MultiView 4000™

User Guide
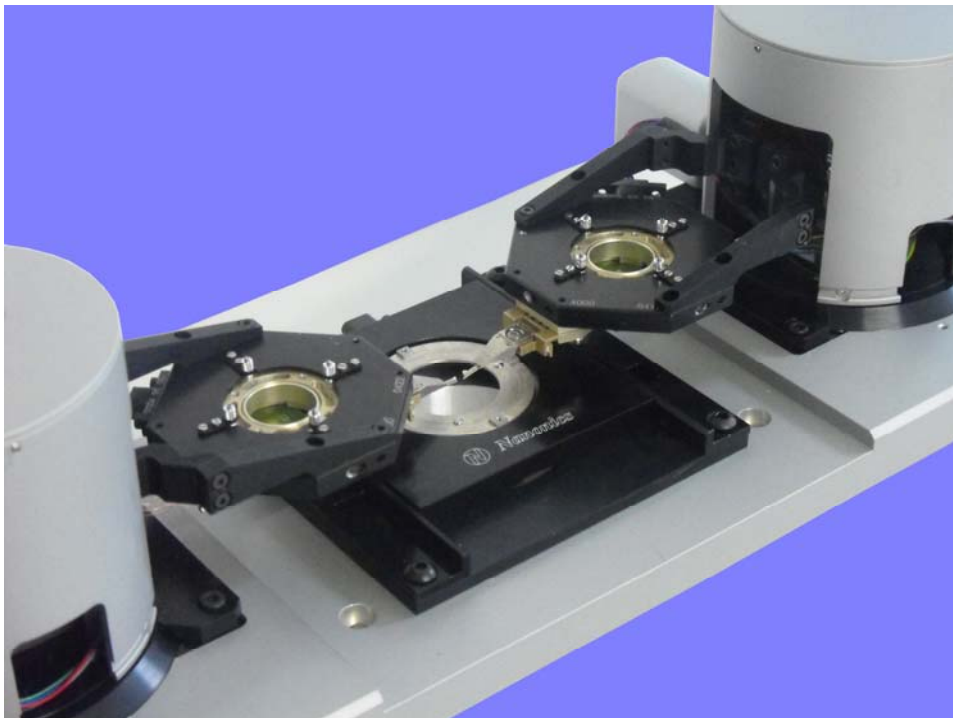
for the Integra Controller with NWS software

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Published 2010

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Note on Printing

This manual is designed to be printed in color, single-sided on A4 paper.

Table of Contents

1   Laser Safety

HEALTH & SAFETY ADVISORY:

1. It is mandatory to read this section before operating Nanonics MultiView™ products.

2. Always wear the appropriate laser safety goggles as designated by the wavelength or wavelengths being used.

Due to its special properties, laser light poses safety hazards not associated with light from conventional sources. The safe use of lasers requires that the laser users are aware of the dangers involved and that they are familiar with the MultiView head, and the Nd-YAG laser if relevant.

The greatest concern when using a laser is eye safety. In addition to the main beam, there are often many smaller beams present at various angles near the laser system. These beams cause specular and other reflections of the main beam as a result of interaction with polished surfaces such as lenses, beam splitters and/or other surfaces. While weaker than the main beam, such beams may still be sufficiently intense to cause eye damage.

Laser beams can be powerful enough to burn skin, clothing or paint. They can ignite volatile substances such as alcohol, gasoline, ether and other solvents, and can damage light-sensitive elements in video cameras, photomultipliers and photodiodes. The laser beam can ignite substances in its path, even at some distance. The beam may also cause damage if it bounces off reflective surfaces. For these reasons the user is advised to follow the precautions below.

1.1   General

Observe all the safety precautions that appear in this manual.

Advise all personnel working in the vicinity of the laser of the precautions listed in this section.

1.2   Restricted Access

1. It is good practice to operate the laser in a room with controlled and restricted access.

2. Limit access to the laser to qualified users who are familiar with laser safety practices and who are aware of the dangers involved.

3. Use the laser in an enclosed room. Laser light will remain collimated over long distances and therefore presents a potential hazard if not confined.

4. Post warning signs in the area of the laser beam to alert all laser users and everyone else near the laser system of the hazards specific to the class of laser present.

5. Affix a laser warning light at all entrances to the area where the laser is used.

1.3 Eye Protection

1. If the eye is exposed to laser beams the damage may not be immediately noticed. In addition, damage to the eye can be cumulative as a result of repeated exposure.

2. As a precaution against accidental exposure to the output beam or its reflection, wear the appropriate laser safety goggles as designated by the wavelength or wavelengths being used.

3. Never look directly into the laser light source or at scattered laser light from any reflective surface.

4. Ensure that you are wearing the appropriate laser safety goggles when viewing the laser through the optical microscope.

5. Maintain experimental setups at low heights to prevent inadvertent beam-eye encounter at eye level.

1.4 Working with Lasers

1. Never leave the laser unattended when it is in operation.

2. Avoid direct exposure to the laser light. The intensity of the beam can easily cause flesh burns or ignite clothing.

3. Before energizing a laser, verify that the prescribed safety devices for the unit are correctly employed. These may include opaque shielding, non-reflecting and/or fire resistant surfaces, goggles and/or face shields, door interlocks, and ventilation for toxic material.

4. Remove your watch or any jewelry to avoid inadvertent reflections.

5. Remove all unnecessary mirror-like surfaces from the vicinity of the laser beam path. Do not use reflective objects, such as credit cards, to check beam alignment.

6. Exercise extreme caution when using solvents in the area of the laser.

2   Introduction

The MultiView 4000 is a multi-probe AFM, NSOM and SPM system, consisting of up to four probes. It has an open architecture which allows for flexible integrations with different analytical tools.

The modular design of the MultiView 4000 allows for the following combinations:

- Single-Probe SPM station which can be upgraded to include up to four Probe SPM platforms.

- Single-Probe SPM station with two Piezo Nanoaligners for side positioning and manipulations while maintaining space for future upgrades.

- Dual-Probe SPM station with two piezo nanoaligners.

Figure 1: MultiView 4000 with four SPM probes

The MultiView 4000 head enables many unique applications, including the following:

- Independent scanning with up to four probes for atomic force and near-field optical scanning. All known probes types may be used for other imaging modes as well.

- Unique probes for multiple probe resistance measurements with two-, three- and four-point probe geometries.

- Unique thermal probes for multiple probe measurements.

- Multiple probe near-field optical measurements (NSOM or SNOM).

- Multiple probe nanochemical writing on a variety of structures with a variety of gaseous, liquid or solid inks using Fountain Pen Nanochemistry.

- Multiple probe nanoindentation with on-line, ultra-high resolution atomic force imaging of the indented structure.

- Multiple probe optical or thermal desorption with tandem collection for mass spectral analysis.

2.1   Optical & Other Complementary Integration

The MultiView 4000 system has a number of advantages in the area of optical microscopy and it can also be integrated with other equipment, as described below:

- Full integration with upright, inverted or dual (4 Pi) optical microscopes.

- Full integration with non-linear and multi-photon microscopes (e.g. second generation harmonic microscopes).

- Completely free optical axes both above and below the sample.

- Open system architecture providing transmission, reflection and collection modes.

- Online Raman.

- Online Scanning Electron Microscopy (SEM).

- Online Focused Ion Beam (FIB).

- Online Dual Focused Ion Beam (FIB) with Scanning Electron Microscope (SEM).

2.2   Normal Force Tuning Fork Feedback

The MultiView 4000 uses normal force tuning fork technology with a high Q factor and Phase Feedback to allow control of the probe/sample separation. Tuning forks in normal force mode with Phase or Amplitude Feedback permit high performance and ease of operation for AFM imaging.

2.3   Scanner Solutions

3D FlatScanner™ Technology: Unlike standard piezo scanners that keep probes separated, the 3D FlatScanner is an excellent solution for multiprobe scanning. The design of the 3D FlatScanner is a novel planar folded-piezo, flexure scan design which provides very good AFM resolution (e.g. atomic steps in highly oriented pyrolytic graphite (HOPG)). The large vertical (axial) displacement of up to – 100 µm for sample scanning and up to 30 µm for tip scanning allows for the use of multiple probes as well as the tracking of structures with very large topographical features, and simultaneous lateral scanning over large areas. The ultra-thin architecture of the 3D FlatScanner provides the flexibility that is critical in developing a variety of different geometries of multiprobe systems.

The 3D FlatScanner can also be incorporated into systems where conventional scan stages are too bulky and geometrically limiting. Its minimal height of 7 mm allows for easy access with high powered microscope objectives from either above or below the scanning stage.

2.4   Probe Solutions

Nanonics glass-based probes are spatially and optically friendly, which allows for the tips to be approached very close together – a critical feature of multiprobe imaging systems. In addition, they keep the Z optical axis free for both upright and inverted microscope views. In

a multi-probe scan, the probes can be very close to each other (nanometric separation), while each probe scans the sample independently.

2.4.1   Environmental Control

The MultiView 4000 can be placed inside an environmental chamber (shown below). This allows SPM scanning to be performed in conjunction with confocal microscopy under controlled conditions. The chamber allows you to have precise control over humidity, temperature, gas inflow and chemical nanolithography via a nanopipette amongst other variables, while performing SPM imaging with completely free optical axes from above and below for all NSOM modes.
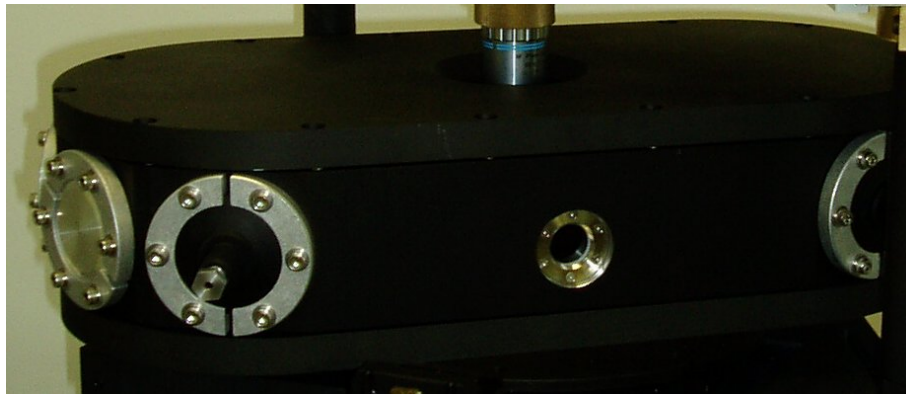
Figure 2: Environmental chamber hosting the MultiView 4000^{TM} inside with free optical axis for upright and inverted optical microscopes.

3   The MultiView 4000 System

3.1   The Standard Hardware Set-up

A typical two-tower MultiView 4000 System is comprised of the following equipment:

- MultiView 4000 Tower (2 units)

- Dual Microscope

- SPM Controller* (2)

- High Voltage Piezo Driver* (3)

- Low Voltage Adaptor* (1)

- DT Interface* (2)

- System Power Supply* (2)

- Stepper Motor Driver (1)

- Computer (2)

*These hardware devices form the Integra Controller system for integrated microscopy. They are fully interoperable and compatible with other MultiView systems.

MultiView 4000 Head p. 14 and p. 39

The MultiView 4000 head is the heart of the system and it contains the sample scanner, towers and upper scanners, probes and stepper motors.
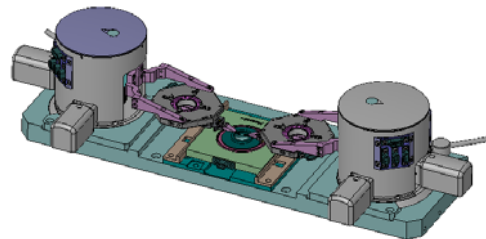
Host Optical Microscope p. 44

The microscope shown is the Nanonics Dual Microscope which is based on two Olympus BX51 microscopes. Other host microscopes are also compatible with the system. The microscopes are installed on the Nanonics dual frame stand and the MultiView 4000 is placed on a custom-made interface plate.

Dimensions: 50 x 50 x 80 cm

SPM Controller p. 20

Controls the scan and feedback mechanism; controls the preamp and Z stepper motor position; contains the lock-in card for signal control.

High Voltage Piezo Driver p. 23

Generates high voltage signals applied to the X, Y and Z axes of the scanner.

Low Voltage Adaptor p. 28

Selects the scanners that are used in the XY and Z axes.

DT Interface p. 28

Interfaces between the DT (data translation) cards installed in the computer and the system hardware ADC/DAC.

System Power Supply p. 30

Provides low-voltage and high-voltage power to the SPM Controller, DT Interface and High Voltage Piezo Driver.

Stepper Motor Driver p. 31

Provides signals for the lateral stepper
motors. It is controlled by the SMC software
and interfaces with the NI card installed on
the computer.

Computer

Nanonics supplies a desktop computer with two DT cards, an NI card and the NWS
software. NWS allows you to define and control the scan parameters – see the "NWS User
Guide" for more information.

3.2   Additional Hardware for NSOM Measurements

The following equipment is required for carrying out NSOM measurements. NSOM scanning is described on page 91.

Counter & Power Supply p. 35

The APD (Avalanche Photo Diode) Counter & Power Supply receives TTL input signals from the Detector and converts them to analog signals. The power supply provides 5 V of power to the Detector.

Detector

The Detector can be an APD, PMT or CCD.

Fiber Coupler p. 94

The Fiber Coupler introduces the laser light into NSOM probes. It is used for NSOM, confocal and fluorescent scanning as well as other optical applications.

Laser and Power Supply

For general NSOM imaging, a 532 nm Nd-YAG laser is used. The laser is provided with its own power supply.

3.3   The Two-Tower Set-up

The two-tower MultiView 4000 system on a dual microscope is shown below.

Figure 3: The MultiView 4000 System with two probes and integrated Dual Microscope

A complete two-tower MultiView 4000 system scheme appears below:
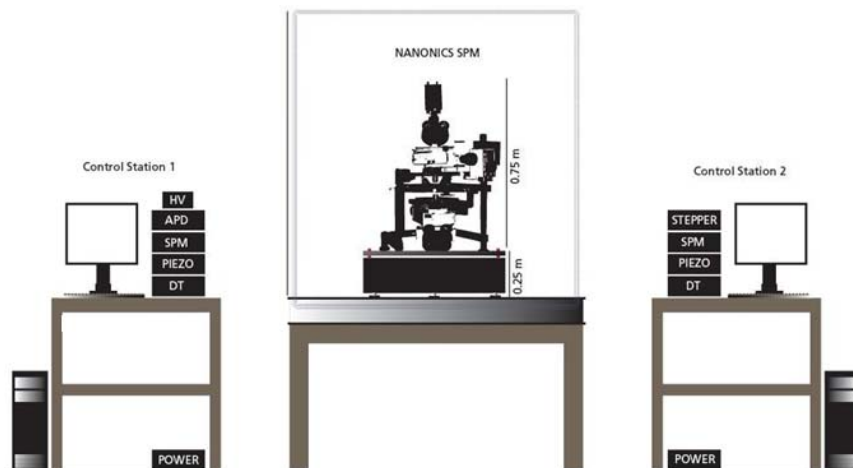

Figure 4: MultiView 4000 - Scheme for a Two- probe System

3.4   A Closer Look

3.4.1   The MultiView 4000 Head

A schema of the MultiView 4000 head in a two tower configuration appears below:
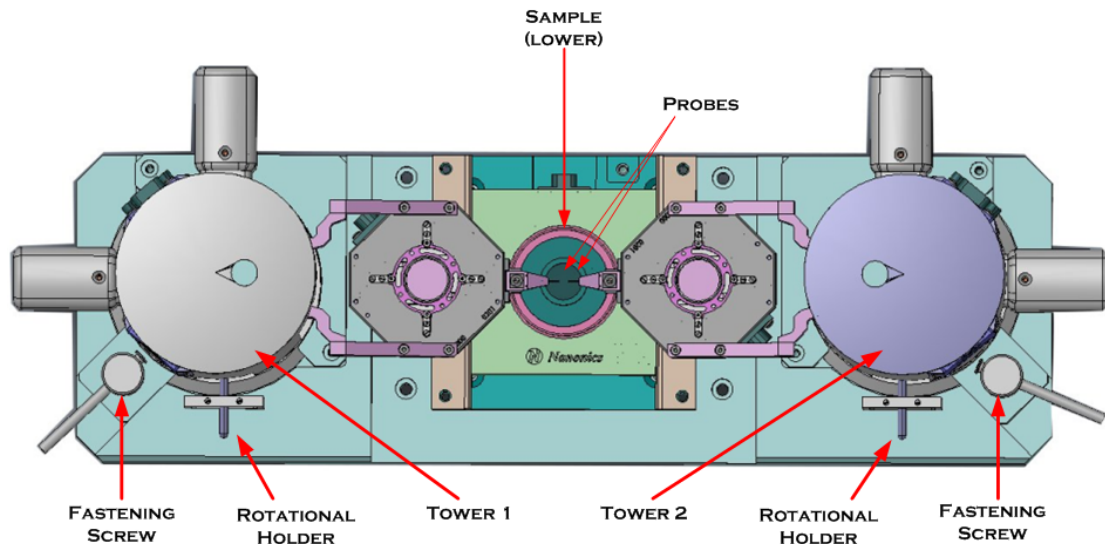
Figure 5: MultiView 4000 Head Assembly

Each tower contains a tip-scanning stage, a tip mount, a pre-amplifier, a Z stepper motor, XY stepper motors and electrical connectors.

The sample is placed on the lower scanner which performs sample scanning.

Each probe's height is individually controlled by a Z stepper motor unit, located inside the tower.

A fastening screw is used to affix the tower to the interface stage after tip-mounting.

Each tower includes two XY lateral stepper motors, used for rough positioning of the tip.

The towers and the lower scanner stage are placed on an interface plate, which sits on the XY stage of the optical microscope. Each tower can be rotated around its base for probe/sample mounting. (In previous versions, the tower slides manually in and out of the interface plate on dovetail rails).

>>   *To manually move the towers or sample stage*

1.   Loosen the fastening screw.

2.   Using the rotational holder, rotate the tower. (For previous versions, move the tower or sample stage out along the dovetail rail).

3.4.2   MultiView 4000 Table
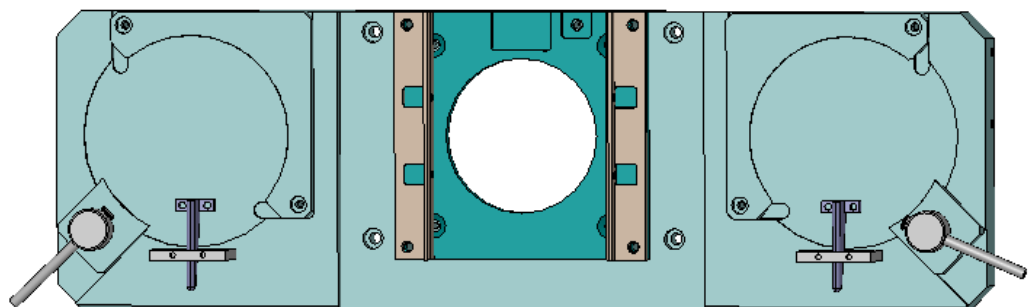
3.4.3   MultiView 4000 Tower

The parts of the MultiView 4000 tower are shown in the diagrams below.
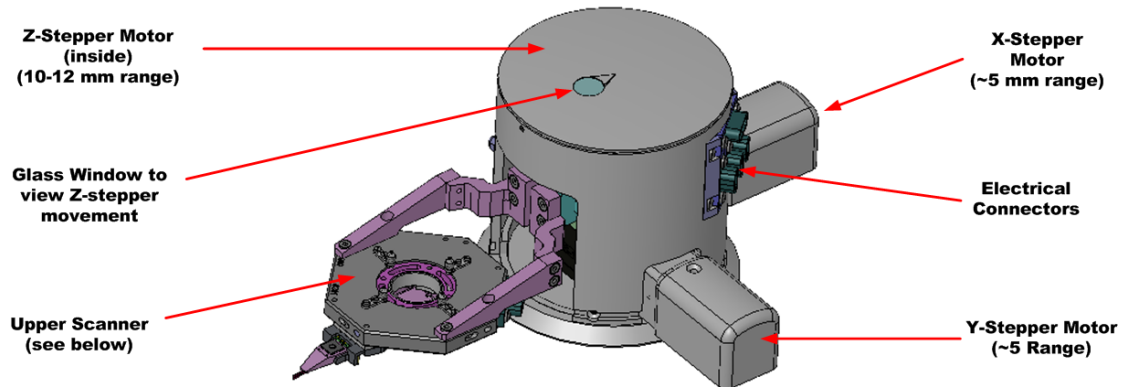
Figure 6: MV4000 Tower Assembly

3.4.4   Upper Scanner

Each tower houses an upper flat-scanner, as shown below.
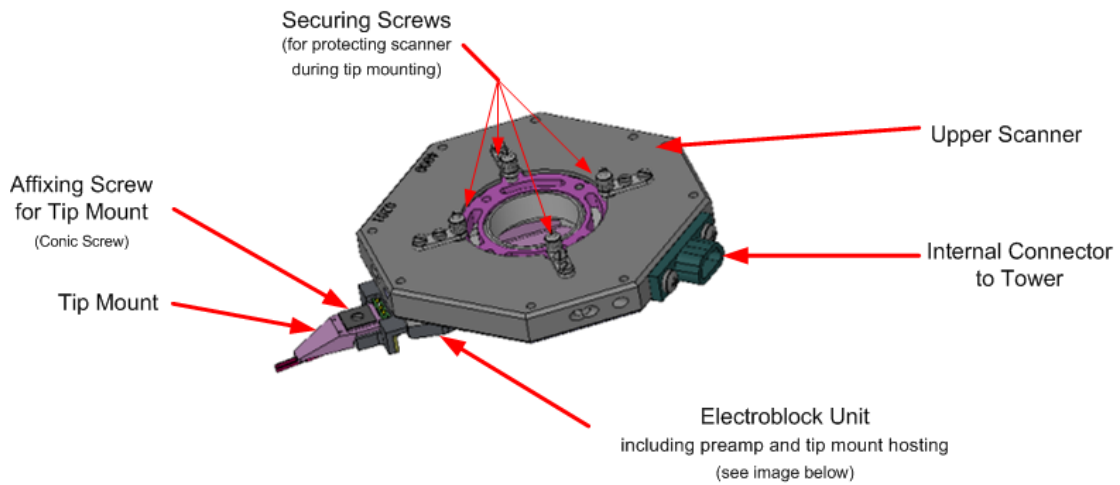
Figure 7: MV4000 Upper Scanner

3.4.5   Electroblock Unit
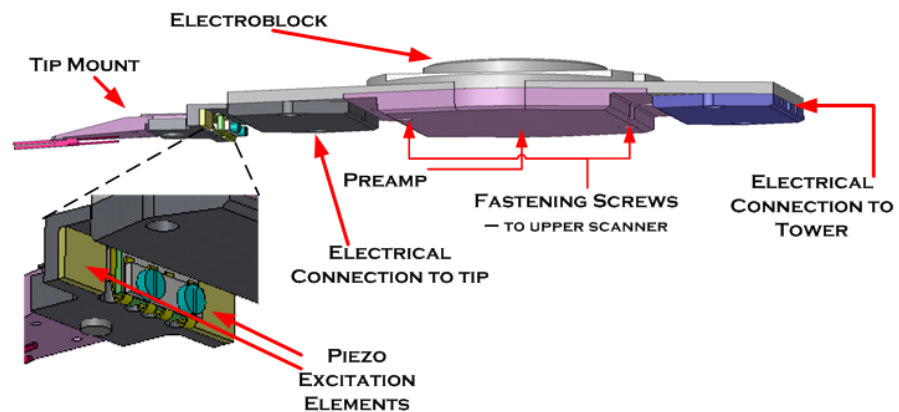
Figure 8: MV4000 Electroblock Unit

The electroblock unit includes:

- Tip Mount (see next)

- Preamp (used to amplify signal received from tuning fork)

- Electrical connection to tower (internal thin wire connection)

- Piezo Excitation Elements (two piezo elements, used to provide high-frequency excitation to tuning fork.

- Fastening Screws (for attaching electroblock Unit to Upper Scanner)

Caution *– fasten these screws with care to avoid damaging the scanner)*

3.4.6   Tip Mount

The MultiView 4000 tip mount is shown below.
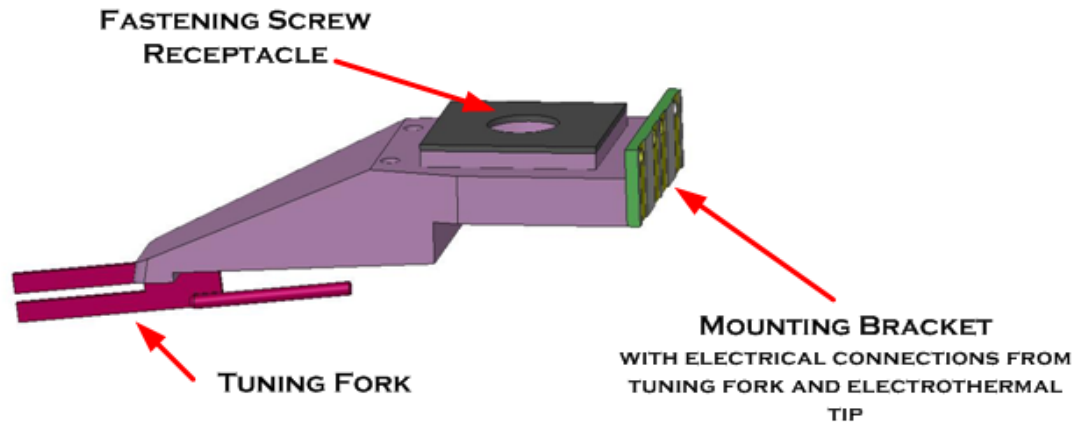
Figure 9: MV4000 Tip Mount

3.5   The MultiView 4000 Tip-Mount Assembly

As shown above, the tip-mount attaches to the electroblock via an electrode panel at its back, and tapers at its front, where a tuning fork is mounted, to which the AFM probe is attached. This structure can be seen in detail in the figures below.
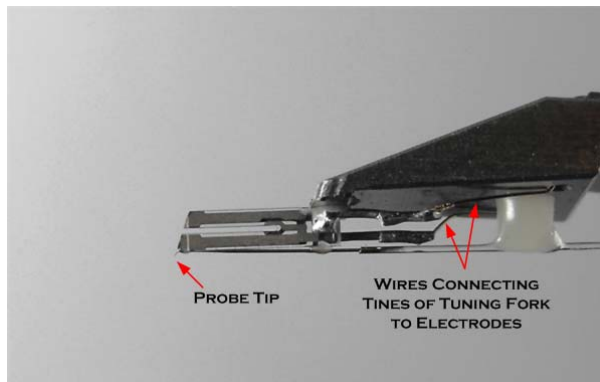
Figure 10: The Tuning Fork Portion of a Tip-Mount
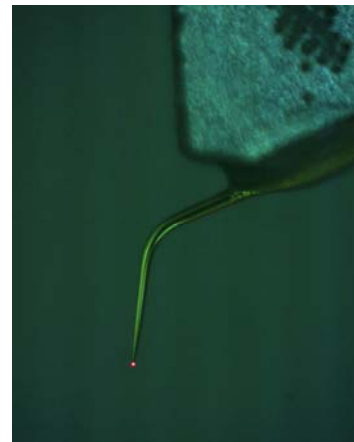
Figure 11: A Probe, extending beyond the end of the Tuning Fork, and showing both Cantilever and Tip

The two tines of the tuning fork are connected via wires, indicated by red arrows in Figure 10, to the two outer electrodes on the tip-mount electrode pad. These electrodes transmit the signals generated by the tuning fork response. These signals are amplified at the electroblock preamp and are sent from there to the SPM Controller for generation of the error signal.

The two inner electrodes on the tip-mount electrode pad are used only with electric or thermal probes. Nevertheless, they are standard on all tip-mounts.

The fiberglass probe is bonded lengthwise along the lower surface of the bottom tine of the tuning fork, and protrudes beyond it at different cantilever lengths, depending upon the type of probe employed (see Figure 11 above). .

The part of the probe protruding beyond the tuning fork consists of a cantilever and the tip proper. The length of each element is customized according to the demands of each application. Longer **cantilevers** are required, for example, for NSOM and TERS measurements, while longer **tips** are needed for deep-trench AFM imaging.

On most probes, the upper tine of the tuning fork is recessed. This is done to give an improved top view when using upright optical microscopes.

3.6   Probe Parameters

When you receive a probe with a tuning fork from Nanonics, the box contains information about the probe(s) inside. This information will be important in configuring the system so as to get good results with the probe.

Figure 12: Tip-mount Box - Back View, with Tip Parameters

Tip Size (ϕ): This is the tip diameter. For NSOM probes this value refers to the open aperture diameter of the probe.

Frequency (f): This is the resonance frequency of the tuning fork with the given tip mounted. The resonance frequency of the tuning fork **before** mounting the tip is 32.678 kHz. This value changes after mounting the tip due to the mass change and due to the mechanical properties of the added glue.

Q Factor: The Q factor (Quality Factor) compares the time constant for decay of an oscillating physical system's amplitude to its oscillation period. Equivalently, it compares the frequency at which a system oscillates to the rate at which it dissipates its energy. A higher Q factor indicates a lower rate of energy dissipation relative to the oscillation frequency.

4   The Integra Controller System

The Integra Controller system is comprised of the SPM Controller, the High Voltage Piezo Driver, the Low-Voltage Adaptor, the DT Interface, the System Power Supply and the Multi-Channel Stepper Motor Driver. They are fully interoperable and compatible with other MultiView systems and they are described in this section.

4.1   SPM Controller

The SPM (Scanning Probe Microscopy) Controller has the following functions:

- Processing the Error signal via the on-board Lock-in amplifier and the PID feedback gains.

- Providing the signals to the preamplifier and the Z stepper motor.

4.1.1   Front Panel
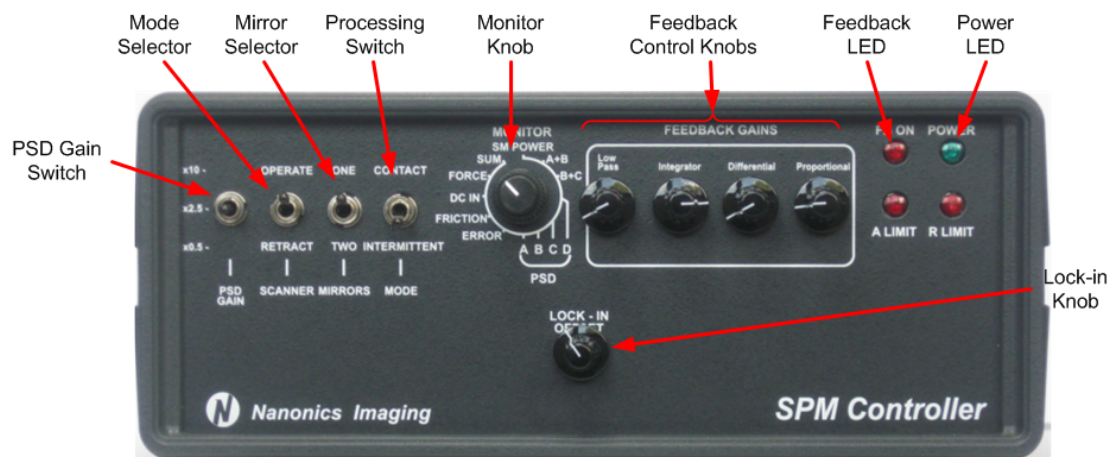
Figure 13: SPM Controller – Front Panel

Table 1: SPM Front Panel - Controls

Control	Description And Settings (in bold)
PSD Gain	Not used with Tuning Fork Feedback
Mode	**For normal operation the position is Upper.** **Note: This is an Emergency Knob.** If the software becomes unresponsive and the tip is still in contact with the sample, move the Mode switch to the lower position and then restart the software. Then, retract the tip from the sample and return the Mode switch to the upper position before bringing the tip toward the sample once again.

Control	Description And Settings (in bold)
Mirrors	Determines the polarity of the output signal from PSD. **For the MV4000 this is always set to the "One" position.**
Monitor	Turn the dial to "DC-In". The monitored signal can be accessed through the "Monitor" BNC on the front panel of the DT Interface.
Feedback Gains	The Feedback Gains are used to optimize the feedback parameters. · Low Pass Filter, p. 89 · Integrator Gain, p. 88 · Differential Gain , p. 88 · Proportional Gain, p. 87
Processing	Selects the card that carries out the signal processing. **Set to "Intermittent" when working with Tuning Fork Feedback.**
Lock-In Offset	Provides an offset to the DC output signal (DC Out) from the internal lock-in card. By default it preset by Nanonics.

4.1.2   Rear Panel

Figure 14: SPM Controller - Rear Panel

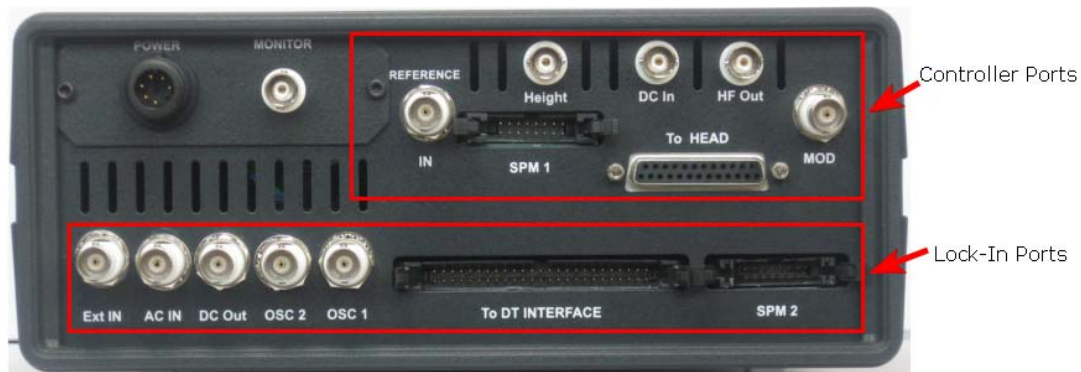The SPM Controller contains a **controller card**, which controls the feedback of the scanner and a **lock-in amplifier card** for signal processing. The two cards are connected externally as follows:

Table 2: SPM Rear Panel – Cable Connections for Ports

Ports	Cable Connection
DC In – DC Out	BNC
MOD – OSC 1	BNC
SPM 1 – SPM 2	Flatband

Ports	Cable Connection
To Head – Ext In	Split cable. The BNC part (short coaxial cable) connects to "Ext In" and the other connectors go to the Tower. The long coaxial cable is used for Electrical Measurement mode.

The tables below describe the ports on the rear panel of the SPM.

Table 3 SPM Rear Panel - Controller Ports

Controller Port	Function
Monitor	Connects to the "Height in" BNC on DT Interface via a BNC cable and provides the height signal to the DT Interface.
Reference In	Inputs a signal from a function generator.
Height	Outputs the processed error signal to the HV Piezo Driver to control the Z position of the scanner.
DC In	Receives the DC output signal from the lock-in card that provides feedback to the scanner. (Amplitude signal in Amplitude Feedback and Phase signal in Phase Feedback mode)
HF Out	Outputs the raw high frequency signal.
MOD	Modulates the oscillating frequency with the reference signal of the lock-in card.
SPM 1	Connects to SPM 2. This connects the Controller ports to the Lock-In ports.
To Head	Triple-split cable: The BNC part of the cable connects to "Ext In" on the rear of the SPM Controller. The two 9-pin connectors go to the Tower: one for the Z stepper motor and the other for the preamp.

Table 4 SPM Rear Panel - Lock-in Ports

Lock-in Port	Function
Ext In	A high gain input of the lock-in which can be used to input weak signals such as the signal from the tuning fork.
AC In	Low gain input of the lock-in. Not used with MV4000 systems.
DC Out	The processed error signal (DC amplitude or phase) is output at this terminal
OSC 1, OSC 2	These terminals output the reference signal to excite the tuning fork. Only OSC 1 is used.

Lock-in Port	Function
To PC	The DT Interface box is connected to this port to provide software control of both the controller card and the lock-in control.
SPM 2	Connects to SPM 1. This connects the Controller ports to the Lock-In ports.

4.2   High-Voltage Piezo Driver

The High Voltage Piezo Driver processes the signals from the SPM Controller and supplies the high-voltage signals necessary to move the height scanner on the Z axis. In addition, it receives the XY low-voltage signals from the DT Interface and converts them to the high-voltage signals needed to perform the XY scan.

The displays for each channel (the X, Y and Z axes) show the voltages that are applied at any given moment. These voltages are monitored during a scan to check that the values are logical and that the scan is functioning correctly.

There are three modes for operating the Piezo Driver and they are described below.

4.2.1   Modes of Operation

The Piezo Driver has three modes of operation:

- Positioning

- Scan & Offset

- Scan & Slope Compensation.

4.2.1.1   Positioning

In Positioning mode , the X, Y and Z knobs are used to move the scanner by providing voltages within the range of ± 145. Tip or sample manipulation is done in this mode, but not AFM scanning. This mode is also used to test the scanner over its full range.

4.2.1.2   Scan & Offset

Scan & Offset mode allows you to offset the scanner slightly on the XY axis during a scan, when the tip is in feedback mode, without fear of damaging the probe. The actual offset is displayed in volts on the X,Y displays on the HV piezo driver This mode is used:

a) When moving the sample on the scanner over small distances. For instance, after an initial scan you wish to adjust the area being scanned,. Alternatively, when you wish to move the sample so that the interesting features will appear nearer the center of the scan.

b) For tip-positioning, such as in tip-enhanced Raman spectroscopy (TERS), when it is necessary to adjust tip-positioning within the laser spot.

c) When using two or more probes and you wish the probes to be close to each other.

NOTE: The scan range is reduced in accordance with the offset value of the selected mode.

4.2.1.3   Scan & Slope Compensation

Scan & Slope Compensation mode is the mode normally used when scanning. This mode allows for Hardware Compensation of sample or scanner tilt encountered during a scan by providing linear voltage offset to the Z-channel. This compensation is provided only for the Z-axis and does not affect the X- and Y-axes. See page 84 for further details on compensating for the tilt.

4.2.2   Front Panel
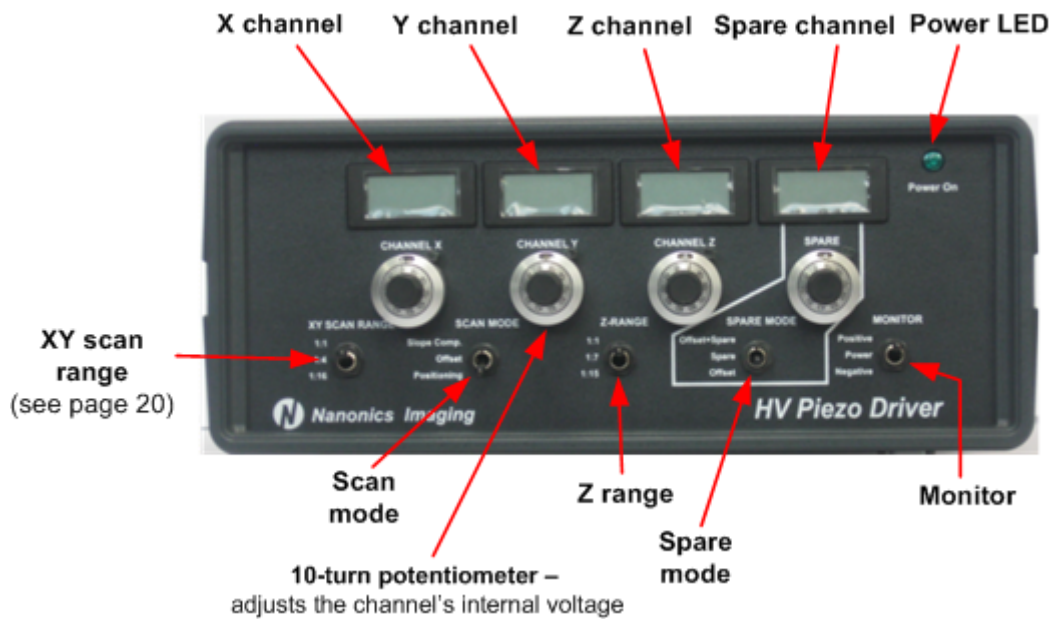
Figure 15: HV Piezo Driver - Front Panel

Table 5: HV Piezo Front Panel Controls

Control	Description
Channels X, Y, Z	High voltage channels applied to scanner; The knobs enable manual adjustment of voltage to be applied on three distinct modes: Scan and Slope Compensation, Scan and Offset and Positioning. Actual voltage is displayed on LCD above each knob. Normal voltage range: – 145 to +145.
XY scan range	Divider knob that sets high–voltage ranges for XY scan. 1:1 is the default, allowing full movement of scanner in XY range; 1:4 and 1:16 are used for special applications which require higher step resolution on the X– and Y–axes, such as STM. The XY scanner range is reduced to $\frac{1}{4}$ or $\frac{1}{16}$ of the full range respectively.

Control	Description
Scan Mode	Allows a choice of voltage mode to be applied to scanner: • **Slope-compensation**: Used to correct Z-tilt during a scan. The offset is provided only on the Z-axis. No offset can be provided on the X- and Y-axes in this mode. • **Scan and Offset**; Provides a high-voltage offset on the X- and Y-axes by manual adjustment of X and Y knobs. The offset can also be invoked when FB is ON and during the scan. • **Positioning**: Provides high-voltage signals to the X-, Y- and Z-axes of the scanner. Neither feedback nor scanning can be obtained in this mode.
Spare Mode	Provides an offset voltage for use in liftup mode. The options are: **Spare:** Default setting for regular operation **Offset + Spare**: For working in lift-up mode. This mode allows use of a single bipolar output as an additional source of offset, controlled with an additional internal adjustable voltage source. (E.g.: in MFM mode, an internal adjustable offset will be integrated with the height signal). **Offset** When DAC4 (on the DT Interface) is connected, a tilted offset is provided to the height.
Monitor	Select which voltages are displayed on the LCDs Options: **Positive:** displays voltage values for X, Y and Z channels (choose this option for normal operation) **Power**: indicates whether voltages emitted by piezo are correct. (correct values are: 12 for XY; +150 for Z, spare) **Negative:** enables working in lift-up mode. (Used when Offset + Spare mode is chosen. This option displays the voltage applied on the negative electrode of the piezo tube in Z direction.

Control	Description
Z Range Divider	Divider for setting high-voltage ranges for Z scanning axis
	• 1:1 . Used for samples with high topographic variations (from hundreds of nanometers to microns) where it may be necessary to make use of the full Z range).
	• 1:7 For normal operation suitable for Z ranges of few nanometers to hundreds of nanometers.
	• 1:15 Used for samples with small topographic variations, i.e. in the nanometer range.
	CAUTION: Never switch this knob when FB in ON!

SOFTWARE NOTE:

In the NWS software, select **Actions & Settings > SPM Control**. If **Automatic Update** is selected (i.e. it is bright green, Figure 16 below), the X-Y and Z (height) range settings are automatically updated in NSW with the settings on the High Voltage Piezo Driver. If it is not selected (i.e. it is dark green), then adjust the settings in the software so that they reflect the settings on the High Voltage Piezo Driver. However, even if Automatic Update is not selected, when you click **Start** to commence scanning, the software will be updated with the correct values. See Setting the Dividers, page 76.

Figure 16: Automatic Image Indicator Illuminated
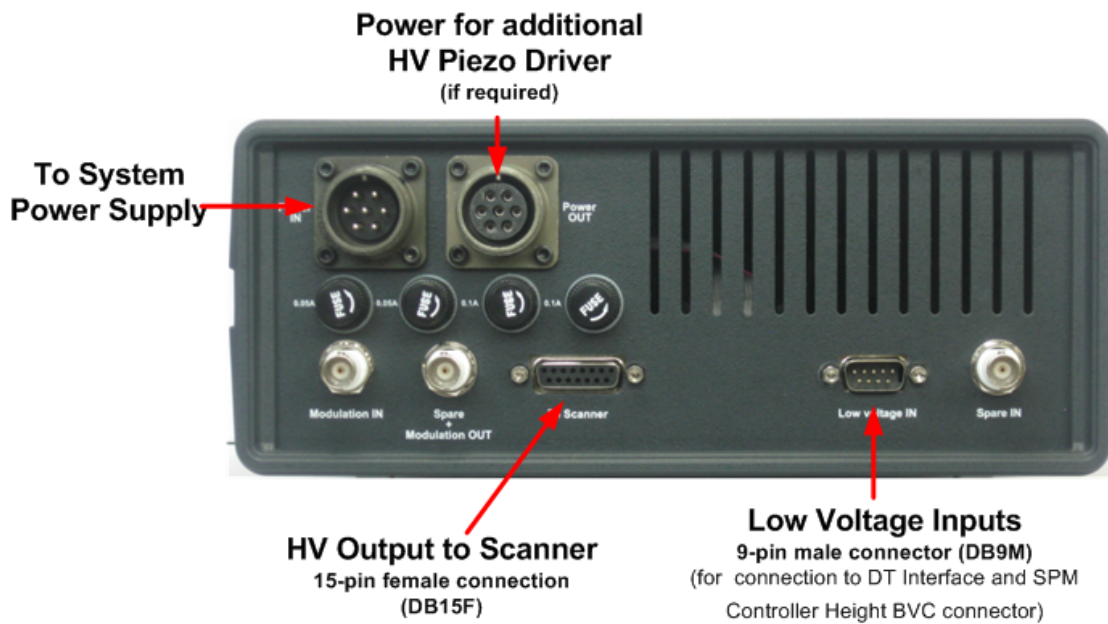
4.2.3   Rear Panel

Figure 17: HV Piezo Driver - Rear Panel

4.2.4   Specifications

The High Voltage Piezo Driver can be driven by either an internal or a variable external voltage source. It provides three bipolar outputs of ±145 V with currents of up to 1 mA, high stability and low noise output voltages.

Table 6: Specifications for HV Piezo Driver

Parameter	Specification
Output Voltage Range	±145 V
Maximum Current Output	1 mA
External Voltage Input Range	±10 V
Output Voltage Stability	0.1 V (after a 30 minute warm–up period has elapsed)
Noise Level	<0.5 mV (using a stable internal or variable external voltage source)

4.3   Low Voltage Adaptor

Figure 18: Low Voltage Adapter - Front Panel

The Low Voltage Adaptor is used to select which scanners will be used for a scan on the Z- and X-Y axes. See Table 7 below for available scanning modes.

Adaptor Front Panel - Controls

Table 7 Scanning Modes

Scanning Mode	Description
Sample Scanning	X–Y Scanning and Z Axis Feedback are in lower positions.
Tip Scanning	X–Y Scanning and Z Axis Feedback are in upper positions.
Combined I	X–Y Scanning in lower position and Z Axis Feedback in upper position.
Combined II	X–Y Scanning in upper position and Z Axis Feedback in lower position.
Both	A simultaneous scan of both scanners can be performed for obtaining a larger scan range.

4.4   DT Interface

The DT Interface contains the ADC/DAC that provides an interface between the Data Translation cards in the computer, and the SPM Controller. The DT provides analog and digital inputs from external devices to be syncrhonized with the scan.

4.4.1   Front Panel

Figure 19: DT Front Panel

Table 8 DT Front Panel - Connectors

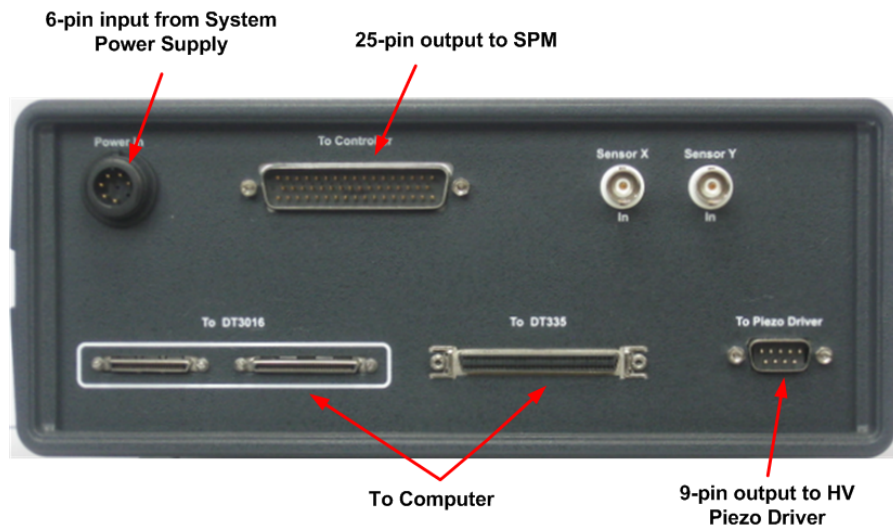| Port	Description
Height – Out	Outputs analog height signal for monitoring with oscilloscope or for connection with other devices.
DAC4	Connection for a free DAC (currently not used; available for customizes usage).
Spare 1	Free port (not connected)
Spare 2	Free port (not connected).
Trigger 1	Digital synchronization output for triggering external devices.
Trigger	Digital synchronization **input** for triggering external devices.
Trigger 2	Digital synchronization output for triggering external devices.
Height – In	Connects to the SPM Controller via a BNC cable and provides the height signal to the DT Interface.
Bias	Outputs analog bias voltage; range: ±10 volts. Used for electrical measurements.
AUX 2	Analog input; (–10 to +10v) can be used for NSOM signals from optical devices, thermal measurements, etc.
NSOM	Analog input; (–10 to +10v) can be used for NSOM signals from optical devices, thermal measurements, etc.
AUX 1	Analog input port (–10 to +10v).
Monitor	Outputs analog signal correlating to monitor knob setting on front panel of SPM controller.
Delayed Trigger	Outputs digital synchronization signal for triggering external devices with a specified time delay (used by certain software applications.)

4.4.2   Rear Panel

Figure 20: DT Rear Panel

Table 9: DT Rear Panel - Ports

Port	Description
To Piezo Driver	Connects to the High Voltage Piezo Driver.
To Controller	Connects to the SPM Controller.
Power	Connects to the System Power Supply.
To Computer	There are three connectors for connecting the DT Interface to the DT cards in the computer.
Sensor X	Analog input for reading voltages from X scanner sensor.
Sensor Y	Analog input for reading voltages from Y scanner sensor.

4.5   System Power Supply

The System Power Supply connects to the SPM Controller, DT Interface and High Voltage Piezo Driver.

It has three outputs to connect to the three hardware devices.

WARNINGS:

1. Ensure that the correct voltage is selected for your location.

2. Make sure the System Power Supply is off before connecting any of the devices.

3. Do not turn the System Power Supply ON or OFF until 3 to 5 minutes have passed since previous on/off action.

4. Make sure all components of the system are powered from the same power socket (like computers, Photon Counter, …).

4.5.1   Front Panel

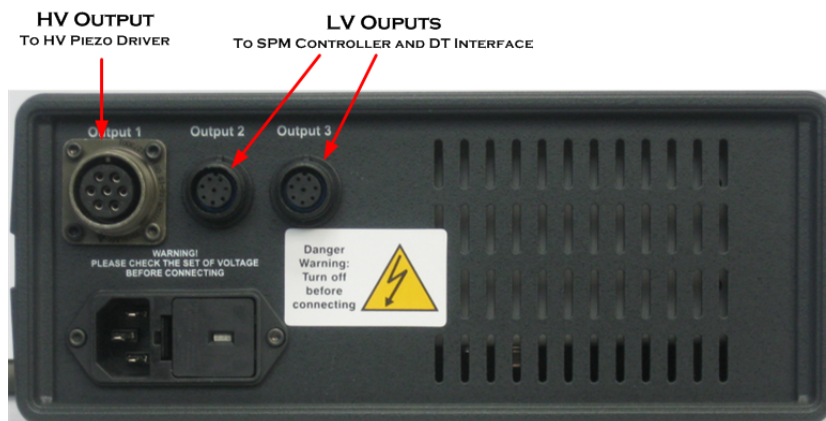*Figure 21: System Power Supply – Front Panel*

4.5.2   Rear Panel

Figure 22: System Power Supply - Rear Panel

The larger socket that protrudes from the power supply (labeled Output 1 above) is for the High Voltage Piezo Driver. The other two sockets are for the SPM Controller and DT Interface.

4.6   Stepper Motor Driver

The MultiView 4000 system uses a number of stepper motors to move the upper scanners (on the towers) and the sample stage. The Multi-channel Stepper Motor Driver (SMD), together with the Stepper Motor Control software, control the stepper motors.

Using the stepper motors to move the towers and sample stage is carried out *prior* to a scan in order to fine tune their position in the millimeter range (5 mm – 7 mm).

NOTES:

1. After you have carried out a scan, if you wish to fine tune the position of the scanner in the *micron* range use the High Voltage Piezo Driver's Scan & Offset mode – see page 23.

2. The Stepper Motor Driver does *not* control the Z movement of the upper scanner. This motion is controlled by the SPM Controller via the Retract and Approach buttons in the SPM Control tab of the NWS software.

4.6.1   Front Panel

The front panel of the Stepper Motor Driver appears below:
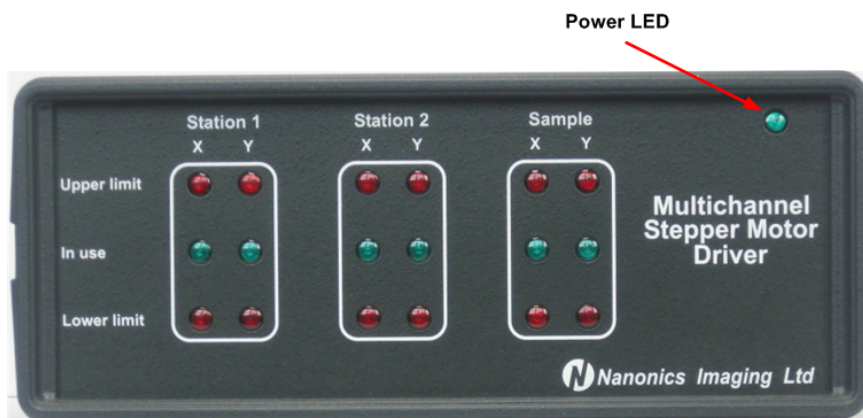

Figure 23: Multi-channel Stepper Motor Driver - Front Panel

The following table describes the SMD LEDs.

Table 10: LEDs on the Stepper Motor Driver Front Panel

SMD Indicator	Description
Station 1	These LEDs relate to the XY movement of Tower I.
Station 2	These LEDs relate to the XY movement of Tower II.
Sample	These LEDs relate to the XY movement of the sample stage. (optional for some systems)
Upper limit	A red LED lights up when the stepper motor has reached its upper limit in the relevant axis.
In use	A green LED lights up when the stepper motor is causing movement.
Lower limit	A red LED lights up when the stepper motor has reached its lower limit in the relevant axis.

4.6.2   Rear Panel

The rear panel of the Stepper Motor Driver appears below:

Figure 24: Multi-channel Stepper Motor Driver – Rear Panel

The following table describes the SMD connectors.

Table 11: Stepper Motor Driver Connectors

SMD Connector	Description
Power Supply	115/230 V AC. **Warning:** Ensure that the correct voltage is selected for your location.
SM1…SM7 Control	Flat cable 50-pin connector for the NI (National Instruments) card on the computer that runs the NWS software. The cable has two connectors, labeled "1–50" and "51–100". Connect the 1–50 prong and leave the other one unconnected.

SMD Connector	Description
SM5…SM7	25-pin connector for sending the commands to the sample stage. This connects to the two 9-pin connectors on the sample stage.
SM1…SM4	25-pin connector for sending the commands to Towers I and II. A split cable connects to the 15-pin ports on Towers I and II respectively.

4.6.3 The Stepper Motor Controller Software

The stepper motors that are controlled by the Stepper Motor Driver are run by the Stepper Motor Controller software. The software is pre-installed on the computer(s) connected to the MultiView 4000 system.
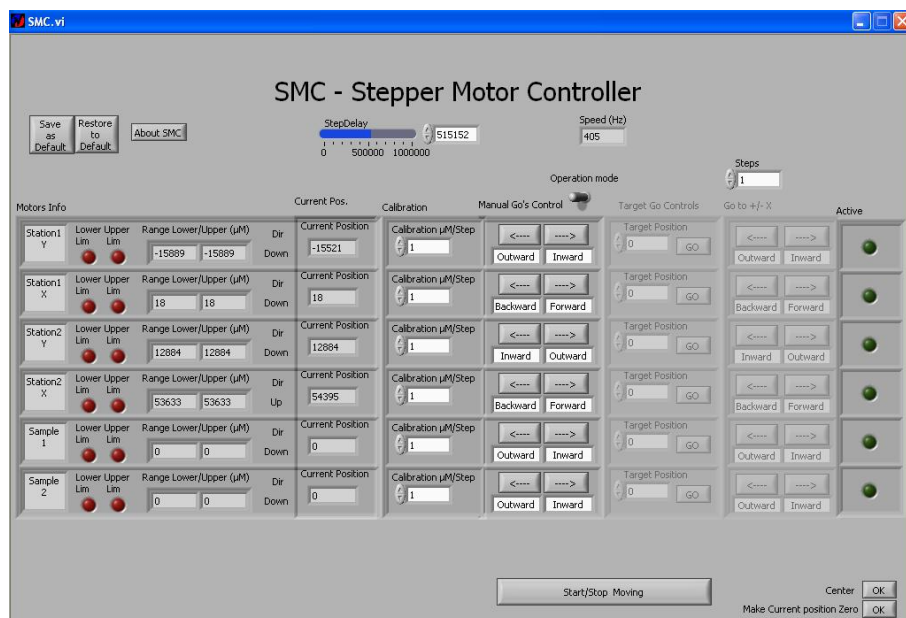

Figure 25: Stepper Motor Controller Software – Graphic User Interface

The **Motors Info** column relates to the different stepper motors. These are described in the table on page 33.

The red LED lights up when a stepper motor has reached its upper or lower limit. The limits (in microns) appear for each motor. The green LEDs light up when a stepper motor is moving. The LEDS lights up both in the software and on the actual SMD.

The **Current Position** of each stepper motor is displayed.

The speed of the stepper motors is controlled via the **Step Delay** control. When the bar is full (blue), the stepper motors are at their slowest and when the bar is clear the stepper motors are at their fastest. The speed is displayed in Hertz in the **Speed** field.

Center: The current position is considered to be the center of the stepper motors' ranges and the values for the upper and lower ranges are updated accordingly.

Make current position zero: The current position is considered to be zero and the values for the upper and lower ranges are updated accordingly.

Calibration: This is used to calibrate the displacement of one step. The standard calibration grid can be used for this.

The SMC has two operation modes: "Manual Go" and "Target Go". Flick the switch underneath the Speed field to choose the mode.

Manual Go: Click the relevant arrow to choose a stepper motor and its direction. The directions are shown in the diagram below. When you click **Start/Stop Moving** the stepper motor moves. Click the button again to stop the movement. You can click a number of arrows to move that number of channels simultaneously. However, it is recommended to move one channel at a time only.

Target Go: Target Go has two options:

- Enter a position in relation to the upper and lower limits in the Target Position field. Click **Go** to move the Tower or Stage to the position.

- Click the relevant arrow to choose a stepper motor and its direction. When you click **Start/Stop Moving** the stepper motor moves the number of steps that is defined in the Steps field. You can click a number of arrows to move that number of channels simultaneously. However, it is recommended to move one channel at a time only.
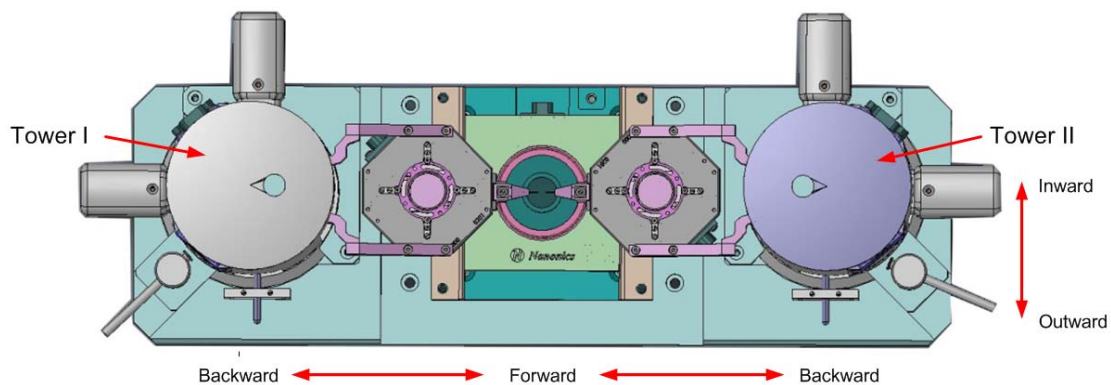

Figure 26: Stepper Motor Directions on Interface Plate

4.7   Counter & Power Supply

While **t**he Avalanche Photo Diode (subsequently: APD) Counter & Power Supply is not part of the Integra Controller System, it is described in this section as it is fully interoperable and compatible with all the components of the Integra Controller System.

The APD Counter & Power Supply is used for NSOM scanning and it has two functions:

- It supplies power for the photon detector (not necessarily an APD).

- It counts the pulses produced by the photon detector and then converts the frequency (TTL signal) into analog voltage output.

Figure 27: APD Counter and Power Supply

WARNING: Ensure that the main voltage selector is set to the local mains voltage.

Table 12: APD Counter/Power Supply - Front Panel Controls and Ports

Port/Control	Description
Time constant	The time constant of the analog channel's smoothing filter.
Overflow warning indicator	Lights up if the frequency range selected is too low for a signal from the APD. Count Rate should be increased, or laser power should be decreased when this indicator is ON
Count Rate	The frequency range (sensitivity) in accordance with the maximum frequency of the APD output.
Measurement	Select the signal to be displayed: **Out:** Monitors the output frequency, which can be up to 16 MHz. "Out" is the usual setting for this knob. See "Display" below for extra information on reading the value that is displayed in the APD Counter & Power Supply. **Protect:** Displays the state of the protection circuit. **Power:** Monitors the APD supply voltage. This should be 5 V, If it is not, press "reset" for a few seconds.
Display	Displays the signal that was selected with the Measurement knob (above). When the Measurement knob is set to "Out", read the value that is displayed as follows: (1) Multiply it by the value that the Count Rate is set to. (2) If X2 is selected (see below), multiply the displayed value by 2. **Example:** Consider the following settings: Count rate "10"; Measurement "Out"; X2. When "5" is displayed, the actual value is 5x10x2=100kHz.

Port/Control	Description
Gate	TTL input to turn the APD Input on and off for lock-in measurements.
	When using the APD Counter & Power Supply in Gating mode, connect the Gate input to a source of 5 V TTL pulses. The APD Counter & Power Supply will count input pulses during these pulses only.
Input	Input for the TTL signal from the APD.
X1/X2/X10	Works together with the Count Rate knob to define the frequency range measured -- 1 kHz/V, 2 kHz/V or 10 kHz/V. X1 is more sensitive.
Signal Out	DC voltage output which is proportional to F multiplied by the range, where F is the input frequency and "range" is the multiplier, corresponding to the selected range.
Frequency Monitor	F/2 output of the TTL pulses received from the APD.
Reset	Turns the APD supply voltage on, if the protection circuit has turned it off.
Power Switch	Turns the voltage for the APD (or PMT) Detector on and off.
	Note: The main power switch for the APD Counter & Power Supply is located on the back panel.
Power Indicator	Lights up when the APD supply voltage is on.
Power Terminals	Connectors for the APD supply voltage to the APD (red connector, the black connector is ground). The cable ending with the dashed lines goes to the red connector.
	Note: The protection circuit protects the APD from overvoltage, but does not protect the APD Counter & Power Supply from shorting.

4.7.1   Specifications

Table 13: APD Counter/Power Supply - Specifications

Parameter	Specification
Output Voltage	5.15 V ± 2%
Maximum output current	1.9 A
Frequency range of counter	10 Hz – 16 MHz
Sensitivity ranges	1000; 100; 10; 1; 0.1 kHz.
Minimum duration of a TTL input pulse	10 ns
Minimum amplitude of a TTL input pulse	2.1 V at 50 Ω input impedance
Outputs	Analog voltage, proportional to the pulse frequency, 5 V full scale. Quasi-symmetric TTL pulses of halved input frequency.
Inaccuracy of frequency/ voltage conversion	Systematic less than 6% of full scale.
Random Error of Digital Output (frequency monitor BNC)	Less than 1% of full scale. It is possible to connect the converter to a computer and to use the Gate terminal for locking input pulses.
Parameters of Gate Input	TTL pulses: Low level – input is locked; high level – transparent. These are the default settings and they can be inverted.
Delay of Gate	5 ns
Power	115/230 V, 50 VA. **Warning:** Ensure that the main voltage selector is set to the local mains voltage.
Dimensions	253 x 98 x 320 mm

5   MultiView 4000 Connectors

This section describes the connectors in the MultiView 4000 system. The Tower Connectors

Figure 28: The MultiView 4000 Tower

Each tower has four connectors:

Z stepper motor connector: (**9 pin**) **Connects to the SPM controller (To Head). It moves the Z stepper motor up and down allowing the tip to approach the sample surface. It also controls the upper and lower limit switches of the stepper motor. These functions are controlled via the NWS software.**

XY stepper motor connector: (**15 pin**) **Controls the X and Y movement of the tower stage. It also has limit switches. It connects to the Stepper Motor Driver and is controlled via the SMC software.**

Preamp connector: (**9 pin**) **Connects to the SPM controller (To Head).**

Upper scanner connector: (**9 pin**) **Provides the high voltage signals for the XY and Z movement of the scanner. It connects either to the High Voltage Adaptor (upper scanner) or directly to the High Voltage Piezo Driver.**

5.1 Sample Stage
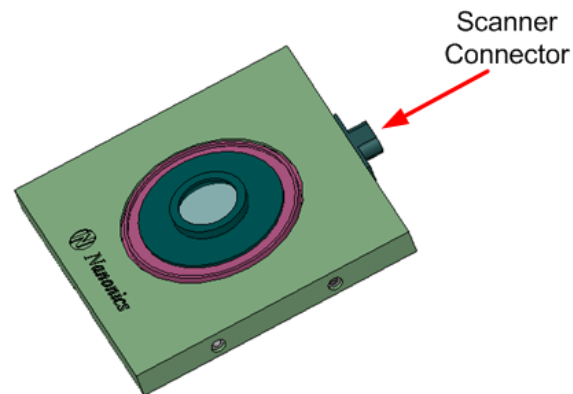
Figure 29: The Sample Stage

The sample stage has a single connector:

Scanner connector: **(9 pin) This connector transmits the high voltage signals to the X, Y and Z axes of the scanner. It connects either to the High Voltage Adaptor ("Output to lower scanner") or directly to the High Voltage Piezo Driver.**

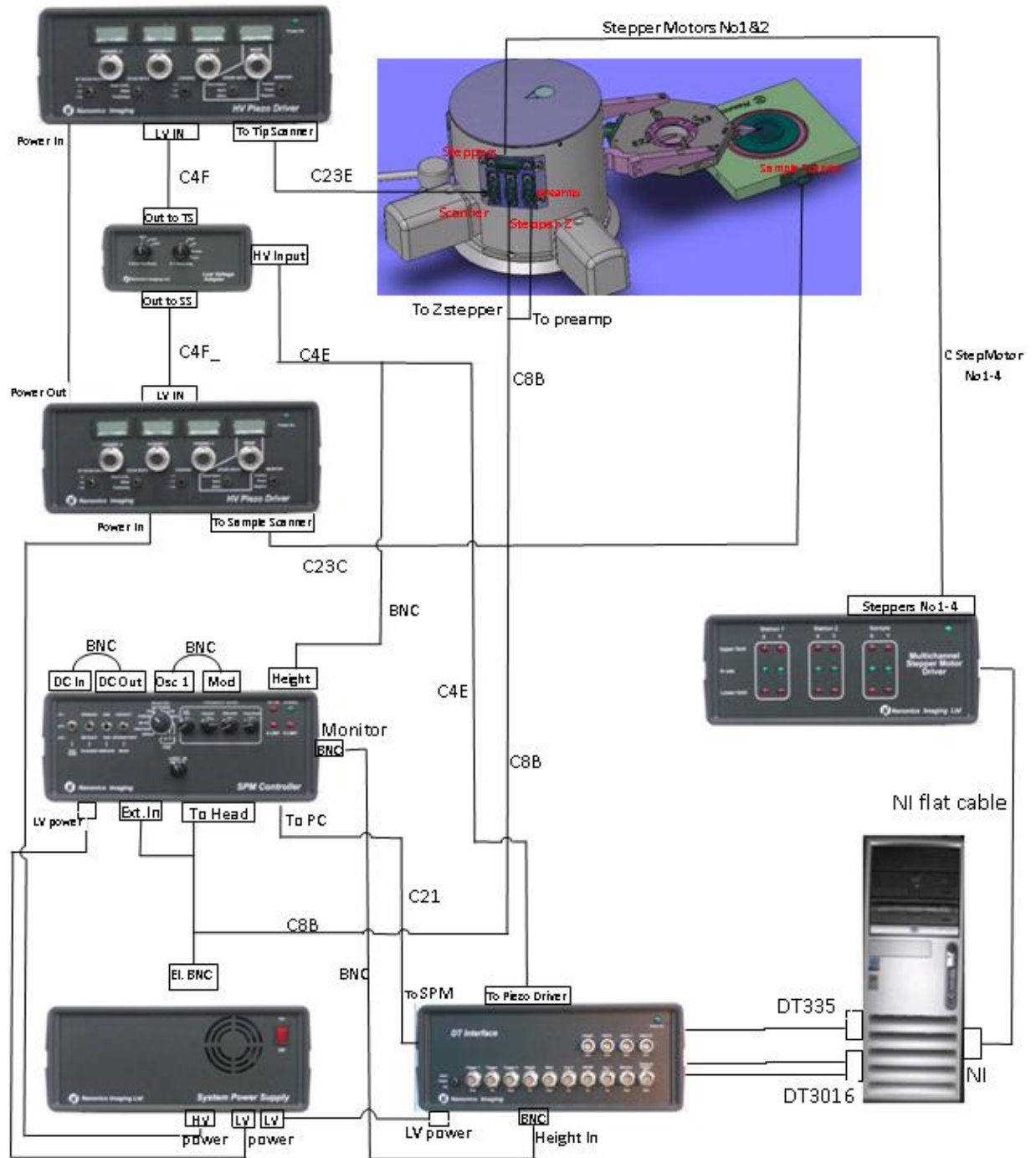## 5.2   Tip/Sample Scanning Tower Schema

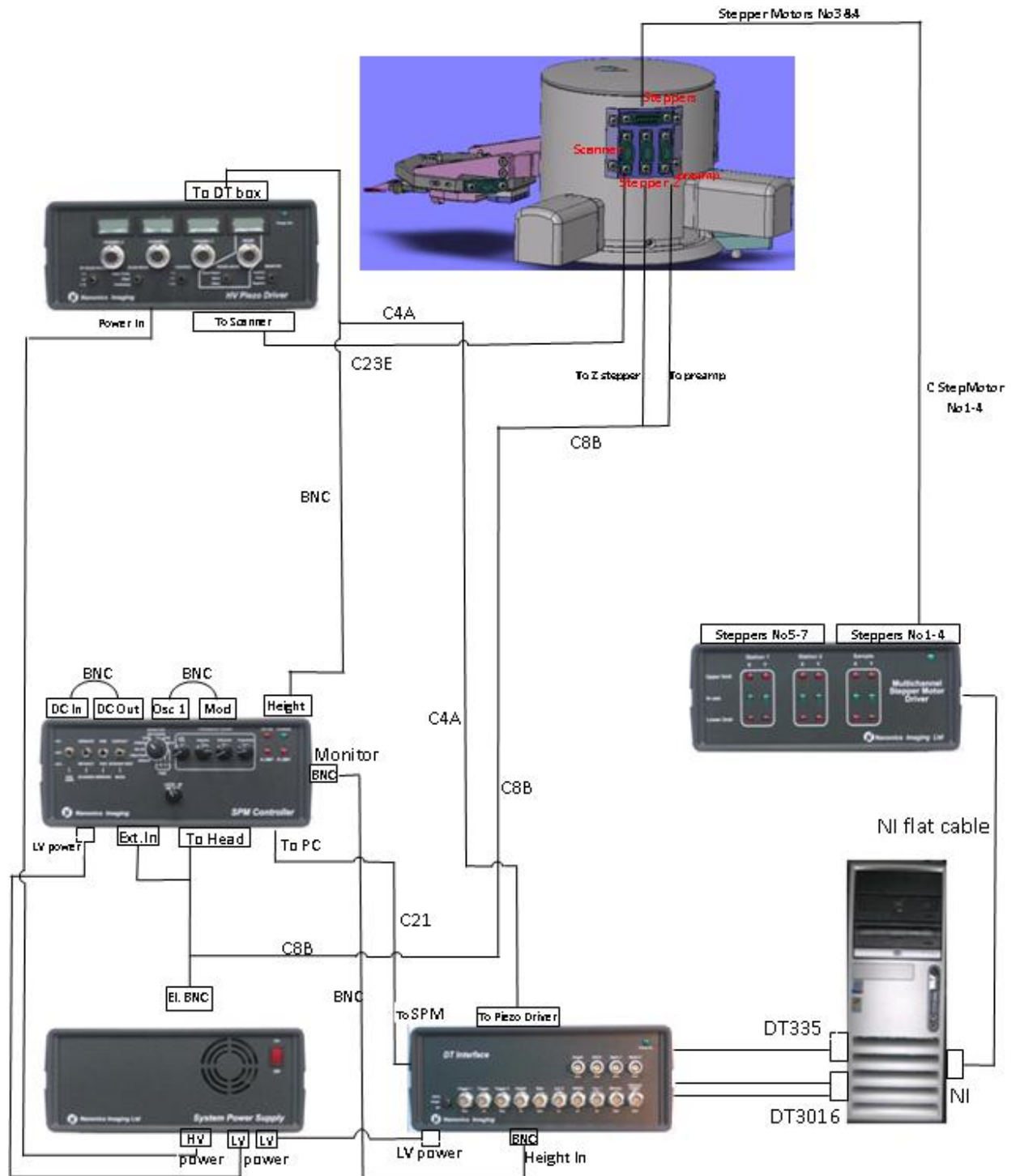*Figure 30(a): Tip/Sample Scanning Tower Schema*

5.3　　　　　　　　Tip Scanning Tower Schema

Figure 31(b): Single Tower Schema with one HV Piezo Driver w/o sample scanner

6   Scanning Modes

6.1   Single Tower

The following scanning modes are possible with the sample scanner and a single tower configuration:

Full sample scanning: **All X, Y and Z movement is carried out through the lower scanner.**

Full tip scanning: **The X, Y and Z axes are all controlled by the upper scanner.**

Sample scanning: **The X and Y axes are all controlled by the lower scanner while the Z axis is controlled by the upper scanner.**

Tip scanning: **The X and Y axes are all controlled by the upper scanner while the Z axis is controlled by the lower scanner.**

6.2   Two Towers

When working with a two tower configuration, the tower designated as Tower I provides the four options listed above, as it has both upper and lower scanners. Tower II provides the tip scanning option only.

When the two probes are working in tandem, there are the following two possibilities:

a) The two tips perform tip scanning via the upper scanners. Two different images will be generated and there is no correlation between the two systems. The tips will be in feedback from slightly different areas of the sample and the scans are managed by two separate instances of the NWS software.

b) Sample scanning and Z feedback are carried out via the two upper scanners. For this mode, the sample scan is carried out by System I which is connected to the lower scanner. Each of the two tips are engaged separately with the sample. The Height channel of System II is split and brought to System I as an AUX signal (AUX 2) through a BNC cable. In this case, the images of the two tips are both viewed in the NWS software on System I.

7   The Dual Microscope

The Nanonics Dual Microscope is a customized microscope based upon two Olympus BX51 microscopes and it is designed to provide optics for both upright and inverted microscopy. This configuration allows the collection of both transmitted and reflected light from the sample.

Nanonics MultiView systems are designed to integrate fully with this dual configuration: the MultiView 4000 head can be placed in between the upright and inverted microscopes with full view of the Z axis from the top and bottom. This allows for multi-mode NSOM operations such as transmission and reflection.

For instructions on working with the Olympus BX51 microscope, see the Olympus documentation.
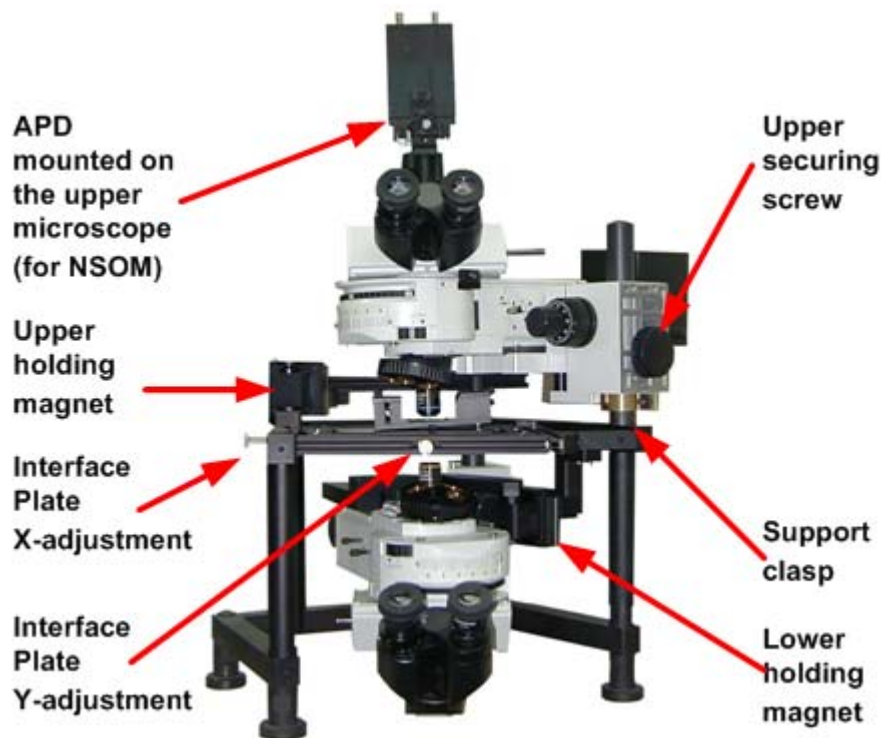
Figure 32 The Dual Microscope

Dimensions: 50 x 50 x 80 cm (not including the vibration isolation platform)

7.1   Opening and Closing the Dual Microscope

>>   *To open the microscope*

1.   Loosen the holding screw of the upper microscope.

2.   Switch off the magnet in order to release the upper turret.

3.   Gently push the upper microscope around the pole in order to gain access to the interface plate.

>>   *To close the microscope*

When closing the microscope, carry out the steps above, in reverse order:

1.   Restore the upper microscope to the correct position.

2.   Switch on the magnet to hold the turret in place.

3.   Tighten the holding screw of the upper microscope.

7.2   Aligning the Two Objectives

When setting up the Dual Microscope, the upper and lower microscopes need to be aligned so that they share the same optical axis.

>> *To align the objectives*

1. Place a sheet of plain white paper on the interface plate, in the sample position.

2. Turn on the illumination spots of the two microscopes.
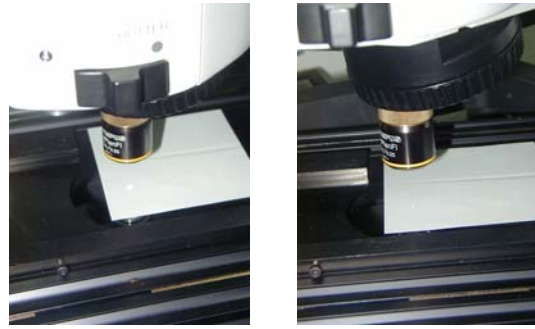
3. For coarse alignment of the two microscopes, release both magnets, both holding screws, and rotate one or both microscopes around their axes until the two illumination spots visually coincide. The objectives used on the two microscopes do not have to be the same.


4. Once the required position of the microscopes has been found, loosen the securing screws of the upper and/or lower holding blocks and pull the holding block to fix the appropriate microscope in the new position.

5. Tighten the screws after adjustment.

MICROSCOPE ROTATIONAL ALIGNMENT

6. For fine adjustment, keep the magnets locked but the large holding screws loosened. Use different objectives for the two microscopes (for example, x50 and x10). Illuminate using the x50 objective and focus the illumination on the same piece of paper, or use a semi-transparent sample with well-defined and very recognizable features.
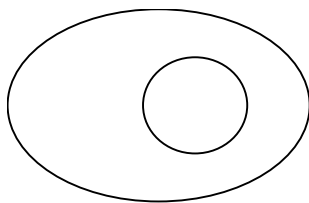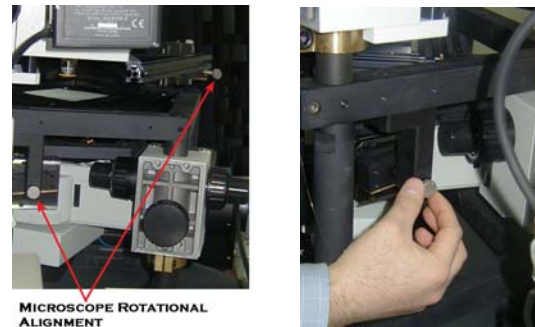
7. Look at the illumination spot from the side of the x10 objective. Illuminate with the x50 objective from below, and look at the illumination spot from above. The image should be similar to the diagram on the left.
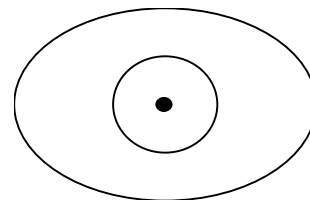
8. For fine adjustment, rotate the screws that each magnet holder is equipped with, until the spot illuminated by the x50 objective is concentric with the field of view of the x10 illumination as shown in the diagram on the right.

9. Tighten the large holding screws of the microscope.

   The objectives are now aligned.

7.3   Focusing the Microscopes

The holding magnets restrict free movement of the microscope optics and allow for fine focusing in the micron range, using the focusing knobs.

To carry out coarse focusing in the centimeter range, turn off the holding magnets in order to release the turret.

7.4   Adjusting the Height of the Upper Microscope

It is sometimes necessary to raise or lower the upper microscope in order to accommodate a large sample or to use a specialized objective.

CAUTION: Exercise great care when adjusting the height of the upper microscope. If you do not follow the instructions below you may cause irreversible damage to the MultiView 4000 head.

The following principles must always be observed:

- Move the upper microscope to the side before adjusting its height.

- Never release both the holding screw and the support clasp simultaneously, as there is nothing to prevent the microscope falling.

- Hold the upper microscope with *both* hands when adjusting its height, as it is heavy.

>>   *To raise the height of the upper microscope*

1. Open the microscope as described on page 45 above.

2. Raise the microscope to the desired height using both hands.

3. Tighten the holding screw.

4. Loosen the support clasp using the M8 metric key.

5. Raise the support clasp to the holding screw and tighten it.

6. Loosen the holding screw and restore the microscope to the correct position.

7. Move the lever to turn on the magnet.

8. Tighten the holding screw.

>>   *To lower the height of the upper microscope*

1. Open the microscope as described on page 45 above.

2. Tighten the holding screw.

3. Loosen the support clasp using the M8 metric key.

4.   Lower the support clasp to the desired position and tighten it.

5.   Loosen the holding screw, and while holding the microscope with both hands lower the screw and microscope to the support clasp.

6.   Restore the microscope to the correct position.

7.   Move the lever to turn on the magnet.

8.   Tighten the holding screw.

8   Preparing the Sample & Tips

8.1   Preparing the Sample

>>   *To prepare the sample*

Select a sample mount. There are several versions of the sample mount supplied with the MV4000 – a flat sample mount, and several with elevated rims of differing height. These mounts allow variable gross Z-positioning depending upon sample thickness and the measurement to be made. Each mount has a slightly recessed groove along the circumference of its middle circular opening (16 mm radius). Into this groove the glass sample holder fits snugly.

The sample may not exceed 70 grams. It must be clean, as must the sample holder. If not clean, these can cause sample tilt and interfere with the inertial transport mechanism (see the NWS Software Manual for an explanation of this mechanism).

A calibrating sample is provided with MV4000. This consists of an array of 5 µm squares, with a pitch of 10 µm. Each square is 120 nm in height.

While gravity is sufficient to insure that the sample mount remains stationary on the scanner, the sample and the holder must be attached using an adhesive for easy of handling. Use a clear lacquer and fine brush applicator. Make sure the adhesive is applied in an uniform and thin layer. An uneven, thick layer of adhesive may cause sample tilt. For experiments which require or cause heating, it is preferable to avoid gluing the sample and mount to avoid thermal drifts in the measurement.

8.2   Placing the Sample

Before mounting the tips, place the sample on the lower scanner.

>>   *To place the sample*

If a tip has already been mounted on the upper scanners, remove it and return it to the case, or release the tower's fixing screw on the interface plate and move the tower away from the sample scanner. This is done to provide a clear working space in the area of the sample scanner and also to ensure that the tip does not touch the sample surface, as contact between the sample and the tip causes damage and renders the tip unusable.

Gently place the sample onto the sample scanner. Use no pressure, as the sample sits above the piezo array and pressure can damage this array.

8.3   Mounting the Tip

A Nanonics AFM probe consists of a specially designed and constructed fiberglass tip, attached to the lower tine of a tuning fork, which itself is attached to a tip mount. These probes are assembled by Nanonics and supplied in a tip mount case, as shown below, Figure 33. The tip parameters are listed on the back of the tip mount box, as depicted in Figure 34 below. Refer to Section Probe Parameters, page 19, for tip structure and geometry.

Figure 33: MultiView 4000 AFM tip mounts in case

Figure 34: Back of AFM tipmount case, showing tip parameters

The tip mount must be installed on the upper scanner. Diagrams of the tip and the upper scanner are shown below:
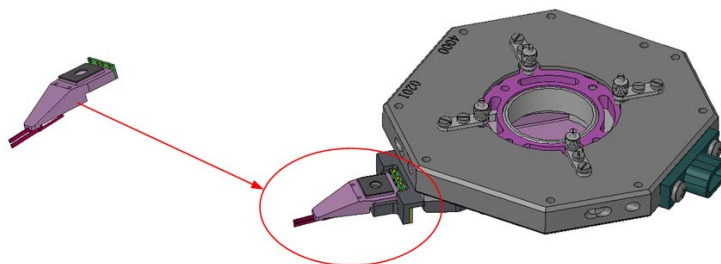

Figure 35: MultiView 4000 tip and upper scanner

Follow the guidelines below when mounting the tips, as they are extremely delicate. Contact between the tip and the sample can damage the tip and render it unusable.

Before installing the tip mount, rotate the tower(s) away from the lower scanner. This is to prevent the tip from coming into contact with the sample or the lower scanner and causing damage.

>> *To place the tip mount on the upper scanner*

Clearing the Working Area around Upper Scanner

1.   Using the Z-stepper motor, raise the upper scanner high enough so as to provide a generous working space and to distance the tip from the sample. To do this,

   (i)   In the NWS software, select **Actions & Settings > SPM Control**.

   (ii)   Click **Retract.**

            The Z-stepper motor will raise the upper scanner.

   (iii)   When sufficient clearance has been achieved, click **Retract** a second time to stop the Z-stepper motor.

2.   Release the tower's fastening screw.

3.   Manually rotate the tower out and clear of the sample stage area of the interface plate.

Handling the Tip Mount

1.   Grasp the desired tip mount between two fingers, being exceedingly careful NOT to touch the tuning fork or the tip. Also, be careful not to squeeze the rear portion of the tip mount, as pressure on the electrode pad could detach the electrode from their internal electrical connectors.

2.   Carefully release the tip mount from its dock in the tip mount box, using an M2 wrench. Do not release until the tip mount is grasped, as releasing it too soon will cause the tip to fall into the box, damaging it.

Installing the Tip Mount on the Electroblock

The electroblock unit on the upper scanner has a recessed dock designed to receive the tip mount. The back of the dock consists of a spring-loaded electrode pad with electrodes which match the positioning of the electrodes on the tip mount.

1. Insert the tip mount gently into its dock onto the upper scanner, so that its electrode pad rests a bit in front of the corresponding spring-loaded pad on the electroblock.

2. Pull it back a bit and, using an M2 hex key (Allen wrench), tighten the screw. This should ensure both a stable mount and adequate contact between the electrodes .

CAUTION!: Be careful not to exert pressure on the electroblock, nor overly tighten the mounting screw,, as the electroblock is suspended from a piezo array that can be damaged by pressure.

Completing the Tip Mount Installation

1.   Ensure that the sample and the tip will not meet as you move the tip mount closer to the sample, in order to avoid damage to the tip. If the sample is relatively high, move tip using the Z-stepper motor up to a safe Z distance, as explained above (.Clearing the Working Area around Upper Scanner).

2.   After installing the tip mount, rotate the tower back to its initial position.

3.   Tighten the fastening screw to fix the tower in position on the interface plate.

4.   Use the XY stepper motors for the fine positioning of the tip relative to the sample.

8.4   Mounting Two Probes

>>   *To mount two probes*

1.   When two probes are being mounted, first use the SMC software (see The Stepper Motor Controller Software, page 34) to retract the stepper motors in the X axis so that each upper scanner is closest to its tower.

2.   Manually remove the two towers from the interface plate. This is to ensure that the two probes do not come into contact while being mounted.

3.   Place the first tip mount as described above.

IMPORTANT: Do **not** return the tower to the interface plate until you have mounted the second probe.

4.   Now mount the second tip as described above.

5.   Before moving the two towers towards the sample stage, ensure that there will be a safe Z distance between the probes and the sample. If necessary, raise the Z stepper motors .

8.5   Aligning Two Probes

Before aligning the two probes, make a rough check of each tip's resonance frequency as described on page 54 (Phase Feedback) or page 68 (Amplitude Feedback). It is sufficient to see that a graph is generated. If a graph is not generated, or it is clearly inaccurate, ensure that the tip mount has been correctly affixed to the upper scanner.

>>   *To align two probes*

1.   Ensure the two towers have been pushed in all the way on the interface plate and that the fixing screws have been tightened.

2.   Move one tip towards the sample using the SMC software to move the tower's XY stepper motor. While doing so, look through the optical microscope to place this tip at one side of the field of view. It is recommended to start the alignment with the 10x objective.

3.   Move the second tip towards the first one using its respective XY stepper motor. Look through the optical microscope to follow the positioning of the two tips.

4.   Reduce the stepper motor speed as the second tip approaches the first tip.

IMPORTANT: Ensure that the two tips do not touch each other. If they do, they may become damaged and unusable.

5.   When the tips are close to each other, use the 50x objective in order to carefully monitor the distance between the tips.

The fine adjustment of the two tips' distance has to be done by supplying offset voltages through the High Voltage Piezo Driver to move the respective upper scanners. See "Scan & Offset" on page 23. Do not use the stepper motors for fine adjustment of the tips' positions.

9   Powering Up the System

It is very important to follow carefully the steps below when powering up the MV 4000 MultiView system. Failure to follow the instructions may well result in inaccurate measurements and even could damage the system.

>>   *To power up the system*

1. Turn on the System Power Supply

CAUTION: Once you have turned on the System Power Supply, do not turn it off again for at least three to five minutes. The same is true AFTER the System Power Supply has been turned off for any reason – do not turn it on again until after three to five minutes have elapsed.

2. Turn on the system computer.

NOTE: Though we have recommended this order for steps 1 and 2, reversing them has no impact on the system's functioning.

3. We strongly recommend waiting for 20 to 30 minutes before beginning any AFM measurements. Although it is possible to work immediately, it is best to give the system time to stabilize to avoid any "noise" in the measurements.

>>   *To open the NWS software*

Select NWS Software from Programs on the Windows Start menu.

The NWS main window will open.
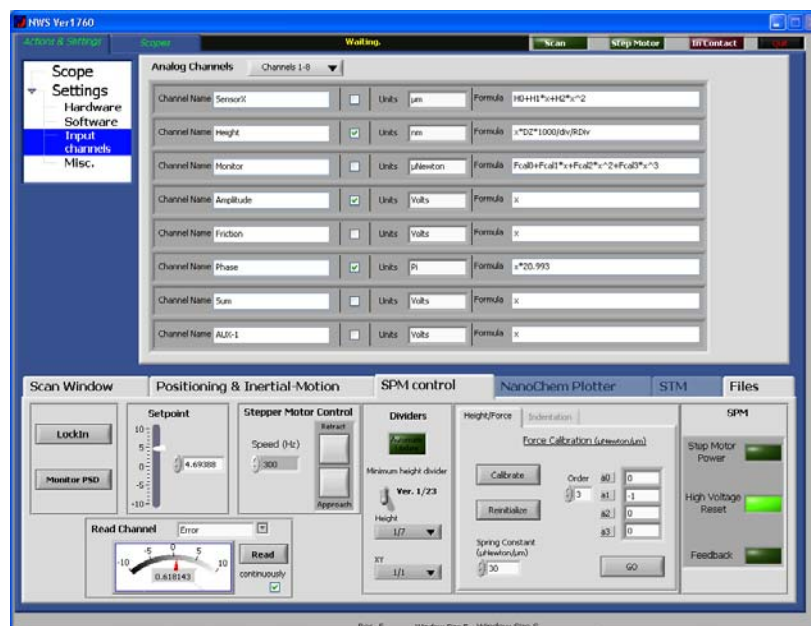
Figure 36: NWS Software Main Window

10   Phase Feedback Settings

This section explains how to configure the Nanoworkshop (NWS) software to carry out an AFM scan using Phase Feedback. Phase Feedback is the default setting in the NWS software. For an overview of the NWS software and its capabilities, see the NWS User' Manual. For details on Amplitude Feedback see page 68 in this manual.

The main configurations stages are as follows:

- SPM Controller Settings, below.

- Opening the Lock-in Controller, below.

- Setting the Total Gain and Oscillation Amplitude, p. 57.

- Generating the Resonance Frequency Graph, p. 59.

- Generating the Phase graph, p. 62.

- Locating the Setpoint, p. 65.

10.1   Hardware Settings

10.1.1   SPM Controller Settings

Adjust the SPM Controller settings, (four switches and a dial on the upper-left of the front panel of the SPM Controller unit), as follows:

PSD Gain: x2.5   **Scanning:** Operate   **Mirrors:** One   **Mode:** Intermittent

Monitor: Force

10.2   Software Settings – The Lock-in Controller

The Lock-in hardware resides inside the SPM Controller unit. This digital hardware is controlled through the NWS software. Through the software's Lock-in Controller, you select the resonance curve which determines the frequency, amplitude and phase of the tuning fork. The Lock-in is used to obtain the Error signal with reference to the Excitation Reference Signal. In obtaining the resonance frequency, both oscillation amplitude and Total Gain should be adjusted, to set the tuning fork amplitude and phase.

10.2.1   Opening the Lock-in Controller

>>   *To open the Lock-in Controller*

1.   In the NWS software, in the top left of the screen, select the **Actions & Settings** tab.

2.   In the lower part of the screen, click the **SPM Control** tab.
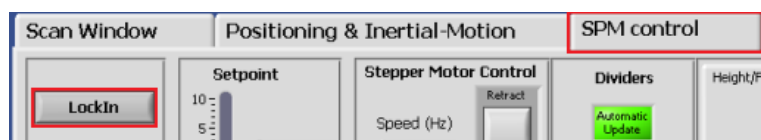
3.   Click **LockIn**, on the left, to open the Lock-in Controller.

The LockIn Controller window opens in the top half of the screen.
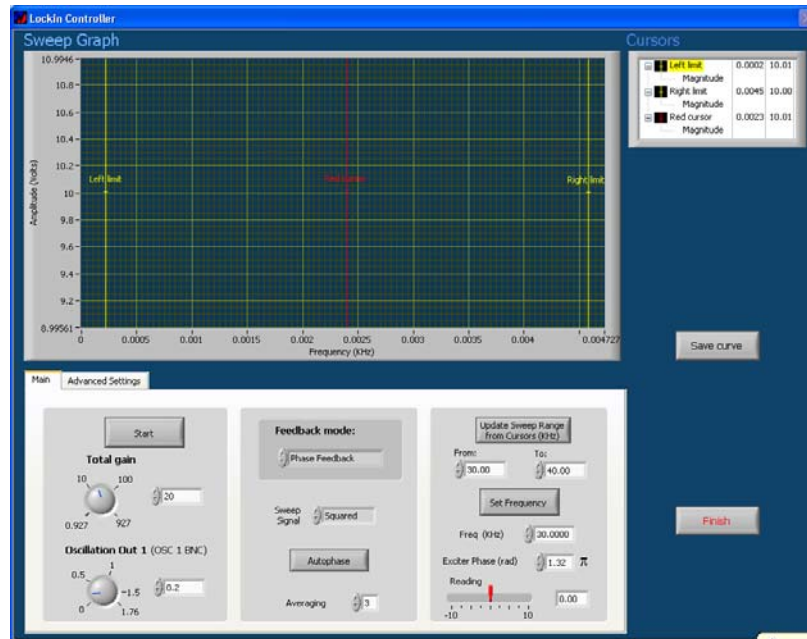
Figure 37: The Lock-in Controller

10.2.2   Setting the Total Gain and Oscillation Amplitude

>>   *To set the Total Gain*

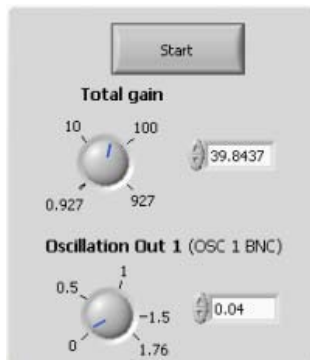1.   On the left panel of the Main tab, set the Total Gain to 20.

Figure 38: Left Panel of Main Tab of Lock-In

NOTE: The above values for Total Gain are initial default values and can be changed
        according to probe and sample characteristics.

10.2.3   Setting Feedback Mode

Overview: There are two Feedback modes available on a Nanonics SPM – Phase Feedback
and Amplitude Feedback. In Phase Feedback, the Error signal is "recorded" according to the
changes of the tuning fork phase. Phase feedback has been found to be much more sensitive

than the amplitude feedback. In this mode of operation there is less energy dissipation between the probe and the sample. The amplitude of the probe essentially remains constant. Therefore Phase Feedback mode is recommended for use with AFM probes and for soft materials.

>>   *To set Feedback Mode*

1.   In **Feedback Mode**, select **Phase Feedback**.
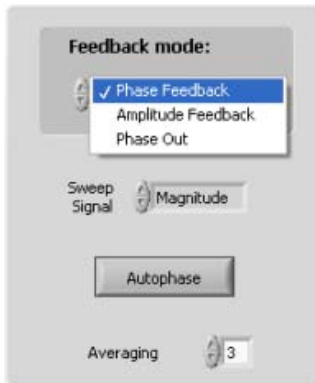
2.   In **Sweep Signal**, select **Magnitude**.
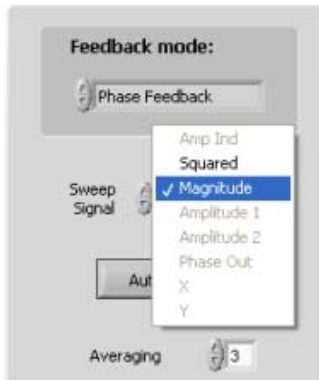
3.   Set **Averaging** to 1. (Averaging sets the displayed curve averaging for each point on the swept signal. The available range is 1 – 5).

10.2.4   Setting Sweep Frequency

>>   *To set the Sweep Frequency*
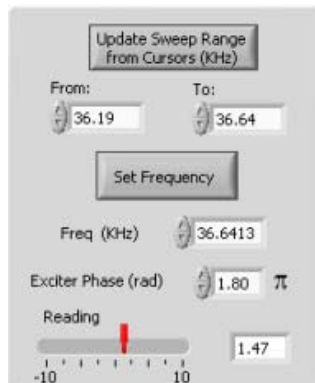
Set the minimum (From:) and ,maximum (To:) values for the frequency range to be swept. The range should be chosen according to the resonance frequency of the probe being used. Use the value for a given probe written on its box. Set From to 1 kHz below that value, and To: to 1 kHz above that value. For example, if the listed value for a probe's resonance frequency (f.) is 32 kHz, then From: should be set to 31 kHz and To: should be set to 33 kHz. Alternatively, you can use the default large sweep range: from 20kHz to 50kHz.

10.2.5   Generating the Resonance Frequency Graph

In generating a resonance frequency graph, the goal is obtain a curve with a peak value of 8 V. If the curve is higher, the peak will be cut off (as the saturation point has been exceeded for a portion of the sweep range). The necessary adjustments needed for successful curve regeneration are explained below.

>>   *To generate the Resonance Frequency Graph*
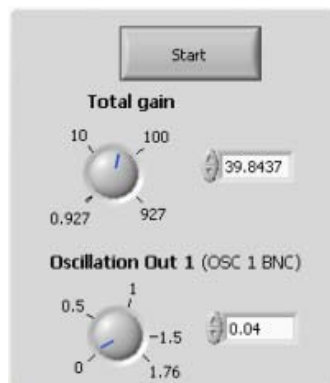
1. Click on **Start**. The Magnitude signal is scanned on the selected frequency range. While the signal is being scanned, the values of **Freq**. and **Reading** in the right panel will change.

> *The result of the scan, a graph of amplitude vs. frequency is displayed in the Sweep Graph window (Figure 39).*
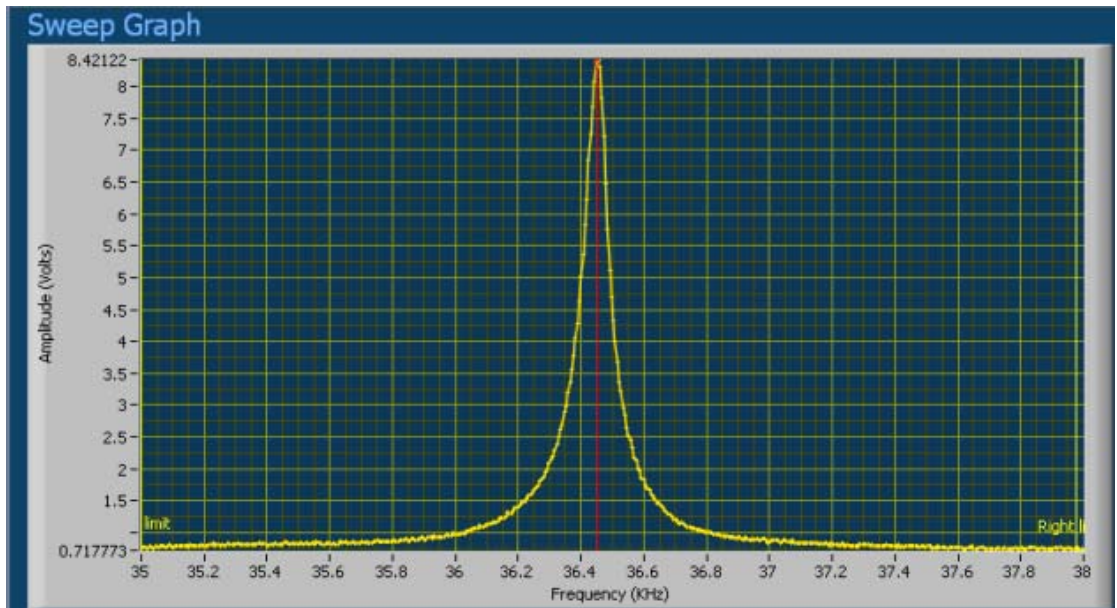
Figure 39 Sweep Graph Window

2.   Move the yellow cursors on the left and right side of the displayed curve to zoom in on the curve's peak. Alternatively, insert frequency values in **From** and **To** on the right panel.

3.   Click **Update Sweep Range** from **Cursor** (right panel).

4.   Click **Start** (left panel) to re-sweep the frequency over the new range.

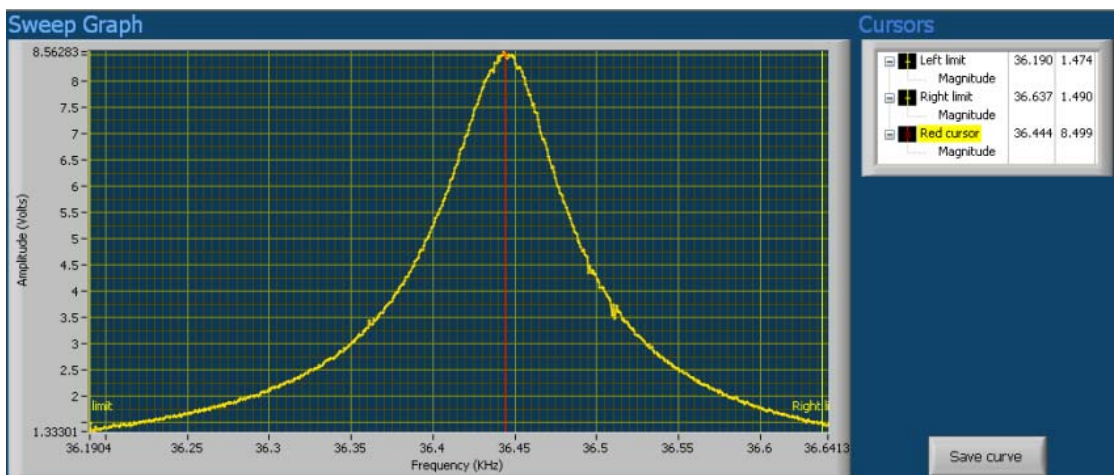   *A new curve will be displayed in the Sweep Graph section of the Lock-in Controller (Figure 40).*

Figure 40 Sweep Graph after reducing the frequency range

5.   Ensure that the curve peak value is 8 V. (The amplitude range (Y-axis) displayed will not exceed 10 V).

   - If the curve peak exceeds 8 V, reduce the 'Oscillation Out 1' value and repeat steps 1 and steps 2 – 4 as needed.

- If the curve peak is less than 8 V., increase the 'Oscillation Out 1' value and repeat steps 1 and 2 – 4 as needed.

NOTE: In some cases, the resonance curve is asymmetrical or has a very low amplitude. The is often caused by improper tip mounting, resulting in poor electrode contact. Removal and remounting of the tip can usually eliminate these problems.

---

6.   Confirm Red Cursor positioning on the maximum of the resonance peak.

NOTE: The red cursor is automatically set to the maximum of the resonance curve. It is possible, however, to shift the cursor with the mouse, if needed. However, the frequency value of the red cursor is not fed into the lock-in automatically; hence pressing 'Set Frequency' has to be carried out.

---

7.   On the right panel, click on **Set Frequency**, to confirm the tuning fork excitation frequency.

The tuning fork is now oscillating at the desired resonance frequency.

NOTE: The **frequency (kHz)** field (red rectangle in figure below) will indicate the frequency at the red cursor position. The **reading** field (red circle in graph below) will indicate the Y-axis value (amplitude) where the red cursor intersects the graph.
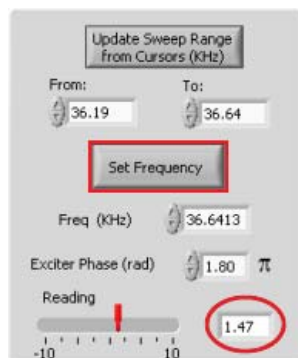
10.2.6   Autophase

Autophase is done to synchronize the phase of the excitation signal with that of the signal detected from tuning fork. . In phase feedback mode this step has to be carried out after pressing 'set frequency'. Only in amplitude feedback mode this step is optional.

>>   *To activate Autophase*

- On the center panel of the Main tab of the LockIn Controller, click **Autophase**.

Three phase equalizing attempts will automatically be performed; at the end of this process, the following graph will be displayed.
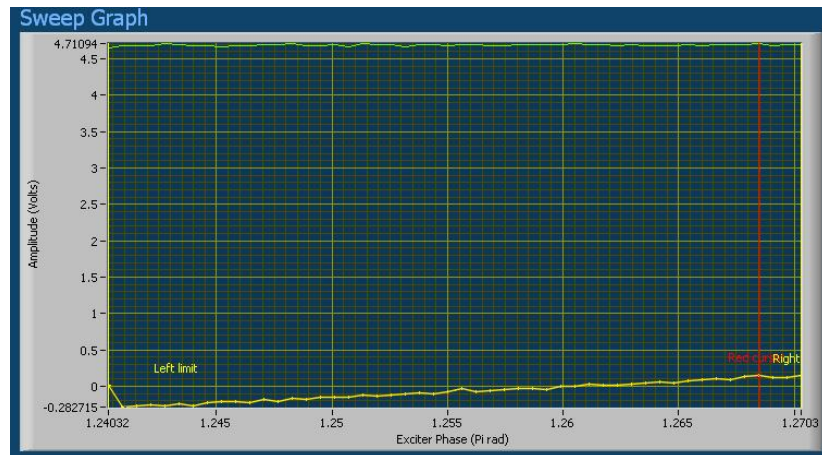
Figure 41 Graph Display upon completion of Autophasing

10.2.7   Generating the Phase Graph

>>   *To generate the Phase Graph*

1.   On the center panel, click **Sweep Signal** and select **Squared** in the pop-up menu (Figure 42). "Squared" is a mathematical formula which determines the phase signal.
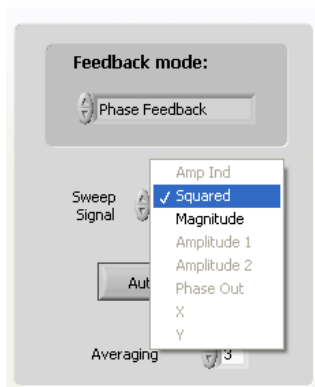

Figure 42 Changing Sweep Signal to "Squared"

2.   In the lower right section of the Lock-in click **Start** .

A Phase vs. Frequency curve is generated. It should be similar to the graph in Figure 43 below, when Autophase is functioning correctly.
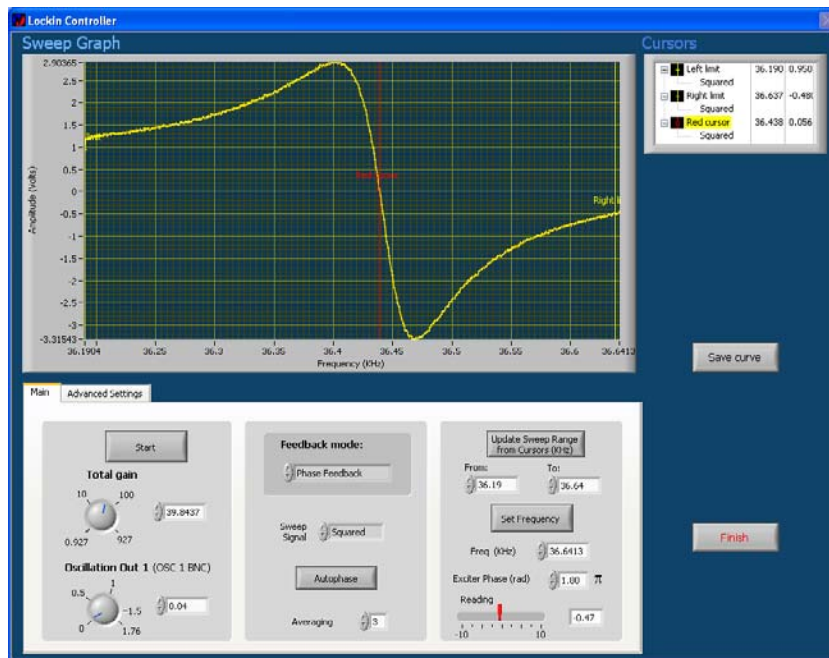
Figure 43: Obtaining the Phase Curve

3.   Move the red vertical cursor along the X axis (the frequency axis) so that it intersects the graph at the vertical center of the curve (see Figure 43 above.).

NOTE: If the red vertical cursor is not visible, move the yellow left cursor to find the red cursor behind.

---

4.   Click **Set Frequency**. on the lower right panel, to confirm this frequency.

5.   Click **Finish**, on the lower right, to exit the LockIn controller.

NOTE: In some cases the new frequency may be lower than the original maximum but this does not affect the scan.

10.2.7.1   Adjusting a Non-zero Amplitude

The amplitude of the squared signal should be zero at the center of the curve, as in Figure 43 above. Should you find that the zero is not at the center, carry out the following adjustment:

a. Obtain a resonance using a large sweep range of 20-50 kHz.

b. You will see a flat curve and the resonance peak. Place the red curser out of the resonance peak, on the flat curve.

c. Press 'Set Frequency'.

d. Press 'Finish'.

e. In the **SPM Controller** tab, set the set-point value to zero.

f. Read the error in the **Read Channel** window in **Continuous** mode.

g. Use the **Lock-in Offset** knob on the front panel of the SPM Controller to bring the error value to zero.

NOTE: This adjustment should only be carried out once

10.2.8   Advanced settings tab

1.   The signal from the tuning fork is sent to a preamplifier and then to the Ext-In Input of the Lock-in board. Hence, in Advanced Settings tab, always use the Ext-In option for the MV4000.
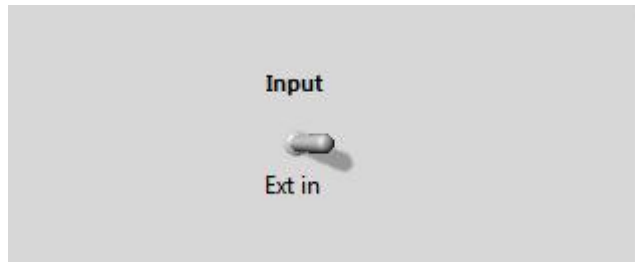
2   The Time constant of the :Lock-in should be set to 1.1ms as a default value.
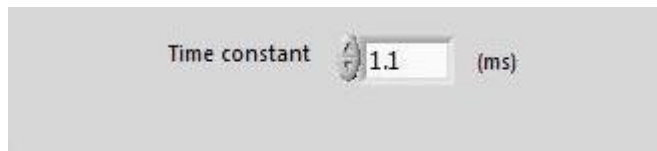
NOTE: The other settings in this tab are for optional use and described below:

10.2.9   Saving the Lock-in Settings

When you exit the Lock-in Controller, the settings are automatically saved. However, it is useful, upon completing all the steps above, to save the settings manually, as explained below. This makes it easy to switch between and compare different tips. It also makes restoring setting simple if the computer crashes.

>>   *To save the Lock-in settings in XML format*

1. On the Advanced Settings tab of the Lock-in Controller, click **Save Settings**.

        A dialogue box will appear.

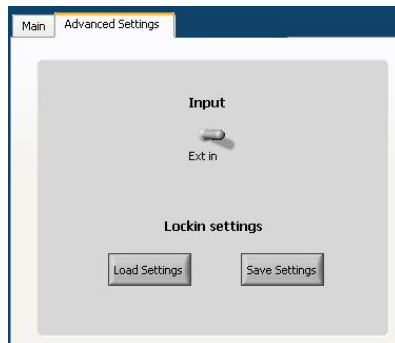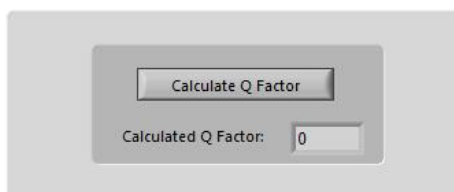2. Choose the path to the folder in which to save the file and click on **Save**.

*Figure 44: Saving Lock-in settings*

10.2.10   Q factor

Use the 'Calculate Q factor' option for checking the Q factor of the probe that is mounted. Q factor calculation is performed through the Phase graph. Use the same procedure as in 10.2.7 to generate the phase graph. Press this button and the calculated Q factor will appear in the display window above.

Set the red cursor to the zero value of the Y axis and click Set Frequency to proceed with lock-in adjustments.

10.2.10.1   Phase Calibration
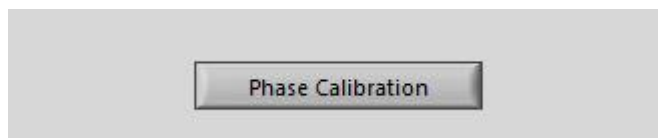
Press this button for obtaining a calibrated phase image. The calibration will be fed automatically into the formula of the Phase channel in Input Channels.

10.2.11   Locating the Setpoint

The setpoint is a parameter that must be adjusted before bringing the tip near a surface. In some cases, it may need to be adjusted during a scan as well. The setpoint is correlated to the strength of the force applied to the surface by the tip. It determines the amount of change in the error signal which will be allowed. When the red cursor is adjusted to zero-phase, the error will be 0.0 V. Before approaching a sample with the tip, the setpoint should be adjusted so that the maximum Error is 0.2 V. The Error value is displayed on **Read Channel** on the **SPM Control** tab when **Error** is selected (see Figure 45 below).

NOTE: While 0.2 V is the Error value to be used in normal circumstances, a smaller Error value before approach may be required when working with soft samples, such as

polymers and biological samples, or with special tips such as those incorporating nanoparticles or nanowires.

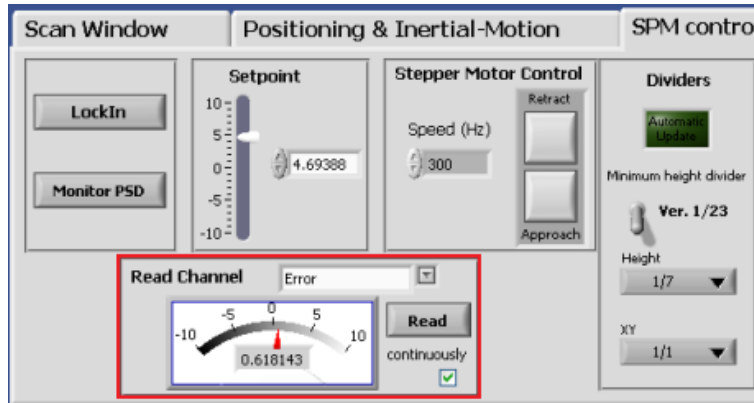**CAUTION**: Error must always be a positive value before tip-approach!

Figure 45: Adjusting the Setpoint in the NWS Software

>> ### To locate the Setpoint

1. Click the **SPM Control** tab.

2. Enter "0" in the **Setpoint** field.

3. From the **Read Channel** drop down list, select "Error".

4. Click **Read**.

5. Adjust the setpoint until the Error signal is 0.2 V.

>> ### For Continuous Reading of Error Signal

1. Check the "continuously" box, under the R**ead** button.

2. Click **O.K.**

  A new window will appear with the Error reading
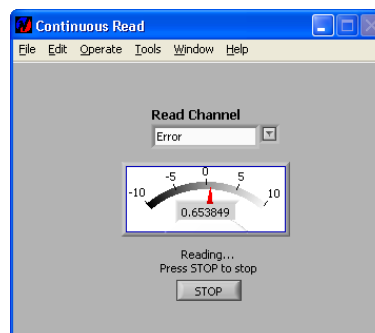
Figure 46: Continuous Reading Display

NOTE: Make sure to close this window by pressing the **STOP** button before moving to the next action.

Best Practices:

- During a scan, take note of the range of the phase signal, which is usually several volts. This range will allow you to define a high setpoint and apply a greater force between the tip and the sample.

- Even though you will now be working with Phase Feedback, the amplitude signal can still be monitored and in some cases it can provide you with extra data on the scan. To view the scan image based on the Amplitude Feedback data, select the Amplitude channel in the Scope Monitor.

11   Amplitude Feedback Settings

This section explains how to configure the Nanoworkshop (NWS) software to carry out an AFM scan using Amplitude Feedback. Amplitude Feedback uses tuning fork amplitude changes to generate the Error signal for feedback. The default setting in the NWS software should be set to Phase Feedback. For details on Phase Feedback see page 56 in this manual.

The main configurations stages, almost the same as those used for Phase Feedback, are as follows:

- SPM Controller Settings, below.

- Opening the Lock-in Controller, below.

- Setting the Total Gain and Oscillation Amplitude, p. 57.

- Generating the Resonance Frequency Graph, p. 59.

- Locating the Setpoint, p. 65.

11.1   Hardware Settings
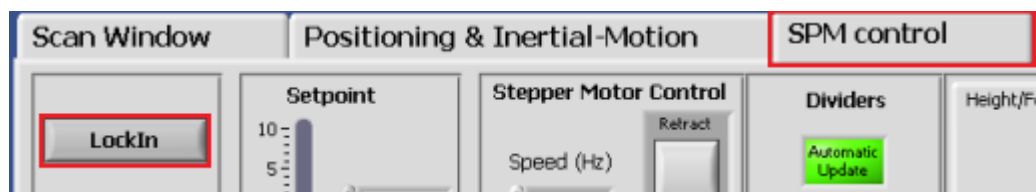
11.1.1   SPM Controller Settings

The hardware settings are exactly the same as for Phase Feedback, described in Chapter 10.

11.2   Software Settings – The Lock-in Controller

The software settings are almost the same as for Phase Feedback. For explanations accompanying each section below, please refer to the corresponding sections in Chapter 10. .

11.2.1   Opening the Lock-in Controller

>>   *To open the Lock–in Controller*

1 .In the NWS software, in the top left of the screen, choose the **Actions & Settings** tab.

2. In the lower part of the screen, click the **SPM Control** tab.

3. Click **LockIn**, on the left, to open the Lock-in Controller.
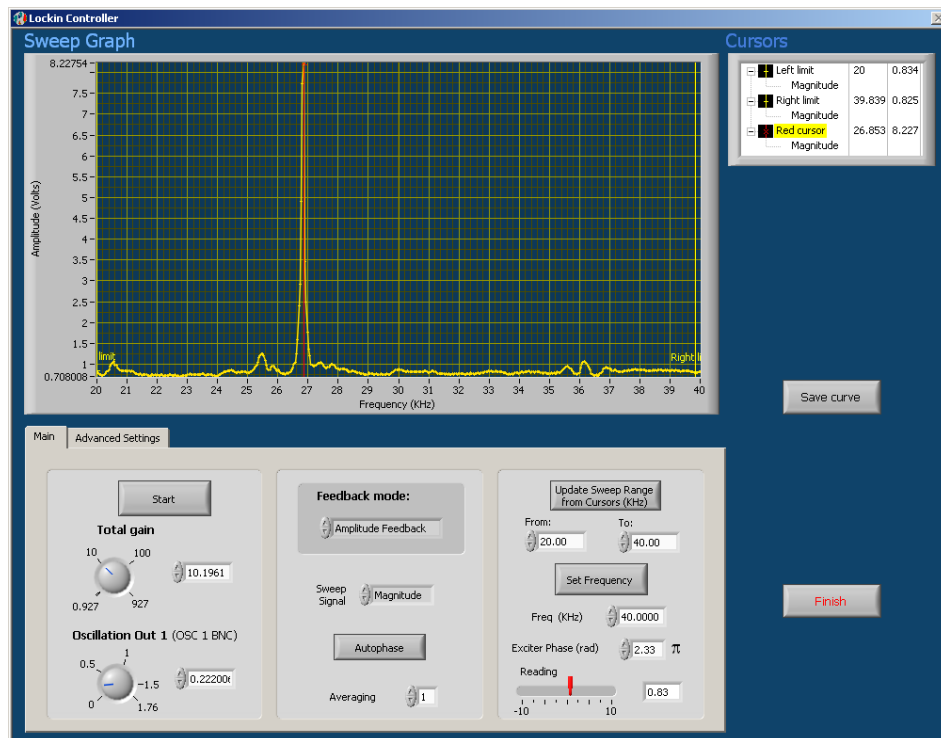
The LockIn Controller window opens.

Figure 47: The Lock-in Controller

11.2.2   Setting the Total Gain and Oscillation Amplitude

Please refer to 10.2.2 for an overview of this section

>>   *To set the Total Gain and Oscillation Amplitude*

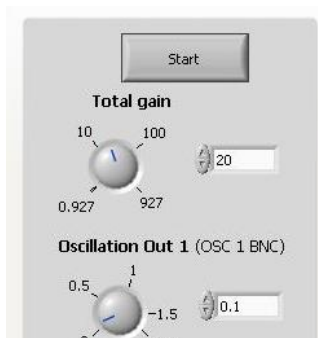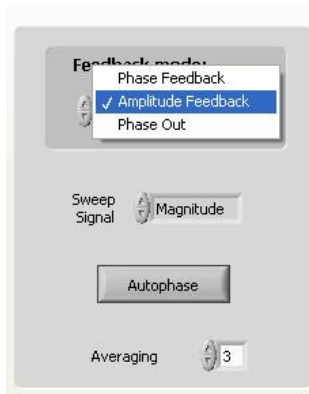On the left panel of the **Main** tab, set the **Total Gain** to 20. .
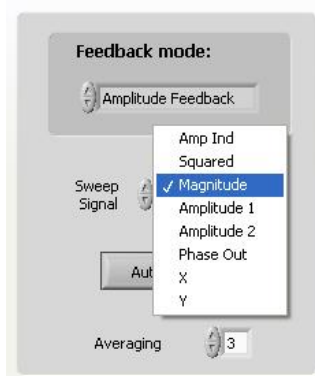

Figure 48: Left Panel of Main Tab of Lock-In

11.2.3   Setting Feedback Mode

>> To set Feedback Mode

1. On the center panel of the Main tab. in **Feedback Mode**, select **Amplitude Feedback.**
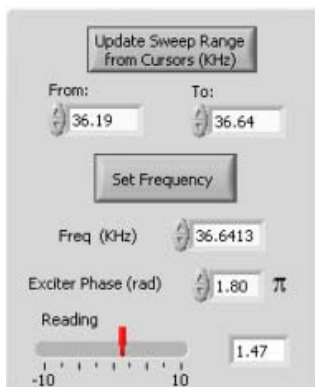
2. In **Sweep Signal**, select **Magnitude**.

3. In **Averaging**, set value to 1. (Averaging sets the displayed curve averaging for each point on the swept signal. The available range is 1 – 5).

11.2.4   Setting Sweep Frequency

>>   *To set the Sweep Frequency*

1.   On the right pane of the Main tab,, set the minimum (From:) and maximum (To:) values for the frequency range to be swept.


NOTE: The range should be chosen according to the resonance frequency of the probe being used. Use the value for a given probe written on its box. Set **From** to 1 kHz below that

value, and **To**: to 1 kHz above that value. For example, if the listed value for a probe's resonance frequency (f.) is 32 kHz, then From: should be set to 31 kHz and To: should be set to 33 kHz.

11.2.5 Generating the Resonance Frequency Graph

In generating a resonance frequency graph, the goal is to obtain a curve with a peak value of 8 V. If the peak value of the curve is higher , e.g. 10 V, the peak will be cut off (as the saturation point has been exceeded for a portion of the sweep range). The necessary adjustments needed for successful curve regeneration are explained below.

>> *To generate the Resonance Frequency Graph*
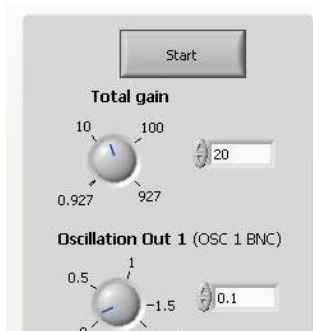
1.   On the left panel of the Main tab, click on Start.

   *The Magnitude signal is scanned on the selected frequency range. The result of the scan, a graph of amplitude vs. frequency is displayed in the Sweep Graph window (**Error! Reference source not found.**).*

NOTE: While the signal is being scanned, the values of **Freq.** and **Reading** in the right panel will change.
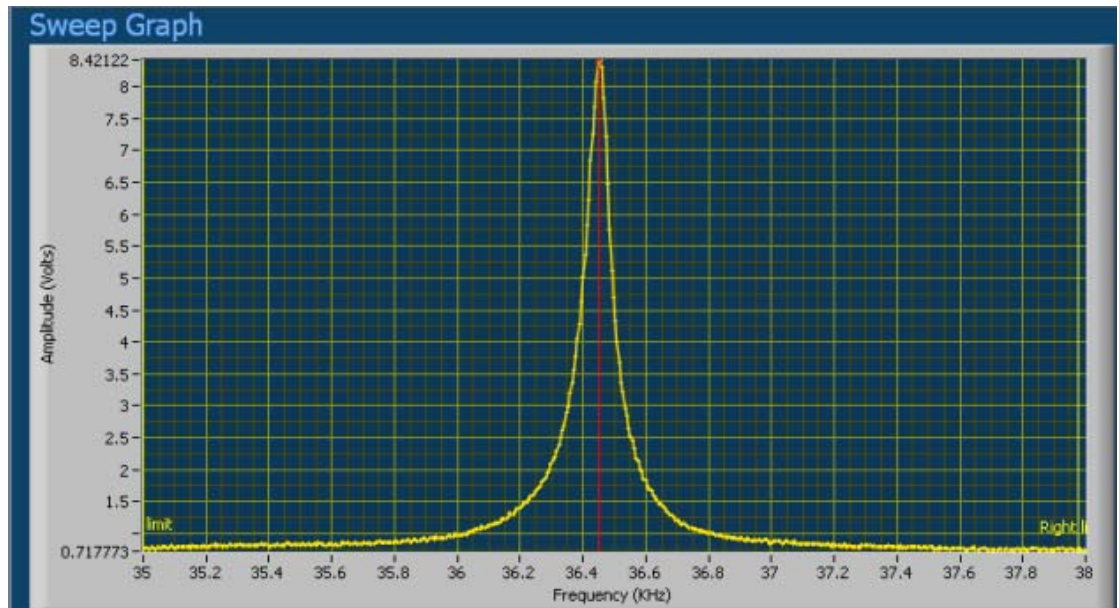
Figure 49: Sweep Graph Window

2.   Move the yellow cursors on the left and right side of the displayed curve to zoom in on the curve's peak. Alternatively, insert frequency values in **From** and **To** on the right panel.

3.   Click **Update Sweep Range** from Cursor (right panel).

4.   Click **Start** (left panel) to re-sweep the frequency over the new range.

   *A new curve will be displayed in the Sweep Graph section of the Lock-in Controller (**Error! Reference source not found.**).*
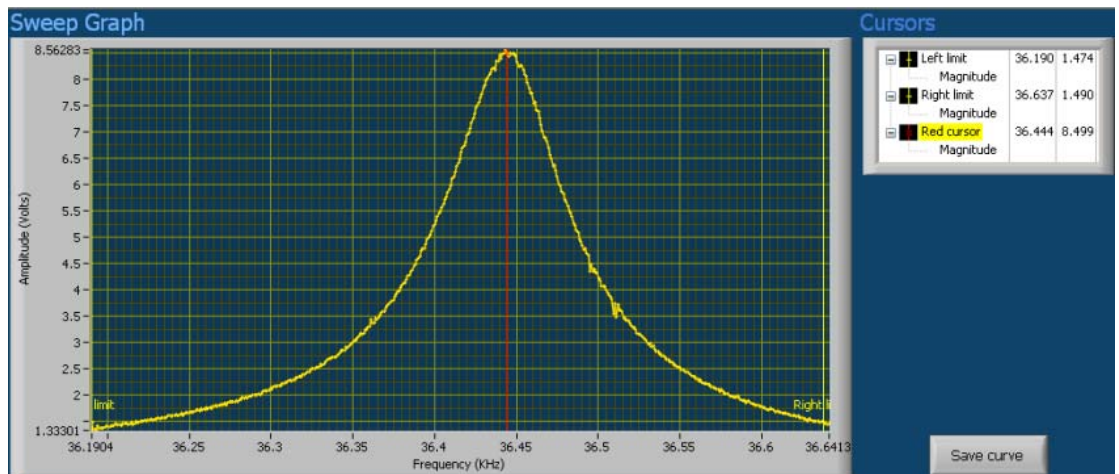

Figure 50: Sweep Graph after reducing the frequency range

5. Ensure that the curve peak value is 8 V. (The amplitude range (Y-axis) displayed will not exceed 10 V).

- If the curve peak exceeds 8 V. reduce the 'Oscillation Out 1' value and repeat steps 1 and steps 2 – 4 as needed.

- If the curve peak is less than 8 V, increase the 'Oscillation Out 1' value and repeat steps 1 and 2 – 4 as needed..

NOTE: In some cases, the resonance curve is asymmetrical or has very low amplitude. This is often caused by improper tip mounting, resulting in poor electrode contact. Removal and remounting of the tip can usually eliminate these problems.

6. Confirm Red Cursor positioning on the maximum of the resonance curve.

NOTE: The red cursor is automatically set to the maximum of the resonance curve. It is possible, however, to shift the cursor with the mouse, if needed. However, the frequency value of the red cursor is not fed into the lock-in automatically, hence pressing 'Set Frequency' has to be carried out..

7. On the right panel, click **Set Frequency**, to confirm the tuning fork excitation frequency.

The tuning fork is now oscillating at the desired resonance frequency.

NOTE: The **frequency (kHz)** field (red rectangle in figure below) will indicate the frequency at the red cursor position. The **reading** field (red circle in figure below) will indicate the Y-axis value (amplitude) where the red cursor intersects the graph.
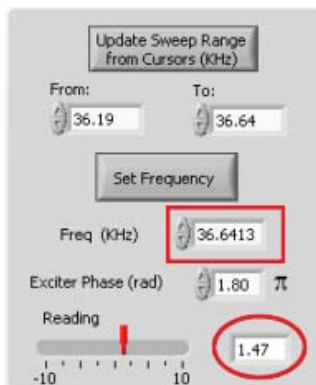
11.2.6   Autophase

Autophase is done to synchronize the phase of the excitation signal with that of the signal detected from tuning fork. This step is not necessary for Amplitude Feedback operation but it is useful for improving Phase Imaging quality when needed. (Phase image is selected through the imaging channels on the NWS software)

>>   *To activate Autophase*

1.   On the center panel of the Main tab of the LockIn Controller, click **Autophase**.

Three phase equalizing attempts will automatically be performed; at the end of this process, the following graph will be displayed.
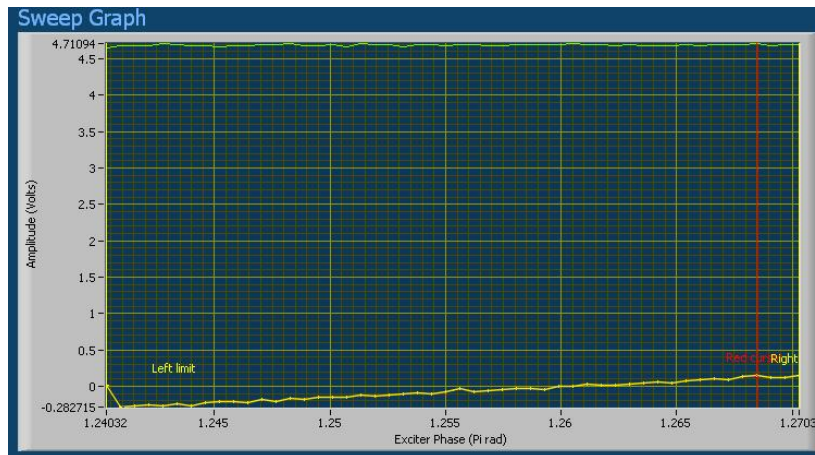
Figure 51: Graph Display upon completion of Autophasing

2.   Click **Finish**, on the lower right, to exit the LockIn controller.

11.2.7   Advanced Settings tab.

Please refer to section 10.2.8 in the Phase Feedback chapter. The advanced settings for Amplitude Feedback are the same as for Phase Feedback. It is possible to calculate the Q factor and calibrate the phase, However to do that, first carry out the Phase Feedback settings and only then set the needed settings for Amplitude Feedback.

11.2.8   Locating the Setpoint

The setpoint is a parameter that must be adjusted before bringing the tip near a surface. In some cases, it may need to be re-adjusted during a scan as well. The setpoint is correlated to the strength of the force applied to the surface by the tip. It is determined by fixing the amount of change in the error signal which will be allowed. When the red cursor is adjusted to Maximum amplitude (8.0v), the error will be 8.0 V at 0.0 setpoint. Before approaching a sample with the tip, the setpoint should be adjusted so that the maximum Error is 10-20% of the maximum amplitude (i.e ~ 0.8-1.6 V. The Error value is displayed on **Read Channel** on the **SPM Control** tab when **Error** is selected (see Figure 52 below).

NOTE: While 10-20% is the Error value to be used in normal circumstances, a smaller Error value may be required when working with soft samples, such as polymers and biological samples, or with special tips such as those incorporating nanoparticles or nanowires.

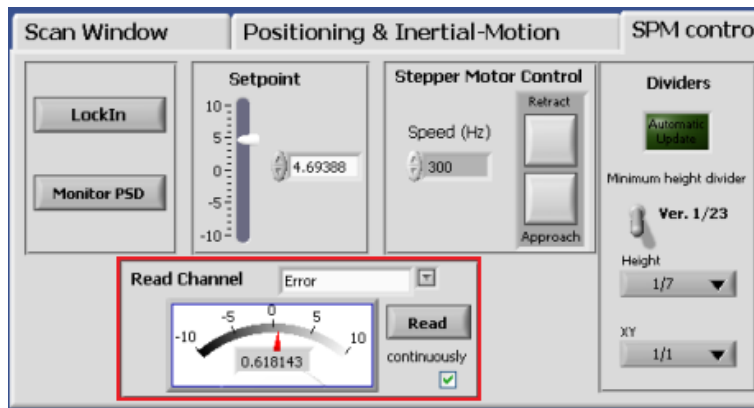**CAUTION**: Error must always be a positive value before tip-approach!

Figure 52: Adjusting the Setpoint in the NWS Software

>>   To locate the Setpoint

1. Click the **SPM Control** tab.

2. Enter "0" in the Setpoint field.

3. From the **Read Channel** drop down list, select "Error".

4. Click **Read**.

5. Adjust the setpoint until the Error signal is ~0.8 - 1.6 V.

>>   For Continuous Reading of Error signal

1. Check the "continuously" box, under the **Read** button.

2. Click **O.K.**
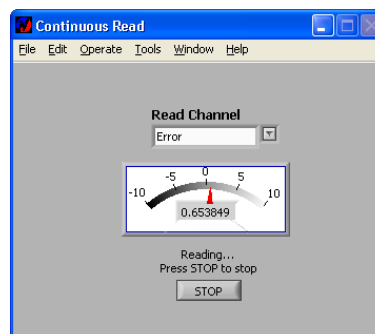
A new window will appear with the Error reading

Figure 53: Continuous Reading Display

NOTE: Make sure to close this window by pressing the **STOP** button before moving to the
   next action.

12   Carrying Out an AFM Scan

When you have configured the MultiView 4000 system and NWS software for Phase (p. 54) or Amplitude Feedback (p. 68) scanning, you are ready to carry out the actual AFM scan, as described below.

The stages for carrying out an AFM scan are as follows:

- Setting the Dividers, below.

- Setting the Feedback Gains, below.

- Approaching the Sample Surface, p. 78.

- Verifying that the Probe has Engaged the Surface, p. 78

- Setting the Scan Parameters, p. 80.

- Starting the Scan, p. 82.

- Adjusting the Tilt, p. 84.

- Saving a Scanned Image, p. 85

- Retracting the Probe, p. 86.

12.1   Setting the Dividers

Before setting the dividers in the software, first set the relevant dividers on the Piezo Driver unit. For a description of the SPM dividers, see page 26.

>>   *To set the X–Y and Z dividers*

- Select the **SPM Control** tab.

    The X-Y and Z (Height) range settings are automatically updated with the current settings on the High Voltage Piezo Driver.

This update is necessary for scanner at the various settings of the XY and Z dividers. The default hardware settings are, for the XY divider 1/1 and, for the Z divider, 1/7. See Figure 54 below (left).

NOTE: For some piezo driver versions, the Z divider range options are 1/1, 1/7 and 1/15, while for others, they are 1/1, 1/7 and 1/23. See Figure 55 below.(right) Depending upon your system, select the correct Z divider version for the scan to be performed.
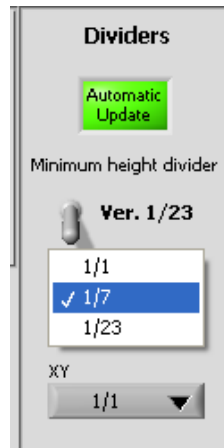
Figure 54: Default Divider Values

Figure 55: Z Divider Values for Piezo Versions

12.2   Setting the Feedback Gains

The control knobs for the feedback gains are located on the front panel of the SPM Controller unit. There are four gain controls:

- Proportional (P)

- Integrator (I)

- Differential (D)

- Low-Pass (LP)

The first three gains (termed PID) are applied to the Error signal. The LP gain is applied to the height signal at the output of the SPM controller. For more details regarding these gains, see Feedback Gains, page 87.

Adjusting the feedback gains is of critical importance for obtaining stable feedback in terms of noise level and scanner response to error signal changes. Select the following settings before approach to ensure safe engagement of the tip with the surface.

>>   *To set the feedback gains*

Turn the knobs on the front panel of the SPM Controller to the positions indicated in Figure 56 below. These are the recommended initial values for the PID gains before approach.
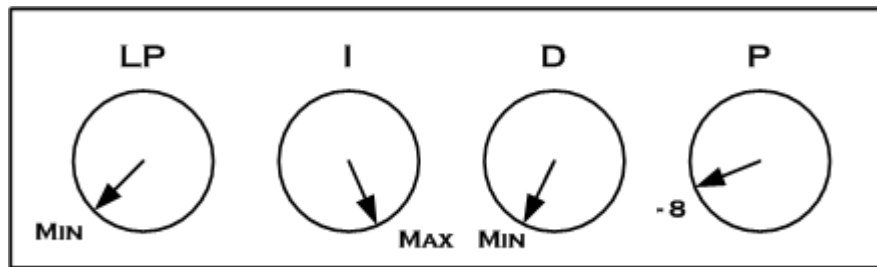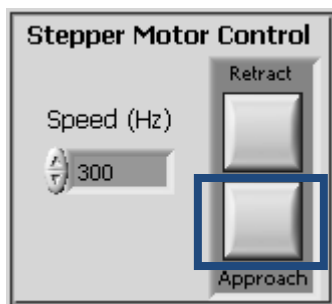
Figure 56: Setting the Feedback Gains

12.3   Approaching the Sample Surface

>>   *To approach the sample surface*

- In the **SPM Control** tab, click **Approach**.

The stepper motor brings the upper scanner, with the tip. toward the sample on the lower scanner and stops when feedback is established.

NOTE: To change the speed of the stepper motor, adjust its frequency using the **Speed** field. 300 Hz is default**.**

12.4   Verifying that the Probe has Engaged the Surface

When the tip has approached the surface and feedback has been established, the following indications should be confirmed:

Hardware: -

- On the Multi-Channel Stepper Motor Controller, the Lower Limit indicator will be illuminated.

- On the SPM Controller, the The **FB On** indicator will be illuminated. See Figure 57 below.

- On the High-Frequency Piezo Driver, the Z-channel will give a voltage reading of around -30v. Confirm that this value is stable.

Software:

- On the **SPM Control** Tab of the NWS software tabset, the Feedback indicator (far right, bottom) will be illuminated bright green. See Figure 58 below.

- The error signal should show only a small fluctuation around zero. (see Continuous Reading of Error Signal, Section 10.2.11)**.**

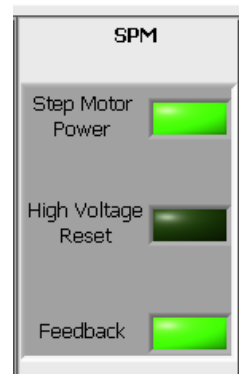*Figure 57: FB ON Indicator on SPM Controller*

Figure 58: Feedback Indicator on NWS Software

A Closer Look at the Approach Process:

When you click **Approach**, as directed above, the engagement of the tip with the surface is always accomplished using a Safe Approach mode. The Safe Approach parameters can be located by clicking **Misc.** on the Actions & Settings tab at the top of the NWS window (see Figure 59 below). The default values should not be changed, except for special applications.

When the approach is begun, the motion is implemented by the Z stepper motor. The Z-stepper moves the probe down toward the sample. Additionally, the scanner chosen for feedback is shifted in Z direction by the piezo-tubes. This scanner is shifted in such a way that the distance between the probe and the sample decreases. (if **the** lower scanner is used for feedback – it is shifted **up** and if the upper scanner is used for feedback it is shifted **down**). This Z shift of the scanner is determined by the **offset initial value** (see see Figure 59 below) and the corresponding voltage offset is observed on the Z channel display of the HV Piezo Driver. The default offset initial value is 2, corresponding to a voltage offset on the Piezo Driver of -30.0v. (To re-emphasize, the *negative voltage* display (-30V) on the Z-channel monitor of the High Voltage Piezo Driver indicates a shift on the Z-axis so that the distance between the probe and the sample decreases, **down** for upper scanner, **up** for lower scanner).

When the tip engages the surface, the Error signal immediately changes. At this point, the stepper motor motion is stopped immediately and the scanner is automatically retracted, using the Z piezo/ The scanner is retracted by a distance set by the negative height value in the NWS (see Figure 59 below). The default value is 3 microns (-3). This procedure is done to allow the final approach to be carried out with the piezo's fine movement capability, with feedback on, to ensure a safe approach.

The Z channel of the Piezo Driver is very useful for confirming a stable feedback. The Z reading should be stable. When the voltage reading is -145v or + 145v this means that the tip is not in feedback anymore! In such cases, the tip should be retracted, the setpoint readjusted and the approach repeated.
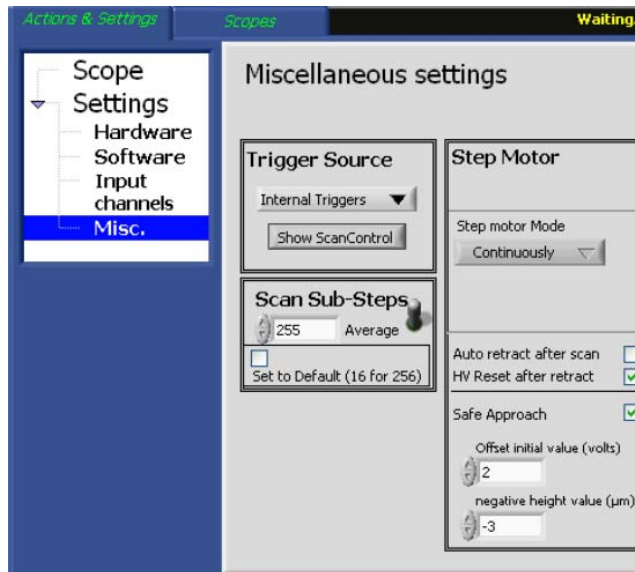
Figure 59: Safe Approach Parameters on the Miscellaneous Settings Pane

12.5 Setting the Scan Parameters

>> *To set the scan parameters*

1. On the Actions & Settings upper tab, select the lower Scan Window tab.

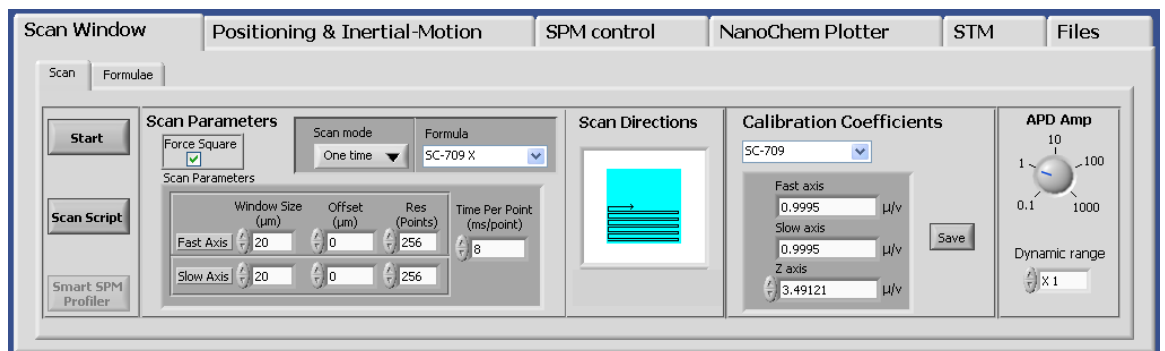   *The tab appears as shown in the figure below:*

*Figure 60: The Scan Window Tab*

2. In **Scan Parameters**, enter the following values:

	Window Size (microns)	Offset (microns)	Res (pixels)
Fast Axis	20	0	256
Slow Axis	20	0	256
Speed	8		

Explaining the Parameters on the Scan Window Tab

- **Fast Axis** refers to the direction of scan (see below).

- **Slow Axis** refers to the perpendicular direction.

- **Speed** can be set to values normally from 8ms to 12ms.

- **Window Size** sets the scan area and is limited by the maximum range of the scanner and any manually-set offsets (if such were set on the Piezo Driver X and Y knobs).

- **Offset** determines the center of the scanned image. If, for example, an offset of (X=2,Y=0) is used, an image would be obtained but its center would be shifted by 2 microns right on the X axis by 2 microns.

- **Resolution** is set to 256x256. Note: if larger resolution is needed then the number of the image channels should be reduced.

- The **Force Squared** sets a squared scan area of similar fast and slow axes.

3.   From the **Formula** drop-down list, select the scanner's linearization and calibration file for the X-Y scan
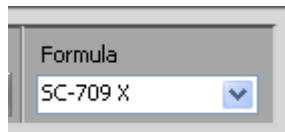
NOTE: The correct scanner file should be chosen according to the hardware in use: lower or upper. Also, select the correct scan direction: X or Y.

4.   Select the appropriate Z calibration files from Calibration Coefficients, (marked in red in figure below), according to the hardware selected for Z-feedback.

NOTE: XY and Z calibration files are separated to cover the cases where XY scan is carried out by the lower scanner while the Z scan is carried out by the upper scanner.
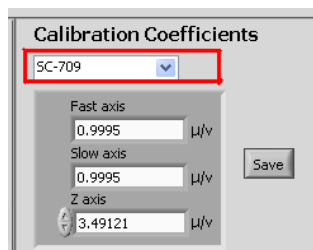
5.   In the **Scan** Direction area, choose one of the turquoise options.

6.   To choose different lengths for the X and Y axes, clear the **Force Square** check box (under Scan Parameters) and adjust the settings in the **Window Size** fields.

12.6   Starting the Scan

>>   *To start the scan*

1.   On the **Actions & Settings** tab, select the **Scan Window** lower tab.

2.   Click **Start**

*The **Scopes** upper tab opens with Trace and Retrace profiles. Each image is a different color and has separate controls. By default, the Height signals of the trace and retrace are displayed on the upper scope window as blue and red profiles. The AFM trace and retrace images will be displayed at the bottom Scope 1 and Scope 2 accordingly.*
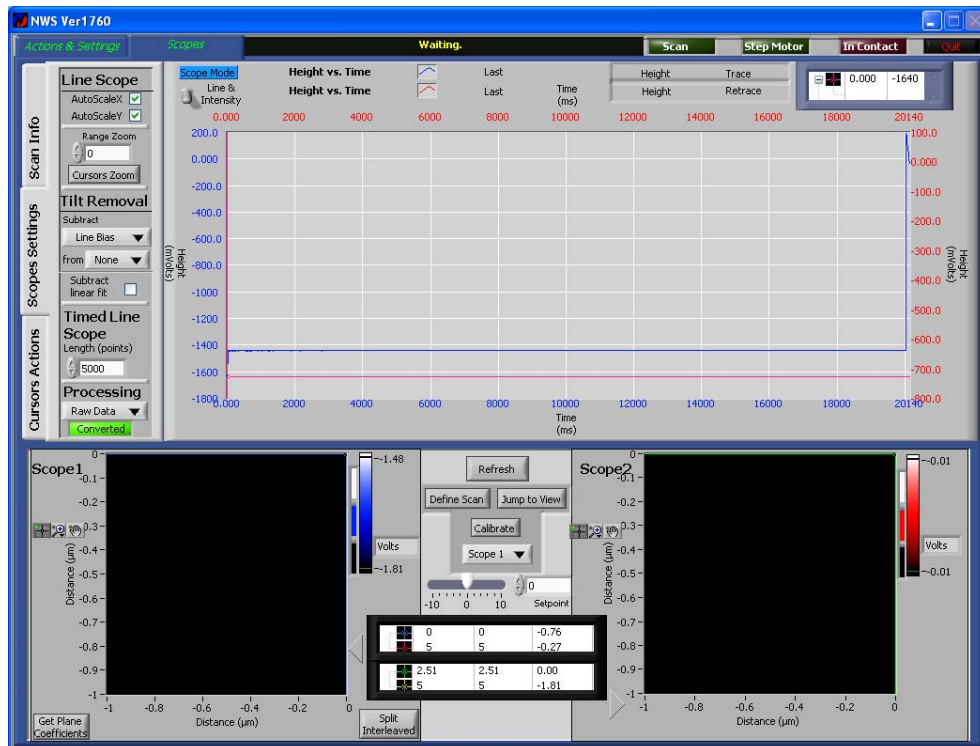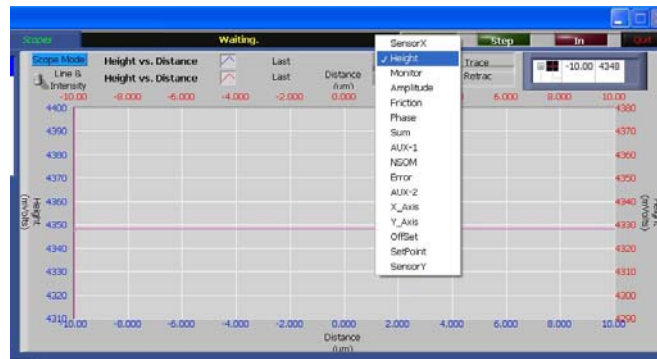

Figure 61: Scopes Tab

Working with the Scopes Tab

- You can select the type of image data (height, phase, NSOM, etc.) that is displayed in the Scope Monitor in the top right of the screen. Click "Height" at the top of the window, right of center, and a list of channels appears, as below.

- You can adjust the setpoint using the slider between the two scopes (see Figure 62 below), or by entering a value in the numerical field and pressing the Tab key. You can also change the setpoint in the SPM Control tab during the scan. Increasing/Decreasing the setpoint might be required during the scan according the tip used or the sample.
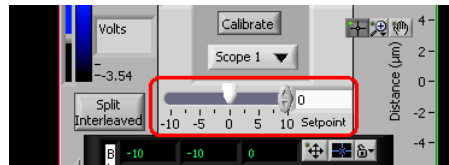

Figure 62: The Setpoint Slider

- To improve the image quality, use the Gain knobs on the SPM Controller. Detailed descriptions of the different types of gains can be found in Section 13: Feedback Gains, beginning on page. 87

- To change the units on the y axis (Volts or nm), select the **Scope Settings** side tab and then choose "Raw Data" or "Calculated" respectively in **Processing** (lower left).

- To view extra information on the progress of the scan, such as the time per line, the time remaining, etc. , select the **Scan Info** side tab.

- Use the Filters Line Bias/ Line Linear Fit/ Line Parabula Fit/ Plane on the scope 1, scope 2 or both. These filters do not affect the acquired data but can improve on-line observation of the obtained image.

- Use 'Subtract Linear Fit' to display the data in the 'upper scope window' with linear fit subtraction. This option is useful when small features are present on a large background and the user wants to observe only the small features.
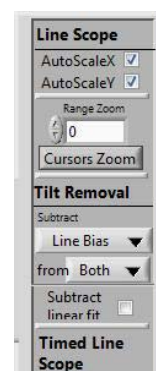
NOTE: If the scanning software becomes unresponsive and the tip is in contact with the sample, set the Mode switch on the SPM Controller (second switch from left) to the lower position. When the tip has retracted, restart the software and use the Z-stepper to retract the probe. Then switch the 'Mode switch' back to the 'operate' position.

12.7   Adjusting the Tilt

When Sub-micron features are scanned, even a small tilt in the sample relative to the probe can have a critical influence. The tilt might be due to the way the sample is affixed to the sample mount or it might be due to the topography of the sample itself. Therefore, when scanning, it is recommended to use Scan & Slope Compensation mode on the HV Piezo Driver (see p. 24) in order to enable correction for tilt, The software interfaces with the HV Piezo driver, when set to Scan & Slope Compensation mode, to obtain the desired tilt correction. The software setting for achieving tilt adjustment are described below. You can also use the software to subtract for the slope, as explained below, but this corrects only the image representation and does not result n any real slope compensation.

>>   *To adjust the tilt*

1.   On the **Scopes** tab, select the **Scope Settings** side tab.

2.   Make sure the channel is "**Height**".

3.   In **Tilt Removal**, uncheck **Subtract Linear Fit**.

4.   Observe the Height profile in the Scopes Monitor graph. If the graph has changed from non-increasing to noticeably increasing, continue with this procedure. If the graph did not greatly change, check Subtract Linear Fit.

NOTE: The "Subtract Linear Tilt" check box affects the software display only and it does not influence the physical scan at the hardware level.

5.   In order to compensate for the tilt, make sure the Mode knob of the Piezo Driver is set to "Scan & Slope Compensation".

WARNING: Do not adjust the Mode knob of the Piezo Driver during a scan as this can break the tip. Switching between the different modes should be done when tip is retracted!

6.   Adjust the fast axis knob on the Piezo Diver until the tilt that is observed in the Scopes Monitor has corrected itself. The fast axis knob is either X or Y, depending on the scan direction – see Setting the Scan Parameters, page 80.

When the tilt has been corrected, check Subtract Linear Fit

>>   *To stop the scan*

•   In the Status Indicator area at the top of the NWS screen, click **Stop Scan**.

When a scan has been stopped you cannot restart it but you can save it, as explained below.

12.8   Saving a Scanned Image

When the scan has finished, you can save the image in the NSW software. It is recommended to always save images in the NWS .nan format as this saves the data from all of the channels.

>>   ***To save the image***

1.   On the **Actions & Settings tab**, select **Files**.

2.   In the NWS tab, look at the next to the Save button.

•   If the field is empty:

a) .   Click **Save**.

b)   In the window that opens, choose a location and enter the name for the file.

•   If the field already contains a path with a file name:

a)   Change the file name to the desired name.

b)   Click **Save**.
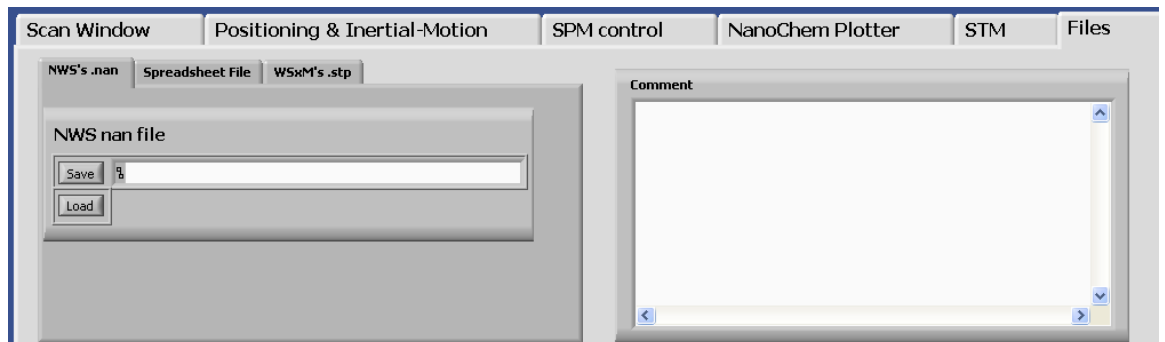
The path and file name appear next to the Save button.

Figure 63: The Files Tab

>>   ***To save in WSxM format***

When you save the image in the WSxM format you can use it in the WSxM image processing software.

1.   On the **Files** tab, click the **WSxM** tab.

2.   Click the dark green lights next to each channel's name in order to save the trace (left) and retrace (right) data.

3.   Click **Save**.

4.   In the window that opens, choose a location and enter the name for the file.

5.   Click **OK**.

The file will be saved with the suffix.stp.

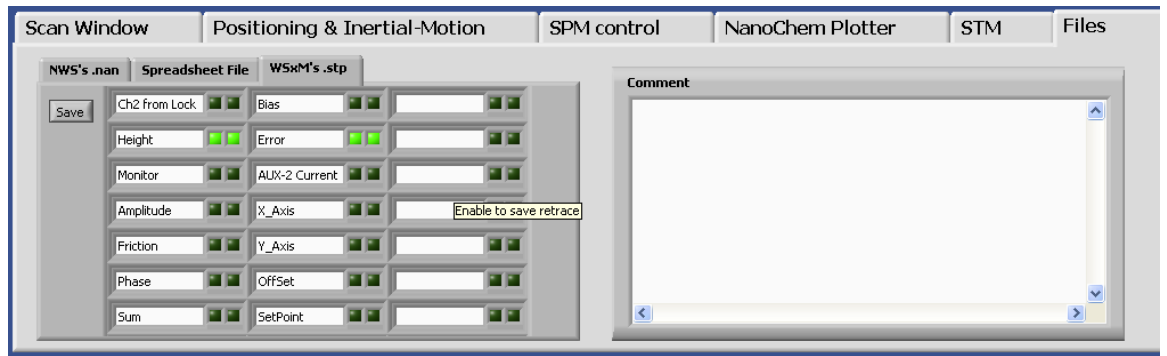You can now open the scan in the WSxM image processing software.

Figure 64: WSxM Subtab on Files Tab

12.9   Retracting the Probe

>>   *To retract the probe*

- In the **SPM Control** tab, click **Retract**.

NOTES:

1. If the "Retract tip after scan" option was selected then the tip will be retracted automatically when the scan has finished. The option is located in **Actions & Settings > Misc**.

2 After automatic retraction, the stepper motor enters 'retract by time' mode. Pressing on **retract** will now cause the stepper to retract for a certain period of time (2 seconds, is the default). To cancel this mode, go to **Misc**. tab and choose '**Continuously'** (see below).

2. If the scanning software becomes unresponsive and the tip is in contact with the sample, move the Scanner switch on the SPM Controller to the Retract position. When the tip has retracted you can restart the software and retract the tip in the normal way.
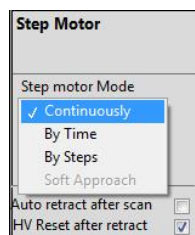

Figure 65 Cancelling 'Retract by Time' Mode

13   Feedback Gains

13.1   The Function and Importance of PID Gains in the AFM Feedback Loop

The settings of the three feedback gains are very important to ensure a proper feedback for preventing tip crash or removal of the fibers. These gains operate directly on the "**Error**" signal. The Error signal in amplitude feedback mode is acquired based on the changes of the Tuning Fork's amplitude during tip-sample interactions. In Phase feedback mode, the Error is acquired based on the Tuning Fork Phase's changes. Error Signals are normally of very small amplitude, the PID gains of the SPM controller work to amplify them and to clean them from noise. The "Height" signal obtained at the output of the SPM controller is in fact the Error after PID processing. In the next step of this feedback loop, the Height signal is transferred to the HV Amplifier (Piezo Driver) and amplified to a signal in the range -145 to +145v which moves the Z piezo up and down, this is called "**Correction**" signal. To summarize: The PID gains start with the **Error** signal acquired by the Tuning Fork and generate a **Correction** signal which physically moves the sample, or, in Tip-Scanning mode, the tip, up and down.

If the PID gains are not set properly and noises are still aliased on the Height signal, then the scanner movements in Z might cause the tip to collide with the sample, either damaging the tip or removing features from the sample.

13.2   **The PID Gains in Detail**

Below follow explanations regarding the nature and function of the various PID gains, as well as hints on choosing the proper PID:

13.2.1   The Proportional (P) Gain

The Proportional gain works to amplify the Error signal. As Error is normally low, the amplification is always required. Low Proportional gain is characterized by a smooth topography profile, with no sharp edges (Figure 66). If the gain is too low, however, it might generate oscillations (ripples) on the scanner (correction signal). High Proportional gain (Figure 67) usually improves the resolution, i.e sharper edges, but, on the other hand, it increases the signal noise. In most cases, the Proportional gain should be set in the range of **7-9** o'clock.
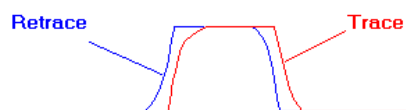

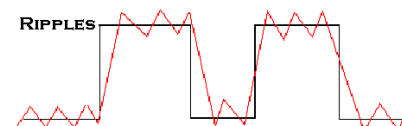*Figure 66: Low Proportional Gain*

Figure 67: High Proportional Gain

13.2.2   The Integrator (I) Gain

The **Integrator** gain sets the integration time or the time response of the scanner. That is, it sets the time for the scanner to respond for any change of the Error signal. The larger the integrator gain, the faster the scanner responds. Low Integrator is characterized by smooth and non sharp edges of the topography profile (Figure 68). High Integrator will make the edges sharper, but normally is more noisy, with overshoots (
Figure 69). It is very important to set the Integrator gain to Max during initial tip- During a scan, the Integrator gain can be set between Max and 15, depending on the scanned sample.
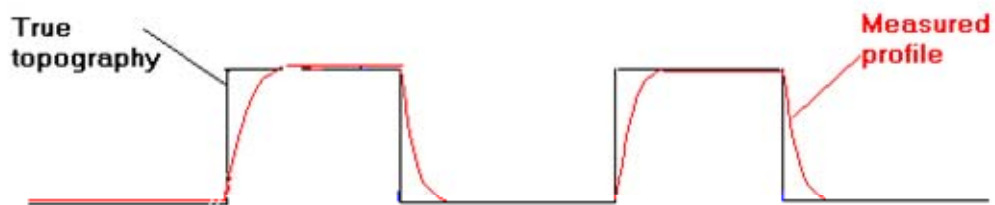
Figure 68: Low Integrator Gain

Figure 69: High Integrator Gain
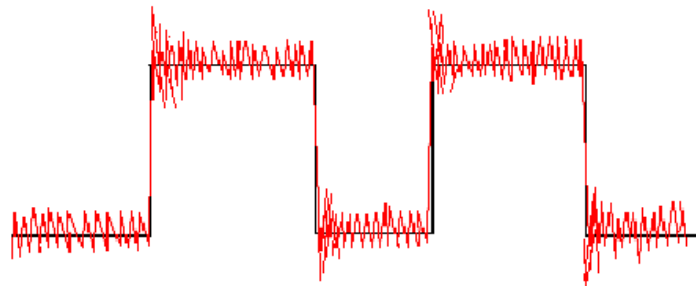
13.2.3   The Differential (D) Gain

The **Differential** [D]: Differential gain works to remove gradients or fast changes on the Error signal. It is useful for removing overshoots caused by a large Integrator gain. In Phase Feedback it is set to Min; it is more useful in Amplitude mode, where it should be set to the 7-8 o'clock position.
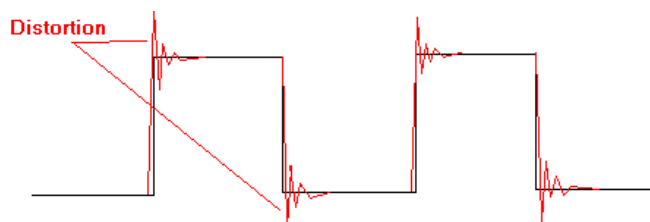

Figure 70: The Differential Gain

13.3   The Low Pass Gain

As mentioned above, the SPM output after these gains operation is the **Height** (Topography profile):

$$Height\ (t) = P \times \text{Error} \ + \ \int \ Error\ dt \ + \frac{dError}{dt}$$

There is one more Gain called **Low Pass** (at the left side of PID knobs in SPM front panel); unlike the PID gains discussed above, the Low Pass gain works on the Height signal and not on the Error. It is in fact a low pass filter which removes high frequency noises on the Height signal. Increasing this filter (clockwise) reduces the cutoff frequency of this filter. Increasing this gain will cause the profile to look cleaner, with less noise, but, on the other hand, it will smoother and less sharp. Raising the Low Pass gain too high will cause a greater delay in the scanner's response time, and could damage the tip. Therefore, initially, the LP gain should be set to Min.

14   Summary: An AFM Checklist

Here is a summary of all the steps explained in detail in the preceding sections. Use this summary as a checklist to ensure you haven't omitted anything as you become more familiar with the various procedures.

1.   Power Hardware and Software ON

2.   Mount the tip.

3.   Mount the sample.

4.   Align tip-sample positioning using the optical microscope and the XY stepper motors in the Tower. For fine positioning use XY piezo offsets and inertial motion of the lower scanner.

5   Align the anti-vibration isolation table.

6.   Obtain the resonance curve (Phase feedback or Amplitude feedback).

7.   Set the setpoint.

8   Select the desired scanner for X-Y and for Z on the Low Voltage Adaptor.

9.   Set XY and Z dividers.

10   Set the mode of operation on the Piezo Driver.

11   Check the voltages on the Piezo Driver display:
        Place the X,-Y knobs in their center position (5-0). The displayed voltages should show ~0V. If not, go to NWS software, positioning tab , set X=0, Y=0 and press **Go**.

12.   Set PID gains to their initial position.

13.   Initiate the tip-approach.

14   Check that the contact is stable. Adjust PID gains while observing the continuous error signal, if needed.

15.   Select scan parameters:
        a. Scan Range
        b. Time per pixel
        c. Calibration/linearization file for XY and Z
        d. Scan Direction

16.   Start the scan.

17.   Readjust PID and Setpoint if needed.

18.   Adjust the sample tilt.

19.   Save the image.

20.   Retract the Tip.

15   NSOM Scanning

This section describes the following topics:

- Connecting a Detector, below.

- Mounting the NSOM Probe, p. 92.

- Preparing the NSOM Probe, p. 93.

- Positioning the Tip, p. 95.

- Aligning the Detector, p. 95.

- Carrying Out an NSOM Scan, p. 96.

15.1   Connecting a Detector

See page 31 for a description of the APD Counter & Power Supply.

>>   *To connect the APD (or other detector) to the system*

1.   Attach the APD to the APD mount.

2.   Insert the required filters in front of the APD. For regular NSOM scanning, use a band pass filter based on the laser wavelength.

3.   Attach the APD to the microscope port.

4.   Connect the APD to the APD Counter & Power Supply with a cable from the +5V terminal of the APD to the positive and negative terminals of the APD power supply. The dashed tine goes to the positive terminal.

5.   Connect the Output terminal of the APD to the Input terminal of the APD Counter & Power Supply with a BNC cable.

6.   Connect the APD Counter & Power Supply to the DT Interface using a BNC cable from the Signal Out terminal to the NSOM or AUX 2 terminal of the DT Interface.

Below is a schematic guide to the connections. See also the schematic on page **Error! Bookmark not defined.**.
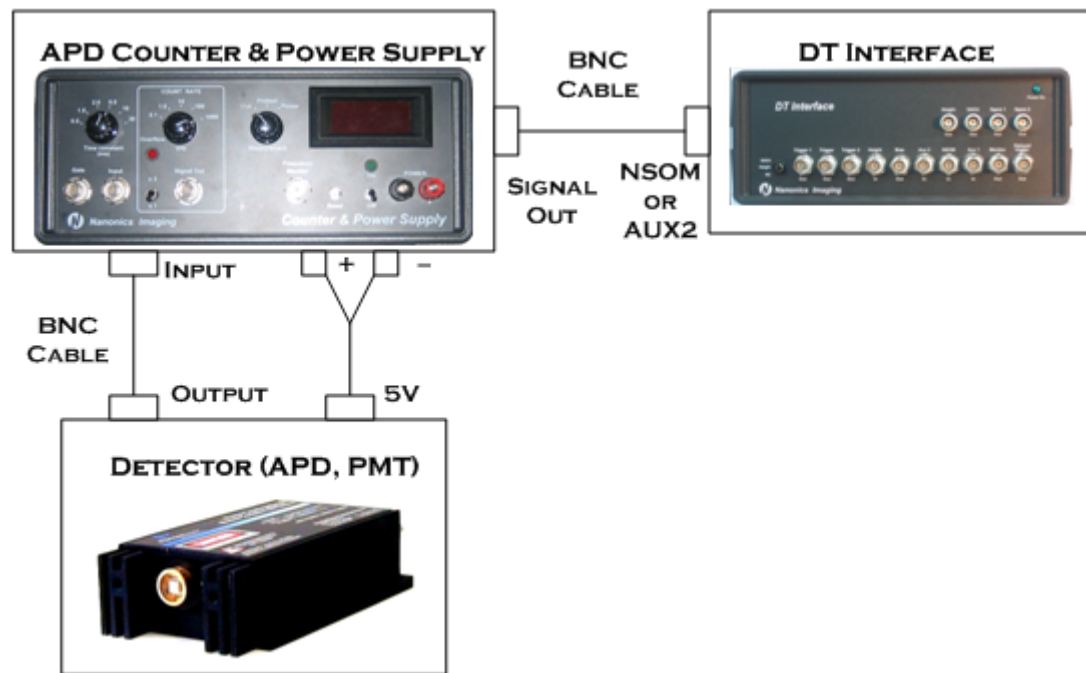
15.2   Mounting an NSOM Probe

When mounting the NSOM probes, follow all the instructions from page 49 onwards. However, due to the NSOM probe's tail, note the points below.

The NSOM tip is shown in its case below. The tail is wound in a coil.

Figure 71: The MultiView 4000 NSOM tip

When you have moved the towers away from the lower scanner and raised the upper scanner, continue below.

>>   *To mount an NSOM tip*

1.   Before removing the NSOM tip from its case, unwind the fiber tail and let it sit freely on the surface.

2.   Remove the tip mount from the box.

3.   Place the tip mount holder on the upper plate's scanner through the dovetail stage.

4.   Make sure that the fiber tail passes through the groove on the upper scanner (underneath the plate).

5.   Tighten the fixing screw to create electrical contact between the upper scanner and the tip mount.

6.   If necessary, place the second tip mount on the other upper plate.

15.3   Preparing the NSOM Probe

Before carrying out a scan with an NSOM probe, you need to prepare it by carrying out the following steps, which are explained on the following pages:

- **Thread the fiber into the fiber coupler's chuck.**

- **Strip the tail end of the fiber.**

- **Cleave the tail end of the fiber.**

- **Insert the chuck in the fiber coupler.**

SAFETY WARNING:

- Take care that the end of the fiber does not prick your finger or hand.

- Ensure that all unused fiber pieces are safely disposed of so that others do not get hurt.

>> To prepare the probe

1. Insert the tail end of the NSOM probe into the fiber coupler's chuck. The tail end must be at the same end as the chuck's screw.

2. Strip 10 mm – 20 mm of the jacket from the tail of the probe.

3. Thread the fiber tail through the cleaver, making sure it passes through the notch.

4. Place the fiber such that the non-stripped part goes up to the "2" mark and the stripped part continues towards the cutting area.

5. Press down on the cleaver

   Do not pull the fiber in order to snap it.

6. Bend the rubber base of the cleaver in order to snap the fiber.

7. The stripped part of the fiber will now be approximately 2 mm long.

8. Pull the fiber through the chuck leaving just 10 mm on the side with the screw.

9. Lightly tighten the screw.

10. The laser intensity coupled to the fiber can be controlled by the intensity attenuator which sits between the laser and fiber coupler.

>> *To couple the laser to the fiber*

LASER SAFETY:

1. During the entire process of coupling the laser to the fiber, wear the appropriate laser safety goggles.

2. Never look directly at the laser source.

3. The transmitted light at the output end of the fiber is very strong. Never look at it directly and never direct the fiber into your eyes.

4. Note that there can be reflected and scattered light from the chuck.

1. Insert the chuck into the fiber coupler and fix the chuck into position using the adjustment screw of the coupler (labeled X).

2. Turn on the illuminating laser.
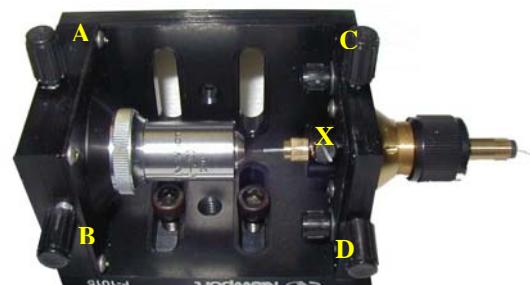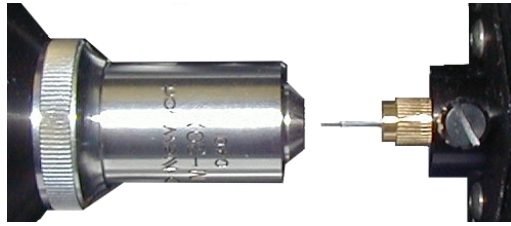
3. Make sure that the stripped end of the fiber is at the focus of the objective lens. This should be 2 mm away from the objective lens, so that the fiber will be in the area of the most concentrated light.

4. Use the adjustment screw on the fiber coupler to fine tune the distance of the fiber from the objective.

5. Couple the laser beam to the optical fiber using the alignment screws (labeled C and D above). To optimize the alignment, check that the laser light reaches the NSOM tip.

15.4   Positioning the Tip

>>   *To position the tip*

The tip must be brought into feedback with the sample surface in the same way as it is for AFM scanning. See section 12, beginning on page 76 above, for instructions on AFM scanning.

The tip position should be in the center of the field of view of the optical microscope.

15.5   Aligning the Detector

>>   *To align the Detector (APD/PMT)*

LASER SAFETY: When looking through the eyepiece of the microscope to carry out the alignment, wear the appropriate laser safety goggles.

1. Launch the NWS software.

2. Before aligning the Detector, select **SPM Control** on the **Actions & Settings** tab in the NWS software.

3. Click **Retract** in the Stepper Motor Control area in order to retract the tip a short distance from the sample and prevent the tip from getting damaged.

4. Turn off all the lights in the room, particularly the sample illumination of the host microscope.

5. Turn on the APD Counter & Power Supply using the switch on the rear panel.

6. On the front panel of the APD Counter & Power Supply, switch the Measurement Knob to the Out position.

7. Turn on the APD using the on/off switch on the front panel. The green LED above the switch lights up. Press the Reset button.

The APD should display a voltage reading due to the dark current.

If the monitor shows a zero reading then:

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(iv)   Check that the APD Counter & Power Supply cable is connected properly to the Detector. See page 91.

(v)   Check that the power supply gives a 5 V reading by moving the Measurement knob to "Power".

(vi)   Switch the Measurement Knob again to the Out position.

8.   Set the Count Rate to 1000 kHz. This prevents an overflow on the APD which may occur due to the high intensity of the laser.

9.   Using the trinocular knob of the host microscope, redirect the light into the APD.

10. If the red overflow LED lights up, the signal is in saturation. Switch the APD off and decrease the intensity of the laser by misaligning the coupling of the laser and the fiber.

11. Set the Time Constant on the APD Counter & Power Supply to a value greater than or equal to the Time per point (speed) in the Scan Window tab of the NWS software.

12. Mount the APD on the XY stage of the APD mount and align the it over the light spot from the tip. To achieve alignment, adjust the X position until the local maximum count is reached, then adjust the Y position to reach the maximum.

NOTE: Open the slider on the upper microscope to ensure that the optical path to the APD is open.

13. To maximize the signal along the Z axis use the fine focus of the host microscope.

•   If the APD counter records a low signal, optimize the coupling of the laser to the fiber.

NOTE: The APD range should be selected according to the intensity of the laser in the NSOM tip, though it should also be below the overflow.

14. Approach the sample surface with the tip and carefully adjust the APD mount's XY stage and microscope focus.

15.6   Carrying Out an NSOM Scan

Now that you have carried out the preparatory steps for an NSOM scan, configure the NWS software for Phase Feedback (p. 54) or Amplitude Feedback (p. 68) and continue with the instructions for carrying out a scan on page 76 and following.

When carrying out a scan, note the following two issues:

1   .When setting the scan parameters (SPM Control tab), ensure that the APD Amplifier setting in the SPM Control tab (left) is the same as the Count Rate (right) on the APD Counter & Power Supply.
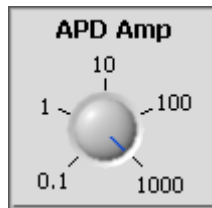
Figure 72: APD Amp (Software)   *Figure 73: APD Counter and Power Supply (Hardware)*

2.   If the signal is in saturation, change the range of the APD/PMT counter (or misalign the APD/PMT) and restart the scan.

15.6.1.1   Nanonics Support Dept

When contacting the Nanonics Support Dept. please note the following:

1. Name of company/university

2. MultiView product

3. Software (NWS or Quartz)

Shipping Address: Nanonics Imaging Support Dept., Manhat Technology Park, Building 1 Floor 2, Malcha, Jerusalem 91487, Israel

Tel: +972-2-678 9573

Fax: +972-2-648 0827

E-mail: support@nanonics.co.il