

BeamScope
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BeamScopeTM-P5

Scanning Slit Beam Profiler

User Manual



Very IMPORTANT

This information is here so that you cannot miss it.

If you received the ISA card version but cannot use the ISA card version, you may return the unit for a full refund. The PCI card version will be available in early Q4 2001.

If you decide to keep and use the ISA card version, and you purchased the unit on or after January 1st 2001, you may upgrade to the PCI card version for \$500 (US List Price) as soon as it becomes available.

Using an older BeamScope-P3? Contact us for a P5 upgrade deal at 50% off.

- Do not 'hot' plug or unplug the head while the software is on. You may damage the unit.
- Do not accidentally plug the monitor cable into the DataRay PC card.
- To avoid slit damage, observe the maximum irradiance limits, section 1.8.2.
- If the software appears to be giving errors, load the defaults by holding down the Shift key when you start the software.
- The beam should be centered on the instrument for the most accurate measurements.
- If you get a result or inconsistency that you do not understand, *before you call*, proceed as follows:

Via the Pull-down menu go:

File, Save ... to save the single profile set or to save a sequence of data, particularly if you are seeing instability.

The saved file (*.dat format) includes some setup data for your instrument. DataRay technical support can then view the data as you see it.

Email the result to **support@dataray.com** with your commentary. Then call.

- If User Manual authors had their way ...* "If you read this manual first, you are entitled to free product support by phone, fax or email. For those who decide not to bother to read this manual before calling for support, a 1-900 Help line charged at a 'per minute' rate is available." ...

... seriously though, read this manual to enjoy the full benefit of your investment.

BeamScope™-P5

Scanning Slit Beam Profiler

User Manual

Serial Number: _____
Purchased by: _____
Date: _____

Rev. 0108A

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Table of Contents

Table
of
Contents

1	INTRODUCTION.....	1-1
1.1	WELCOME	1-1
1.2	FUNCTIONAL DESCRIPTION.....	1-3
1.3	MANUAL CONVENTIONS	1-4
1.4	MANUAL AND COPYRIGHT NOTICE	1-4
1.5	PRODUCT SPECIFICATIONS	1-5
1.5.1	<i>Computer Requirements.....</i>	<i>1-12</i>
2	INSTALLING BEAMSCOPE-P5	2-1
2.1	UNPACK THE BEAMSCOPE HARDWARE.....	2-1
2.2	PC CARD INSTALLATION	2-3
2.3	SOFTWARE INSTALLATION	2-4
2.3.1	<i>Installation under Windows 95 or 98.....</i>	<i>2-4</i>
2.3.2	<i>Installation under Windows NT.....</i>	<i>2-6</i>
2.4	FIELDPACK INSTALLATION.....	2-8
2.5	MOUNTING & STARTING BEAMSCOPE.....	2-13
3	QUICK-START TUTORIALS	3-1
3.1	SOFTWARE ONLY QUICK-START TUTORIAL.....	3-1
3.1.1	<i>Start the Software.....</i>	<i>3-2</i>
3.1.2	<i>Examine previously saved Data.....</i>	<i>3-3</i>
3.1.3	<i>Beam Centroid.....</i>	<i>3-4</i>
3.1.4	<i>Beam Wander and Absolute position.....</i>	<i>3-5</i>
3.1.5	<i>Change the Beam Diameter Definition.....</i>	<i>3-5</i>
3.1.6	<i>Pass/Fail Indication for QA & Production Testing</i>	<i>3-6</i>
3.1.7	<i>'Included Power' and Distance Measurements on the Profile</i>	<i>3-7</i>
3.1.8	<i>Additional Profile Views.....</i>	<i>3-7</i>
3.1.9	<i>2-D and 3-D Views.....</i>	<i>3-7</i>
3.1.10	<i>Print the Results</i>	<i>3-8</i>
3.1.11	<i>Other Great Features</i>	<i>3-8</i>
3.1.12	<i>Short Cuts.....</i>	<i>3-9</i>
3.2	HARDWARE QUICK-START TUTORIAL.....	3-10
3.2.1	<i>Setting Up</i>	<i>3-10</i>
3.2.2	<i>Head Setup and Options.....</i>	<i>3-11</i>
3.2.3	<i>Search for the Beam.....</i>	<i>3-12</i>
3.2.4	<i>Practice with the Software.....</i>	<i>3-13</i>
3.2.5	<i>Log the Data.....</i>	<i>3-13</i>
3.2.6	<i>Short Cuts.....</i>	<i>3-15</i>

4	BEAMSCOPE FUNCTIONS	4-1
4.1	THE MAIN SCREEN.....	4-2
4.1.1	<i>Pull-Down Menus</i>	4-3
4.1.2	<i>The Button Bar</i>	4-6
4.2	MAIN SCREEN SECTIONS.....	4-8
4.2.1	<i>Pass/Fail for QA and Production Testing</i>	4-8
4.2.2	<i>Button Colors Setup</i>	4-9
4.2.3	<i>'Button' Areas and Help Hints</i>	4-9
4.2.4	<i>Ellipticity Button</i>	4-10
4.2.5	<i>Centroid Button</i>	4-10
4.2.6	<i>Beam Wander Button</i>	4-10
4.2.7	<i>Gain and Power Button</i>	4-11
4.2.8	<i>Gaussian Fit Button</i>	4-12
4.2.9	<i>Head Status</i>	4-12
4.2.10	<i>2D View button</i>	4-13
4.2.11	<i>3D View Button</i>	4-13
4.2.12	<i>Beam Widths Buttons</i>	4-14
4.2.13	<i>Beam Profiles Area</i>	4-15
4.2.14	<i>Search</i>	4-17
4.3	PULL-DOWN MENUS - ADDITIONAL DETAILS.....	4-18
4.3.1	<i>Options Menu</i>	4-18
4.3.2	<i>Log Menu</i>	4-21
4.3.3	<i>Setup</i>	4-22
4.4	SLIT MODE.....	4-27
4.5	KNIFE-EDGE MODE	4-288
4.6	GAUSSIAN FIT ALGORITHM.....	4-299
4.6.1	<i>Gaussian Fit Algorithm</i>	4-299
5	USING THE M² ACCESSORY.....	5-1
5.1	NEW M ² ACCESSORY USER?	5-2
5.2	M2 HARDWARE SETUP	5-4
5.3	OPERATION	5-6
5.4	SAVING & PRINTING THE RESULTS.....	5-7
5.5	INTERPRETING THE RESULTS.....	5-7
6	2D SCANNING STAGE	6-1
6.1	INITIAL SETUP	6-1
6.2	OPERATION	6-2
6.3	FREQUENTLY ASKED QUESTIONS.	6-3

APPENDICES

Appendix A: BeamScope-P5 function Request Form

Appendix B: M-Squared and its Measurement

Appendix C: Technical Support, Returns, Distributors & Representatives

Appendix D: BeamScope-P5 Data Structures

INDEX

CHAPTER ONE

1 INTRODUCTION

1.1

1.1	WELCOME	1-1
1.2	FUNCTIONAL DESCRIPTION.....	1-3
1.3	MANUAL CONVENTIONS	1-4
1.4	MANUAL AND COPYRIGHT NOTICE	1-4
1.5	PRODUCT SPECIFICATIONS	1-5
1.5.1	Computer Requirements.....	1-12

1.1 WELCOME

Welcome to the BeamScope-P5. This P5 version of the BeamScope product family was first introduced in December 1998, continuously improved since then, and defines state-of-the-art large beam profiling in accordance with the ISO 11146 standard.

- ❑ The 2-phase stepping motor in the original P3 version has been replaced by a 5-phase motor with enhanced micro-stepping to give a scan speed which is three times faster, smoother and more accurate.
- ❑ The kevlar drive band has been replaced by a tensioned stainless steel band to ensure longer life and higher accuracy.
- ❑ A PIN photodiode has increased the linear dynamic range.
- ❑ Improved circuit grounding and other amplifier improvements have reduced the noise floor. Relocation of the analog-to-digital converter has further reduced noise.
- ❑ Improved four screw slit mounting avoids warping and simplifies aperture assembly replacement.
- ❑ New True2D™ sapphire substrate slits, with multi-metal opaque areas only 0.4 μm thick improve the profiling of small and highly divergent beams.

The P5 software combines easy-to-use intuitive logic and proven beam profiling algorithms. The P5 version is completely new. Users of previous versions will not see many similarities. However with a little time and patience, we think you will be pleasantly surprised with how easy to use we have made it.

BeamScope is designed to be used as a manufacturing tool that can be easily customized to your application. 'Job' files can be linked to the BeamScope Icon allowing different configurations to be easily launched by clicking on the appropriate BeamScope Job icon.

Introduction

At any time, you may download the latest version of the software and/or this manual from our website at www.dataray.com. Visit the site in order to determine whether an update is available and the revision number of the current version.

DataRay is committed to providing the ultimate in beam profiling performance, and welcomes constructive criticism on its products and on this manual. Contact us at the addresses or numbers shown on the title page of this manual.

If you need a function that is not included in the current version of BeamScope-P5, please fill out and fax a Function Request form found in Appendix A of this manual, or email support@dataray.com. Many requested functions can be added with relative ease, and *may* be done for free, and possibly added to future releases. However, if the requested embellishment is considered extensive and/or obscure, DataRay reserves the right to quote and charge for the requested change.

Warranty. Standard product warranty is three years from the date of shipment; this warranty excludes customer damage to the unit.

Calibration. Recalibration services are available. Please contact DataRay or your local Distributor.

1.2 FUNCTIONAL DESCRIPTION

BeamScope-P5 implements slit profiling in accordance with the ISO 11146 standard by using a linear slit scan probe to sample the beam. The following is a brief description of the working principle.

- ❑ The BeamScope scans a slit, slit pair or pinhole in a plane orthogonal to the beam axis. The energy transmitted by the aperture(s) falls upon a silicon detector and is measured as a function of lateral slit position. (Germanium and Indium Arsenide detectors are employed for the longer wavelengths.) In Slit Mode, the normal mode of operation, the slit is much smaller than the beam diameter. In Knife-Edge Mode the slit must be wider than the beam diameter.
- ❑ The pinhole, single slit, or XY slit pair, sits in a fixed position in front of the detector. All the energy, whether passing through one slit/pinhole or two slits, falls upon a single detector or upon two detectors connected in parallel.
- ❑ The slit plus detector is carried on a rectangular moving carriage which rides on precision linear bearings in a plane set orthogonal to the beam axis.
- ❑ The carriage is driven by a taut stainless steel band. The center section of the band wraps round and is locked to a capstan on the shaft of a 5-phase stepper motor. (Similar drive principles are employed in some disk drive heads.)
- ❑ The stepper motor is driven in micro-stepping mode at 51,200 steps per revolution resulting in sub-micron linear steps of the moving carriage. The minimum scanned range is 120 μm .
- ❑ The probe is driven to scan region(s) defined by the search routine. The search routine actively centers the scanned region about the centroid of the beam profile(s) and automatically adjusts the width(s) of the scanned region(s).
- ❑ For each scanned profile, the amplified detector output amplitude is digitized in 2048 levels using a 12-bit ADC (Analog to Digital Converter), at 2048 intervals spaced equally across the scanned region.
- ❑ The software processes the digitized profile to give the data required for display and data logging, and feeds back some information to the automatic search routine above.
- ❑ The user configures screen functions to implement the measurements in the desired manner.

1.2

1.3 MANUAL CONVENTIONS

In this manual:

- ❑ 'click' always means 'left-click the mouse button'.
- ❑ 'double-click' always means 'double-click with the left button'.
- ❑ 'click and drag' means 'left-click on the object indicated, hold down the button, drag the object across the screen to the desired position, and then release the button'.
- ❑ If a right-click is required this is clearly indicated as 'right-click'.
- ❑ 'select' or 'check' means 'left-click with the mouse button'.
- ❑ 'press' always means 'press the keyboard key'
- ❑ 'enter' means enter using the keyboard.

e.g. Enter **Alt F, S** means press the **F** key while holding down the **Alt** key, then release the **Alt** key and press the key marked **S**. Sometimes it is also necessary to finish with the **Enter** key in order to complete the process.

1.4 MANUAL AND COPYRIGHT NOTICE

This manual describes the operation of the BeamScope-P5 Scanning Slit Beam Profiler.

DataRay Inc. reserves the right to make changes to this manual and to the equipment described herein without notice. DataRay has made considerable efforts to ensure that the information in this manual is accurate and complete. However, DataRay will not be liable for any technical or editorial errors or omissions made herein or for any incidental, special, or consequential damages of any nature resulting from the furnishing of this manual, or for the operation and performance of equipment in connection with this manual.

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BeamScope, Beam'R, BeamMap ColliMate and WinCam are trade marks of DataRay Inc.

Windows 95, 98, NT and 2000 are trademarks of Microsoft Corporation. Pentium is a trademark of Intel Corporation.

1.5 PRODUCT SPECIFICATIONS

N.B. All product specifications are subject to change without notice.

Measurable Sources

CW

Pulsed sources: >few kHz PRR (Pulse Repetition Rate) (Higher PRR is better). Low PRR lasers require a high duty factor, 10% or higher.

Wavelength Range

Silicon Detector

190 to 1150 nm

Germanium Detector

800 to 1800 nm

Indium Arsenide Detector

1.5 μm to 3.5 μm

II-VI detectors

>3.5 μm , [To special order, call for delivery]

Measured Beam Powers

See the graph in the Notes, below.

E.g. 2 μW to 0.7 W, for a 1 mm diameter ($1/e^2$) Gaussian beam @ 633 nm, 5 μm slit.

Optical Dynamic Range


55 dB (= 300,000:1) [75 dB with Neutral Density 2.0 film (3.5" diskette cut-out) after slit]

Shape of Maximum Scanned Area

Important: For accurate measurements, beamwidth should be < 0.5 x Scan Dimensions. For the extended probe head, dimension 23 mm below, becomes 35 mm.

Pinholes (PA series) 

Shape Cross Scan x Scanned Length
Line Scan Pinhole diameter x 23 mm

Single Slits (SS series) 

Rectangle 7* x 23 mm, (* 5 for Ge, 3 for InAs, 1 for II-VI)

X-Y Slits (XY series) 

Trapezoid 5* x 15/5 mm, (* 3 for Ge, 2 for InAs; 0.7 for II-VI; 3.5 x 13.5/6.5 for 5 μm planar slits)

2-D Stage (M2B) 

Rectangle 45 x 23 mm scanned area image. Scans a pinhole over this area.

Measured Beam Diameters/Widths

1 μm to ~15 mm (single slits & pinholes) (Defined as the $1/e^2$ diameter, = 13.5% of peak for Gaussian beams)

Measurement Resolution

<0.1 μm , or 0.1% of the measured beam diameter, whichever is greater

Measurement Accuracy

$\pm 1 \mu\text{m} \pm 1\%$ of measured beam diameter

Measured Beam Profiles

X & Y

Linear & logarithmic profile display modes

Measured Profile Parameters

Gaussian beam diameter

Gaussian fit

Second Moment beam diameter

Knife-Edge beam diameter


Centroid position, relative and absolute

Ellipticity + Orientation of Major Axis

Beam Wander display

1.5

Introduction

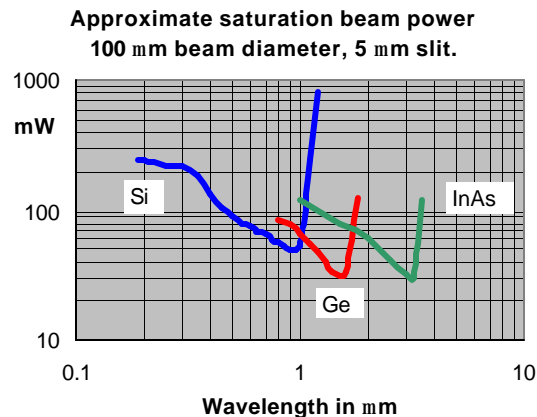
Displayed Profiles (Note 1)	X only, Y only, X & Y 2-D plot (10,16 or 256 colors) 3-D plot (10,16 or 256 colors)
Update Rate	>1 Hz typical, 2 Hz max. Depends upon the PC processor Speed, the Scanned Profile & the Selected Options
Data Analysis	
Pass/Fail	On all measured parameters, on-screen, in Pass/Fail colors
Averaging	Beam Diameter Running Average and Accumulation Average options
Standard Deviation	On Accumulation Averaging Screen
Power Measurement	Units of mW (relative to a reference measurement provided by the user.) Not a calibrated power meter.
Source to Slit Distance	1.0 mm minimum
Aperture sizes (Note 2)	<i>Important: See Scanned Area (above) for measurable beam dimensions</i>
True2D™ Slits	2.5, 5, 10, 25 and 100 µm wide 7 mm long (Planar version of 5 µm slits are 5 mm long)
Pinholes	5, 10, 25 and 50 µm diameter (Smaller or larger to special order)
Dimensions	
Probe Style Head	Across axis width x Height x Along axis depth 115 x 51 x 62 mm (4.5 x 2.0 x 2.5 inches) [Probe fully extended width: 140 mm (5.9")]
Rotatable Head	94 (Diam.) x 84 mm (3.7 x 3.3 inches)
Dual slit separation	Dual slit center-to-center separation 10 mm Bottom end separation 5 mm for 7mm long slits.
	
Mounting	¼"-20 & M6 threaded mounting holes
Weight: Probe Style Head	540 gm (1.2 lb)
Rotatable Head	700 gm (1.6 lb)
Temp. Range (including Accessories)	10° to 35° C
Operating	5° to 45° C
Storage	
Minimum PC Requirements (Mac version is <i>not</i> available)	66 MHz PC-486 (100 MHz or better Pentium preferred) running Windows 3.1x, 95, 98 or NT; 4 MB RAM; ISA Slot; (PCI card coming Q4 2000) 10 MB Hard Drive space; SVGA (600 x 800) monitor.

Notes:

- ❑ The 2-D and 3-D profiles are 'reconstructed' from the X-Y scan, making the assumption that the measured X beam profile is the same for all values of Y, and that the measured Y beam profile is the same for all values of X.
- ❑ In Slit (or Pinhole) mode, the slit/pinhole width should be $\leq 1/3^{\text{rd}}$ of the diameter of the beam under measurement. For X-Y slit pairs inclined at $\pm 45^\circ$, the ratio is approximately $1/5^{\text{th}}$. E.g., for any beam below 20 μm diameter, use the 2.5 μm slits wherever possible.
- ❑ In Knife-Edge mode, the slit width should be $\geq 3x$ the beam diameter. For X-Y slit pairs inclined at $\pm 45^\circ$, the ratio is ≥ 4.3 times the beam diameter.

The graph allows you to simply determine the *approximate* maximum CW optical power that BeamScope can measure without additional attenuation. The limit is a detector current limit.

The graph shows the approximate saturation beam power in mW versus wavelength for a 100 μm diameter beam ($1/e^2$) & a 5 μm slit.



- 1) Determine the plotted value, P_S mW, for your wavelength. (e.g. 70 mw at 633 nm)
- 2) For a different slit or beam, multiply P_S by: $0.05 \cdot (\text{beam diam.}, \mu\text{m}) / (\text{slit width}, \mu\text{m})$
- 3) For a pinhole multiply P_S by: $0.05 \times (\text{beam diam.}, \mu\text{m})^2 / (\text{pinhole diam.}, \mu\text{m})^2$
- 4) *The total incident power must never exceed 2.0 W.*

The *minimum* detectable signal at useful SNR is *lower* by:

~55 dB (optical) for the Silicon detector

~50 dB for Ge

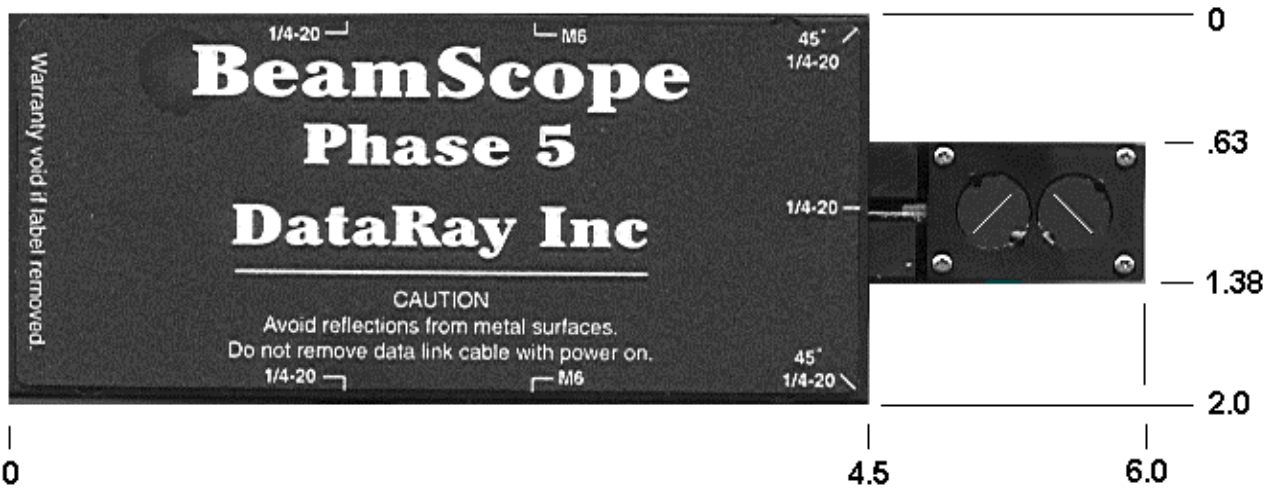
~25 dB for InAs.

For **Pulsed Beams**, use the peak power in the pulse as your starting point in the calculations. The actual saturation power *may* be higher than this, but this is pulsedwidth & PRR dependent.

For higher power densities insert neutral density film* up to ND 2.0 behind the slit.

* A typical 3.5" floppy diskette is ND 2.0 at 630 nm.

Introduction

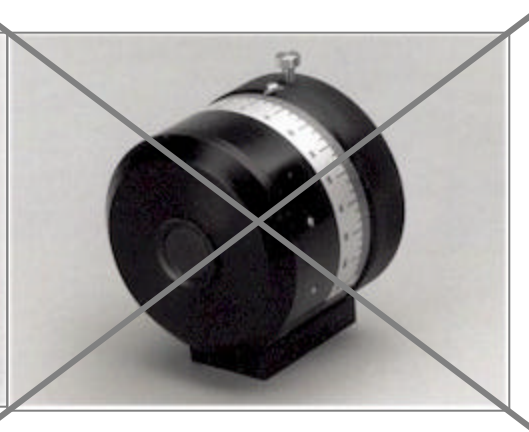


In most laser assemblies elliptical beams have a major axis at 0°, 45° or 90° to the horizontal and the Rectangular Head BeamScope may be mounted at any of these angles.

The Rotatable head larger than the standard head but is useful when the BeamScope must be aligned with an elliptical beam of unknown orientation. **Discontinued January 2001.**

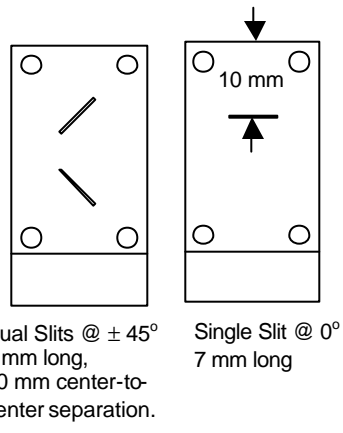
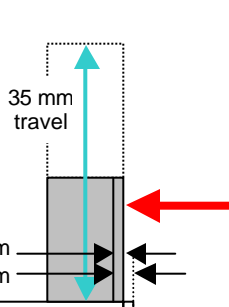
Rectangular Head

Rotatable Head

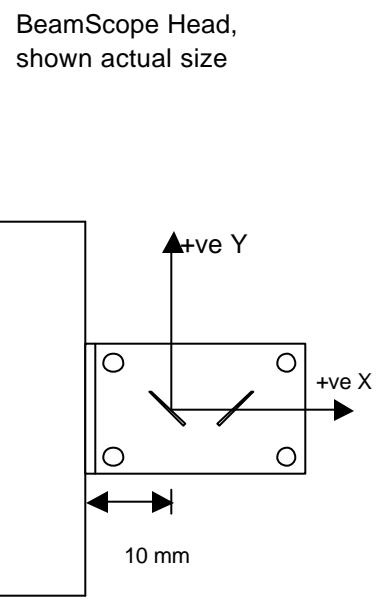
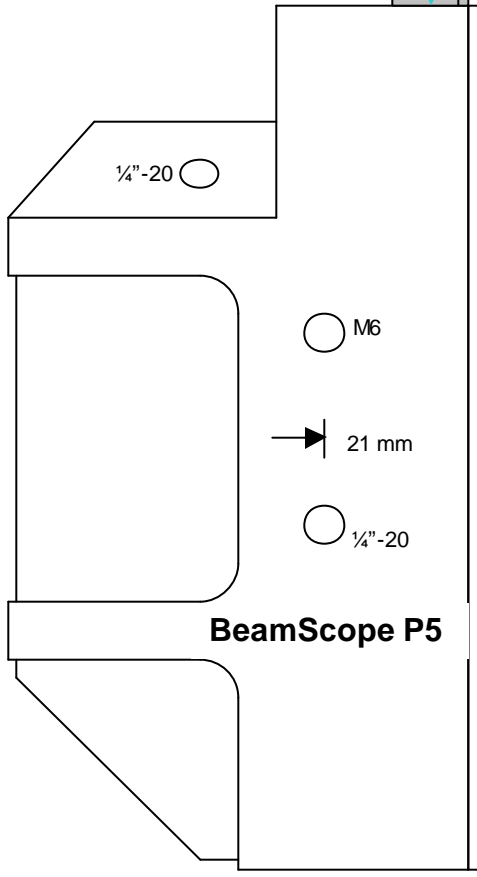


For the 'EPH' version (Extended Probe Head), the probe sticks out an additional 30 mm. It still travels 35 mm.

Probe face to slit plane: 0.75 mm
Head face to slit plane: 2.75 mm



1.5

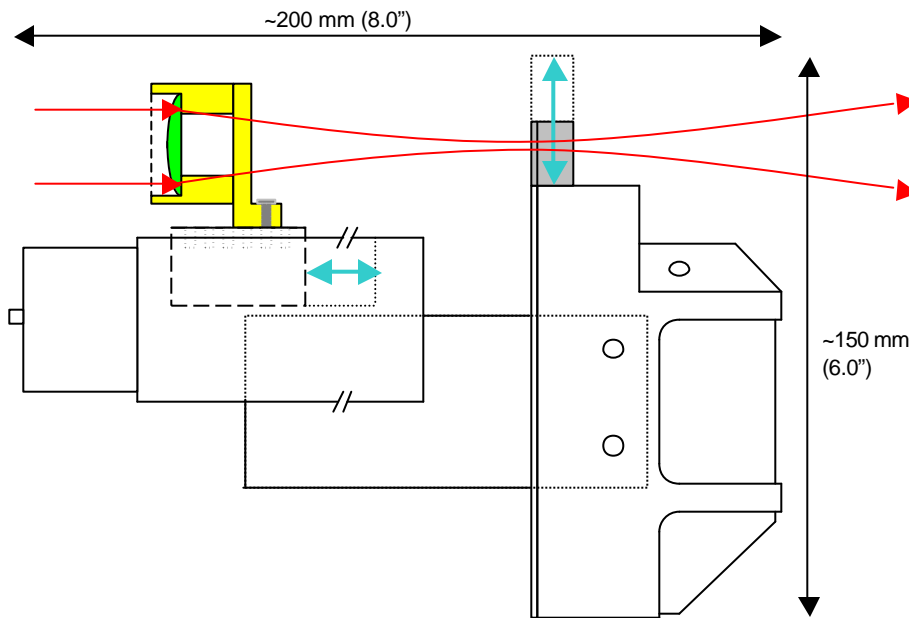


M² Accessory/2-D Stage Specifications

Lens (Detached for 2-D Stage operation)	Coated Achromat, $\lambda/4$ @ 550 nm Focal Length 85 mm (± 1.5 mm or ± 2 %) Clear Aperture 17.5 mm
Stage Travel/Step Size	M2B & 2DSS 45 mm / 3.5 μ m M2C & 2DSSC 45 mm / 2.5 μ m
Dimensions	Across axis width x Height x Along axis depth
M ² Accessory/2-D Stage	71 x 87 x 140 mm (2.8 x 3.5 x 5.6 inches)
M ² Accessory Plate	50.4 x 6.3 x 127 mm (2.0 x 0.25 x 5.0 inches)
M ² Base Plate	152 x 25.4 x 305 mm (6.0 x 1.0 x 12.0 inches)
Weight M ² Accessory	680 gm (1.5 lb)

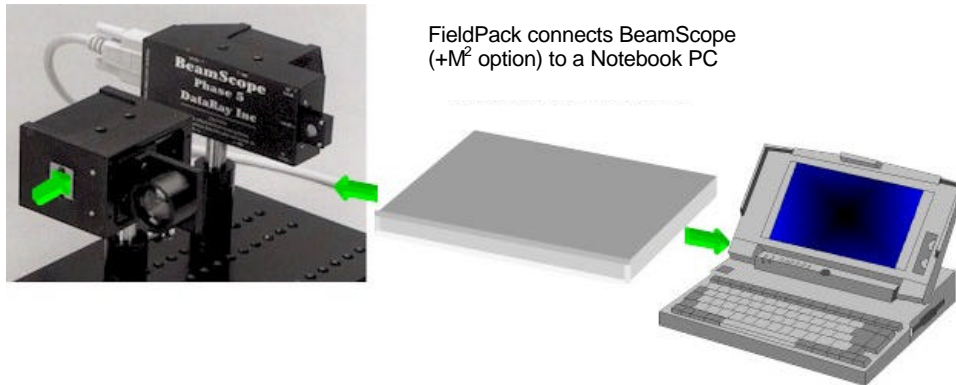
FieldPack Specifications

Dimensions (excluding connectors)	Length x Width x Height 257 x 195 x 25 mm (10.1 x 7.7 x 1.0 inches)
Weight	1090 gm (2.4 lb)



1.5

M² accessory mounted to BeamScope Head with M2-AAP plate.



Schematic FieldPack Function

1.5.1 Computer Requirements

- ❑ *BeamScope-P5 is not available in a Mac-compatible software version.*
- ❑ 66 MHz '486 minimum, 100 MHz Pentium or faster preferred.
- ❑ Open ISA half-slot. (PCI slot version coming Q4 2000)
- ❑ SVGA or better video system:
 - 800 x 600 with 256 colors or better
 - Will work on 640 x 480, but NOT recommended.
- ❑ A Microsoft compatible mouse.
- ❑ Windows 3.1x, Windows 95, 98, NT, 2000.
- ❑ 4 MB RAM
- ❑ A hard drive with 10 MB or more available space.

BeamScope-P5 does NOT use any DMA (Direct Memory Access) or IRQ (interrupt).
BeamScope-P5 does NOT use the negative 12 V power supply available within the PC.

CHAPTER TWO

2 INSTALLING BEAMSCOPE-P5

2.1	UNPACK THE BEAMSCOPE HARDWARE.....	2-1
2.2	PC CARD INSTALLATION.....	2-3
2.3	SOFTWARE INSTALLATION.....	2-4
2.3.1	Installation under Windows 95 or 98.....	2-4
2.3.2	Installation under Windows NT.....	2-6
2.4	FIELDPACK INSTALLATION.....	2-8
2.5	MOUNTING & STARTING BEAMSCOPE.....	2-13

2.1

2.1 UNPACK THE BEAMSCOPE HARDWARE

Check your purchase. If you have any questions contact us. The purchased BeamScope consists of the PC-BS5 plus a Head (e.g. 3XY5), plus accessories if ordered.

Do not unpack a PC card until you are ready to install it in the PC or the FieldPack unit.

Part Number	Part Description
Core Products	
PC-BS5	Software + Half-slot ISA Card + 3 m long cable with D-15 connectors. (Will be a PCI card come Q2 2000)
3XY5	Probe Style Head, Silicon Detector, with XY5 5µm Slits
3GXY5	Probe Style Head, Germanium Detector, with XY5 5µm Slits
3IXY5	Probe Style Head, Indium Arsenide Detector, with XY5 5µm Slits
3IRXY5	Probe Style Head, II-VI Detector, with XY5 5µm Slits
4XY5	Rotatable Head, Silicon Detector, with XY5 5µm Slits
4GXY5	Rotatable Head, Germanium Detector, with XY5 5µm Slits
4IXY5	Rotatable Head, Indium Arsenide Detector, with XY5 5µm Slits
4IRXY5	Rotatable Head, II-VI Detector, with XY5 5µm Slits
/EPH	Appears after the head P/N for the 30 mm 'Extended Probe Head'.
Accessories	Part Description

Installation

M2B or M2C	M ² Accessory + 3 m long high current cable with RJ-45 8-pin connectors + M2-AAP + BP1
M2-AAP	M ² Accessory Adaptor Plate + Screws. (Attaches M ² Accessory to BeamScope)
M2-BP	M ² BasePlate + 2 adjustable mounting posts
2DSS or 2DSSC	2D Scanning Stage: 3.5 mm steps, 45 mm travel + 3 m long cable with RJ-45 8-pin connectors + 2DSS-AAP + BP1
2DSS-AAP	2DSS Accessory Adaptor Plate + Screws. Free with 2DSS. Attaches BeamScope Probe-Style Head to 2DSS Accessory
BP1	BasePlate. Free with M2B or 2DSS. BasePlate is 6 x 12 x 1 inch with 3 rows of 1/4"-20 holes at 0.5" pitch
RHMB1	Rotatable Head Mounting Block + Screws. (Attaches the BeamScope Rotatable Head to 1" pitch 1/4"-20 holes)
FieldPack	FieldPack enclosure for PC-BS5 PC card + power supply + 2 m long parallel port cable
BS-CAB	BeamScope/BeamMap/Beam'R spare cable, 3.0 m (10 ft) long
BS-CABS/3.0	Triple-shielded BS-CAB cable, 3.0 m (10 ft) long
BS-CABS/4.5	Triple-shielded BS-CAB cable, 4.5 m (15 ft) long
PA5	Pinhole 5 μm diameter
PA10	Pinhole 10 μm diameter
PA25	Pinhole 25 μm diameter
SS2.5	Single Slit 2.5 μm wide x 7 mm long
SS5	Single Slit 5 μm wide x 7 mm long
SS10	Single Slit 10 μm wide x 7 mm long
SS25	Single Slit 25 μm wide x 7 mm long
XY2.5	X-Y Slit 2.5 μm wide x 7 mm long @ ±45°
XY5	X-Y Slit 5 μm wide x 7 mm long @ ±45°
XY10	X-Y Slit 10 μm wide x 7 mm long @ ±45°
XY25	X-Y Slit 25 μm wide x 7 mm long @ ±45°
XY100	X-Y Slit 100 μm wide x 7 mm long @ ±45°
	(XY-- center to center separation is 10 mm. Planarity ± ~40 μm)
XYPI2.5	Dual planar X-Y Slit 2.5 μm wide x 3mm long, planarity set to ± 4 μm
XYPI5	Dual planar X-Y Slit 5 μm wide x 4mm long, planarity set to ± 4 μm

2.2 PC CARD INSTALLATION.

The BeamScope-P5 controller card has been designed to be easy to use and easy to install. There are no switches or jumpers to set. Follow the simple steps below.

It is recommended that you work at a static safe work-station and wear a wrist strap.

- 1) Turn off the power to your computer & disconnect all power cords.
- 2) Remove the cover.
- 3) Select an expansion slot for the BeamScope-P5. It is preferable that the card have a maximum amount of 'breathing-room' for heat dissipation.
- 4) Remove the rear slot cover bracket, if present. Save the screw for future use.
- 5) If you are not working at a static safe work station & wearing a wrist strap, to reduce the risk of static damage, contact the bag in which the card is packed to the computer metalwork before removing the card and immediately placing it in the computer.
- 6) Carefully hold the BeamScope-P5 card by its top edges and guide it into its expansion slot. Ensure that the BeamScope-P5 card sits firmly in the slot.
- 7) Secure the BeamScope-P5 in place by fastening its metal bracket to the computer frame with screw.
- 8) Replace the computer cover.
- 9) Connect the supplied 15-pin D connector cable to the BeamScope-P5 card.

WARNING: *The BeamScope cable connector is the same type as an SVGA monitor cable and MUST NOT be inadvertently misconnected to the video card.*

- 10) If you are also installing the M² Accessory or the 2D stage, you may also connect the 8-pin RJ-45 (network-like) cable to the BeamScope-P5 card. Also attach the cables to the BeamScope head and, if present, the M² Accessory or the 2D stage.
- 11) Reconnect previously disconnected power cords. Power up the computer.

WARNING: *Never 'hot' connect or disconnect the head while the software is powered up. This can cause damage to the head and/or the PC card electronics.*

2.2

2.3 SOFTWARE INSTALLATION

This software does not run under Windows 2000. An upgrade with PCI card for Windows 2000 will be available in Mid 2001.

It is recommended, but not necessary, that PC cards are installed before the software.

The software can be used to view data whether or not the BeamScope-P5 hardware is installed. The latest version of the BeamScope-P5 software is available from your representative or from DataRay's web site at www.dataray.com.

Visit **www.dataray.com** in order to verify that you have the most recent software revision (5.3G at the time of writing). If you do, install the BeamScope software in the (Windows standard) manner instructed on the diskettes. If you do not have the latest version, you *must* upgrade or we cannot provide support.

Either: If you have already loaded the BeamScope software, download the **Bsex.exe.zip** file to a temporary file and extract into the Bscope5 directory. When the **Confirm file Overwrite** warning appears, select **Yes to All**.

Or: To start again from scratch, download the **BSDisk1.zip** and **BSDisk2.zip** files

Extract both of them to a temporary folder (e.g. c:\DRaydisk) [or to diskettes].

Open Windows Explorer and double-click **Setup.exe** to install the program.

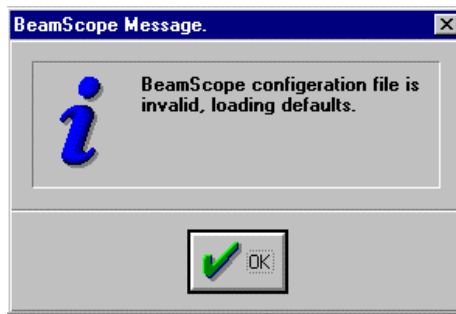
WARNING: *Never 'hot' connect or disconnect the head while the software is powered up. This can cause damage to the head and/or the PC card electronics.*

2.3.1 Installation under Windows 95 or 98.

These instructions assume that you are running Windows 95, or 98. However, you can use it with Windows 3.1x, with some allowances on your part. This tutorial also assumes that you are reasonably familiar with Windows. **We do not support Windows Me.**

- 1) The BeamScope-P5 software is installed from within Windows. If your computer is not running Windows at this time, please run it now.
- 2) Windows 3.1x. Select **R**un and enter **a:setup** , press **Enter** or click **OK**.
- 3) Windows 95, 98, Press the **S**tart button, select **R**un, enter **a:setup** (or **b:setup**) and press **Enter** or click **OK**.
- 4) The install program will allow you the option of changing the name and drive location of the BeamScope-P5 software.
- 5) Click the **OK** button and the install program will do the rest.

- ❑ During the last stages of the install program there may be an unsettling extended pause; this is normal.
- ❑ If this is not the first installation, there may be more than one BeamScope icon present. If so, you may simply highlight the undesired icon and press **Delete**.



- 6) Double-click the BeamScope icon to start the program. The first time the BeamScope-P5 program is run, or if a newer version has been installed, the message shown may appear. It simply warns you that the old configuration file was discarded and you will need to verify your **Setup** parameters (press **F6**) after BeamScope opens. (If a JOB file is linked to the icon or shortcut file, it will still be attached.)

[**TIP:** In the unlikely event that the software ever refuses to start, you can force the BeamScope software to flush its configuration file to the defaults by holding down the **Shift** key while launching the program.]

- 7) There are no other drivers or components to be installed. See Section 3.1 to see how the software works.

Congratulations. You have successfully completed BeamScope Installation.

Go to Section 2.5

WARNING: *Never* 'hot' connect or disconnect the head while the software is powered up. This can cause damage to the head and/or the PC card electronics.

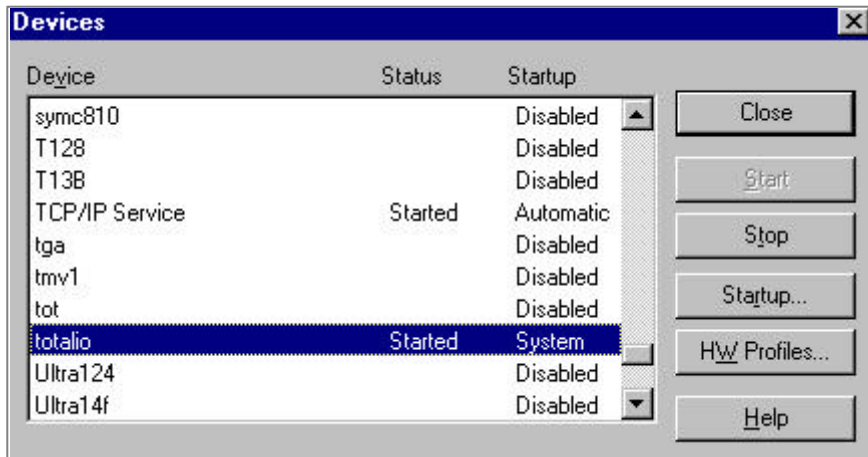
2.3

2.3.2 Installation under Windows NT

- 1) You must be running NT 4.0 with Service Pack 5 or higher. We do not support older versions.

You must install BeamScope software as 'Administrator'. 'User with Administrator Rights' may not be enough. [If you cannot even install the software, it may be that your NT Administrator (i.e. the person) has restricted your software installation rights, and must therefore be called in to install the software.]

- 2) Double-click the BeamScope icon to start the software.
- 3) If the BeamScope software refuses to work, or it works once and then quits, you can thank Microsoft for making NT much too fussy. Here's what you need to do:
- 4) With BeamScope closed, make sure that the file **totalio.sys** is in the WinNT root directory. Use Explorer to verify and/or copy it there, or in DOS, type: **copy \bscope5\totalio.sys \winnt** then press **Enter**
- 5) In the Control Panel there is an Icon called **Devices**. Double-click it to open the following dialog:



- 6) Select **totalio**. Note that **totalio** should be **Started** and is labeled **System**. **IT MUST BE THIS WAY.**
- 7) If it is not labeled **System**, press the **Startup** button and change it to the **System** option. It may or may not complain about something, but if it does, just ignore it.
- 8) If **Started** is not there, press the **Start** button. Finally **Close** the dialog box and restart BeamScope.

- 9) That's it. BeamScope should run now, next time, and every time after that. If not contact technical support at support@dataray.com

Congratulations. You have successfully completed BeamScope Installation.

Go to Section 2.5

WARNING: Never 'hot' connect or disconnect the head while the software is powered up. This can cause damage to the head and/or the PC card electronics.

2.3

2.4 FIELDPACK INSTALLATION

FieldPack works with most standard Desktop or Notebook PC's with a parallel port input running Windows 95/98/NT. Combining FieldPack with a Notebook PC creates a compact portable beam profiler.

Due to the non-rigorous nature of the implementation of the parallel port standard, we cannot guarantee that FieldPack will work with just any PC. This is particularly true of budget products and some Compaq models with non-standard Bios. We have had good experience using IBM ThinkPad Notebooks with FieldPack.

A) Install the Software.

1. From the Application Notes at the website, download any version of **FPInstall.zip** dated later than this manual and any User Manual supplements from the site.
2. Install the BeamScope software in the (Windows standard) manner instructed in sections 2.3.1 and 2.3.2 above.

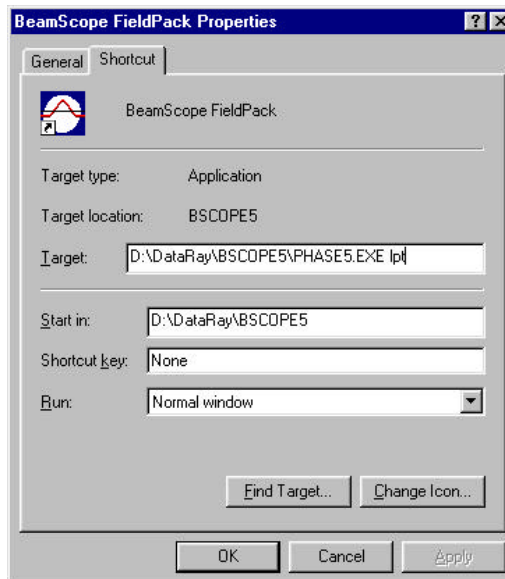
B) Change the Shortcut Icon Properties.

3. Once the BeamScope software is installed, right-click the BeamScope icon on the **Start** screen Desktop, then left-click **Properties**.



[If no icon is present on the Desktop, use Windows Explorer to find **Phase5.exe** in the **Bscope5** directory, found under **c:** if a normal installation was made. Click, drag and drop it onto the Desktop in order to create a shortcut.]

In the **Shortcut** folder under **Properties**, in the **Target:** line, add a **space** followed by **lpt** and click **OK**, to give:
C:\BSCOPE5\PHASE5.EXE lpt



For Windows NT, add ' NT ', to give: C:\BSCOPE5\PHASE5.EXE NT lpt

4. Rename the icon by clicking once, then once more on the name to allow it to be edited. Suggested names are:

BeamScope FieldPack

or **BeamScope lpt**

... your decision.



C) Connect the Cables & Start the Software.

5. Connect the cables as follows:
 - 12 VDC Power supply between a 100-240 VAC 50/60 Hz wall socket and the **+12 Volts DC only** input on FieldPack.
 - 25-pin D-connector cable from the parallel port on the computer to **Parallel Port** on the FieldPack.
 - 15-pin D-connector cable from the connector on the BeamScope head to the 15-pin D-connector on the FieldPack.
 - If you also have an M2B Scan Stage, connect the 8-pin flat network connector from the Scan Stage to the connector on the FieldPack. This can be a tight fit.
6. Double-click the **BeamScope FieldPack** icon to start the software. A DOS screen may flash before you eyes. Wait up to ten seconds. The BeamScope head will make clicking noises as it references to an internal physical stop and the BeamScope main screen should appear. If this does not happen, see **Q1** below. If it does, got to Section 2.5.

2.4

Congratulations. You have successfully completed FieldPack Installation.

WARNING: Never 'hot' connect or disconnect the head while the software is powered up. This can cause damage to the head and/or the PC card electronics.

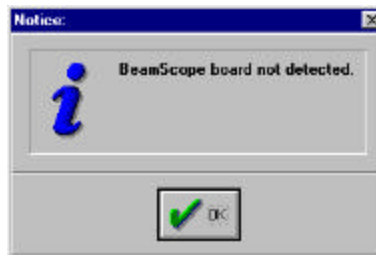
Frequently Asked Questions.

Q1. I started the BeamScope software and this 'Notice:' appeared:

'BeamScope board not detected.'

Or: 'BeamScope head not detected'.

What has gone wrong? What do I do next?



Answer: **a)** Check that the cables are properly connected and the power was on, (Step 5). If so, then the most probable cause of the **Notice** is that the parallel port is not correctly configured for bi-directional communication. You must change the parallel port mode in your PC's System BIOS setup.

The System BIOS is accessed by pressing a particular key while the computer is rebooting. This is commonly the **F1**, **F2**, **F10** or **Delete** key, or whatever your PC manufacturer decided on. To find out, ideally consult the Owner's Manual/Documentation that came with your PC (no, we are not joking, some people keep it) or contact the PC manufacturer.

http://www.hp.com/cposupport/multifunction/support_doc/bpu50187.html has a section on 'ECP and Bi-Directional Interfaces' addressing how various manufacturers access Bios to set the parallel port.

Alternatively, restart you computer and scan the white on black text screen that appears for a message naming the particular key to be pressed: **Press <__> to enter SETUP** , or some similar message. Quick, press the key. If you are too late, restart the computer and this time press the key immediately after the beep, as soon as the black and white screen appears. If absolutely necessary, *and completely at your own risk*, experiment with the **F__** keys.

Once in the BIOS program, normally a gray or blue DOS screen, find the **Parallel Port Mode** [typically found under **Advanced** in a submenu called **Peripheral Configuration** or something similar]. All PC manufacturers in theory follow the IEEE 1294 Standard for the Parallel Port, but in practice there are differences. Choose **Bi-Directional** mode. If this does not work, next try **ECP**, then try **EPP**. i.e. select from the following modes, listed *in order of preference*:

- a) **Bi-Directional** b) **ECP** c) **EPP**

(The BeamScope FieldPack will **NOT** work in **Standard** mode.)

Save the BIOS changes (normally by pressing **F10**) and re-boot the computer. Retry the BeamScope software, Step 6. The program should now work.

b) If you have tried a) without success, then in order to restore the BeamScope defaults, in case they somehow got corrupted, proceed as follows:

From the Desktop. single-click the BeamScope icon, hold down the **Shift** key and then press **Enter**. Keep holding down the **Shift** key until either the BeamScope main screen appears, indicating success, or an error message/notice appears. Note any error message/notice.

Please carefully record the exact words that appear (you can use **Alt, Print Screen** to put the message window to the clipboard and then save it under **Paint** as a ***.bmp** file) and send the file, optionally zipped, to DataRay Technical Support - see website.

Q2. What addresses does FieldPack software look for when trying detect and configure for the parallel port?

Answer: The following four:

378	278	222	3BC
Preferred		OK	Sometimes conflicts with the video card.

2.4

Q3. I tried to print the results and nothing happened. Why not?

Answer: Your printer parallel port is 'occupied' by the BeamScope cable and or software. Save the BeamScope results file and print out the results after you have taken all the measurements that you need and have closed BeamScope.

[If you are networked via other than the parallel port, then you may use a network printer while FieldPack is connected. If you have two LPT ports then devote one to FieldPack and one to your printer.]

Q4. Can I install a second parallel port devoted to BeamScope?

Answer: BeamScope is generally intended for use with portable PC Notebook computers which have a single parallel port and no expansion facility, so the answer to your question is No.

[If you are networked then use a network printer. If you find a second parallel port third-party solution that works, please inform us.]

Q5. I started the BeamScope software and a DOS screen entitled Xcopy32 appeared. What do I do next?

Answer: This is only true for BeamScope Versions 5.1x and earlier, and has been fixed in later versions. (It was related to NT issues.) For a permanent solution, visit www.dataray.com/support.htm, download the **BSExe.zip** file, and unzip it to the **c:\Bscope5** directory.

The problem is that you started BeamScope without the FieldPack parallel port cable attached to the parallel port, or with the FieldPack power supply disconnected. Close out the DOS program (x in top right corner), answer **Yes** to the Windows Warning box, click **OK** in the **BeamScope board not detected** box. BeamScope will open. If all you want to do is to analyze some previously saved data, then just carry on. To use BeamScope in live mode, you must first close BeamScope and correctly attach the cable and/or power supply. BeamScope may be then be reopened and should function normally.

Job files

It is possible, either now or at any later stage to link a ***.job** file (Saves the BeamScope settings, see Section 4.6) to the current BeamScope icon. To do this, right-click the BeamScope icon, select the **Properties** item, then select the **Shortcut** folder.

- ❑ In the **Target:** section it should look similar to the following:
C:\BSCOPE\BSCOPE5.EXE
- ❑ Add at the end, **JobName.job** . It should then look similar to:
C:\BSCOPE\BSCOPE5.EXE JobName.job
(Where a **Jobname** such as **Defaults** is the name to be assigned to the Default settings)
- ❑ If the attached *.job file does not already exist, the BeamScope-P5 software will automatically create one. A warning that it didn't exist will be displayed.

WARNING: ***Never** 'hot' connect or disconnect the head while the software is powered up. This can cause damage to the head and/or the PC card electronics.*

You may also create additional icons linked to other job files.

To create an additional icon, in Windows Explorer find **Phase5.exe** and click and drag it onto the desktop. Then rename it as above.

2.5 MOUNTING & STARTING BEAMSCOPE

These instructions apply to both the standard Probe-style head and to the Rotatable Head. (The Rotatable Head does *not* have a rotating slit or drum. It takes the standard linear probe mechanism and mounts it on a circular bearing with scale to allow simple manual rotation).

- 1) Mount the BeamScope head *in a rigid manner* using the ¼-20 and M6 tapped blind holes and appropriate mounting hardware, such that the probe will intercept the laser beam and will move in a plane perpendicular to the beam axis. See the Aim and Search functions described in Sections 4.1.2 and 4.2.14.
 - ❑ For beams below <50 µm, in order to minimize vibration it is highly recommended that you mount the BeamScope Head vertically on a single post, with the probe pointing down.
 - ❑ If the beam profile is elliptical and you are using dual X-Y slits, set the head such that the slit axes correspond to the beam axes.

A rigid mount is required because BeamScope employs a linear motion probe with what is essentially a square wave oscillating velocity profile; (linear motion is required to meet the ISO 1146 beam profiling standard). Therefore if you simply attach BeamScope to the end of a long rod, the probe's alternating linear motion may lead to oscillatory motion of a few microns of the head/rod combination, and you may not achieve the stability you seek.

WARNING: *Never 'hot' connect or disconnect the head while the software is powered up. This can cause damage to the head and/or the PC card electronics.*

Starting Up: Double-click the **BeamScope** icon to start the software. Wait a few seconds. The head should make clicking noises as it references to an internal physical stop, and the BeamScope main screen should appear. If so, go to Section 3.

If you see: **Notice: BeamScope board not detected** , this means that the software has not detected the presence of a PC card. Carefully reinstall the hardware and the software. If this fails, contact DataRay Technical Support.

If you see: **Notice: BeamScope head not detected** , this means that the software has detected the presence of a PC card, but not the head. If this occurs, try the following. Press **Ctrl E** and change the **Maximum travel** by 1 mm. Click **OK**. If this succeeds, try restarting the software. If the attempt to **Write to EEPROM failed**, contact DataRay Technical Support.

2.5

Installation

CHAPTER THREE

3 QUICK-START TUTORIALS

Okay, so you want to get started quickly without reading the manual, but you don't want to damage the hardware, or you just want to evaluate the software. This short-as-possible chapter is for you. Just follow the step-by-step instructions, refer to other sections where noted, and you will learn enough to measure beam profiles.

Later on, you *must find time to read Section 4* of the manual if you are become a BeamScope power-user, but for now ...

- ❑ *Unfamiliar with BeamScope, or just evaluating the software?* Read Section 3.1 first.
- ❑ *Acquainted with the software but never used the hardware?* Go to Section 3.2.

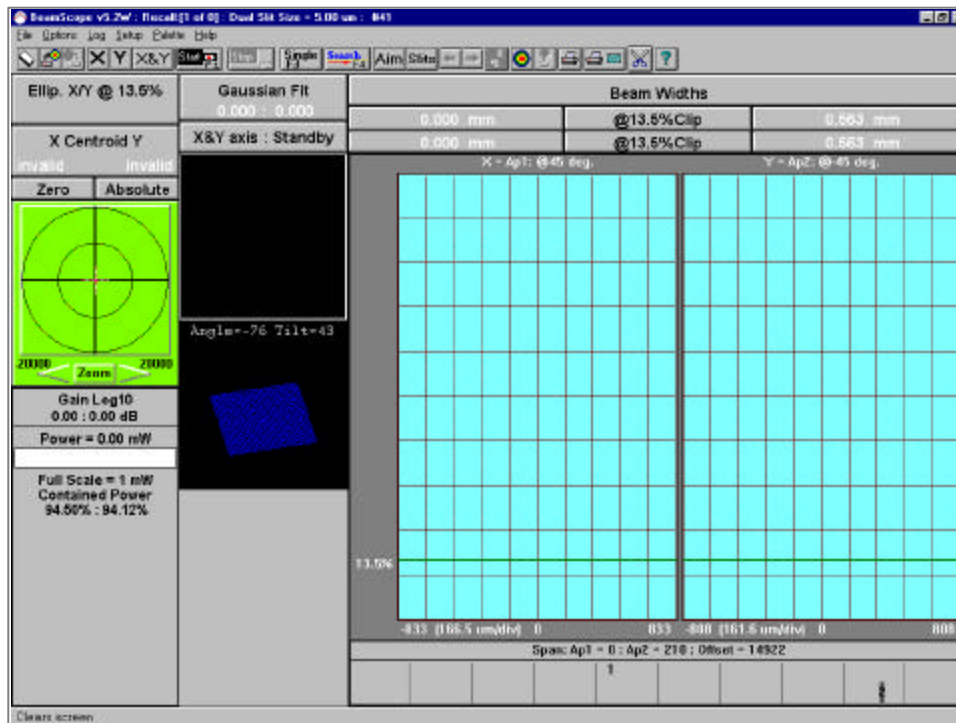
3.1	SOFTWARE ONLY QUICK-START TUTORIAL.....	3-1
3.1.1	Start the Software.....	3-2
3.1.2	Examine previously saved Data.....	3-3
3.1.3	Beam Centroid.....	3-4
3.1.4	Beam Wander and Absolute position.....	3-5
3.1.5	Change the Beam Diameter Definition.....	3-5
3.1.6	Pass/Fail Indication for QA & Production Testing.....	3-6
3.1.7	'Included Power' and Distance Measurements on the Profile.....	3-7
3.1.8	Additional Profile Views.....	3-7
3.1.9	2-D and 3-D Views.....	3-7
3.1.10	Print the Results.....	3-8
3.1.11	Other Great Features	3-8
3.1.12	Short Cuts.....	3-9
3.2	HARDWARE QUICK-START TUTORIAL.....	3-10
3.2.1	Setting Up.....	3-10
3.2.2	Head Setup and Options.....	3-11
3.2.3	Search for the Beam.....	3-12
3.2.4	Practice with the Software.....	3-13
3.2.5	Log the Data.....	3-13
3.2.6	Short Cuts.....	3-15

3.1 SOFTWARE ONLY QUICK-START TUTORIAL

This section will teach you the basics. *It does not try to cover everything.* Yes you will eventually have to read Section 4!

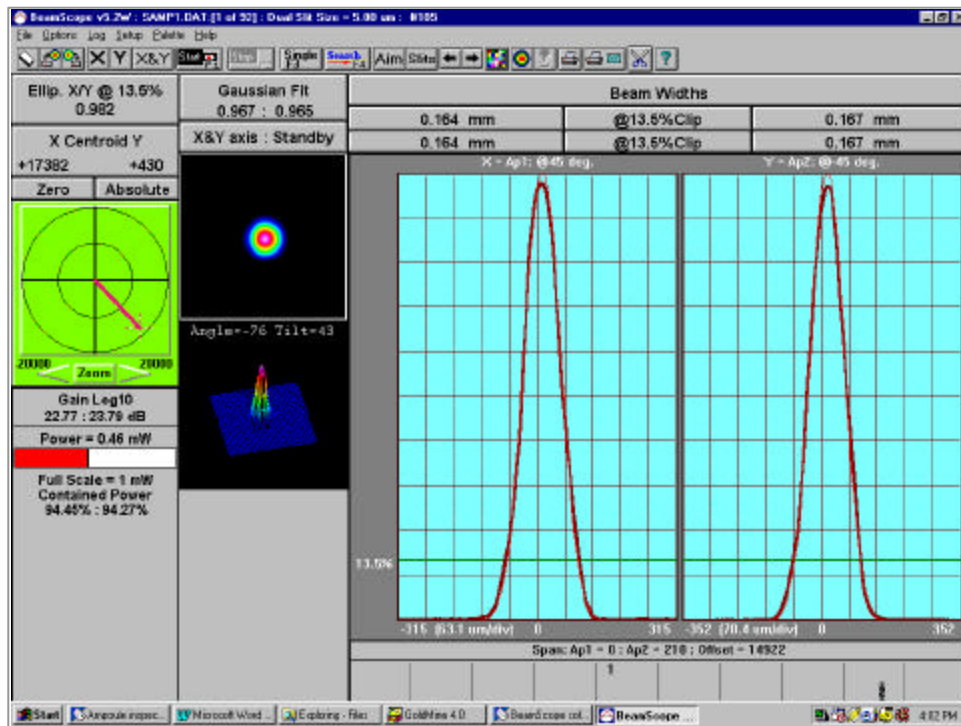
3.1.1 Start the Software

See Section 2.2 if the software is not yet installed. Double-click the BeamScope icon to start the software. **Notice: BeamScope board not detected** will appear if the hardware is not present. Click **OK**. The main screen display should appear.



3.1.2 Examine previously saved Data

Click on this button or Enter **Alt F, O** to open the **Open** dialog box, select the **samp1.dat** file, and click **OK** to see the screen below.



3.1

Note that the Caption bar (at the very top) displays the BeamScope-P5 software version and the name of the file you just loaded. It also states that you are currently looking at profile 1 of 92. The BeamScope-P5 has a data buffer that can hold up to 100 profile pairs. Finally there is a number (#369 in this case) which indicates the number of profiles processed since either the software was started or since the last **Clear Screen Data and Data Buffers** operation was performed. (X & Y count as separate profiles.)



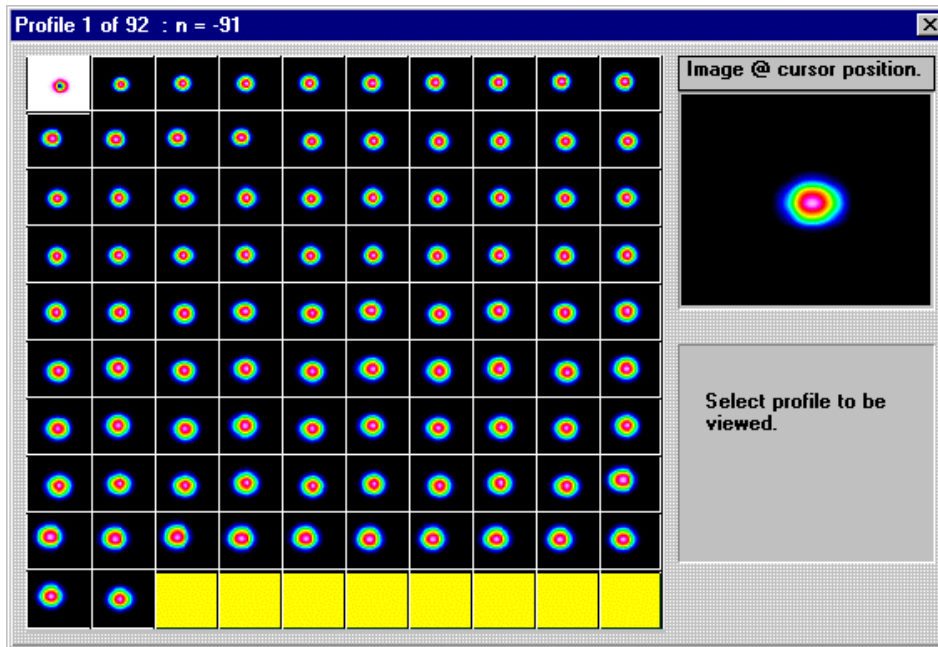
There are two methods you can use to change the currently viewed profile.



Press one of these buttons to move to the next or the previous profile. The **Page Up** and **Page Down** keys perform the same function.



Clicking on this button opens a dialog box that allows you to view all of the profiles in the buffer and scan through them by passing the cursor over them. Press it now. The dialog box below should appear:



Note that the first image is highlighted; it is the *most recent* one, the one that you were just viewing. Pass the cursor over some of the “thumbnail” images. As you do, the larger image changes to match the image that is being selected. The data in the main window is also updated to reflect which thumbnail has the cursor on it. Look at the Caption bar at the very top. It tells which image is selected and has an ‘n’ with a value after it. When n equals zero, that is the most recently scanned profile, and ‘n = -1’, indicate that it is the second most recent profile and so forth.

Clicking on a recent image (Click on the n = 0 image) returns you to the main window. You have the most recently examined profile on the screen. You have now covered how to step through or select a profile set from the data buffer.

3.1.3 Beam Centroid.

Press the **Zero** button, and the **x Centroid y** values should go to zero. Now press the **Page Up** key, and the values will change indicating the difference between the centroids of the first and last profiles. It should be (in this case) a LARGE change, since this data

was taken from a M-Squared test, where the translation stage caused a quite large movement of the beam. This is only meant to show you how Centroid works. It is NOT normal for most beams to wander that much. Press the **Page Down** key and the Centroid values should return to zero. Note that X & Y are in the normal sense as viewed by an observer travel along the axis of beam propagation; i.e. +ve X is to the Right and +ve Y is Up, assuming that the head is oriented with the faceplate label letters upright.

3.1.4 Beam Wander and Absolute position

The **Absolute** button references the beam centroid to a position that you can set as your absolute reference. Click in the target-like area beneath the **Absolute** button in order to open the dialog box. There is a set of edit boxes labeled **Absolute** where you set the point that you wish to define as the absolute position. For convenience for now, press the **Copy zero** button to make the current zero point the **Absolute** point. (You can first record the absolute point and re-enter later if you choose.)

The Wander screen shows the position vector traced from the center of the display to the dashed crosshair which indicates the beam center. The dashed ellipse indicates the 13.5% intensity contour of the beam profile.

Clicking on the arrows either side of **Zoom** changes the displayed area. If the **Auto-Scale On** box is checked (See **Wander Setup Information** in Section 4.2.6) the arrow zoom is disabled.

See Sections 4.2.5 and 4.2.6 for more detail, including how to change the colors of the target area and vector.

3.1.5 Change the Beam Diameter Definition

'Beam Widths' Buttons

This is a set of seven button areas controlling the display of the beam diameters and their corresponding clip levels.

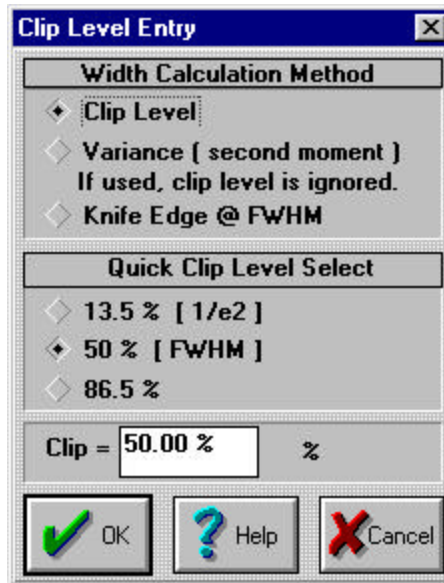
Beam Widths		
0.164 mm	@13.5%Clip	0.167 mm
0.164 mm	@13.5%Clip	0.167 mm

The two center Clip Level buttons open the **Clip Level Entry** dialog box allowing the user to set a desired clip level or select the use of the Variance (Second moment) beam diameter definition. With a beam profile that is pure Gaussian the Variance definition is *exactly* the same as selecting 13.5%, but if your beam is non-Gaussian, the Variance method is more consistent.

Note that two distinct clip levels and/or methods can be set concurrently in the upper (Level 2) and lower (Level 1) levels. Knife-edge is only valid for a 50% Clip Level.

The outer set of buttons displays the calculated beam diameters in microns (**um**), or millimeters (**mm**), as selected in the **Pass – Fail Parameter Setup** dialog box. The beam diameters on the left corresponds to **Aperture 1** profiles (normally designated **X**) and the right to **Aperture 2** (normally designated **Y**).

A bracketed number, e.g. **[10]** after the reading, indicates that the reading is being averaged. In this example it would be the average of the last ten diameter readings.



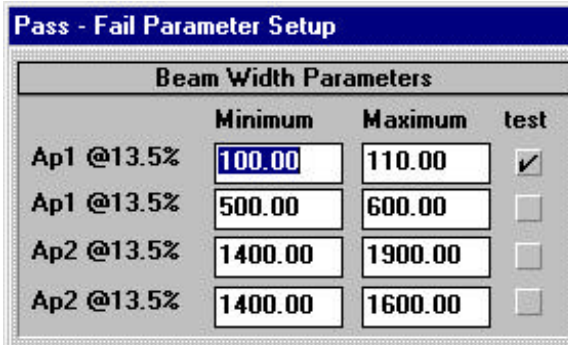
Place the cursor on one of the four beam diameter buttons (results) and click the right mouse button. You can now customize the color of the button and the colors of text in different states.

3.1.6 Pass/Fail Indication for QA & Production Testing

BeamScope makes it simple to test measured parameters as above or below a preset level, and to display this fact in real time. This makes BeamScope an ideal tool for use by non-technical staff in QA and Production Test.

Pass/Fail can be set for all displayed parameters. Enter **Alt S, P** to access the **Pass – Fail Parameter Setup** dialog box, and change the upper left hand corner to read as shown.

Click OK and note that the lower left beamwidth result is now displayed in red, because it failed the **Maximum Beam Width** criterion.



Right-click on this result and then click on the red color patch to see how to choose a different color.

3.1.7 ‘Included Power’ and Distance Measurements on the Profile

Enter **Ctrl 3** and **x** to display the x profile only. Put the cursor to any point on the plotted profile, click, drag and release the mouse. The percentage of the total power within the region is displayed, together with a **Delta** measurement in microns corresponding to the horizontal width of the region. Selecting the single profile allowed you to do this with maximum resolution. Enter **Ctrl 3** and **b** to display both profiles and their 2-D and 3-D representations.

3.1.8 Additional Profile Views

Place the cursor on one of the two profile plots and click the right mouse button. A menu appears allowing you to customize and/or select various modes. Logarithmic mode in particular allows you to examine deep wings of the profile and assess the background noise level. Try selecting a **Log10** scale. Later on when you are taking real data, the **Plot History** can be interesting if your laser is noisy.

3.1.9 2-D and 3-D Views

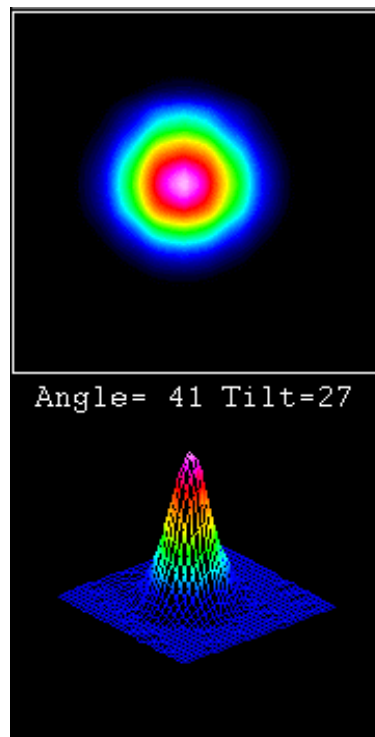
If the 2D and 3D images are not already visible, enter **Ctrl 3**. These are the 2D and 3D images are *only* visualization tools, see Section 4.2.10, but they are also fun and useful!

Place the cursor on the 2D image, and click and drag a rectangle. You have just zoomed in on the profiles and the 3D image. Now click on the 2D image and cancel the zoom.

Double-click the 3D (or 2D) image and it swaps panes with the profiles. Place the cursor on the 3D image, click and drag to change the view of the 3D image. Side-to-side motion rotates the image. Up-down motion changes the viewed tilt angle. Now click the 3D image with the RIGHT mouse button, and a floating menu appears. Experiment, have fun!

The rotating 3D image is great for display when the V-Ps come round, but consumes processor power and should not be left on during serious work.

Double-click the 3D image to swap the main pane back to the profiles view.



3.1

3.1.10 Print the Results



Click the **Print this screen, with notes** button at top right, add some spurious comments and print the results.

3.1.11 Other Great Features ...

... exist within the BeamScope software, including:

- The ability to log the data to the hard drive over an extended period (Section 4.3.2).
- The measurement of Beam Quality Parameter M^2 (Chapter 5).

... but apart from the short cut keys listed on the next page, this is enough for a start. Read Chapter 4 to get the complete story.

3.1.12 Short Cuts

Note the following keyboard based Short Cuts, and as the cursor moves over the screen, watch the 'Help Action Line' at the bottom of the screen.

Try now, using every Short Cut key with a **description shown in bold** (Keys not shown in **bold** require hardware to be present.) See Chapter 4 for full descriptions.

F1 Starts a scan	F5 Repetitive Search
F2 Stops a scan	F6 Scan Head Set-Up
F3 Single scan	F7 Aims Head
F4 Searches for signal	F8 Opens Profile Log
b Selects both profiles	Alt F4 Exits the program
x Selects x profile only	Alt F7 Toggles Angular width and normal width.
y Selects y profile only	Alt F9 Reconfigures for a Pinhole scan
Shift R Recall & Process profiles	Alt A Opens Auto/Manual Gain dialog
Page Up Access the previous profile	Alt N Opens the Accumulation Averaging dialog
Page Down Access the next profile	
Ctrl 3 Toggles between profiles only and also showing the 2-D and 3-D views	
Ctrl E Opens the Program Head dialog – rarely required	
Ctrl G Toggles between Geometric and Centroid based centroid definition	
Ctrl J Opens a Job file	
Ctrl M Reconfigures the screen for M ² measurements, and toggles back to Normal.	
Ctrl O Opens the Slit Orientation Dialog box	
Ctrl S Opens a dialog box for setting up the Auxiliary stage motion	
Ctrl T Screen dump to clipboard. [Image does not include the Button Bar, Menu and Page Header above, or the Help Notes and Task Bar below.]	
Ctrl V Opens the Average dialog box	
Ctrl X Opens the Slit assignment dialog box	

3.2 HARDWARE QUICK-START TUTORIAL

3.2.1 Setting Up

If you have not already done so install the PC Card and software - Sections 2.2 and 2.3. *With the software off*, connect the head to the PC card using the cable provided. Then start the software.

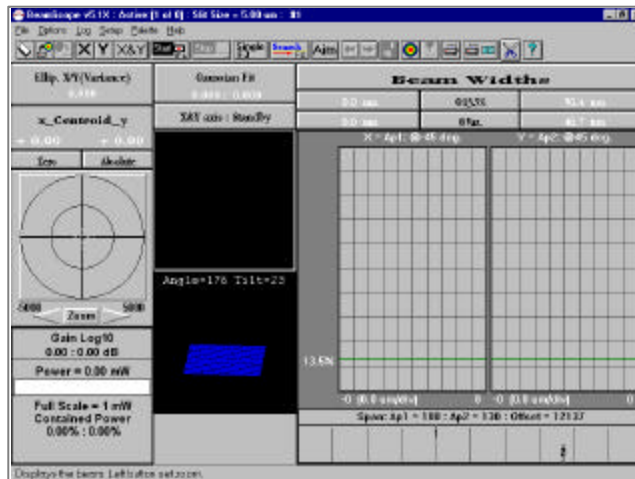
WARNING: *Never* 'hot' connect or disconnect the head while the software is powered up. This can cause damage to the head and/or the PC card electronics.

Slits If you need to change the slits, click on this button and the probe will come out of the head. Use a #0 Phillips head (crosshead) 'jeweller's' screwdriver to unscrew the four screws which hold the slit assembly. Remove the current slits and place them in a labeled box. Screw the new aperture plate into place on the head. Remember to enter the slit details when you get to Section 3.2.2 of these instructions.

Eye Safety: Put on your laser safety goggles before you turn on the laser.

Mount the BeamScope head *in a rigid manner* (See Section 2.4) such that the probe will intercept the laser beam and will move in a plane perpendicular to the beam axis. If the beam profile is elliptical and you are using dual X-Y slits, set the head such that the slit axes correspond to the beam axes. For beam below $\sim 50 \mu\text{m}$, it is highly recommended to mount the BeamScope vertically with the probe pointing down in order to minimize vibration that might degrade the measurement.

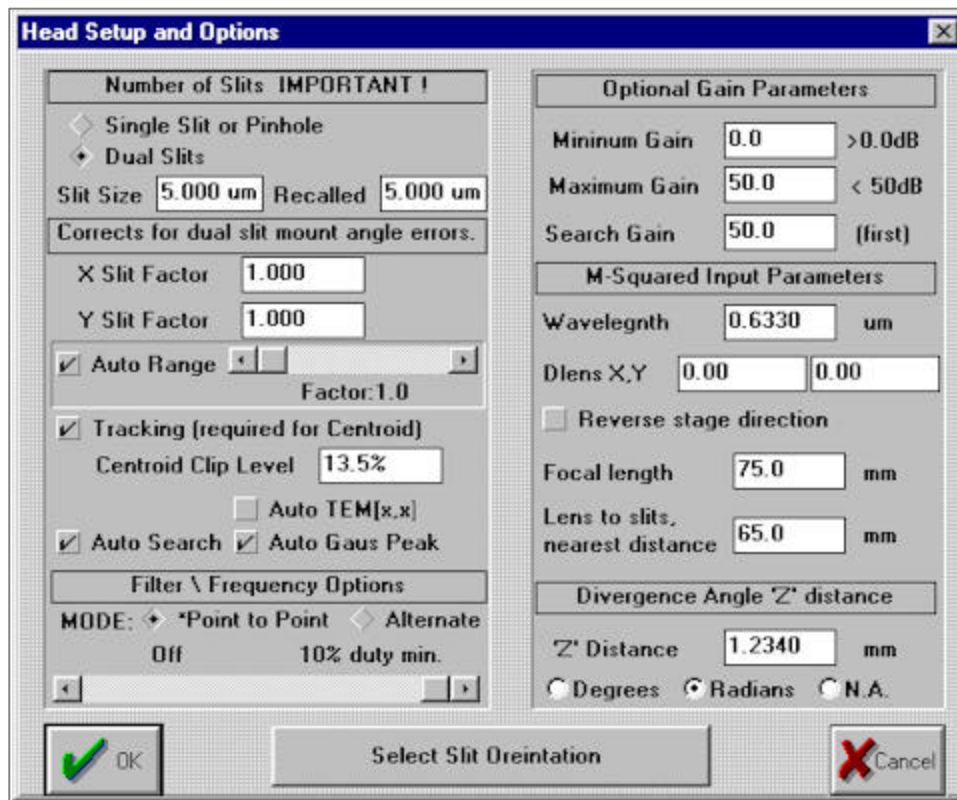
Double-click the BeamScope icon to start the software. The head will make a buzzing sound for a few seconds as the software starts up and verifies the physical end stop. This is normal and is not a problem. The main screen display (Section 4.2) should appear.



3.2.2 Head Setup and Options

Press **F6** and fill in the **Head Setup and Options** dialog box as per section 4.3.3. The most common configuration values are those shown below.

Make sure that your **Setup** screen values are the same. If you are using slits other than the standard 5 μm dual XY slits, make sure that you enter the details under **Number of Slits IMPORTANT!**. (Note that when a results file is saved, the slit details are also saved and cannot be subsequently changed in the saved data.)



3.2

3.2.3 Search for the Beam

*It is **CRITICALLY** important that you properly understand this section. Read it at least twice.*



In Search mode, the probe determines the location of the beam to be scanned.

- 1) Click **Aim** to move the probe out, and aim the beam at the center of the outer slit. Then Press **F4** to instruct the probe head to search for the beam.

TIP. If necessary, press **F5** to perform repetitive searches, then **F2** to stop the search once successfully aligned as defined in 2) through 5) below.

- 2) *When a Search has been performed, inspect the search display, (reproduced above) and verify that the scan regions found by the search routine make sense.*

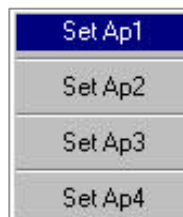
The X slit (**Ap1**) and Y slit (**Ap2**) scan regions are indicated as dark gray regions marked **1** and **2**. The width of this plot is the 34 mm long physical scan of the probe.

*With dual slits, after a search is performed there should always be two distinctly separated peaks displayed. That is, there should always be a horizontal distance between the right-hand edge of the **1** region and the left-hand edge of the **2** region. The scan regions should never overlap along the horizontal axis.*

- 3) It is possible for the Auto-Search function to mistakenly place the X and Y scan areas at the same location, which may or may not be desirable. Sometimes the software will allocate **Ap3** and **Ap4**. The user must overwrite this as follows:

- Click and drag to move a scan region manually to the desired scan region.
- Define a new scan region by placing the cursor outside the gray region and clicking and dragging a new region with the mouse. When the mouse button is released a menu will appear asking to which aperture the defined region should be allocated. In the current release, only allocate **Ap1** or **Ap2** to scan regions.

Warning: To ensure valid results, the entire profile must be within the scanned area.



- 4) Double click on the lower part of the search area to cycle the size of the search display from normal to large to minimum and back to normal.

- 5) Press **F1** to start the scan, and look at the profiles. Press **F2** to stop the scan.
- 6) Perform a sanity check. Does what you observe make sense? If so great, it is almost certainly correct. If not, then the most likely problem is the scanned region. Reread the previous section and be sure that you understand it. If all is fine, repeat Section 3.2.2 above and verify that all the correct options have been checked. If the beam is much smaller than the slit dimension change to Knife-Edge mode (Section 4.4) and reinterpret the data.
- 7) In Section 4.3.3 you will learn how to turn the **Auto Range** and **Auto Search** functions on and off under **Setup** in order to keep the scans over a preset region.

3.2

3.2.4 Practice with the Software

If you have not already done so, go through sections 3.1.3 to 3.1.10 above, and refer to Chapter 4 for any areas which you wish to pursue in more detail.

3.2.5 Log the Data

It is frequently desirable to be able to investigate drift in the measured parameters. Enter **Alt L, L** to open the **Log profiles to drive** dialog box.

Click on **CAPTURE ENABLE IS OFF** or **NEW** to open a **Save As** dialog box which allows you specify a filename and location. Click **OK**.

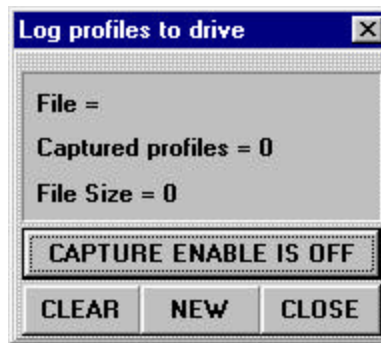
The button will change to **CAPTURE ENABLE IS ON**. Click **F1** to start the scans. The data will be logged to file. Click **F2** to stop the scans.

Click on **Analyze profiles...** to open a **BeamScope Data Analysis** window. Click on **File Load** to **Open** a logged data file.

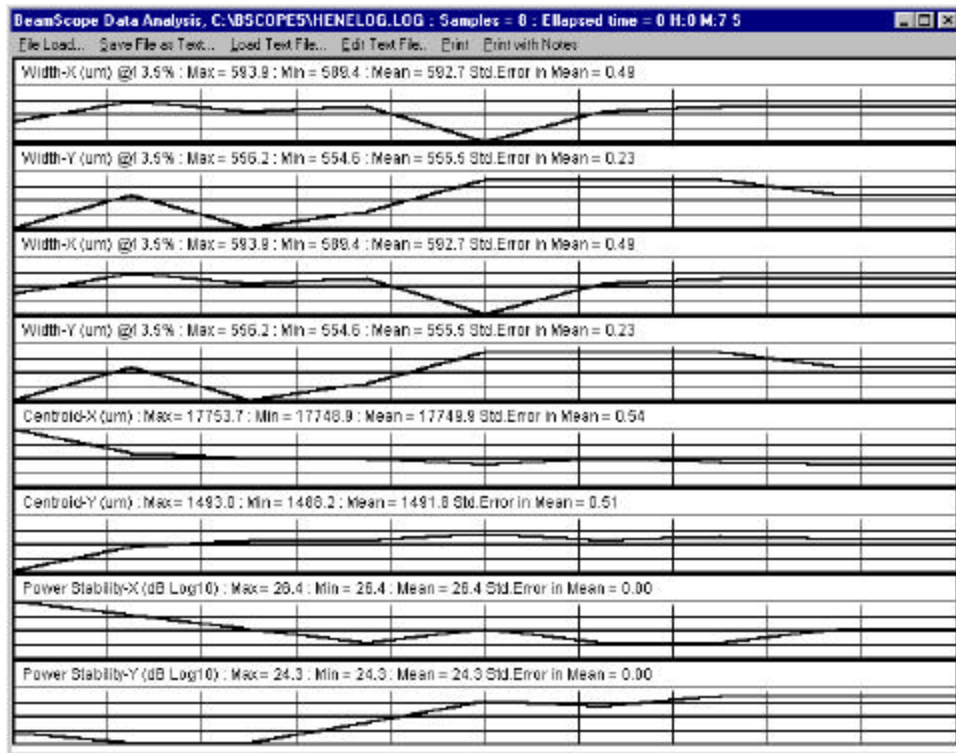
Examine the logged profiles and statistical data. An example is given below. Note the **Save**, **Load**, **Edit** and **Print**. Analytically the **Std. Error in the Mean** is:

$$[\text{Sum}\{(\text{Value} - \text{Mean})^2\} / \{n \cdot (n - 1)\}]^{0.5}$$

Where n is the number of values considered in the calculation.



Quick-Start Tutorial



3.2.6 Short Cuts.

Note the following Short Cuts. As the cursor moves, watch the 'Help Action Line' at the bottom of the screen. Try every Short Cut key *now*. See Section 4 for full descriptions.

F1 Starts a scan	F5 Repetitive Search
F2 Stops a scan	F6 Scan Head Set-Up
F3 Single scan	F7 Aims Head
F4 Searches for signal	F8 Opens Profile Log
b Selects both profiles	Alt F4 Exits the program
x Selects x profile only	Alt F7 Toggles Angular width and normal width.
y Selects y profile only	Alt F9 Reconfigures for a Pinhole scan
Shift R Recall & Process profiles	Alt A Opens Auto/Manual Gain dialog
Page Up Access the previous profile	Alt N Opens the Accumulation Averaging dialog
Page Down Access the next profile	
Ctrl 3 Toggles between profiles only and also showing the 2-D and 3-D views	
Ctrl E Opens the Program Head dialog – rarely required	
Ctrl G Toggles between Geometric and Centroid based centroid definition	
Ctrl J Opens a Job file	
Ctrl M Reconfigures the screen for M ² measurements, and toggles back to Normal	
Ctrl O Opens the Slit Orientation Dialog box	
Ctrl S Opens a dialog box for setting up the Auxiliary stage motion	
Ctrl T Screen dump to clipboard. [Image does not include the Button Bar, Menu and Page Header above, or the Help Notes and Task Bar below.]	
Ctrl V Opens the Average dialog box	
Ctrl X Opens the Slit assignment dialog box	

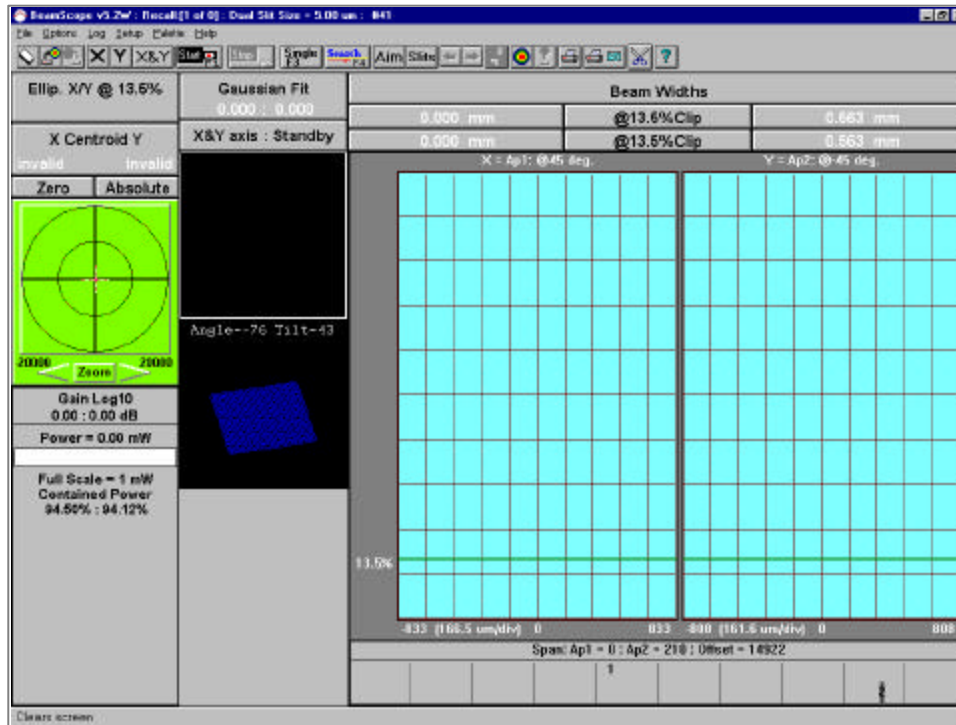
CHAPTER FOUR

4 BEAMSCOPE FUNCTIONS

4.1	THE MAIN SCREEN.....	4-2
4.1.1	<i>Pull-Down Menus.....</i>	4-3
4.1.2	<i>The Button Bar.....</i>	4-6
4.2	MAIN SCREEN SECTIONS.....	4-8
4.2.1	<i>Pass/Fail for QA and Production Testing.....</i>	4-8
4.2.2	<i>Button Colors Setup.....</i>	4-9
4.2.3	<i>'Button' Areas and Help Hints.....</i>	4-9
4.2.4	<i>Ellipticity Button.....</i>	4-10
4.2.5	<i>Centroid Button.....</i>	4-10
4.2.6	<i>Beam Wander Button.....</i>	4-10
4.2.7	<i>Gain and Power Button.....</i>	4-11
4.2.8	<i>Gaussian Fit Button.....</i>	4-12
4.2.9	<i>Head Status.....</i>	4-12
4.2.10	<i>2D View button.....</i>	4-13
4.2.11	<i>3D View Button.....</i>	4-13
4.2.12	<i>Beam Widths Buttons.....</i>	4-14
4.2.13	<i>Beam Profiles Area.....</i>	4-15
4.2.14	<i>Search.....</i>	4-17
4.3	PULL-DOWN MENUS - ADDITIONAL DETAILS.....	4-18
4.3.1	<i>Options Menu.....</i>	4-18
4.3.2	<i>Log Menu.....</i>	4-21
4.3.3	<i>Setup.....</i>	4-22
4.4	SLIT MODE.....	4-27
4.5	KNIFE-EDGE MODE.....	4-28
4.6	GAUSSIAN FIT ALGORITHM.....	4-29
4.6.1	<i>Gaussian Fit Algorithm.....</i>	4-299

4.1 THE MAIN SCREEN

Double-click on the BeamScope icon to open BeamScope. Below is the view of the Main Window of the BeamScope-P5 software. (From time to time there will be changes and additions to the software. However, the latest version will always be available from the DataRay website at www.dataray.com.)



The functions contained in the individual pull-down menus and the main screen sections are described on subsequent pages. *Note the keyboard alternatives to working with the mouse. They can be a much faster route to many useful screens and functions.*

4.1.1 Pull-Down Menus

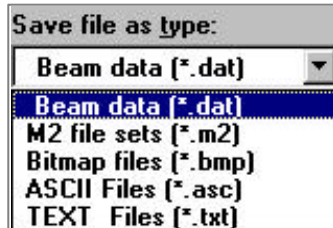
Do not simply read this section. Click on each function in turn so that it opens up and so that at least your subconscious becomes aware of and imprinted with the existence of these functions! Use and learn the keyboard shortcuts where provided. They are listed in Section 3.2.6, page 3-13 a few pages back. This will save you much time later.

File

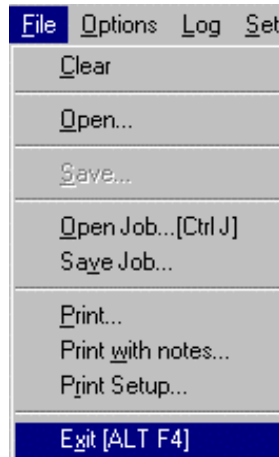
Clear Clears the screen and data buffers.

Open... Opens a saved data or M² file.

Save Saves current data, either active or recalled, in all, in part or as selected.



Data may be saved as a *.txt file, and then imported into an Excel spreadsheet by choosing **Delimited** with **Space** and **Comma** as delimiters.



Open Job...[CtrlJ] Recalls a previously saved Job file.

Save Job... Stores the current Job file parameters.

Print... Prints the current BeamScope-P5 screen, with the date.

Print with Notes... Prints the current BeamScope-P5 screen with the date and user supplied notes added.

Print Setup... Opens the printers setup dialog box.

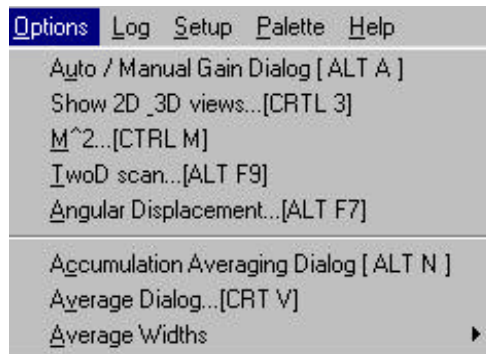
Exit [ALT F4] Terminates the BeamScope-P5 program.

4.1

Options

Auto / Manual Gain Dialog [Alt A]

Opens the **Auto / Manual Gain Dialog** box. Most users will never need to use this function. See section 4.3.1 for additional detail.



Show 2D_3D views...[CTRL 3]

Opens 2D and 3D representations of the current profile(s). **CTRL 3** toggles these 2D and 3D displays on and off.

M^2...[CTRL M]

Reconfigures the main window into the M^2 window. See Section 5.

TwoD scan...[ALT F9]

Reconfigures the main window into the **Two-D Scan window** for use in 2-D pinhole scans. See Section 6.

Angular Displacement...[ALT F7]

Opens the **Head Setup and Options** dialog box, to allow input of distance **z** from the source and angular unit setting for angular beamwidth measurements. See Section 4.3.1 for additional detail.

Accumulation Averaging Dialog [ALT N]

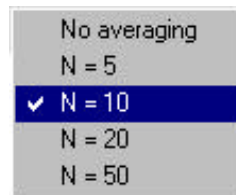
Opens the **Accumulation (Averaging)** dialog box. See Section 4.3.1.

Average Dialog...[CTRL V]

Opens the **Beam Widths Averaging** dialog box. See Section 4.3.1.

Average Widths

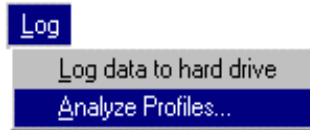
The user can select a simple rolling average of 1, 5, 10, 20 or 50 samples. After the maximum sample number is reached, the oldest readings are dropped from the average as new readings are added. See above and Sec. 4.3.1 for more complex averaging.



Log

Log data to hard drive:

Opens a dialog box that allows the user to create a log file which is updated at the user defined update interval (set in **Pass/Fail Setup**) while the system is operating.



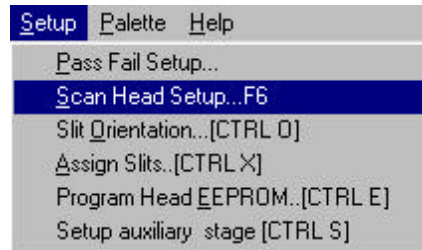
Analyze Profiles...

Opens an existing log file and generates measurement statistics.

Setup

Pass Fail Setup...

Opens a dialog box that allows the user to specify **PASS/FAIL** values for measured parameters. Pass/Fail will be indicated automatically by changing the on-screen color of the parameters.



Scan Head Setup...F6

F6 opens the **Head Setup and Options** dialog box that allows the user to set important head parameters such as the number and size of the slits/pinholes, gain limits, and other options. See Sec. 4.3.2.

Slit Orientation...[CTRL O]

Opens the **Slit Orientation** dialog box which allows the user to adjust for the mounting orientation of the head. See Section 4.3.2.

Assign Slits...[CTRL X]

Designates which slit corresponds to which axis. See Section 4.3.2.

Program Head EEPROM..[CTRL E]

Allows the user to reprogram the EEPROM in the head. There are almost no circumstances under which this is required. Contact DataRay before changing anything. See Section 4.3.3.

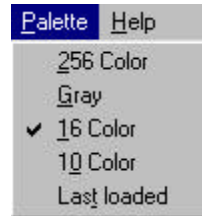
Setup auxiliary stage [CTRL S]

Allows choice between the two auxiliary stage motor drive defaults. Choose **default 2** unless specifically instructed to do otherwise.

4.1

Palette Lets you choose the number of displayed colors.

- Use **10 color** for 10% increments.
- Use **16 color** or **256 color** for more level resolution.
- Use **Gray** for black and white printing.
- Use **Last loaded** sets the palette to that of the most recently loaded file.



Help Opens the BeamScope-P5 “Help” system, which is essentially an online version of the BeamScope-P5 manual. (The latest revision may be this printed manual rather than the program’s Help file)

4.1.2 The Button Bar

The Buttons are an extension to the Menu System. They are all activated by clicking with the mouse.



Clears screen data and data buffers.



Recalls previously saved profile data or M2 data sets.



Initiates the save data procedure, which allows you to save one highlighted profile, or all current profiles.



Sets the BeamScope-P5 to display profile ‘X’ from Aperture 1. **X** is the keyboard shortcut.



Sets the BeamScope-P5 to display profile ‘Y’ from Aperture 2. **Y** is the keyboard shortcut.



Sets the BeamScope-P5 to display scans ‘X’ and ‘Y’ from Apertures 1 and 2. **B** (for Both) is the keyboard shortcut.



Causes the BeamScope-P5 to start scanning.
F1 is the keyboard shortcut.



Causes the BeamScope-P5 to stop scanning.
F2 is the keyboard shortcut.



Causes the BeamScope-P5 to perform a single scan.
F3 is the keyboard shortcut.



Causes the BeamScope-P5 to perform a search scan operation.
F4 is the keyboard shortcut.



Sets the BeamScope probe at the X profile centroid. You may aim your beam at this lit to set up the approximate alignment. **F7** is the keyboard shortcut.



Fully extends the BeamScope probe head to allow simple access to change the aperture plate.



When clicked, steps the data to the previous profile in the data buffer.
Page Down is the keyboard shortcut.



When clicked, steps the data to the next profile in the data buffer.
Page Up is the keyboard shortcut.



If activated opens profile selection dialog box.



If activated, reverts to active data.



If activated, reverts to recalled data.



Prints the current screen without user supplied notes.



Prints the current screen with user supplied notes.



Screen dump to clipboard. [Image does not include the Button Bar, Menu and Page Header above, or the Help Notes and Task Bar below.]



Opens the Help system. This manual is frequently the better reference.

4.2 MAIN SCREEN SECTIONS

*If you read nothing else, read section 4.2.14 on the **Search** function.*

Before introducing sections of the main screen (top to bottom and left to right) in section 4.2.4, sections 4.2.1 to 4.2.3 address issues common to all sections of the screen.

4.2.1 Pass/Fail for QA and Production Testing

BeamScope makes it simple to test measured parameters against a preset level, and to display this fact in real time. Pass/Fail can be set for all displayed parameters, making BeamScope an ideal tool for use by less technical staff in QA and Production Test.

Enter **Alt S, P** to access the **Pass – Fail Parameter Setup** dialog box.

Beam Width Parameters			
	Minimum	Maximum	test
Ap1 @13.5%	15.00	25.00	<input type="checkbox"/>
Ap1 @13.5%	15.00	25.00	<input type="checkbox"/>
Ap2 @13.5%	15.00	25.00	<input type="checkbox"/>
Ap2 @13.5%	15.00	25.00	<input type="checkbox"/>

Gaussian Fit Parameters			
	Minimum	Maximum	test
Ap1 Gauss. Fit	80.0%	100.0%	<input checked="" type="checkbox"/>
Ap2 Gauss. Fit	80.0%	100.0%	<input checked="" type="checkbox"/>
Mean Fit	0.0%	100.0%	<input type="checkbox"/>

TopHat Parameters			
	Minimum	Maximum	test
Ap1 TopHat	0.0%	100.0%	<input type="checkbox"/>
Ap2 TopHat	0.0%	100.0%	<input type="checkbox"/>
TopHat Mean	0.0%	100.0%	<input type="checkbox"/>

BeamScope-P5 (c) 1996 DataRay Inc.			
	Minimum	Maximum	test
Ellipticity	0.9	1.0	<input checked="" type="checkbox"/>
Centroid X offset absolute.	1000.00		<input checked="" type="checkbox"/>
Centroid Y offset absolute.	1000.00		<input checked="" type="checkbox"/>
Password			<input type="checkbox"/> Lock
Update Interval	0.00		Seconds

Yes
 Show as percentages
 Display Form:
 1234 um
 Show as factors
 1.23 mm
 1.234 mm
 No

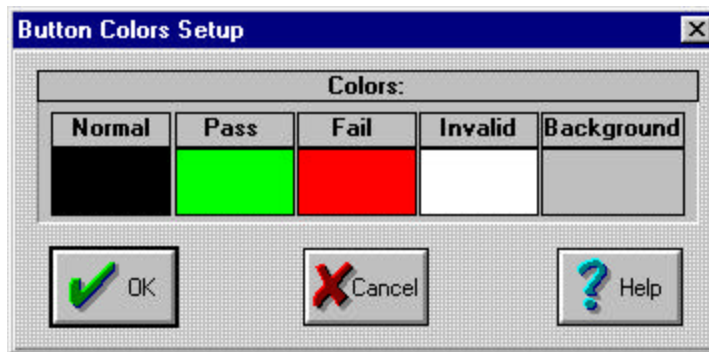
In most cases you will want to work at:

Show as percentages
 Display Form:
 1234 um

Select the parameters which you wish to test, enter the **Minimum** and **Maximum** values and click to enable the appropriate **test** boxes. Once you have selected the required parameters for pass/fail testing, click **Yes**. When you resume profiling, values will display in Green for Pass, Red for Fail and White for Invalid, unless you have changed them, Section 4.2.2 below.

4.2.2 Button Colors Setup.

Normally, the values are shown in black on a gray background, turning to a white value if the software deems the value 'Invalid'. If the value is Tested, it will print in the **Pass** or **Fail** color.



The **Normal**, **Pass**, **Fail**, **Invalid** and **Background** colors can be customized by the user by right-clicking the screen area. Then select the desired text and button colors.

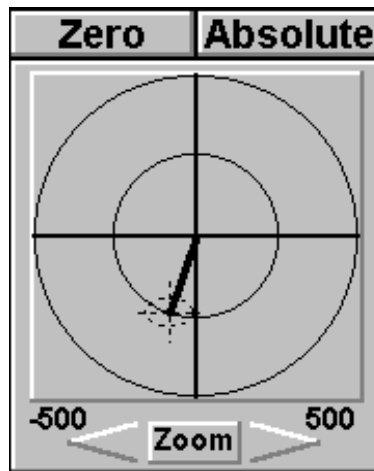
To choose a button color other than the defaults, click on the color patch and a **Color** dialog box appears, offering 48 **Basic colors** and an almost infinite variety of **Custom colors**. *It is strongly suggested that you stick to the default colors or the **Basic colors**, and avoid multi-hued and hence confusing screen layouts. In particular do not change the background color to a (default or chosen) color used to display values.*

4.2.3 'Button' Areas and Help Hints

All areas of the BeamScope-P5 screen having a 3-D beveled edge appearance, or that display data, may also be Windows 'buttons' and may be activated by clicking the left, right or both mouse buttons.

As the cursor passes over such button areas, a **Help** hint is presented at the bottom of the screen. (A high percentage of questions are answered by this on-screen Help Hint information.)

For example, the Beam Wander button area shown actually contains five distinct buttons: **Zero**, **Absolute**, **Zoom In**, **Zoom Out** and a general button in the Beam Wander area. User parameters may be set in a secondary dialog box, which may be opened by clicking on the Beam Wander button area. (See section 4.2.6 over the page.)

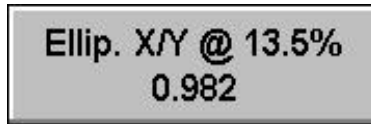


4.2

4.2.4 Ellipticity Button

Ellipticity is defined as the deviation of an ellipse or from the form of a circle or a sphere.

As it relates to BeamScope, Ellipticity is the ratio of the chosen diameter measure (Clip Level, Variance or Knife Edge) as measured by aperture 1 and aperture 2.



4.2.5 Centroid Button

The calculated **X Centroid Y** (center of 'mass') of the current profile is referenced to the **Absolute** point 0, 0 (units μm) ~10 mm out from the point at which probe exits the head, or to the user defined zero point, set by pressing the **Zero** button.



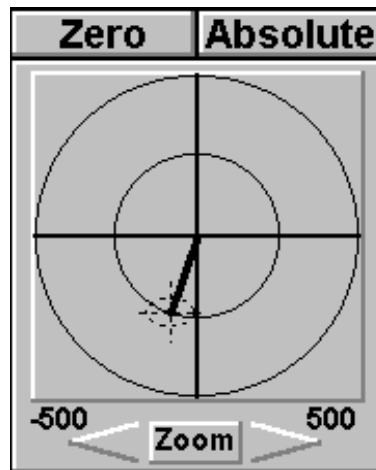
The initial values shown indicate the position of the centroid along the scan axis. The user would normally then click the Zero button in order to determine centroid position relative to some reference starting point. this reference could be a reference laser beam or the initial position of the beam under investigation. It is also possible to enter zero position numbers in the Wander Setup Information dialog box. See the next page.

4.2.6 Beam Wander Button

A position vector is traced from the center of the display to the dashed crosshair which indicates the beam center. The dashed ellipse indicates the 13.5% intensity profile of the beam.

If **Auto-Scale On** box is checked (see below) the arrow zoom is disabled, then clicking on the arrows either side of **Zoom** changes the displayed area.

At any point in time, the user can press the **Zero** button to set the most recent beam position, as calculated by the BeamScope software as zero. This current reference point will be used in subsequent Centroid and Beam Wander results.

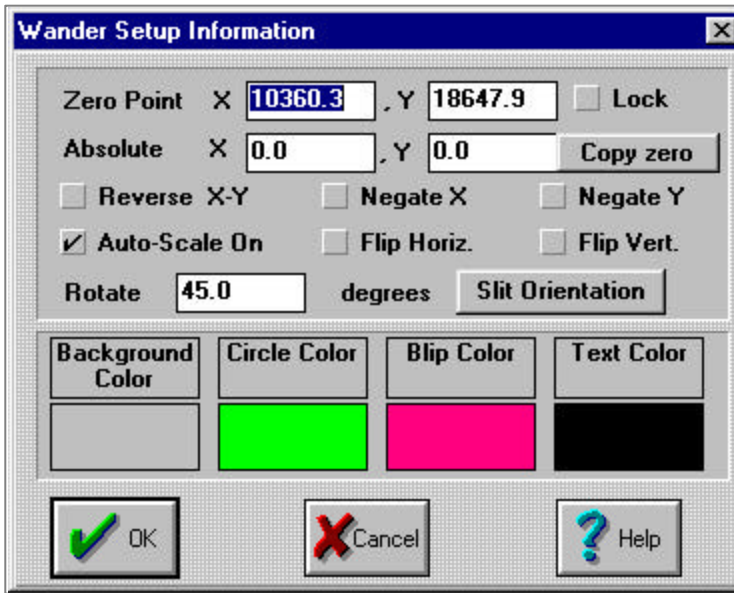


The Beam Wander button area contains five distinct buttons: **Zero**, **Absolute**, **Zoom In**, **Zoom Out**

and a general button in the Beam Wander area. Click on this area to open the **Wander Setup Information** dialog box and set parameters. The screen shown indicates typical settings, including **Auto-Scale On**.

Values for a zero or an absolute reference position may be entered in the **Zero Point** & **Absolute** boxes. **Absolute** point 0, 0 (units μm) is 10 mm out from the point at which probe exits the head.

Check the **Lock** box to prevent resetting of the zero. **Copy zero** copies the **Zero Point** settings into the **Absolute** settings.



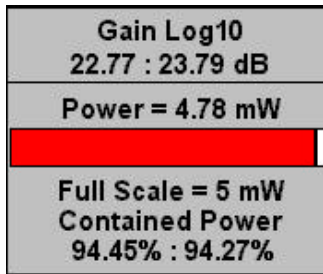
4.2

The **Reverse X-Y**, **Negate X**, etc. check boxes allow the user to change the orientation of the position vector in the beam wander display. It is used with particular

Circle Color **bright green** and **Blip Color** **rose** gives a better looking display.

4.2.7 Gain and Power Button

Gain is the amount of amplification, both electrical *and software* derived, required to display the profile, the default being in *normalized* form. This gain is expressed in dB ($10 \cdot \log_{10}$ of the linear value of the gain). In many instances it can be helpful to turn off the software normalization. To do this press **F6** and uncheck the **Normalize Profiles** box in the upper right of the dialog box. The user can set manual gain if so desired. Press **Alt A** to open the dialog box.



As it relates to the BeamScope **Power** is a purely relative measurement based entirely on the user's input, which is assumed to be correct.

Use a separate calibrated optical power meter to determine the total beam power, then enter that power by clicking on the **Power** area to open the **Power Calibrate Dialog** and entering a value and unit (e.g. **4.78 & mW**). The BeamScope-P5 software will monitor any subsequent changes in power even if the beam diameter varies. *However, no claim is made or implied that the BeamScope-P5 is a calibrated and/or reliable power meter.*

The **Contained Power** is the power within the limits defined by the Clip Level shown in the lower center of the **Beam Widths** area. If Variance (**@var.**) is chosen, the clip level is automatically set at 13.5%.

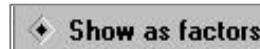
Note that the contained power percentage within any limits may be measured on the beam profile display area by clicking and dragging the mouse across the screen. See sec. 4.2.13.

4.2.8 Gaussian Fit Button

A laser beam operating in the TEM₀₀ mode has a 'Gaussian' profile, and many more complex beams have profiles close to Gaussian.



Gaussian Fit is the calculated agreement (best fit) expressed as a fraction or as a percentage of an ideal Gaussian beam. For information on the calculation of Gaussian Fit percentage function, refer to the **Gaussian Fit Calculation**, Section 4.6 of this manual. Click on the button area in order to toggle between enabled and disabled Gaussian Fit. To change from % to fraction, enter **Alt S, P** to access the **Pass – Fail Parameter Setup** dialog box and choose:



4.2.9 Head Status

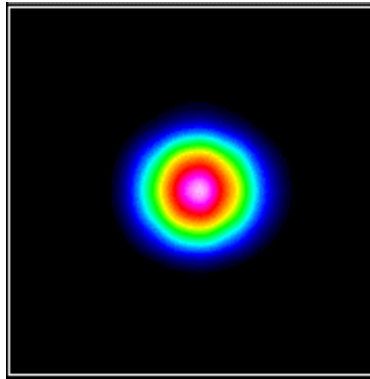
This is only used to indicate the operating status of the BeamScope scan head and has no other function.



4.2.10 2D View button

This area is used to display a derived 2D plan view interpretation of the beam profiles. It is meant to be used as visualization tool.

The algorithm assumes that the measured X profile is the same for all values of Y, and that the measured Y profile is the same for all values of X, since this is the only reasonable reconstruction of the information contained in two orthogonal scans. (If only X or Y has been scanned the software assumes the X & Y profiles to be the same, and generates a pseudo-reconstruction with 2D symmetry.)



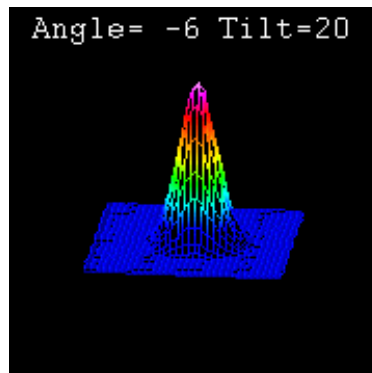
Click and drag anywhere in the 2D display area to generate a yellow bordered zoom box that defines a zoomed region of the displayed profile widths and of the 3-D scan. The zoomed 3D scan dimension will correspond to the long side of the zoom box. Click again to cancel this zoomed region. The zoomed-in region is also cancelled whenever a new scan is started.

Double-click on the 2D area, to alternately swap the 2D view with the larger area normally occupied by the 1D profiles.

4.2.11 3D View Button

This area is used to display a derived 3D view interpretation of the beam profiles. It is meant to be used as visualization tool.

The algorithm assumes that the measured X profile is the same for all values of Y, and that the measured Y profile is the same for all values of X, since this is the only reasonable reconstruction of the information contained in two orthogonal scans. (If only X or Y has been scanned the software assumes the X & Y profiles to be the same, and generates a pseudo-reconstruction with 2D symmetry.)

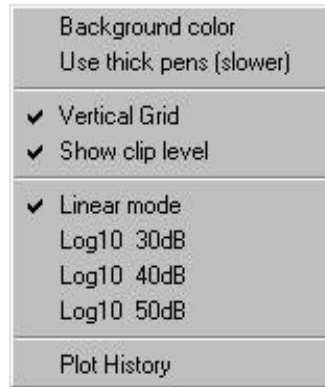


To set the view angle and tilt, press and hold down the left button of the mouse while the cursor is on the 3D area and move the cursor. Left-right cursor motion rotates the 3D display about a vertical (intensity) axis. Up-down motion changes the tilt angle.

4.2

Right-click on the 3D area to open a floating menu that allows various display options to be selected. Since the **3D Auto Rotate** option consumes PC processor power, it is recommended that this display option be turned off when taking data.

Double clicking on the 3D area to alternately swap the 3D view with the larger area normally occupied by the 1D profiles.



4.2.12 Beam Widths Buttons

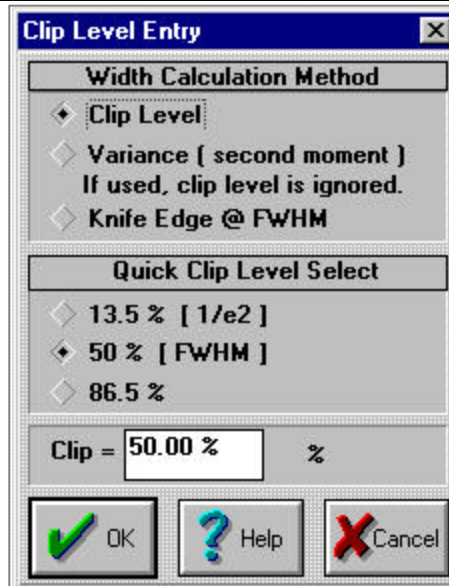
This set of seven button areas controls the display of the beam diameters and their corresponding clip levels. Right-click on any of the buttons to set custom display colors.

Beam Widths		
0.164 mm	@13.5%Clip	0.167 mm
0.164 mm	@13.5%Clip	0.167 mm

The two center Clip Level buttons open the **Clip Level Entry** dialog box allowing the user to set a desired clip level or select the use of the Variance beam diameter. (Also known as Second moment or 4σ width, see page A-11) Note that two distinct clip levels and/or methods can be set concurrently in the upper and lower levels.

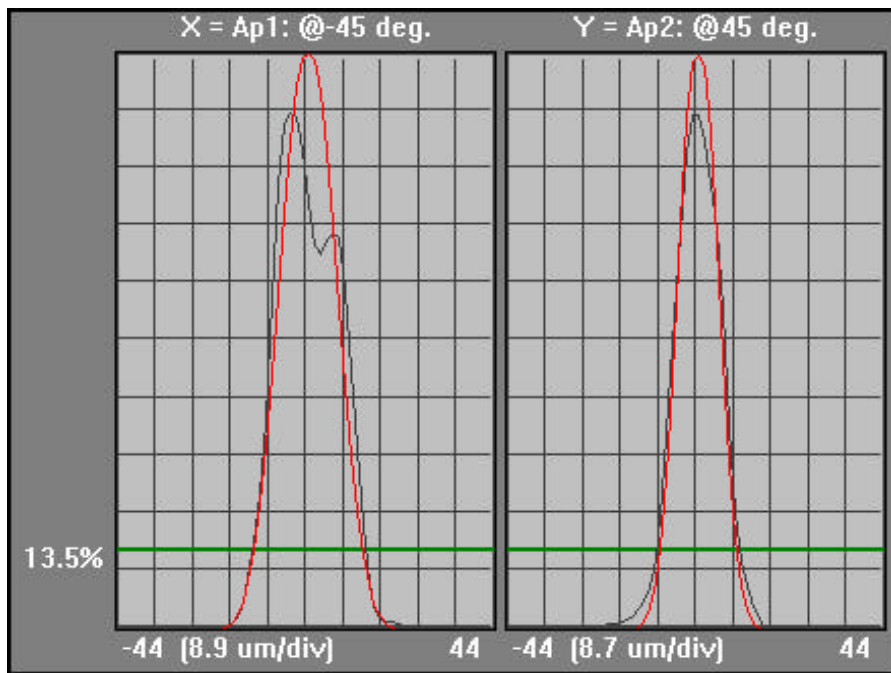
The outer set of buttons displays the calculated beam diameters in microns (μm), or millimeters (mm), as selected in the **Pass – Fail Parameter Setup** dialog box. The beam diameters on the left corresponds to aperture 1 profiles (normally designated X) and the right to aperture 2 (normally designated Y).

A bracketed number e.g. **[10]** following the width reading indicates that it is being averaged. See Page 4-4.



4.2.13 Beam Profiles Area

This is the area used to display the actual profiles.

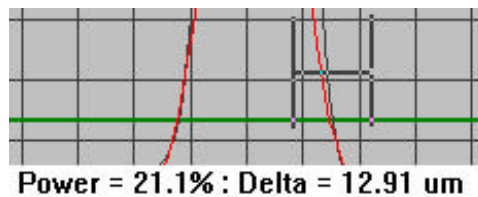


4.2

For clarity, the above image is shown with display parameters set to their default settings. The vertical axis gridlines are displayed (in linear mode) at 10% intervals. The X axis is labeled in microns.

- The measured profile is shown in black. The fitted Gaussian profile is shown in red.
- *The relative heights of the measured and Gaussian profiles is determined by equalizing the areas under the measured profile and the Gaussian profile, and then setting the taller profile to 100%.*
- To normalize both profiles to 100%, press **F6** and disable **Auto Gauss Peak**.
- The clip levels are shown in green and labelled in white.

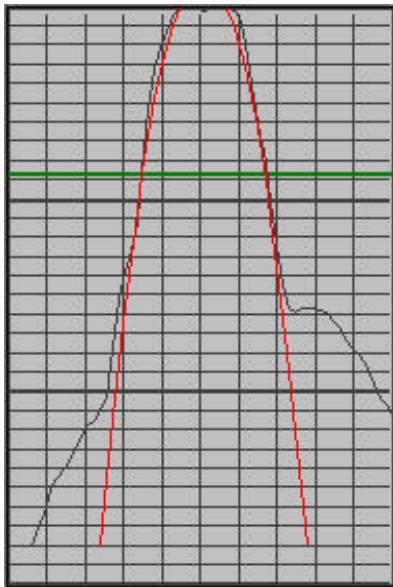
Pressing **X** or **Y** on the keyboard will cause the program to display only that profile. Pressing **B** will cause the program to show both profiles side-by-side. **Ctrl 3** toggles between a wider profile display and the 2D and 3D displays.



BeamScope Functions

Click and drag the cursor from one point to another on a profile to show the lateral distance between the points and the percent of total power between the points. This is useful in measuring beam features.

You may display the profile(s) in a logarithmic form by right-clicking in the plot area and selecting one of the log ranges. This is especially useful for viewing the noise floor or the (normally hidden) low intensity structure in the wings.



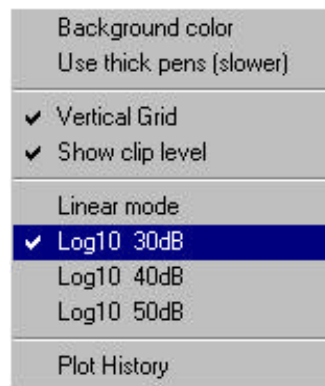
In such instances it may also be useful to press **F6**, disable **Auto Search**, and manually set the scan range wider than that set by **Auto Search**.

The plot options box also gives access to the background color and vertical grid commands, and to sometimes useful functions such as:

Use thick pens [slower] to give more visible profiles at the expense of processing speed.

Plot history superimposes successive profile plots, useful for indicating the level of noise in noisy lasers, or, e.g., to show the envelope of the profile change as a laser warms up.

See Section 4.3.1 for a discussion of **Accumulation Averaging** which produces an averaged profile, useful for averaging noisy profiles.



4.2.14 Search

*It is **CRITICALLY** important that you properly understand this section. Read it at least twice.*



In Search mode, the probe determines the location of the beam to be scanned.

- 1) Click **Aim** to move the probe out, and aim the beam at a point on the probe 10 mm out from the head. Then Press **F4** to instruct the probe head to search for the beam.

TIP. To align the beam with the slits, Press **F5** to perform repetitive searches, then **F2** to stop the search once successfully aligned as defined in 2) through 5) below.

- 2) *When a Search has been performed, inspect the search display, (reproduced above) and verify that the scan regions found by the search routine make sense.*

The X slit (**Ap1**) and Y slit (**Ap2**) scan regions are indicated as dark gray regions marked **1** and **2**. The width of this plot is the 34 mm long physical scan of the probe.

*With dual slits, after a search is performed there should always be two distinctly separated peaks displayed. That is, there should always be a horizontal distance between the right-hand edge of the **1** region and the left-hand edge of the **2** region. The scan regions should never overlap along the horizontal axis.*

- 3) It is possible for the Auto-Search function to mistakenly place the X and Y scan areas at the same location, which may or may not be desirable. Sometimes the software will allocate **Ap3** and **Ap4**. The user must overwrite this as follows:

- Click and drag to move a scan region manually to the desired scan region.
- Define a new scan region by placing the cursor outside the gray region and clicking and dragging a new region with the mouse. When the mouse button is released a menu will appear asking to which aperture the defined region should be allocated. In the current release, only allocate **Ap1** or **Ap2** to scan regions.



Warning: To ensure valid results, the entire profile must be within the scanned area.

- 4) Double click on the lower part of the search area to cycle the size of the search display from normal to large to minimum and back to normal.

4.2

4.3 PULL-DOWN MENUS - ADDITIONAL DETAILS

4.3.1 Options Menu

Auto / Manual Gain Dialog [ALT A]

Gain is the amount of amplification, both electrical *and software* derived, required to display the profile, the default display mode being *normalized* form. This gain is expressed in dB ($10 \cdot \log_{10}$ of the linear value of the gain).

Auto Gain (normal) is the default selection.

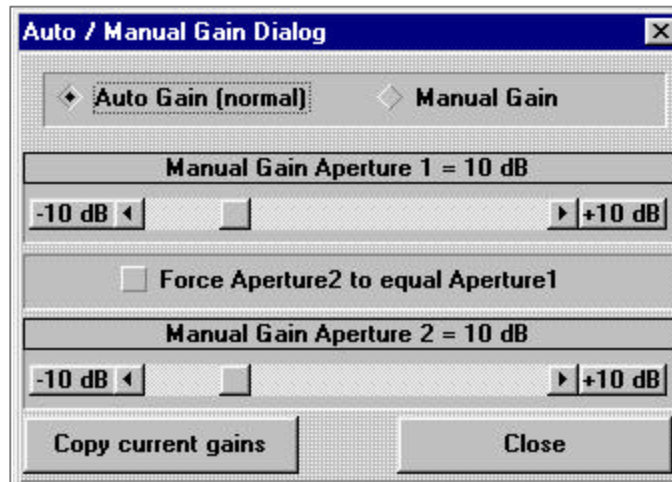
Manual Gain allows the user to set the gain in the slide boxes and keep it constant.

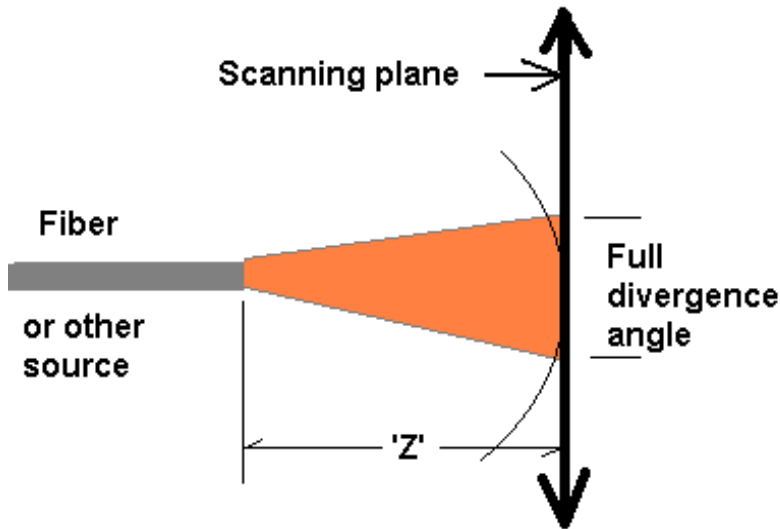
- If the gain is set too low the profile will not normalize on the display.
- If the gain is set too high the profile will saturate and the results will be in error.

Force Aperture2 to equal Aperture1 does precisely that. Note that for a highly elliptical beam it does not make sense to do this.

Copy current gains does exactly that. It copies the current gains to the sliders and allows these to be set as manual gains.

In many instances it can be helpful to turn off the software normalization. To do this press **F6** and uncheck the **Normalize Profiles** box in the upper right of the dialog box. The user can set manual gain if so desired. Press **Alt A** to open the dialog box.





4.3

Angular Displacement...[ALT F7]

Angular Displacement is calculated by the BeamScope-P5 software using the known, user entered distance 'Z' between the source and desired clip level.

The clip level refers to the percentage of intensity at which the angle is defined as the beam is diverging. Since the BeamScope scans in a linear motion, the linear scan data is adjusted by an appropriate algorithm to simulate a scan along an arc having its origin at the source. BeamScope calculates and displays the Full Divergence Angle.

Press **Alt F7** to toggle the results displayed in the **Beam Widths** portion of the main screen between normal and angular displacement.

Beam Widths		
50.49e-3 rad	@13.5%Clip	52.53e-3 rad
50.49e-3 rad	@13.5%Clip	52.53e-3 rad

To change Z, press **F6** to open the **Head Setup and Options** dialog box. Look at the lower left area of the box. (If Z was set at zero, the box will open automatically.)

Divergence Angle 'Z' distance	
'Z' Distance	<input type="text" value="1.2340"/> mm
<input type="radio"/> Degrees <input checked="" type="radio"/> Radians <input type="radio"/> N.A.	

Enter the **Z** value in mm.

Select **Degrees**, **Radians** or **N.A.** [**N.A.** = Numerical Aperture = Sin(half angle)].

Accumulation Averaging Dialog [ALT N]

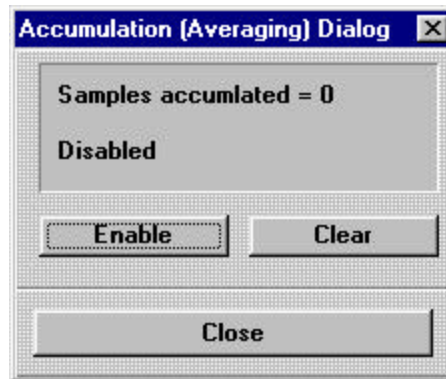
Opens the **Accumulation (Averaging) Dialog** box. (See page 44 for a running average). During Accumulation the gain is locked.

Click on **Enable** to start accumulating an averaged profile, with no limit on the number of samples 'n' which are averaged. The displayed profile and beamwidths are the average of the n accumulated samples.

The profile buffer holds the nth, (n-1)th, (n-2)th, etc. averaged profiles up to the buffer limit of 100 profiles. It does not hold the raw profiles.

Click **Disable** to stop **Accumulation Averaging**.

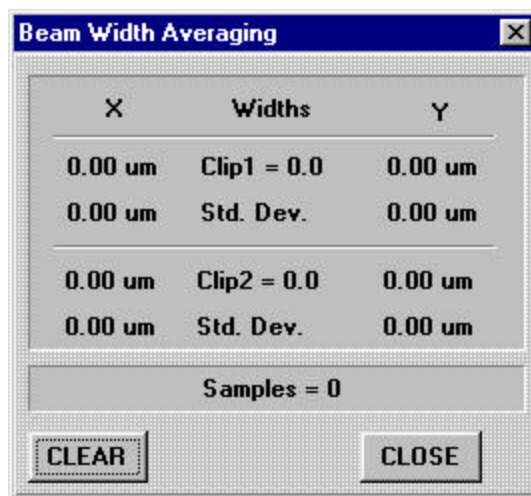
Click **Clear** to clear the buffer location.



Average Dialog...[CTRL V]

Opens the **Beam Width Averaging** dialog box. this is similar to the Accumulation Averaging, but includes calculation of the Standard Error in the Mean. (See page 4-4 for a running average)

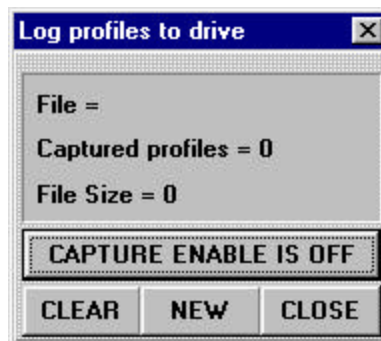
(See also Section 4.3.2 **Log Menu**. The Max., Min., Mean and Standard Deviation of Beam Diameter, Centroid Position and Power are calculated and displayed on graphs of the logged data.)



4.3.2 Log Menu

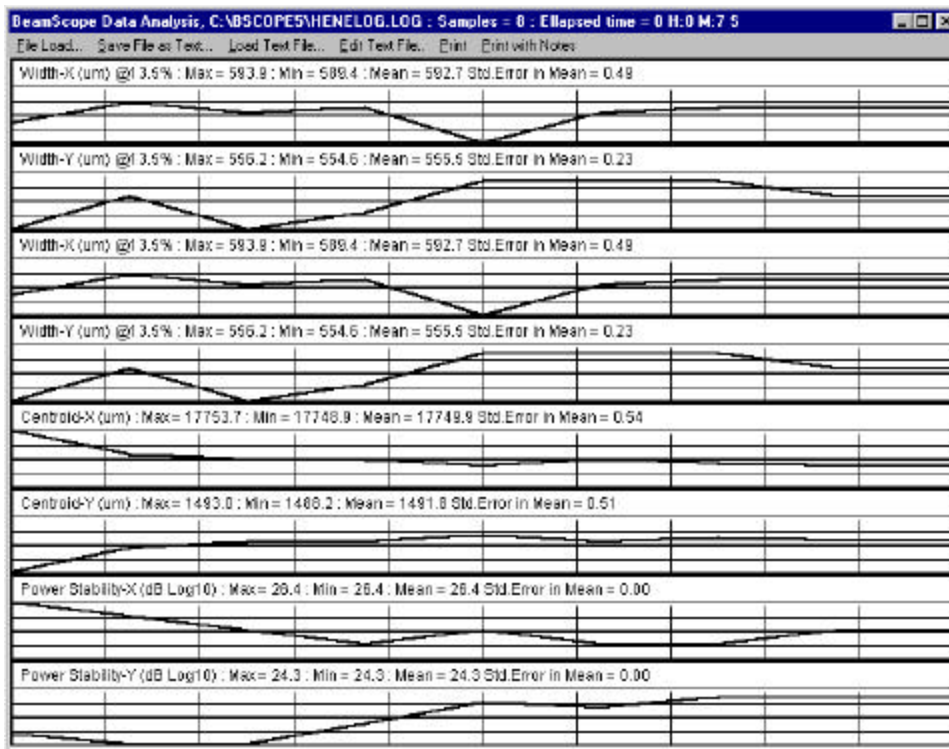
Log Data to Hard Drive

[First set the **Update Interval**, password protected if you so choose, in the Pass/Fail dialog box, Section 4.2.1.] Click on **CAPTURE ENABLE IS OFF** or **NEW** to open a **Save As** dialog box which allows you specify a filename and location. Click **OK**. The button will change to **CAPTURE ENABLE IS ON**. Enter **F1** to start the scans & data logging. **F2** stops the scans.



Analyze Profiles...

Click on **Analyze profiles...** to open a **BeamScope Data Analysis** window. Click on **File Load** to **Open** a logged data file. Examine the logged profiles and statistical data including the mean and its standard error. Below is an example of the whole screen display. Note the **Save, Load, Edit** and **Print** options, allowing export to reports.

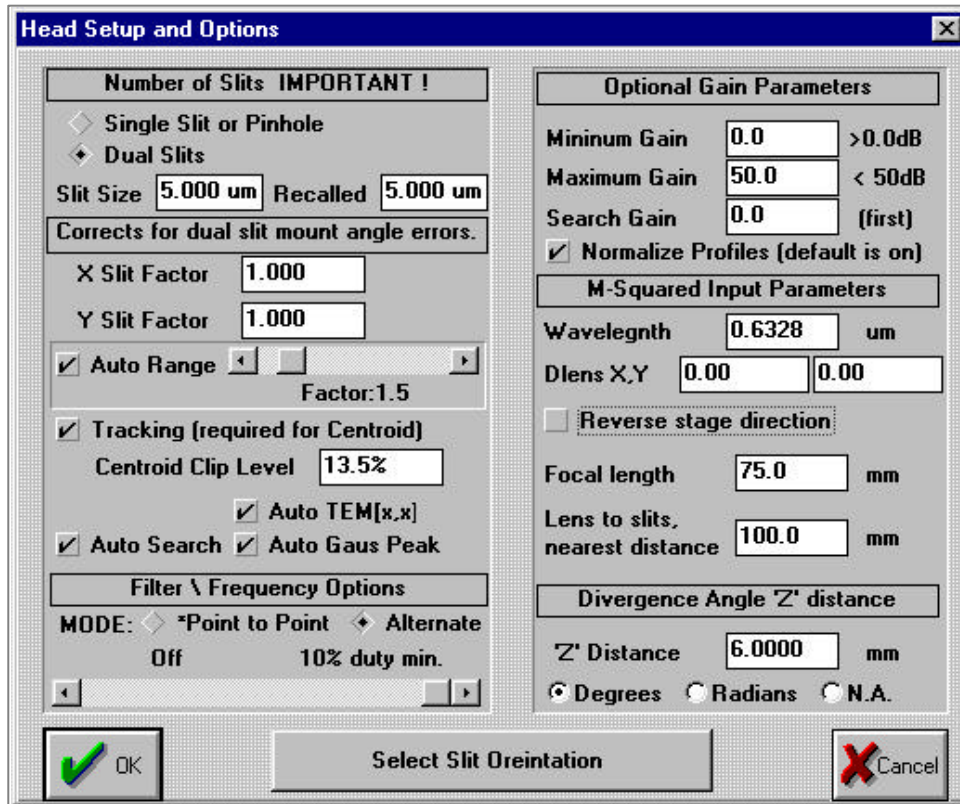


4.3

4.3.3 Setup

Scan Head Setup...F6

The **Head Setup and Options** dialog box is shown below. Going down the left hand side column.



- ❑ **Number of Slits.** Click in the appropriate diamond to choose the appropriate slit or pinhole type. Enter the **Slit Size** in microns. The **Recalled** box shows the slit dimension for the most recently recalled data file.
- ❑ **X Slit Factor** and **Y Slit Factor.** A cosine correction factor for misaligned slits (an occasional issue on older P3 models). Normally leave these factors at 1.000.
- ❑ **Auto Range.** Normally leave this box checked and the slider set at the default position of 1.3 . Slide the slider to the right to increase the scan range over that

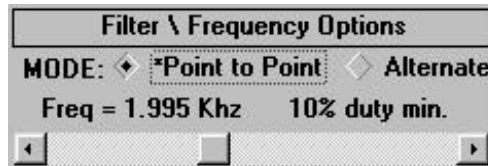
determined by the software to be adequate. Unchecking the box reverts to a user set scan range, see section 4.2.14.

- ❑ **Tracking.** Leave this box checked if you want the software to track the centroid and to continuously reset the scan range about the centroid.
- ❑ **Centroid Clip Level.** Leave this at **13.5%** unless you have a good reason to select otherwise. ‘A good reason’ might be significant structure in the wings that went above the 13.5% level. To ignore this structure set the **Clip Level** appropriately higher.
- ❑ **Auto TEM[x,x].** Normally this box is unchecked. However, if the laser is not close to a Gaussian TEM₀₀, but has dips within the profile that go below the clip level set under **Beam Widths**, check this box to tell the software to find the outer dimension of the beam and to ignore inner structure that takes the profile below the clip level.

For example, a TEM₁₀ beam is double-peaked and has a central intensity that falls close to zero. If the **TEM[x,x]** box were left unchecked, the measured beam diameter would be only approximately half the actual diameter. It will also fit the appropriate TEM profile to the beam.

- ❑ **Auto Search.** Normally this box is left checked, telling the software to continually reassess the optimum scan range for the beam, and to search for the beam if it moves out of range. Uncheck the box if you wish to leave the scan range at that set up during **Search**, Section 4.2.14 .
- ❑ **Auto Gauss Peak.** Normally this box is left checked. See Section 4.2.13 for a more detailed explanation of the function. *The relative heights of the measured and Gaussian profiles is determined by equalizing the areas under the measured profile and the Gaussian profile, and then setting the taller profile to 100%.* To normalize both profiles to 100%, disable **Auto Gauss Peak**.
- ❑ **Filter \ Frequency Options.** This function is useful for Pulsed Lasers and Modulated Sources. For CW lasers *normally* leave the slider at the extreme right in order to leave this function **Off**.

Pulsed lasers. (Note that the duty cycle of any pulsed laser must be at least 10%, with a repetition rate of μ 300 Hz, preferably >500 Hz.). Using a pulsed laser at a high repetition rate leads to a ‘comb’ of samples.



- Click and drag the slider to set **Freq = X.XXX KHz** , closely equal to the laser pulse repetition rate, and hence a sample interval equal to **1/Freq** .

BeamScope Functions

- If the peak height of the pulses is constant and the peaks represents the profile envelope, then check ***Point to Point** to 'connect the dots'.
- If the average energy of the pulses over the sample period is constant, check **Mode: Alternate** to average the signal over the sample period

Modulated sources.

Move the slider to the left to set a *rejection* filter centered at the frequency shown.

E.g. For the rejection of line frequency harmonics in the source or background (e.g. twice line frequency from an incandescent lamp).

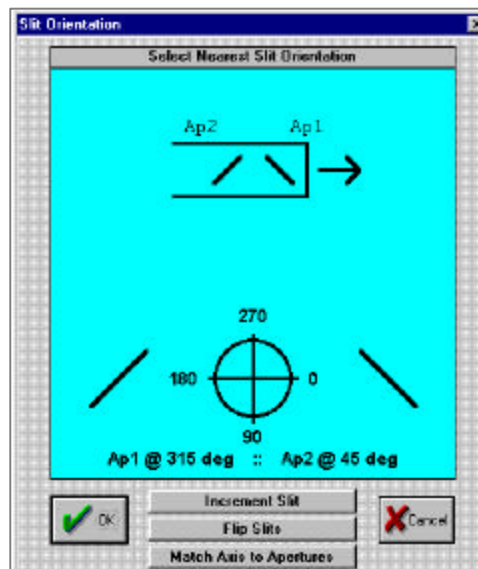
Important: With pulsed lasers, in order to avoid EMI (ElectroMagnetic Interference), it is frequently necessary to use the BSCABS/3.0 or /4.5 shielded cable. See page 2-2.

- ❑ **Optional Gain Parameters.** This is normally set as shown. See Section 4.2.7 for a more detailed description.
- ❑ **M-squared Input Parameters.** Only relevant when using the M² Accessory. See Chapter 5.
- ❑ **Divergence Angle 'Z' distance.** See Section 4.3.1.

Slit Orientation...[CTRL O]

This box sets the slit orientation. As shown is the normal orientation.

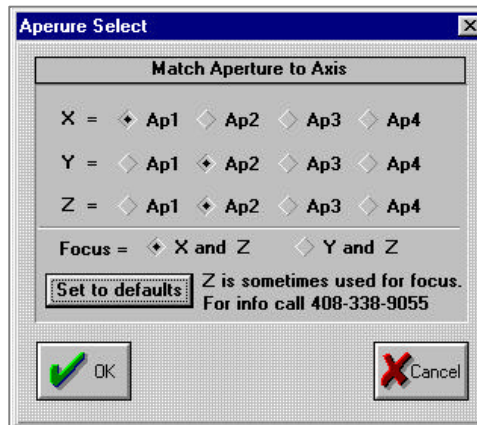
- ❑ Click on **Increment Slit** to increment the slit orientation in 45° steps.
- ❑ Click on **Flip Slits** to flip the slits as illustrated to a mirror image. If the slit orientation is set wrong, the Y centroid will display in the wrong sense.



- ❑ Click on **Match Axis to Apertures** to open the **Aperture Select** dialog box shown left. The checked boxes should be as shown.

For current releases of the software ignore **Z**, **Ap3**, **Ap4** & **Set to defaults**, which are hangovers from earlier versions

ASSIGN SLITS...[CTRL X] also takes you to this box.



4.3

Program Head EEPROM...[CTRL E]

As previously mentioned, there are almost no circumstances in which you will need to program the head, except ...

Maximum Speed. 6 typ. Greater than 6 is slower!

Software version 5.3A changed this default to **15**. If the head is inadequately mounted, head vibration may affect the measurement of profiles particularly small ones. The affected profiles appear to have multiple shoulders on the profile. As a last resort, set this value much higher, e.g. to **100**, to drastically slow the head, and click **OK**. If the structure remains it is almost certainly real.

The screenshot shows a dialog box titled "EEPROM_DATA" with a close button (X) in the top right corner. The header text reads "Header = 'BeamScope P5 : (C) 1996 DataRay Inc.'" Below the header, there are several configuration parameters, each with a text input field and a data type label:

Parameter	Value	Type
Serial Number 9 digits =	[Empty]	string
Adc Bits, 12 is normal =	12	integer
Motor step size, 187 typical	187.0	nanometers
Maximum travel, 32.5 typical	33.0	millimeters
Minimum travel, 120 typical	120	microns
Speed Factor, 50 typical =	50	integer
Maximum Speed, 6 typ, Greater than 6 is slower!	15	integer
Min Adc Rate, 54 typ. Greater than 54 is slower!	54	integer
Detector type.	Silicon-UV	string
Head type.	1	integer [CO2 = 3]

At the bottom of the dialog box, there are two buttons: "OK" (with a green checkmark icon) and "Cancel" (with a red X icon).

4.4 SLIT MODE

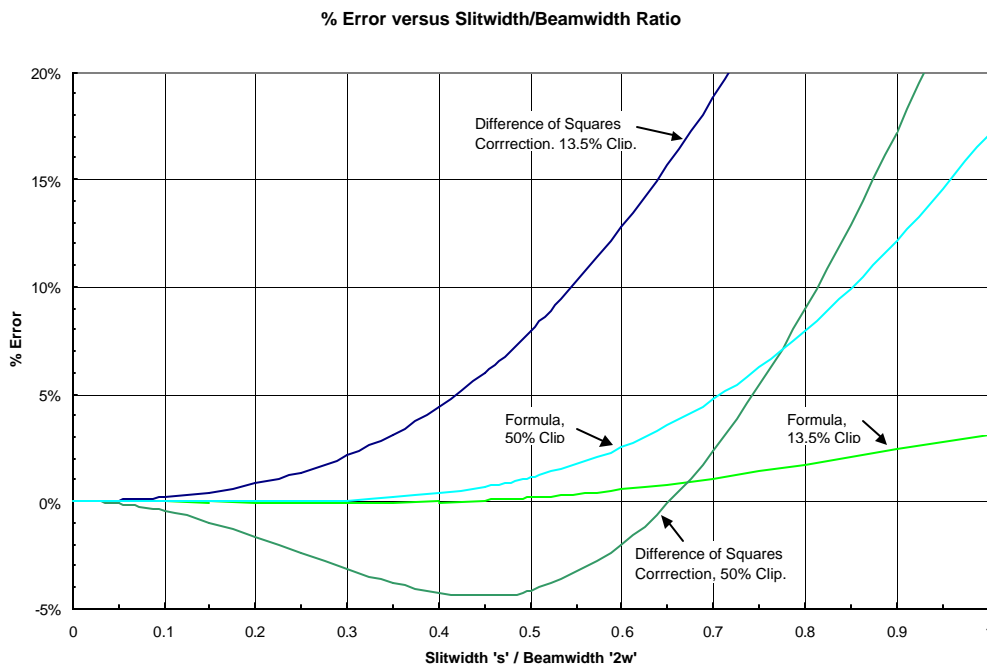
This is the 'normal' mode of operation for the BeamScope.

A slit narrower than the beam diameter is employed to measure the beam diameter. The slit should be *at least a factor of three smaller* than the beam being measured. To strictly meet the ISO 11146 standard use a ratio of 1:20 for slit width:beam width and 2 for slit height:beam width. In addition the average of five beams should be taken.

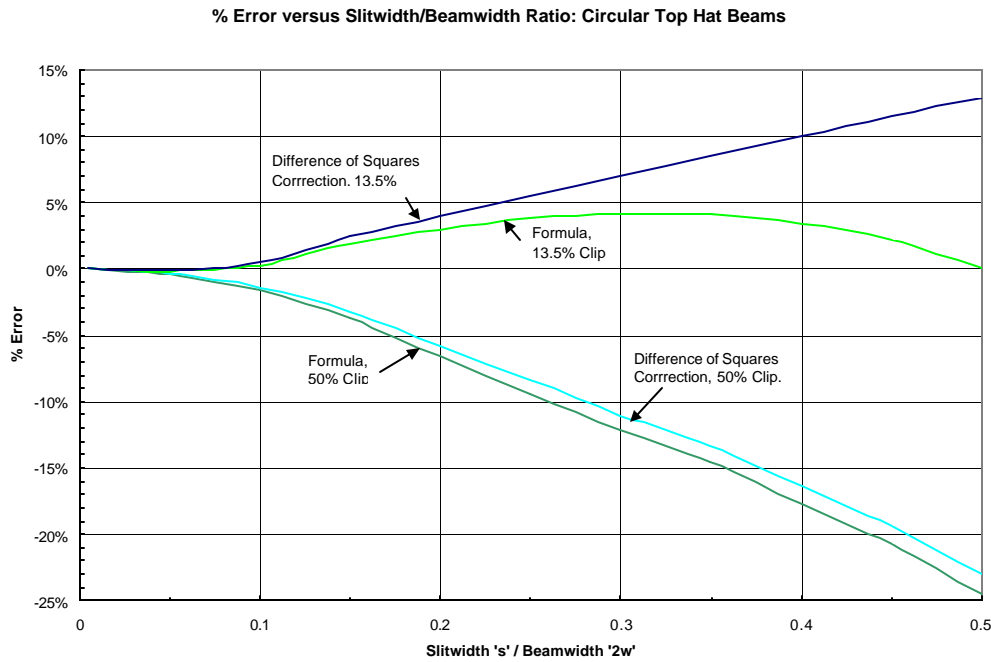
When the slits are set in their normal mode at $\pm 45^\circ$ to the probe scan direction, the software automatically multiplies the width of X,Y slits entered under **Slit Size** in **Head Setup and Options** by a factor of $\oplus 2$

When the slit width approaches the beam diameter, software correction should be made for the slit width. DataRay automatically compensates the diameter readings for slit diameter. If this is not done, the error is nearly 5% for Gaussian beams when the slit width to beam diameter ($s/2w$) is 25% of the $1/e^2$ beam diameter. A simple correction (difference of squares) for slit width reduces this error to 1.35%. DataRay's algorithm reduces the error to $<0.1\%$, and to $\sim 1\%$ at $(s/2w)$ ratios as high as 0.70.

4.4



This compensation has been modeled as the movement of a slit across two-dimensional Gaussian beams and ‘top-hat’ distributions. The graphs show the compensation error as a function of [beam diameter/slit width] for a simple compensation algorithm (square root of the difference of the squares, clip level independent), and for the more complex, clip-level dependent, algorithm employed by DataRay.



4.5 KNIFE-EDGE MODE

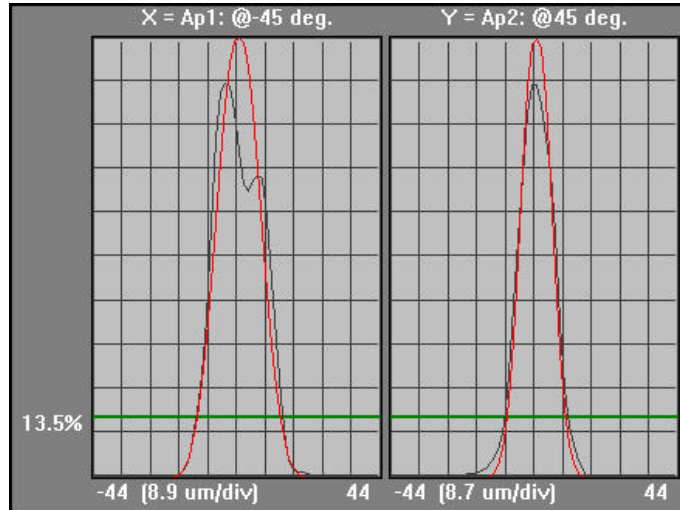
When the beam is smaller than the slit, you may use knife-edge mode to measure the FWHM (Full Width Half Maximum) beam diameter, i.e. at the 50% Clip Level. The slit should be *at least a factor of two wider* than the $1/e^2$ width of the beam being measured.

Note that the displayed profile will be the normalized raw detector output, uncompensated for slit width. For example a 10 μm diameter beam scanned with a 25 μm slit will display a flat-topped signal profile with width of 25 μm at the 50% level.

In this mode the software employs a knife-edge scan algorithm to analyze the data. The displayed raw scan signal is differentiated for one of the edges to give the beam profile. No correction for slit width is made. The red Gaussian profile is the fit to the calculated profile width.

4.6 GAUSSIAN FIT ALGORITHM

Shown is a typical pair of beam profiles with Gaussian Fit profiles overlaid in red. Whether in linear or in logarithmic mode, the displayed *beam* profile is *always* the raw data taken by the detectors. Processing described below only determines the displayed Gaussian profile and the Gaussian fit.



4.6

4.6.1 Gaussian Fit Algorithm

The Gaussian Fit is calculated as follows. (Formulae are given for x only. In Knife-Edge mode the software first differentiates one edge of the raw profile in order to create a beam profile exactly analogous to that taken with a slit.)

- 1) The software determines the peak and minimum (background) levels in the raw profile $I_{rawp}(x)$. It then subtracts the background level, to generate a revised data set, called $I_p(x)$.
- 2) The peak position x_p value $I_p(x_p)$ and beam diameter at the 13.5% points $2w_p$ are determined.

Initially all points below 13.5% of peak are ignored to give position x_p and value $I_p(x_p)$. Then, having defined $I_p(x_p)$, x_p and $I_p(x_p)$ are defined by ignoring all points below 2% of $I_p(x_p)$.

- 3) In subsequent processing all values below 2% of peak and all points at greater than $\pm 2w_p$ from x_p are ignored (treated as zero). In the formulae which follow, \hat{a}_x implies the sum from $-2w_p$ to $+2w_p$.

- 4) The centroid to the profile (first moment) is calculated: $x_c = \dot{a}_x [x \cdot I_p(x)] / \dot{a}_x I_p(x)$
- 5) The area under the curve is calculated: $A_p = \dot{a}_x I_p(x)$.
- 6) The variance (second moment) is calculated: $s_x^2 = \dot{a}_x [(x-x_c)^2 \cdot I_p(x)] / \dot{a}_x (I_p(x))$.
- 7) The variance based beam diameter is calculated: $2w_v = 4s_x$
- 8) A Gaussian profile $I_G(x)$ is defined with 13.5% diameter $2w_G = 2w_v$ (the calculated second moment diameter), and the same centroid x_c . The peak height of this Gaussian is adjusted to give it an area equal to A_p .
- 9) On a point-by-point basis, this reference Gaussian profile $I_G(x)$ is compared with the beam profile $I_p(x)$. Positive and negative errors are summed separately. *Keeping the area A_p constant*, the Gaussian peak height and width are iteratively adjusted until the sum of the positive and negative differences is zero, to give a revised Gaussian width $2w_G$, and a height given by $[A_p / 2w_G]$.
- 10) The **Gaussian Fit** (displayed as a factor or a percentage) is calculated as the absolute sum of the profile differences, divided by the total area:

$$\text{Gaussian Fit} = [\dot{a}_x \text{Abs}[I_p(x) - I_G(x)].dx] / A_p$$

- 11) The Gaussian profile is displayed in red on the profile display. *The relative heights of the measured and Gaussian profiles is determined by setting the taller profile to 100%*. To normalize both profiles to 100%, disable **Auto Gauss Peak**.
- 12) Finally, the measured width is compensated for the width of the slit as described in Section 4.4.

Note:

- The Pass/Fail criteria are the *only* user set Gaussian Fit parameters.
- The Gaussian Fit peak *is not* always at the same position as the object profile peak. The Gaussian Fit peak *is* always at the same position as the object profile centroid.

(The BeamScope-P5 algorithm avoids assuming that the object profile peak position is identical to the Gaussian Fit peak.)

CHAPTER FIVE

5 USING THE M² ACCESSORY

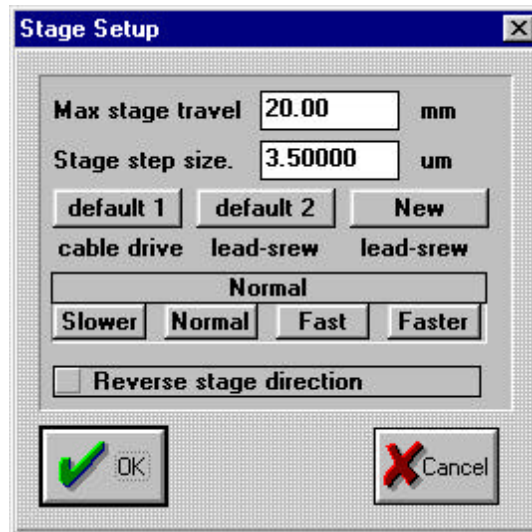
5.1	NEW M ² ACCESSORY USER?	5-2
5.2	M2 HARDWARE SETUP	5-4
5.3	OPERATION	5-6
5.4	SAVING & PRINTING THE RESULTS.....	5-7
5.5	INTERPRETING THE RESULTS.....	5-7

This Chapter assumes familiarity with BeamScope-P5. If you are not familiar with BeamScope, read the earlier parts of the BeamScope manual before reading this chapter.

If you are unfamiliar with M² as a concept see the Appendix B.

To access the M² screen, press **Ctrl M**, or select the **M²** item in the **Options** pull-down menu.

When **Stage Setup** box appears, select your stage and click **OK**. The M² screen will appear. If the **Stage Setup** box does not appear, press **Ctrl + S** to view the box.



	Part #	Scan Range	Step Size
default 1	M2A	20 mm	44.3 μm
default 2	M2B/2DSS	45 mm	3.5 μm
default 3	M2C/2DSSC	45 mm	2.5 μm

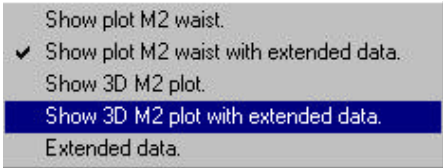
5.1 NEW M² ACCESSORY USER?

If you are already familiar with the M² software go straight to Section 5.1.2.

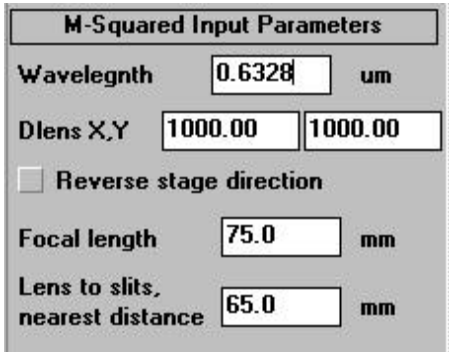
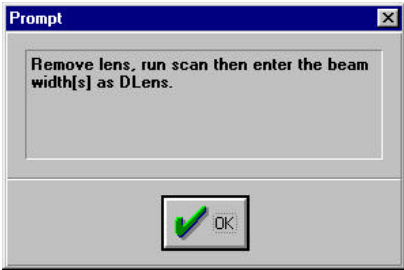
If not, first view a sample data file by clicking on **Recall M2** and double-clicking **samp1.m2** in the **Open** dialog box.

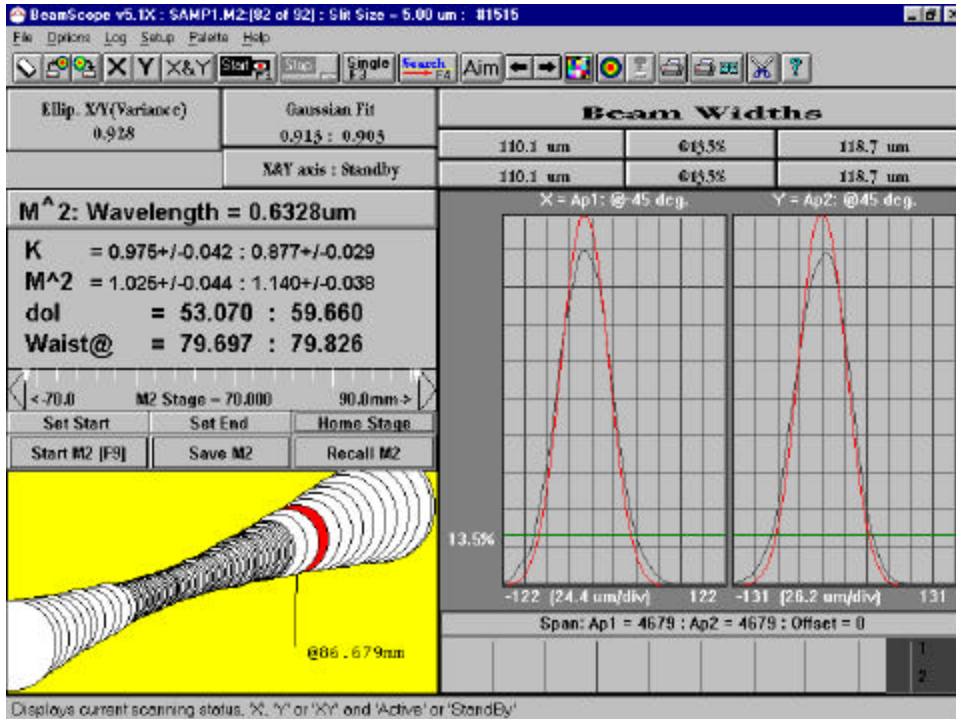


You should see the screen shown on the next page. (As the software version evolves, and dependent on the last configuration saved, minor differences in appearance may occur.) Right-click on the turquoise blue graph area to access the display options shown right:



- 1) If the **Prompt** shown appears, click **OK** , and fill in the **Head Setup and Options** dialog box (right) for **Wavelength, Dlens X,Y, Focal Length** and **Lens to slits, nearest distance**. (0.6328, 1000, 1000, 75 & 65).





5.1

- 2) In **Show 3D M2 Plot** display mode, Page Up, Page Down keys scroll through the actual individual measurements taken. Experiment with the other display options.
- 3) Working from top to bottom, the results are shown in X-value : Y-value format:
 - M²: Wavelength = 0.6328um
 - K = 0.975+/-0.042 : 0.877+/-0.029
 - M² = 1.025+/-0.044 : 1.053+/-0.041
 - Waist diameters dol = 53.070 : 59.660
 - Waist positions Waist@ 75.322 : 75.588

The '**Extended data**' display option accessed by left clicking in the lower left panel shows:

- | | |
|---------------------------------------|---|
| RI = 79.843mm, 80.015mm | Beam radius of curvature after the lens |
| Rs = 1236.515mm, 1196.726mm | Beam radius of curvature before the lens. |
| Do = 0.7146mm, 0.7397mm | Calculated source waist diameter. |
| Zo(slits) = 684.89mm, 621.91mm | Calculated distance from source to slits. |

- 4) In order to take actual measurements, you will need the optional M² Accessory, DataRay Part Number M2B (or the older M2A stage). The M² Accessory works in conjunction with the BeamScope-P5 to measure M² in accordance with the ISO 11146 standard.

5.2 M² HARDWARE SETUP

- 1) Set up the M² Accessory and the BeamScope Head on the M² plate (if provided) as shown on the next page, or use the hardware provided/available to achieve a similar configuration. N.B. You *cannot* substitute an Ethernet cable for the high current M² cable which has similar connectors. The M2B stage is assumed, see page 5-1.
- 2) *If you are using the BeamScope Rotatable Head, then you must use an optical breadboard or optical table plus appropriate mounting hardware, to position the Head with respect to the M² Accessory.*
- 3) The lens should be nearest to the BeamScope's slit when the stage is in the **Home** position. The focussed beamwaist should be ~15 to 25 mm (5 to 15 for the M2A stage) behind the BeamScope probe head. To verify alignment, the laser should reflect off the center of the lens & back *near to*, but not back *into* the source.
- 4) With the lens out, press the **Aim** button and set the laser ~7 mm out from the head. Then screw back in the lens and check that the laser hits the center of the lens.

If the beam is substantially elliptical, align the beam major axis with the X or Y slit.

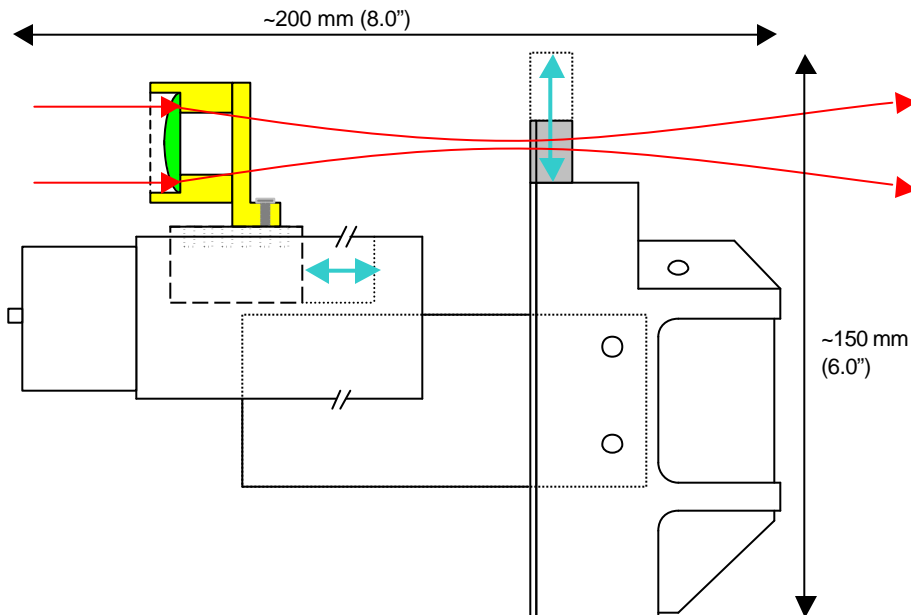
The laser should be at least one Raleigh distance from the lens. If the estimated z_R is less than 250 mm, then use a minimum source to lens separation of 250 mm (10 inches). Estimate the Rayleigh range of the source from the estimated (or specification) source waist diameter and source far field full angle divergence. Calculate $z_R (= 2W_0/\Theta)$. E.g. for a 'typical' laboratory HeNe, diameter $2W_0 \approx 0.8$ mm, divergence $\Theta \approx 1$ mrad, $z_R \approx 800$ mm.

*This source to lens distance is **ABSOLUTELY CRITICAL**. If it is not observed, near field anomalies **WILL** lead to false values of M².*

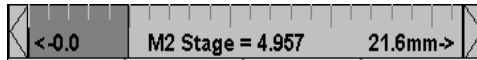
- 5) To enter or change the wavelength, press the button shown to bring up the **Head Setup and Options** dialog box and enter the correct wavelength *in microns* in the **M-Squared Input Parameters** section. *If the wrong wavelength is entered, the M² result will be wrong.*

M²: Wavelength = 0.6328um
- 6) In the M² screen, the rectangle shown here displays the position of the M² stage. While the M² is not scanning, placing the cursor on a location on the bar and clicking

the left mouse button, moves the stage to that location. You can use this feature to setup for the M² scan; e.g. to verify that the locus of the waist centroid is not skew.




- 7) **HOME** the stage and physically verify that it is at the BeamScope Head end of its travel. If necessary, press Home two or three times until the stage stalls at the BeamScope end. Press f2 to stop the stage once it stalls. If the stage position bar is at zero, but the stage is at its furthest from the BeamScope's slit, open the Head Setup dialog box (press **F6**) and click the **Reverse stage direction** check box and click **OK**. Click the **HOME** button again and verify that the stage is at Slits end of its travel. By pressing the ends of the stage control bar, you can single step the stage from end-to-end.



Ensure that the two ends of the travel, indicated by the downward pointing white arrows are at the two extreme ends. If one is not, click that end of the bar and the stage will move there. Once it is there, click the **Set End** button. Then **HOME** the stage, if it is not already there.

5.3 OPERATION

- 1) Press **F6** and verify that the **Head Setup and Options** dialog box looks identical to that shown in Section 3.2.2, except that **Slit size**, **Wavelength** or **Lens to slits nearest distance** may be different from those shown if they are known to be different.
- 2) To measure the **Lens to slits nearest distance** (mm) set the stage at the **HOME** position and set the BeamScope probe head at the Aim position.  Enter the **Lens to slits nearest distance** in the **Head Setup and Options** dialog box. This **Lens to slits nearest distance** equals:

The distance in mm that you measure from the *back of the lens mount* to the *front surface of the slit mount*,

Plus 23.0 mm, [The distance shown on the label on the lens. The distance, ± 0.5 mm, from the principal plane of the lens to the back of the mount.]

Plus 0.75 mm, [The distance between the slits and the front surface of the mount.]

- 3) Two lines below **Beam Widths** on the main screen, if **@Var.** is not already displayed, left click the lower central box and select **Variance (second moment)** in the dialog box. Similarly the top line is normally set to a **Clip Level** of **@13.5%**.
- 4) Unscrew the lens and set it to one side.
- 5) Press **F4** to search for the profile and then **F1** to start a measurement. Use the **Average Widths, N=10** function under **Options** to take a ten reading average.
- 6) Enter the measured X and Y values as **DLens X,Y** in the **Head Setup and Options**. Screw the lens back on again and reset the **Average Widths** to **No averaging**.
- 7) Press **F4** to search for the profile and then **F1** to start a measurement. let it run for about ten measurement cycles to stabilize and then press **F2** to halt the measurement.
- 8) Now click the **START M2** button. A confirmation box will appear. Check its contents and click **OK**. The button will change to a **STOP M2** button and the M² test will begin. The software will test the X and/or Y axis depending on the current status state. As the M² scan proceeds, the software will calculate and display the results. The developed waist will be shown in the chosen 2-D or 3D view.
- 9) A red warning box may initially appear:

Error: Invalid (impossible) results.
Verify: Wavelength, Slits and clip level.

... indicating that the software has not yet found a convergent solution for M² (i.e. the largest reading is not yet adequately greater than the smallest). The box normally disappears fairly quickly, but if it is still there at the end of the M² scan then recheck the set-up in the manner suggested in the box.

- 10) Click on **SAVE M2** to save the scan.
- 11) It is *VERY* important that the waist occurs somewhere in the center of the scan, say within ± 4 mm. If not, change the lens to BeamScope distance to adjust the waist position, and redo the M² scan. This is normally most easily accomplished by unbolting the lens and bolting it back into a different position on the moving carriage.
- 12) Once a successful scan has been accomplished the factors K, M² and waist location are displayed, as described in Section 5.1. The waist location is the distance from the principal plane of the lens. You can change the clip level or width method mode and re-calculate the M² data by left-clicking on the lower central box below the **Beam Widths** title as described in 4.3.3.

5.3
5.4

5.4 SAVING & PRINTING THE RESULTS

- 1) Save the results by pressing the **SAVE M2** button and completing the dialog box.
- 2) You can recall the results by pressing the **RECALL M2** button.
- 3) You can also recall the M² data into the BeamScope's 100 profile data buffer by pressing the **Recall File** button and selecting the *.m2 file.

You can then look up each profile individually.



- 4) You can print the M² full screen, with or without notes, by using the print hot buttons or from the **File** pull-down menu.
- 5) You can copy the screen to the clipboard by simply pressing **Ctrl T**



5.5 INTERPRETING THE RESULTS

Sanity checks. Interpretation of any set of results must be done carefully. Perform a few sanity checks on the results. For example:

- Do the calculated source dimensions and distances make sense? If the beam overfilled the lens or the slits then the results will be imperfect.
- If the beam is elliptical does this show in the results and displays? If not, was the laser accurately aligned with the slits?

M² Accessory

- ❑ If the M2 values are much higher or lower than expected, double-check your setup. Perhaps the results are correct, but if the beam was not centered on the lens and on axis, then measured M2 values will be worse than actual values.

CHAPTER SIX

6 2D SCANNING STAGE

6.1	INITIAL SETUP	6-1
6.2	OPERATION	6-2
6.3	FREQUENTLY ASKED QUESTIONS.....	6-3

This Chapter assumes familiarity with BeamScope-P5. If you are not familiar with BeamScope, read the earlier parts of this manual before reading this chapter.

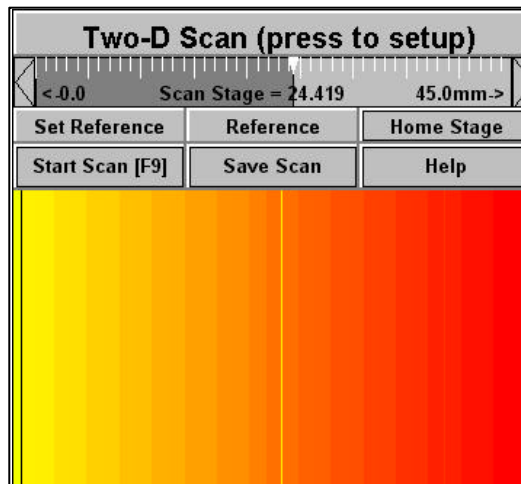
6.1 INITIAL SETUP

See page 6-4 for the schematic set-up.

To access the 2D Stage screen, press **Alt + F9**, or select **TwoD scan...[Alt F9]** in the **Options** pull-down menu.

Click on **TwoD Scan (press to setup)** to open the **TwoD Scan Setup** dialog box. Initially **Auto Width** should be checked. Once you have determined the beam dimensions and locations, consider setting the **Scan Width** and **Height** in order to maximize resolution on your beam.

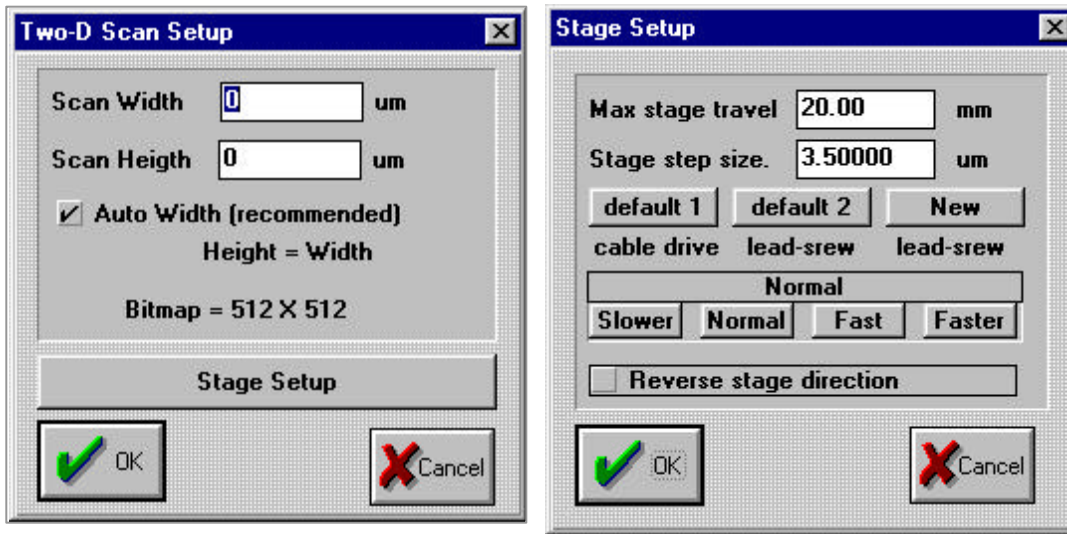
Click on **Stage Setup** to open the box, (or enter **CTRL S**), select your stage and click **OK**.



6.1

	Part #	Scan Range	Step Size
default 1	M2A	20 mm	44.3 μ m
default 2	M2B/2DSS	45 mm	3.5 μ m
default 3	M2C/2DSSC	45 mm	2.5 μ m

2D Scanning Stage

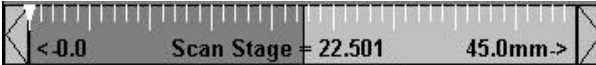


You may choose the scanning speed to be **Faster** or **Slower**, but **Normal** works for most scenarios. [If you have any stalling problem, click on the **Slower** button.]

Click **OK** to leave **Stage Setup**. Click **OK** to leave **TwoD Scan Setup**.

Click the **Home Stage** button. Once the stage stalls on the internal physical endstop *at the motor end of the stage*. The stage will make a buzzing noise as it stalls. Press **F2** to stop the motor. This sets the zero position of the stage. If it stops before reaching the end, press the **Home Stage** button again until the stage does reach the end. [If for any reason the stage homes to the end opposite the motor, go to the **Stage Setup** dialog box, right, and click on the **Reverse stage direction** button.]

6.2 OPERATION

- 1) Click in the center (± 1 mm) the graduated scan stage position indicator. The image shows a horizontal graduated scale with tick marks. The left end is labeled "<0.0" and the right end is labeled "45.0mm->". In the center, it says "Scan Stage = 22.501".

The stage will move to the center of its range.
- 2) Click **Aim** on the main button bar to set the pinhole in the middle of its travel.
- 3) Adjust the source, or the stage support, such that the source is approximately centered on the pinhole. [You may also move the stage. To adjust the stage position, you may use the 'Step' arrows at either end of the graduated scan stage position indicator. If you do move the stage in this manner, you reduce the maximum scan range by twice the off-center adjustment that you make.] Click the **Search** button on the button bar and verify that the search display shows a signal. If it does, click the **Set Reference** button.
- 4) Click on **Start Scan [F9]**. The following occurs:

- The software instructs the head to measure the line profile 13.5% clip level diameter of the source at the reference position. The program will automatically set the gain and lock it. In order to allow for any hotspots, the gain is set to 25% of the peak value detected during the search,. The software also turns off all 'Auto' functions in **Scan Head Setup** (as opposed to **Stage Setup**) during the scan.
 - Using the scanning stage, it then moves the head to the start of the scan. It scans a 2D region centered about the reference position. The width of the region is twice the diameter of the beam detected by the scan. The scan will build up on the screen from left to right. The size of the scan is always 512 x 512 steps. The minimum step on the 2DSS scanning stage is 3.5 μm , therefore the minimum scanned area is 1.792 mm long.
- 5) At the end of the scan, click on **Save** to save the image as a Bitmap. The step sizes are stored in the bitmap so that when it is imported into WinCam software, the size information is not lost.
 - 6) If you find the scanned area to be inadequate, for example your beam had the minor axis set parallel to the probe scan axis, then you will need to over-ride the **Auto Width** [Item 3) above] by unclicking **Auto Width** and entering a **Scan Width** in microns.
 - 7) Open the saved file under WinCam and analyze the image. At this point in time, WinCam software and a WinCam user manual are supplied with the 2DSS stage. Both are available from DataRay, or may be downloaded from www.dataray.com .

6.2
6.3

6.3 FREQUENTLY ASKED QUESTIONS.

Q1. My source appears crescent shaped and I don't believe it. What's going on?

Due to an assembly error, a few pinhole assemblies made in late'98, early '99 have shown leakage round the edge of the pinhole disk. This tends to show up as a crescent of a circle with a diameter of ~10 mm. You may cure the leakage with black paint/epoxy/nail polish, or return it to DataRay for repair/replacement.

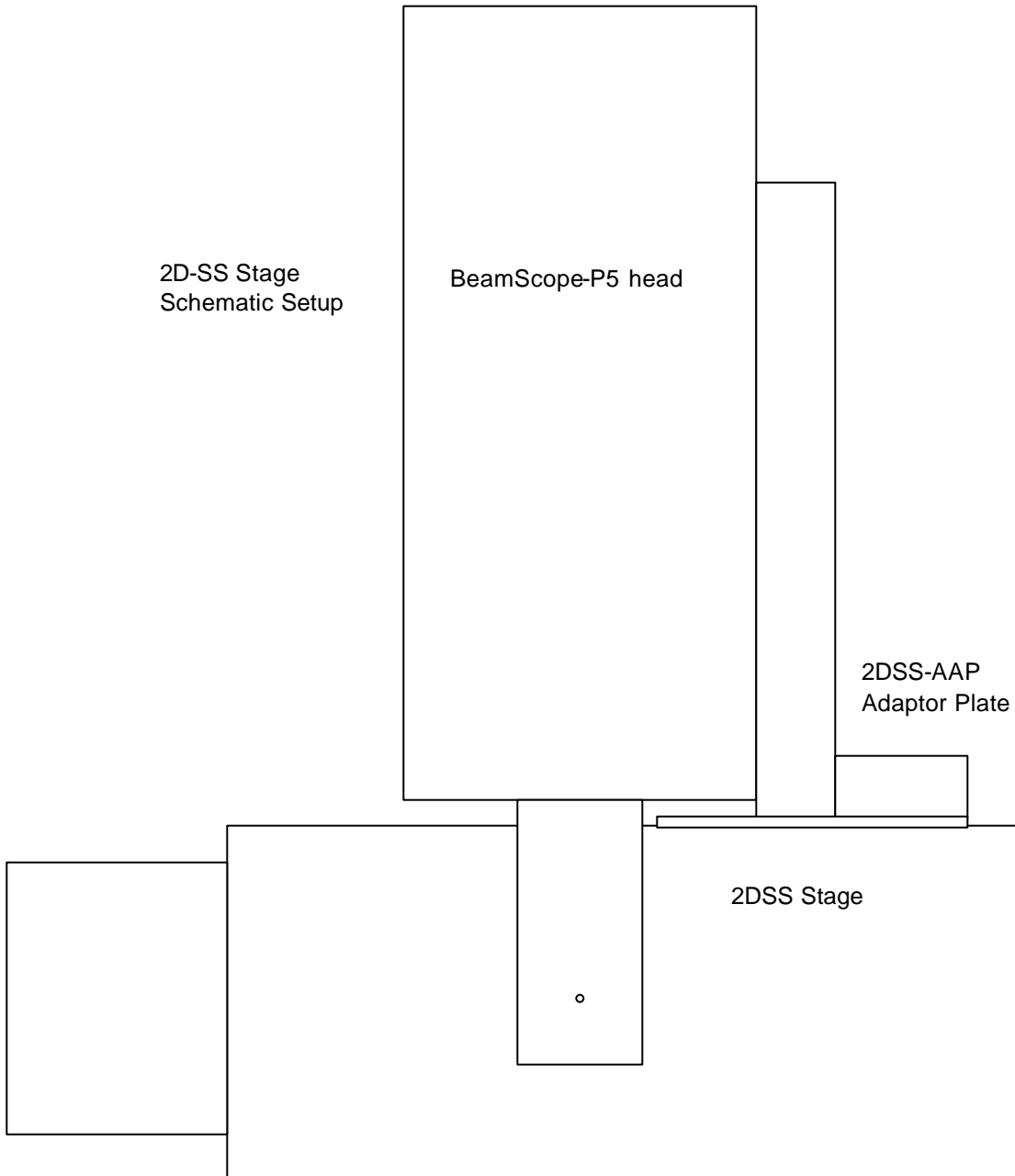
Q2. My source image appears compressed/skewed/'windwept' in the horizontal direction. Why?

Your stage is probably stalling due to the load and or load orientation. This was an issue with some early versions of the 2DSS stage and board. See the bottom of page 4-1 for a temporary solution. Contact DataRay Technical support for a permanent solution.

Q3. There is a vertical oscillation in the beam image which I do not believe is real. Why?

This is residual side-to-side movement in the stage at the screw pitch of 700 μm . It will be corrected in the M2C/2DSSC stage, due early summer 2001.

2D Scanning Stage



APPENDICES

APPENDIX A: BEAMSCOPE-P5 FUNCTION REQUEST FORM	2
APPENDIX B: M-SQUARED AND ITS MEASUREMENT	3
1. WHY CARE ABOUT M-SQUARED?.....	3
2. M ² DEFINITION & FORMULATIONS.....	3
2.1 A SYMMETRIC & ASTIGMATIC BEAMS.....	6
2.2 THE ISO 11146 STANDARD.....	6
3. M ² MEASUREMENT.....	7
3.1 <i>Accurately Measuring the Waist</i>	7
3.2 <i>Accurately Measuring Divergence and/or 2w(z) versus z.</i>	7
3.3 <i>Inaccessible Beam Waists</i>	8
3.4 <i>Correct Waist formation using a Lens</i>	9
4. BEAMWIDTH DEFINITION	10
4.1 <i>Gaussian Beams</i>	10
4.2 <i>Beam Irradiance</i>	10
4.3 <i>Second Moment Beam Diameter</i>	10
5. ACKNOWLEDGEMENTS	12
6. REFERENCES.....	12
APPENDIX C: TECHNICAL SUPPORT, SALES, RETURNS, DISTRIBUTORS AND REPRESENTATIVES	13
APPENDIX D: BEAMSCOPE DATA STRUCTURES	14

App.

Appendix A: BeamScope-P5 Function Request Form

To DataRay Inc. Fax #: (303) 494-1431

Please answer the questions on this form to request/suggest a software and/or hardware upgrade. Fax the completed form to DataRay. We will normally give an initial response within five working days.

Your Name: _____ Organization: _____
Phone#: _____ Fax #: _____ Email: _____

1) What is the request/suggestion? What exactly would this do?

2) What equations and/or parameters does this function use?

3) How do you want the results displayed and/or printed ?

4) Please briefly describe the beam that you are trying to measure:

Wavelength _____ CW _____ Pulsed _____

Mean Power _____ Beam Dimensions _____ mm

Other _____

APPENDIX B: M-Squared and Its Measurement

1. Why Care about M-Squared?

There are several possible reasons for understanding M-squared (M^2) and wanting to measure its value for a laser system:

- ❑ It is the QA delivery or acceptance criterion on a laser or laser system.
- ❑ You are attempting to understand why your ‘focused’ laser spot diameter is larger than calculation predicted.
- ❑ You are tasked with measuring M^2 , and/or somebody gave you a copy of the ISO 11146 standard ^{Ref.1}.
- ❑ Because M^2 is an invariant property of a laser beam propagating through an optical system. M^2 may therefore be used to describe the beam at any point in that optical system. (The optical system must neither aberrate nor truncate the beam.)

Whichever reasons apply, if you are to ensure that your measurements are valid, it is useful, even necessary, to understand what you are measuring and the limitations of the technique. This Note attempts to comprehensively yet concisely address:

- ❑ The concept of M^2
- ❑ M^2 formulae and how it is measured
- ❑ Useful ‘Rules of Thumb’ and ‘Sanity Checks’

2. M^2 Definition & Formulations

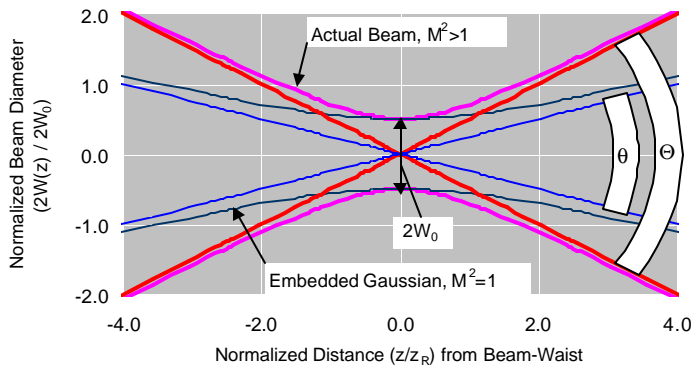
M^2 is a dimensionless parameter that characterizes the degree of imperfection of a real-world laser beam. The lower the value of M^2 , (i.e. the closer the beam is to diffraction-limited TEM₀₀ perfection), the more tightly the beam can be focused to a small spot.

No laser beams are ‘perfect’. Due to limitations of the optical cavity, the lasing medium, and/or the output/ancillary optics, most beams are not the ‘perfect’, diffraction-limited, Gaussian profile, pure TEM₀₀ mode described in textbooks. Complex beams can contain multiple TEM_{xy} mode contributions leading to high values of M^2 . Even a good laboratory HeNe laser has an M^2 of around 1.1 to 1.2, rather than the 1.0 of a ‘perfect’ TEM₀₀ beam.

At its simplest M^2 may be defined as: *The ratio of the divergence of the actual beam, to that of a theoretical, diffraction-limited beam with the same waist diameter.*

A prerequisite of M-Squared measurement is the availability or creation of an accessible beam-waist. Referring to Figure 1.

Figure 1. M^2 : The 'Embedded Gaussian' Concept



$$M^2 = \frac{\Theta}{\theta} \quad \dots 1)$$

Where: Θ = The measured, far-field, full-angle divergence of the actual beam
 θ = The theoretical far-field divergence of a 'perfect' TEM_{00} Gaussian beam which has the same waist diameter as the measured beam.

And since: $\theta = \frac{2\lambda}{\pi W_0} \quad \dots 2)$

Where: $2W_0$ = The beam waist diameter. (The measured beam waist diameter must be the second moment definition of beam diameter – see Section 3.5.3)

Substituting 2) into 1) gives: $M^2 = \left(\frac{\pi}{4\lambda}\right) \Theta \cdot 2W_0 \quad \dots 3)$

The shape of the M^2 curve may be shown to be hyperbolic of the form:

$$2W(z) = 2W_0 \sqrt{1 + \left(\frac{z}{z_R}\right)^2} \quad \dots 4)$$

Where z_R is the Rayleigh Range, which is defined as the distance at which the beam diameter is $\sqrt{2}$ greater than the diameter at the waist. z_R may be shown to be:

$$z_R = \frac{2W_0}{\Theta} = \frac{\pi W_0^2}{M^2 \cdot \lambda} \quad \dots 5)$$

Rearrangement of equations 3) to 5) gives a redefinition of M^2 in terms of a measured diameter at distance z from the beam waist:

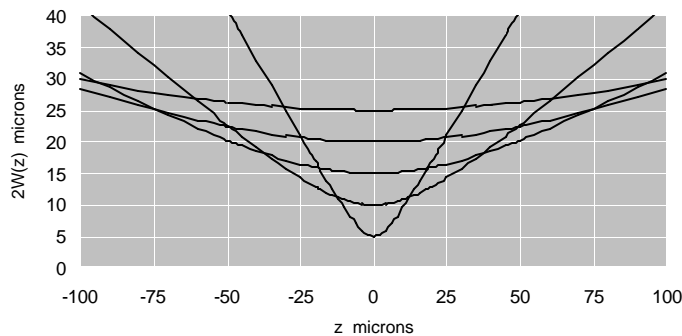
$$M^2 = \frac{\pi \cdot W_0^2}{\lambda \cdot z} \cdot \sqrt{\left(\frac{2W(z)}{2W_0}\right)^2 - 1} \quad \dots 6)$$

Therefore any system that claims to measure M^2 must adequately measure the waist diameter $2W(z)$ versus z over an appropriate range of z . (See Section 3)

It is important to understand that, at any given wavelength, *a given value of M^2 does not define a single curve*. From equation 3) it is apparent that a single value of M^2 defines a family of curves with a constant $\Theta \cdot 2W_0$ product.

To better illustrate this point, Figure 2 shows the curves for five different 1064 nm beams with the same M^2 value of 3, but with waist widths $2W_0$ of 5, 10, 15, 20 & 25 μm , and therefore different values of Θ .

Figure 2. **Curves with Constant M^2 but with Differing Waist Widths & Divergence**



App.
B
2

To reiterate this point: Curves with identical divergence Θ , or with identical beamwaist $2W_0$, do not necessarily have identical M^2 values. Curves with identical M^2 do not necessarily have identical divergence or identical beamwaist diameter.

Figure 2 emphasizes the necessity of measuring *both* Θ (i.e. $2W(z)$ versus z) *and* $2W_0$ in order to determine M^2 .

If either side of the beam waist region is inaccessible - for example, within or at the end of the laser housing, or within a closed optical chain - then an ancillary optic must be used to form a waist region. See Sections 3.3 and 3.4.

2.1 Asymmetric & Astigmatic Beams

So far this note has assumed circularly symmetric beams; the shapes are identical in X and Y. Real beams are frequently asymmetric and astigmatic. That is:

- a) The beams may be purely asymmetric, having the same waist positions $z_{0X} = z_{0Y}$, but different waist diameters, $2W_{0X} \neq 2W_{0Y}$
- or b) The beams may be purely astigmatic, having different waist positions, $z_{0X} \neq z_{0Y}$, but with $2W_{0X} = 2W_{0Y}$
- or c) The beams may be asymmetric and astigmatic having different waist positions, $z_{0X} \neq z_{0Y}$, and different widths, $2W_{0X} \neq 2W_{0Y}$
- or d) The beams may exhibit neither astigmatism nor asymmetry at the beamwaist, but may have asymmetric divergence, $\Theta_{0X} \neq \Theta_{0Y}$

Condition a), b), c) or d), or any combination thereof, leads to $M_X^2 \neq M_Y^2$. Any attempt to measure M^2 must realistically assume c) until the measurements prove otherwise.

Although the rest of this note assumes circular symmetry and a single dimension, the reader should always bear in mind that both X and Y measurements should be taken in order to characterize the beam accurately and adequately.

2.2 The ISO 11146 Standard

The ISO 11146 standard (See Section 4 of this Application Note and Ref. 1), discusses both beamwidth and M^2 measurement in more detail. Importantly it defines that:

- ❑ Second Moment rather than Gaussian equivalent diameter must be used when establishing $2W(z)$ versus z . (See section 3.5.3 for the second moment formulation). The second moment diameter is specified because only the product (M^2) of divergence and waist diameter measured in this manner is conserved for a generalized non-Gaussian beam. (A mixture of TEM_{xy} modes). (And this product is only conserved in an optical system which does not truncate the beam.) The Gaussian equivalent beam diameter is only appropriate for a TEM_{00} laser beam.
- ❑ Five separate measurements of diameter must be averaged.
- ❑ Any slit, pinhole or knife-edge scanner must scan the beam in a plane at right angles to the z -axis. Rotating drum scanners with slits or knife-edges in tangential planes around the circumference scan in a circular trajectory rather than a plane. Not an issue for CCD camera based systems.

3. M² Measurement

Rules-of-Thumb and Sanity Checks

M² is not a quantity that can be measured to the last fraction of a percent. An M² value accuracy of ±10 % is often acceptable; ±5 % is good, and better than ±5 % is exceptional. What accuracies need to be achieved in the raw measurements in order to measure M² accurately?

3.1 Accurately Measuring the Waist

From equation 4), and figure 1), it is apparent that in order to measure 2W₀ accurately, a measurement must be made within a certain fractional distance (z/z_R) of the waist.

For the fractional error in 2W₀ to be less than ‘g’, the measurement must be made within a normalized distance from the waist given by (Ref.2):

$$\left(\frac{z}{z_R}\right) = \sqrt{2g} \quad \dots 7)$$

E.g. For g < ±0.01 (1%), (z/z_R) ≤ ±0.14 (14%). Therefore any measurement within 1/7th of a Rayleigh range of the z = 0 beamwaist position can in principle measure 2W₀ to within ±1%.

A small table can be constructed:

2W ₀ Accuracy Sought	Allowable (z/z _R) error	
	± 1%	± 14%
	± 2%	± 20%
	± 5%	± 32%
	± 10%	± 45%

App.
B
3.1

3.2 Accurately Measuring Divergence and/or 2w(z) versus z.

Divergence Θ *may* be measured directly at large values of (z/z_R). Referring to figure 1, at large z the diagonals defining Θ are asymptotic to the hyperbolic curve of 2W(z) versus z, and Θ *could* be calculated from 2W(z) as:

$$\Theta = 2 \cdot \arctan(W(z)/z) \quad \dots 8)$$

[= (2W(z)/z) for small Θ]

The error in this assumption may be calculated from equations 4) and 8) to be:

Q Error from 2W(z) Error	(z/z _R) value
<+1%	≥5.7
<+2%	≥4.4
<+5%	≥3.0
<+10%	≥2.2

Since some of these (z/z_R) values may be inconveniently large, Θ is *not normally measured directly*. Instead, M² is calculated by fitting the measurements of 2W(z) versus z to the hyperbolic curve of equation 6). Ref.2 shows that for maximum sensitivity to the fractional change versus z in the shape of the hyperbolic curve, it is preferable to work within the region:

$$0.5 < |z/z_R| < 2.0 \dots 9)$$

Working at values of $|z/z_R| < 0.5$ *compromises the accuracy of the measurements*.

Working at values of $|z/z_R| > 2.0$ is not as big a problem, but leads to lower accuracy as the ratio increases.

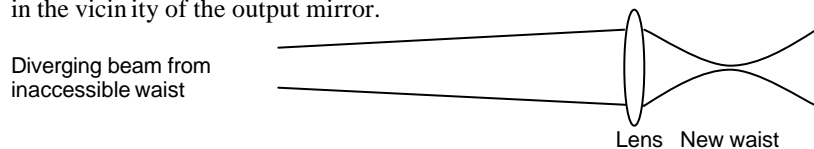
But unless M² is already known, how can you know z_R and work within the (z/z_R) regions indicated by the discussions above?

In practice:

- ❑ An approximate value of M² may be known and z_R can then be estimated before setting up and starting the measurements.
- ❑ z_R can be calculated from the M² measurements. After the first run, the set-up can be assessed in order to verify that the (z/z_R) region is in accord with condition 9).

3.3 Inaccessible Beam Waists

If no accessible beam waist exists, then an ancillary lens must be used to form the waist. This is normally the case when the laser itself is being measured, since the beam waist is in the vicinity of the output mirror.



The ancillary lens used to form the waist should be in the far-field of the laser, preferably $> z_R$ (i.e. z_R for the laser source) from the limiting aperture or laser waist.

(‘Away from diffractive overlay from the mode selecting aperture of the laser’, Ref. 2).

For a ‘typical’ HeNe, 2W₀ ≈ 0.8 mm, divergence $\Theta \approx 1$ mrad, z_R = 2W₀/ $\Theta \approx 0.8$ m.

3.4 Correct Waist formation using a Lens.

In order not to increase the M^2 of the original beam, this lens must be used within its aberration-free, diffraction-limited region of operation. For a plano-convex singlet, typically employed in these applications, spherical aberration is the dominant on-axis aberration. In order to keep this contribution well below (a factor of five below) the diffraction limit, it may be shown (Ref.3) that:

$$f\text{-number} \geq (137.f/\lambda)^{0.25} \quad \dots(10)$$

Where: f mm is the focal length of the lens
 λ μm is the laser wavelength
 f-number is defined as f divided by the $1/e^2$ diameter of the beam at the lens

For a 25 mm diameter, 75 mm focal length, plano-convex lens, this leads to:

l nm	f/#	Max. Beamwidth at Lens
400	> f/12.7	2.0 mm
633	> f/11.3	2.2 mm
830	> f/10.6	2.4 mm
1064	> f/9.9	2.5 mm

(Due to the 0.25 power dependence in equation 10), even a wider tolerance, such as allowing the aberration contributions to be equal, only decreases the f/number to >f/7.6 at 633 nm for a maximum beamwidth of 3.3 mm. Ref. 2 conservatively recommends >f/20 in all circumstances.)

It is therefore important to perform such a calculation for the lens employed, and if necessary use a lens with either with lower aberrations or a longer focal length.

Typically, the choice to reduce spherical aberration would be either an achromat, which normally has significantly reduced spherical aberration, or a laser focusing singlet. A longer focal length plano-convex singlet may be a solution. [But only if the Rayleigh range can be kept low enough for the scan range if a scanning M^2 stage is employed. See, e.g., DataRay's BeamScope™-P5 with its M^2 Accessory scan stage.]

App.B
3.3
3.4

4. Beamwidth Definition

4.1 Gaussian Beams

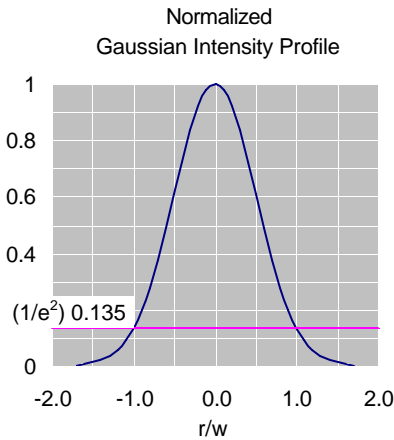
True Gaussian beams have no ‘edges’; that is, the intensity of a *perfect* Gaussian never actually falls to zero at large distances from the center. This arises from the nature of the (circularly symmetric) Gaussian intensity profile:

$$I(r) = I_0 \cdot e^{-2r^2/w^2} = \frac{2P}{\pi w^2} \cdot e^{-2r^2/w^2} \quad \dots 11)$$

Where: r is the radius

w is the *radius* at the point at which the intensity has fallen to 13.5% ($1/e^2$) of the peak value.

P is the total power in the beam



Replace r^2 by $(x^2 + y^2)$ and consider the profile at constant x and varying y . It is apparent that the shape of the profile is Gaussian wherever a cut is taken across the profile. It is this principle which allows slits and knife-edges to be employed in the measurement of beams which are close to Gaussian.

4.2 Beam Irradiance

In order to assess whether the irradiance (W/mm^2) from a given laser might overload a beam profiler, it is useful to be able to calculate the peak irradiance. From equation 11), the on-axis irradiance at $r = 0$ is given by:

$$I(0) = \frac{2P}{\pi w^2} = 2.6P/(2w)^2 \text{ W/mm}^2 \text{ for diameter } 2w \text{ in mm.}$$

For example:

- The peak irradiance from a 1 mm diameter, 10 mW HeNe is 26 mW/mm^2 .
- The peak irradiance from a 5 mm diameter, 5 W NdYag is 520 mW/mm^2 .

4.3 Second Moment Beam Diameter

Conventionally beam diameters have been measured at the $1/e^2$ intensity point; i.e. at 13.5% of the maximum intensity. For the reason outlined in section 2.2a), ISO 11146 mandates the use of a ‘Second Moment’ definition of beam diameter:

$$2W_\sigma(z) = 2\sqrt{2} \cdot \sigma(z) \quad \dots 12)$$

where the variance, $\sigma^2(z)$, is calculated as:

$$\sigma^2(z) = \frac{\iint r^2 I(r, \phi, z) \cdot r \cdot dr \cdot d\phi}{\iint I(r, \phi, z) \cdot r \cdot dr \cdot d\phi} \quad \dots 13)$$

Where $I(r, \phi, z)$ is the radial intensity distribution versus angular position ϕ along propagation axis z .

In more useful x and y terms, (since these are what actually get measured):

$$\sigma_x^2(z) = \frac{\iint (x - \bar{x})^2 I(x, y, z) \cdot dx \cdot dy}{\iint I(x, y, z) \cdot dx \cdot dy}$$

$$\sigma_y^2(z) = \frac{\iint (y - \bar{y})^2 I(x, y, z) \cdot dx \cdot dy}{\iint I(x, y, z) \cdot dx \cdot dy}$$

$$2W_{\sigma_x}(z) = 4 \cdot \sigma_x(z)$$

$$2W_{\sigma_y}(z) = 4 \cdot \sigma_y(z) \quad \dots 14)$$

\bar{x}, \bar{y} denotes the centroid of the $I(x, y, z)$ intensity distribution.

(The ISO 11146 standard actually terms the quantities $E(x, y, z)$ rather than $I(x, y, z)$, and $d_{\sigma_x}(z)$ & $d_{\sigma_y}(z)$ rather than $2W_{\sigma_x}(z)$ & $2W_{\sigma_y}(z)$. Here we have used the more familiar terminology rather than the less common terminology used in the ISO standard.)

For a pure Gaussian intensity distribution, the second moment width is identical to the more familiar $1/e^2$ (13.5% of peak intensity) width.

There are a number of potential disadvantages to the use of second moment as a beam diameter definition, none of which are insurmountable in a well-designed system.

- a) Unless the results are gathered and processed automatically, the second moment diameter is non-trivial to calculate. It is not possible to simply ‘measure’ it directly from a graphical plot of the data.
- b) Any unsubtracted background in the wings, either purely analog noise or quantization noise due to inadequate dynamic range in the sensor or the ADC (analog to digital converter) leads to errors in the second moment. In general it leads to an over-estimation of the second moment width.
- c) If the $I(x, y, z)$ intensity profile has wings which fall at a rate slower than $1/x^2$ or $1/y^2$, then the double integral actually *increases* as x and y increase.

For reasons b) and c) most commercial second moment beam diameter software first automatically determines and subtracts the background, and then truncates $I(x, y, z)$ to the

zeroed background level at a predetermined distance from the $1/e^2$ diameter. Some software allows the user to override this distance.

5. Acknowledgements.

In parts, this Application Note draws on Reference 2, and we have used the same notation wherever possible.

6. References

1. ISO 11146. "Optics and optical instruments. Lasers and laser related equipment. Test methods for Beam widths, divergence angle and beam propagation factor." Published by the International Organization for Standardization.
2. T. F. Johnston Jr., "Beam propagation (M^2) measurement made as easy as it gets: the four-cuts method", Applied Optics, Vol. 37, No. 21, 20 July 1998, pp. 4840-4850.
3. Anonymous; 'Fundamental Optics, Lens Selection, Example 4:' ; Melles Griot 1997-98 Catalog Appendices. Equation 4 assumes *equal* contributions from diffraction and spherical aberration. This application note modifies that assumption to five times greater diffraction than spherical aberration.

Appendix C: Technical Support, Sales, Returns, Distributors and Representatives

DataRay maintains a network of knowledgeable, non-exclusive, Distributors and Representatives, and also offers direct product support.

As with all companies, contact names and telephone numbers vary with time, and therefore have not been included here.

Visit www.dataray.com for a complete listing.

The current procedure for returning product is also posted at the website, in the On-line Support area.

App.
C

Appendix D BeamScope Data Structures

Almost no users will need this information. contact DataRay for any updates before attempting to use it. The information is given as a courtesy only; all associated rights are retained by DataRay Inc.

The beam data structure is defined as follows: name.dat or name.log ;

```
typedef struct {
    int      Size                ; // Size of this structure
    WORD     Direction          ; // scan direction 0 = left to right
    WORD     Axis               ; // 0=x 1=y 2=z
    int      Count              ; // number of data samples
    WORD     GainPeak           ; // max ADC value before base removal
    WORD     Peak               ; // max value after base removal
    WORD     MotorSpeed         ; // 4.0 MHz/MotorSpeed = clocks per second
    WORD     AdcRate            ; // 4.0 MHz/AdcRate = clocks per second
    BOOL     Valid              ; // 0 = not valid
    BOOL     LogRange           ; // Range of log input ie 0 to 34.6 dB
    BOOL     Converted          ; // Was, if true, an old type BEAM
    BOOL     Proccesed          ; // has been data proccesed (not used)
    int      Resolution         ; // 4096 , for 12 bits
    int      HeadType           ; // old = 0 ; 1 = 4 phase, 2 = 5 phase ;
    float    Gain               ; // Gain used to get data 200 = 20.0 db log10
    int      Slits              ; // one or two, very important for width calcs
    float    SlitSize           ; // 5.0 um typical
    float    StartPosition      ; // used internally
    float    Center             ; // center of scan in microns referenced to full scan
    float    Span               ; // Span in microns
    float    SpanCenter         ; // Span in microns
    float    StepSize           ; // Step Size in microns, used to calculate widths
    long     DataStart          ; // position motor started for data, used internally
    long     MotorStart         ; // position motor started for data, used internally
    long     MotorEnd           ; // position motor ended for data, used internally
    long     xCenter            ; // weighed center in samples, not microns
    int      TotalWidth         ;
    float    TotalArea          ;
    int32    Key                ; // A unique identifier
    long     Position2          ; // M^2 position in steps
    BYTE     Resv[196]          ; // may be used for expansion
    WORDData[2048]             ; // start point of samples
} BEAM_P5 ;
```

The beam data structure(s) are prefixed with the following header:

```
typedef struct { // header for BeamScope data files
char    lead[35] ; // must read "BeamScope Beam Data P5"
char    Time[35] ; // time/date is was saved
WORDSize[2] ; // size of the two BEAMS,
           // one may be zero [ or sets of Beams ]
}      BEAMHEADER ;
```

To read a file, follow these steps:

- 1: Read the header,

```
BOOL stat = (file.Read(&BeamHeader, sizeof(BEAMHEADER))==
              sizeof(BEAMHEADER)) ;
```
- 2: Verify that it is a BeamScope-P5 data file,

```
stat = (strcmp(BeamHeader.lead , "BeamScope Beam Data P5")==0) ;
```
- 3: Read the profiles:

```
BEAM_P5 Beam0,Beam1 ;

if(BeamHeader.Size[0])
    file.Read(&Beam0, BeamHeader.Size[0]) ;

if(BeamHeader.Size[1])
    file.Read(&Beam1, BeamHeader.Size[1]) ;
```
- 4: Example to access data: //

```
int    w=0 ;
int    clip = int(.135* Beam0.Peak) ;
for(int i=0;i<Beam0.Count;i++) {
    int data = Beam0.Data[i] ;
    if(data>=clip) w++
}
float    Width = Beam0.StepSize * w ;
if(Beam0.Slits==2) Width = Width * .70710678 ; // dual slits ?
float    Slit = Beam0.SlitSize ;

// To deconvolve
Width = sqrt( (Width* Width) - (Slit* Slit) ) ;
```

WARNING: For clarity, the above code is OVER simplified.

IMPORTANT NOTE: BeamScope-P5 Log files follow the same format as above, except that many BEAM_P5 data structures may be present, so get the file length and load data until the file is exhausted.

App.
D

INDEX

IMPORTANT: Chapter 3 references are part of the Quick-Start Tutorials. Chapter 4 sections are almost always the most comprehensive reference. 'A-' refers to pages in the Appendices.

A

Aim, 3-12, 4-17
Alt key Short cuts, 3-14
Alphanumeric key Short Cuts, 3-14
Analyze Profiles, 4-21
Angular Displacement, 4-19
Apertures, 4-24 *also see Search*
Average, 4-4
 Accumulation Averaging Dialog, 4-20
 Average Dialog, 4-20
 Logged data, 3-13, 4-21
 Profile, *see* Accumulation Averaging Dialog, 4-20
 Rolling, of n values, 3-6, 4-4
 Running Average, 4-4
Auto-Gauss Peak, 4-15, 4-23
Auto Gain, 4-18
Auto / Manual Gain Dialog, 4-18
Auto Range, 4-22
Auto Rotate, 3D, 4-14
Auto-Search, 4-17
Auto-scale, beam wander, 4-10
Auto-TEMxx, 4-23
Axis, match to apertures, 4-24

B

Beam
 Centroid, 3-4, 4-10
 Diameter, 3-5, 4-15
 Irradiance, A-10
 Profiles, 4-15 Structures, A-13
Distance, on a profile, 3-7, 4-16
Distributors, A-13
Divergence angle, 4-19

E

EEPROM, program, 4-26
Ellipticity, 4-10
EXCEL, save then export data to, 4-3

F

F Function key short cuts, 3-14
Feature, Included Power & Distance, 3-7, 4-16
FieldPack
 FAQ, 2-9
 Installation, 2-8
 Schematic, 1-11
 Specifications, 1-10
File, 4-3
Filter \ Frequency options, 4-23
Functional description (BScope), 1.3
Functions, 4-1
 Button Bar, 4-6
 Button Colors Setup, 4-9
 Pull-down menus, 4-2
 Pass/Fail QA Testing, 4-8
 Request Form, A-1

G

Gain
 Auto Gain, 4-18
 Auto / Manual Gain Dialog, 4-18
 Gain and Power button, 4-11
 Manual Gain, 4-18
Gaussian Beams, A-10
Gaussian Fit
 Beams, A-10
 Button, 4-12
 Algorithm, 4-29

Auto-Gauss Peak, 4-15, 4-23
 Grid, vertical, 4-16

H

Head
 Changing slits, 3-10
 Mounting, 2-13
 Program Head EEPROM, 4-26
 Setup and Options, 4-22
 Speed, 4-25
 Help, 4-6
 Help Hints, 4-9

I

Included Power, 3-7, 4-16
 Installation, 2-1
 BeamScope mounting, 2-13
 FieldPack, 2-8
 PC Card, 2-3
 Software, 2-4
 ISO 11146 Standard, 4-27, A-6

J

Job
 File, 2-12, 4-3
 Icon, 2-4

K

Knife-Edge mode, 4-28
 Algorithm, 4-28

L

Laser
 CW, 4-23
 Divergence angle, 4-19
 Pulsed, 4-23
 Log, 4-5, 4-21
 Log Data to Hard Drive, 4-21
 Log Data, 3-13, 4-5, 4-21
 Logarithmic profiles, 3-7, 4-16

M

M², M-Squared, 5-1
 Hardware, 5-4
 Interpreting the Results, 5-8
 Meaning of, A-3
 Plate
 Baseplate, 1-10
 Mounting, 1-11, 5-5
 Saving and Printing the results, 5-7
 Software, 5-1
 Specifications, 1-10
 Main Screen, 4-2
 Modulated sources, 4-23

N

Noise floor, 4-16

O

Options, 4-4
 Options Menu, 4-4, 4-18
 Orientation, *see Ellipticity*

P

Palette, 4-6
 Pass/Fail, 3-6, 4-8
 Part Numbers, 2-1
 PC Card Installation, 2-3
 Plot History, 4-16
 Power, 3-7, 4-11
 Calibrate, 4-12
 Contained, 4-12
 Included, 3-7
 Print
 Current screen with date, 4-3
 Print with notes, 3-8, 4-3
 Setup, 4-3
 Profile
 2D, 3D, 3-7, 4-13
 Access, Page Up, Page Down
 keys, 3-14

Analyze, 3-13, 4-21
Beam Profiles Area, 4-15
Capture, 3-13, 4-5
Data Buffer, 3-3
Feature, Included Power &
 Distance, 3-7, 4-16
Linear, 3-7, 4-16
Log, 3-13, 4-16
Logarithmic profiles, 3-7, 4-16
Recall and Process, 3-14
Rotating, 3-7, 4-14
Tilt, 3-7, 4-13
Program EEPROM, 4-26
Pulsed lasers, 4-23

Q

QA, *see Pass/Fail*
Quick-Start Tutorials
 Software only, 3-2
 Hardware, 3-10

R

Range, Auto Range, 4-22,
 see also Search
Rayleigh Range, A-5
Representatives, A-13
Returns, A-13

S

Save, 4-3
Saved Data, examining, 3-3
Scanning Stage, Chapter 6
Search, 3-12, 4-17
 Auto Search, 4-23
Setting up, 3-10, 4-22
 Setup, 4-5, 4-22
 Set Up and Options, 3-11, 4-22
Short Cuts keys, 3-15
Slit Mode, 4-26
Slit Size, entering 4-22

Size, recommended, 4-27
Slits
 Changing, 3-10
 Orientation, 4-24
Setup screen, 3-11, 4-22
Software Installation, 2-4
Specifications
 BeamScope P-5, 1-5
 FieldPack, 1-10
 M² Accessory, 1-10
Stage Setup, 5-1
Start, F1, 3-13
Status Button, 4-12
Stop, F2, 3-13
Support, Technical, A-13

T

Technical Support, A-13
TEMxx, 4-23
Test, *see Pass/Fail*
Tilt, profiles, 4-13
Tracking, centroid, 4-23
Tutorials

 BeamScope software, 3-2
 BeamScope hardware, 3-10
 M-Squared software, 5-2
 M-Squared hardware, 5-4

U

V

View profiles, 3-7, 4-13, 4-15
 2D, 3D, 4-13

W

Wander, 3-5, 4-10
Wavelength, 5-4
Width, 3-5, 4-14
Windows 95, 98 installation, 2-4
Windows NT installation, 2-6

X

X, profiles, aperture *see Profiles topics*
X Slit Factor, 4-22

Y

Y, profiles, aperture *see Profiles topics*
Y Slit Factor, 4-22

Z

Zero, centroid, 4-10,
Zoom, beam wander, 4-10

Numeric

2D, 3D profile views, 3-7, 4-13, 4-15
2D Scanning Stage, Chapter 6
Specifications, 1-10

Appendices
