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NanoScan v2™

User Guide

For NanoScan2 & NanoScan2s

For Sales, Service or Technical Support

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Dear Ophir-Spiricon Customer,

Thank you for your recent purchase of the NanoScan system.

At Ophir-Spiricon we strive to provide the highest level of leading edge photonic measurement technology and service possible. We hope that your experience with us is a pleasant one, and anticipate the relationship we build will serve your photonic measurement needs for years to come.

As a valued customer, your comments and opinions are always very important to us. If you have any concerns, questions, or comments, bring them to our service department's attention. We are ready to help with everything from basic setup to working with you to find solutions for your most complex photonics measurement needs.

Please let us know if there is any way we can be of service. Thank you once again for your business.

Sincerely,

Ophir-Spiricon, LLC

How to Use this Guide

Read this user guide before setting up your NanoScan system. Become familiar with the laser beam analysis theory and acquire a basic understanding of how NanoScan operates. Insights gained through this review facilitate achieving a correct system setup and help with interpreting results.

Symbol Notation

Indicates general information that poses no risk.

Indicates important information about the product with little or no risk.

Indicates warning information. Failure to follow instruction may result in harm to the user or product damage.

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Safety

While NanoScan itself does not present the user with any safety hazards, this instrument is intended for use with laser systems. Therefore, the user should be protected from any hazards that the laser system may present. The greatest hazards associated with laser systems are damage to the eyes and skin due to laser radiation.

Optical Radiation Hazards

Use of this instrument requires the operator to work near the optical path of lasers. Exposure to radiation from these lasers may be sufficient to warrant the use of protective equipment.

Unless the laser's optical path is enclosed, the operator, and any other personnel should be protected against accidental exposure. Hazards include direct beam exposure and reflected radiation.

When working with an unenclosed beam path, it is advisable to do so while the laser is powered down or at reduced power levels. Whenever there is a risk for dangerous exposure, protective eye shields and clothing should be worn.

Electrical Hazards

NanoScan utilizes only low voltages, derived from the USB cable. Thus there is little risk of electrical shock presented to the user.

When installing or removing hardware form a PC, the power to the computer should always be disconnected.

The computer should always be operated with its covers in place and in accordance with its manufacturer's recommendations.

The computer should always be operated with a properly grounded AC power cord.

IMPORTANT WARNING!

Do **NOT** expose NanoScan2 to **ANY** laser beam when the drum is not spinning!

Scanhead damage thresholds drop below specifications when the drum is not spinning, increasing the risk of damage. Laser beam's incident in the aperture may cause damage to the slits and detector if the drum is not spinning.

The drum only spins when the software is running and the USB cable is connected and providing power. The slit substrates are thin membranes which can be damaged if stopped in the beam. Use of a beam dump is recommended when the drum is not spinning.

During long term tests, configure the PC Power Management to never go off, and turn off automatic updates. These cause the computer to reboot, closing NanoScan v2, and stopping the drum rotation.

Chapter 1 Introduction

Thank you for the purchase of your new NanoScan2 Laser Beam Profiling System with NanoScan v2 software! Ophir-Spiricon's philosophy is to produce instruments that enable both end users and original equipment manufacturers to receive the utmost accuracy and precision in beam profile measurement and characterization.

For over 20 years Photon's scanning slit technology has been the industry standard for optical beam profiling, providing accurate and repeatable measures of beam width and beam position to the µm range. It has been recognized worldwide as the benchmark for all other beam profiling instruments.

The NanoScan v2 software enhances the user experience with a number of features and a modernized graphical user interface (GUI) makes it easy to learn and use.

1.1   About this Guide

This user guide is designed to help you setup and operate your NanoScan2 system.

Chapter 1 includes a NanoScan2 system overview, a brief explanation of the NanoScan2 operation, an overview of the NanoScan v2 Analysis Software, and some practical suggestions on proper care and regular calibration of your new instrument.

Chapter 2 shows unpacking and inspection instructions, the system's packing list, and step-by-step system setup instructions for installing and configuring the hardware and software.

Chapter 3 describes the features and operation of the NanoScan v2 software and GUI.

Chapter 4 defines the theory of operation of the NanoScan2 scanhead and principles of laser beam profiling measurement.

Chapter 5 lists Frequently Asked Questions (FAQs).

Appendix A includes the Scanhead Specifications.

Appendix B shows the Mechanical Dimensions of the scanheads.

Appendix C shows the operating space charts of the various NanoScan2 models.

1.2   Product Description

NanoScan2 is a PC-based instrument for the measurement and analysis of optical beam spatial profiles in accordance with ISO standards. Beam profiles are measured in accordance with the International Standard ISO 11146. Integrated power meters can measure power in accordance with ISO 13694.

The system is comprised of a USB 2.0 NanoScan2 scanhead and NanoScan v2 software. An optional automation feature includes an ActiveX automation server.

NanoScan2 uses moving slits, an ISO Standard scanning aperture technique. Measurement is possible for beam sizes from microns to centimeters and at beam powers from microwatts to kilowatts, without attenuation. Detector options (silicon, germanium, and pyroelectric technologies) allow measurement at wavelengths from the ultraviolet to the far infrared. NanoScan2 can simultaneously measure multiple beams. An integrated power meter is installed which provides calibrated power measurements.

A typical NanoScan2 system includes the following:

- NanoScan2 scanhead with rotation mount and protective cap
- NanoScan v2 Beam Profiling and Analysis Software for Microsoft Windows 7 or Windows 10
- NanoScan v2 User Guide

1.3 Operation and Use

The scanhead "senses" incident laser beams directed into the scanhead entrance aperture. The digital output signal is proportional to the spatial beam profile and the total power in the beam. The NanoScan v2 software controls the scanhead scan rate, signal amplification, signal filtering, and the spatial sampling rate. The acquired digital profile data is transferred into the computer memory for data analysis and display.

NanoScan2 is useful in any photonic application that requires precise and accurate measurement of beam size and position. NanoScan2 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. It is 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, NanoScan2 provides considerable savings in time and improves productivity and throughput.

1.4 NanoScan v2 Software Overview

1.4.1 NanoScan v2 Beam Profiling GUI

NanoScan v2 beam profiling software is an intuitive standalone application that provides scanhead control plus profile display and data analysis. The software is written specifically for MS Windows platforms, and is compatible with Windows 7 and Windows 10 32-bit or 64-bit operating systems.

Ophir-Spiricon no longer verifies or certifies operation with Windows XP.

1.4.1.1 Scan control and Profile Acquisition

The scanhead contains programmed characteristics unique to each scanhead model. It also contains power calibration information once a calibration is made using the NanoScan v2 software.

Available scan rates are 1.25, 2.5, 5, 10, and 20Hz. The spatial sampling interval is determined by the user programmable sampling clock. As an example, spatial sampling can be set as fine as 0.0427µm at a 10Hz scan rate. The available amplifier gain settings are scanhead dependent and are given in the gain table. The filter frequency can be adjusted over a range from 2kHz to 190kHz. The filter is used to improve the signal-to-noise ratio in the acquired profile data within the limits of beam diameter measurement requirements. The spatial sampling interval, the gain, the filter setting, and the scan rate can be set to optimize profile acquisition and measurement.

Profiles are acquired with 16-bit digitization and analyzed in real-time to the maximum scan rate of 20Hz.

1.4.1.2 Data Display and Visualizations

The data display screens show X and Y profiles for up to 16 regions of interest (ROIs), the position plots of the beams, and 2D and 3D renderings of the beam. Quantitative displays of user-selected results are displayed in real time.

1.4.1.3　Measured Beam Results

Results measured include:

- Beam Width at various clip levels
- Centroid Position
- Peak Position
- Ellipticity
- 1D Gaussian Fit
- Beam Divergence

- Beam Separation
- Pointing Stability
- ROI Power
- Total Power
- Peak (in digitizer counts)
- Pulsed Laser Repetition Rate

1.4.1.4　Data Export

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

1.4.2　ActiveX Automation Server

The automation feature is available for Professional (PRO) licensed scanhead models. The Photon NanoScan v2 analysis software includes an ActiveX Automation server interface for integrating the NanoScan2 system into custom automated test and measurement applications. A Developer Guide for using the ActiveX Automation server as well as example applications with sample code for LabVIEW and MS Excel written in Visual Basic are provided in the Automation folder (C:\Program Files (x86)\Photon\NanoScan v2\Automation).

1.5　NanoScan2 Hardware Specifications

The NanoScan2 is a self-contained scanhead that incorporates a powerful digital signal processor and a 16-bit analog to digital converter. All NanoScan2 scanheads are provided with a power meter that can be user calibrated to make power measurements; see section 4.4.11.

Bus interface	USB 2.0, Powered via USB port
Signal digitization	16-bit
Maximum digitization clock	21.4MHz
Maximum scan rate	20Hz
Data transfer	Bulk Transfer Mode
On-board memory	64MB SDRAM
Weight	434g (15.3 ounces)
Operating temperature	0-50°C
Humidity	90%, non-condensing
Sample transfer data time	0.4ms for 10K samples (20Kb)

1.5.1　NanoScan2 Scanhead Models

Standard NanoScan2 scanheads come with various combinations of detector, entrance aperture diameter, and slit width. These are listed below. Model names designate the groupings in the format "detector type/aperture diameter in mm/slit width in µm." See Appendix A for hardware specifications on the following scanhead models. See Appendix B for the mechanical dimensions of the scanheads. See Appendix C for the scanheads Operating Space Charts.

1.5.1.1   Silicon Detectors (190-950nm)

- PH00456 NS2s-Si/3.5/1.8-STD
- PH00457 NS2s-Si/9/5-STD
- PH00464 NS2s-Si/3.5/1.8-PRO
- PH00465 NS2s-Si/9/5-PRO

1.5.1.2   Germanium Detectors (700-1800nm)

- PH00459 NS2s-Ge/3.5/1.8-STD
- PH00460 NS2s-Ge/9/5-STD
- PH00467 NS2s-Ge/3.5/1.8-PRO
- PH00468 NS2s-Ge/9/5-PRO

1.5.1.3   Pyroelectric Detectors (0.2-20µm)

- PH00462 NS2s-Pyro/9/5-STD
- PH00470 NS2s-Pyro/9/5-PRO
- PH00496 NS2s-Pyro/9/5-MIR-PRO

1.6   Protecting Your Investment

In order to ensure that your measurement accuracy meets specification and that internal ISO requirements are met, strictly follow the following guidelines:

- Make sure all electrical connections, including your PC, are plugged into a surge protection outlet strip.
- Keep the protection cap on the device whenever the scanhead is not in use. The system must be free of debris to provide accurate measurements.
- Never touch the scanning slits with hands or objects. The slits are thin fragile membranes that can be easily damaged. Damaged stilts can seriously compromise measurement accuracy.
- Excessive beam power and power density from high power lasers, and largely focused beams may also damage the apertures. Refer to the Slit Damage Threshold (section 4.3.1), Scanhead Operating Space Charts (section 4.3.3), and the Operating Space Charts (Appendix C).
- Visually verify that the scanhead drum is spinning before directing the beam into the scanhead.
- Return your device to the factory annually for calibration and evaluation. This ensures the product will continue to measures within specification. Ophir-Spiricon offers several Calibration and Preventative Maintenance options.

Ophir-Spiricon provides a limited warranty on parts and labor for 12 months. Ophir-Spiricon 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 warrantied for any reason. Please refer to Ophir-Spiricon's Warranty Policy for complete details.

Chapter 2 Installation and Setup

2.1   Inspection

Your NanoScan2 device has been tested extensively at Ophir-Spiricon to ensure proper operation. All components were inspected and carefully packaged for shipment. Upon receipt, please do the following:

- Check the contents of your shipment against the included packing list. 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 system components for any signs of damage. If damage is observed, immediately report the damaged container to the shipping company. **Ophir-Spiricon does not warrant damage that occurs as a result of shipment.**

2.2   Packing List

1. NanoScan2 scanhead with Rotation Mount and protective dust cap
2. 2-meter USB 2.0 A to mini-B cable
3. NanoScan v2 Acquisition and Analysis Software DVD
4. NanoScan2 Damage Information Pamphlet
5. Calibration Certificate
6. NanoScan2 Declaration of Conformance
7. Accessories
   a. USB Connector Strain Relief with #2-56 screws
   b. 1/4"-20 set screw
   c. M6 set screw
8. Case

2.3   PC Requirements

To take full advantage of your NanoScan2 system's capabilities, the following minimum PC requirements are recommended:

- A dual core processor CPU, 2GHz or better
- Microsoft Windows 7 or Windows 10, 32-bit or 64-bit Operating System[1]
- 2GB of RAM or better[2]
- A USB 2.0 port available
- At least 250MB of free HDD space
- 1400 x 900 display resolution or better
- Add-in PCI/PCI-Express graphics card w/hardware accelerator
- DVD-ROM drive
- Microsoft compatible pointing device (e.g., mouse, trackball, etc.)

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[1] A business/professional version of Windows is recommended. The NanoScan v2 software has not been tested with home versions of Windows. NanoScan v2 is no longer tested on Windows XP 32-bit operating systems.
[2] The computer memory (RAM) will affect the performance of the software in the Data Recorder. Refer to section 3.8.3 for more information on the Data Recorder.

2.4   NanoScan v2 Installation

There are two steps to installing NanoScan2

1. Install the Software
2. Connect the Scanhead

The software should be installed before the hardware otherwise you will have to dismiss many "Failed to Install" notifications.

2.4.1   Before you Install

The NanoScan2 model scanheads are not compatible with the legacy NanoScan v1.47 or earlier releases. NanoScan2 scanheads must be used with NanoScan v2 release v2.2 or later.

Upgrading to the new NanoScan v2 software does not require the previous v1.47 be uninstalled before installing. The two versions can both reside on a single PC platform and can operate independent of each other. Meaning, older style NanoScan scanheads may continue to be used with the legacy NanoScan software. However two instances of the software cannot connect to the same head.

2.4.2   Installing the Software

There are two ways to install the software from the provided CD. These steps are laid out for Windows 7, but similar steps are taken in Windows 10. All installations must be performed with Administrator privileges.

A. If the computer is setup to Auto Play CD's do the following:
1. Insert the supplied CD into the CD-ROM drive and wait for the **Spiricon Software Auto Install** screen to appear.
2. Select **Software Install**.
3. Follow the directions on screen.

B. If the computer does not have the Auto Play feature enabled:
4. Insert the supplied CD into the CD-ROM drive and open **Windows Explorer**.
5. Select **My Computer** and right-click on the CD-ROM drive with the Ophir-Spiricon CD. Select **Autoplay**, and wait for the **Spiricon Software Auto Install** screen to open.
6. Select **Software Install**.
7. Follow the directions on screen.

The NanoScan v2 shortcut icon appears on the desktop.

2.5 Installing the Scanhead

2.5.1 USB 2.0 Connection

The NanoScan2 scanhead is supplied with a protective dust cover. Do not remove this cover until you have the scanhead securely mounted and are ready to expose the scanhead to laser radiation.

1. Connect the supplied USB2 cable's mini-B connector to the NanoScan2 scanhead.
2. Connect the USB2 cable's A-connector to an available USB2 port on the computer.
3. The Windows Plug-and-Play feature should indicate that the NanoScan2 driver has been successfully connected to the scanhead. This could take a few seconds to cycle.
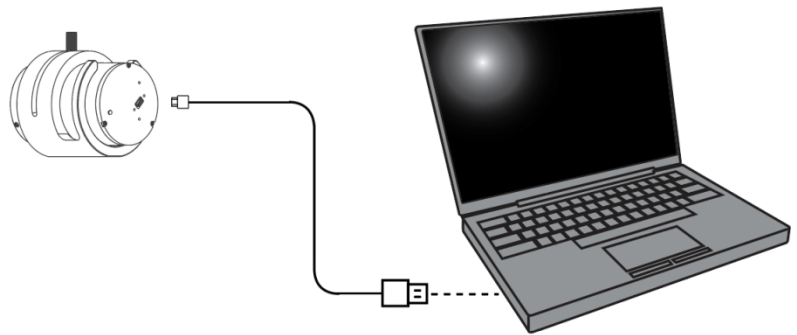
2.5.2 Rotation Mount

A rotation mount comes standard with all NanoScan2 scanheads. The rotation mount allows smooth continuous adjustment of the angular position of the scanhead over a range of 190°. The rotation mount sleeve fits over the scanhead and permits attachment via either a 1/4-20 or M6 thread. After mounting, the scanhead can be rotated within the sleeve by loosening and sliding the knurled knob retaining screw.

The rotation mount also allows for vertical beam sampling. It can be achieved by removal of the knurled locking screw, sliding the rotation ring back to the next thread location, and reinserting the locking screw. Figure 2.1 depicts the scanhead in both mounting configurations. Note that the mounting stand is less stable if loosely mounted onto a surface without the addition of a clamping device.
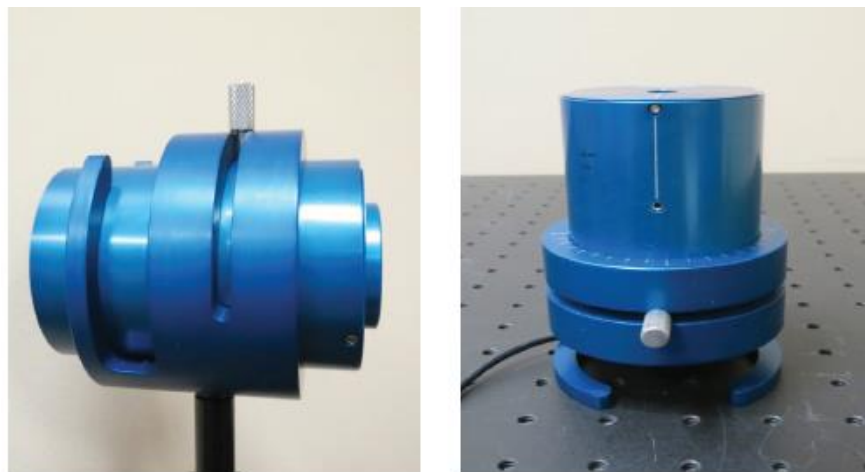
Figure 2.1 Rotation mount in horizontal and vertical directions

2.5.3 Scanhead Positioning and Alignment

The NanoScan2 scanhead has features to aid in the positioning and alignments required for accurate beam measurements. These are illustrated in Figure 2.2. The front cap has scribe lines at the entrance aperture that represent the orthogonal scan axes.
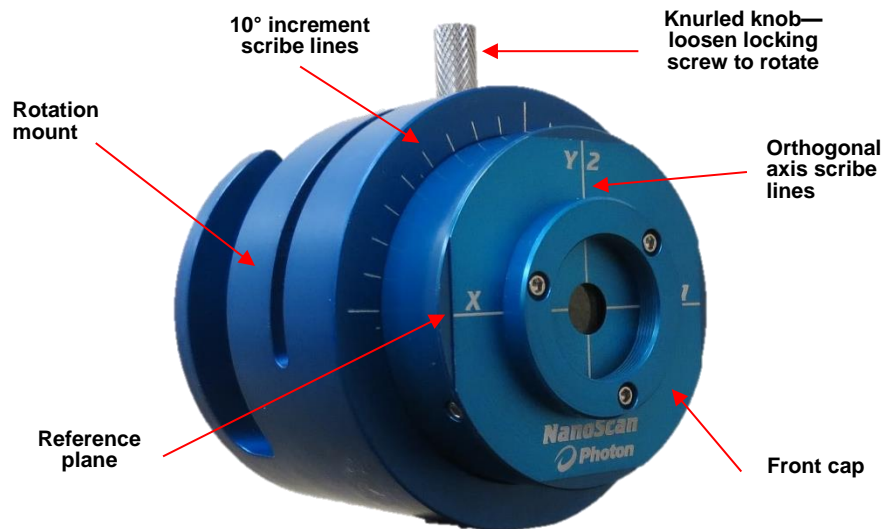
Figure 2.2 Features of the NanoScan2 Scanhead

2.5.3.2 The Measurement Plane

The measurement plane in the scanhead is at the surface of the slit materials. This plane is accurately controlled and is mechanically referenced to the rim of the housing tube. Refer to Appendix B for specific model information regarding Scanhead Dimensions and measurement plane location.

2.5.3.3 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.

2.5.3.4 User Defined Origin Position

It is possible to redefine the arbitrary origin (0,0) position for the scanhead entrance aperture in the software using the **Origin Location** panel (section 3.5.5). There are several ways to determine the new origin position:

- Train the software with a good, functional component or assembly. Make your setup and then record the X and Y coordinates. Load these coordinates as the new origin position. If you remove the head from your setup, it is unlikely you can maintain the origin location to a micron level and recalibration becomes necessary.
- Another method 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. Load these coordinates as the new origin position into the software.
- The final method is to translate the scanhead in the X and Y directions and observe the profiles along the entrance aperture edges. As the beam hits the edges of the slit the profiles will start to clip. Note the two edge position numbers for each X and Y and use the midpoints for the origin location.

2.5.3.5   Angular Alignment and Elliptical Beams

Use the rotation mount to align the slits scanning direction to the laser beams axial orientation. This allows accurate measurement of elliptical beams' major and minor beam widths. The rotation mount on the scanhead can maintain axial location to ±0.01mm. If greater accuracy is required, the rotation sleeve should be replaced by a custom designed stage.
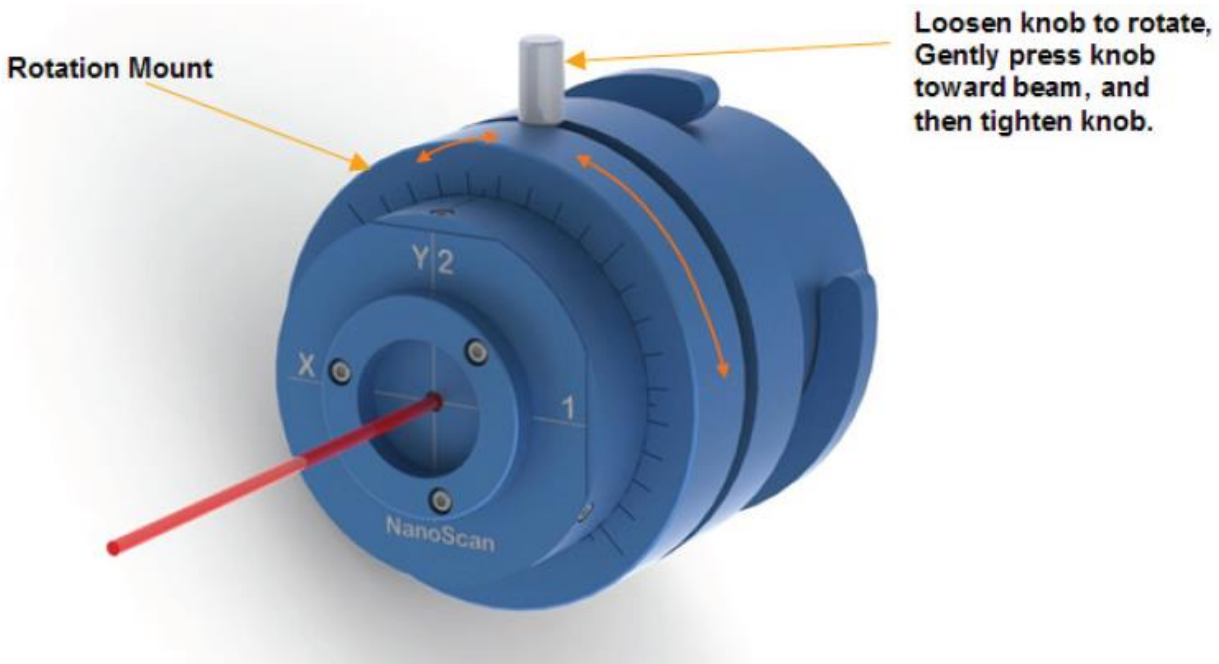
Figure 2.3 NanoScan2 Rotation Mount

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 as the scanhead rotates.

When rotating the scanhead:

1. Loosen the knurled knob locking screw.
2. 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.
3. 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 X and Y profile displays in the software and looking for the point at which the minor axis is narrowest in one axis and the major axis is widest in the other.

Measurement of an elliptical beam is illustrated in Figure 2.4. 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 points 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.
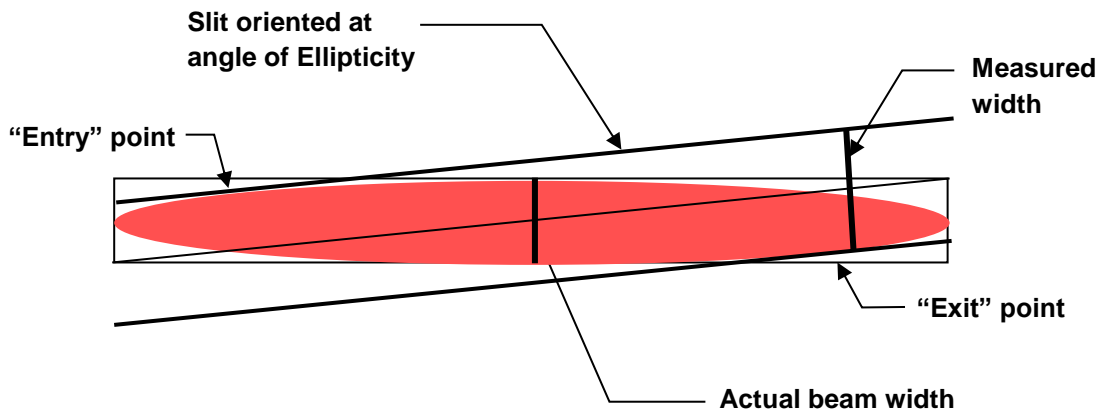
Figure 2.4 Error due to scan misalignment when measuring elliptical beams

This figure shows a condition where the Ellipticity is of the order of 0.1, and a corresponding angle of ~5.7°. To get a good measure the scan axis must be adjusted to <~0.57°. This range of adjustment is easily achieved using the NanoScan2 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, which is the case for many applications, the Ellipticity angle becomes 0.57° and the alignment requirement is of the order of 0.057° or less. The adjustment in this case is very difficult and the use of a high-precision rotation stage with micrometer adjustment is recommended.

2.5.4   Launching NanoScan v2

The NanoScan2 scanhead is factory licensed for either Standard or Professional (STD or PRO) operation with the NanoScan v2 software. Standard licensed products can be upgraded to Professional by purchasing an upgrade License Key.

With the scanhead connected to the PC:

1. Double click the NanoScan v2 icon to launch the application.
2. The NanoScan v2 application opens with the **Source** ribbon displayed and the head connected.
3. Click **Start** to begin data collection.
4. Without a laser beam present the software only displays background noise.

2.5.5   Uninstalling NanoScan v2

The uninstall process is slightly different if both the older legacy **NanoScan** application and the newer **NanoScan v2** is installed on the same PC.

To remove NanoScan v2, do the following:

1. Close NanoScan v2
2. Unplug all USB2 scanheads from the PC
3. Click the **Start** menu
4. Select **Control Panel**

5. Open **Programs and Features**
6. Click **NanoScan v2** and **Uninstall**
7. The following window opens.
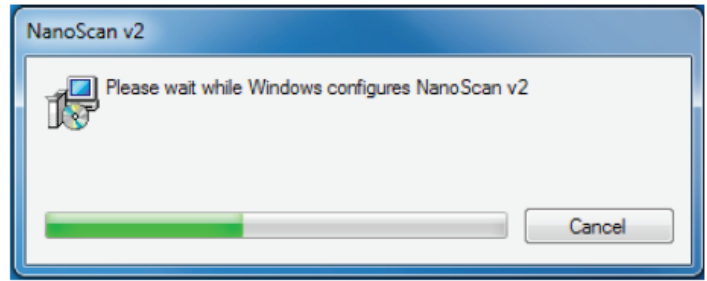
8. Note that this next window opens behind the one shown above in step 7. Click on it to bring it to the front.

    If you only have NanoScan v2 installed and are removing it, click **Yes**.

    If you have the legacy NanoScan application installed and also plan to remove it click **Yes**.

    If you have the legacy NanoScan application installed and want to retain its operation after NanoScan v2 is removed click **No**.

    *All saved *.nsd, *.nsdx, *.txt, and *.log files will not be removed.*

9. When all of the windows have closed, the uninstall process to remove NanoScan v2 is complete.
10. If you are also planning to remove the legacy NanoScan application proceed to the next section.

To remove the legacy NanoScan software, do the following:

1. Click the **Start** menu
2. Select **Control Panel**
3. Open **Programs and Features**
4. Select **NanoScan** from the software list
5. Click Uninstall
6. If a **User Account Control** dialog box appears stating an unidentified program wants access to your computer, select **Allow** to continue uninstalling the software.

Chapter 3 NanoScan v2 Software

The NanoScan v2 Beam Profiling and Analysis software is a stand-alone graphical user interface (GUI) for beam profiling with a NanoScan2 scanhead. The GUI includes ribbon tabs for source setup, display selections, capture settings, computation settings, power calibration, results charting, results logging, and M^2 calculations.

Measurement of up to 16 multiple beams is accomplished by defining specific Regions of Interest (ROIs) for beam analysis. Separate results can be computed for each enabled ROI. For multiple beams the separation of beam centroids and peaks can also be computed.

The default screen layout is shown below.
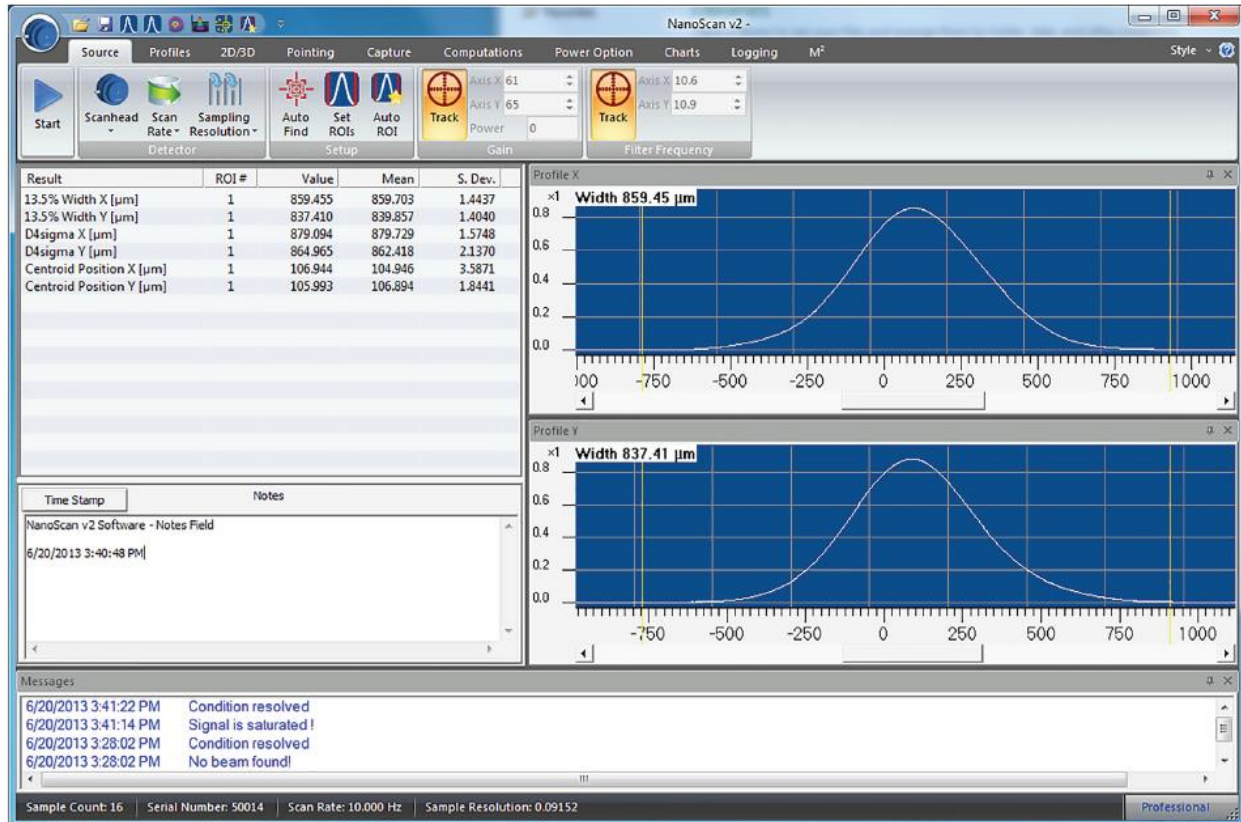
3.1   Nomenclature Changes

The legacy NanoScan software referred to the scanned profiles, axes, and results items as 1 and 2, or sometimes A1 and A2. This nomenclature is not common to the industry and is replaced with the more common X and Y notation. In some places both usages are referenced, while in others just the X/Y terminology is indicated. The face of the NanoScan2 scanhead now bears the X and Y markings. The 1/2 markings are also retained so that older users can see how the new axis markings correlate to the old.

3.2   Displays

A flexible display environment is available to meet your specific needs. A main display window that shows specific items can be transformed into a complex, multi-tasking display with floating desktop windows and multiple pinned charts or display windows. The example shown below contains all main display windows.
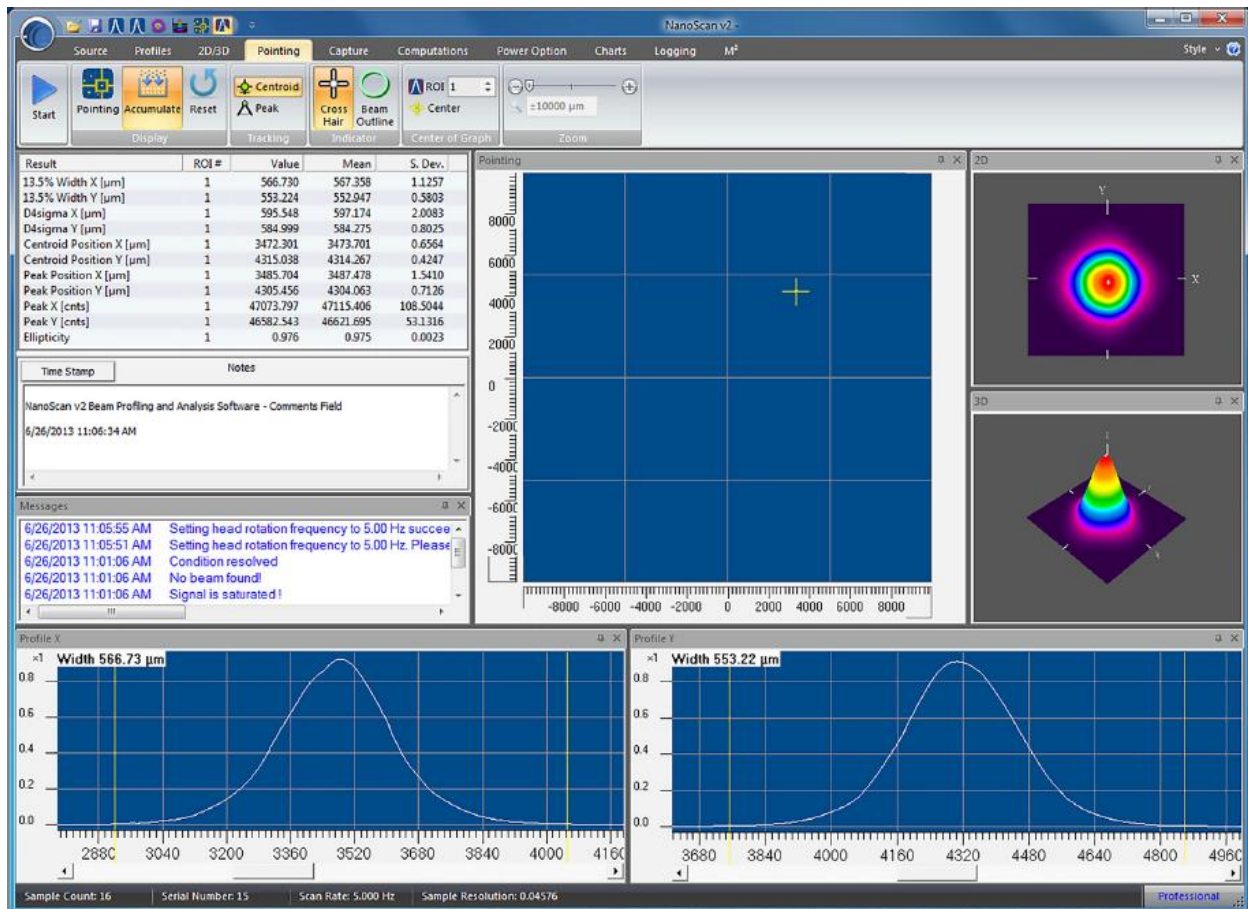
The screen layout is automatically saved when the application is closed and is restored the next time it is launched.

3.2.1   Terminology

The tools used employ terminology that may be new to some Windows users. This section provides a graphical glossary of terminology.

Within the industry there is some variation on the naming conventions in the ribbon motif that is employed with NanoScan v2. The terms used here are for consistency.
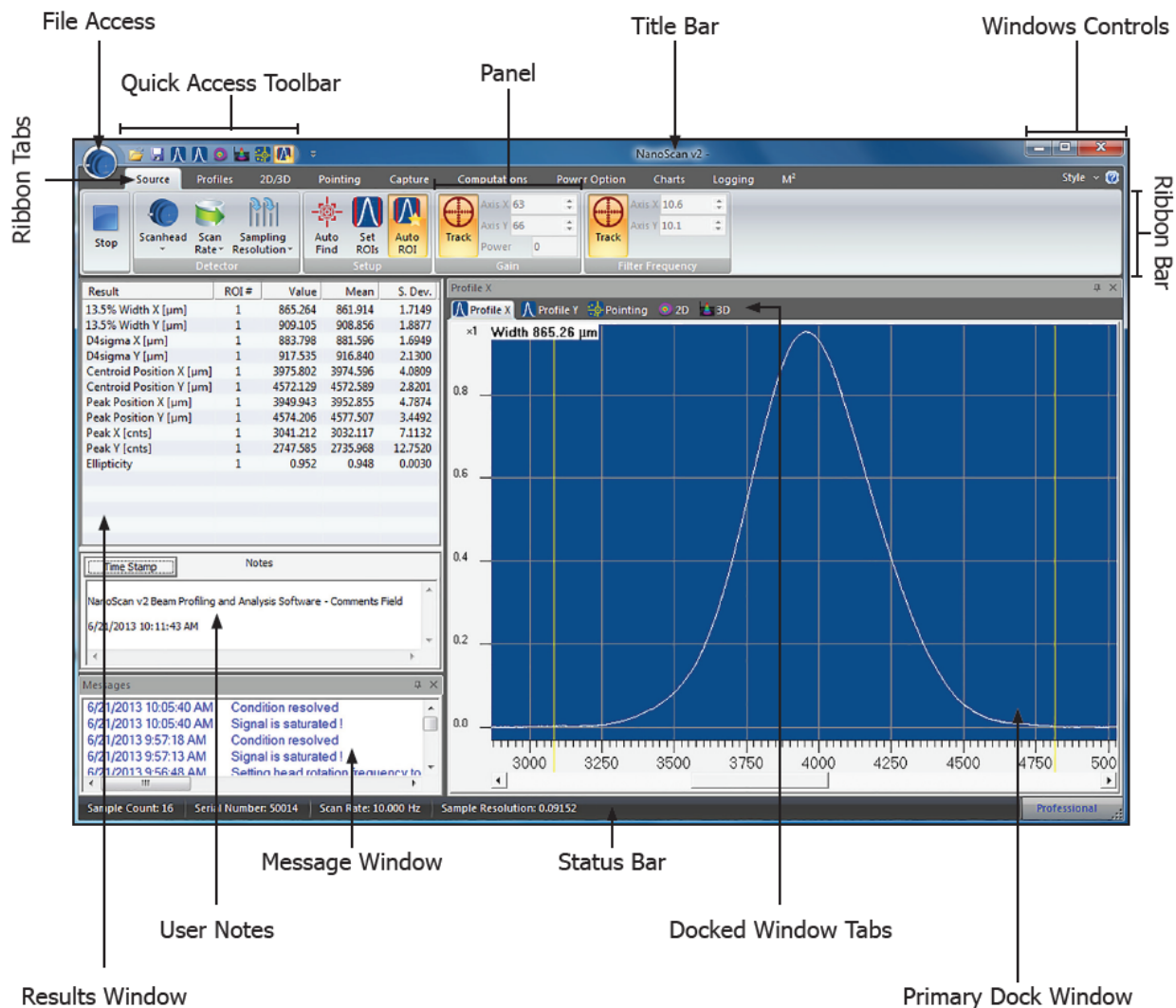
3.2.2 Primary Dock Window and Dock Handles

The Results/Notes display window is a permanently docked window and always appears in the main window. All other windows can be docked, floated, and hidden.

The first time a display window is opened, it is placed as a tab in the Primary dock window. All primary dock windows can be removed and repositioned by the user.

To undock a primary dock window, grab the tab with the mouse and drag down into the application window area. When dislocated from a docked position a set of docking handles appear as shown below.

Docking Handles

All view displays can be dragged and docked to the four sides of the application window. In this example, the 3D view is the object being dragged to a dock handle. Displays can be grabbed with the mouse in their Title bar or Tab region and dragged onto a dock handle. This can also be done with the Chart displays.
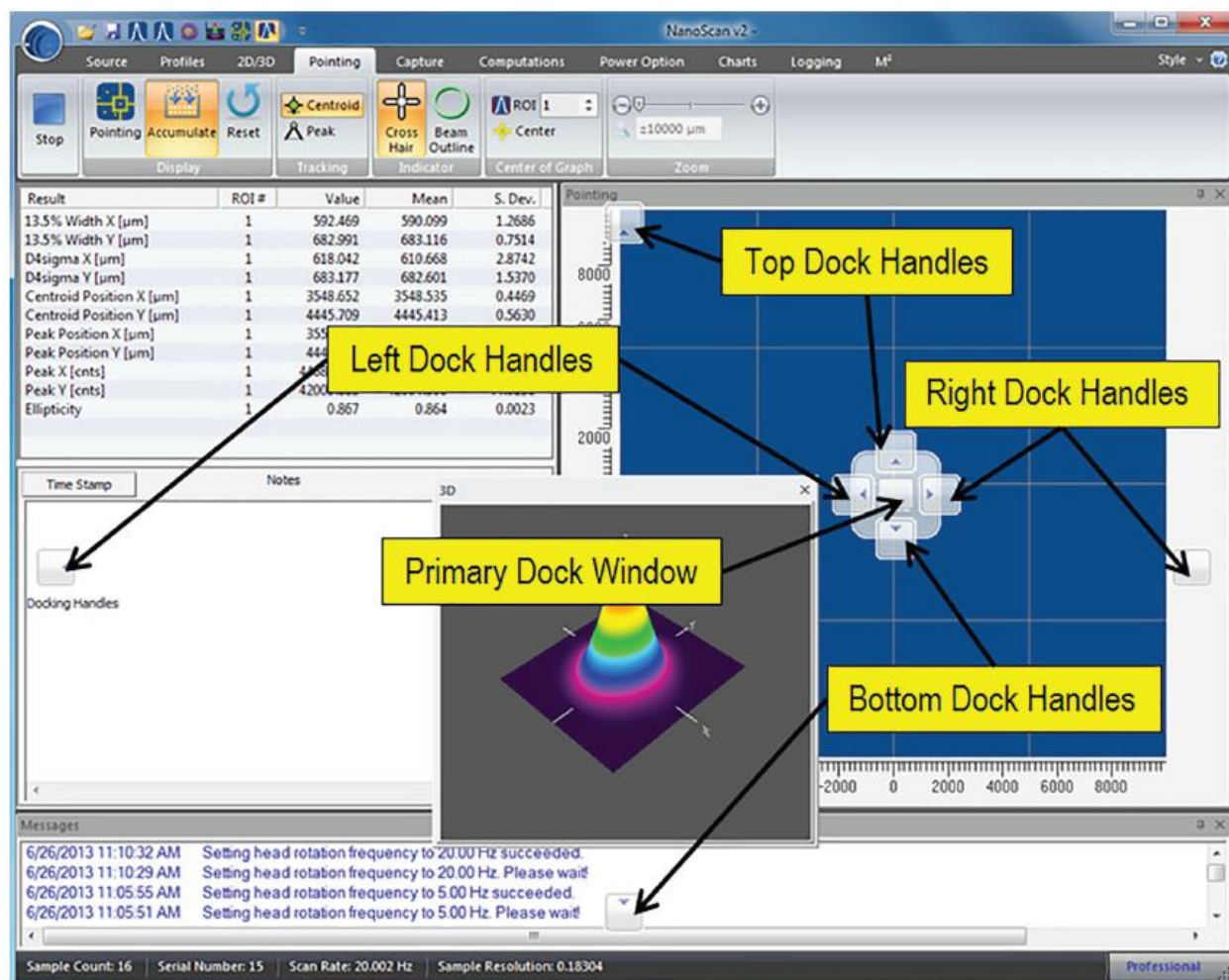
While dragging the view in the display, place the mouse over a docking handle. When the mouse button is released, the view docks to the window in the selected location. After positioning, the view can be resized. This is done by grabbing an edge with the mouse and dragging to the desired dimensions. If no docking position is indicated, the view sets to Floating and can be positioned and sized anywhere on the screen.

3.2.3   Dock Handle Cloning

Each view has its own set of dock handles. This allows docking views side by side, over, and under each other. Below is an example of many windows, some docked inside of other windows, and some floating. The best way to learn how to manipulate the windows and use the docking handles is to experiment.
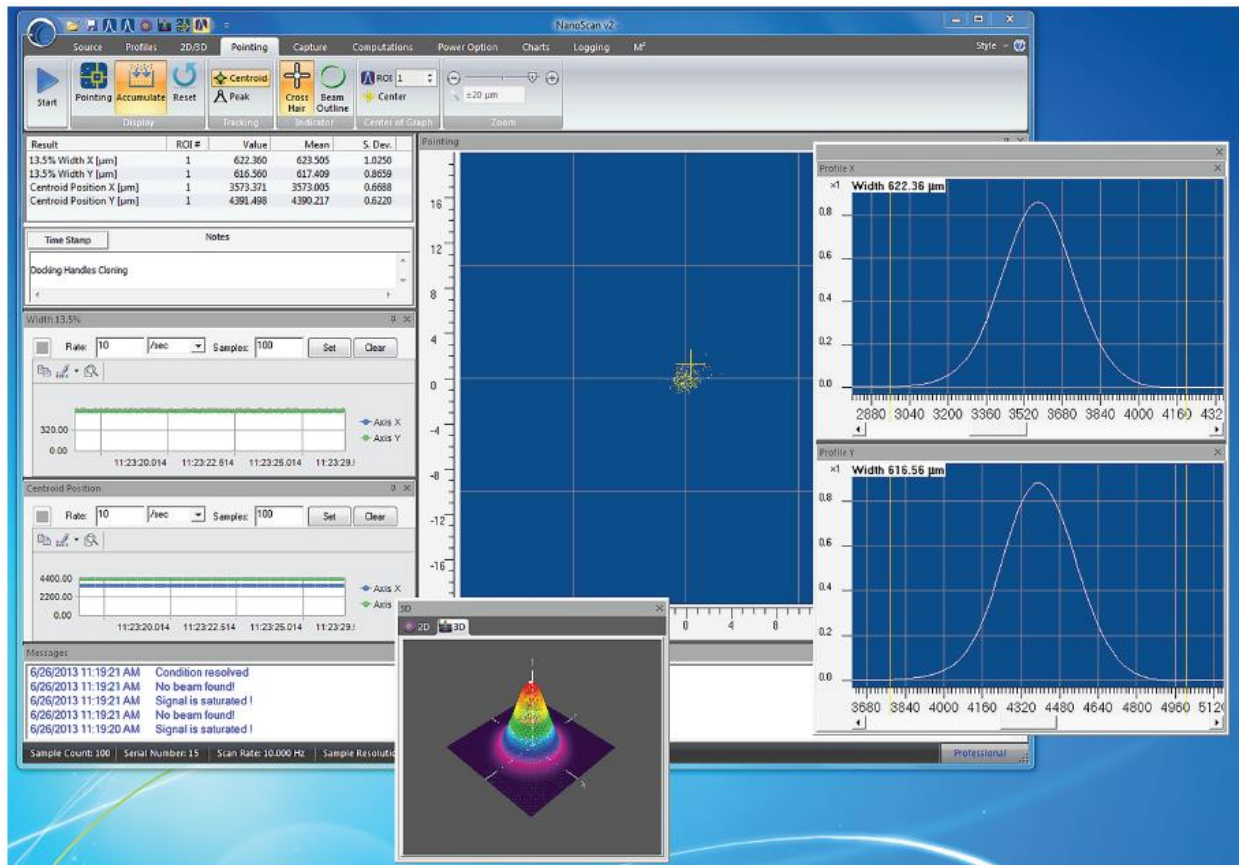
Floating windows clone the docking handles and can be combined with other floating windows. When set to floating, the function of each view is the same as when the view is docked to the main display.

3.2.4 Auto Hide

Click to hide a docked view.

Click to display a hidden docked view.

The **Auto Hide** feature is available on docked views and allows hiding many items in a single dock site. Clicking the view's Auto Hide button causes the selected display to collapse into the edge of the dock frame. The view can be opened by hovering the mouse over or clicking on the hidden view's tab. The figure below shows hidden view tabs at the bottom and the right side of the main window.
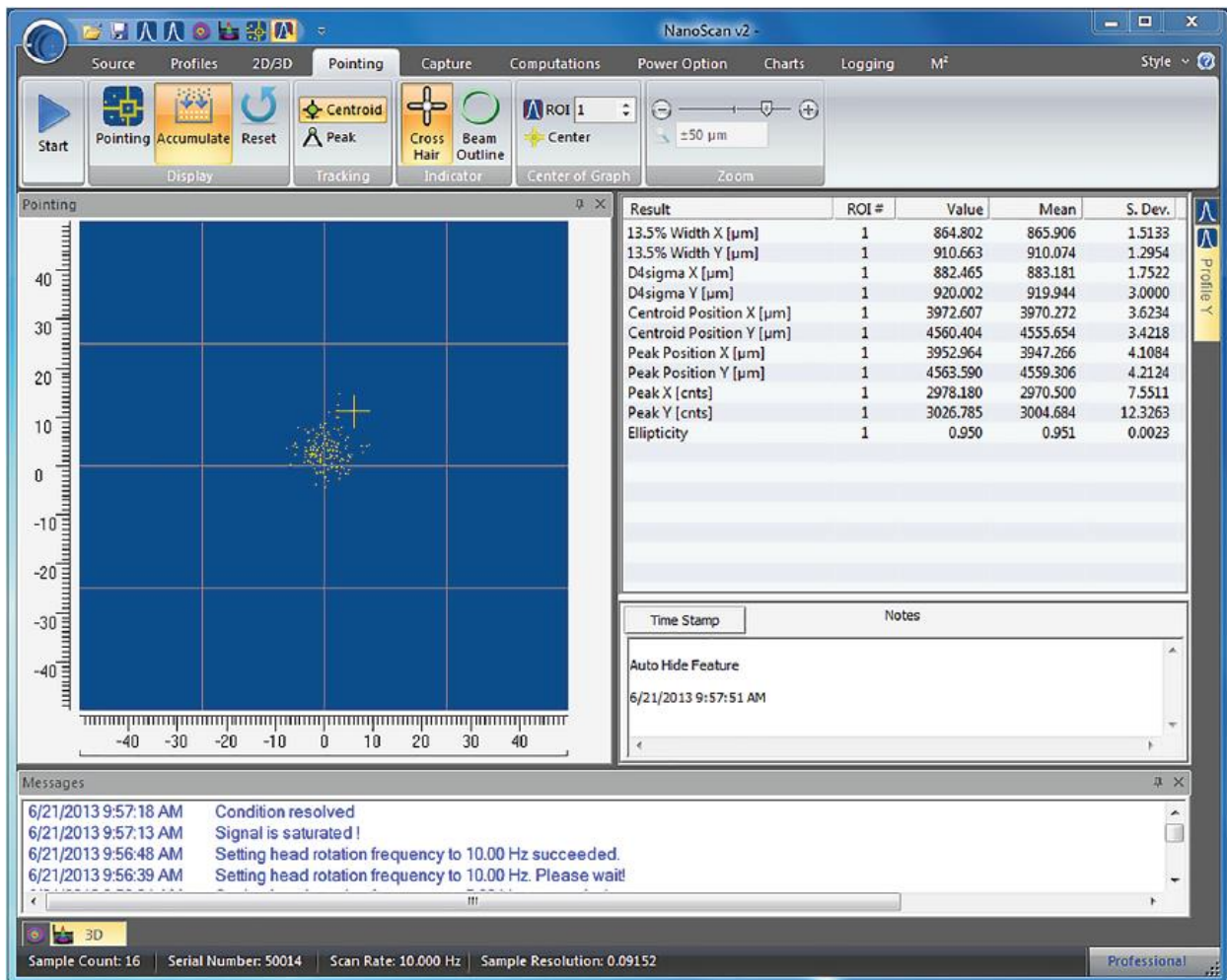
To restore a hidden view, click on the rotated pin unhide tool and the view will be restored to the former docked location.

Auto Hide allows for using a large number of Charts but not occupying a lot of screen space. When a specific chart needs to be viewed, it can slide out without opening the other charts.

3.2.5   Keyboard Shortcuts

Keyboard shortcuts allow navigation through the display window without the mouse. These controls are accessed by first pressing the **Alt** key on the keyboard, followed by a sequence of letters and/or numbers that appear beneath the ribbon and panel options. A list of some default keyboard shortcuts is provided below.

Alt-F-O	File Open Dialog Box	Alt-F-S	Save
Alt-F-A	Save As	Alt-F-P	Print
Alt-F-U	Print Setup	Alt-F-X	Close/Exit NanoScan v2
Alt-F-R	Reset Window Layout	Alt-F-B	About/Update License
Alt-S-L	Select Black Background Style	Alt-S-B	Select Blue Background Style

Alt-S-S	Select Silver Background Style		Alt-S-A	Select Aqua Background Style
Alt-S-D	Select Windows 7 Background Style		Alt-A	Open the NanoScan v2 User Guide
Space	When 3D window is active, the view is reset to the default display			

The controls can also be selected by pressing **Alt** followed by the arrow keys or the **Tab** button on the keyboard. Pressing **Shift+Tab** allows moving backwards through the control selections. **Enter** enables the highlighted control.

3.3 Controls

The controls include ribbon tabs and ribbon bars used for choosing various settings. The ribbon tabs include Source, Profiles, 2D/3D, Pointing, Capture, Computations, Power, Charts, Logging, and M2. Above the ribbon tabs is the Quick Access Toolbar with buttons for Open, Save, Profile X, Profile Y, 2D, 3D, Pointing, and Auto ROI.

3.3.1 Quick Access Toolbar

Hover the mouse over the buttons in the quick launch tools to see a short description of each icon's function.

Load
Opens the **File Open** dialog box so previous data files/setups can be loaded from saved *.nsd/*.nsdx files

Save
Saves the current data and setup into the last used *.**nsdx** data file

Profile X
Opens the **Profile X** view of the X (1) axis

Profile Y
Opens the **Profile Y** view of the Y (2) axis

2D Display
Opens the **2D** view

3D Display
Opens the **3D** view

Pointing View Display
Opens the **Pointing** view

Auto ROI
Enables/Disables Auto ROI

Help
Gives Quick access to this User Guide

Quick Access Settings

Buttons can be added or removed by selecting **Customize Quick Access Toolbar** from the drop down arrow or by right-clicking in the ribbon bar. Any control located in a ribbon bar can be added to the Quick Access Toolbar by right-clicking on the button and selecting **Add to Quick Access Toolbar**. To remove controls from the Quick Access toolbar, right-click on the button to be removed and select **Remove from Quick Access Toolbar**.

3.3.2   File Menu

The File Menu is used for basic file handling operations, including opening files, file saving, and printing.
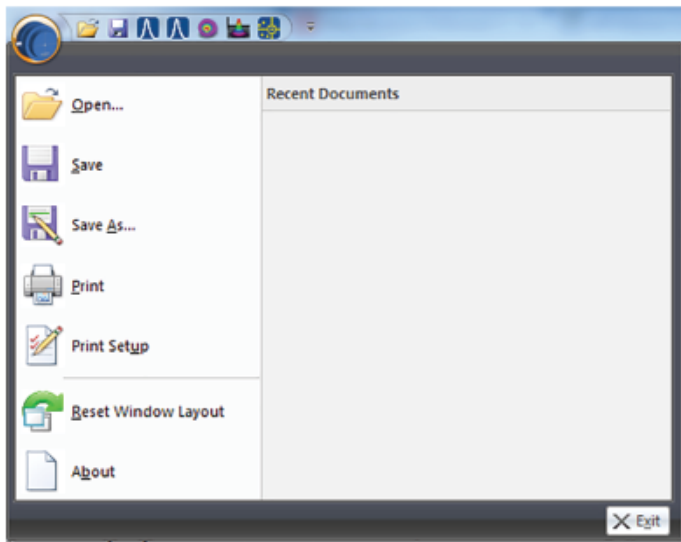
Open…

Opens saved data files. The **File Open** dialog box appears. This can be used to open *.nsd and *.nsdx file types.

Save

Saves the current image data and settings in an ***.nsdx** or ***.txt** ASCII file format, based on the file name and type last saved.

Save As…

Opens the **File Save As** dialog box for naming files and selecting the file format. The possible selections are:

*.nsdx NanoScan v2 binary software data format for review and reanalysis using the NanoScan v2 software.

*.txt ASCII text file format that contains setup parameters and comma delimited ASCII outputs of the 1D beam profiles contained within any enabled ROI. Both profiles are saved even if only one is being displayed.

Print

Print dialog for printing the NanoScan v2 report.

Print Setup

Opens a dialog for selecting and configuring printers.

Reset Window Layout

Returns the layout of the application to its original state.

About

Displays software version information and allows entering a new scanhead upgrade license key or updating the firmware.

Exit

Closes the NanoScan v2 application.

3.3.3   Ribbon Tab
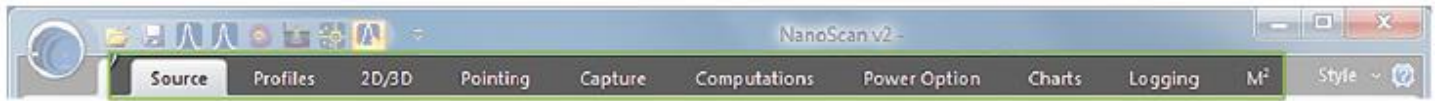
Select a tab to swap ribbon bars. Right-click in the tab area and select **Minimize the Ribbon** to hide the ribbon bar area. When hidden, click on a tab to temporarily view its ribbon bar until a selection is made or the focus is directed elsewhere. Right-click and deselect **Minimize the Ribbon** to restore the view. The ribbons are:

Source
Select and control the scanhead.

Profiles
Select and control the profile displays.

2D/3D
Select and control the 2D/3D displays.

Pointing
Select and control the Pointing display.

Capture
Select and control the capture modes.

Computations
Select which results items to display.

Power
Calibrate, select, and save power calibration settings.

Charts
Enable various results Charting displays.

Logging
Control results logging

M²
Make manual M2 measurements using the M2 Wizard.

3.3.4   Ribbon Bar

The Ribbon Bar contains the controls available within a selected ribbon tab.

3.3.5 Status Bar

| Sample Count: 16 | Serial Number: 50014 | Scan Rate: 10.000 Hz | Sample Resolution: 0.09152 | Professional |
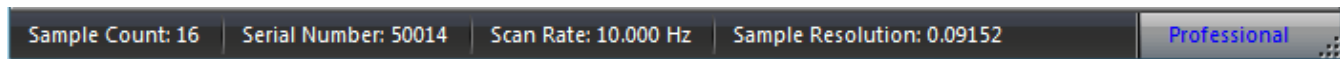
The **Status bar**, located at the bottom of the display window displays useful information including:

- The number of **Samples** used in the statistics results
- The connected head's **Serial Number**
- The current **Scan Rate** in Hz
- The current **Sample Resolution** in µm
- The **Automation** indicator informs the user if the automation option is available for the connected scanhead. If automation is available, **Professional** is displayed. If automation is not available, **Standard** is displayed.

This information can be shown/hidden by right-clicking on the **Status bar** and selecting/deselecting the desired items.

*If the head scan rate is not operating within 0.01% accuracy, the **Scan Rate** value turns red.*

3.4 Source Ribbon

The Source ribbon is used to select a NanoScan2 scanhead, set the scan rate, set the spatial sampling resolution, adjust the ROI, and automatically or manually set the gain and filter frequency values for the X and Y axes. The Power Gain is always operating if using a silicon or germanium scanhead. The Source controls are unavailable until a scanhead is selected.

3.4.1 Source Ribbon: Start/Stop Panel

Start and Stop profile data acquisition. This panel is available in each ribbon bar.

3.4.2 Source Ribbon: Detector Panel
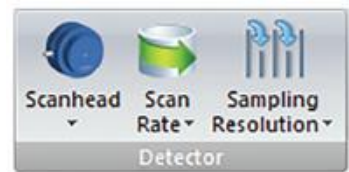
Select and control the scanhead.

Scanhead
Open the drop-down list to display scanhead status ("Free" or "In use") and select a scanhead to connect. NanoScan v2 can control only one scanhead at a time,

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and only one instance can run at a time. A serial number of 0 indicates that the software could not connect to a scanhead.
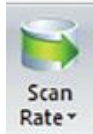
Scan Rate

Sets the scanning speed of the connected scanhead in Hz. The sampling resolution changes with the scan rate. An information message is displayed in the **Message** window when the scanning speed is changed.

6/21/2013 9:56:48 AM   Setting head rotation frequency to 10.00 Hz succeeded.
6/21/2013 9:56:39 AM   Setting head rotation frequency to 10.00 Hz. Please wait!

If the head scan rate cannot be set within 0.01% accuracy, a warning message will be displayed in a dialog box and in the **Message** window.

The NanoScan v2 software continues to operate as close to the selected scan rate as possible. When the actual scan rate is not within the 0.01% accuracy, the **Scan Rate** in the **Status** bar turns red.

At the 0.01% stability level, the beam position accuracy is 0.1µm/mm. Beam diameter accuracy is only affected if the stability exceeds the 1% level.

Scan Rate selection is disabled when **Data Recorder** is enabled.

Sampling Resolution

Sets the Sampling Resolution in microns. The **Sampling Resolution** is the same for both axes and is related to the **Scan Rate** and **Magnification** settings. This value controls the number of samples taken across the beam. The smaller the number, the more data is collected. The automatic setting tries to ensure there are about 100 data points across the beam width. In **Pulsed** mode, the spatial sampling is limited to smaller sampling values in order to resolve narrow high frequency pulses.

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 tends to slow down the acquisition and make data files much larger. The effects of **Sampling Resolution** are discussed in more detail in section 4.4.3.2.

Sampling Resolution selection is disabled during **Data Acquisition** and when **Data Recorder** is enabled.

3.4.3   Source Ribbon: Setup Panel
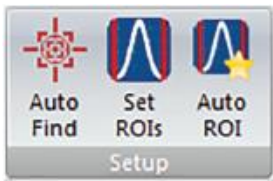
Use to define setup values for **Gain**, **Filter Frequency**, and **ROI** boundaries.

Auto Find

Initiates a "one-shot" auto setup of the **Gain**, **Filter Frequency**, and **Sampling Resolution** for each axis, and enables **Auto ROI**. **Auto Find** also establishes a view of the beam in the **Views** window for **Profile X**, **Profile Y**, **Pointing**, **2D**, and **3D**.

Auto Find is disabled when **Data Recorder** is enabled.

Set ROIs

Use this option to open the **ROI** edit window. The edit window allows enabling/disabling the **Automatic ROI** operation and setting ROI boundaries.
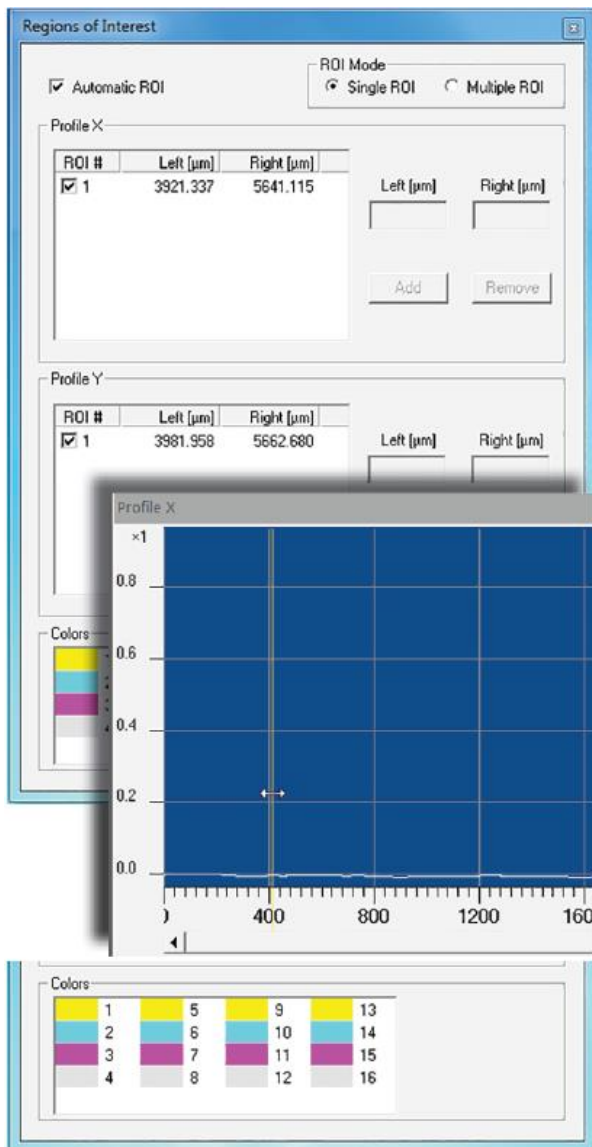
Check the box to toggle **Automatic ROI** mode, or Manual mode.

In Automatic mode, the ROIs are determined automatically. The algorithm defines beams and generates ROI boundaries based on the $1/e^2$ beam width and the beam centroid position.

In Manual mode the ROI boundaries in **Profile X** and **Profile Y** can be set manually.

ROI Mode
Choose either **Single ROI** or **Multiple ROI**.

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

Multiple ROI supports up to 16 ROIs.

Profile X/ Profile Y
Lists the Left and Right boundary positions for each ROI in **Profile X** and **Y**. The Left and Right edit boxes and the **Add** and **Remove** buttons are inactive when in Automatic mode.

In Manual mode, set the boundaries with the edit boxes. Enter the **Left** and **Right** boundaries in µm and select **Add** to create a new ROI. To update a ROI, either select the row and enter a new **Left** and **Right** boundary and select **Update**; or drag and drop the ROI boundary in the **Profile** window. Remove a ROI by selecting the row and choosing **Remove**.

Colors
The color of the respective ROI boundaries displayed in the **Views** window can be individually set using the **Colors**

control.

Double-click the left mouse button on the color in front of the ROI number to open the color dialog and change the color.

*The easiest way to adjust ROIs is to allow the software to generate Automatic ROIs. Then turn off the **Automatic ROI** feature. The automatically generated ROIs remain in the display, and can then be adjusted manually.*

*When ROIs have been edited, switching from **Multiple ROI** mode to **Single ROI** mode enables **Automatic ROI** mode and all defined ROI values are deleted. To save the defined ROI values, stop data acquisition, switch to Single ROI mode, then disable Automatic ROI mode. Computations are then only made in the first defined ROI.*
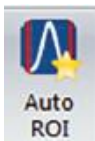
Automatic ROI

Select **Auto ROI** to toggle the **Automatic ROI** feature without entering the **ROI** edit window.

3.4.4 Source Ribbon: Gain Panel

This panel controls the electronic gain settings in dB for both the X and Y axes.

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 **Gain Track**.

Track

Enable/Disable automatic **Gain Tracking** on both Axis X and Axis Y. The gain for each axis is set so the maximum of the peak values of all ROIs is 1dB below saturation. In **Pulsed** mode the gain for both axes are reduced.

If the gain values for Axis X or Axis Y appear unstable while **Track** is enabled, then **Frame Averaging** and **Rolling Frame Averaging** in the **Capture** ribbon may not be meaningful. It is best to disable the **Gain** and **Filter Frequency Track** When changing frame averaging values.
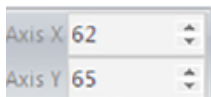
Axis X/Y

Sets the **Gain** setting of the scan for the X and Y axes in dB. The allowable range varies with the scanhead type. When **Track** is enabled, this parameter is set automatically to match the operating conditions. In most cases the value set by the software is the most appropriate for use.

Power

Automatically displays the **Auto Gain** setting for the power reading if using a silicon or germanium scanhead.

3.4.5　Source Ribbon: Filter Frequency Panel

This panel controls the photo detector amplifier electronic 3dB cutoff of the sampled head signals for both the X and Y axes. **Filter Frequency Tracking** is sufficient for most laser beams. Manual filtration requires trial and error to learn. A filter too large allows noise into the profile signal which increases the spot size and position variance; too low measures the spot size smaller than actual.

In **Pulsed** mode, the **Filter Frequency** is automatically set to 190kHz and filter control is disabled.

Track

Enables/Disables automatic **Filter Frequency Tracking** to reduce noise on both the X and Y axes. The filter setting is based on the beam width.

If the **Filter Frequency** values for Axis X or Axis Y appear unstable while **Track** is enabled, then **Frame Averaging** and **Rolling Frame Averaging** in the **Capture** ribbon may not be meaningful. When changing frame averaging values, it is best to disable the **Gain** and **Filter Frequency Track**.

Axis X/Y
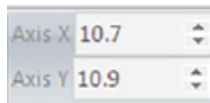
Low-Pass filter frequency setting of the slit scan on Axis X and Axis Y in kHz. The allowable range is 2-190kHz.

When **Track** is enabled, this parameter is set automatically to match the operating conditions. In most cases the value set by the software is the most appropriate for use. However, it can be manually set by the user.

3.5　Profiles Ribbon

The **Profiles** ribbon is used to select profile viewing options of the beam and to define the origin of the beam axes. The display options include selections for both Horizontal and Vertical view scaling. The horizontal view can be set for either **Auto Zoom** or manual scaling. The amplitude Vertical view scale can be either linear with 1X, 10X, or 100X magnification, or logarithmic. The spatial X and Y origins can be set with the **Origin Location** panel.

3.5.1　Profiles Ribbon: Display Panel
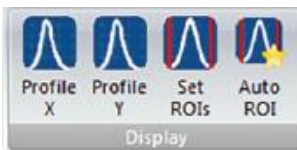
Select a view for display in the **Views** window and define ROI boundaries.

Profile X/Profile Y

Enable the **Profile X** or **Profile Y** view.

Set ROIs

Open the **ROI** edit window. The edit window allows enabling/disabling the **Automatic ROI** operation and setting ROI boundaries. See section 3.4.3 for more details.
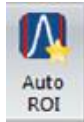
Auto ROI

Select **Auto ROI** to toggle the **Automatic ROI** feature without entering the **ROI** edit window.

3.5.2 Profiles Ribbon: Scaling Panel
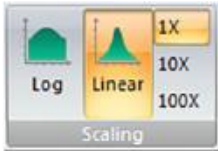
Select either **Linear** or **Logarithmic** scaling for the profile vertical axis for both Profile X and Profile Y.

In Linear mode, select **1X**, **10X**, or **100X** magnification for the vertical axis. When **Pulsed-Short** operation mode is selected, the vertical scale is forced to 10X magnification.

For **Log** scaling, the vertical scale choices are disabled.

3.5.3 Profiles Ribbon: Horizontal Scaling Panel

Use to set the horizontal zooming for Profile X and Profile Y or set to **Auto Zoom**.
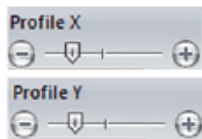
Profile X/Profile Y

Use to zoom in or out along the horizontal axis in the **Profile X** or **Profile Y** view.
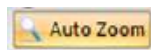
Auto Zoom

When enabled, the horizontal view is scaled automatically to display all enabled ROIs. If the horizontal zoom or position is manually adjusted, **Auto Zoom** is disabled.

3.5.4 Profiles Ribbon: Overlay Panel

When selected, the Gaussian fit is displayed over **Profile X** and **Profile Y** in the Profile views. The ROI boundaries define the region where the fit calculation is performed.

3.5.5 Profiles Ribbon: Origin Location Panel

Use these controls to define a spatial origin (0,0) for the X and Y axes.

ROI#

Define the **ROI** used for the **Current** centroid selection.

Axis Current/New Reference

Enter the new origin location for Axis X and Axis Y then select **Apply** to execute the change. The entered values must be based on the current origin placement. The entry can be manually entered, use **Current**, or use **Default**. This change effects the spatial location in all spatial controls (such as ROI) and displays, including **Pointing**.
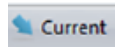
Current

Enter the selected **ROI** beam's current centroid into the **New/Current** edit control for both Axis X and Axis Y. **Centroid** results must be enabled in the **Computations** ribbon for the **Current** entry to load correctly. Click **Apply** to make this the new origin.

Default

Enters the factory **Default** origin into **New/Current** for both X and Y axes. Click **Apply** to use the default origin locations. The **Default** represents the geometric center of the aperture. When applying the **Rotation Transform** (see section 3.9.7) it is recommended that you use the **Default** setting for the **Origin Location**.
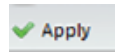
Apply

Sets the displayed **New/Current/Default** value offsets as the new origin location for the X and Y axes.

Reference

Displays the current origin locations relative to the **Default** factory settings.

3.5.5.1   Profile Views
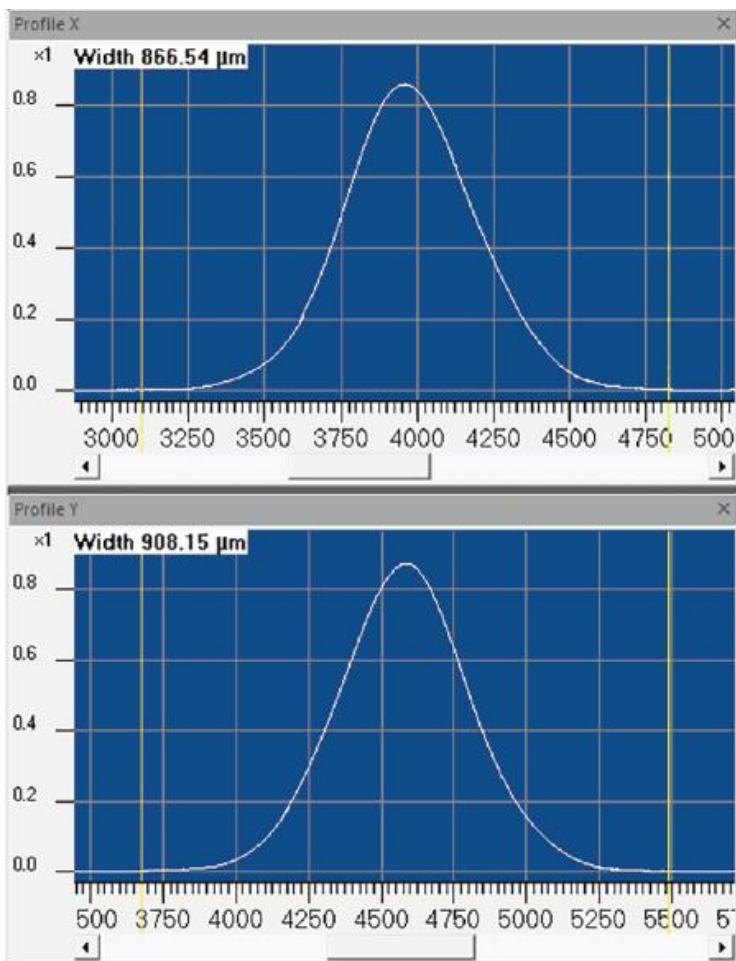
The **Profile** view displays the acquired beam profile data for an individual axis of the NanoScan2 scanhead. Options for setting the profile amplitude **Vertical Scale** and the spatial **Horizontal Scale** are located in the **Profiles** ribbon. The axes can be viewed simultaneously by docking or floating the views on the screen. See section 3.2 for more details on docking and floating.

The **Horizontal Position** bar located below the profile display allows for positioning of the horizontal axis within the aperture. Adjusting this position disables **Auto Zoom**.

The beam width chosen with the **BW Basis** in the **Computations** ribbon is displayed in the upper left corner of the profile views when in **Single ROI** mode.

3.6   2D/3D Ribbon
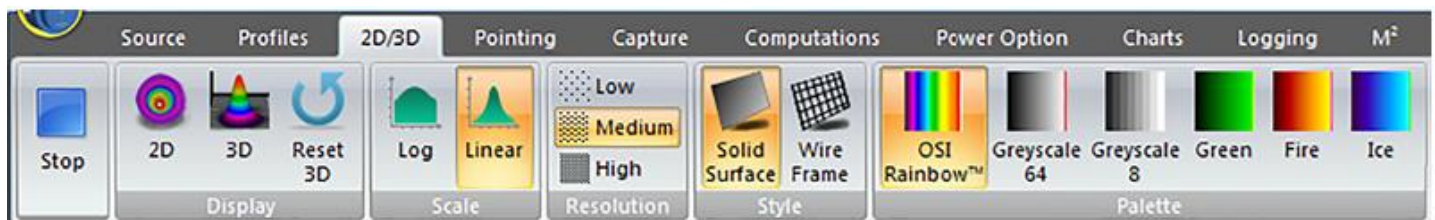
The **2D/3D** ribbon is used to select 2D and 3D viewing options. These options define both the 2D and 3D displays. The display options include selecting either **Linear** or **Logarithmic** scale, **Resolution**, **Rendering Style**, or **Color Palette**.

3.6.1   2D/3D Ribbon: Display Panel
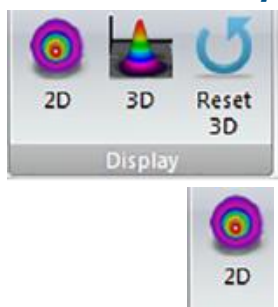
Use these controls to enable the **2D** and **3D** rendered images for display.

2D
Enable the **2D** view.
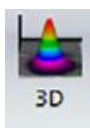
3D

Enable the **3D** view.

Reset 3D

Zoom and rotation of the **3D** window return to their default values.

3.6.2   2D/3D Ribbon: Scale Panel
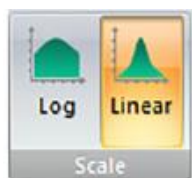
Select either **Linear** or **Logarithmic** scaling in the Z axial direction.

In **Logarithmic** scaling, the contour levels are fixed at 0, -3, -10, -13, -20, -23, -30, -33, -40, and -48dB levels.

3.6.3   2D/3D Ribbon: Resolution Panel
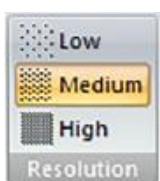
Allows resolution selection for both the **2D** and **3D** displays. Medium is the default setting. The data update rate may be reduced and image manipulation may be slower as resolution is increased.

Resolution can also be increased by selecting a smaller **Sample Resolution** in the **Source** ribbon.

3.6.4   2D/3D Ribbon: Style Panel

Choose either **Solid Surface** or **Wire Frame** rendering.

3.6.5   2D/3D Ribbon: Palette Panel

Choose one of the preset color palettes. The color palette is always auto ranged to the full display height of the displayed beam.

3.6.5.1   2D/3D Views
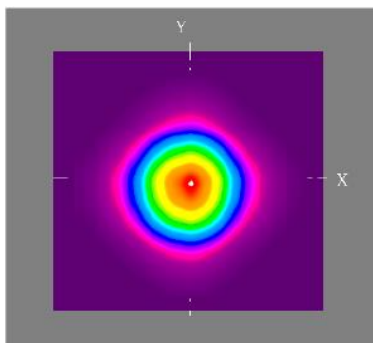
The **2D** and **3D** views display the laser beam image in a topographic or 3-dimensional viewing format. The laser beam image can be rendered with either **Wire Frame** or **Solid Surface**. Display colors can be selected from a list of predefined palettes. This display is available only in **Single ROI** mode. Refer to section 3.4.3 to set the software in Single ROI mode.
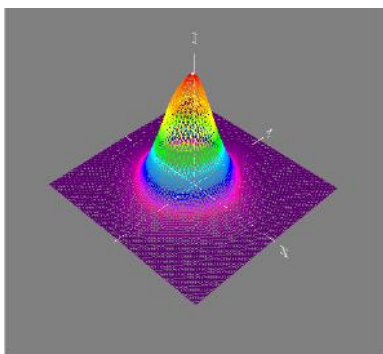
3D View Mouse Controls

Left-click and drag the display to rotate. If the mouse is released while moving the display continues to rotate; click again to stop.

Click and drag both mouse buttons, or scroll wheel button, to pan the view. If the screen continues to pan; click again to stop.

Scroll the mouse wheel to zoom, or right-click and drag up or down.

3.7   Pointing Ribbon
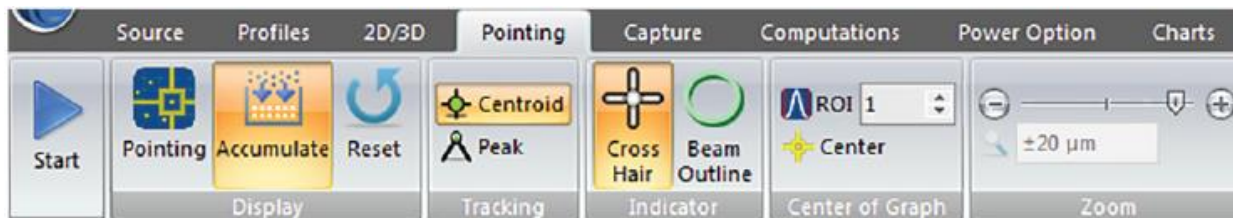
The **Pointing** ribbon allows charting of either the beam centroid or peak movement. An **Accumulate** mode can be used to map motion over extended time periods. This feature can chart multiple centroids when multiple ROI's are enabled.

3.7.1   Pointing Ribbon: Display Panel

Enable the **Pointing** view for display. Enable/Disable **Accumulation** mode, and reset the chart.
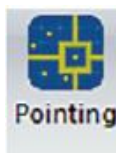
Pointing
Enable the **Pointing** view.
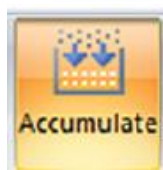
Accumulate
When selected, enables the **Accumulate** mode which displays a history of beam positions. Enabled is the default setting.

Reset
Clears and restarts the accumulated data in the **Pointing** view.

3.7.2 Pointing Ribbon: Tracking Panel

Select to chart either the **Centroid** or the **Peak** locations.

Centroid

Sets the point plotting to chart the spatial **Centroid** position of the beam.

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.
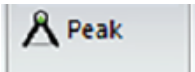
Peak

Sets the point plotting to chart the **Peak** position.

In a scanning slit system the observed profile peaks may or may not represent the actual peak location of the beam. For a Gaussian TEM$_{00}$ beam, the peak ideally coincides with the centroid. In the real world, the peak is often in a slightly different place and may be less stable than the centroid.

> If **Rotation Transform** is enabled in the **Computations** ribbon, **Peak** results may not be valid.

3.7.3 Pointing Ribbon: Indicator Panel

Select to display the Centroid/Peak location with or without a crosshair or a beam outline.
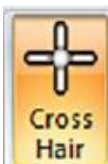
Crosshair

When enabled, the Peak or Centroid position of the last plotted scan in each enabled ROI is displayed as a crosshair.

Beam Outline

When enabled, the 13.5% beam widths for each enabled ROI is displayed as an elliptical overlay around the last plotted data point.

> If **Beam Outline** is selected and not visible, zooming out may be necessary to bring it into view.

3.7.4   Pointing Ribbon: Center of Graph Panel

Use to bring the selected ROI to the center of the **Pointing** display.
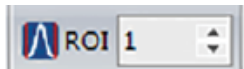
ROI

Select an ROI.
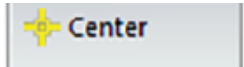
Center

Centers the chart to the Centroid/Peak position of the selected ROI based on the following rules:

- If data acquisition is running and **Centroid/Peak** result is enabled, the chart centers on the **Mean** of the selected result.
- If data acquisition is running and **Centroid/Peak** result is disabled, the chart centers on the last captured centroid/peak.
- If data acquisition is stopped, the chart centers on the last captured centroid/peak.

3.7.5   Pointing Ribbon: Zoom Panel

Controls the zoom scaling of the **Pointing** view. The maximum scale depends on the scanhead aperture size. The minimum scale is ±10µm.

3.7.5.1   Pointing View

The **Pointing** view displays spatial positions of the beam profile in each enabled ROI on a Cartesian grid. The perspective of the view is looking toward the NanoScan2 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 **Computations** ribbon.
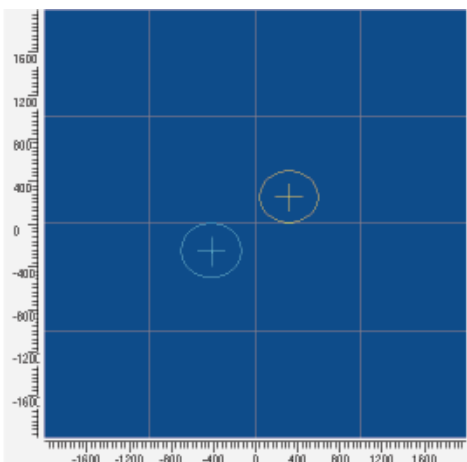
| **Pointing** view display showing the beam position in 2 ROIs as cross hairs with overlays for the $1/e^2$ profile contours. | **Pointing** view display with accumulation enabled showing the sequentially accumulated beam positions for a single ROI. |
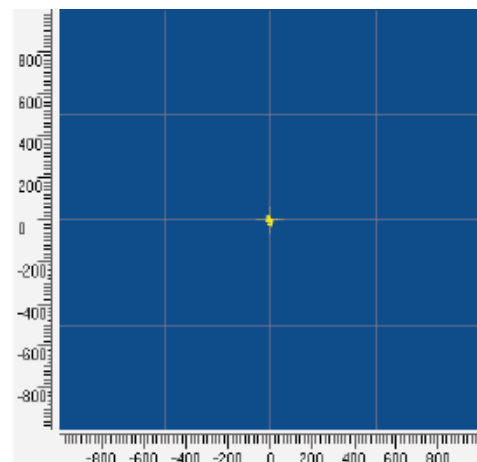
3.8   Capture Ribbon
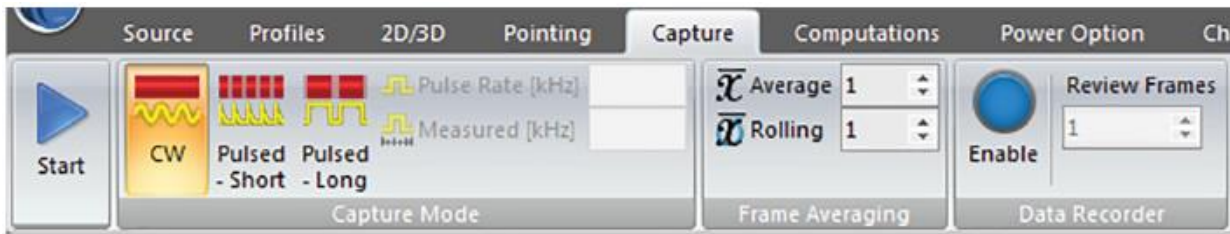
The **Capture** ribbon is used to set the **Capture Mode** of the scanhead for either Continuous Wave or Pulsed lasers, enable the number of data frames to average and the method to employ while averaging, and to enable/disable **Data Recording**.

3.8.1   Capture Ribbon: Capture Mode Panel
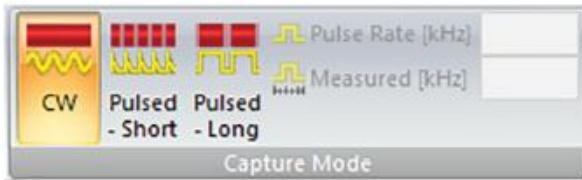
Select an appropriate **Capture Mode**. Enter the laser pulse repetition rate if operating in pulsed mode.

Changes in **Capture Mode** must be made prior to enabling **Data Recorder**. This panel is disabled when **Data Recorder** is enabled.

CW

Selects operation for Continuous Wave lasers.

Pulsed-Short

Selects operation for Pulsed lasers with pulse widths <10ns. To provide best accuracy, the profile peak amplitude must be <4096 counts to avoid amplifier nonlinearity. The **X** and **Y Profile** displays force vertical scaling to **10X**. With **Gain Track** selected the amplitude is limited to <4096 counts. However, **Gain** can also be set manually. If the **Gain** is manually set so that the peak amplitude is >4096 counts, an information message displays in the **Message** window warning the user to decrease the gain.

Pulsed Mode Warning: Signal above max counts; reduces accuracy. Decrease gain.

Pulsed-Long

Selects operation for Pulsed lasers with pulse widths >10ns. In this mode the full-scale amplitude is limited to 32769 counts to avoid amplifier nonlinearity and subsequent measurement error.

In **Pulsed** mode, the **Filter Frequency** is automatically set to 190kHz and the filter controls are disabled. The peaks of the individual pulses in the profile are connected to construct a smooth profile. **Frame Averaging** can be employed to help create a more detailed profile construct.

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

A minimum of 15 pulses through the beam profile is required to obtain specified accuracy. If there are not enough pulses present in a single scan, the software computes the corresponding head Scan Rate and displays an information message in the **Message** window recommending a lower Scan Rate.

> The Head Rotation Frequency is too high for the beam diameter and the
> Laser Pulse Frequency. The recommended Head Rotation Frequency is 2.50 Hz!

If the computed head Scan Rate for the current conditions is below 1.25Hz, an information message displays in the **Message** window warning the user about operating the NanoScan2 system outside the ±2% accuracy specification.

> Accuracy Warning!Reported beam diameters for the selected Laser
> Repetition Frequency lies outside the 2% NanoScan accuracy specification!

Refer to section 4.1.5 for more information about measuring pulsed beams.

Pulse Rate [kHz]

Enter the laser pulse repetition rate in kHz between 0.1-1000kHz. When no value or an invalid value is entered, NanoScan v2 assumes the Pulse Rate to be either 1 or the previous acceptable value. The more accurate this value is, the better the ability to measure the pulses and reconstruct the beam's profile. See below.

Measured [kHz]

The observed laser pulse rate is measured and displayed here as a check against an incorrect value entered above. Use this displayed value to adjust the **Pulse Rate**. This parameter is also reported in the **Results** window when **Pulse Rate** is selected in the **Computations** ribbon. A value of "0" is reported if the measurement is uncertain.

3.8.2   Capture Ribbon: Frame Averaging Panel
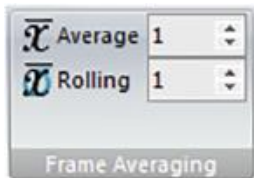
Use these controls to average scan data frames.

If the **Gain** or **Filter Frequency** settings are unstable while **Track** is enabled, frame averaging may yield less meaningful outputs. If this is the case, disable the **Gain** and/or **Filter Frequency Track** modes as applicable.

Average

Set the number of profiles to be averaged per beam analysis (N). Values can range from 1 to 1000. Displayed profiles and computed results are based on an average of N profiles. Results and display update rate is N times slower than the normal scan rate.

Rolling

Set the rolling average number of profiles to be used in rolling profile analysis (N). Values can range from 1 to 16. Displayed profiles and computed results are based on an average of N profiles. After the first N samples are acquired the data update is at the normal rate.

3.8.3 Capture Ribbon: Data Recorder Panel
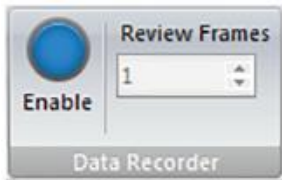
The **Data Recorder** allows for recording and reviewing a collection of beam profiles. The recorded data can be reviewed in **Profile** views, **2D** and **3D** views, and the **Pointing** view. The maximum number of data records depends on the Sampling Resolution (the finest Sampling Resolution is 0.0053µm at 1.25Hz). The software computes the memory needed to record one full scan and then, based on the total memory of the computer, sets the maximum number of scans that can be recorded (no more than 100). When Enabled, **Data Recorder** acquisition can be started by clicking the **Start** button. Data collection automatically stops after the maximum number of frames (usually 100) is reached. The actual time that data is collected depends on the head Scan Rate; e.g., for 100 scans at 10Hz, 10 seconds of data is acquired; at 2.5Hz, 40 seconds are acquired.

While recording data, the **Data Recorder** controls are disabled until the **Stop** button is pressed or the maximum frame count is reached. The data can be reviewed and analyzed frame-by-frame and statistics gathered for selected frames. The recorded data can be saved as a *.**nsdx** file. This file can be opened and the data reviewed at a later date.

Many controls are disabled during the recording process. Thus it is important to have things set up properly before starting the record cycle.

With **Gain Track** enabled, the **Data Recorder** takes three or four scanhead revolutions to set the proper gain values. After that, good data is collected. **Gain** and **Filter Frequency** settings for each axis are stored for each recorded frame.

Enable/Disable

Enable/Disable the recording process. This control is active only when data acquisition is stopped. Click **Start** to begin recording. The recording process stops once the allocated frame buffer is filled. When the **Data Recorder** is enabled, the software computes and allocates the necessary buffers. Refer to the table below for memory allocation for minimum Sampling Resolution at different head Scan Rates. After scanning is complete, scanned data can be reviewed and saved as long as the **Data Recorder** remains enabled.

Head Rotation Rate [Hz]	20	10	5	2.5	1.25
Minimum Sampling Interval [µm]	0.08542	0.04271	0.02136	0.01068	0.00534
Memory Allocation for one Scan [MB]	0.7503	1.5005	3.0011	6.0021	12.004
Memory Allocation for 100 Recorded Scans	75.027	150.054	300.107	600.215	1200.429
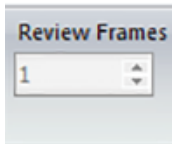
Review Frames

During the recording cycle **Review Frames** displays the number of frames collected in real time. After the recording stops it controls which data frame displays.

Use the arrows or enter a frame number to choose a frame to display with its results.

3.9   Computations Ribbon
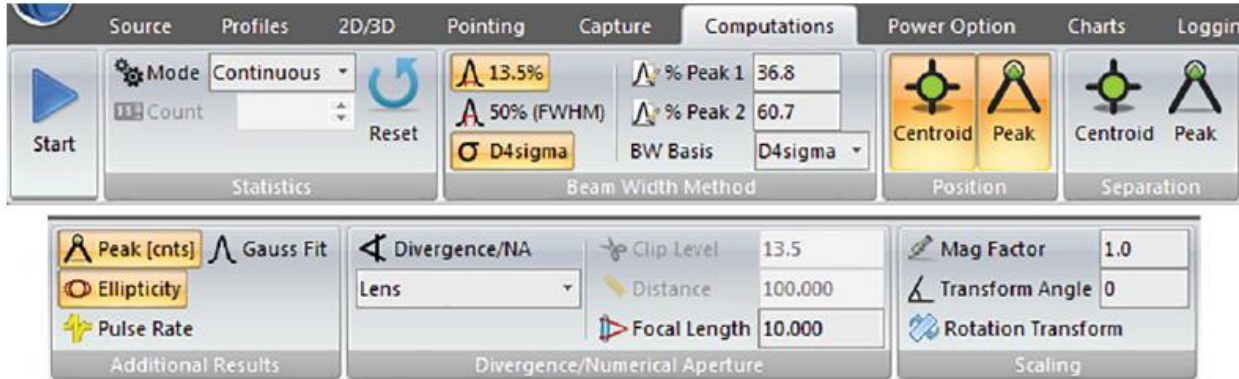
The **Computations** ribbon is used to enable and control what computed items appear in the **Results** window, and how some items are calculated. Enabling/Disabling results resets the statistics. Controls for the following are provided:

- Define how statistics are calculated
- Select which results to display
- Choose a **Beam Width Basis**
- Select and setup the **Divergence** or **Numerical Aperture** results
- Program the system **Magnification Factor**
- Adjust scaling for multiple ROI's with the beam **Rotation Transformation**

3.9.1   Computations Ribbon: Statistics Ribbon
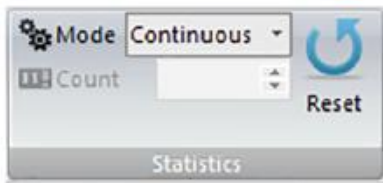
Determines how the statistics are computed and can stop results updating if a **Finite** mode is selected.
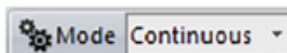
Mode

Sets the statistics results operating mode. The **Status** bar indicates the **Sample Count** that is currently used in formulating the displayed statistical results.

- **Continuous**- Sets the statistics for continuous calculations based on all collected frames of data.
- **Rolling**- Sets the calculation of statistics based on a rolling average of the last N collected profiles. Set N in the **Counts** edit control. Rolling mode is the default with a count of 16.
- **Finite**- Sets the calculation of statistics to stop after a specified number of collected frames.

The display views continue to update in real-time after the statistics have stopped.

Count
Sets the number of **Rolling** or **Finite** frames on which to compute and display statistical results.
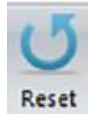
Reset
Resets the statistical results. If **Data Acquisition** is running, statistics automatically restart.

3.9.2   Computations Ribbon: Beam Width Method Panel

Enable/Disable beam width calculated results items and select which **Beam Width Method** to apply to secondary calculations. Controls are common for multiple ROI's.

13.5% of Peak
Enable/Disable the 13.5% of Peak beam widths in the **Results** window. For TEM_{00} beams this yields the $1/e^2$ second moment beam widths.
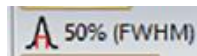
50% of Peak
Enable/Disable the 50% of Peak (Full Width Half Max) beam widths in the **Results** window.

D4sigma
Enable/Disable the second moment ISO Standard 11146 D4σ beam widths in the **Results** window.
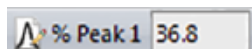
% Peak 1
Enable/Disable the first user programmable % of Peak beam widths in the **Results** window.
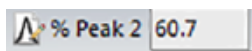
% Peak 2
Enable/Disable the second user programmable % of Peak beam widths in the **Results** window.

BW Basis
Select which beam width result to apply to secondary calculations such as **Divergence** and **Ellipticity**. This also selects which beam width result is displayed in the **Profile** views when in **Single ROI** mode.

3.9.3 Computations Ribbon: Position Panel

Enable/Disable spatial position results for beam **Centroid** and profile **Peak** locations. Controls are common for multiple ROI's.

Centroid

Enable/Disable the computed **Centroid** positions of the beam profiles in each enabled ROI.

Peak

Enable/Disable the **Peak** positions of the beam profiles in each enabled ROI.

> **!** If **Rotation Transform** is enabled, **Centroid Position** and **Peak Position** results may not be valid.

3.9.4 Computations Ribbon: Separation Panel

Enable/Disable the spatial separation distances for multiple beams when using multiple ROI's. Separation distances are only calculated between adjacent ROI's. No results appear in **Single ROI** mode.

Centroid

Enable/Disable the computed **Centroid** separation distances between all of the enabled ROI profiles.

Peak

Enable/Disable the profile **Peak** separation distances between all of the enabled ROI profiles.

> **!** If **Rotation Transform** is enabled, **Peak Separation** results may not be valid.

3.9.5 Computations Ribbon: Additional Results Panel
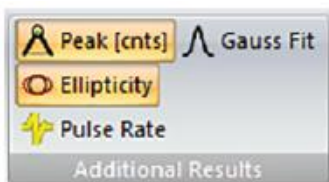
Enable/Disable additional result items. Controls are common for multiple ROI's.
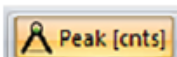
Peak [cnts]

Enable/Disable the beam **Peak** in each enabled ROI. Previously known as **Irradiance**, the values are a magnitude of the observed profile peaks in raw digitizer counts. They are not calibrated power or energy densities.

Ellipticity

Enable/Disable the beam **Ellipticity** result for each enabled ROI. This calculation is performed using the selected **Beam Width Basis** described above.

Ellipticity is only meaningful if the scan axis is aligned with the major and minor axes of the beam. This is usually not the case in multi-beam analysis. **Ellipticity** is computed by dividing the smaller beam width by the larger (d_{min}/d_{max}). Values approaching one (1) indicate the beam is circular.
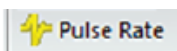
Pulse Rate

Enable/Disable the measured **Pulse Rate** (kHz) in the **Results** window when operating in **Pulsed** mode. If the pulse rate is indeterminate, a value of 0 is displayed. This result is not functional when operating in **CW** capture mode.

Gauss Fit

Enable/Disable the **Gauss Fit** results for each enabled ROI. Gauss fit results are calculated using a **Least Squares Fit** method and displays a **Goodness of Fit** and a **Roughness of Fit** value for each profile in the **Results** window.

3.9.6   Computations Ribbon: Divergence/Numerical Aperture Panel
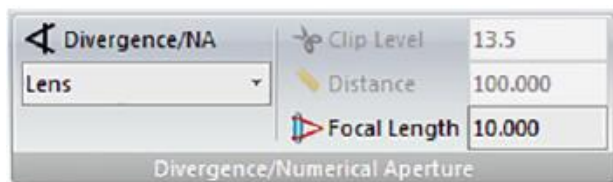
Enable and control the **Divergence** and **Numerical Aperture (NA)** results.

For **Divergence** calculations, the beam width employed is determined by the selected **Beam Width Basis** (described above). For **NA**, a special programmed **Clip Level** must be employed.
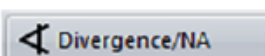
Divergence/NA

Enable/Disable the **Divergence/NA** results for each enabled ROI. This control is common for multiple ROI's.
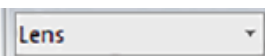
Method

Select which **Divergence** method or **NA** result to calculate. Lens results are in mrad, **Point Source** results are in degrees, and **Numerical Aperture** results are dimensionless. See section 4.4.6.1 for more details on the **Divergence/NA** methods.

Clip Level

Used for **NA** calculations. Enter the **% of Peak Clip Level** to use in making the **Numerical Aperture** measurement. For fiber optic measurements, the industry standard clip level is 5%.

Distance `100.000`
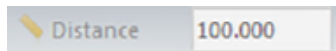
Divergence

Used for both **Point Source Divergence** and **NA** calculations. Enter the distance between the source and the NanoScan2 measurement plane in mm.
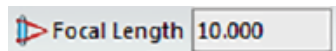
Focal Length `10.000`

Focal Length

Used for the **Lens Divergence** calculation. Enter the focal length of the lens in mm.

3.9.7 Computations Ribbon: Scaling Panel

Mag Factor `1.0`
Transform Angle `0`
Rotation Transform
Scaling
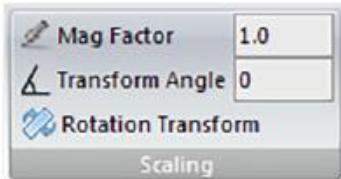
This panel allows for rescaling the profile image and to adjust for multiple ROI beams which are placed rotated to the normal X/Y axial orientation.
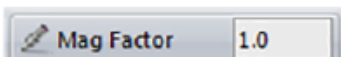
Mag Factor `1.0`

Mag Factor

Sets the magnification factor when using magnifying optics for beam profiling. When used with external imaging optics, the spatial results can be rescaled to indicate beam image expansion or reduction. Acceptable values are between 0.01 and 300. The default setting is 1.
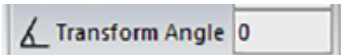
Transform Angle `0`

Transform Angle

The beam centroid values are computed along the scanhead axes (default coordinate system). The **Transform Angle** determines a new coordinate system, which is used for computing the **Centroid Position** and **Separation**. When the scanhead is rotated to accommodate a series of multiple ROI's, correct the spatial distance measurements by entering the rotation angle in degrees. Accepted angles are between 0 and 180 degrees. 45 degrees is the preferred angle to use whenever possible. This entry only corrects the measured distances if **Rotation Transform** is enabled.

> ⚠ *Peak results are not affected by the **Transform Angle** and therefore may not be valid if **Rotation Transform** is enabled.*

Rotation Transform
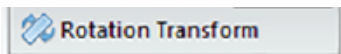
Rotation Transform

Enable/Disable **Rotation Transform** spatial correction based on the entered **Transform Angle**.

3.10 Power Ribbon

| Source | Profiles | 2D/3D | Pointing | Capture | Computations | **Power** | Charts | Logging | M² |

Stop | Total Power | % Power | Descriptor `HeNe Laser` | Wavelength `632.000000` | Reference `5.000000` | Delete | Descriptor `HeNe Laser` | Wavelength `632.000000` | Reference `5.000000` | Power Units `mW` | Calibrate
Results | *Power Calibration Selection* | *Create Calibration Point*
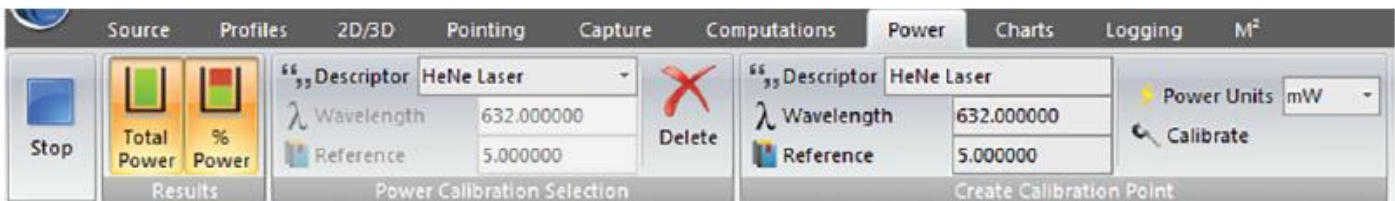
The **Power** ribbon controls define power calibrations for single or multiple lasers. With this option, the user can manually calibrate the scanhead for power measurements of CW lasers.

For example, an Ophir power meter is used to calibrate a HeNe laser to 5mW. A calibration point is set in NanoScan v2 and the results shown here are produced.

Power [%]	1	99.890	99.886	0.0074
Total Power [mW]		5.264	5.270	0.0052

Each saved calibration is stored in the scanhead's memory with a maximum of 256 possible calibrations. A calibration entry contains a **Reference** power value, a **Wavelength**, and a **Descriptor** title. This ribbon allows the user to create and store a calibration, and select which calibration to apply.

3.10.1   Power Ribbon: Results Panel

Enable/Disable **Power** results in the **Results** window.

Total Power

Enable/Disable the measured beam **Total Power** in the **Results** window. At least 1 calibration file must be generated for the **Total Power** measurement to operate.
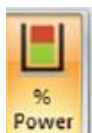
Power

Enable/Disable the calculated power in each enabled ROI as a percent of the total power in the **Results** window.

3.10.2   Power Ribbon: Power Calibration Selection Panel
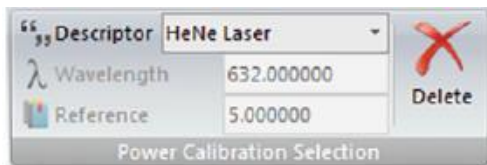
This panel selects which calibration set point is used in measuring the laser beam's power. A newly created set point becomes the current set point. This panel can also be used to delete a previously stored set point.
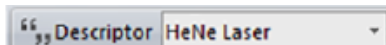
Descriptor

Displays the title of the selected calibration entry. With multiple calibrations, use the drop-down list to selected a different calibration entry.

Wavelength

Displays the wavelength of the current calibration in nm.
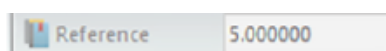
Reference

Displays the calibration reference power used when the entry was created.

Delete

Permanently delete the selected calibration entry from the scanhead.

3.10.3   Power Ribbon: Create Calibration Point Panel
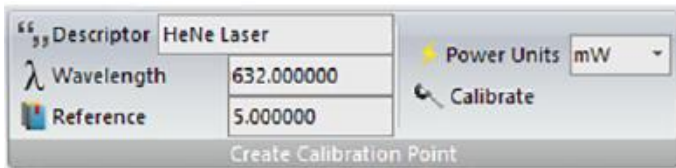
This panel is used to create calibration entries for various operating conditions.
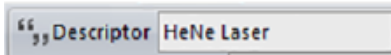
Descriptor

A text field to enter a unique title name for the new calibration. Maximum 32 characters. The **Descriptor** must be different for each calibration entry.

If a new calibration is created with the same title as a previous entry, an information message displays. Click **Yes** to overwrite the previous calibration.
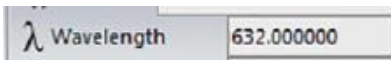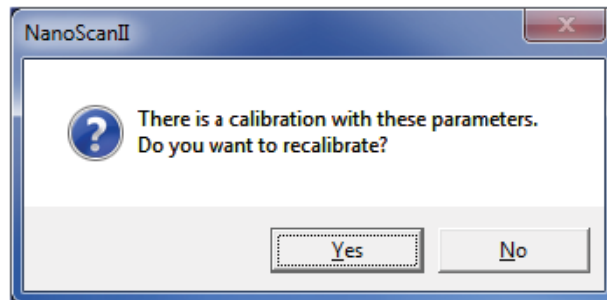
Wavelength

A text field for entering the wavelength in nm, applicable to the new calibration.
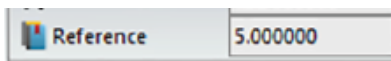
Reference

A text field to enter the new calibration reference power value.
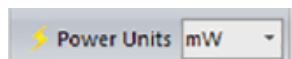
Power Units

Enter the applicable power units for the new calibration. Changing the units also changes the power units of the **Total Power** result.
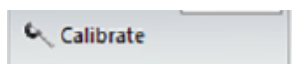
Calibrate

Create and save a new calibration entry based on the above settings. There should be a separate calibration for each laser wavelength and setup variation.

3.11   Charts Ribbon
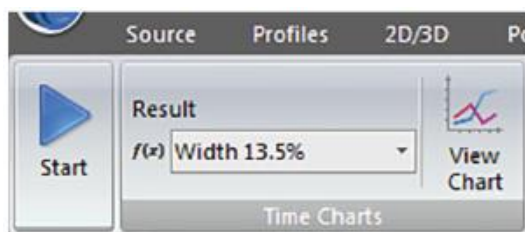
The **Charts** ribbon enables charting of select results items. Multiple Time Charts can be viewed and run simultaneously. The X and Y axes for a selected result are plotted on the same chart.

3.11.1   Charts Ribbon: Time Charts Panel
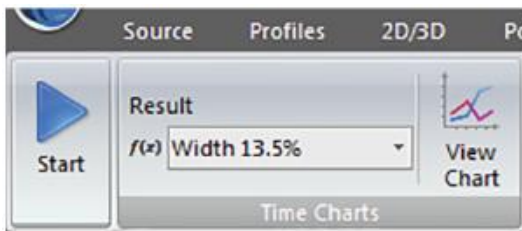
This panel is used to manually create time charts of result items. Charts are only available in **Single ROI** mode.
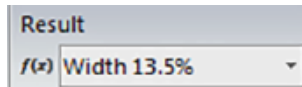
Result

Select the result for a new chart.

View Chart

Displays the time chart of the selected result. See 3.11.1.1 for more details.

> ! The **Gaussian Fit Time Chart** only plots the **Goodness of Fit** values and the **Gauss Fit** results must be enabled in the **Computations** ribbon.

3.11.1.1   Charts View

The **Charts** view displays strip charts for select beam results. Any available beam results may be charted. Multiple time charts can be created and run simultaneously. Charts are only available in **Single ROI** mode. Refer to section 3.4.3 to set the software in **Single ROI** mode. Charts behave similarly to the other view displays and can be set to docked or floating as described in section 3.2.2.

If a chart is closed, it is hidden from view but retains all information. Charts can be reopened by selecting the result in the **Charts** ribbon and clicking **View Chart**. Chart data is not saved when loading an *.nsd or *.nsdx file. However, data can be saved by clicking the **Copy to Clipboard** icon in the chart's toolbar and transferring it to a different program.
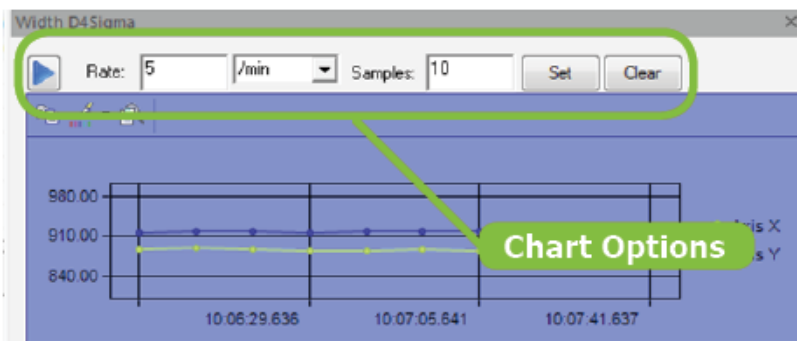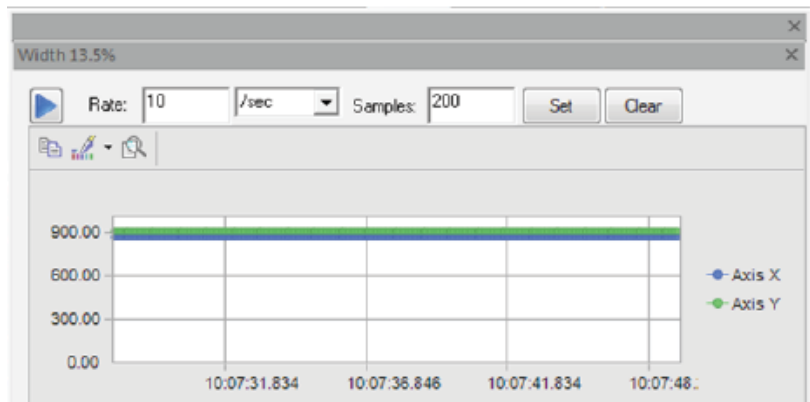
Chart Options for the **Time Charts** view are located at the top of each chart display. Options are set for each chart individually.

Start/Stop

Start/Stop the data collection for the chart.

Rate

Enter the update rate and units for the chart. Available rate selections are: /sec, /min, /hour. Update rate limits are based on the update unit selection: 1-10/sec, 1-60/min, and 1-60/hour.

Samples

Enter the rolling buffer size for the chart. A minimum of 10 samples must be entered. Samples are collected in a first-in, first-out manner.

Set

Validates **Rate** and **Sample** entries for the chart and clears any collected data.

Clear

Clears all data in the chart.
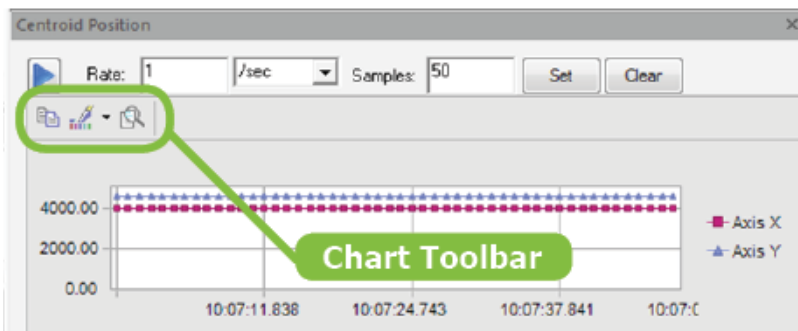
Some of the chart formatting features can be accessed through each **Chart Toolbar** or context menu.

Copy To Clipboard

Click to open a drop-down menu to copy the chart as a Bitmap image, Metafile, or Text data. Once copied, the image or data can be transferred to a different program and pasted.

Palette Selector

Click to open a drop-down menu to select a color-scheme for the chart.

Zoom

Toggles the chart zoom control allowing click-and-drag zooming. Once enabled, draw a box inside the plot and the chart zooms to the selected area. This allows viewing the value and time of an individual sample.

3.11.1.1.1 Chart Background Context Menu
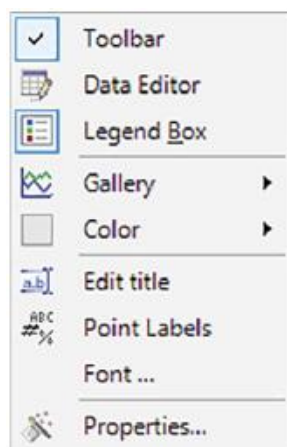
Right-click in an empty chart space to open the **General Context** menu. Options in this menu affect the entire chart. For example, changes made using "**Font…**" apply to the entire chart.

3.11.1.1.2 Point or Series Context Menu
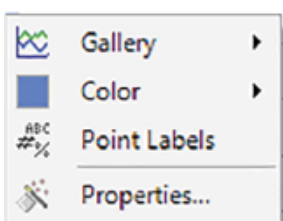
Right-click on a particular point or series to open a **Limited Context** menu. This menu provides options to change the gallery type and color of the series as well as enable point labels and open a properties dialog specific to the selected series.

3.11.1.1.3 Axis Context Menu
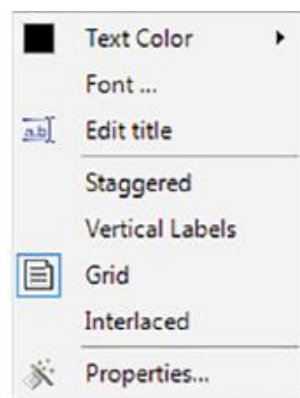
Right-click on the labels of an axis to open the **Axis Context** menu. This menu is used to configure an axis title, change the font color, or open a properties window specific to the axis.

3.12 Logging Ribbon
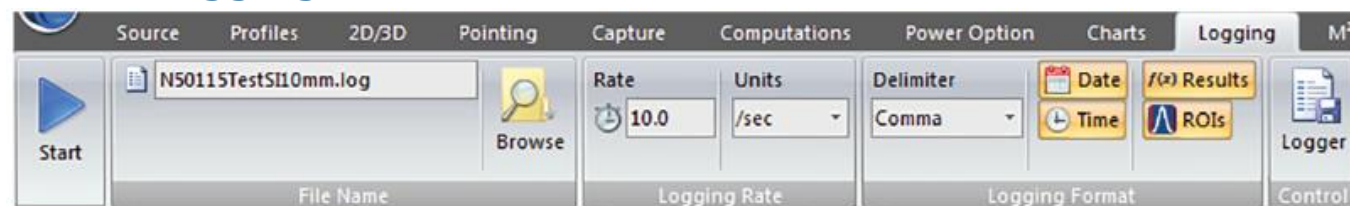
The **Logging** ribbon is used to select and control results logged into an ASCII text file.

3.12.1 Logging Ribbon: File Name Panel

This panel is used to create a logging file name and select the save location.
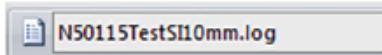
File Name

Enter a name for the log file. Displays the current or last used log file name. The folder path is preserved from the previous use. A *.**log** file extension is added upon saving.

Browse

Click to specify a save location and filename for the log file. If a previously saved log file is selected, the new data is appended. If no location is specified, the file is saved in the users Documents folder.

*It is recommended that a NanoScan folder be created in the users Documents folder for saving *.log, *.nsdx, and *.txt files.*

3.12.2 Logging Ribbon: Logging Rate Panel
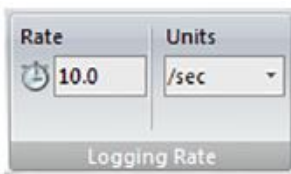
This panel controls the logging rate.
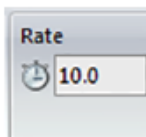
Rate

Enter the desired logging rate. If the rate **Units** is /sec the maximum update **Rate** is the current scan rate of the head. If the **Units** is /min or /hour, the maximum **Rate** is 60. The minimum **Rate** is 1 for all unit settings. If the min/max rate is exceeded, logging proceeds at the applicable min/max rate.
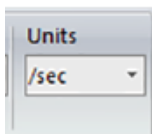
Units

Select the time **Units** for the log rate. Available values are /sec, /min, /hour. Rates set for /min and /hour divide the time period into equal periods based on the set rate. Example: 6/hour saves one log record every ten minutes.

3.12.3 Logging Ribbon: Logging Format Panel
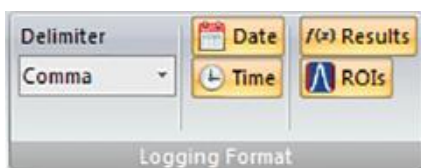
Select the log format and log items. Log records are created for each frame of computed results and appended to the log file. The first entry in a log file will be the titles of the results in the following entry records.
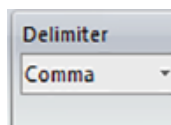
Delimiter

Selects the delimiting character used between the results entries in the log record: comma, semicolon, space, or tab.

Date and Time

Start each log record entry with a date/time stamp indicating the date/time that the results were collected. These selections can be used together.

Results

When selected, all results enabled in the **Computations** ribbon are included in the log file in the order they appear in the **Results** window.

ROI

When selected, the current ROI boundaries are included in the log file for each enabled ROI.

3.12.4   Logging Ribbon: Control Panel

Enable/Disable results logging to the specified file name. Log files are appended if a new file name is not specified between logging operations. This control is disabled until a **File Name** has been entered.

3.13   M² Ribbon
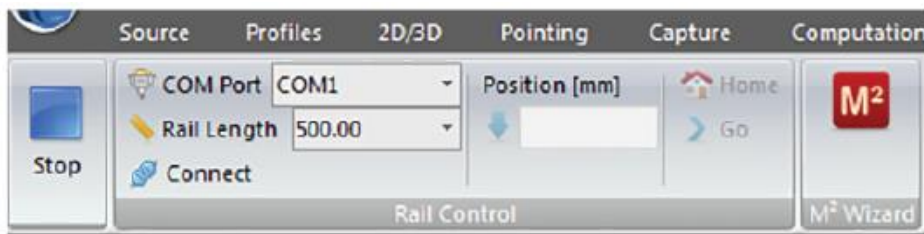
An **M² Wizard** button is provided to initiate a script that walks through the M² measurement process. The **Rail Control** panel can be used to connect and control an optional legacy Photon NanoModeScan RailScan automated translation table.

Communication with the RailScan is established through a selected serial COM port. It allows the operator to move the scanhead to a desired position along the rail, or by using the provided NanoModeScan software, make these measurements automatically.

Note that the use of the automated translation table is optional and movement may be performed manually using an optical rail and a user provided lens.

3.13.1   M² Ribbon: Rail Control Panel

Operation with a RailScan.
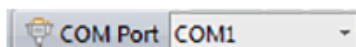
COM Port

The software generates a list with all available COM

ports on the system. Make sure the rail system is connected to one of these ports and then select the appropriate COM port in the dropdown menu.
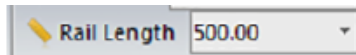
Rail Length

Select the **Rail Length** in mm. Available lengths for the rail system are 100, 200, and 500 mm.
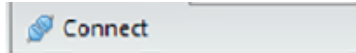
Connect/Disconnect

Establishes communication to the rail 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. An error message displays if the software cannot connect to the rail's motion controller.
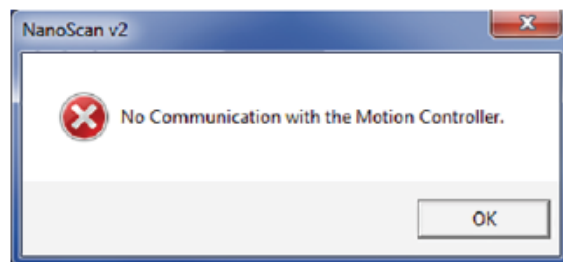
Check the connections and the COM port connection and try again. After the software connects to the motion controller, the **Disconnect** button and rail controls become active. **COM Port** and **Rail Length** selections are not available while the software is connected to the rail system.

Press **Disconnect** to close the COM port connection to the motion controller and disables the rail controls. When the motion controller is disconnected, the scanhead moves to the **Home** position on the rail.
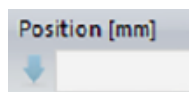
Position [mm]

Enter the desired position of the scanhead along the rail in millimeters. Note that this position is not the distance from the scanhead to the lens principle plane.

Home

Sends the scanhead to the home position (0mm) and checks if the home position was reached successfully. Always send the rail to the home position for accurate calibrations. If the scanhead does not reach the home position, an error message appears.

The RailScan is equipped with two limit switches, one at each end of the rail. If one of the limit switches is tripped, an error message appears. Follow the

procedure outlined in the error message to reset the system.
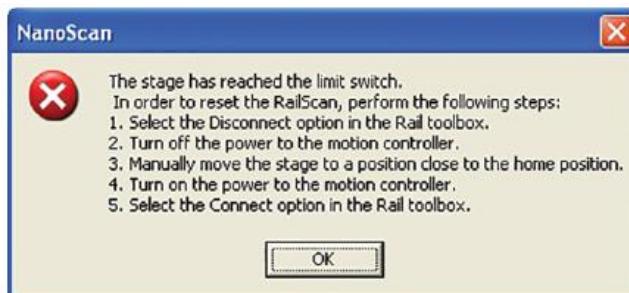
Go

Sends the scanhead to the above specified **Position**.

3.13.2   M^2 Ribbon: M^2 Ribbon Panel

The **M^2 Wizard** is an interactive program for determining the "times diffraction limit" factor, M^2, by the Rayleigh Method. M^2 is also known as the "beam propagation" factor. The **M^2 Wizard** view 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. This is only displayed on the last page of the Wizard.

Measurement Summary

Displays the measurement data for all the steps. In the final step, M^2 is computed and displayed here.

BeamWidth

Select the beam width computation method used in the measurement:

- **13.5% of Peak** – the 13.5% of Peak (1/e^2) clip level d$_{slit}$ width is used for computations
- **D4sigma** – the ISO Standard 11146 D4σ beam width is used for computations

This selection can be made only in the first step of the Wizard.

Wavelength

Enter the laser wavelength in nanometers. This entry can only be made in the first step of the Wizard. The laser wavelength is used in the computation of M^2.
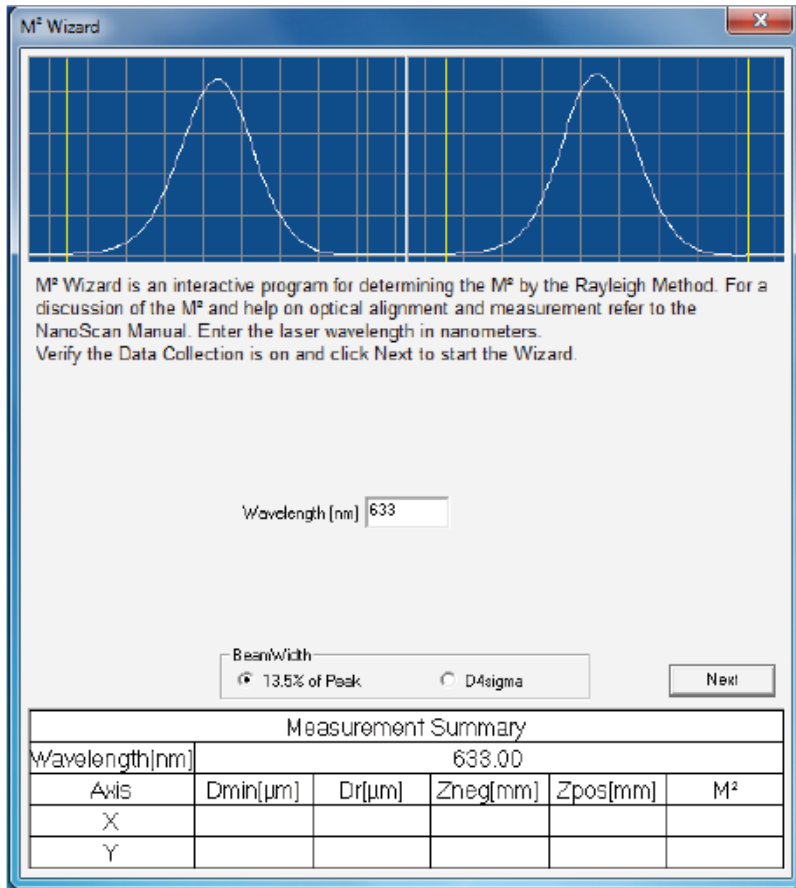
Setup the laser and sensor so that you can easily move the sensor along the Z-axis (nearer or farther from the laser), then start the **M² Wizard**. Follow the instructions that appear. Upon completing each step, select the **Next** button to continue. If an error has occurred select the **Previous** button and redo that step. After each step, the wizard updates the **Measurement Summary**. When the measurement is completed the data can be printed as a report or saved in the NanoScan2 file format. Refer to section 3.3.2 for saving, loading, and printing.

3.13.2.1 Measuring M²

M² is a propagation constant for a laser source defined in the ISO standard as:

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

where:

D_{min} — Beam diameter at the beam waist

λ — Wavelength

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

Z_{max} — Distance along Z axis where beam diameter is $\sqrt{2}D_{min}$

Z_{min} — Distance along Z axis on the other size of the waist where beam diameter is $\sqrt{2}D_{min}$

Physically, M² 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 M²=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, 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 M² 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.

3.13.2.2   Lens Selection and the Expected Rayleigh Length

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 ($1/e^2$) beam width.

Example:

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

The divergence for a diffraction limited source (M=K=1) is:

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

We can select the lens by assuming:

$$d = f \times \theta$$

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

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

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

$$d = f \times \theta = 75,000 \times 0.0018 = 135 \mu m$$

The expected Rayleigh length in the region of the waist is:

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

where d is the above 135µm calculated spot width.

$$Z = \frac{\pi}{4} \times \frac{135^2}{0.7} = 20,448 \mu m = 20.4 mm$$

Thus we have a rough starting point for M² measurements. If M² is much greater than 1.0, the spot size will be larger than calculated and the Rayleigh length will be less than calculated. We suggest that one try this method with a small, visible HeNe laser which is nearly always close to M²=1 to gain an appreciation for the method before trying an unknown source. If you get an M² value close to 1 with the HeNe source, you will have the measurement method understood! Although theoretically M² ≥ 1, it is possible to get values slightly less than 1 due to beam diameter measurement errors. If you get M² 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.

3.13.2.3   Alignment

To measure M², 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.

3.13.2.3.1   Rayleigh Test Fixture Accessory

The legacy Rayleigh Translation Test Fixture consisted of a base plate, a slide that allowed manual axial (Z) translation of the scanhead, and an LCD measurement ruler. The base plate rigidly mounted to an optical table

or rail. The translation distance readout was a Mitutoyo LCD ruler that spanned 150mm of travel and gave position values to the nearest 25µm. The total 150mm travel allowed the Rayleigh range to be such that a beam waist of approximately 200µm could be measured.

The Mitutoyo scale can be zeroed at the first Rayleigh location and translated to the second to find a single, direct read number in mm to be inserted into the wizard. This accessory's purpose was to make measurements of the Rayleigh range easy and repeatable. Users provide a source, a focusing lens, and a mount.

3.13.2.3.2 Sensor and Laser Beam Alignment 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 ±1-2 beam widths. For the example source listed above (section 3.13.2.2) this means one should see no more than ±500µm motion in either X or Y axis as one translates the sensor along the beam axis through a distance of 2Z (41mm for our example). The **Pointing** view can be used to measure the misalignment over the Rayleigh range.

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

Record the Z axis position in millimeters. 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 the **Reset** button. Moving the scanhead too 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. Translate the sensor through the 2Z 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 machine 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 2mm hole) during alignment. Be sure to remove the stop once aligned in order to prevent truncation of the source and consequently errors in the measured M^2.

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

3.13.2.3.3 Dual Axis Measurements with Astigmatism

To measure M^2 when the source is astigmatic, the user will need to modify the basic procedure slightly. Figure 3.1 shows what this looks like.
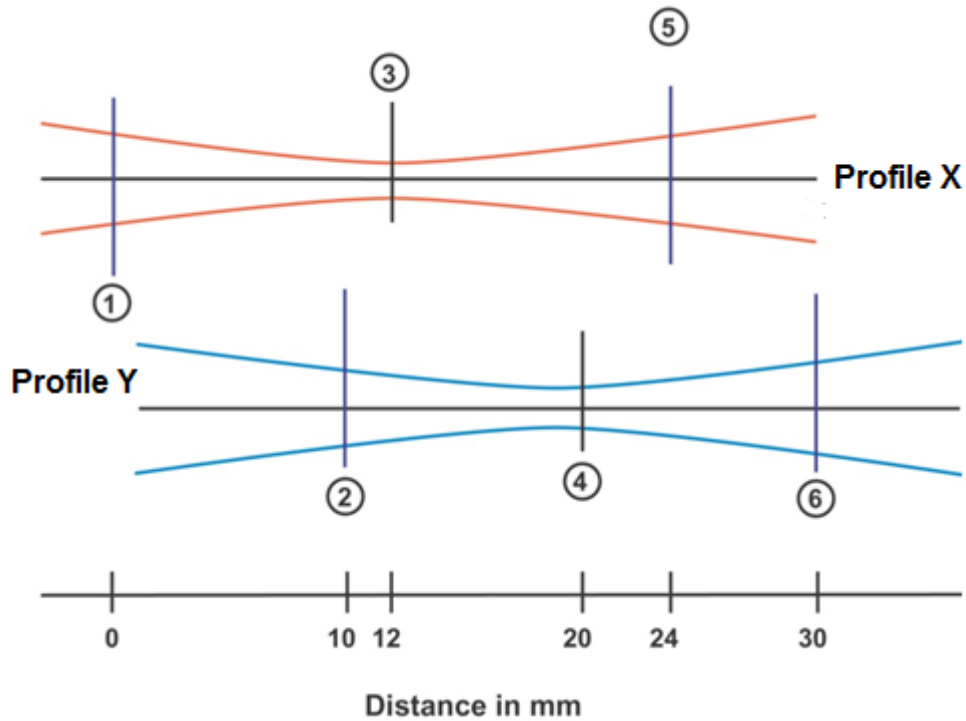
Figure 3.1 Measurement of Astigmatic Source Using the M² Wizard.

Example:
1.   Move the sensor to D Target for Profile X. Enter 0 for **Z Negative** under the **Axis X** heading.
2.   Move the sensor to D Target for Profile Y. Enter 10 for **Z Negative** under the **Axis Y** heading. Select the **Next** button.
3.   Move slowly through the waist for Profile X and verify the D_{min} is correct.
4.   Move slowly through the waist for Profile Y and verify the D_{min} is correct.
5.   Move the sensor to D Target for Profile X. Enter 24 for **Z Positive** under the **Axis X** heading.
6.   Move the sensor to D Target for Profile Y. Enter 30 for **Z Positive** under the **Axis Y** heading. Select the **Next** button.

For more details, visit:
http://www.ophiropt.com/laser-measurement-instruments/beam-profilers/knowledge-center/tutorial/measurement-solutions

Information can also be found by contacting your local Ophir-Spiricon representative.

3.14   Results Window

The **Results** window displays the values and statistics for calculated beam results selected using the **Computations** ribbon. Rows are organized first by ROI number, then by results item.

Result	ROI #	Value	Mean	S. Dev.
13.5% Width X [μm]	1	292.090	294.540	2.0485
13.5% Width Y [μm]	1	331.312	328.746	2.8375
D4sigma X [μm]	1	431.359	430.860	2.4490
D4sigma Y [μm]	1	461.278	453.764	4.7486
Centroid Position X [μm]	1	3665.775	3665.661	0.5010
Centroid Position Y [μm]	1	4271.701	4273.281	0.7959
Peak Position X [μm]	1	3791.155	3790.932	0.7221
Peak Position Y [μm]	1	4410.201	4410.035	0.3104
Peak X [cnts]	1	2008.686	2025.625	26.4996
Peak Y [cnts]	1	2106.527	2091.021	19.0899
Ellipticity	1	0.882	0.896	0.0115
13.5% Width X [μm]	2	422.132	415.700	3.7958
13.5% Width Y [μm]	2	389.819	387.774	2.0048
D4sigma X [μm]	2	529.058	525.810	2.5851
D4sigma Y [μm]	2	504.717	504.521	1.8555
Centroid Position X [μm]	2	4157.069	4155.674	1.1641
Centroid Position Y [μm]	2	4796.538	4796.736	0.5948
Peak Position X [μm]	2	3990.487	3988.239	0.8823
Peak Position Y [μm]	2	4640.284	4640.473	0.3788
Peak X [cnts]	2	2668.686	2657.938	11.3996
Peak Y [cnts]	2	2623.527	2637.146	17.8349
Ellipticity	2	0.923	0.933	0.0110

Column spacing can be modified by using the column controls in the **Heading** bar and the mouse. The font size of the **Results** window can also be changed by setting the focus by clicking inside the window, then hold down the **Control** button on the keyboard and scroll with the mouse wheel or select Ctrl+(+) or Ctrl+(-).

The status bar at the bottom of the screen displays the number of samples used in the **Results** window statistics. The number of samples and the display of beam results can be reset with the statistics reset button located in the **Computations** ribbon. Options for the **Results** window are selected using the **Computations** ribbon described in section 3.9.

3.14.1   Notes Window

The **Notes** view is a text editor for entering test information, comments, and time stamping. The **Time Stamp** button adds the current date and time to the end of the comments field. Multiple comments and time stamps can be added to the Notes view.
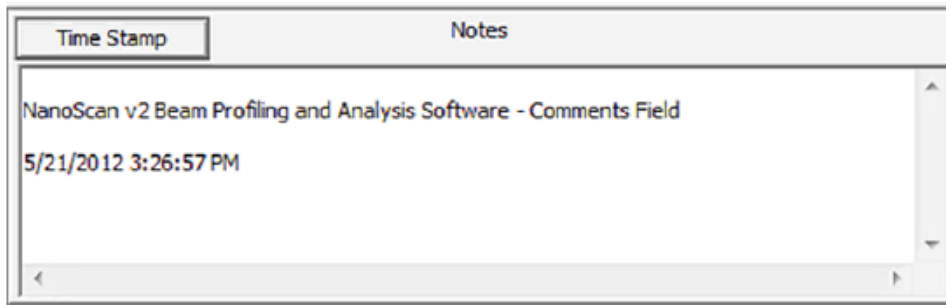
3.14.2   Message Window

The **Message** window displays message communications between the NanoScan2 scanhead and the NanoScan v2 application, along with the time the event occurred. If the scanhead is operating outside of normal operating parameters, an error message appears and instructs the user on what is out of tolerance and may suggest actions to correct the situation. Only the last 100 messages are displayed with the most recent message on top. The **Message** window can be closed, but reopens each time a new message is displayed. Below is a view of the **Message** window showing typical operation messages.
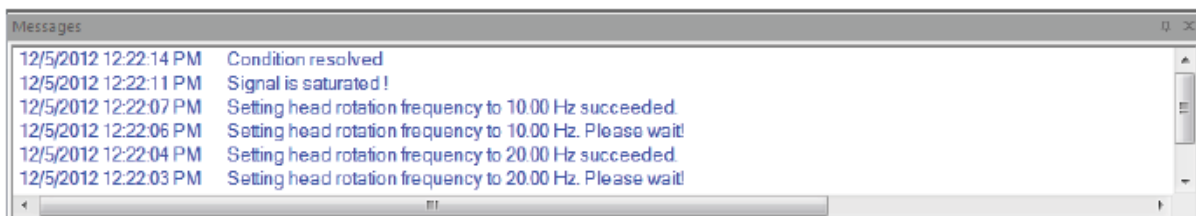
3.15 NanoScan2 Status Codes

The following table contains hardware and device driver related status messages. NanoScan v2 software displays these messages in a dialog box that contains the following message:

"Code (Status code: X). Contact Ophir-Spiricon"

Although most of the status codes indicate a hardware problem, some of them arise from bad connections between the PC's USB port and the scanhead. Some of the status codes only apply to the legacy NanoScan scanhead and controller board.

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.
-5	The function failed to allocate memory space.
-6	The head EEPROM cannot be read. This usually indicates a communication problem. Check all connections.
-7	An error occurred in the communication with the NanoScan2 scanhead. Check USB and scanhead connections.
-8	An error occurred in the communication with the NanoScan2 scanhead. Check USB and scanhead connections.
-9	An error occurred while reading the head EEPROM. EEPROM information may be corrupt, or there may be a problem in the EEPROM communication interface. Check all scanhead connections. Ophir-Spiricon 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 scan rate 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 scan rate.
-19	The device driver could not read the head scan rate.
-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, or 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.
-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.

Chapter 4 Beam Profiling with NanoScan2

NanoScan2 creates spatial beam irradiance profiles using scanning slit techniques. The profiles are analyzed to provide beam width measurements. They can also be 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.

With NanoScan2, beam profile measurement process is straight forward. Simply position the scanhead in the beam path and the system does the rest.

Consideration of the wavelength, beam size, and beam power ensure a particular scanhead is appropriate for a given application.

For accurate beam profiling with the NanoScan2 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 11146-1, -2, -3

These standards govern profile measurements and analysis using scanning apertures, variable apertures, and 2D detector arrays. Profiles obtained using these methods differ fundamentally. Each requires specific analyses to determine beam characterization parameters. Most important of which is the beam width or diameter. Profile measurements using various scanning aperture techniques were considered, including the moving slit, moving knife-edge, variable-aperture, and scanning-pinhole.

4.1.1   Beam Width Analysis Methods

The four preferred methods for the measurement of beam widths were determined to be:

1. Moving slit, ISO 11146-3 (section 4.4)
2. Moving knife-edge, ISO 11146-3 (section 4.3)
3. Variable aperture, ISO 11146-3 (section 4.2)
4. Direct 2D Second-moment, ISO 11146 (all)

The first three methods involve mechanical moving devices. The fourth method typically involves 2D focal plane arrays that employ various imaging technologies.

In theory, all of the methods give exactly the same results for the $1/e^2$ widths of a perfect TEM_{00} Gaussian beam. For all other beam profiles different values are obtained, although for typical beams the values are usually within 10% of each other.

Method 1 provides superior spatial measurement accuracy over a wide range of beam widths. Method 2 is similar to method 1 but yields no beam profile detail. Method 3 gives no spatial detail and is not appropriate for elliptical beams. Method 4 is the only method that displays the actual 2D structure of the beam profile.

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

4.1.1.1 Moving Slit Analysis

Moving Slit Beam Width Analysis, also known as Clip-Level Beam Width Analysis, 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 standards is defined as the spatial width at the 13.5% ($1/e^2$) level (for a TEM_{00} beam) and is designated as d_{slit}. It is also common in practice to use the beam size at other %-irradiance levels, or "clip" levels, for example 50% or full-width-half-max (FWHM) beam width.
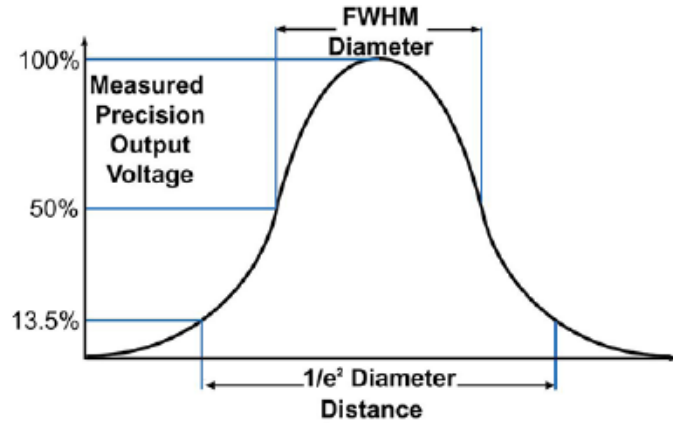
Figure 4.1 Moving Slit Beam Width Analysis

One nice feature of the moving slit method is that the scanned profile can also be used to directly calculate the second moment beam widths of non-TEM_{00} beams. This is not possible with the knife-edge or variable aperture methods.

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 Second Moment Method Analysis

Over time, the second moment method has become the industry standard for beam width definition since it is the measurement that follows laser beam propagation theory. However, it is not always the measurement preferred by some users with differing laser applications. The second moment method defines the beam width as four times the square root of the second moment of the beam's spatial profile. This width, designated D4σ, is equivalent to the $1/e^2$ slit and knife-edge method widths for a TEM_{00} Gaussian beam where M2 = 1.

The second-moment integral for the x coordinate is:

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

The corresponding beam diameter is $D_{4\sigma} = 4\sigma_x$

4.1.2 Comparison of Beam Profiling Methods

During the development of the ISO standards, the committee compared what was measured by the different methods for several laser modes. The second moment method was designated as the reference method because it provides the beam profile width that is always consistent with the laser beam propagation theory.

Table 4.1 is a guide from the 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.

To avoid confusion, the standard suggests the measurement method be stated along with the reported beam width. It is also recommended to report the standard deviation of the measurement.

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 $1/e^2$	D at $1/e^2$ 1.5606	D at $1/e^2$	D 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

Table 4.1 Comparison of Beam Width Measurement Methods

4.1.3 Moving Slit Techniques

NanoScan2 employs the moving slit method. The various 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 frequency determines 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, 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 are dependent on the beam irradiance distribution.
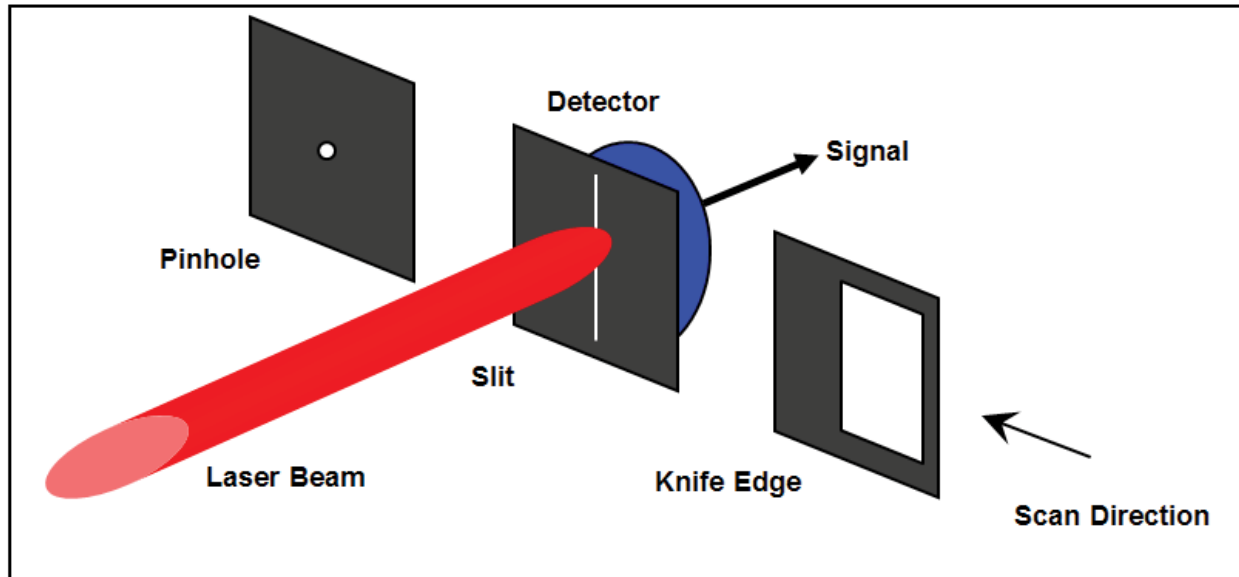
Figure 4.2 Illustration of scanning aperture beam profiling techniques

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. The NanoScan2 configuration uses two slits mounted on a rotating drum oriented at 90° to each other, thus two orthogonal profiles are measured for each scan. This technique is illustrated in Figure 4.3 and Figure 4.4. Note that 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.
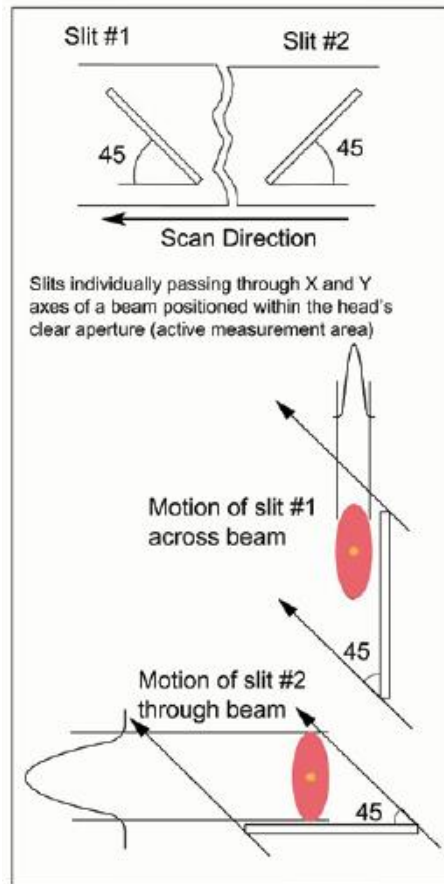
Figure 4.3 Measurement of the major and minor axes of an elliptical beam using the moving slit method with 2 orthogonal slits
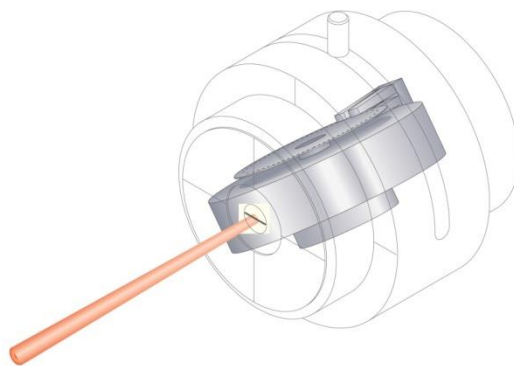
Figure 4.4 Scanning slit instrument for laser beam profiling. A slit mounted to a motorized drum scans repetitively through the beam. An optical encoder provides motion control feedback and ensures accurate beam sampling.

4.1.4   NanoScan2 Dual-Axis Scanhead

Figure 4.5 illustrates the operation of a dual-axis scanhead. The slits are typically closely matched in width and oriented at ±45° (90° to each other) with respect to the drum rotation 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 (0°) and vertical (90°) directions, respectively. An elliptical beam oriented with the major axis horizontal and the minor axis vertical is incident on the scanhead. Slit 1 (shown on the cover of the scanhead as X) scans along the vertical axis of the beam and slit 2 (shown on the cover of the scanhead as Y) scans along the horizontal axis. The measured beam profiles for each aperture are shown.

NanoScan2 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 2.5.3.5 for additional information).

The internal workings of a dual-axis NanoScan scan head
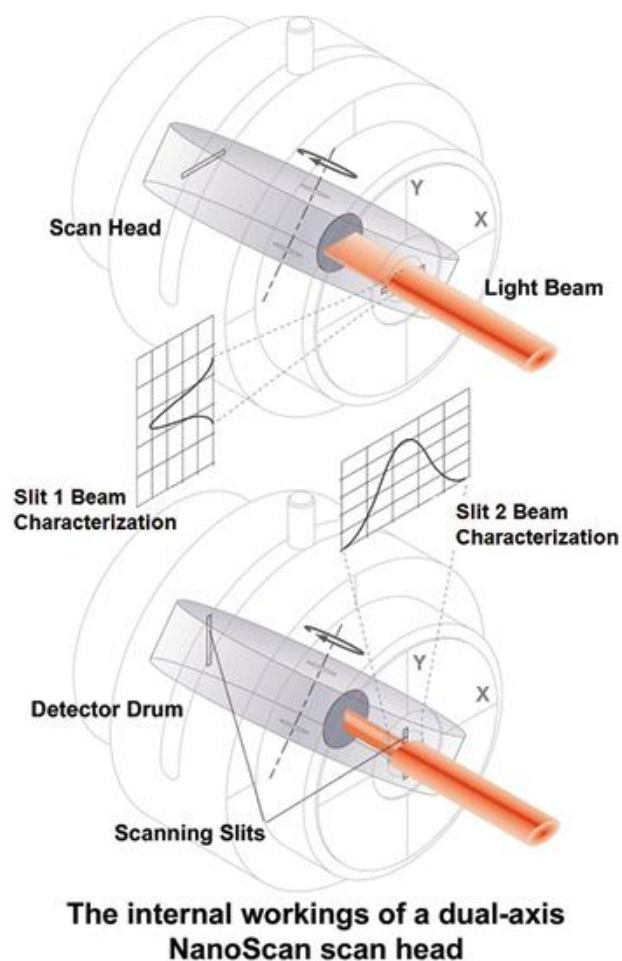
Figure 4.5 Illustration of NanoScan2 profiling with dual orthogonal slits

4.1.5   Pulsed Beam Profiling

NanoScan2 can also profile pulsed laser beams with repetition rates in the 1kHz range and above. To enable the measurement of these pulsed lasers, the NanoScan2 profiler incorporates a "peak connect" algorithm. NanoScan2 is ideal for measuring Q-switched, pico/femtosecond pulsed lasers, and lasers operating in pulse width modulation (PWM) mode. 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, Profile Averaging, and the number of pulses in the profile during a single scan, which in turn depends on the laser repetition rate and beam diameter.

There are two modes of operation for pulsed lasers; **Short** for pulsed widths <10ns, and **Long** for pulse widths >10ns.

To provide ±2% measurement accuracy in **Short** mode, the input signal/gain combination must limit the digitized pulse amplitude to <4096 counts in order to avoid amplifier nonlinearity. This adjustment is performed automatically by the NanoScan v2 software. Should the operator override the automatic gain control and exceed 4096 counts, the following message will be displayed in the **Message** window warning the user to decrease the gain.

Pulsed Mode Warning: Signal above max counts; reduces accuracy. Decrease gain.

In **Long** pulse mode, the Full-Scale amplitude is limited to 32768 counts in order to avoid amplifier nonlinearity and subsequent measurement error. As in the previous **Short** pulse mode, the gain can be set manually. In this case, if the gain is set so the amplitude is greater than 32768 counts, the above warning message will be displayed.

4.1.5.1 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-to-noise ratio and pulse-to-pulse repeatability. Use of **Frame Averaging** and **Rolling Frame 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 rates, longer pulse widths or duty cycle, and slower scanhead scan rates.

To make a visual determination if a beam profile is quasi-CW, turn off **Filter Frequency Tracking** 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 scan rate.

In these cases, it is recommended to experiment with the different measurement modes in order to obtain the most consistent results.

4.1.5.2 Accuracy Requirement: Minimum of 15 pulses per scan

As shown in Table 4.2, a minimum of 15 pulses per single scan is required to obtain the specified accuracy. This condition depends on the laser spot size and the scanhead scan rate. If there are not enough pulses present in a single scan (<15), the software computes the corresponding head scan rate and displays a message in the **Message** window recommending a lower head speed.

The Head Rotation Frequency is too high for the beam diameter and the Laser Pulse Frequency. The recommended Head Rotation Frequency is 2.50 Hz!

If the computed head scan rate for the current conditions is below 1.25Hz, a different message displays in the **Message** window warning the user about operating the NanoScan2 system outside the ±2% accuracy specification.

Accuracy Warning!Reported beam diameters for the selected Laser Repetition Frequency lies outside the 2% NanoScan accuracy specification!

4.1.5.3 Calculating the Minimum Beam Diameter per Laser Pulse Repetition Rate

Table 4.2 gives a list of calculated minimum beam diameters at a given pulse rate for a desired number of pulses per profile. The more pulses per profile, the more accurate the measurement is likely to be. Due to the 45° 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.

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

where:

v Drum velocity (µm/ms)
f Pulse frequency (kHz)
N Pulses per profile
D_{min} Minimum beam diameter (µm)

The NanoScan2 pulsed operation can operate at any scan rate, however it is recommended that the scan rate be 1.25 or 2.5Hz unless the laser repetition rate is above 50kHz.

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 rate be entered into pulse acquisition parameters. NanoScan v2 provides for the measurement of all pulsed beams with all scanheads and detectors. Beams with an average power that is too low to be measured with the pyroelectric detector can be profiled using silicon or germanium scanheads.

At high laser repetition rates, it may be better to operate the NanoScan2 in **CW** mode and let **Filter Frequency Tracking** smooth the beam. When this method is preferred depends on the 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.

	Minimum Beam Size/Pulse Rate				
Scan Rate (Hz)	1.25	2.50	5.00	10.00	20.00
Slit Speed (µm/msec)	116.63	233.25	466.50	933.01	1866.01
Data Points per Profile	15	15	15	15	15
Pulse Rate (kHz)	Minimum Beam Diameter in µm				
0.5	3499	6998	N/A	N/A	N/A
1	1749	3499	6998	N/A	N/A
2	875	1749	3499	6998	N/A
3	583	1166	2333	4665	N/A
4	437	875	1749	3499	6998
5	350	700	1400	2799	5598
6	292	583	1166	2333	4665
7	250	500	1000	1999	3999
8	219	437	875	1749	3499
9	194	389	778	1555	3110
10	175	350	700	1400	2799
11	159	318	636	1272	2545
12	146	292	583	1166	2333
13	135	269	538	1077	2153
14	125	250	500	1000	1999
15	117	233	467	933	1866
16	109	219	437	875	1749
17	103	206	412	823	1646
18	97	194	389	778	1555
19	92	184	368	737	1473
20	87	175	350	700	1400
21	83	167	333	666	1333
22	80	159	318	636	1272
23	76	152	304	608	1217
24	73	146	292	583	1166
25	70	140	280	560	1120
50	35	70	140	280	560
100	17	35	70	140	280
150	12	23	47	93	187

Table 4.2 Minimum Beam Size per Pulse Rate

4.1.5.4 Software Measurement of Laser Repetition Rate

The software connects the pulse peaks based on the user input Laser **Pulse Rate**. If the actual and input frequencies are significantly different, the resulting profiles may not be smooth. When selected in software, the actual Laser Pulse Rate is measured and displayed as a check for a possible incorrectly entered Laser **Pulse Rate** value. When rough profiles appear, try using the measured rate value and the beam profiles may become smoother.

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

4.2 NanoScan2 System Description

4.2.1 Scanhead

The NanoScan2 is a self-contained scanning slit system. The scanhead employs a high performance digital signal processor that controls all head electronic and electro-mechanical functions including communications via its USB2 port.

The scan rate, spatial sampling interval, signal amplifier gain, filter settings, and DC offset are controlled by the scanheads internal firmware. An EEPROM in the scanhead contains all of the scanheads model specific parameters. This information includes head ID, available scan rates, amplifier gain tables, slit and aperture information, power window, and calibration information.

The firmware in the scanhead is upgradeable to accommodate new features that may be developed.

4.2.2 Scanhead Mechanicals

The mechanical configuration of the main components of the scanhead is shown in Figure 4.6. This includes the scan drum with optical position encoder and motor, scan slits, a power aperture, a stationary large-area photo detector, and a rotation mount with a knurled locking screw. The scanhead electronics are not shown.
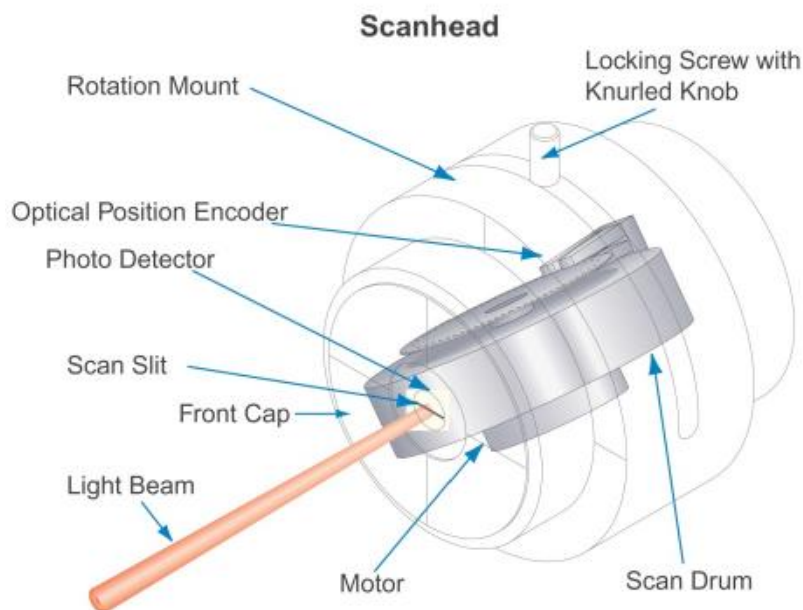
Figure 4.6 Scanhead Components

4.2.2.2　Front Cap with Entrance Aperture and C-Mount

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 NanoScan2 scanheads have nominal entrance aperture diameters of 3.5mm or 9mm depending on the detector type.

The scribe lines on the front cap define the 2 orthogonal scan axes. The housing tube edge is the reference surface for the scanhead measurement datum plane.

A C-mount threaded front cap feature is included on the NanoScan2 scanhead. This feature simplifies the addition of many Ophir-Spiricon optical accessories that are also useful on CCD camera systems. The C-mount ring comes standard, but can be removed if the user needs the space for a closer approach to the aperture. The mounting screws can also be employed for attachment of a user built custom accessory.

4.2.2.3　Photo Detector

NanoScan2 heads 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, germanium, and pyroelectric detectors used in the NanoScan2 are shown in Figure 4.7. The response for the pyroelectric detector is flat for wavelengths from 190nm to >20µm, with a nominal value of 3.8×10^{-6} A/W.
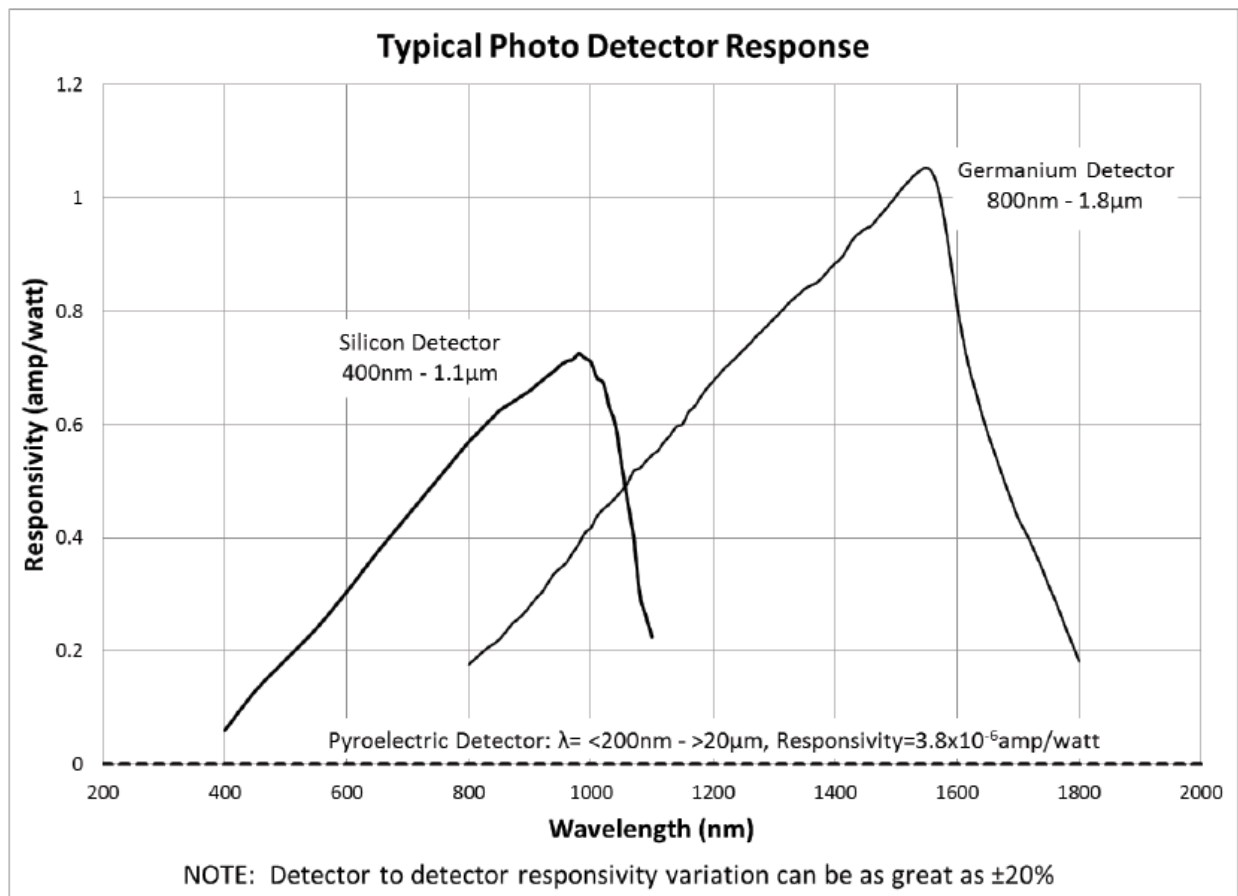
Figure 4.7 Typical Photo Detector Response for Silicon, Germanium, and Pyroelectric Detectors

4.2.2.4　Air Slits

NanoScan2 scanheads come standard with matched pairs of air slits of 1.8μm or 5μm widths. Legacy products also included a 25μm width option. Air slits comprise a clear opening in a thin metallic membrane.

The edge quality of the slit 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 exceptional edge quality of the slits in terms of straightness is shown in Figure 4.8. The figure shows photographs from a scanning electron microscope (SEM) for standard 1.8μm and 5μm slits.
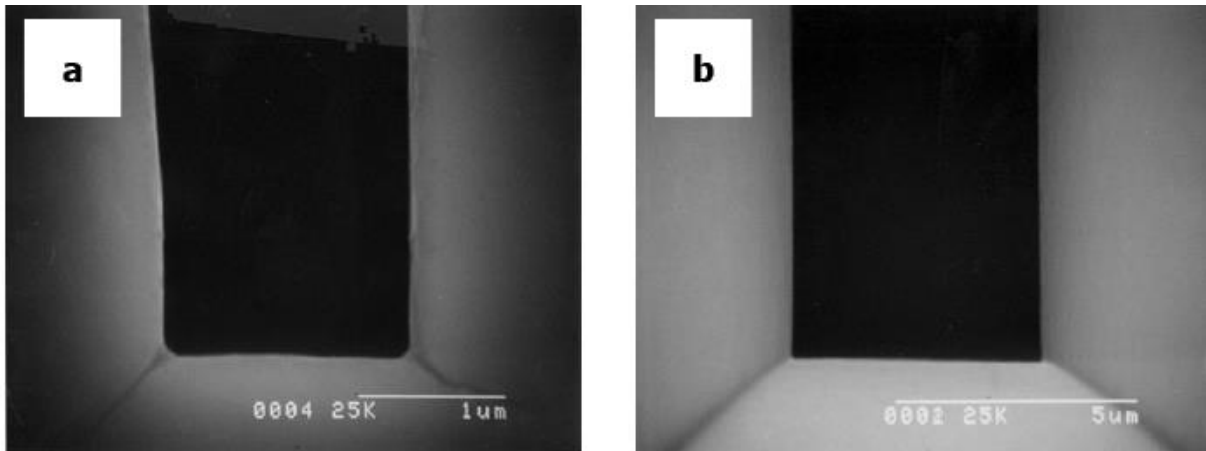
Figure 4.8 SEM images for 1.8μm (a) and 5μm (b) slits

NanoScan2 scanheads with silicon or germanium detectors come standard with blackened slits to reduce light reflected back into the laser and thus prevent laser cavity oscillations. As a result of the blackening process, the slit edges become slightly rougher.

4.2.2.5　Power Meter

The power meter provides for measurement of total beam power. It requires the user to manually calibrate the power based on an external power meter reading. Separate manual calibrations are required for each change in wavelength.

When using a pyroelectric sensor, separate manual calibrations are also required for each head rotation speed. The user generated calibrations can be stored for reuse in the scanhead's memory. Up to 256 calibrations can be stored.

In silicon and germanium scanheads an attenuator placed behind the power aperture reduces the incident beam power to avoid detector saturation. Power aperture attenuators are a metallized quartz glass substrate, useable for power levels up to 200mW.

The metallized quartz glass filter has a neutral response with wavelength. They tolerate higher input laser power and show little change of attenuation with angle of incidence.

4.3　Care of NanoScan2 Slits

The air slit aperture substrates are very thin and extremely fragile. Because of their fragility, **never touch them with anything!** Fiber tips placed too close to the aperture can easily damage a slit.

Debris such as dust particles can lodge in the very fine openings of the slits and obstruct the passage of the incident beam. This can compromise instrument performance, resulting in inconsistent measurements.

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 Ophir-Spiricon for slit inspection, cleaning or replacement, and recalibration**.

4.3.1   Slit Damage Threshold

Damage thresholds reported in Table 4.3 below are determined under specific test conditions and should not be taken as absolute. Ophir-Spiricon **does not warrant damage to slit material and detectors due to damage from high power lasers**. Users of high-power lasers must exercise caution when measuring their laser beams with the NanoScan2.

Scanhead slits are made from a proprietary metallic alloy. The slit material is often blackened to reduce reflectivity. Because of possible slit damage, Ophir-Spiricon performed damage threshold tests on various slit materials to establish general use guidelines for prevention of damage. If you are concerned and still not sure, Ophir-Spiricon can provide slit material that you can use as a test before applying your beam to the scanhead.

Blackened and unblackened slits with 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 NanoScan2 operating conditions with the slits **moving**. Damage to the slit material can occur at much lower power levels if the laser beam is directed into the slit while they 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 slit material 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 NanoScan2 and cause other failures.

Note that for the case of blackened slit materials, the onset of visual damage occurs when the black coating begins to ablate. This type of damage does not affect the integrity of the slit but only the reflectivity of the base metal. Slit integrity is only compromised at the higher laser irradiance associated with damage to unblackened metals. This damage takes the form of wrinkling or creasing of the metal fabric due to thermal stress, and scoring due to melting of the metallic alloy. At higher irradiance and longer exposure times, the metal fabric can be cut. Below is a summary of 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.

SLIT TYPE	NOMINAL SLIT WIDTH (μm)	VISUAL DAMAGE THRESHOLD (W/cm^2)		
		532nm	1.06μm	10.6μm
UNBLACKENED	1.8	3×10^5	1×10^6	N/A*
UNBLACKENED	5-25	4×10^5	1.2×10^6	3.5×10^6
BLACKENED	1.8	1×10^4	3×10^4	N/A*
BLACKENED	5-25	1×10^4	3×10^4	N/A*

Table 4.3 Recommended Maximum Average Laser Irradiance Incident on NanoScan2 Slits
***Not Applicable**

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

Ophir-Spiricon does not warrant damage to slit material and detectors due to damage from high power lasers.

4.3.2   Pulsed Laser Damage Considerations

Pulse width modulated (PWM) sources do not increase the peak power density in your beam over CW operation values.

Q-Switched, picosecond, and femtosecond lasers increase peak irradiance above CW and may increase it enough to damage the slits and/or detectors. Be sure to read these next three sections carefully to protect your investment; call or email if you have questions.

4.3.2.1   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%. In this case, the beam operates as if it was CW and many operators do not realize 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 NanoScan2, the laser's pulse rate must be at least 1kHz, and the combination of the rate 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 rate is a fairly simple mathematical model. The NanoScan2 drum speed is software controlled from 1.25Hz to 20Hz. At the 1.25Hz scan 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 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 meaningful profile.

Table 4.2 displays the minimum beam sizes and pulse frequencies for the hubs at each of the set scan speeds. It is recommended that the 1.25Hz scan rate 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 rate to 2.5Hz or above. The NanoScan v2 software generates 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 for your scanhead when measuring PWM sources. Your maximum saturation power is still the CW (100% on-time) maximum for your laser even as the duty cycle decreases.

4.3.2.2   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 NanoScan2 even though the average power remains within the operating space. CW beams are measured as power (P) in watts; pulsed beams are measured as energy (E) in joules. Therefore it is necessary to understand the beam's energy (E_{pulse}) in order to determine whether the unattenuated beam can be directly measured with the NanoScan2.

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

Therefore a beam with an average power of 300 Watts with a pulse rate of 8 kHz has energy as follows:

$$E_{pulse} = \frac{P_{avg}}{f_{laser}} = \frac{300 \text{ W}}{8 \times 10^3 \text{ Hz}} = 37.5 \text{ mJ}$$

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:

$$P_{pulse} = \frac{E_{pulse}}{\tau} = \frac{37.5 \text{ mJ}}{1 \times 10^{-3} \text{ s}} = 37.5 \text{ W}$$

4.3.2.3   Picosecond and Femtosecond Lasers

When the pulse duration of the laser gets very short, such as with picosecond 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 slit 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 picosecond 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 example, the E_{pulse} would be:

$$E_{pulse} = \frac{P_{avg}}{f_{laser}} = \frac{1\ \text{W}}{80 \times 10^3\ \text{Hz}} = 12.5\ \mu\text{J}$$

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

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

For a 100µm diameter beam at 12.5µJ:

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

Once the energy density is calculated, it can be compared to the damage threshold for the slit type and the wavelength range for the slit 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/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 slit material can withstand. For the standard unblackened 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 legacy high power copper slits, the values are 2.5J/cm^2 from 700nm to 3µm and 5J/cm^2 above 3µm. Copper slits are not recommended for use below 700nm.

Figure 4.9 below is a graph that can be used in lieu of the above calculations. For the above case, the 12.5µJ energy at 100µm would be below the 600mJ/cm^2 damage line, but would certainly be well above the damage level for blackened slits.
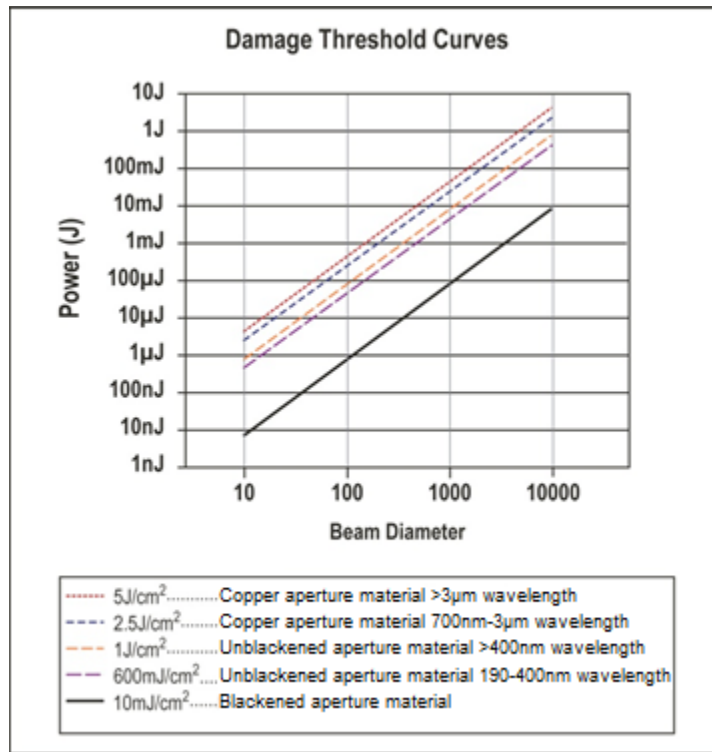
Figure 4.9 Damage Threshold Curves

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 slit material. 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.

4.3.3 Scanhead Operating Space

The Operating Space Chart maps the useful measurement range for a given NanoScan2 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 scanhead with a silicon detector and 1.8µm slits is shown in Figure 4.10. The horizontal axis of the chart is the $1/e^2$ beam diameter in microns and the vertical axis is the incident beam power in watts. Operating Space Charts for all standard scanheads are in Appendix C.
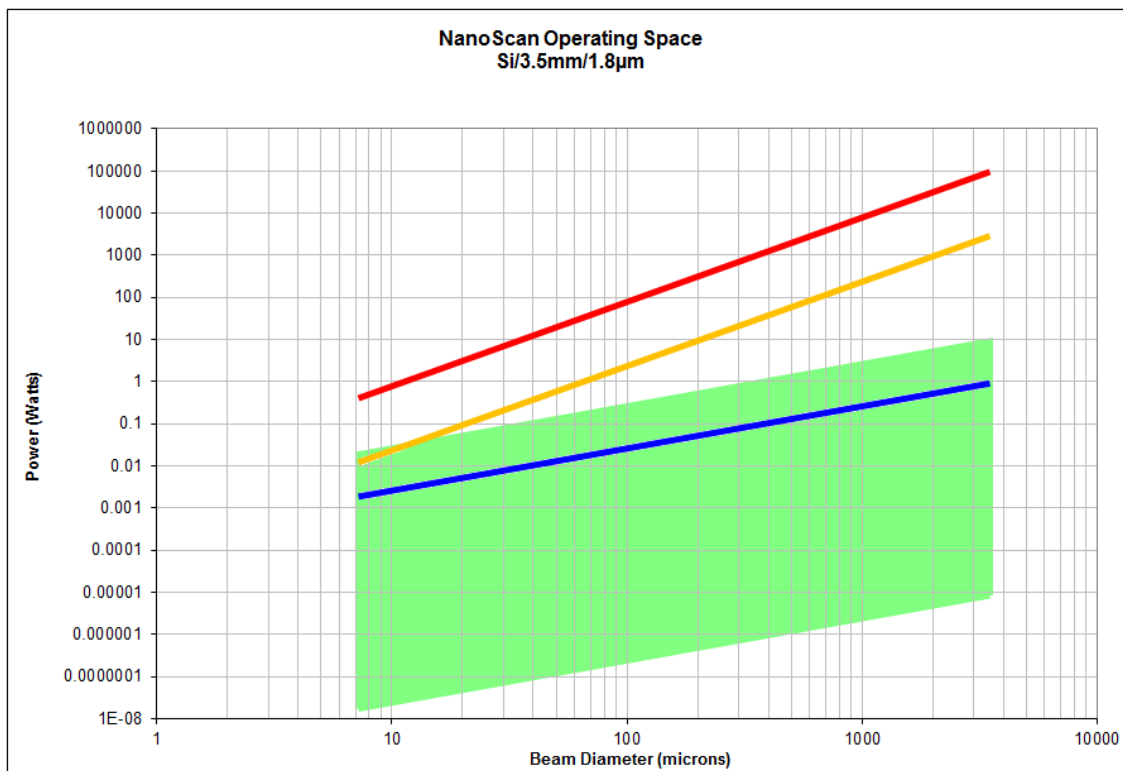
Figure 4.10 Operating Space for a NanoScan2 with silicon detector, 3.5mm aperture, and 1.8µm slits

The boundaries of the operating space define the power density of laser beams that can be measured directly and are defined as follows:

- The left boundary is based on acceptable errors due to slit convolution. The boundary is set at a beam diameter of four times the slit width, at which point a 5% systematic convolution error in the raw profile is introduced. This error can be corrected per the diameter correction charts in section 4.4.9.
- 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 of beam power above which the detector saturates.
- The right boundary is defined by the dimension of the entrance aperture, which determines the largest beam profile and diameter that can be measured. For a TEM_{00} Gaussian beam the $1/e^2$ diameter needs to be ≤1/2 the aperture diameter to measure and see the entire profile out to the tails. Similarly for a Flat-top distribution the $1/e^2$ diameter needs to be ≤~95% of the aperture diameter. To obtain any given clip level diameter for any beam (but not the full profile) approximately 95% of the aperture is usable.

The axes of the Operating Space Chart are logarithmic.

For pulsed operation in **Short Pulse** mode, the signal amplitude is limited to roughly 10% of the maximum. This effectively sets a limit indicated in the operating space by a blue line at 10% below the upper boundary.

The red and yellow lines display the damage thresholds. The lower yellow line describes the power density where the slit blackening begins to ablate. The upper red line describes the level at which the slits are physically damaged and can be cut. Operation above the yellow line is not advised for Si and Ge scanheads

with blackened slits; operation above the red line will result in immediate permanent damage to the NanoScan2.

Damage to scanheads from a high laser power is not covered by the Ophir-Spiricon warranty.

4.3.4 Instrument Calibration

Ophir-Spiricon recommends an annual calibration on all its beam profilers, especially the scanning-slit profilers including NanoScan2. Ophir-Spiricon profilers are precision instruments with moving parts. Over time, minuscule movements may occur which could affect measurement accuracy. Many instruments are used 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. Ophir-Spiricon sends a calibration/preventive maintenance reminder on the anniversary of the delivery of your NanoScan2.

4.4 Measurement Considerations and Guidelines

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

4.4.1 Use the Appropriate Scanhead

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 is 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 NIR beams at 1550nm and UV beams at 355nm. Such diverse applications may demand the use of different scanhead types.

4.4.2 Slit Width Selection Criteria

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 1.8µm.

The power measurement range is inversely proportional to the slit width; beam diameter size is directly proportional to the slit width. 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. The severity of the error depends on the beam profile. This is discussed in detail for TEM_{00} Gaussian beams in section 4.4.9. 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.

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　Profile Setup and Acquisition

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

4.4.3.1　Scan Rate

The scan rate is the maximum update rate for profile acquisition and display of profiles and reported parameters. NanoScan2 operates at user selectable scan rates of 1.25Hz, 2.5Hz, 5Hz, 10Hz, and 20Hz. For each scan rate, 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 generally decreases at higher rates.

The lower scan rates of 1.25 and 2.5Hz should be used for pulsed beam operation. Refer to section 4.1.5 for an explanation of the pulsed operation and the effects of scan speed.

4.4.3.2　Spatial Sampling Resolution

The spatial sampling interval is determined by the sampling clock, the scan rate, the drum radius, and the angle of the slit with respect to the drum axis of rotation. The sampling intervals available with NanoScan2 cover a very wide range, from approximately 5.3nm at 1.25Hz to 18.3μm at 20Hz. Based on the scanhead scan rate, the available sampling interval selections are shown below in Table 4.4.

1.25 Hz	2.5 Hz	5 Hz	10 Hz	20 Hz
0.005	0.011	0.021	0.043	0.085
0.008	0.015	0.031	0.061	0.122
0.011	0.023	0.046	0.092	0.183
0.023	0.046	0.092	0.183	0.366
0.057	0.114	0.229	0.458	0.915
0.114	0.229	0.458	0.915	1.830
0.229	0.458	0.915	1.830	3.661
0.572	1.144	2.288	4.576	9.152
1.144	2.288	4.576	9.152	18.304

Table 4.4 Spatial Sampling Intervals

NanoScan2 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 scan rate and sampling interval. However, to reduce the number of data points, such as for a custom automation client, 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 measurement requirements. If so, a cosine correction can be applied to the sampling interval to compensate for the error.

4.4.3.3   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.

4.4.3.4   Filter Cutoff Frequency

Bandwidth for a given scan rate affects both the signal-to-noise ratio (SNR) 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 rates.

Figure 4.11 is an indication that the bandwidth is limited. Either increase the filter frequency or reduce the scan rate. Excessive noise in a profile indicates that the bandwidth should be reduced.

Figure 4.11 Profile Undershoot

The filter cutoff frequency control is used to adjust the bandwidth at a given scan rate and amplifier gain to optimize the signal-to-noise ratio in the acquired profile. The data acquisition system must have sufficient bandwidth to faithfully record all the signal components in the profile.

As a general rule of thumb when setting the filter frequency manually for Gaussian profiles, a bandwidth of about 190kHz is required to faithfully measure a 10μm diameter beam at 10Hz scan rate. At a 5Hz scan rate, the required bandwidth is then 100kHz, or for a 5μm diameter beam it is again 190kHz, and so on.

The algorithm for **Filter Auto Track** computes a minimum Filter bandwidth based on 10x the minimum filter required for a sinusoidal equivalent beam diameter, or 12x 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.

4.4.3.5   Region 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.

4.4.3.6   Profile Frame Averaging

Profile frame averaging provides for improvement in the signal-to-noise ratio with subsequent improvement in profile fidelity and accuracy, and the precision of derived results. Two types of Profile Averaging are available: **Frame Averaging** and **Rolling Frame Averaging**. These can also be used in combination. **Frame Averaging** takes the average of N frames before reporting a resulting profile, and **Rolling Frame Averaging** uses the average of the last reported N frames.

The specified lower boundary for the NanoScan2 Operating Space 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 to even lower power levels.

Averaging is also very effective at improving the precision if the measured Centroid position. Standard scanheads exhibit a 1σ standard deviation precision of approximately 0.2-0.4μm. Use of a rolling average of 16 profiles can reduce this to values <0.1μm. However, averaging can also distort the pointing accuracy measurement of a laser that is moving so you must use this measurement tool based on the pointing stability of the laser under test.

Averaging is also useful to stabilize measured profiles when using the NanoScan2 in Pulsed capture modes. This provides more accuracy and precision in measured results.

4.4.3.7   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 can be done through the software's **Scaling** panel.

4.4.4 Scanning Slit Obliquity Correction

Slit 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. This feature is not built into the software and must be performed externally by the user.

4.4.5 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 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 slit 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 slit material reflect MORE of the incident beam in order to avoid damage to the slits 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 a slightly tilted attenuator plate in the collimated beam path (Figure 4.12) 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.

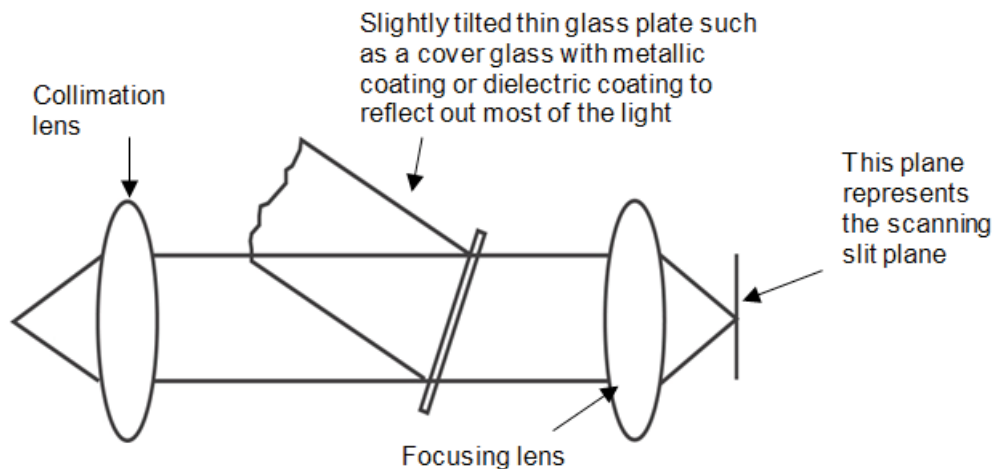**Figure 4.12 Use an attenuator in the beam path to reduce back reflection**

Bulk absorbing filters are subject to thermal lensing, see section 4.4.8.

4.4.6 Beam Divergence and Angle of Incidence

When considering the accuracy of a raw profile measurement, two factors influence and limit the range of the beam widths: beam divergence and angle of incidence. These factors relate to the detector dimension and the

dimension and thickness of the slit, 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 slit misses the detector which is 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 NanoScan2 scanheads. If the beam is incident near the edge of the aperture this angle is reduced. The angular limit is also lessened for larger beams.

A more stringent limit is due to the dimension and thickness of the slits. As the divergence or angle of incidence increases, the slit vignettes and the transmitted light is reduced. For a particular slit thickness, the vignetting decreases as the slit dimension increases, allowing for larger divergence and incident angles.

In practice, the NanoScan2 is ideally suited to the measurement of typical laser beams with low divergence in the milliradian range and 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.

4.4.6.1 Divergence/NA Measurement
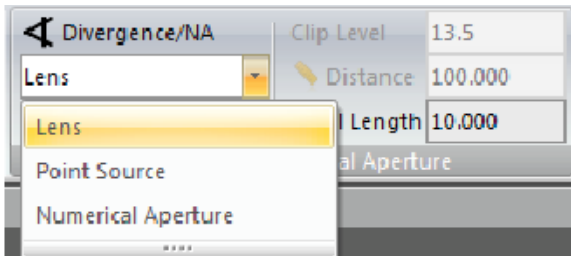
NanoScan v2 software provides two methods for determining divergence and one for Numerical Aperture (NA): the **Lens** divergence method, the **Point Source** divergence method, and the **Numerical Aperture** method. Selection and configuration of the different methods is done through the **Computations** ribbon, in the **Divergence/Numerical Aperture** panel.

4.4.6.1.1 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

$$\frac{f}{1.5D_{4\sigma}} \geq 16$$

Place the NanoScan2 slit plane coincident with the plane of the lens geometric focus. The beam divergence at the focal length is:

$$\frac{D_f}{f} = \theta$$

where:

D_f Second moment beam width at the focal length of the lens
f Lens focal length
θ Full angle divergence of the input beam

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 4.13).
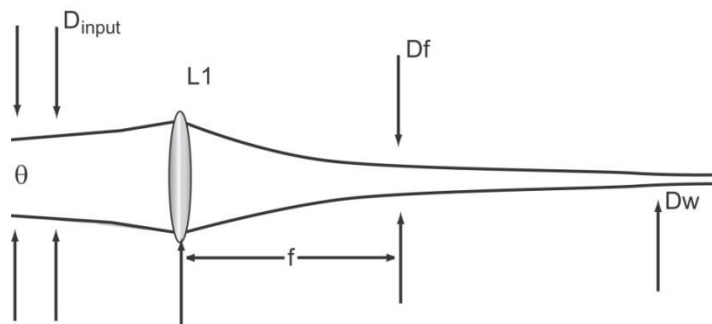
Figure 4.13 Measuring Divergence using the Lens Method

To use the **Lens** method, select **Lens** from the **Method** drop-down control. Enter the **Focal Length** of the lens (mm) in the corresponding edit box, and select the Clip Level using the **BW Basis**. The beam divergence is reported in milliradians in the **Results** window.

For lasers, divergence is typically measured using the D4σ second moment beam width method which is compatible with laser beam propagation theory.

4.4.6.1.2 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 4.14):

Figure 4.14 Measuring Divergence using the Point Source Method

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

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

where:

L	Distance from the point source
D_0	Beam width at the source
λ	Wavelength

The divergence measured in the far field is:

$$\theta = 2 \arctan\left(\frac{r}{L}\right)$$

where:

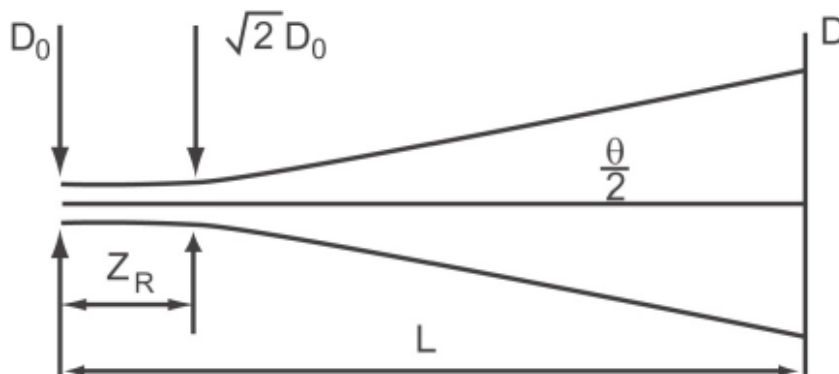|	
θ	Full angle divergence
r	Beam radius, D/2
L	Distance from source

To use the **Point Source** Method, select **Point Source** from the **Method** drop-down control. Enter the distance from the point source (in mm) in the corresponding edit box and select the Clip Level using the **BW Basis**. The beam divergence is reported in degrees in the **Results** window.

For lasers, divergence is typically measured using the D4σ second moment beam width method which is compatible with laser beam propagation theory.

4.4.6.1.3 The Numerical Aperture Method

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

$$NA = \sin\left(\frac{\theta}{2}\right)$$

To use the **Numerical Aperture** method, select **Numerical Aperture** from the **Method** dropdown control. Enter the values for **Clip Level** (%) and **Distance** (mm) from the end of the optical fiber.

NA is a dimensionless result. Fiber optic NA is typically measured with a 5% clip level based on the TIA/EIA-455-177A standard.

4.4.7 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. Room lights can cause significant stray background light. 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 an enclosure to shield out stray light is recommended.

4.4.8 Beam Attenuation

Attenuation may be required for measurements of beams with power levels exceeding the upper limit of the scanhead's operating space. When attenuation is necessary, it must be done properly. Ophir-Spiricon offers a number of beam attenuation options that can thread directly into the NanoScan2's C-mount ring. Contact your local Ophir-Spiricon sales representative for assistance in selecting the best attenuation option for each application.

4.4.9 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 exactly maps 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 $\sqrt{-\ln(p)}$
x Ratio of the slit width to the beam width (slit width/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:

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

This formula can be used without significant error (less than 1% error in F) for values of the slit width parameter x<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<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 4.15 and Figure 4.16 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 is also explained. (For distributions other than Gaussian, these

corrections may be invalid. We believe the best condition is to use a sufficiently small slit, and Ophir-Spiricon offers standard slits in 1.8µm and 5µm. Legacy products also included 25µm slit sizes.)

1. Use the graph in Figure 4.15 for all corrections if beam diameters are measured to the $1/e^2$ (13.5%) points. Use the graph in Figure 4.16 if the beam diameters are measured to the FWHM points (50%).
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.
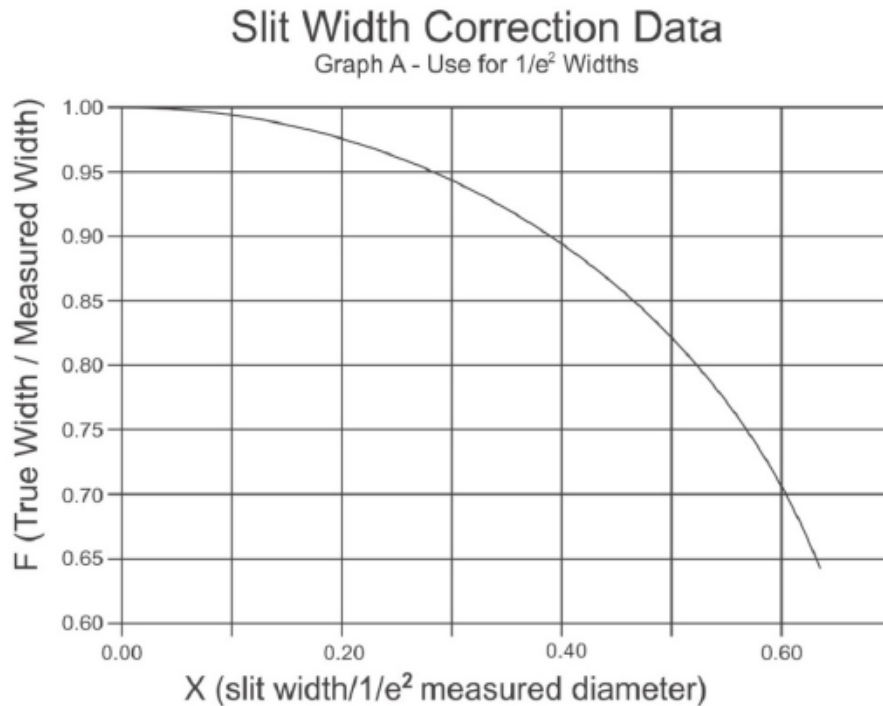

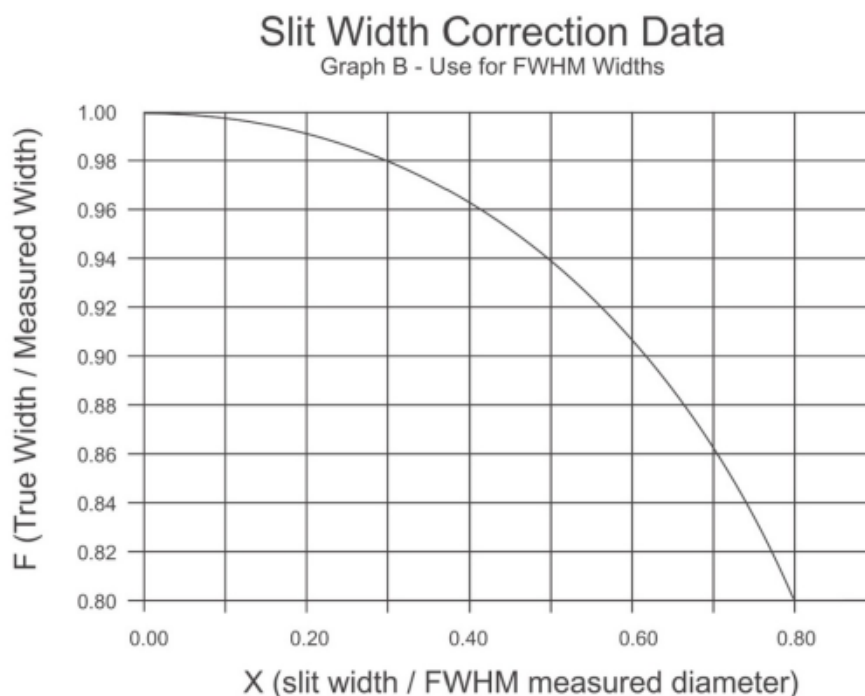**Figure 4.15 Slit Width Correction Data for $1/e^2$ Measured Widths**

Figure 4.16 Slit Width Correction Data for FWHM Measured Width

4.4.10   Near-Field Profiling

Ophir-Spiricon legacy products included several near-field profiling accessories for measurement of very small spots.

- Model NFP VIS operates at 60:1 magnification and is useful from 400-700nm.
- Model NFP 980 operates at 60:1 magnification and is useful from 700-1100nm.
- Model NFP 1550 operates at 40:1 magnification and is useful from 1300-1600nm.

To find profiling accessories that are currently available contact your Ophir-Spiricon sales representative.

Accessories for small spot measurement include the Option H/I, which is a bracket that positions a finite conjugate DIN 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's necessary to have sufficiently high quality mechanical fixtures for measurements in this domain. Everything moves around on the micron level. If you require measurements less than 10-20µm, you 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.

4.4.11 Power Measurements
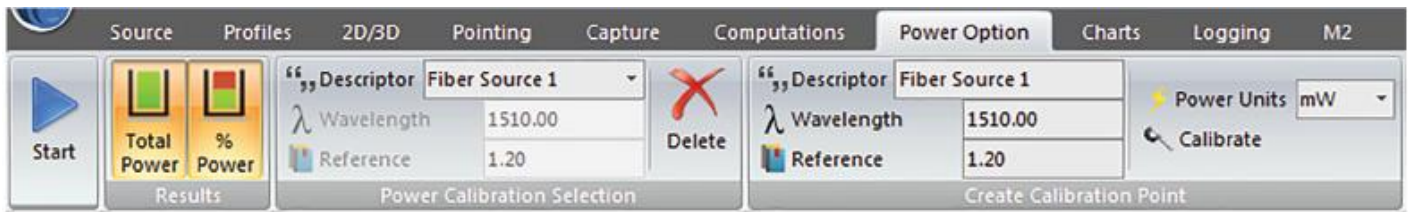
The NanoScan2 **Power** meter provides calibrated measurements of CW beam power based on a user-generated calibration stored in the scanhead's memory. See section 3.10 for detailed information on how to use this feature.

The input **Reference** value must be obtained from an independent measurement of the beam's power from a calibrated power meter. Thus the absolute accuracy of the displayed result depends partly on the accuracy of the power meter.

To achieve the most accurate and consistent results, it is advised that calibration records be generated for each source, wavelength, and measurement configuration to account for factors such as angle of incidence and beam size.

If there is any doubt about the measurement accuracy, always retest the different conditions for your application before proceeding.

4.4.12 Multiple Beam Measurement

When measuring multiple beams, the arrangement of the beams, the beam divergence, and the plane of measurement determines whether or not NanoScan2 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 NanoScan2 software to provide the beam positions in coordinates common to the linear array. When beams overlap, it is not possible to completely resolve each profile. However, it is possible to extract information such as peak separation by defining specific ROI's around each beam's peak.

Chapter 5 FAQs

The following is a list of questions that might be useful during installation and/or operation of your NanoScan2. If you do not see a question/answer that fits your situation, please view the Beam Profiler FAQ's.

http://www.ophiropt.com/laser-measurement-instruments/beam-profilers/services/faqs

Or fill out and submit the online Ask an Expert to Ophir-Spiricon Technical Support.

http://www.ophiropt.com/laser-measurement-instruments/beam-profilers/services/ask-expert

We try to resolve your problems quickly but 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 a unit for calibration or repair.

Q.1.   Can I get an electronic copy of the manual?
Yes, you already have one on your NanoScan v2 Installation CD. Look in Start, All Programs, Photon, NanoScan v2, Documentation.
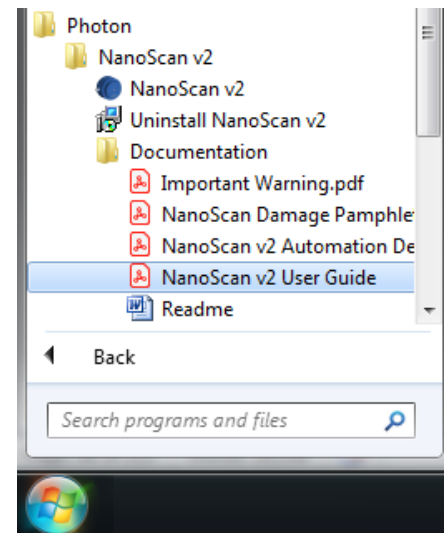
Q.2.   Are there examples of ActiveX programs anywhere?
ActiveX support documentation and examples are included in your software and can be found in the Automation Folder of the software installation. Look on your hard disk in **C:\Program Files (x86)\Photon\NanoScan v2\Automation** if operating on a 64-bit machine or **C:\Program Files\Photon\NanoScan v2\ Automation** if operating on a 32-bit machine.

Q.3.   Is there a Viewer for the NanoScan v2 data files?
No, this is not necessary. NanoScan v2 can run without a scanhead attached. You will get a warning message, but if you ignore this, the software starts and allows you to view previously acquired data files.

Q.4.   Can my NanoScan2 operate on a Mac?
No.

Q.5.   Can my NanoScan2 operate under Linux?
No.

Q.6. What is the longest cable available for NanoScan2?

USB2 cables should be used with the standard length of 2 meters. Cables beyond this length have not been tested and a USB2 repeater with separate power supply is needed.

Q.7. Where is the detector in the NanoScan2?

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 in Appendix B for more detailed information.

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

In general, the NanoScan2 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 NanoScan2?

Yes, see section 3.4.3 for a discussion of the Regions of Interest (ROIs) and multiple beam analysis.

Q.10. What does "relative power meter" mean?

The NanoScan2 power meter is a relative measurement; 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 v2 software. The NanoScan2 then measures relative to this measured value.

Q.11. Can I get a power meter option with a pyro NanoScan2?

Yes, power meter measurements are available using a pyroelectric detector with one caveat. The calibration is only valid at the same wavelength and head rotation speed at which the power was measured. See section 4.4.11.

Q.12. Why is the silicon NanoScan2 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 pyroelectric detector for these wavelengths.

Q.13. How can I increase the sensitivity of my NanoScan2?

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 4.4.3.6 for a description.

Q.14. The signal is oscillating in my NanoScan v2 display. What could be the cause?

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.

Q.15. What is the largest angle of incidence I can measure with the NanoScan2?

The NanoScan2 can measure up to 45° under most circumstances. See section 4.4.6 for a detailed discussion of divergence and angle of incidence.

Q.16. How do I measure divergence?

The NanoScan v2 software has several divergence measurement methods available. See section 4.4.6 for a detailed discussion of divergence measurement.

Q.17. How can stray light impact the NanoScan2?

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 sensed 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. Be sure to shield the scanhead from unintended light sources.

Q.18. Can NanoScan2 measure pulsed lasers?

The NanoScan2 will measure pulsed lasers, provided that the pulse rate is high enough to get a decent profile. This is discussed at length in section 4.1.5.

Q.19. Slit Damage Calculation

Damage to the slits and detector of your NanoScan2 is always a possibility with higher 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 helps determine if you are in danger of damaging the slits. If you do not have this spreadsheet, contact Ophir-Spiricon for a free copy. Remember, damage to the slits is never covered under warranty.

Q.20. Pulse Damage to NanoScan2 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 being quite low. This means that the energy delivered by the beam can cause damage, even if the average power would not or if the laser was 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 NanoScan2 if the frequency is reduced to 60kHz. The slit damage calculator (see Q.19) will indicate safe levels for both CW lasers and pulsed lasers.

Q.21. Frequency measurement with the NanoScan2

Proper measurement of pulsed lasers requires the actual pulse rate be entered into the software. This number is not always the value that is suspected based on the laser manufacturer's specification. In order to make these measurements work more smoothly the NanoScan v2 software measures the actual pulse rate. Enter this number into the software and the pulsed measurements will be more accurate.

Q.22. Why are there two types of pulsed modes with the NanoScan2?

There are two reasons that lasers are pulsed. One 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 NanoScan2 amplifiers work differently with long pulses than with short ones, therefore we use two different algorithms for these different laser types.

Q.23. How can I export data from the NanoScan v2 software?

There are several ways to export data from NanoScan v2 to spreadsheets, math and statistical analysis programs, process/instrumentation control programs, or reports, papers, and other documents. Logging to files is described in section 3.12. ActiveX communication is also available and is described at length in the Automation Developer Guide (see Q.2). Use the **Save As** option as described in section 3.3.2 for saving

*.**nsdx** or *.**txt** files. Saving a screen capture to a file is an easy way to get figures for reports, papers, or other documents.

Q.24. 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 is the EEPROM in the scanhead has been erased by a transient, power surge, electrostatic discharge (ESD), or the like. Check all connections to the scanhead and if you continue to get a Status Code (error code) -9, contact Ophir-Spiricon to get the head data and reloading utility to reprogram the EEPROM. In most cases this will resolve the problem.

Q.25. Status Code -22

This is more common with earlier software versions, prior to v1.31. If you get this message, first check to ensure that you are operating with a software version later than v1.31. If not, contact Ophir-Spiricon 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 Ophir-Spiricon for an RMA.

Appendix A   Scanhead Specifications

NanoScan2 Scanhead Model	Si/3.5/1.8μm	Si/9/5μm
Wavelength	190nm - 950nm	190nm - 950nm
Detector	Silicon	Silicon
Entrance Aperture	3.5mm	9mm
Slit Size	1.8μm	5μm
Slit Orientation	+45° and -45°	+45° and -45°
$1/e^2$ Beam Diameter Range[3]	7μm – ~2.3mm	20μm – ~6mm
Spatial Sampling Resolution	5.3nm – 18.3μm	5.3nm – 18.3μm
Profile Digitization	16-bit	16-bit
Amplifier Gain Range	1-103dB	1-103dB
Filter Frequency Range	2 – 190kHz	2 – 190kHz
Scan Rate	1.25, 2.5, 5, 10, 20Hz	1.25, 2.5, 5, 10, 20Hz
Power Aperture	Standard	Standard
Power Aperture OD	Metallized Quartz (200mW)	Metallized Quartz (200mW)
Laser Type[4]	CW or Pulsed	CW or Pulsed
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

[3] Assumes Gaussian (TEM$_{00}$) Beam
[4] Pulsed Operation Limited to Beam Diameter >>100μm and Pulse Repetition Rate ≥5kHz

NanoScan2 Scanhead Model	Ge/3.5/1.8μm	Ge/9/5μm
Wavelength	700nm - 1800nm	700nm - 1800nm
Detector	Germanium	Germanium
Entrance Aperture	3.5mm	9mm
Slit Size	1.8μm	5μm
Slit Orientation	+45° and -45°	+45° and -45°
$1/e^2$ Beam Diameter Range[5]	7μm – ~2.3mm	20μm – ~6mm
Spatial Sampling Resolution	5.3nm – 18.3μm	5.3nm – 18.3μm
Profile Digitization	16-bit	16-bit
Amplifier Gain Range	1-73dB	1-73dB
Filter Frequency Range	2 – 190kHz	2 – 190kHz
Scan Rate	1.25, 2.5, 5, 10, 20Hz	1.25, 2.5, 5, 10, 20Hz
Power Aperture	Standard	Standard
Power Aperture OD	Metallized Quartz (200mW)	Metallized Quartz (200mW)
Laser Type[6]	CW or Pulsed	CW or Pulsed
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

[5] Assumes Gaussian (TEM$_{00}$) Beam
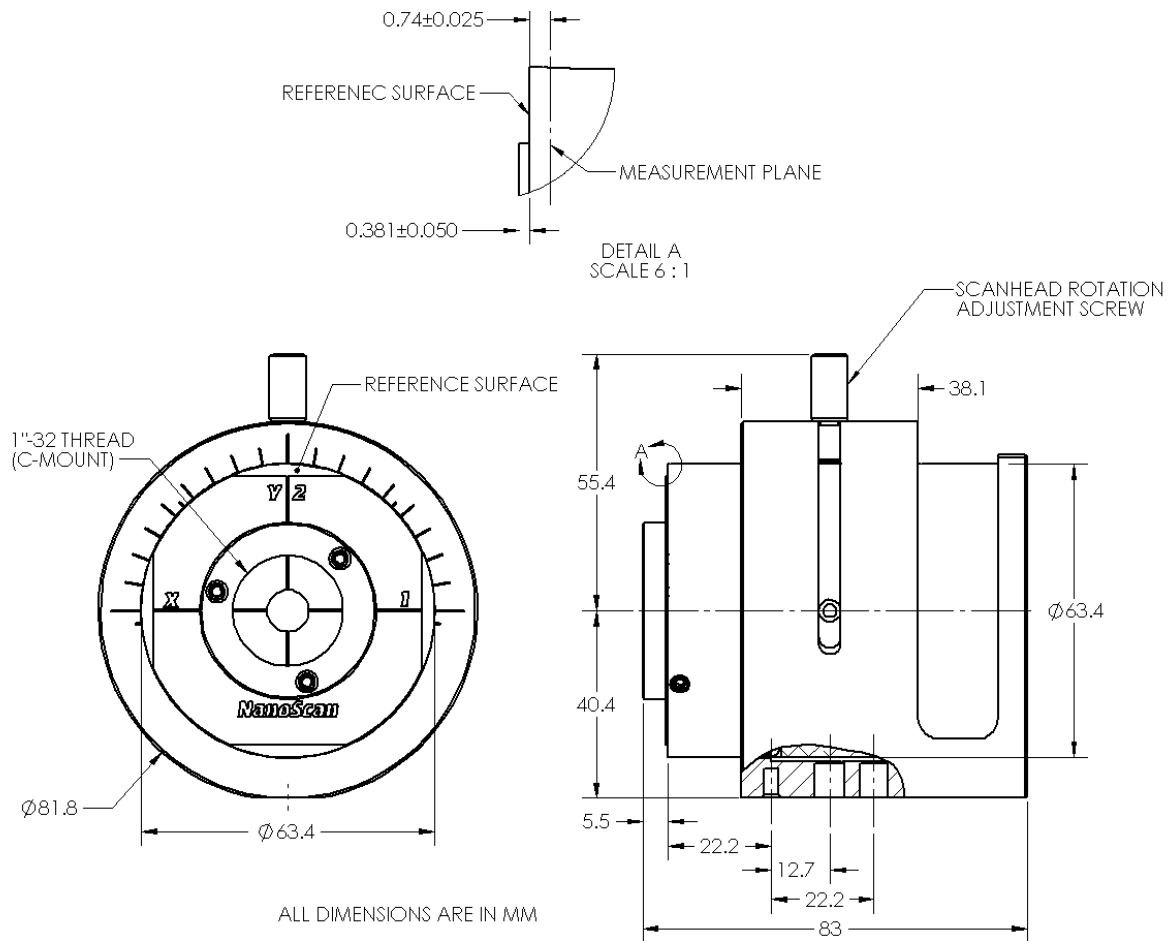[6] Pulsed Operation Limited to Beam Diameter >>100μm and Pulse Repetition Rate ≥5kHz

NanoScan2 Scanhead Model	Pyro/9/5µm	Pyro/9/5-MIR
Wavelength	200nm - 20µm	900nm-5µm
Detector	Pyroelectric	Pyroelectric
Entrance Aperture	9mm	9mm
Slit Size	5µm	5µm
Slit Orientation	+45° and -45°	+45° and -45°
1/e2 Beam Diameter Range[7]	20µm – ~6mm	20µm – ~6mm
Spatial Sampling Resolution	5.3nm – 18.3µm	5.3nm – 18.3µm
Profile Digitization	16-bit	16-bit
Amplifier Gain Range	1-85dB	1-85dB
Filter Frequency Range	2 – 190kHz	2 – 190kHz
Scan Rate	1.25, 2.5, 5, 10, 20Hz	1.25, 2.5, 5, 10, 20Hz
Power Aperture	N/A	N/A
Power Aperture OD	N/A	N/A
Laser Type[8]	CW or Pulsed	CW or Pulsed
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

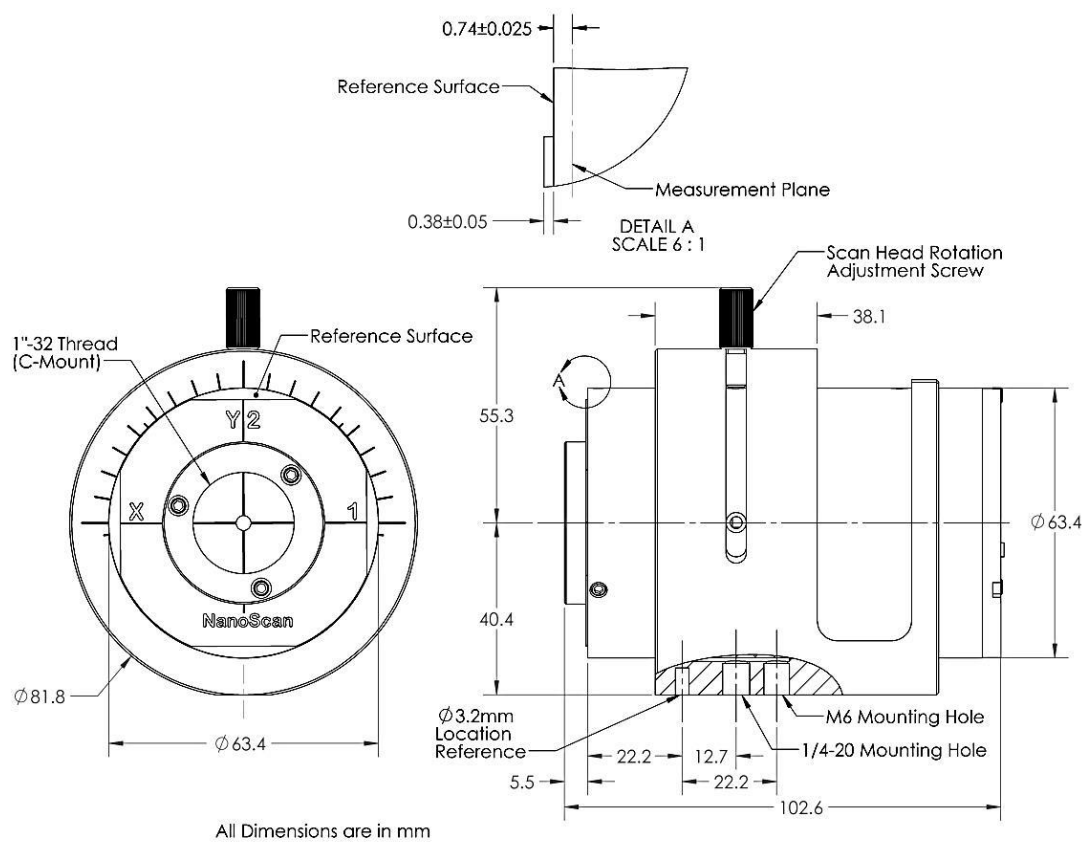[7] Assumes Gaussian (TEM$_{00}$) Beam
[8] Pulsed Operation Limited to Beam Diameter >>100µm and Pulse Repetition Rate ≥5kHz

Appendix B   Mechanical Dimensions

NanoScan 2s Mechanical Dimensions

NanoScan 2 Mechanical Dimensions

0.74±0.025

Reference Surface

Measurement Plane

0.38±0.05

DETAIL A
SCALE 6 : 1

Scan Head Rotation
Adjustment Screw

38.1

1"-32 Thread
(C-Mount)

Reference Surface

55.3

⌀63.4

40.4

⌀81.8

⌀3.2mm
Location
Reference

M6 Mounting Hole

1/4-20 Mounting Hole

22.2

12.7

⌀63.4

5.5

22.2

102.6

All Dimensions are in mm

Appendix C   Operating Space Charts

Operating Ranges are for the Peak Detector Responsivity

Operating Spaces are <u>NOT</u> absolute

THESE CHARTS TO BE USED AS A GUIDE ONLY

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

Germanium Detector: Responsivity varies with wavelength. Detects between 800-1800nm. Peak responsivity is 1.05 amps/watt at 1550nm. Detector to detector responsivity variation can be as great as ±20%.

Pyroelectric Detector: Uniform responsivity of 3.8×10^{-6} amps/watt between 0.2-20µm wavelength.

Power: Average power in the laser beam.

Beam Diameter: Assumes a round beam. The operating point for an elliptic beam can be approximated by using the average diameter. For extremely elliptic beams (ratio >4:1), contact Ophir-Spiricon.

Pulsed Operation (▬▬▬▬▬): Upper limit of the operating space for pulsed laser measurements.
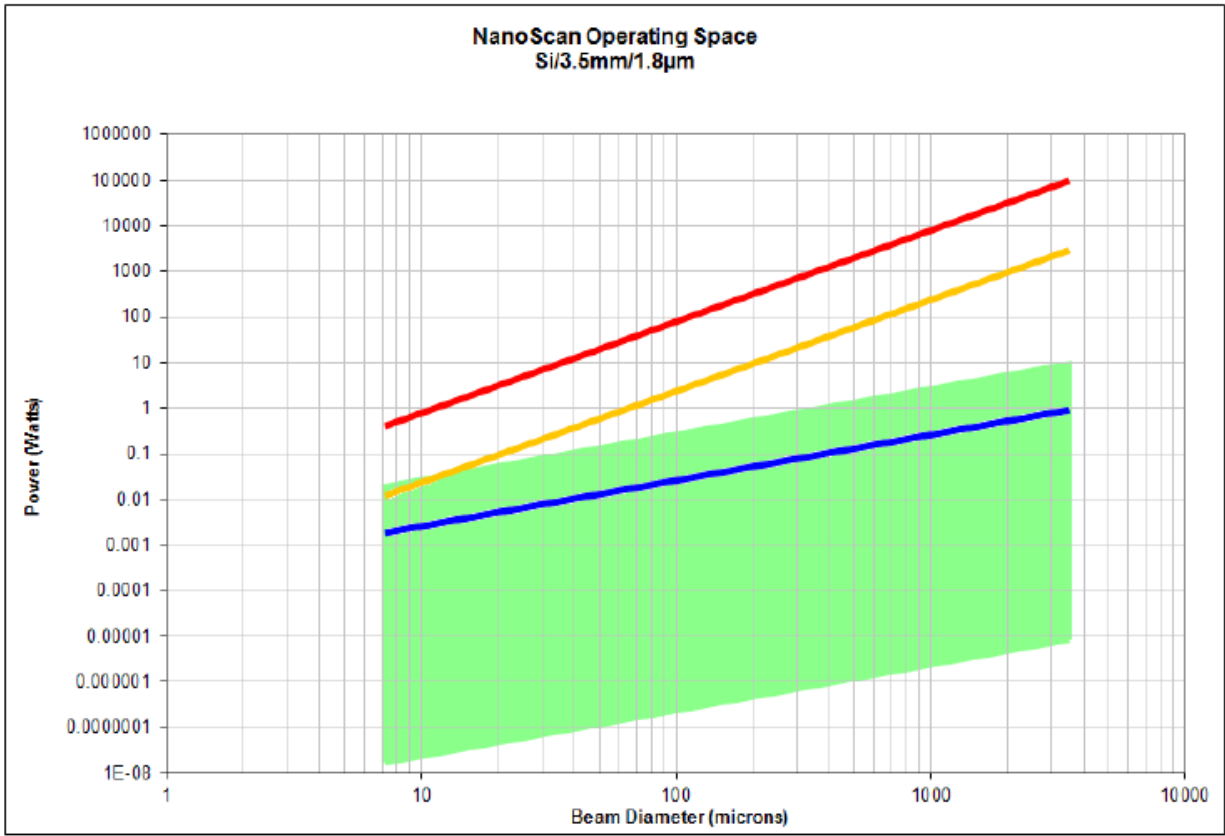
Black Coating Removed (▬▬▬▬▬): Slits are blackened to reduce back reflections; blackening begins to ablate near this line. Slits in pyro models are not blackened.

Slit Damage (▬▬▬▬▬): Power density (watts/cm^2) where one can begin to cause permanent damage and/or cut the slits. Refer to Ophir-Spiricon's *Damage Threshold with High Power Laser Measurements* document.
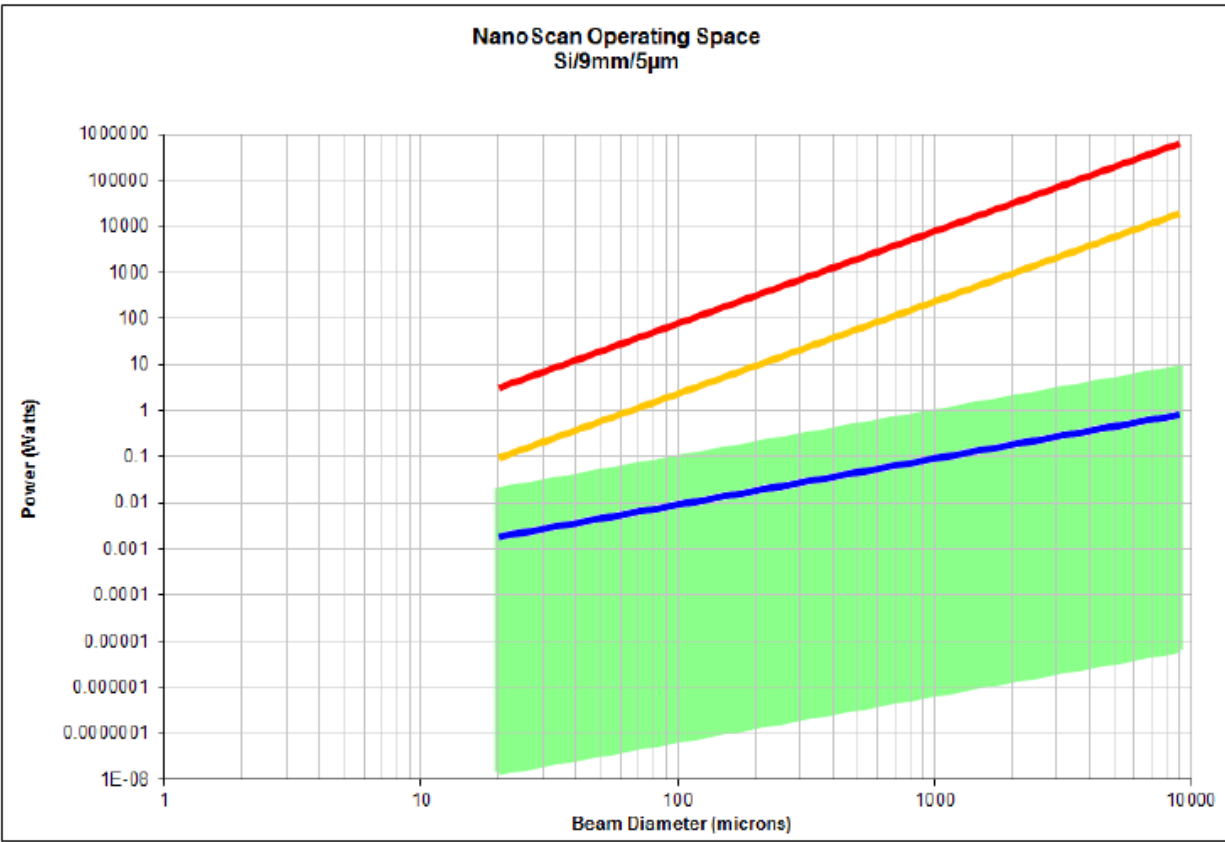
Left Boundary: The left boundary is 4 times the slit width, where slit convolution error becomes significant to the 5% level for reported $1/e^2$ diameter of a TEM$_{00}$ Gaussian beam.

Right Boundary: The right boundary is the instrument entrance aperture diameter, which determines the largest beam profile and diameter that can be measured. For a TEM$_{00}$ Gaussian beam the $1/e^2$ diameter needs to be ≤1/2 the aperture diameter to measure and see the entire profile out to the tails. Similarly for a Flat-top distribution the $1/e^2$ diameter needs to be ≤~95% of the aperture diameter. To obtain any given clip level diameter for any beam (but not the full profile) approximately 95% of the aperture is usable.
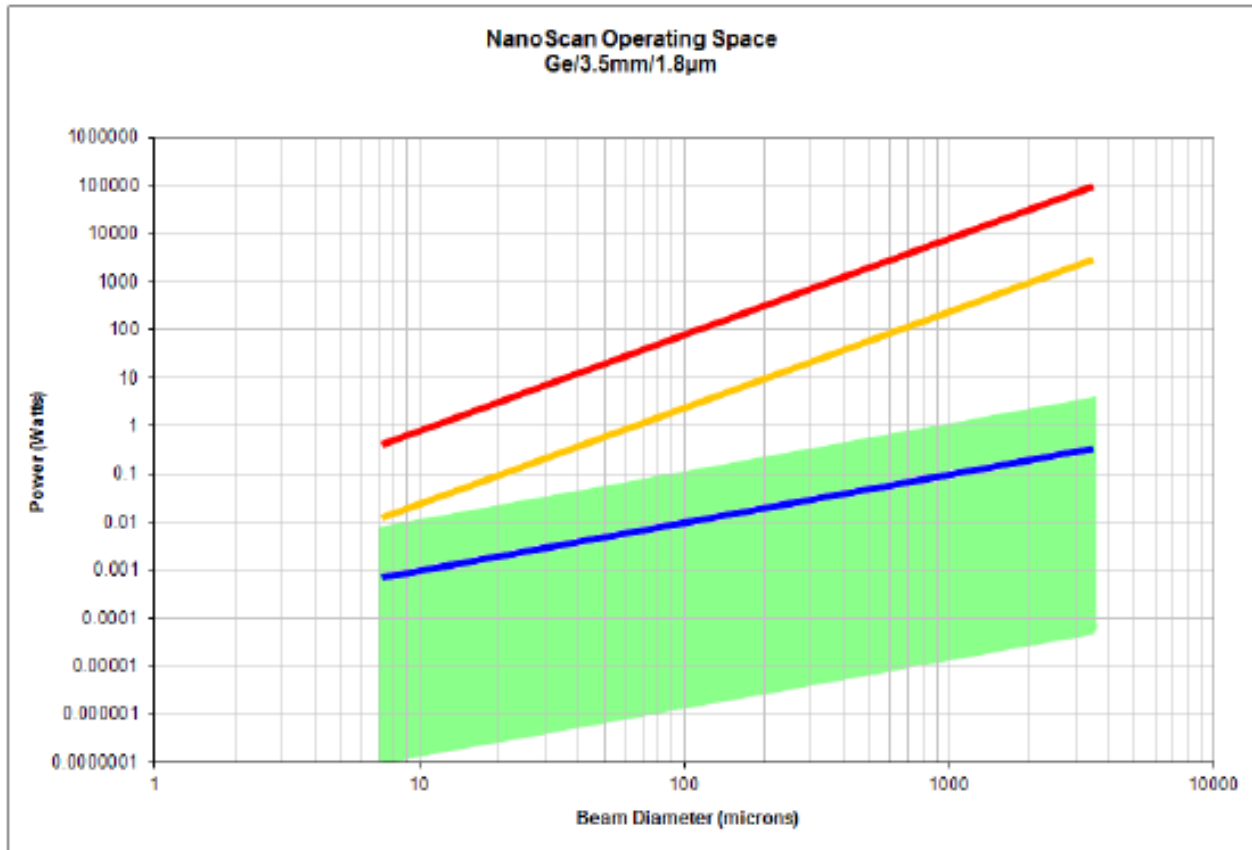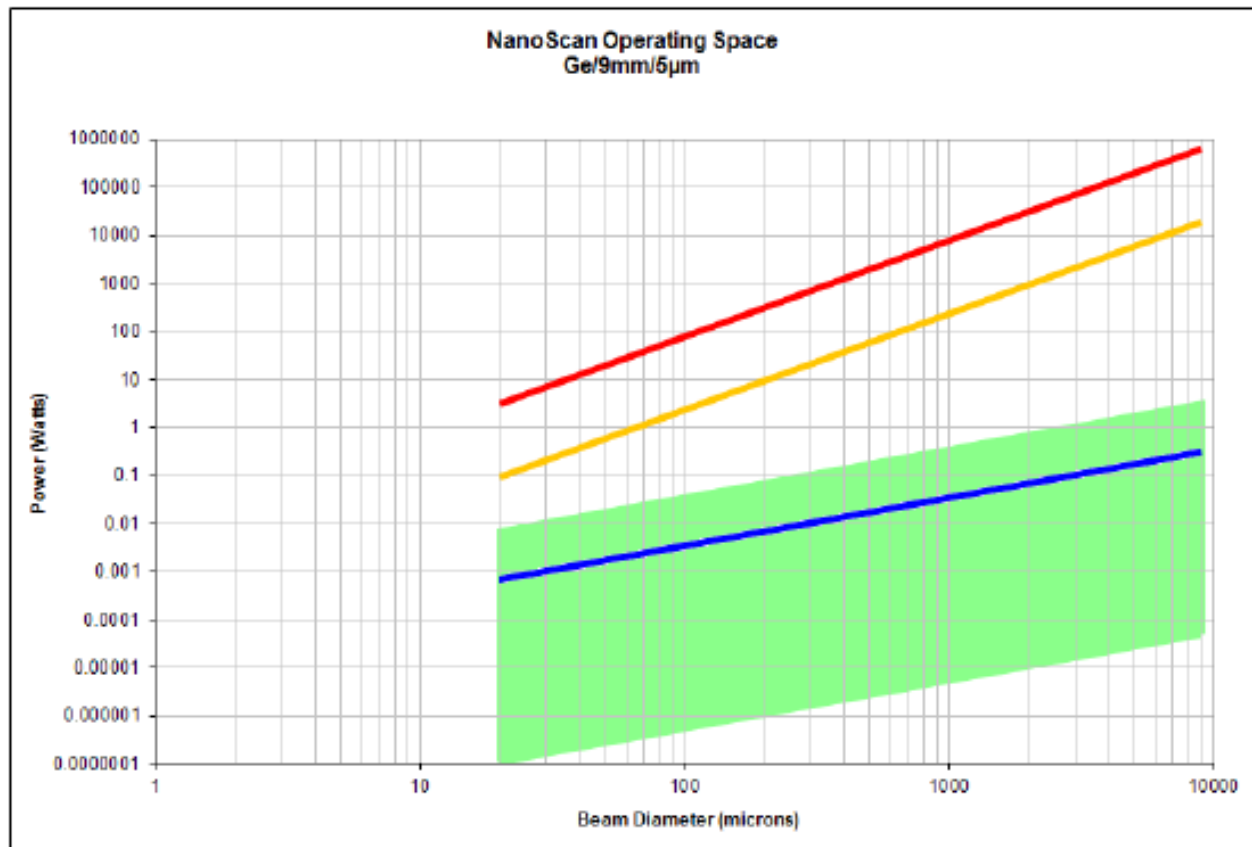
Silicon/3.5mm/1.8μm

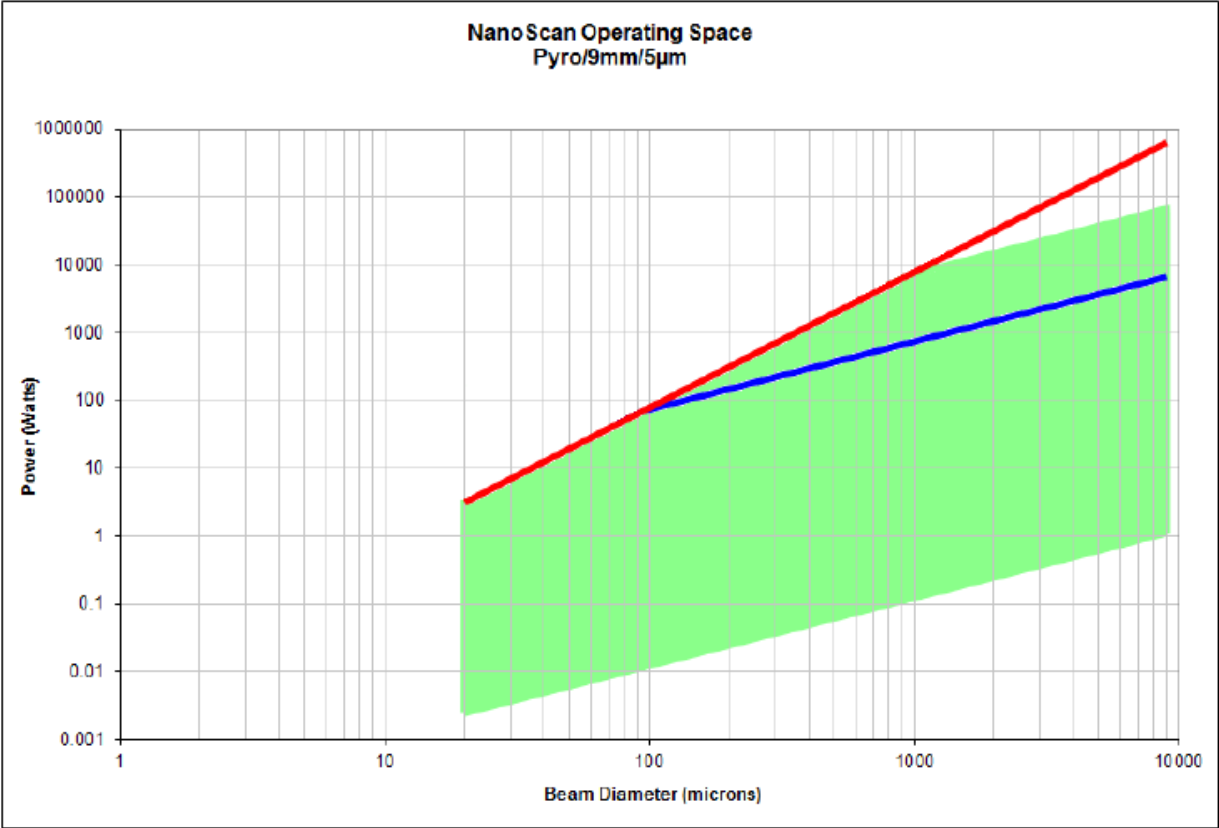**NanoScan Operating Space**
Si/3.5mm/1.8μm

Power (Watts) vs Beam Diameter (microns)

Silicon/9mm/5μm

NanoScan Operating Space
Si/9mm/5μm

Power (Watts) vs Beam Diameter (microns)

Germanium/3.5mm/1.8μm

Germanium/9mm/5μm

Pyroelectric/9mm/5µm

NanoScan Operating Space
Pyro/9mm/5µm

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