NX12 USER'S MANUAL

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Preface

The Scanning Probe Microscope (SPM) is not only at the top of the list of equipment pioneering the nano scale world, it is also the most fundamental technology. Succeeding the first generation optical microscope, and the second generation electron microscope, the SPM has every right to be known as a “third generation” microscope since it enables us to look into the nano scale world. At the same time it has many advantages over manual microscopes which passively observe the samples. The SPM is like a miniature robot, fabricating specific structures by manipulating atoms on the sample surface and using a probe tip to take measurements of those structures.

The SPM originated with the invention of the Scanning Tunneling microscope (STM). The STM uses a tunneling current between a probe tip and a sample in a vacuum state to measure surface height. As a result, it is limited in that it can only measure a sample which is a conductor or a semiconductor. Once the Atomic Force Microscope (AFM) was developed, however, a whole new range of measurement capabilities became possible. Now it is not only possible to measure non-conductors in air, but also to measure the physical, chemical, mechanical, electrical, and magnetic properties of a sample’s surface, and even measure live cells in solution.

The SPM is indeed the key to entering the world of nano technology that has yet to flourish, and it is essential equipment for various research in the basic sciences – physics, chemistry, and biology - and in applied industry - mechanical and electrical engineering.

The importance of the SPM stands only to grow greater and greater in the future.

Safety Precautions

This section describes the procedures related to the general operating safety of the NX12 in detail. For your safety, this section should be thoroughly understood before operating the NX12.

1. Hazard Labels

On the NX12 system, there are hazard labels at the site of possible hazards. Caution must be taken for each hazard label warning.

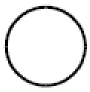
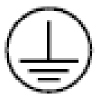
Symbol	Description
	"ON" (power) To indicate connection to the mains, at least for main switches or their positions, and all those cases where safety is involved.
	**"OFF" (power)** To indicate disconnection from the mains, at least for main switches or their positions, and all those cases where safety is involved.
	**"Caution, Risk of Danger"** This symbol denotes conditions or activities that could cause damage to the equipment.
	**"Caution, Risk of Electric Shock"** This symbol denotes conditions or activities that could cause an electrical shock or burn.
	"**Protective Earth(Ground)"** This symbol denotes a need for protective grounding of equipment.

Table. Hazard label List

CAUTION!

If the User operates the NX12 in a manner not specified in this User's Manual, serious damage to the instrument may result.

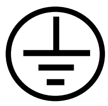
1-1. Electrical Hazard Label

The Electrical Hazard label notifies the area that might cause electrical damage to the system or to personnel. Care must be taken.

The Electrical Hazard label is attached to the areas listed below.

- **AFM Controller**
- **AFM Head**
- **XY Scanner**
- **Computer**
- **Monitor**

1-2. Protective Ground label



The protective ground label indicates that this equipment needs to be electrically grounded.

2. Operating Safety

2-1. Definition of safety symbols

Table shown below explains the meaning of the safety symbols – **WARNING**, **CAUTION**, **NOTE**.

Table. Safety terms and their meanings

Symbols	Meaning
WARNING!	Alerts Users to potential danger. Consequences and countermeasures are described. If users fail to follow the procedures described in this manual, serious injury or instrument damage may occur. Such damage will NOT be covered by warranty.
CAUTION!	Calls attention to possible damage to the system that may result if Users do not follow the procedures described in this manual.
NOTE!	Draws attention to a general procedure that is to be followed.

Please understand these safety terms thoroughly, and follow the associated instructions. It is important that you read all safety terms very carefully. **WARNING**s, **CAUTION**s, and **NOTE**s include information that, when followed, ensure the safe operation of your NX system.

2-2. General Operating Safety

The following are most of the **WARNING**s, **CAUTION**s, and **NOTE**s necessary to operate the NX12 safely.

WARNING!

The NX12 should be grounded before its components are connected to electric power. The main power plug needs to be connected to a three-prong outlet which includes a protective earth ground contact.

WARNING!

Before the power is turned on, the power selections for the individual components need to be inspected. The voltage selector switch is located on the rear panel of the NX12 Control Electronics, and can be set to the following voltages: 100 V, 120 V, 230 V, or 240 V.

WARNING!

Do not open the NX12 Control Electronics or the AFM/SICM head. Doing so may result in serious electrical shocks, as high voltages and electrostatic sensitive component are used in the NX12 Control Electronics and the AFM/SICM head.

WARNING!

NX12 System uses a 830 nm luminescent diode. Do not allow direct exposure of the beam to personel's eyes. Any deviation from the procedure described in this manual may result in hazardous beam exposure.

CAUTION!

You should regularly check to ensure that the NX12's cables are free from damage and that all connections are secure. If any damaged cables or faulty connections are found, contact your local Park Systems service representative. Never try to operate the equipment under these conditions.

CAUTION!

All parts in the NX12 system should be handled with extreme care. If not handled properly, these parts can be easily damaged as they are made of fragile electrical equipment.

CAUTION!

The AFM/SICM head should always be handled with care. When removed from the AFM and SICM, the AFM/SICM head needs to be carefully placed on a flat surface. This will protect the scanner, the cantilever, and the laser beam adjustment knobs. Never allow anything to impact the AFM/SICM head. When separated from the main frame, it is safe to keep the head in its storage box.

CAUTION!

Before the AFM head is mounted or unmounted from the Z stage, the on/off switch for the AFM beam must be turned off. Otherwise, the AFM beam diode in the AFM head may be damaged.

CAUTION!

During PSPD alignment, please turn off the light source to prevent interference between the light source and laser beam.

CAUTION!

When the AFM/SICM head is mounted or unmounted from the Z stage, ensure that the AFM head does not sustain any damage, and that it is properly grounded. The AFM head is extremely sensitive to electrostatic discharge.

CAUTION!

To meet the EMC guidlines, the Acoustice Enclosure should be closed while making measurements with the NX12.

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Chapter 1. Introduction to NX12

The NX12 is an SPM (Scanning Probe Microscope) designed specifically for bi ological applications. For imaging biological sample in dynamic conditions such as live c ell imaging, the NX12 provides the user with a wide array of imaging modes including SI CM (Scanning Ion Conductance Microscope).

1-1. Scanning Probe Microscope

The Scanning Probe Microscope (SPM) proved false the prevailing concept that an atom is too small to be observed with even the best microscope. It now has every right to be called the third generation microscope, with optical and electron microscopes being the the first and second generations. Whereas the maximum magnifying power o f an optical microscope is several thousands and that of a scanning electron microscop e (SEM) is tens of thousands, an SPM has the magnifying power of tens of millions, eno ugh to observe individual atoms. Even though a transmission electron microscope (TE M) has the lateral resolution high enough to image at the atomic level, its vertical resolut ion is much weaker at observing individual atoms. On the other hand, the vertical resolu tion of SPM is even better than its horizontal resolution making it possible to measure o n the scale of fractions of the diameter of an atom (0.01nm). The SPM, with its exceptio nal resolution, not only makes it possible to understand the various nanoscale worlds w hich heretofore were not completely revealed, but also to bring the unbelievable into rea lity. It provides such capabilities as allowing a user to change the position of individual a toms or to write letters by transforming the surface of a material at the atomic level.

1-2. Atomic Force Microscope

Among SPMs, the first to be invented was the Scanning Tunneling Microscope (STM). The STM measures the tunneling current between a sharp, conducting tip and a conducting sample. The STM can image the sample's height and also measure the electrical properties of the sample by the "tunneling current" between them.

The STM technique, however, has a major disadvantage in that it cannot measure non-conducting material. This problem has been solved by the invention of the Atomic Force Microscope (AFM) which may be used to measure almost any sample, regardless of its electrical properties. As a result, the AFM has greatly extended the SPM's applicability to all branches of scientific research.

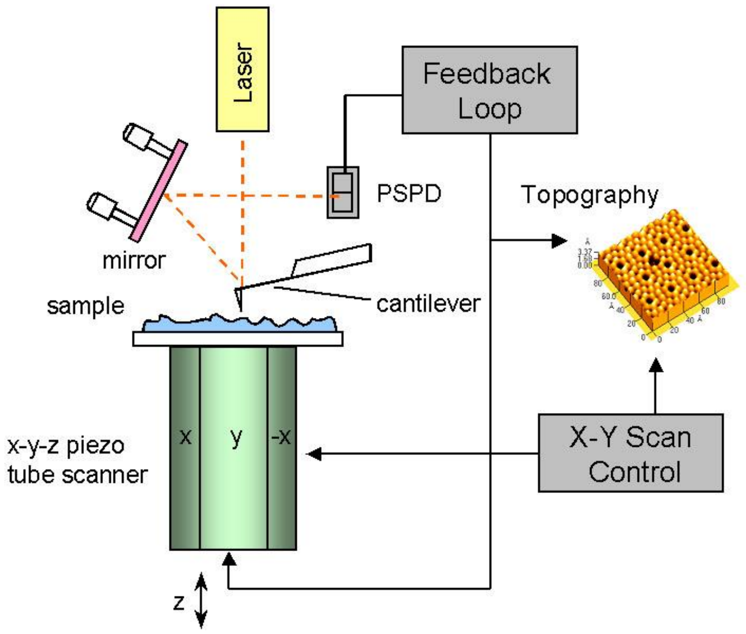

Figure 1-1. Diagram of Conventional AFM's Scanning

Instead of a conducting needle, the AFM uses a micro-machined cantilever with a sharp tip to measure a sample's surface. Depending on the distance between the atoms at the tip of the cantilever and those at the sample's surface, there exists either an attractive or repulsive force/interaction that may be utilized to measure the sample surface. See the "AFM in Contact Mode" and AFM in "Non-Contact Mode" chapters for a further discussion on utilizing these atomic forces.

Figure 1-1 displays the basic configuration for most AFMs. This scanning AFM is typically used to measure a wide variety of samples, which have a relatively small roughn ess. The force between the atoms at the sample's surface and those at the cantilever's t ip can be detected by monitoring how much the cantilever deflects. This deflection of th e cantilever can be quantified by the measurement of a beam that is reflected off the ba ckside of the cantilever and onto the Position Sensitive Photo Detector (PSPD).

The tube-shaped scanner located under the sample moves a sample in the horizon tal direction (XY) and in the vertical direction (Z). It repetitively scans the sample line by line, while the PSPD signal is used to establish a feedback loop which controls the verti cal movement of the scanner as the cantilever moves across the sample surface.

The AFM can easily take measurements of conductive, non-conductive, and even s ome liquid samples without delicate sample preparation. This is a significant advantage over the extensive preparation techniques required for TEM or SEM.

Despite its many advantages, the AFM does have some drawbacks as well.

1. In general, the scanners used in AFMs are piezoelectric ceramic tubes (Figure 1-1). Due to the non-linearity and hysteresis of piezoelectric materials, this may result in measurement errors as shown in Figure 1-2.
2. The geometrical and structural restraints imposed by the tube type scanner results in cross coupling of the individual scan axes. Thus, independent movement in the x, y, and z directions is impossible.
3. Since the tip has a finite size, it is very difficult and sometimes impossible to measure a narrow, deep indentation or a steep slope. Often, even though such a measurement may be possible, the convolution effect due to the shape of the tip and the sample profile may result in measurement errors.
4. Since the tip has to mechanically follow a sample surface, the measurement speed of an AFM is much slower than that of an optical microscope or an electron microscope.

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The most inconvenient aspect of using the AFM is its slow speed. As mentioned above, since the image is obtained by the tip mechanically following a sample surface, it is much slower than other microscopes that use electrons or light. The main factors slowing the speed of the AFM are the Z scanner's response rate and the response rate of the circuit which detects changes in the cantilever's resonant frequency. The resonant frequency of the typical tube scanner is several hundred Hz. In order to accurately measure a sample area with 256×256 pixels (data points), it is necessary to scan at a rate of about one line per second. Thus, it takes approximately 4 minutes to acquire an image.

For most cases, the second and third problems listed above can be minimized by software calibration. This is a reasonably simple and inexpensive procedure that involves imaging a standard sample, (usually a grid structure with a known pitch) in order to create a calibration file that will be used to control the scanner's movements when unknown samples are imaged. Correction using software, however, still depends heavily on the scan speed and scan direction, and such a correction becomes accurate only when the center of the scan range used to measure an unknown sample coincides exactly with the center of the scanning range that was used to image the standard sample and to create the calibration file.

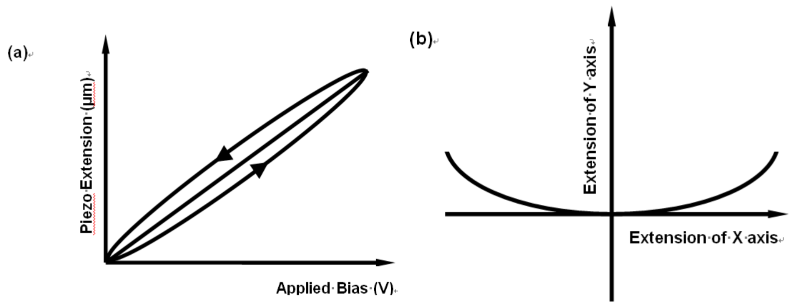


Figure 1-2. Nonlinearity and Hysteresis (a), and Cross Coupling (b) Observed in Piezoelectric Tube Scanners

1-3. Park Systems AFM

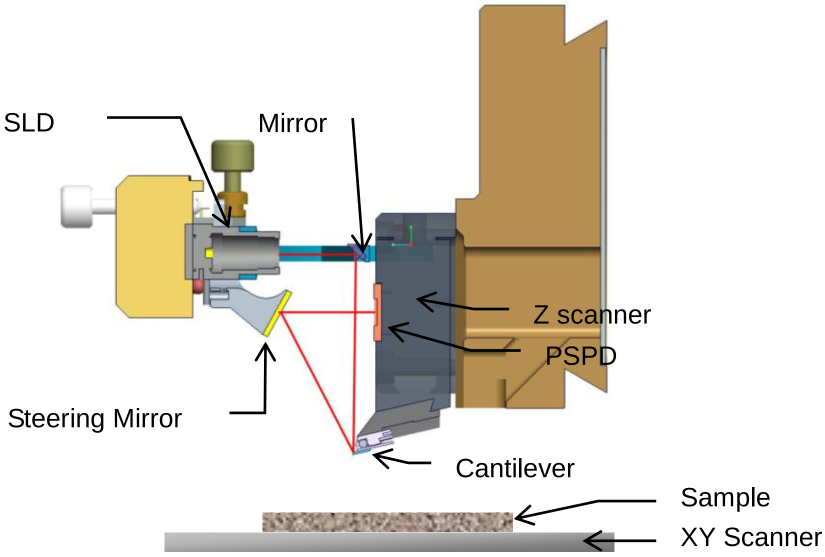


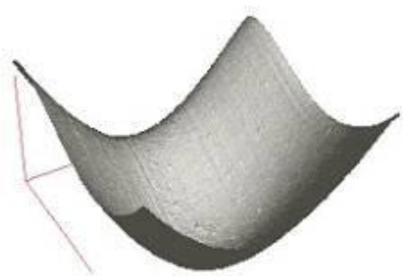
Figure 1-3. Z Scanner Separated from XY scanner

Since the conventional tube type scanner cannot move in one direction independen tly from other directions, movement in one direction will always simultaneously affect the scanner's movement in other directions. This cross talk and non-linearity caused by the scanner's three axes being non-orthogonal to another has a more pronounced effect in t he case of measuring larger areas or flat samples. This intrinsic problem can be elimina ted completely, however, by physical separation of the Z scanner from the XY scanner (see Figure 1-3). .

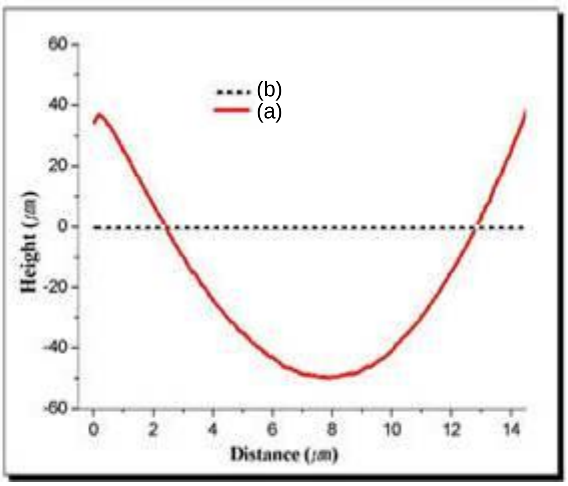
The breakthrough that eliminated these cumbersome problems came when the Par k Systems SPMs introduced a new concept of separating the Z scanner from the XY sc anner. The NX system is designed so that the XY scanner scans a sample in two-dimen sional space, while the Z scanner moves the tip only in the z direction. Figure 1-3 shows a diagram of the NX system, in which the Z scanner is separated from the XY scanner. The symmetrical flexure scanner used in the NX system moves only in the XY plane, an d has superb orthogonality. This scanner's design also makes it possible to place much larger samples on the sample stage than could normally be accommodated by a piezoel ectric tube type scanner. Furthermore, since the flexure scanner only moves in the XY d irection, it can be scanned at much higher rates than would be possible with a standard

AFM. Because the stacked piezoelectric actuator used for the Z scanner has a very fast response speed, at least 5 kHz, it is able to respond to topographic changes on the sam ple surface more than 10 times faster than is possible with a conventional tube type sca nner.

Having the XY scanner separated from the Z scanner in the uniquely designed NX system not only increases the data collecting speed by at least 10 times compared to a conventional tube type scanner, but also isolates the vertical and horizontal scan axes, completely eliminating cross coupling, resulting in a very accurate measurement. Moreo ver, this independent scanning system improves the error due to the inherent non-lineari ty of the scanner itself. Figure 1-4 compares the background image of a conventional tu be scanner compared to that of the new NX scan system.



(a) Conventional AFM



(b) Park Systems AFM

Figure 1-4. Background Flatness Images from a Conventional AFM (a) and Park Systems AFM (b)

Figure 1-5 shows a diagram that explains the cantilever movement detection mechanism used in the NX system. This super luminescent diode (SLD) Beam/PSPD configuration, which permits the accurate acquisition of stable images at high measurement speeds, satisfies the following two important imaging conditions:

First, the PSPD should be able to measure only the deflection of the cantilever without interference from the Z scanner.

Second, to improve the response rate in the Z direction, the weight of the Z scanner must be minimized.

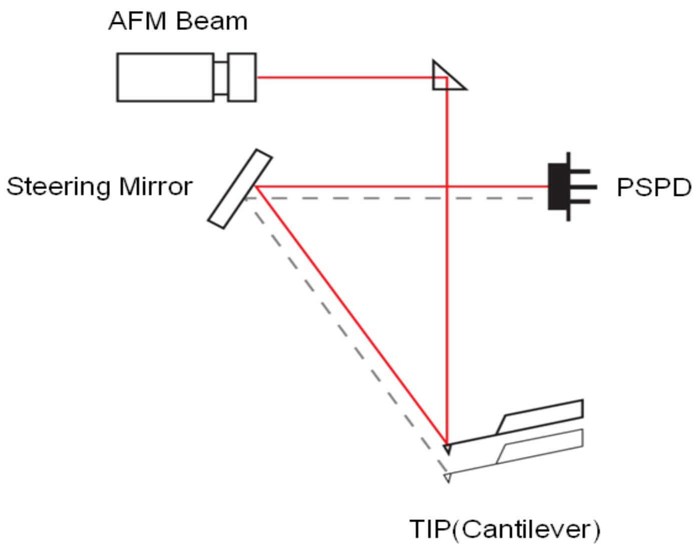


Figure 1-5. Beam path related to the cantilever's movement

The cantilever and the PSPD move together with the Z scanner while the SLD beam, a steering mirror and a fixed mirror are fixed relative to the scanner frame. The SLD beam, positioned in front of the Z scanner, is aimed at a fixed mirror that is situated above the cantilever. The mirror reflects the SLD beam downward and onto the back surface of the cantilever. The SLD beam will always hit the same spot on the cantilever's surface since the Z scanner only moves vertically. Therefore, once the SLD beam is aligned, there is no need to realign the SLD beam, even after the Z scanner has been moved up and down to change samples. The steering mirror, located at the front of the Z scanner assembly, adjusts the reflection angle of the SLD beam that is reflected off the cantilever's surface. The steering mirror reflects the SLD beam to the PSPD. Another feature of this alignment design is that as a result of placing the PSPD onto the scanner frame, it allows the change of the Z scanner position without having to readjust the position of the

PSPD. Therefore, only the deflection of the cantilever will be detected, independent of the Z scanner movement.

The superiority of the NX system's design, and its intention to accommodate the convenience of the user, appears in many different aspects in addition. The SLD beam used in the NX head ha low coherence and enables for accurate imaging of highly reflective surfaces and precise measurements for approach spectroscopy. An additional advantage of the SLD head is its compatibility with experiments that utilize light in the visible region of the spectrum. The unique head design of the crosstalk elimination allows a wide open side access to a sample and the tip. In addition, the replacement of the tip/nano-pipette is easy, and no special tools are required for this procedure. Figure 1-7 shows the simple operation of replacing a tip or a nano-pipette by hand.

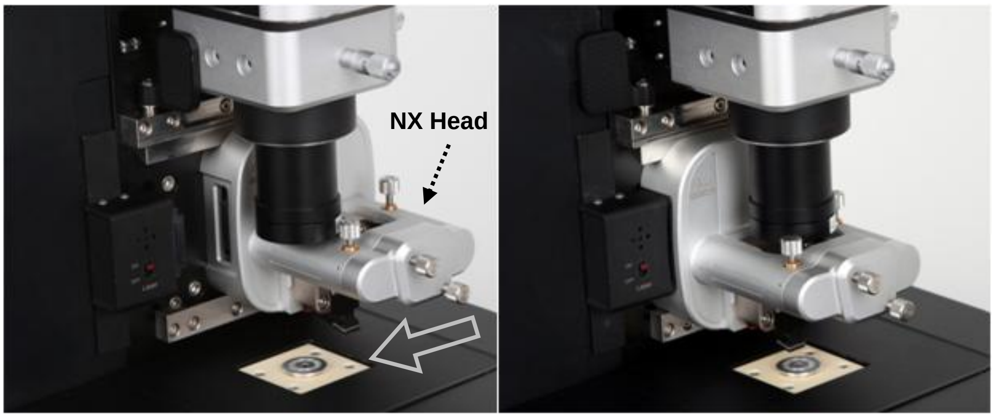


Figure 1-6. Lock Head

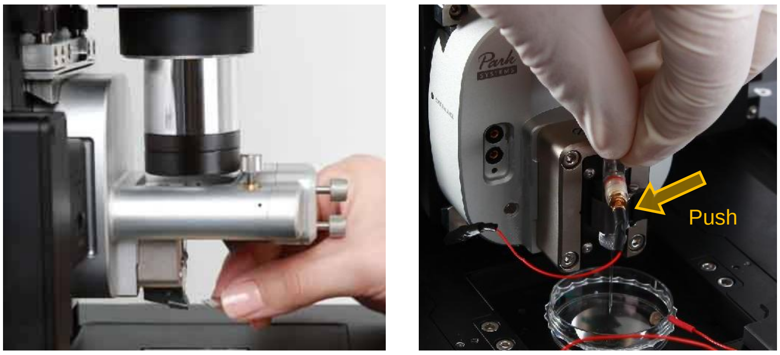


Figure 1-7. Probe/Pipette Exchange

The NX system not only achieved a structural design change that yielded exemplary SPM efficiency, but it also brought lots of improvements to the electronic controller and to the supporting software. The AFM control unit has a fast, powerful DSP (Digital Signal Processor), high speed ADC/DACs and offers built-in support for Digital lock-in and digital Q control functions without the need for additional instruments. The NX Control Electronics are designed to enable the scanner, the core unit of the AFM, to provide efficient, accurate and fast control, and to facilitate the acquisition of a stable image. In addition, the controller contains input/output terminals that provide a simple means for users to design advanced experiments that extend far beyond and are much more complicated than obtaining basic images. Furthermore, the up to date computer is equipped with the most recent high-power Pentium chip and Windows 7 system. Two 23" LCD monitor displays crystal clear images using a DVI (Digital Video Interface). All necessary software, including SmartScan, the Data Acquisition program, and XEI, the Image Processing program, is installed on the computer. Figure 1-8 shows the SmartScan program's clean and easy-to-use interface, complete with safety functions and various measurement capabilities that are required to perform advanced applications. Figure 1-9 shows the XEI program that is used to convert acquired data into an image and to perform various analyses that meet the user's requirements.

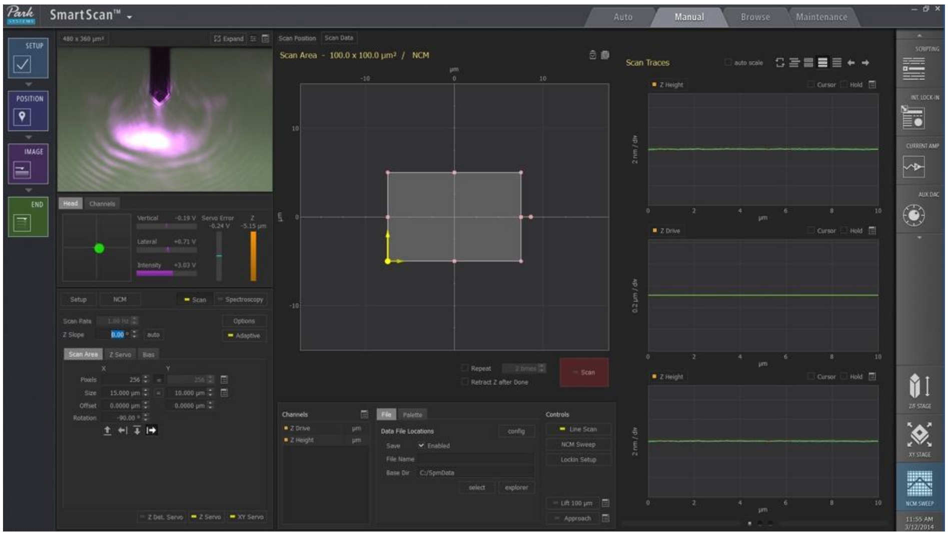


Figure 1-8. SmartScan™ - Data Acquisition Program

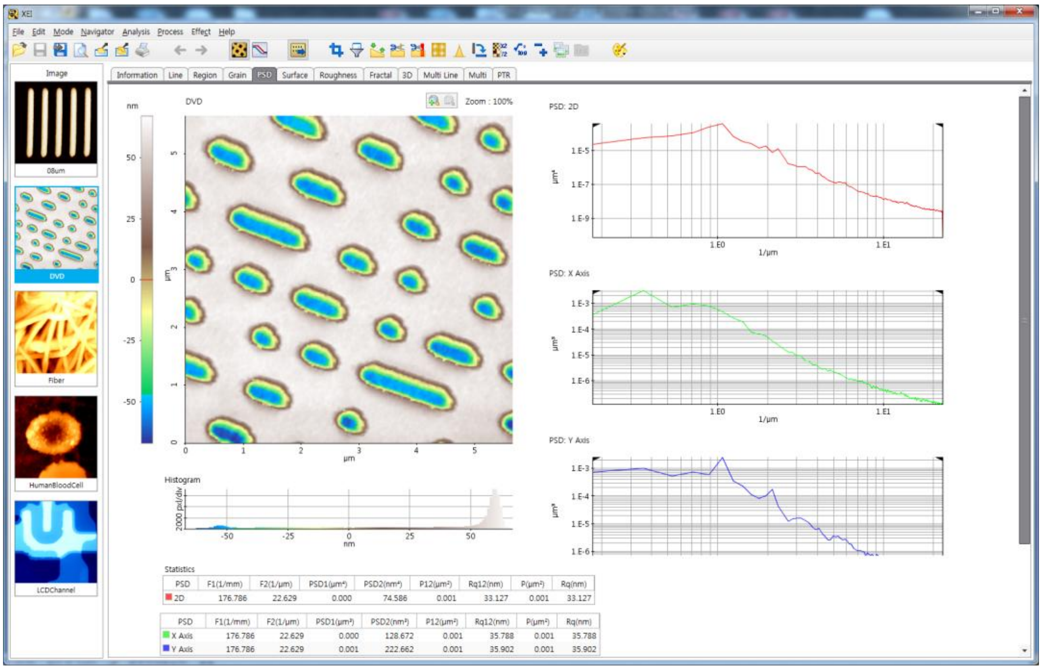


Figure 1-9. XEI - Image Processing Program

Chapter 2. Components of NX12

The NX12 System is an SPM (Scanning Probe Microscope) designed specifically for biological applications. For imaging biological sample in dynamic conditions such as live cell imaging, the NX12 provides the user with a wide array of imaging modes including the SICM (Scanning Ion Conductance Microscope). Also, with the versatility of an inverted optical microscope, the NX12 enables optical sample surface identification together with imaging in air or liquid.

The NX12 SPM System consists of four primary components: the NX12 main system mounted on an inverted optical microscope, the NX12 control electronics, a computer and monitors.

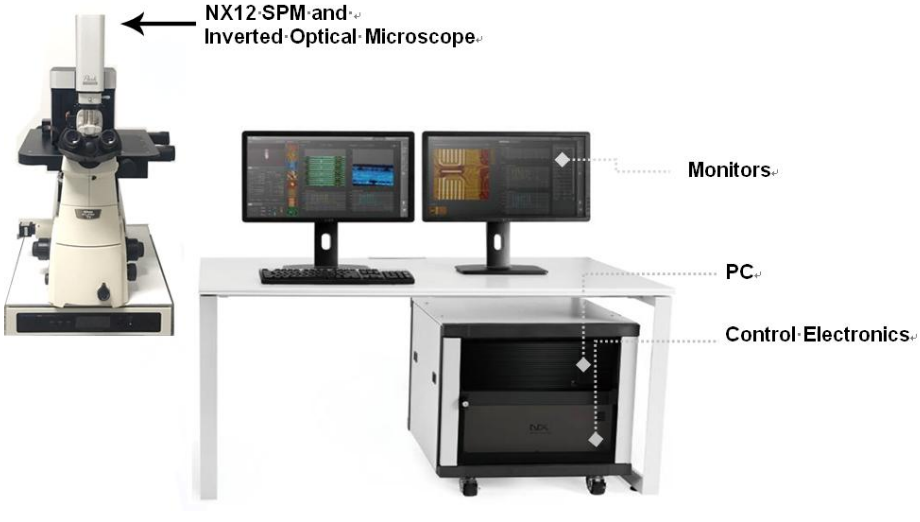


Figure 2-1. NX12 SPM System

The NX12 main system is where actual measurements are made, and the NX12 control electronics control the movement of the NX12 main system according to the commands from the computer. All necessary software, including SmartScan (the Data Acquisition program), XEI (the Image Processing program) and the vision program, is installed on the computer.

2-1. NX12 Main System

The NX12 SPM System, sits on a Kinematic Mount on the inverted microscope is much more efficient and easier to operate than a conventional SPM, and measurements are made faster and more accurately. The NX12 main system is divided into three components as shown in Figure 2-2. The following explains individual components in detail.

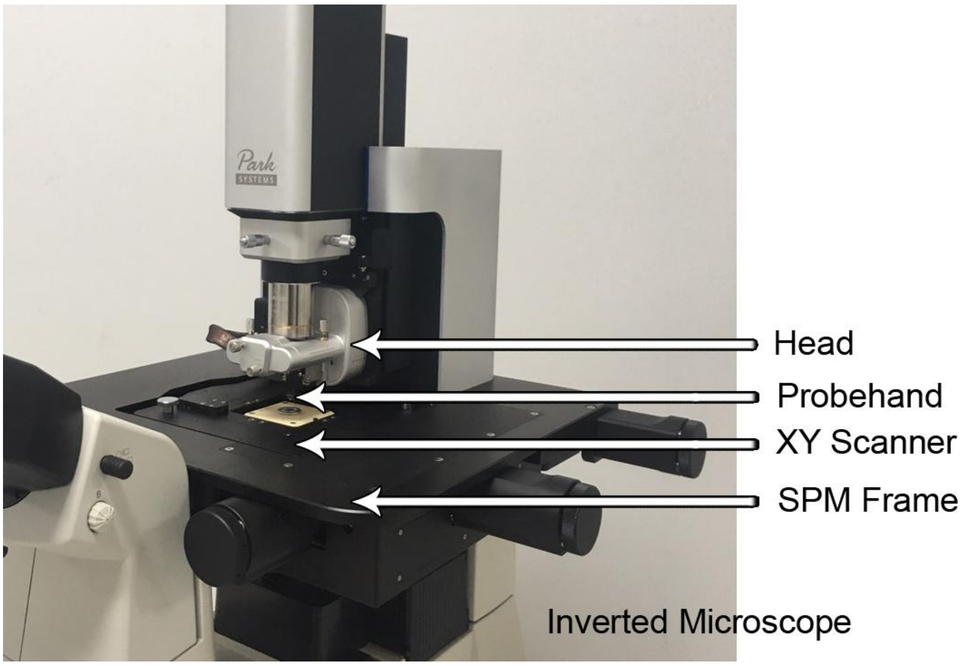


Figure 2-2. NX12 Scanning Probe Microcope

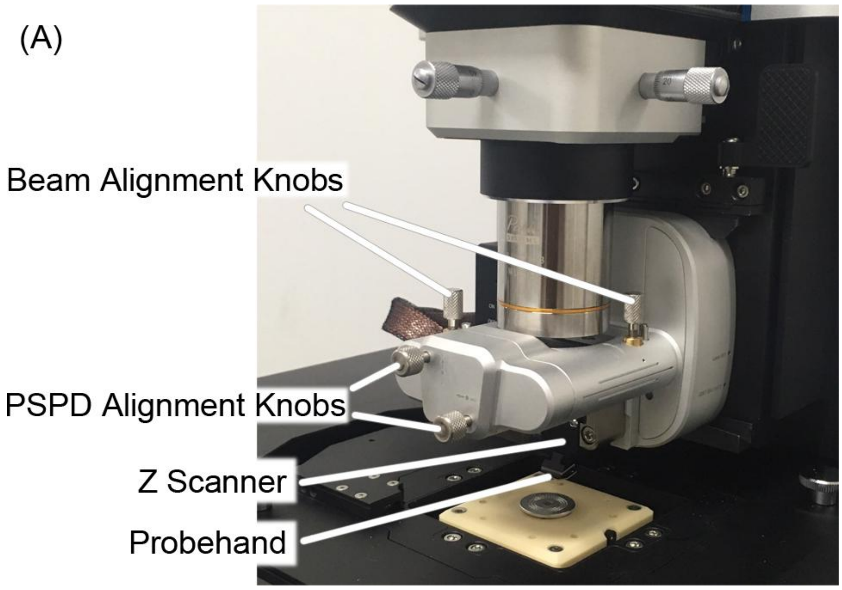
2-1-1. Z Stage

The NX12 Z stage controls the coarse vertical positioning of the NX12 Head containing the Z scanner, probehand, tip or nano-pipette by using a motor. The Z stage motor’s full stroke is 19 mm and its repeatability is < 2 μm.

- **NX12 Head**

The NX12 head is the component which actually interacts with the sample and takes measurements. NX12 provides two types of head as default: the NX12 AFM Head used for AFM measurements and the NX12 ICM Head used for SICM measurement. Please use the appropriate head for your measurement. The NX12 head is a core component of the Park SYSTEMS AFM and its structure is as follows. Refer to Section 7-2-1 and Section 8-2-1 for detailed information of each component.

- Cantilever/Nano-pipette Mount
- Cantilever Modulation (for AFM head)
- Beam Detection (for AFM head), Current Detection (for SICM)
- Movement in Z axis



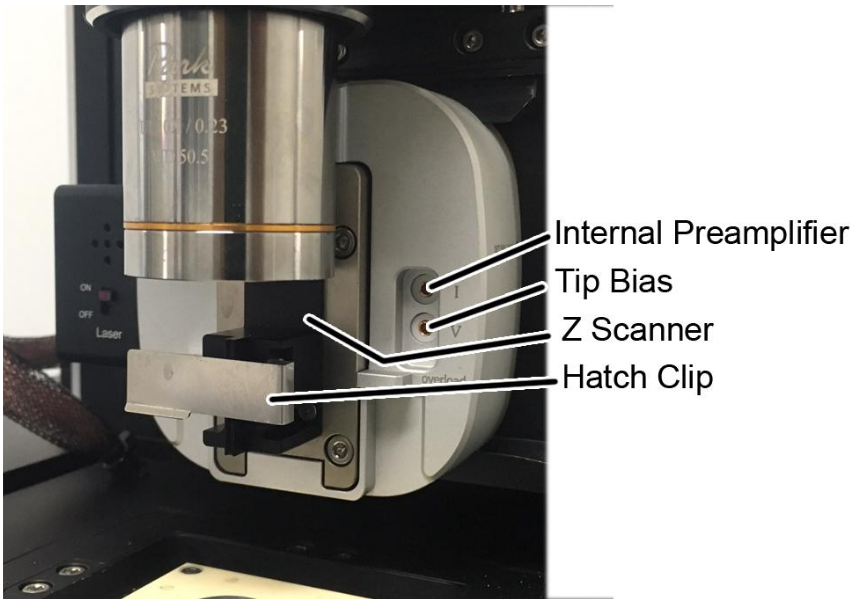


Figure 2-3. (Top) AFM Head and (Bottom) SICM Head (Opional)

WARNING!

Do not disassemble the NX12 head on your own. Park Systems will not be responsible for any personal, physical damage or degraded performance that may result from unauthorized disassembly.

NX12 Z Scanner

The Z scanner, which is mounted on the NX12 head (ICM head and AFM head), consists of stacked piezoelectric material which makes it possible to move through the applied voltage. The cantilever/Nano-pipette is attached to the Z scanner via the probeh and/nano-pipette holder and makes it possible for the cantilever tip/nano-pipette end to maintain constant feedback conditions (force/ion current or distance) as it is moved over a sample surface. The maximum sample height’s measurement is determined by the Z scanner range. The NX12’s Z scanner can move up to 25μm. On the other hand, the mi nimum obtainable vertical pixel resolution is determined by the control unit and the elect ric voltage that is applied to the Z scanner. Also, the noise level in the Z axis can be acq uired using zero-scan condition. It can be considered the vertical resolution for actual m easurement. The noise level is less than 0.05nm for the NX12 with optimized installation condition.

WARNING!

> Never disassemble the Z scanner on your own. Park Systems will not be responsible for any personal, physical damage or degraded performance that may result from unauthorized disassembly.

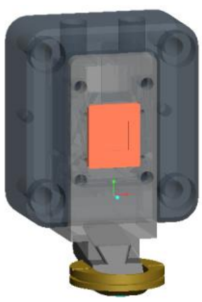


Figure 2-4. Z scanner Assembly

A unique characteristic of the NX12 compared to that of conventional SPM is that the Z scanner, which controls vertical movement of the SPM tip, is completely separated from the XY scanner, which moves in the horizontal direction on the sample. This structural change provides the user with several operational advantages.

1. The Z scanner, being separate from the XY scanner, is designed to have a higher resonant frequency than conventional piezoelectric tube scanners. This enables the tip to precisely follow the height of a sample's surface at a faster rate, increases the speed of the measurement, and protects the tip/nano-pipette, resulting in the ability to acquire clear images for an extended period of time.

2. Since the tip/nano-pipette wears out eventually, it is necessary to replace it after some amount of use. The NX12 AFM head has a Kinematic Mount and the NX12 ICM Head has a hatch clip, which makes tip/nano-pipette exchanges routine and easy.

3. Whenever it is necessary to remove the NX12 head from the main frame, it is very easy to do so. This procedure can be accomplished by unlocking the dovetail thumb locks and sliding the NX12 head off the dovetail rail. Remounting the head is just as easy as removing it.

CAUTION!

Before disconnecting the head, the beam switch on the NX12 head must first be turned off.

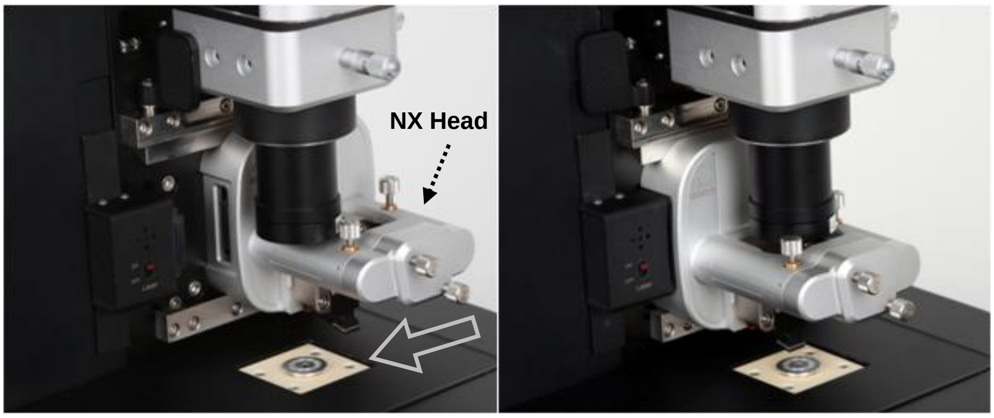


Figure 2-5. Removing NX12 Head

2-1-2. XY Stage

The XY stage is used to horizontally position the XY scanner loading sample. The XY scanner rests on a kinematic mount on the XY stage. The motorized XY stage has a maximum range of 10mm in both X and Y with resolution of 5㎛. It facilitates a precise offset control of the XY scanner, and is able to reproduce a position on the desired sample surface for imaging.

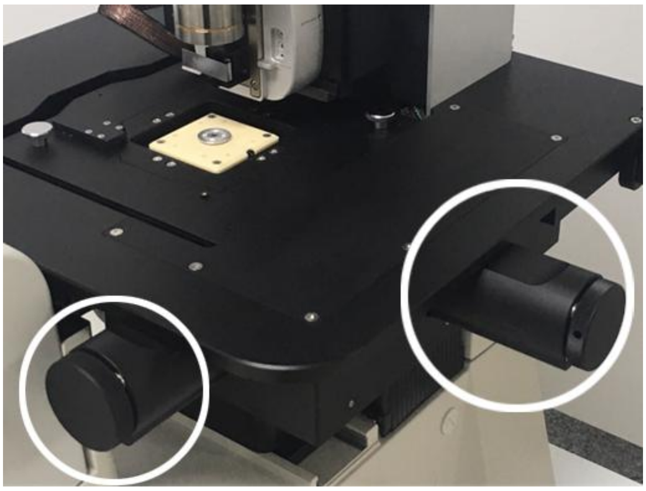


Figure 2-6. XY Stage

Kinematic Mounts

Kinematic Mounts used in the manual XY stage & NX12 Body Stage movements allow the two parts to always come into contact in the same location and alignment. One surface is fitted with three spheres or half-spheres, and the other surface is fitted with a flat surface, a straight groove, and a cone The spheres on the first surface fit into the three receptacles in exactly the same position every time, making it simple and convenient to replace or reposition parts. The XY stage/NX12 Body Stage has the position adjustment knobs to push the straight groove block and the cone block. Therefore, pushing the cone block makes the XY scanner move along the straight groove. Pushing the straight block makes the XY scanner move in the theta direction. In this way, the XY scanner/system’s main body moves with ease and control.

■ **NX12 XY scanner**

The NX12 XY scanner that moves the sample in the XY plane is a Body Guided Flexure (leaf-spring type) scanner. The XY scanner is fabricated from a solid aluminum block. The desired area is cut out from inside the aluminum block, and the lines indicated in Figure 2-7 are then fabricated with a special technique called 'Wire Electric Discharge Machining' - this results in a flexure hinge structure.

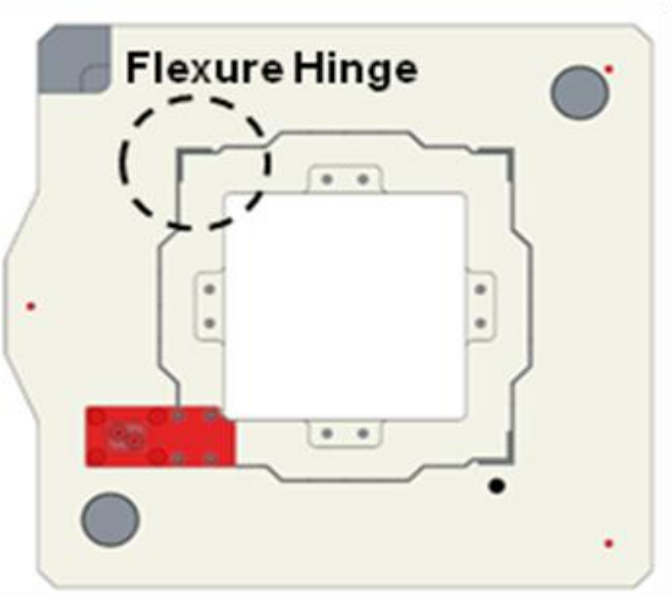


Figure 2-7. Flexure Hinge on XY scanner

WARNING!

Never disassemble the XY scanner on your own. Park Systems will not be responsible for any personal or physical damage, or reduced performance resulting from unauthorized disassembly.

An XY scanner with a flexure hinge structure has the advantage of highly orthogon al two-dimensional movement with minimal out-of-plane motion. Due to the Parallel Kin ematics design, the XY scanner has low inertia and axis-independent performance. Hys teresis-correcting ServoScan is accomplished by means of an optical sensor in the flexu re scanner. The XY scanner used with the NX12 has a 100 ㎛ × 100 ㎛ scan range.

There is a sample bias connector on the XY scanner, and voltage biases from -10V to 10V can be applied to a electrolyte easily.

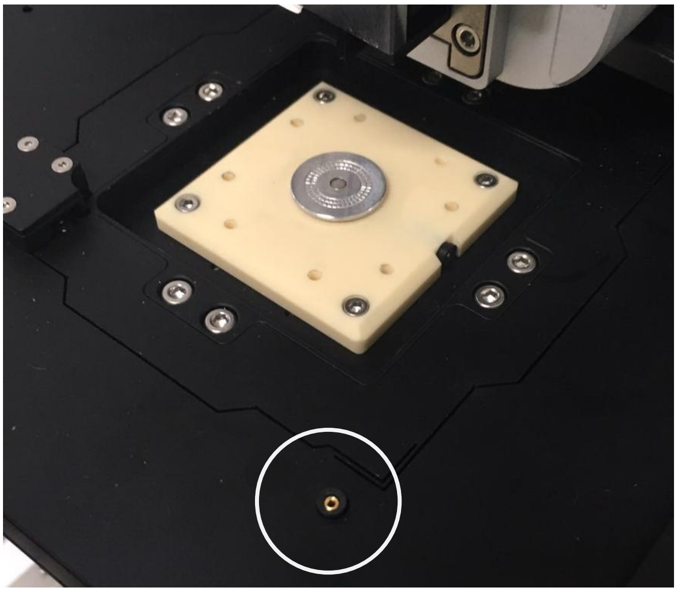


Figure 2-8. Sample Bias Connector

2-1-3. NX12 Body Stage

The NX12 Body Stage is used to horizontally position the NX12 system's main body (except for the XY Scanner) via manual control. In other words, its control makes the cantilever/nano-pipette move along with the laser and the fixed sample. The system's main body rests on a kinematic mount on the NX12 Body Stage. The motorized NX12 Body Stage has a maximum range of 8mm in both X and Y with a resolution of 5㎛. It facilitates a precise offset control of the cantilever/nano-pipette, and makes it easy to use.

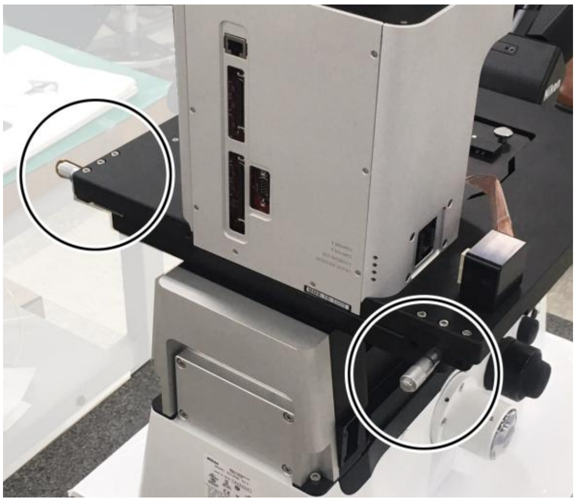


Figure 2-9. NX12 Body Stage

2-2. NX12 Control Electronics

The Control Electronics plays an important role as a mediator between the NX12 main system and the computer.

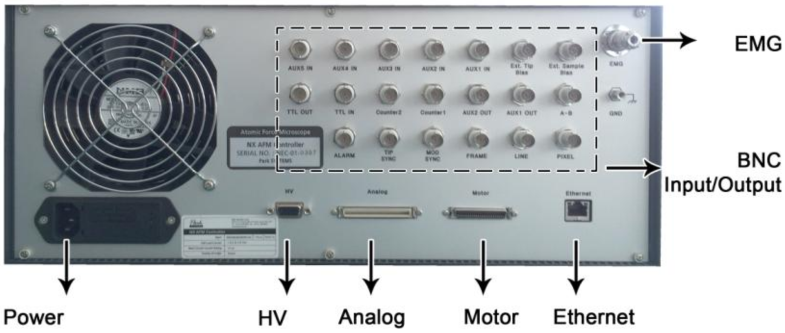
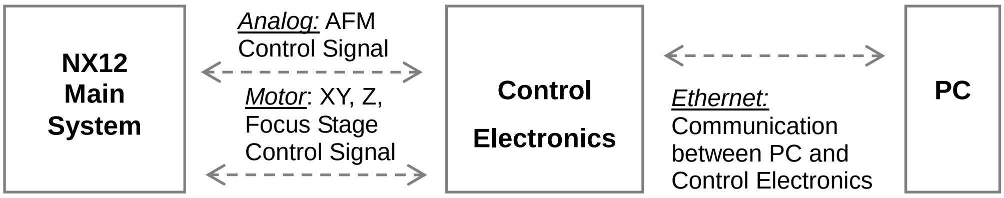


Figure 2-10. Control Electronics (Rear View)

In order to maintain fast, effective communication between the computer and the NX12 main system, a Ethernet is used.



Connector Label	Type	Connection to	Purpose
Analog	1.27 mm pitch, 68 pin	Frame PCB	Analog signal I/O for AFM operation.
Motor	1.27 mm pitch, 50 pin	Frame PCB	I/O for XY, Z, Focus Stage control.
Ethernet	RJ45 Cat.5e	PC	Connect Electronics with PC for controlling the NX20 system by PC.
EMG	Circular 4pin		Motor can be stopped by disconnecting it in an urgent status. This function is disabled for research system.

Table 2-5. Connector Information

NX control Electronics support the access of important Input/output signal like VER

TICAL, Tip bias and so on by connecting external instruments using a BNC connector (Figure 2-12).

Connector Label	Purpose	Specification
AUX 5 IN	Go through internal lock-in of data acquisition system or directly save as image file using user software.	BW 20 kHz, +/- 10V
AUX 4 IN	Go through internal lock-in of data acquisition system or directly save as image file using user software.	BW 20 kHz, +/- 10V
AUX 3 IN	Go through internal lock-in of data acquisition system or directly save as image file using user software.	BW 20 kHz, +/- 10V
AUX 2 IN	Go through internal lock-in of data acquisition system or directly save as image file using user software.	BW 20 kHz, +/- 10V
AUX 1 IN	Go through internal lock-in of data acquisition system or directly save as image file using user software.	BW 5 MHz, 50 Ω input impedance. +/- 5V
AUX 1 OUT		BW 5 MHz, 50 Ω input impedance. +/- 2V
AUX 2 OUT		BW 20 kHz, +/- 10V
Ext. Tip Bias	Input connector used when the experimenter wants to apply bias from an external source to the sample.	Input voltage range: -10V to ~ +10V If experimenter wants to apply a higher bias to the sample, user can use 'External High Voltage toolkit' Full Power Bandwidth: <100kHz
Ext. Sample Bias	Input connector used when the experimenter wants to apply bias from an external source to the sample.	Input voltage range: -10V to ~ +10V If experimenter wants to apply a higher bias to the sample, user can use 'External High Voltage toolkit' Full Power Bandwidth: <100kHz
TTL OUT	Reserved	
TTL IN	Reserved	

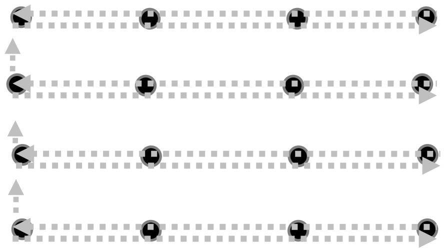
Counter 1	Input connector when the experimenter wants to count the signal from the detector.	LVTTL input compliant Minimum pulse width: 10 ns Max counting value: 2^32 Time constant: 1 ms ~ 1 sec. (To be determined)
Counter 2	Input connector when the experimenter wants to count the signal from the detector.	LVTTL input compliant Minimum pulse width: 10 ns Max counting value: 2^32 Time constant: 1 ms ~ 1 sec. (To be determined)
VERTICAL	Difference between the voltage from upper and lower cells of the quad cell PSPD. Experimenter can use this connector to process the VERTICAL signal from an external device such as a lock-in amplifier.	Output range: -5V ~ +5 V Small Signal Bandwidth: 5 MHz Impedance: 50 Ω
Alarm	Reserved	
Tip SYNC	Tip bias (sample bias, Z scanner modulation) frequency output.	LVTTL compliant.
MOD SYNC	frequency output of NCM modulation	LVTTL compliant.
FRAME	Indicates if the images are acquired.	LVTTL compliant.
LINE	Indicates the direction of scanner movement	LVTTL compliant.
PIXEL	Indicates the scanner status	LVTTL compliant.

Table 2-6. BNC Input/Output

- **Image Sync.**

NX12 provides Image Sync outputs (Frame, Line, Pixel) for your experiment. If you measure the 4 X 4 pixel image, the sync signal of Pixel, Line, and Frame on the measu red image is shown in Figure 2-11. The numbers are forward (left to right scan) images and the alphabets are backward images (right to left scan).

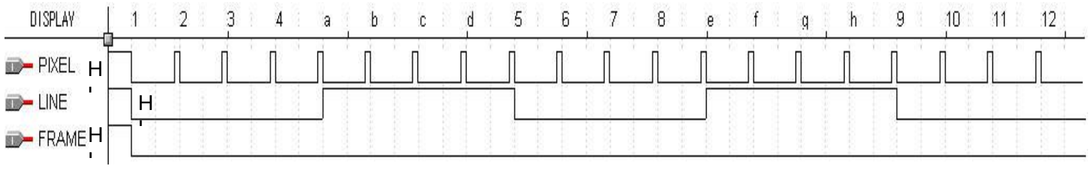
Slow scan



Fast scan →

13 p	14 o	15 n	16 m
9 l	10 k	11 j	12 i
5 h	6 g	7 f	8 e
1 d	2 c	3 b	4 a

<Display>



(H: High Status, L: Low Status)

Figure 2-11. Standard Scanning

Table 2-7 explains each sync signals.

Items	Low/High Status	Low	High
FRAME	Indicates if the images are acquired	Acquiring the image	No activity
LINE	Indicates the direction of scanner movement	Trace (or forward) direction	Retrace (or backward) direction
PIXEL	Indicates the scanner status	Acquiring the pixel data (hence the scanner is stationary)	Moving to the next point

Table 2-7. Image Sync

2-2-1. Power/Fuse Change

■ **Power**

The power to the NX12 Control Electronics is not free voltage. So to change the inp ut power voltage, follow the configuration shown below.

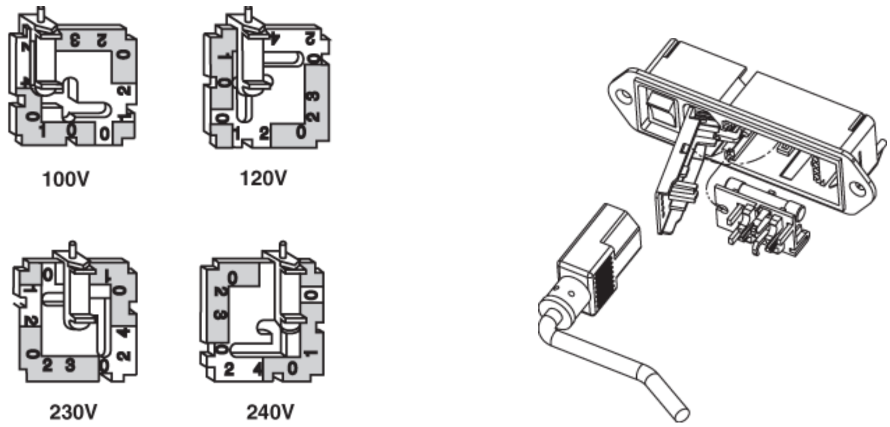


Figure 2-12. Change Power

1. Remove power cord.
2. Pry door open at socket.
3. Lift and swing door into socket.
4. Lift fuse holder out of housing.
5. Install one AG fuse or two metric fuses.
6. Replace fuse holder into housing.
7. Swing and snap door back in place.

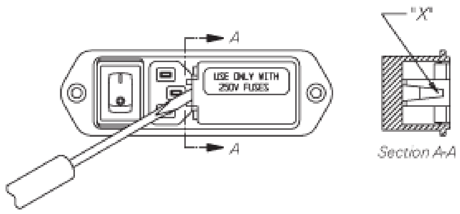
■ **Fuse**

[Fuse Specification in : 230V/240V:2A or 100V/120V:4A]

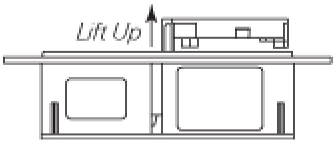
You can change the fuse by following the procedure below:

a) Removing Fuse Holder

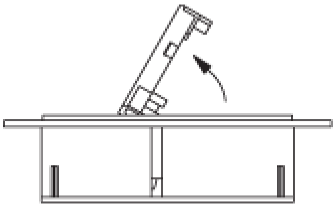
1. Insert a pocket screwdriver at point "X" as shown



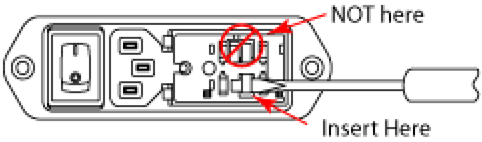
Gently lift UP until the entire door lifts up approximately 1/4" (minimum)



2. Once lifted, the door will pivot on its hinges and expose the fuse holder



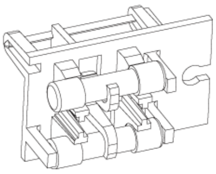
3. When the fuse holder is installed in the single fuse position, apply the screwdrive r as shown and gently pry up. Insert screwdriver as shown - do not use fingers to pry the unit loose.



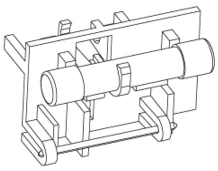
When the fuse holder is installed in the dual fuse position, it will normally release as soon as the door is opened.

b) Changing Fuse

European Fusing Arrangement



North American Fusing Arrangement



Install fuses on one side only. Do not install both AG and Metric fuses at the same t ime.

2-3. Optical Microscope

2-3-1. NX12 Optical Microscope

The Optical microscope is used when positioning the SLD beam onto the cantilever, and for locating regions of interest on the sample surface for measurement. Since the optical microscope's axis is parallel with the Z scanner's, it is possible to have a direct on-axis view of the cantilever in conjunction with the sample area that will be scanned

All of the components of the optical microscope - the objective lens, the frame, and CCD camera - are rigidly fixed on a single body. Since the entire assembly moves toget her for focusing and panning, the axis lining the sample and the CCD camera are alway s fixed, and a high quality optical view is preserved.

The NX10 provides two options for the objective lens' choice- 10X and 20X. Please ref er to the table below for details.

Figure 2-13. Optical Microscope of NX12

Table 2-4. Specification of Objective Lens

EL20**X** (Enhanced long working distance objective lens)	UL10**X** (Ultra long working distance objective lens)
NA 0.4	NA 0.23
WD 25 mm	WD 50.5 mm
Compatible for Long Travel Head	Compatible for Standard Head, Long Travel Head

The 10X objective lens yields about 500 times magnification and the optional 20X object ive lens yields about 1000 times magnification

■ **NX12 Filter Holder**

To insert the NX12 filter, as shown in figure below, please remove the default filter

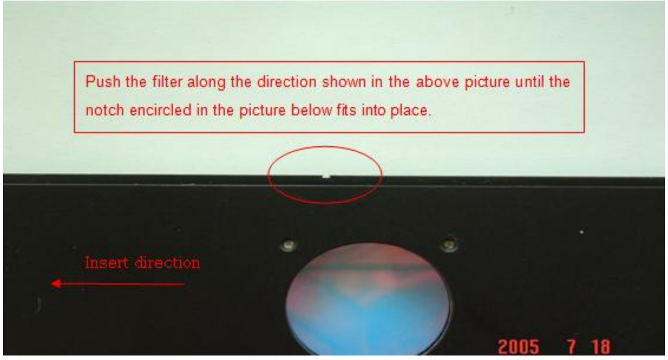


Figure 2-14. Assemble Filter Holder

2-3-2. Camera (Optional)

The digital CCD camera is used to focus the beam onto the cantilever and to locate the cantilever to the region of interest on the sample surface that is to be measured. Effective high resolution digital camera has 1024 x 768 pixel resolution and a speed of 20 frames/sec. Digital magnification is up to 100 times.

Figure 2-15. CCD Camera

2-4. Computer & Monitor

Programs related to controlling the system, performing measurements and image processing, are installed in the computer. They are SmartScan, XEI and the Vision program. SmartScan is used for system operation, data acquisition and communication between the control electronics and the computer. XEI is used for image processing and analysis. The Vision program is used to observe the cantilever/sample/beam/etc for system operation. See the software manual for further description of the software.

The computer is connected to the NX12 Control Electronics via an Ethernet cable. The two 23 inch LCD monitor utilizes 1920×1080 pixels with 32 bit color. This monitor is digitally connected to the computer via an SVGA DVI (Digital Video Interface) port. The specifications for the computer are listed below. (The computer and monitor specifications and configurations can be change to a higher version without notice.)

2-5. Vibration Isolation Systems

The Acoustic Enclosure (AE) shields the AFM from acoustic and electromagnetic noise. AFMs are instruments that are very sensitive to vibrations. Both vibrations from the floor and acoustic noise of the surroundings have adverse effects on AFM measurements. It is recommended that the NX12 system is placed in an Acoustic Enclosure to block acoustic noise from the surrounding environment, and supported by an Active Vibration Isolation System to block floor vibrations.

Designed exclusively for the NX series system, the integrated acoustic enclosure and granite table isolate the NX system from external acoustic and light noise for an improved performance. The walls of the acoustic enclosure are 40 mm thick, consisting of a 1.5mm stainless steel board, filled with soundproof material. The inner surfaces are covered with ESD coated micro fibers, which won't emit particulates. Acoustic enclosure reduces typically over 10 dB of acoustic noise level, varying with frequency. The Acoustic Enclosure also blocks EMI noise, and is specially coated to prevent electrostatic discharge.

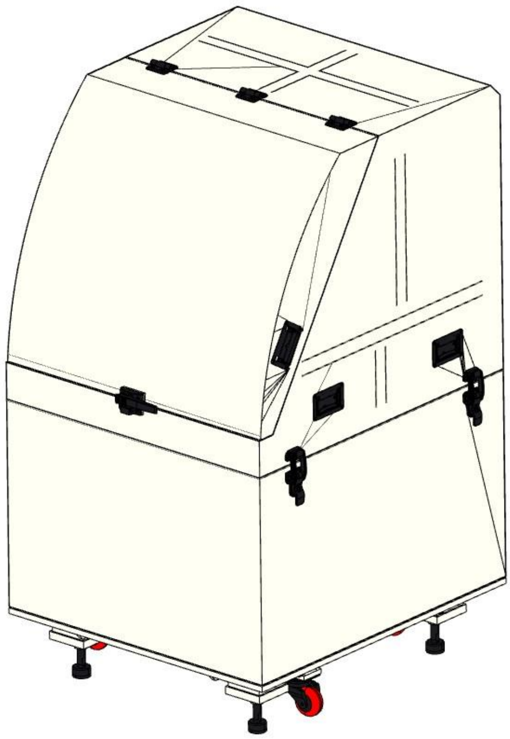


Figure 2-15. Acoustic Enclosure

2-6. NX12 Stand Alone Base (Optional)

NX12 Stand Alone is a part that provides Optionally when the equipment is used without IOM (Inverted optical microscope).

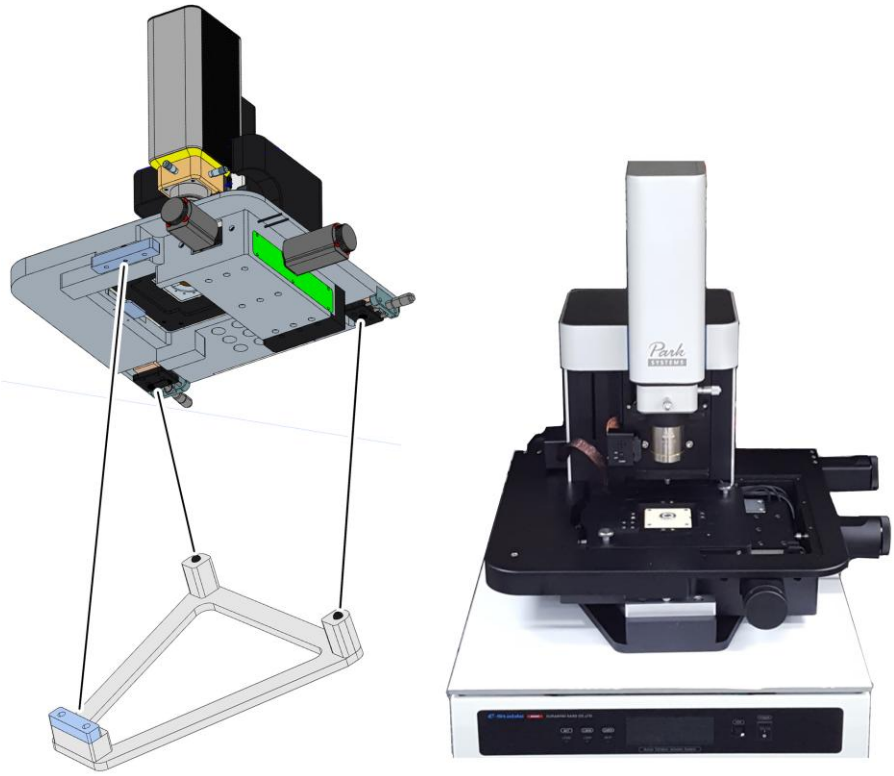


Figure 2-16. NX12 Stand Alone Base on Main Body

Chapter 3. Installation

The installation procedure and environmental specifications for the NX12 play a significant role in the safe operation of the system. Since the durability, safety and overall performance of the NX12 depend on the environment and proper installation, please pay close attention to the following installation environment and procedures that are recommended in this chapter.

3-1. Environment

Facility Requirements	
Room Temperature (Stand By)	10 °C ~ 40 °C
Room Temperature (Operating)	18 °C ~ 24 °C
Humidity	30% to 80% (not condensing)
Floor Vibration Level	VC-D (6㎛/sec)
Acoustic Noise	Below 65 dB
Floor Space (mm)	2440 (w) x 920 (d)
Ceiling height (mm)	2000 or more
Operator Working Space (mm)	2440 (w) x 1200 (d)

Table 3-1. Facility Requirement

- **Temperature and Humidity**

The NX12 should be installed in a clean, dry atmosphere with proper ventilation. The maximum acceptable relative humidity is 80% for temperatures up to 30 °C, and decreases linearly to 50% at 40 °C.

■ Vibration and Noise

The NX Series should be installed on a leveled and hard table for efficient operation. Further improvements can be achieved by placing the system in an acoustica lly shielded room, basement, or lower level of a building which is less susceptible tovibr ations. It is recommended that the AFM is installed near a wall or pillar.

As measurement dimensions decrease, the significance of noise from external vibrations increases.

Since the vibration can flow in through cables, system cables should not be stretch ed taut. The AFM should not be placed near fans or other sources of noise.

In addition to mechanical vibrations, AFM measurements can be influenced by acoustic and electromagnetic noise. Therefore, the AFM needs to be installed away from areas where there is great flow of air or electromagnetic radiation.

Temperature variance can also continbute noise, and can cause most types of samples to expand or contract on a significant scale. The AFM should be installed away from NX systems and windows.

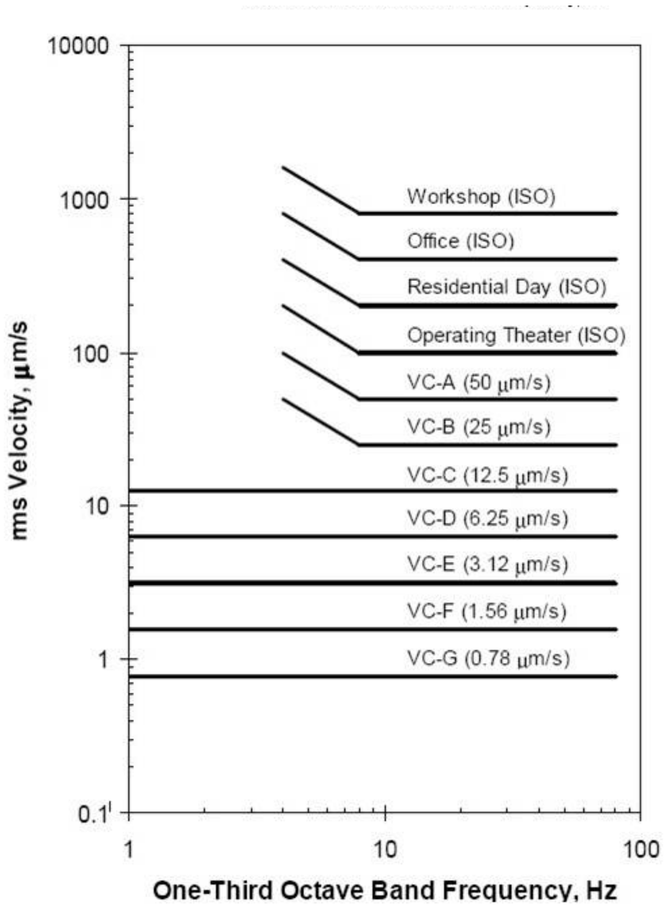


Figure 3-1. Vibration Criteria Graph

After determining a suitable location, the Acoustic Enclosure and Active Vibration Isolation System can be used to mitigate any remaining sources of noise.

The Vibration Criteria for the NX12 should be below the line labeled **“VC-D”** from t he criteria plot in Figure 3-1. The vibration level will be improved with the Acoustic Enclo sure and Active Isolation System. In this case, the Vibration Criteria would be below the dotted line labeled **“VC-C”**.

■ Electrical Requirements

-The NX12 requires an AC power supply.

-Power Supply: 100/120 V or 230/240V, Single Phase, 50~60Hz

-Consumption: 1000VA (max)

-Ground Resistance: Recommended below 100ohms

Since the NX12 SPM is highly sensitive equipment, it is ideal to use it with an Uninterruptible Power Supply (UPS) installed to provide a stable power supply. It is also recommended to connect all the ground pins in the power lines to a ground source to re duce noise.

■ System Layout

The following table displays system dimensions. The space requirement for the NX 12 system installation is shown in Figure 3-2.

Dimensions and Weight	Width (mm)	Depth (mm)	Height (mm)
NX12 (without IOM)	423	450.5	482
AFM Controller	450	480	190
Computer	178	445	448
Monitor	330	585	595

3-2. Component List

- NX12 SPM Main System

  NX12 Head with cable (Guided flexure Z scanner, 25 µm)

  NX12 XY Scanner with cable: Single module parallel-kinematics flexure scanner (100 µm)

  - Clip for Sample

  Cables

  - Motor cable, 50pin, 3m
  - Analog cable, 68pin, 3m
  - Crossed LAN cable
  - Power cable
  - Camera cable 3m

  NX12 Control Electronics
- PC
- Adapter stage for Inverted Optical Microscope (Optional)
- Enhanced Acoustic Enclosure for NX12 (Optional)
- NX Manuals
- NX Software Installation CD
- Accessories

  Standard Sample 1ea

  - 5 µm x 5 µm, 10 µm x 10 µm XY Pitch and 100nm Z height Grating

  Cantilevers

  - Silicon Cantilevers for Contact AFM (mounted on chip carrier) 10ea
  - Silicon Cantilevers for Non-contact AFM (mounted on chip carrier) 10ea
- Power Strip – 110V or Multi Tab – 220 V, Ground Type
- Tweezers 1ea
- Sample plate 10ea
- Clip type chip carrier 2ea
- Exchanger for clip type chip carrier 1ea
- Scanning Ion Conductance Microscopy (SICM) Module (refer to Chapter 6)

Options may vary when purchasing Premium System.

3-3. System Setup

3-3-1. Install Inverted Optical Microscope (IOM)

1. Carefully, place the Inverted Optical Microscope (IOM) to the center of the granite table in the AE.

WARNING!

Make sure that the MOD is “locked” before placing the IOM on top of the granite table.

3-3-2. Install NX12 Nikon System Stage Base

During the installation process, it might help with the tightening of the bolts if a long bolt was added to the shorter side of the wrench (the point where the force will be applied) and the added bolt was used to turn the wrench. This is a small tip in order to increase the torsional force of the wrench by extending the leverage.

Order of assembly: Assemble as seen in the picture below.

1) Install the System Stage Base using the bolts, M5X25.

2) Install the System flat surface using the bolts, M5X15.

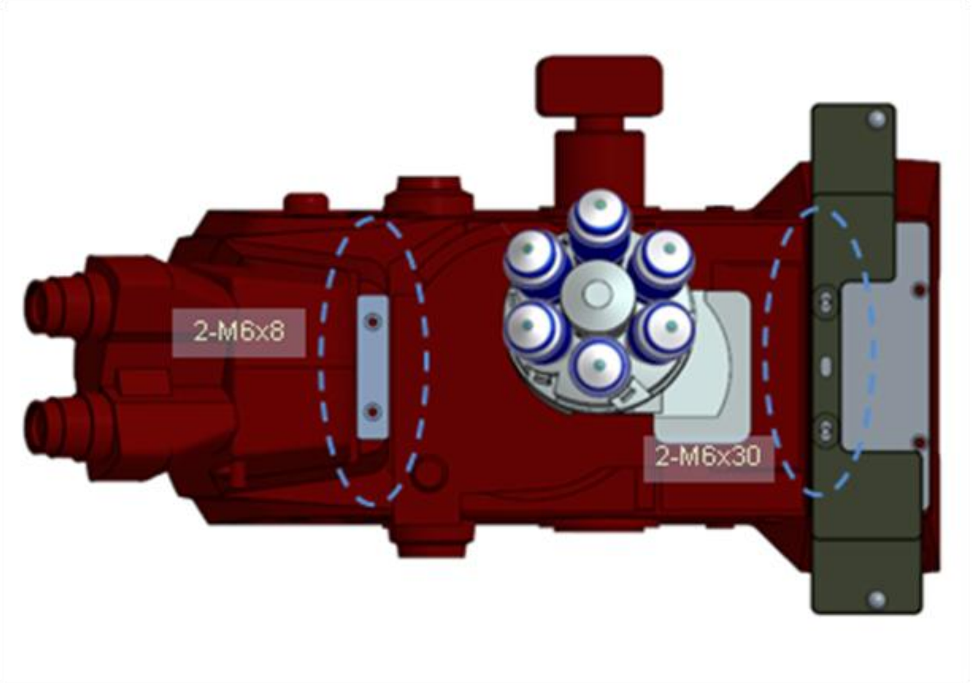


Figure 3-7. Nikon Flat Surface & System Stage Base Installation

CAUTION!

Make sure that the AVIS is "locked" when installing the System Base and the System Flat Surface to the IOM.

3-3-6. Load NX12 main system

1. Carefully place the NX12 main system on the system's stage base and syste m's flat surface.

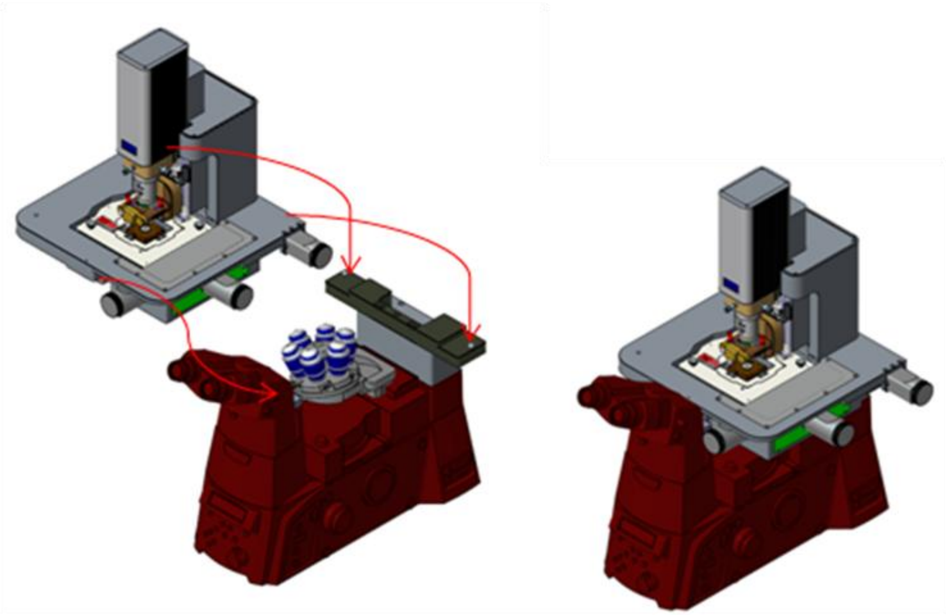


Figure 3-8. NX12 placed on IOM

CAUTION!

Make sure that the AVIS is "locked" when installing the NX12 main system.

3-3-7. Load Control Electronics & Computer/Monitor

1. Load the NX12 control electronics and placce the monitors/keyboard/mouse/PC onto the desk.

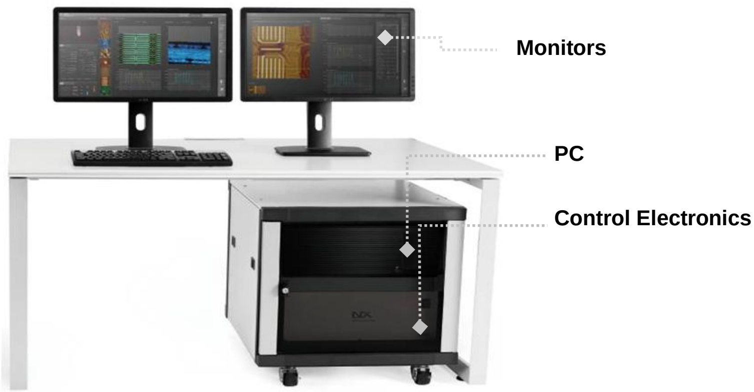


Figure 3-9. Electronics, Monitor, Computer Desk Setup

3-3-8. Cabling

1. **Required Cables**

   (a)Camera cable

   (b)Ethernet cable

   (c)Power Cable

   (d)Analog Cable

   (e)Motor cable

   (f)High Voltage cable

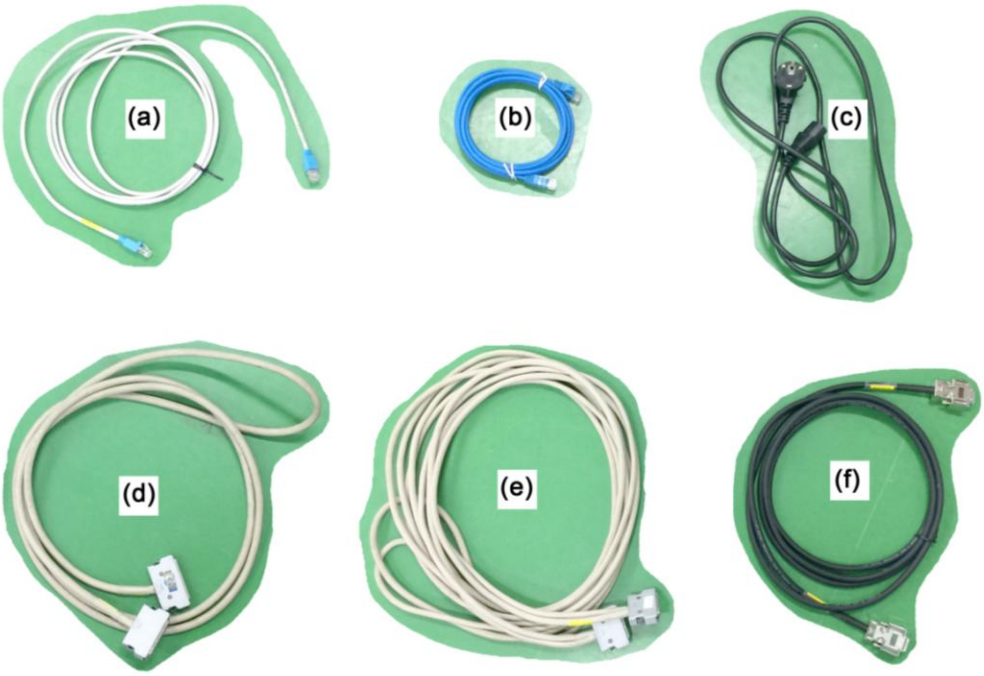


Figure 3-10. NX12 Main System Cables

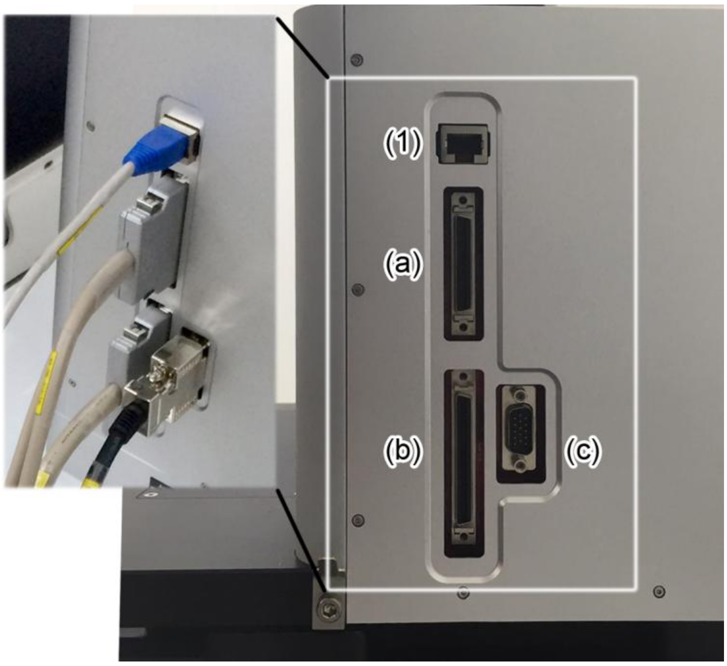


Figure 3-11. Cabling NX12 control electronics

2. **Cabling the NX12 main system**

1) Connect the **Camera cable** between the illuminator connector (1) on the back of the NX12 main system and the LAN port of the computer.
2) Connect the **Motor cable** between the 50 pin connector (a) on the back of the NX12 main system and the motor connector (A) on the rear panel of the NX12 control electronics.
3) Connect the **analog cable** between the 68 pin connector (b) on the back of the NX12 main system and the analog connector (B) on the rear panel of the NX12 control electronics.
4) Connect the **High Voltage cable** between the High Voltage connector (c) on the back of the NX12 main system and the Voltage connector (C) on the rear panel of the NX12 control electronics.
5) Connect the **Ethernet cable** between the Ethernet connector (2) on the rear panel of NX12 control electronics and the LAN port of the computer.
6) Connect the **power cable** (3) on the NX12 control electronics.

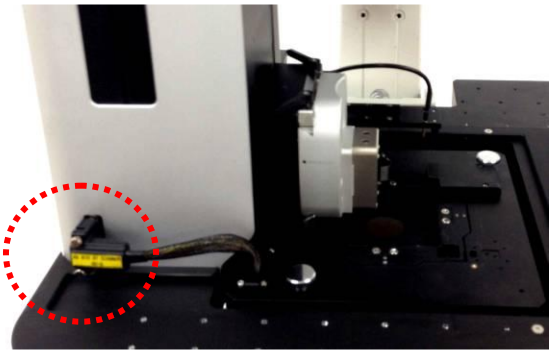


Figure 3-12. XY Scanner Cable Connection

7) Cabling Camera (Optional)

① Connect the **Camera USB Cable** between the camera on the side of the Inverted Optical Microscope and the LAN port of the computer.

Figure 3-13. CCD Camera Cable Connection

8) Cabling Computer

Please refer to the manual supplied by the computer manufacturer.

3-3-9. Power On

1. Connect to Power Supply

Connect the NX12 control electronics, the computer and the monitor to the grounded power supply. Make sure that all the switches are turned off to prevent any damage to the equipment.

2. Power On

Turn on the power supply of all the components of the NX12 system.

NOTE!

> The power on each component can be switched on in any order but the NX12 control electronics has to be turned on before running the SmartScan Software.

3-3-10. Installation Checkup

1. Run SmartScan™ program

Click the SmartScan™ icon on the main window screen or in the folder C:\Park Systems\SmartScan\Bin. The program will start and you can check to ensure that system initialization completes without any error messages. If there is a problem, check whether the power supply is on, and make sure all the components are arranged correctly as shown in Figure 3-14 Components Setup.

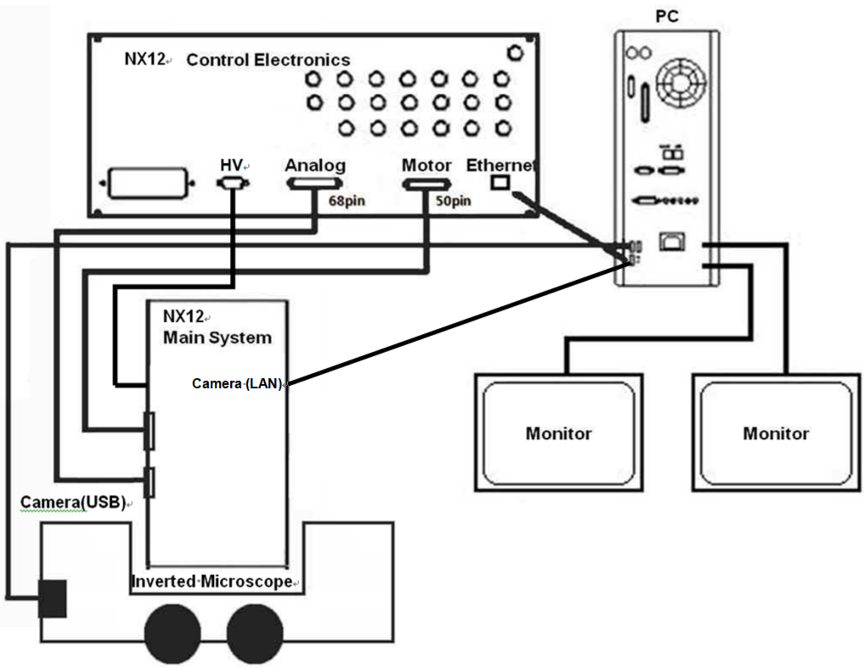


Figure 3-14. Diagram of Cables Connections for the NX12

2. Check Calibration of Scanners

① Load the standard sample on XY Scanner.

② Take image and check if the dimensions of the standard sample measured from the obtained image correspond to the specification of the standard sample.

3. Zero Scan Test

① Load a flat sample such as a bare silicon wafer into the magnetic sample holder of the XY Scanner.

② Mount Non-contact cantilever (NCHR) to the probehand.

③ Set the head mode to 'Contact mode' and approach the sample.

④ Set the XY/Z scanner range to 0.2 at part selection.

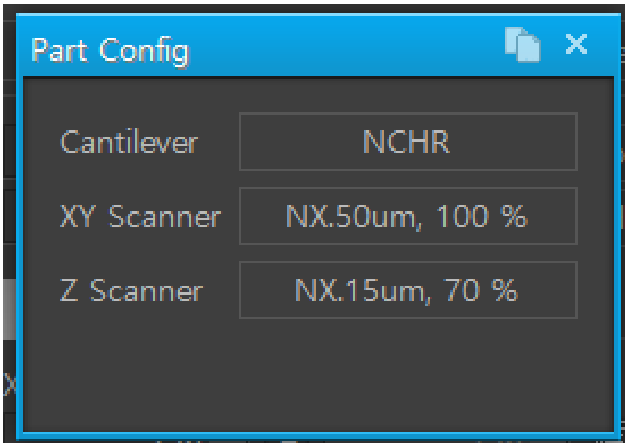


Figure 3-15. Scanner Range

⑤ Set Scan rate to 2 Hz, Gain 0.5, LPF 0, 256×256pixels and take sample image with a Scan Size of 0.

⑥ Open the obtained Height image on XEI and flatten with the following conditions.

[2nd Order line by line in both X and Y direction]

⑦ Check the RMS roughness of the processed image.

3-4. System Relocation

① Check the system (See Section 3-3-12) before transferring the system.

WARNING!

AVIS system (if you have it) should be in “Lock” mode in order to protect from outside impacts that may occur during shipping or storage (Please refer to the manual provided by the manufacturer for more detail of the AVIS system)

Lock the mini-450F
(Refer to the manufacturer’s manual for more detail of the AVIS system)
Before relocating the system, the AVIS should be in “Lock” mode in order to protect the Mini-450F from outside impacts that may occur during shipping or storage. If the AVIS is to be kept in storage or transported, you may scroll the screen while the power is still on, until the message “to lock push↲ ” appears. Pushing the “↲ ” button will initialize the motor which slowly lowers the isolation stage until it finally halts. You may turn off the power when the “System locked’ message appears. The AVIS will remain locked until the power supply is turned on again.

① Reset the motorized Z stage by selecting the [Reset] button.

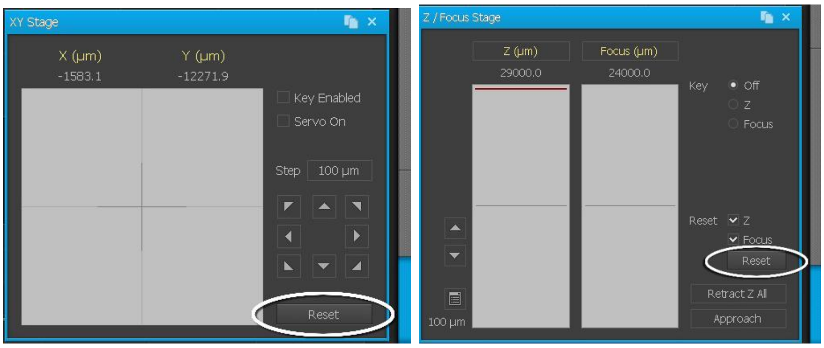


Figure 3-16. Reset the motorized Stages

② Turn the NX12 system’s [Control Electronics, Computer, Monitor] power off.

③ Disconnect the cables.

④ Lift the foot of the acoustic enclosure.

⑤ Relocate the acoustic enclosure to the new installation site by pushing it using the wheels on the bottom.

WARNING!

Do not move the acoustic enclosure with the NX12 main system inside it as the system can be damaged when the acoustic enclosure passes some bumps on the floor. Move the NX12 main system separately from the acoustic enclosure.

Figure 3-20. System Relocation

⑥ Set up the NX12 system after finishing the system relocation. Refer to Section 3-3.

Chapter 4. Sample Loading

4-1. Lift NX12 Head

First, raise the head high enough so that you have no difficulties in loading the sam ple onto the XY scanner.

CAUTION!

If the head is not rasied high enough, the sample or the cantilever may be damaged.

4-2. Load Sample on the XY Scanner

4-2-1. Using the Clip

1. Remove the XY scanner sample chuck.
2. Mount the clips to the scanner using the M2 x 3 S/H bolts first.
3. Loose the fixing bolts a little and put the sample between and tighten the bolts.

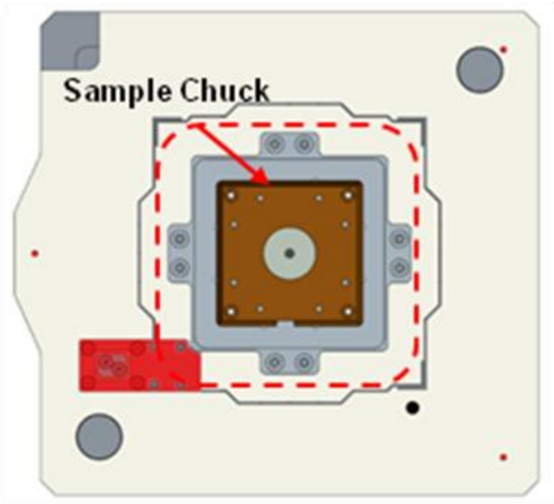


Figure 4-1. Assemble Sample Holding Clip

CAUTION!

Mount the clips so that the end of the clip heads towards the Z stage.

4-2-2. Using Sample Chuck (For On-axis Optics)

When using the on-axis optical microscope, the sample chuck with a magnetic sample holder can be used to fix the sample. A magnetic holder allows samples prepared on metal plates to be easily loaded onto the scanner. In this case, attach the sample on the sample plate with superglue, tape, etc. There is the sample bias connector on the sample chuck. The sample bias line is easily connected using the cable between the sample chuck and the XY scanner. Voltage biases can be applied to a sample in electrical contact with a metal plate by way of the magnetic sample holder. Using the inverted microscope, please remove the sample chuck to allow us to observe the sample or cantilever/nano-pipette.

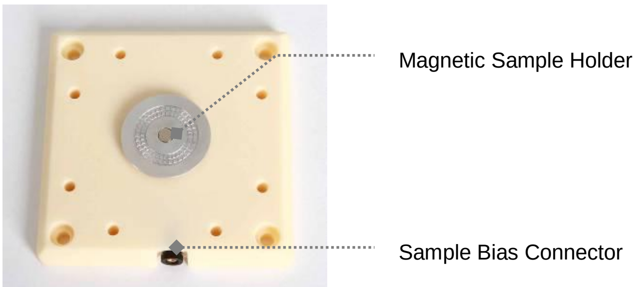


Figure 4-2. Sample Chuck

There are four holes from the sample chuck on the XY scanner. Install the sample chuck on them with bolts and the 2mm wrench.

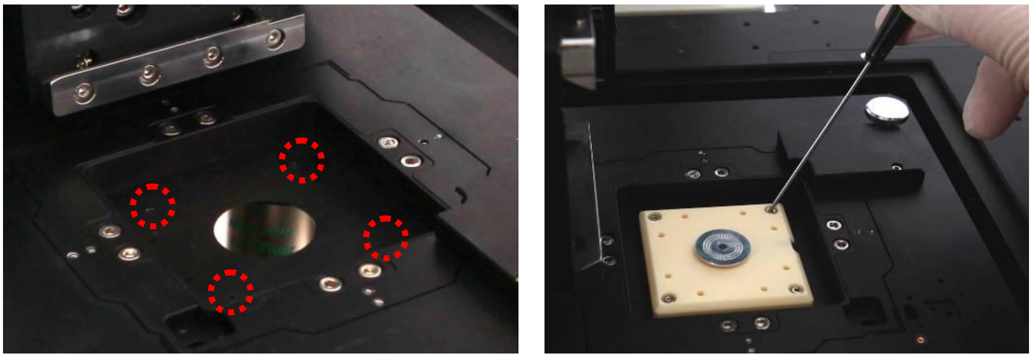


Figure 4-3. Magnetic Sample Holder

When the sample is larger than a sample plate it can be placed directly on the sam ple chuck after removing the magnetic sample holder. (remove magnetic sample holder by turning it counter-clockwise). In this case, however, the sample may have some drift during imaging because it is not as securely fixed.

To fix the sample on the sample plate, the glass or etc, you can use one of the following methods:

■ **Instant Adhesive**

You can fix the sample using an adhesive. Hard-setting adhesives such as cyanoac rylate glues are recommended; otherwise, the sample may move significantly during the imaging procedure. When the sample is glued on a metal sample plate using an electro -conductive adhesive, such as silver paste, it will be grounded through the magnetic sa mple holder, but it will also take a longer time to dry.

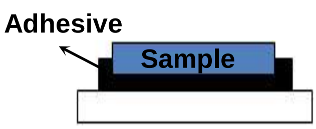


Figure 4-4. Instant Adhesive

■ **Tape**

You can fix the sample using tape. When using tape to fix the sample, it makes it easy to secure and detach, but may cause drift because its adhesion is not as strong as superglue's. Using double sided tape will lessen this problem, but the user should be aware that the sample position will take some time to stabilize due to minute changes in the thickness of the tape underneath the sample over time.

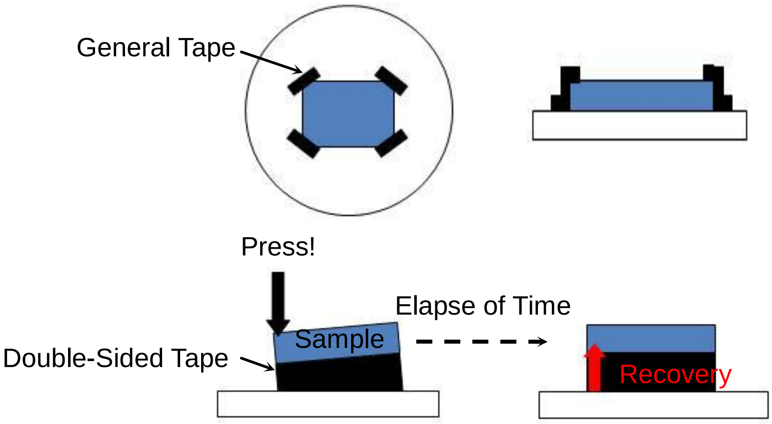


Figure 4-5. Tape

When the sample is a film, the user should be especially careful when mounting it in preparation for imaging because unintended gaps between the tape and sample can allow the film to move during scanning.

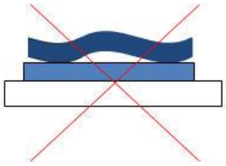


Figure 4-6. Air between Sample and Tape

Chapter 5. Operating Concept

5-1. Basic Operating Concept

The NX12 scanner is separated into an XY scanner and a Z scanner instead of the single piezoelectric tube scanner used in most other SPMs. The XY scanner moves the sample in the horizontal directions for the range you want to image. The Z scanner mov es the cantilever in the vertical direction to trace the morphology of the sample. These i ndependent movements of the XY direction and the Z direction are combined to make a three-dimensional image.

There are two measurement types for XY Scanner. ‘Closed Loop’ and ‘Open Loop’ measurements are possible depending on the status of the XY Servoscan. ‘Closed loop’ refers to when XY Servoscan is “ON” and ‘Open loop’ is when XY Servoscan is “OFF”.

In general, piezoelectric materials display nonlinear behavior in response to an appl ied voltage. Therefore the scanner, which is made of a piezoelectric material, displays n onlinearity and hysteresis (Refer to Chapter 1). When the scanner’s range of motion inc reases, nonlinearity and hysteresis can be calibrated by means of hardware corrections

In the NX12 system, detectors are used to measure the actual movement of XY or Z scanners. This information is compared with the desired movement, and discrepancie s are corrected for by modifying the voltage applied to the scanner. This ServoScan syst em effectively eliminates the nonlinearity of the piezoelectric actuators.

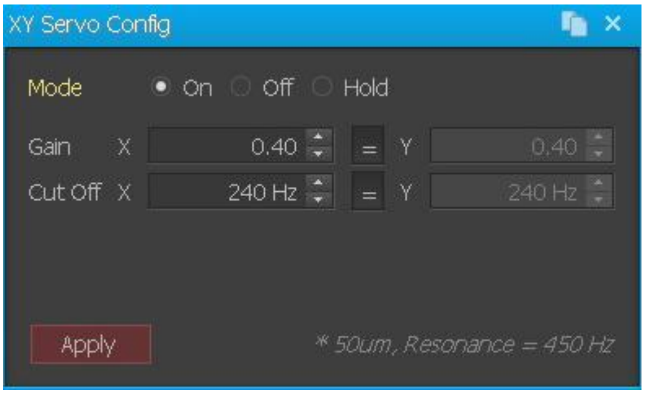


Figure 5-1. XY Servoscan is ON

Figure 7-2 depicts the maximum XY scan range as a solid gray-shaded square. The area outside of this square cannot be observed. For example, if the scanner's maximum range is 100 ㎛, it is not possible to scan both areas ***A*** and ***C*** even though they have the same scan size (30 ㎛). Area ***A*** is impossible to scan because its offset (the black point) extends its range over the maximum range of the scanner. Area ***C***, however, is possible to scan. Also, although ***B*** and ***D*** have the same size and the same offset, it is impossible to scan area ***B*** which extends over the maximum range due to its different angle of rotation. Whenever the user enters an "excessive range" like ***A*** and ***B***, the scan range will be changed automatically to an observable area that falls within the scanner's maximum allowable range.

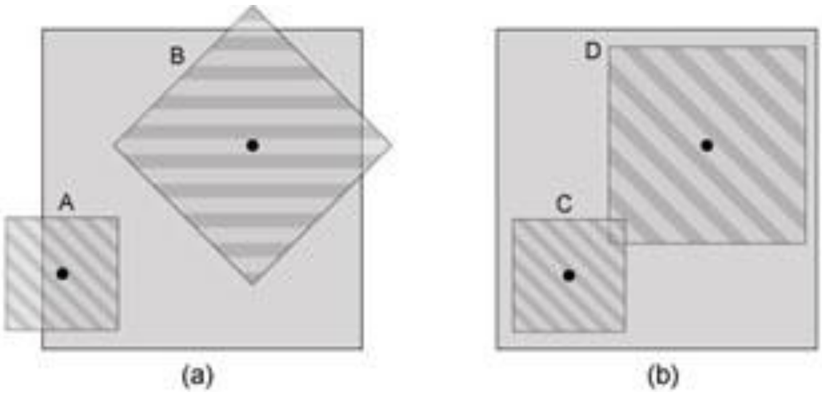


Figure 5-2. Scanner's observable area

The lateral resolution of an image acquired by AFM is calculated by dividing the sca n size by the pixel size. If you measure a 10 ㎛ square image with 256 x 256 pixels, the lateral resolution is 10 ㎛/256 = 39.1 nm. This means the size of one data point in the 1 0 ㎛ square image is 39.1 nm. Even though you can increase an image's pixel count to get higher lateral resolution, it will take a much longer time to acquire an image. Another solution to getting higher resolution data is to decrease the scan size. If you measure a 100 nm image with 256 x 256 pixels, you can get a lateral resolution of 3.91Å per data point. Therefore, when you want to measure fine structure, it is desirable to reduce the s can size.

Also, the scanner's ability to make an elaborate motion is another factor that influen ces the lateral resolution. The scanner expands or shrinks in proportion to an applied vo ltage. Hence, you can manage the scanner's motion more precisely by dividing the appli ed voltage into smaller units in the DAC (digital-to-analog converter). The NX12 system uses a 20-bit DAC for controlling scan movements in X and in Y. A 16-bit DAC is used fo r determining scale so that the scanner's motion and position can be elaborately controll ed. When an applied voltage that can make the scanner move 100㎛ is controlled using a simple 20-bit DAC, the lateral resolution is 100 ㎛ / 2^{20} = 0.95 Å .

The resolution of the Z scanner can be adjusted by limiting the Z scanner's motion r ange. The number entered in the text box labeled Z scanner range can be regarded as a proportionality factor relating the Z scanner's maximum amount of movement. Basicall y, if the Z scanner Range is 1.0, then the Z scanner in the standard head can move thro ugh a 15㎛ range. However, if the Z scanner Range is 0.5, then the Z scanner's maximu m movable range would be reduced to 7.5㎛. This adjustment that effectively reduces th e Z-scanner's maximum range results in an increase in vertical resolution. To use the Z scanner Range feature effectively, you should consider two points: the z-scanner's avail able maximum range and the vertical resolution. Before adjusting the Z scanner Range, one must first consider the overall height variation of the sample surface. This height diff erence should not be greater than the Z scanner's maximum available range. For exam ple, if a sample has 30㎛ height difference, it cannot be measured if the standard head i s used.

■ XY Scan Method

The XY Scanner movement is controlled using piezoelectric elements which expan d or contract in length in response to an applied voltage. This allows for circuits containi ng several DACs (digtal-to-analog converter) and high-voltage amplifiers to electronicall y drive the XY Scanner in a raster pattern while imaging samples.

That is, the X scanner moves the sample first along a line from left to right and then retraces this line until it is back to its original position. Next, the Y scanner takes a singl e step along the orthogonal direction and the process repeats. In this way, the XY Scan ner can get two dimensional data by repeating the process many times. The user can d efine the amount of data per line and the number of lines to be collected, corresponding to image pixel width and height, respectively AFM data is most commonly collected in s quare, n x n pixel scans. In this example, the X direction is known as the fast-scan direc tion and the Y is known as the slow-scan direction (See Figure 5-3). The fast-scan direc tion can be selected by software arbitrarily within the XY-plane the slow-scan direction w ill always be orthogonal.

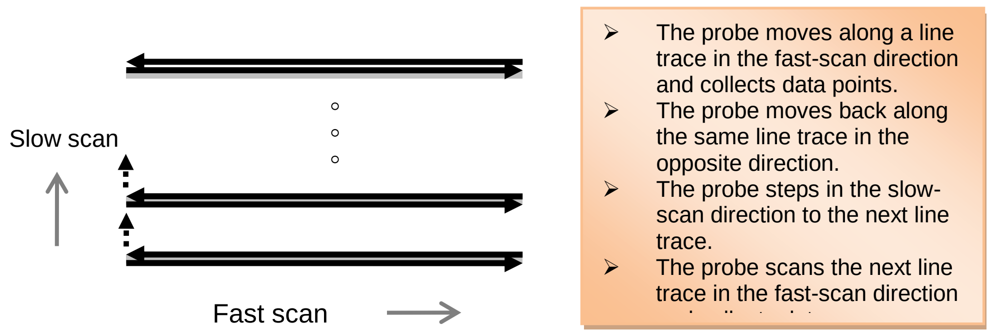


Figure 5-3. Standrad Scanning

■ **Z Scan Method**

When the XY Scanner is moving in the fast scan direction, the Z scanner is vertically moving to track the sample morphology. The AFM image is created by the digitized Z scanner feedback signal which is collected at every X and Y position corresponding to a pixel as defined by the user's scan parameters. Point data is acquired and forms a line; this line is a collection of consecutive points throughout the X axis, in form of digitalized data that derives from Z scanner's feedback signals. Second, these lines are now consecutively acquired along the Y axis, thus creating an AFM image. The brightness of the AFM image indicates the sample height information. Park SYSTEMS AFMs have strain gauge sensors on the Z scanner in order to accurately measure sample heights regardless of the non-linear characteristics inherent to all piezoelectric devices.

5-2. Image Data Type

Unlike other common file formats, the 'TIFF' files have tags. The 'TIFF' file format includes a header and many tagged fields. The tagged fields can describe dimensional information such as the width and the height of the images so that the software that handles the 'TIFF' file can read these tagged fields and then extract information from them in order to generate images to display in the image viewer. Consequently, the 'TIFF' does not affect the original image file and has superior compressibility as well as no resolution limit. These advantages make the TIFF format ideal for handling larger, capacious files.

The data files produced by conventional SPM instruments are not a common image file format. Thus, to see these acquired images in an Image viewer and the traditional Windows Explorer display, it is necessary to change the file format saved by individual SPM instruments into the image file format by using image processing software.

If the collected data is saved as a common image file format, it may be quite conve nient to view the images without any special software conversion process of the informa tion file. However, this is difficult since conventional image file formats include only imag e data (R, G, B) and cannot save the large amount of sample data which is measured b y the NX systems.

Considering these difficulties, the TIFF format is a more flexible means of storing S PM images. Therefore, in the NX system, the image data is saved as a 'TIFF' file format, in which a huge amount of data can be saved in the private-tagged area and the acquir ed images from this data can be saved in the standard-tagged fields as an image file so that it can be viewed in the common image viewer.

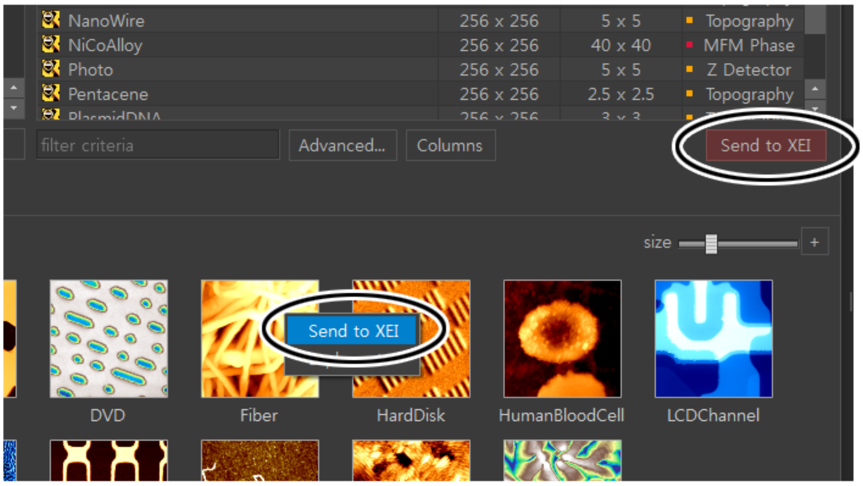
When you see the NX system's acquired data in the common image viewer, you ca n identify this data as a familiar sample image, and you can process the images without transforming original measurement data.

The part changed in the common Image viewer is the information that is saved in th e standard-tagged fields of the data file. Therefore, the collected data saved in the privat e-tagged field will be secure from the transformation of the data in the image viewer. Thi s data may be changed or processed in the XEI image processing program.

- **Data Export**

Obtained images can be exported to Text or bitmap format to allow analysis by exte rnal software. Tiff files can be exported in the form of a text file or an image file (jpg, png, bmp, and emf) from the "Export" command in the context menu of the Image display pa nel in the XEI image processing program. The raw tiff file consists of two parts, the scan data and the image. When the tiff file is exported as a text file, the file will contain basic information about the tiff file and the data array of the scan data. When the tiff file is exp orted as an image file, the exported image file only includes the image of the tiff file but not the scan data within it; the image will not include any dimensional information.

On SmartScan



On XEI

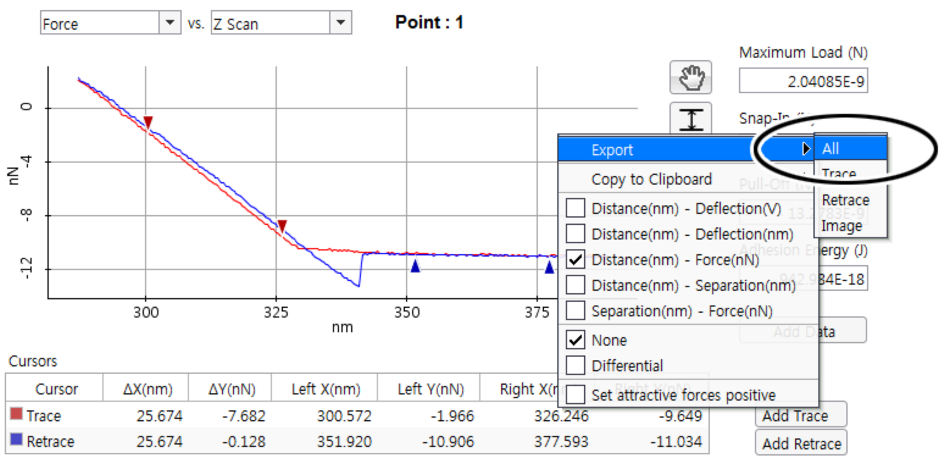


Figure 5-4. Data Export

Chapter 6. Initial Setting

Once you are ready to use your NX SPM to perform the sample measurement, you can follow the procedure described in this chapter to get started. This chapter describes the basic procedures required before taking any SPM measurement with your NX system.

6-1. Power On

1. Turn on the components of your NX12 system
   [Computer, Monitors and Control Electronics]

NOTE!

> The Control Electronics must be turned on before the SmartScan Program is started; otherwise, you will receive a initialization error message and will need to restart SmartScan.

2. The NX12 is operated by the SmartScan™ software. When you click the Smart Scan™ icon in the desktop or in C:\Park Systems\SmartScan\bin of your compu ter, you can start SmartScan™, the software program for controlling NX12.

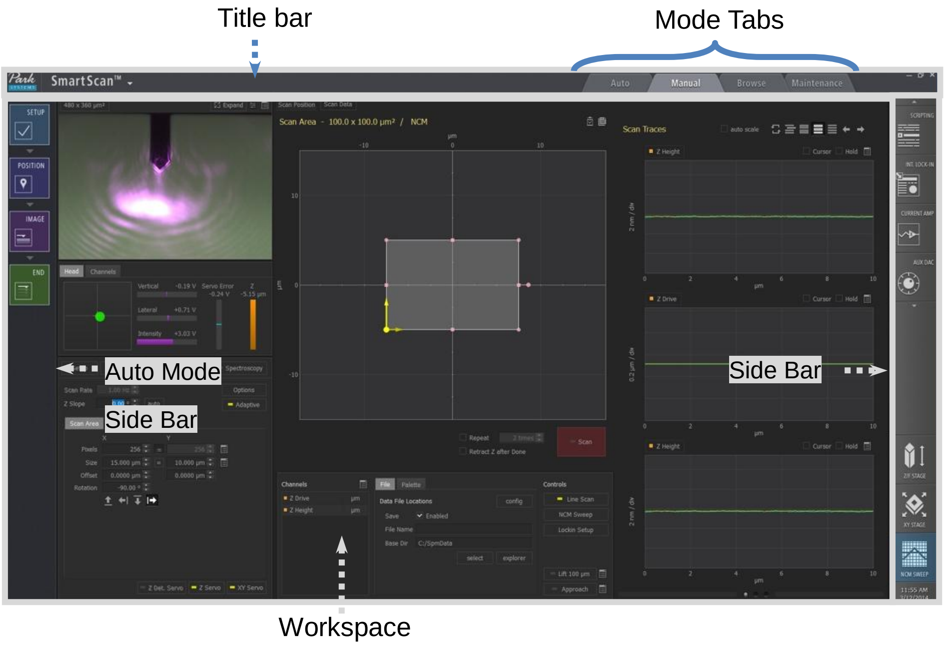


Figure 6-1. SmartScan User Interface

6-2. Sample Loading

Prepared samples must be loaded onto the NX stage using the following steps:

1. First, raise the head high enough so that you have no difficulties in loading the sample onto the XY stage.

NOTE!

> Before you use the XY stage pad, be sure to lift the tip off the sample by using the Z stage control pad.

WARNING!

> When the Z scanner's arm and the sample are very close, any rapid movement of the Z scanner may cause the scanner's arm to collide with the sample. This may result in severe damage to the probe tip, the sample, and/or the scanner itself.

NOTE!

The cantilever depiction in the Z Stage pad is not the center bar. Treating it as the center bar will result in unintended movement of the Z Stage.

2. Load the sample on the XY Scanner.

   - (Using IOM) Fix the sample on a petri-dish using an adhesive. Place the petri-dish on the XY stage after removing the sample chuck. You should use a petri-dish with a 9mm or less height for AFM measurement otherwise the tip cannot approach the sample properly. You can use a liquid chamber provided with the Universal Liquid Cell instead of a petri-dish.

   - (Using IOM) Fix the sample on the glass slide. Place the slide on the XY stage using the clip.

   - (Using On-Axis Optics) Fix the sample on a sample disk using an adhesive. Hard-setting adhesives such as cyanoacrylate glues are recommended; otherwise, the sample may move significantly during the imaging procedure.

     Place the disk on the magnetic sample holder. The magnet will keep the sample disk in place. If the sample is large, unscrew the magnetic sample holder from the XY sample chuck and place it directly on the XY Scanner.

CAUTION!

Mount the clips so that the end of the clip heads towards the Z stage.

3. Locate the sample underneath the probehand using the XY stage control.

NOTE!

Before you use the XY stage pad, be sure to lift the tip off the sample by using the Z stage control pad.

WARNING!

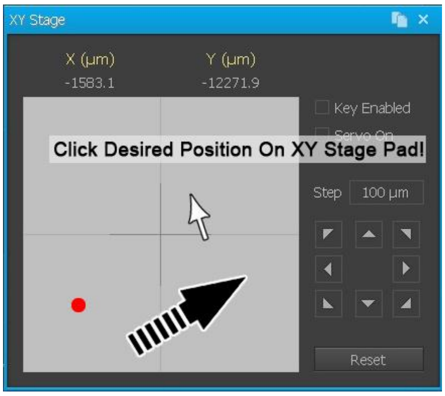
When the Z scanner's arm and the sample are very close, a rapid movement of the Z scanner may cause the scanner's arm to collide with the sample. This may result in severe damage to the probe tip, the sample, and/or the scanner itself.

NOTE!

The cantilever depiction in the Z Stage pad is not the center bar. Treating it as the center bar will result in unintended movement of the Z Stage.

***XY Stage Control Window**

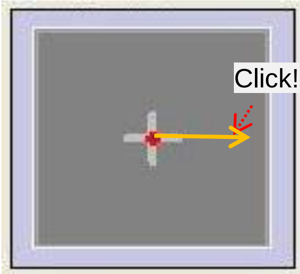
For the NX10, you can see both XY and Z/F stage pads on the screen. If there is no "X-Y stage control window" on your computer screen, you can open this window by clicking the X-Y stage icon.



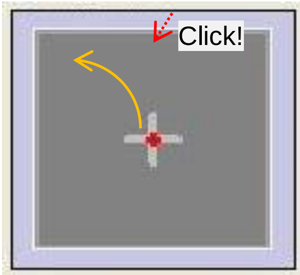
The XY stage pad is used to move the tip around the sample surface before you take an image. The XY stage can be moved in both the x and y directions, which moves the sample relative to the probe tip. The XY stage pad controls both the direction and the speed of the XY stage. Move the cursor with your mouse and click the cursor where you want to get images in the X-Y stage pad, then the X-Y stage will move in the opposite direction so that the NX head move to the defined location. The red point represents the position of the NX head, and you can see its movement by watching this point. This allows for convenient repositioning of the NX head around the sample surface. To increase the speed of movement, click the cursor further from the center cross on the XY stage pad.

***Optical Stage Control Window**

For the NX12, you can see the Optical stage pad on SmartScan as below. The Optical stage pad is used to move the NX12 main body except for the XY scanner.



Optical Stage goes to → direction!



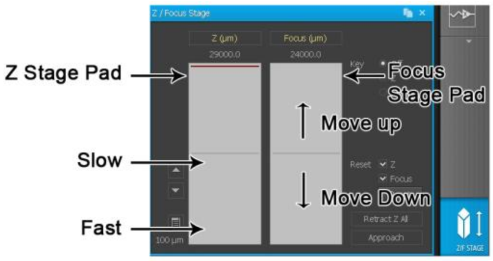
Bio Stage goes to ↰ direction!

Since the Optical stage is attached on a kinematic mount, the Optical stage can be moved in the r and Θ directions and differ with the XY stage control window. The Optical stage pad controls only the direction from the current position. Move the cursor with your mouse and click the cursor in the direction where you want to move in the Optical stage pad, then the NX12 main body attaching the head will move in that direction. The red point represents the current position of the NX12 head, and you can see its movement by watching this point. This allows for convenient repositioning of the NX head around the sample surface. You can change the moving speed by controlling the speed per one step (X/Y Step).

*Z Stage Control Window

The Motor Control window contains the Z Stage and Focus components. These control pads are used to lower or raise the Z Stage and Focus Stage

Clicking above the center bar will raise that stage, and clicking below the center bar will lower it. The speed depends on how far away from the bar you click. The NX10 Focus stage's movement is synchronized with that of the Z stage. Therefore clicking Z stage pad will move the Z stage and the Focus stage together. However clicking Focus stage pad will move the focus stage only.



CAUTION!

When the encoder is not installed in the Z Stage, the displayed value on the Z(μm) digital panel does not match the exact coordinate of the Z Stage. Therefore, please make sure to verify the distance between the tip and sample with optical microscopy.

6-3. Focus on Sample Surface

-Focus on the sample surface by adjusting the inverted optical microscope.

-The view from the optical microscope can be seen in the vision panel on SmartScan or UEYE. You can turn on the vision panel by clicking the button in SmartScan. You can click this button a second time and drag the window to the second monitor for convenience. Also, you can turn on UEYE by clicking the button.

6-4. Cantilever/Nano-pipette Mount

6-4-1. Remove Head from NX12 Main System

1. Confirm that the head has clearance. If it is too close to the sample, raise the Z stage.

2. Turn off the AFM beam switch for the AFM head.
   Take off the pipette for the ICM head.

3. Unlock the dovetail locks on the sides of the head. Disconnect the head from th e connector of the NX12 main system. Then, slide the head out to the right.

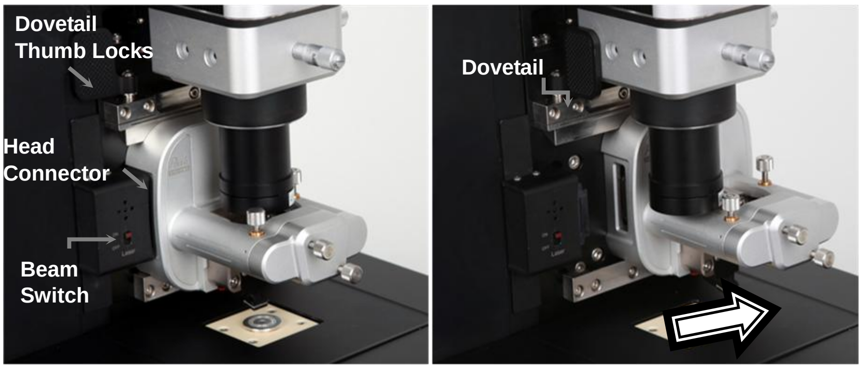


Figure 6-2. Removing NX12 Head

6-4-2. Mounting Cantilever/Nano-pipette onto Head

- **Mounting Cantilever**

1. Mount the cantilever onto the probehand on the head. To ensure no damage to the cantilever occurs, the cantilever chip mount should be held between your th umb and your index finger. The alignment is simple since two holes on the chip mount should fit directly over the two ruby balls on the magnetic tip holder on the probe hand.

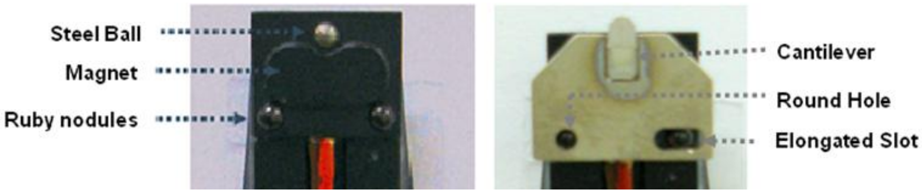


Figure 6-3. Load Cantilever onto Probehand

2. The center of the camera on the monitor screen is the approximate position of t he last user's cantilever, and therefore the beam. It is very important to NOT adj ust the optics in order to find the cantilever/laser beam more easily.

6-4-3. Attach Head to NX12 Main System

1. Attach the head to the NX12 main system in the inverse order of Section 6-4-1.

6-5. Select Head Mode/Cantilever

1. Attach the head to the NX10 main system in inverse order of Figure 6-5
   Turn off the Line scan by clicking the Head mode box to select Head mode and then clicking the Setup box in the SmartScan™ software.

2. Select the desired Head mode in this SmartScan™ Part Selection dialog. Then, turn on the Line scan.

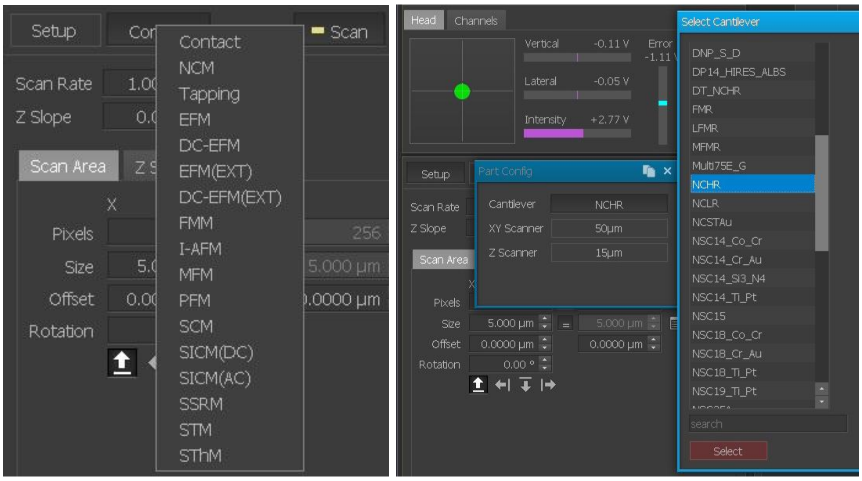


Figure 6-5. Part Selection Dialog

6-6. Find Cantilever/Nano-pipette using IOM

NOTE!

The center of the camera on the monitor screen is the approximate position of the last user's cantilever/nano-pipette, and also of the beam in the AFM measurement. It is very important to NOT adjust the NX12 Body Stage using the motor control.

- Focus on the sample surface.
- Move the Z stage down until the shadow of the cantilever/nano-pipette is shown.
- Focus on the cantilever in the case of AFM Modes.
- Position the cantilever/nano-pipette on the center of the optical camera moving the motorized NX12 Body Stage.

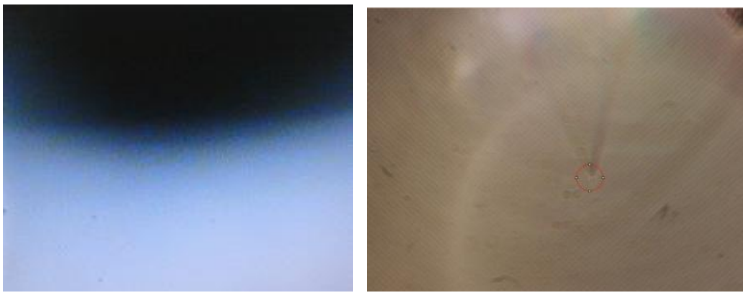


Figure 6-6. Shadow of (Left) Cantilever & (Right) Pipette on Sample Surface

6-7. (Align Beam on Cantilever)

You may skip this section for SICM measurement.

The AFM obtains images of the sample surface by detecting the bend of the cantile ver using the position of a reflected laser beam since these deflections are too small to detect directly. Align the laser beam on the backside of the cantilever.

1. Focus on the Cantilever:

2. Find the Beam Spot: While turning the X beam alignment (large knob on the left side of head) CLOCKWISE, you should see the beam spot move downward. Position the beam spot onto the backside of cantilever.

3. Turn the Y beam alignment knob and position the beam spot along the edge of t he cantilever chip.

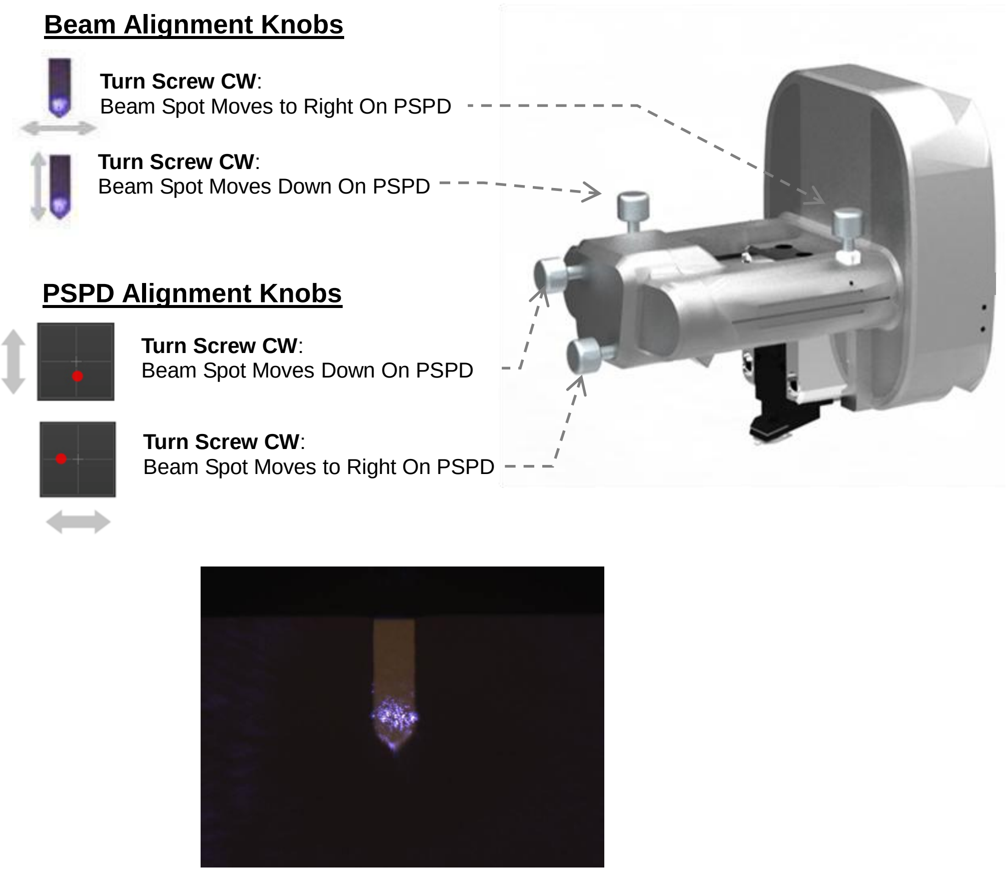


Figure 6-7. Beam Alignment Controls

NOTE!

> If you don’t observe ALL of the above, then the spot you see on the cantilever is not the direct laser beam.

NOTE!

> When the beam spot cannot be found, you can easily find it using the IR chip carrier. Please refer to Appendix D for details regarding how to use it.

6-8. (Align Beam on PSPD)

You may skip this section for SICM measurement.

The reflected laser beam from the cantilever travels to the PSPD (position sensitive photo detector) where its position is tracked. This data is then fed into a feedback loop controlling the vertical motion of the Z scanner. This feedback is active at all times when the AFM is powered on. This detection scheme allows cantilever movement smaller tha n an atomic radius to be measured by the AFM.

Align the reflected laser beam from the cantilever to the PSPD by controlling the P SPD alignment knobs. ,

1. Turn the Y PSPD alignment knob to maximize INTENSITY.
2. Turn the X PSPD alignment knob to maximize INTENSITY.

NOTE!

Align the PSPD to find the maximum INTENSITY signal. The easiest way to do this is to change only one alignment knob at a time (either the X or the Y) until a maximum is found, then move to the other knob and repeat the process. If you adjust both knobs at once, the process will be difficult.

CAUTION!

If the PSPD alignment knob is too tight or loose during adjustment, the Sus ball between the knob and mirror can fall out. The laser beam will not align to the PSPD when the knob is too tight or too loose.

3. Repeat steps 1 and 2 until beam intensity become maximized (2-3V when the b ackside of the cantilever is, as is general, metal-coated) on PSPD.

NOTE!

Sometimes if the backside of the cantilever is rough or coated, INTENSITY can be smaller and bigger. In general, when the cantilever surface is not coated with metal, the INTENSITY value is closer to 1V because of the difference in surface reflectivity.

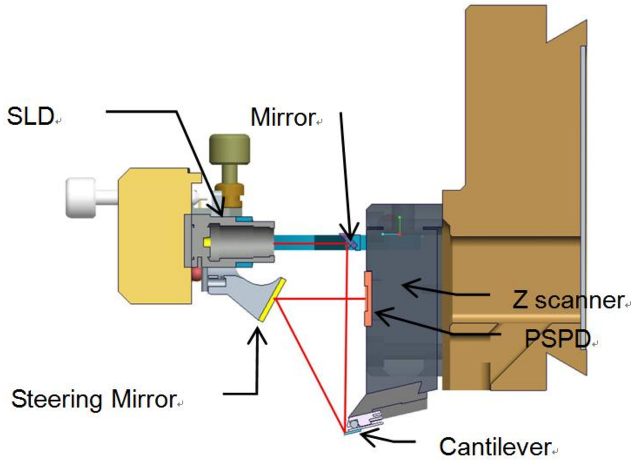
4. When INTENSITY is maximized, turning the X PSPD alignment knob (small rig ht knob on the front of the head) CLOCKWISE will move the red spot on the PS PD to the LEFT. Turning the Y PSPD alignment knob (small left knob on the fro nt of the head) CLOCKWISE will move the red spot on the PSPD UP. By adjusti ng the knobs, position the beam spot (red spot) on the center of the PSPD in S martScan so that VERTICAL, C-D value is smaller than ±0.5V.

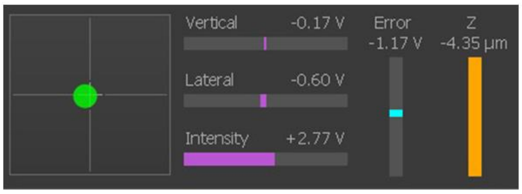
NOTE!

Turning X or Y PSPD alignment knobs can make the INTENSITY (beam intensity) suddenly smaller. In this case, stop turning X or Y PSPD alignment knobs and turn it the opposite direction.

When INTENSITY value on PSPD is too small:

Even if the VERTICAL value is within the acceptable range, if the INTENSITY value is too small, then it may be difficult for the beam to approach the center of the PSPD, and for the tip to approach the sample properly. Therefore, a proper INTENSITY value should be obtained prior to adjusting VERTICAL. If INTENSITY is too small, then the beam path depicted in the figure below is not optimized. If this happens, using the IR detector card, check if the beam is located in the beam path. After adjusting the direct beam spot on the PSPD, proceed to the next step of PSPD alignment.





6-9. Approach and Image

Please approach the cantilever/nano-pipette end to the sample surface according to each mode imaging process and acquire an image. Definition of the parameters in the Scan Control Window for imaging is explained below:

- **Repeat**: After selecting “Image”, the same area will be imaged repeatedly.
- **Two way**: Successive images will be acquired by alternating the slow scan direction.
- **X,Y**: The fast scan direction can be chosen to be either the X or Y axis.
- **Slope**: The slope of the tip/sample interaction can be adjusted via software.
- **Scan OFF**: The XY scanner is stopped while the Z scanner continues to operate and maintain feedback conditions.
- **Offset X, Y**: Specifies the center of the scan area in a relative coordinate system with (0,0) being the center of the XY scanner.
- **Rotation**: Allows the direction of scanning to be changed within the range of –45˚~＋45˚.
- **Z Servo**: Select Z scanner feedback on/off
- **Z Servo Gain**: Controls the sensitivity of the Z scanner feedback loop. If this value is too high, the Z scanner will oscillate, producing noise in the image or line scan. If it is too small, then the AFM probe will not track the sample surface properly.
- **Set point**: In AFM Contact mode, it specifies the force that will be applied by the end of the tip to the sample surface when the system is in feedback. In AFM Non-Contact Mode, the absolute value of the set point refers to the distance between the tip and the sample surface, representing the cantilever’s amplitude change due to attractive forces between the AFM probe and the sample surface.

  In SICM (DC) mode, it specifies the ion flow between the sample electrolyte and the Ag/AgCl electrode through the nano-pipette hole when the system is in feedback.

- **Tip Bias**: Controls the voltage applied to the tip when EFM or C-AFM modes are used.

Chapter 7. Atomic Force Microscope (AFM)

The Scanning Probe Microscope (SPM) proved false the prevailing concept that an atom is too small to be observed with even the best microscope. It now has every right to be called the third generation microscope, with optical and electron microscopes being the first and second generations. Whereas the maximum magnifying power of an optical microscope is several thousands and that of a scanning electron microscope (SEM) is tens of thousands, an SPM has the magnifying power of tens of millions, enough to observe individual atoms. Even though a transmission electron microscope (TEM) has the lateral resolution high enough to image at the atomic level, its vertical resolution is much weaker at observing individual atoms. On the other hand, the vertical resolution of SPM is even better than its horizontal resolution making it possible to measure on the scale of fractions of the diameter of an atom (0.01nm).

The SPM, with its exceptional resolution not only makes it possible to understand the various nanoscale worlds which heretofore were not completely revealed, but also brings the unbelievable into reality. It provides such capabilities as allowing a user to change the position of individual atoms or to write letters by transforming the surface of a material at the atomic level.

7-1. Principle of AFM Measurement

Among SPMs, the first to be invented was the Scanning Tunneling Microscope (STM). The STM measures the tunneling current between a sharp, conducting tip and a conducting sample. The STM can image the sample's height and also measure the electrical properties of the sample by the "tunneling current" between them.

The STM technique, however, has a major disadvantage in that it cannot measure non-conducting material. This problem has been solved by the invention of the

Atomic Force Microscope (AFM) which may be used to measure almost any sample, regardless of its electrical properties. As a result, the AFM has greatly extended the SPM's applicability to all branches of scientific research.

Instead of a conducting needle, the AFM uses a micro-machined cantilever with a sharp tip to measure a sample's surface. (Please refer to Section 7-2-2 for a more information on the cantilever). Depending on the distance between the atoms at the tip of the cantilever and those at the sample's surface, there exists either an attractive or repulsive force/interaction that may be utilized to measure the sample surface.

Figure 7-1 displays the basic configuration for most AFMs. This scanning AFM is typically used to measure a wide variety of samples, which have a relatively small roughness. The force between the atoms at the sample's surface and those at the cantilever's tip can be detected by monitoring how much the cantilever deflects. This deflection of the cantilever can be quantified by the measurement of a laser beam that is reflected off the backside of the cantilever and onto the Position Sensitive Photo Detector (PSPD). The tube-shaped scanner located under the sample moves a sample in the horizontal direction (XY) and in the vertical direction (Z). It repetitively scans the sample line by line, while the PSPD signal is used to establish a feedback loop which controls the vertical movement of the scanner as the cantilever moves across the sample surface.

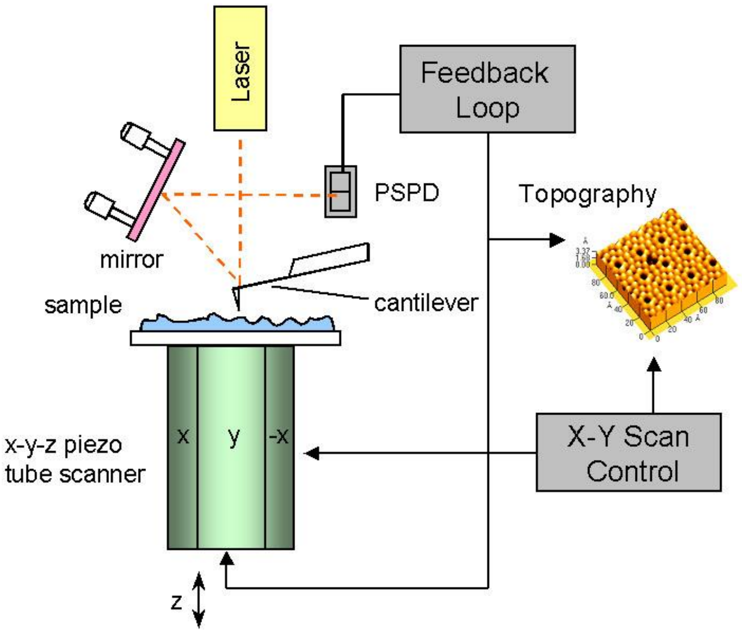


Figure 7-1. Diagram of conventional AFM's scanning

The AFM can easily take a measurement of a conductor, a non-conductor, and even some liquids without delicate sample preparation, unlike SEM or TEM. Also, it is a powerful tool that can measure extremely small structures which other instruments have difficulties in investigating.

7-2. AFM Component List

1. NX12 AFM Head
2. Cantilever

7-2-1. NX12 AFM Head

The NX12 AFM head is the component which actually interacts with the sample and takes the AFM measurements. The NX12 AFM Head provides the following:

- Cantilever/Nano-pipette Mount
- Cantilever Modulation
- Beam Detection
- Movement in Z axis

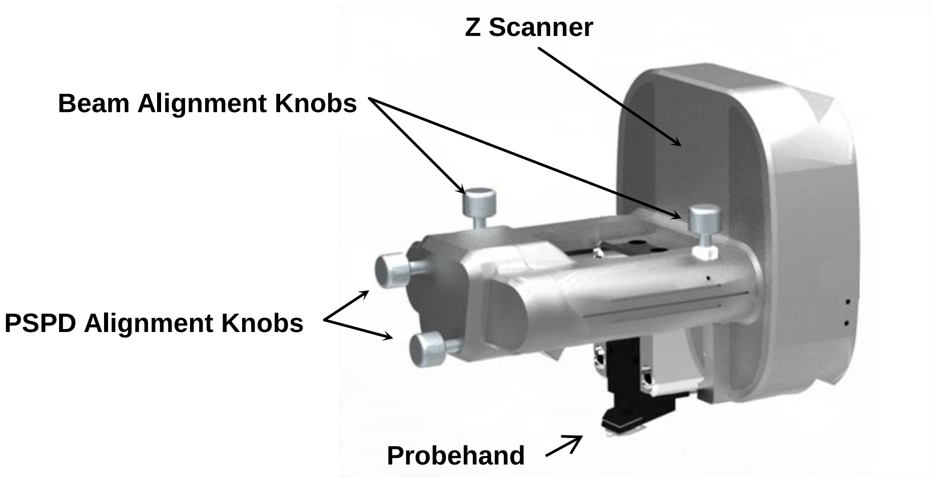


Figure 7-2. Structure of AFM Head

Probehand

The probe hand is the part of the AFM head which holds the cantilever. Its design dep ends on the head mode (operating mode) of the AFM. This means that the appropriate pro be hand must be selected by the user according to their application. However, in the NX sy stem, the probe hand is easily interchangeable by a head probe arm dovetail, as explained by the following figure below (Figure 7-3). The liquid probe hand provided as de fault with the NX12 system is designed to vibrate the cantilever by a bimorph in non-conta ct mode.

In some cases, you need to remove the probehand which can be easily done by following the procedure below:

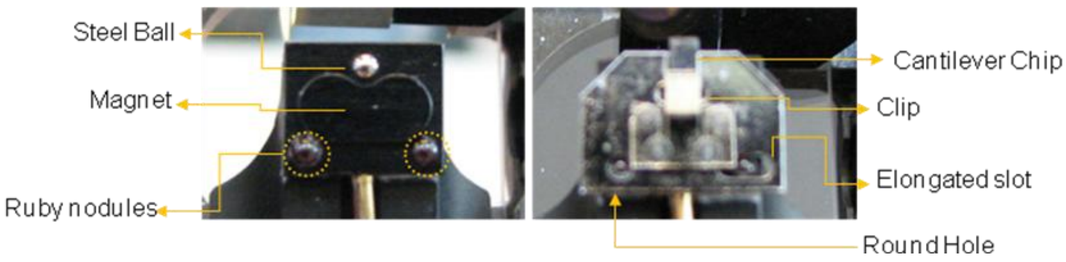


Figure 7-3. Checking Probe Hand

CAUTION!

Do not pull the probe hand forcefully, as this may cause damaged.

AFM Beam Detection Array

The NX12 AFM head should collect the beam signal (SLD beam, wavelength~830nm), is used in the NX12) after it is reflected from the back side of a cantilever in order to detec t the probe's movement.

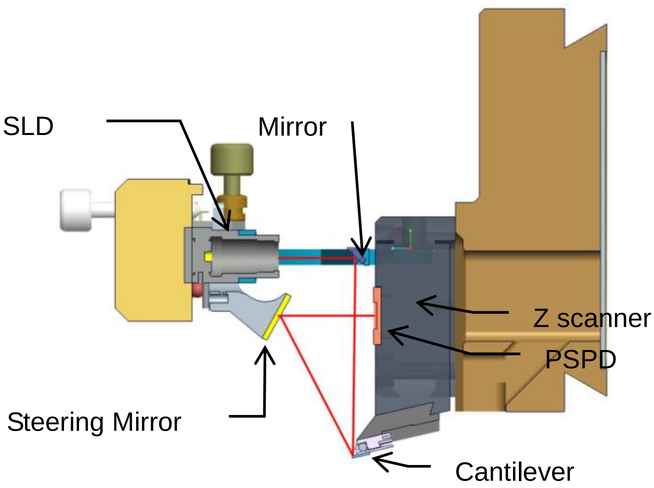


Figure 7-5. Beam Detection

The cantilever and the PSPD move together with the Z scanner while the SLD beam, a steering mirror and a fixed mirror are fixed relative to the scanner frame. The SLD beam, positioned in front of the Z scanner, is aimed at a fixed mirror that is situated above the ca ntilever. The mirror reflects the SLD beam downward and onto the back surface of the cant ilever. The SLD beam will always hit the same spot on the cantilever's surface since the Z scanner only moves vertically. The steering mirror, located at the front of the Z scanner as sembly, adjusts the reflection angle of the SLD beam that is reflected off the cantilever's su rface and reflects the SLD beam to the PSPD. The beam alignment knobs, which are locat ed on the head, control the fixed mirror angle and make it possible for the beam to align on to the cantilever's surface as shown in figure 7-5 & 7-6. The PSPD alignment knobs in fron t of the head control the steering mirror angle to adjust the reflected beam to go to PSPD a s shown in figure 7-5 & 7-6.

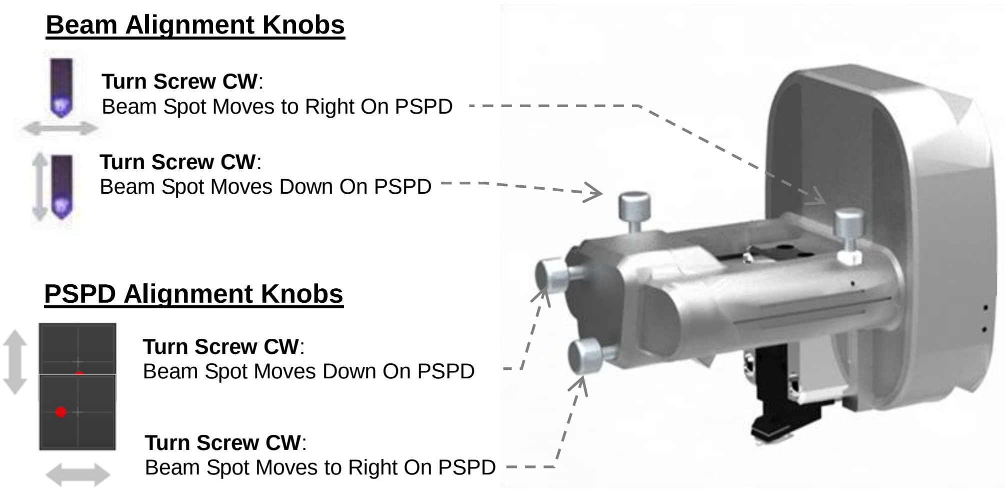


Figure 7-6. Beam & PSPD Alignment Knobs

7-2-2. Cantilever

In general, the term 'cantilever' includes the silicon chip, a cantilever hanging from the chip, and a tip hanging from the end of the cantilever. Figure 7-8 below shows the overall view and the names of the parts of the cantilever used in the SPM.

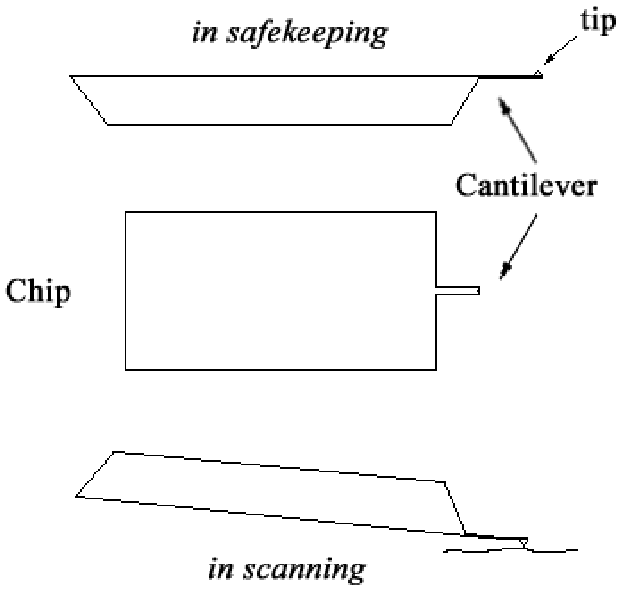


Figure 7-8. Cantilever Chip

The chip, the cantilever, and the tip are made from Silicon (Si) or Silicon Nitride (Si_3N_4), and are manufactured using macro-machining techniques.

Because a cantilever has very small dimensions - 10㎛ width, 100㎛ length, and several ㎛ thickness - it is very difficult to handle in the process of attaching to the SPM. To make it easier to use, the SPM uses a relatively large chip of size several millimeters. Figure 7-9 is the SEM image of a cantilever manufactured this way.

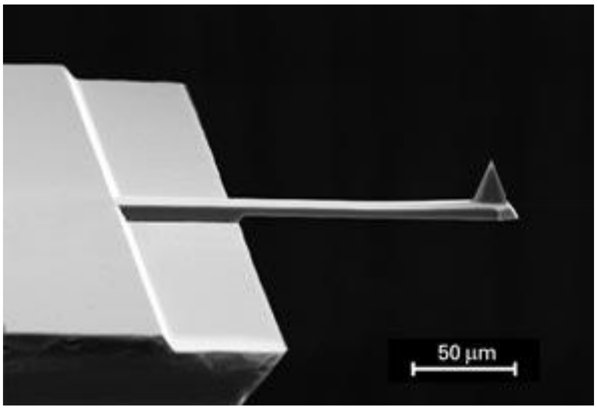


Figure 7-9. SEM image of silicon cantilever

The cantilever is the part sensing the surface properties (for example, the topographic distribution, the physical solidity, electrical properties, magnetic properties, chemical properties, etc.) by detecting the degree of deflection due to the interaction with the sample surface, and is a very important component when determining the sample resolution.

When viewed from the top, the structures of cantilevers are divided into two groups: those with a rectangular shape and those with a triangular shape. Each design has a different force constant depending on the width, depth, thickness, and the composition of the material. Among them, the Silicon Nitride cantilever is stronger that the Silicon cantilever, but it has some disadvantages:

1. When the thickness is more than 1㎛, contortion may occur.
2. The curvature of the end of the tip is large – on the order of tens of nanometers.
3. It has a low aspect ratio.

Compared to the Silicon Nitride cantilever, the Silicon cantilever has a smaller tip curvature, less than 10nm, and is more commonly used. In non-contact mode, which has a high resonant frequency, the rectangular shaped cantilever, with a bigger Q-factor and a high force constant, is used more than the V shape. The cantilever provided with the NX12 by default is a silicon, rectangular shaped cantilever for use in both contact and non-contact mode.

In addition, the upper surface of the cantilever (the opposite side of the tip) is coated very thinly with a metal such as gold (Au) or aluminum (Al) to enhance the reflectivity. However, for EFM (Electrostatic Force Microscopy) or MFM (Magnetic Force Microscopy), when the whole cantilever and tip is coated to measure the electric or magnetic properties, there is no extra coating on the cantilever.

■ Cantilever Selection

There are several types of cantilevers varying in material, shape, softness (represente d by the spring constant), intrinsic frequency, and Q-factor. The choice of a cantilever from among these is primarily determined by the type of measurement mode.

For contact mode, a "soft" cantilever, which has a small spring constant of about 0.01 N/m ~ 3N/m, is chosen. The softer cantilever has a more sensitive response to the tiny for ces between atoms. The probe tip used in contact mode has a thickness of about 1㎛ to a chieve a small spring constant. The smaller spring constant results in larger deflections in response to smaller forces, and thus provides a very fine image of the surface structure.

Cantilevers used for non-contact mode are thicker (4μm), with a typical spring constant of 40N/m and a high resonant frequency.

In Non-Contact mode, the AFM vibrates a cantilever near its resonant frequency, and measures the force gradient via the amplitude and phase shift due to the interaction betw een the probe and the sample. When an AFM is operating in the atmosphere, if the probe t ip is situated on a moist or contaminated layer, it may often stick to the layer due to the sur face tension of the tip. This happens more frequently when the spring constant of the cantil ever is smaller. Because of the small spring constant, it is difficult to bring it back to the ori ginal position. Therefore we need a cantilever with a spring constant which can overcome t he surface tension. The sharper the tip, the more stable the operation because the surface area of the tip and the surface tension are reduced.

Selecting the proper cantilever depends partly on the morphology of a sample's surfac e. For example, when the tip radius is bigger than the features of a sample, the tip's shape will influence the resulting image, as shown in Figure 7-10(b). Therefore, a tip sharper tha n the smallest sample features should be selected in order to avoid these artifacts. Sharpe r tips, however, have shorter life times and are more expensive than general-purpose canti levers. The standard cantilevers have a tip radius of 10nm.

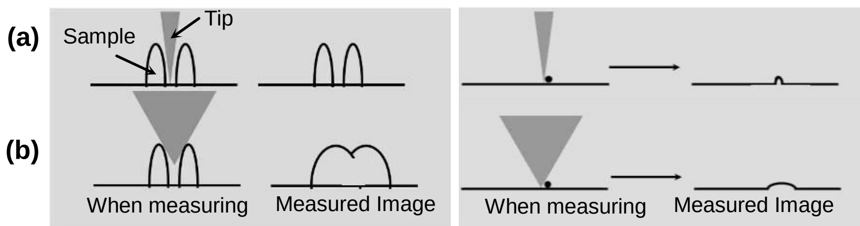


Figure 7-10. Tip Convolution

Measuring a sample twice before and after rotating it relative to the sample stage allows a user to determine if there are any tip-shape artifacts in images. If such artifacts are present, one will see image features with the same orientation in both scans. However, if the original image is a true representation of the sample surface, then every feature within the images will appear rotated along with the sample.

■ Cantilever Mounting

Cantilever chips must be mounted on chip carriers before use. Park Systems provides various types of chip carriers for different measurements. Both pre-mounted and unmount ed cantilever chips are provided. If your cantilever chip is not mounted onto a chip carrier, you must do so with an adhesive using glue type chip carriers or with a clip type chip carri ers. Once your cantilever chip is on a chip carrier, you can simply attach it to the probehan d, where it will be held in place by magnets.

Glue Type Chip Carrier

The cantilever chip is attached onto the marked area on the glue type chip carrier (Fig ure 7-11) using glue. There are various glue type chip carries:

Figure 7-11. Glue Type Chip Carrier

- Standard Chip Carrier
- Ceramic Chip Carrier for SThM
- Ceramic Chip Carrier for SCM
- Teflon Coated Chip Carrier for I-AFM
- Teflon Coated Chip Carrier for EC-Cell

The following items are required to load un-mounted cantilever chips in general.

- Glue type chip carrier
- Instant adhesive for metal

(Cyanoacrylate (superglue) adhesives provided with NX system are recommended)

- Un-mounted cantilever chips

How to Load Un-mounted Cantilever Chip

① Remove any dust from the chip carrier.

② Pour some glue onto any flat area. Use a small stick, such as a toothpick, to place a dab of the adhesive on the chip carrier using the stick. The two small points (or grooved lines) on the chip carrier should be used as guidance for aligning the cantilever chip.

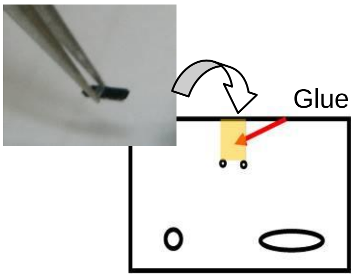


Figure 7-12. Loading Cantilever Chip on Glue Type Chip Carrier

③ Place the cantilever chip on top of the adhesive using forceps and align the edge with the two small points (or grooved lines).

④ Gently press down on the chip for several seconds.

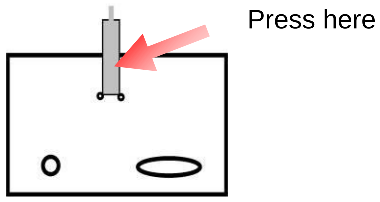


Figure 7-13. Cantilever Chip Positioned on Glue Type Chip Carrier2

NOTE!

You should allow several hours for the adhesive to completely dry; otherwise, Non-Contact mode images may be affected.

NOTE!

Make sure that the cantilever chip isattached the right way up. If necessary, reattach the cantilever chip.

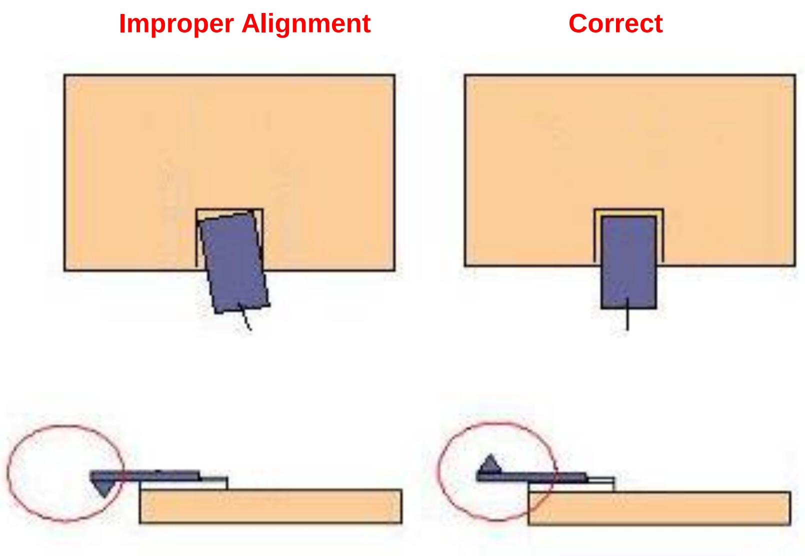


Figure 7-14. Correct Mounting of Cantilever Chip

Clip Type Chip Carrier

Using the clip type chip carrier, anun-mounted cantilever chip can be easily stabilized without glue. Figure 7-15 shows the structure of the clip type chip carrier.

- Chip Mount: Cantilever chip is placed here.
- Clip: Holds cantilever chip.
- Lift Hole: Meets with Cantilever Exchanger Pin. Pressing down this hole will open space between the Clip and Chip Mount area for mounting.
- Round Hole & Slot: These two Hole & Slot will be mounted on the probehand. They will guide Clip Type Chip Carrier to be placed on the probehand in a consistent position.

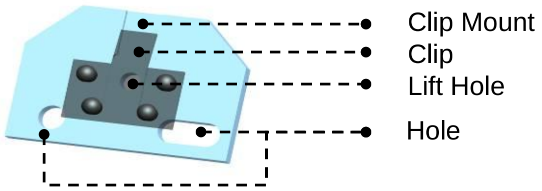


Figure 7-15. Structure of Clip Type Chip Carrier

The chip type chip carrier is coated with chromium, is designed for various environme nts such as air, liquid, wiring, and does not need electrically conductive glue to be connect ed between the cantilever and chip carrier electrically.

Please refer to the Appendix. Clip type chip carrier for further details on use.

■ **Chip Carrier Mount**

Mount the chip carrier with a cantilever chip to the probehand.

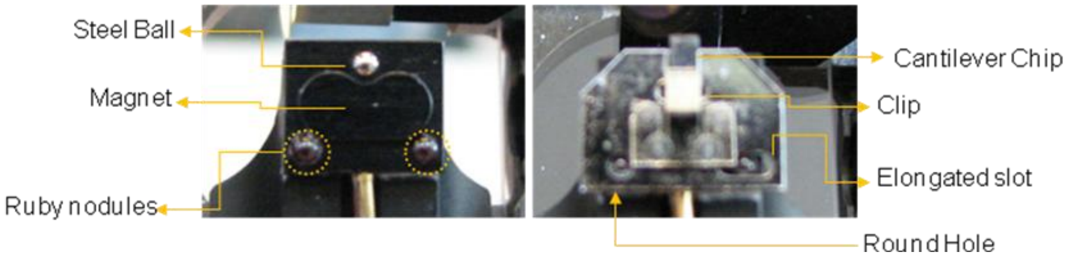


Figure 7-16. Edge of Probe Hand before (left) and after (right) Chip Carrier is attached to it

There are two holes in a chip carrier: a round hole and an elongated slot. When you o verlay the two ruby nodules located on the end of the probe arm with these holes, the canti lever chip will be attached into place by a magnet, and the position of the cantilever will be firmly fixed in one position.

■ Cantilever DB

The cantilever DB stores specifications for each cantilever type. The SmartScan™ software comes preloaded with database entries for cantilevers shipped with the system. The user can specify which cantilever is in use in SmartScan™ through the Setup menu: [Line Scan Click>Setup>Cantilever]. If an entry doesn’t exist for your cantilever, you can create one with the following steps:

[Step]: Create Cantilever DB

Create Cantilever DB -> Input Cantilever Spec -> Calibrate VERTICAL Sensitivity

1.Create Cantilever DB

5. Turn off the head.
6. Open the ‘SmartScan™ Part Selection’ dialog by clicking [Line Scan Click>Setup>Cantilever] on SmartScan™.
7. Clicking the [Advanced] button will display the ‘Create Part’ panel. In this panel, select ‘Part Type’ as ‘Cantilever’.
8. Write a name for your cantilever in the blank space on the left of the [Create] button, and click the [Create] button. It creates a new cantilever DB using the currently selected cantilever DB and switches to the newly created cantilever DB.

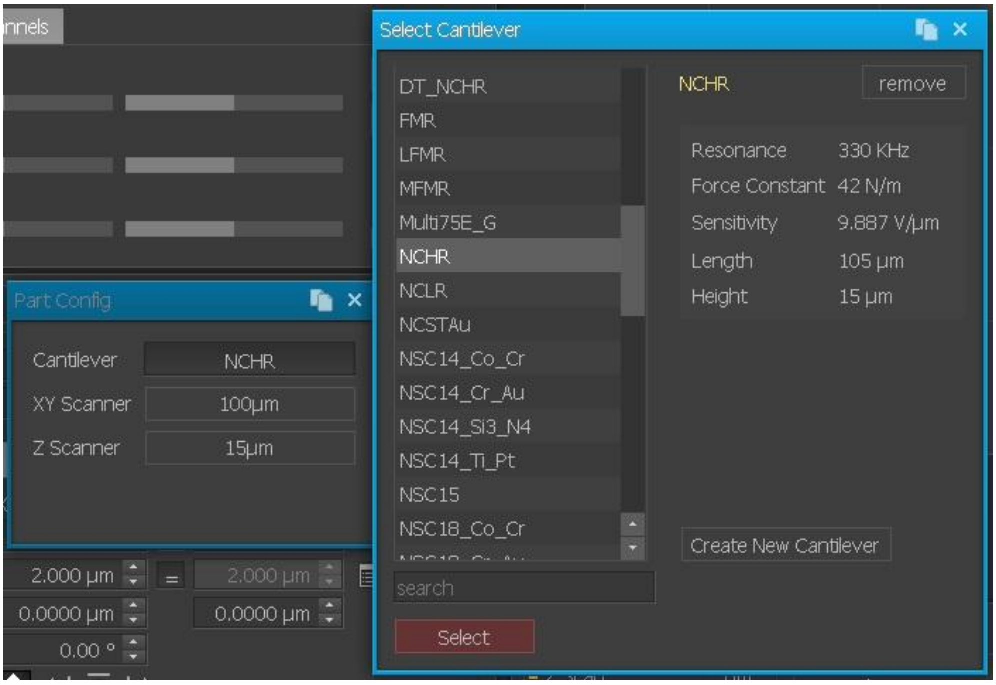


Figure 7-17. Create Cantilever DB

NOTE!

Before you create the cantilever DB, it is recommended to select the cantilever type with a similar force constant since the cantilever DB is created by copying the previous selected one.

2. Input Cantilever Specification

1. Turn on the head and switch to 'Maintenance' mode by selecting [Mode>Maintena nce Mode].

NOTE!

The defult password is set to 'cantilever'.

2. Go to 'Cantilever Calibration' by clicking [Mode>Calib Mode>Cantilever].
3. Write the resonance frequency range (Minimum Frequency, Maximum frequency), the typical resonance frequency and the force constant. Refer to the cantilever sp ecification sheet provided by the cantilever manufacturer.
4. Save the input values by clicking the **Apply** button.

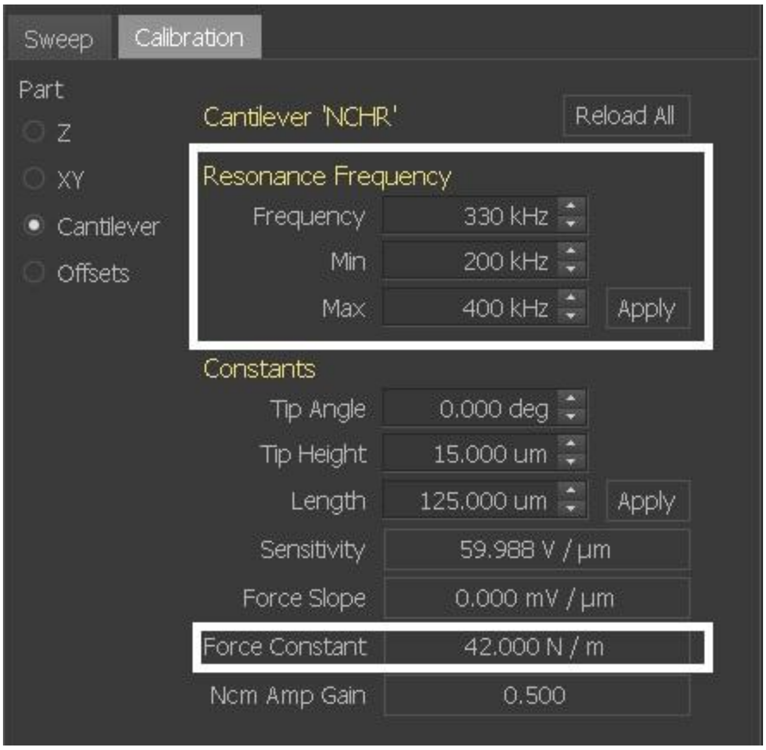


Figure 7-18. Input Cantilever Specification

3. Calibrate VERTICAL Sensitivity

VERTICAL sensitivity is the calibration factor between the deflection of the cantilever and the movement of the reflected beam on the PSPD. In contact mode, this PSPD position is converted to a distance deflected by the cantilever using the VERTICAL sensitivity calibration. That deflection is then converted to a force in Newtons using the spring constant of the cantilever stored in its DB file.

For Force (V), F=Sx

For Force (N), F=kx

(F: Force (N or V), k: Force constant (N/m), x: Deflection (m), S: VERTICAL Sensitivity (V/m))

VERTICAL sensitivity is obtained by taking a F/D (Force vs. Z scanner displacement) curve. Before this curve can be taken accurately, however, one first needs to calibrate the AFM's Z scanner and the force constant of the cantilever

1. Taking an F/D curve (in contact mode) on a bare Si wafer sample with your cantilever.

***F/D Curve**

a) Approach your cantilever to the sample.
b) Go to FD spectroscopy by selecting [Mode>Scan Mode>FD Spectroscopy] or the icon.
c) Add a point on the scan image.
d) Set the parameters on FD spectroscopy control window.
e) Perform FD spectroscopy by clicking the [Acquire] button.
f) Zoom in the region that has a linear slope by dragging the mouse after acquiring the FD curve and click the [Apply] button. Then, the Z scanner moving range (Min, Max) is automatically changed to one in the selected region.
g) Perform FD spectroscopy again by clicking the [Acquire] button.

2. Switch to 'Maintenance' mode by selecting [Mode>Maintenance Mode].

NOTE!

The default password is set to 'cantilever '.

3. Go to 'Cantilever Calibration' by clicking [Mode>Calib Mode>Cantilever] or by click

ing the icon.

4. Select ‘Sensitivity’ in the ‘Cantilever’ tab.
5. Open the curve you obtained in FD spectroscopy. If it was the last FD curve obtain ed with this system, it should already be open.
6. Select the linear area in this curve by clicking and dragging on the mouse.
7. Click the [Calculate] button to calculate VERTICAL sensitivity value.
8. Click the [Calibrate] button for VERTICAL Sensitivity to apply the value obtained in the previous step. Click the **Apply** button to make the calibration permanent.

Figure 7-19 shows a labeled image of SmartScan™, showing some of the steps for V ERTICAL sensitivity calibration.

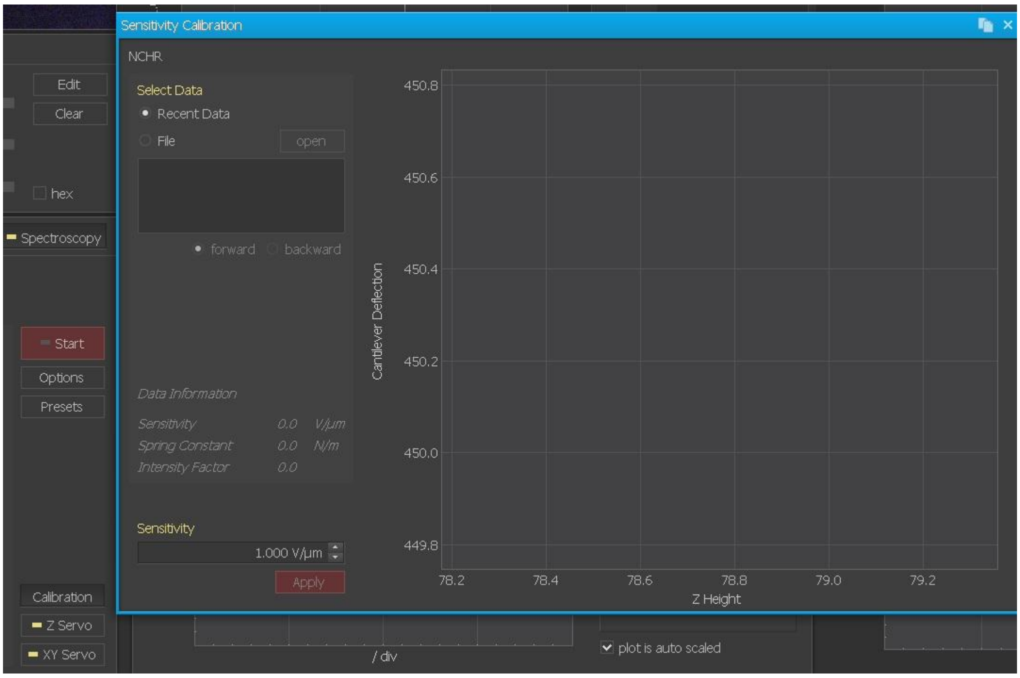


Figure 7-19. VERTICAL Sensitivity Calibration

■ Cantilever Storage

When cantilevers are kept in ambient conditions with variable temperature and humidi ty for long periods, their reflected beam intensity can decrease due to oxidation of the canti lever coating material. It is also possible that the end of the tip can become damaged. For these reasons, it is recommended to store cantilevers in a desicator.

7-3. Initial Setting for AFM Measurement (Beam Alignment)

The NX AFM measures the changes in the cantilever by bouncing a beam off of it and measuring the changes in the reflected beam. Because the actual movement of the cantilever is too small to measure directly, this beam bouncing setup is critical. The changes in the reflected beam are measured by the Position Sensitive Photo Detector, or PSPD.

There are two major steps in aligning the beam on the top of the cantilever. First, the beam must hit the cantilever. Second, the beam reflected from the cantilever must hit the PSPD.

The beam’s path is controlled by the Beam Alignment Knobs on the NX Head. Turning these knobs will change the location of the beam. Move the NX12 Body Stage motor in the software until you find the beam spot and use the beam alignment knobs to place the beam on the end of the cantilever.

For a detailed guide for beam alignment, please refer to the “Align Beam on Cantilever/PSPD” section.

7-4. AFM in Contact Mode

7-4-1. Principle of Contact Mode AFM

The AFM (Atomic Force Microscope) is an instrument that is used to study the surface structure of a sample by measuring the force between atoms.

At the lower end of the Z scanner, there is a cantilever with tiny dimensions: 100 µm long, 10 µm wide and 1 µm thick, which is manufactured by means of micro-machining techniques. At the free end of the cantilever, there is a very sharp cone-shaped or pyramid-shaped tip. As the distance between the atoms at this tip and the atoms on the surface of the sample becomes shorter, these two sets of atoms will interact with each other. As shown in Figure 7-20, when the distance between the tip and the surface atoms becomes very short, the interaction force is repulsive due to electrostatic repulsion, and when the distance gets relatively long, the interatomic force becomes an attractive force due to the long-range van der Waals forces.

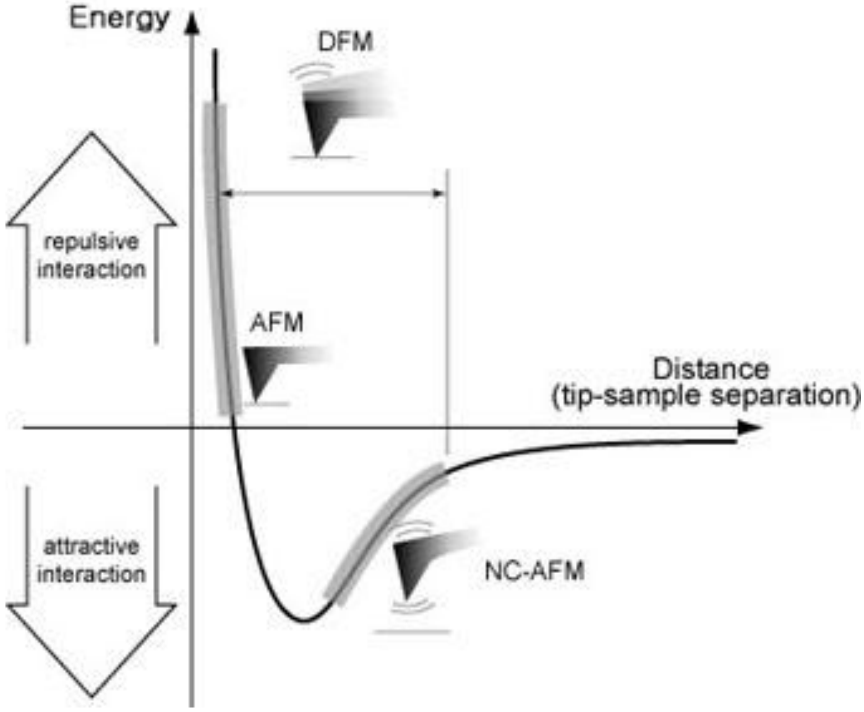


Figure 7-20. Relation between the force and the distance between atoms

This interatomic force between atoms can bend or deflect the cantilever. The amount of deflection causes a change in the reflection angle of the laser beam that is bounced off the upper surface of the cantilever. This change in the laser’s path will in turn be detected by the PSPD (Position Sensitive Photo Detector), thus enabling the computer to generate a map of the surface’s height

In contact mode the probe makes “soft contact” with the sample surface, and the study of the sample’s height is then conducted by utilizing the repulsive force that is exerted vertically between the sample and the probe tip. Even though the interatomic repulsive force, in this case, is merely 1~10 nN, the spring constant of the cantilever is also sufficiently small (less than 1 N/m), thus allowing the cantilever to react very sensitively to very minute forces. The AFM is able to detect even the slightest amount of deflection as it moves across a sample surface. Therefore, when the cantilever scans a convex area (凸) of a sample, it will deflect upward, and when it scans a concave area (凹), it will deflect downward. This probe deflection will be used as a feedback loop input that is sent to an actuator (z-piezo). In order to produce an image of the surface height, the z-piezo will maintain the same cantilever deflection by keeping a constant distance between the probe and the sample.

7-4-2. Contact mode setup

To use contact mode AFM, select the appropriate Head mode with the followng steps:

1. Turn off the beam by clicking the “Beam On/Off “ button  in the Tool bar.
2. Once the beam is off, set the Head mode to C-AFM after clicking the “Select Part s” button  .
3. Turn on the beam by clicking the “Beam On/Off” button .

7-4-3. Cantilever Selection

Selecting the appropriate probe is a critical aspect of using AFM. Choosing a probe means determining the combination of a tip, which interacts with sample surface atoms, and a cantilever, which deflects depending on the interatomic forces and quantifies the deflection. Generally, the upper surface of a cantilever is coated with a metal such as gold (Au) or aluminum (Al). This coating, which enhances the surfaces reflectivity, has a thickness of about 1000Å. There are several types of cantilevers that vary in material, shape, softness (represented by the spring constant), intrinsic frequency, and Q-factor. The type of cantilever selected is primarily determined by the measurement mode. A “soft” cantilever is used for contact mode AFM. Typically, such cantilevers are made of silicon and have a spring constant less than 1~3 N/m. With such a low spring constant, the contact mode cantilever is sensitive to extremely small forces, and will bend more significantly than a cantilever with a higher spring constant when exposed to an equal force. This allows the AFM to measure even extremely tiny structures.

Figure 7-21 shows the SEM image of a cantilever commonly used for contact mode, the NSC36 series. To improve the beam’s reflectivity, the upper surface of the cantilever (the opposite side of the tip) is coated with aluminum.

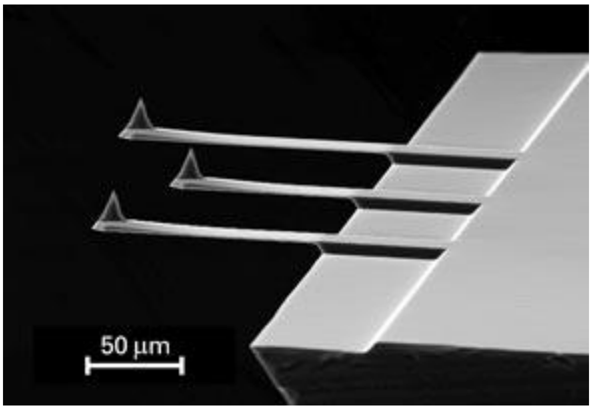


Figure 7-21. SEM image of the shorter cantilevers (A, B, C) from a chip of the NSC36 series

Figure 7-22 shows the detailed standardized gauge of the NSC36 series chip. Altogether, this chip contains three cantilevers, all with different spring constants. If the unmounted cantilevers are purchased separately, you may choose from the set of cantilevers A,B,C.

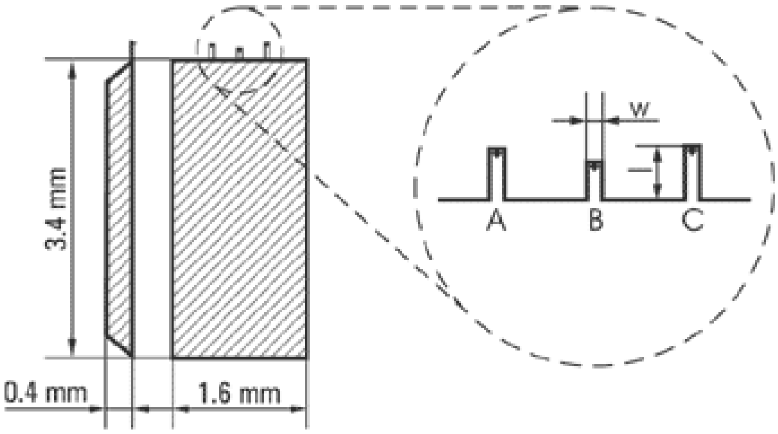


Figure 7-22. Silicon chip of the NSC36 series has 3 rectangular cantilevers

Table 7-1 shows the specification for the three cantilevers in the NSC36 series.

Table 7-1. NSC36 Series Cantilever Specifications

Cantilever Type	A			B			C		
	Min	Typica	Max	Min	Typica	Max	Min	Typica	Max
Length, l±5, µm		110			90			130	
width, w±3, µm		35			35			35	
Thickness, µm	0.7	1	1.3	0.7	1	1.3	0.7	1	1.3
Resonant frequency, kHz	65	105	150	95	155	230	50	75	105
Force constant, N/m	0.3	0.95	2.5	0.5	1.75	5	0.2	0.6	1.5

7-4-4. Measurement Procedure

■ **Perform Initial Setup**

- Perform the initial setting by following the instructions in Chapter 6.

■ **Approach Tip to Sample**

1. <u>**Set Point Setting**</u>:
   - **Set Point in Contact Mode: Reference force for Z feedback.**
     As the cantilever and sample's surface get closer, the repulsive force between the tip and sample grows, the cantilever bends more, and PSPD's VERTICAL value changes. We can calculate the force between the sample's surface and cantilever through the changed VERTICAL value. For the Z scanner feedback loop, the specific force is chosen. This is called the 'Set Point' in Contact mode.
   - <u>Check if the cantilever DB is selected accurately. According to the cantilever specification, the Set Point is selected automatically.</u>
   - Contact Mode uses the repulsive force that actually makes physical contact between the tip and sample's surface. In other words, applying the Set Point more means that the tip pushes on the sample stronger.

2. <u>**Lower the Z stage to place near the sample surface.**</u>
   - Focus on the sample surface using the inverted Optical Microscope.
   - Move the Z stage down by placing and clicking the cursor at the lower part of the Z stage pad. This positions the cantilever close to the sample surface(within 1cm).

WARNING!

> If the Z stage is lowered too quickly, the cantilever may "crash" into the sample surface. Such a forceful interaction may break the tip, damage or destroy the sample, and/or seriously have a harmful effect on the Z scanner.

- Slowly move the cantilever tip down until the shape of the cantilever starts to show faintly while watching the monitor.

CAUTION!

> When lowering the cantilever, go slowly to avoid a potential collision with the sample.

3. **Move to the desired sample position.**
   - Slowly adjust the XY Scanner to the desired sample position using the motori zed XY stage.

4. **Approach**
   - Click "Approach" (underneath the Z stage motor control). When the light to th e right of the motor controls stops blinking, the tip's approach is complete.
   - The upper half of the Z scanner bar in the PSPD window will be green if "App roach" is successful. Before approaching, it is recommended to set the scan size to 0 and Z servo gain to 1 in the scan control window.

CAUTION!

> Don't move the XY position using XY stage after approach.

CAUTION!

> Don't turn off the beam after approach.

■ Imaging

1. **<u>Input Signal Setting</u>**
   - Select the desired input signals in Input Configuration [Setup->Input Config].
   - If the desired input signal isn't shown in the main panel of Input Config, Click the [Setup] button to see hidden signals. The selected signals in the popup di alog shows in main panel of Input Config.
   - It is recommended to set the 'Z Drive', the 'Error Signal', and the 'Height' to c ontact mode.

- **Z Drive**: Calculated Value from the driving voltage to the Z scanner in the feedback system. Considered as the height information of the sample surface since the Z scanner is in feedback to respond to the sample height.

- **Error Signal**: PSPD(VERTICAL)-SetPoint. The feedback loop works this signal to be 0. During the scan, this signal returns to 0 rapidly in good feedback but slowly in poor feedback. For such reasons, through this signal, the feedback status can be confirmed, and it is recommended to monitor the Error Signal during the parameter setting.

- **Height**: Z scanner's actual movement from the sensor directly. Considered the height information of the sample surface since the Z scanner is in feedback to respond to the sample height.

- **Lateral Force**: (C-D) value in PSPD containing the cantilever's twisting.

- **Force**: Calculated force from (VERTICAL) value in PSPD.

- **VERTICAL**: (VERTICAL) value in PSPD containing cantilever deflection information.

2. **<u>Select the desired monitoring signals</u>** (Height, Z Drive and Error signal) in the Trace Control Window.
   - If none are open, open one by clicking the button.
3. **<u>Parameter Setting</u>**
   - Input a value for the "Scan Size." This will be the size of your image. Your XY Scanner will begin moving back and forth by this amount. This movement may be visible on the vision program.
   - Select a "Scan Rate". The Hz unit in the Scan Rate represents the frequency or how many times per second the scanner moves in the fast scan direction. Too high of a speed will result in tip and sample damage.
   - Adjust the "Z Servo Gain" field until the trace line is stable. Increase or decrease the gain, as necessary, until the forward and the backward line profile match. The line trace is repeatable and there no oscillations should be present.
   - Adjust the Set Point if needed.

7-5. Lateral Force Microscopy (LFM)

7-5-1. Principle of Lateral Force Microscopy (LFM)

The principle of Lateral Force Microscopy (LFM) is very similar to that of Contact mode AFM. Whereas in contact mode we measure the deflection of the cantilever in the vertical direction to gather sample surface information, in LFM we measure the deflection of the cantilever in the horizontal direction. The lateral deflection of the cantilever is a result of the force applied to the cantilever when it moves horizontally across the sample surface, and the magnitude of this deflection is determined by the frictional coefficient, the height of the sample surface, the direction of the cantilever movement, and the cantilever's lateral spring constant. Lateral Force Microscopy is very useful for studying a sample whose surface consists of inhomogeneous compounds. It is also used to enhance contrast at the edge of an abruptly changing slope of a sample surface, or at a boundary between different compounds.

Since the LFM measures the cantilever movement in the horizontal direction as well as the vertical one to quantitatively indicate the surface friction between the probe tip and the sample, it uses a PSPD (position sensitive photo detector) that consists of four domains (quad-cell), as shown in Figure 7-25.

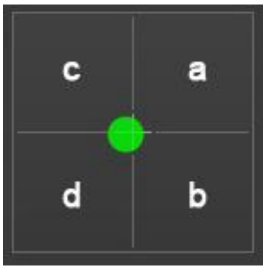


Figure 7-25. Quad-cell PSPD

Generally, in AFM, to measure the height of a sample's surface, the "VERTICAL" signal is used. This signal is related to the difference between the upper cells (a+c) and the lower cells (b+d) of the PSPD.

Topographic information = (a+c)-(b+d) (VERTICAL on NXP)

The LFM signal, which is related to the change in the surface friction on a sample surface, measures the deflection of the cantilever in the horizontal direction and can be represented as the difference in the signals recorded in the right cells (a+b) and the left cells (c+d).

Frictional information = (a+b) – (c+d) (C-D on NXP)

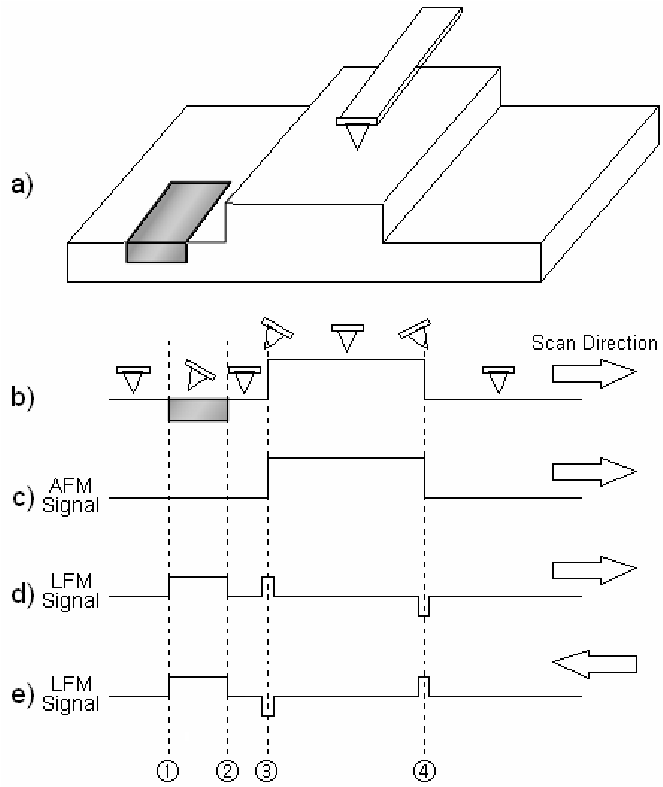


Figure 7-26. AFM and LFM signal

Figure 7-26 (a) shows a surface structure with a centrally located step with low, smooth areas on either side. The flat part on the left contains a domain with a relatively high frictional coefficient. **Profile b** indicates the cantilever’s deflection as it encounters topographic features as well as different frictional coefficients as it scans from left to right. **Profile c** is an AFM image of the surface height and structure; it is represented by the change in the vertical deflection of the cantilever which does not include the horizontal deflection. **Profile d** and **Profile e** show the LFM signal which indicates the horizontal deflection of the cantilever. When scanning from left-to-right, a surface structure with a sudden peak will instantaneously twist the cantilever to the right. This results in a lateral force signal with a convex shape as seen in Figure 7-26 (d) ③. The opposite occurs when the probe encounters a sudden downward step as depicted at location ④. The region between ① and ② indicates an area on the sample surface where there is a material with a higher surface frictional coefficient compared to the surrounding area. There are no distinguishable surface features that will allow the user to differentiate this region utilizing the height signal. Even though the topographical information is the same between ① and ②, there will be a conspicuous difference noticeable in the LFM signal. When the cantilever scans this area from left to right, an increase in relative friction will cause it to tilt to the right, thus producing an increase in the LFM signal.

Figure 7-26 (e) shows the LFM signal when the scan direction is reversed. If the cantilever scans in the direction as indicated by the arrow, there will be no change in the LFM signal at region ③ and ④ which are related to the topographic features of the sample surface. However, when the scan direction is reversed, the cantilever will now tilt to the left in the area where the frictional coefficient between ① and ② is larger, yielding a decrease in the LFM signal in this area.

Considering the simple comparison described above, the LFM result contains the surface frictional information as well as the surface topographical information.

Hence, when you analyze the results of the LFM measurement, it is necessary to distinguish the information due to difference in the frictional coefficient from the information due to the change in the sample surface height by taking the AFM image into account.

7-5-2. Conversion to LFM

As mentioned above, since lateral force mode is an extension of contact mode, the H ead mode will be set to “Contact mode”.

1. Turn off the beam by unclicking the beam control check box at the bottom left porti on of the Vision View.

2. Once the beam is off, click the Head Mode tab at the top of parameters view and s elect **Contact**.
3. Turn on the beam by clicking the beam control check box.

7-5-3. Cantilever Selection

The Lateral Force Microscope (LFM) measures the horizontal cantilever deflection under the same conditions as contact AFM. Therefore, LFM uses the same type of cantilever.

7-5-4. Measurement Procedure

You can obtain an LFM image and a topographic image simultaneously when you me asure in contact mode. If you press the "Input Config" button, the "Input Configuration" win dow will appear as shown in Figure 7-27 below. You can take an LFM image if you selecte d the 'Lateral Force' option in this "Input Configuration" box. When the selected input signa l, the 'Lateral Force', does not appear, press the "Setup" button which will open the "Select Input" window. There you can choose 'Lateral Force" for both scan directions. Also, LPF a nd Flattening can be chosen based on the sample. It is recommended to consult the SmartScan software manual for instructions on how to set them.

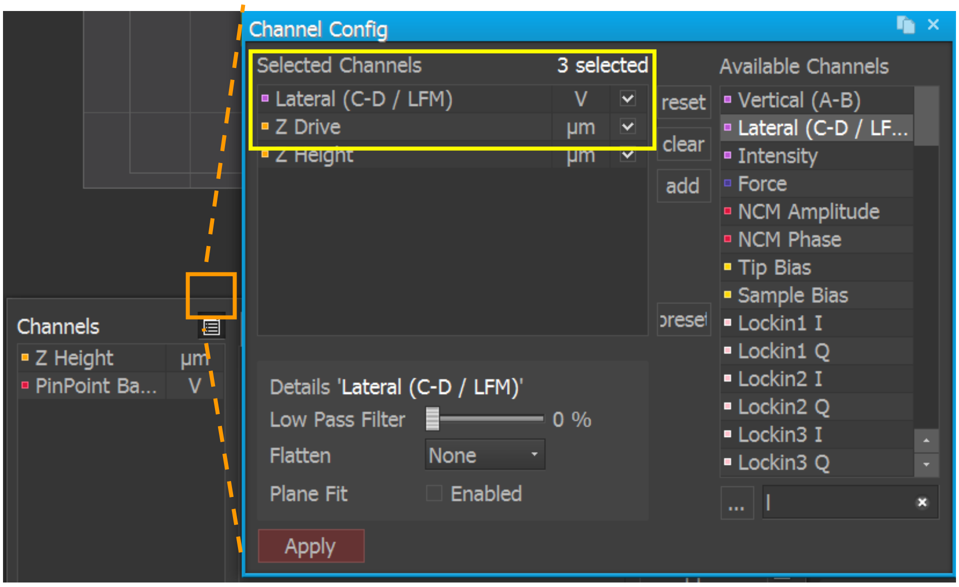


Figure 7-27. Setup for LFM mode

The procedure to measure in 'Lateral Force' mode is the same as that in contact mod e. The measurement method hereafter can be found by consulting Section 7-4.

7-6. AFM in Non-Contact Mode

7-6-1. Principle of Non-contact Mode AFM

There are two major forces existing between atoms a short distance apart: the static electric repulsive forces (F_{ion}) between ion cores and the static electric attractive forces (F_{el}) between valence electrons and ion cores. When the distance between the atoms at the end of the probe tip and the atoms on the sample surface becomes much shorter, the repulsive forces between them become dominant, and the force change due to the distance change becomes greater and greater. Therefore, contact AFM measures surface height by utilizing the system's sensitive response to the Repulsive Coulomb Interactions that exist between the ion cores when the distance between the probe tip and the sample surface atoms is very small. However, as shown in Figure 7-28, when the distance between the probe tip and the sample atoms is relatively large, the attractive force F_{el} becomes dominant. Ion cores become electric dipoles due to the valence electrons in the other atoms. The force induced by the dipole-dipole interaction is the van der Waals Force. Non-contact AFM (NC-AFM) measures surface height by utilizing this attractive atomic force in relatively larger distance between the tip and a sample surface.

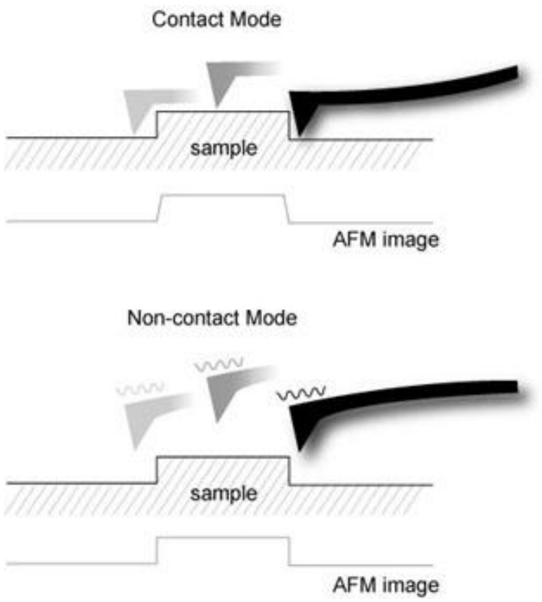


Figure 7-28. Concept diagram of contact mode and non-contact mode

Figure 7-28 compares the movement of the probe tip relative to a sample surface for images being acquired in contact AFM and non-contact AFM. Contact mode uses the "physical contact" between the probe tip and a sample surface, whereas non-contact AFM does not require this physical contact with the sample. Also, in non-contact AFM, the force between the tip and a sample is very weak so that there is no unexpected change in the sample during the measurement. Therefore, non-contact AFM is very useful for a biological sample or any other very soft sample. The tip will also have an extended lifetime because it is not abraded during the scanning process. On the other hand, the force between n the tip and a sample in the non-contact regime is very low, and it is not possible to measure the deflection of the cantilever directly. So, non-contact AFM detects the changes in the phase or the vibration amplitude of the cantilever that are induced by the attractive force between the probe tip and a sample while the cantilever is mechanically oscillated near its resonant frequency.

A cantilever used in non-contact AFM typically has a resonant frequency between 100 kHz and 400 kHz with a vibrational amplitude of a few nanometers. Because of the attractive force between the probe tip and the surface atoms, a cantilever vibrating at its resonant frequency near the sample surface experiences a shift in its spring constant from its intrinsic spring constant (k_o). This is called the effective spring constant (k_{eff}), and the following equation holds:

$$k_{eff} = k_o - F' \quad (1)$$

When the attractive force is applied, k_{eff} becomes smaller than k_0 since the force gradient F' (=∂F/∂) is positive. Accordingly, the stronger the interaction between the surface and the tip (in other words, the closer the tip is brought to the surface), the smaller the effective spring constant becomes. This alternating current method (AC detection) creates a more sensitive response to the force gradient as opposed to the force itself. Thus, it is also applied in such techniques as MFM (Magnetic Force Microscopy) and Tapping mode (Dynamic Force Microscopy).

A bimorph is used to mechanically vibrate the cantilever. When the bimorph's drive frequency reaches the vicinity of the cantilever's natural/intrinsic vibration frequency (f_0), resonance will take place, and the vibration that is transferred to the cantilever becomes very large. This intrinsic frequency can be detected by measuring and recording the amplitude of the cantilever vibration while scanning the drive frequency of the voltage being applied to the bimorph. Figure 7-29 displays the relationship between the cantilever's amplitude and the vibration frequency. From this output, the cantilever's intrinsic frequency can be determined.

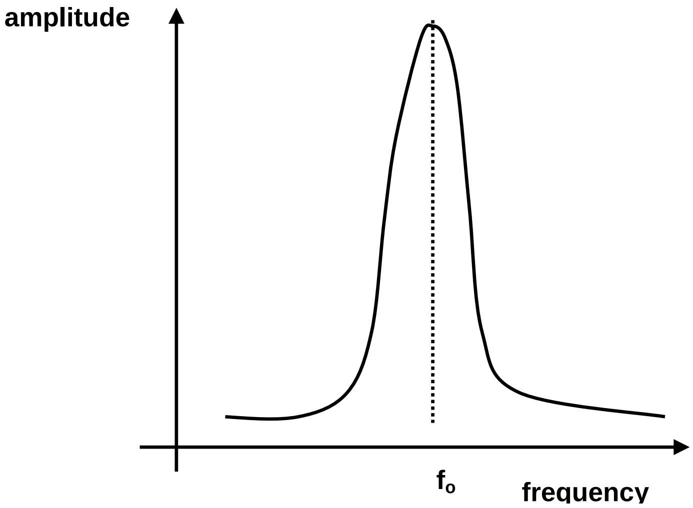


Figure 7-29. Resonant Frequency

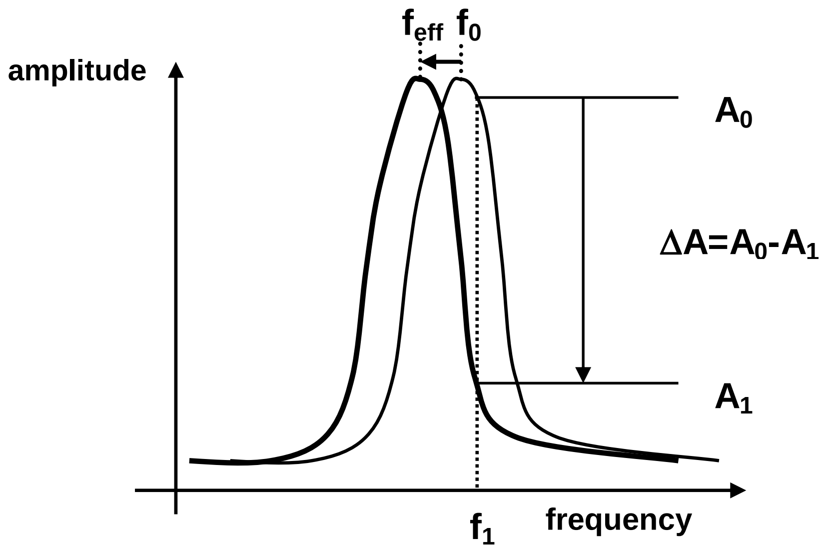
On the other hand, the spring constant affects the resonant frequency (f_0) of the cantilever, and the relation between the spring constant (k_0) in free space and the resonant frequency (f_0) is as in Equation (2).

$$f_0 = \sqrt{\frac{k_0}{m}} \quad (2)$$

As in Equation (1), since k_{eff} becomes smaller than k_0 due to the attractive force, f_{eff} too becomes smaller than f_0 as shown in Figure 7-30 (a). If you vibrate the cantilever at the frequency f_1 (a little larger than f_0), where a steep slope is observed in the graph representing free space frequency vs. amplitude, the amplitude change (ΔA) at f_1 becomes very large even with a small change of intrinsic frequency caused by atomic attractions. Therefore, the amplitude change measured in f_1 reflects the distance change (Δd) between the probe tip and the surface atoms.

If the change in the intrinsic frequency, resulting from the interaction between the surface atoms and the probe or the amplitude change (ΔA) at a given frequency (f_1), can be measured, the non-contact mode feedback loop will then compensate for the distance change between the tip and the sample surface as shown in Figure 7-30 (b). By maintaining constant cantilever amplitude (A_0) and distance (d_0), non-contact mode can measure the height of the sample surface by using the feedback mechanism to control the Z scanner movement following the measurement of the force gradient represented in

Equation (1).



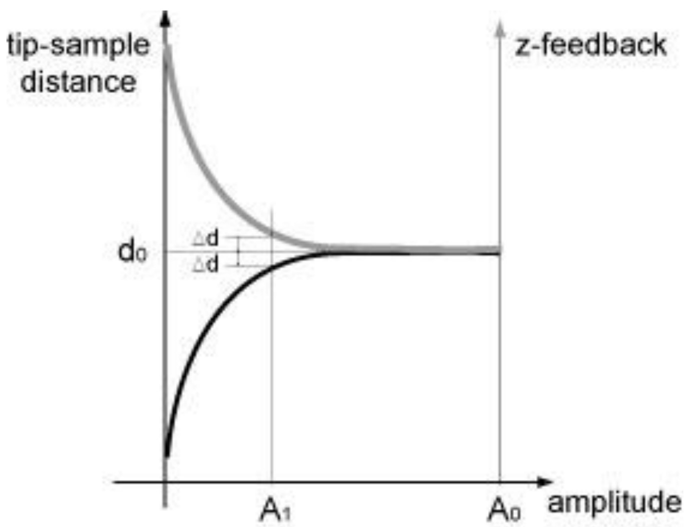


Figure 7-30. (a) Resonant frequency shift (b) Amplitude vs. z-feedback and tip-sample distsance

7-6-2. Non-contact Mode Setup

The non-contact mode setup can be done easily by selecting NC-AFM as the Head m ode, similar to the setup for contact mode explained in Section7-4-2.

1. Turn off the beam switch by unclicking the beam control check box on the bottom left portion of the Vision View.

2. Once the beam is off, click the Head Mode tab at the top of parameters view and select **NCM** .

3. Turn on the beam by clicking the beam control check box.

7-6-3. Resonant Frequency Setup

Once the Head mode is selected as NC-AFM, turn on the beam by clicking the beam control check box. The system will then automatically find the resonant frequency. Instead of turning the beam on and off, you can also access the Frequency Sweep dialog by clicki ng the ( ) NCM Sweep button in the Scan Control Window.

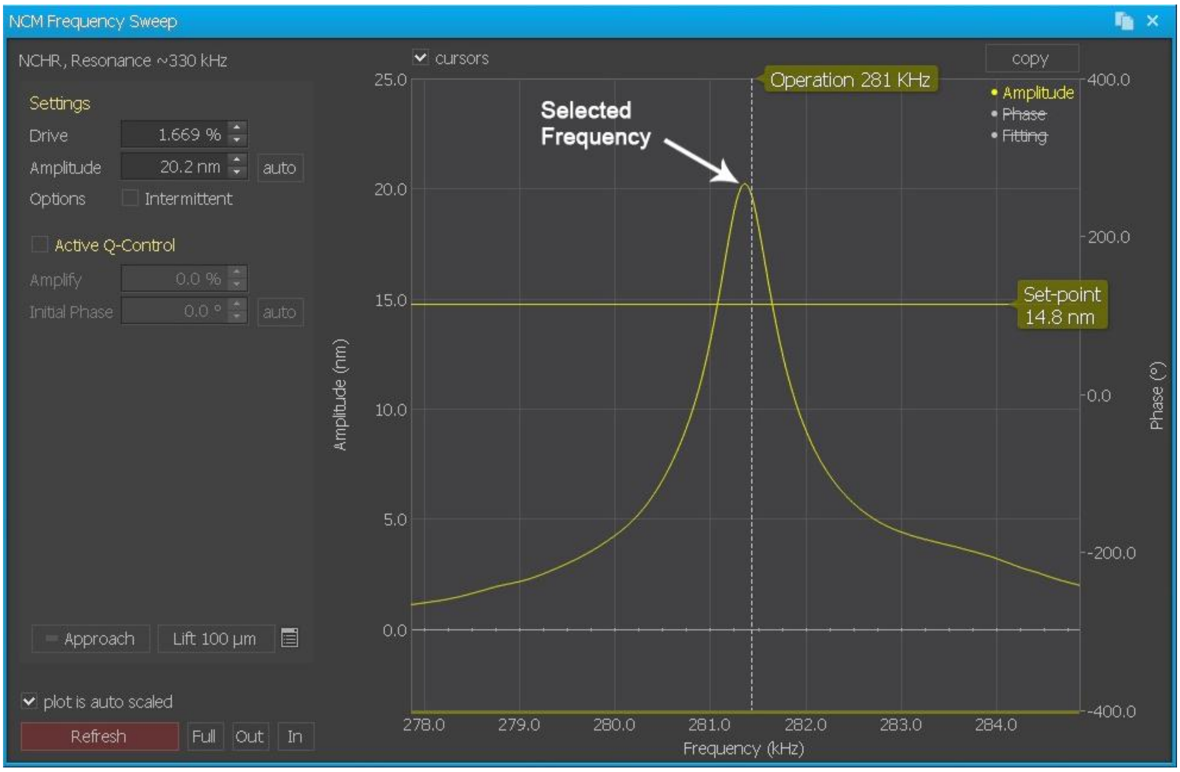


Figure 7-31. Resonant Frequency setup in Non-Contact Mode

When the "NCM Frequency Setup" window opens, you can manually select the reson ant frequency using the following instructions.

4. If the 'Refresh' button or 'Zoom Out' button is clicked, one unit on the X-axis repre sents 5 kHz as shown above.

5. Select the resonant frequency as follows: First, press the 'Refresh' button and the n the graph of frequency vs amplitude will appear. Press the 'Refresh' button again while adjusting the drive % to make the strongest peak fall within 20nm in the Y-a xis(You can check the Y-axis unit on the upper left corner of graph. It is adjustable using the mouse wheel). After adjusting the height of the peak, press the (Zoom) "I n" button until the X-axis unit is 1kHz/div

6. After positioning the mouse pointer on the slope just to the right hand side of the st rongest peak as shown in Figure 7-31, click on it with the left mouse button and a '+' sign will appear. The location of the '+' sign corresponds to the selected frequen cy f1 at which the cantilever will vibrate in non-contact mode. After positioning the mouse pointer on the red horizontal line, move this red line up and down while hol ding the left mouse button; this will allow you to change the set point value. In gen eral, make the set point just higher than half of the peak height, and press the "O K" button once to enter the selection.

   The value of the drive amplitude (%) and set point can also be changed in the "Sc an Control" window.

7-6-4. Cantilever Selection

The non-contact mode cantilever has a relatively large frequency since the non-contact mode uses the vibrating cantilever method which enables it to measure the force gradient by the amplitude and phase change due to the interaction between the probe and a sample surface. Figure 7-32 shown below is a SEM image of a typical non-contact mode cantilever, the PPP-NCHR series. The upper surface of the cantilever (the opposite side of the tip) is coated with aluminum (Al) to enhance the beam's reflectivity.

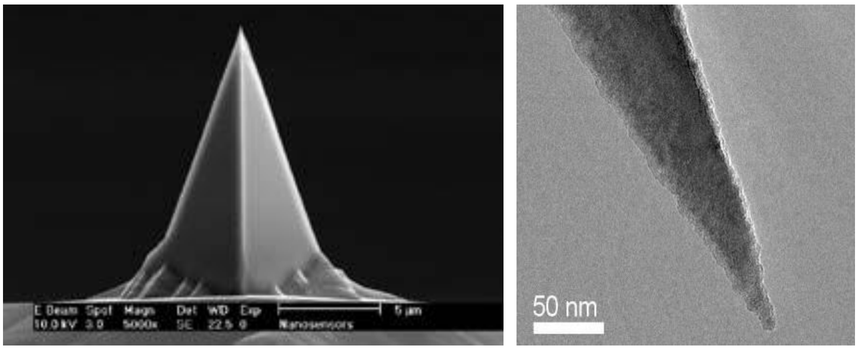


Figure 7-32 SEM image of ULTRASHARP silicon cantilever (the PPP-NCHR series)

Figure 7-33 shows the standard dimensions of the NCHR series chip. The thickness of the chip is 0.4 mm, and a rectangular shaped cantilever is at the end of the chip. Table 7-2 lists the specifications for this cantilever. The non-contact mode cantilever has a thickness of about 4㎛, and the spring constant is very large (42N/m) relative to that of a contact mode cantilever's.

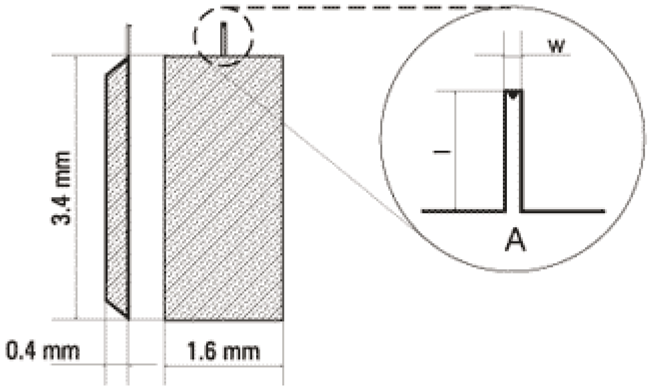


Figure 7-33. Silicon chip of the NCHR series has 1 rectangular cantilever

Table 7-2. NCHR series Cantilever Specifications

Cantilever Type	Cantilever Length, l ± 5, µm	Cantilever Width, w ± 3, µm	Cantilever Thickness, µm			Resonant Frequency, kHz			Force Constant, N/m		
			min	typical	max	min	typical	max	min	typical	max
A	125	30	3.0	4.0	5.0	204	330	495-5	10	42	130

7-6-5. Measurement Procedure

- **Perform Initial Setup**

  - Perform the initial setting by following the instructions in Chapter 6.

- **Approach Tip to Sample**

1. <u>**Set Point Setting**</u>:
   - **Set Point in Non-contact Mode: Reference amplitude for Z feedback**
     The cantilever vibrates after setting up the drive frequency and drive amplitude at resonant frequency. As the cantilever and sample's surface get closer, the attractive force between the tip and sample increases and the cantilever's vibration amplitude will decrease. For Z scanner feedback loop, a specific amplitude is chosen. This is called the 'Set Point' in Non-contact mode.
   - Drive amplitude changes depending on the distance between the tip and sample surface. Therefore, the 'Set Point' also means the distance between the probe tip and the sample surface.
   - <u>Perform frequency sweep (NCM ASetup). Please make sure if the selected frequency is within the range of resonant frequency. The amplitude of the selected frequency(red cross)-drive amplitude is recommended to be set near 20 nm.</u>
   - You need to adjust the drive amplitude depending on your sample. For example, setting the drive amplitude to over 20nm might be more effective when the sample is fragile and/or consists of strong adhesion forces.

2. <u>**Lower the Z stage to place near the sample surface.**</u>
   - Focus on the sample surface using the inverted Optical Microscope.
   - Move the Z stage down by placing and clicking the cursor at the lower part of the Z stage pad. This positions the cantilever close to the sample surface(within 1cm).

<u>WARNING!</u>

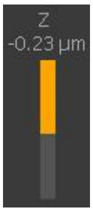
> If the Z stage is lowered too quickly, the cantilever may "crash" into the sample surface. Such a forceful interaction may break the tip, damage or destroy the sample, and/or seriously have a harmful effect on the Z scanner.

   - Slowly move the cantilever tip down until the shape of the cantilever starts to show faintly while watching the monitor.

CAUTION!

When lowering the cantilever, govery slowly to avoid a potential collision with the sample.

3. **Move to the desired sample position.**
   - Slowly adjust the XY Scanner to the desired sample position using the motori zed XY stage.
4. **Approach**
   - Click "Approach" (underneath the Z stage motor control). When the light to th e right of the motor controls stops blinking, the tip's approach is complete.
   - The upper half of Z scanner bar in the PSPD window will be green if "Approach" is successful. Before approaching, it is recommended to set the scan size to 0 and Z servo gain to 1 in the scan control window.
   - The upper half of Z scanner bar in the PSPD window will be green if "Approa ch" is successful. Before approaching, it is recommended to set the scan siz e to 0 and Z servo gain to 1 in the scan control window.



CAUTION!

Don't move the XY posiotion using the XY stage after approach.

CAUTION!

Don't turn off the beam after the approach.

■ Imaging

5. **Channel Config Setting**
   - Select the desired input signals in Input Configuration [Setup->Channel Confi g].
   - If the desired input signal don't show in the main panel of Input Config, Click the [] button to see hidden signals or use the channel search feature at th e bottom right portion of the window. The selected signals in the popup dialo g will be displayed on the main panel of Channel Config.

- It is recommended to set the 'Height', the 'Error Signal', the 'Z Drive', the 'NCM Amplitude' and the 'NCM Phase' in non-contact mode.

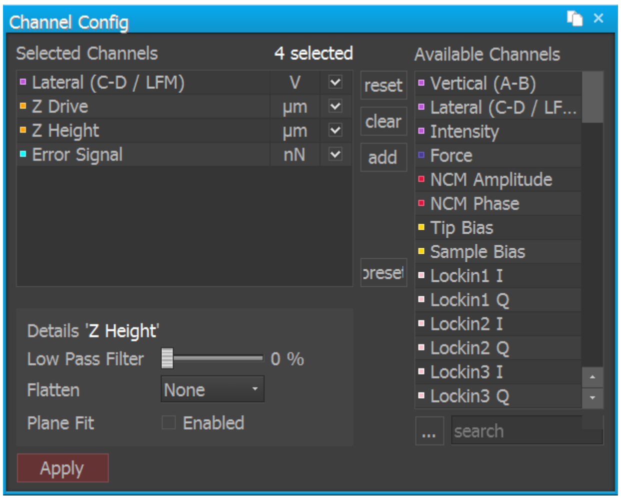


Figure 7-34. Input Config

- **Z Drive**: Calculated value from the driving voltage to the Z scanner in the feedback system. Considered as the height information of the sample surface since the Z scanner is in feedback to respond to the sample height.

- **Error Signal**: PSPD(VERTICAL)-SetPoint. The feedback loop works to make this signal go to 0. During the scan, this signal returns to 0 rapidly in good feedback but slowly in poor feedback. For such reasons, through this signal, the feedback status can be confirmed. It is recommended to monitor the Error Signal during the parameter setting.

- **Height**: Z scanner's actual movement from the sensor directly. Considered the height information of the sample surface since the Z scanner is in feedback to respond to the sample height.

- **NCM Amplitude**: Amplitude of cantilever vibration in NCM. This signal is maintained to a constant in the feedback loop. During the scan, it returns to the reference amplitude rapidly in good feedback but slowly in poor feedback. For such reasons, through this signal, the feedback status can be confirmed. It is recommended to monitor this NCM amplitude during the parameter setting in NCM and Tapping mode.

- **NCM Phase**: Phase of cantilever vibration in NCM and Tapping mode. This signal is sensitive to elasticity and viscosity of the surface. These properties can be displayed on phase imaging. It is recommended to acquire this signal in NCM.

6. **Select the desired monitoring signals** (Height, Error Signal and NCM Phase are recommended for monitoring) in the Trace Control Window.
   - If none are open, open one by clicking the button.

7. **Parameter Setting**
   - Input a value for the “Scan Size.” This will be the size of your image. Your X Y Scanner will begin moving back and forth by this amount. This movement may be visible on the vision program.
   - Optimize the scan parameters (Set Point, Scan Rate, Z Servo Gain) to matc h the forward/backward line profiles.

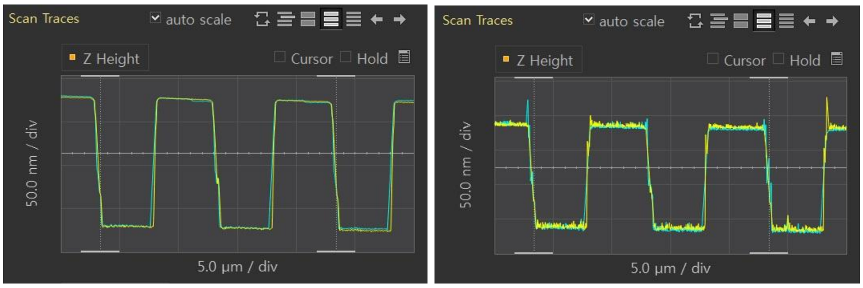


Figure 7-35. Proper Gain (top); Noise from Excessive Gain (bottom)

- **Scan Rate:** The Hz unit in the Scan Rate represents the frequency or how many times per second the scanner moves in the fast scan direction. Too high of a speed will result in tip and sample damage.

- **Z Servo Gain:** Feedback Sensitivity. Increasing the Z Servo gain too much can create oscillations. Please adjust it properly.

- **Set Point:** Reference Amplitude for Z feedback. It means the tip-sample distance, as well. Decreasing the Set Point increases the interaction between the tip and sample but also makes it more possible for the tip to touch to the sample during the scan.

7-7. Tapping mode

7-7-1. Principle of Dynamic Force Microscopy

Dynamic Force Microscopy (Tapping mode) is very similar to non-contact mode AFM in many ways such as the applied force and the measurement principle. Before you read this chapter, please carefully read *Section 7-6.*

Tapping mode is a hybrid of the two most fundamental measurement methods, represented by contact mode and non-contact mode. In LFM, the cantilever vibrates in free-space in the vicinity of the resonant frequency like in non-contact mode. At the same time, since the vibrating cantilever gets very close to the sample surface, it taps the surface repeatedly, and the tip “contacts” the sample surface as it does in contact mode.

If you measure the amplitude of vibration of the cantilever used in Tapping mode while changing the frequency, as shown in Figure 7-36, there appears a special frequency where the amplitude resonates and amplifies greatly. This is called the intrinsic frequency (f_0).

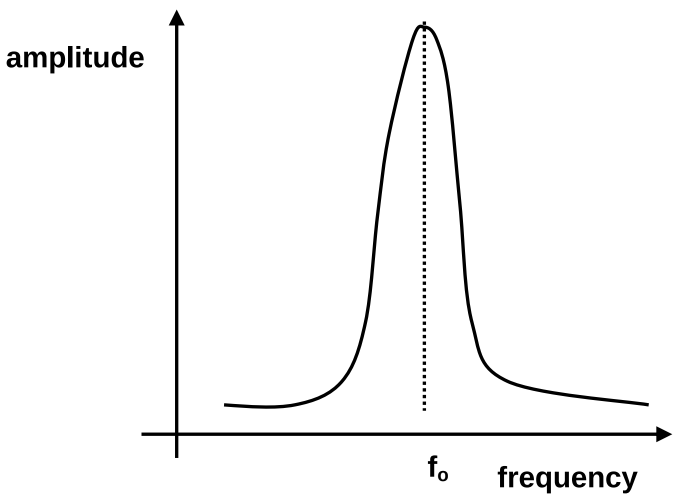
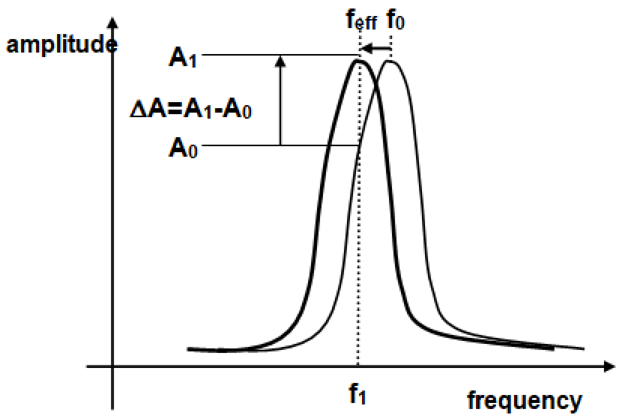


Figure 7-36. Resonant frequency

Tapping mode uses the non-contact mode feedback circuit with keeping the vibrating frequency (f_1) a little bit lower than the resonant frequency while oscillating in free-space. Then, as the tip is lowered, the real spring constant reduces due to the attractive Van der Waals force which increases as the tip approaches the sample surface, as shown in Figure 7-37 (a). Therefore the resonant frequency changes to the effective frequency (f_{eff}) in non-contact regime and the amplitude at the frequency f_1 increases by ΔA. Since the amplitude increases by ΔA, the non-contact mode feedback circuit decreases the distance between the tip and the sample surface by Δd, indicated in the graph of vibration amplitude vs tip-sample distance and z-feedback as shown in Figure 7-37 (b) (This part was explained in detail in *7-4. AFM in Contact Mode*). Therefore, the vibrating cantilever, which is oscillating above the sample, approaches the sample almost in contact or in collision with the surface. This method, keeping intermittent contact between the sample surface and the vibrating cantilever is called Dynamic force microscopy (Tapping mode).

Similar to the initial approach of making contact with the sample, while scanning, a larger amplitude reduces the distance between the tip and sample, and a smaller amplitude increases the distance depending on the surface roughness to determine the surface topology.



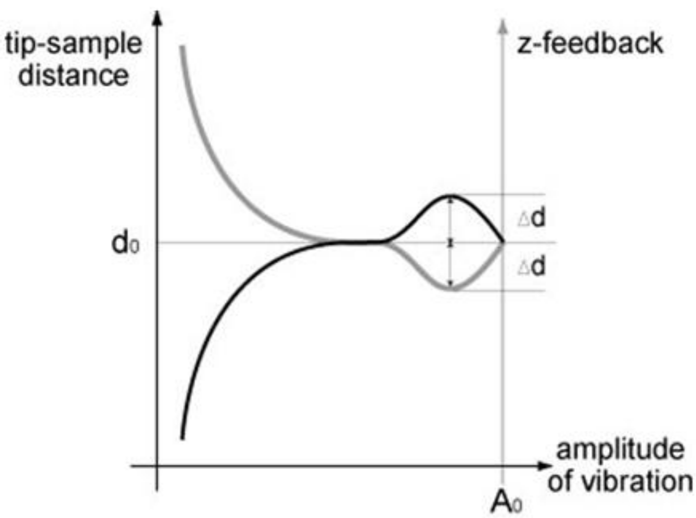


Figure 7-37. (a) Resonant frequency shift (b) Amplitude vs. Z-feedback

For certain samples, Tapping mode yields better measurements than contact mode or non-contact mode AFM. Dynamic force microscopy (Tapping mode) has an advantage over contact mode in the sense that it will damage the sample less since there is no frictional force as the cantilever “skips” across the sample surface instead of “dragging” across it. Since the amplitude of oscillation is so large, there is a much better chance that the probe will not be caught by the meniscus forces of moisture condensed on the sample surface, as there is with NC-AFM.

7-7-2. Conversion to Tapping mode

In dynamic force microscopy, the Head mode will be set to NC-AFM just as in non-contact mode. However, the “Intermittent” checkbox in the Scan Control Window must be selected.

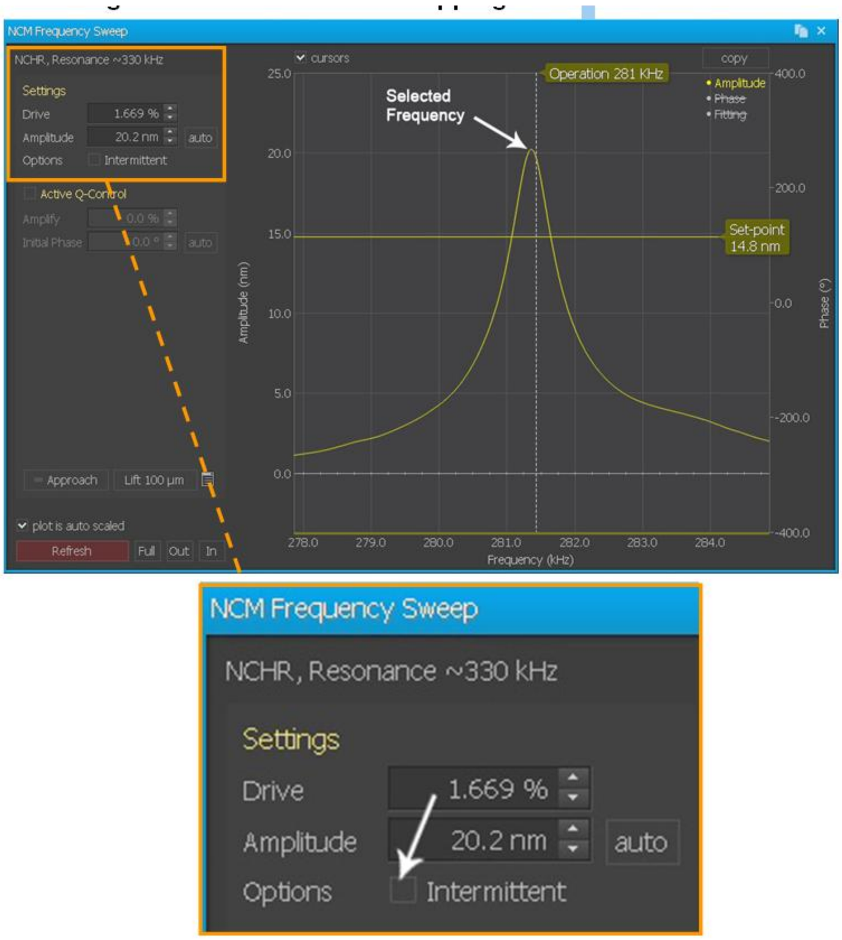


Figure 7-38. Conversion to Tapping mode

7-7-3. Resonant Frequency setup

As explained in section 7-7-1, Tapping mode uses non-contact mode feedback, but, as opposed to non-contact mode, the driving frequency should be selected at the left part of the peak in the graph. The other conditions are the same as for non-contact mode.

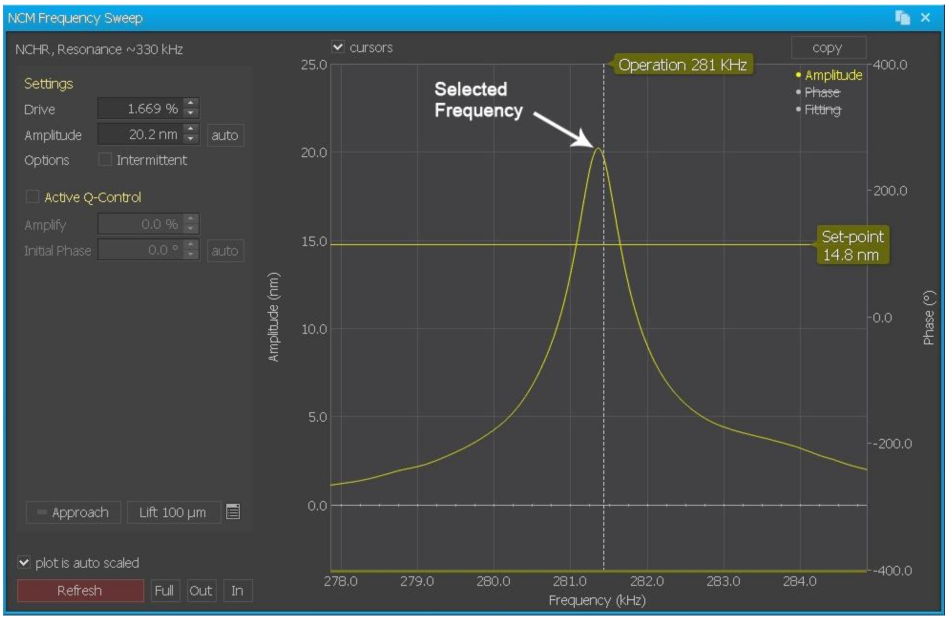


Figure 7-39. Resonant frequency setup in Tapping mode

7-7-4. Cantilever Selection

Since Tapping mode uses the same method as non-contact AFM, which is to vibrate the cantilever when measuring the sample surface, the same type of cantilevers are used in Tapping mode as in non-contact mode unless the user prefers a different type of cantilever for a specific purpose. See the Cantilever Selection section in the Non-Contact AFM Section.

7-7-5. Measurement Procedure

The method of measurement of Tapping mode is the same as that of non-contact mode. The absolute value of the set point also means the distance between the probe tip and the sample surface, just as in non-contact mode, but the value is much smaller. As explained in Section 7-6, the vibrating probe tip moves as if it is pecking the sample surface using the same feedback circuit. Determining the set point plays a very important role in obtaining the best image.

The measurement method hereafter is the same as in Section 7-6-5. Please review to Section 7-6-5.

7-8. Approach Spectroscopy

Approach Spectroscopy is used in the investigation of a sample's mechanical properties. An approach curve (F/D curve) plots how the cantilever's interaction with the sample changes as its distance from sample changes.

This section assumes that the operator is familiar with the NX SPM system, as well as the SmartScan software. Otherwise, it is recommended that you consult this NX User's Manual and the SmartScan Software Manual while going through this section.

7-8-1. What is Approach Spectroscopy

Modes

Approach curves can be acquired in several different modes. These modes and their differences are as follows:

- In F/D Mode (Force/Distance Mode), the cantilever is simply approached to the sample to find where the surface is, then raised to the MIN position, lowered to the MAX position, and raised again to the MIN position. Only the cantilever's deflection vs. the Z scanner's position is measured.

- In Tip Oscillation Mode, the cantilever is oscillated near its resonance frequency as it is being raised and lowered. The amplitude and phase of the oscillating cantilever are considered with respect to the Z scanner's position. To use Tip Oscillation Mode, the Head Mode (from Parts Config) must be on a setting that uses tip oscillation, such as NC-AFM, and the "Use Tip Oscillation in Spectroscopy" option in Preferences must be selected.

Other Considerations

The actuator which moves the cantilever closer and farther from the sample surface consists of a stacked PZT material. This material is controlled by varying the electric field. However, the PZT actuator does not actually move in a linear relationship to the control voltage, but rather displays hysteresis and other nonlinearity. This deviation from the assumed linear movement, although small on the nanometer scale, becomes significant on the micrometer scale.

To correct for these deviations, SmartScan implements "Z ServoScan", a corrective feedback loop. Z ServoScan compares the Z Scan signal to the actual movement of the Z Scanner, which is measured by the Z Detector. When there is a discrepancy, the ServoScan modifies the Z Scan signal (now known as the Z Scan Corrected signal) to eliminate the nonlinearity. The drawback to the Z ServoScan system is that it introduces electrical noise, which may become significant when the scan size decreases.

It is up to you to decide whether the nonlinearity of the actuator or the Z ServoScan system's noise is more significant for your experiment. You can select Z ServoScan by deselecting the "Auto Offset" item in the Spectroscopy Control Panel and selecting "ON" in Z ServoScan Setup which is shown in the Setup.

Figure 7-40. Auto Offset option

7-9-2. Acquiring an Approach Curve

No hardware modifications are required for taking approach curve measurements with an NX SPM system.

It is typical to obtain an SPM image of the sample to identify regions of interest for approach curve acquisition. You may skip this process and instead identify the region of interest with an optical microscope, or image a random point on the sample.

For more information on SPM imaging procedures, consult your NX User's Manual or the relevant Operation Manual for your SPM mode. The following sections describe the procedures for taking approach curves. For more information on each parameter of F/D spectroscopy control window, please consult your SmartScan manual.

Chapter 8. Scanning Ion Conductance Microscope (SICM)

8-1. Principle of Scanning Ion Conductance Microscope

SICM is the offspring of AFM, replacing the silicon-based cantilever with an electrolyte–filled glass nano-pipette that is scanned across the sample surface immersed under electrolyte solution. The ion current decreases when the nano-pipette opening becomes blocked by the sample surface, and the feedback system raises the nano-pipette to recover its constant distance above the surface. Similarly, the ion current increases when the distance between the nano-pipette and the sample surface become larger. The feedback system corrects for this as well. Therefore, similar to Scanning Tunneling Microscope operation in air, the SICM images the sample without “physical contact.” Non-contact imaging is particularly valuable to imaging soft biological samples, such as live cells. In addition, the electrolyte-filled glass nano-pipette can contain or release chemical substances and record electrical signals from alteration of ionic current. These features enable the functional and physiological studies of live cells. In contrast, the AFM provides invaluable data from the physical contact with the sample, such as interaction of various molecules, even though it has shortcomings for imaging soft dynamic samples. Utilizing both SICM and AFM techniques on the same sample could bring a great deal of benefits for nanobio science and research.

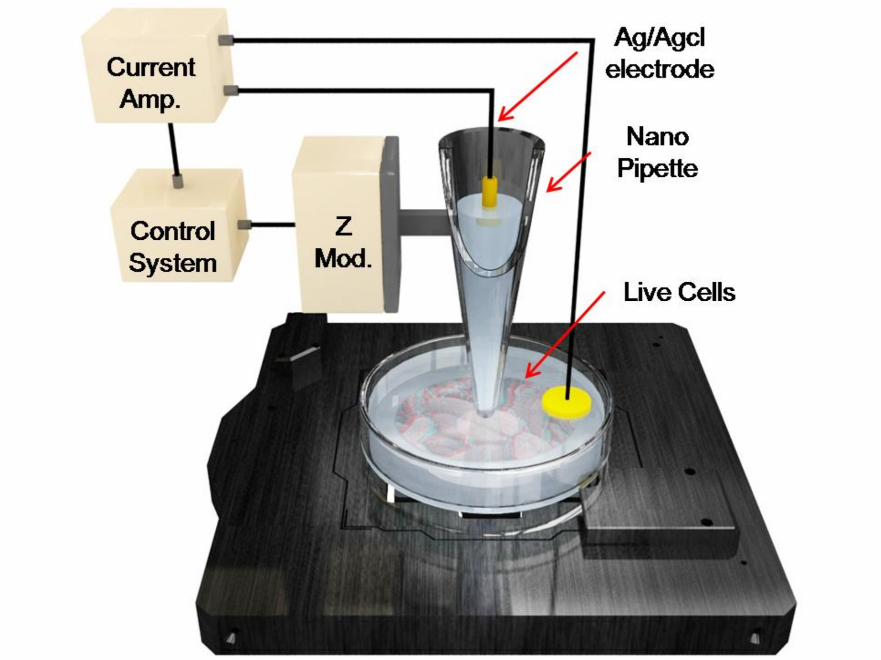


Figure 8-1. SICM Diagram

8-2. SICM Component List

The components for SICM below are provided;

1. Faraday cage
2. SICM Head & Block
3. Pipette 50ea & Qurtz **30ea**
4. Pipette Electrode **2ea**
5. Bath Electrode **2ea**
6. Silver wire **3ea**
7. Petri dishes **10ea**
8. Syringe Filter **2ea**
9. MF 34G – Micro Fil Syringe **1set**
10. 1ml Syringe **5ea**
11. PDMS Sample XY 10um & Z 118.5nm

8-2-1. SICM Head

The NX12 SICM head is the component which actually interacts with the sample and takes the AFM measurements. The NX12 ICM Head provides the following:

- Hatch Clip: Nano-pipette Mount
- I (Internal Pre-amplifier): Ion Current Detection
- V: Tip Bias Input
- Z Scanner: Movement in Z axis

WARNING!

Do not disassemble the NX12 ICM head on your own. Park Systems will not be responsible for any personal or physical damage, and/or degraded performance that may result from unauthorized disassembly.

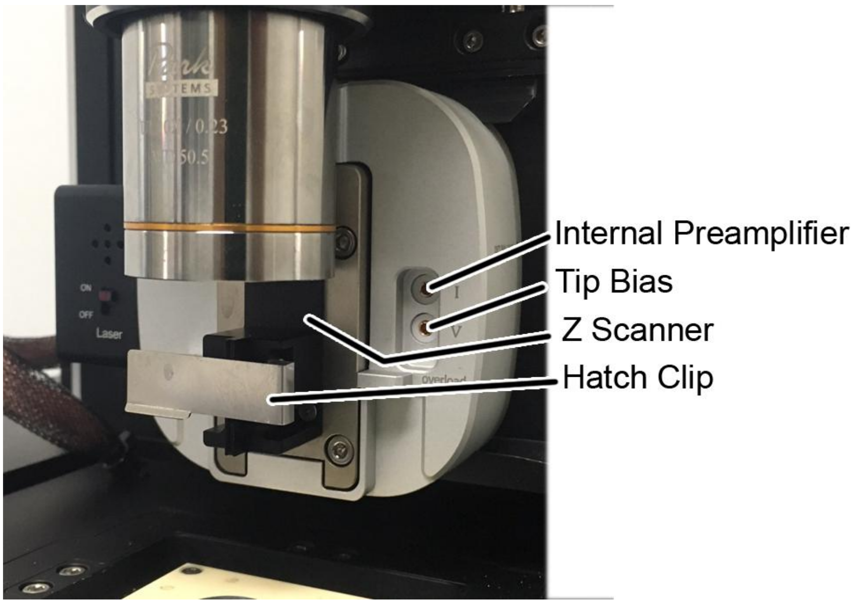


Figure 8-2. NX-SICM Head

Current Detection

In order to map the height of the sample surface, the nano-pipette scans the surface for the SICM measurement while ion currents flow through the pipette hole. Generally, the flowing current generated in SICM has a very small magnitude and needs to be amplified by a current amplifier. The NX12 currently supports the internal current amplifier with a fixed gain of 10^9 V/A, and can detect currents up to 10nA. The upper connector marked as 'I' is for current detection through the internal current amplifier of the NX12.

8-2-2. Nano-pipette

The Nano-pipettes are made from glass capillaries (Inner diameter: 0.58mm, outer diameter: 1mm, length: 5-55mm) or quartz capillaries (Inner diameter: 0.5-50mm, outer distance: 1.0mm, length: 5-55mm) by using a nano-pipette puller. The NX12 provides quartz (Range of Nano-pipette end size: 30~50nm) and glass Nano-pipettes (Range of Nano-pipette end size: 80 ~100nm). The inner diameter is determined by the tip length, the glass capillaries' inner diameter, the wall thickness, and the puller parameters. Fgure 8-3 a SEM image of the nano-pipette tip coated with 5 nm of gold. The scale bar is 2um (left) and 300nm (right), respectively. You can fill the electrolyte using a non metallic syringe needle. Please refer to Figure 8-4.

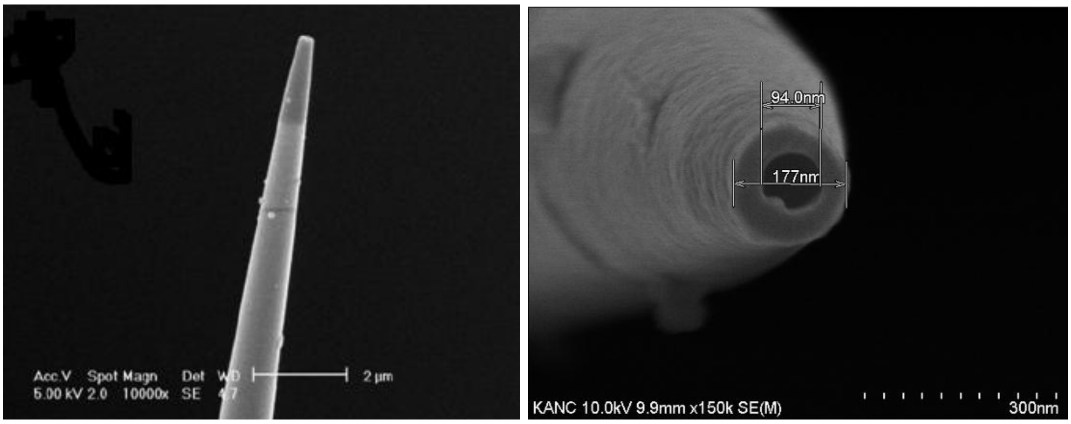


Figure 8-3. Nano-pipette SEM Image

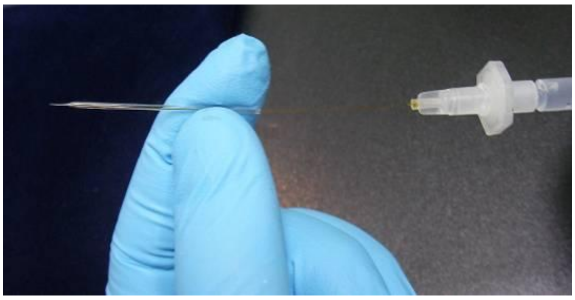


Figure 8-4. Filling the electrolyte on the nano-pipette

8-2-3. Ag/AgCl Electrodes

The SICM Mode uses two Ag/AgCl electrodes: a Nano-pipette Electrode and a bath electrode.

The nano-pipette electrode is put into the nano-pipette holder body and detects the ion current during the measurement. 6 cm Ag wires with a diameter of 0.2mm is provided so that you can also make this nano-pipette electrode on your own. 3.5 cm of one end of the wire is covered with a chlorine layer to prevent the wire from reacting with the electrolyte. You can easily make it by dipping an Ag wire end in electrolyte, such as KCl, and by applying a voltage for a few minutes. The potential of this electrode is determined by the concentration of the electrolyte.

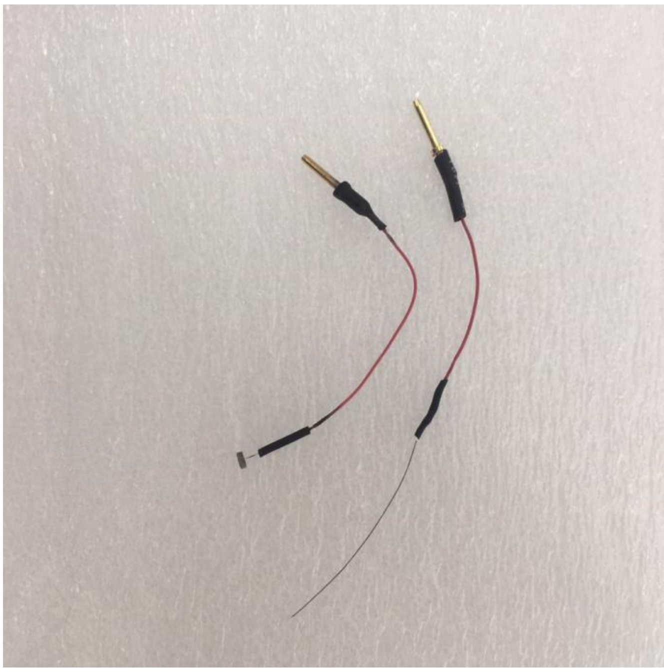


Figure 8-5. Ag/AgCl Electrode and Nano-pipette Holder

The bath electrode is put into the electrolyte on the sample and can be used to apply a sample bias. You can connect the bath electrode into the sample bias socket. This bath electrode has an Ag wire (Disc 4.0 x 1mm) embedded in Ag/AgCl.

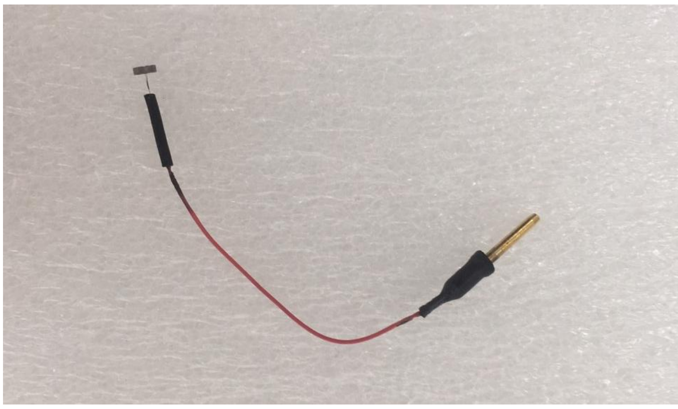


Figure 8-6. Bath Electrode

8-2-5. Faraday Cage

The Faraday cage shields the external electromagnetic interferences. The faraday cage component is shown in figure 8-9. It is essential used to get good images.

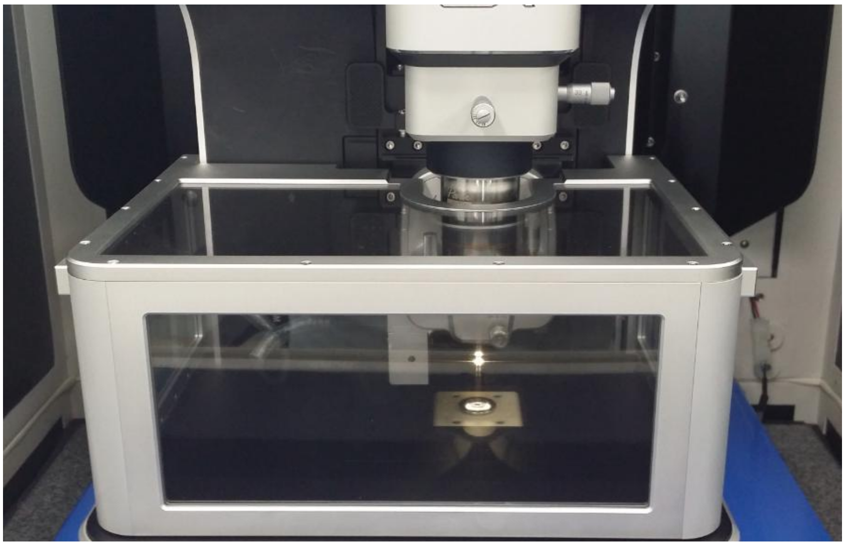


Figure 8-9. Faraday Cage

The jig should be installed to equip the NX12 with the faraday cage first. Please match between the holes on the main body bottom and on the jig and fix with provided screws.
The figure below shows the NX12’s main body equipped with the faraday cage after the jig’s installation.

8-3. SICM Hardware Setup

8-3-1. Sample Loading

Prepared samples must be loaded onto the XY stage using the following steps:

1. First, raise the head high enough so that you have no difficulties loading the sample onto the XY stage.

CAUTION!

If the head is not rasied high enough, the sample or the cantilever may be damaged.

2. Disassemble the sample chuck by removing the 4 screws.

3. Place the slide or Petri dish on the XY stage.

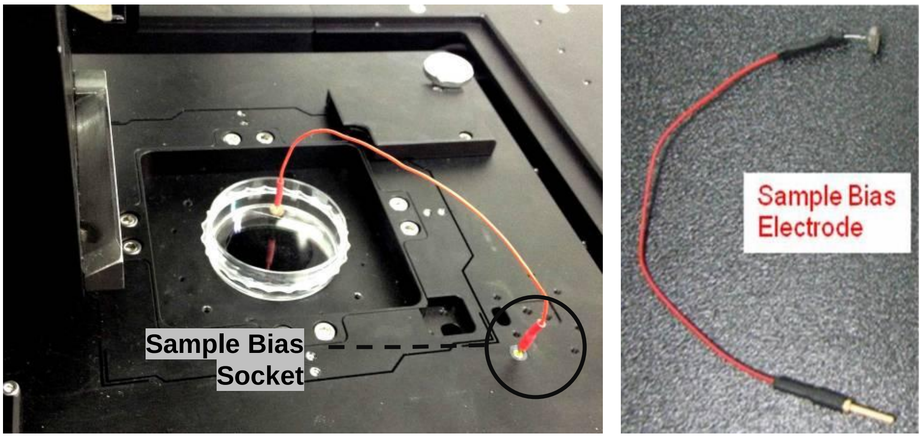


Figure 8-14. Left: Sample Bias Socket, Right: Bias Electrode

4. Connect the sample bias electrode to the sample bias socket. Put the bath electrode into the electrolyte.

5. Position the sample location by adjusting the XY Stage motor in software. Focus

on the sample surface with the CCD or Eyepiece.

8-3-2. Assembling Nano-pipette Holder

Prepare the nano-pipette holder using the components as shown in Figure 8-15. For further information on how to make the nano-pipette holder, please refer to Appendix A. A complete unit is shown in Figure 8-16.

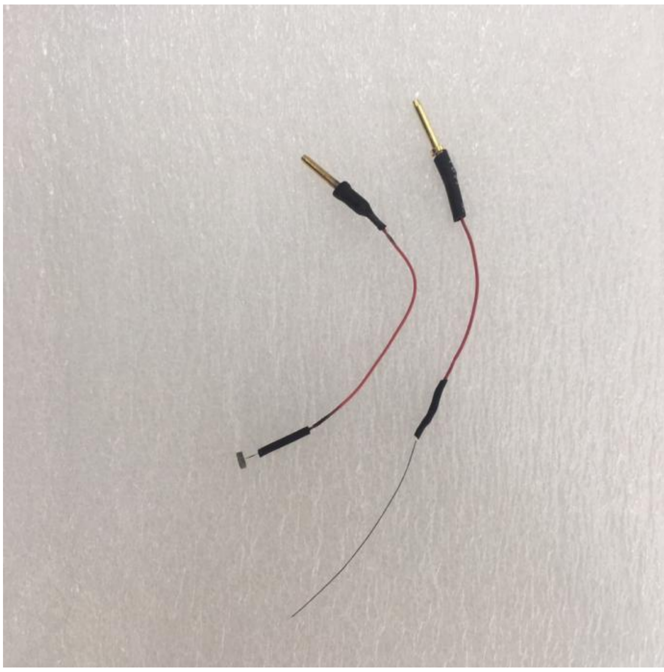


Figure 8-15. Nano-pipette holder components

① Nano-pipette
② Pallet
③ Nano-pipette Holder Body
④ Nano-pipette Holder Connector
⑤ Rubber Stopper (Hole size: small 1ea, large 1ea)
⑥ Ag/AgCl Electrode
⑦ Ag/Cl wire

8-3-3. Installing ICM Head

During the imaging procedure, some steps may become easier if you remove the NX Head. Removing and replacing the Head is very easy.

- First, confirm that the Head has clearance.
- If it is too close to the sample, raise the Z Stage.
- Click the "Head On/Off " button in the Tool bar in SmartScan to head off
- Remove the nano-pipette holder by pushing the hatch clip.

CAUTION!

You can skip step 4, but it is recommended to disassemble the nano-pipette holder. Otherwise, the nano-pipette may be damaged.

- Unlock the dovetail rail locks on the sides of the Head. Then, slide the Head out to the left.

Replacing the head is as easy as removing it: slide it in, engage the dovetail locks, mount the nano-pipette holder and Click the "Head On/Off " button in the Tool bar in SmartScan to head on

8-3-4. Installing ICM Head

During the imaging procedure, some steps may become easier if you remove the NX Head. Removing and replacing the Head is very easy.

- First, confirm that the Head has clearance.
- If it is too close to the sample, raise the Z Stage.
- Click the "Head On/Off " button in the Tool bar in SmartScan to head off
- Remove the nano-pipette holder by pushing the hatch clip.

CAUTION!

You can skip step 4, but it is recommended to disassemble the nano-pipette holder. Otherwise, the nano-pipette may be damaged.

- Unlock the dovetail rail locks on the sides of the Head. Then, slide the Head out to the left.

Replacing the head is as easy as removing it: slide it in, engage the dovetail locks, mount the nano-pipette holder and Click the "Head On/Off " button in the Tool bar in SmartScan to head on

8-4. SICM (DC) Mode

8-4-1. Principle of SICM (DC) Mode

In SICM, electrolyte-filled nano-pipette is used as a Probe. This Nano-pipette measures the ion flow between the sample electrolyte and the Ag/AgCl electrode through the nano-pipette hole. The nano-pipette hole dimension can be as small as 30 nm and as it gets closer to the sample, there's a partial blockage of ion flow through this hole based on the distance between the sample and the opening. As you can see from Figure 8-17, current decreases. To maintain this current at a constant level, the NX system uses Z-scanner feedback. The movement of Z scanner will be the height data. The current flowing between the nano-pipette and sample has a very small magnitude and needs to be amplified by a current amplifier. The NX12 currently support the internal current amplifier with a fixed gain of 10^9 V/A and can measure currents up to 10nA.

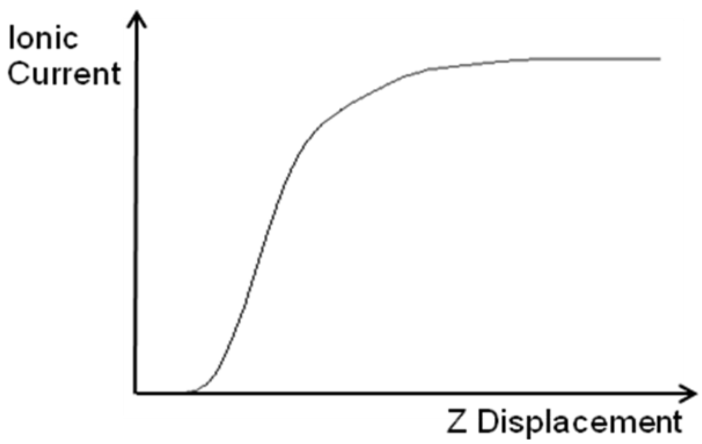


Figure 8-17. Measured Current VS Distance Curve (DC Mode)

8-4-2. SICM DC mode and Cantilever setup

To use SICM DC mode, select the appropriate Head mode using the following steps:

1. Click the “Head On/Off “ button in the Tool bar.

2. Set the Head mode to SICM(DC) and the cantilever type to ICM after clicking the “Select Parts” button .

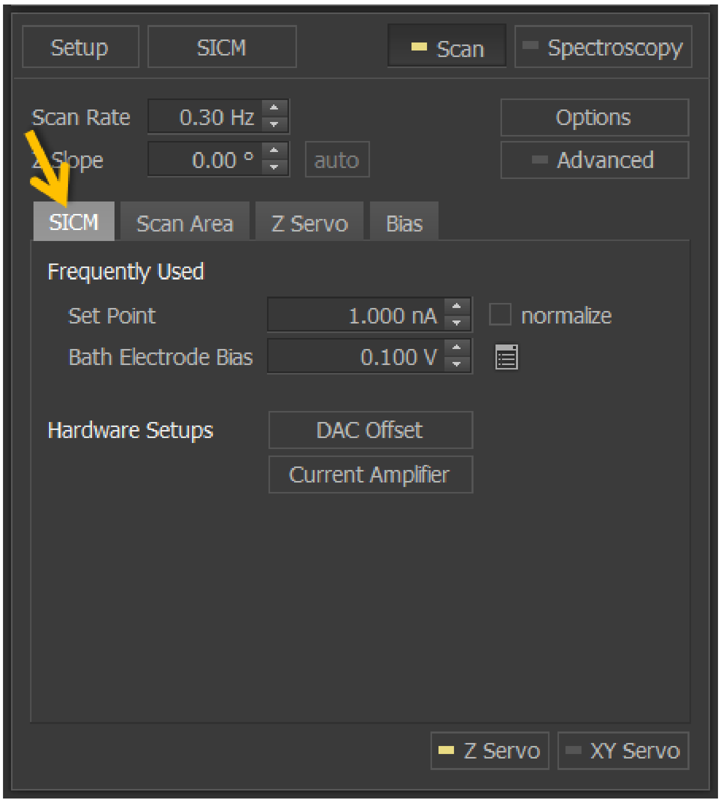


Figure 8-18. SICM Selection

NOTE!

Do not change other settings in the “advanced” selection. Otherwise, the scanner and stage may move improperly.

3. Click the “Head On/Off” button. .

8-5. Approach-Retract Scanning (ARS) Mode

8-5-1. Principle of Approach-Retract Scanning Mode

The image of a very delicate feature of a biological sample or cell which has a height of several microns, can be distorted by imaging with AC mode using continuous feedback. In approach-retrace scanning mode, continuous feedback is no longer used. Instead, to get every imaging pixel point, the nano-pipette's linear approach and retract procedure is operated repeatedly on the sample surface while monitoring current signals. At first, when the nano-pipette is distant from the sample surface, reference current is measured. Secondly, the nano-pipette approaches until it reaches a height where 2.0 % current is reduced. When 2.0 % current reduction is achieved, the position of the Z scanner is recorded. Lastly, the nano-pipette is retracted far enough from the sample and then moves to next imaging point.

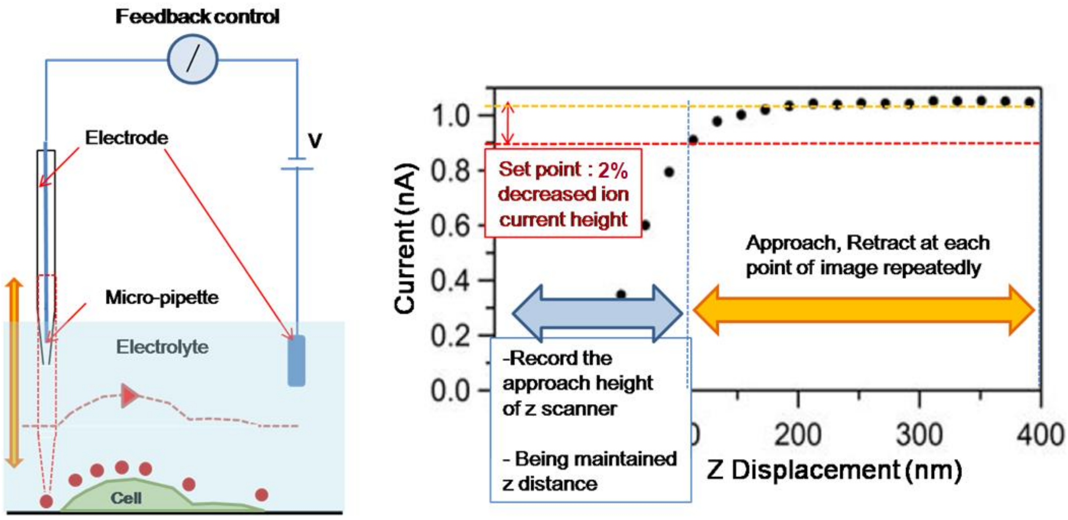


Figure 8-22. Approach Retract Scan Mode

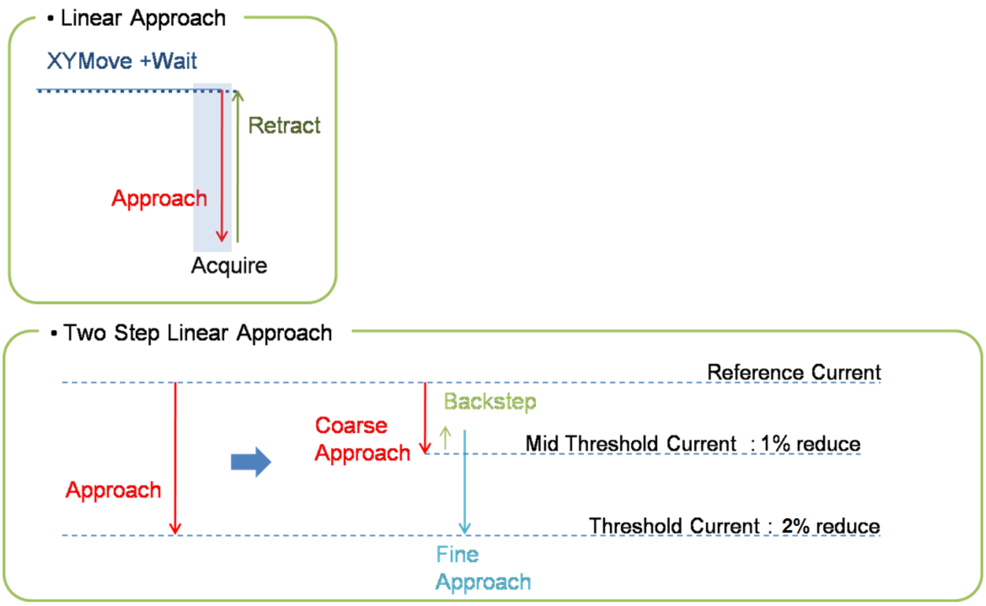


Figure 8-23. ARS Operation

8-5-2. Measurement Procedure

1. After approaching in DC mode, select 'ARS Mode Setup'. Z servo will automatically be deactivated. Changin Head Mode top SICM Mode will add "ARS" to Advanced, as shown in Figure 8-24. (Does not appear in Advanced Window selection menu when not in SICM Mode.)

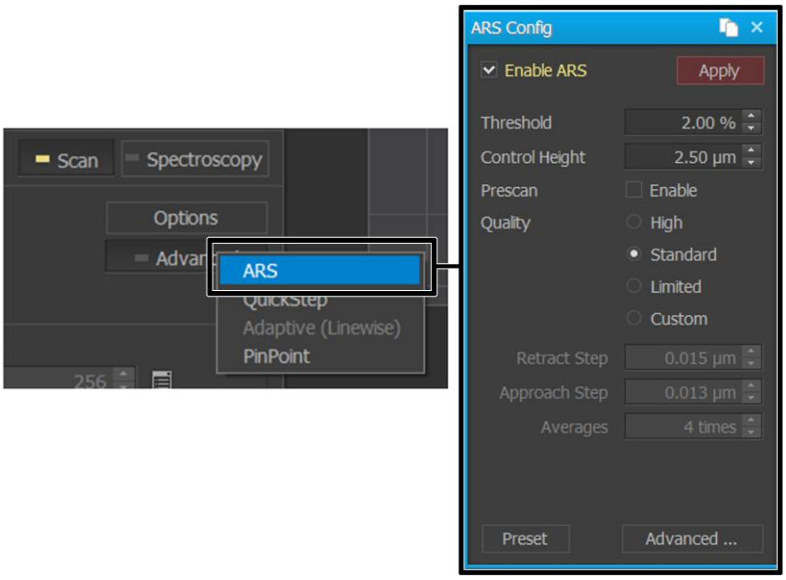


Figure 8-24. ARS Mode Setup

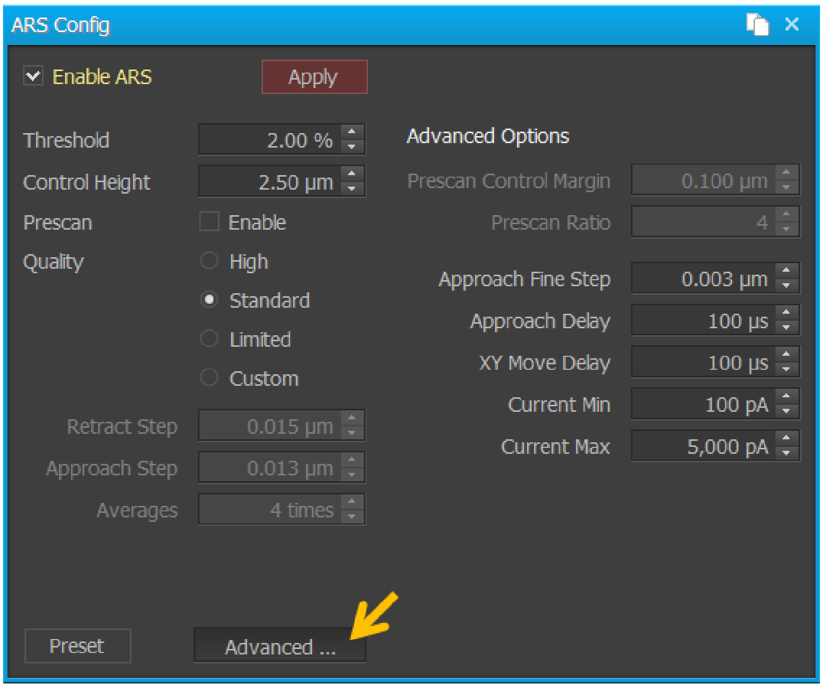


Figure 8-25. ARS Mode Setup U/I

- **Threshold:**

  This value is used to calculate the target current which determines how much to lower by. Before lowering the pipette, the average current value is calculated and the % specified here is deducted from it to arrive at the value to set as Target. The default value is 2%.

  For example, if the average current value measured before lowering the Pipette was 1000pA, the lowering Pipette stops Approach and switches to Retract state when it reaches 980 pA (98% point of average value).

- **Control Height:**

  This value is the same as "Retract Height" of XEP. After measurement of an XY point is complete, the pipette is raised to move to the next point – this height difference is the value. If this height value is large, it reduces the chances of the pipette crashing into the sample but can delay the time taken to complete Approach at the next point, increasing the overall scan time.

- **Prescan:**

Select this Option to 'Prescan.' Prescan is a function for reducing overall Scan time. In other words, the objective is to scan beforehand to obtain approximate height, then reduce Approach-Retract time in the Z direction for each Prescan section. This has the same effect as conducting 'Adaptive ARS' in XERP before. Prescan can be toggled On/Off even after ARS scan has begun.

When using the Prescan option, a line Scan operates as below.

1. Intermittently scans in Fast Scan direction. (Defaults to once per 4 pixels, can be changed in Advanced options. The Retract Height used here is 'Control Height.')

2. Returns to Fast Scan starting point.

3. Prescan data is used to redetermine "Control Height" per section.

4. Carry out scan using Control Height determined above per section.

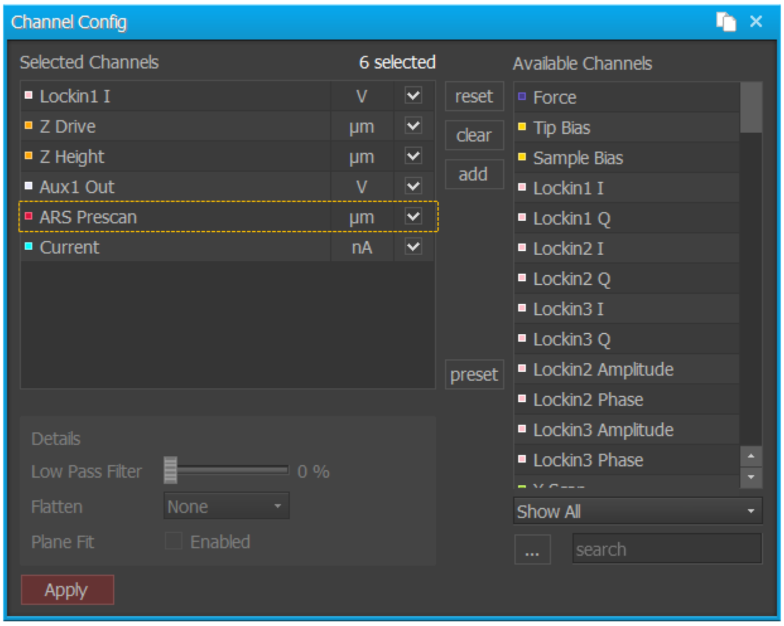


Figure 8-26. Channel Config

"ARS Prescan" is a channel related to the Prescan. As described above, this means the approximate height of scans taken beforehand. In order to determine whether Prescan is operating correctly, compare "ARS Prescan" channel with "Z Height."

Figure 8-27. Compare to ARS Prescan and Z Height

- **Quality:**

  The Parameters which have great effect on measurement results here are Retract Step, Approach Strep, Averages. These three parameters mainly use specific sets, and there are not many instances detracting from those. The user may select [Custom] Options in order to set these values according to individual circumstances. Look below for the values applied when selecting each Option.

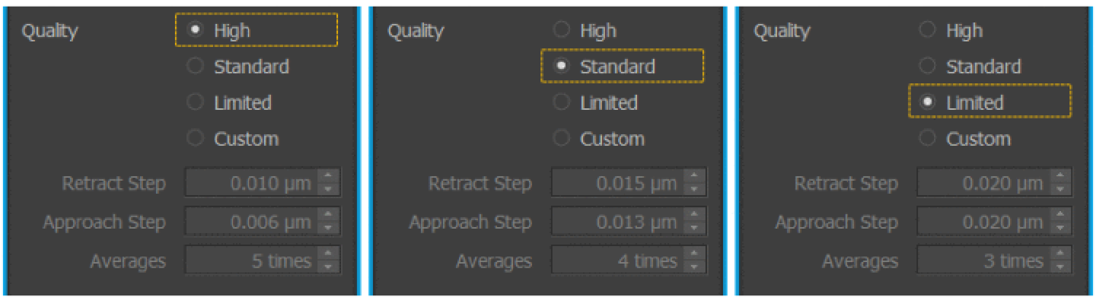


Figure 8-28. ARS Config of Quality

- **Advanced Option:**

  This function is the miscellaneous Parameters which are accessed when clicking [Adavanced …]. Parameters which are judged to rarely require changes are gathered here.

Parameter	Function
Prescan Control Margin	This Parameter is used in calculating Control Height per section after Prescan is complete The value of this setting is added to section heights obtained from Prescan data to use as the final Control Height. The larger this value, the lower the chances of the Pipette crashing into the sample, but overall imaging time increases.
Prescan Ratio	Indicates length of Prescanned section. If length is 256 pixels in FastScan direction, and this is set to 4, then Prescan is carried out in 64 (= 256/4) total points and one section is defined in 4 pixel units..
Approach Fine Step	Length unit used when lowering Z scanner and Pipette during Approach. When the half point of the Threshold (for example, if the Threshold is 2% the half point is the 1% point) is reached, the lenfth of the default step used in each Approach is changed to this value.
Approach Delay	Delay time before Approach begins.
XY Move Delay	Parameter determining the time taken to move in XY direction. Only multiples of 20 us can be entered here.
Current Min	Indicates range of Current value, breaching this range will cease Approach in order to protect the Sample.
Current Max	

C. Measurement Procedure

1. After approaching in DC mode, select ‘ARS Mode Setup’. Z servo will automatically be deactivated.

2. Insert a ‘Control height’ higher than the sample’s expected height.

3. Insert scan size while monitoring the Height.

4. Adjust ‘Control height’. The ‘Control height’ must be higher than the sample height for nano-pipette protection. ex) sample height: 0.5 ㎛ → Control height: 1 ㎛

5. Adjust ‘Control height’ again. If the oscillation is too big and the signal is shown on the sample profile of the trace mode, reduce the ‘Control Height and Step’ value slowly until the oscillation signal decrease enough to match the sample’s profile.

6. Adjust ‘Approach’. Reduce the ‘Coarse step’ to decrease some oscillation-like

signal as well as reducing 'retract step'. It is usually recommended to set 'Fine step' to at least a minimum value of '0.005 ㎛'.

7. Adjust 'Delay'. Increase the 'overall' value step by step, checking the height signal.
8. Increasing the 'Current Average' value allows for a more stable height signal. However, applying too much of a delay value will increase the time to acquire images.
9. Adjust all value giving detail parameter settings to obtain a precise and stable height signal.
10. Once all parameter settings are completed, activate 'skip scan' to reduce time. The 'Lift Height' must be higher than the sample height.
11. Click 'start' to obtain an image

Appendix A. Calibration

1. Calibration

Access the maintenance mode workspace by clicking the **Maintenance** tab or by clicking **SmartScan ▼ -> Maintenance**. Figure A-1 shows the maintenance mode workspace and labels for each view area (Vision View, Monitoring View, Setup View, and Sweep Result View). Each view area is described below.

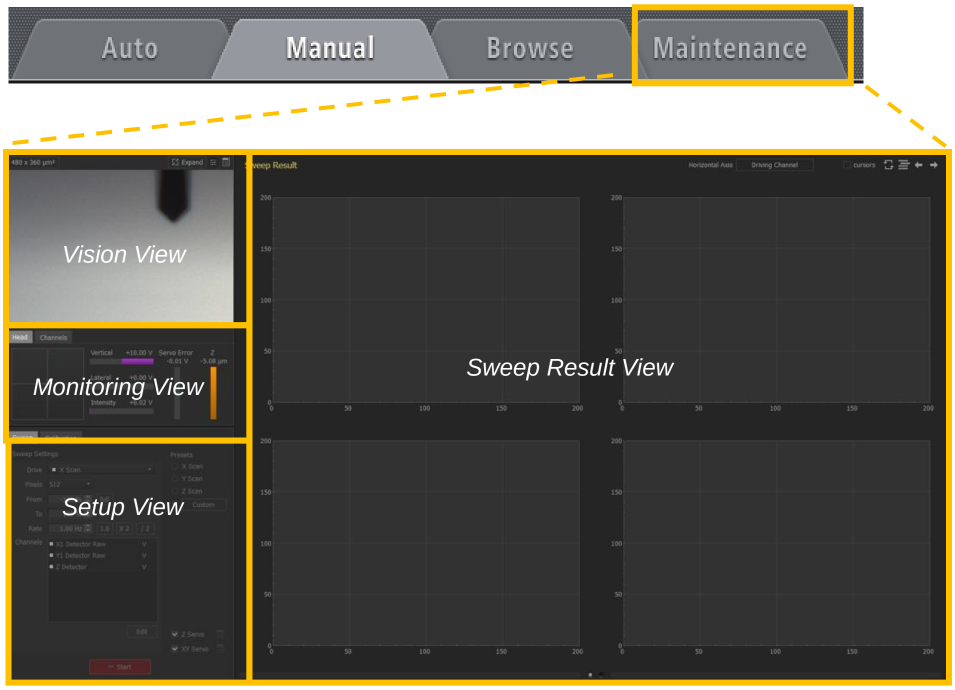


Figure A-1. The maintenance mode workspace

■ **setup View**

Setup View displays setup parameters for sweep tests and scanner and cantilever calibration. Setup View is separated into two tabs: the Sweep Setup View and the Calibration Setup View.

Sweep Setup View

Use the controls here, you can perform a sweep of the desired driving channel and view various resulting signal traces..

Calibration Setup View

Various instrument components, including the Z scanner, XY scanner, and cantilever can be calibrated from this tab. The sub-interface for each component can be toggled by clicking the desired radio button.

- **Calibration/Z Scanner**

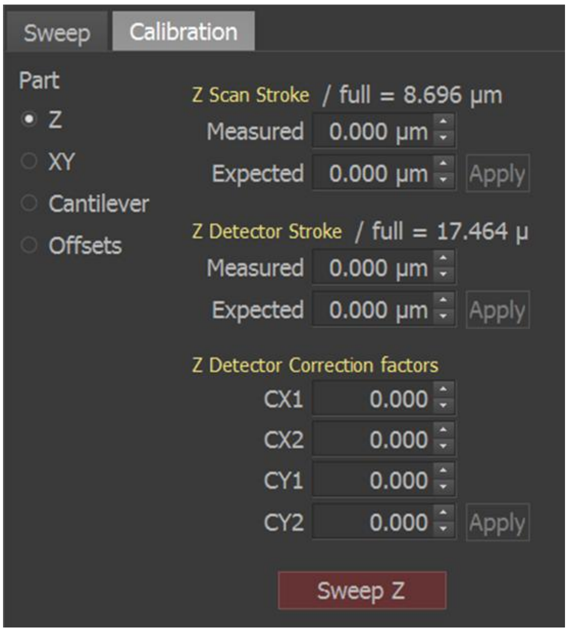


Figure A-2. Z Scanner calibration setup

Z Calibration Parameters	Function
Z Scan Stroke	**Z Scan Stroke** is the Z scanner movement determined by the applied voltage bias to the Z piezo/scanner. The **Measured** value is the height derived from the Z scan calibration image. The **Expected** value is the height value reported for the known sample. After entering the **Measured** and **Expected** values, click **Apply** to adjust the calibration.

Z Detector Stroke	**Z Detector Stroke** is the Z scanner movement determined by the linearized sensor. The **Measured** value is the height derived from the Z height calibration image. The **Expected** value is the height value reported for the known sample. After entering the **Measured** and **Expected** values, click **Apply** to adjust the calibration.
Z Detector Correction Factors	These are factory calibrated nonlinear correction factors.

- **Stroke Calibration**

The Z scanner stroke can be calculated by imaging a grating sample that has a known height. Differences between the known value and the measured value can be adjusted through calibration tables.

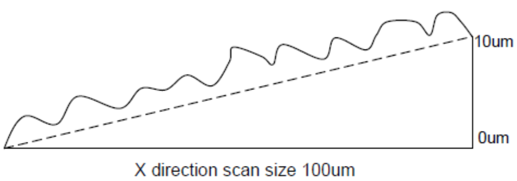
For example, a grating sample of height 3µm×3µm is measured as 120nm. If the known height reported by the manufacturer is 100nm +/- 7nm, the measured value is off by 13-20nm. Calibration of the scanner stroke can correct the measurement discrepancy.

The Z stroke is calculated two ways. The first way to determine the stroke is using the voltage applied to the Z piezo. The second way determines the stroke using a sensor. Each signal must be calibrated separately using different channels.

- **Non-Linear Correction Factors**

The Z scanner calibration provides software correction for non-linear Z scanner movement. For example, if you can see a non-linear image like the one below, you can correct it by calibrating **CX**, **CX2**, **CY**, and **CY2**.

The X direction and Y direction of this surface are expressed as $AX^2+BX+CY^2+DY$, where $AX^2=CX2$, $BX=CX$, $CY^2=CY2$ and $DY=CY$. When you obtain a 1st order slope from the Z height as below, you can enter +0.1 into CX since the equation is $Y=AX^2+BX+C$, where A=0, B=10µm/100µm=0.1, and C=0. Please note that currently the software does not calculate the values of X, Y, X2 and Y2. You will need to calculate these values manually.



To calibrate the Z scanner, image a standard sample with a known step height and enter the measured and known (expected) heights into the calibration setup interface. A summary of the parameters for Z scanner calibration can be found in the table below. For more information about scanner calibration, please refer to the NX User's Manual.

- **Sweep Z**

Clicking this button sweeps the Z scanner in full bias range and displays the result in the Sweep Result panel on the right. With this, you can check the full stroke of the Z drive/detector. When the button is active, the system will continuously sweep the scanner range, and **Cancel** will appear in the button. Clicking **Cancel** will stop the sweep.

- **Calibration/XY Scanner**

Figure 11-3-2 below shows the XY scanner calibration setup. XY calibration values include **Scan Stroke**, **Detector Stroke**, and **Detector Offset**. Each can be adjusted independently for the X and Y directions. When calibrating the scanner, the X scan values are used when then XY servo is off (open loop), while the X detector values are used when the XY servo is on (closed loop). Please see the NX manual for more detailed information about XY scanner calibration.

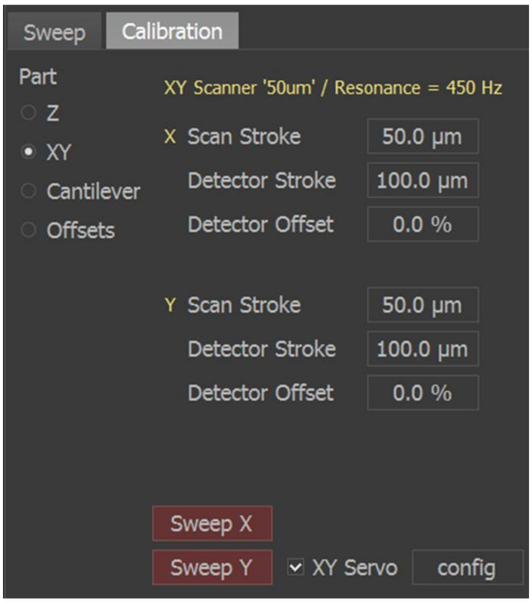


Figure A-3. XY scanner calibration setup

To change XY scanner calibration values:

1. Click the appropriate display button next to the parameters to change.
2. A dialog box will open. Enter the measured and expected values for the desired pa rameter.
3. Click **Apply**. The software will calibrate the scanner automatically.

Figure A-4 gives an example of how to change the X **Scan Stroke** value.

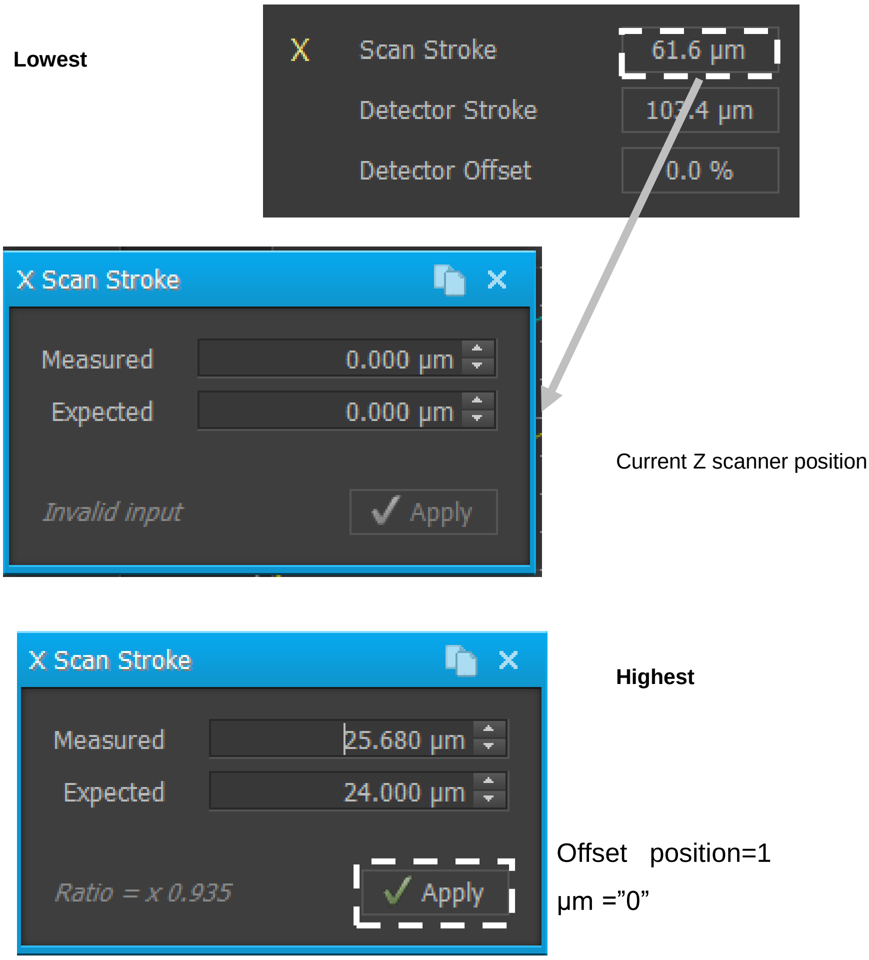


Figure A-4. XY scanner calibration example

■ **Stroke Calibration**

Stroke calibration changes the movement in the X or Y direction. Scan signals are used for calibration of open loop scanning (XY servo off). Detector signals are used for calibration of the detector used for closed loop scanning (XY servo on). It is verified by checking the measured scanner movement against a known structure. For example, if a known 3μm×3μm grating sample is measured, the width of three gratings is known to be 3μm×3 gratings=9μm. If the actual measured value is 9.8μm, then the X or Y scanner needs calibration. In this example, depending on the direction of measurement, you would enter 9μm and 9.8μm in the **Expected** and **Measured** fields for the X or Y row.

- **Offset Detector**

The offfset detector is used to center scanner movement within the stroke range. For the detectors' offset calibration, you should enter the **Offset** value. This value describes how the detector shifts from the origin in the X and Y directions. You can estimate the **Offset** values by performing a sweep test of the X and Y scan and monitoring the non-zero X and Y coordinates of the origin in the the **Oscilloscope** screen. Then the X and Y detectors can be calibrated by entering the **Offset** value and then clicking **Apply**. For more information, please refer to the NX User's Manual.

Panel	Function
Measured X(Y) Scan/Detector	Input the measured XY scan/detector's stroke length.
Expected X(Y) Scan Detector	Input the known XY scan/detector's stroke length.
Offset of X(Y) Detector	Input how the detector shifts from the origin.

**XY Scan: XY movement in open loop (XY servo off)*
**XY Detector: XY movement in closed loop (XY servo on)*

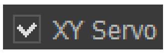
- **Sweep X**

Click this button to sweep the X scanner in full bias range and display the result in the Sweep Result panel on the right. With this, you can check the full stroke of the X scan and X detector. When the button is active, the system will continuously sweep the scanner range, and **Cancel** will appear in the button. Clicking **Cancel** will stop the sweep.

- **Sweep Y**

Click this button to sweep the Y scanner in full bias range and display the result in the Sweep Result panel on the right. With this, you can check the full stroke of the Y scan and Y detector. When the button is active, the system will continuously sweep the scanner range, and **Cancel** will appear in the button. Clicking **Cancel** will stop the sweep.

- **XY Servo Check box**



Checking this box turns on the XY servo. Unchecking this box turns off the XY servo.

- **Config**

Clicking **config** opens the XY Servo Configuration dialog. Please see Section 8-4-11 for more information about XY servo configuration.

- **Calibration/Cantilever**

Different models of cantilevers are produced with varying force constants and resonance frequencies, resulting in differing values in various performance metrics. Because these values cannot always be obtained nondestructively, SmartScan maintains a database of known cantilever properties. This database is pre-populated with several common cantilevers. If you choose a different cantilever, you must perform a cantilever calibration and create a database entry for it. Cantilever calibration is divided four main sections: resonance frequency range, cantilever constants, A-B sensitivity, force constant, and NCM amplitude gain.

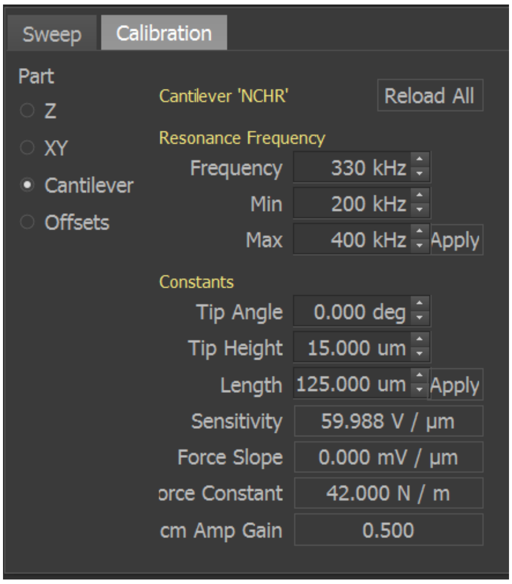


Figure A-5. Cantilever calibration setup

- **Cantilever Resonant Frequency**

When performing an NCM sweep, the frequency is varied from the known minimum to the known maximum resonance range for the current cantilever type. Enter the minimum, maximum, and typical resonant frequencies for your cantilever. These values are usually provided by the cantilever manufacturer. Click **Apply** to finish calibration.

- **Cantilever Constants**

Descriptions for cantilever constants are provided by the manufacturer and defined as follows:

Tip Angle	This is the angle between the cantilever arm and the tip.
Tip Height	This is the height of the tip, defined as the length from the end of the tip to the center of the cantilever beam. This value is provided by the cantilever manufacturer.
Cantilever Length	This is the length of the cantilever. This value is provided by the cantilever manufacturer.

To change values, update values in the appropriate fields and click **Apply**.

- **A-B sensitivity calibration**

As the cantilever moves across a sample surface and deflects upwards or downwards, the A-B signal on the PSPD is changed because the beam is reflected off the top of the cantilever. The A-B sensitivity value determines how much the A-B signal changes in respect to the cantilever deflection (A-B sensitivity=A-B/height).

To input this value automatically using acquired data, click the **Data** button. A dialog box will appear. Select a file containing an FD curve obtained in contact mode. Select the linear region and click **Apply**. The A-B Sensitivity Cantilever Calibration dialog is shown in Figure i-6.

- **Force Constant**

Input the typical force constant for the cantilever. You can find this value in the cantilever manufacturer’s specifications. Update the field for the force constant and click **Apply** to save the force constant to the cantilever file listed at the top of the view area. [Thermal Tune]

- **NCM Amp Gain**

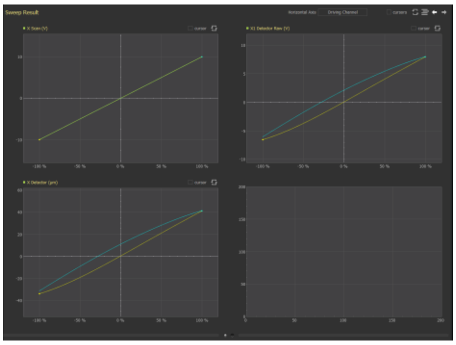
The A-B(AC) signal on the PSPD is amplified by a lock-in circuit. This electronics gain is called **NCM Amp Gain** (V/V). The value for **NCM Amp Gain** can be entered into the text field. Click **Apply** to save the values into the cantilever calibration.

To determine the gain automatically, click the **Data** button, which opens the NCM Amplitude Calibration Dialog window.

Sweep Result

The Sweep Result workspace displays up to eight signal channels resulting from sweeping the driving signal. Figure i-6 shows the Sweep Result workspace.

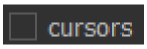
Figure 5-23. Sweep Result workspace



The horizontal axis of the all the graphs displayed can be set by clicking the **Horizontal Axis** button and choosing the desired parameter from the drop-down menu. The name of the channel used for the horizontal axis will be displayed in the button.

Figure 5-24. Horizontal Axis button with Driving Channel selected

Options buttons for the Sweep Result graphs are as follows:



Displays cursors on all sweep result graphs

Auto scales the graph to display the enter curve

Allows for graphs to be rearranged by clicking and dragging graphs to the desired location. Re-click the button once rearrangement is complete.

Moves to the previous or next page of graphs in the sweep results.

For more information about the Sweep Result workspace and Graphs View.

Appendix B. How to Use Clip Type Chip Carrier

The **standard clip type chip carrier** features fast and easy loading of un-mounted cantilevers. This chip carrier is compatible for *standard probe hand* and *liquid probehand*.

1. Required Components

The items below are required to load an un-mounted cantilever chip to a standard clip type chip carrier.

- Standard Clip Type Chip Carrier
- Cantilever Exchanger
- Un-mounted Cantilever Chips

Below is an explanation for each item.

① **Clip Type Chip Carrier**

Using a Clip Type Chip Carrier, an un-mounted cantilever can be easily stabilized without glue. Figure 1 shows the structures of Clip Type Chip Carrier.

- Chip Mount: Where the un-mounted cantilever will be placed. Clip: Holds Un-mounted cantilever chip.
- Lift Hole: Meets with the Cantilever Exchanger Pin. Pressing down this hole will open space between the Clip and Chip Mount area for mounting.
- Round Hole & Slot: These two Holes & Slots will be mounted on the probehand. They will guide the Clip Type Chip Carrier to be placed on the probehand in a consistent position.

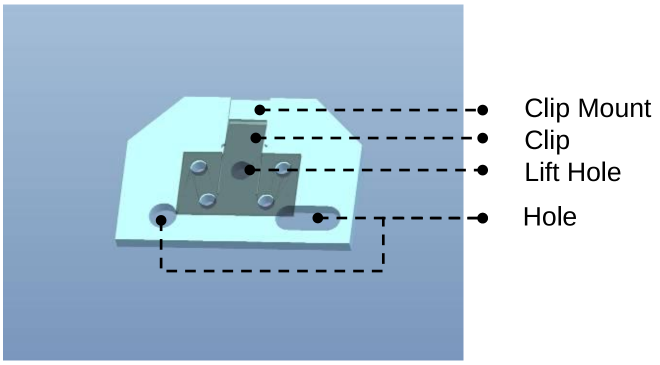


Figure 1. Structure of Clip Type Chip Carrier

The Chip Type Chip Carrier is coated with chromium, is designed for various environments such as air, liquid, wiring, and does not need electrical conductive glue to be connected between the cantilever and chip carrier electrically.

② **Cantilever Exchanger**

There is a round hole when the Upper Base is uncovered. When you overlay the chip carrier hole above the pin located on the *chip carrier mount* part of the *cantilever exchanger* and press the upper base of *cantilever exchanger,* then the bottom part of chip carrier will go down and the clip will be opened. Then, the un-mounted cantilever can be easily placed.

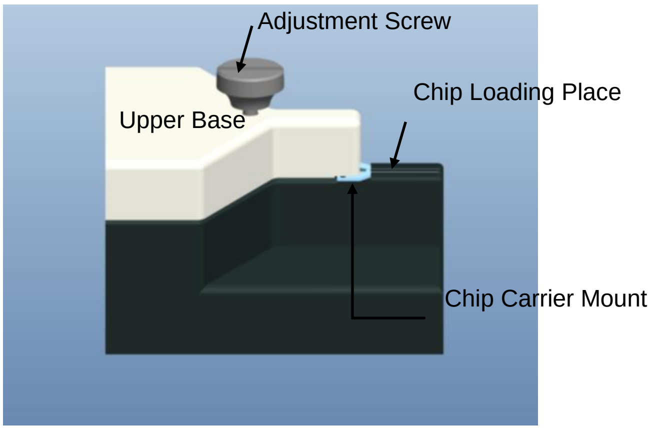


Figure 2. Cantilever exchanger

There is an adjustment screw on the upper base of the *cantilever exchanger* to move the upper base up or down. Turning the screw clockwise moves the upper base down and keeps the clip opened. On the other hand, turning the screw counter-clockwise moves the upper base up and keeps the clip closed.

2. How to Load Un-mounted Cantilever Chip

① Lift up the Upper Base of the *cantilever exchanger*.

② Place *Clip Type Chip Carrier* on top of *Chip Carrier Mount*. Please make sure that the round hole on the bottom of the chip carrier overlays with the pin on the *Chip Carrier Mount* part.

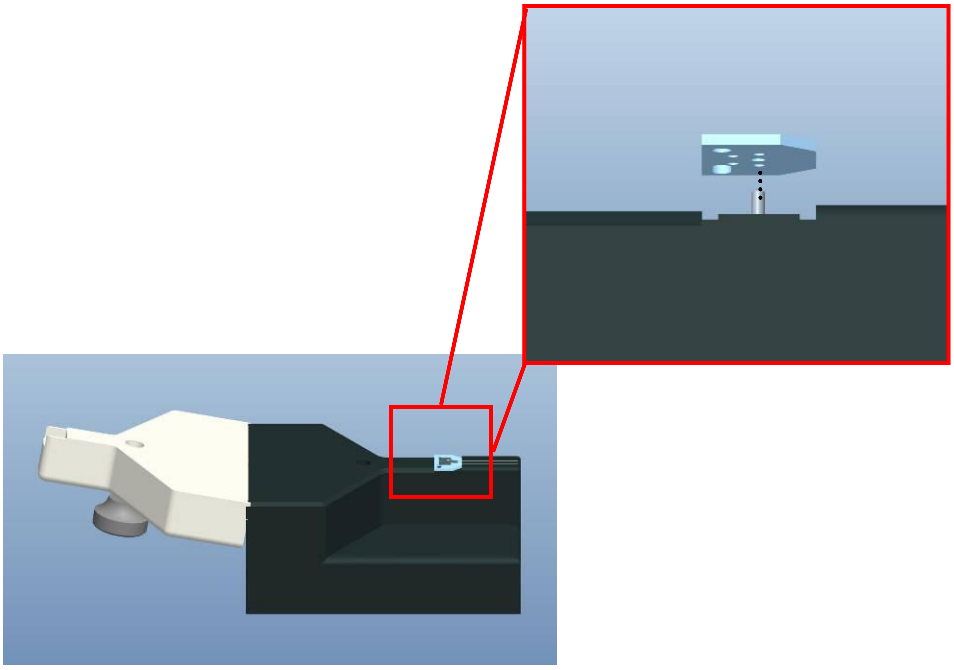


Figure 3. Placing Clip Type Chip Carrier on Cantilever Exchanger

NOTE!

Please be cautious so that the cantilever chip did not cross over the *chip mount place*.

③ Close the upper base of *Cantilever Exchanger* and turn the adjustment screw clockwise to open the chip carrier’s clip.

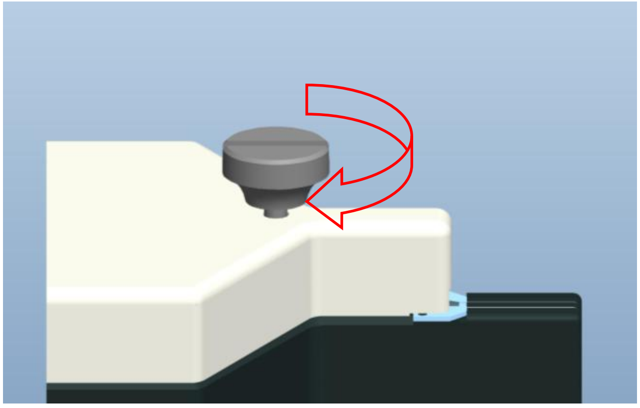


Figure 4. Adjust Clip Position

④ Pick an un-mounted cantilever chip using tweezers and place it on the *chip loading place* of the *Cantilever Exchanger.*

⑤ Slide the cantilever chip into the end of the *chip groove* on the chip carrier.

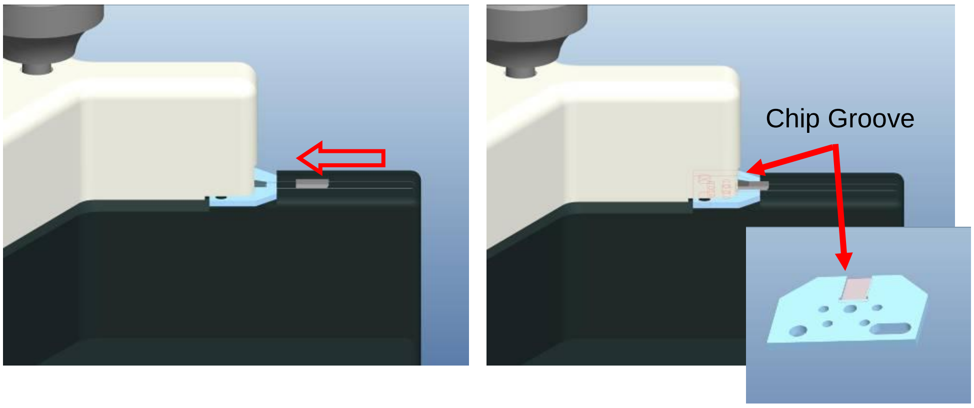


Figure 5. Mount Cantilever Chip

NOTE!

Make sure that the cantilever chip is placed the right way correctly. If necessary, please reinsert the cantilever chip.

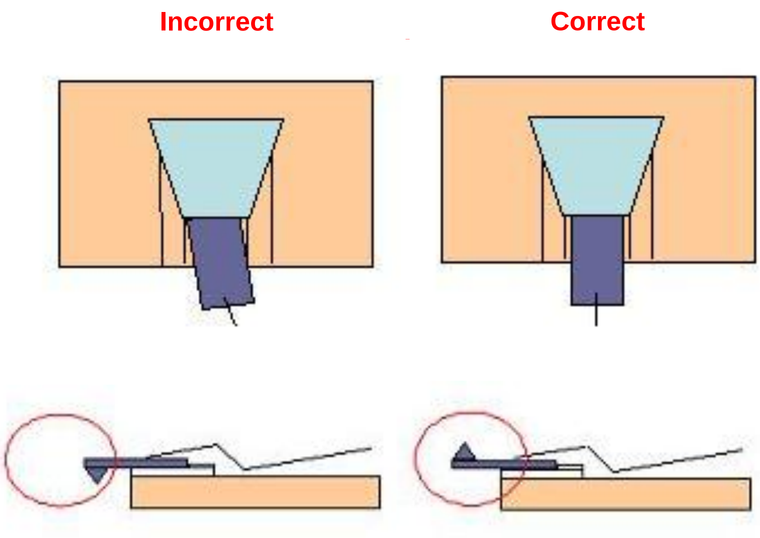


Figure 6. Correct Mounting of Cantilever Chip

⑥ Turn the *Adjustment Screw* of *Cantilever Exchanger* counter-clockwise to lift up the Upper Base.

⑦ Mount the chip carrier with a cantilever chip to the probe hand.

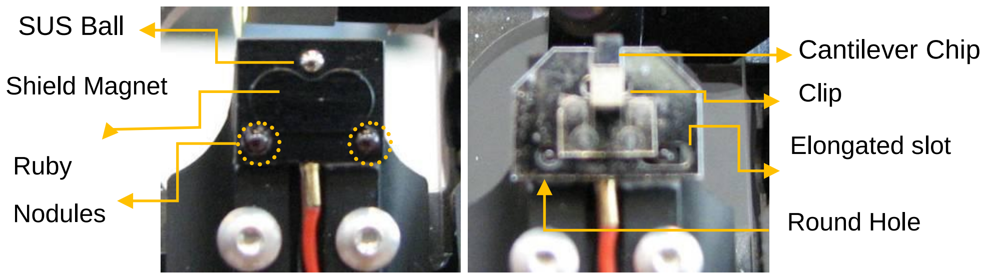


Figure 7. Edge of Probe Hand before (left) and after (right) Chip Carrier is attached to it

There are two holes in a chip carrier: a round hole and an elongated slot. When you overlay the two ruby nodules located on the end of the probe arm with these holes, the cantilever chip will be attached into place by a magnet, and position of the cantilever will be firmly fixed in one position.

Appendix C. SLD Detector Chip Carrier

When the SLD beam is aligned to the Infrared Ray Detector for AFM measurement, it is vi sible to the naked eye. The beam falls on the same location as the cantilever when using t he Standard Chip Carrier, marked by the ↑ arrow in the figure above, so it is easy to positio n the SLD beam onto the SLD detector.

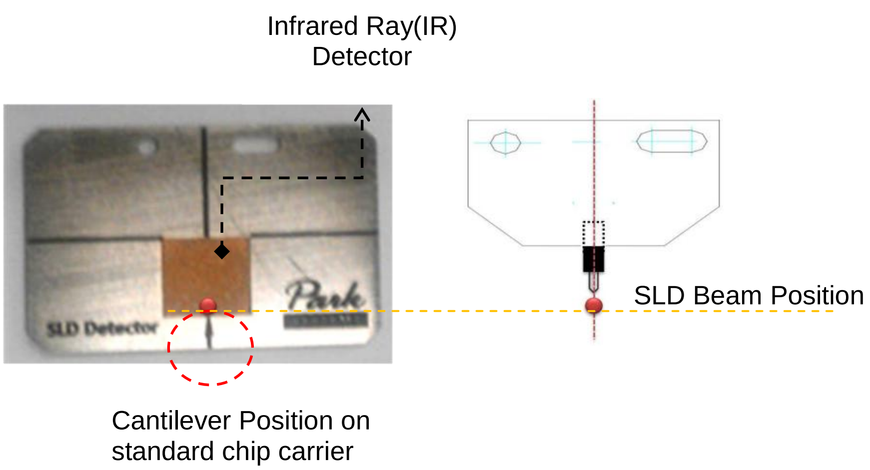


Figure 1. (Left) Beam position when using SLD detector Chip Carrier, (Right) Beam position when using Standard Chip Carrier

1. Attachment

There are two holes in the chip carrier, a round hole and an elongated slot. Overlay the two ruby nodules located on the probehand with these holes. The detector chip carrier will be attached into place by a magnet, and its position will be firmly fixed in one position.

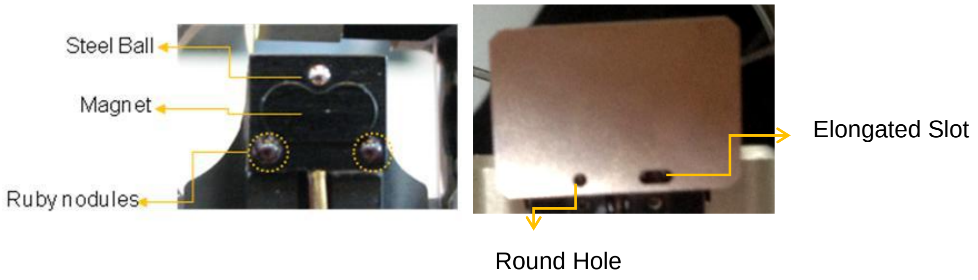


Figure 2. (Left) Standard Probehand, (Right) with the SLD detector chip carrier attached.

2. Usage

1. Attach the detector chip carrier on the probehand (Figure 2).
2. Position the SLD beam on the location marked by the ↑ by adjusting the beam ali gnment knobs until the SLD beam becomes visible (Figure 3).

Figure 3. SLD beam on the Detector Chip Carrier

3. Re-attach the chip carrier with cantilever after removing the detector chip carrier.
4. Move the SLD beam upward or downward while turning the Y beam alignment kn ob (large knob on the left side of head), since the SLD beam has been located on the cantilever's position in the X axis but with an offset in the Y axis, depending on the cantilever type (Figure 1).

NOTE!

When using the SLD detector Chip Carrier, please turn off the illuminator.

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