.

In general, care should be exercised in the measurement setup to avoid such conditions. Precautions such as turning off room lights, or use of enclosures to shield out stray light are recommended.

4.4.9 Beam Attenuation

Attenuation is normally not required when measuring laser beams with NanoScan, due to the natural attenuation provided by the slit or pinhole apertures and to the very wide measurement dynamic range specific to each scanhead. However, for measurements of beams with power levels exceeding the upper limit of the appropriate operating space, attenuation of the beam is required. This attenuation can be accomplished either by direct optical filtering or by beam sampling techniques using some type of beamsplitter. Thermal lensing may occur so quickly that this method does not work. As a rule of thumb, absorbing filters should only be used with laser powers less than 100mW per mm diameter. In general beams requiring attenuation with a NanoScan will be higher powered than this and should therefore be attenuated using reflective attenuators.

When attenuation is necessary, it must be done properly. For absorbing filters, the material must be of high optical grade that can withstand the beam power without significant heating that can cause thermal lensing and distortion of the beam. Thermal lensing sometimes can be observed as a continuous change in measured beam size, but sometimes it goes unobserved as the heated optic is in a steady state. To test for thermal lensing, either turn the beam off for a while to let things cool, or slightly translate the filter in the beam. The beam width reading should not change significantly. If it does, then the attenuator material is producing thermal lensing, and should not be used.

Since attenuation is only required with NanoScan for the most powerful beams, beam sampling using beamsplitters is the preferred method. One simple method is to use a wedge of quartz glass, and measure the beam reflected off the front surface, which is nominally 4% (25X attenuation) of the incident beam. The wedge shape separates the beam reflected off the rear surface by twice the wedge angle. This allows placement of the scanhead so as only to intercept the front surface reflection and eliminate ghosting.

Another method is to use a duplicate of the laser output mirror as a beamsplitter, and measure the transmitted beam. The transmitted beam is typically 0.5-1% of the incident beam, so this method provides 100X–200X attenuation.

4.4.10 Slit Convolution and Small Beams

If an infinitely narrow slit is scanned across a Gaussian beam, the light intensity transmitted by the slit as it moves across the beam will exactly map out the Gaussian profile. However, a slit of finite width is required to transmit a measurable amount of light, and the width of the slit has a detectable effect on the shape and width of the measured intensity profile. The effect of finite slit widths on beam profile measurements is explained in the following paragraphs.

Begin with the assumption that the actual profile of the beam is Gaussian.

Actual Profile = $G(z) = \exp(-z^2)$

Measure this profile by passing a slit of width w across the beam.

Express the measured profile as follows:

$$M(z) = \frac{\mathrm{erf}(z + ax) - \mathrm{erf}(z - ax)}{2 \times \mathrm{erf}(ax)},$$

where:

$M(z)$ = Measured Profile, $a = \sqrt{-\ln(p)}$, and $x = \frac{\text{slit width}}{\text{beam width}}$.

The beam width is measured between the points where the intensity falls to a fraction, *p*, of the peak intensity at the center. The most commonly used values are p=0.5 for the full width at half-maximum (FWHM), and p=0.1353 at the $1/e^2$ diameter. The measured profile *M(z)* is similar in shape to the Gaussian profile *G(z),* and M(z) approaches *G(z)* as *x* in the above formula approaches zero. For any given slit width, the width of the measured profile *M(z)* is greater than that of the true profile *G(z).* This discrepancy becomes greater as the width of the slit increases.

When the slit width is small compared with the measured width of the beam, the ratio, *F*, of the true beam width to the measured beam width can be computed accurately from the value of *x*, which is the slit width divided by the measured beam width, using the following semi-empirical formula:

$$f = \sqrt{1 - \frac{2}{3}(\mathrm{ax})^2}$$

This formula can be used without significant error (less than 1% error in *F*) for values of the slit width parameter $x \leq 0.45$ when the beam widths are measured to the $1/e^2$ points. If the FWHM beam width is used instead, the formula is accurate to 1% for values of $x \leq 0.60$.

The semi-empirical formula is based on the fact that for the convolution of two Gaussians, the squares of the width of the convolution is equal to the sum of the squares of the widths of the Gaussians forming the convolution. When the slit width is small, its Fourier transform—a sine function—may be regarded as Gaussian without serious error. For larger slit widths, the error in the approximate formula exceeds 1% and the results of the exact calculation of the ratio of true beam width to the measured beam width must be used instead.

The graphs in Figure 4.19 and Figure 4.20 are provided so that the actual width of the Gaussian profile *G(x)* can be easily determined from the width of the profile *M(x).* These corrections have been computed for the two most commonly used threshold fractions, $1/e^2$ and FWHM. When other values of the threshold fraction *p* are used, the semi-empirical formula for *F* provides a closer approximation to the correction factor, provided that the slit width parameter *x* remains less than 0.5. The procedure for using these graphs to determine the true beam width of a Gaussian profile beam follows. (For distributions other than Gaussian, these corrections may be invalid. We believe the best condition is to use a sufficiently small slit, and Photon offers an optional 1µm slit. Standard slits are 1.8µm, 5µm, and 25µm.

1. Use the graph in Figure 4.19 for all corrections if beam diameters are measured to the $1/e^2$ (13.5%) points. Use the graph in Figure 4.20 if the beam diameters are measured to the half-intensity points (FWHM).
2. Determine the slit width of the slit used to measure the beam profile.
3. Determine the measured width of the beam ($1/e^2$ or FWHM) from the output data provided.
4. Divide the slit width by the measured beam width to determine the value of *x*.
5. Enter *x* in the graph and find the correction factor *F.*
6. Multiply the measured beam width of step 3 by the correction factor *F* to obtain the true width of the Gaussian Beam.

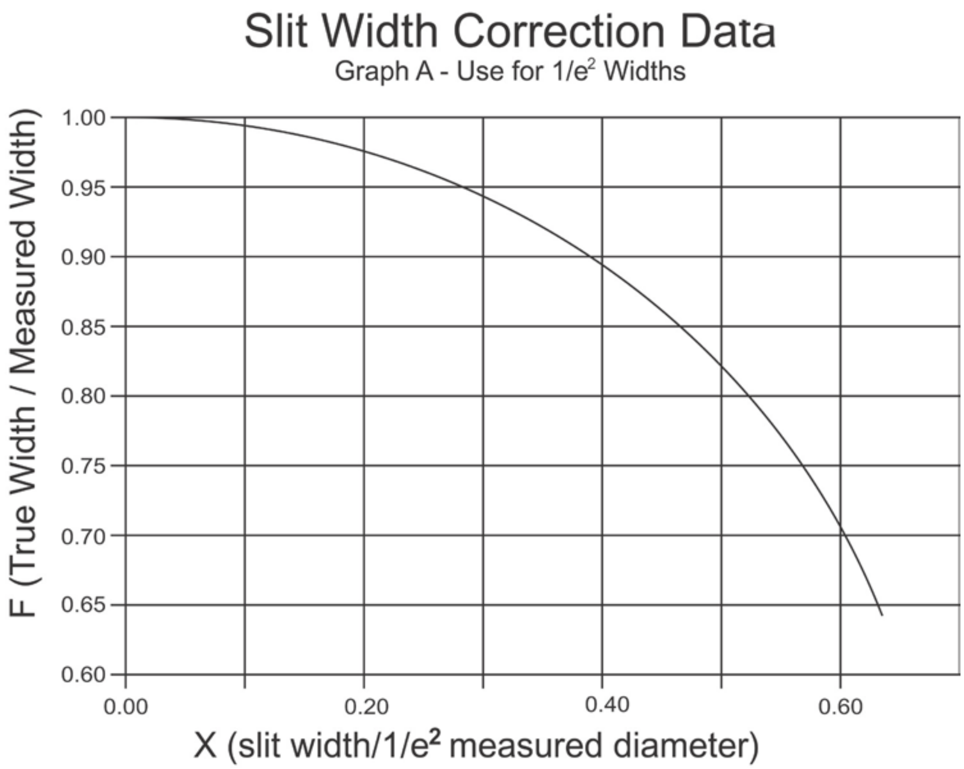


Figure 4.19 Slit Width Correction Data for 1/e² Measured Width

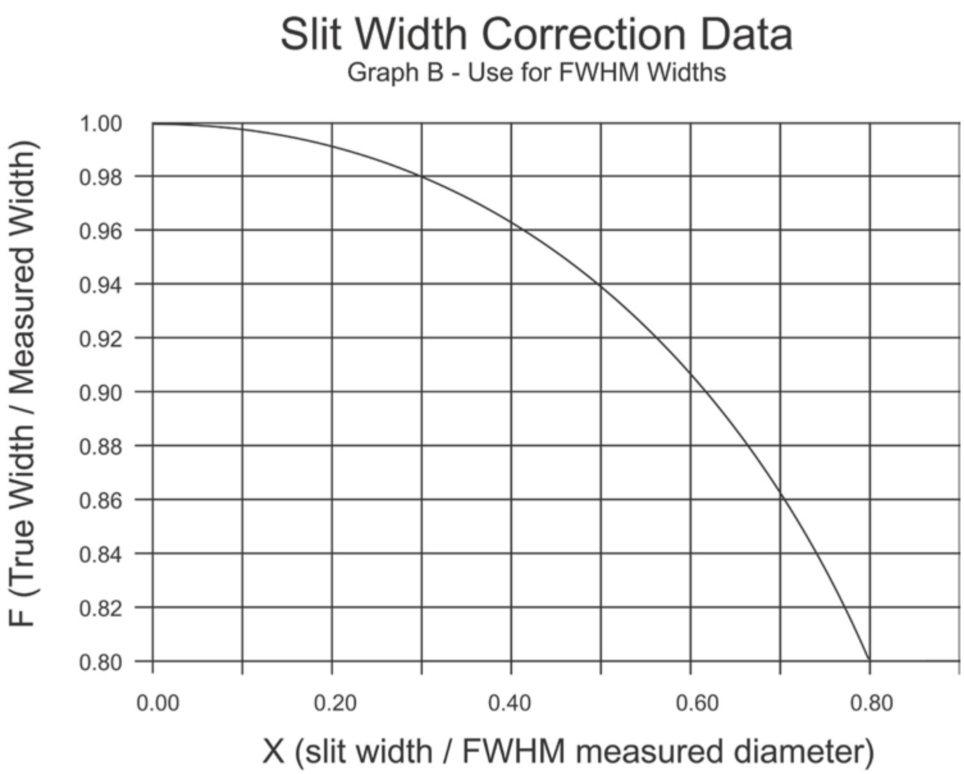


Figure 4.20 Slit Width Correction Data for FWHM Measured Width

4.4.11 Near-Field Profiling

Photon also provides several near-field profiling solutions for measurement of very small spots. Model NFP 980 operates at 60:1 magnification and is useful from 700-1100nm. Model NFP 1550 is useful from 1300-1600nm and operates at 40:1 magnification. For more information, see our data sheet at www.photon-inc.com.

Accessories for small spot measurement include the Option H/I, which is a bracket that positions a finite conjugate microscope objective lens 160mm in front of the measurement plane. For measurement of very small spots when magnifying lenses are used, an important consideration is the Modulation Transfer Function (MTF) of the lens for the wavelength of use, which determines the system optical resolution. Depending on the MTF relayed images in the micron domain may or may not be accurate. As a general guideline, use a well-corrected objective for the wavelength of use.

Objectives with numerical apertures (NA) greater than 0.4 and magnifications greater than 40 perform better than low power, low NA objectives. Higher-price objectives are nearly always better than the alternative.

Spot measurements below a few microns are also *very* difficult to perform due to system vibration. It is necessary to have sufficiently high quality mechanical fixtures for measurements in this domain. Everything moves around on the micron level. If you require measurements at less than 10-20µm, you will need to acquire very high quality mechanical fixtures and stages. Many off-the-shelf stages do not provide the stability or sensitivity to measure very small spots.

4.4.12 Measuring Elliptical Beams

To obtain accurate measurements of elliptical beams, it is necessary to orient the scanhead so that the orthogonal scan axes are very closely aligned with the major and minor axes of the beam. The angular precision of the alignment depends on the ellipticity of the beam.

Measurement of an elliptical beam is illustrated in Figure 4.21. In the figure, the slit is misaligned by the angle of ellipticity of the beam. The measured width is equal to the projection along the scan direction of the line defined by the point at which the slit first enters the beam and the point at which it exits. The entry and exit point are shown, as well as the actual beam width, and the measured beam width, which is significantly in error. To obtain accurate results, a good rule-of-thumb is the requirement that the misalignment angle be less than 1/10 the angle of ellipticity.

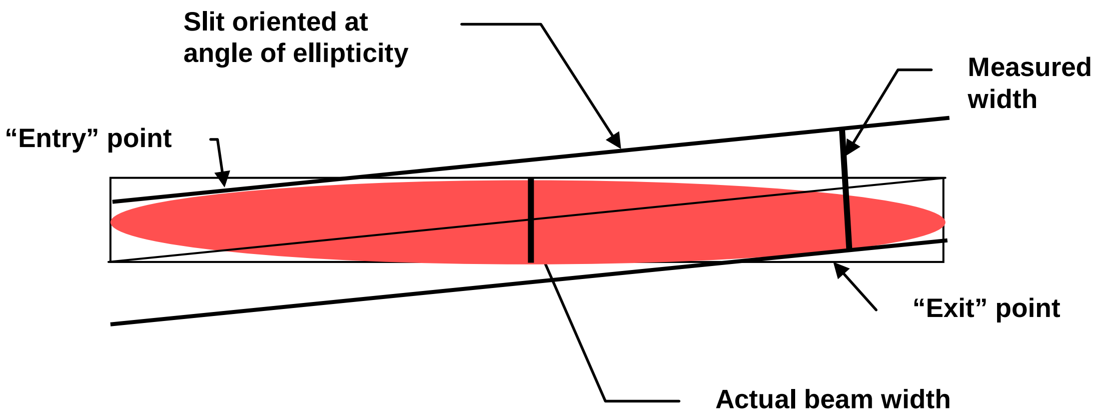


Figure 4.21 Error due to scan misalignment when measuring elliptical beams

The figure shows a condition where the ellipticity is of the order of 0.1, and a corresponding angle of ~5.7°, so to get a good measure the scan axis must be adjusted to <~0.57°. This range of adjustment is easily achieved using the NanoScan rotation mount. The optimal scan angle is set by rotating the scanhead to minimize the reported minor axis width while observing the beam profile.

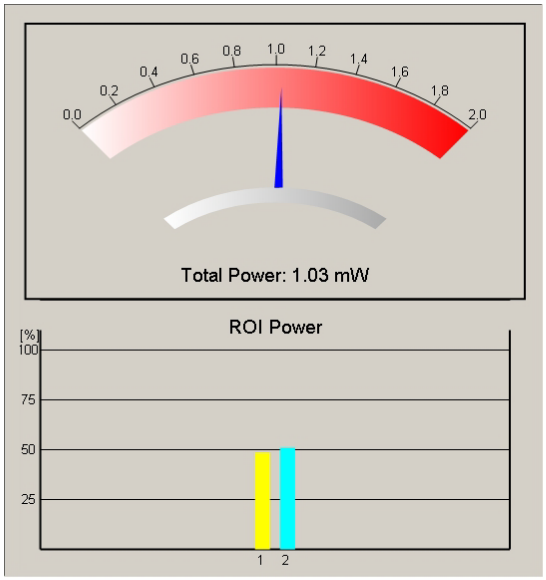
However, if the beam ellipticity is of the order of 0.01 or greater, which is the case for many applications, the ellipticity angle becomes 0.57° or less, and the alignment requirement is of the order of 0.057° or less. The adjustment in this case is very difficult. In this situation, the use of a high-precision rotation stage with micrometer adjustment is in order. Alternatively, the measurement can be made using a scanhead with a pinhole aperture, in which case the alignment of the scan axis becomes much less critical.

4.4.13 Power Measurements

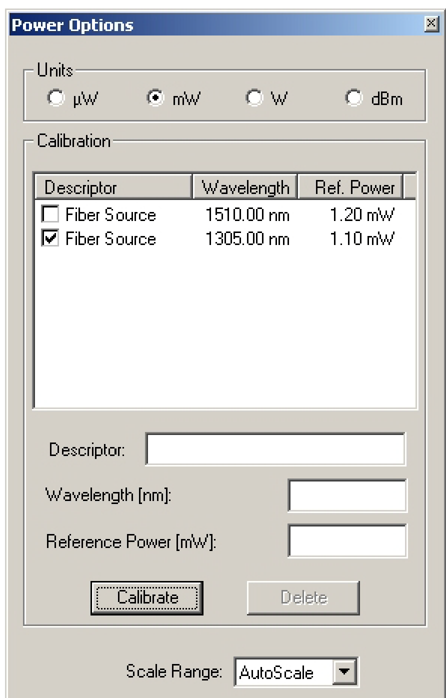
The optional NanoScan Power Meter provides relative measurements of total power based on user-generated calibration files stored in the scanhead EEPROM.

The Power View displays the Total Beam Power measured in the NanoScan scanhead entrance aperture and the calculated ROI Power in each ROI. The measured Total Power is displayed in an analog power meter format with the current value of the Total Power reported. The ROI Power is shown as a bar chart showing the percent of the Total Power in each ROI. The colors of the bar for each ROI are the same as those selected for the ROI boundaries in the Profile View.

Power parameters can also be reported in the Parameters Panel and the Time Charts View.



At least 1 calibration file must be generated for the power measurement to operate. Calibration files are generated using the Power ToolControl Dialog. A calibration file contains a reference power value, the wavelength, and a text field for source and configuration description, all entered through the software. The scanhead EEPROM can store up to 256 calibration files, allowing accurate operation for many wavelengths and configurations.



The reference values are obtained from independent measurement of the beam power using a standard calibrated power meter. To operate and report power values, the NanoScan power meter must be linked to a calibration file. The absolute accuracy of the measurement depends on the accuracy of the reference power measurement.

To get the most accurate and consistent results, it is advised that calibration files be generated for each source and wavelength, and also for different measurement configurations to account for factors such as angle of incidence and beam size.

The Kodak Wratten Neutral Density filter will change attenuation with a change of angle of incidence. If calibrated at near normal incidence to the drum, one can expect accurate results when the measured beam maintains ±3-5° incidence angles. Higher incidence angles will begin to alter the power reading due to the increased path through the Wratten filter . The metallized quartz glass attenuators are less sensitive to small changes in incidence angle. With either type of filter, when there is any doubt about the measurement accuracy, always test the different conditions for your application with a separate power meter.

4.4.14 Multiple Beam Measurement

When measuring multiple beams, the arrangement of the beams, the beam divergence, and the plane of measurement determine whether or not NanoScan can resolve them. In general, each beam in a linear array of collimated beams can be resolved. The measurement must be performed with the scan axes oriented at ±45° to the array. Also, it is useful to use the rotation transformation feature in the NanoScan software to provide the beam positions in coordinates common to the linear array. When beams overlap, it is not possible to completely resolve the profiles. However, it is possible to extract information such as peak separation by defining specific Regions-of-Interest around the beam peaks.

4.4.15 Care of NanoScan Apertures

The air slit and pinhole aperture substrates are very thin and extremely fragile. Any physical contact will likely damage them. For example, fiber tips placed too close to the aperture can easily damage a slit. Treat the slits with care; because of their fragility, ***never touch them with anything!***

Debris such as dust particles can lodge in the very fine openings of the slits or pinholes and obstruct the passage of the incident beam. This can compromise instrument performance, resulting in erroneous or inconsistent measurements. With slits, a few dust particles may or may not be a problem, depending on the application and measurement configuration, and contamination by many particles is more likely to create a problem. With pinhole apertures a single particle can be disastrous. Therefore, when the system is not in use, it is recommended that the protective plastic cap be used to cover the scanhead entrance aperture and avoid possible contamination.

If inconsistent performance is observed and contamination by debris is suspected, a clean jet of compressed gas may solve the problem, but excessive pressure may also damage the apertures. Do not under any circumstances attempt to clean the apertures with solvents! If aperture contamination is suspected, it is recommended that ***the unit be returned to Photon for aperture inspection, cleaning or replacement, and recalibration.***

4.4.16 Aperture Damage Threshold

Damage thresholds reported in Table 4.4 below are determined under specific test conditions and should not be taken as absolute. Photon Inc. **does not warrant damage to slit apertures and detectors due to damage from high power lasers**. Users of high-power lasers must exercise caution when measuring their laser beams with their NanoScan.

Slit apertures in NanoScan scanheads are made from a proprietary metallic alloy. The slit apertures are often blackened to reduce reflectivity and minimize reflections back into the laser cavity. Because of possible slit damage, Photon performed damage threshold tests on various NanoScan slit apertures to establish general use guidelines for prevention of damage to slit apertures. If you are concerned and still not sure, Photon can provide aperture material that you can use as a test before using your source on a NanoScan.

Blackened and unblackened apertures with 1µm, 1.8µm, 5µm and 25µm nominal slit widths were tested. Tests were made at laser wavelengths of 532nm, 1.06µm, and 10.6µm. Damage thresholds are defined here to be the average laser irradiance at which the onset of visual damage occurs. The average irradiance is defined as the average power divided by the beam area at the $1/e^2$ beam diameter.

All tests were performed under normal NanoScan operating conditions with the aperture slits **moving**. Damage to the slit apertures can occur at much lower power levels if the laser beam is directed into the slit apertures while the apertures are stationary. The tests were performed at laser power levels <3 watts for **short time exposures** on the order of **5 minutes**. The damage thresholds that were determined are therefore applicable **only** for short time exposures at these power levels. For high power lasers and long exposure times the damage thresholds are likely to decrease due to excessive heating of the apertures and/or possible ablation that does not manifest itself as visual damage in short term exposure tests. These effects have not yet been quantified, so users are advised to exercise extreme caution when attempting to measure high power beams for long time intervals. Long exposures may heat the entire NanoScan and cause other failures.

Note that for the case of blackened slit apertures, the onset of visual damage occurs when the black material begins to ablate. This type of damage does not affect the integrity of the slit but only the reflectivity of the aperture. Slit integrity is only compromised at the higher laser irradiance associated with damage to unblackened apertures. This damage takes the forms of wrinkling or creasing of the aperture due to thermal stress and scoring of the aperture due to melting of the metallic alloy. At higher irradiance and longer exposure times the apertures can be cut. Recommended upper limits of average laser irradiance based on the results of the visual damage threshold tests for short time exposure (~5 minutes) at power levels less than 3 watts are summarized below.

Table 4.4
Recommended maximum average laser irradiance incident on metallic alloy NanoScan slit apertures for short time exposures <5 minutes

APERTURE TYPE	NOMINAL SLIT WIDTH (µm)	VISUAL DAMAGE THRESHOLD (W/cm^2)		
		532nm	1.06µm	10.6µm
UNBLACKENED	1-2	3×10^5	$1 X 10^6$	NA*
UNBLACKENED	5-25	$4 X 10^5$	1.2×10^6	3.5×10^6
BLACKENED	1-2	1×10^4	3×10^4	NA*
BLACKENED	5-25	1×10^4	3×10^4	NA*

*** Not Applicable**

The values of average irradiance listed in the above table should be used as guidelines to determine if your operating conditions may cause damage to the apertures in your NanoScan scanhead for short time exposure at power levels <3W only. For long term exposures (>5 minutes) at higher power levels the damage thresholds may be reduced. **Exercise Caution!**

Photon Inc. does not warrant damage to slit apertures and detectors due to damage from high power lasers.

4.4.17 Instrument Calibration

Photon recommends an annual calibration on all its beam profilers, most especially the scanning-slit profilers, including NanoScan. Photon profilers are precision instruments with moving parts; over time, miniscule movements may occur which could affect measurement accuracy. Many instruments are used in production in manufacturing plants, where dust and other particles could possibly enter the scanning-slit aperture. We recommend regular calibration to ensure that the precision is maintained and any tiny particles are cleaned. Most companies that must comply with ISO 9001 or other standards insist that instruments receive an annual calibration, cleaning, and preventive maintenance. Photon sends a calibration/preventive maintenance reminder on the anniversary of the delivery of your NanoScan. All Photon instruments are calibrated to NIST-traceable standards.

4.5 Scanhead Specifications

4.5.1 Standard Scanheads

Standard NanoScan scanheads come with various combinations of detector, entrance aperture diameter, and slit width. These are listed below. Please see Appendix A for hardware specifications on the following standard available scanhead models:

- NS-SI/3.5/1.0
- NS-GE/3.5/1.8
- NS-SI/3.5/1.8
- NS-GE/9/5
- NS-SI/9/5
- NS-Pyro/9/5
- NS-GE/3.5/1.0
- NS-Pyro/20/25

4.5.2 Operating Space Charts

Please see Appendix C for the following Operating Space Charts.

4.5.2.1 Silicon Detectors (190-950nm) Responsivity 0.4 amps/watt

- NS-SI/3.5/1.0
- NS-SI/3.5/1.8
- NS-SI/9/5
- NS-SI/25/25

4.5.2.2 Germanium Detectors (700-1800nm) Responsivity 0.7 amps/watt

- NS-GE/3.5/1.0
- NS-GE/3.5/1.8
- NS-GE/9/5
- NS-GE/12/25

4.5.2.3 Pyroelectric Detectors (0.2-20μm) Responsivity 3.8×10^{-7} amps/watt

- NS-Pyro/9/5
- NS-Pyro/9/25
- NS-Pyro/20/25

4.5.3 Mechanical Dimensions

Please see Appendix B for the mechanical dimensions for the following scanheads:

Models NS-SI/3.5/X and NS-GE/3.5/X

Models NS-SI/9/X and NS-GE/9/X

4.5.4 Power Aperture

The power aperture provides for measurement of total beam power in NanoScan scanheads with either silicon or germanium detectors. There is no power aperture on scanheads with a pyroelectric detector. Standard power aperture attenuators are either a Kodak Wratten Neutral Density Filter No. 96, used for power levels up to 75mW, or a metallized quartz glass substrate, used for power levels up to 200mW.

- P75: Kodak Wratten No. 96
- P200: Metallized quartz

4.6 NanoScan PCI Scan and Acquisition Interface Card Specifications

- Bus interface: PCI
- Signal digitization: 12bit
- Maximum digitization clock: 20MHz
- Maximum update rate: 20Hz
- Data transfer: DMA
- On-board memory: 4MB SDRAM
- Weight: 125g (4.4 ounces)
- Operating temperature: 0…50°C
- Humidity: 90%, non-condensing
- Card Dimensions: 185.4mm × 107mm
7.3 in × 4.2 in
- Sample transfer data time: 0.4 ms for 10K samples (20 Kb)
- Interchangeable heads and controller cards

4.7 NanoScan USB 2.0 Scan and Acquisition Controller Specifications

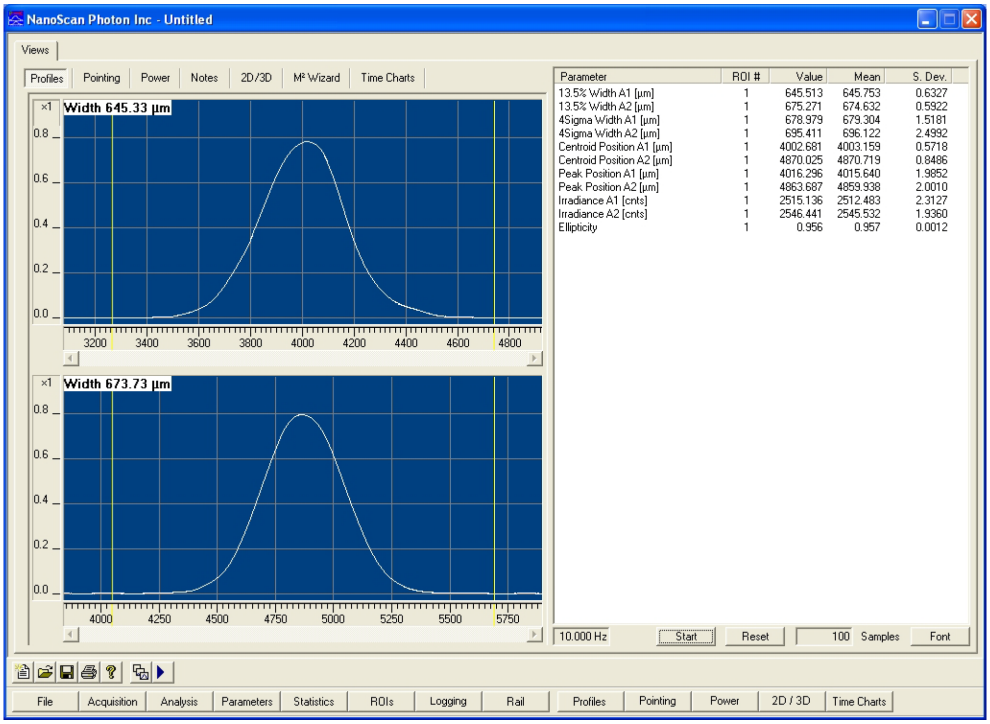
- Bus interface USB 2.0
- Signal digitization 12bit
- Maximum digitization clock 20MHz
- Maximum update rate 20Hz
- Data transfer Bulk Transfer Mode
- On-board memory 8MB SDRAM
- Weight 125g (4.4 ounces)
- Operating temperature 0…50°C
- Humidity 90%, non-condensing
- Controller Dimensions 1.5”(3.8cm) H × 17”(10.6cm) W × 8.75”(22.2cm) L
- Sample transfer data time 0.4 ms for 10K samples (20 Kb)
- Interchangeable heads and controllers
- External Wall-mount 5 Volt DC Power Supply
- Domestic 5V DC 2.6A
- International: 5V DC 3.2A with international plug set

5 NanoScan Analysis Software

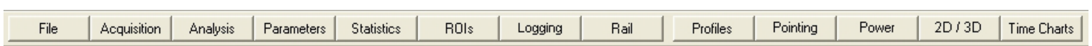
The NanoScan Beam Profiling and Analysis software is a stand-alone graphical user-interface (GUI) for beam profiling with the NanoScan Beam Profiling System. The GUI screen display includes a panel for displaying views of beam Profiles, beam Pointing, beam Power, user Notes, beam 2D/3D view M² Wizard or Time Charts; a panel for displaying beam Parameters and Controls for data acquisition, data analysis, data display, file handling, printing, data logging and rail control. The software includes an ActiveX Automation server for interfacing to applications such as LabVIEW or Excel.

Measurement of beam profile and power for up to 16 multiple beams is accomplished by defining specific Regions of Interest (ROIs) for beam analysis. For each ROI, the analysis provides values for beam width by the slit method at various clip levels, beam width by the $d_{4\sigma}$ method, beam centroid, beam ellipticity, and Gaussian Fit in accordance with ISO Standard 13694 or using a Photon Least Square Fit. In addition, the separation of beam centroids and peaks, the total beam power in the NanoScan aperture and the power in each ROI are provided. Due to the nature of multibeam analysis, ellipticity cannot be measured reliably concurrent with multibeam analysis.

The NanoScan Beam Profiling and Analysis Software display screen (next page) is organized into three main sections: including one—the **Controls**—for control of data acquisition and analysis; and two—for data display—the **Views** panel and the **Parameters** panel. The **Controls** are located along a toolbar at the bottom of the screen, with the **Views** panel on the left, and the **Parameters** panel on the right. The **Controls** tool buttons activate **ToolControl** dialog boxes for making selections and settings in the NanoScan Software for profile acquisition, power measurement, analysis and display. The **Views** panel provides graphical display of either beam **Profiles**, beam **Pointing**, beam **Power**, **Notes** for test information and comments, **2D/3D** beam view, **M² Wizard** or **Time Charts**. The **Parameter** panel displays beam parameters with statistics.



5.1 Controls



The control tool buttons that activate **ToolControl** dialog boxes for making selections and settings include, **File**, **Acquisition**, **Analysis**, **Parameters**, **Statistics**, **ROIs**, **Logging**, **Rail**, **Profiles**, **Pointing**, **Power, 2D/3D** and **Time Chart**. Just above the Controls toolbar, there is also a toolbar with icons for starting and stopping data acquisition, and for setting the system in Automatic mode, **New**, **Open**, **Save**, **Print**, and **Help**.

5.1.1 Control Buttons

File	Opens/Closes the File Tool Dialog box
Acquisition	Opens/Closes the Acquisition Tool Dialog box
Analysis	Opens/Closes the Analysis Tool Dialog box
Parameters	Opens/Closes the Parameters Tool Dialog box
Statistics	Opens/Closes the Statistics Tool Dialog box
ROIs	Opens/Closes the ROIs Tool Dialog box
Logging	Opens/Closes the Logging Tool Dialog box

Rail	Opens/Closes the Rail Tool Dialog box
Profiles	Opens/Closes the Profile View Options Tool Dialog box
Pointing	Opens/Closes the Pointing View Options Tool Dialog box
Power	Opens/Closes the Power View Options Tool Dialog box If the scanhead in use does not have the power option the button is disabled
2D/3D	Opens/Closes the 2D/3D View Options Tool Dialog box
Time Charts	Opens/Closes the Time Charts View Options Tool Dialog box

5.1.2 Icons

 Opens a new file

 Opens saved files The File Open dialog box will appear

 Saves the current data in the NanoScan software *nsd format for review and reanalysis using the NanoScan software

 Opens the Print Dialog box for printing the NanoScan Report

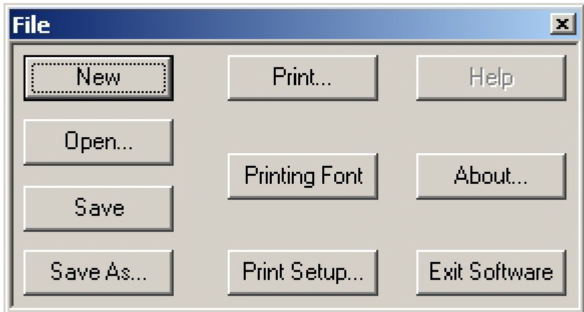
 Opens Help for NanoScan

 Performs a single AutoFind

 Starts and Stops Profile Data Acquisition

5.1.3 File ToolControl Dialog Box

The **File ToolControl** Dialog box is used for basic file handling operations, including opening files, file saving, and printing.



New — Opens a new file.

Open… — Opens saved files. The File Open dialog box will appear.

Save — Saves the current data in the NanoScan software***.nsd** format for review and reanalysis using the NanoScan software.

Save As… — Opens the File Save As dialog box for renaming files and selecting the file format.

Possible selections are:

- ***.nsd** — NanoScan software format for review and reanalysis using the NanoScan software;
- ***.txt** — Text (ASCII) format for review and reanalysis using other programs.

The dialog lists files from the current working directory in the selected format.

Print — Print dialog for printing the NanoScan Report.

Printing Font… — Opens a dialog box for selecting the font for printing the NanoScan Report.

Print Setup… — Opens a dialog for selecting and configuring printers.

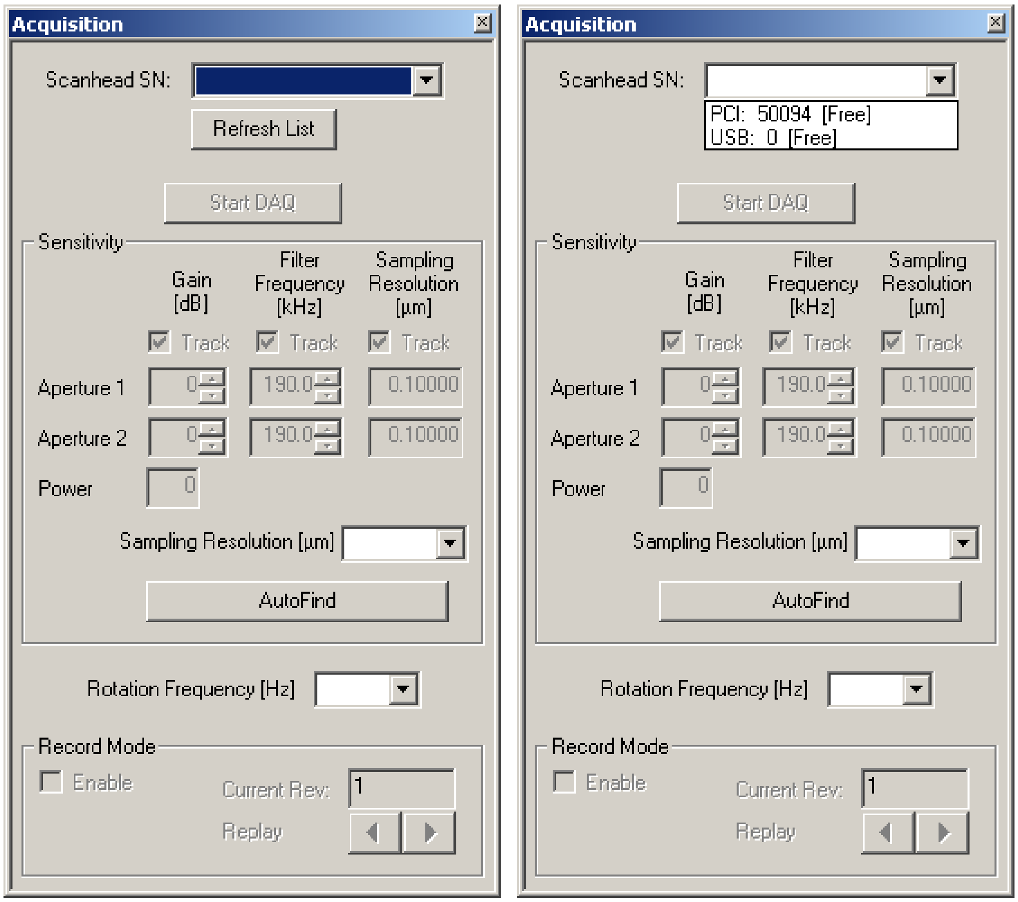
Help — Opens Help for NanoScan.

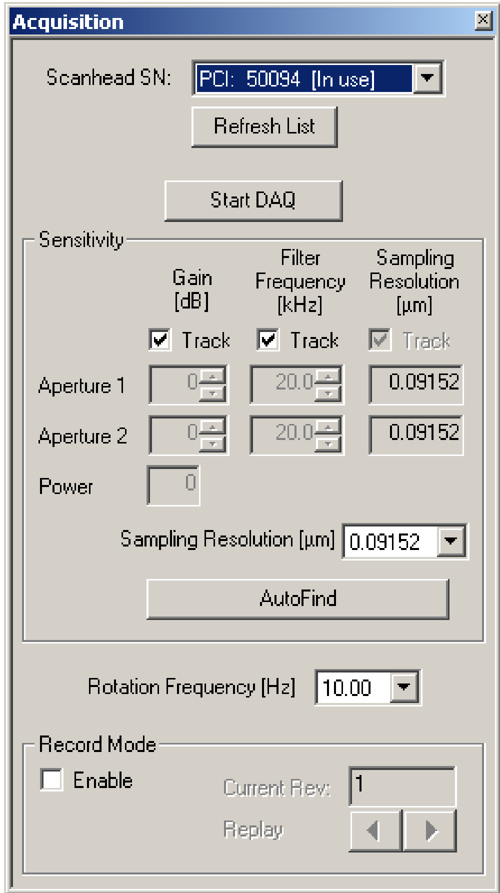
About… — Displays software version information.

Exit Software — Closes the NanoScan application.

5.1.4 Acquisition ToolControl Dialog Box

The **Acquisition ToolControl** dialog box is used to select a NanoScan scanhead, start and stop data acquisition; for automatic or manual selection of gain and filter settings for aperture 1, aperture 2, and the power aperture; for setting the NanoScan scanhead rotation rate; and for setting the resolution sampling factor. A scanhead MUST be selected prior to starting data acquisition; the Acquisition Controls are grayed out until a selection is made. Selection of a scanhead is by serial number (SN). A SN of 0 indicates a NanoScan PCI or USB card has been detected, but no scanhead is connected. Once a scanhead is selected, the controls for Start DAQ, Gain, and Filter Frequency, Sampling Resolution, AutoFind, Rotation Frequency, and Record Mode become active.





Scanhead S/N — Dropdown list for displaying status (“Free” or “In use”) and for selection of installed NanoScan PCI or USB 2.0 Cards. A single instance of the NanoScan software can control only one card at a time, selected from this dropdown list. Similarly, there can be up to 10 instances of the NanoScan Software running simultaneously, but each instance can operate only a single card at a time, also selected from the dropdown list in each instance.

Refresh List — Refreshes the list of available devices to the present state; (in the event of disconnects)

Start DAQ/ Stop DAQ — Starts and Stops Profile Data Acquisition.

Sensitivity — Sets and displays the profile acquisition parameters for Aperture 1, Aperture 2, and the Power Aperture. These include the amplifier gain in dB, the filter frequency in kHz, and the Spatial Sampling Resolution in microns.

Gain Track

Enables Gain Tracking to automatically set the gain for all apertures. The gains for Aperture 1 and Aperture 2 are set so the maximum of the peak values of all ROIs is 1dB below saturation. In Pulsed Mode the gains for both apertures are set so the maximum of the peak values of all ROIs is below half scale. When Gain Tracking is enabled, the Profile Averages and Rolling Profile Averages in the Acquisition ToolControl Dialog Box are disabled and the averaging is set to one.

Filter Frequency Track

Enables Filter Tracking to automatically set the filter to reduce noise. The filter setting is based on beam width. When Filter Frequency track is enabled, the Profile Averages and Rolling Profile Averages in the Acquisition ToolControl Dialog Box are disabled and the averaging is set to one.

Aperture 1

All of the parameters below are set automatically by the NanoScan to match the operating conditions, and in most cases the software-chosen values will be the most appropriate for use. They can be manually set by the user, however. In order to understand the effects of setting different values for these parameters, we provide explanations for each parameter.

Gain

Sets the amplifier gain for Aperture 1 in dB.

Gain is the amplifier setting that provides the best full-scale output of the beam profile that is not saturated. This value is most easily chosen by activating the AutoGain feature of the NanoScan Software.

Filter Frequency

Sets the filter frequency for Aperture 1 in kHz.

This function controls the photo detector amplifier electron 3dB cutoff. A filter too large allows noise onto the profile signal. Noise will increase the spot size and position variance. A filter that is too small for a given beam size will measure the spot size larger than actual, so one should experiment to set the filter manually. The automatic filter settings will suffice for most laser beams.
Q-switch operation opens the filter to maximum to allow capture of narrow rapid pulses.

Sampling Resolution

Displays the sampling resolution for Aperture 1 in microns.

This value controls the number of samples taken across the beam. The smaller the number the more data is collected. The automatic setting will try to set this value so that there are ~100 data points across the beam width. Setting the sampling resolution to a number too small does not improve the quality of the data, but it does increase the amount of data. This will tend to slow down the acquisition and make data files much large than they need to be. There is a more detailed discussion of the effects of sampling resolution in Chapter 4.4.4.2 on Spatial Sampling.

Aperture 2

All of the parameters below are set automatically by the NanoScan to match the operating conditions, and in most cases the software-chosen values will be the most appropriate for use. They can be manually set by the user, however. In order to understand the effects of setting different values for these parameters, we provide explanations for each parameter.

Gain

Sets the amplifier gain for Aperture 1 in dB.

Gain is the amplifier setting that provides the best full-scale output of the beam profile that is not saturated. This value is most easily chosen by activating the AutoGain feature of the NanoScan Software.

Filter Frequency

Sets the filter frequency for Aperture 2 in kHz.

This function controls the photo detector amplifier electron 3dB cutoff. A filter too large allows noise onto the profile signal. Noise will increase the spot size and position variance. A filter that is too small for a given beam size will measure the spot size larger than actual, so one should experiment to set the filter manually. The automatic filter settings will suffice for most laser beams.
Q-switch operation opens the filter to maximum to allow capture of narrow rapid pulses.

Sampling Resolution Displays the sampling resolution for Aperture 2 in microns.

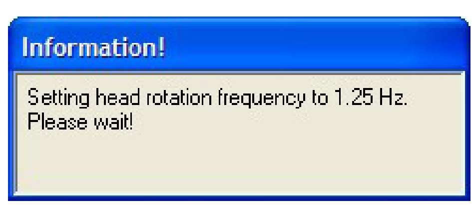
This value controls the number of samples taken across the beam. The smaller the number the more data is collected. The automatic setting will try to set this value so that there are ~100 data points across the beam width. Setting the sampling resolution to a number too small does not improve the quality of the data, but it does increase the amount of data. This will tend to slow down the acquisition and make data files much large than they need to be. There is a more detailed discussion of the effects of sampling resolution in Chapter 4.4.4.2 on Spatial Sampling.

Power Aperture Gain Displays the gain that is set automatically for the Power Aperture

Sampling Resolution Sets the sampling resolution in microns. The sampling resolution is the same for Aperture 1 and Aperture 2 and is related to the scanhead rotation frequency. In Pulsed Mode operation, the spatial sampling is limited to fine sampling values (small numbers) to allow capture of narrow rapid pulses. The sampling resolution selection is disabled in Record Mode. Select the desired sampling resolution before enabling the Record Mode.

AutoFind Initiates a “one-shot” operation that automatically adjusts the amplifier gain, filter setting and sampling resolution for each aperture, and the gain for the power aperture. AutoFind function is disabled in Record Mode.

Rotation Frequency Sets the NanoScan scanhead rotation frequency. The sampling resolution changes with the rotation frequency. An information message is displayed until the head reaches the new rotation frequency.



If the head rotation frequency cannot be set within 0.01% accuracy, a warning message will be displayed.

The rotation frequency is related to the spatial sampling. At the 0.01% stability level, the beam position accuracy is .1um/mm. The beam diameter accuracy is only affected if the stability exceeds the 1% level.

Head Rotation Frequency selection is disabled in Record Mode. Select the desired head rotation frequency before enabling the Record Mode.

Record Mode

The maximum number of scans depends on the sampling resolution (the finest sampling resolution is 0.00572 µm at 1.25Hz). The software will compute the memory needed to record one full scan and then, based on the total memory of the computer, it will set the maximum number of scans that can be recorded (not greater than 100). When Record Mode is enabled, data acquisition stops automatically after it reaches the maximum number of scans. Actions like changing the head rotation frequency, changing the sampling resolution, performing an AutoFind, or enabling pulsed beam analysis are disabled in this mode. Make these selections before entering the Record Mode. Gain and filter frequency settings for both apertures are stored for each recorded revolution. The recorded revolutions data can be saved only as an .nsd file.

Enable

Enable/disable the record/replay mode. This option is available only when the data acquisition is stopped. When the Record Mode is enabled, the software will compute and allocate the necessary buffers. Refer to the table below for memory allocation for minimum sampling resolution at different head rotation speeds.

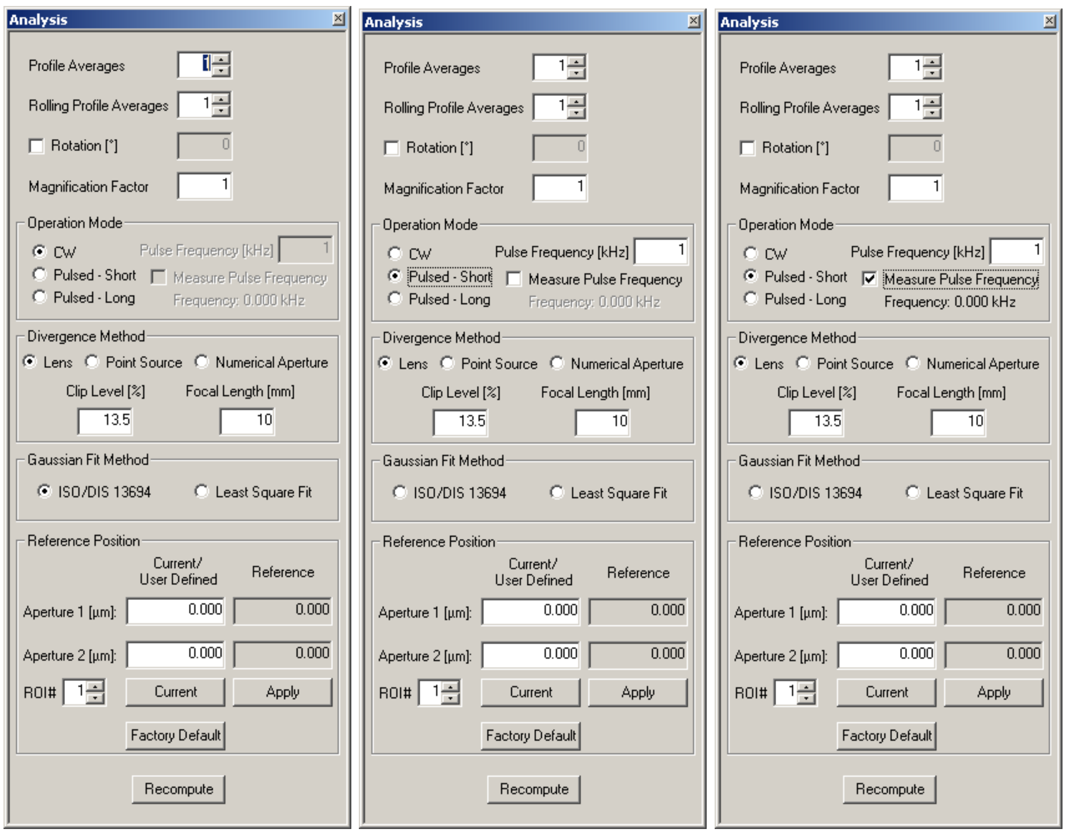
Head Rotation Frequency [Hz]	20	10	5	2.5	1.25
Minimum Sampling Interval [µm]	0.09152	0.04576	0.02288	0.01144	0.00572
Memory allocation for one Scan [MB]	0.7503	1.5005	3.0011	6.0021	12.004
Memory allocation for 100 recorded Scans [MB]	75.027	150.054	300.107	600.215	1200.429

Current Rev

Displays the current recorded/replayed revolution.

5.1.5 Analysis ToolControl Dialog Box

The **Analysis ToolControl** Dialog box is used to set the Operation Mode of the Scanhead for either CW or Pulsed measurements; to set the number of Profile Averages and Rolling Profile Averages for profile and rolling profile analysis; to set the angle for the Pointing view rotation transformation; to set the system Magnification; to select the Divergence Method and Gaussian Fit Method; to set the Reference Position for Centroid Analysis; and for executing a re-computation of data for analysis.



Profile Averages Selects the number "N" of profiles to be used in beam analysis. Reported profiles and parameters for each beam are for a sum of N profiles. Data update rate is 1/N the normal rate. If the Gain or Filter Frequency Tracking is enabled in the Acquisition ToolControl Dialog box, the number of averages is set to one and averaging is disabled.

Rolling Profile Averages Selects the number "N" of profiles to be used in rolling profile analysis. Reported profiles and parameters for each beam use the latest N profiles acquired. After the first N samples are acquired the data update is at the normal rate.

Rotation

Selects the Rotation Transformation mode for the Pointing View, and allows for entering the rotation angle. The beam centroid values are computed along the scanhead axis (default coordinate system). The rotation angle determines a new coordinate system, which is used for computing centroid position and separation.

Magnification Factor

Sets the magnification factor when using magnifying optics for beam profiling. The magnification factor scales the spatial sampling resolution. The default setting is 1.

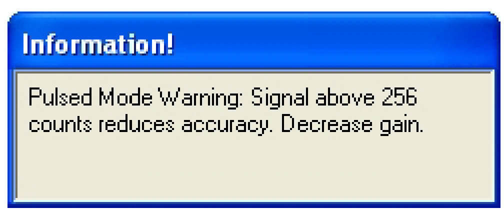
Operation Mode

CW

Selects operation for CW lasers

Pulsed - Short

Selects operation for Pulsed lasers with “Short” pulse duration <~10ns. In this mode to provide the specified accuracy the profile amplitude must be < 256 counts to avoid amplifier nonlinearity. The Profile View Display switches vertical scale to ×10. With Gain Tracking selected the amplitude will be limited to <256 counts. However, Gain can also be set manually. In this case if the Gain is set so that the amplitude is greater than 256 counts, an information message will be displayed warning the user to decrease the gain.



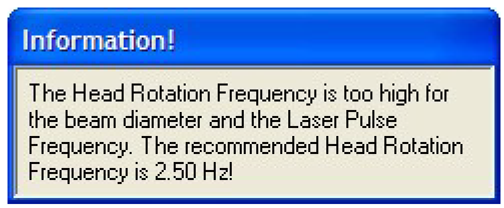
Pulsed - Long

Selects operation for Pulsed lasers with “Long” pulse duration >~10ns. In this mode the Full-Scale amplitude is limited to 2500 counts to avoid amplifier nonlinearity and subsequent measurement error.

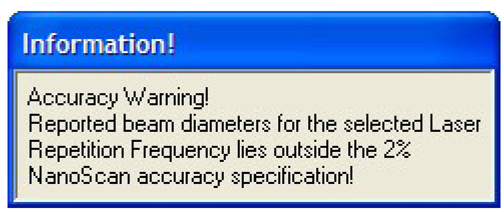
When operating in Pulsed Mode, the peaks of the individual pulses in the profile are connected to form a smooth profile. All parameter computations will be performed on the resulting smooth profile.

Measurement accuracy depends on the Pulse-to-Pulse Repeatability, on the number of pulses in the profile during a single scan, which in turn depends on the laser repetition rate and beam diameter, and on Profile Averaging.

A minimum of 15 pulses per single scan is required to obtain specified accuracy. If there are not enough pulses present in a single scan (<15), the software computes the corresponding head rotation frequency and displays an information message recommending a lower head speed.



If the computed head rotation frequency for the current conditions is below 1.25Hz, an information message will be displayed warning the user about operating the NanoScan system outside the ±2% accuracy specification.



Refer to chapter 4.2.4 Pulsed Beam Measurement for more information about measuring pulsed beams.

Pulsed Mode selection is disabled in Record Mode. Enable/disable the pulsed mode and input the laser pulse repetition rate before entering the Record Mode. In Pulsed Mode the filter is automatically set to 190KHz and filter control is disabled.

Pulse Frequency [kHz]

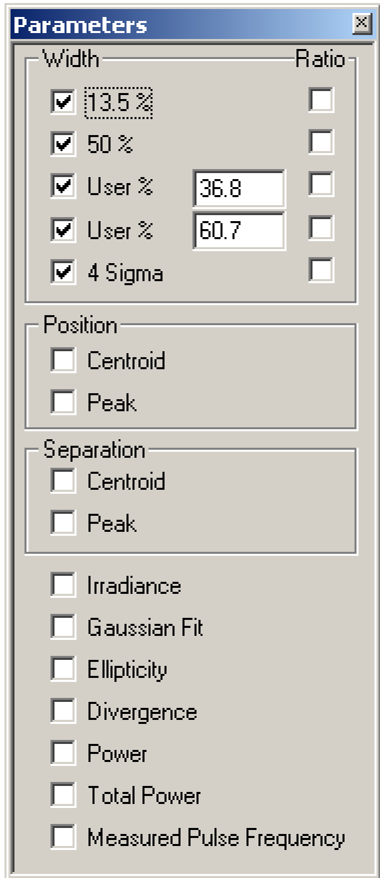
Used to enter the laser pulse rate in kHz. The allowed frequency range is 0.1-1000kHz.

Measure Pulse Frequency	When selected, the Laser Pulse Frequency is measured and displayed here as a check for incorrect user entered values. If the new measured value is uncertain, the display “grays out” and the previous measured value is still displayed. This parameter is also reported in the Parameter View. Here a value of “0” is reported if the measurement is uncertain.
Divergence Method	Selects the divergence analysis method. Divergence parameters are computed and displayed only if the **Divergence** is selected in the **Parameters ToolControl Dialog Box**.
Lens	Selects the Lens Method for divergence.
Clip Level	Sets the Clip Level for the divergence.
Focal Length	Used for entering the lens focal length in millimeters.
Point Source	Selects the Point Source Method for divergence.
Clip Level	Sets the Clip Level for the divergence.
Source Distance	Used for entering the distance between the source and the NanoScan measurement plane in millimeters.
Numerical Aperture	Selects the Numerical Aperture Method for divergence.
Clip Level	Sets the Clip Level for the divergence.
Source Distance	Used for entering the distance between the source and the NanoScan measurement plane in millimeters.
Gaussian Fit Method	Selects the Gaussian Fit computation method. The Gaussian Fit parameter is computed and displayed only if the **Gaussian Fit** is selected in the **Parameters ToolControl Dialog Box**.
ISO/DIS 13694	Computes the Gaussian Fit using the ISO 13694 standard method.
Least Square Fit	Computes the Gaussian Fit using the Least Square Fit method.
Reference Position	Displays and sets the reference position used for centroid computation. The reference position can be anywhere in the scanhead entrance aperture within an ROI for Aperture 1 and Aperture 2.

Aperture 1	
Current/User Defined	Displays the current centroid value for aperture 1 in the selected ROI, or is used to enter a User Defined centroid reference value.
Reference	Displays the reference position for Aperture 1
Aperture 2	
Current/User Defined	Displays the current centroid value for aperture 2 in the selected ROI, or is used to enter a User Defined centroid reference value.
Reference	Displays the reference position for Aperture 2
ROI #	Selects the ROI used for the reference
Current	Sets the value in the Current/User Defined display to the current value
Apply	Sets the Current/User Defined value as the reference
Factory Default	Sets the Factory Default position as the reference
Recompute	Recomputes the selected parameters.

5.1.6 Parameters ToolControl Dialog Box

The **Parameters ToolControl** Dialog box is used to select parameters reported in the Parameters Panel.



Width

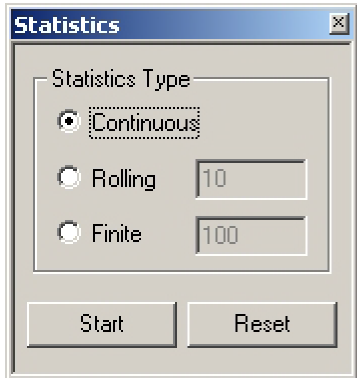
13.5%	Displays the 13.5% ($1/e^2$) clip level d_{slit} - width in the Parameters panel.
50%	Displays the 50% (FWHM) clip level d_{slit} -width in the Parameters panel.
User%-1	Displays a User selected %-clip-level d_{slit} - width in the Parameters panel.
User%-2	Displays a User selected %-clip level d_{slit} - width in the Parameters panel.
4 Sigma	Displays the ISO Standard 11146 $d_{4\sigma}$ beam width in the Parameters panel.
Width Ratio	Displays the selected width ratio. The width ratio is defined to be ≤ 1.

Position	
Centroid	Displays the positions of the Centroids of the ROI profiles in the Parameters panel.
Peak	Displays the positions of the Peaks of the ROI profiles in the Parameters panel.
Separation	
Centroid	Displays the separation between the Centroid positions of the ROI profiles in the Parameters panel.
Peak	Displays the separation between the Peak positions of the ROI profiles in the Parameters panel.
Irradiance	Displays the beam Irradiance in each ROI in the Parameters panel.
Gaussian Fit	Displays the Gaussian Fit for each ROI in the Parameters panel. Select the Gaussian Fit computation method in the Analysis ToolControl Dialog Box.
Ellipticity*	Displays the beam Ellipticity for each ROI in the Parameters panel.
Divergence	Displays the divergence parameters. Select the Divergence analysis method in the Analysis ToolControl Dialog Box.
Power	Displays the calculated power in each ROI as percent of the total power in the Parameters panel.
Total Power	Displays the measured beam Total Power in NanoScan scanhead Power Aperture in the Parameters panel.
Measured Pulse Frequency	Displays the Measured Pulse Frequency when operating in Pulsed Mode

*Ellipticity is only meaningful if the axis of scan is aligned with the major and minor axes of the beam(s). This is usually not the case in multibeam analysis.

5.1.7 Statistics ToolControl Dialog Box

The **Statistics ToolControl** Dialog box is used to set the Statistics Type, and to Start and Reset display of parameters in the Parameters panel.



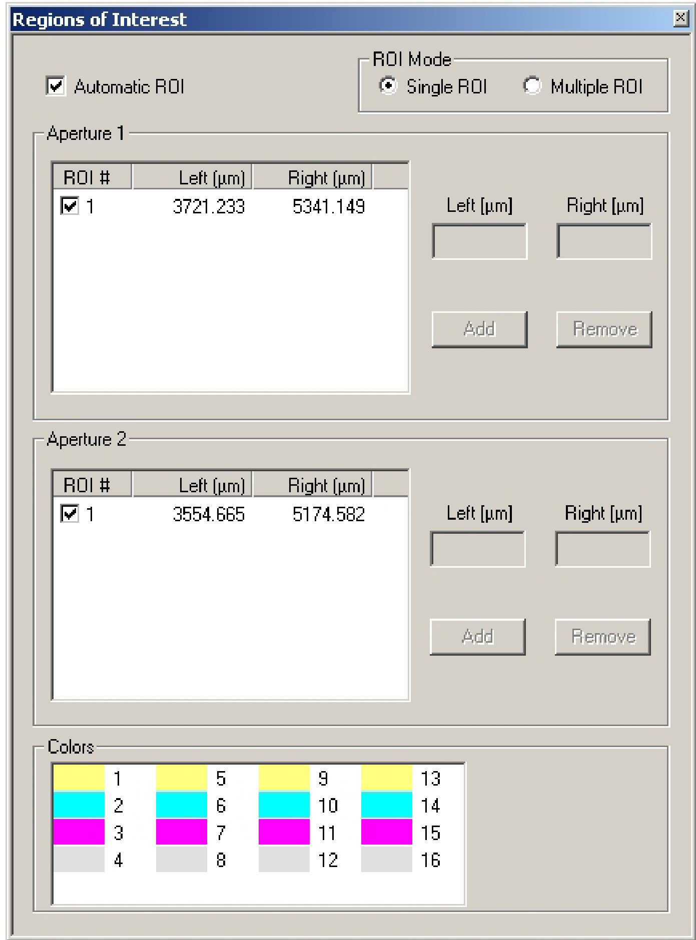
Continuous	Sets the parameter panel for display of statistics for continuous sequential profile samples.
Rolling	Sets the parameter panel for display of statistics for a rolling average of "N" profiles.
Finite	Sets the parameter panel for display of statistics for a finite average of "N" profiles.
Start/Stop	Starts/stops statistics in the Parameters panel.
Reset	Resets the Parameters display panel.

5.1.8 Regions of Interest (ROI) ToolControl Dialog Box

The **Regions of Interest ToolControl** Dialog Box is used for configuring the ROI mode, either Automatic or Manual, for selecting the Multiple Beams ROI option, and for setting ROIs and adjusting their boundaries.

5.1.8.1 Automatic ROI Mode

When **Automatic ROI** is selected, the system operates in Automatic ROI Mode. In Automatic mode, the ROIs are determined automatically by the NanoScan software. The algorithm defines beams and generates ROI boundaries based on the $1/e^2$ beam width and the beam centroid position.



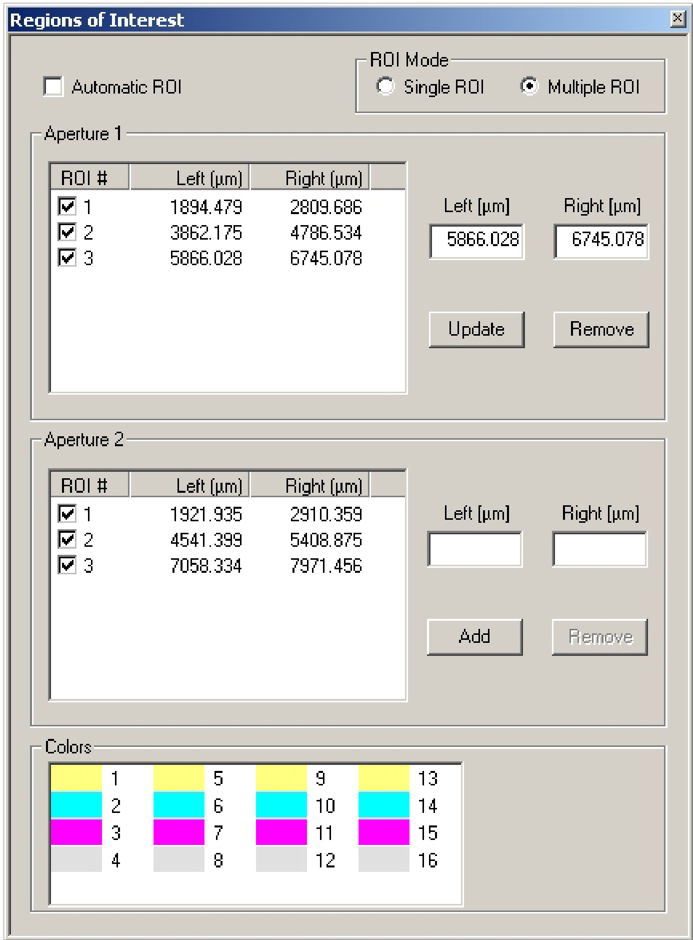
Aperture 1 Lists the Left and Right boundary positions for each ROI in Aperture1. The Left and Right edit boxes and the Add and Remove buttons are inactive when in Automatic mode. The check box under ROI # selects the display of parameters for the corresponding ROI.

Aperture 2 Lists the Left and Right boundary positions for each ROI in Aperture2. The Left and Right edit boxes and the Add and Remove buttons are inactive when in Automatic mode. The check box under ROI # selects the display of parameters for the corresponding ROI.

Colors The color of the respective ROI boundaries displayed in the Profile View can be individually set using the Colors control. Selecting an ROI opens the Color Dialog for changing the color.

5.1.8.2 Manual ROI Mode

When **Automatic ROI** is not selected, the system operates in Manual ROI Mode. In Manual mode, the ROI boundaries in Aperture 1 and Aperture 2 can be set manually using the Left and Right edit boxes, or by using the mouse pointer to drag and drop the ROI boundaries in the Profile View.



Aperture 1

Lists the Left and Right boundary positions for each ROI in Aperture 1. To manually set the boundaries using the edit boxes, first select the ROI to be adjusted. Then enter the boundaries in the appropriate edit box, and use the **Update** button to set the boundaries. To add an ROI, be sure there is no ROI selected in the list, then enter the boundaries in the edit boxes and then click the **Add** button. To remove an ROI, select the ROI and use the **Remove** button or the Delete key. The check box under **ROI #** enables the computation and display of parameters for the corresponding ROI.

Aperture 2 Lists the Left and Right boundary positions for each ROI in Aperture 2. To manually set the boundaries using the edit boxes, first select the ROI to be adjusted. Then enter the boundaries in the appropriate edit box, and use the **Update** button to set the boundaries. To add an ROI, be sure there is no ROI selected in the list, then enter the boundaries in the edit box and then click the **Add** button. To remove an ROI, select the ROI and use the **Remove** button or the Delete key. The check box under **ROI #** enables the computation and display of parameters for the corresponding ROI.

Colors The color of the respective ROI boundaries displayed in the Profile View can be individually set using the Colors control. By double clicking the left mouse button on the color in front of the ROI number opens the Color Dialog for changing the color.

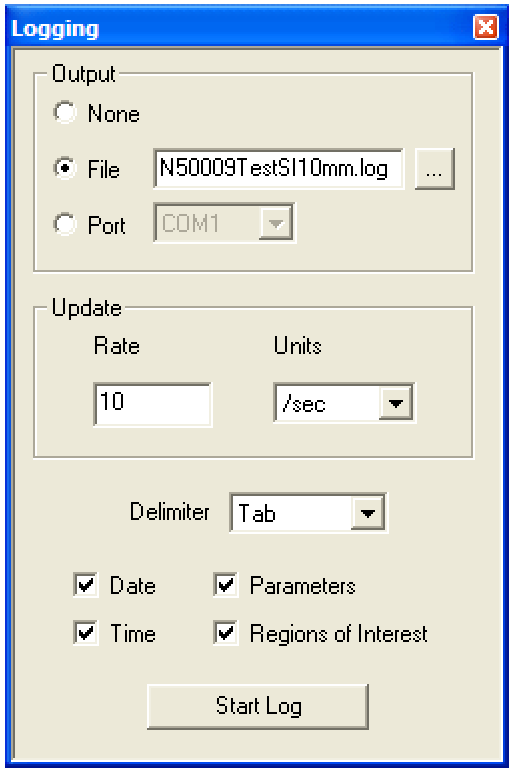
5.1.8.3 ROI Mode

Note: The easiest way to adjust ROIs is to allow the software to generate automatic ROIs. Then turn off the Auto ROI feature. The automatically generated ROIs will remain in the display, and they can then be adjusted manually.

Single ROI When selected, the system assumes a single beam and only one ROI can be automatically determined or manually defined for analysis.

Multiple ROI When selected, a maximum of 16 ROIs can be automatically determined or manually defined for analysis.

5.1.9 Logging ToolControl Dialog Box



The **Logging ToolControl** Dialog Box is used to select data logging to files or transmission of data to PC COM ports.

Output

None	Turns data logging off.
File	Enables data logging in file format (*.txt)* and allows for entry of the file directory path and name.
Port	Enables data transmission to the selected PC COM port.

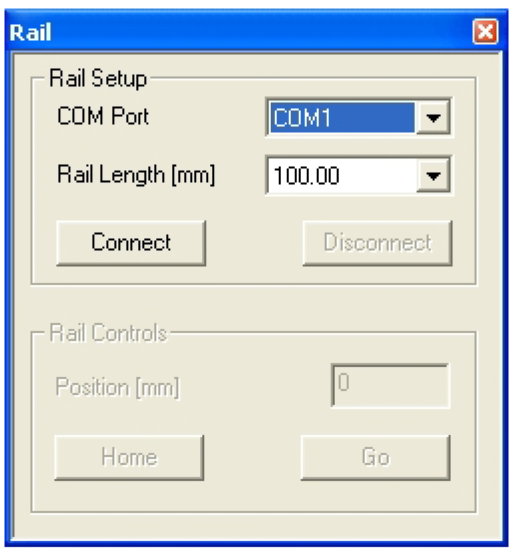
Update

Rate	Set the Log update Rate for the selected Units. If the Log Update Unit is “/sec” the maximum update rate is the current scanhead rotation frequency. If the Update Unit is “/min” or “/hour” the maximum update rate is 60. Minimum update rate is 1 for all time units.
Units	Select the time units for the Log Update. Available values are “/sec”, “/min”, “/hour”.

Delimiter	Selects the delimiter used in the data file: comma, semicolon, space, tab
Date	When selected, the date is appended to the log file.
Time	When selected, the time is appended to the log file.
Parameters	When selected, beam parameters checked in the Parameter ToolControl Dialog Box are included in the log file.
Regions of Interest	When selected, the ROI boundaries are appended to the log file.
Start/Stop Log	Starts and stops data logging. When data logging is stopped, the file is closed.

5.1.10 Rail ToolControl Dialog Box

The **Rail ToolControl Dialog Box** is used to control a RailScan system. Communication to the RailScan is established through the selected COM port. Once connected, it allows moving the scanhead to the desired position along the rail.



Rail Setup

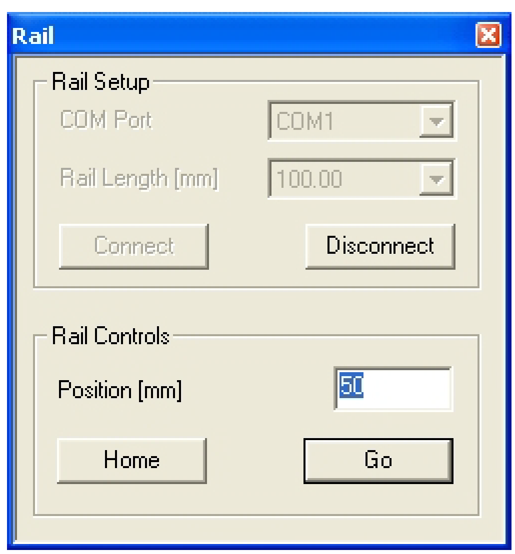
COM Port	The software will generate a list with all available COM ports on the system. Make sure the RailScan system is connected to one of these ports and then select the appropriate COM port in the dialog box.

Rail Length [mm] Select the Rail length. Available rails for the RailScan system are: 100, 200 and 500 mm.

Connect Establishes communication to the RailScan system through the selected COM port. Make sure the Motion controller is connected to the COM port and Rail system and is turned on before selecting this option. If the software cannot connect to the RailScan motion controller an error message will be displayed

Check the connections and the COM Port connection and try again. After the software connects to the Motion Controller, the Disconnect button and Rail Controls become active. COM Port and Rail Length selections are not available while the software is connected to the RailScan system.

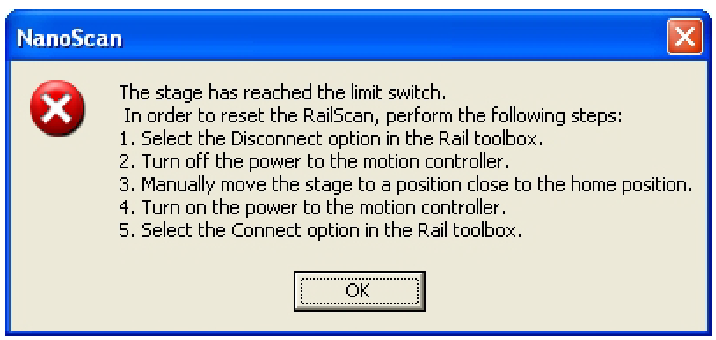
Disconnect Closes the COM Port connection to the RailScan Motion Controller and disables the Rail Controls. When the Motion Controller is disconnected, the scanhead is automatically sent to the HOME position.



Rail Controls

Position [mm]	Enter the desired position along the Rail in millimeters.
Go	Sends the scanhead to the specified position.
Home	Sends the scanhead to the HOME position (0 mm) and checks if the HOME position was reached successfully. If the scanhead does not reach the HOME position, an error message will be displayed.

The RailScan system is equipped with two Limit Switches, one at each end of the Rail. If one of the Limit Switches is tripped, an error message will be displayed. Follow the procedure outlined in the error message to reset the RailScan system.



5.1.11 Profile View Options ToolControl Dialog Box

The **Profiles View Options ToolControl Dialog Box** is used for selecting options for the Profile View. See section 5.2.1.1 for a complete description.

5.1.12 Pointing View Options ToolControl Dialog Box

The **Pointing View Options ToolControl Dialog Box** is used for selecting options for the Pointing View. See section 5.2.2.1 for a complete description.

5.1.13 Power View Options ToolControl Dialog Box

The **Power View Options ToolControl Dialog Box** is used for selecting options for the Power View. See section 5.2.3.1 for a complete description.

5.1.14 2D/3D View Options ToolControl Dialog Box

The **2D/3D View Options ToolControl Dialog Box** is used for selecting options for the 2D/3D View. See Section 5.2.5.1 for a complete description.

5.1.15 Time Chart View Options ToolControl Dialog Box

The **Time Chart View Options ToolControl Dialog Box** is used for selecting options for the Time Charts View. See section 5.2.6.1 for a complete description.

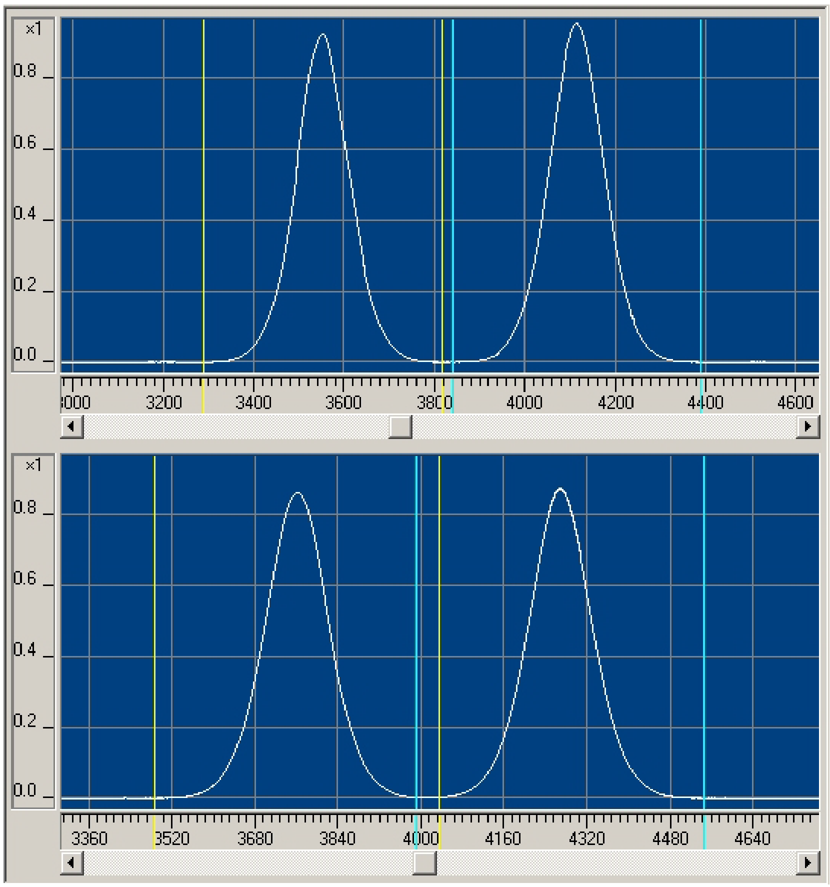
5.2 Views Panel

The Views panel displays the Profile View, the Pointing View, the Power View, or the Notes View. The View for display is selected using the control buttons at the top of the panel.

Profiles	Selects the Profile View for display in the Views panel.
Pointing	Selects the Pointing View for display.
Power	Selects the Power View for display.
Notes	Selects the Notes View for display.
2D/3D	Selects the 2D/3D View for display.
Time Charts	Selects the Time Charts View for display.

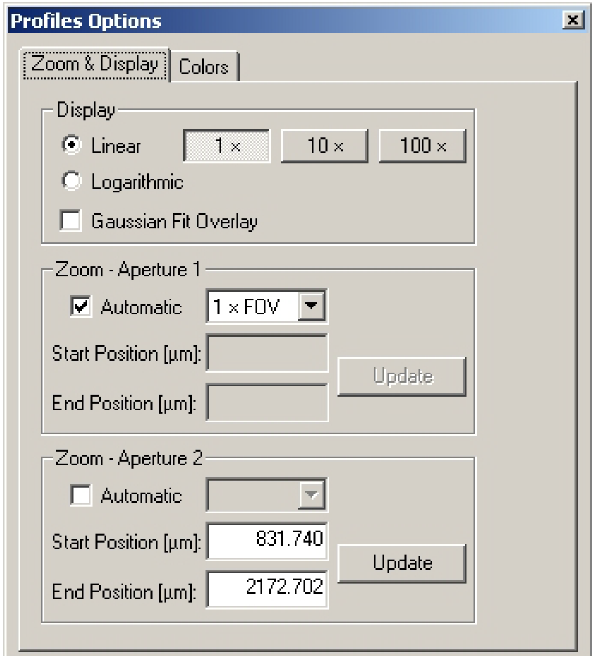
5.2.1 Profile View

The Profile View displays the acquired beam profile data for each aperture of the NanoScan scanhead. Options for setting the profile amplitude Vertical scale, the spatial Horizontal Scale, and the color format of the display are available using the Profiles Control button.



5.2.1.1 Options for Profiles View

Options for the Profile View are made using the **Profiles View Options ToolControl** Dialog Box. The display options include selections for horizontal and vertical scale, and colors. The horizontal and vertical scales can be set either automatically or manually. In Automatic Mode, the NanoScan Software sets the spatial Horizontal scale of the display automatically. The Manual Mode allows for manually setting the Horizontal scale. The profile amplitude Vertical scale can be either linear with up to 1x, 10x, or 100x magnification, or logarithmic.



5.2.1.1.1 Zoom & Display

Display

Linear — Selects the Linear Vertical scale, with either 1x 10x, or 100x magnification. When Pulsed Mode operation is selected, the vertical scale is set to 10x magnification and the 1x option is unavailable.

Logarithmic — Selects the Logarithmic Vertical scale.

Gaussian Fit Overlay — When selected, the Gaussian fit will be displayed over the profiles in the Profile View. Gaussian Fit parameter must be selected for computation for the fit overlay to work.

Zoom-Aperture 1

Automatic — When selected, the Aperture 1 display operates in Automatic Mode, with selectable Field of Views (FOV) of 1x, 2x, 5x, 10x, or entire aperture. The FOV is the extent of all ROIs. When not selected the Aperture 1 display operates in Manual Mode.

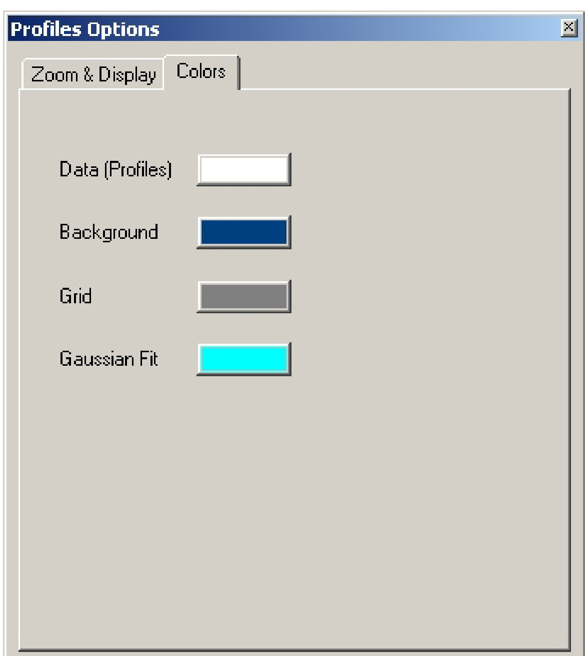
Start Position — Edit box for displaying and entering the Start position of the Horizontal scale. Available only in the Manual mode.

End Position	Edit box for displaying and entering the End position of the Horizontal scale. Available only in the Manual mode.
Update	Sets the Start and End positions entered in the Edit boxes. Available only in the Manual mode.

Zoom-Aperture 2

Automatic	When selected, the Aperture 2 display operates in Automatic Mode, with selectable Field of Views (FOVs) of 1x, 2x, 5x, 10x, or entire aperture. The FOV is the extent of all ROIs. When not selected the Aperture 2 display operates in Manual Mode.
Start Position	Edit box for displaying and entering the Start position of the Horizontal scale. Available only in the Manual mode.
End Position	Edit box for displaying and entering the End position of the Horizontal scale. Available only in the Manual mode.
Update	Sets the Start and End positions entered in the Edit boxes. Available only in the Manual mode.

5.2.1.1.2 Colors



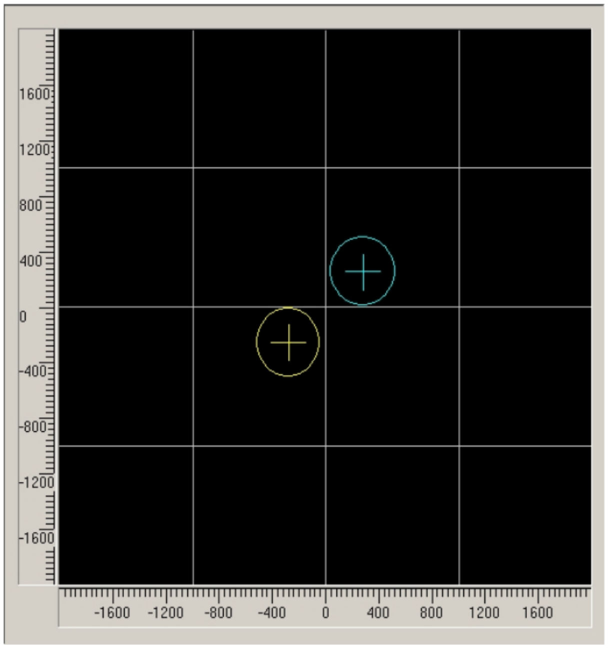
Data(Profiles)	Opens the Color Dialog for selecting the color of the Profiles.

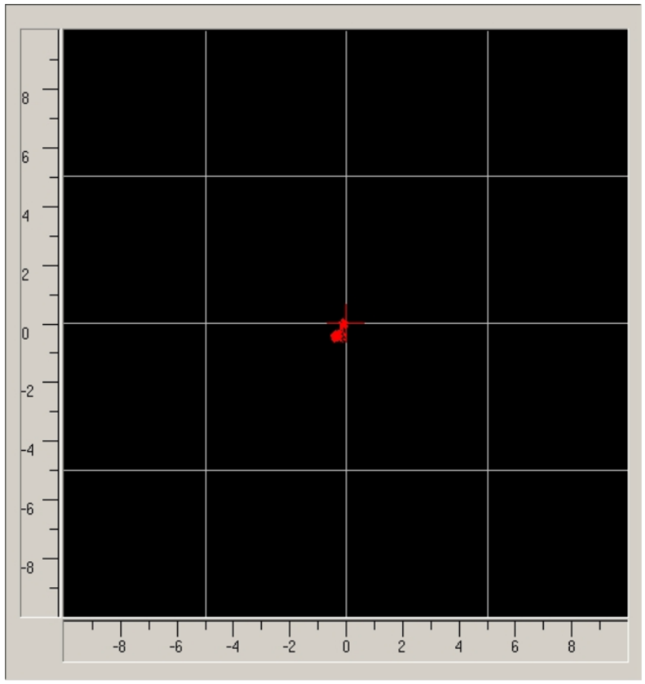
Background	Opens the Color Dialog for selecting the color of the display background.
Grid	Opens the Color Dialog for selecting the color of the display grid.
Gaussian Fit	Opens the Color Dialog for selecting the color of the Gaussian Fit.

5.2.2 Pointing View

The Pointing View displays spatial positions of the beam profile in each ROI on a Cartesian grid. The perspective of the view is looking toward the NanoScan scanhead entrance aperture. The axes of the display are oriented along the scanhead axes or along the direction determined by the rotation angle set in the **Analysis ToolControl Dialog Box**. The spatial position of either the Peak or Centroid is displayed as cross hairs or points. The beam contour at the $1/e^2$ clip level can also be displayed. An Accumulate Mode can be used to overlay a sequence of beam positions. The Zero Reference of the position scale can be set manually and the range of the scale can be changed using the Zoom feature. The color of the background and the grid are selectable. The color of the cross hairs and contour overlay for each ROI are the same as that selected for the ROI boundaries in the Profile View.

Example: Pointing View display format Pointing View display showing the beam position in 2 ROIs as cross hairs, with overlays for the $1/e^2$ profile contours.

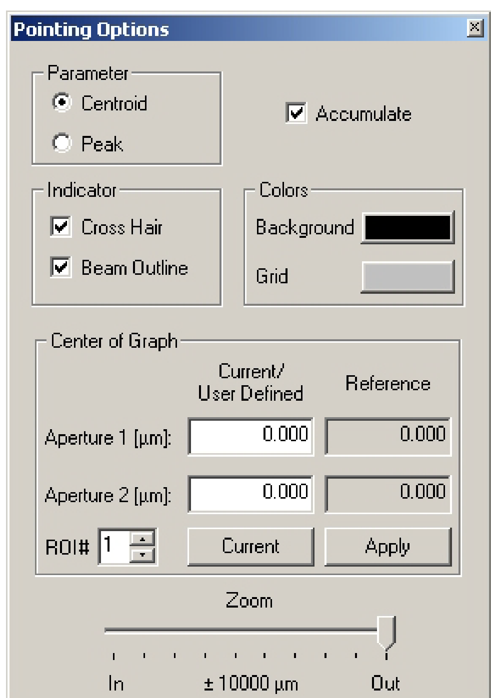




Example: Pointing View display format Pointing View display in Accumulate Mode, showing the sequentially accumulated beam positions for a single ROI.

5.2.2.1 Options for Pointing View

Display options for the Pointing View are selected using the **Pointing View Options ToolControl** Dialog Box.



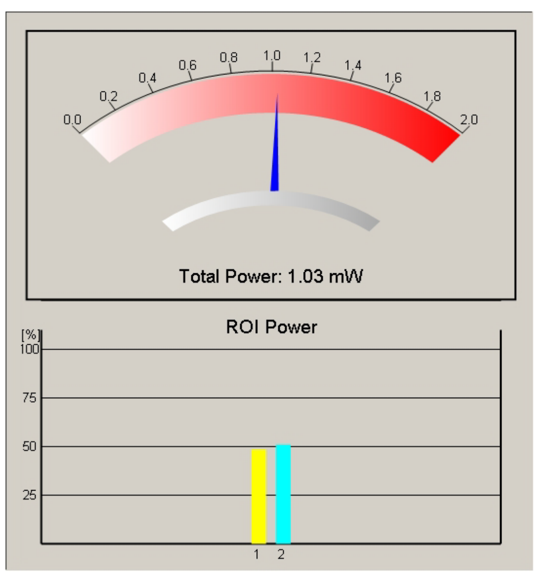
Parameter	
Centroid	Sets the location of the beam to the Centroid position. The Centroid is a calculated value for the beam location that is based on its center of mass, also known as the “first moment.” This is the point when equal amounts of the beam are on either side of the Centroid.
Peak	Sets the location of the beam to its Peak position. Peak is the point of highest intensity in a TEM_{00} Gaussian beam. Peak and Centroid will coincide. In the real world, the Peak is often in a slightly different place and may be less stable than the Centroid. It is the center-of-work for many applications and thus may be important to monitor.
Accumulate	When selected, activates the Accumulate Mode for display.
Indicator	
Cross Hair	When selected, the Peak or Centroid position of the beam profile in each ROI is displayed as a cross hair.
Beam Outline	When selected, the $1/e^2$ contour of the beam profile in each ROI is displayed as an overlay.
Colors	
Background	Opens the Color Dialog for selecting the color of the display background.
Grid	Opens the Color Dialog for selecting the color of the display grid.
Center of Graph	
Aperture 1	
Current/User Defined	Edit box for displaying the current Peak or Centroid position for Aperture 1 in the selected ROI, and for manually setting the Zero Reference.
Reference	Displays the current Zero Reference position for Aperture 1.
Aperture 2	
Current/User	Edit box for displaying the current Peak or

Defined	Centroid position for Aperture 2 in the selected ROI, and for manually setting the Zero Reference.
Reference	Displays the current Zero Reference position for Aperture 2.
ROI#	Selects a ROI.
Current	Sets the Center of Graph to the current measurement of Peak or Centroid in the selected ROI.
Apply	Sets the Zero Reference to the values in the Current/User Defined Edit boxes.
Zoom	Control for setting the scale of the Pointing View. The maximum scale is ±10,000μm. The minimum scale is ±10μm.

5.2.3 Power View

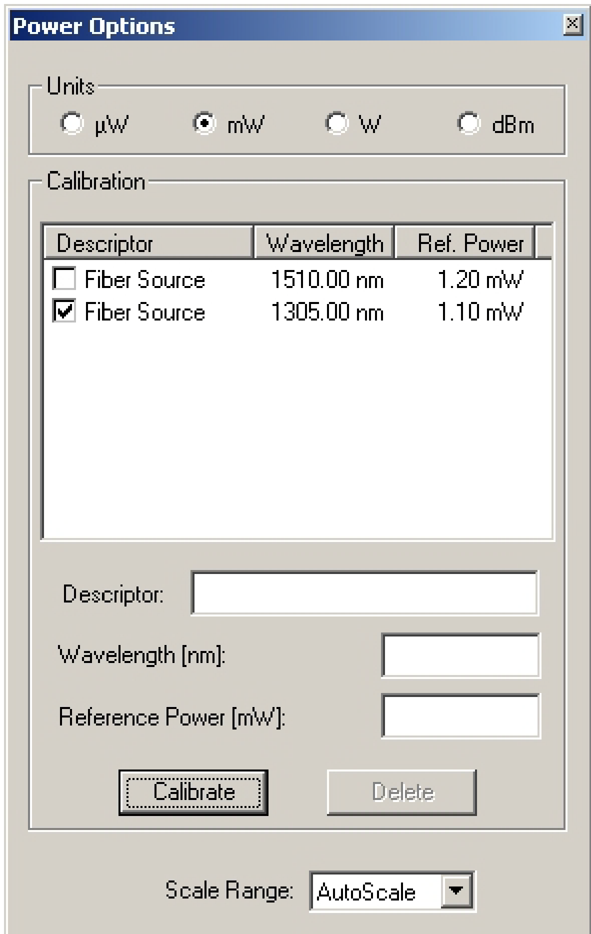
The Power View displays the Total Beam Power measured in the NanoScan scanhead entrance aperture and the calculated ROI Power in each ROI. The measured Total Power is displayed in an analog power meter format with the current value of the Total Power reported. The ROI Power is shown as a bar chart showing the percent of the Total Power in each ROI. The colors of the bar for each ROI are the same as those selected for the ROI boundaries in the Profile View.

The Power View is available only if the scanhead in use has the power option.



5.2.3.1 Options for Power View

Options for the Power View are selected using the **Power View Options ToolControl** Dialog Box. Power View Options Tool Control is available only if the scanhead in use has the power option.



Units	
µW	Selects Power View units of µW.
mW	Selects Power View units of mW.
W	Selects Power View units of W.
dBm	Selects Power View units of dBm.
Calibration	When the first calibration has been added, it will display as the default and the box will be checked. With multiple calibrations, set the default calibration by checking the desired checkbox.
Descriptor	A Text Field for entering Calibration information. Maximum 32 characters.

Wavelength A Text Field for entering the Calibration Wavelength.

Reference Power A Text Field for entering the Calibration Reference Power.

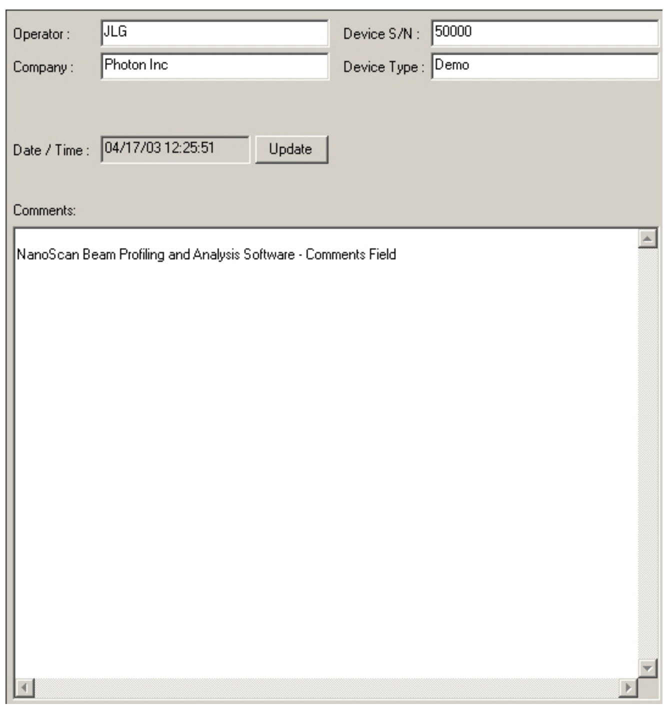
Calibrate Initiates the Calibration Procedure. At least one of the calibration text fields must be different from the previous calibration. There should be a calibration for each type of laser to be measured. The optional power meter is a relative meter and must be calibrated to a known source for each wavelength and power range to be measured.

Delete Deletes the selected Calibration.

Scale Range Selects the Full Scale range of the analog Power Meter. Selections available are AutoScale or various user-selectable ranges.

5.2.4 Notes View

The Notes View is a text editor for entering test information, comments, and time stamping.



Text Fields

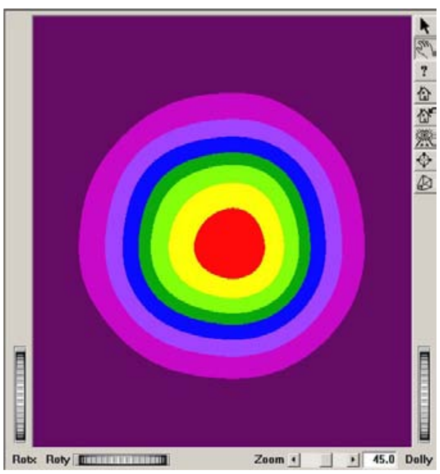
Operator Text Edit box for entering the Operator Name.

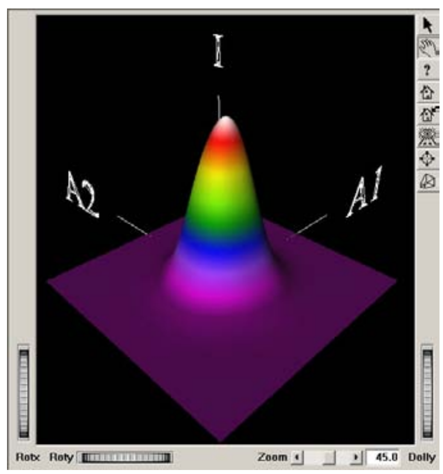
Company	Text Edit Box for entering the Company Name.
Device S/N	Text Edit Box for entering the Serial Number of the device under test.
Device Type	Text Edit Box for entering the Device Type of the device under test.
Date/Time	Displays the Date/Time stamp of the data.
Update	Time stamps the data with the current date and time.
Comments	Text Editor for entering the Comments.

5.2.5 2D/3D View

The 2D/3D View displays the laser beam image in a topographic or 3-dimensional viewing format. The laser beam image can be rendered with either a wire frame or solid surface. Display colors at different user selectable clip levels. This display is available only in **Single ROI Mode**. Refer to section **5.1.8.2** to set the software in **Single ROI Mode.**

The 2D View and the 3D View work similarly. They use the same controls.



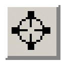


The toolbar at the right border of the view contains 8 buttons used to select several viewing and image manipulation features.

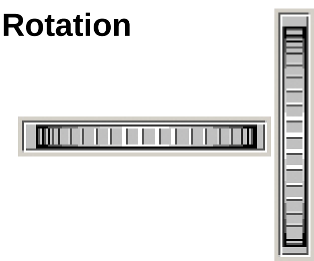
These buttons are, from top to bottom:

Select/Pick  Chooses the Arrow cursor. Allows image manipulation only using the mouse and the thumbwheel controls.

View  Chooses the Hand cursor. Allows image manipulation using the mouse *directly in the image* or by using the thumbwheel controls. (When the mouse is moved to the window border the Hand cursor changes to the Arrow cursor.)

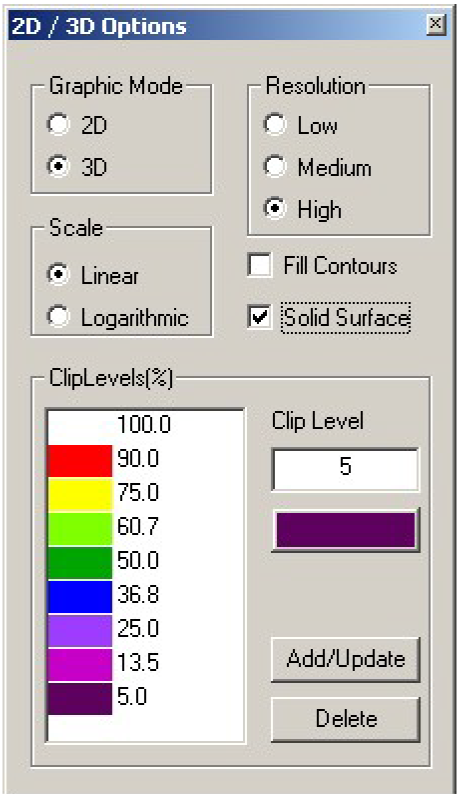
Help		This Help menu is inactive. Please use the main Help menu.
Home		Resets the view to a preset Home default position, size and orientation.
Set Home		Sets the default settings for the Home button.
View All		Restores the view to include the entire image.
Seek		Activates the Seek cursor. After positioning this cursor on a selected point in the image and clicking the left mouse button, a close-up zoom to that point will be performed automatically. Also, the center of rotation will be set to that point.
Projection		Toggles between the Perspective and Orthographic projection modes.

The image can be rotated, translated, panned, and zoomed using the mouse with the Arrow cursor and the thumbwheel control knobs or using the mouse with the Hand cursor, as described below.

Rotation		Rotate the image using the mouse and the Arrow cursor with the thumbwheels labeled ROTX and ROTY. Alternatively, use the mouse and the Hand cursor to directly rotate the image. Position the hand cursor over the image, depress the left mouse button, and drag the mouse to obtain the desired orientation.
Pan/Translate		While depressing the control key <CTRL>, use the mouse and the Hand cursor to directly pan the image. Position the hand cursor over the image, depress the left mouse button, depress the control key, and drag the mouse to move the image to the desired location.
Zoom		The method for zooming the image depends on the type of display projection selected. In the Perspective projection mode, use either the zoom control arrows at the bottom of the window, or use the Dolly thumb-wheel at the lower right border of the window. In the Orthographic projection mode, use the Zoom thumb-wheel at the lower right border of the window. Zooming in or out can also be done by depressing the Ctrl + Shift keys while dragging the mouse with the left button held down toward the center (zoom in) or away from the center (zoom out).

5.2.5.1 Options for 2D/3D View

Options for the 2D/3D View are selected using the **2D/3D View Options ToolControl** Dialog Box.



Graphic Mode	Opens a menu that allows switching the view from **2D** to **3D** and vice versa.
2D	Switches the view to 2D mode
3D	Switches the view to 3D mode
Resolution	Allows resolution selection for the display. Data update rate may be reduced and image manipulation may be slower as resolution is increased.
Low	Low display resolution.
Medium	Medium display resolution. It is the default software option.
High	High display resolution.

Scale

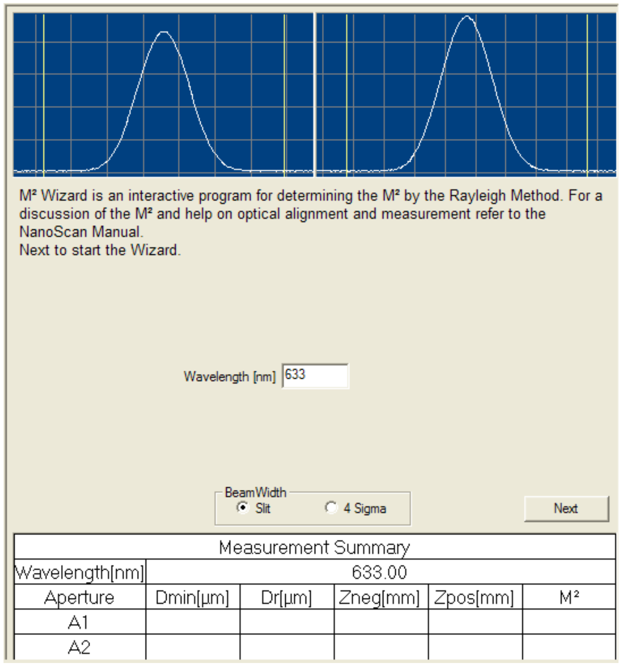
Linear	Selects linear data scaling.
Logarithmic	Selects logarithmic data scaling. In this case, the contour levels are fixed at the 0, -3, -10, -13, -20, -23, -30, -33, -40, and the –48 dB levels.
Fill Contours	When selected, different clip levels on the beam will be clearly delineated by drawing contour lines on the beam. Please be aware that this option will dramatically slow down the acquisition rate of the system. Photon does not recommend using this option while acquiring data.
Solid Surface	When selected, the image will have a solid surface. When not selected, the image will be rendered as a wire frame.
Clip Levels	When Linear Scale is selected, it allows the user to add, delete and display the clip level in various colors for different percentages of clip levels. Up to 64 different clip levels can be displayed at one time. There must be at least two clip levels in the list for normal functioning. When Logarithmic Scale is selected it displays the dB clip levels.
Clip Level List	Displays the colors associated with the clip levels. Clip levels can be selected by clicking on the desired clip level in the list.
Clip Level Edit Box	Displays the selected clip level value (%). It allows the user to enter new clip level values. The clip level values must be between 5% and 100%.
Clip Level Color	Displays the selected clip level value. It allows the user to change the color of a clip level by opening a Color Selection dialog box.
Add/Update	Adds the new clip level value and color to the list or updates the color of an existing clip level.
Delete	Deletes the selected clip level from the list.

5.2.6 M^2 Wizard View

The M^2 Wizard View is an interactive program for determining the “times diffraction limit” factor M^2 by the Rayleigh Method. The M^2 Wizard View prompts and guides the user through a series of measurements and data entries required for calculating M^2. The entered and calculated values are displayed in each step of the Wizard.

The M^2 Wizard View includes a few buttons and options for controlling the measurement.

Next	Advances to the next step in the Wizard. This button becomes available when all measurement required data has been entered.
Previous	Displays the previous step in the Wizard for modifying measurement data.
Start Over	Restarts the M^2 Wizard. All computed data is lost.
Measurement Summary	Displays the measurement data for all the steps. In the final step M^2 is computed and displayed here.
BeamWidth	Selects the beam width computation method used in the measurement: ♦ **Slit** – the 13.5% ($1/e^2$) clip level d_{slit} width is used for computations ♦ **4Sigma** – the ISO Standard 11146 $d_{4\sigma}$ beam width is used for computations This selection can be made only in the first step of the Wizard.
Wavelength [nm]	Enter the laser wavelength in nanometers. The laser wavelength is used in the computation of M^2. This selection can be made only in the first step of the Wizard.



Setup the laser and sensor so that you can easily move the sensor along the Z-axis (nearer or farther from the laser). Then start the M^2 Wizard. Follow the instructions that appear. Upon completing each step, select the **Next** button to continue. If you make a mistake select the **Previous** button and redo that step. After each step the Wizard will update the **Measurement Summary**. When the measurement is completed the data can be printed as a report or saved in the NanoScan or ASCII file format. Refer to section 5.1.3 for printing, file saving and loading.

For more information, please read Application Note 230 available from your nearest Photon Inc. representative.

The formula is:

$$M^2 = \frac{\pi \times D_{\min}^2}{2\lambda \times 2Z_r}$$

where:

$$Z_r = \frac{|Z_{\max} - Z_{\min}|}{2}$$ - Rayleigh length.

λ Wavelength.

$D_{\min}$ Beam diameter at the beam waist.

$Z_{\max}$ Distance along Z axis where beam diameter is $1.414 \times D_{\min}$ $\left(\sqrt{2}D_{\min}\right)$.

$Z_{\min}$ Distance along Z axis on the other size of the waist where beam diameter is $1.414 \times D_{\min}$ $\left(\sqrt{2}D_{\min}\right)$.

5.2.6.1 Measuring M^2

M^2 is a propagation constant for a laser source defined in the ISO standard as:

$$M^2 = \frac{\pi \times D_{\min}^2}{2\lambda \times 2Z_r}$$

Physically, M^2 can be thought of as a factor times the diffraction limit. For example, if one calculates the diffraction limit for a particular lens, the source with an M^2 = 1.2 will produce a spot width 1.2 times the theoretical calculated value.

The ISO standard requires 10 beam measurements and a curve-fitting algorithm. A faster method, called the Rayleigh method, provides accurate result with only 3 measurements.

The Rayleigh Method can easily be derived from the definitions and gives fast highly accurate and repeatable M^2 values. This method requires you to measure twice the Rayleigh length for a source. A long focal length lens (high F# ≥20) should be used. You also need the wavelength and the minimum observed beam width, $D_{\min}$, while sweeping through the beam waist.

5.2.6.2 Lens Selection and the Expected Rayleigh Length

How does one select a focusing lens? How does one determine the Rayleigh distance for a source and a lens?

We have found that the distance along the beam axis can be measured to the nearest ½mm if one selects a focused beam size from 80µm to 200µm $\left(1/e^2\right)$beam width.

Example:

Source nearly collimated wavelength 0.7μm and approximate exit beam width is 500µm $\left(1/e^2\right)$.

The divergence for a diffraction limited source ($M = k = 1$) will be:

$$\theta = \frac{4 \times \lambda}{\pi \times D}; \quad \theta = \frac{4 \times 0.7}{\pi \times 500} = 0.0018\,\text{rad}$$

We can select the lens by assuming:

$$d = f \times \theta$$

or, if we want the predicted waist diameter *d* near the focal plane to be 125µm, the required focal length is:

$$f = \frac{125}{0.0018} = 69{,}444\,\mu\text{m or } 69\,\text{mm}$$

Let's use a 75mm lens, which is more commonly found in a laboratory. The expected spot size is:

$$d = f \times \theta = 75{,}000\,\mu\text{m} \times 0.0018 = 135\,\mu\text{m}.$$

The expected Rayleigh length in the region of the waist will be:

$$Z = \frac{\pi}{4} \times \frac{d^2}{\lambda}$$

where *d* is the above 135µm calculated spot width.

$$Z = \frac{0.7854 \times 135^2}{0.7} = 20{,}448\,\mu\text{m or } 20.4\,\text{mm}$$

Thus we have a rough starting point for M^2 measurements. If M^2 is much greater than 1.0, the spot size will be larger than calculated and the Rayleigh length will be less than calculated. What is important is that by using the diffraction-limited case one has a starting point. We suggest that one try this method with a small visible HeNe laser which is nearly always close to M^2=1 to gain an appreciation for the method before trying an unknown source. If you get an M^2 value close to 1 with the HeNe source, you will have the measurement method understood! Although theoretically $M^2 \geq 1$, it is possible to get values slightly less than 1 due to beam diameter measurement errors. F you get M^2 values **significantly** <1.0 recheck alignment as well as go through the waist slow enough to allow the software time to pick the correct minimum waist.

5.2.6.3 Alignment

To measure M^2, it is necessary to move the scanhead along the optical axis of the beam through the beam waist. This alignment along the optical axis is extremely important for getting accurate results!

5.2.6.3.1 Rayleigh Test Fixture accessory

Photon offers an accessory called a Rayleigh Test Fixture, which consists of a base plate, a slide that allows manual axial [Z] translation of the scanhead, and an LCD measurement ruler. The base plate is rigidly mounted to an optical table or rail. The translation distance readout is a Mitutoyo LCD ruler that spans 150mm of travel and gives position values to the nearest 25µm. The total 150mm travel allows the Rayleigh range to be such that a beam waist of approximately 200µm can be measured.

The Mitutoyo scale can be zeroed at the first Rayleigh location, translated to the second to find a single direct read number in mm units to be inserted into the Wizard software. This accessory's purpose is to make measurements of the Rayleigh range very easy and very repeatable. The user provides a source, a focusing lens and mount.

5.2.6.3.2 Alignment of the sensor and laser beam without the focusing lens:

Before inserting the lens into the path, align the sensor axial travel motion parallel to the axis of the laser. We suggest that the non-alignment be no more than a couple of beam widths. For the example laser above, this would be ±500μm. The Pointing View can be used to measure the misalignment over the Rayleigh range.

For the example source (previous section) this means one should see no more than ±500μm motion either X or Y as one translates the sensor along the beam axis through a distance of 2*Z* (or 41mm for our example).

Note! Move slowly through the waist region so the software can keep up with the measurement process.

Record *Z*-axis position in millimeters (mm). Be sure to move slowly as you approach the beam waist minimum. The software gathers multiple samples of minimum beam width to assure accuracy. The software automatically selects the minimum value. If you want to reset this minimum value, select **Reset** button. Moving the scanhead to quickly through beam waist may cause errors.

Insert the lens:

Once the sensor and source are aligned, insert and center the lens into the beam path. Now translate the sensor through the 2*Z* length and again try to keep the cross translation to less than ±1-2 beam widths. For the example beam, use the calculated 135μm as a goal.

Be sure the lens is well centered or you will be measuring the lens aberration as well as the M^2 for the source. With a visible source, one can usually observe a back reflection from both lens surfaces. Place the back-reflected beams just slightly to the side of the laser exit aperture. Sending the reflections back into the source may cause laser oscillations due to interference.

Another centering approach is to use a machined centered removable aperture stop just before the lens. This could fit into the lens mount during alignment and be removed before measurements. Direct the beam through this small aperture (our source example uses a 2 mm hole) during alignment. Be sure to remove the stop once aligned to prevent truncation of the source and consequently errors in measured M^2.

Now you are ready to use the M^2 Wizard.

5.2.6.4 Dual Axis Measurements w/Astigmatism

To measure M^2 when the source is astigmatic, the user will need to modify the basic procedure slightly. Figure 5-1 shows what this looks like.

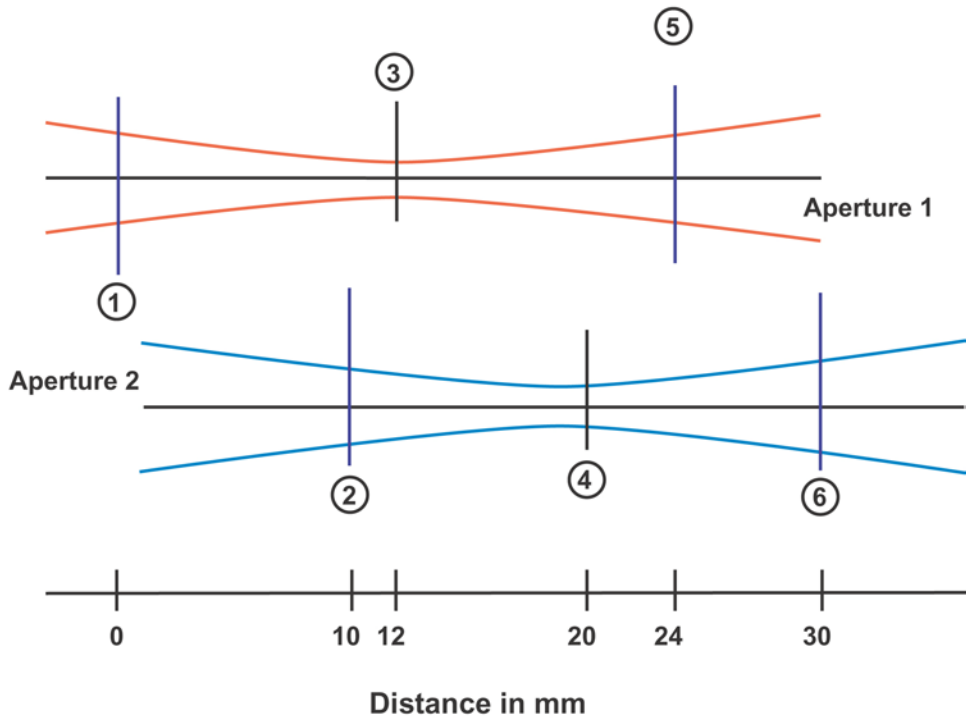


Figure 5-1. Measurement of Astigmatic Source Using the M^2 Wizard.

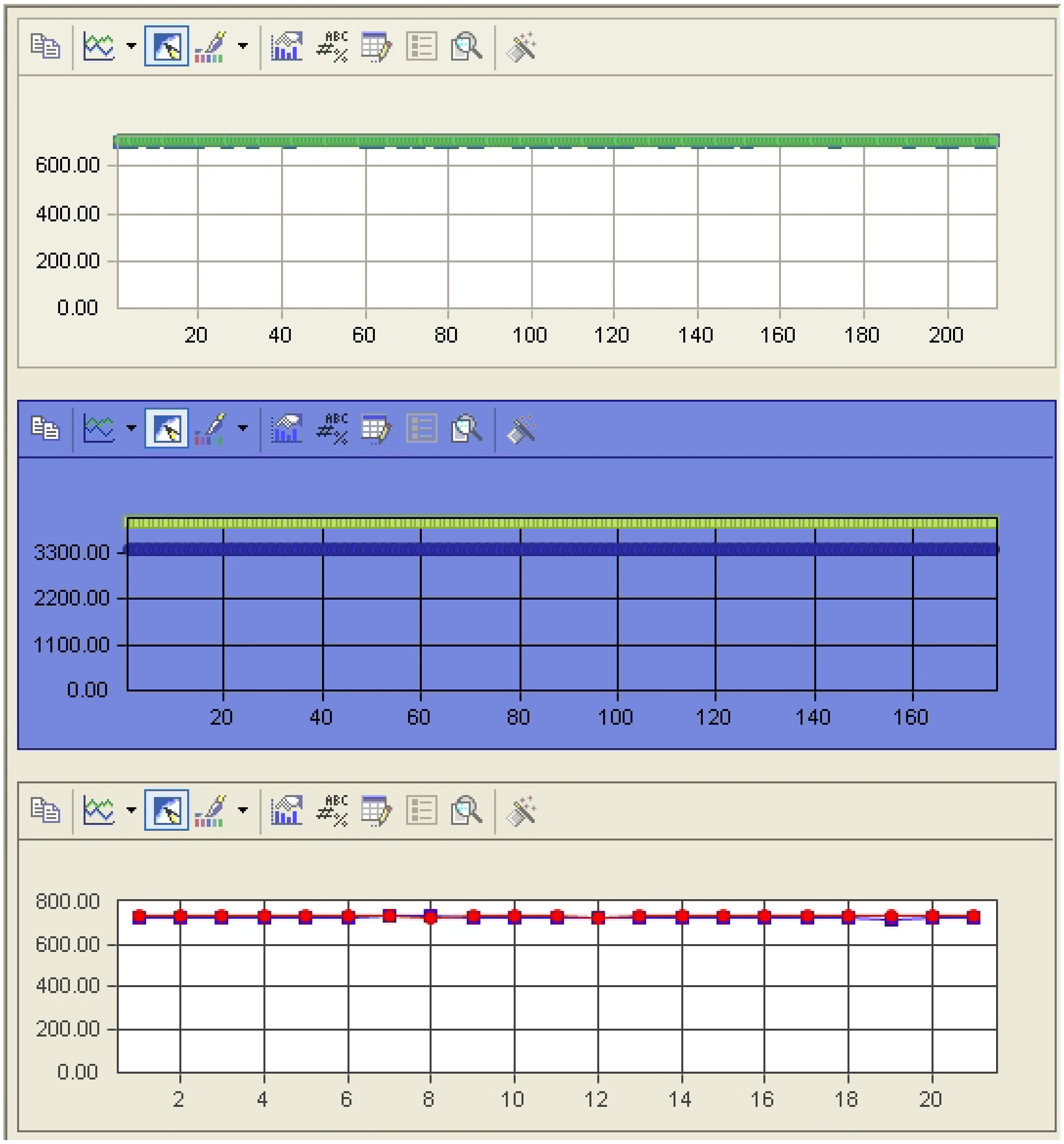
Example:

1. Move the sensor to D Target for Aperture 1. Reset the Mitutoyo scale. Enter 0 for Z Position 1 under the Aperture 1 heading.
2. Move the sensor to D Target for Aperture 2. Enter 10 for Z Position 1 under the Aperture 2 heading. Select the Next button.
3. Move slowly through the waist for Aperture 1 and verify the D_{min} is correct.
4. Move slowly through the waist for Aperture 2 and verify the D_{min} is correct.
5. Move the sensor to D Target for Aperture 1. Enter 24 for Z Position 2 under the Aperture 1 heading.
6. Move the sensor to D Target for Aperture 2. Enter 30 for Z Position 2 under the Aperture 2 heading. Select the Next button.

For more details, visit our website at www.photon-inc.com and view Application Note 230 *Fast M^2 Measures with Photon Beam Profilers*, or contact Photon.

5.2.7 Time Charts View

The Time Charts View displays strip charts for beam parameters.



Any of the selected beam parameters may be viewed this way. The three Time Charts may be run simultaneously.

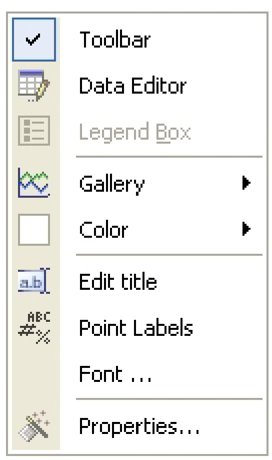
Some of the chart formatting features can be accessed through each chart's toolbar or context menu:

Copy To Clipboard		Provides options to copy the chart as a Bitmap image or as a Metafile. An option is also available to copy the chart data.
Gallery		Provides a selection of available gallery types to be applied to all chart data.
Anti-Aliasing		A graphical feature that smoothes lines and edges in a chart.
Palette Selector		Provides a selection of color schemes to be applied to the entire chart.
Axes Settings		Provides a menu of available Axis settings such as enabling an axis grid and staggering the axis labels.
Point Labels		Toggles displaying point labels on the chart.
Data Editor		Toggles displaying the data editor for the chart.
Legend Box		Toggles displaying the series legend box.
Zoom		Toggles the chart zoom control allowing click-and-drag zoom.
Properties		Opens the chart properties window to allow for configuration of various chart features.

The context menus provide many of the same features found in the toolbar.

Depending on where in the chart a user right-clicks a different context menu is provided.

5.2.7.1 Chart Background Context Menu

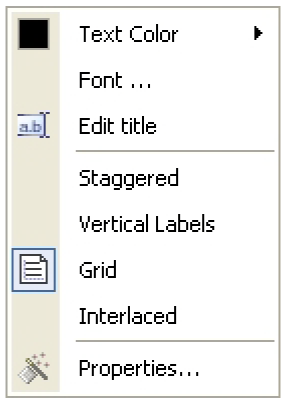


Right clicking in an empty chart space will open the general context menu. Options provided in this menu will affect the entire chart. For example changes made using “Font...” will apply the font changes to the entire chart.

5.2.7.2 Point or Series Context Menu

Right clicking on a particular point or series will open a limited context menu. This menu provides options to change the gallery type and color of the series as well as enable point labels and open a properties dialog specific to the selected series.

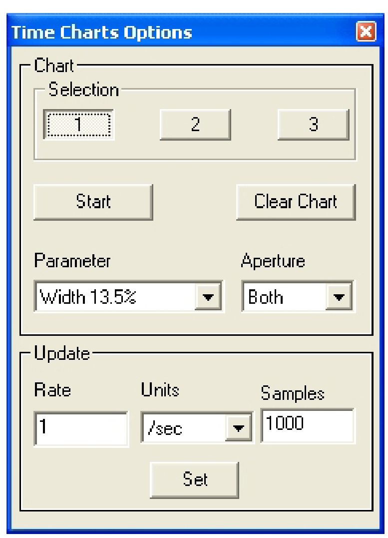
5.2.7.3 Axis Context Menu



Right-clicking on the labels of an axis will open an axis-specific context menu. This menu is used to configure an axis title, change the font color, or open a properties window specific to the axis.

5.2.7.4 Options for Time Charts View

Options for the Time Charts View are selected using the Time Charts View Options ToolControl Dialog Box.



Chart

Selection Select the chart (chart 1 is the topmost in the Time Charts View) for which the options need to be modified.

Start Start the data collection in the selected chart.

Clear Chart Clear all data in the selected chart.

Parameter Select the parameter for the selected chart. Parameters need to be enabled for computation in the Parameters ToolControl Dialog Box to be available for charting. Changing the Parameter selection will clear the chart.

Aperture Select the Aperture option for the specified parameter. Available selections are Aperture 1, Aperture 2 or Both.

Update

The selections made in the Update section apply to all charts.

Rate Select the update rate of the charts. Update rate limits change depending on the update unit selection: 1-10 for updates/sec, 1-60 for updates/min and updates/hour.

Units Select the update unit for the charts. Available selections are: /sec, /min, /hour.

Samples Selects the rolling buffer size for the charts. If the buffer is set to N samples, when sample N+1 is acquired, the first sample is dropped and the last acquired sample is added to the chart.

Set Validates all Chart Update settings. All charts are cleared when new update settings are applied.

5.3 Parameters Panel

The Parameter panel displays the values and statistics for beam parameters selected using the **Parameters ControlTool** Dialog Box. The Parameter panel includes a toolbar with buttons for starting and resetting parameter display and for font selection, and reported values of the scanhead rotation rate and the number of samples in the Parameter panel statistics.

Start	Starts the display of beam parameters.
Reset	Resets the display of beam parameters**.**
Font	Opens the Font Selection Dialog for choosing the display font.
Hz	Displays the scanhead rotation rate.
Samples	Displays the number of samples in the Parameter panel statistics.

Column spacing, column position, and column order can all be modified using the column controls in the Heading Bar and the mouse. Options for the Parameters Panel are selected using the Parameter **ToolControl** Dialog Box, described in section 4.1.6.

5.4 NanoScan Status Codes

The following table contains hardware and device driver related status messages. NanoScan software displays these messages in a dialog box that contains the following message:

"Code (Status code:). Contact Photon Inc."

Although most of the status codes indicate a hardware problem, some of them arise from bad connections between the board and the system (NanoScan card may not be properly seated in the slot), between the NanoScan card and scanhead or because of scanhead overheating (this problem may occur when profiling high power lasers).

Status Code	Description
-1	An error occurred while opening the device driver.
-2	An error occurred while closing the device driver.
-3	The board is already in use by another program.
-4	A DMA read error occurred. The pointer to the data buffer is invalid, an error occurred in the communication with the device driver or a data transfer timeout (2 seconds) occurred.

Status Code	Description
-5	The function failed to allocate memory space.
-6	The head EEPROM cannot be read. This usually indicates a communication problem. Check all card and head connections.
-7	An error occurred in the communication with the **NanoScan scanhead**. Check all card and head connections.
-8	An error occurred in the communication with the **NanoScan scanhead**. Check all card and head connections.
-9	An error occurred while reading the head EEPROM. EEPROM information may be corrupt, or, Or there may be a problem in the EEPROM communication interface. Check all card and head connections. Photon can provide a utility for reprogramming the EEPROM in the field that may solve the problem.
-10	The selected EEPROM descriptor cannot be found in the head EEPROM.
-11	One of the parameters passed to the function is not valid.
-12	An error occurred in the communication with the device driver.
-13	Power Calibration could not be saved to the head EEPROM. This usually indicates a communication problem or a faulty EEPROM.
-14	The head rotation frequency cannot be set with precision.
-15	Data acquisition cannot be started in the hardware.
-16	Data acquisition cannot be stopped in the hardware.
-17	An error occurred in the communication with the device driver. The motor cannot be started.
-18	The device driver could not set the head rotation speed.
-19	The device driver could not read the head rotation speed.
-20	The sampling clock divider could not be set.
-21	The retrieved sampling clock divider does not match the one set on the board.
-22	Nominal baseline could not be determined. There are several causes for this, including detector failure, detector overheating with a high power laser, failure of the amplifier gain setting interface, and too much laser illumination incident in the aperture at program launch. If this error occurs, make sure the laser is blocked from entering the scanhead aperture and try restarting the software. If the system was used for high power laser profiling, let the scanhead cool down before restarting the software. If these attempts fail the unit likely needs to be returned.
-23	The acquisition mode could not be set.

Status Code	Description
-24	The acquisition mode does not match the acquisition mode set on the board.
-25	Acquisition channels cannot be enabled.
-26	The enable-acquisition value does not match the value sent to the board.
-27	Channel acquisition parameters cannot be set.
-28	The device driver cannot read the channel acquisition parameters from the board.
-29	Channel end position is beyond 360 degrees.
-30	Two of the defined acquisition channels overlap.
-31	First acquisition channel is disabled.
-32	The acquisition parameters set and retrieved to/from the NanoScan card do not match.
-33	Gain channels cannot be enabled.
-34	An error occurred in the communication with the device driver. The enable status of the gain channel cannot be retrieved.
-35	Gain channel (position) cannot be set.
-36	Gain channel (position) value cannot be retrieved.
-37	The gain value cannot be set.
-38	The gain value cannot be retrieved.

5.5 ActiveX Automation

ActiveX Automation is a method of communication between a “master” named Automation Client and a “slave” usually named Automation Component (or Automation Server). The “master” (Automation Client) initiates the communication by constructing a component object (usually by loading the component program) or by attaching to an existing object in a component program that is already running. After this the “master” (client) calls methods and properties implemented in the component’s interface. The “master” and “slave” do not necessarily need to run on the same computer. It is possible to connect “master” and “slave” over the network.

The NanoScan software implements an Automation Server that can be used by an Automation Client written in Visual Basic for Applications (VBA), C/C++ or by an application with support for ActiveX Automation, such as Microsoft Excel, Microsoft Word or National Instruments’ LabVIEW.

NanoScan software has to be started at least once so that the appropriate information is added to the Windows registration database. After that, the NanoScan software can be operated by any ActiveX Automation compliant client.

In order to get information about the methods and properties implemented in the NanoScan Automation Server the type library file NanoScan.tlb can be opened in an OLE2Viewer. The NanoScan.tlb file can be found in the Automation folder where the software has been installed.

The methods and properties exposed by the NanoScan Automation Server are explained below.

5.5.1 NsAsDataAcquisition

Property Type:

VT_BOOL – global data acquisition

Remarks:

Sets or retrieves the status of data acquisition. If the value is TRUE, the system is acquiring data.

5.5.2 NsAsShowWindow

Property Type:

VT_BOOL – show window flag

Remarks:

Shows or hides the NanoScan Acquisition and Analysis Software main window. Set this property to FALSE in order to hide the NanoScan main window. Set this property to TRUE in order to show the NanoScan main window.

5.5.3 NsAsAutoROI

Property Type:

VT_BOOL – auto ROI flag

Remarks:

Enable or disable the AutoROI option. Set this property to TRUE in order to enable the automatic detection for all regions of interest (ROIs). Setting this property to FALSE will disable automatic detection for ROIs and all ROIs must be added and enabled manually using NanoScan automation methods.

5.5.4 NsAsTrackGain

Property Type:

VT_BOOL – gain track flag

Remarks:

Enable or disable the gain tracking option. Set this property to TRUE to enable the automatic gain tracking in both apertures. Use **NsAsGetGain** to read back the gain that was set for a particular aperture. If this property is set to FALSE gain tracking is disabled and gain must be set manually for each aperture using automation methods **NsAsSetGain** or **NsAsAutoFind**.

5.5.5 NsAsTrackFilter

Property Type:

VT_BOOL – filter tracking flag

Remarks:

Enable or disable the filter tracking option. Set this property to TRUE to enable the automatic filter tracking in both apertures. Use **NsAsGetFilter** to read back the filter that was set for a particular aperture. If this property is set to FALSE filter tracking is disabled and filter must be set manually for each aperture using automation methods **NsAsSetFilter** or **NsAsAutoFind**.

5.5.6 NsAsPulsedMode

Property Type:

VT_I4 – pulsed mode flag

Possible Values:

Operation Mode	Value
CW Mode	**0**
Short Pulse mode	**1**
Long Pulse mode	**2**

Remarks:

Changes the operation mode, only values for the above table should be used; passing TRUE will set NanoScan to Short Pulse mode, for backward compatibility. In pulsed either pulse mode the filter is automatically set to 190kHz.

After enabling the Pulsed mode operation, use **NsAsSetPulseFrequency** to set the laser repetition rate.

To find out the maximum sampling resolution available for the current pulsed beam conditions and head rotation frequency, use the NsAsGetMaxSampling Resolution.

5.5.7 NsAsDefaultCalibration

Property Type:

VT_I2 – default power calibration index

Remarks:

Use this property to set or read the default power calibration index. The default power calibration is used to compute all power parameters. All power calibrations must be performed in the NanoScan software prior to using the automation methods. Use **NsAsGetNumPowerCalibrations** to find out how many power calibrations are stored in the NanoScan scanhead and **NsAsGetPowerCalibration** to read a selected calibration.

5.5.8 NsAsPowerUnits

Property Type:

VT_I2 – power unit selection

Remarks:

Use this property to set or read the power units used for reporting all power measurements.

Power units	Value
NSAS_SELECT_POWER_UNIT_UW	0x00
NSAS_SELECT_POWER_UNIT_MW	0x01
NSAS_SELECT_POWER_UNIT_W	0x02
NSAS_SELECT_POWER_UNIT_DB	0x03

These values are defined in the “NsAsError.h” file that is redistributed with the software.

5.5.9 NsAsMultiROIMode

Property Type:

VT_BOOL – flag for multiple/single ROI analysis mode.

Remarks:

Select single or multiple ROI analysis modes. Set the flag to FALSE to select the single ROI mode or TRUE to select the multiple ROI mode.

5.5.10 NsAsRailLength

Property Type

VT_R4 – Rail Length in millimeters.

Remarks:

Set/get the Rail size. The available options for rails are 100mm, 200mm or 500mm.

5.5.11 NsAsGaussianFitMethod

Property Type

VT_I2 – Gaussian Fit computation method selection

Remarks:

Use this method to set/get the Gaussian Fit computation method.

Gaussian Fit Method	Value
NSAS_SELECT_GAUSS_FIT_ISO	0x00
NSAS_SELECT_GAUSS_FIT_LEAST_SQUARE	0x01

These values are defined in the "NsAsError.h" file that is redistributed with the software and in NsAsGaussianFitMethod enumeration type defined in the redistributed Type Library

5.5.12 NsAsMagnificationFactor

Property Type

VT_R4 – Magnification Factor.

Remarks:

Set/Get the magnification factor. Available range is between 0.01 and 300.

5.5.13 NsAsGetHeadCapabilities

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I4 – capability ID number

VTS_PVARIANT – array of gains or rotation frequencies. This variant packs a **dynamic array of variants** and is passed by reference to the method.

Remarks:

This method retrieves the head capability identified by the capability ID number. The capability table is retrieved in the second parameter. Use this method to retrieve all the gains (capability ID 0) and drum rotation frequencies (capability ID 1) available for the head connected to the NanoScan board.

5.5.14 NsAsSetGain

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_I2 – gain value in dB

Remarks:

This method set the aperture gain value. Aperture number can be 0 or 1 and possible gain values are those retrieved by NsAsGetHeadCapabilities method.

5.5.15 NsAsGetGain

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_PI2 – gain value (passed by reference)

Remarks:

Gets the aperture gain value in dB. Possible values for aperture number are 0 and 1 and for gains are all the values returned by NsAsGetHeadCapabilities method for capability ID 0.

5.5.16 NsAsSetFilter

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_R4 – filter value in kHz (passed by reference)

Remarks:

Sets the filter value in the aperture. Possible values for aperture number are 0 and 1 and for the filter between 2kHz and 190kHz.

5.5.17 NsAsGetFilter

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_PR4 – filter value in kHz (passed by reference)

Remarks:

Gets the aperture filter value. Possible values for aperture number are 0 and 1.

5.5.18 NsAsSetRotationFrequency

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_R4 – drum rotation frequency value in Hz

Remarks:

Sets the drum rotation frequency. Possible values for drum rotation frequencies are those returned by NsAsGetHeadCapabilities method for capability ID 1. After setting the desired rotation frequency, it is recommended to use NsAsGetMaxSamplingResolution to find out the maximum sampling resolution allowed for the current rotation frequency.

5.5.19 NsAsGetRotationFrequency

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_PR4 – drum rotation frequency in Hz (passed by reference)

Remarks:

Gets the drum rotation frequency (the value previous set by NsAsSetRotationFrequency method).

5.5.20 NsAsGetMeasuredRotationFreq

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_PR4 – measured drum rotation frequency in Hz (passed by reference)

Remarks:

Measure the drum rotation frequency in the last revolution.

5.5.21 NsAsSelectParameters

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I4 – selected parameters

Remarks:

This method selects all the parameters that will be computed every revolution. Selected parameters value is a collection of flags, every flag enabling or disabling a parameter. To select more than one parameter a bitwise OR has to be done between all the parameters to be computed.

Parameter selected for computations	Flag value (hex)
Beam width at clip level 1 parameter	0x00000001
Beam width at clip level 2 parameter	0x00000002
Beam width at user clip level 1 parameter	0x00000004
Beam width at user clip level 2 parameter	0x00000008
Beam width 4Sigma parameter	0x00000010
Beam centroid position parameter	0x00000020
Beam peak position parameter	0x00000040
Centroid separation parameter	0x00000080
Peak separation parameter	0x00000100
Beam irradiance parameter	0x00000200
Profile gaussian fit parameter	0x00000400
Ellipticity parameter	0x00000800
Power parameter	0x00001000
Total power parameter	0x00002000
Divergence parameter	0x00004000
Beam width ratio at clip level 1 parameter	0x00008000
Beam width ratio at clip level 2 parameter	0x00010000
Beam width ratio at user clip level 1 parameter	0x00020000
Beam width ratio at user clip level 2 parameter	0x00040000
Beam width 4Sigma ratio parameter	0x00080000

5.5.22 NsAsGetSelectedParameters

Method Return Value:

VT_ERROR – error code

Method Parameters List:

VTS_PI4 – selected parameters (passed by reference)

Remarks:

Gets the selected parameters for computation.

5.5.23 NsAsSetUserClipLevel1

Method Return Value:

VT_ERROR – error code

Method Parameters List:

VTS_R4 – user clip level 1

Remarks:

Sets the user clip level 1 value. Possible values for user clip level 1 are between 0.0% and 100%. To have the beam width computed for user clip level 1 the parameter beam width at clip level 1 has to be selected for computations using NsAsSetSelectedParameters method.

5.5.24 NsAsSetUserClipLevel2

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_R4 – user clip level 2

Remarks:

Sets the user clip level 2 value. Possible values for user clip level 2 are between 0.0% and 100%. To have the beam width computed for user clip level 2 the parameter beam width at clip level 2 has to be selected for computations using NsAsSetSelectedParameters method.

5.5.25 NsAsGetUserClipLevel1

Method Return Value:

Method Parameter List:

VTS VT_ERROR – error code

_PR4 – user clip level1 (passed by reference)

Remarks:

Gets the user clip level 1 value.

5.5.26 NsAsGetUserClipLevel2

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_PR4 – user clip level2 (passed by reference)

Remarks:

Gets the user clip level 2 value.

5.5.27 NsAsSetSamplingResolution

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_R4 – sampling resolution (µm)

Remarks:

Sets the sampling resolution used to acquire data.

The recommended sampling resolutions (in microns) for specified drum rotation frequency can be found in the table below.

1.25 Hz	2.5 Hz	5 Hz	10 Hz	20 Hz
0.0057	0.0114	0.0229	0.0458	0.0915
0.0086	0.0172	0.0343	0.0686	0.1373
0.0114	0.0229	0.0458	0.0915	0.1830
0.0229	0.0458	0.0915	0.1830	0.3661
0.0572	0.1144	0.2288	0.4576	0.9152
0.1144	0.2288	0.4576	0.9152	1.8304
0.2288	0.4576	0.9152	1.8304	3.6608
0.5720	1.1440	2.2880	4.5760	9.1521
1.1440	2.2880	4.5760	9.1521	18.3041

Use the NsAsGetMaxSamplingResolution method to find out the maximum sampling resolution allowed for the current head rotation frequency.

5.5.28 NsAsGetSamplingResolution

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_PR4 – sampling resolution (µm)

Remarks:

Gets the sampling resolution in the specified aperture. Possible values for aperture are 0 and 1.

5.5.29 NsAsAutoFind

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_NONE – none

Remarks:

This method does a single shot AutoFind and finds the appropriate values for gains, filters, sampling resolution and ROIs in every aperture. Also the AutoROI flag is set to TRUE.

5.5.30 NsAsAddROI

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_R4 – ROI left boundary (µm)

VTS_R4 – ROI right boundary (µm)

VTS_BOOL – ROI enable flag

Remarks:

Add an ROI to the ROI list. Possible values for the aperture number are 0 and 1 and ROI left and right boundaries have to be within aperture limits. The left boundary has to be smaller than the right boundary. ROI enabled flag can enable (if TRUE) or disable (if FALSE) this ROI. All the computations related to an ROI are done only if the ROI is enabled. Maximum number of ROIs allowed in the aperture is 16 (ROI index goes from 0 to 15).

5.5.31 NsAsDeleteROI

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_I2 – ROI index

Remarks:

Deletes the ROI identified by ROI index in the specified aperture.

Possible values for the aperture number are 0 and 1. ROI index values must be between 0 and the total ROIs number (returned by NsAsGetNumberOfROIs) –1.

Once the ROI is deleted it cannot be used any more. The method NsAsUpdateROI can be used to temporary disable an ROI (none of the computations will be done in the disabled ROIs)

5.5.32 NsAsUpdateROI

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_I2 – ROI index

VTS_R4 – ROI left boundary (µm)

VTS_R4 – ROI right boundary (µm)

VTS_BOOL – ROI enable flag

Remarks:

Update the ROI fields with the new values. Possible values for the aperture number are 0 and 1. ROI index values must be between 0 and the total ROIs number (returned by NsAsGetNumberOfROIs) –1. (cont. next page)

The left and right boundaries have to be within aperture limits and left boundary has to be smaller than right boundary. The ROI enable flag enable (if TRUE) or disable (if FALSE) the ROI.

5.5.33 NsAsGetNumberOfROIs

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_PI2 – total number of ROIs (passed by reference)

Remarks:

Gets the total number of ROIs in the specified aperture. Possible values for aperture number are 0 and 1.

5.5.34 NsAsGetROI

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_I2 – ROI index

VTS_PR4 – ROI left boundary (µm) (passed by reference)

VTS_PR4 – ROI right boundary (µm) (passed by reference)

VTS_PBOOL – ROI enable flag (passed by reference)

Remarks:

This method gets the ROI boundaries and ROI enable flag. Possible values for the aperture number are 0 and 1. ROI index values must be between 0 and the total ROIs number (returned by NsAsGetNumberOfROIs) –1.

5.5.35 NsAsGetApertureLimits

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_PR4 – aperture left boundary (µm)

VTS_PR4 – aperture right boundary (µm)

Remarks:

Gets the acquisition limits (µm) for the specified aperture.

5.5.36 NsAsReadProfile

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_R4 – start position (µm)

VTS_R4 – end position (µm)

VTS_I2 – decimation factor

VTS_PVARIANT – profile amplitude array. This variant packs a **dynamic array of VTS_R4** and is passed by reference to the method.

VTS_PVARIANT – profile position array. This variant packs a **dynamic array of VTS_R4** and is passed by reference to the method.

Remarks:

Reads the profile amplitude and position for the specified aperture within the specified limits (start position and end position). Decimation factor can be used to read a smaller amount of data. For example, if the decimation factor is set to 10, profile amplitude and position will have data from indexes 10, 20, 30, … Decimation factor does not affect the precision of computations because all the computations are done using the entire set of acquired data.

Start position and end position have to be within aperture acquisition limits returned by **NsAsGetApertureLimits** method.

5.5.37 NsAsGetBeamWidth4Sigma

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_I2 – ROI index

VTS_PR4 – beam width 4Sigma (passed by reference)

Remarks:

Gets the beam width (4Sigma method) for the specified aperture and ROI. Before using this method the beam width 4sigma parameter has to be selected for computations.

Possible values for the aperture number are 0 and 1. ROI index values must be between 0 and the total ROIs number (returned by NsAsGetNumberOfROIs) –1.

5.5.38 NsAsGetCentroidPosition

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_I2 – ROI index

VTS_PR4 – centroid position (µm) (passed by reference)

Remarks:

Gets the centroid position in microns for the specified aperture and ROI. Before using this method the centroid position parameter has to be selected for computations. Possible values for the aperture number are 0 and 1. ROI index values must be between 0 the total ROIs number (returned by NsAsGetNumberOfROIs) –1.

5.5.39 NsAsGetPeakPosition

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_I2 – ROI index

VTS_PR4 – peak position (µm) (passed by reference)

Remarks:

Gets the peak position in microns for the specified aperture and ROI. Before using this method the peak position parameter has to be selected for computations. Possible values for the aperture number are 0 and 1. ROI index values can be between 0 and the total ROIs number (returned by NsAsGetNumberOfROIs) –1.

5.5.40 NsAsGetCentroidSeparation

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_I2 – ROI index

VTS_PR4 – centroid separation (µm) (passed by reference)

Remarks:

Gets the centroid separation between the centroid in the specified ROI and the centroid in the next ROI (ROI index +1). Before using this method the centroid separation parameter has to be selected for computations.

Possible values for the aperture number are 0 and 1. ROI index values must be between 0 and the total number of ROIs (returned by NsAsGetNumberOfROIs) –1.

5.5.41 NsAsGetPeakSeparation

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_I2 – ROI index

VTS_PR4 – peak separation (µm) (passed by reference)

Remarks:

Gets the peak separation between the peak in the specified ROI and the peak in the next ROI (ROI index +1). Before using this method the peak separation parameter has to be selected for computations.

Possible values for the aperture number are 0 and 1. ROI index values must be between 0 and the total number of ROIs (returned by NsAsGetNumberOfROIs) –1.

5.5.42 NsAsGetBeamIrradiance

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_I2 – ROI index

VTS_PR4 – beam irradiance (passed by reference)

Remarks:

Gets the beam irradiance for the specified aperture and ROI. Before using this method the beam irradiance parameter has to be selected for computations.

Possible values for the aperture number are 0 and 1. ROI index must be between 0 and the total number of ROIs (returned by NsAsGetNumberOfROIs method) –1.

5.5.43 NsAsGetGaussianFit

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture

VTS_I2 – ROI index

VTS_PR4 – goodness fit (passed by reference)

VTS_PR4 – roughness fit (passed by reference)

Remarks:

Gets the goodness and roughness Gaussian fit for the profile in the specified aperture and ROI. Before using this method the Gaussian fit parameter has to be selected for computations.

Possible values for aperture are 0 and 1. ROI index must be between 0 and the total number of ROIs (returned by NsAsGetNumberOfROIs) –1.

5.5.44 NsAsGetBeamEllipticity

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – ROI index

VTS_PR4 –beam ellipticity (passed by reference)

Remarks:

Gets the beam ellipticity for the specified ROI. The specified ROI has to be enabled in both aperture (0 and 1) to get a value for beam ellipticity. Before using this method the beam ellipticity parameter has to be selected for computations. Ellipticity is usually only meaningful for single ROI applications

ROI index values must be between 0 and the total number of ROIs (returned by NsAsGetNumberOfROIs) –1.

5.5.45 NsAsGetBeamWidth

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_I2 – ROI index

VTS_R4 – clip level

VTS_PR4 – beam width (passed by reference)

Remarks:

Gets the beam width for the specified aperture, ROI index and clip level. Possible values for aperture number are 0 and 1. ROI index values must be between 0 and total number of ROIs (returned by NsAsGetNumberOfROIs) –1. Clip level has to be 13.5, 50, user clip level 1 or user clip level 2.

5.5.46 NsAsSetPulseFrequency

Method Return Value:

VT_ERROR – error code.

Method Parameter List:

VTS_R4 – laser pulse frequency

Remarks:

Set the laser pulse frequency in Pulsed Mode operation. To enable the Pulsed Mode operation use **NsAsPulsedMode.**

5.5.47 NsAsGetPulseFrequency

Method Return Value:

VT_ERROR – error code.

Method Parameter List:

VTS_PR4 – laser pulse frequency

Remarks:

Get the laser pulse frequency in Pulsed Mode operation.

5.5.48 NsAsAcquireSync1Rev

Method Return Value:

VT_ERROR – error code.

Method Parameter List:

VTS_NONE – none

Remarks:

Data acquisition should be turned off when using this function. If data acquisition (DAQ) is on this function will stop DAQ, acquire one rev, then restart DAQ; calling this function while the DAQ is running is pointless.

Aquires a single revolution of data; the software acquires the data for one revolution at the current gain and filter settings and stops. This function only aquires the data, nothing else happens: no tracking, no calculations, nothing else happens. When the function returns, only calling **NsAsReadProfile** will see any change, other functions will act as if nothing has happened.

Calling **NsAsRecompute** after this function returns will compute all parameters based on this new data. **NsAsRecompute** will not activate any tracking even if it is enabled.

NsAsRunComputation is provided to run the computation and trigger any tracking algorithms that are enabled, just like the continuous DAQ loop would if it were running.

This function is provided to allow the user complete control over data acquisition; not to be mistaken with the continuous data acquisition loop.

This function, along with **NsAsRunComputation**, allows the ActiveX client to ‘pump’ the NanoScan software to provide synchronization with their code.

If the drum has already passed the start index, NanoScan will wait for the next revolution to start the acquisition; the effective update rate may be lower than the continuous DAQ loop.

5.5.49 NsAsGetNumPowerCalibrations

Method Return Value:

VT_ERROR – error code.

Method Parameter List:

VTS_PI2 – number of power calibrations.

Remarks:

Get the number of power calibrations from the scanhead. At least one power calibration must exist and set as default for the power measurement and computations to work. All power calibrations must be performed using the

NanoScan software. Select the default power calibration (calibration used for measurement and computation) using **NsAsDefaultCalibration**.

5.5.50 NsAsGetPowerCalibration

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – power calibration index

VTS_PVARIANT – VARIANT of type VT_RECORD that contains the power calibration structure

Remarks:

The method gets the power calibration structure with the specified index. The power calibration structure is defined as a *UDT* in NanoScan.tlb. The VARIANT parameter is of type VT_RECORD and wraps a *RecordInfo* object, which contains the necessary information about the *UDT* and a pointer to the *UDT* itself. The *RecordInfo* implements a new interface, **IRecordInfo**, for access to the information.

The client needs to get the **IRecordInfo** interface from the type library.

The power calibration structure has three members:

- *pstrDescriptor* – string that contains a description of the power calibration;
- *fRefPower* – power reference. The power reference is stored in the calibration structure only in mW;
- *fWaveLength* – wavelength of the measured source.

5.5.51 NsAsGetTotalPower

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_PR4 – total power value

Remarks:

The method gets the total beam power measured through the NanoScan scanhead power aperture. The method works only if there is a valid calibration and if a default calibration is selected. Power calibrations must be performed in the NanoScan software prior of using the automation methods.

5.5.52 NsAsGetPower

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – ROI index

VTS_PR4 – computed power for the selected ROI

Remarks:

The method gets the calculated power in the selected ROI as percent of the total power. The method works only if there is a valid calibration and if a default calibration is selected. Power calibrations must be performed in the NanoScan software prior of using the automation methods.

5.5.53 NsAsGetNumDevices

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_PI2 – number of NanoScan devices (cards) in the system

Remarks:

The method gets the number of NanoScan cards in the system.

5.5.54 NsAsGetDeviceID

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_PI2 – current NanoScan device (card) index

Remarks:

The method gets the index of the device in use.

5.5.55 NsAsSetDeviceID

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – NanoScan device index

Remarks:

The method selects a NanoScan device index When a new instance of the NanoScan ActiveX server is created, it will try to link to the first device in the system. If the first device is already in use, or the device does not have a scanhead connected to it, the new instance will disable the data acquisition. The client must use automation function **NsAsGetNumDevices** to get the total number of NanoScan devices in the system and set the device index to the next one available. Use the **NsAsGetDeviceList** to get an array of all available devices in the system.

This method will return an ID not found error if the **NsAsGetDeviceList** has not been called previously or if the list has changed since the last call to **NsAsGetDeviceList**.

For backward compatibility purposes calling **NsAsGetNumDevices** causes this function to work as if **NsAsGetDeviceList** was called.

5.5.56 NsAsOpenMotionPort

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_BSTR – COM Port string

Remarks:

The method takes a string as parameter. For example if the motion controller is located on COM port 1, the parameter will be “COM1”. Only one NanoScan instance can communicate with the motion controller. Once the Rail Motion Controller has been opened by a NanoScan instance all subsequent calls to this function will result in an error.

5.5.57 NsAsCloseMotionPort

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_NONE – none

Remarks:

The method closes the COM Port communication with the Motion Controller.

5.5.58 NsAsGo2Position

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_R4 – position along the rail (in mm)

Remarks:

The method sends the scanhead to the specified position along the rail. Position 0 can be used to send the scanhead to its HOME position and perform a HOME check.

5.5.59 NsAsIsSignalSaturated

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture number

VTS_PBOOL – signal saturation flag (passed by reference)

Remarks:

Verifies if the signal is saturated for the specified aperture. Possible aperture values are 0 and 1. Boolean variable is TRUE if the signal is saturated, FALSE otherwise.

5.5.60 NsAsRecompute

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_NONE – none.

Remarks:

Re-computes all parameters for the current data set.

5.5.61 NsAsGetBeamWidthRatio

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – ROI Index

VTS_R4 – clip level

VTS_PR4 – beam width ratio for the selected clip level (passed by reference)

Remarks:

Returns the computed beam ratio for the selected ROI index and clip level. The selected ROI must exist and be enabled in both apertures and the clip level must be one of the standard values (i.e. 13.5 or 50.0), or one of the user defined clip levels set with the **NsAsSetUserClipLevel1** or **NsAsSetUserClipLevel2.** The beam width ratio is computed only if the beam width and beam width ratio parameters for the desired clip level are enabled for computation using **NsAsSelectParameters**.

5.5.62 NsAsGetBeamWidth4SigmaRatio

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – ROI Index

VTS_PR4 – 4Sigma beam width ratio (passed by reference)

Remarks:

Returns the computed 4Sigma beam ratio for the selected ROI. The selected ROI must exist and be enabled in both apertures. The beam width ratio is computed only if the 4Sigma beam width and 4 sigma beam width ratio parameters are enabled for computation using **NsAsSelectParameters**.

5.5.63 NsAsGetMaxSamplingResolution

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_PR4 – Maximum Sampling Resolution (passed by reference)

Remarks:

Returns the maximum available sampling resolution for the current head rotation frequency. This value is different in CW and Pulsed Mode.

5.5.64 NsAsSetDivergenceMethod

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – Divergence Method

VTS_R4 – Clip Level

VTS_R4 - Distance

Remarks:

Sets the Divergence method and the parameters for the selected method. Available options for the Divergence Method:

Divergence Method	Value
NSAS_SELECT_DIVERGENCE_LENS	0x0
NSAS_SELECT_DIVERGENCE_SOURCE	0x1
NSAS_SELECT_DIVERGENCE_NUM_APERTURE	0x2

For the Lens Method, the third parameter, Distance, represents the focal length (distance) of the lens. For the other two methods it represents the source distance.

5.5.65 NsAsGetDivergenceMethod

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_PI2 – Divergence Method (passed by reference)

VTS_PR4 – Clip Level (passed by reference)

VTS_PR4 – Distance (passed by reference)

Remarks:

Returns the Divergence Method and the parameters for the selected method. Available options for the Divergence Method:

Divergence Method	Value
NSAS_SELECT_DIVERGENCE_LENS	0x0
NSAS_SELECT_DIVERGENCE_SOURCE	0x1
NSAS_SELECT_DIVERGENCE_NUM_APERTURE	0x2

For the Lens Method, the third parameter, Distance, represents the focal length (distance) of the lens. For the other two methods it represents the source distance.

5.5.66 NsAsGetDivergenceParameter

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 – aperture index

VTS_I2 – ROI index

VTS_PR4 – Divergence (passed by reference)

Remarks:

Returns the divergence for the selected aperture and ROI, computed using the method selected using NsAsSetDivergenceMethod. The divergence must be enabled for computation by using NsAsSelectParameters.

5.5.67 NsAsGetDeviceList

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_PVARIANT – devices array. This variant packs a **dynamic array of VTS_I4** and is passed by reference to the method.

Remarks:

Returns a variant that contains an array with all NanoScan devices detected on the computer. The devices are in the order the operating system enumerates them. PCI devices are enumerated first, followed by the USB devices. The devices are identified by the serial number of the scanhead connected to the device. If a device is present in the system but it does not have a scanhead attached to it, the device is listed with the number 0 in the list. The variant passed to the function is safely re-dimensioned internally to accommodate all the devices in the system.

5.5.68 NsAsGetAveraging

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_PI2 Finite Average count (passed by reference)

VTS_PI2 Rolling Average count (passed by reference)

Remarks:

This method gets the current settings for profile averaging. A value of 1 for either averaging type means the data is not averaged.

5.5.69 NsAsSetAveraging

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_I2 Finite Average count

VTS_I2 Rolling Average count

Remarks:

Changes the current settings for profile averaging, the values are automatically clamped into the allowable ranges; 16 for rolling, and 1000 for finite.

Setting either value to 1 disables that type of averaging. Values less than 1 are not allowed.

5.5.70 NsAsRunComputation

Method Return Value:

VT_ERROR – error code

Method Parameter List:

VTS_NONE no parameters

Remarks:

This method, along with NsAsAcquireSync1Rev, is provided to allow the user to 'pump' the NanoScan software, i.e. the client software can synchronize NanoScan's operation with its own.

When the NanoScan DAQ loop is running, ActiveX clients have no way of being notified when new data has arrived, the various Get* methods will return the same value if called repeatedly until new data arrives. ActiveX clients that need this information can instead 'Pump' the NanoScan software, and remove this limitation.

NsAsRunComputation runs any activated tracking algorithms, and the globally selected computations (see **NsAsSelectParameters** for details). **NsAsRecompute** will also run the selected computations, but will not run any tracking algorithms as it was designed for a different purpose.

5.6 Error codes returned by NanoScan Automation Server

Error code (hex value)	Description
0x80040200	Wrong head capability ID number
0x80040201	Aperture number out of range
0x80040202	Gain value out of range
0x80040203	Error occurred while setting gain on the board
0x80040204	Error occurred while setting filter on the board
0x80040205	Filter value out of range
0x80040206	Speed not available
0x80040207	Error occurred while setting speed on the board
0x80040208	Error occurred while setting sampling resolution
0x80040209	AutoFind algorithm failed
0x8004020A	ROI boundary out of range
0x8004020B	ROI index out of range
0x8004020C	Cannot delete ROI
0x8004020D	Cannot add more than 16 ROIs
0x8004020E	Error occurred while adding ROI
0x8004020F	Error occurred while editing ROI
0x80040210	Error occurred while reading ROI fields
0x80040211	Clip level out of range
0x80040212	Start position out of the aperture acquisition limits
0x80040213	End position out of the aperture acquisition limits
0x80040214	Start position bigger than end position
0x80040215	Decimation factor out of range
0x80040216	This parameter was not selected for computations
0x80040217	The pulse frequency is out of range
0x80040218	Error acquiring 1 revolution
0x80040219	Invalid power calibration index
0x8004021A	Error reading the power calibration structure
0x8004021B	Error creating the power calibration copy
0x8004021C	Error setting the device ID. Selected device ID was not set

Error code (hex value)	Description
0x8004021D	No device ID is set for the current instance
0x8004021E	Invalid device ID
0x8004021F	Rail is already in use by another NanoScan instance.
0x80040220	No communication with the motion controller.
0x80040221	Rail has reached a limit switch.
0x80040222	HOME position check has failed.
0x80040223	COM Port communication failure.
0x80040224	Motion failure.
0x80040225	Invalid position on the rail. Check if position is within Rail limits.
0x80040226	Sampling resolution is higher than the maximum accepted sampling resolution for the current head rotation frequency.
0x80040227	Invalid lens focal distance.
0x80040228	Invalid selection for the Divergence Method.

5.7 Sample files for using NanoScan ActiveX server

The NanoScan software comes with various samples written in/with various ActiveX Clients:

- LabView
  - NanoScan ActiveX Sample.LV09.vi
  - NanoScan ActiveX Sample.LV71.vi
  - NanoScan ActiveX Sample.LV86.vi
  - NanoScan ActiveX Sample.LV851.vi
- Microsoft Excel (VBA)
  - NanoScan ActiveX Sample.xls
- Visual Basic.net
  - NanoScanPerodicSampling-freerunning.vb
  - NanoScanPerodicSampling-Sync1Rev.vb

Note: all the sample files are located in the "./Automation" subfolder, located where Nanoscan was installed.

These sample files are intended only as samples, they are intended to illustrate how to use nanoscan via ActiveX. As samples some omissions, e.xe error checking, may have been made for clarity.

5.7.1 Microsoft Excel (VBA) Sample

A detailed example for using NanoScan ActiveX server, written in Visual Basic for Applications (VBA) for Excel, can be found in "NanoScan ActiveX Sample.xls" file located under Automation, in the folder where the software has been installed.

Listed below are some fragments from that sample file. These fragments illustrate how to open the NanoScan software, get the number of NanoScan devices in the software, the gain and rotation frequency tables and close the NanoScan software.

```
Dim NSServer As Object
Dim UpdatesControlEnabled As Boolean
Dim UpdatesParametersEnabled As Boolean

' Start the NanoScan Software
Sub OpenNanoScan()
  On Error GoTo ErrorHandler
  Dim RetCode As Variant
```

```
  Dim NrDevices As Integer
  Dim ID As Integer
  Application.DisplayAlerts = True
  UpdatesControlEnabled = False
  UpdatesParametersEnabled = False
  Range("Control!UpdateControl") = False
  Range("Parameters!UpdateParam") = False

  ' Get the reference to the NanoScan ActiveX Server
  Set NSServer = GetObject("", "Photon-NanoScan")

  ' Get the number of NanoScan devices present in the system
  RetCode = NSServer.NsAsGetNumDevices(NrDevices)
  Range("Control!NrDevices") = NrDevices
  ' and the current device used
  GetDeviceID

  ' Get information about this head
  GetRotationTable
  GetGainTable

  ' Get initial state of various flags
  Range("Control!ShowNanoScan") = NSServer.NsAsShowWindow
  Range("Control!GainTrack") = NSServer.NsAsTrackGain
  Range("Control!FilterTrack") = NSServer.NsAsTrackFilter
  Range("Control!PulsedMode") = NSServer.NsAsPulsedMode
  Range("Control!DAQ") = NSServer.NsAsDataAcquisition
  Range("Parameters!AutoROI") = NSServer.NsAsAutoROI
  Range("Parameters!MultiROI") = NSServer.NsAsMultiROIMode

  ' Get initial state of the software
  GetRotationFrequency
  GetGain
  GetFilter
  GetSamplingResolution
  GetPulseFrequency
  GetParameterSelection
  GetUserClipLevel

  Exit Sub

ErrorHandler:
  Dim Str
  Str = "Error " + CStr(Err.Number) + ". " + Err.Description
  MsgBox (Str)
  Resume Next
```

```
End Sub

' Stop the NanoScan Software
Sub CloseNanoScan()

 Set NSServer = Nothing

 UpdatesControlEnabled = False
 UpdatesParametersEnabled = False
 Range("Control!UpdateControl") = False
 Range("Parameters!UpdateParam") = False

End Sub
```

5.7.2 LabVIEW Sample

There are four otherwise identical LabVIEW samples written & tested with various versions of LabVIEW starting with 6.0.2:

- NanoScan ActiveX Sample.LV09.vi
  - Written with 2009, tested with 2009 & 2010
- NanoScan ActiveX Sample.LV71.vi
  - Written with 6.0.2, tested with 6.0.2 & 7.1
- NanoScan ActiveX Sample.LV86.vi
  - Written and tested with 8.6
- NanoScan ActiveX Sample.LV851.vi
  - Written and tested with 8.5.1

The versions of files provided were chosen for compatability reasons; one of these files should work on any version of labview 6.0.2 or later.

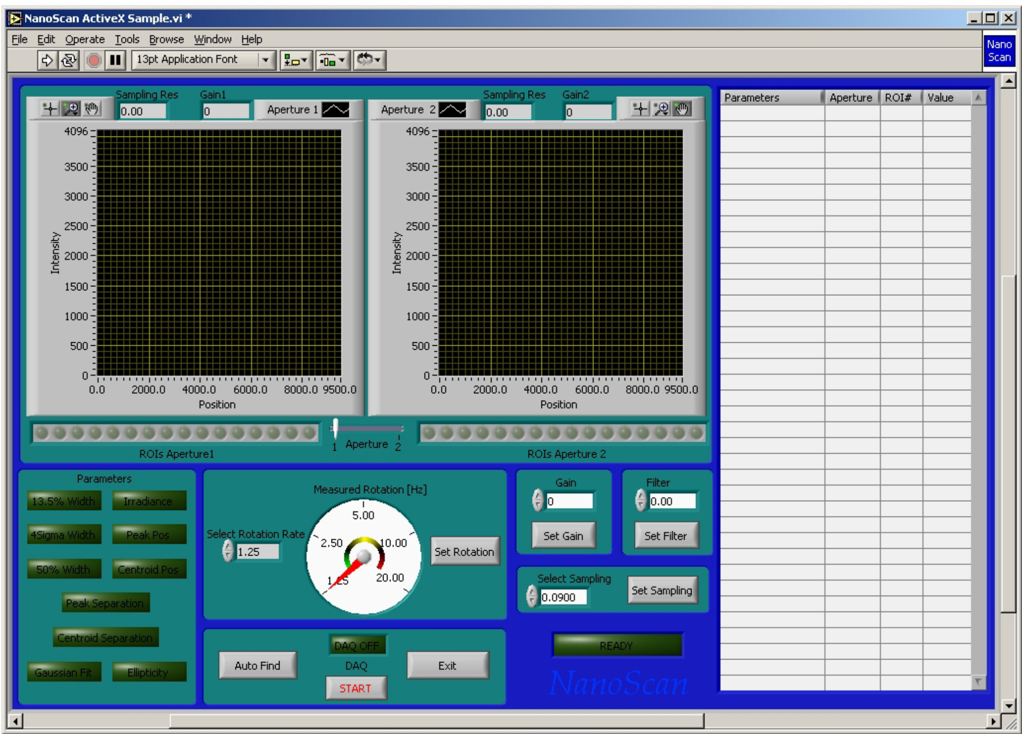
This sample demonstrates the creation of an ActiveX controller that uses data from the NanoScan ActiveX automation server. The sample file is located under the Automation folder, in the NanoScan installation folder.

The sample illustrates how to:

- Initiate communication with the NanoScan automation server;
- Retrieve scanhead parameters;
- Perform an AutoFind that will set the appropriate values for the sampling resolution, gain and filter;
- Do an acquisition loop which will retrieve beam profiles and the position arrays associated with them;

- Enable parameter computations;
- Retrieve computed parameters;
- Set the gain and filter for the selected aperture;
- Set the sampling resolution;
- Set and measure the rotation frequency of the scanhead;
- End communication with the NanoScan automation server.

For details on the ActiveX functions that are used in this sample, please refer to the function description.



5.7.3 Visual Basic.Net Examples

There are two VB.Net examples:

- NanoScanPerodicSampling-freerunning.vb
- NanoScanPerodicSampling-Sync1Rev.vb

To run these samples you will need a VB.Net complier or interpreter. Microsoft provides a free version: Visual Basic.net 2010 express, which can be found at <http://www.microsoft.com/express/Downloads/#2010-Visual-Basic>

These samples are written assuming they are a console application, i.e. there is no GUI, see the documentation for your VB complier for details.

The free running example runs with data acquisition turned on and synchronizes with it very naively.

The Sync1Rev example runs with data acquisition turned off and uses **NsAsAcquireSync1Rev** and **NsAsRunComputation** to “pump” the nanoscan software, so there is no need to synchronize with NanoScan’s acquisition loop.

The Sync1Rev Version is preferred; both versions are hevilly documented.

This sample demonstrates how to perform periodic sampling, i.e. take N samples after some time interval.

6 Frequently Asked Questions

The following is a list of questions that might be useful during installation and/or operation of your NanoScan. If you do not see a question/answer that fits your situation, please fill out and submit the online "Ask a Photon Expert" [link to “Ask a Photon Expert] or the "Troubleshooting Checklist" [link to “Troubleshooting Checklist] to Photon Technical Support. We will try to resolve your problems quickly, but we need your help. Please provide as many details as you can when you fill out the checklist. For example, "My scanhead [instrument] does not work" is fairly broad. Tell us what it does or does not do, and include operating conditions and information as requested in the form. The more information you provide, the faster we can answer your questions.

To determine a more definite cause for a specific symptom or problem, the instrument may have to be returned to our factory for a complete evaluation.

Please obtain an RMA number before returning unit for calibration or repair.

Q.1. Can I get an electronic copy of the manual?

Yes, you already have one on your NanoScan Installation CD. Look in ***Program Files/Photon/NanoScan***

Q.2. Is there a Viewer for the NanoScan?

No, this is not necessary. Unlike the BeamScan, the NanoScan software will run without a scanhead attached. You will get a Status Code -9 message (see **Q.27**), but if you ignore this, the software will start and allow you to view previously acquired data files.

Q.3. Can my NanoScan operate on a Mac

It is possible to use the NanoScan with a Mac, provided that the Mac has installed the Parallels and Windows operating system available from your Apple dealer. The NanoScan operates under the virtual Windows machine normally.

Q.4. Can my NanoScan operate under Linux

As far as we know, this is not possible. If you try it and it works, please let us know.

Q.5. What is the longest cable available for NanoScan?

We have tested NanoScans with cables up to 50 feet. We can provide custom cable up to this length.

Q.6. Can my NanoScan be used with different controllers?

Yes, unlike the BeamScan, the NanoScan is not calibrated to a particular controller and can be used with any controller, both PCI and USB. The only exception is the High Power NanoScan, which has a modified controller to power the fan.

Q.7. Where is the detector in the NanoScan?

The detector is mounted behind the slits. This position is not important to the measurements. The measurement plane is the scan plane of the slits which is nominally 1.1mm from the face of the front cap. Refer to the mechanical drawings for more detailed information.

Q.8. What is the smallest beam I can measure?

In general the NanoScan can measure a beam that is 4x larger than the slit width without correcting for convolution error. For beams smaller than this you can either make mathematical convolution correction or use magnification to enlarge the beam. See section **4.4.9** for a discussion of convolution error or section **4.4.10** for information on the magnification with the near-field profiler.

Q.9. Can I measure multiple beams with the NanoScan?

Yes, see section **5.1.8** for a discussion of the Regions-of-Interest (ROIs) and multiple beam analysis.

Q.10. What does ‘relative power meter” mean?

The power meter available as an option on silicon and germanium detector NanoScans is a “relative” measurement, which means that the meter is not calibrated to an absolute standard in the factory. You need to measure the source with a calibrated power meter, and then input the value into the NanoScan software. The NanoScan will then measure relative to this measured value.

Q.11. Why can’t I get a power meter with the pyro detector NanoScan?

The pyroelectric detector is a universal detector, but it operates differently than the silicon and germanium detectors. All the power meter detectors require an attenuator window, but because of the wide wavelength and power ranges used with the pyro detector, it is not possible to select a single window that would work with this detector.

Q.12. Can the power meter be added after purchase?

No, the power meter option must be selected when the system is purchased because it is built into the scanhead.

Q.13. Why is the silicon NanoScan not recommended for 1064nm beam measurements?

the silicon detector is very transparent to NIR light >1000nm. If it is used for measuring these beams, you will often see a tailing profile, because the signal does not decay fast enough. This will lead to erroneous results. We recommend using the germanium, or if there is enough power, the pyro electric detector for these wavelengths.

Q.14. How can I increase the sensitivity of my NanoScan?

It is sometimes possible to increase the detection of low level beams by using profile averaging to increase the signal to noise ratio. See section **4.4.4.7** of your manual for a description.

Q.15. The signal is oscillating in my NanoScan; what's wrong?

Back reflections from the slits can cause the laser to become unstable. You can tip the scanhead slightly to make sure that reflections do not feedback into the laser cavity. See section **4.4.5** of the manual.

Q.16. What is the largest angle of incidence I can measure with the NanoScan?

The NanoScan can measure up to 45^o under most circumstances. See section **4.4.6** of the manual for a detailed discussion of divergence and angle of incidence.

Q.17. How do I measure divergence?

The NanoScan software has several divergence measurement methods available. See section **4.4.6** of the manual for a detailed discussion of divergence measurement.

Q.18. How can stray light affect the NanoScan?

Both silicon and germanium detectors are quite sensitive. Stray light in the visible or NIR wavelengths are present in most settings, and they will be detected by the detectors, raising the background. This can have an effect on the accuracy of the measurement by changing the baseline of the beam profile. You should be sure to shield the scanhead from sources of light other than those you are intending to measure.

Q.19. Pulsed laser operation with the NanoScan

The NanoScan will measure pulsed lasers, provided that the pulse rate is high enough to get a decent profile. This is discussed at length in the *NanoScan Installation and Operation Manual* Chapter **4.2.4**.

Q.20. Slit Damage Calculation

Damage to the slits and detector of your NanoScan is always a possibility with high power lasers. Care should be taken to ensure that the damage thresholds are never exceeded. Remember also that the smaller the beam diameter impinging on the slits the lower the power or energy needed to damage the slit material. There is a slit damage calculator (an Excel spreadsheet) included on your software disk. This will help you determine if you are in danger off damaging the slits. If you do not have this spread sheet, contact Photon for a free copy. ***Remember,*** damage to the slits is never covered under warranty.

Q.21. Pulse Damage to NanoScan Slits

Pulsing lasers is a method of increasing the effect of the laser beam by concentrating the power into a short duration pulse. These pulses can have a very high peak power, despite the average power's being quite low. This means that the energy delivered by the beam can cause damage, even if the average power would not, if the laser were CW. The important parameter to be aware of with pulsed lasers is the energy, measured in Joules and calculated as the average power divided by the frequency $E=p/f$. It is important to recognize that the energy increase as the frequency decreases. In other words a laser beam that is safe at 80kHz may damage the NanoScan if the frequency is reduced to 60kHz. The slit damage calculator (see above) will indicate safe levels for both power of CW lasers and energy of pulsed lasers.

Q.22. Frequency measurement with the NanoScan

Proper measurement of pulsed lasers requires that the actual pulse rate be entered into the software. This number is no always the value that is suspected based on the laser's manufacturer's specification. In order to make these measurements work more smoothly the NanoScan measures the actual pulse rate. Enter this number into the software and the pulsed measurements will be much better.

Q.23. Why are there two types of pulsed operation with the NanoScan?

There are two reasons that lasers are pulsed. One, discussed above, involves concentrating the energy in short pulses; the other uses pulsing to reduce the duty cycle of the laser to actually control the output power. The latter type, called pulse width modulation, generally has fairly long pulse durations, >1µsec. We have found that the NanoScan amplifiers work differently with the long pulses than with the short ones, therefore we use two different algorithms for these different laser types.

Q.24. How can I export data from the NanoScan software?

There are several ways to export data from the NanoScan to spreadsheet, math and statistical analysis programs, process/ instrumentation control programs, or reports, papers and other documents. Logging to COM ports or files is described in the manual Chapter **5.1.9**. ActiveX communication is also available and is described at length in Chapter **5.5**. Saving a screen capture to a file is an easy way to get figures for reports, papers or other documents.

Q.25. Are there examples of ActiveX programs anywhere?

ActiveX examples are included in your software and can be found in the Automation Folder of the software installation. Look on your hard disk in ***Program Files/Photon/NanoScan/Automation*****.**

Q.26. Status Code -9

This indicates that there is no scanhead recognized by the software. This can mean that either nothing is plugged in or that there is something wrong with the communication. One cause of this that can be fixed remotely is that the EEPROM in the scanhead has been erased by a transient, power surge, electrostatic discharge (ESD) or the like. If you get a Status Code (error code) -9, contact Photon to get the head data and reloading utility to reprogram the EEPROM. In more than half the cases this will resolve the problem.

Q.27. Status Code -22

This message was much more common with earlier software versions, prior to v. 1.31. If you get this message, first check to ensure that you are operating with a software version later than 1.31. If not, contact Photon or your local distributor to obtain an updated version. If you have the right software version, then this message indicates that there is a problem with the detector and the system should be returned for repair. Contact Photon or your dealer for an RMA.

Appendix A – Scanhead Specifications

NanoScan Scanhead Model	Si/3.5/1.0µm	Si/3.5/1.8µm
Wavelength	190nm - 950nm	190nm - 950nm
Detector	Silicon	Silicon
Entrance Aperture	3.5mm	3.5mm
Slit Size	1µm	1.8µm
Slit Orientation	+45° and -45°	+45° and -45°
$1/e^2$ Beam Diameter Range[1]	4µm – ~2.3mm	7µm – ~2.3mm
Spatial Sampling Resolution	5.7nm – 18.3µm	5.7nm – 18.3µm
Profile Digitization	12 bit	12 bit
Amplifier Gain Range	1-103dB	1-103dB
Filter Frequency Range	2 – 190kHz	2 – 190kHz
Scan Frequency	1.25, 2.5, 5, 10, 20Hz	1.25, 2.5, 5, 10, 20Hz
Power Aperture	Standard	Standard
Power Aperture OD	Metallized Quartz (200mW) or Wratten No.96 (75mW)	Metallized Quartz (200mW) or Wratten No.96 (75mW)
Laser Type	CW or Pulsed[2]	CW or Pulsed[2]
Operating Range	See Operating Space Chart in Appendix C	See Operating Space Chart in Appendix C
Damage Threshold	See Operating Space Chart in Appendix C	see Operating Space Chart in Appendix C
Rotation Mount	Standard – see drawing in Appendix B	Standard – see drawing in Appendix B
Scanhead Dimension	See Mechanical Drawing in Appendix B	See Mechanical Drawing in Appendix B

[1]Assumes Gaussian (TEM_{00}) Beam
[2]Pulsed Operation Limited to Beam Diameter >≥100µm and pulse repetition frequency ≥5kHz.

NanoScan Scanhead Model	Si/9/5µm	Si/25/25µm
Wavelength	190nm - 950nm	190nm - 950nm
Detector	Silicon	Silicon
Entrance Aperture	9mm	25mm
Slit Size	5µm	25µm
Slit Orientation	+45° and -45°	+45° and -45°
$1/e^2$ Beam Diameter Range[1]	20µm – ~6mm	20µm – ~21mm
Spatial Sampling Resolution	5.7nm – 18.3µm	5.7nm – 18.3µm
Profile Digitization	12 bit	12 bit
Amplifier Gain Range	1-103dB	1-103dB
Filter Frequency Range	2 – 190kHz	2 – 190kHz
Scan Frequency	1.25, 2.5, 5, 10, 20Hz	1.25, 2.5, 5, 10Hz
Power Aperture	Standard	Standard
Power Aperture OD	Metallized Quartz (200mW) or Wratten No.96 (75mW)	Metallized Quartz (200mW) or Wratten No.96 (75mW)
Laser Type	CW or Pulsed[2]	CW or Pulsed[2]
Operating Range	See Operating Space Chart in Appendix C	See Operating Space Chart in Appendix C
Damage Threshold	See Operating Space Chart in Appendix C	See Operating Space Chart in Appendix C
Rotation Mount	Standard – see drawing in Appendix B	Standard – see drawing in Appendix B
Scanhead Dimension	See Mechanical Drawing in Appendix B	See Mechanical Drawing in Appendix B

[1]Assumes Gaussian (TEM_{00}) Beam
[2]Pulsed Operation Limited to Beam Diameter >≥100µm and pulse repetition frequency ≥5kHz.

NanoScan Scanhead Model	Ge/3.5/1.0µm	Ge/3.5/1.8µm
Wavelength	700nm - 1800nm	700nm - 1800nm
Detector	Germanium	Germanium
Entrance Aperture	3.5mm	3.5mm
Slit Size	1µm	1.8µm
Slit Orientation	+45° and -45°	+45° and -45°
$1/e^2$ Beam Diameter Range[1]	4µm – ~2.3mm	7µm – ~2.3mm
Spatial Sampling Resolution	5.7nm – 18.3µm	5.7nm – 18.3µm
Profile Digitization	12 bit	12 bit
Amplifier Gain Range	1-73dB	1-73dB
Filter Frequency Range	2 – 190kHz	2 – 190kHz
Scan Frequency	1.25, 2.5, 5, 10, 20Hz	1.25, 2.5, 5, 10, 20Hz
Power Aperture	Standard	Standard
Power Aperture OD	Metallized Quartz (200mW) or Wratten No.96 (75mW)	Metallized Quartz (200mW) or Wratten No.96 (75mW)
Laser Type	CW or Pulsed[2]	CW or Pulsed[2]
Operating Range	See Operating Space Chart in Appendix C	See Operating Space Chart in Appendix C
Damage Threshold	see Operating Space Chart in Appendix C	See Operating Space Chart in Appendix C
Rotation Mount	Standard – see drawing in Appendix B	Standard – see drawing in Appendix B
Scanhead Dimension	See Mechanical Drawing in Appendix B	See Mechanical Drawing in Appendix B

[1]Assumes Gaussian (TEM_{00}) Beam
[2]Pulsed Operation Limited to Beam Diameter >≥100µm and pulse repetition frequency ≥5kHz.

NanoScan Scanhead Model	Ge/9/5µm	Ge/12/25µm
Wavelength	700nm - 1800nm	700nm - 1800nm
Detector	Germanium	Germanium
Entrance Aperture	9mm	12.5mm
Slit Size	5µm	25µm
Slit Orientation	+45° and -45°	+45° and -45°
$1/e^2$ Beam Diameter Range1	20µm – ~6mm	20µm – ~10mm
Spatial Sampling Resolution	5.7nm – 18.3µm	5.7nm – 18.3µm
Profile Digitization	12 bit	12 bit
Amplifier Gain Range	1-73dB	1-73dB
Filter Frequency Range	2 – 190kHz	2 – 190kHz
Scan Frequency	1.25, 2.5, 5, 10, 20Hz	1.25, 2.5, 5, 10Hz
Power Aperture	Standard	Standard
Power Aperture OD	Metallized Quartz (200mW) or Wratten No.96 (75mW)	Metallized Quartz (200mW) or Wratten No.96 (75mW)
Laser Type	CW or Pulsed2	CW or Pulsed2
Operating Range	See Operating Space Chart in Appendix C	See Operating Space Chart in Appendix C
Damage Threshold	see Operating Space Chart in Appendix C	see Operating Space Chart in Appendix C
Rotation Mount	Standard – see drawing in Appendix B	Standard – see drawing in Appendix B
Scanhead Dimension	See Mechanical Drawing in Appendix B	See Mechanical Drawing in Appendix B

[1]Assumes Gaussian (TEM_{00}) Beam
[2]Pulsed Operation Limited to Beam Diameter >≥100µm and pulse repetition frequency ≥5kHz.

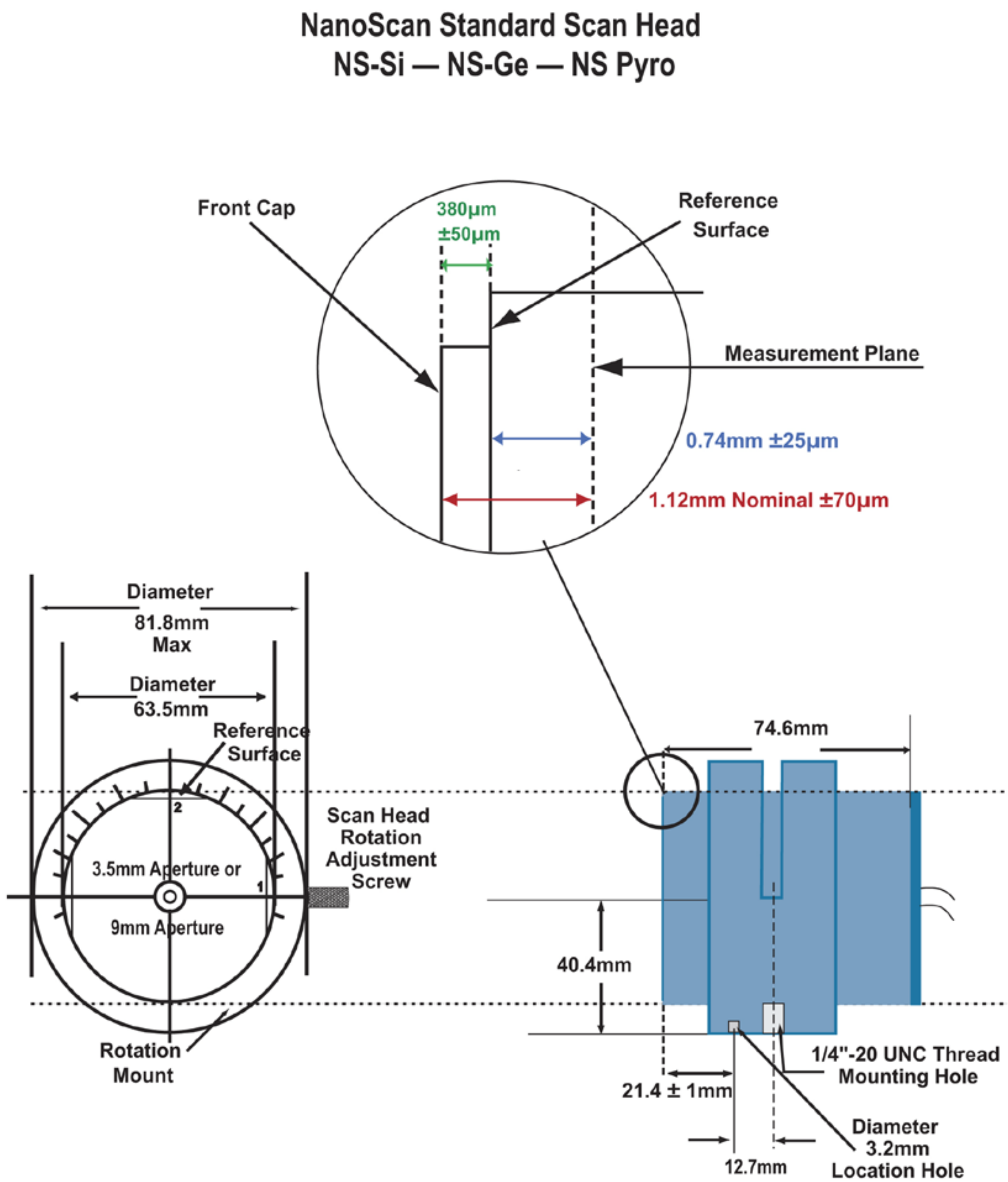
NanoScan Scanhead Model	Pyro/9/5µm	Pyro/20/25µm
Wavelength	200nm – 20µm	200nm – 20µm
Detector	Pyroelectric	Pyroelectric
Entrance Aperture	9mm	20mm
Slit Size	5µm	25µm
Slit Orientation	+45° and -45°	+45° and -45°
$1/e^2$ Beam Diameter Range1	20µm – 6mm	100µm – 14mm
Spatial Sampling Resolution	5.7nm – 18.3µm	5.7nm – 18.3µm
Profile Digitization	12 bit	12 bit
Amplifier Gain Range	1-85dB	1-75dB
Filter Frequency Range	2 – 190kHz	2 – 190kHz
Scan Frequency	1.25, 2.5, 5, 10, 20Hz	1.25, 2.5, 5, 10Hz
Power Aperture	N.A.	N.A.
Power Aperture OD	N.A.	N.A.
Laser Type	CW or Pulsed[2]	CW or Pulsed[2]
Operating Range	See Operating Space Chart in Appendix C	See Operating Space Chart in Appendix C
Damage Threshold	See Operating Space Chart in Appendix C	see Operating Space Chart in Appendix C
Rotation Mount	Standard – see drawing in Appendix B	Standard – see drawing in Appendix B
Scanhead Dimension	See Mechanical Drawing in Appendix B	See Mechanical Drawing in Appendix B

[1]Assumes Gaussian (TEM_{00}) Beam
[2]Pulsed Operation Limited to Beam Diameter >≥100µm and pulse repetition frequency ≥5kHz.

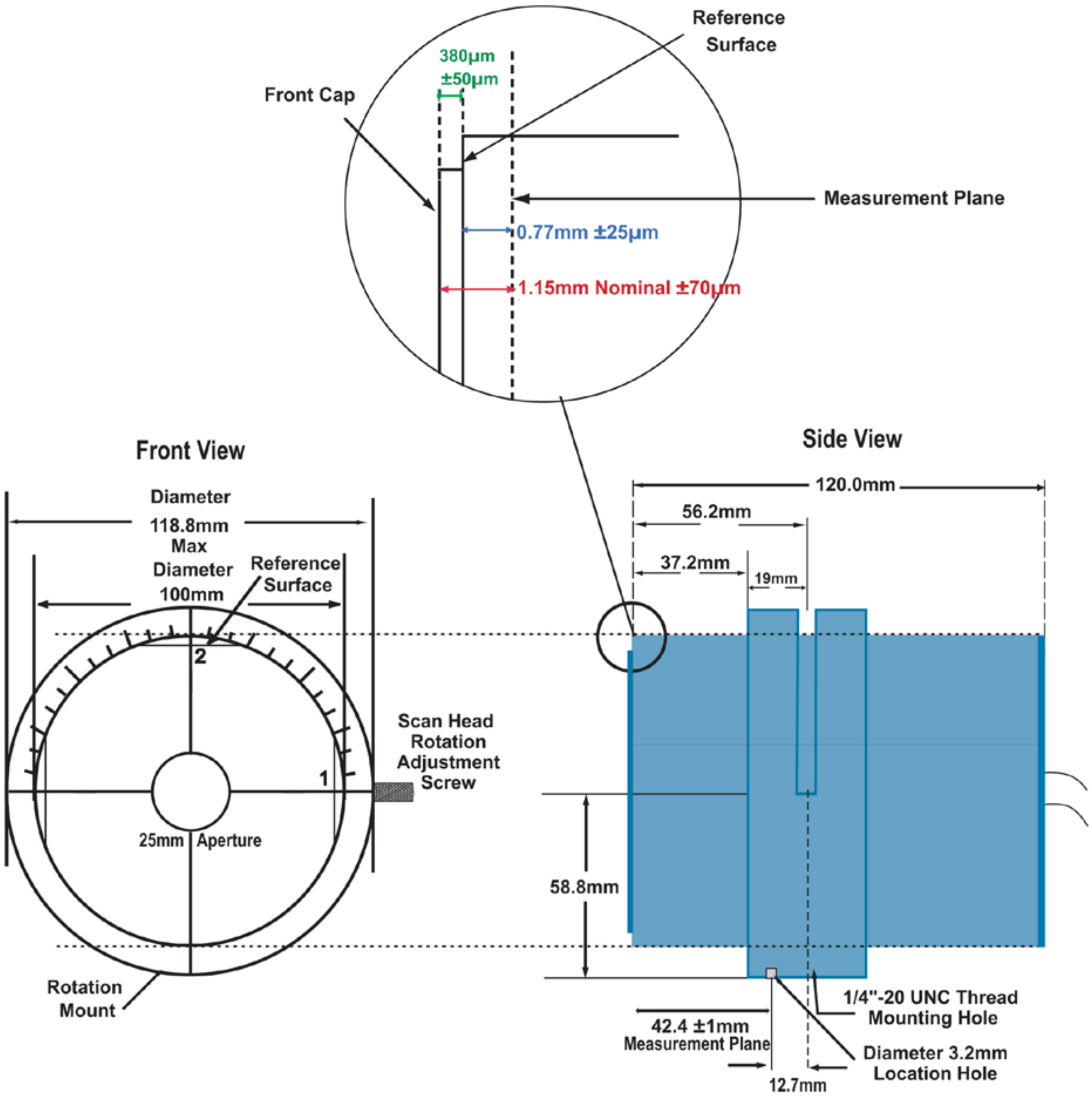
Appendix B – Mechanical Dimensions

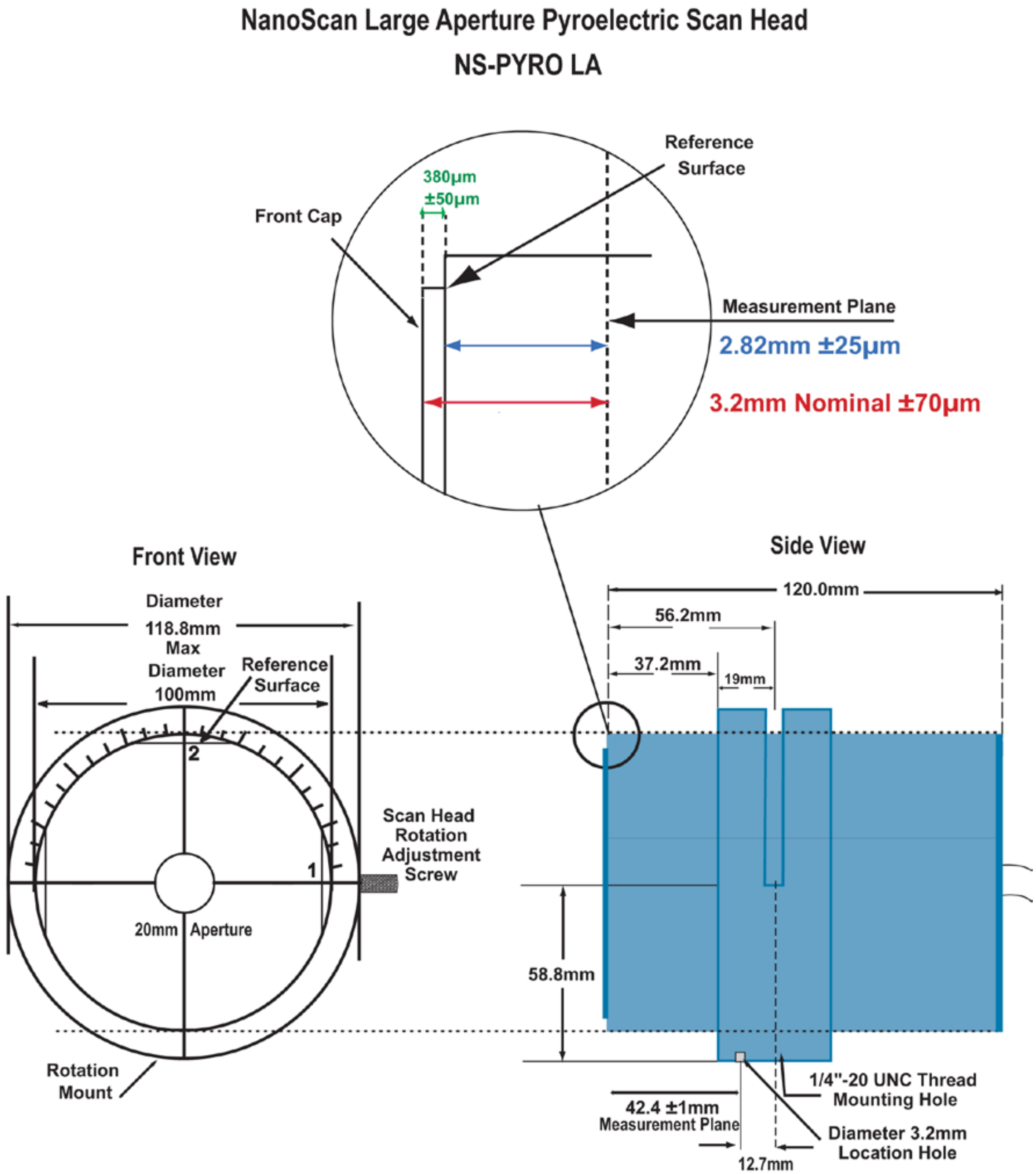
NanoScan

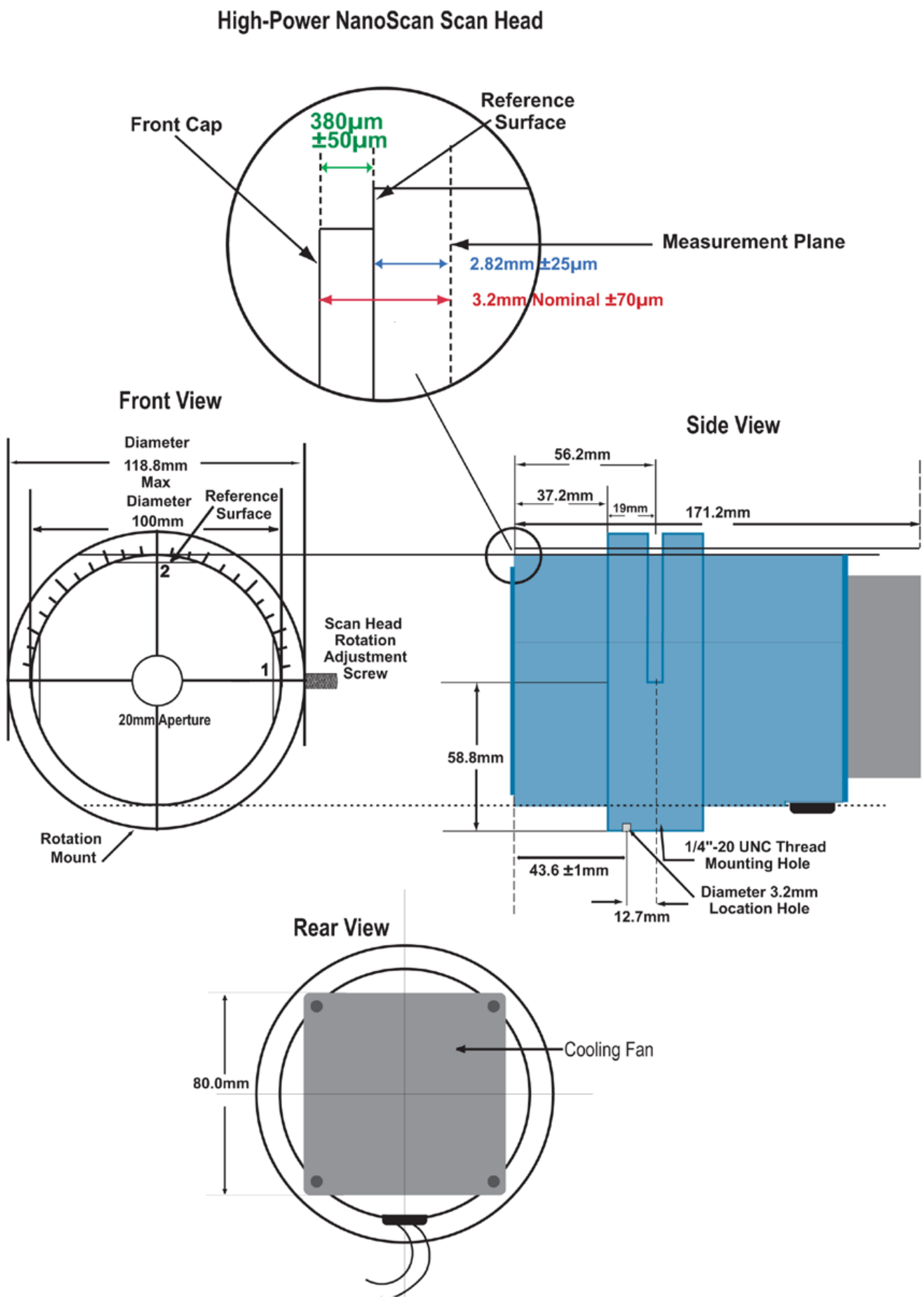
Mechanical Dimensions



NanoScan Large Aperture Silicon and Germanium Scan Heads
NS-Si LA — NS-Ge LA




NanoScan Large Aperture Pyroelectric Scan Head
NS-PYRO LA
Reference Surface
380µm ±50µm
Front Cap
Measurement Plane
2.82mm ±25µm
3.2mm Nominal ±70µm
Front View
Diameter 118.8mm Max
Diameter 100mm
Reference Surface
2
1
Scan Head Rotation Adjustment Screw
20mm Aperture
Rotation Mount
Side View
120.0mm
56.2mm
37.2mm
19mm
58.8mm
42.4 ±1mm Measurement Plane
12.7mm
1/4"-20 UNC Thread Mounting Hole
Diameter 3.2mm Location Hole


High-Power NanoScan Scan Head
Front Cap
380µm ±50µm
Reference Surface
Measurement Plane
2.82mm ±25µm
3.2mm Nominal ±70µm
Front View
Diameter 118.8mm Max
Diameter 100mm
Reference Surface
2
1
Scan Head Rotation Adjustment Screw
20mm Aperture
Rotation Mount
Side View
56.2mm
37.2mm
19mm
171.2mm
58.8mm
43.6 ±1mm
12.7mm
1/4"-20 UNC Thread Mounting Hole
Diameter 3.2mm Location Hole
Rear View
80.0mm
Cooling Fan

Appendix C – Operating Space Charts

Operating Ranges are at Peak Sensitivity of Detector.
Operating Space is NOT absolute.
THESE CHARTS TO BE USED AS A GUIDE ONLY.

The following information is a guide to reading the charts pertaining to **Silicon** detectors.

Silicon Detector: Responsivity varies with wavelength. Detects between 190-950nm. Peak responsivity is 0.4 amps/watt at 850nm. Detector to detector responsivity variation can be as great as ±20%.

Power: Power in the measured laser beam. Assumes a round beam diameter. An elliptic beam can be approximated by using the maximum width dimension and assuming all the energy is in a beam of this diameter. For extremely elliptic beams (ratio >4:1)/ contact the factory.

Pulsed Operation: ( ) Upper limit of the operating space for pulsed laser measurements.

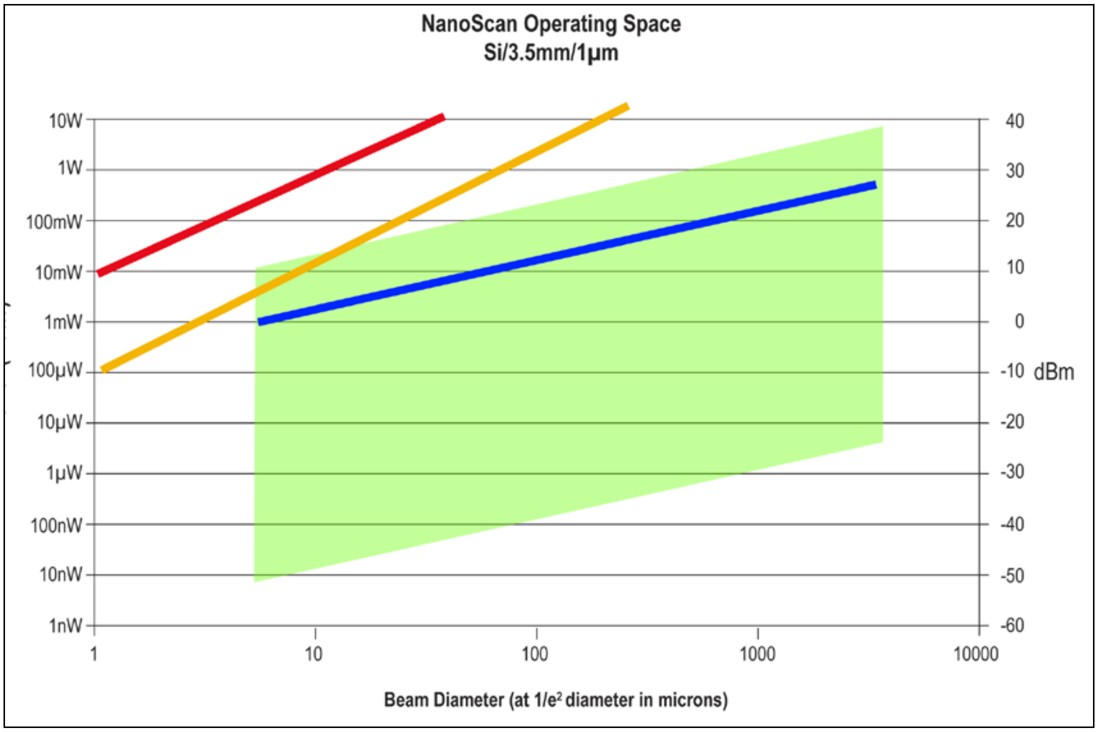
Black Coating Removed ( ): Slits are blackened to reduce back reflections; blackening begins to vaporize near this line. Slits in pyro detectors are not blackened.

Slit Damage ( ): Power density (watts/cm^2) where one can begin to cut the slits. Refer to Photon's *Damage Threshold with High Power Laser Measurements* document.

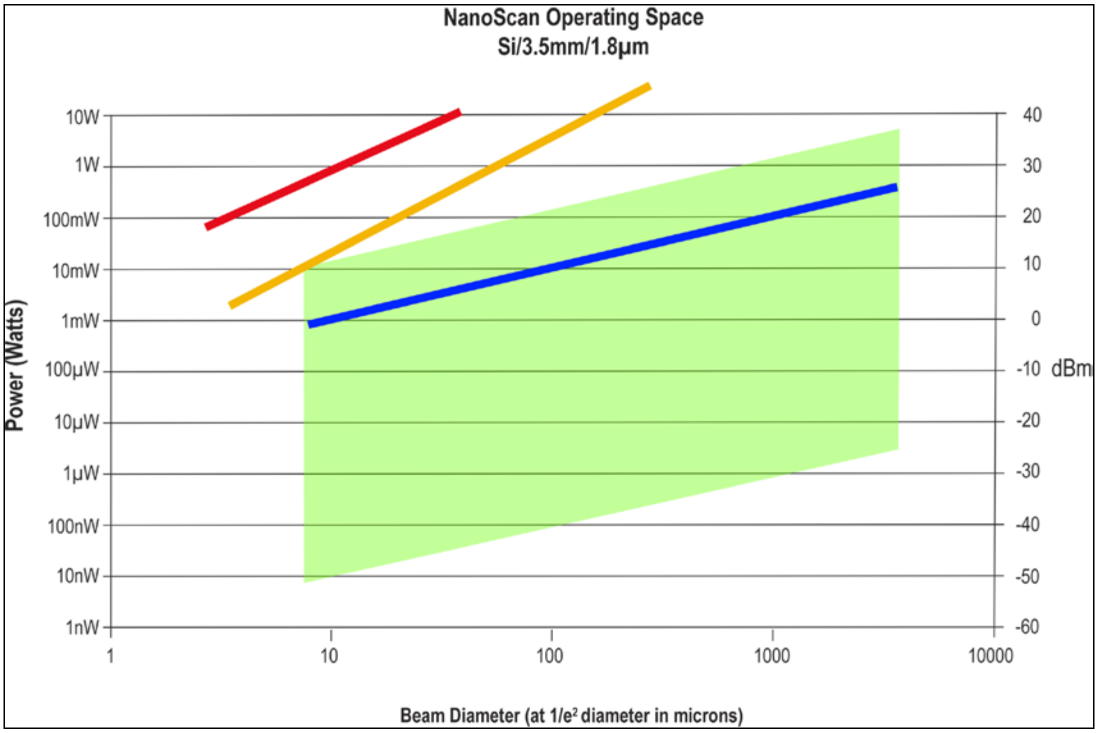
Left Boundary: Smallest beam size limited to 4-5 times the slit width. Some models have another limit due to electrical bandwidth.

Right Boundary: Instrument entrance aperture. The largest beam width ($1/e^2$) will be the aperture divided by 1.2-1.4.

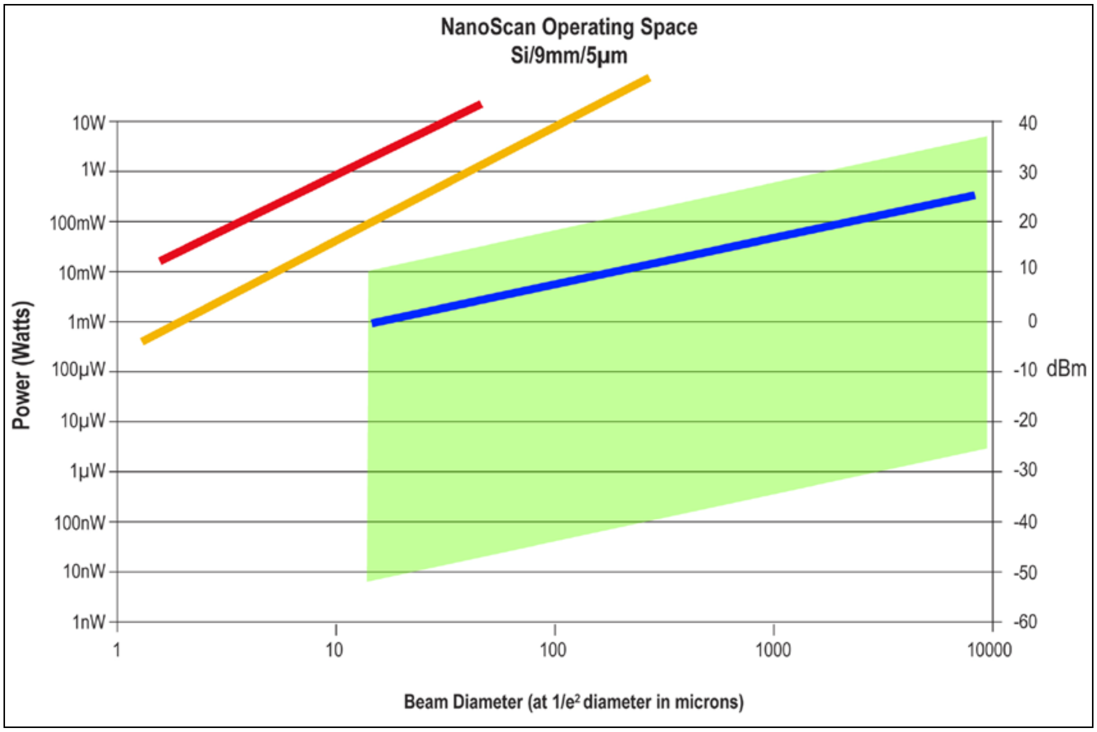
Silicon/3.5mm/1µm



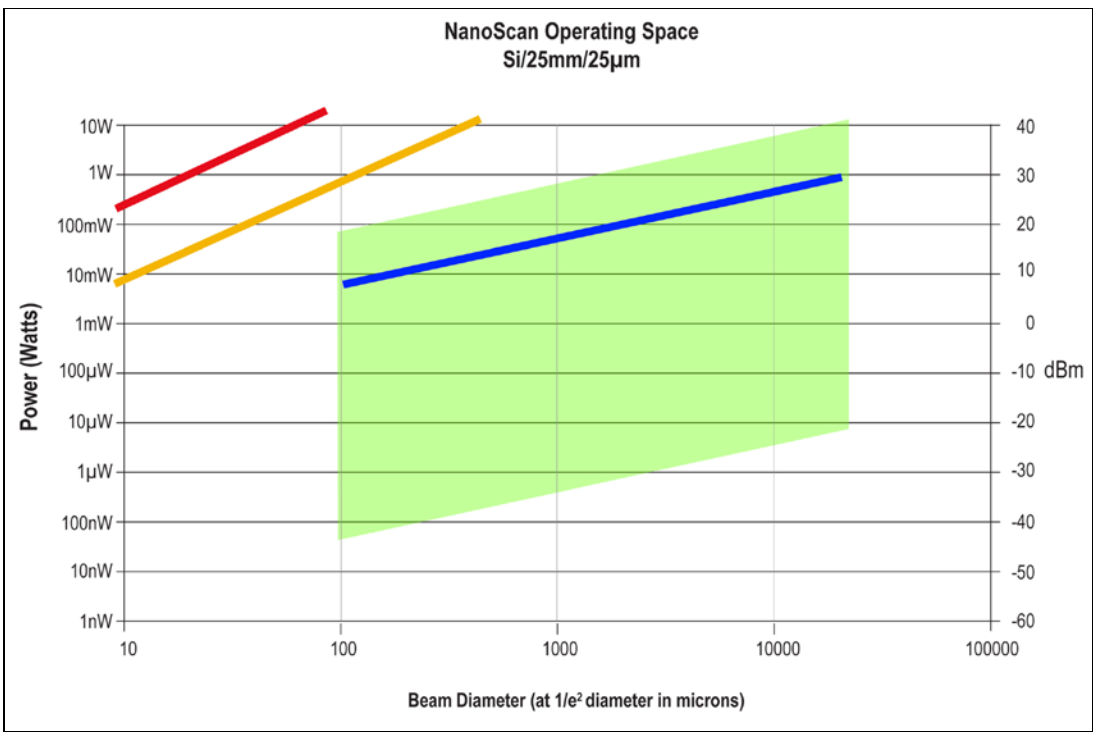
Silicon/3.5mm/1.8µm



Silicon/9mm/5µm



Silicon/25mm/25µm



The following information is a guide to reading the charts pertaining to **Germanium** detectors.

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

Detector: Responsivity varies with wavelength. Detects between 800-1800nm. Peak responsivity is 0.7 amps/watt at 1550nm. Detector to detector responsivity variation can be as great as ±20%.

Power: Power in the measured laser beam. Assumes a round beam diameter. An elliptic beam can be approximated by using the maximum width dimension and assuming all the energy is in a beam of this diameter. For extremely elliptic beams (ratio >4:1) contact the factory.

Beam Diameter: Circular laser spot being measured by a narrow slit. Clip level method.

Pulsed Operation: ( ): Upper limit of the operating space for pulsed laser measurements.

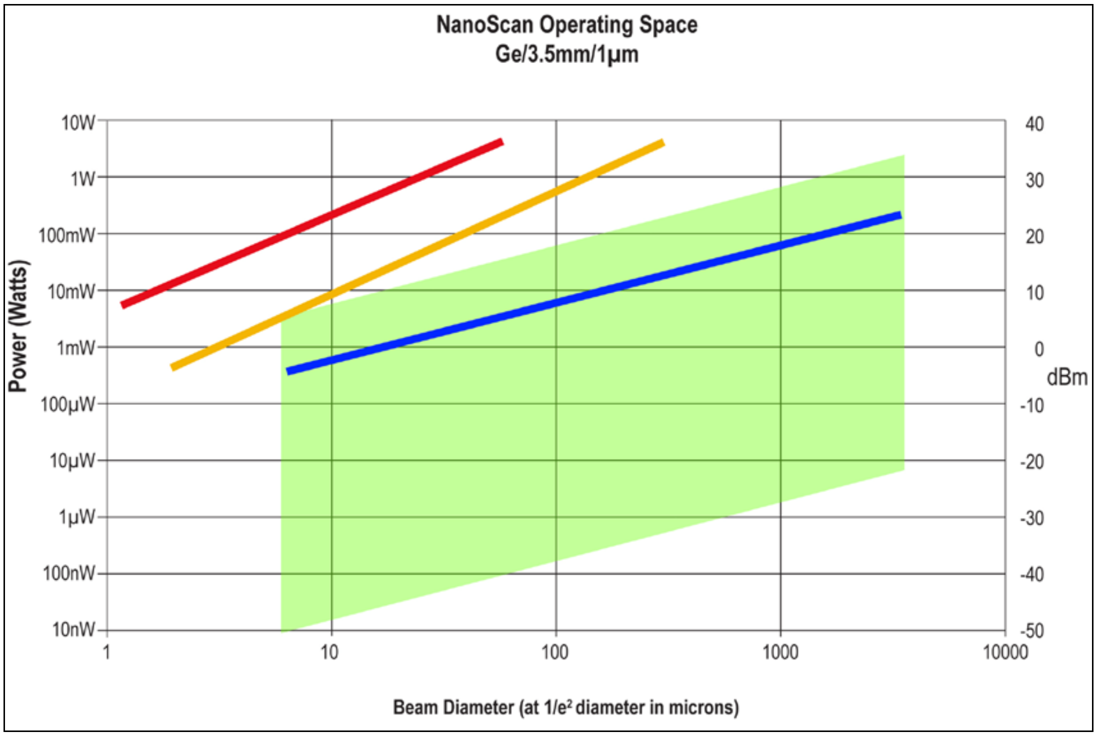
Black Coating Removed ( ): Slits are blackened to reduce back reflections; blackening begins to vaporize near this line. Slits in pyro detectors are not blackened.

Slit Damage ( ): Power density (watts/cm^2) where one can begin to cut the slits. Refer to Photon's Aperture Damage due to High Incident Power document.

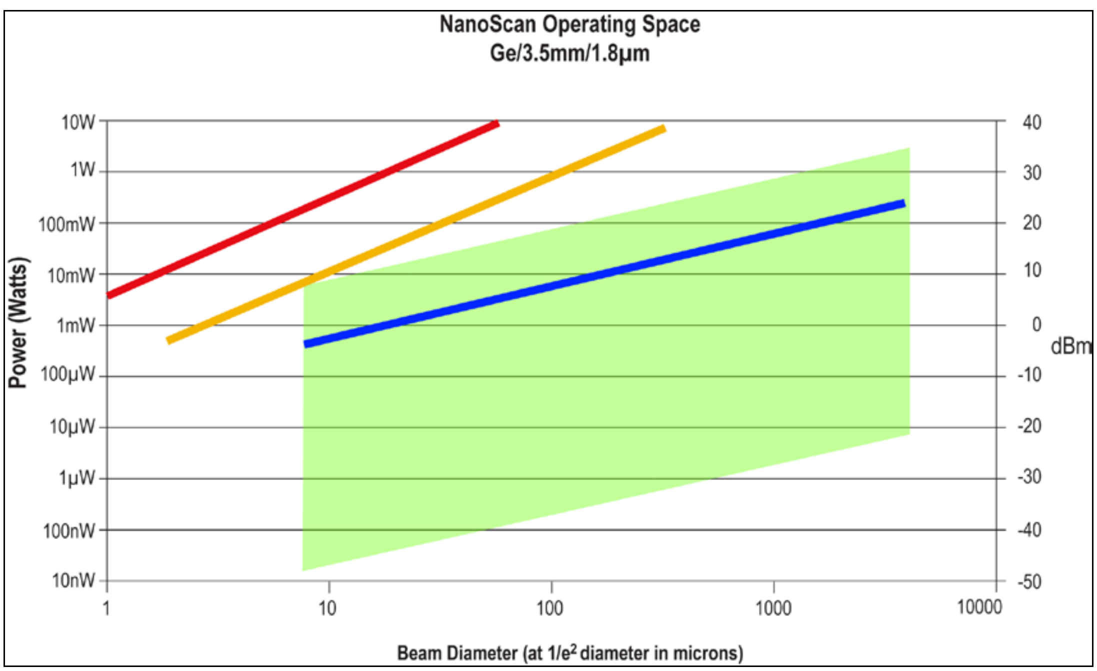
Left Boundary: Smallest beam size limited to 4-5 times the slit width. Some models have another limit due to electrical bandwidth.

Right Boundary: Instrument entrance aperture. The largest beam width (1/e^2) will be the aperture divided by 1.2-1.4.

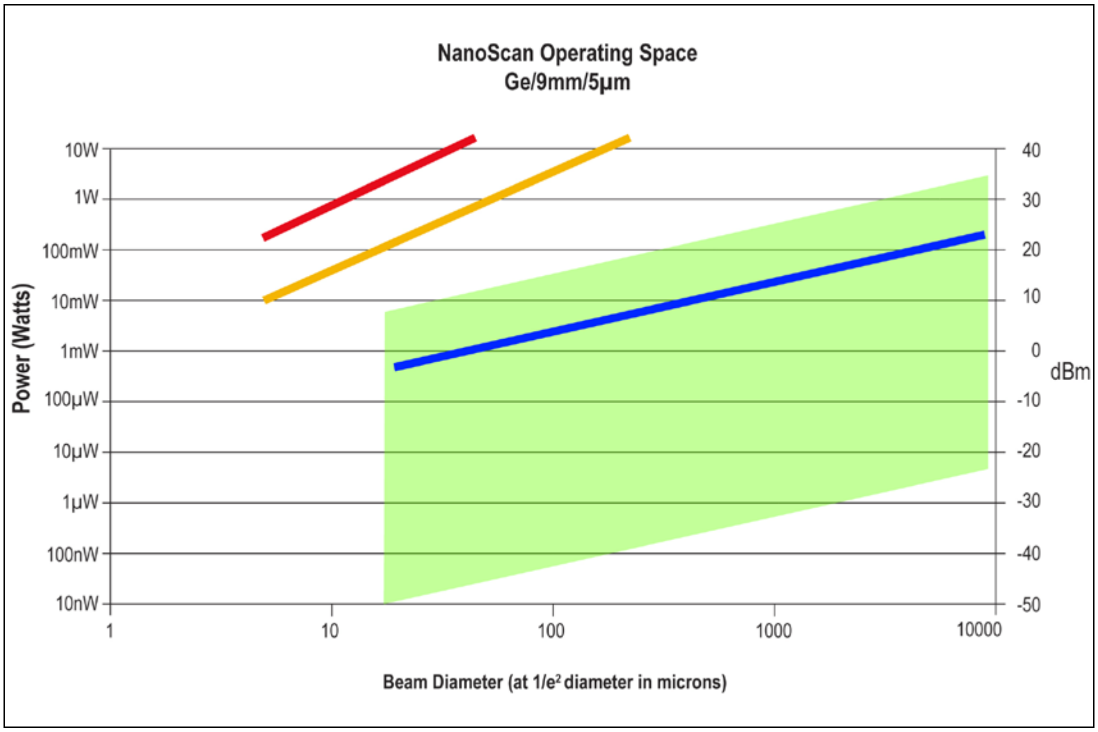
Germanium/3.5mm/1µm



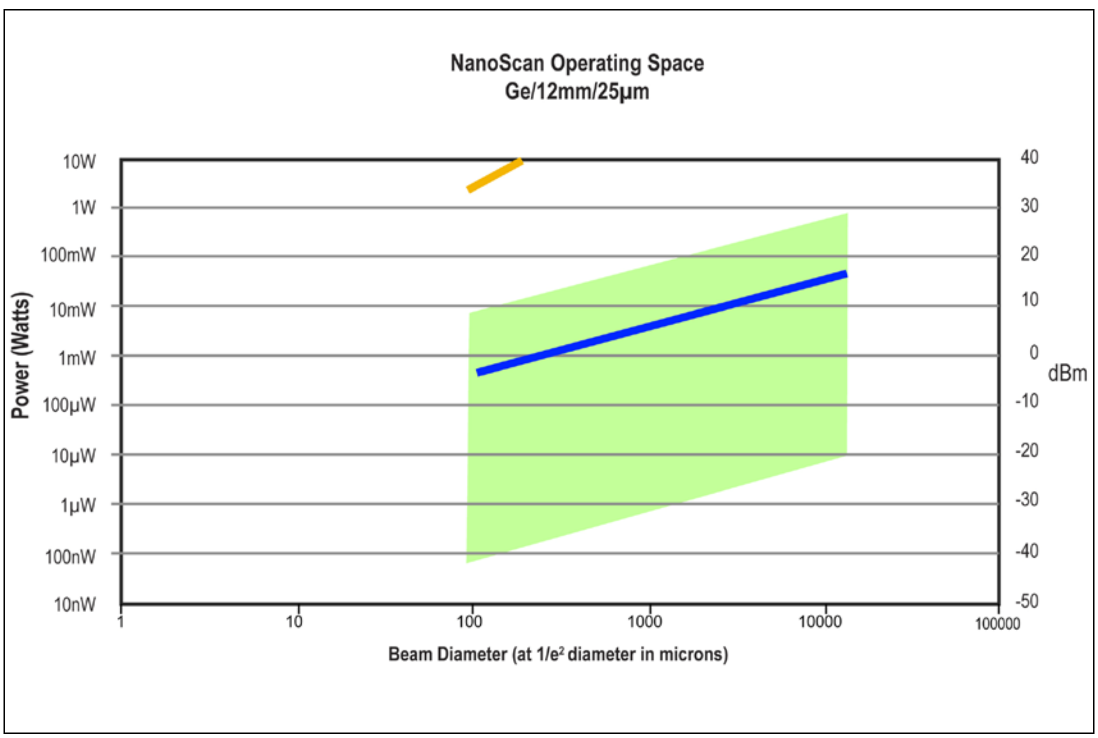
Germanium/3.5mm/1.8µm



Germanium/9mm/5µm



Germanium/12mm/25µm



The following information is a guide to reading the charts pertaining only to **Pyroelectric** detectors.

Pyroelectric Detector: Uniform in response between 0.2 and 20 microns wavelength.

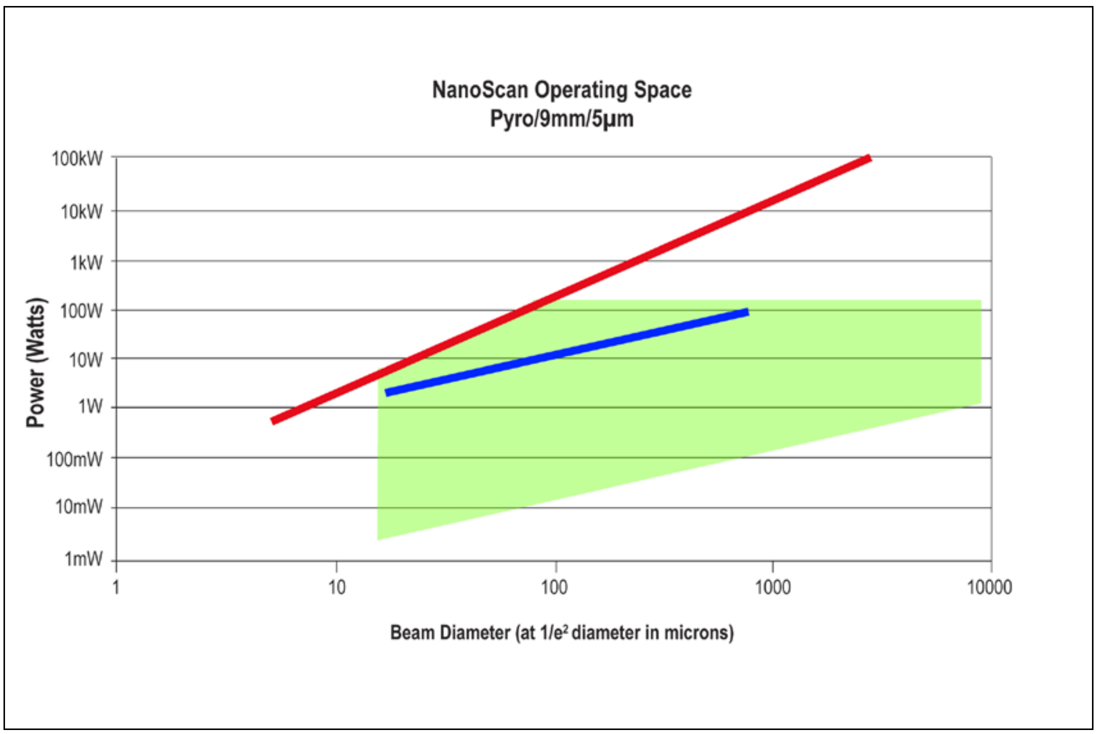
Pulsed Operation: (▬▬▬) Upper limit of the operating space for pulsed laser measurements.

Slit Damage (▬▬▬): Power density (watts/cm^2) where one can begin to cut the slits. Refer to Photon's Aperture Damage due to High Incident Power document.

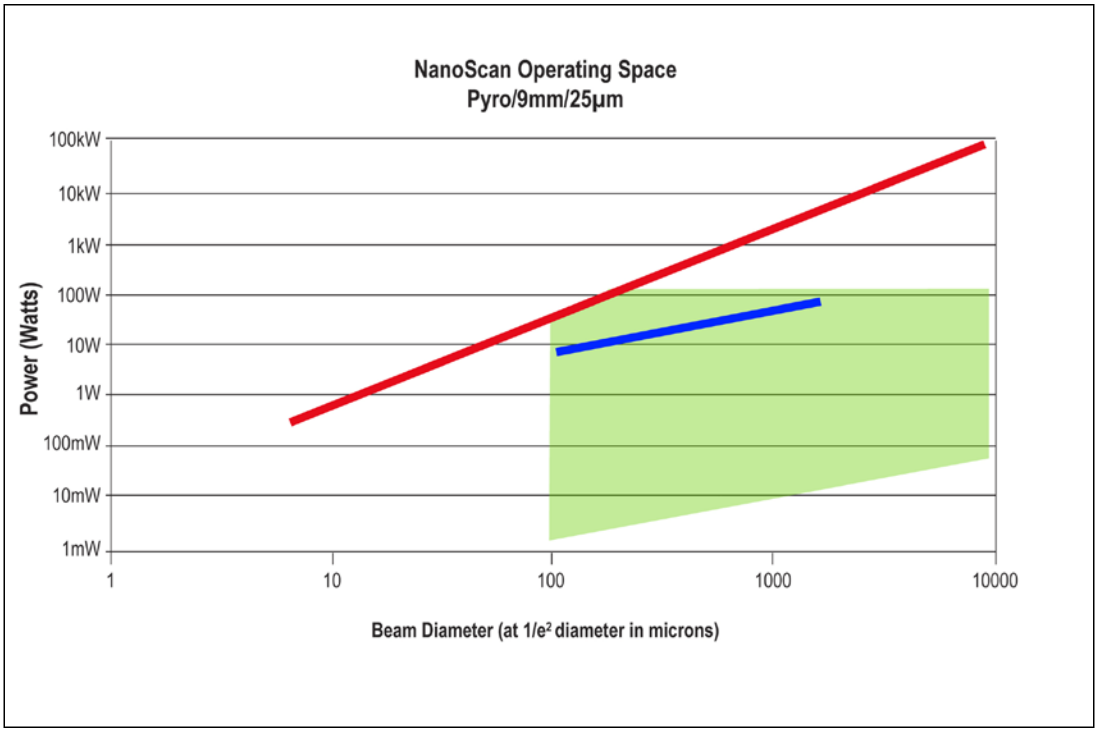
Left Boundary: Smallest beam size limited to 4-5 times the slit width. Some models have another limit due to electrical bandwidth.

Right Boundary: Instrument entrance aperture. The largest beam width (1/e²) will be the aperture divided by 1.2-1.4.

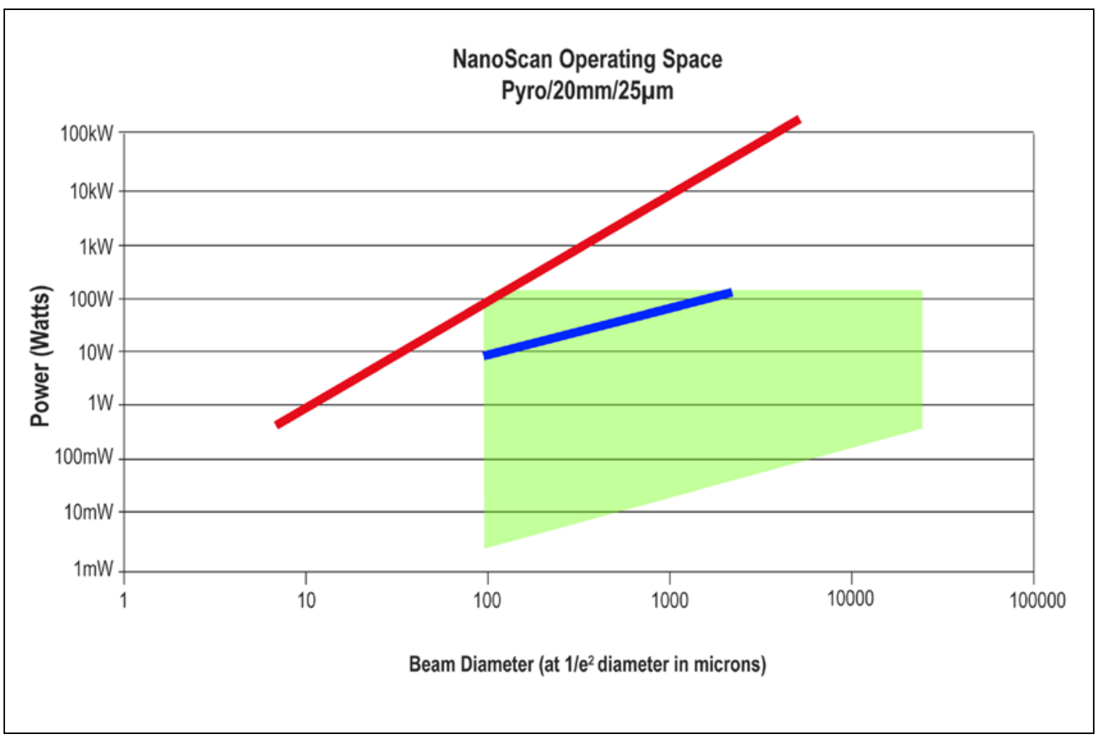
Pyroelectric/9mm/5µm



Pyroelectric/9mm/25μm



Pyroelectric/20mm/25μm



Index