

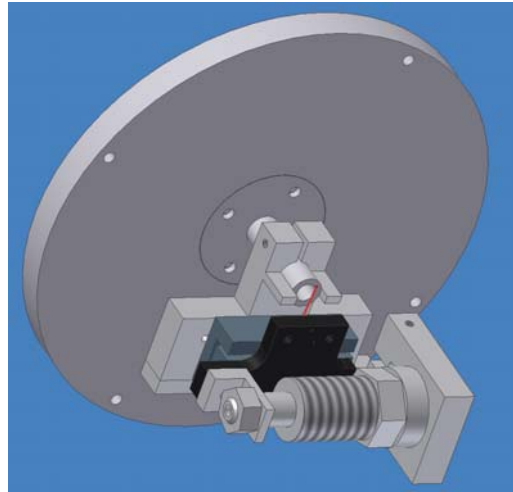
## The Beam Width Probe

Key word: homing, limit switch

The Beam Width Probe (BWP) is an optional module that can be added to all versions of the AMS. It is designed to precisely step an object (a wire or a ribbon) of a known dimension (typically 0.3 to 1 mm diameter) across the particle beam path in a controlled fashion inside the vacuum system of the AMS. The resulting attenuation of the particle beam as measured by a decrease in ion intensity for a given mass component can be used to determine information on the width of the particle beam. This device has been developed to measure beam widths and to provide a quantitative correction to AMS mass loadings resulting from less than unit collection efficiency of particles at the detector. In addition, since particle beam width is related to particle morphology this device can also provide insight to particle shape.

The beam width probe assembly is designed to mount on the 1/4" OD channel aperture located at the end of the TOF chamber (see Figure 1). This design provides an "alignment free" mounting solution as the channel aperture (0.252" OD x 0.15" ID) is mounted in the center of the chamber and defines the beam axis. The beam width probe is fully assembled and adjusted outside of the vacuum system. Installation into the AMS is accomplished by removing one of the 2-3/4 blank flanges at the end of the TOF chamber, sliding the probe assembly onto the channel aperture and tightening the #2 clamping screw. The assembly will operate in any orientation.

The beam width probe has five components: 1) a control box (stepper motor control circuitry and USB chip), 2) a 2-3/4 (NW63) custom vacuum flange with electrical feedthru, 3) an NW63 Lexan flange, 4) cables and 5) the probe assembly. The individual components are shown in Figure 2. The probe assembly consists of the attenuating wire or ribbon that is mounted to a precision linear bearing slide and a stepper motor which sets the position of the slide. The theoretical resolution of this device is 20  $\mu\text{m}$ .



**Figure 1. Beam width probe assembly shows mounting on 1/4"OD channel aperture located on internal flange at end of TOF chamber. Attenuating wire shown in red.**



**Figure 2. Beam Width Probe components.**

The control box has several LEDs which indicate the status of the controller. These LEDs indicate USB power on (red), direction of travel (yellow), drive stage enabled (green), and beam probe at “edge” (red). See Figure 3. In addition there is a BNC connector which can be used to control the probe via an external TTL level signal. External control operation is discussed further in the software section.

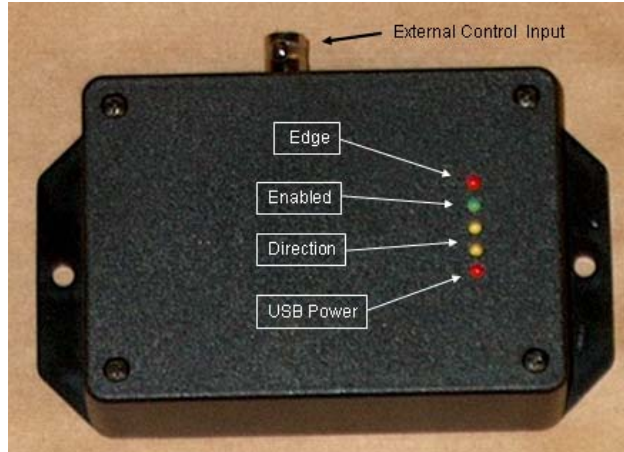


Figure 3. BWP controller showing status LEDs and external control BNC connector.

### Hardware and Electrical Requirements

The BWP is driven by a linear stepper motor which is controlled by a Universal Serial Bus (USB) computer interface digital I/O device. To operate the probe the control box requires 7-32 DCV input which is used to power the stepper motor. The 5VDC USB power from the computer powers the control electronics so the USB Power LED should light as soon as it is plugged into the USB port. The supplied 5mm power connector has two flying leads which should be connected to a suitable DC supply in this voltage range. The center contact in this connector is the positive (+) voltage lead and the outside of the 5mm plug is the ground. Verify proper polarity before plugging into the control box, reversing the leads will damage the components. Power (24 VDC) is most conveniently obtained from the screw terminal strip on the AMS which is used for the turbo pump cooling fans. An external power supply in this voltage range could also be used.

Computer control of the BWP requires use of one USB port on the computer. The USB device is “hot plug-able” so you can plug it in or unplug it with the computer turned on or off. When plugged in to the USB port Windows™ will automatically detect the device and search for required device driver. If the driver is not already installed on your computer Windows™ will display “New Hardware Found” and prompt you to enter the location of the USB driver. Place the USB driver disk in the computer drive and select that drive to install the driver. The loading of the driver is only required once.

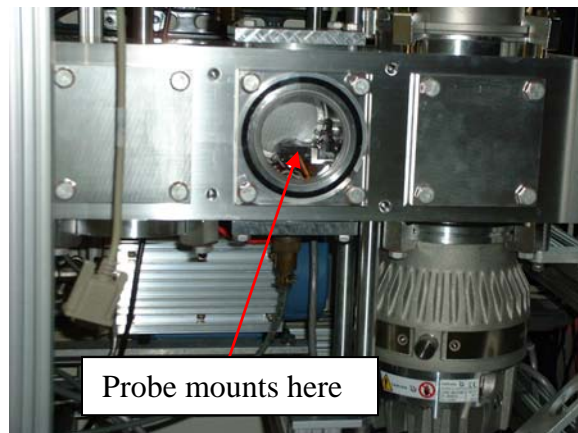


Figure 4. Mounting location of the BWP inside the vacuum chamber. Electrical feedthru is on the bottom port

Once the driver is loaded you can operate the BWP with the control software. The required files for installation of the driver are USBIODS.inf and USBIOD.sys. Each USB device has a unique ID or handle which is displayed in the title bar of the BWP control software. This driver supports operation from Win98, Win2K and WinXP operating systems.

This version of the probe assembly is designed to be mounted at the end of the TOF chamber (see Figure 4). The clear Lexan flange provides a viewing port but is not essential. The recommended mounting location for the electrical feedthru connector flange is on the bottom port. For systems that include the light scattering module this arrangement will be different as the light scattering components consume this section of the chamber. In this case the electrical feedthru flange will be mounted at the next forward port (see drawings in Appendix I). *When mounting the assembly in the vacuum system, make sure the beam probe does not touch the channel aperture. Try to provide 2-3 mm of clearance between the probe and the front surface of the channel aperture. If these two components make contact the control circuit will be inactive.*

The suggested mounting location of the BWP control box is on the top of the AMS Electronics box as shown in Figure 5. This location allows easy viewing of the status LEDs and easy access to the electrical connectors.



Figure 5. Suggested mounting location for the BWP control electronics.

### Description of Operation

The motion of the BWP is controlled in a semi-closed loop mode. At either end of travel the wire makes contact with a wire stop. The known distance between these two stops (0.252", 6.4 mm) determines the range of motion of the wire. The beam attenuating wire is biased at a TTL "high" level and this TTL state is monitored by the control circuitry. When the wire makes contact with the edge stop (which is at ground potential) the TTL level drops to low thus indicating the end of travel has been reached. The control circuitry senses this change in state then disables the stepper motor and reverses direction. The total number of positions or steps between the two feedback points is determined by the software and since the distance between the two points is known,

intermediate wire positions can be calculated/predicted. This stepper motor has a theoretical resolution of ~20  $\mu\text{m}$ . The red "Edge" LED on the power supply box indicates the TTL signal level status. When lit (the TTL level is low) this LED indicates the wire is at the edge position, also referred to as the "parked" position.

The BWP movement is computer controlled and operates independently from the AMS data acquisition program (unless it is operated in the External Control mode). The following discussion describes the BWP control interface. The program has three modes of operation: Manual, Automated and External control. The manual mode of operation allows the user to set/step the wire position. This mode also provides a calibration sequence that defines the range of motion that the probe can travel. The calibration sequence must be run before activating the Automated or External operating modes.

The Automated movement mode is used in parallel with the AMS acquisition program. In this mode the wire position is stepped at defined time intervals which must be set to the "auto data save interval" in the AMS acquisition program for proper synchronization. Each data file output from the AMS program then corresponds to a given wire position. Although neither the AMS acquisition program nor the beam width program "know" one another they both monitor the same system clock and can operate in sequence.

The External mode of operation allows the BWP to be stepped when a user supplied TTL signal is applied the BNC connector mounted on the control box (see Figure 3). Each time the external control signal changes state (a high to low, or low to high transition) the probe moves to the next "pre-programmed" position set in the Model display form discussed below.

When operated in the Automatic or External control mode the control program appends data to a file *wire.dat* under C:\AMS\AMSDData\AMSLogFiles\. Data is written to the file *wire.dat* just before the probe is moved to a new position.

The structure of the output file is listed below, there are no headers or footers and it is space delimited (note that the letters A,B,C... are added here for reference only).

{A	B	C	D	E	F	G	H	I	J	K	L	M	N}
2004	17:46:00	66	63.9600E+03	0	1	0	0	0	0	256	-2.95	0.00	0.00
2004	17:46:30	66	63.9900E+03	75	1	1	0	0	0	256	-1.22	11.84	0.37
2004	17:47:01	66	64.0210E+03	0	1	1	0	0	0	256	-2.95	0.00	0.00
2004	17:47:31	66	64.0510E+03	102	1	2	0	0	0	256	-0.61	19.27	24.56
2004	17:48:01	66	64.0810E+03	0	1	2	0	0	0	256	-2.95	0.00	0.00
2004	17:48:31	66	64.1110E+03	128	1	3	0	0	0	256	0.00	21.12	31.50
2004	17:49:01	66	64.1410E+03	0	1	3	0	0	0	256	-2.95	0.00	0.00
2004	17:49:31	66	64.1710E+03	154	1	4	0	0	0	256	0.61	19.27	24.56
2004	17:50:01	66	64.2010E+03	0	1	4	0	0	0	256	-2.95	0.00	0.00
2004	17:50:30	66	64.2300E+03	181	1	5	0	0	0	256	1.22	11.84	0.37
2004	17:51:00	66	64.2600E+03	0	1	5	0	0	0	256	-2.95	0.00	0.00
2004	17:51:30	66	64.2900E+03	75	1	1	1	0	0	256	-1.22	11.84	0.37
2004	17:52:00	66	64.3200E+03	0	1	1	1	0	0	256	-2.95	0.00	0.00
2004	17:52:31	66	64.3510E+03	102	1	2	1	0	0	256	-0.61	19.27	24.56
2004	17:53:01	66	64.3810E+03	0	1	2	1	0	0	256	-2.95	0.00	0.00
2004	17:53:30	66	64.4100E+03	128	1	3	1	0	0	256	0.00	21.12	31.50
2004	17:54:00	66	64.4400E+03	0	1	3	1	0	0	256	-2.95	0.00	0.00
2004	17:54:30	66	64.4700E+03	154	1	4	1	0	0	256	0.61	19.27	24.56
2004	17:55:01	66	64.5010E+03	0	1	4	1	0	0	256	-2.95	0.00	0.00
2004	17:55:30	66	64.5300E+03	181	1	5	1	0	0	256	1.22	11.84	0.37
2004	17:56:01	66	64.5610E+03	0	1	5	1	0	0	256	-2.95	0.00	0.00
2004	17:56:30	66	64.5900E+03	75	1	1	2	0	0	256	-1.22	11.84	0.37

```

2004 17:57:01 66 64.6210E+03 0 1 1 2 0 0 256 -2.95 0.00 0.00
.
.

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The columns in the file are listed below:

- A) *Year*
- B) *Time*
- C) *Julian day*
- D) *seconds after midnight*
- E) *servo digital position*
- F) *servo direction (will always be 1, movement is to the right to reduce histeresis effects)*
- G) *Step number*
- H) *Number of passes*
- I) *No value- always zero*
- J) *Left edge digital position*
- K) *Right edge digital position*
- L) *Position in millimeters with center position defined as zero*
- M) *Vaporizer coverage (%)*
- N) *Beam coverage (%)*

When the program is operated in the Automated Control mode the variables *JulianDay* and *SecondsAfterMidNight* should be identical (within 1 to 2 seconds) to the corresponding values saved by the AMS program when it is operating in the auto save mode allowing the data to be temporally aligned. The variable *Vaporizer coverage* represents the percent coverage of the 3 mm diameter projected vaporizer area by the probe. The variable *Beam coverage* represents the percent attenuation of the beam diameter that is input in the program under the Model View form. For simplicity, these calculated values assume a uniform and homogeneous circular area for the beam.

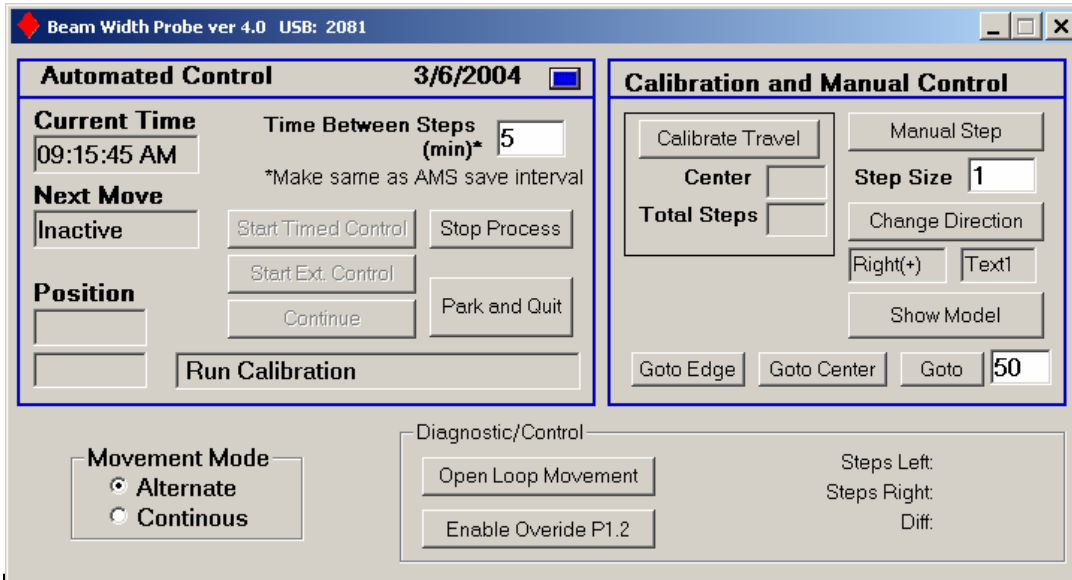
### **Beam Width Control Program**

The software that controls the movement of the probe is introduced below. There are three views or form sizes that show or hide certain aspects of the control program. The small blue button at the top of the Automated Control panel (near the date display) toggles the different views. *Before installing the probe assembly in the vacuum chamber it is recommended to operate the probe "on the bench" to become familiar with how the assembly responds to the various software commands.*

Figure 6 shows the full size form. This view is used to set the movement mode of probe and shows some diagnostics. *It is not a good idea to press the "Open Loop Movement Mode"*. Generally, the full size view need not be displayed. The default display is shown in Figure 7. When the program is first started the calibration sequence needs to be initiated by pressing the "Calibrate Travel" button. This routine finds the range of digital steps between the two wire stops and must be run prior to operating the

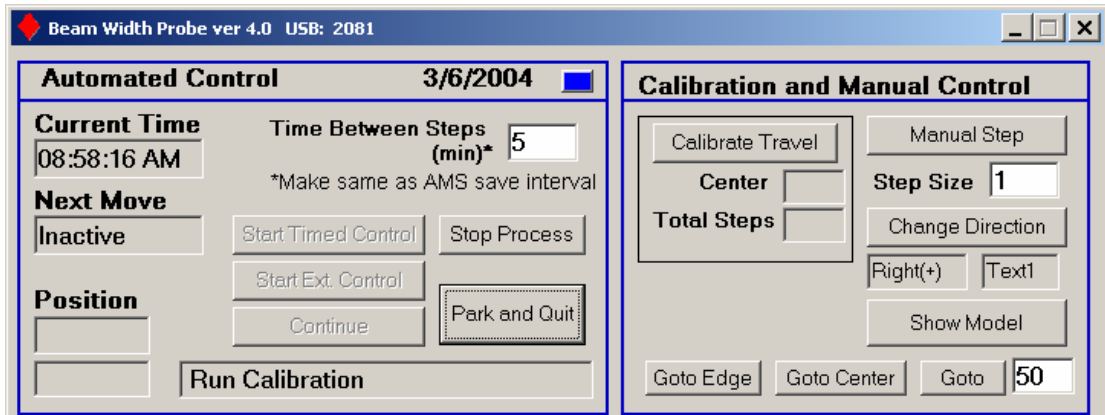
device. This routine determines the values for the variables “Center”, and “Total Steps”. *Note that the “Start Timed Control”, Start Ext. Control” and “Continue” buttons are deactivated until the unit undergoes the calibration routine.*

Also within the Calibration and Manual Control window one can move the probe position to the “Edge” or “Center” defaults or to a user defined “Goto” position. In addition the probe can be stepped in either direction by pressing the “Direction Button”. If the probe is stepped beyond the range of calibrated travel it will automatically change



**Figure 6. Full program form view showing Automated Control, Calibration and Manual Control and NI board parameters. Blue button toggles between different form sizes.**

direction. Note that the "Center" position is the calculated center and not necessarily *exactly* where the particle beam is. Manually stepping the probe while looking at a particle signal (or air beam) may give a different "Center" position. Differences here indicate that the lens may need slight adjustment of alignment.

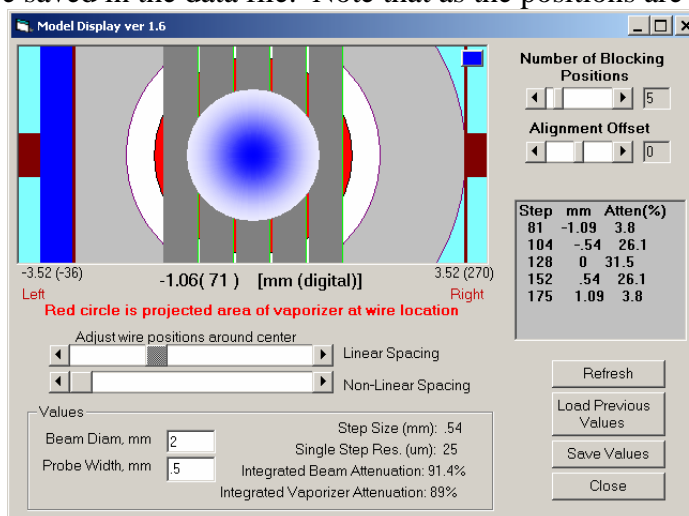


**Figure 7. Default program form view showing Automated Control, External Control, Calibration and Manual control features.**

At the end of the calibration procedure the Model Display form is called ("Show Model" button). This display gives a model view looking down the beam axis showing probe positions, probe thickness, aperture diameter and particle beam diameter. By clicking on the horizontal scroll bar, this routine can be used to adjust the number of steps and the step size around the center position. The red circle is the projected area of the 3.8 mm diameter vaporizer at the location of the BWP. As the positions are changed they are displayed in the text window [*Step mm Atten(%)*]. The attenuation values displayed are with respect to the input beam diameter size, not the effective beam diameter (red circle), although both attenuation values are saved in the data file. Note that as the positions are changed the center position is not altered. The center position can be changed by using the "Alignment Offset" horizontal scroll bar.

The model (and software) assume that the center position determined by the calibration routine is the true geometric center. If it is determined experimentally that the particle beam is not attenuated at maximum at this position then to compensate the "Alignment Offset" feature can be used.

Alternatively, and more correctly, the particle lens should be adjusted to make maximum blockage at the calculated center position. This is most conveniently performed with  $\text{NH}_4\text{NO}_3$  300-350 nm DMA generated particles. It has been observed that the particle beam for this size range is nearly 100% blocked by a 0.5 mm diameter device.



**Figure 8. Model display. Outer gray circular area is channel aperture structure. Inner white area is entrance aperture to detector. Center circle represents particle beam diameter and vertical gray bars show programmed wire positions. Red blocks are wire stops.**

Inside the Model view form the user can set the total number of blocking positions and locations. Current thinking suggests that the two outer most positions should be just within the beam diameter (red area) as shown in the figure. The dark red squares on the left and right hand side represent the probe stops (or edges) that are machined into the assembly (6.40 mm between stops). The red vertical lines are the "Right" and "Left" edge wire positions. After selecting the wire positions click the *Save* button. These values are written to the file *C:\ams\amscode\wire\_positions.dat* and can later be reloaded with the *Load Previous Values* button. *Unreasonable values for selected wire positions will be displayed in the table in red text and are not accepted.*

### Automated Control

After the probe travel is calibrated and step positions are selected inside the Model Display form the program is ready to be operated in the Automated or External Control modes. At this point it is assumed that the AMS program is in the AutoSave mode logging data as typically done. The user next needs to set/enter the step interval, or Time Between Steps. This variable must be set to the same value as the auto save data interval in the AMS program. At this point the “Start Timed Control” button is pressed which moves the probe to the LHS edge. The probe will be stepped at each AMS data save and the step number and total number of passes across the beam path are counted and displayed. The file “Wire.dat” will be created if it does not exist and data will appended to it listing the various parameters described above. If the file already exists, data will continue to be appended so this file will need to be edited or maintained. If External control mode is selected, movement is suspended until the externally supplied TTL signal changes state.

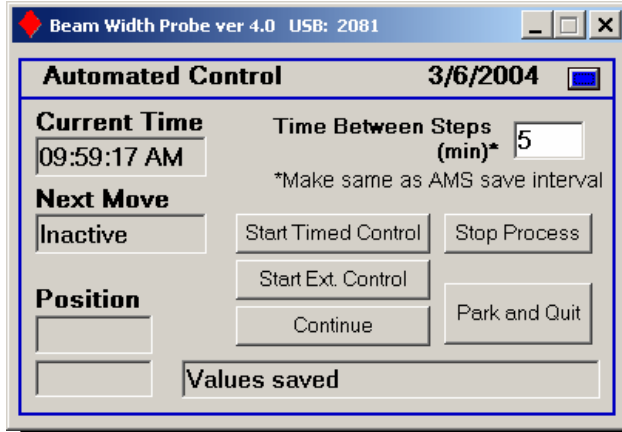


Figure 9. Program form view showing automated control features.

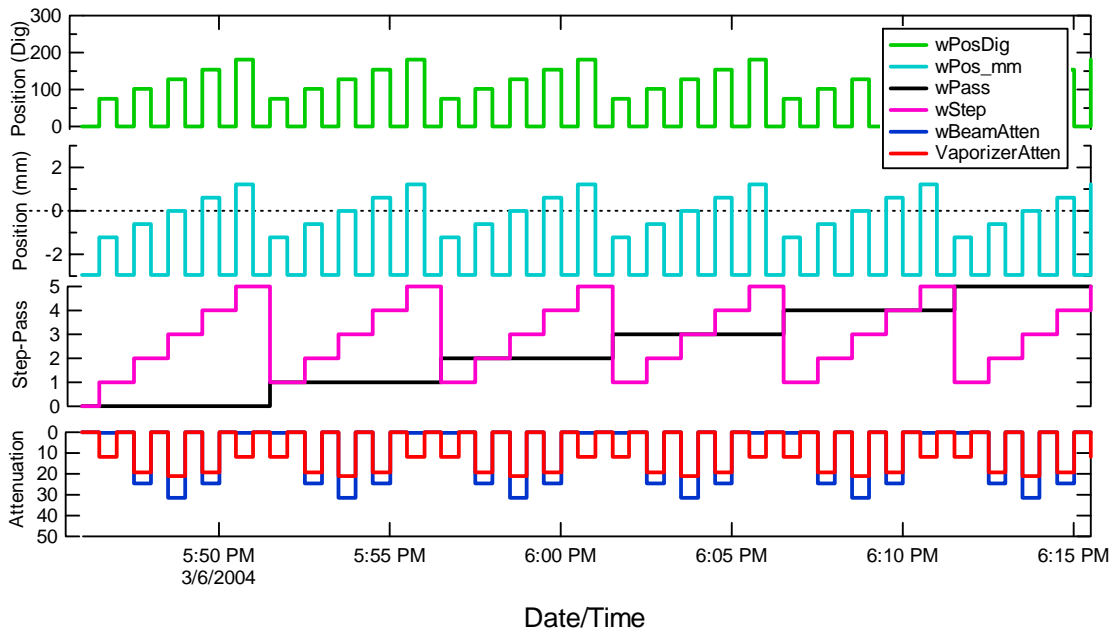
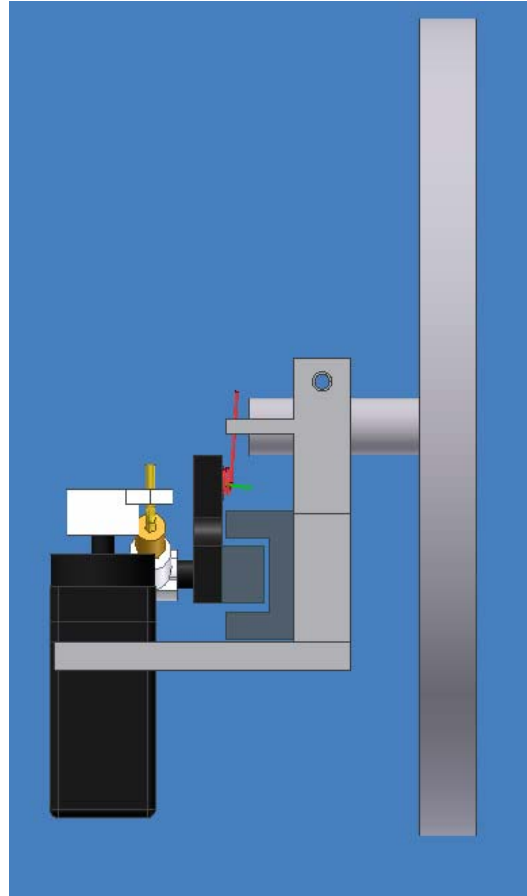
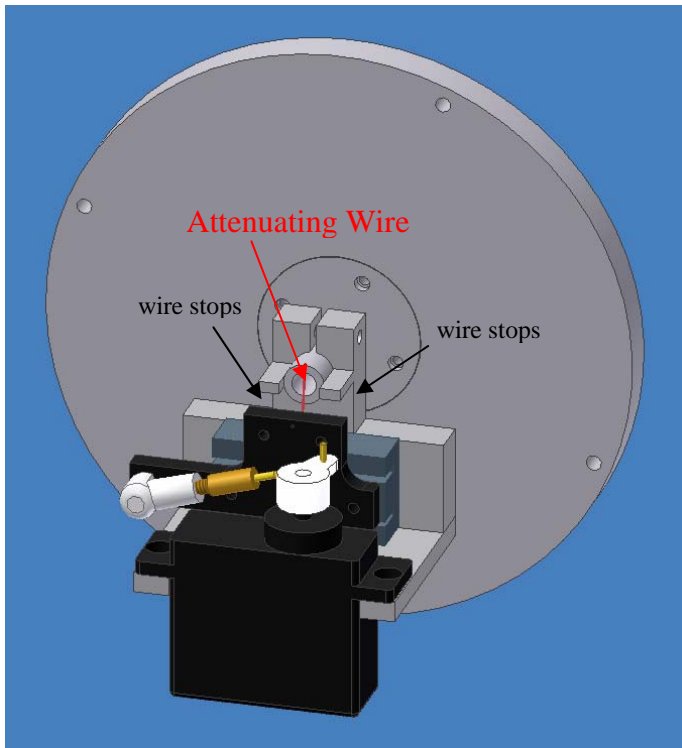


Figure 10. Example of plotted program output illustrating movement of beam width probe in Automated *Alternate* movement mode. Five passes are show with 5 steps per pass and 30 seconds between steps selected.

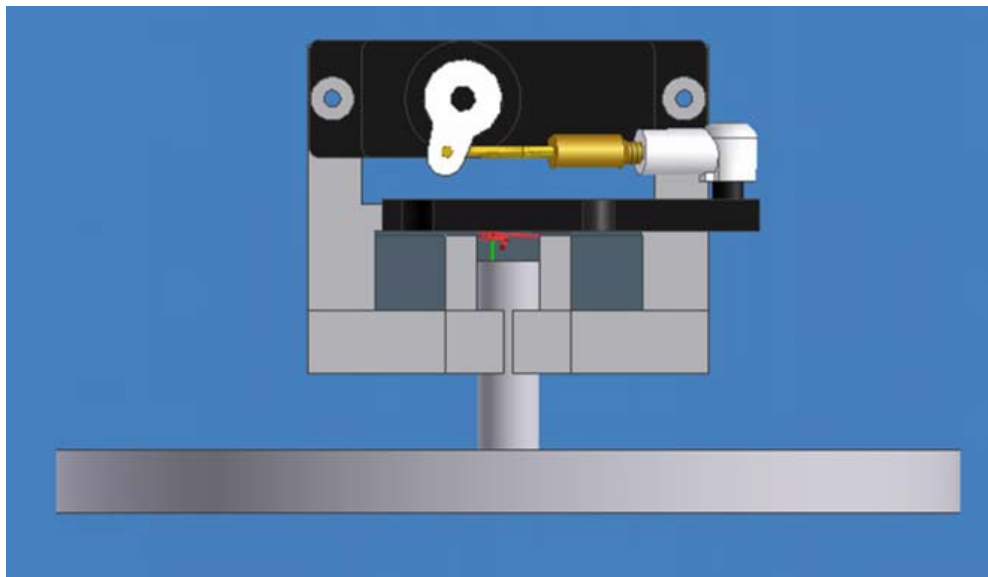


Automated movement in the default "Alternate" movement mode (see Figure 10) begins by first moving the probe to the left edge. The first step moves the probe towards the center of the beam. The second step moves the probe back to the left edge (off axis) and the third movement advances the probe to the second step position (beyond the first step), etc. Information that describes the probe position and movement is recorded in the *wire.dat* output file. A graphical example of how the probe is moved in the Alternate mode is shown in the figure below. In the Alternate movement mode the particle beam is potentially blocked only 50% of the time. One can also chose to operate the automated control in a continous mode by selecting "Continous" in the full form view (see **Figure 6**). In the Continous movement mode the preprogrammed wire positions are stepped through without "alternately" returning to an edge or non-blocking position.

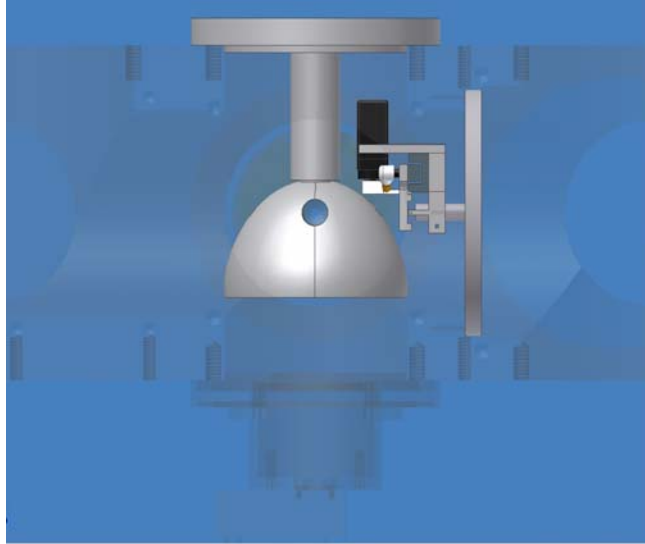
Also plotted in Figure 10 are calculated attenuation values. These values are calculated for two cases; one for the coverage of the probe over the vaporizer area and one for the coverage of the probe over the beam area. The calculation of attenuation of the beam area is based on the input value for the beam diameter in the Model Display form. The attenuation value for the beam coverage assume a uniform beam density for simplicity.



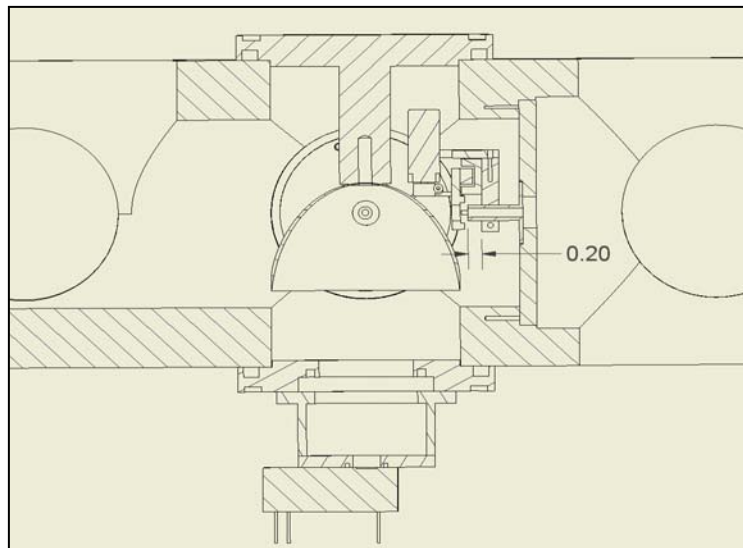
**Additional views of Beam Width Probe assembly mounted to channel aperture. The attenuating wire is spring loaded to prevent deformation from possible servo override.**



**Appendix I.** Incorporation of beam width probe with light scattering module.



**Figure 5.** View showing the moveable wire assembly mounted with the light scattering module.



**Figure 1.** Cross-sectional view showing moveable wire assembly installed with light scattering module. Beam probe assembly must be  $>0.20''$  down from channel aperture face. The procedure for this installation requires that the beam width probe be installed first (before light scattering parts). The elipsoid and its mounting flange are next installed in separate pieces.