UNIBEAM25

BEAM PROFILER SYSTEM

User Manual

Rev 2.2

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2.1	Addition of gain/offset adjustment. Add remote command library	DP	26 Feb 2020
2.2	Correct connection diagram	DP	22 May 2021

REVISION HISTORY

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1 Introduction

UniBEaM is a particle beam profiling system - similar to a wire scanner except an optical sensor fiber is used instead of a metal wire. Sensing fibers scintillate in the visible spectrum as they pass through the beam. The scintillation light is transmitted through the short sensor fiber into a standard multimode optical fiber, which transmits the light long distances with minimal attenuation and no electromagnetic susceptibility. The light is converted by a high-sensitivity photo sensor located in the UniBEaM controller, amplified, digitized, and displayed on a monitor.

Horizontal and vertical beam scans can be obtained independently or simultaneously. This inline diagnostic has an insertion length[1] as short as 70mm in the beam direction and comes complete with an integral aluminum vacuum chamber. The UniBEaM software plots the beam intensity distribution in both the horizontal and vertical planes, and calculates the beam locations and integrated profile areas, which correlates well with total beam current for radially symmetric beams.

UniBEaM has a large dynamic range, operating with beam currents of ~pA to mA, and a large range of particle kinetic energies of ~keV to GeV, depending on the absorbed power density. The maximum absorbed power density of the optical fiber before thermal damage is related to the dE/dx energy deposition as a function of particle type and kinetic energy, and the thermal radiative emission characteristics of the fibers.

Communication with the UniBEaM controller is via Ethernet. The end user initiates scans and retrieves scan data utilizing text-based commands. A windows-based user interface is also provided, which can be installed on a remote PC to operate the system.

UniBEaM was conceived by the Albert Einstein Center for Fundamental Physics, Laboratory for High Energy Physics, University of Bern (Switzerland), and licensed by D-Pace Inc.

1.1 Intended Use

UniBEaM is an alternative to conventional wire scanners. It was designed to profile charged particle beams (including electrons and positrons), and X-rays. The beam intensities measured by UniBEaM are relative measurements and are not calibrated to provide absolute readings.

UniBEaM was designed to be operated in a clean, temperature controlled industrial environment. The operator must be familiar with proper grounding techniques, wire routing and high-voltage safety.

[1] Depending on flange option – see drawings in Appendix, section 15.

2 Safety Information

2.1 Warning Symbols

This manual utilizes the following warning symbols. To avoid injury or death, the warnings and accompanying descriptions in the manual must be observed.

CAUTION – RISK OF ELECTRIC SHOCK

CAUTION – RISK OF DANGER – REFER TO MANUAL

2.2 Beam Voltage

UniBEaM is an optical device. The beam intercepted by the sensor fiber is converted to an optical signal. As such, there is no user access to beam voltages when the probe is properly earth grounded.

Ensure beamline, UniBEaM probe, and UniBEaM controller is grounded to earth ground. See installation section.

Do not operate UniBEaM without proper earth grounding. High voltages could develop which can cause injury or death, and damage sensitive components within the system.

2.3 System Voltages

The UniBEaM controller is powered with 100 - 230VAC.

Do not operate the controllers without protective covers installed.

2.4 Mechanical Hazards

The UniBEaM probe contains moving parts.

Do not operate the system without the probe protective covers.

3 SPECIFICATIONS

3.1 System

Mass, packaged system	19 kg
Dimensions, packaged system W x D x H	53 cm x 52 cm x 52cm
Cable lengths (standard)	15 m
Operational temperature / Humidity (non-condensing)	0 to 60 ºC 40 ºC @ 95% RH
Non-operational temperature / Humidity (non-condensing)	-20 ºC to 75 ºC 60 ºC @ 90% RH

3.2 UniBEaM25 Scanner Probe

Probe Flange Option	Drawing	Insertion Length	Clear Aperture
UniBEam25-KF (KF40 bulkhead mount)	1800672	70 mm	41 mm
UniBEaM25-KFQ (KF40 quick flanges)	1800673	98 mm	35 mm
UniBEaM25-CF (CF flanges, 70mm OD)	1800674	92 mm	36 mm
Axial distance between X & Y fibers		7.6 mm	
Distance from X fiber to front probe face		30 mm	
Maximum nominal beam diameter		25 mm	
Sensor fiber travel range		31 ± 0.5 mm	
Minimum fiber movement step size		0.025 mm	
Scan speed		20 mm/s	
Stepper motors, 2 phases		5V, 1.3A per phase	
Alignment fiducials, laser line grooves		cross hairs, front	
Alignment fiducials, spherical ball mount		6.008/6.012 mm, 12 deep 3x front, 1x side	
Maximum absorbed power density[2]		10 W/cm^2	
Mass		5 kg	
Packaged Dimensions W x D x H		43 cm x 51 cm x 18 cm	
Packaged Mass		6.5 kg	

[2] See manual, section 13 for details.

3.3 UniBEaM Controller

AC Power	
AC Input Voltage Range	100 – 230 VAC
AC Input Frequency Range	47 – 63 Hz
Inrush Current (100 / 200VAC)	16 / 32 Amps
Power Factor (100 / 200VAC)	Meets EN61000-3-2 (0.95 / 0.9)
Safety Approvals (Internal AC/DC power supply only)	IEC/EN/UL/CSA60950-1, IEC/EN/UL/CSA62368-1, UL508 and CE Mark
Conducted & Radiated EMI (Internal AC/DC power supply only)	EN55011 / EN55022-B, FCC Class B, VCCI-B
Fuse, rear panel	2x 5mm x 20mm 5A 250V Slow Blow
Rear panel I/O connectors	
Ethernet	10/100/1000Mbps
Optical signal input	2x SMA 905
Motor output	2x push/pull Lemo™ 8 pin
AC power inlet with rocker switch & integral 5A fuses (2x)	IEC 320-C14
Power switch	Rocker-type
Front panel	
USB	1 x USB2.0
Optical Sensors	
Number	2
Type	SiPM
Active area	3mm x 3mm
Optical input connection	SMA 905
Signal Amplifiers	
Number	2
Type	Transimpedance
Gain ranges, software controlled	0.5x, 1x, 2x, 5x, 10x, 20x, 50x, 100x, 200x, 500x, 1000x
Signal bandwidth, maximum	1 kHz (-3dB)
Programmable low pass filter	1 Hz - 1 kHz
Cooling	
Convection	Front air inlet, rear vent

Analog to Digital Conversion	
Number channels	2
Resolution	12 bits
Sample rate	50 kS/s/channel
Output (as displayed in software)	+/-10V
Physical	
Mass	3.5 kg
Height, 19-inch rack mount	2U (89mm)
Overall dimensions W x D[3] x H	482mm x 370mm x 89mm
Packaged Dimensions W x D x H	56 cm x 45 cm x 19 cm
Packaged Mass	4.5 kg

3.4 Sensor Fibers, Replacement

Fiber Cartridges, Ce1-200-25	
Optical connector	SMA 905
Fiber diameter	200 ± 20 microns
Beam diameter, nominal	25 mm
Fiber length	29 ± 1 mm
Mass (including holder)	10 grams

3.5 Cables [4]

Cables, fiber optic signal	
Core	400µ SiO_2
NA	0.5
Connectors	SMA 905
Length (standard)	15 m
Outside diameter sheath	3.8 mm
Sheath material	PVC
Minimum bend radius	64mm
Cables, motor	
Connectors	Lemo™ push/pull
Length (standard)	15 m
Cable diameter	7 mm
Sheath material	PVC
Minimum bend radius	70 mm

[3] 340mm excluding front handles.
[4] Custom cable lengths available. Contact D-Pace.

4 SUPPLIED COMPONENTS

Table 1: UniBEaM25 System, Supplied Components

Item	Qty	Part Number	Description	Box
1			UniBEaM System	1
1.1	1	1800598	UniBEaM Controller	3
1.2	2	1800643	Replacement Fiber Cartridge, Ce1-200-25, 200µ, 25mm	2
1.3	2	1800940	Cable, Motor, Beam Profiler, 15m	1
1.4	2	1901759	Cable, Fiber Optic, 400µ, 15m	1
1.5	1	1901588	Empty Cartridge, 25mm	2
1.6	1	1901757	Hex Wrench, Tee Handle, 3mm	2
1.7	1	1800647	Manual, UniBEaM 25	1
1.8	1	1800676	Grounding Kit, UniBEaM	3
1.9	1	1800939	USB Drive, Diagnostics GUI	3
2			UniBEaM25 Probe, Flange Options[5]	
2.1	☐	1800672	UniBEaM25-KF Probe (KF40 Bulkhead)	2
2.2	☐	1800673	UniBEaM25-KFQ Probe (KF40 Quick Flange)	2
2.3	☐	1800674	UniBEaM25-CF Probe (CF Flange, OD 2-¾”)	2
3			AC Power Cord Option[6]	
3.1	1	1901761	Power Cord, IEC 320 C13 to C14, 10A, 250V, 1m	3
3.2	☐	1901762	Power Cord, IEC 320 C13 to CEE 7/7, 10A, 250V, 2.5m	3
3.3	☐	1901763	Power Cord, IEC 320 C13 to NEMA 5-15P, 10A, 250V, 2.5m	3
3.4	☐	1901764	Power Cord, IEC 320 C13 to SEV1011, 10A, 250V, 2.5m	3
3.5	☐	1901765	Power Cord, IEC 320 C13 to CEI23-16, 10A, 250V, 2.5m	3
3.6	☐	1901766	Power Cord, IEC 320 C13 to BS1363, 10A, 250V, 2.5m	3
3.7	☐	1901767	Power Cord, IEC 320 C13 to AS3112, 10A, 250V, 2.5m	3
3.8	☐	1901768	Power Cord, IEC 320 C13 to JS8303, 10A, 250V, 2.5m	3

[5] See probe drawings in section 15 for details.
[6] See section 17 for details.

4.1 UniBEaM Controller

Figure 2: UniBEaM Controller, front

Figure 1: UniBEaM Controller, back

4.2 UniBEaM Probe

Figure 2: UniBEaM25 Probe (KFQ flange option shown)

4.3 Power Cord

The AC power cord included with UniBEaM is a 1-meter-long IEC C13/C14 power cord. Other regional-specific IEC power cords are available – see section 17.

Figure 3: IEC C13/C14 AC power cord (standard)[7]

4.4 UniBEaM Sensor Fibers

UniBEaM is supplied with two sensor fibers pre-installed in the probe. Two replacement fiber cartridges are also provided with the system. The replacement fibers are provided in a protective housing. This housing serves as the installation tool. See section 12 for details on replacing a fiber.

A spare empty fiber cartridge is provided as a tool to remove old fibers from the UniBEaM probe.

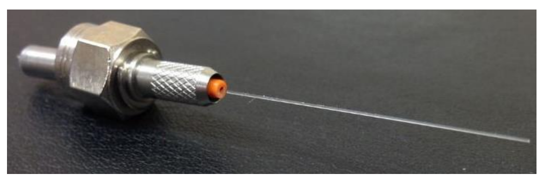


Figure 4: Ce3+ doped SiO_2 fiber

Figure 5: Replacement fiber cartridge, CE1-200-25 (200µm x 25mm)

[7] Other power cords available. See section 17.

4.5 Cables

Figure 6: Fiber optic cable, 400µ, 15m (Left) and motor cable, 15m (Right)

4.6 Grounding Kit

Figure 7: UniBEaM grounding kit

4.7 Fiber Port Hex Wrench

A hex wrench is provided for removal of fiber replacement port/window.

Figure 8: Fiber port hex wrench

5 PRINCIPLE OF OPERATION & SYSTEM OVERVIEW

Each UniBEaM probe has two sensing fibers; one for X-profiles and one for Y-profiles (see *Figure 9*). The sensor fibers are moved through the beam by stepper motor actuators. Home switches ensure accurate fiber positioning. There are no electronic components in the probe, making the probe radiation resistant. Two ports in each probe provide access to replace the fibers. Replacement sensor fibers are provided in protective cartridges which also serve as the installation tools. Fiber replacement takes about two minutes following vacuum venting.

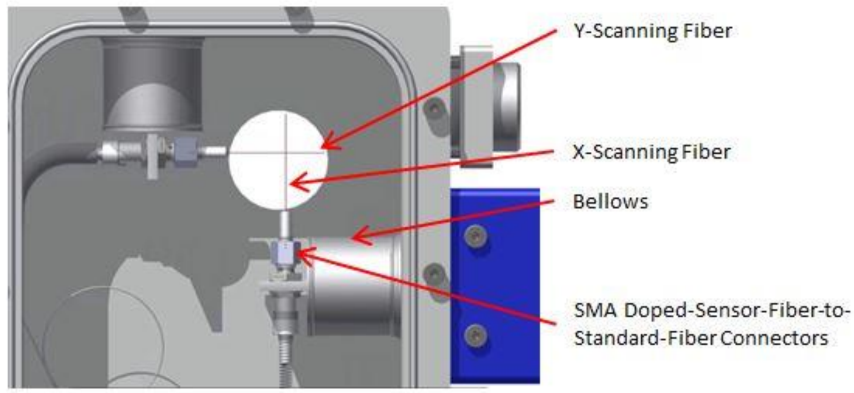


Figure 9: X & Y scintillating fibers and fiber connectors

The optical sensing fibers are SiO_2 doped with Ce3+ ions as luminescent activators and have a diameter of 200μm. The scintillation is produced by charged particle or X-ray beams. The fiber produces intense and fast radio luminescence emitted by the Ce^{3+} dopant ions, with an emission band centered at 450nm. [i, ii, iii] The SiO_2 fiber also produces luminescence due to Cherenkov radiation, which is characterized by a broad spectral emission in the blue-UV wavelength region. [iv, v]

The sensor fibers are coupled to 200μm core, 0.5 NA fibers within the probe using in-vacuum SMA connectors (see Figure 10). These non-scintillating, in-vacuum fibers pass through vacuum feedthroughs and are terminated on the atmosphere side of the probe with a second pair of optical SMA connectors.

Another pair of optical fibers is used to connect the probe to the UniBEaM controller. These fiber-optic patch cables are 400μm, 0.5 NA fibers, which transmit the optical signal, to a silicon photo multiplier (SPM) located in the UniBEaM controller. The scintillation light can be transmitted tens of meters with minimal signal loss, and with no susceptibility to electromagnetic fields.

The SPM sensors are sensitive, fast, compact, and robust solid-state light sensors. The SPM sensor's spectral sensitivity is well matched to the spectral emission of the cerium-doped fiber. The SPMs utilizes approximately 3600 independent sensor channels. Each channel acts as an independent avalanche photo diode. Each sensor channel behaves as a photo-activated switch, but the integrated total current of the large number of SPM channels results in a quasi-analog signal.

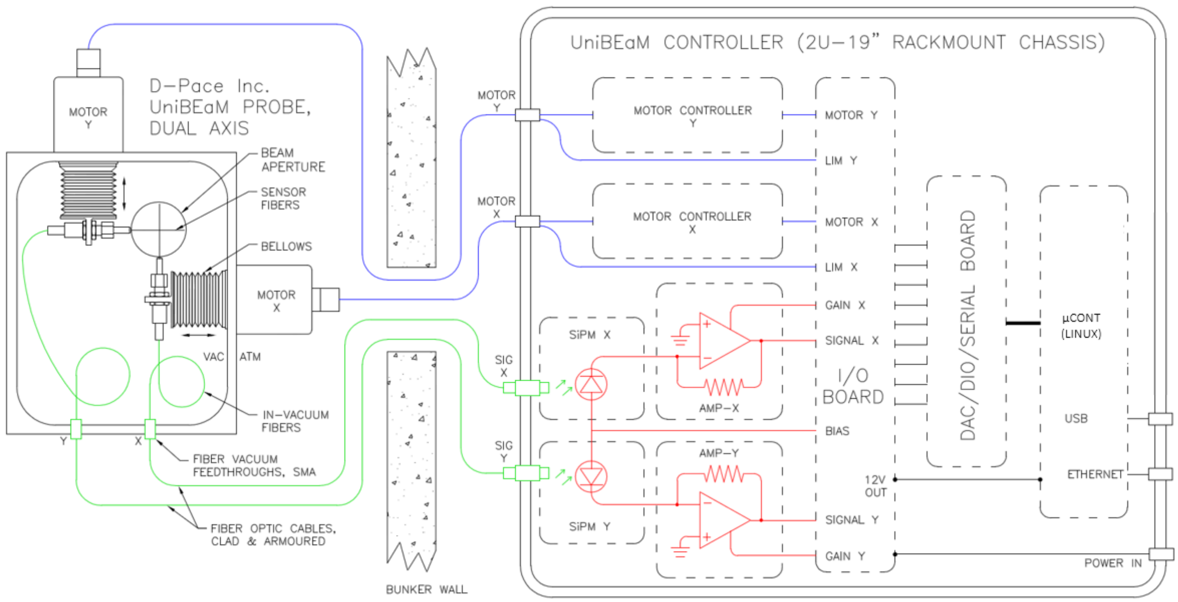


Figure 10: UniBEaM Commercial System Architecture

Programmable amplifiers with three orders of magnitude of programmable gain are used to provide user-controlled voltage signal amplification. The system's analog-to-digital converters (ADCs) specifications are ±10V, 12bit, 50kS/s/channel. A dedicated amplifier for each axis allows simultaneous X & Y profile scanning.

Graphical user interface software is provided. The user can install this software on their own PC to control the system via Ethernet. The user can also interface directly with the system's controller using text-based commands over Ethernet.

The UniBEaM software acquires and analyzes beam profiles. The user can change the position step size, and scan range. Single or continuous scans can be acquired.

The scan speed is user adjustable. Slower scan speeds enable greater signal averaging for improving the signal-to-noise ratio of low beam current scans, but at the cost of longer scan times. The software calculates the beam centroid and the integral of the intensity profile. The user can set the zero value for the position and integral calculations. Profiles are saved in a CSV-format file with header data. See section 11 for file format details.

6 DESIGN

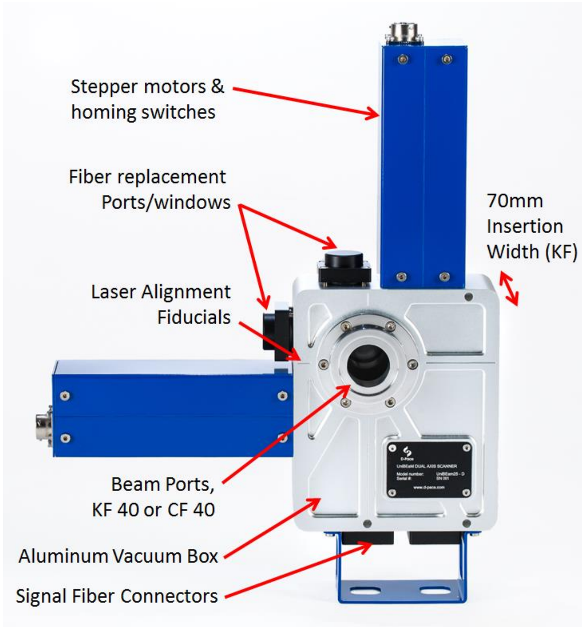


Figure 11: Features of UniBEaM Probe

UniBEaM was designed with the following features and advantages over conventional wire scanners in mind:

1) Large dynamic range. UniBEaM can measure beam currents from ~pA to mA depending on absorbed dose

2) Orthogonal Scans. Unlike oscillating and helical scanners, UniBEaM profiles are truly orthogonal.

3) In-Plane Scans. UniBEaM profiles are measured in the same plane, whereas rotating helix scanners measure over a range of positions in the beam axis (Z coordinate).

4) Proximity of X & Y scans. UniBEaM X & Y profiles are only 7.6mm apart in the beam axis.

5) Sensor fiber position control. The position resolution of UniBEaM is 25µm. Start and stop positions are set by the operator. Sensor fiber speed can be controlled to allow current signal averaging to improve signal-to-noise.

6) Effective Resolution. UniBEaM25 standard fiber diameter is 200µm. The optical fiber is not affected by resolution broadening caused by secondary electrons, as is the case with conventional wire scanners.

7) Stop-Start Control. With UniBEaM, the operator can set a wait period between scans. This allows time for sensor fiber to cool, out of the beam path, if required.

8) Fixed Position Intensity Monitoring. The UniBEaM sensor fiber can be moved to fixed locations for measurements in time domain. This can be used to monitor beam intensities at the periphery of high-power beams over time – similar to a beam scraper or collimator jaw.

9) Short Insertion Length. UniBEaM does not require a vacuum box or Tee. It is an in-line probe and requires only 70mm insertion length.

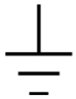
10) Inexpensive Sensor Fiber. Sensor fibers are inexpensive and can be replaced in less than two minutes without removing the device from the beamline.

11) Radiation Resistance. UniBEaM has no semiconductor electronic components in the probe.

12) Immunity to electrical interference. Unlike conventional wire scanners, the UniBEaM intensity signal is optical and not affected by electrical and magnetic fields.

7 SYSTEM INSTALLATION

The installer must be familiar with making sensitive measurements and understand methods to mitigate electrically noisy environments through grounding techniques, wire routing and shielding.



Earth (Ground) Terminals

Chassis Terminal

7.1 Controller Installation

The controller can be mounted in a 19” rack. The controller chassis is 325mm deep excluding the connectors and front handles. It can be mounted by its rack mounting brackets without support shelfs or side rails, however it is recommended to use support rails if it will be transported mounted in a rack.

7.2 Ground Connection, Controller

The controller is connected to earth ground via the AC power connector. A supplemental ground stud is available on the back panel of the controller (see section 4.6).

Figure 12: Supplemental chassis ground stud on back panel

7.3 Connect Power to Beam Profiler Controller

Connect AC power to the controller with the IEC power cable provided (see *Figure 13*).

7.4 Connect Fiber Optic Signal Cables and Motor Cables

Connect the two fiber optic signal cables and motor cables between the probe and the controller (see *Figure 13*).

(1) Cables, Fiber Optic Signal
(2) Cables, Motor
(3) Cable, Ethernet, CAT5e or better (user-supplied)

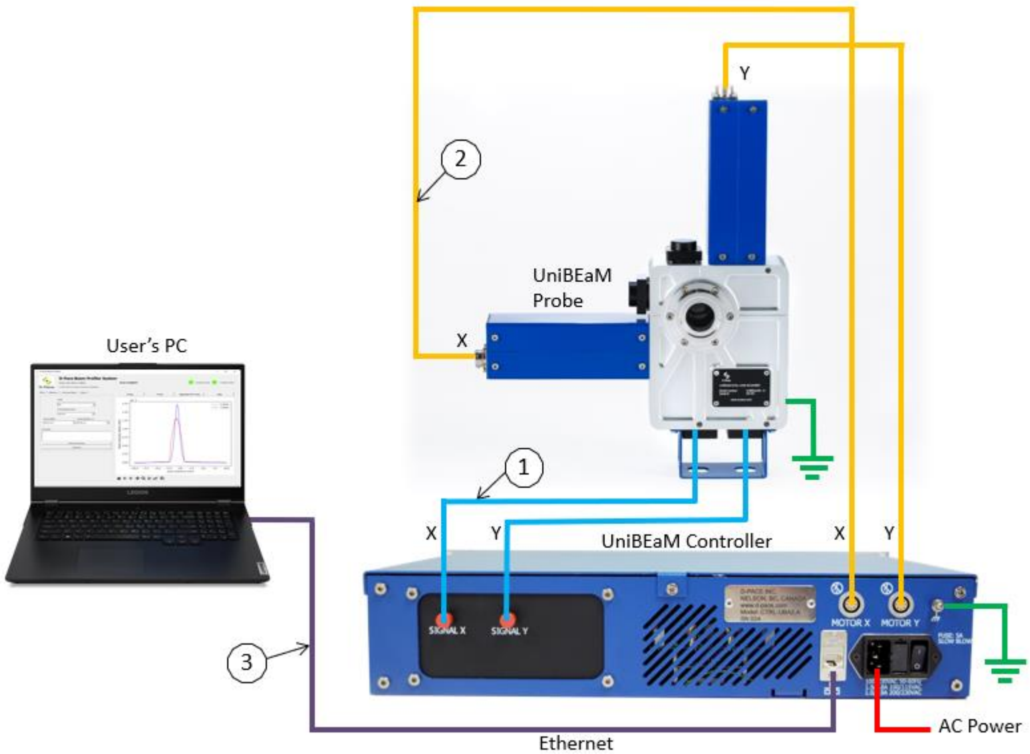


Figure 13: UniBEaM Connections

<u>The fiber optic cables should be run in a protective tray or conduit to avoid damage.</u>

<u>The minimum bend radius of this fiber is 64 mm. Bending the fiber at smaller radius will cause signal loss or break the fiber.</u>

7.5 Probe Installation

7.5.1 Probe Orientation

UniBEaM is installed with the front face of the probe facing upstream. In this configuration, the X fiber is 30mm from the front face of the probe. The Y fiber is an additional 7.6mm from the X fiber's measurement plane (see *Figure 14*).

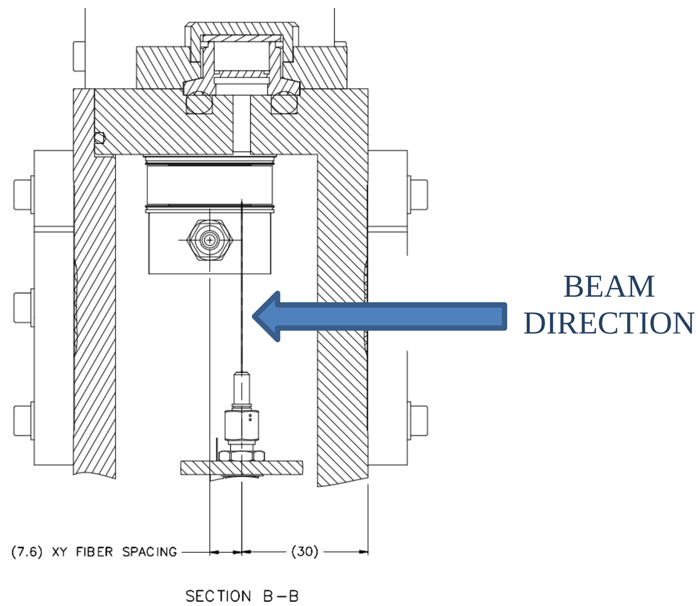


Figure 14: X & Y sensor fiber positions

UniBEaM can be installed front to back, or in any rotational position.

UniBEaM25 has a total fiber travel of 31 ± 0.5mm (see *Figure 15*):

1. *Beam center to home position: - 16mm*
2. *Beam center to maximum extension: +15mm*

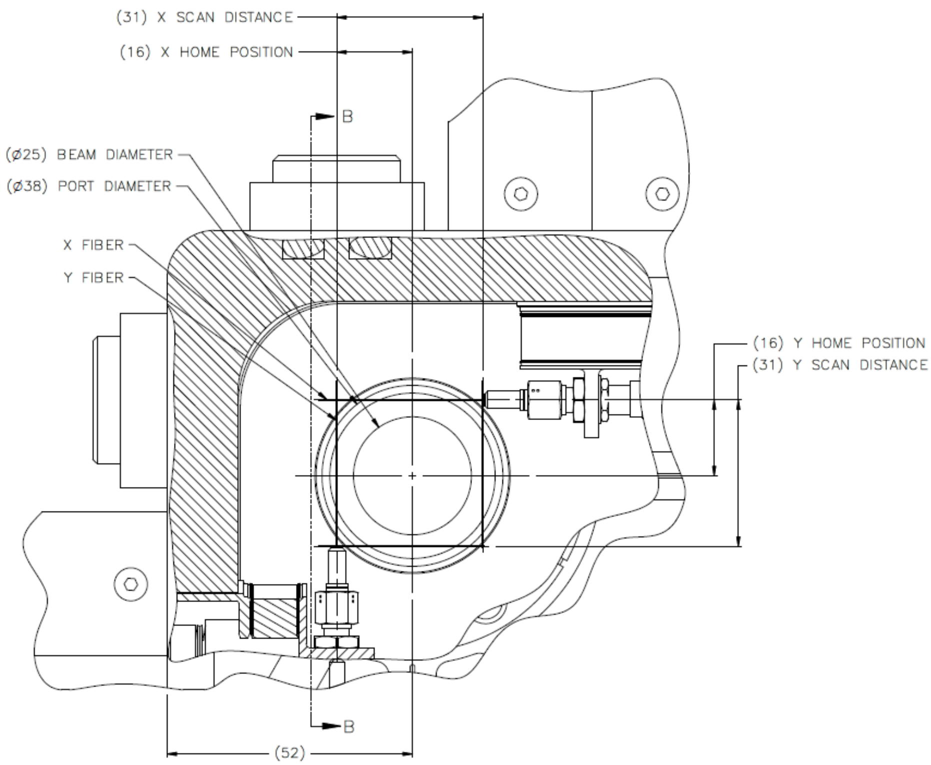


Figure 15: X & Y scan fibers (viewed in beam direction)

7.5.2 Support for UniBEaM Probe

UniBEaM can be cantilevered from a beam pipe.

Additional loads, such as lengths of beam pipe or other instruments must be supported OR UniBEaM must be supported by means of a bracket or stand. UniBEaM flanges may be damaged by excessive loads.

A support bracket may be attached to the UniBEaM probe. The probe has four M4x0.7 mounting holes on the side of the probe for supporting the probe (See drawings, section 15) for locations of the holes.

7.5.3 UniBEaM Probe Alignment

The UniBEaM probe has laser-line alignment fiducials on the front face of the probe. These markings indicate the nominal beam axis of the probe.

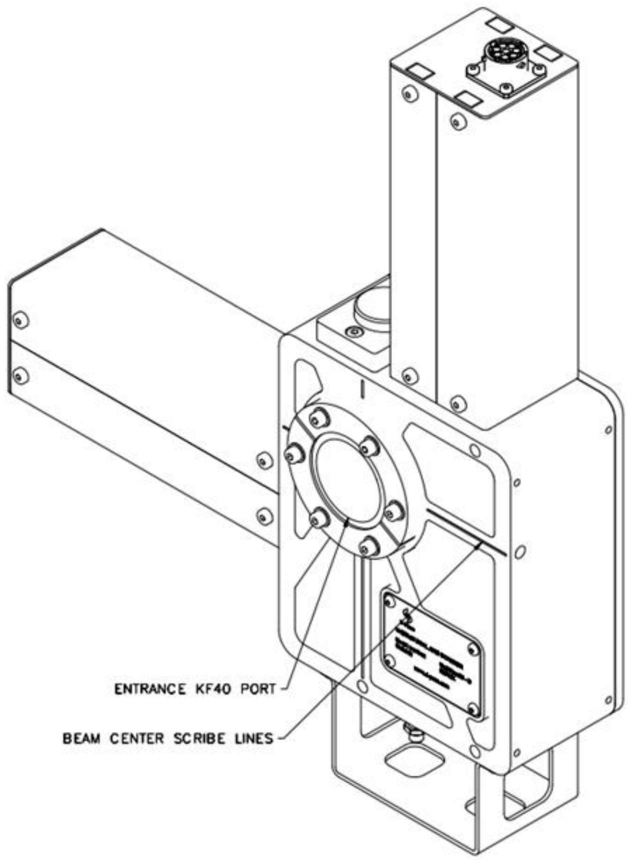


Figure 16: Laser-line alignment fiducials

The UniBEaM beam probe also has four mounting locations for laser tracker spheres mounts. There are three mounts on the front face, and one on the right side. These holes are for 6mm pins. See drawings in section 15.

7.6 Ground Connection, Probe

The probe must be connected to earth ground to prevent damaging the controller or the risk of shock. Use the M4 screw and terminal provided.

An M4 screw, washer, and ground wire is provided for grounding the probe (see section 4.6). Ground the probe using this wire to the location shown below. If these holes are used for a mounting bracket, use an alternate grounding location such as a flange bolt.

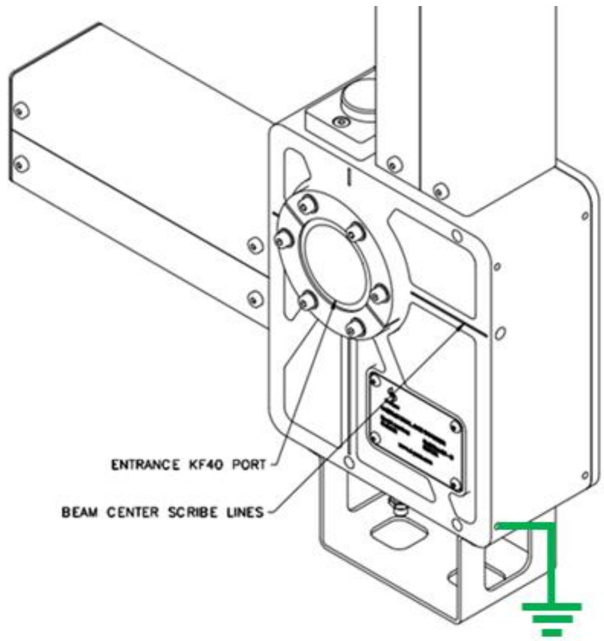


Figure 17: Connect UniBEaM probe to earth ground.

8 INSTALLING USER INTERFACE SOFTWARE

D-Pace provides a graphical user interface (GUI) with the system on a USB drive. Follow the steps below to install the GUI software onto the user's PC.

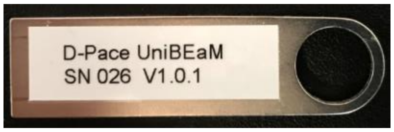


Figure 18: USB drive with GUI and Manual

1. Copy the entire D-Pace Beam Profiler directory to C:\ of the PC on which the user interface will be operated.
2. From the Beam Profiler directory, copy the Beam Profiler Shortcut to the desktop or add it to the start menu.
3. Run the Beam Profiler user interface from the shortcut.

Alternatively, you may create your own GUI software, and interface directly with the beam profiler controller. See section 15 for further details.

9 OPERATING UNIBEAM

9.1 Powering the Controller

Turn on power switch to power system.

Allow system to warm up for minimum 4 minutes before use.

Figure 19: Powering Beam Profiler Controller

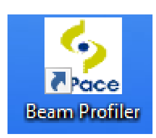
There are five LEDs on the front panel:

4.	POWER:	Power switch is turned on
5.	BIAS:	Not applicable to UniBEaM
6.	REMOTE:	Ethernet communication established
7.	SCAN X:	Horizontal scan in progress
8.	SCAN Y:	Vertical scan in progress

Figure 20: Power Indicator

9.2 Starting graphical user interface software

Start graphical user interface software by clicking on the icon:



9.3 Main Screen

The profiler software has four tabs – Setup, Reference, Advanced Setup and Debug (see *Figure 21*).

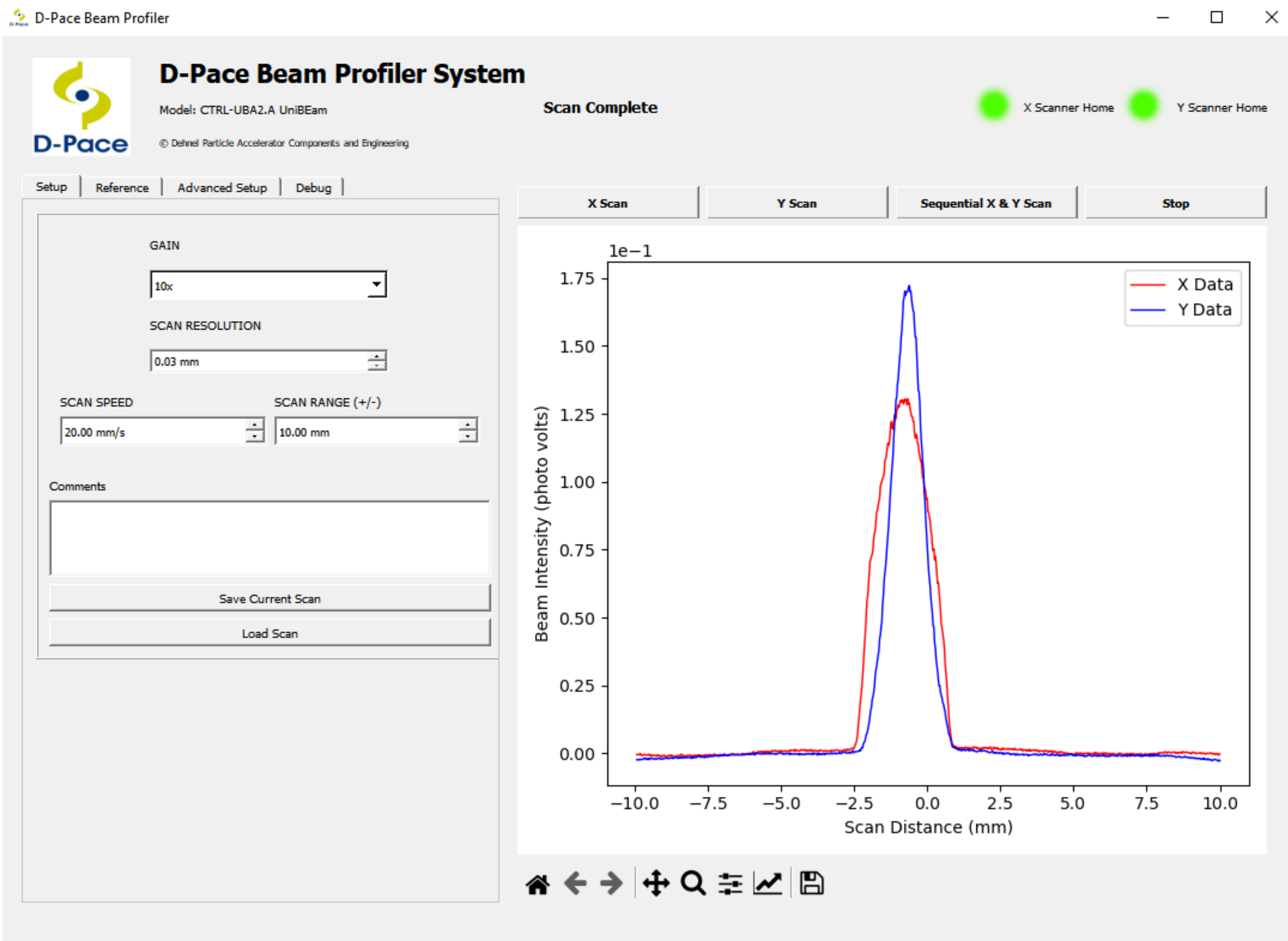
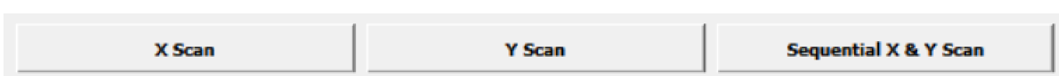


Figure 21: Profiler Software - Setup

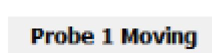
9.3.1 Single Scans and Sequential Scans

Single scans or sequential scans may be conducted. For sequential scans, X scans precede Y scans.



When the home indicator is yellow, a scan is in progress.

The status indicator also states which scan is in progress.



Scans can be stopped at any time. When a scan is stopped the probe returns to home position, and the partial scan data is displayed.

9.3.2 Scan Range

Enter the scan range in mm. These distances are relative to the nominal beam axis of the scanner.

9.3.3 Scan Speed

Enter the scan speed in mm/s.

The system acquires beam intensity measurements at a fixed rate of 50,000 samples per second per channel. The faster the scan speed, the fewer samples are averaged per position, and the more noise will appear in the beam profile. For example, if the scan speed is 20mm/s, and the scan resolution is set to 0.10 mm, the number of samples averaged per position is (0.1 mm)/(20mm/s)·(50,000 samples/s) = 250 samples.

Conduct a scan at the maximum allowable scan speed for the probe. If the signal noise is acceptable, use this scan speed. If the signal noise is excessive, then reduce the scan speed. The signal noise can also be reduced by decreasing the scan resolution, as described below.

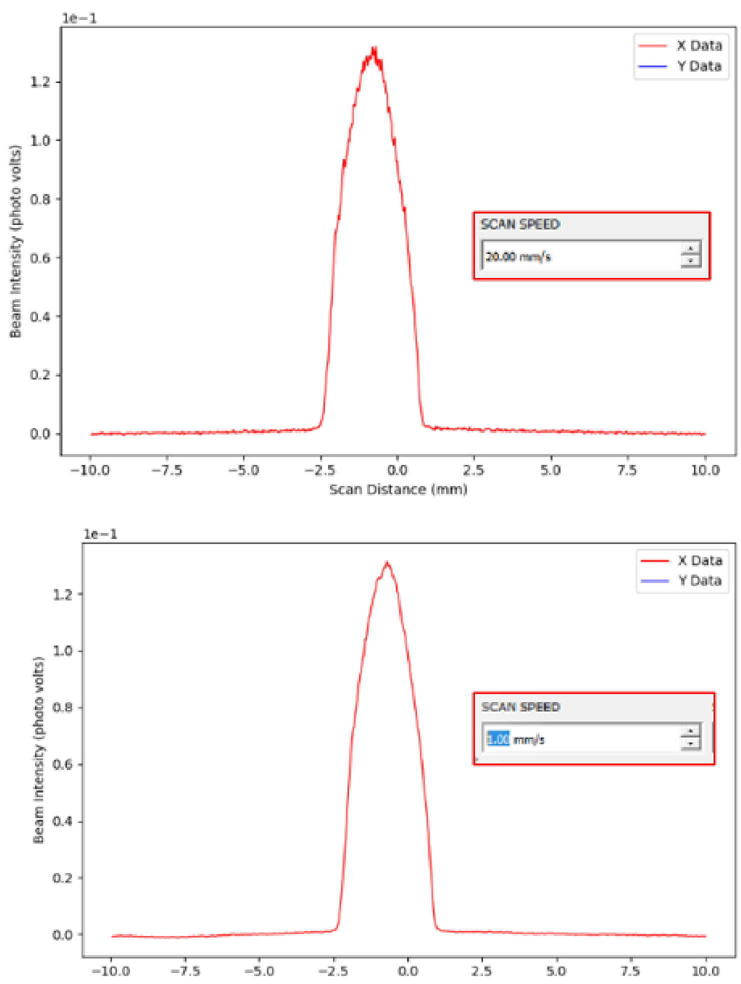


Figure 22: Reducing profile noise by reducing scan speed.

9.3.4 Scan Resolution

The scan resolution setting is the resolution of the data returned by the controller, plotted in the user interface, and written to the data file.

The highest resolution of the UniBEaM probe is 0.0254 mm which is the smallest increment of the scanner. This limits the absolute positional accuracy and resolution. If the user sets the resolution to 0.100mm, the actual resolution will be (0.100 mm / 0.0254 mm) = 3.937 steps. This is rounded down to 3 steps, resulting in an actual resolution of 0.0762 mm.

Reducing the scan resolution will reduce the beam profile noise, because more beam intensity measurements are averaged per position.

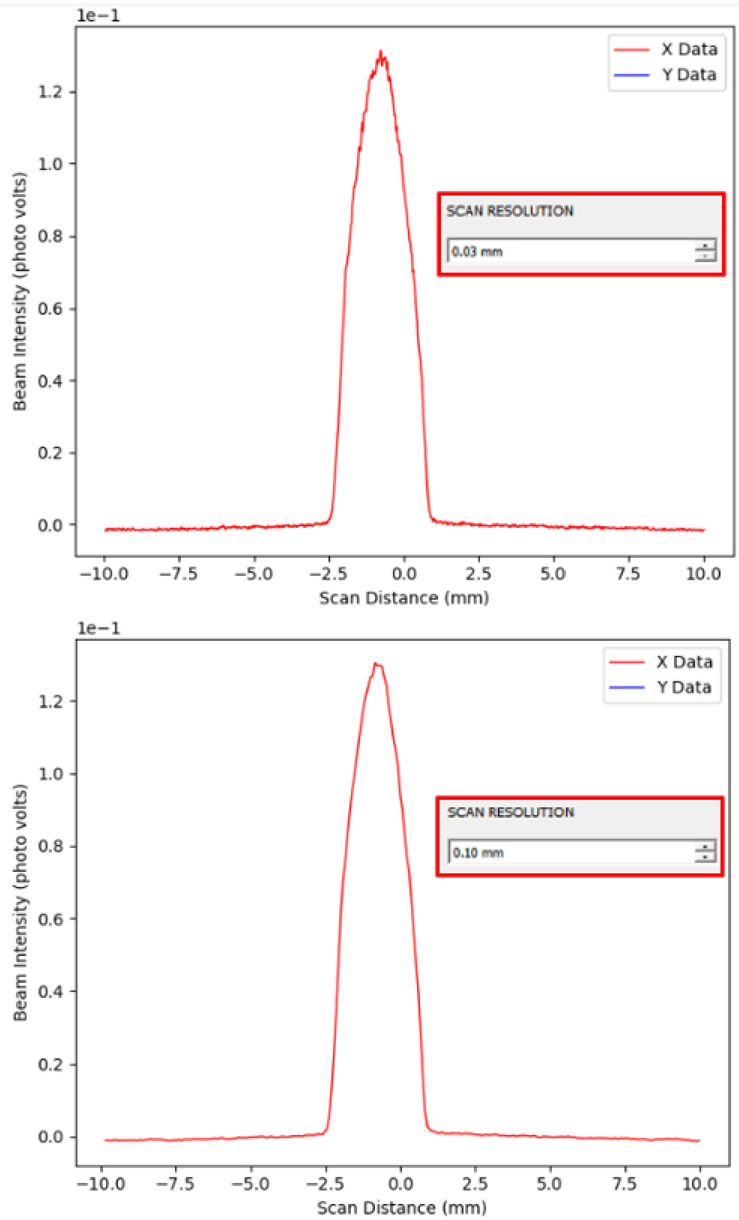


Figure 23: Reducing profile noise by reducing scan resolution

9.3.5 Gain

The profiler controller has a programmable amplifier. To maximize the dynamic range of the controller, use the maximum gain that does not result in saturation of the controller's analog to digital convertor (ADC). The ADC range is +/- 10V.

If the beam profile signal becomes saturated, where the maximum exceeds 10V, then reduce the gain as shown in the illustration below.

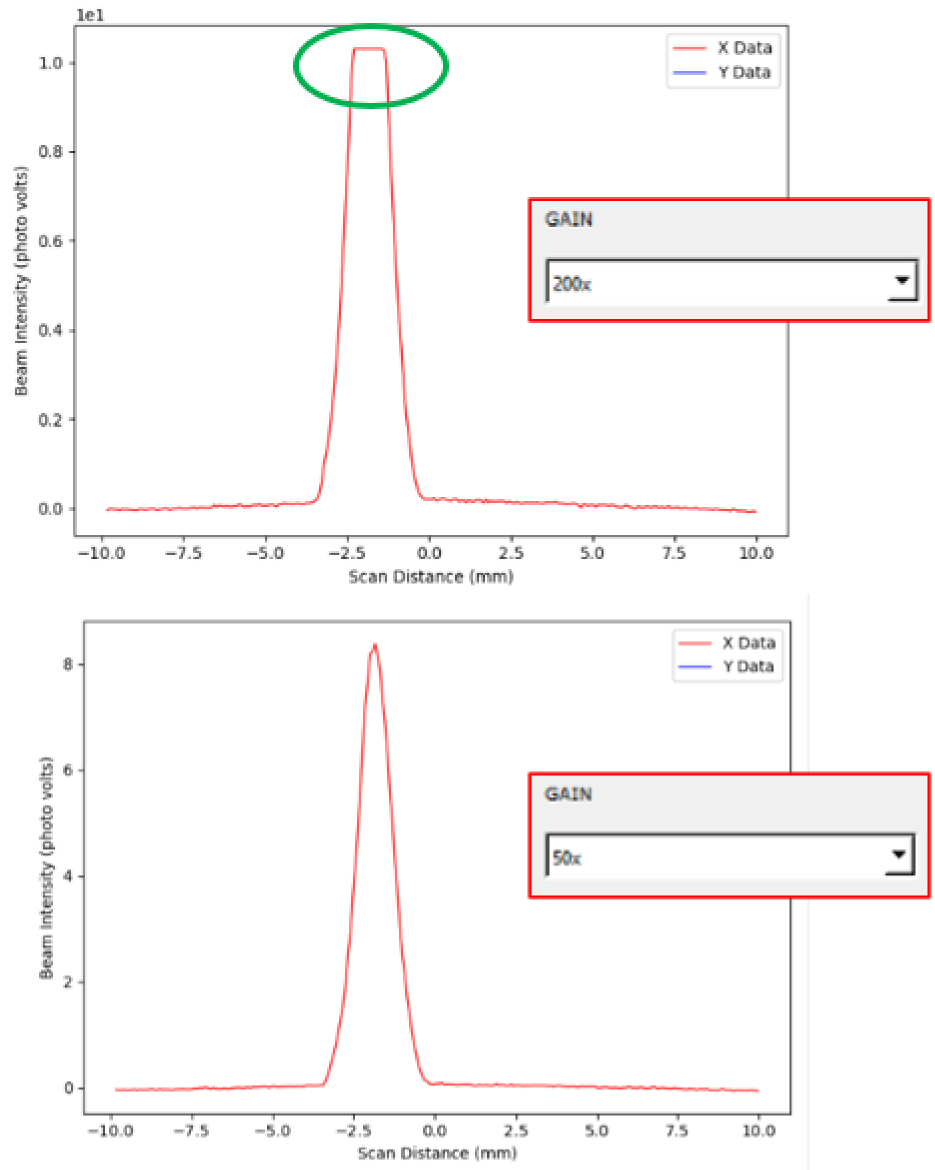
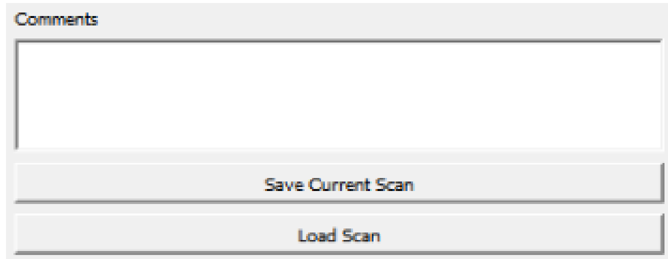


Figure 24: Adjusting the amplifier gain to avoid saturation

9.3.6 Comments / Save / Load

Text entered in the comments field are saved in the data file.



9.4 Reference Tab

The coordinate system utilized by UniBEaM is right-hand Cartesian, as shown in *Figure 25*.

When the fibers of a UniBEaM25 system are retracted to their home position, they are +16mm from the scanner axis.

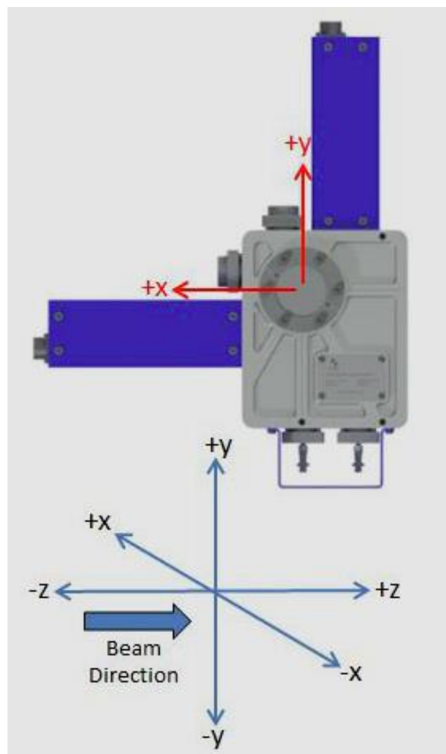


Figure 25: UniBEaM Coordinates: Right-Hand Cartesian

9.5 Advanced Tab

9.5.1 Scanner Model

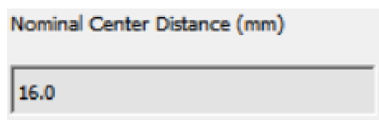
The '*Scanner Model'* indicates the model number of the controller. The example below indicates a two-axis UniBEaM controller.

9.5.2 Step Size

This is the smallest step the probe can move. It is a property of the probe.

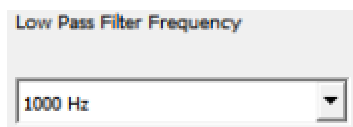
9.5.3 Nominal Beam Center Distance

The '*Nominal Beam Center Distance'* is a property of the probe. It is the distance between the home position of the probe and the nominal center axis of the probe.



9.5.4 Low Pass Filter Frequency

The profiler controller incorporates a low pass filter to reduce signal noise and prevent aliasing. The optimum setting is 500 Hz.

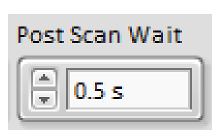


9.5.5 Post Scan Wait Time *(Feature pending)*

For beam scans of higher absorbed power density, a wait period is required after each scan to allow the scan fiber time to cool.

For lower beam powers, where the absorbed beam power is less than $100mW/mm^2$, this wait period is not required, and the wait period can be set to 0 seconds.

For higher power densities, wait periods of up to a minute per scan may be required. See section 13 for further details.



9.5.6 Profile Integrals & Beam Centroids *(Feature Pending)*

This feature calculates the integrals of the beam intensity profiles. For radially symmetric beams, the integrals correlate well with total beam current.

X and Y integrals are in units of (*Beam Intensity · mm)* or *(V · mm).*

The beam intensity profile integrals are dependent on the amplifier gain. If the gain is increased by a factor of 10, the integral will also increase by a factor of 10.

The beam intensity profile centroids (X_0 and Y_0) are also calculated.

The background signal will affect the beam integral and centroid calculations. To reduce the effect of the background signal, adjust the X and Y offset values to match the background signal amplitude. An example of this is shown in *Figure 26* below.

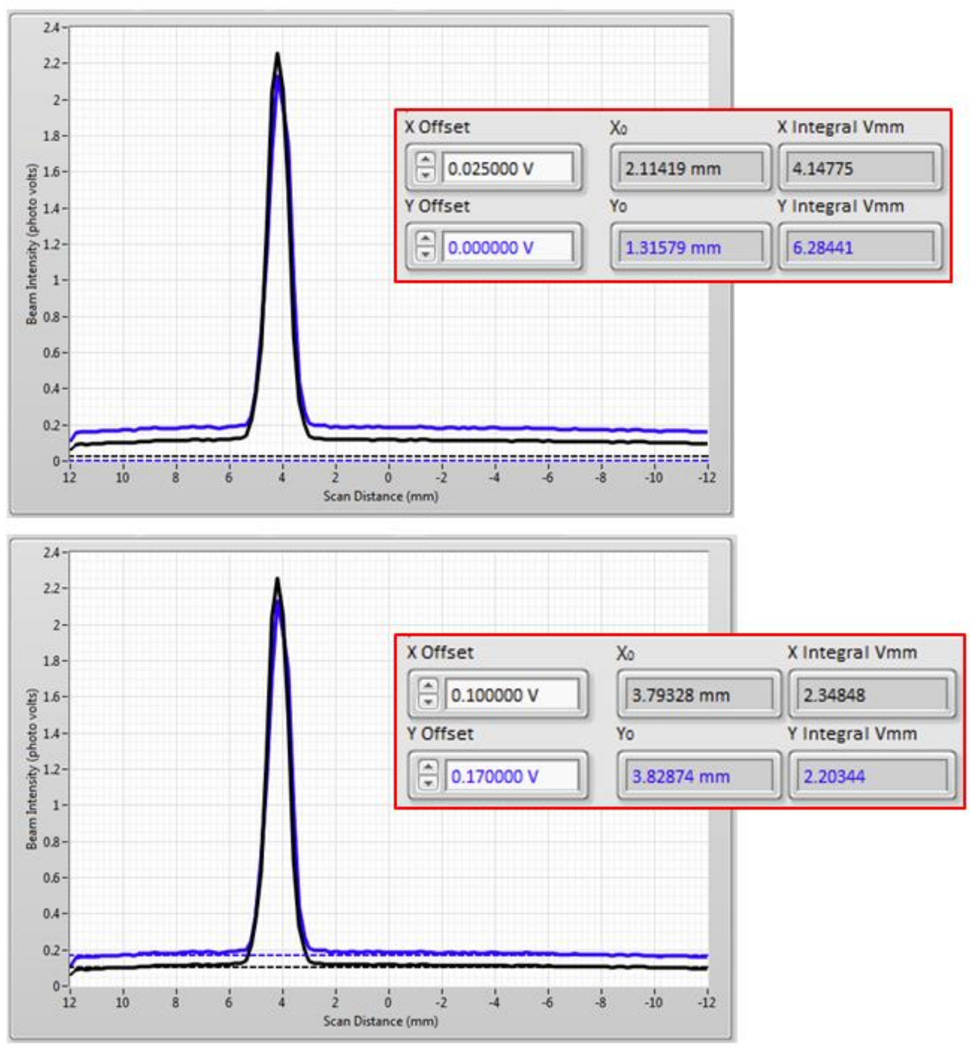


Figure 26: Adjust X & Y offsets to subtract the background signal

9.5.7 Adjusting Channel Offsets

Differences between the X & Y channels (sensor fibers, fiber connections, optical sensor offsets, and amplifier offsets) will result in different offsets for the X & Y channels. This is normal.

Corrective offsets can be applied to the X & Y channels to compensate for this. See *Figure 27: Scan Prior to* for an example.

These adjustments can be applied by manually entering values for the gains and offsets, and selecting '*Apply Adjustment*'. The adjustment will only be applied to the current scan unless '*Always Apply Adjustment*' is selected.

The offsets can also be calculated automatically by selecting *Calculate Offset* – this determines the minimum value with the current data scan and utilizes this value as the offset when '*Apply Adjustment*' is selected (see *Figure 27* and *Figure 28*).

Similarly, both gain and offset can be calculated automatically by selecting '*Calculate Gain and Offset*'. The gain of the scan with the lower peak intensity is increased to normalize the value at the same peak intensity as the other channel (see *Figure 29*).

These adjustments are applied to the displayed data only. They are not applied to the saved data files.

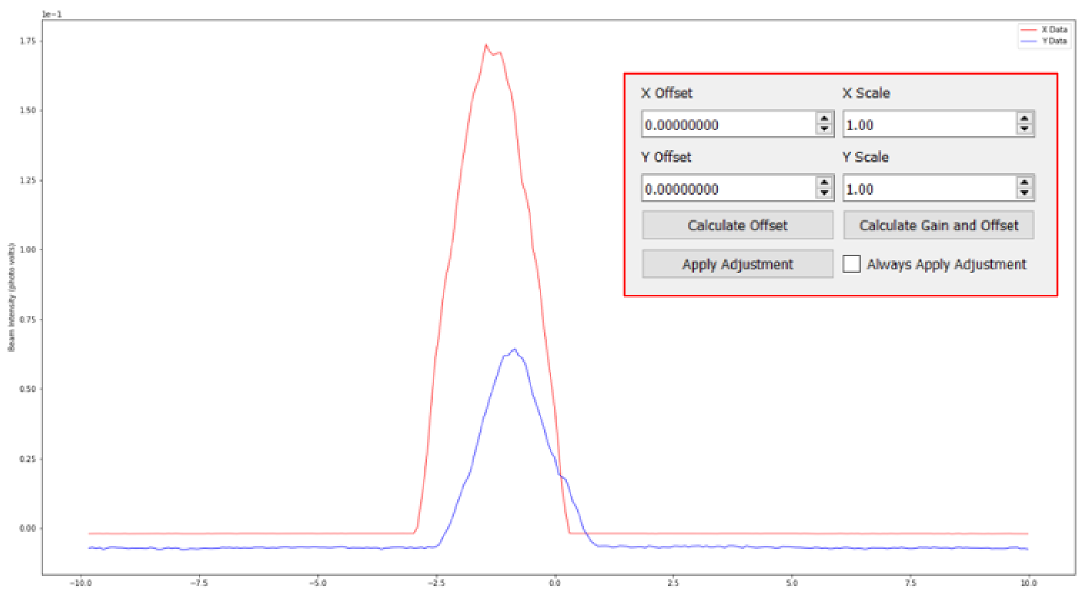


Figure 27: Scan Prior to Gain & Offset Adjustment (Offset = 0.0, Gain = 1.0)

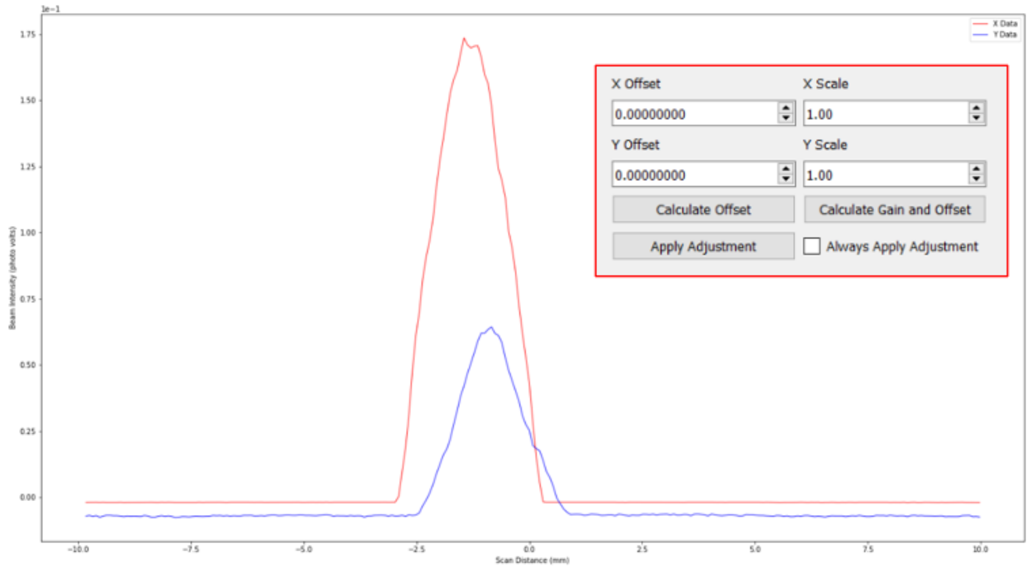


Figure 28: Scan after application of offset adjustment

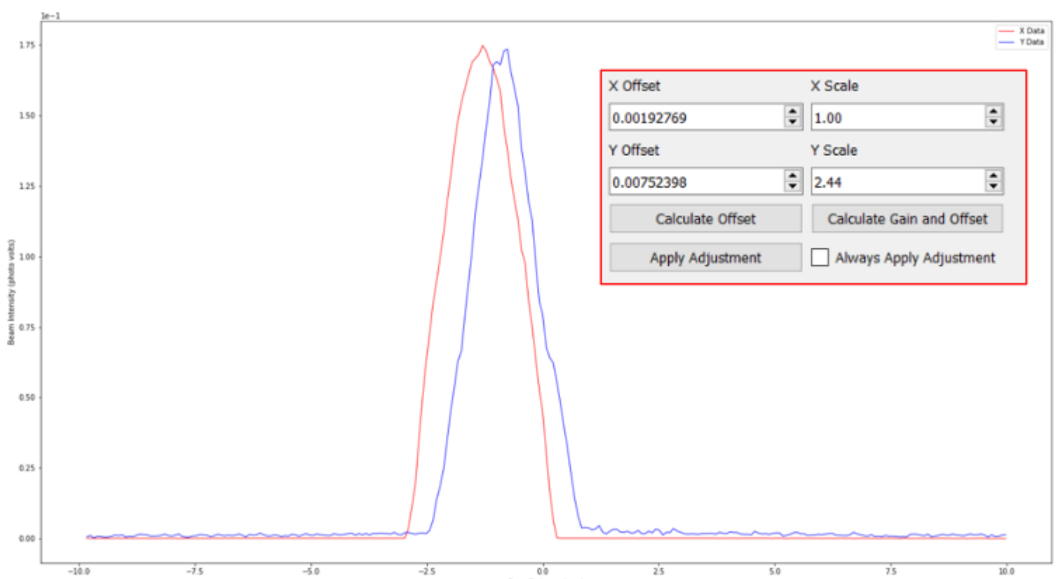
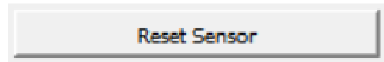


Figure 29: Scan after application of offset and gain adjustment

9.6 Reset Sensor

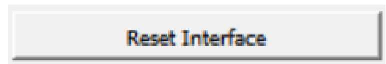
The SiPM light sensors used in UniBEaM will shut down when exposed to excessive light to protect themselves from damage. This may occur if the optical connectors are removed from when the controller is powered.

If no beam signal is observed, the light sensors may need to be reset.



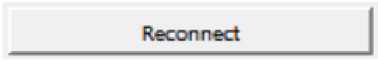
9.7 Reset Interface

Press the reset interface button to revert to the default controller settings.



9.8 Reconnect

Press the reconnect if the graphical user interface loses it's connection with the profiler controller. The '*Remote*' LED on the front panel indicates if a connection is present.



9.9 Debug Tab

The profiler controller has a debug tab for troubleshooting purposes. If technical assistance is required, D-Pace may request system messages from this tab.

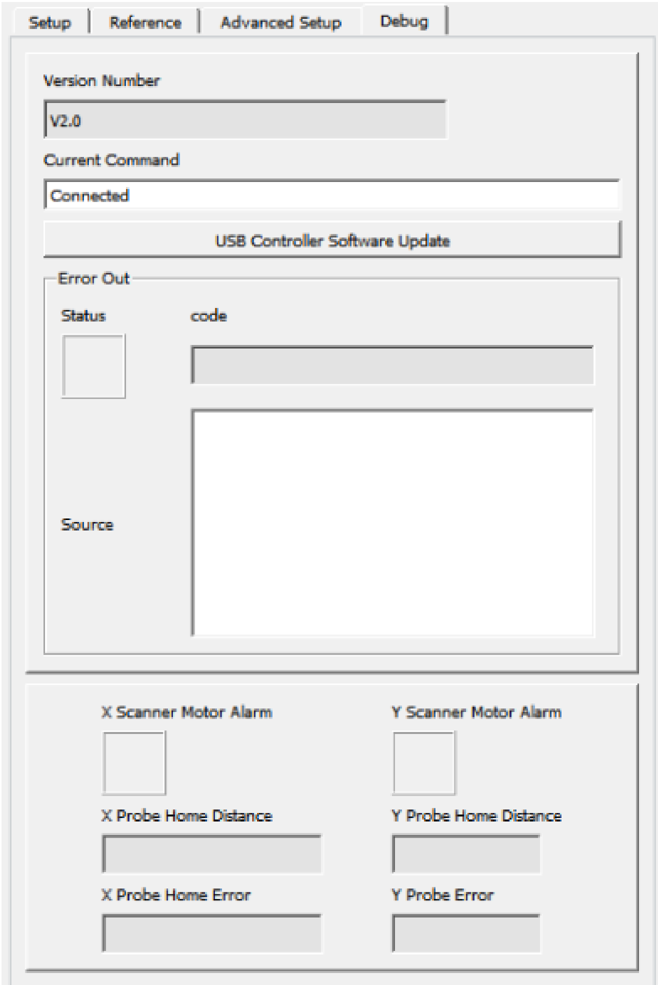


Figure 30: 'Debug' Tab

9.10 Fixed Position Mode (*feature pending*)

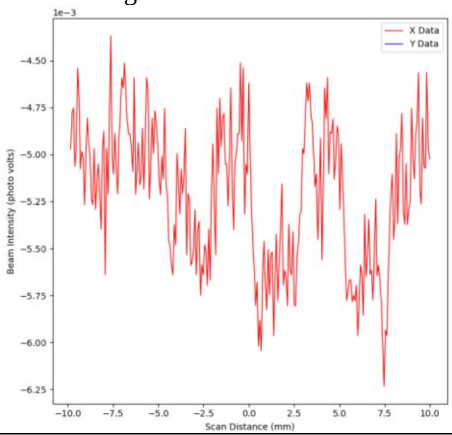
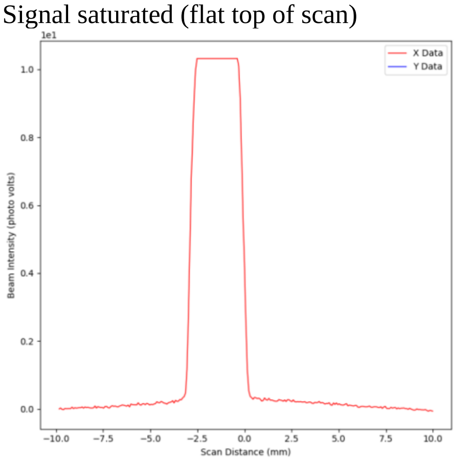
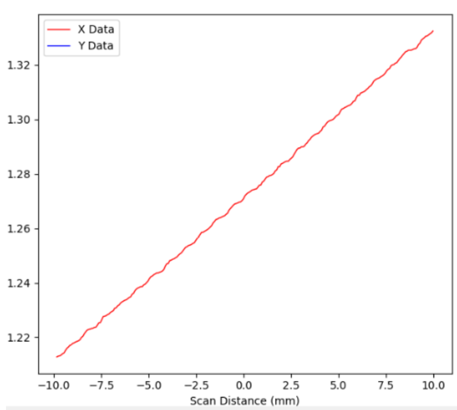
'*Fixed Position*' mode allows the operator to move the fiber to a stationary location and monitor the beam signal over time.

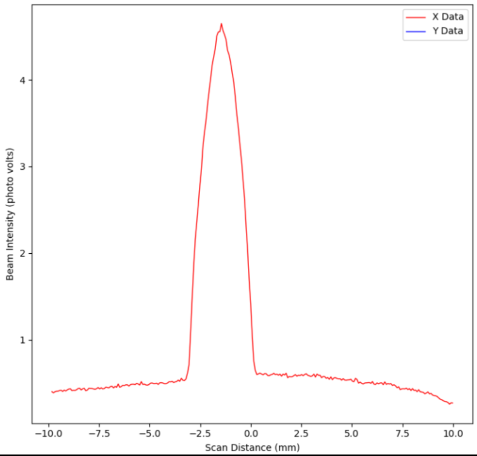
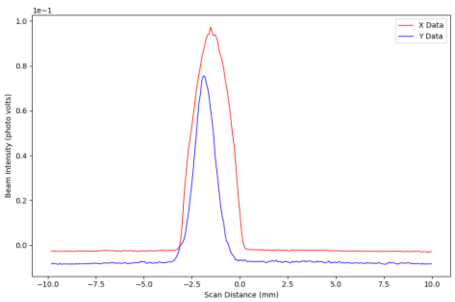
This feature is useful for monitoring the intensity at the edges of a beam, which is particularly useful when the beam power density is too high for the sensor fiber.

In fixed position mode, the operator can move the fiber to a fixed position using the slider bar controls or by entering a position using a keyboard. The plot displays the measured beam intensity at this location over time.

The fiber will be stationary in the beam subject to thermal damage at lower power densities than for scanning mode, where the fiber is moving. **See section 13 details.**

10 Trouble Shooting

<table>
<tr><th>Problem / Symptom</th><th>Possible Cause</th><th>Solution</th></tr>
<tr><td rowspan="2">No beam signal measured.

</td><td>Light sensor saturated with excessive light.
This may occur when the fiber cables are detached from the controller when the controller is powered.</td><td>Reset the light sensors in software (see section 9.6).
If this does not solve the problem, power cycle the controller for five seconds.</td></tr>
<tr><td>Sensor fibers damaged or broken.</td><td>Open probe and check fiber condition.
Replace sensor fiber if required.</td></tr>
<tr><td rowspan="2">Signal saturated (flat top of scan)

</td><td>Beam profile controller gain is set too high. The controller analog to digital (ADC) convertor is saturated. Signal must be
(-10V < signal < +10V)</td><td>Decrease the system gain (see section 9.3.5).</td></tr>
<tr><td>Beam profile is saturated, but gain is set to minimum.
Beam intensity is too high for UniBEaM, and fiber damage may occur.</td><td>Reduce beam intensity.
Move probe to different beam location.</td></tr>
<tr><td>Beam signal ramping of current:

</td><td>System is still warming up.
When the system is turned on, and warming up, the optical sensor electronics perform a zero-offset correction. This will take about two minutes.</td><td>Allow minimum of two minutes for system to warm up.</td></tr>
</table>

<table>
<tr>
<td>Beam signal detected outside expected range of the beam.

</td>
<td>This can be caused by stray light.</td>
<td>Ensure optical windows in vicinity of UniBEaM are covered.</td>
</tr>
<tr>
<td rowspan="2">Vertical signal offset between X and Y scans.

</td>
<td rowspan="2">There is an inherent voltage offset between the amplifiers for the X and Y channels. This is more pronounced for small signals at low gains.</td>
<td>Increase the system gain (see section 9.3.5).</td>
</tr>
<tr>
<td>Adjust signal offsets in software (see section 9.5.7).</td>
</tr>
</table>

11 DATA FILE

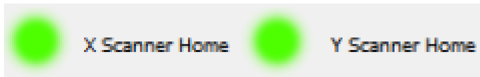
Scan data is saved in a comma separated value (CSV) file. The header of the data file contains the probe and scan parameters used for the scanning session. The integral and beam centroid data for the last complete scan is recorded in the header (feature pending).

Parameter	**Value**	***Comment***
File Name:	C:/Beam Profiler/TestScan.csv	
Data File Format:	V1.0	
Scanner Model:	CTRL-UBA2.A	*Model number of 2 axis analog UniBEaM*
Scanner Serial Number:	25	
Controller Serial Number:	11	
File Time Stamp:	2020-12-12T19:54:00	*Time stamp file opened*
Comments:	Test Scan	
Scan Data:		*No data – marks beginning of per-scan data*
Scan Time Stamp:	2020-12-12T19:54:00	*Time stamp of scan start*
PGA Gain:	1x	*Programmable amplifier gain. Controller applies this gain multiplier to signal sent to controller*
TIA Gain:	1x (1000 uA/V)	
Scan Speed (mm/s):	40	
Scan Resolution (mm):	1	*Resolution of scan data provided by controller. Smallest steps are 0.0254mm. Resolution is rounded down.*
Scan Range (mm):	10	
Filter Frequency (Hz):	500Hz	*Low pass filter cut-off frequency.*
X Offset:		*Set by user to adjust signal zero for beam centroid and integral calculation*
Y Offset:		
Xo:		*Beam centroid position*
Yo:		
X Integral:		*Beam integral in V·mm*
Y Integral:		
Scan Direction:	extend	*Direction is either extend or retract*
Probe 1 Position (mm)	Probe 1 Data (V)	
4.9802	0.51464	
4.8	0.52081	
4.6	0.52004	
4.4	0.52441	
...	...	
Probe 2 Position (mm)	Probe 2 Data (V)	
5	0.64553	
4.8	0.76366	
4.6	0.82373	
4.4	0.87136	

. . .	. . .	

12 Replacing a Sensor Fiber

Ensure both UniBEaM sensor fibers are in their home positions before replacing the fibers. When the UniBEaM controller is on, the two home position indicators must be lit before proceeding. Otherwise, fibers may be damaged.



Probe damage may result if the probe is actuated when the tool is inserted in the probe.

The old fiber must be removed before the new one is inserted, or the new fiber will be broken.

To replace a UniBEaM sensor fiber, first vent the beamline.

Use the 3mm T-handle hex key (see section 4.7) to remove the port window. The two screws are captive – they do not need to be fully removed from the window port clamp.

Figure 31: Loosen 2 screws and remove fiber access port

12.1 Removing Old Sensor Fiber

An empty fiber cartridge is used to remove old fibers from the UniBEaM probe. One end has a hexagonal socket to loosen the fiber, and the other end of the cartridge is used to extract the fiber.

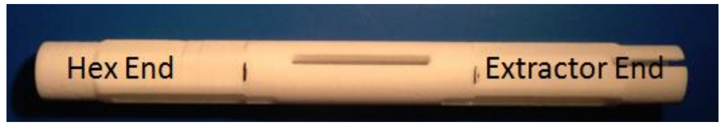


Figure 32: Empty fiber cartridge used to extract old fiber.

Insert the hexagon-wrench end into the port while slowly turning the cartridge until the wrench engages with the nut of the old fiber to be removed. Loosen the nut 1/8 turn counter clockwise. Do not try to remove fiber yet. Remove tool from port.

Figure 33: Insert hex-socket of empty cartridge to loosen fiber 1/8 turn.

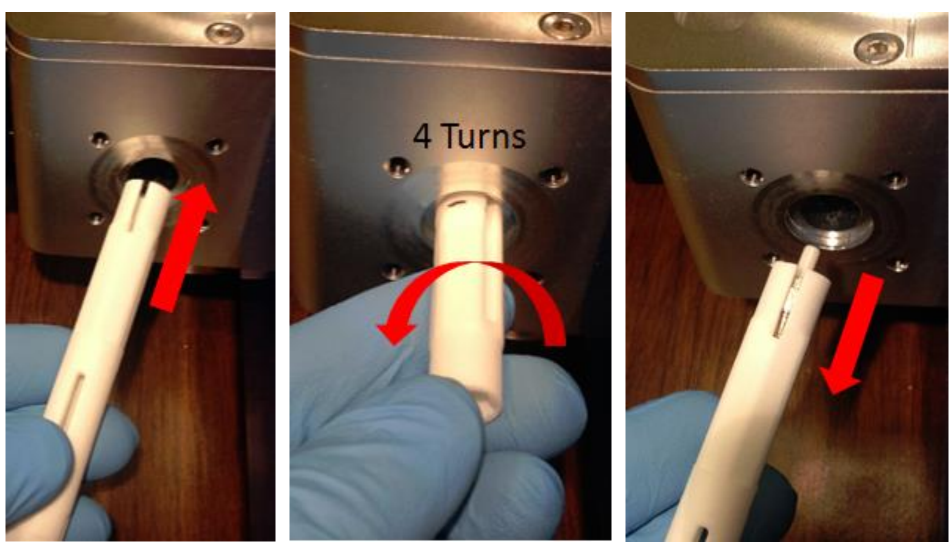


Figure 34: Insert extractor-end of tool. Turn 4 turns ccw & extract fiber.

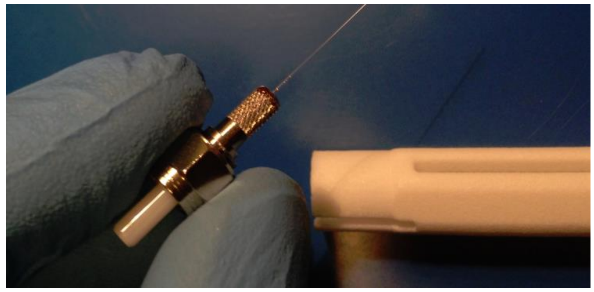


Figure 35: Remove and discard old fiber. Keep tool for future use.

12.2 Installing New Sensor Fiber

New fibers are provided in a protective cartridge, which also serves as the installation tool.

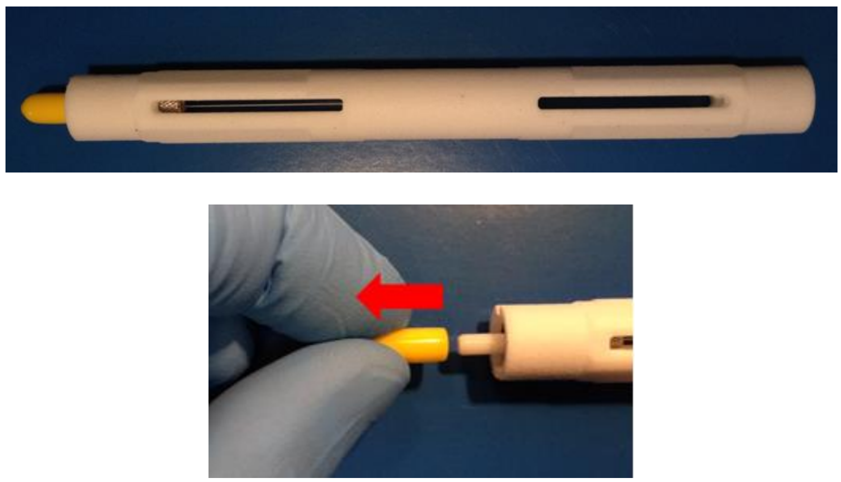


Figure 36: Remove protective cap from the tip of the fiber of new cartridge.

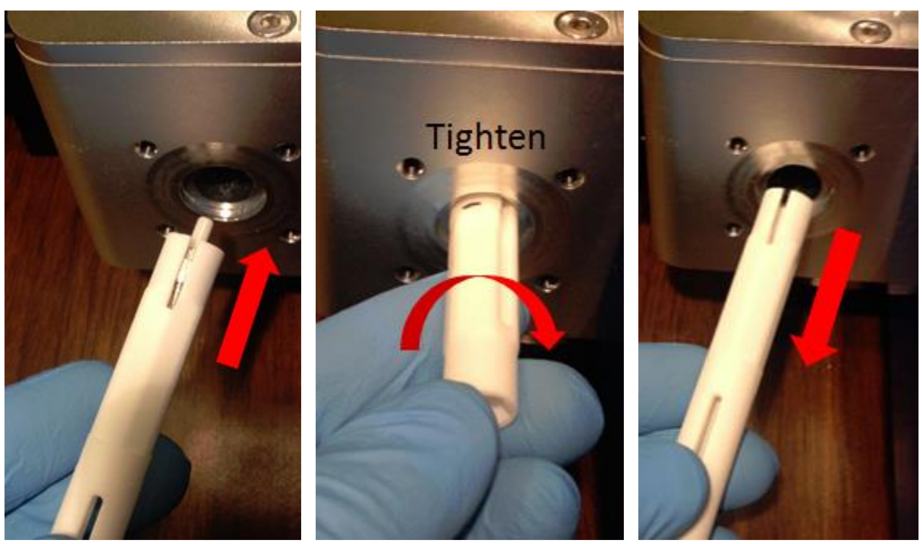


Figure 37: Insert new cartridge, tighten fiber, and remove tool

When tightening the new fiber using the insertion end of the tool, the tool will slip. The hex-wrench end of the tool should be used to further tighten the sensor fiber nut.

Replace the port cap assembly. Some models will have a window assembly (4 parts), while others will have a just the cap and O-ring (2 parts).

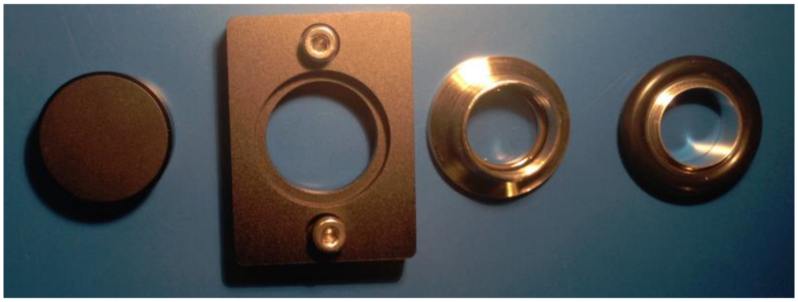


Figure 38: Replace the fiber port. 1) Cap, 2) Clamp, 3) Window, 4) O-Ring

13 APPENDIX A: MAXIMUM BEAM POWER/CURRENT DENSITY

For low energy beams, the beam is completely stopped by the fiber, imparting all of the beam energy in the fiber. The fiber heats up and heat is radiated from the fiber to its surroundings. The maximum absorbed power density of a UniBEaM fiber is 0.5 $W \cdot mm^{-2}$. Exceeding this power density may permanently damage the fiber and will impact the linearity of the sensor fiber.

Experiments conducted [vi, vii, viii] with 18MeV proton beams with diameter 5mm resulted in fiber sensitivity reductions of less than 2% per pass at beam currents of 3µA. This corresponds to an absorbed power density of ~0.14$W \cdot mm^{-2}$.

Between absorbed power density of ~0.1 $W \cdot mm^{-2}$ and ~0.9 $W \cdot mm^{-2}$ the sensitivity of the fiber decreases by approximately 2% to 30% per pass (respectively) through the beam. However, the fiber sensitivity will recover by allowing the fiber to cool between each pass through the beam. A wait period can be set in the software.

The method used to calculate the sensor fiber linearity and damage threshold was the following.

1. Calculate the whether the beam will be completely deposited into the beam. This is done by calculating $z = \frac{E}{\frac{dE}{dx}}$ at every energy. If $z < d$, where d is the diameter of the fiber, then the maximum beam power will be 0.1 W/mm^2 and the maximum current density can be calculated by dividing by the beam energy.
2. If the beam isn't totally absorbed by the fiber, then the absorbed energy is calculated by
$$E_{abs} = \frac{dE}{dx} d.$$
3. The maximum power density applied to the fiber is then calculated by dividing the maximum absorbed power by the ratio of the beam energy over the absorbed energy, as
$$P = P_{abs,m} \frac{E}{E_{abs}}.$$

The maximum current density can then be calculated by dividing by the beam energy.

The following plots illustrate the recommended maximum current density for the sensor fibers as a function of beam kinetic energy, based on a maximum absorbed power of 0.1 W·mm^{-2}. These plots were generated as follows:

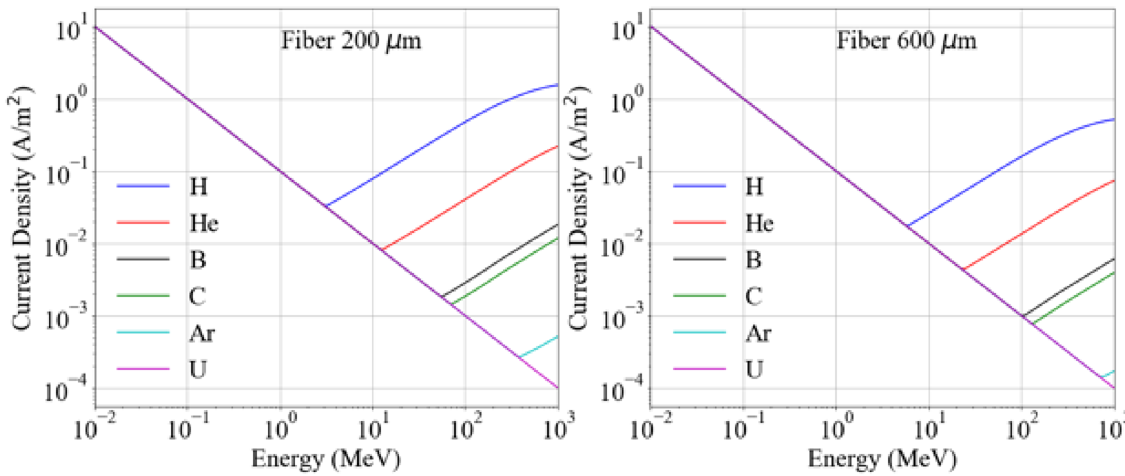


Figure 39: Maximum current density vs beam particle kinetic energy for best linearity (based on maximum absorbed power ~0.1 W·mm^{-2})

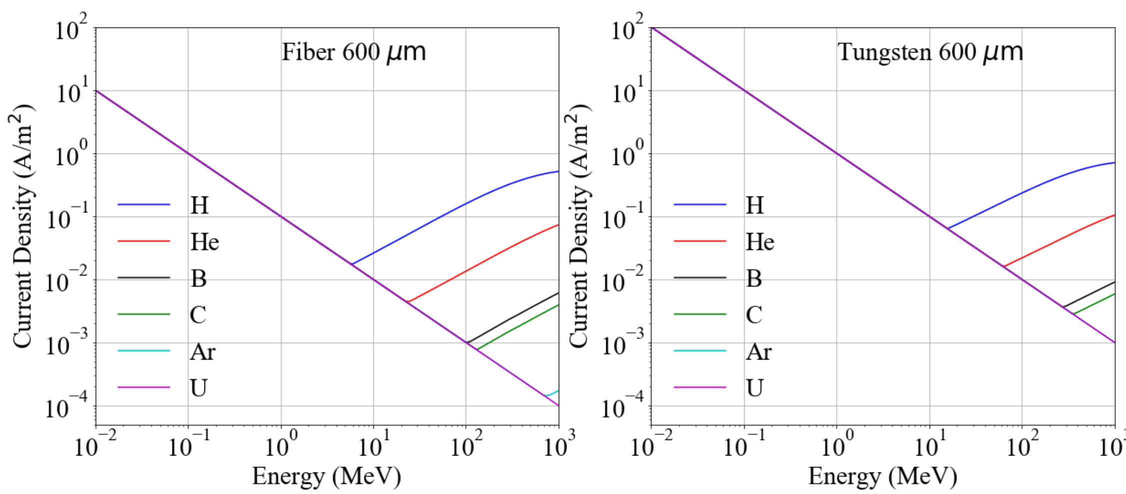


Figure 40: Maximum current density vs beam particle kinetic energy at which sensor fiber will be damaged (based on maximum absorbed power ~1 W·mm^{-2})

14 APPENDIX B: UNIBEAM MAINTENANCE & SPARE PARTS

Contact D-Pace (info@d-pace.com) to order replacement UniBEaM fiber cartridges. Two fibers are required per dual axis system.

Fiber Cartridges, Ce1-200-25	
Dopant	Cerium
Fiber diameter	200 ± 20 microns
Beam diameter, nominal	25 mm

UniBEaM requires little other maintenance or spare parts. The following table lists the O-rings used on UniBEaM which will need to be replaced periodically – depending on the radiation levels the probe is used in.

Contact D-Pace for instructions on how to replace the bellows O-Rings should this be necessary. The remainder of the O-rings are easily replaced by removing the relevant port or the vacuum box lid. Standard O-ring sizes are utilized, which may be ordered from D-Pace or sourced by the customer.

Part Number	Part Description	Quantity	Part Location
1800629	UniBEaM25 SCANNER PROBE (All Models)		
	O-RING, #-314, VITON	2	Fiber replacement port
	O-RING, #-126, VITON	2	Bellows
	O-RING, #-163, VITON	1	Vacuum box lid
	CENTERING RING, QF16-075-ARB, KF (QF) 16, AL, BUNA-N, KJL	2	Optical feed thru
1800672	UniBEaM25-KF, SCANNER PROBE (KF 40 Bulkhead Model)		
	CENTERING RING, QF40-150-ARB, KF (QF) 40, AL, BUNA-N, KJL	2	Beamline Port
1800673	UniBEaM25-KFQ, SCANNER PROBE (KF 40 Quick Flange Model)		
	O-RING, #-223, VITON	2	Flange, KF40 Quick Connect
	QF40-150-ARB, CENTERING RING, KF (QF) 40, AL, BUNA-N, KJL	2	Beamline Port
1800674	UniBEaM25-CF, SCANNER PROBE (CF Flange Model)		
	O-RING, #-223, VITON	2	Flange, CF

15 Appendix C: Remote Ethernet Control of Profiler Controller

D-Pace provides a PC-based graphical user interface (GUI) to operate the beam profiler controller remotely via an Ethernet connection – see section 0.

The end-user can also operate the D-Pace diagnostic controller via commands issues over TCIP via an Ethernet connection. The following is a list of commands that can be sent to the controller, followed by examples of the command usage required to conduct a scan.

15.1 Public Commands

Name	Command	Value	Unit	Example
Reset Sensor	'PWR_MPPC!'	-	-	PWR_MPPC!
Resets the optical sensor				
Set Scan Resolution	'RES#{value}!'	Float	mm	RES#0.02!
Sets the scan resolution				
Set Corner Frequency	'FCOF#{value}!'	integer	Hz	FCOF#500!
Sets the corner frequency for the filter				
Set Scan Range	'XYRNG#{value}!'	Float	mm	XYRNG#12.00!
Sets the scan range				
Set BIAS	'BIAS#{value}!'	0 or 1	-	BIAS#0!
Turns the bias on or off				
Set TIA	'TIA#{value}!'	Float	-	TIA#10!
Sets the TIA				
Set PGA	'PGA#{value}!'	integer	-	PGA#50!
Sets the PGA				
Set Scan Speed	'SPD#{value}!'	Float	$^{mm/s}/_{pitch}$	SPD#786.6141732283463!
Sets the speed of the scan. In the interface this is set as mm/s, but that number is then divided by the screw pitch of the motor (mm) before being sent to the controller. It				
Stop Scan and Home Probe	'STOP!'	-	-	STOP!
Stops any current scan and returns the probe(s) to the home position				
Set Post Scan Wait Time	'PSW#{value}!'	Float	s	PSW#0.05!
Sets the time to wait after a scan before starting another				
Start Scan for Probe 1	'STA#0!'	-	-	STA#0!
Starts a scan for probe 1				
Start Scan for Probe 2	'STA#1!'	-	-	STA#1!
Starts a scan for probe 2				
Start Sequential Scan	'STA#2!'	-	-	STA#2!
Starts a scan with probe 1 followed by a scan with probe 2				

15.2 Private Functions

These functions are used by D-Pace for testing purposes.

Name	Command	Value	Unit	Example
Average Sensor Reading	'ASVR#{value}!'	float	seconds	ASVR#5.00!
Generates a sample reading for DAQ channel for a time period. Used to get amplifier offsets				
Move Motor 1 Clockwise	'M1CW#{value}!'	integer	step	M1CW#4!
Moves motor 1 clockwise one step				
Move Motor 1 Counter clockwise	'M1CCW#{value}!'	integer	step	M1CCW#5!
Moves motor 1 counter clockwise one step				
Move Motor 2 Clockwise	'M2CW##{value}!'	integer	step	M2CW#3!
Moves motor 2 clockwise one step				
Move Motor 2 Counter clockwise	'M2CCW#{value}!'	integer	step	M2CCW#4!
Moves motor 2 counter clockwise one step				
Move Motor 1 to Position	'M1_MTP#{value}!'	Float	mm	M1_MTP#5.23!
Move motor 1 to a position				
Move Motor 2 to Position	'M2_MTP#{value}!'	Float	mm	M2_MTP#5.23!
Move motor 2 to a position				
Move Motor 1 Home	'M1_HOM!'	-	-	M1_HOM!
Moves motor 1 to the home position				
Move Motor 2 Home	'M2_HOM!	-	-	M2_HOM!
Moves motor 2 to the home position				
Set Motor 1 Brake	'MB1#{value}!'	0 or 1	-	MB1#0!
Set the brake for motor 1 true or false				
Set Motor 2 Brake	'MB2#{value}!'	0 or 1	-	MB2#0!
Set the brake for motor 2 true or false				

15.3 Not Currently Used for UniBEaM

Name	Command	Value	Unit	Example
Set Stop Position	'STP#{value}!'	Float	mm	STP#-15.00!
Sets the stop position for the scan				
Set Start Position	'STR#{value}!'	Float	mm	STR#15.00!
Sets the start position for the scan				
Set Continuous Scan	'CSB#{value}!'	0 or 1	-	CSB#0!
Set continuous scan mode true or false				
Set Retracting Data	'RTD#{value}!'	0 or 1	-	RTD#0!
Sets retracting data true or false				

15.4 Incoming Commands

Name	Command	Value	Example
Scan Finished	'SCA#END!'	-	SCA#END!
Indicates that all the data from the current scan has been sent			
X Scan Data	'XSCA#{value}!'	List	XSCA#[0.30447563598949207, 0.30359665966527083,........]!
This is a package of the data from the X scan in the form of a list, the first half of the list is the reading from the probe, and the second half is the positional data. UniBEaM units are photo volts for the probe data and mm for position			
Y Scan Data	'YSCA#{value}!'	List	YSCA#[0.306627083852848, 0.29760096796531327,....]!
This is a package of the data from the Y scan in the form of a list, the first half of the list is the reading from the probe, and the second half is the positional data. UniBEaM units are photo volts for the probe data and mm for position			
Info	'INF#{value}!'	String	INF#SPD%786.6141732283463!
This is a string sent from the controller with some information, for example the speed that the scan is set to.			
Config Info	'CONF#{value}!'	List	CONF#22,CTRL-UBA2.A,0.0254,16.0,20.32,14.5,0.0254!
This is a list with the configuration data from the controller. It contains The serial number, the model number, the pitch for the motor (mm), nominal beam center (mm), max speed (mm/s), max range (mm), and default resolution (mm)			
Fixed Scan Data	'FIX#{value}!'	List	
This is a list with the fixed scan data, not currently implemented			
UDI	'UDI#{value}!'	String	UDI#HOM1!
This is a string that indicates information about the probe, it will contain HOM1 when probe1 is in the home position, NHOM1 when probe1 is not home, HOM2 when probe2 is in the home position, NHOM2 when probe2 is not home, and NSCA when a new scan is started.			

15.5 App Initialization

When a socket connection is established with the controller, the controller software sends out a command with the configuration information for that controller, to the connected interface. This is only sent once and there is no way to explicitly request the server to send it. The only trigger to send the command is when the connection is established.

Receive: CONF#22,CTRL-UBA2.A,0.0254,16.0,20.32,14.5,0.0254!

Config info received from the controller, information is split and assigned to variables in the interface.

15.6 Example Commands for a Scan

Send: RES#0.10!

Set a scan resolution of 0.10 mm to the controller.

Send: SPD#787.4015748031496!

Set a scan speed of 787.4015748031496 to the controller. ($^{20mm/s}/_{0.0254mm}$) where 0.0254mm is the pitch received from the CONF command above.

Send: FCOF#500!

Set the low-pass filter corner frequency of the controller to 500 Hz.

Receive: INF#SPD%787.4015748031496!

Receive a message from the controller that the scan speed is set to 787.4015748031496.

Send: STA#0!

Sends a command to begin a scan with probe 1, the X axis probe in most cases.

Receive: UDI#NHOM1!

Receives a message from the controller that motor 1 is not at the home position, this indicates that the probe has begun moving.

Receive: XSCA#[0.19383406531752181, 0.19475179495836345, 0.1945435491141075, 0.19130573080351862, 0.19519128312047418, 0.19358280755042365, 0.19450394407624289, 0.19513123677274394, 0.19784013619055998, 0.1985168287192363, 0.19965983862922185, 0.20126661075678307, 0.20462494762345348, 0.21095834679681502, 0.22112151054562418, 0.2361113785864498, 0.2516101500708023, 0.2662014125692465, 0.27755230159337074, 0.2848362216754844, 0.2915933521679352, 0.2984267117117595, 0.30996242424592013, 0.31031333339861283, 0.32070646188340884, 0.32363808640663566, 0.33385235343010783, 0.3347964864295257, 0.33992938450890503, 0.3417282197770787, 0.3445129223856464, 0.34931748192531004, 0.3454161727653333, 0.3491416014883411, 0.34426379392165923, 0.3495453173581866, 0.3458526799030883, 0.3461797408609384, 0.3461592995510728, 0.34560993934843437, 0.34464238401479536, 0.34526371466258554, 0.34689689014872355, 0.3447935645356764, 0.3444124192788071 7, 0.3419654241436443, 0.3454072296922671, 0.3437310422832867, 0.34314420634589476, 0.3448604246533619, 0.34306201524581004, 0.343595618605427, 0.3417409955957448, 0.3415817237230418, 0.3427677455558698, 0.34410068930335647, 0.3405324031499404, 0.3430351860266114, 0.3407521472309956, 0.3465536464872303, 0.3434912827529879, 0.34510699795361577, 0.3447569405221671, 0.3454102107166225, 0.34686537646268084, 0.3477511665568574, 0.348924412571019, 0.34915480316762915, 0.350086160348381, 0.35066362735208456, 0.35339381980101, 0.35286319746574857, 0.3560805744664708, 0.35446272996273237, 0.3575996193058588,

0.3566478208152415, 0.35289343356992475, 0.350111286125091, 0.3386696887884367,
0.3290873989283096, 0.3135520034304453, 0.29397902337350074, 0.25658760902307826,
0.23775903333374235, 0.22754008184342517, 0.22720450367313139, 0.22306087981912387,
0.2235987417849627, 0.2211125674725581, 0.2206160139870727, 0.21904629173364254,
0.2178381251484604, 0.21831849593030228, 0.21649964521288487, 0.21475446838310805,
0.2132797130484284, 0.21411567744980758, 0.2148456025562589, 0.2118858712319668,
0.21259024470108612, 9.980200000000002, 9.904000000000002, 9.827800000000002,
9.751600000000002, 9.675400000000002, 9.599200000000002, 9.523000000000001, 9.446800000000001,
9.370600000000001, 9.294400000000001, 9.218200000000001, 9.142000000000001, 9.065800000000001,
8.989600000000001, 8.913400000000001, 8.837200000000001, 8.761000000000001, 8.684800000000001,
8.608600000000001, 8.5324, 8.4562, 8.38, 8.3038, 8.2276, 8.1514, 8.0752, 7.9990000000000006,
7.922800000000001, 7.846600000000001, 7.770400000000001, 7.694200000000001, 7.618000000000001,
7.541800000000001, 7.465600000000001, 7.389400000000001, 7.313200000000002, 7.237000000000002,
7.160800000000002, 7.084600000000002, 7.008400000000002, 6.932200000000002, 6.856000000000002,
6.779800000000002, 6.703600000000002, 6.6274000000000015, 6.5512000000000015,
6.475000000000001, 6.398800000000001, 6.322600000000001, 6.246400000000001, 6.170200000000001,
6.094000000000001, 6.017800000000001, 5.941600000000001, 5.865400000000001, 5.789200000000001,
5.713000000000001, 5.636800000000001, 5.560600000000001, 5.484400000000002, 5.408200000000002,
5.332000000000002, 5.255800000000002, 5.1796000000000015, 5.1034000000000015,
5.0272000000000014, 4.951000000000001, 4.874800000000001, 4.798600000000001,
4.722400000000001, 4.646200000000001, 4.570000000000001, 4.493800000000001, 4.417600000000001,
4.341400000000001, 4.265200000000001, 4.189000000000002, 4.112800000000002, 4.036600000000002,
3.9604000000000017, 3.8842000000000017, 3.8080000000000016, 3.7318000000000016,
3.6556000000000015, 3.5794000000000015, 3.5032000000000014, 3.4270000000000014,
3.3508000000000013, 3.2746000000000013, 3.1984000000000012, 3.122200000000001,
3.046000000000001, 2.969800000000001, 2.893600000000001, 2.8174000000000015,
2.741200000000002, 2.665000000000002, 2.5888000000000018, 2.5126000000000017,
2.4364000000000017]!

NOTE: The above received command is the first package of scan data for the X probe. The first half of the list is the data from the probe, and the second half is the matching positional data. The packages are stored in a list with [] denoting each package of data. The list is split into to two separate lists for probe data and position for the purpose of graphing, after all packages have been received. See sample code for processing.

***Receive**: XSCA#[0.2122265597297271, 0.212715447724013, 0.21325203210798538,*
*0.21262601699335096, 0.2108254782826881, 0.21250720187975705, 0.21064704268198617,
0.21149748634452015, 0.2091535494799301, 0.20994139163100042, 0.20841297785792406,
0.20812594779856095, 0.20939799347707283, 0.2101010893643255, 0.2102054252167645,
0.20907561698606741, 0.20940565896827268, 0.21006914981766045, 0.2068739175692925,
0.20737856240659974, 0.20811615300425032, 0.20888014696047755, 0.2071503011131004,
0.20782188331431006, 0.20866508734626638, 0.20708940304412576, 0.208232412954111,
0.2096011289938625, 0.20915738222552976, 0.20958026182337458, 0.2101760408338327,
0.2101262151410353, 0.21021351656858633, 0.21018328046441012, 0.21230278878110093,
0.21224827862145937, 0.21305315519741783, 0.2143963195998376, 0.21786878711325883,
0.2209362611749672, 0.22821251576587928, 0.23896890336141355, 0.2512656288274432,
0.2587739774574519, 0.26719196437648485, 0.27280140049210544, 0.2764936120865809,
0.2840181434202378, 0.2821349877488681, 0.2883938613133453, 0.28762049842342974,
0.29419365712708945, 0.29319331052554115, 0.2963715083490211, 0.298213355540037,
0.3001041767026065, 0.30254904253465814, 0.3033419950131951, 0.3043653380883424,
0.3074268501013402, 0.31176083365347124, 0.30757334615537696, 0.311794050782003,
0.3077121767182141, 0.31169184423267493, 0.3131014428921575, 0.3149079436515306,
0.31372703214616954, 0.3154879658189672, 0.31923255826997365, 0.31428235439751856,
0.31996887128575807, 0.31560124474447254, 0.32290901302142877, 0.32031509597160673,
0.32158756751074125, 0.31971889110052637, 0.3257614274689263, 0.32332507884931844,*

0.32537176499961307, 0.3264551544224905, 0.3244208182302398, 0.32590920110482985, 0.32634315307885164, 0.3279767544256122, 0.3269998301582846, 0.3289174805400522, 0.3266800088310122, 0.3266523278905692, 0.32586789262447635, 0.32874883973366104, 0.32725619825284913, 0.32328973241767583, 0.3233932165488705, 0.32286131663174233, 0.32282128573325547, 0.32020352048859024, 0.32598372671371495, 0.3192602392104167, 0.32279956684152333, 2.3602000000000016, 2.2840000000000016, 2.2078000000000015, 2.1316000000000015, 2.0554000000000014, 1.9792000000000018, 1.9030000000000022, 1.8268000000000022, 1.7506000000000022, 1.674400000000002, 1.598200000000002, 1.522000000000002, 1.445800000000002, 1.369600000000002, 1.2934000000000019, 1.2172000000000018, 1.1410000000000018, 1.0648000000000017, 0.9886000000000017, 0.9124000000000017, 0.8362000000000016, 0.7600000000000016, 0.6838000000000015, 0.6076000000000015, 0.5314000000000014, 0.4552000000000014, 0.37900000000000134, 0.3028000000000013, 0.22660000000000124, 0.1504000000000012, 0.07420000000000115, -0.0019999999999988916, -0.07819999999999894, -0.15439999999999898, -0.23059999999999903, -0.3067999999999991, -0.3829999999999991, -0.45919999999999916, -0.5353999999999992, -0.6115999999999993, -0.6877999999999984, -0.7639999999999976, -0.8401999999999976, -0.9163999999999977, -0.9925999999999977, -1.0687999999999978, -1.1449999999999978, -1.2211999999999978, -1.2973999999999979, -1.373599999999998, -1.449799999999998, -1.525999999999998, -1.602199999999998, -1.6783999999999981, -1.7545999999999982, -1.8307999999999982, -1.9069999999999983, -1.9831999999999983, -2.0593999999999983, -2.1355999999999984, -2.2117999999999984, -2.2879999999999985, -2.3641999999999985, -2.4403999999999986, -2.5165999999999986, -2.5927999999999987, -2.6689999999999987, -2.7451999999999988, -2.821399999999999, -2.897599999999999, -2.973799999999999, -3.049999999999999, -3.126199999999999, -3.202399999999999, -3.278599999999999, -3.354799999999999, -3.4309999999999983, -3.5071999999999974, -3.5833999999999975, -3.6595999999999975, -3.7357999999999976, -3.8119999999999976, -3.8881999999999977, -3.9643999999999977, -4.040599999999998, -4.116799999999998, -4.192999999999998, -4.269199999999998, -4.345399999999998, -4.421599999999998, -4.497799999999998, -4.573999999999998, -4.650199999999998, -4.726399999999998, -4.802599999999998, -4.878799999999998, -4.954999999999998, -5.031199999999998, -5.107399999999998, -5.183599999999998]!

Note: Receives second package of scan data.

Receive: XSCA#[0.3186448706113372, 0.32260622611904444, 0.3165568759806898, 0.31490027816033106, 0.3089740017417933, 0.2973714290899473, 0.2862053635758578, 0.2632246468200666, 0.23731187968043196, 0.2195164418605513, 0.21506108803109225, 0.20978467492203115, 0.207770780039646, 0.20541364149576816, 0.20385797264287098, 0.2022656797764662, 0.2005613855664196, 0.20026541243399035, 0.1987391279640248, 0.20090803611289035, 0.19806158371410418, 0.19884303795584168, 0.19776561058167497, 0.1985232166285693, 0.1975416078943976, 0.1965216717042279, 0.19469643307747742, 0.19456271284210652, 0.19562480923387407, 0.1936679796748637, 0.19418752963394806, 0.19375400352054817, 0.19362454189139927, 0.193260431059418, 0.1922609361791139, 0.19088114776318493, 0.1929716975575662, 0.19272043979046802, 0.19215660032667484, 0.1924023219056844, 0.19061498487430983, 0.19249771468505728, 0.1918320945325582, 0.19262419528985075, 0.19090627353989476, 0.19433019294238515, 0.1926957398743804, 0.1928396807646841, 0.19361645053957746, 0.1949472649839534, 0.1925313576742111, 0.19158637295354863, 0.19489232896368955, 0.1945354577622857, 0.1957010382852479, 0.19484633601649193, 0.1971434282126403, 0.199098980189784, 0.19917222821680247, 0.20109456306541418, 0.202777138383727, -5.2597999999999985, -5.3359999999999985, -5.412199999999999, -5.488399999999999, -5.564599999999999, -5.640799999999999, -5.716999999999999, -5.793199999999999, -5.869399999999999, -5.945599999999999, -6.021799999999999, -6.097999999999999, -6.174199999999999, -6.250399999999999, -6.326599999999999, -6.402799999999999, -6.478999999999999, -6.555199999999999, -6.631399999999999, -6.707599999999999, -6.783799999999999, -6.859999999999999, -6.9361999999999995, -7.0123999999999995, -7.0886, -7.1648, -7.241, -7.3172, -7.3934, -7.4696, -7.5458, -7.621999999999998, -7.698199999999996, -7.774399999999996, -7.8505999999999965, -7.9267999999999965, -8.002999999999997, -8.079199999999997, -8.155399999999997, -

8.231599999999997, -8.307799999999997, -8.383999999999997, -8.460199999999997, -8.536399999999997, -8.612599999999997, -8.688799999999997, -8.764999999999997, -8.841199999999997, -8.917399999999997, -8.993599999999997, -9.069799999999997, -9.145999999999997, -9.222199999999997, -9.298399999999997, -9.374599999999997, -9.450799999999997, -9.526999999999997, -9.603199999999998, -9.679399999999998, -9.755599999999998, -9.831799999999998]!SCA#END!

Note: Receive last package of scan data as well as a command SCA#END that indicates the scan is finished. The commands are parsed into two separate commands XSCA#[…] and SCA#END.

Receive: UDI#HOM1!

Receive a message from the controller that probe 1 is back in the home position.

NOTE: See coding example below for plotting the XSCA data packages.

15.7 Sample Python Code

On Send: STA#0!

Initialize variable current_scan_x as an empty list when sending the start scan command.

```
self.current_scan_x = []
```

On Receive: XSCA#[ ]!

Append each data package to current_scan_x. As per example above, current_scan_x = '[1][2][3]' with three packages of data since we received three XSCA commands.

```
def xscan_data_handle(self, data):
    self.current_scan_x.append(data)
```

On Receive: SCA#END!

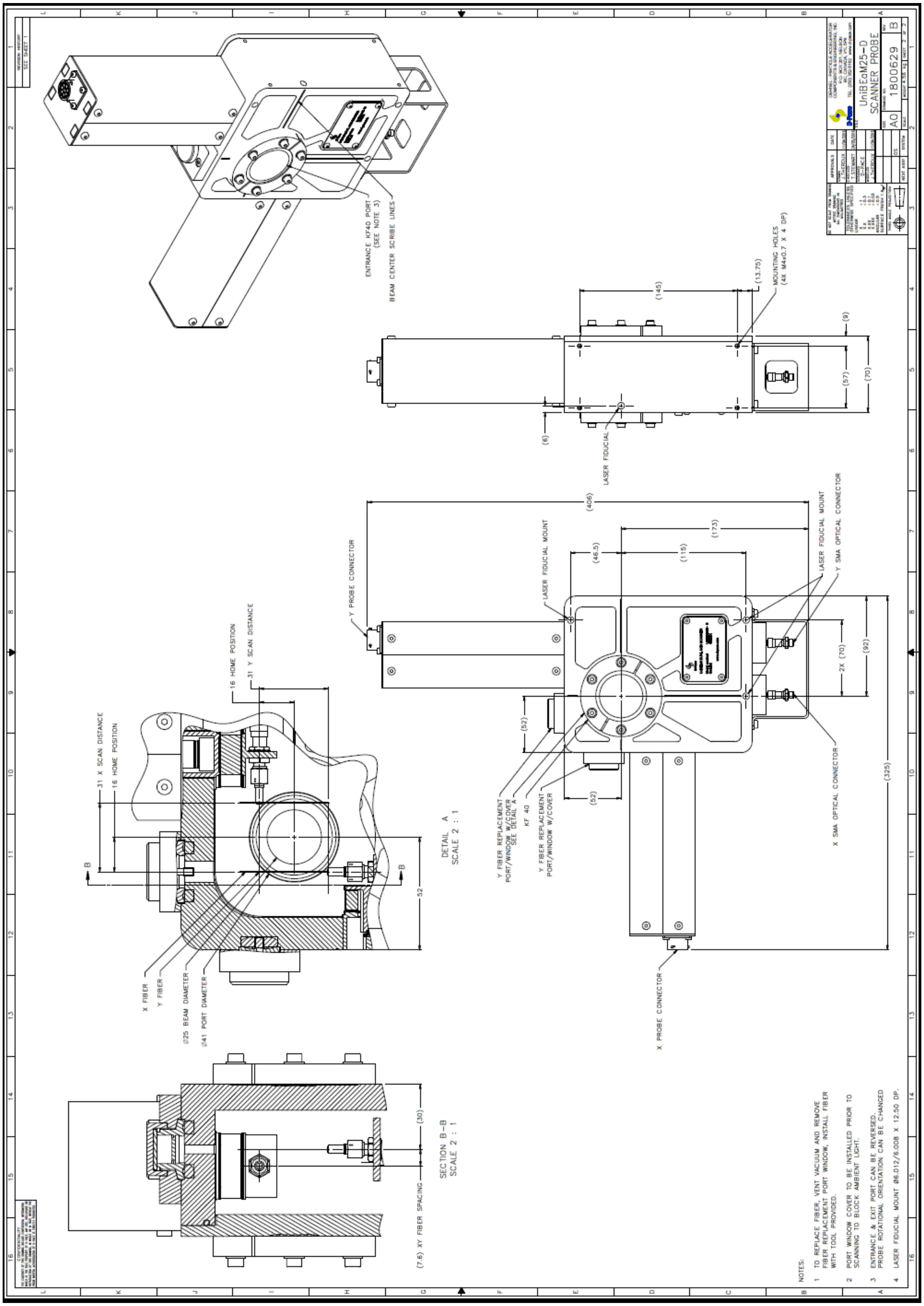
The SCA#END command signals that we have received all the data packages. The code below converts each package data to float, then splits and appends the package into two separate lists: scan_data, pos_data. The returned lists are now ready to be used in a plot.

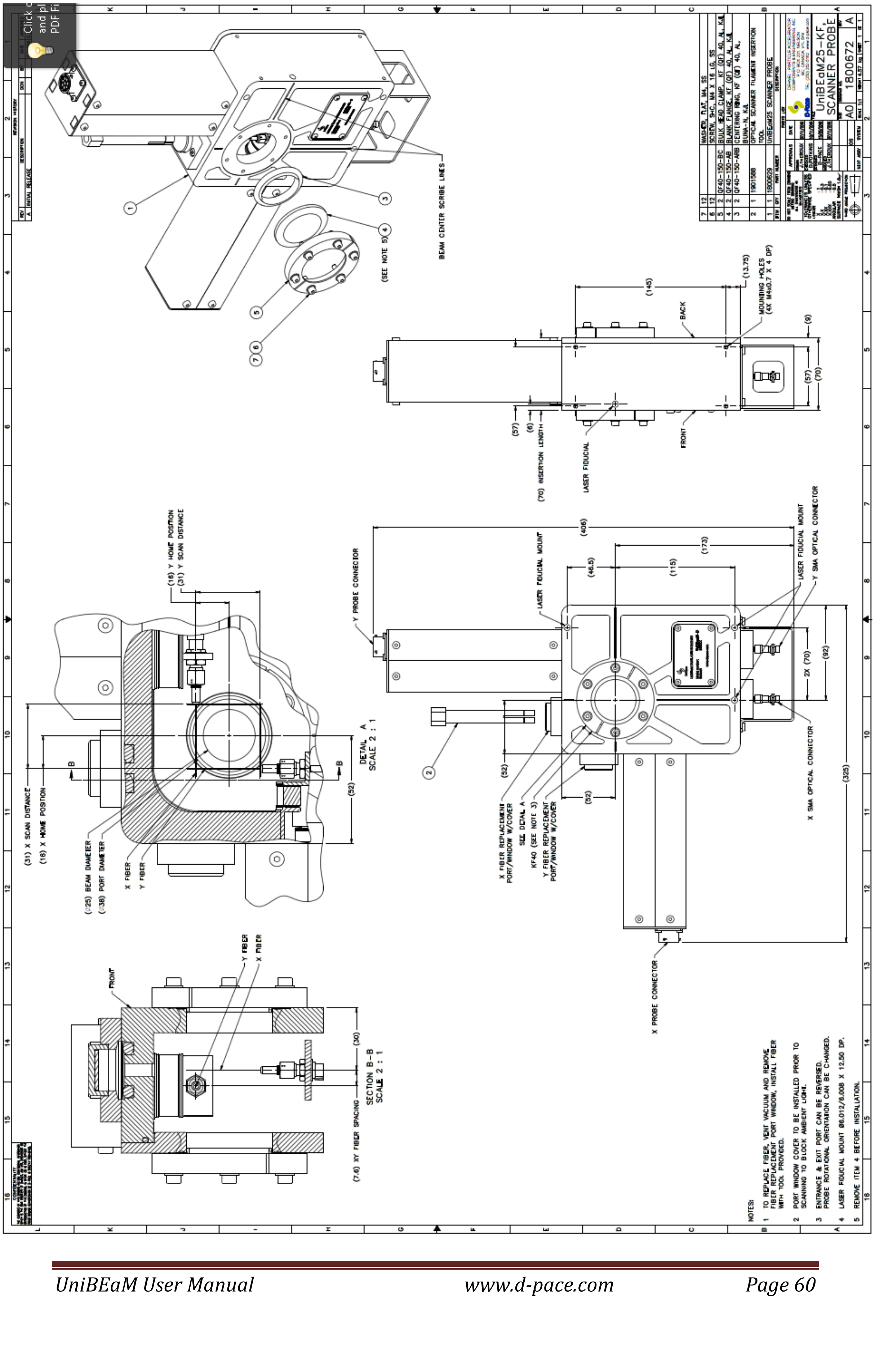
```
def sort_scan_data(self, data):
    scan_data = []
    pos_data = []
    for package in data:
        fl_lst_data = []
        lst_data = ast.literal_eval(package)
        for element in lst_data:
            fl_lst_data.append(float(element))
        scan_data = scan_data + fl_lst_data[0:int(len(fl_lst_data)/2)]
        pos_data = pos_data + fl_lst_data[int(len(fl_lst_data) / 2):]
    return(scan_data, pos_data)
```

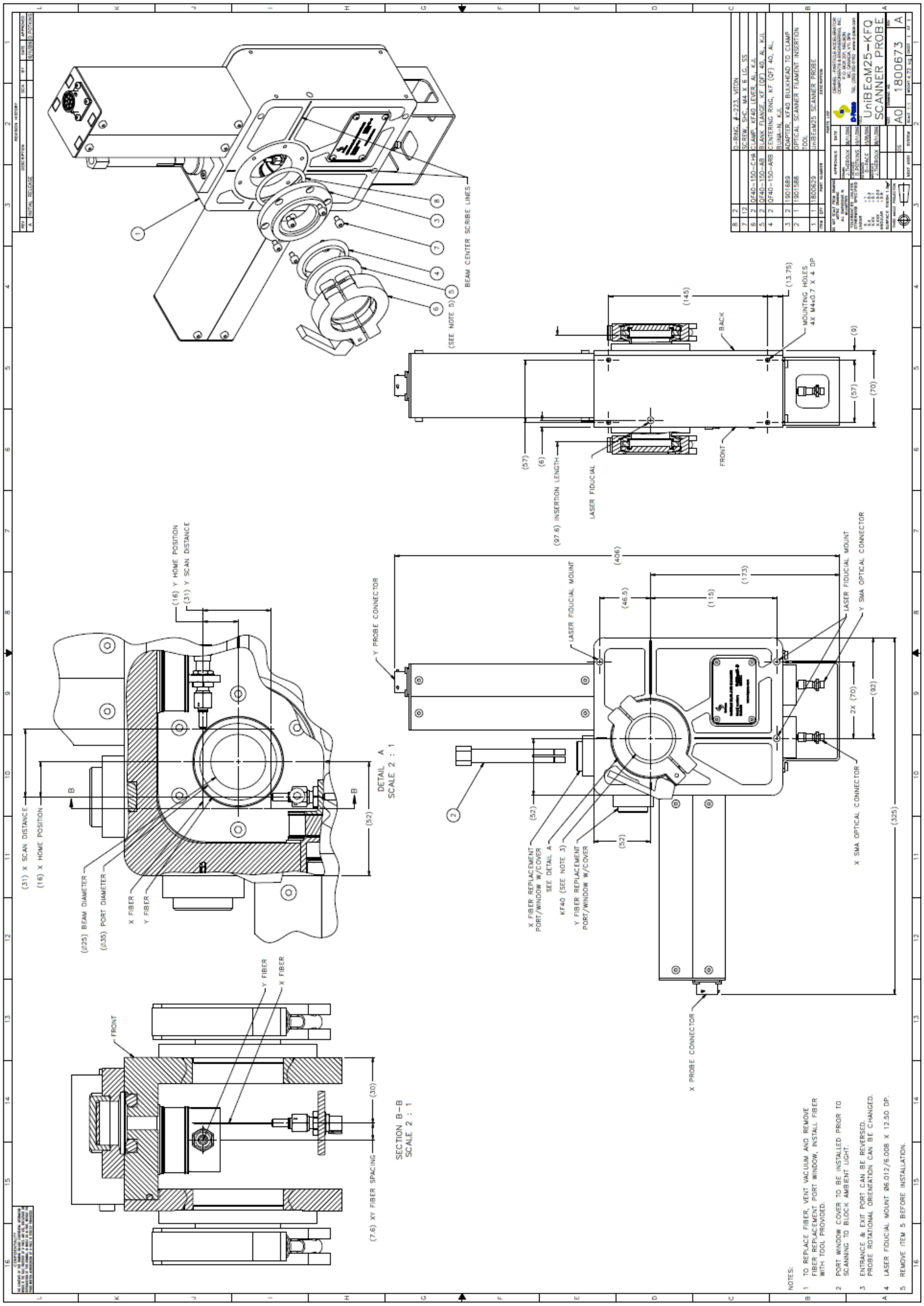
16 Appendix D: UniBEaM Probe Drawings

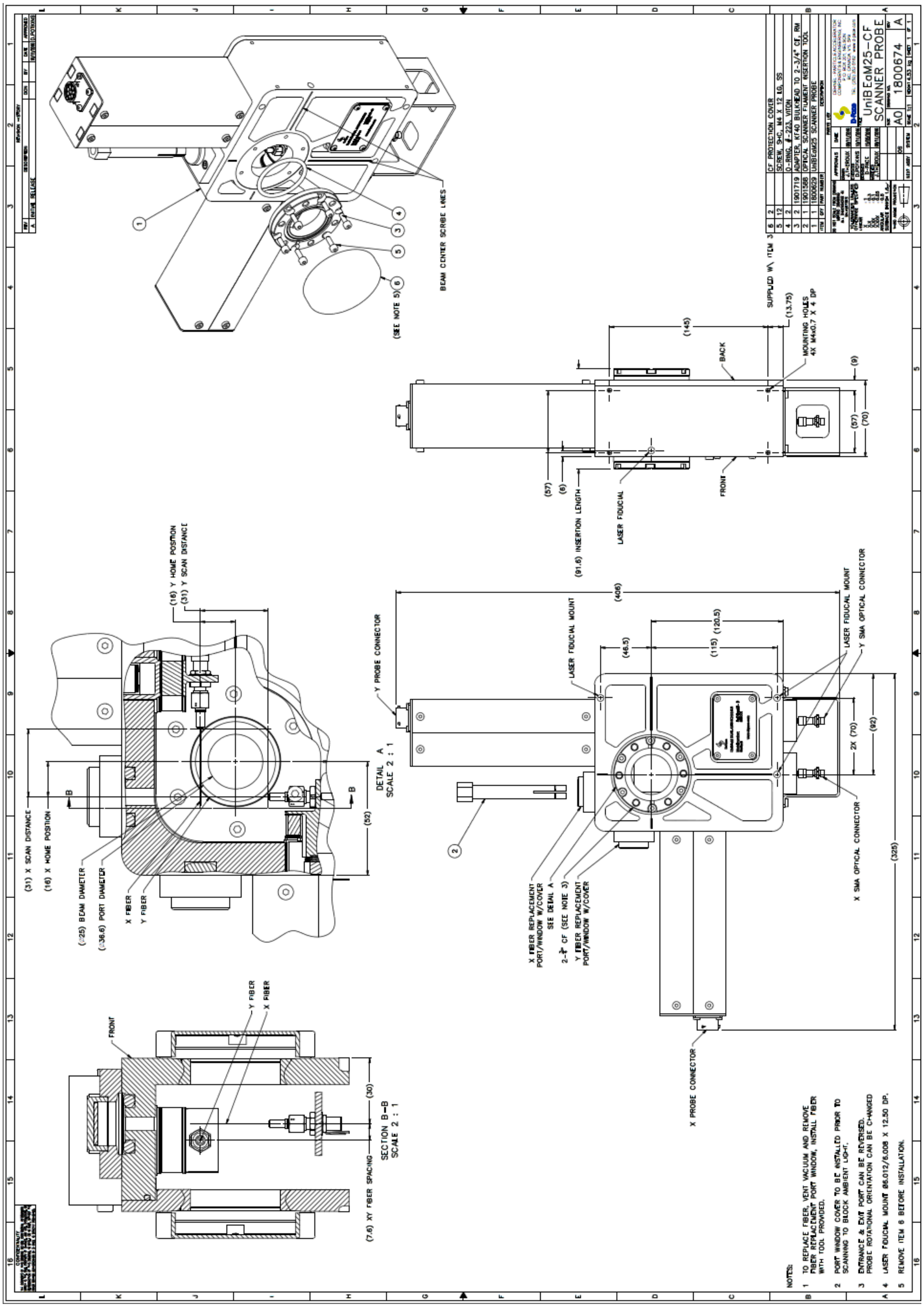
Drawing Number	Description
1800629	UniBEaM25 Probe
1800672	UniBEaM25-KF Probe KF 40 Bulkhead Flange Option
1800673	UniBEaM25-QKF Probe KF 40 Quick Connect Flange Option
1800674	UniBEaM25-CF Probe CF 40 Conflat Flange Option

For high resolution electronic copies of the above drawings visit www.d-pace.com.


ENTRANCE KF40 PORT (SEE NOTE 3)
BEAM CENTER SCRIBE LINES
MOUNTING HOLES (4X M4x0.7 X 4 DP)
LASER FIDUCIAL
Y PROBE CONNECTOR
LASER FIDUCIAL MOUNT
Y SMA OPTICAL CONNECTOR
X SMA OPTICAL CONNECTOR
X PROBE CONNECTOR
Y FIBER REPLACEMENT PORT/WINDOW W/COVER SEE DETAIL A
KF 40
Y FIBER REPLACEMENT PORT/WINDOW W/COVER
31 X SCAN DISTANCE
16 HOME POSITION
31 Y SCAN DISTANCE
X FIBER
Y FIBER
Ø25 BEAM DIAMETER
Ø41 PORT DIAMETER
DETAIL A
SCALE 2 : 1
SECTION B-B
SCALE 2 : 1
(7.6) XY FIBER SPACING
UniBEaM25-D
SCANNER PROBE
1800629
NOTES:
1 TO REPLACE FIBER, VENT VACUUM AND REMOVE FIBER REPLACEMENT PORT WINDOW, INSTALL FIBER WITH TOOL PROVIDED.
2 PORT WINDOW COVER TO BE INSTALLED PRIOR TO SCANNING TO BLOCK AMBIENT LIGHT.
3 ENTRANCE & EXIT PORT CAN BE REVERSED. PROBE ROTATIONAL ORIENTATION CAN BE CHANGED
4 LASER FIDUCIAL MOUNT Ø6.012/6.008 X 12.50 DP.

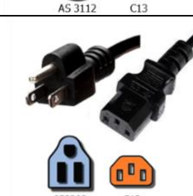

UniBEaM25-KF SCANNER PROBE
1800672
BEAM CENTER SCRIBE LINES
(SEE NOTE 5)
MOUNTING HOLES (4X M4x0.7 X 4 DP)
BACK
FRONT
LASER FIDUCIAL
(70) INSERTION LENGTH
Y PROBE CONNECTOR
X PROBE CONNECTOR
LASER FIDUCIAL MOUNT
Y SMA OPTICAL CONNECTOR
X SMA OPTICAL CONNECTOR
X FIBER REPLACEMENT PORT/WINDOW W/COVER
SEE DETAIL A
KF40 (SEE NOTE 3)
Y FIBER REPLACEMENT PORT/WINDOW W/COVER
(16) Y HOME POSITION
(31) Y SCAN DISTANCE
(31) X SCAN DISTANCE
(16) X HOME POSITION
(Ø25) BEAM DIAMETER
(Ø38) PORT DIAMETER
X FIBER
Y FIBER
DETAIL A SCALE 2 : 1
SECTION B-B SCALE 2 : 1
(7.6) XY FIBER SPACING
NOTES:
1 TO REPLACE FIBER, VENT VACUUM AND REMOVE FIBER REPLACEMENT PORT WINDOW, INSTALL FIBER WITH TOOL PROVIDED.
2 PORT WINDOW COVER TO BE INSTALLED PRIOR TO SCANNING TO BLOCK AMBIENT LIGHT.
3 ENTRANCE & EXIT PORT CAN BE REVERSED. PROBE ROTATIONAL ORIENTATION CAN BE CHANGED.
4 LASER FIDUCIAL MOUNT Ø6.012/6.008 X 12.50 DP.
5 REMOVE ITEM 4 BEFORE INSTALLATION.


UniBEaM25-KFQ SCANNER PROBE
1800673
BEAM CENTER SCRIBE LINES
(SEE NOTE 5)
DETAIL A
SCALE 2 : 1
SECTION B-B
SCALE 2 : 1
(31) X SCAN DISTANCE
(16) X HOME POSITION
(16) Y HOME POSITION
(31) Y SCAN DISTANCE
(Ø25) BEAM DIAMETER
(Ø35) PORT DIAMETER
X FIBER
Y FIBER
FRONT
BACK
(7.6) XY FIBER SPACING
(30)
(52)
(406)
(173)
(115)
(46.5)
(325)
2X (70)
(92)
(97.6) INSERTION LENGTH
LASER FIDUCIAL
LASER FIDUCIAL MOUNT
Y PROBE CONNECTOR
X PROBE CONNECTOR
Y SMA OPTICAL CONNECTOR
X SMA OPTICAL CONNECTOR
MOUNTING HOLES
4X M4x0.7 X 4 DP
X FIBER REPLACEMENT PORT/WINDOW W/COVER
SEE DETAIL A
KF40 (SEE NOTE 3)
Y FIBER REPLACEMENT PORT/WINDOW W/COVER
NOTES:
1 TO REPLACE FIBER, VENT VACUUM AND REMOVE FIBER REPLACEMENT PORT WINDOW, INSTALL FIBER WITH TOOL PROVIDED.
2 PORT WINDOW COVER TO BE INSTALLED PRIOR TO SCANNING TO BLOCK AMBIENT LIGHT.
3 ENTRANCE & EXIT PORT CAN BE REVERSED. PROBE ROTATIONAL ORIENTATION CAN BE CHANGED.
4 LASER FIDUCIAL MOUNT Ø6.012/6.008 X 12.50 DP.
5 REMOVE ITEM 5 BEFORE INSTALLATION.


(31) X SCAN DISTANCE
(16) X HOME POSITION
(∅25) BEAM DIAMETER
(∅36.6) PORT DIAMETER
X FIBER
Y FIBER
(16) Y HOME POSITION
(31) Y SCAN DISTANCE
(52)
DETAIL A
SCALE 2 : 1
FRONT
Y FIBER
X FIBER
(7.6) XY FIBER SPACING
(30)
SECTION B-B
SCALE 2 : 1
Y PROBE CONNECTOR
X FIBER REPLACEMENT PORT/WINDOW W/COVER
SEE DETAIL A
2-¾" CF (SEE NOTE 3)
Y FIBER REPLACEMENT PORT/WINDOW W/COVER
LASER FIDUCIAL MOUNT
(406)
(46.5)
(115)
(120.5)
X PROBE CONNECTOR
X SMA OPTICAL CONNECTOR
Y SMA OPTICAL CONNECTOR
2X (70)
(92)
(325)
(57)
(6)
(91.6) INSERTION LENGTH
LASER FIDUCIAL
FRONT
BACK
(145)
(13.75)
MOUNTING HOLES
4X M4x0.7 X 4 DP
(57)
(70)
(9)
(SEE NOTE 5)
BEAM CENTER SCRIBE LINES
SUPPLIED W\ ITEM 3
6 2 CF PROTECTION COVER
5 12 SCREW, SHC, M4 X 12 LG, SS
4 2 O-RING, #-223, VITON
3 2 1901719 ADAPTER, KF40 BULKHEAD TO 2-3/4" CF, RM
2 1 1901588 OPTICAL SCANNER FILAMENT INSERTION TOOL
1 1 1800629 UniBEaM25 SCANNER PROBE
UniBEaM25-CF
SCANNER PROBE
A0 1800674 A
NOTES:
1 TO REPLACE FIBER, VENT VACUUM AND REMOVE FIBER REPLACEMENT PORT WINDOW, INSTALL FIBER WITH TOOL PROVIDED.
2 PORT WINDOW COVER TO BE INSTALLED PRIOR TO SCANNING TO BLOCK AMBIENT LIGHT.
3 ENTRANCE & EXIT PORT CAN BE REVERSED. PROBE ROTATIONAL ORIENTATION CAN BE CHANGED
4 LASER FIDUCIAL MOUNT Ø6.012/6.008 X 12.50 DP.
5 REMOVE ITEM 6 BEFORE INSTALLATION.

17 Appendix E: IEC320 C13 Power Cord Options

UniBEaM is available with the following C320 C13 international power cord options. All cords are rated 10A/250V.

Region	Represenative Image	Length
International C14 (Provided)		1m
EU Schuko (Optional)		2 m
North America 5-15P (Optional)		2 m
Swiss SEV1011 (Optional)		2 m
Italy CEI23-16 (Optional)		2 m
UK BS1363 (Optional)		2m
Australia AS 3112 (Optional)		2m
Japan JS8303 (Optional)		2m

18 References

[i] E. Mones et al., *Feasibility study for the use of Ce^{3+}-doped optical fibres in radiotherapy*. Nuclear Instruments and Methods in Physics Research A 562 pp. 449-455 (2006).

[ii] A. Vedda et al., *Ce^{3+}-doped fibers for remote radiation dosimetry*, Applied Physics Letters, Volume 85, Number 26 (2004).

[iii] D. E. Potkins et al., *UniBEam-Beam Profiler For Beam Characterization and Position Feedback"*, Proc. IBIC 2017, Grand Rapids, Michigan, USA (2017).

[iv] E. Mones et al., *Feasibility study for the use of Ce^{3+}-doped optical fibres in radiotherapy*. Nuclear Instruments and Methods in Physics Research A 562 pp. 449-455 (2006).

[v] A. Vedda et al., *Ce^{3+}-doped fibers for remote radiation dosimetry*, Applied Physics Letters, Volume 85, Number 26 (2004).

[vi] S. Braccini et al., *A beam monitor detector based on doped silica and optical fibres*, JINST 7 (2012) T02001.

[vii] M. Auger et al*., A detector based on silica fibers for ion beam monitoring in a wide current range*, JINST 11 (2016) P03027.

[viii] K.P. Nesteruk et al. *"Study of the transverse beam emittance of the Bern medical cyclotron."* Proceedings of IBIC2015. Melbourne: MOPB041 (2015).