*INSTRUCTIONS*

# JSPM-4200 / TM-54031

# SCANNING PROBE MICROSCOPE

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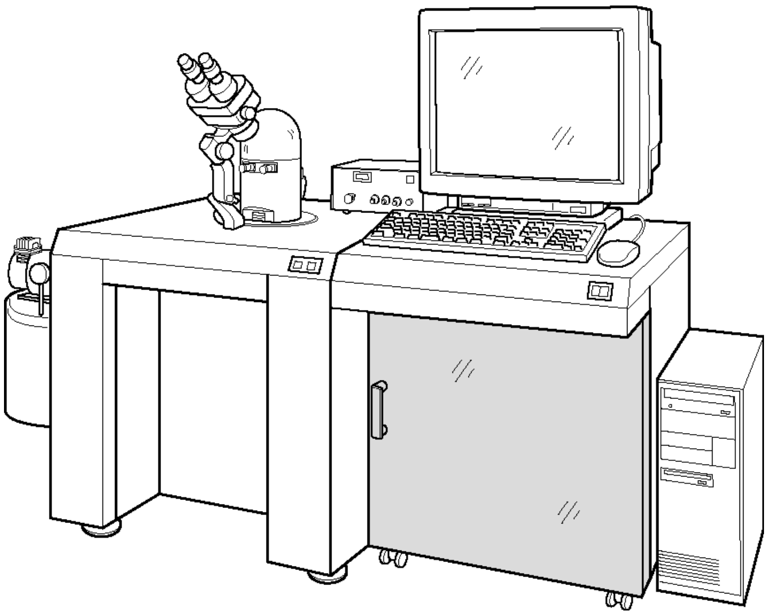
# JSPM-4200/ TM-54031

# SCANNING PROBE MICROSCOPE



## NOTICE



## MANUFACTURER


JEOL LTD.
1-2 Musashino 3-chome Akishima Tokyo 196-8558 Japan
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Note: For servicing or inquires, please contact your JEOL service office.

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## 6. OPERATION

## 7. REFERENCE

# SAFETY PRECAUTIONS

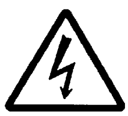
For the proper use of the instrument, be sure to read the following safety precautions prior to starting operation or maintenance. The descriptions below contain important information related to safety. Contact your local service office whenever you are unclear about an operation or maintenance. Please keep the operation manual on hand so that you can consult it whenever necessary.

The safety definitions and their meanings used in our company's operation manuals are as follows:

**WARNING:** A potentially hazardous situation which, if not avoided, will result in death or serious injury.

**CAUTION:** A potentially hazardous situation which, if not avoided, may result in minor injury or material damages.

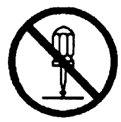
Do not touch the parts labeled with the following signs:
Examples:



Beware of electric shock

Beware of high temperature

Beware of getting caught



Don't disassemble

We request that you use the instrument in a proper manner and in the scope of the purposes and usage described in the brochures and operation manuals. Never make modifications such as removing protective parts, exchanging component parts and unlocking safety measures.

## WARNINGS

- Be sure to turn OFF the power to the SPM CONTROL unit before installing or removing the scanner holder or head unit, because a high voltage is applied to the connector pins from the SPM CONTROL unit while the power is ON. Otherwise, there is a risk of electric shock.
- Never exchange a specimen while a high bias voltage is being applied to the specimen. You might get an electric shock due to the high voltage applied to the specimen.
- When storing the instrument, avoid a high-humidity palace. There is a risk of deterioration of insulation at the tunneling current detector unit and scanner units, causing insufficient instrument- performance or electric shock.

- Be sure to turn OFF the power to the SPM CONTROL unit in advance when mounting or dismounting the scanner, specimen holder or head unit. There is a risk of electric shock due to the high voltage applied to the connector pins from the SPM CONTROL unit.
- Exchange the optical microscope lamp more than 30 minutes after it is turned off. Do not touch the lamp immediately after it is turned off. If you do, you might get burnt.
- Be careful not to put your hand(s) under the surface plate. Your hand(s) might be pinched.

## CAUTIONS

- Never install this instrument in a place where a fluorescent lamp shines directly on the AFM head. The fluorescent lamp blinks at 100 Hz (in the areas of power frequency 50 Hz) or 120Hz (in the areas of power frequency 60 Hz) and this noise may appear on the displayed image. Regarding the installation and layout plan, please consult your local JEOL office.
- The bias voltage to be applied to a specimen is superposed on the “B+” wire in the heating cable. Therefore, the heating power supply must be electrically isolated from the ground (GND). If one of the heating cable wires is grounded, the bias voltage circuit might be damaged.
- Handle the scanner holder very carefully. Since it is a precision mechanism, it could easily be damaged by a strong shock.
- Be sure to insert the cantilever along the groove. Otherwise, the cantilever may be damaged due to an excessive force being applied when the spring retainer is released.
- Never touch the area around the cantilever on the cantilever holder with a naked finger. If that part is contaminated with hand grease, that might give rise to insufficient insulation, thus possibly causing tunneling current leakage or incorrect operation of the piezoelectric element.
- Push the spring retainer vertically. If you force it diagonally, the ceramic might be damaged.
- The specimen stub is gold-plated. Be careful not to scratch the stub surface.
- Insert or remove the specimen stub horizontally with care. If an excessive force is applied to the scanner holder, the scanner inside it might be damaged.
- Although the focus of the laser beam has been adjusted in the factory before shipment, the beam may be out of focus for some reason. If so, readjust the beam focus referring to Chapter 8 “MAINTENANCE.”
- The waveform will change from sine to triangular when the amplitude exceeds about 2 Vp-p. If you maintain this triangular waveform for a long time, the cantilever might break.

- When applying conductive paste to the cantilever and the cantilever holder, be sure not to touch the conductive paste to the cantilever piezoelectric element. When replacing a cantilever, be sure to confirm that no previously used conductive paste remains on the holder. Otherwise, the cantilever will tilt, causing the reflected laser beam not to irradiate the right position.
- When you select and use a short cantilever out of two cantilevers, long and short, be sure to remove the long one with a pair of tweezers. Otherwise, the top of the long cantilever touches the specimen before the short one does.
- If the Sample Bias is set by using the bar-chart during image observation, be careful not to move the bar-chart button across 0 V. The tip would collide with the specimen surface if the bias voltage became 0 (zero).
- When the tip is moved close to the specimen in the “Coarse Stage” window, the tip never stops even if a tunneling current or atomic force is actually detected.
- In order to prevent the tip from colliding with the specimen surface, the speed of the tip movement must not be faster than 200 nm/s.
- Cantilevers must be stored in a desiccator when they are not in use. If they are stored in a high-humidity place, the cantilevers could bend and irregular reflection of the laser beam may occur. Especially, a gold-coated $Si_3N_4$ cantilever is prone to deteriorate with humidity.
- When handling the instrument, be sure to wear Nylon gloves. Hand grease may cause deterioration of the vacuum. Also, there is a risk of deterioration of insulation at the tunneling current detector unit and scanner units, causing insufficient instrument-performance or electric shock.
- Wait 10 seconds or more before restarting the system.
- The software must be terminated before the power is turned off. Never turn off the power while the software is in operation.

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# 1

# GENERAL

# 1.1 INTRODUCTION

The Scanning Probe Microscopes (SPM), such as the Atomic Force Microscope (AFM) and the Scanning Tunneling Microscope (STM), utilize as the observation means physical phenomena that occur between a specimen and a tip when they are brought very close to each other but are not touching. It is possible, therefore, to observe the surface of a specimen with atomic- or molecular-level resolution under nondestructive and non-contact conditions. Moreover, they can be used under many different observation environments, not only in a vacuum environment but also at atmospheric pressure, and in gas and liquid environments.

The JSPM-4200 Scanning Probe Microscope is designed to handle applied observation modes that increase year by year and to make the most of the intrinsic functions of a scanning probe microscope. This instrument is easy to use and is superb in its expandability, being able to be used by a number of people from beginners to professional researchers of scanning probe microscopy.

The following are the main features of this instrument.

- It is possible to observe specimens under various conditions, from in a liquid to under high vacuum, by attaching optional accessories without making any modification of the basic unit, not to mention under atmospheric pressure.
- Moreover, it is possible to observe a specimen that is being heated or cooled by attaching a simple optional accessory.
- Quite a variety of modes such as AFM (Contact and AC modes), phase image, FFM, STM, CITS and I-V can be handled with the standard instrument configuration. In addition, the observation mode for Kelvin Force Microscope images or viscoelasticity images can be handled by attaching an appropriate optional accessory.
- The control software is supported by Windows95™, and the control panel is a tab type control panel accommodating only the minimum necessary functions, thus being easy to use even to beginners.
- A personal login function with which one can set one’s own environment has been employed, thus greatly improving the operation of the instrument.

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# 2

# SPECIFICATIONS

## 2.1 MAIN SPECIFICATIONS

| | |
|---|---|
| Resolution | |
| AFM: | Atomic resolution (an image of atoms in mica in contact mode) |
| STM: | Atomic resolution (an image of atoms in HOPG) |
| System drift: | 0.05 nm/s or less |
| Measurement modes | |
| AFM: | Contact mode<br>Topography image, force image, FFM, force curve, friction force curve, I-V, CITS, contact electric-current image<br>AC mode<br>Topography image, phase image, MFM (cantilever to be purchased separately)<br>Lateral modulation FFM (option)<br>Viscoelasticity (option)<br>Surface potential (option)<br>Electrochemistry (option) |
| STM: | STM mode<br>Topography image, electric-current image, CITS<br>Spectroscopy<br>I-V, S-V, I-S |
| XY scanning range: | 0 to 10 µm (when the standard scanner is used) |
| Driving voltage: | ±150 V |
| Resolution: | 25 bit (offset included) |
| Z range: | 0 to 3 µm (when the standard scanner is used) |
| Driving voltage: | ±150 V |
| Resolution: | 20 bit (offset included) |
| Specimen size: | Standard: 10 mm × 10 mm × 3 mm (thickness)<br>Maximum: a 2-inch wafer |
| Specimen movement: | |
| XY specimen movement: | ±3 mm |
| Z specimen movement: | 5 mm |

### 2.1.1 SPM Base Unit

| | |
|---|---|
| Coarse movement: | Z coarse-movement distance: Manually operated up to 5 mm (motor approach included)<br>Approach function: Motor approach up to 1.5 mm<br>X,Y coarse movement function: Manually operated up to ±3 mm |
| Stage: | Drift-free stage |
| Ports: | Gas introduction and drainage × 1 each<br>Evacuation port (ISO63) × 1<br>Utility × 2<br>Cooling accessory (option) × 1 |

Vibration isolation system:
Air suspension: Gimbal piston type air compressor (built-in)
Gel damper: Built-in

### 2.1.2 SPM Head

Scanning method: Specimen scanning
Scanner: Tube type scanner (replaceable)
X,Y = 10 µm, Z = 3 µm (one standard scanner provided as standard)
Detection method: Light-lever method
Laser beam source: Red-colored: Class 2 semiconductor laser Laser beam detector: Four-segment photodiode
Cantilever holder: Common cantilever holder for contact mode and AC mode
Cantilever mounting method: One-touch push-in method
Current detection terminal: Built-in
Mounting method: Slide-in method
Tip holder: Tip: 0.3 mm diameter
Tip mounting method: Push-in knock-on method
Mounting method: Slide-in method

### 2.1.3 SPM Control System

Scanning function: Scanning range: Continuously variable from 0 to maximum scanning range (25 bit)
Scanning speed: 0.01 ms to 10 ms/point
Bias voltage: Continuously variable from 0 to ±10 V (16 bit)
Can be manually applied from 0 to ±150 V
Scanning in a region of 512 × 512, 256 × 256 and 128 × 128 pixels and in Top Mirror
Line scanning in 512, 256 and 128 pixels
Max. 4ch simultaneous input and simultaneous display
Automatic tilt correction mechanism, automatic contrast and brightness function, arbitrary position zoom function
Scanning rotation: 1° step
Lithography function

AFM function:
Contact mode: Constant Force mode, Constant Height mode, Force Curve setting: $10^{-8}$ to $10^{-11}$ N
AC mode: Detection method: Amplitude detection and FM detection
Excitation freqency: 3 to 500 kHz
STM function: Constant Current mode, Constant Height mode, I-V, CITS, S-V, I-S
Current setting: 30 pA to 1 µA

## 2.1.4 Computer Control System

| | |
|---|---|
| Computer: | IBM-PC/AT compatible<br>High-resolution color display (1,280 × 1,024 pixels) |
| External storage: | Magnetic optical disk (option) |
| External image output device: | S-VHS image output/NTSC image input (option) |

## 2.1.5 SPM Software

| | |
|---|---|
| File operations: | File writing: TIFF, Binary, ASCII<br>File reading<br>File searching |
| Image-processing functions: | 10 kinds of spatial filters: Low pass, median pass, high pass, horizontal, vertical smoothing and user-defined<br>5 kinds of edge enhancement: Vertical, horizontal, lower right, lower left, Laplace differential filter<br>2 kinds of normalized filters<br>2 kinds of median filters<br>Tilt correction: X, Y, selected region, whole region<br>Image processing: Inverse video, integration, division, AND, OR, XOR, add, subtract |
| Image-analysis functions: | Height analysis<br>Line profile<br>Image enlargement<br>Image cutting<br>FFT function: Fourier transform, inverse Fourier transform, windowing<br>Surface ruggedness measurement function: Entire area, designated area<br>Particle analysis function: Binarizing function, particle count, area-measurement function<br>Image rotation, mirror-image function<br>Image-size change function<br>Drift-correction function |
| Image-conversion functions: | Histogram function: Histogram display, leveling, real-time contrast and brightness adjustment function |
| CITS analysis functions: | I-V curve taking-out function: Point, arbitrary area |
| Display functions: | Three-dimensional display function: Wire frame, beam display, contour mapping display<br>Color display: Pseudo color and user defined<br>Fixed-height display function |

## 2.2 DIMENSIONS AND WEIGHT

| | Height (mm) | Width (mm) | Depth (mm) | Weight (kg) |
|---|---|---|---|---|
| Main console | 1,100<br>1,400 (when optical microscope is mounted) | 710 | 710 | 250 |
| Control unit | 680<br>1,400 (monitor included) | 570 | 710 | 80 |
| Air compressor | 530 | 290 ϕ | | 17 |

## 2.3 INSTALLATION REQIREMENTS

Installation room
- Room temperature: 20°C ± 5°C
- Humidity: 60% or less
- Acoustic vibration: 50 dB or less (A mode)
- Floor vibration: 5 µm (5 Hz) or less

Power supply
- Capasity: Single-phase AC100 V 50/60 Hz 1.5 kVA (one receptacle with a grounding terminal)
  When an optional evacuation system is installed, 1.5 kVA × 2 (2 receptacles with grounding terminals)
- Fluctuation: ±10% or less
- Grounding terminal: 100 Ω or less
- Cable length: Main console: 2.5 m
  Evacuation system: 2.5 m

**CAUTION**

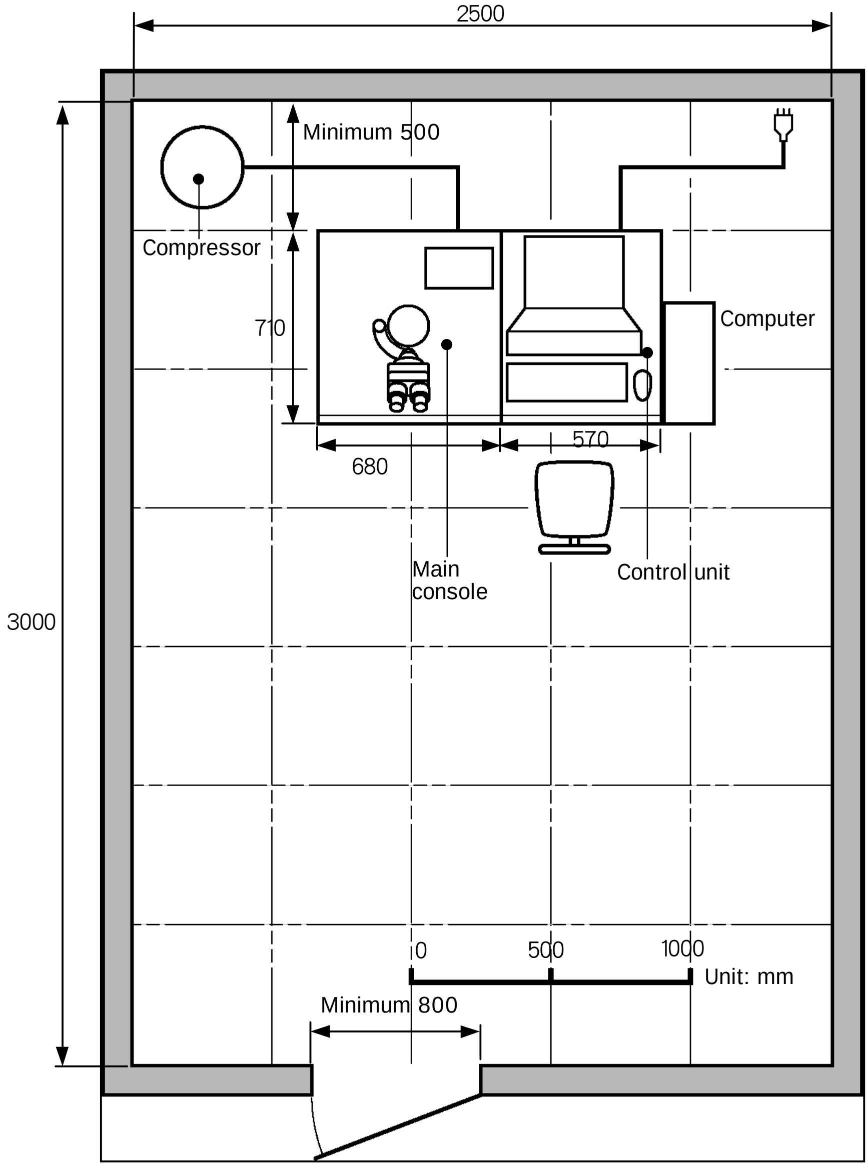
**Never install this instrument in a place where a fluorescent lamp shines directly on the AFM head. The fluorescent lamp blinks at 100 Hz (in the areas of power frequency 50 Hz) or 120Hz (in the areas of power frequency 60 Hz) and this noise may appear on the displayed image. Regarding the installation and layout plan, please consult your local JEOL office.**

### ■ Installation room

- Floor space: 2,500 mm (W) × 3,000 (D) or larger
- Ceiling: 2,000 mm or higher
- Entrance: 800 mm (W) × 1,800 mm (H) or larger

When the optional evacuation system is installed, it is necessary to have a space of 500 mm or more between the rear of the instrument and the wall of the room.

## ■ Typical installation layout



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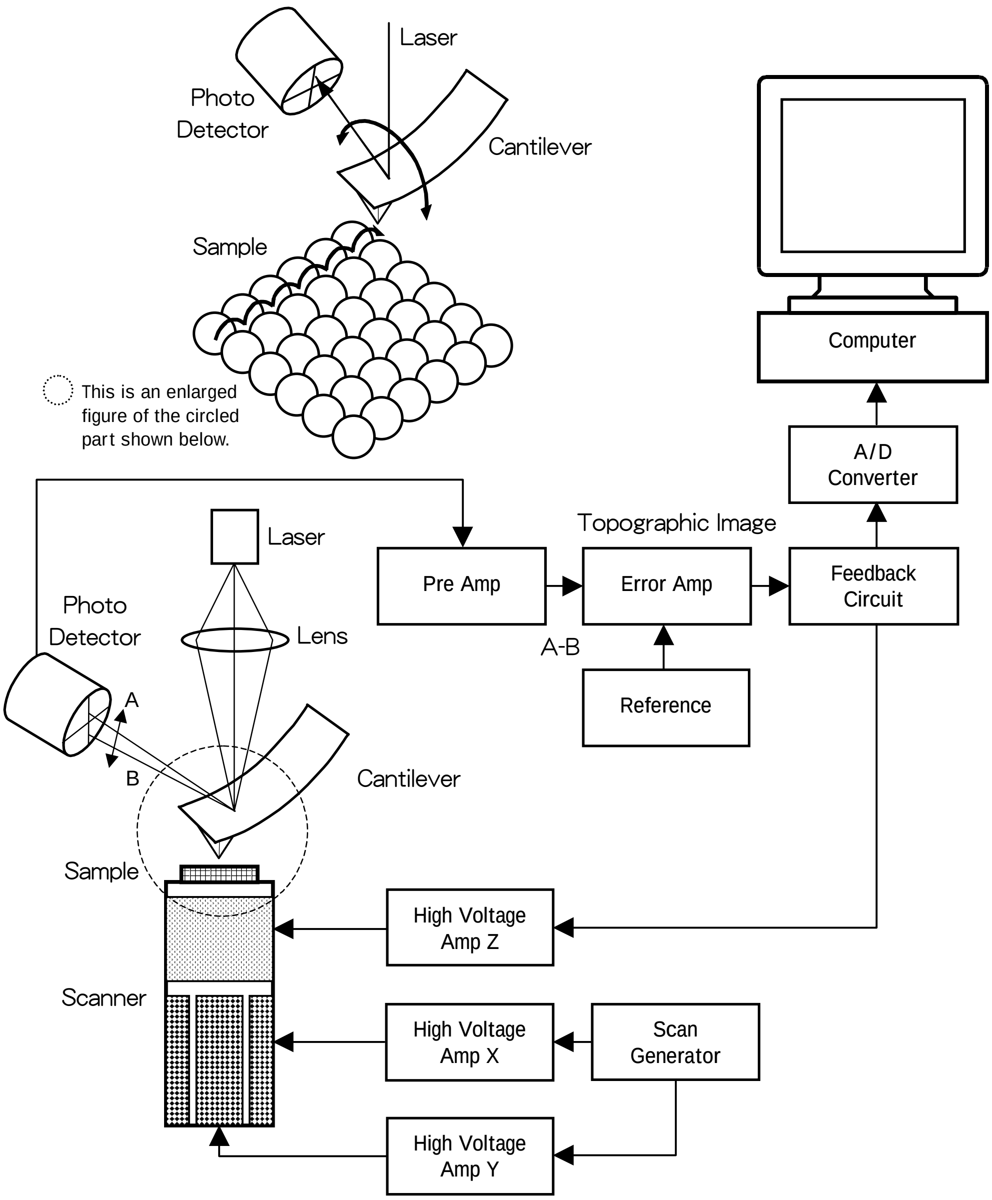
# 3

# PRINCIPLE AND BLOCK DIAGRAM

# 3.1 PRINCIPLE AND BLOCK DIAGRAM OF AFM

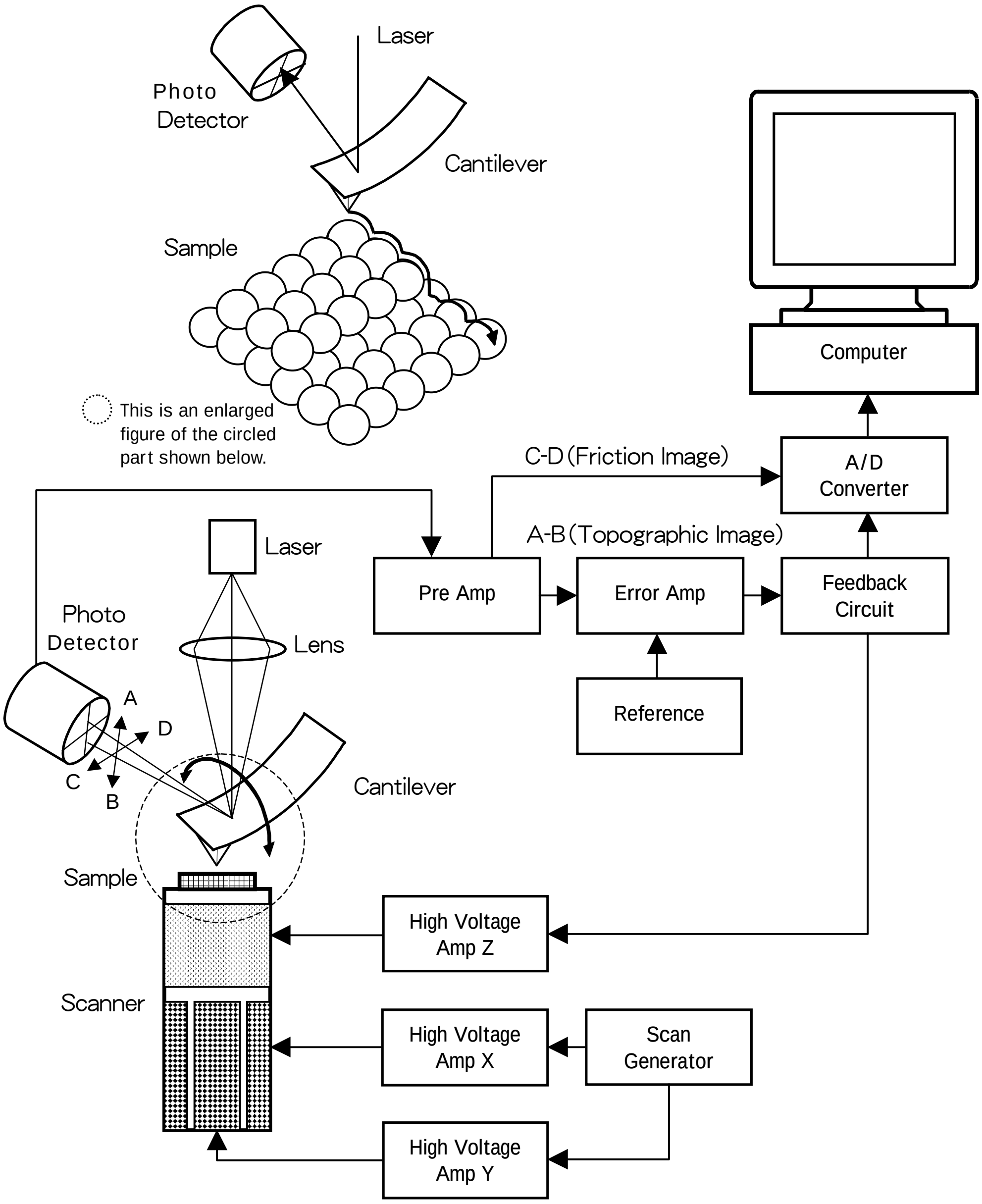
## 3.1.1 Principle and Block Diagram of Contact-Mode AFM

In the contact-mode AFM, when a tip mounted on the end of a cantilever is brought as close as a few nm to a specimen, an atomic force is generated between an atom of the top of the tip and an atom of the specimen. The detected atomic force is fed back so that the atomic force between them is kept constant while the tip scans the specimen, thus observing the specimen surface. The contact-mode AFM can be applied to the observation of not only conductive materials but also non-conductive insulating materials.



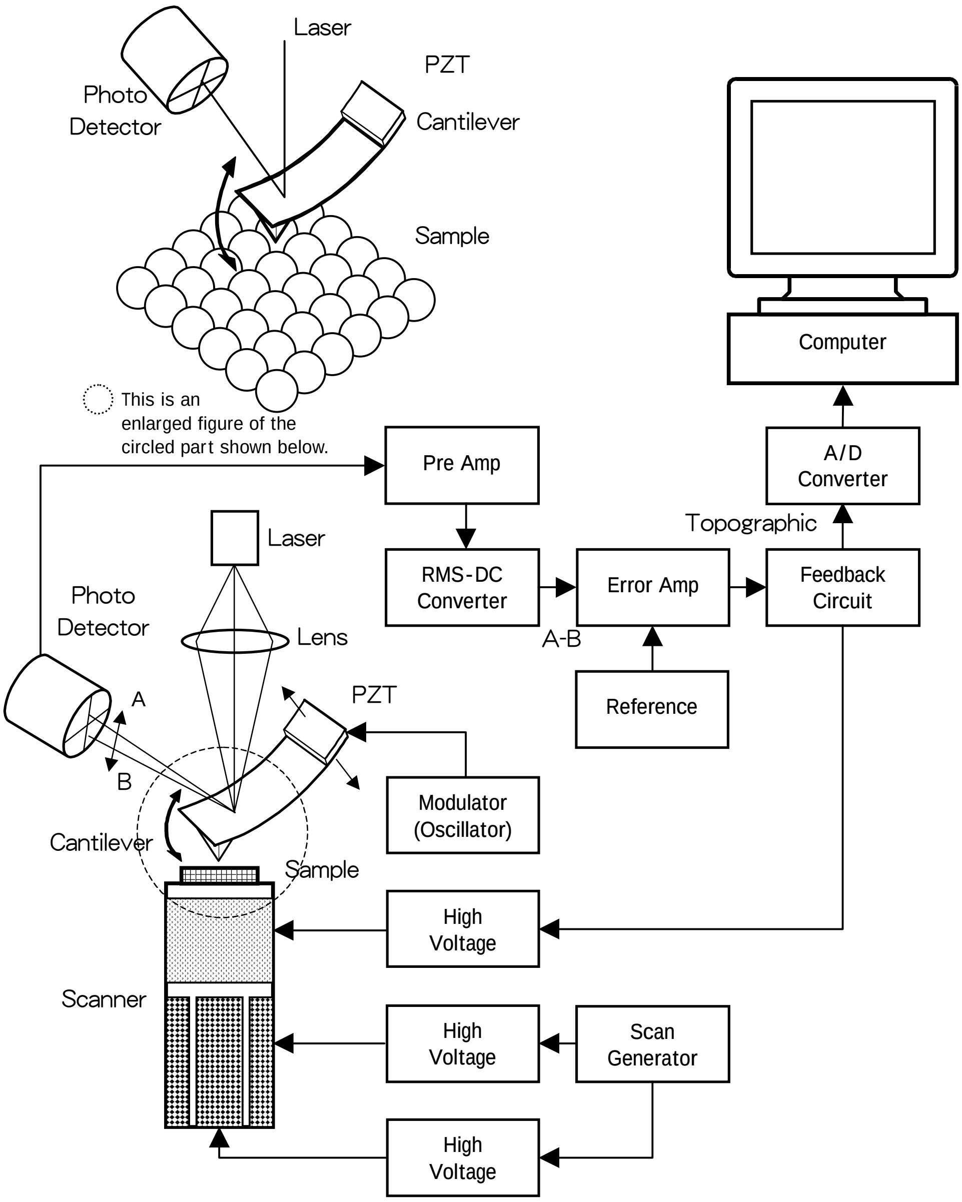
## 3.1.2 Principle and Block Diagram of Friction-Force Microscope (FFM)

Friction-Force Microscopy (FFM) is the measurement of a friction force occurring between a cantilever and a specimen from a lateral deflection of the cantilever by scanning the specimen in a direction lateral to the cantilever in the contact mode AFM. As a four-segment photodetector is used, both topography and friction-force images can be obtained simultaneously.



### 3.1.3 Principle and Block Diagram of AC-Mode AFM

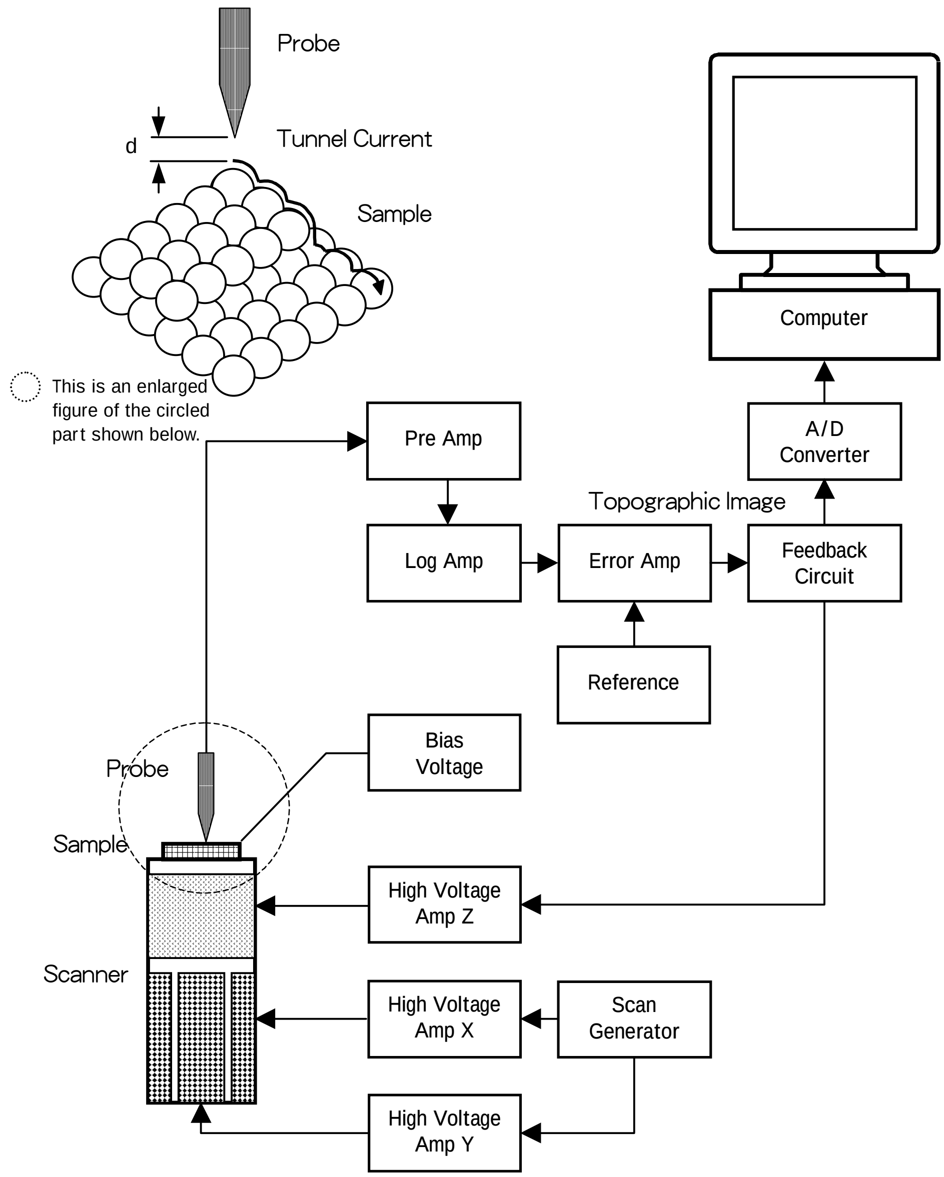
When a vibrating cantilever is brought close to a specimen, the amplitude of the atomic force generated between the specimen and the cantilever changes. In the AC-mode AFM, the specimen is scanned so that this amplitude is kept constant. If the specimen is scanned with the cantilever amplitude reduced and the force applied to the cantilever in the attractive-force region, it can be observed without making the cantilever contact it (non-contact mode). Therefore, the AC AFM can be also used to observe soft specimens such as living specimens.



## 3.2 PRINCIPLE AND BLOCK DIAGRAM OF STM

When a metal tip approaches as close as 1 nm or closer to an electrically conductive specimen and a bias voltage (up to several volts) is applied between the tip and the specimen, a tunneling current (from several pA to several nA) flows due to the tunnel effect.

The tunneling current is fed back so that it is kept constant while the tip scans the specimen surface; thus the specimen surface is observed from the tip movement in the Z-direction.



CONTENTS

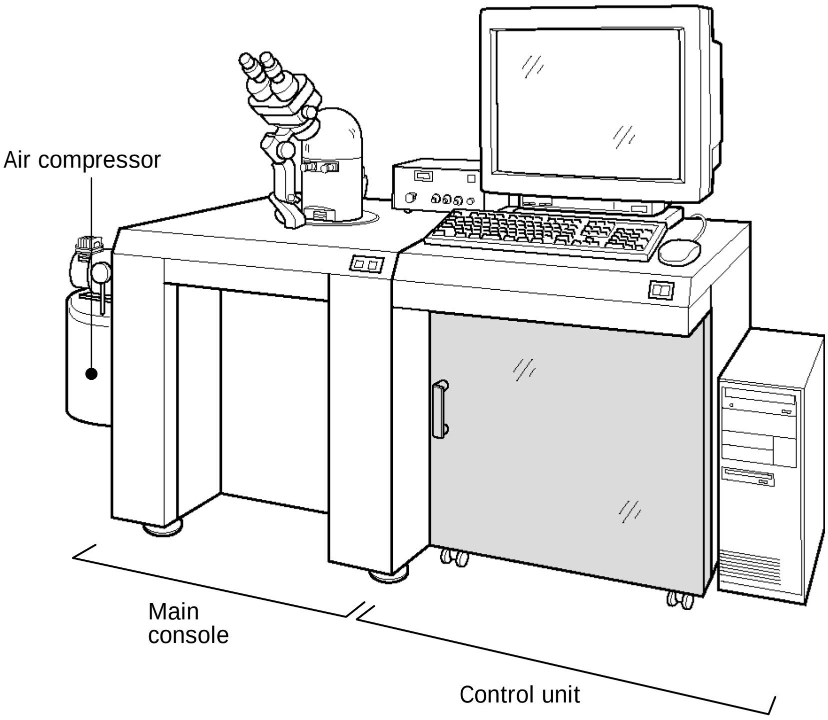
# 4

# DESCRIPTIONS OF COMPONENTS

The names and functions of each unit are given in this chapter.

## 4.1 OVERALL COMPOSITION

This instrument is composed of a main console, a control unit and an air compressor.



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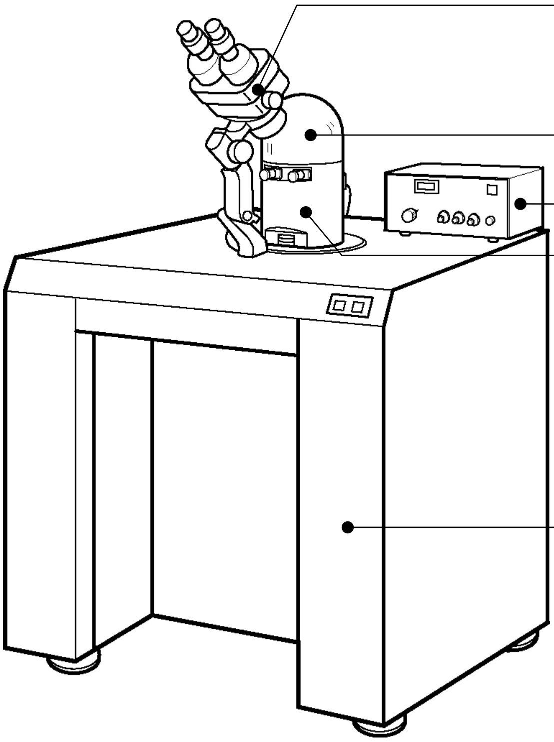
# 4.2 MAIN CONSOLE

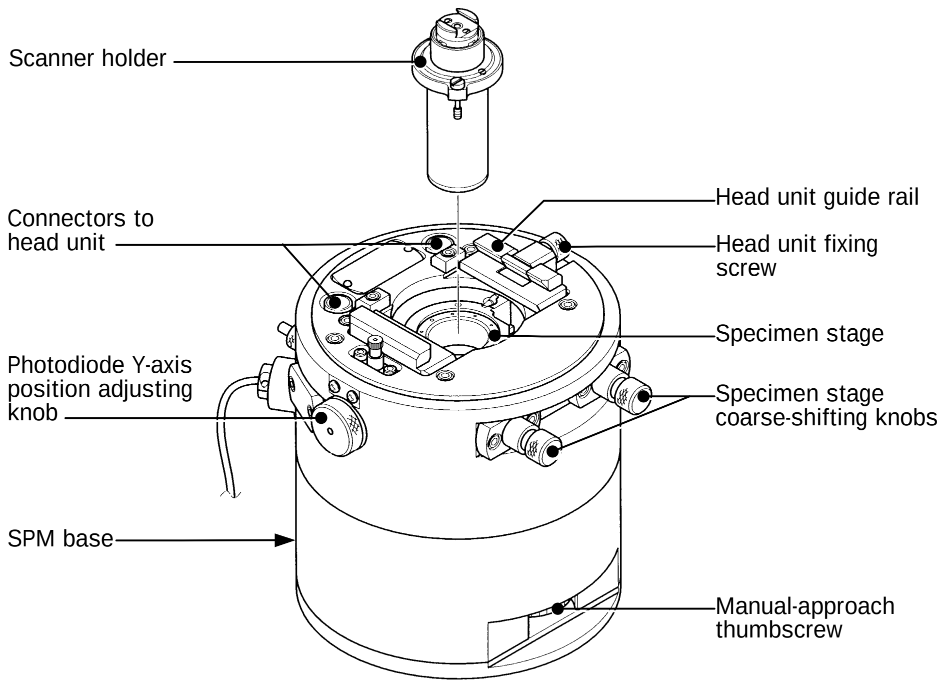
## 4.2.1 SPM Unit

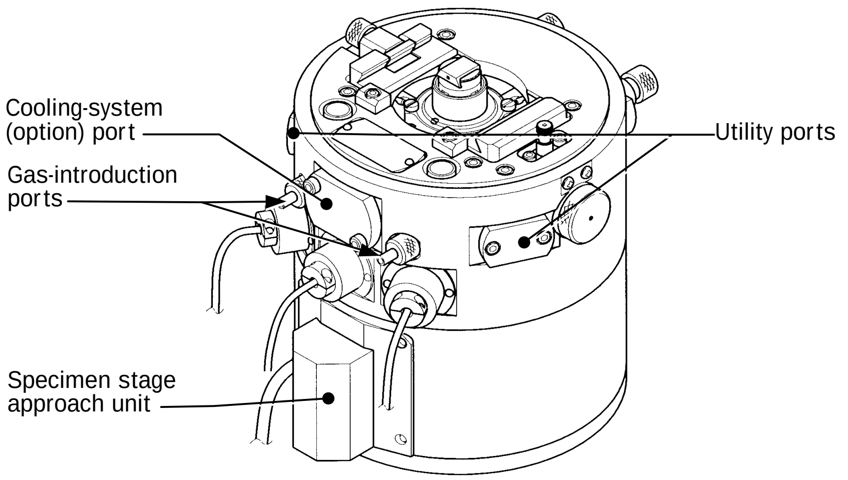
The SPM unit consists of a vibration isolator, an SPM base unit and an SPM head.



## ■ SPM base unit

The SPM base unit includes a specimen stage, a stage-approach unit and a stage-shift unit.



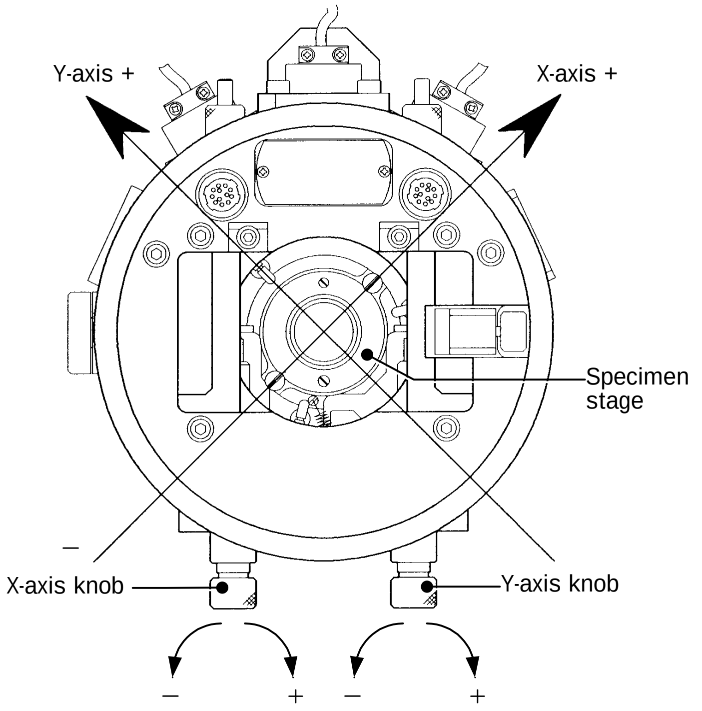




### ● Specimen stage

The specimen stage is the part on which the scanner holder is mounted. A feature of the specimen stage is that it employs a drift-free mechanism in which thermal expansion occurs concentrically with the expansion center always kept at the specimen-observation point.

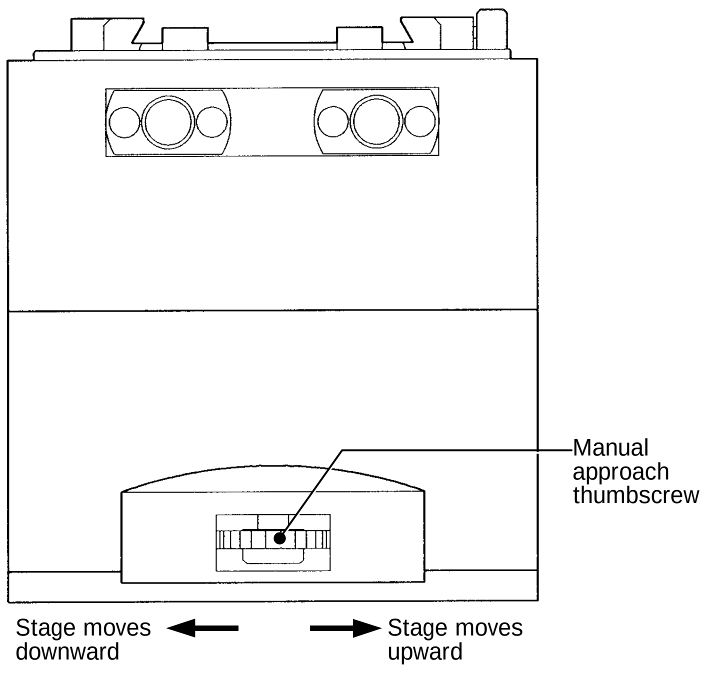
- **Specimen stage coarse-shifting knobs**

  The specimen stage can be moved, with these knobs, to any point in a circle with a radius of 3 mm from the stage center. It is moved about 0.35 mm by one revolution of these knobs. The relationship between the knob operation and the specimen movement is shown below.




- **Manual approach thumbscrew**

  This screw is used to move the specimen stage up and down. The range of movement is 0 to 5 mm with 0.4 mm per revolution of the screw.



- **Specimen stage approach unit**

  This unit accommodates a motor that moves the specimen stage up and down. The motor is controlled by the Controller. The range of the stage movement by motor driving is up to 1.5 mm.

- **Photodiode Y-axis position adjusting knob (only for AFM)**

  This knob is used for AFM observation to adjust the Y-axis position of the photodiode in the SPM head. For the details, refer to Subsection 5.2.2 “Adjustment of Photodiode Position.”

- **Scanner holder**

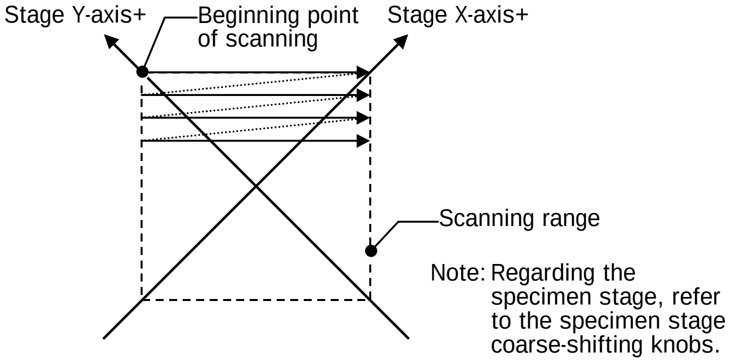
  The scanner holder consists of a scanner (with a Piezoelectric scanning element) and a specimen-stub holder.

  **CAUTION**

  **Handle the scanner holder very carefully. Since it is a precise mechanism, it could easily be damaged by a strong shock.**

- **Scanning direction**

  The scanning direction in relation to the specimen stage axes is shown in the figure below (at scan angle 0°).




- **Head unit guide rails**

  Guide rails used to install the SPM head unit.

- **Head unit fixing screw**

  Used to attach the SPM head unit to the SPM base unit.

- **Connectors to head unit**

  Used to connect the signal cables of the SPM head unit.

- **Gas-introduction ports**

  Gas inlet/outlet ports. Usually covered with caps. When introducing gas, change the caps to the gas-introduction caps supplied.

- **Cooling-system port**

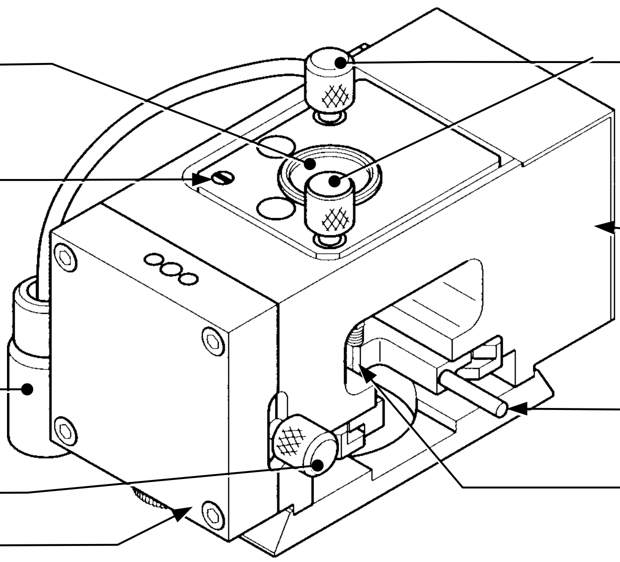
  When the optional Cooling System is used, the cooling tank is installed at this port. Usually covered with a cap.

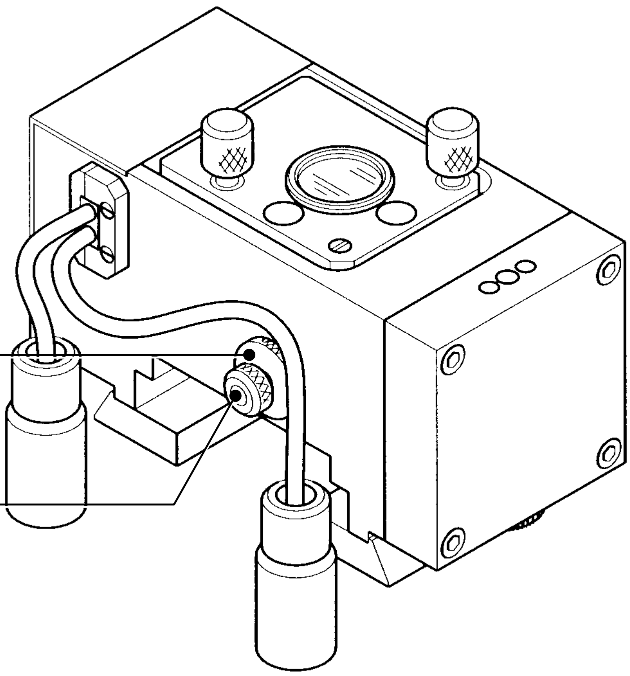
- **Utility ports**

  The JSPM-4200 is provided with two utility ports for the user's optional use. Usually covered with caps. Regarding the size and other details of the utility ports, refer to Chapter 9 "APPENDIX."

## ■ SPM head unit

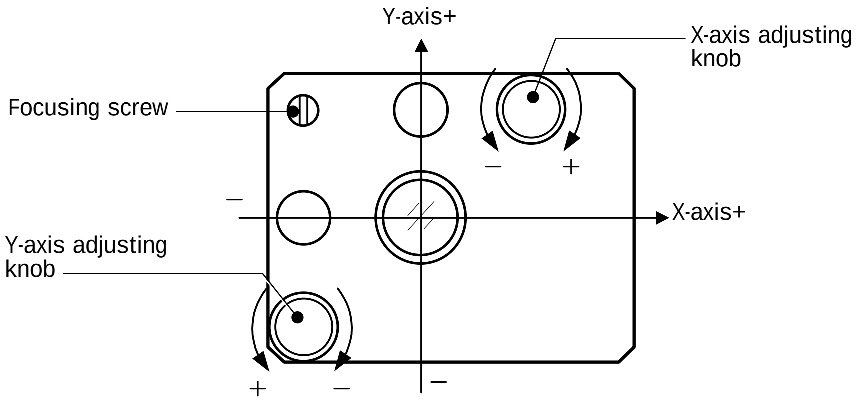
The SPM head unit is composed of a laser source, a detector and a pre-amplifier.



## ● Laser source position adjusting knobs

The point of laser illumination on the cantilever is adjusted with these two knobs.



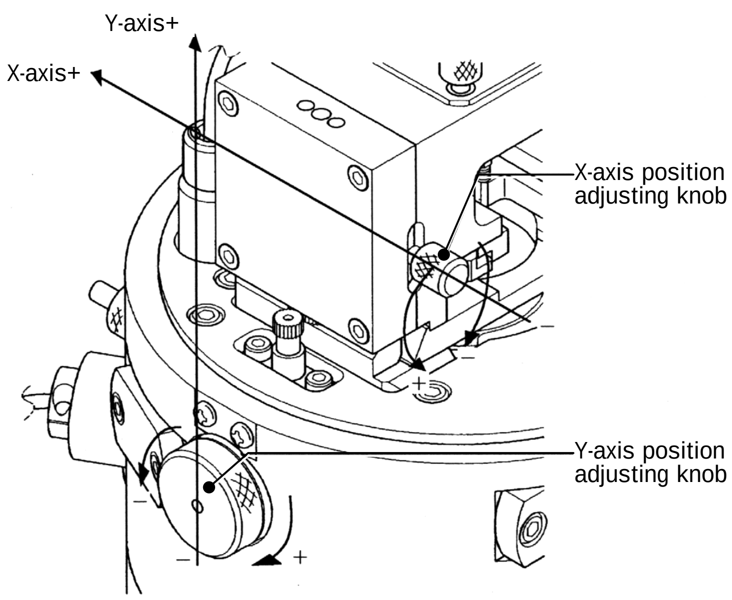

The illuminated point moves about 0.64 mm in both the X and Y directions per revolution of either knob. The focusing screw is used to focus the laser beam on the detector. For laser beam focusing, refer to Chapter 8 “MAINTENANCE.”

## ● Detector

The detector contains a four-segment photodiode.

## ● Photodiode position adjusting knobs

Used to adjust the position of the photodiode in the detector. The photodiode position moves 0.5 mm in the X direction and 0.25 mm in the Y direction per revolution of the respective knob.




## ● Mirror

This mirror directs the laser beam, after it is reflected by the cantilever, to the photodiode.

- **Mirror angle adjusting knob**

  Used for adjusting the mirror angle so that the laser beam irradiates the detector correctly. Loosen the mirror fixing screw, then adjust the mirror angle by turning the mirror angle adjusting knob. For the details, refer to Chapter 8 “MAINTENANCE.”

- **Preamplifier**

  A preamplifier for photodiode detector output and a preamplifier for tunneling current (for STM) are contained in the SPM head unit.

- **Connectors to SPM base unit**

  Used to connect the SPM head unit to the SPM base unit.

- **Cantilever holder**

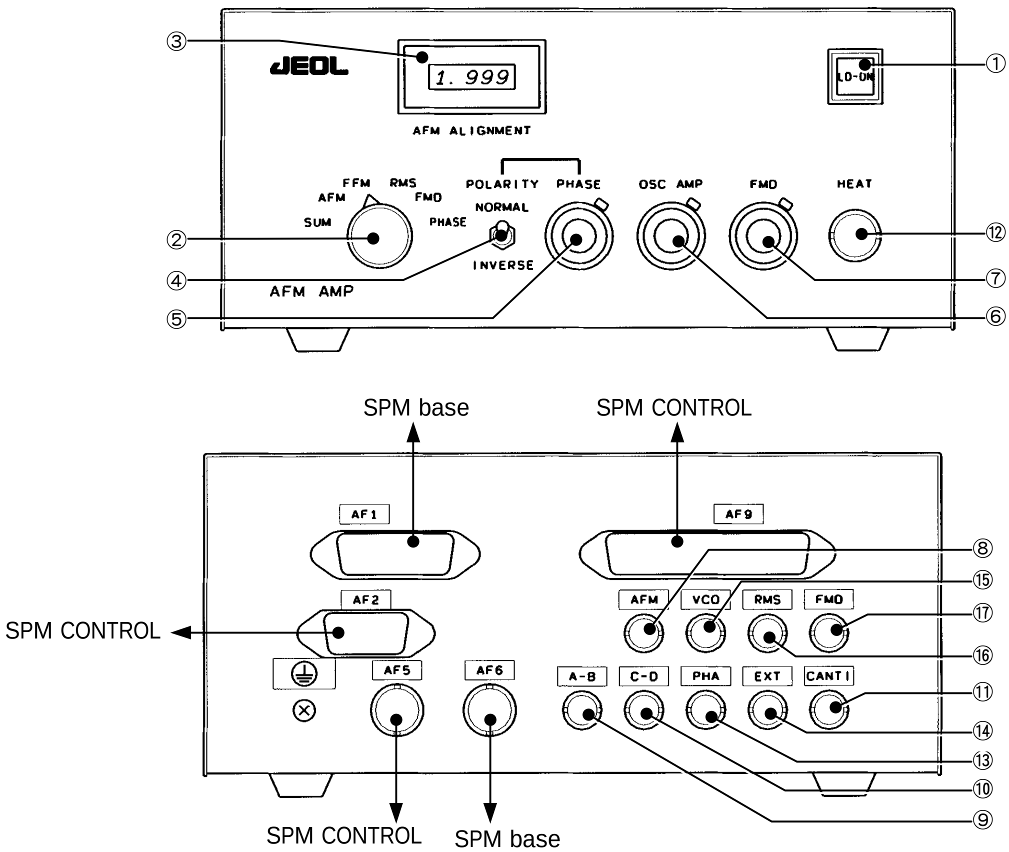
  The holder on which the cantilever is mounted. The cantilever holder is inserted into the SPM head unit.

- **Tip holder**

  The holder on which the tip for STM observation is mounted. The tip holder is inserted into the SPM head unit.

## 4.2.2 AFM Amplifier Unit

This amplifier unit is used for AFM observation. Described below are the names and functions of the switches, knobs, terminal and other parts on the front and rear panels of the amplifier unit.

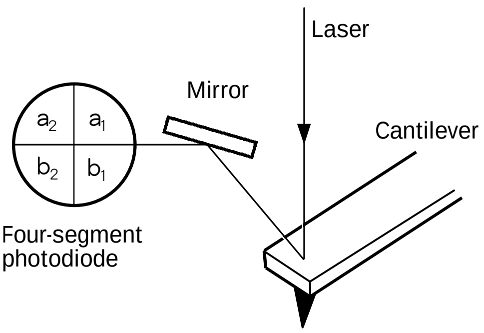


① LD-ON switch

Used to turn the semiconductor laser source in the SPM head ON and OFF. While the switch is lit, the laser source is ON. To turn off the power of the SPM CONTROL unit, first turn off the LD-ON switch and then turn off the power of SPM CONTROL unit.

② Indicator selection knob

Used to select the indication (SUM, AFM, FFM) of the photodiode output, the values (RMS, FMD) corresponding to the vibration amplitude and the frequency of the cantilever during AFM observation in the AC mode, and the phase output value (PHASE). A schematic diagram of the photodiode, mirror and cantilever is shown below.




$$\left( \begin{array}{ll} a_1 + a_2 = A & b_1 + b_2 = B \\ a_1 + b_1 = C & a_2 + b_2 = D \end{array} \right)$$

SUM: A+B output
The summation of the output from all four detector elements is shown on the indicator ③ when the knob is in this position.

AFM: (A-B)/(A+B) output
The difference between the laser beam intensity of the two upper detector elements and that of the two lower detector elements is indicated. If the laser beam irradiates the center of the detector, the indication is zero. If the beam irradiation point shifts upward, the indication becomes negative, and if it shifts downward, the indication becomes positive.

FFM: (C-D)/(C+D) output
The difference between the beam intensity of the two right detector elements and that of the two left detector elements is indicated. If the laser beam irradiates the center of the detector, the indication is zero. If the beam irradiation point shifts to the right, the indication becomes positive, and if it shifts to the left, the indication becomes negative.

RMS: This value is the RMS (root mean square) of (A-B)/(A+B) and corresponds to the vibration amplitude at or near the characteristic frequency of the cantilever during the AC mode AFM operation by the Slope detection method. This value can be changed by setting gain (×1, ×2, ×5, ×10) with the software.

Note: As the RMS value is an output value of the signal input to the RMS-DC circuit, the higher the frequency becomes, the more effect of the low pass filter inserted before the RMS-DC circuit the RMS value receives, thus attenuating the amplitude. So, the RMS value sometimes becomes smaller than the (A-B)/(A+B) value.

FMD: Frequency of the cantilever vibration
The indicated value corresponds to the characteristic frequency of the cantilever in the AC mode AFM operation by the FM detection method. Since a PLL (phase-locked loop) is used for the frequency-to-voltage conversion circuit, the indicated value corresponds to the lock range frequency.

Note: Since the output of the PLL is largely dependent upon temperature, the PLL is temperature-controlled. Therefore, the PLL output greatly fluctuates for some time after the power is turned on. In order to obtain stable data, at least 30 minutes of warm-up time is necessary after turning on the power.

PHASE: The indicated value corresponds to the displacement between the phase of the excitation signal to the cantilever and the phase of the (A-B) signal, in the AC mode AFM operation by the Slope detection method.

③ Indicator

Indicates the signal output selected with the indicator selection knob in V (volt).

④ POLARITY switch

Used to select the feedback phase from NORMAL (0°) and INVERSE (180°). In the FM detection method, the phase is adjusted so that the positive feedback oscillation becomes a maximum.

⑤ PHASE knob

Used to adjust the feedback phase. In the FM detection method, the phase is finely adjusted, so that the positive feedback oscillation or the cantilever oscillation amplitude becomes a maximum, using this knob and the POLARITY switch.

⑥ OSC AMP knob

Used to adjust the actual cantilever oscillation amplitude for the FM detection method. The amplitude of the voltage applied to the piezoelectric element for cantilever vibration is set by turning this knob and the cantilever vibration amplitude is kept constant. Rotating the knob clockwise increases the vibration amplitude (up to 3.6 V [H*] or 0.5 V [L*], square-wave).

⑦ FDM knob

Used to set the lock range of the PLL to the cantilever oscillation frequency (characteristic frequency) for the FM detection method. As the frequency can be adjusted over a range of several tens of kilohertz, a range in which the cantilever characteristic frequency is included must be preset with the software. Rotating the knob clockwise increases the frequency.

⑧ AFM terminal

This is the feedback-signal output terminal for AFM. Usually, this terminal is connected to the AFM terminal on the SPM CONTROL unit and outputs the signal corresponding to the observation mode selected with the software.

* H or L selection switch for oscillation.

There are two modes for AFM: the Contact mode and the Non-contact mode (Slope detection, FM detection and FM/Slope detection).

Note: The JSPM-4200 mainly uses the Slope detection method as the AC mode.

⑨ A-B terminal

This is the (A-B)/(A+B) signal output terminal. Usually, it is connected to the A-B 1 terminal on the SPM CONTROL unit. The oscillation waveform is checked with an oscilloscope through the SPM CONTROL unit.

⑩ C-D terminal

This is the (C-D)/(C+D) signal output terminal. Usually, it is connected to the C-D 2 terminal on the SPM CONTROL unit.

⑪ CANTI terminal

This terminal is used to monitor the signal applied to the cantilever vibration piezo element in the AC mode. The amplitude of the output voltage can be adjusted with the SPM software in the Slope detection method, and with the OSC AMP knob in other detection methods. This terminal is not used in the JSPM-4200.

⑫ HEAT terminal

Used when a specimen is heated on the specimen stage. Usually, it is connected to an optional heating power supply using a special heating cable.

**CAUTION**

**The bias voltage to be applied to a specimen is superposed on the "B+" wire in the heating cable. Therefore, the heating power supply must be electrically isolated from the ground (GND). If one of the heating cable wires is grounded, the bias voltage circuit might be damaged.**

⑬ PHA

This is the terminal for phase image output.

⑭ EXT

This is the external oscillator input terminal. A 1.0 V sine wave is input to this terminal. The signal input to this terminal is adjusted to a suitable voltage using the SPM software and is added to the cantilever vibration piezoelectric element. Set the frequency with an external oscillator.

⑮ VCO

This terminal outputs the reference voltage ($\pm$10 V sine wave) for the voltage applied to the cantilever vibrating piezoelectric element when the Slope detection method is used in the AC mode AFM operation. Turning the VCO terminal ON and OFF and changing its frequency are performed with the SPM software.

Note: In the OFF state, the VCO terminal is disconnected, so the terminal is virtually short-circuited to GND (0 V) through the amplifier.

⑯ RMS

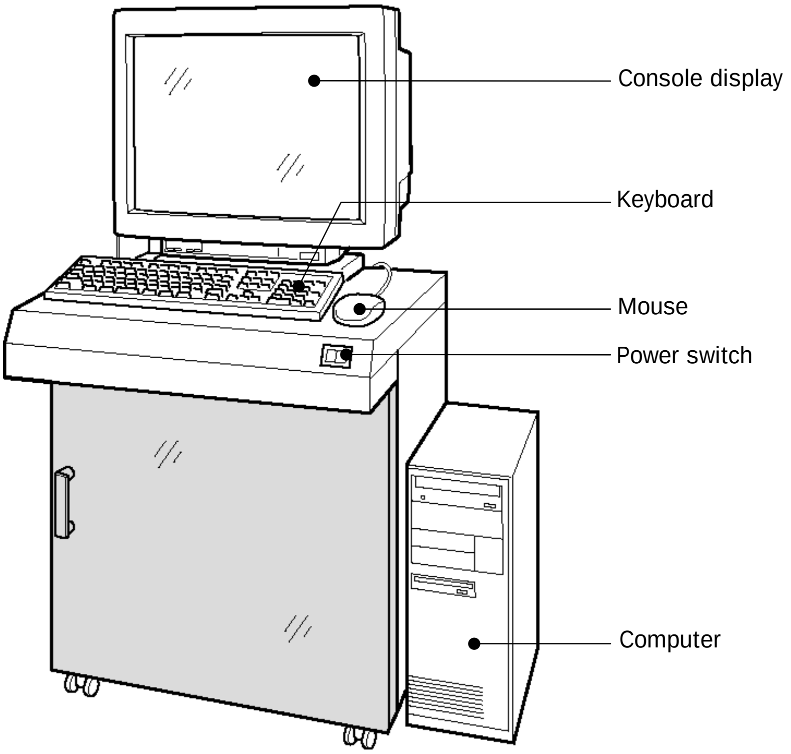
This terminal outputs the RMS value of the A-B signal when the Slope detection method is used in the AC mode AFM operation.

⑰ FMD

This terminal outputs the signal corresponding to the cantilever characteristic frequency when the FM detection method is used in the AC mode AFM operation.

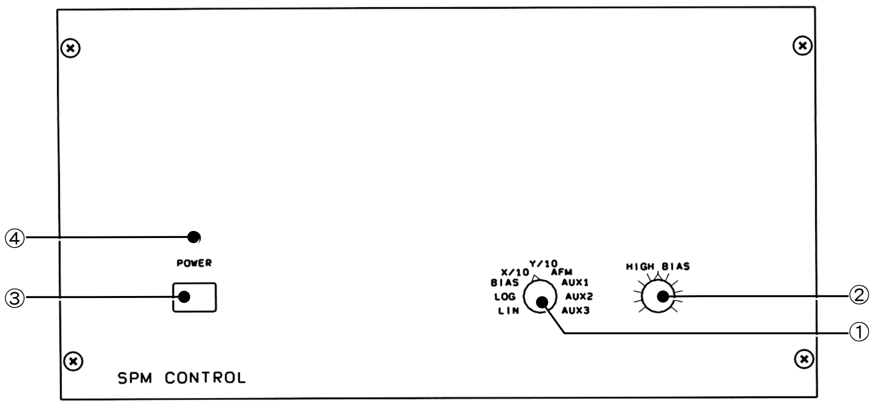
## 4.3 CONTROL UNIT

The control unit accommodates an SPM CONTROL unit that controls the main console, a computer and a console display. Also, an optional accessory such as the Viscoelasticity, Lateral Modulation FFM, the Kelvin Force Microscope or the control unit of the Evacuation System is contained in this control unit.

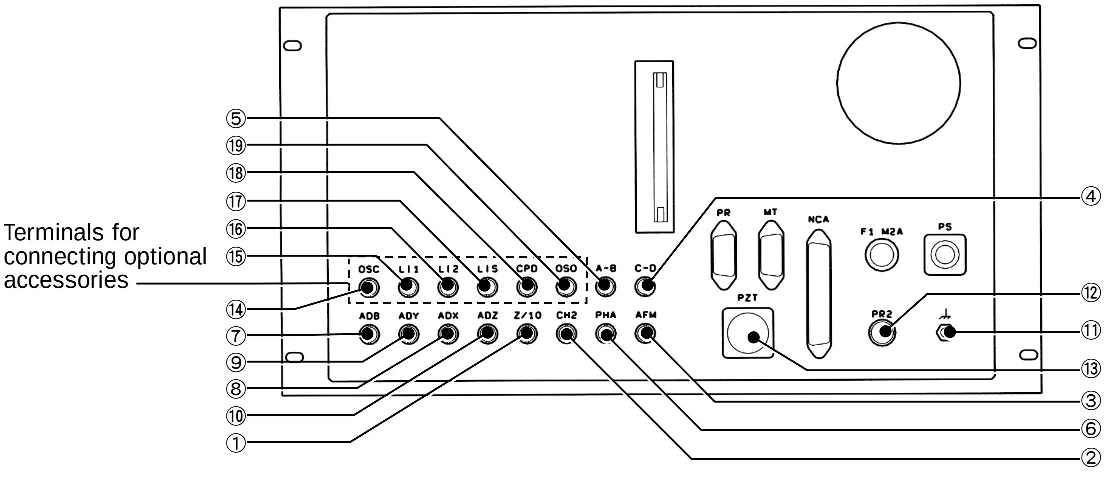


### 4.3.1 SPM CONTROL

The names and functions of each knob, button and terminal on the front and rear panels of the SPM CONTROL unit are shown below.




Front panel




Rear panel

## ■ Front panel

① SELECT knob

Selects the signal to be output to the CH2 terminal on the rear panel. The CH2 terminal is connected to an oscilloscope. When reading the tunneling current, usually set this knob to LOG. When performing AFM (Contact, AC mode) operation, usually set it to AUX1.

LIN: In this mode, the detected tunneling current is output to CH2 as a voltage signal in the ratio set in Preamp Gain. Set "Preamp Gain" on the "SPM Parameters"–"Feedback/Filters"–"Advanced" windows. Usually, set "Pre-amp Gain" to "1 V/nA." In this case, a voltage corresponding to the detected tunneling current at 1 V/nA is output to an oscilloscope.

LOG: The LIN mode signal is transformed to a logarithmic scale before being output to CH2. In the LOG mode, the voltage output to the oscilloscope is $V_{LOG} = -2\log(10 \times V_{LIN})$, where $V_{LIN}$ is the output voltage in the LIN mode.

BIAS: The bias voltage applied to a specimen is output to CH2. The voltage set on the “SPM Parameters” window is output to the oscilloscope.

X/10: One tenth of the output voltage of the X-axis driving amplifier (the voltage applied to the X-axis piezoelectric element) is output to CH2.

Y/10: One tenth of the output voltage of the Y-axis driving amplifier (the voltage applied to the Y-axis piezoelectric element) is output to CH2.

AFM: In this mode, a feedback signal is output to CH2 to perform AFM observation. Usually, a signal from the AFM terminal on the AFM Amp unit is output. The signal from the AF3 (AFM) terminal can be switched over by changing the AFM measurement mode of the SPM software.

AUX1: In this mode, the voltage output from the A-B terminal is output to CH2. The signal output from the A-B terminal on the AFM AMP unit , i.e. (A-B)/(A+B), is output in inverse polarity. This signal corresponds to the bending of the cantilever. In the SPM software it corresponds to “AUX1.”

AUX2: In this mode, the voltage output from the C-D terminal is output to CH2. The signal output from the C-D terminal on the AFM AMP unit, that is, (C-D)/(C+D), is output in inverse polarity. This signal gives the torsion of the cantilever, or the friction force generated between the tip and the specimen. In the SPM software it corresponds to “AUX2.”

AUX3: In this mode, the voltage output from PHA is output to CH2. The phase input from the PHA terminal on the AFM AMP unit is output in inverse polarity.

② HIGH BIAS knob

Controls the high voltage (-150 to +150 V) applied between the tip and the specimen. This knob is used to clean the tip in the STM mode operation. Turning the knob clockwise increases the voltage. In the usual image-observation conditions the knob should be set to 0 V (center). To use “High Bias,” select “High Bias” on the “Tip” window in the “SPM Parameters” window.

③ POWER button

Is the power switch of the SPM CONTROL unit. When starting the system, if this power switch is turned on before the computer power switch is turned on, no “Reset” operation is required.

④ POWER lamp

Lights when the POWER button is on and goes off when the POWER button is off.

## ■ Rear panel

① Z/10 terminal

Outputs one tenth of the output voltage of the Z-axis driving amplifier (applied to the Z-axis PZT). This terminal is connected to the oscilloscope.

② CH2 terminal

Outputs the signal selected with the SELECT knob. This terminal is connected to the oscilloscope.

③ AFM terminal

Outputs the feedback signal for AFM observation. Usually, the signal output from the AFM terminal on the AFM AMP unit is input. The output signal of the AFM terminal is switched over by changing the AFM measurement mode of the SPM software.

④ C-D terminal

Inputs the signal output from the C-D terminal on the AFM AMP unit. This signal corresponds to the twist of the cantilever, from which information on the friction force occurring between the tip and the specimen can be obtained. By selecting "AUX2" as the signal source on the SPM software, you can display this signal as an image.

⑤ A-B terminal

Inputs the signal output from the A-B terminal on the AFM AMP unit. This signal corresponds to the twist of the cantilever and is used as the feedback signal for the contact mode AFM operation. By selecting "AUX1" as the signal source on the SPM software, you can display this signal as an image.

⑥ PHA terminal

Inputs the output signal from the PHA terminal on the AFM AMP unit.

⑦ ADB terminal

Is an input terminal used to add an external signal to a specimen bias signal. A voltage that is 15 times as large as this input signal voltage is applied to the piezoelectric scanner. The maximum input voltage is ±10 V. However, the maximum voltage that can be applied to the piezoelectric scanner is ±150 V in total. Select "Add External Bias Signal" on the "Scan" window of the "SPM Parameters" window.

⑧ ADX terminal

Is an input terminal used to add an external signal to an X-axis scanning signal. A voltage that is 15 times as large as this input signal voltage is applied to the piezoelectric scanner. The maximum input voltage is ±10 V. However, the maximum voltage that can be applied to the piezoelectric scanner is ±150 V in total. Select "Add External X Signal" on the "Scan" window of the "SPM Parameters" window.

⑨ ADY terminal

Is an input terminal used to add an external signal to a Y-axis scanning signal. A voltage that is 15 times as large as this input signal voltage is applied to the piezoelectric scanner. The maximum input voltage is ±10 V. However, the maximum voltage that can be applied to the piezoelectric scanner is ±150 V in total. Select "Add External Y Signal" on the "Scan" window of the "SPM Parameters" window.

⑩ ADZ terminal

Is an input terminal used to add an external signal to a Z-axis scanning signal. A voltage that is 15 times as large as this input signal voltage is applied to the piezoelectric scanner. The maximum input voltage is ±10 V. However, the maximum voltage that can be applied to the piezoelectric scanner is ±150 V in total. Select "Add External Z Signal" on the "Scan" window of the "SPM Parameters" window.

⑪ PR2 terminal

Outputs an offset voltage to apply an offset to the signal of the C-D terminal on the AFM AMP unit.

⑫ REF terminal

Must be connected to the ground terminal of the main console and the SPM CONTROL unit.

⑬ PZT terminal

Used to drive the PZT (piezoelectric) scanner in the main console.

### ■ Terminals for connecting optional accessories

#### ● Terminal for TM-26010 or TM-26020 Viscoelasticity, Lateral Modulation FFM

⑭ OSC

Connect OSC to the OSC OUT terminal on the Lock-in Amplifier.

⑮ LI1

Connect LI1 to the CH1 terminal of OUTPUT on the Lock-in Amplifier.

⑯ LI2

Connect LI2 to the CH2 terminal of OUTPUT on the Lock-in Amplifier.

⑰ LIS

Connect LIS to the A terminal on the Lock-in Amplifier.

#### ● Terminal for TM-26030 Kelvin Force Microscope

⑱ CPD

Connect CPD to the CPD terminal on the SKPM CONTROL unit.

⑲ OSO

Connect OSO to the OSCO terminal on the SKPM CONTROL unit.

## 4.3.2 Computer System

A video printer, a video recorder, a video converter, a video monitor and a MO disk are optional attachments.

#### ● Computer

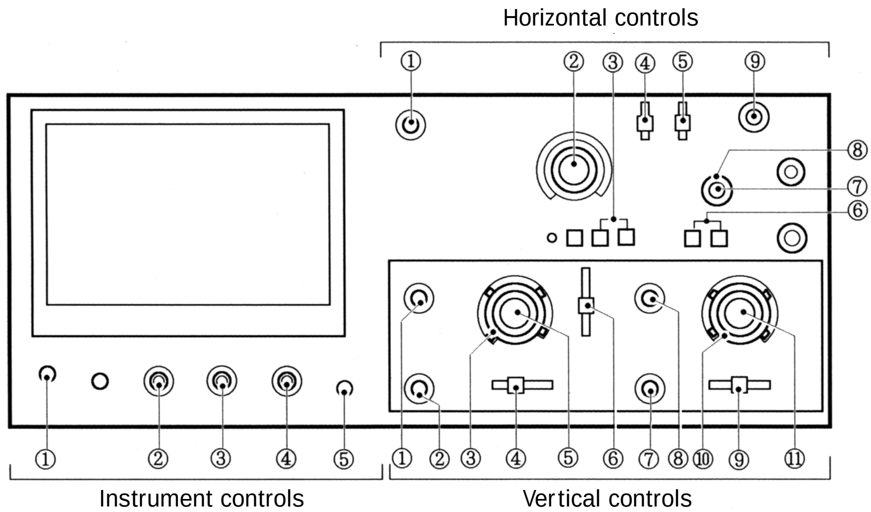
An IBM-PC/AT compatible computer is used as the control computer for this system.

#### ● Display

The control menu and a specimen-surface image are indicated on this display. Image files stored in the computer memory and hard disk are also indicated on this display. Various image-processing operations are directly carried out on this display using the mouse.

### 4.3.3 Oscilloscope (Option)

Below described are the names and functions of the switches, knobs and buttons on the front panel of the oscilloscope.




## ■ Instrument controls

① POWER

Power ON/OFF switch.

② INTENSITY

A knob for the CRT brightness adjustment. Adjust the brightness to make the display easy to see using this knob.

③ FOCUS

A knob for the CRT focus adjustment. Adjust the focus in such a manner that the trace in the CRT looks the sharpest.

④ SCALE ILLUM

A knob for the CRT illumination adjustment. Usually, this knob is not used. Leave the knob turned counterclockwise to the limit.

⑤ TRACE ROTATION

This knob is used to correct the trace tilt occurring due to the geomagnetic effect.

## ■ Vertical controls

① χ Vertical position control

A knob for adjusting the vertical position of the trace.

② INPUT

A signal input terminal. Connect the Z/10 terminal on the SPM CONTROL unit to CH1 and the CH2 terminal on the SPM CONTROL unit to CH2, using the respective BNC-BNC cables supplied.

③ VOLTS/DIV

A switch for selecting signal input sensitivity for the CH1 and CH2 signals. Usually, set it to “5V/div”(turn it counterclockwise to the limit).

④ AC, GND, DC switch

A switch for selecting input-signal coupling mode. Usually, select “GND” when adjusting the luminescent line position and “DC” during scanning.

⑤ VARIABLE

A knob for varying the input signal sensitivity continuously. Pulling the knob increases the sensitivity 5 times. Usually push it and turn it counter-clockwise to the limit (CAL position).

⑥ Display function selection switch

When the switch is set to CH1, only the signal input to the CH1 (Z/10) terminal is displayed. When it is set to CH2, only the signal input to the CH2 terminal (the signal selected with the SELECT knob on the SPM CONTROL unit) is displayed. Usually set it to the “CHOP” position.

⑦ INPUT

Same as ② above.

⑧ χ Vertical position control

Same as ① above.

⑨ AC, GND,DC

Same as ④ above.

⑩ VOLTS/DIV

Same as ③ above.

⑪ VARIABLE

Same as ⑤ above.

## ■ Horizontal controls

① ⇔ Horizontal position control

A knob for adjusting the horizontal position of the trace. Pulling the knob increases the scanning rate 10 times. Usually, push the knob. Adjust the trace with the knob pressed so that it does not cut on the CRT.

② TIME/DIV

A switch for selecting the scanning rate. Set it to such an position that the observation waveform can be easily seen. Usually, “2 ms/div” is used.

③ NORM, AUTO

A switch for switching over the scanning rate. Usually, “AUTO” is used.

④ TRIGGER COUPLING

A switch for selecting the trigger signal coupling. Usually, “AC” is used.

⑤ TRIGGER SOURCE

A switch for selecting the trigger signal. Usually, “INT” is used.

⑥ INTERNAL TRIGGER SOURCE

A switch for selecting the trigger signal. The function of this switch is in effect only when the TRIGGER SOURCE switch (⑤) is set to “INT.”  Usually, “VERT” (both switches are pressed) is used.

⑦ VARIABLE

A knob for varying the scanning rate continuously. Usually, push the knob and turn it clockwise to the limit (CAL position).

⑧ HOLD OFF

A knob for adjusting the holdoff time. Usually, turn it clockwise to the limit (NORM position).

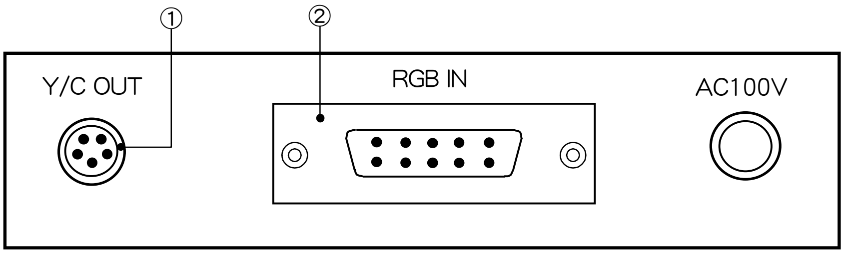
⑨ LEVEL

A knob for setting the trigger level. Usually, turn it counterclockwise to the limit (FIX position).

## 4.3.4 Video Converter (option)

An image displayed on the "Display Window" can be converted to an S-VHS signal and output. In addition, the NTSC image signal can be captured in the software. Refer to Subsection 7.2.7b "Display Param."

**Video Converter (front panel)**




**Video Converter (rear panel)**

① Y/C OUT

An image displayed on the "Display Window" is converted to the S-VHS signal and output. Connect it to the S-VHS input terminal on the Video Recorder.

② RGB IN

Connect it to the connector of the frame memory board, using the attached cable. For the cable connection, refer to Chapter 10 "APPENDIX."

CONTENTS

# 5

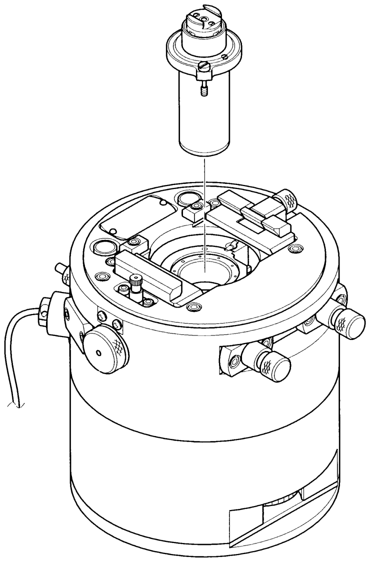
# PREPARATION FOR OBSERVATION

# 5.1 PREPARATION FOR AFM OBSERVATION

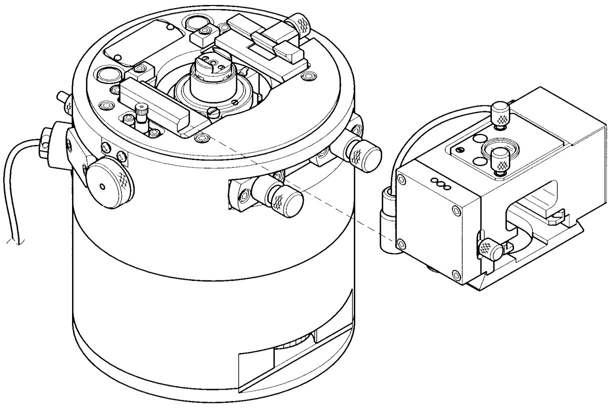
## 5.1.1 Outline

This subsection outlines the preparation for AFM observation from scanner setting to specimen inserting.

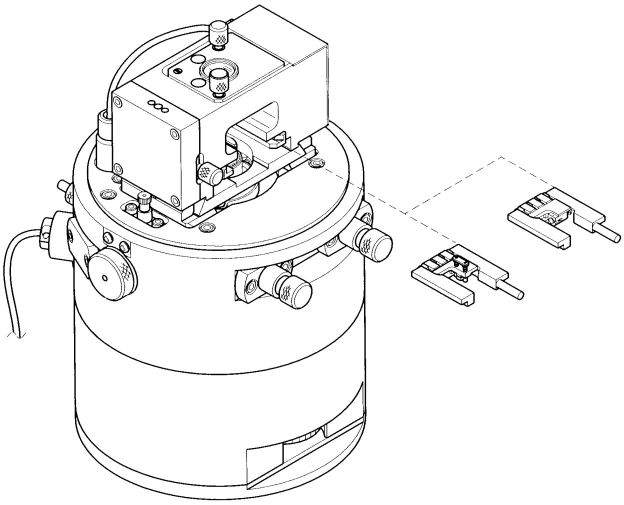
1. Attach an appropriate scanner holder to the SPM base according to the scanning area to be observed.



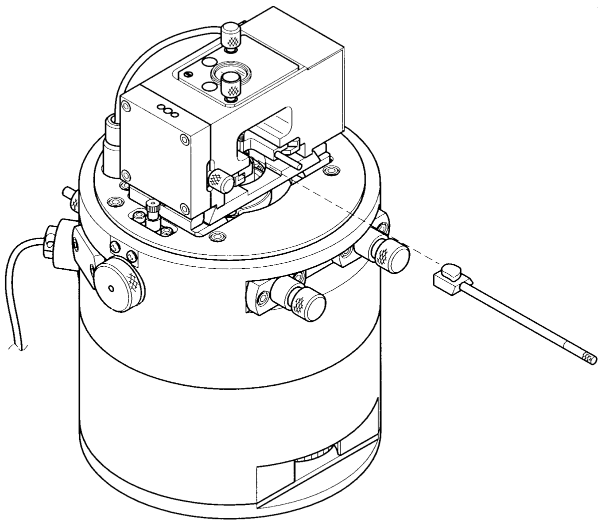
2. Attach the SPM head to the SPM base.



**3.** Insert the cantilever holder or the tip holder.

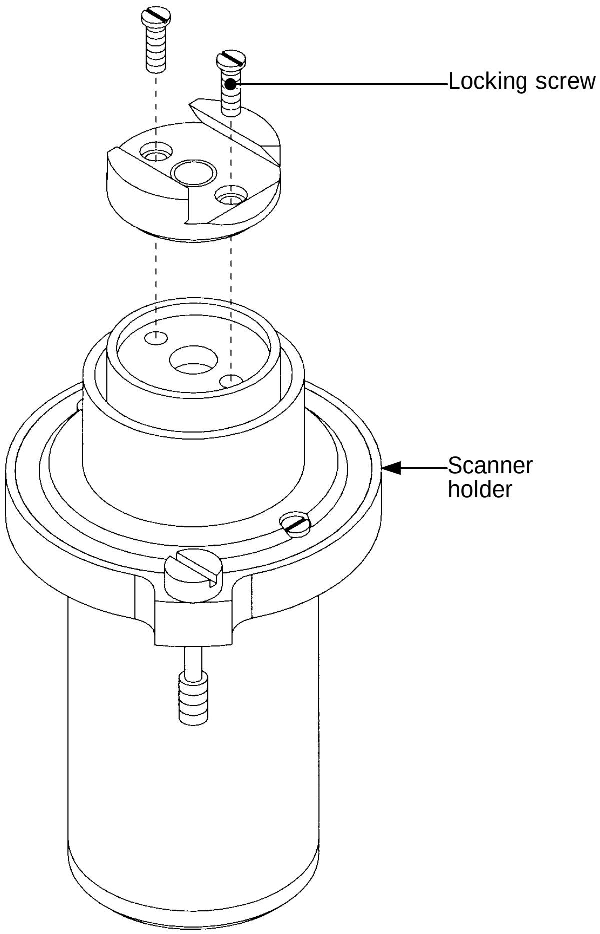


**4.** Insert a specimen stub into the scanner holder.



## 5.1.2 Mounting the Specimen Holder

The mounting of the specimen holder on the scanner holder is described in this sub-section.




Note: When mounting the specimen holder on the scanner holder, be careful to tighten the two fixing screws evenly.

**CAUTION**

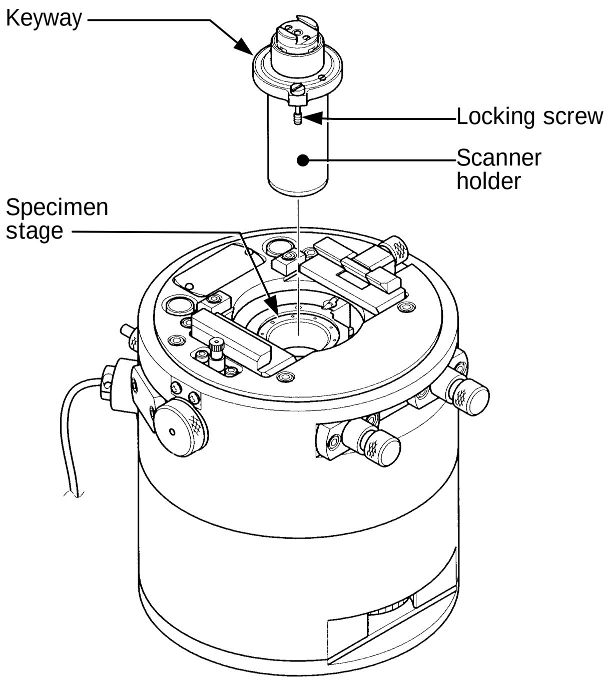
**Handle the scanner holder very carefully. Since it is a precision mechanism, it could easily be damaged by a strong shock.**

### 5.1.3 Mounting the Scanner Holder

**1.** Turn OFF the SPM CONTROL unit.

> **WARNING**
>
> **Be sure to turn OFF the power to the SPM CONTROL unit before installing or removing the scanner holder or head unit, because a high voltage is applied to the connector pins from the SPM CONTROL unit while the power is ON. Otherwise, there is a risk of electric shock.**

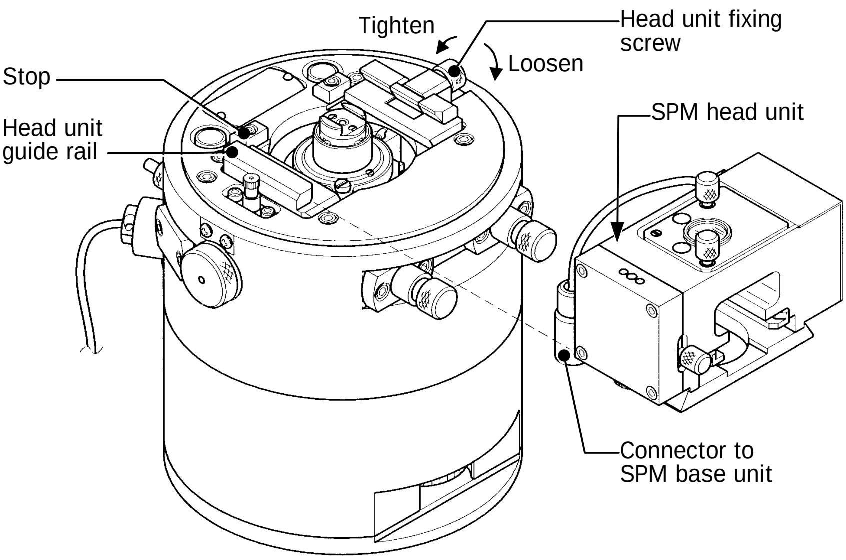
**2.** Select the scanner holder having the most suitable scanning range according to the specimen to be observed (if you have optional scanner holders). Insert it into the specimen stage along the keyway. Then, lock it with the two screws.




Note: When you replace the scanner holder with an optional one, you have to designate the new one with the software. For the designating procedure, refer to Chapter 6 "OPERATION."

### 5.1.4 Mounting the SPM Head Unit

1. Loosen the head unit locking screw.
2. Insert the SPM head unit in parallel with the head unit guide rails on the SPM base unit until it touches the stop. Then, lock it with the head unit locking screw.
3. Insert the two connectors to the SPM base unit provided on the SPM head unit into the receptacle connectors on the SPM base unit, along the key way, until you hear a click.

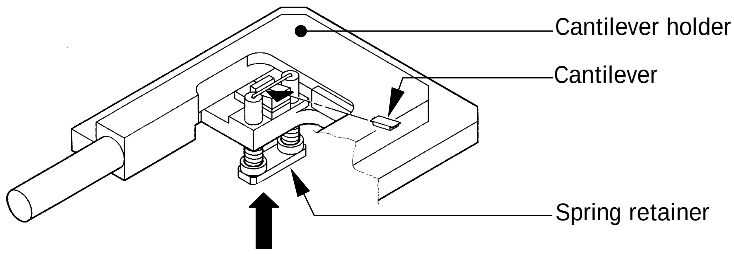



### 5.1.5 Mounting the Cantilever

Described in this subsection is the procedure for mounting the cantilever on the cantilever holder in order to perform AFM observation. When performing STM observation, refer to 5.1.6 “Mounting the Tip.”

1. Cut out a cantilever element from a strap.

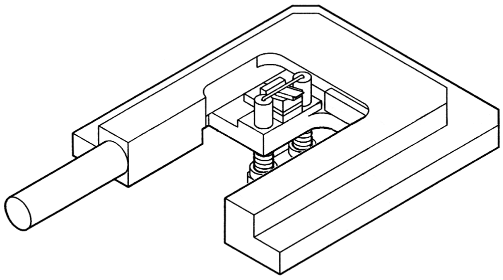
   Note: For more details about handling the cantilever, refer to the instruction manual provided with the cantilever.
2. Insert the cantilever element into the cantilever groove while pushing up the spring retainer (for example, by pushing the cantilever holder body onto a desk).



**CAUTION**

1. **Be sure to insert the cantilever along the groove. Otherwise, the cantilever may be damaged due to an excessive force being applied when the spring retainer is released.**
2. **Never touch the area around the cantilever on the cantilever holder with a naked finger. If that part is contaminated with hand grease, that might give rise to insufficient insulation, thus possibly causing tunneling current leakage or incorrect operation of the piezoelectric element.**
3. **Push the spring retainer vertically. If you force it diagonally, the ceramic might be damaged.**

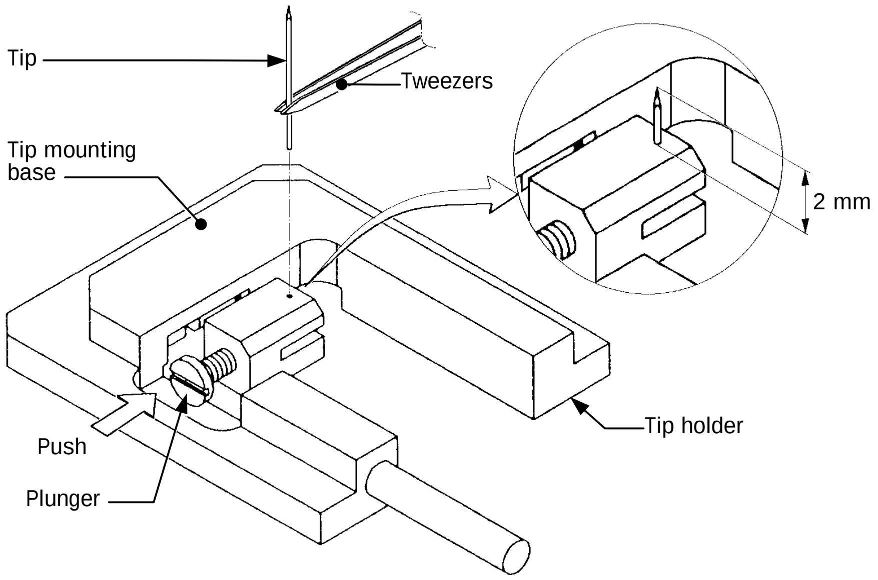
**3.** Release the spring retainer slowly to lock the cantilever in place.



## 5.1.6 Mounting the Tip

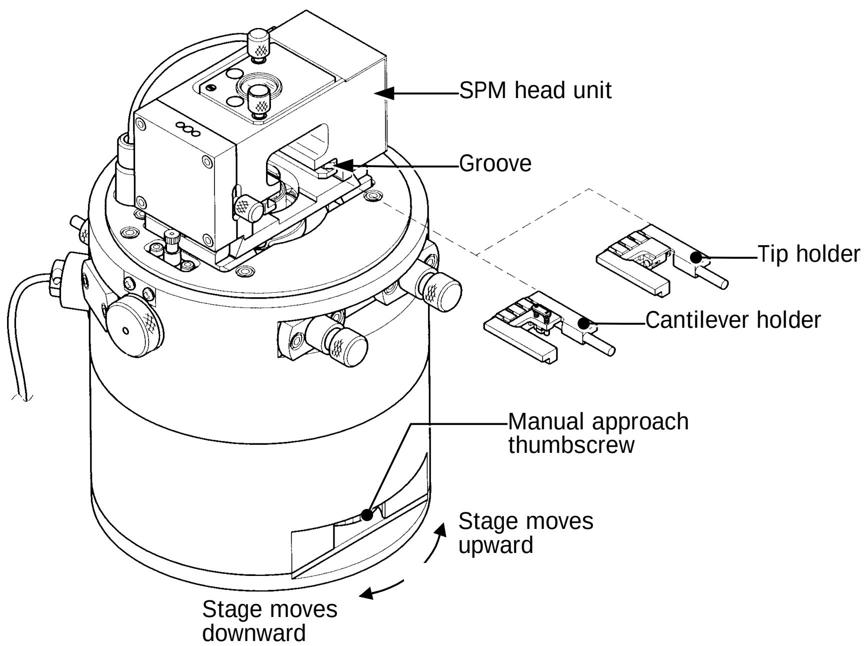
Described in this sub-section is the procedure for mounting the tip on the tip holder in order to perform STM observation.

To mount the tip on the tip holder, insert the tip into the plunger while pushing the plunger as shown in the figure below to align the external and internal tip-mounting holes. Make sure that the length of the tip is 2 mm from the top of the tip to the surface of the tip mounting base.




### 5.1.7 Inserting the Cantilever Holder or the Tip Holder into the SPM Head Unit

**1.** In order to prevent the cantilever or the tip from colliding with the scanner holder, confirm that the specimen stage is lowered to a low enough position. If it is not, move the specimen stage downward by turning the manual approach thumbscrew.

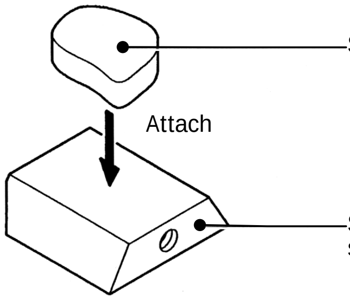



**2.** Insert the cantilever holder or the tip holder into the groove until it touches the innermost wall.

## 5.1.8 Inserting a Specimen

**1.** Attach a specimen to the specimen stub with an appropriate material such as double-faced adhesive tape or conductive paint.

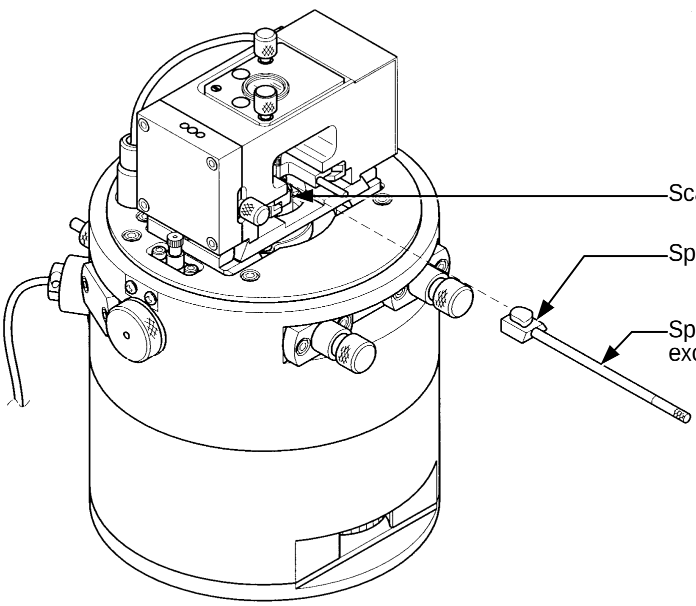
> **CAUTION**
>
> **The specimen stub is gold-plated. Be careful not to scratch the stub surface.**




**2.** In order to prevent the specimen or specimen stub from colliding with the cantilever or the tip, confirm that the specimen stage is set at a low enough position. If it is not, move the specimen stage downward by turning the manual approach screw as shown in 5.1.7.

**3.** Insert the specimen exchange rod into the specimen stub and slide the specimen stub into the groove of the scanner holder until it clicks.

> **CAUTION**
>
> **Insert or remove the specimen stub horizontally with care. If an excessive force is applied to the scanner holder, the scanner inside it might be damaged.**



### 5.1.9 Specimen Exchange

When you replace the specimen just observed with a new specimen, you do not have to turn off the SPM CONTROL unit.

> **WARNING**
>
> **Never exchange a specimen while a high bias voltage is being applied to the specimen. You might get an electric shock due to the high voltage applied to the specimen.**

**1.** Click on “SPM Scan” on the main menu of the SPM software and select “Scan ···” from the pull-down menu. Then, select the “Advanced” tab. The “SPM Parameters” window will be displayed.

**2.** Select the “Tip” button and the “Tip” window will be displayed. Confirm that the “High Bias” check box ☐ located at the bottom left of the “Tip” window has not been checked. If the check box has been checked (“✓”), click on it to remove the check mark from the check box (☐).

CONTENTS

## 5.2 PRE-ADJUSTMENT STEPS FOR AFM OBSERVATION

Described in this section are the procedures for adjusting the laser beam and the photo-diode in the AFM head and for the rough approaching of a specimen.

### 5.2.1 Adjusting the Laser Beam Position

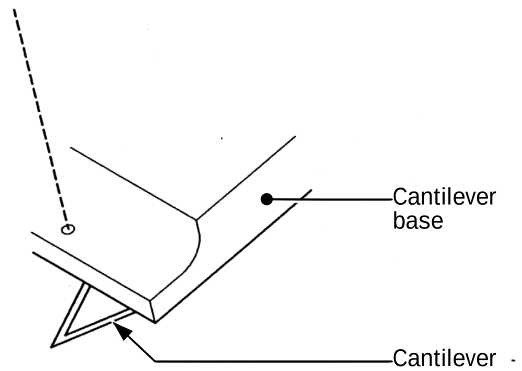
Turn on the SPM CONTROL unit according to the procedure of Section 6.2 “SYSTEM STARTUP.”

**1.** Turn on the “LD-ON” switch on the AFM amplifier unit.
The switch lamp lights and the laser beam will be emitted.

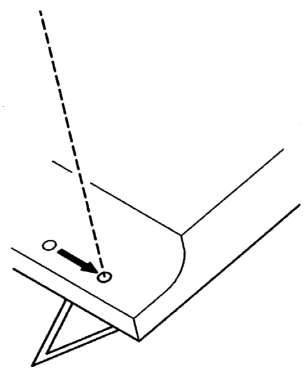
**2.** Adjust the laser beam illumination position using the laser beam illumination position adjustment knobs so that the laser beam correctly illuminates the top of the cantilever.

**a.** Adjustment procedure 1

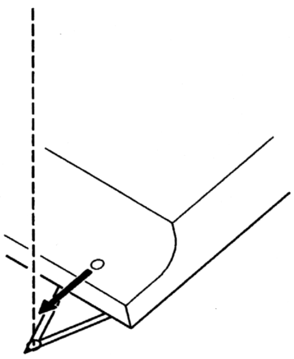
① Adjust the laser beam using the knobs so that the laser beam spot illuminates the edge of the cantilever base.




② Shift the laser beam spot so that it illuminates the edge of the cantilever base corresponding to the center of the cantilever, as shown below.

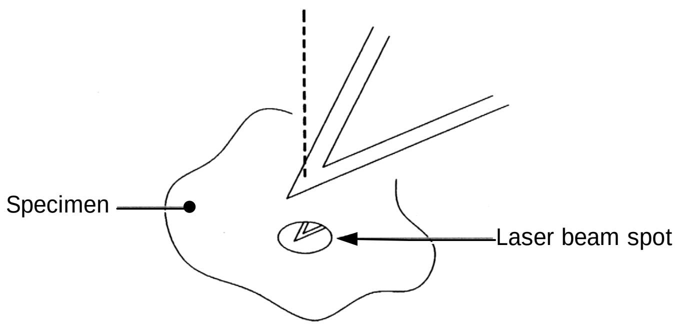


③ Shift the laser beam spot so that it illuminates the top of the cantilever, as shown below.



**b.** Adjustment procedure 2

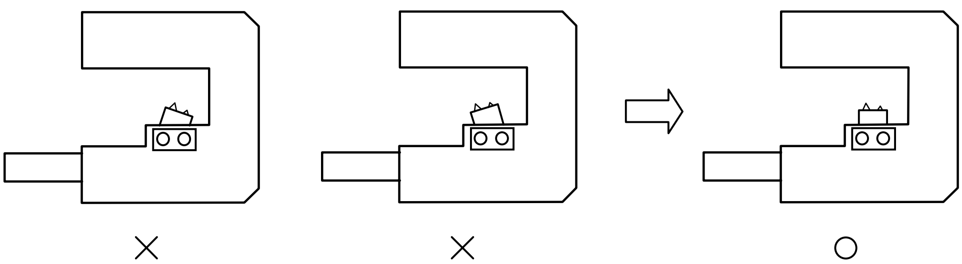
① At this stage of adjustment, observe the laser beam spot on the specimen surface.




② Carry out fine adjustment of the laser beam spot position so that the laser beam spot on the specimen becomes as dark as possible.

The range of the laser beam position adjustment is wide enough to cope with almost all cantilevers. If the laser beam position fails to shift even though the laser beam illumination adjustment knobs are turned, the laser beam position may have shifted out of the beam position adjustment range. In such a case, check the following points.

- Is the cantilever holder inserted properly (does it touch the innermost wall) ? Especially in the case of the cantilever holder for the non-contact mode, its insertion becomes difficult when the holder gets near the innermost wall due to the electrode on the holder. Be sure that the holder touches the innermost wall.
- Is the cantilever set at a proper angle on the cantilever holder ?

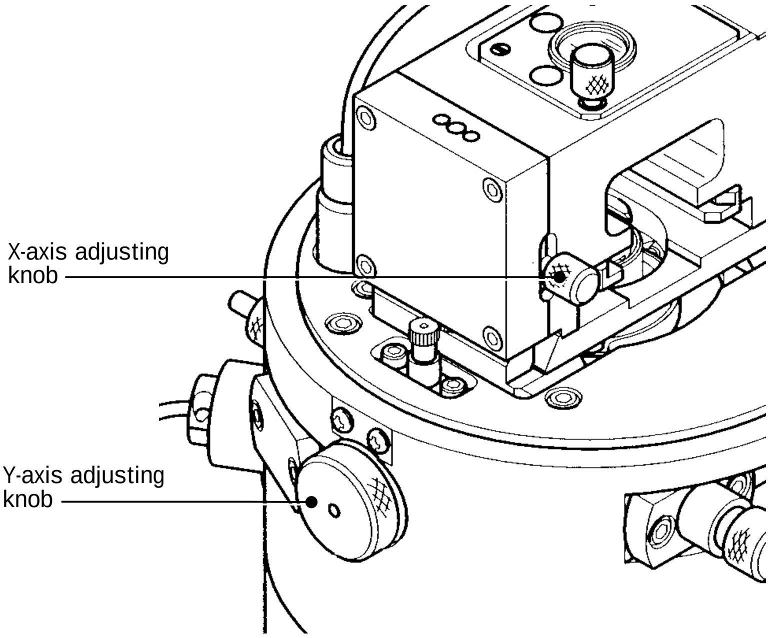


**CAUTION**

**Although the focus of the laser beam has been adjusted in the factory before shipment, the beam may be out of focus for some reason. If so, readjust the beam focus referring to Chapter 8 "MAINTENANCE."**

### 5.2.2 Adjusting the Photodiode Position

1. Set the indicator selection switch on the AFM amplifier unit to "SUM."
2. Turn the Y-axis adjusting knob so that the indicated "SUM" value becomes as negative as possible.



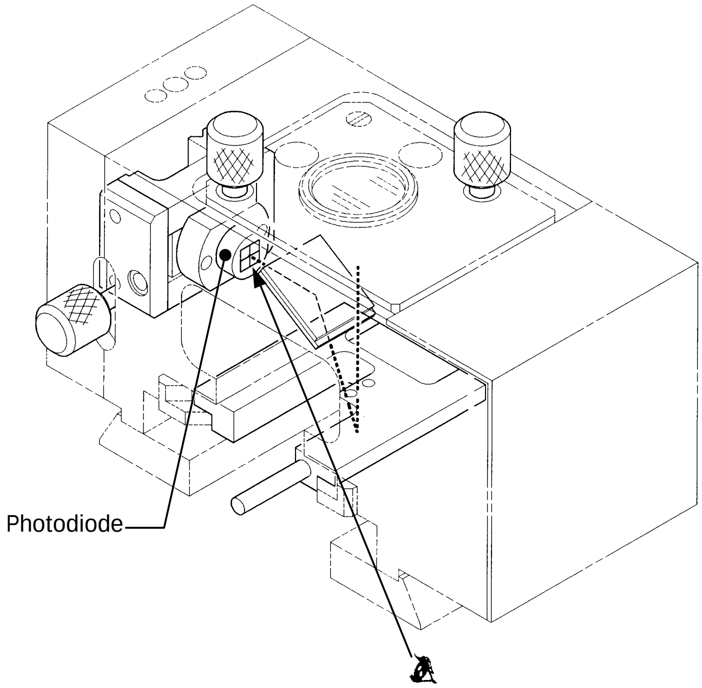

3. Turn the X-axis adjusting knob so that the indicated "SUM" value becomes as negative as possible.
4. Set the indicator selection switch on the AFM amplifier unit to "AFM." Turn the Y-axis adjusting knob so that the indicated "AFM" value becomes ±0 V.
5. Set the indicator selection switch on the AFM amplifier unit to "FFM." Turn the X-axis adjusting knob so that the indicated "FFM" value becomes ±0 V.
6. Repeat steps 4 and 5 above until both the "AFM" and "FFM" indications become ±0 V.

Now, the laser beam illuminates the center of the photodiode.

Note: When the $Si_3N_4$ cantilever is used in this state, the value of "SUM" is about –8.0 V to –10.0 V. When the Si cantilever for the AC mode is used, the value of "SUM" is about –5.0 V. If the "SUM" value less than –8.0 V, the laser beam position on the cantilever may have shifted from the correct position. Readjust the laser beam position according to Subsection 5.2.1 "Adjusting the Laser Beam Position."

**7.** To perform approaching in the contact mode, set the indicator selection switch on the AFM amplifier unit to “AFM.” Turn the Y-axis adjusting knob so that the indicated “AFM” value becomes about –2.0 V. To perform approaching in the AC mode, turn the Y-axis adjusting knob so that the indicated “AFM” value becomes 0 (zero).

- Photodiode adjustment procedure




**a.** To roughly adjust the photodiode position, watch the laser beam spot on the photodiode from the right-hand side of the AFM head unit.

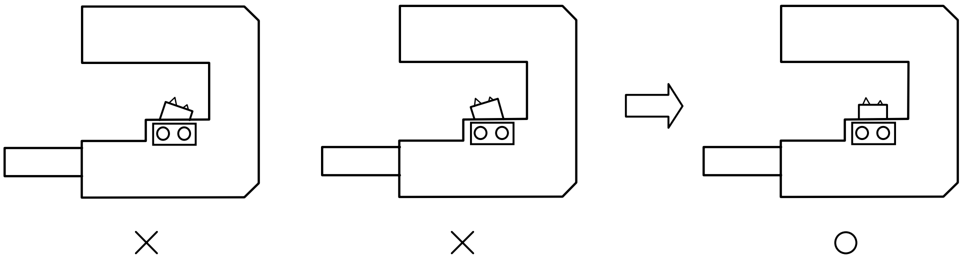
**b.** Adjust the photodiode position using the X- and Y-axis adjusting knobs so that the center (▪▪) of the photodiode is positioned at the center of the laser beam.

Once this rough adjustment of the photodiode position has been made, you can adjust the photodiode position using the “Adjust PD” function in the software. Refer to Chapter 6 “OPERATION.” If the photodiode position cannot be adjusted despite steps 1 to 6 above, check the following points.

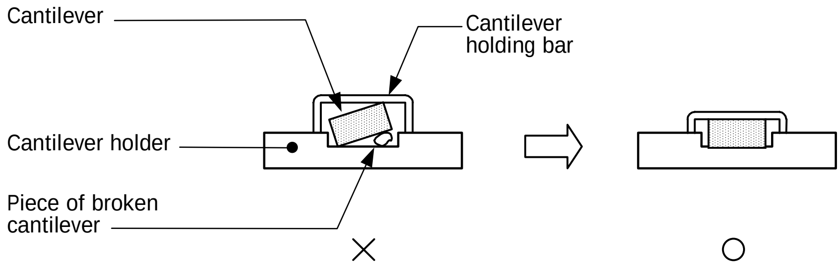
- **The FFM value cannot be adjusted to 0 (zero).**

Such a case probably occurs when the cantilever is not set correctly on the cantilever holder. Check the following four points.

- Is the cantilever set straight on the cantilever holder ?




- Is the cantilever inclined in the cantilever groove ?
  Such a case occurs mainly when burrs or broken pieces produced when the cantilever is cut out are inserted between the cantilever and the cantilever holder.

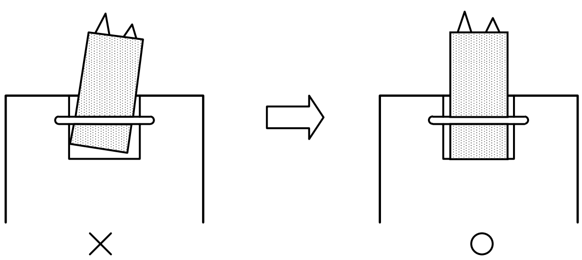



- Is the cantilever holder inserted properly (does it touch the innermost wall) ?
  Especially in the case of the cantilever holder for the non-contact mode, its insertion becomes difficult when the holder gets near the innermost wall due to the electrode on the holder. Be sure that the holder touches the wall.
- Is “External” zero ?
  Confirm that the “External” value of “Feedback/Filters Advanced” in the “Advanced” tab on the “SPM Parameters” window is 0.0 V.

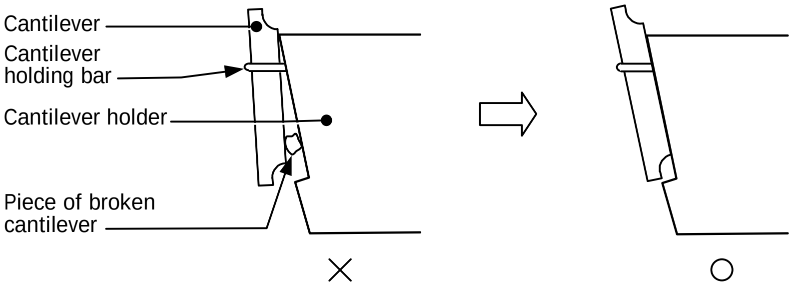
- **The AFM value cannot be adjusted to zero, or the laser beam reflected by the cantilever does not illuminate the mirror.**

Check the following two points.

- Is the cantilever inserted properly into the cantilever groove until it touches the innermost wall of the holder ? Or, is there a piece of broken cantilever or something between the cantilever and the holder ?



- Is the cantilever holder inserted properly? Or, is there a piece of broken cantilever or something in the groove ?




If the AFM value still can not be adjusted to zero after the above checks, try to adjust the mirror position according to Chapter 8 “MAINTENANCE.” If you cannot adjust it correctly, the cantilever itself may be bent or broken. Check the cantilever storage condition according to Chapter 8 “MAINTENANCE.” If all these attempts are unsuccessful, replace the cantilever.

### 5.2.3 Rough Approaching

1. Using the “Coarse Stage” function of the SPM software, confirm that the stage is positioned within the range for approaching. For the confirmation procedure, refer to Chapter 6 “OPERATION.”
2. Watching the distance between the cantilever and the specimen using the optional optical microscope, turn the manual approach thumbscrew so that this distance becomes about 0.3 mm or less. For the procedure for operating the optional optical microscope, refer to Chapter 9 “APPENDIX.”

This completes the preparation for AFM observation.

# 6

# OPERATION

# 6.1 FUNDAMENTAL KNOWLEDGE FOR SOFTWARE OPERATION

This system operates under the Windows95™ operation system. Described in this section is the fundamental knowledge of the terms and operations required for using the software.

- **Main menu**

The main menu is displayed on the top line of a window. The displayed menu automatically changes according to the image or graph currently displayed on the "Display Window." For example, the image-processing menu appears if an image is displayed in the window, or the graph-processing menu appears if a graph is displayed in the window.

- **Pull-down menu**

When the "▼" mark is selected in the main menu or in a window, a related lower-level menu is displayed just below the selected mark. To select one of the pull-down menu items, point the cursor to the menu item; then the menu item is highlighted. You can click the left mouse-button on it to select the highlighted menu item.

- **Click**

Move the cursor on the screen to the position of the item to be selected by moving the mouse; then press the left mouse-button once.

- **Double-click**

Move the cursor on the screen to the position of the item to be selected by moving the mouse; then press the left mouse-button twice quickly.

- **Input window**

This is a window in which a character string or numerical value can be entered from the keyboard. Place the cursor in the window and double-click the mouse; then the character string or numerical value already in the window is highlighted. You can enter a new character string or numerical value directly from the keyboard. The new character string or numerical value has been entered, but has not been finalized yet. To finalize it, press the TAB key or click on any other item in the window.

- **Check-box**

A check box is a box displayed at an item to be selected. If a check mark "⌉" is displayed in the box ("⌋"), this item is selected. If nothing is displayed in the box ("□"), this item is not selected. Clicking on a box makes the item selected, and clicking on a "⌋" mark deselects the item.

- **Radio button**

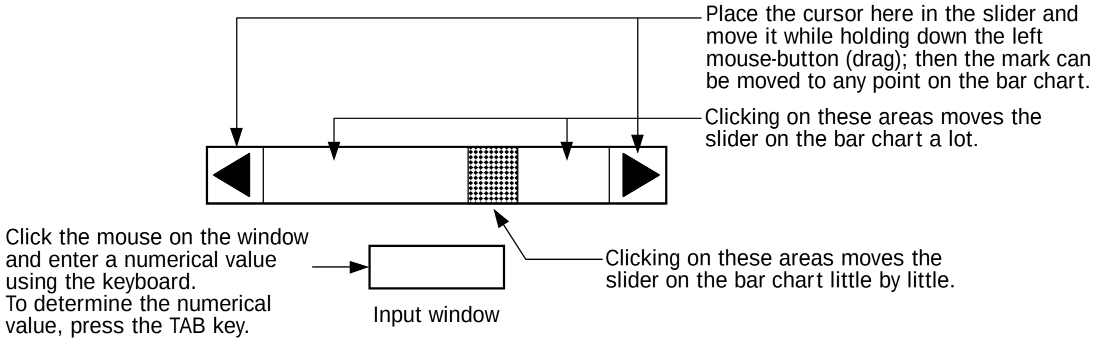
A radio button is used to select one item from among two or more items. A radio button "○" mark, is displayed at every item that can be selected. If a small is displayed in the radio button ("⁄"), this item is selected. If nothing is displayed in the radio button ("○"), this item is not selected. Clicking on a radio button selects the item. To deselect the selected item, click on one of the other radio buttons or click on the radio button to be selected (then, the already-selected radio button is automatically deselected).

## ● Gray display

If check boxes, radio buttons or input boxes are displayed in gray, that shows that these cannot be selected.

## ● Bar chart

A numerical value on the bar-chart can be changed using either the keyboard or the mouse.



# 6.2 SYSTEM STARTUP

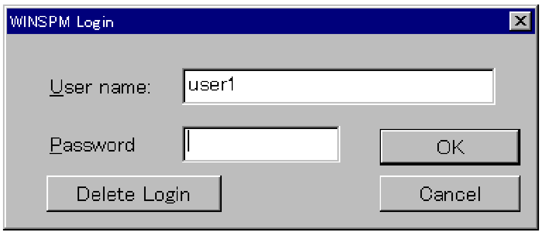
## 6.2.1 System Startup

1. Confirm that a specimen and a cantilever and tip are properly mounted and are at an appropriate position for approaching.
2. Turn on the POWER switch on the SPM CONTROL unit; then set the computer switch to the ON position. Confirm that the computer and the CRT display are turned on.

   Notes: 1. Switch ON the computer manually because the computer cannot be switched ON by turning on the POWER switch of the SPM CONTROL unit.

   2. With this operation, the computer automatically starts and the SPM CONTROL unit is reset.

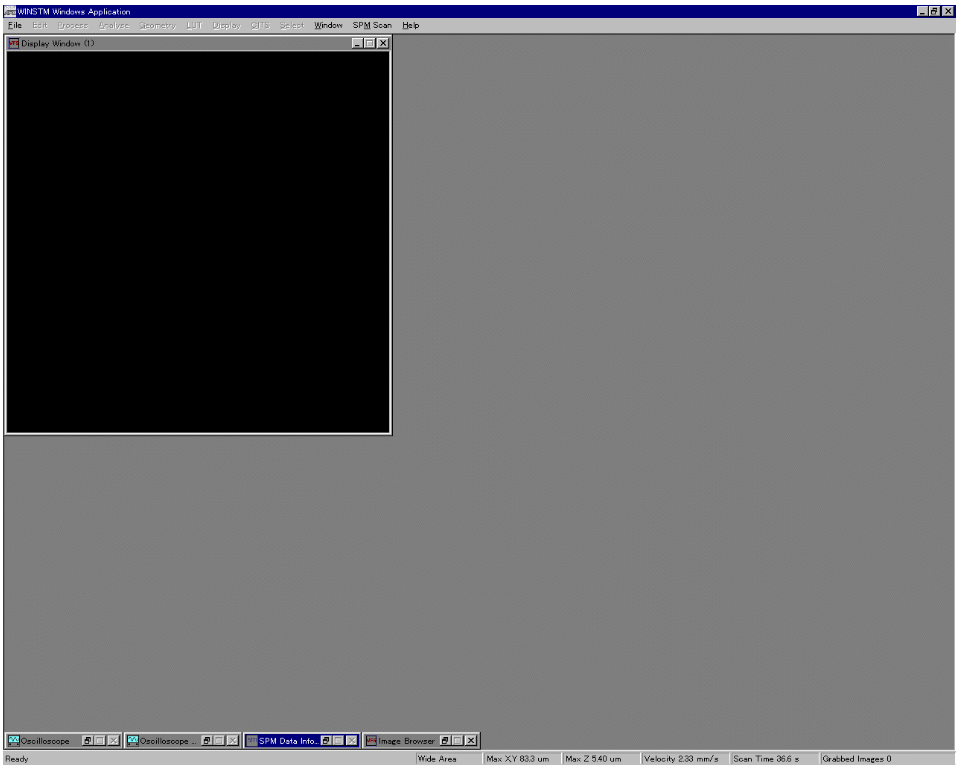
   3. If optional attachments are installed, confirm that these attacments are also switched on.
3. The SPM software automatically starts, and the computer screen asks you for your User name and Password.




When you use the system for the first time after it is installed, simply click on “OK.” The software operates with the conditions set before shipment from the factory. If you want to make a personal file, create it referring to Subsection 6.2.2 “Personal File Creation.” If the software starts with a user name other than “User1,” the user name is the one that was most recently used. If you want to start the software with the default conditions, double-click on “User name”; then enter “User1” using the keyboard and click on “OK.” Thus, you can start the software without entering the password.

4. Enter the user name and password; then click on "OK."

   The computer screen displays the window below.




## 6.2.2 Personal File Creation

Scanning parameters and window positions can be stored in a personal file for later use. This function is useful when the system is used by two or more operators. The following is the procedure for registering a personal file.

1. Turn ON the system according to Sub-section 6.2.1 "System Startup."

   The SPM software automatically starts up and asks you the user name and password.

2. Double-click on "User name" and enter a new name using the keyboard.

   Note: Only alphanumerical characters are acceptable for "User name."

3. Double-click on "Password" and enter a password using the keyboard.

   Note: Only alphanumerical characters are acceptable for "Password." Asterisks (*) will be displayed in the window instead of the entered password.

4. After entering the new user name and password, click on "OK"; then the following message will appear in the window:

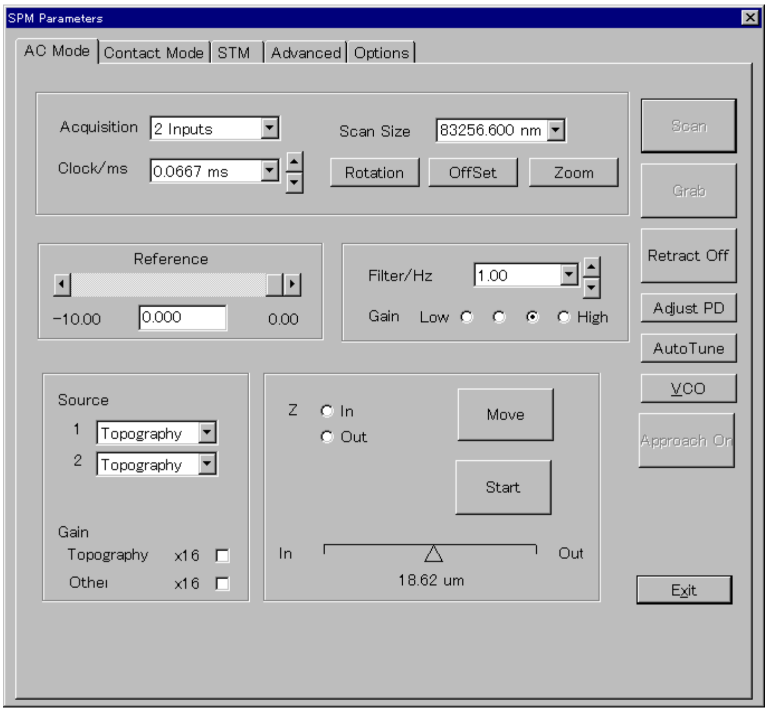
   ```
   *user name not recognized
   Add as new user ?
   ```

   Click on "OK"; then the system will return to the User name and Password window again; then click on "OK."

Now, the software is started with the new settings. When a new user name is entered, the initial settings return to the condition set before shipment from the factory.

## 6.2.3 Control Panel

There are two kinds of control panel, one for Tiny Mode and the other for Advanced mode. To display the control panel on the screen, click on “SPM Scan” on the main menu and select “Scan···” from the displayed pull-down menu; then the following control panel will be displayed.




There are tabs on the top of this control panel. When you click on one of the tabs, the control panel for its mode is displayed.

| | |
|---|---|
| Tiny | Mode |
| | AC Mode |
| | Contact Mode |
| | STM Mode |
| | Options |
| Advanced Mode | |
| | Advanced |

- Tiny mode

  Necessary parameters are automatically set according to the measurement mode, thus allowing the operator to perform image observation easily.
- Advanced mode

  The operator must set every parameter manually. Setting the parameters in full detail is possible for image observation at an advanced level.

# 6.3 PREPARATION FOR APPROACHING

The meaning of "approach" is to make the distance between a specimen and a cantilever (or tip) so close that an atomic force exists (or tunneling current flows) between them. In the approaching function, the cantilever (tip) is moved toward the specimen by a motor and stops automatically when an atomic force (or tunneling current) is detected. Confirm the following points before starting approaching.

## 6.3.1 SPM CONTROL Unit Resetting

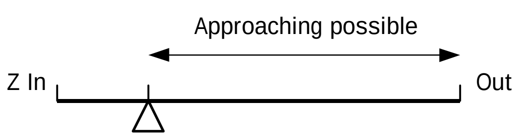
The SPM CONTROL unit is initialized by a signal from the computer when the software is started. As explained in Subsection 6.2.1 "System Startup," the SPM CONTROL unit must be turned ON before the software is started. However, if the SPM CONTROL unit is turned ON after the software is started up or if the SPM CONTROL unit is turned OFF and then ON for some reason such as replacing the scanner, the unit must be reset using the software. The procedure for resetting the SPM CONTROL unit is as follows.

1. Click on "SPM Scan" in the main menu and select "Reset SPM" from the displayed pull-down menu.
2. The "Reset SPM?" window will be displayed. After confirming that the SPM CONTROL unit has been turned ON, click on "OK" on the window.

## 6.3.2 Checking Stage Position

In this system, approaching is performed automatically using a motor. The Z stage moving range for motor approach is about 1.5 mm maximum, so the stage must be positioned within this range for approaching. Check whether or not the stage is positioned within the for approach range. The following is the procedure for checking this.

1. Click on "SPM Scan" in the main menu and select "Scan···" from the pull-down menu.
   The "SPM Parameters" window will be displayed.
2. Click on the "Advanced" tab indicated on the top of the "SPM Parameters" window.
   The control panel of the "Advanced" mode will be displayed.
3. Select the "Stage" button at the lower part of the window.
   The "Stage" window will appear. Note the location of the triangle ("△") showing the Z position in the "Position" frame. If it is positioned at 1/4 or more of the range from the "In" side, approaching may be possible.




If the triangle's position is closer to the "In" side, move the stage to the "Out" side according to the following procedure.

**4.** Select “Out” in the “Direction” frame and “4-Fast” in the “Speed” frame.
When selecting them, click on the radio button (“○”) in front of these items; then the button changes to “⁄.” In the JSPM-4200, the only usable “Speed” is “4-Fast.”

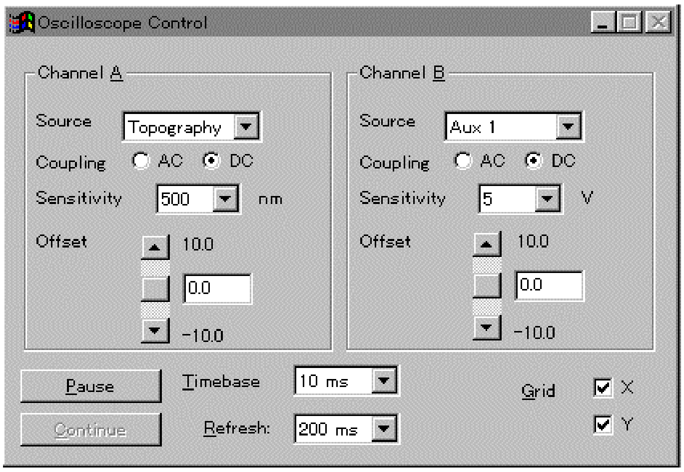
**5.** Click on the “Start” button.

**6.** When the triangle has reached the “approach range,” click on the “Stop” button.

## 6.3.3 Software Oscilloscope Setting

The software provides the functions of an oscilloscope. Click on the “🗗” mark in the “Oscilloscope” and “Oscilloscope···” buttons. The “Oscilloscope” and “Oscilloscope Control” window will appear. The state of approaching can be monitored on the “Oscilloscope” window. To check whether or not approaching has finished, perform the following operations.

**1.** Click on the “🗗” mark in the “Oscilloscope···” button. The “Oscilloscope Control” window will open.




**2.** Click on the “ ▼ ” mark in the “Timebase” selection box; then select “10 ms” from the pull-down menu.

**3.** Click on the “ ▼ ” mark in the “Refresh” selection box; then select “200 ms” from the pull-down menu.

### ■ Channel A Setting

Input signals from two channels can be displayed at a time. Channel A is displayed in red and Channel B in blue. Usually, Channel A is set to “Topography” (Z-direction movement of the scanner). The setting of Channel B varies according to the scanning mode such as the Contact mode, the AC mode and STM (refer to each section). The following is the procedure for setting Channel A.

**1.** Click on the “ ▼ ” mark in the “Source” selection box; then select “Topography” from the pull-down menu.

**2.** Select “DC” for “Coupling” by clicking on the “DC” radio button; then the button changes to “⁄.”

**3.** Click on the “ ▼ ” mark in the “Sensitivity” selection box and select a sensitivity from the pull-down menu.

The sensitivity value indicated in the pull-down menu automatically changes according to the Z sensitivity of the currently selected scanner. In this system, the piezoelectric control voltage for the Z direction is ±150 V, and the shift amount in the Z direction of the standard scanner is 3 μm at ±150 V. So, the calibration value (sensitivity) in the Z direction of the standard scanner is about 10 nm/V. Confirm the calibration value on the "SPM Calibration" window. Set the sensitivity so that the swing in the positive direction of the oscilloscope becomes 2/3 of the full scale when +150 V is applied to the scanner.

**[Example]**

When the calibration value Z is 10.0 nm/V, select "500 nm" for "Sensitivity." Then, the swing becomes 3/4 of the full scale when +150 V is applied to the scanner.

**4.** Double-click on the "Offset" input box and enter 0 using the keyboard.

Shown below is a summary of the conditions for setting the software oscilloscope.

| | | | |
|---|---|---|---|
| Channel | A | Channel | B |
| Source: | Topography | Source: | Depends on scanning mode |
| Coupling: | DC | Coupling: | DC |
| Sensitivity: | Depends on scanner | Sensitivity: | Depends on scanning mode |
| Offset: | 0 | Offset: | 0 |
| Timebase: | 10 ms | Grid | X, Y On |
| Refresh: | 200 ms | | |

**5.** After completing the setting, click on "File" in the main menu and select "Store Configuration" from the pull-down menu. The set conditions are stored.

Note: If the "Store Configuration" operation is omitted, the setting returns to the initial conditions at the next startup time.

## 6.3.4 Setup of Optional Oscilloscope

An optional oscilloscope can be installed in this system. By using an oscilloscope, phenomena faster than the software oscilloscope can be observed, and real-time waveform measurement can be performed during image observation. In addition, it can be used for checking scanning waveforms, bias voltages and so on. The following is the procedure for setting the oscilloscope.

### ■ Correction of tilt due to geomagnetism effect

1. Turn ON the oscilloscope power.
2. Adjust the “INTENSITY” and “FOCUS” knobs so that the trace can be better seen.
3. Set the “MODE” switch to “CH1” and the “AC, GND, DC” switch to “GND.”
4. Adjust “TRACE ROTATION” with a screwdriver so that the trace becomes horizontal to the scale axis on the CRT.

### ■ Input adjustment

Set the oscilloscope according to the following procedure.

1. Set the “MODE” switch to “CH1” and the “AC, GND, DC” switch of CH1 to “GND.”
2. Adjust the vertical position control knob ($\chi$) of CH1 so that the trace is positioned at the center of the CRT.
3. Set the “MODE” switch to “CH2” and the “AC, GND, DC” switch of CH2 to “GND.”
4. Adjust the vertical position control knob ($\chi$) of CH2 so that the trace is positioned at the center of the CRT.

#### ● Other settings

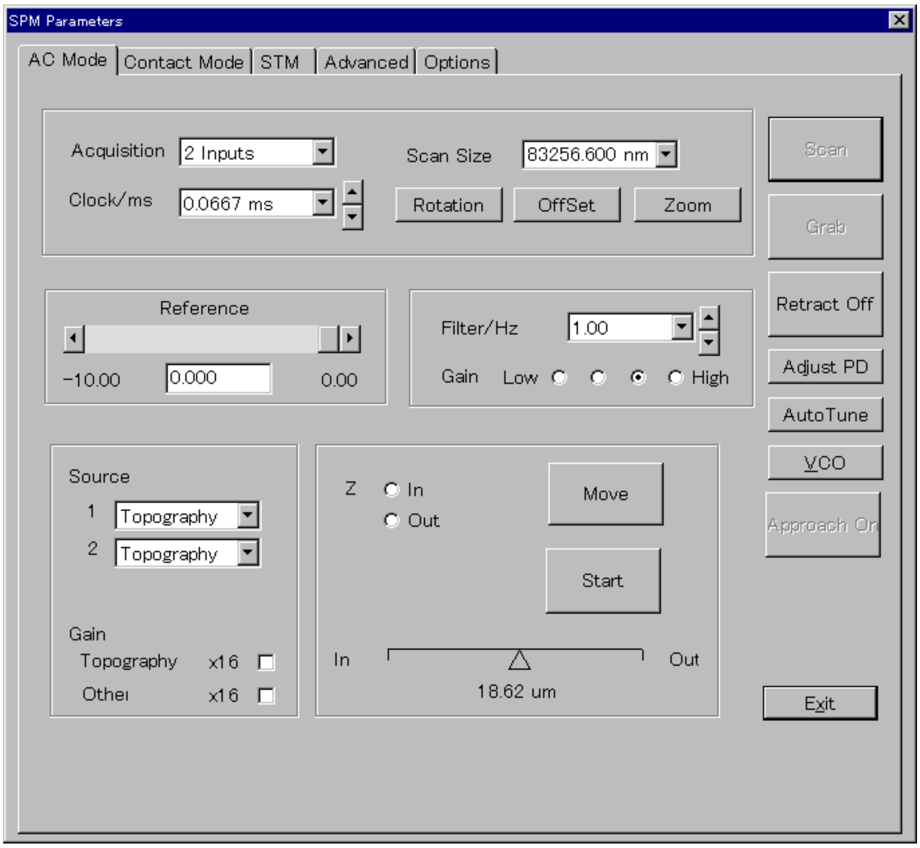
| CH1, CH2 | | | |
|---|---|---|---|
| VOLTS/DIV: | 5 V/div | VARIABLE: | Push in, CAL |
| AC, GND, DC: | DC | | |
| Mode: | CHOP | | |

| | | | |
|---|---|---|---|
| TIME/DIV: | 2 ms/div | NORM, AUTO: | AUTO |
| Trigger coupling: | AC | Trigger source: | INT |
| VARIABLE: | CAL | Internal trigger source: | VERT |
| HOLD OFF: | NORM | LEVEL: | FIX |

The signal input to CH2 is designated by the CH2 signal selection knob on the SPM CONTROL unit. The setting of CH2 varies according to the scanning mode such as the Contact mode, the AC mode, STM. Refer to the description of each scanning mode.

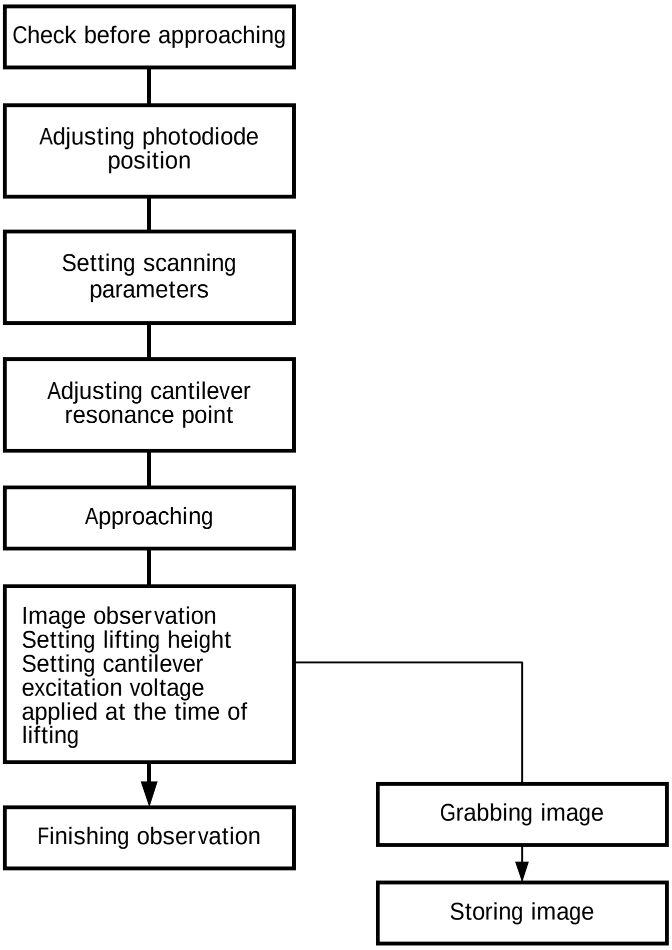
# 6.4 OBSERVATION (TINY MODE) USING AC MODE CONTROL PANEL

In the AC mode AFM, a cantilever is vibrated in the vicinity of its characteristic frequency, and the Z scanner is controlled so that the amplitude and phase of the cantilever remain constant during scanning. Using the AC mode, AFM observation in the attraction range and attraction-repulsion critical range becomes possible. Described in this Section is the procedure for AFM observation by use of the AC mode control panel.




AC Mode control panel

The following is the flow chart of the operation in the AC mode:




## 6.4.1 Check Before Approaching

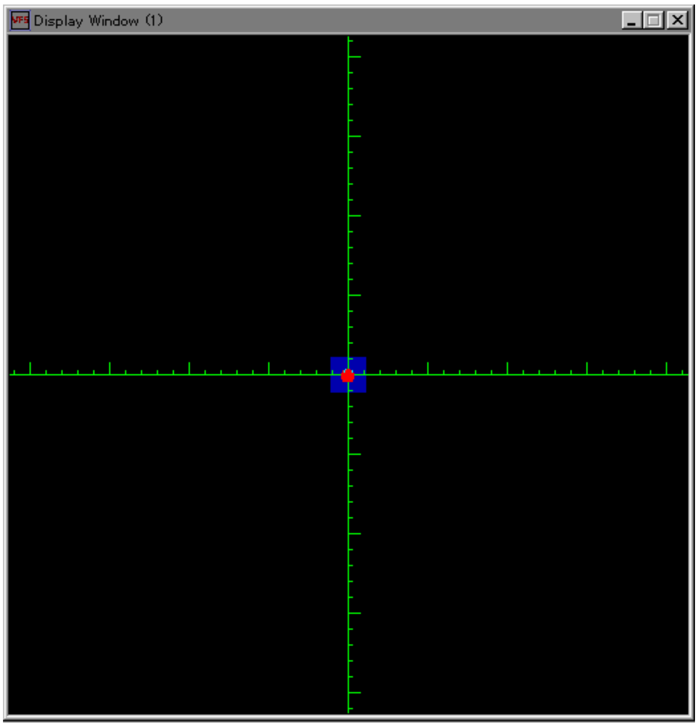
Before performing approaching, check whether the preparation has been completed according to the procedure described in Section 6.3.

- Is a cantilever for AC mode AFM properly mounted on the cantilever holder ?
- Has rough approaching been executed in such a way that the distance between the cantilever and the specimen surface is within 0.3 mm or less ?
- Is the Z stage position in the approaching-possible range ?
- Is the “SUM” value of the AFM amplifier unit as negative as possible (–5.0 V or more) ?

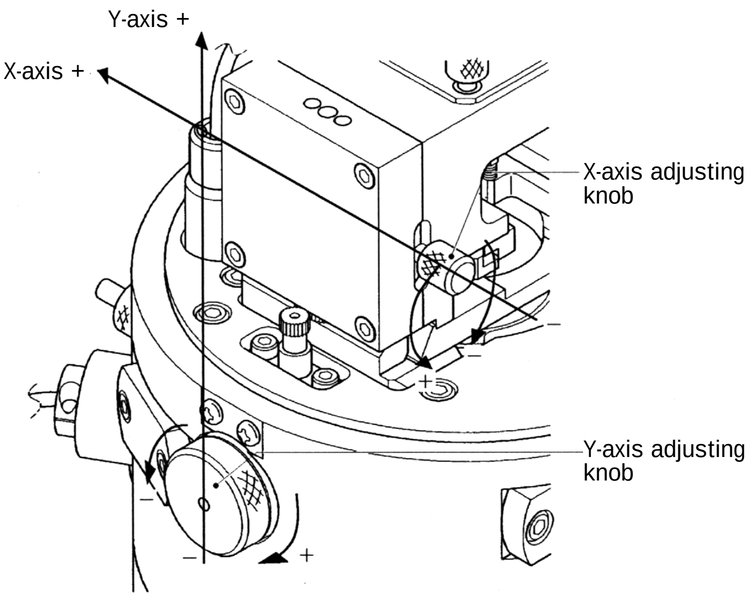
Note: After checking these points, set the indicator selection knob on the AFM amplifier unit to “RMS.”

## 6.4.2 Adjusting Photodiode Position

Click on the “Adjust PD” button on the right-hand side of the control panel. The following display will appear on “Display Window.”




Adjust the X-axis and Y-axis adjusting knobs so that the red spot goes into the blue region.



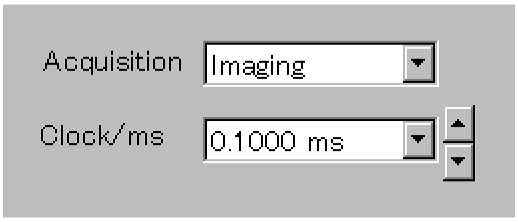
## 6.4.3 Setting Scanning Parameters

Before carrying out approaching, set the scanning parameters such as the scanning range. These parameter values vary according to the kinds of specimens and the purpose of observation, but generally, set the parameters as follows.

### ● Acquisition

◆ Click on the “ ” mark in the “Acquisition” selection box and select “Imaging.”

Then, the SPM CONTROL unit enters the image observation mode.



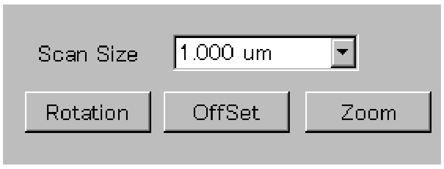

### ● Clock/ms

◆ Click on the “ ” mark in the “Clock/ms” selection box and select “0.100 ms.”

This is the parameter that determines the scan speed. Naturally, this parameter should be changed according to the observation area and the unevenness of the specimen.

### ● Scan size

◆ Click on “Scan Size”. When the numerical value is highlighted, enter 1 um using the keyboard and finalize the numerical value by pressing the TAB key. Or, click on the “ ” mark in the “Scan Size” selection box and select a numerical value near “1,000 nm.”

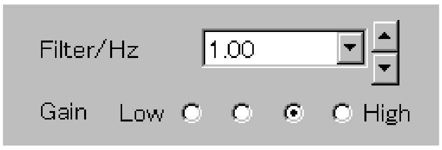



Note: Here, it is assumed that the standard scanner (scanning range is 10 μm×10 μm) is installed. In practice, set an appropriate value according to the observation area.

### ● Filter/Hz

◆ Click on the “ ” mark in the “Filter/Hz” selection box and select “1.00” from the pull-down menu.

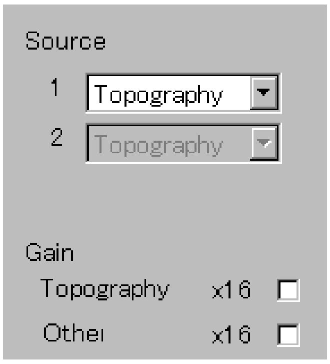
“Filter/Hz” is the parameter that determines the response speed of the feedback circuit. The larger the set value is, the faster the response speed becomes, thus producing a sharp image, but the feedback circuit easily oscillates. Usually, set the highest speed at which the feedback circuit does not oscillate while watching an image during scanning.




- **Gain**
  - ◆ Set “Gain” to the third position by clicking on the third radio button from the left; then the button changes to “⁄.”

    The setting determines the gain of the feedback circuit. If it is set to “High,” the response gain increases, thus causing an uneven specimen surface to be easily observed, but the feedback circuit easily oscillates.

- **Source**
  - ◆ Click on the “ ” mark in the “Source 1” selection box and select “Topography.”




- **Gain**
  - ◆ Click on the “×16” check box of “Topography” to remove the check mark.

    When the check mark is removed, the check box changes to “☐.”

Now you have completed the parameter setting for observing a topography image in the AC mode.

## 6.4.4 Adjusting the Cantilever Resonance Point

◆ Click on the “Auto Tune” button on the right-hand side of the control panel.

The cantilever resonance point will be adjusted, and the excitation frequency, the voltage to be applied to the cantilever and the value of Reference/V will be automatically set.

### ■ Considerations for Using “Auto Tune”

#### ● Voltage to be applied to cantilever

In this system there is a switch that changes the voltage to be applied to the cantilever to High or Low. When, in observing a specimen under vacuum after installing the optional evacuation system, you set the voltage to “High,” the cantilever might break. Generally, the voltage to be applied to the cantilever is set as follows.

| | | |
|---|---|---|
| Under atmospheric pressure | ☑VCO | High Output |
| Under vacuum | ☐VCO | High Output |

#### ● Usable cantilever resonance frequency

The range of cantilever resonance frequencies that can be adjusted using the “Auto Tune” function is 50 kHz to 500 kHz.

#### ● If “Auto Tune” fails

If the message “Auto Tune Failed” is displayed, carry out the operations described in Subsection 6.4.1 “Check Before Approaching” and in Subsection 6.4.2 “Adjusting Photodiode Position.” If the “Auto Tune Failed” message still does not disappear, adjust the resonance frequency manually, referring to Subsection 6.8.5 “Setting VCO.”

## 6.4.5 Approaching

**1.** Click on the “Approach On” button.

Automatically, approaching starts. When approaching finishes, the “Auto Approach Stopped” window is displayed in the center of the screen.

**2.** When this window is displayed, click on “OK.”


### ■ Considerations for Using “Approach”

#### ● When the “Approach On” button is displayed in gray

Click on the “Retract Off” button. Regarding the meaning of “Retract,” refer to Subsection 6.14.1 “Tip Retract.”

- **Speed of approaching**

  You can set the speed of approaching on the "Advanced" control panel. In the JSPM-4200 it is set at the time of shipment from the factory. For further details, refer to Subsection 7.1.1l "Tip."

- **Judgement of approaching conditions**

  Whether approaching has finished or not is judged by measuring the voltage applied to the Z scanner. The voltage is set to $\pm 0$ V at the time of shipment from the factory. For further details, refer to Subsection 7.1.1l "Tip."

- **Halt of approaching**

  When approaching has begun, the "Approach On" button changes to the "Approach Off" button. If you click on this button, you can stop the approaching.

## 6.4.6 Image Observation

To observe an image, click on the " " mark in the "Acquisition" selection box, select "Imaging," and click on the "Scan" button. Scanning will start and an image will be displayed on the Display Window.

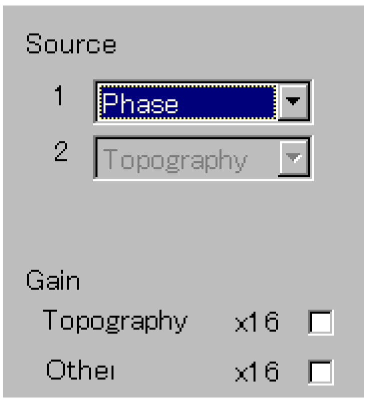
## 6.4.7 Phase Image Observation

The image observation in the AC mode that has been explained so far in this section is the constant-force mode used to observe the topography of a specimen while keeping the cantilever amplitude constant, and in this mode it is possible to observe a phase image by obtaining the change of the phase in the vicinity of the cantilever resonance point as an image. The following is the procedure for observing a phase image.

1. Carry out approaching according to the procedures in Subsections 6.4.1. through 6.4.5.

   Note: If approaching has already been completed, this operation is not necessary.

2. Click on the " " mark in the "Source 1" selection box in the control panel and select "Phase" from the pull-down menu.




3. Carry out Phase observation according to the procedure in 6.4.6 "Image Observation."

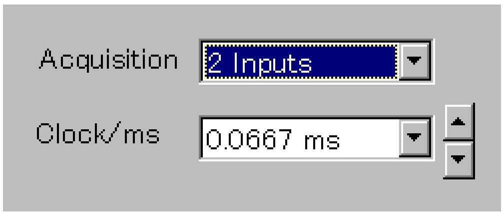
## 6.4.8 Simultaneous Observation of Topography and Phase

Simultaneous capturing of both topography and phase images is possible. Carry out the observation according to the following procedure.

**1.** Carry out approaching according to the procedures in Subsections 6.4.1 through 6.4.5.

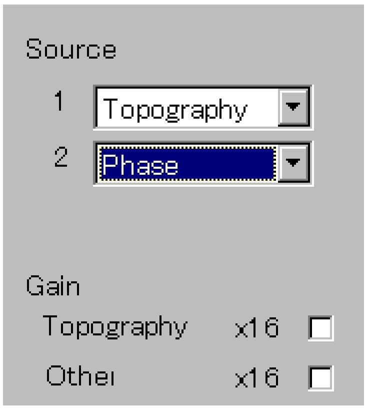
Note: If approaching has already been completed, this operation is not necessary.

**2.** Click on the “ ” mark in the “Acquisition” selection box and select “2 Inputs” from the pull-down menu.



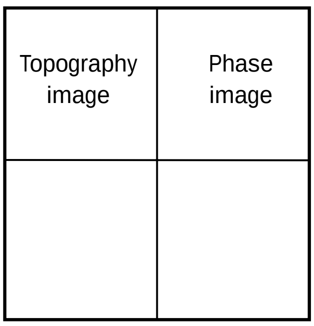

**3.** Click on the “ ” mark in the “Source 1” selection box in the control panel and select “Topography” from the pull-down menu.

**4.** Click on the “ ” mark in the “Source 2” selection box in the control panel and select “Phase” from the pull-down menu.




**5.** Click on “Scan” to scan the specimen.

Then, the following display will appear.



### 6.4.9 Capturing Image

◆ To capture an image, click on the "Grab" button during scanning.

When the scanning of one image has completed, the image is grabbed (stored) in the memory. For further details, refer to Subsection 6.14.6 "Storing Data in the Memory."

- In the AC mode, an image is displayed after an offset voltage is automatically calculated. For further details, refer to Subsection 6.14.7 "Cautions for Auto Set."
- Regarding the storage of the grabbed image in the disk memory, refer to Subsection 6.14.8 "Image Saving."

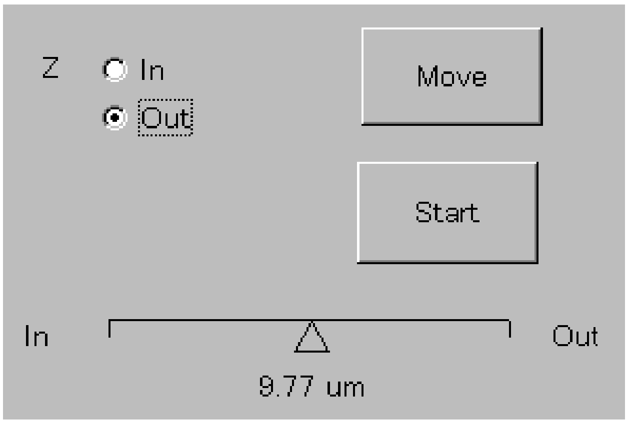
### 6.4.10 Caution for Image Observation

In the case of the AC mode AFM, an important factor for obtaining a quality image is the distance between the specimen and the cantilever tip. If this setting is inappropriate, not only can a quality image not be obtained, but also the specimen and the cantilever may be damaged. The distance between the specimen and the cantilever tip is set with "Reference/V." If the RMS value indicates –5.6 V, it means that the cantilever tip is too far from the specimen. If the RMS value indicates 0 V, it means that the cantilever tip has collided with the specimen surface. Usually, change the "Reference/V" value gradually from the value for approaching toward 0 V (closer to the specimen surface) while watching the image, and set it to the value that produces the best quality image.

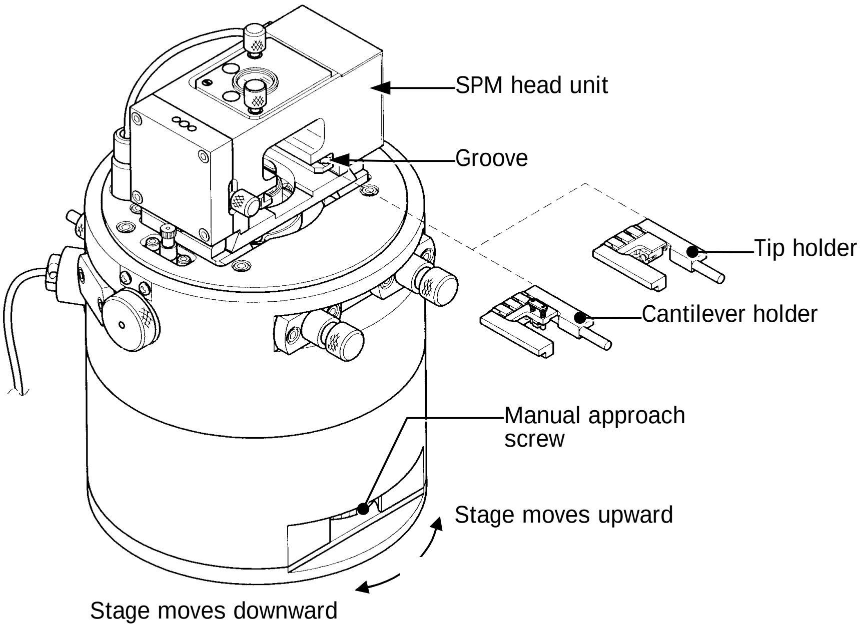
### 6.4.11 Terminating Observation

Terminate the observation according to the following procedure.

1. Stop scanning.
2. Click on the "Retract" button to retract the cantilever tip.
3. Click on "Out" for "Z" and click on the "Start" button.



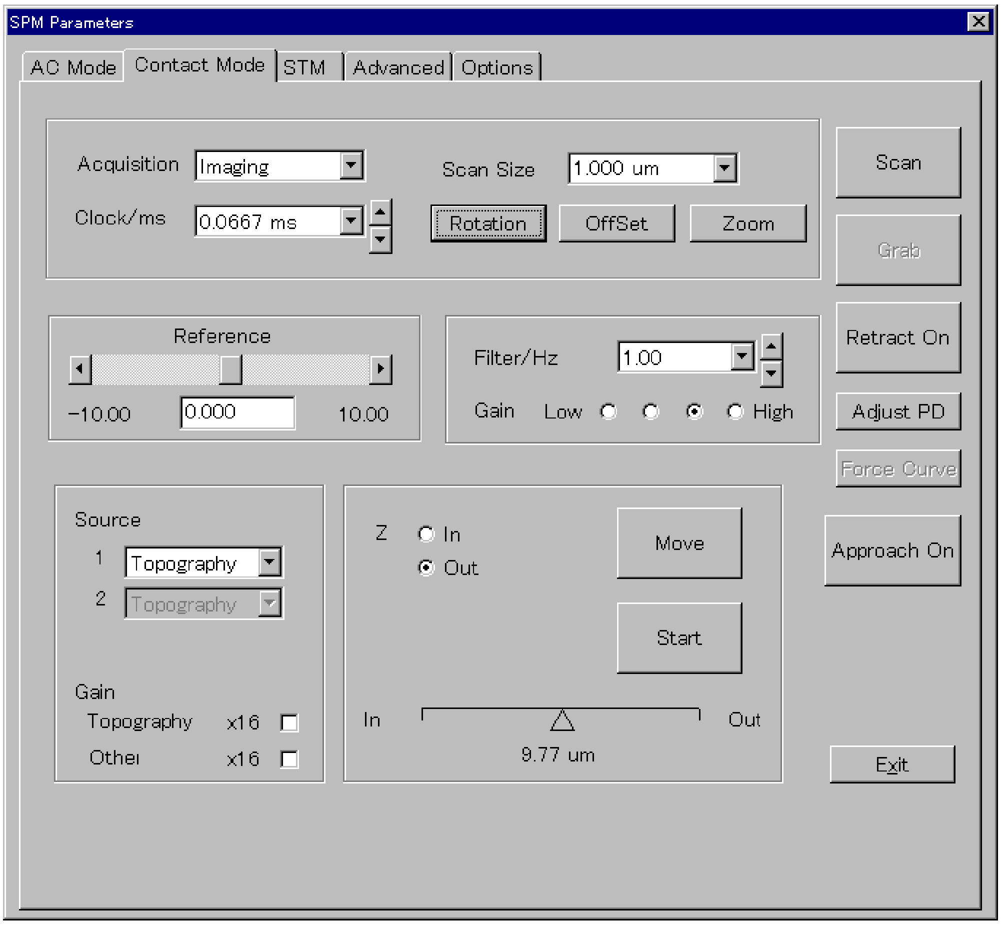

4. When the cantilever has moved 0.1 to 0.2 mm away from the specimen, click on the "Stop" button to stop the movement.
5. Turn the manual approach screw to move the specimen stage down.


SPM head unit
Groove
Tip holder
Cantilever holder
Manual approach screw
Stage moves upward
Stage moves downward

# 6.5 OBSERVATION (TINY MODE) USING CONTACT MODE CONTROL PANEL

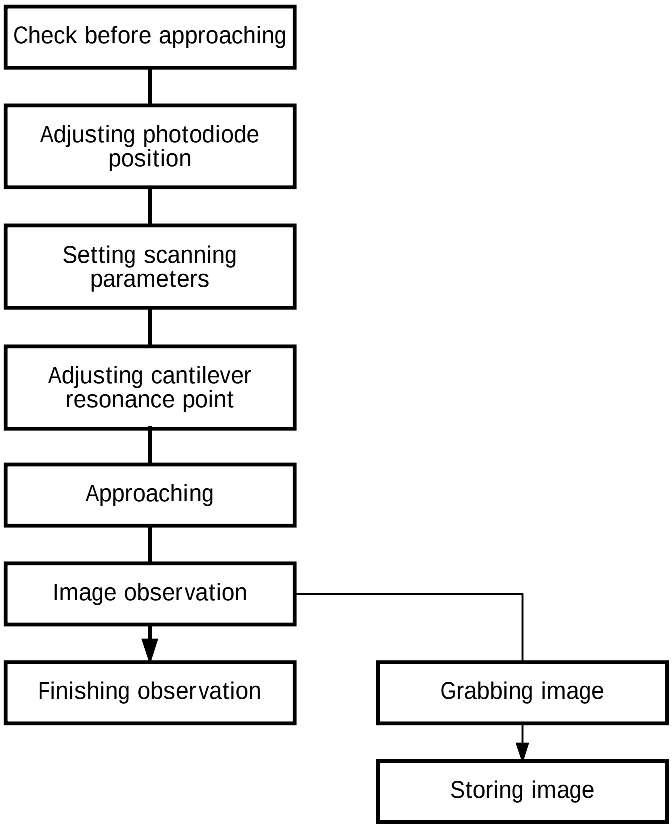
In the contact mode AFM, observation is performed in the range where a repulsive force acts between a cantilever tip and a specimen.

- Described in this Section is the procedure for AFM observation by use of the contact mode control panel.




Contact Mode control panel

- The following is the flow chart of the operation in the contact mode.




## 6.5.1 Check Before Approaching

Before performing approaching, check whether the preparation has been completed according to the procedures in Section 6.3.

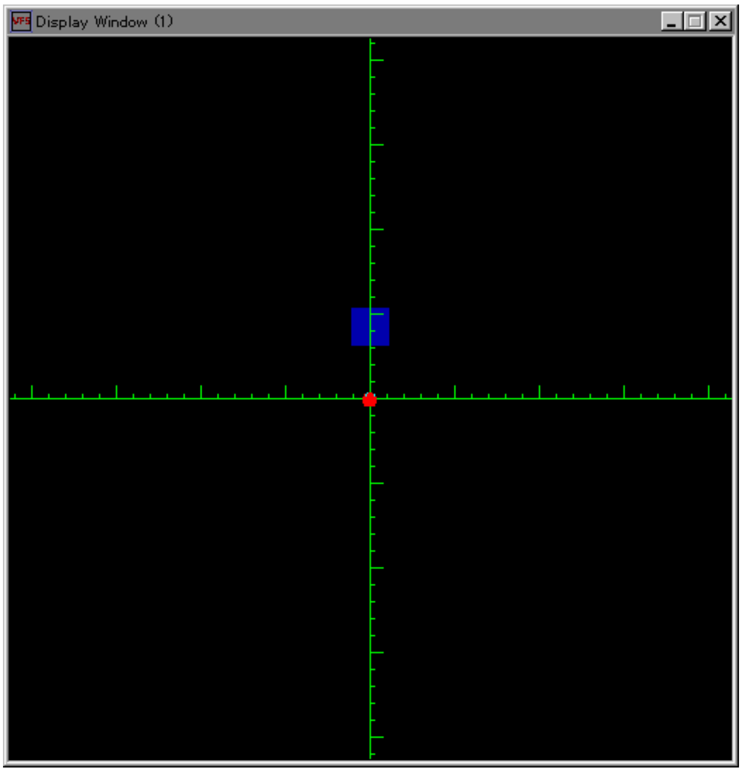
- Has rough approaching been executed in such a way that the distance between the cantilever and the specimen surface is within 0.3 mm or less ?
- Is the Z stage position in the approaching possible range ?
- Is the “SUM” value of the AFM amplifier unit as negative as possible (–5.0 V or more) ?

Note: After checking these points, set the indicator selection knob on the AFM amplifier unit to “AFM.”

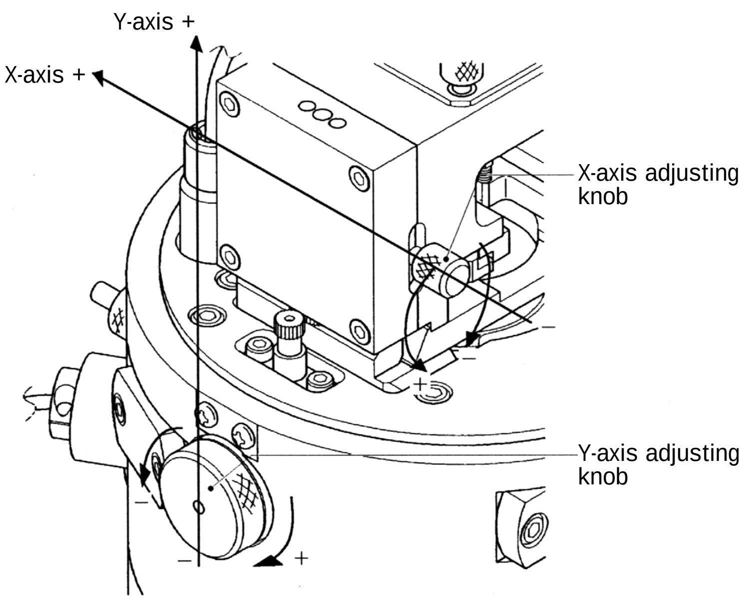
## 6.5.2 Adjusting Photodiode Position

◆ Click on the “Adjust PD” button on the right-hand side of the control panel.

The following display will appear on the Display Window.




Adjust the X-axis and Y-axis adjusting knobs so that the red spot goes into the blue region.

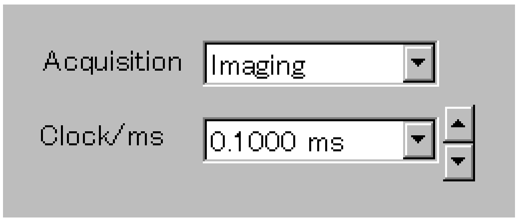


## 6.5.3 Setting Scanning Parameters

Before carrying out approaching, set the scanning parameters such as the scanning range. These parameters vary according to the kinds of specimens and the purpose of observation, but generally, set the parameters as follows.

- **Acquisition**

◆ Click on the “ ” mark in the “Acquisition” selection box and select “Imaging.”
Then, the SPM CONTROL unit enters the image observation mode.

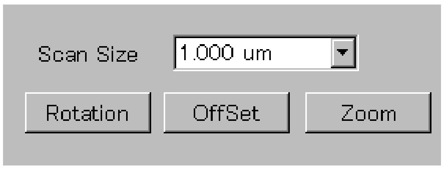



- **Clock/ms**

◆ Click on the “ ” mark in the “Clock/ms” selection box and select “0.100 ms.”
This is the parameter which determines the scan speed. Naturally, this parameter should be changed according to the observation area and the unevenness of the specimen.

- **Scan size**

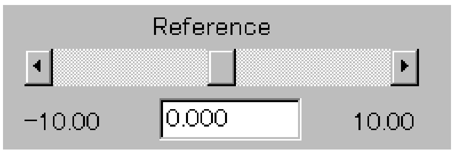
◆ Click on “Scan Size”. When the numerical value is highlighted, enter 1 um using the keyboard and determine the numerical value by pressing the TAB key. Or, click on the “ ” mark in the “Scan Size” selection box and select a numerical value near to “1,000 nm.”




Note: Here, it is assumed that the standard scanner (scanning range is 10 μm×10 μm) is installed. In practice, set an appropriate value according to the observation area.

- **Double-click on “Reference” to highlight the numerical value and enter “0” using the keyboard. Then, determine “0” by pressing the TAB key on the keyboard.**

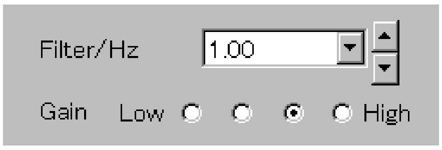
“Reference/V” is used to specify the force acting between the specimen and the cantilever tip. The value must be changed while watching the image, but now set it to “0.000” provisionally.




- **Filter/Hz**

◆ Click on “Filter/Hz” and select “1.00” from the pull-down menu.

“Filter/Hz” is the parameter that determines the response speed of the feedback circuit. The larger the set value is, the faster the response speed becomes, thus producing a sharp image, but the feedback circuit easily oscillates. Usually, set the highest speed at which the feedback circuit does not oscillate while watching an image during scanning.



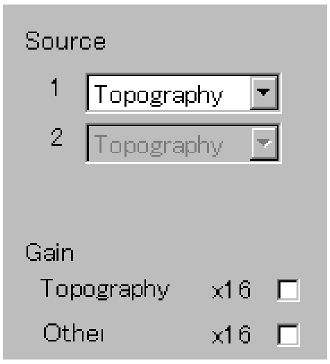

## ● Gain

◆ Set “Gain” to the third value by clicking on the third radio button from the left; then the button changes to “⁄.”

The setting determines the gain of the feedback circuit. If it is set to “High,” the response gain increases, thus causing an uneven specimen surface to be easily observed, but the feedback circuit easily oscillates.

## ● Source

◆ Click on the “ ” mark in the “Source 1” selection box and select “Topography.”




## ● Gain

◆ Click on the “×16” check box of “Topography” to remove the check mark.

When the check mark is removed, the check box changes to “□.”

Now you have completed the parameter setting for observing a topography image in the contact mode.

## 6.5.4 Approaching

**1.** Click on the “Approach On” button.

Automatically, approaching starts. When approaching finishes, the “Auto Approach Stopped” window is displayed in the center of the screen.

**2.** When this window is displayed, click on “OK.”


### ■ Considerations for Using “Approach”

#### ● When the “Approach On” button is displayed in gray

Click on the “Retract Off” button. Regarding the meaning of “Retract,” refer to Subsection 6.14.1 “Tip Retract.”

#### ● Speed of approaching

You can set the speed of approaching on the “Advanced” control panel. In the JSPM-4200 it is set at the time of shipment from the factory. For further details, refer to Subsection 7.1.1l “Tip.”

#### ● Judgement of approaching conditions

Whether approaching has finished or not is judged by measuring the voltage applied to the Z scanner. The voltage is set to $\pm 0$ V at the time of shipment from the factory. For further details, refer to Subsection 7.1.1l “Tip.”

#### ● Halt of approaching

When approaching has begun, the “Approach On” button changes to the “Approach Off” button. If you click on this display, you can stop the approaching.

## 6.5.5 Image Observation

To observe an image, click on the “ ▼ ” mark in the “Acquisition” selection box, select “Imaging,” and click on the “Scan” button. Scanning will start and an image will be displayed on the Display Window.

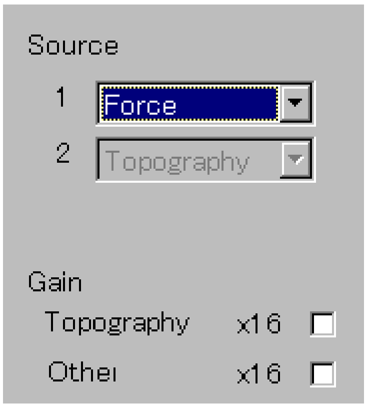
## 6.5.6 Force Image Observation

The image observation in the contact mode that has been explained so far in this Section is the constant-force mode used to observe the topography of a specimen while keeping the repulsive force constant. In this mode it is also possible to observe a force image (an atomic-force image) by obtaining the movement of the cantilever as an image while keeping the distance between the cantilever and the specimen constant. The following is the procedure for observing a force image.

**1.** Carry out approaching according to the procedures in Subsections 6.5.1 through 6.5.4.

Note: If approaching has already been completed, this operation is not necessary.

**2.** Click on the “ ” mark in the “Source 1” selection box in the control panel and select “Force” from the pull-down menu.



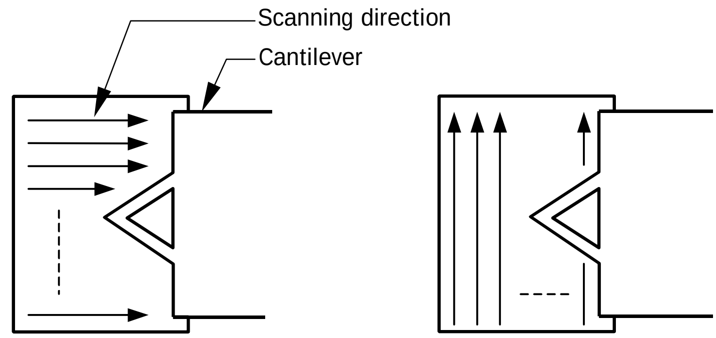

**3.** Click on the “ ” mark in the “Fback Filter/Hz” selection box and select “0.5” from the pull-down menu.

Usually, a force image is observed by applying a very slow feedback while keeping the height constant. Use a slower response for the feedback than that used for observing a topography image.

**4.** Carry out force observation according to the procedure in 6.5.5 “Image Observation.”

## 6.5.7 FFM Observation

In the ordinary contact-mode AFM, the specimen-scanning direction is parallel to the cantilever axis as shown in the left figure below. In the case of FFM (Friction Force Microscope), on the other hand, the specimen-scanning direction is orthogonal to the cantilever axis as shown in the right figure below. The cantilever is twisted during scanning due to the friction force occurring between the specimen surface and the cantilever tip. The FFM measures the friction force from this torsion of the cantilever.




**Ordinary contact mode AFM** **FFM**

The following is the procedure for FFM observation.

**1.** Perform approaching according to the procedures in Subsections 6.5.1 to 6.5.4.

Note: This operation is not necessary if approaching has been completed.

**2.** Click on the “ ” mark in the “Acquisition” selection box and select “FFM” from the pull-down menu; then click on the “Scan” button.

Scanning starts, and a topography image and an FFM image are displayed on the Display Window.


- The scanning direction automatically changes by 90° when “FFM” is selected.
- The white locations in the FFM image indicate the areas where the friction force is large.

## 6.5.8 Force Curve Measurement

The force acting between the specimen surface and the cantilever tip is measured from the bending of the cantilever while the distance between the specimen surface and the cantilever tip is being varied in the contact mode. This measurement is called “Force Curve” measurement. The following is the procedure for Force Curve measurement.

**1.** Perform approaching according to the procedures in Subsections 6.5.1 to 6.5.4.

Note: This operation is not necessary if approaching has been completed.

**2.** Click on the “ ” mark in the “Acquisition” selection box and select “Force Curve” from the pull-down menu.

**3.** Click on “Force Curve.”

The “F-C Parameters” window will be displayed.

**4.** Double-click on “Tip Displacement/nm” on the “F-C Parameters” window and enter the maximum value of the scanner Z scanning range using the keyboard.

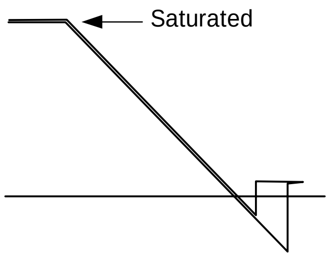
When the standard scanner (10 μm × 10 μm × 3 μm) is installed, enter about 1,500 nm (the total scanning range in the Z direction is 3,000 nm, because the value input is the limit of the scan in both the positive and the negative directions). In practice, however, even if a value exceeding the scanner Z scanning range is entered, the software automatically calculates and indicates the maximum possible value.

**5.** Click on “Scan” on the “SPM Parameters” window.

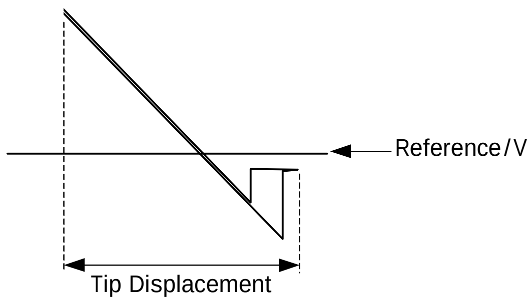
The Force Curve will be displayed on the Display Window.

- To grab the measured Force Curve, click on the “Grab” button during the measurement.
- To change the display style of the Force Curve, change it on the “Plot Parameters” menu of “Display” after grabbing the Force Curve.

- If the Force Curve goes out of the linear region and becomes saturated in the repulsive force domain, as shown below, it means that the measurement has been attempted outside the measurable range. In such a case, change the “Tip Displacement/nm” value to a smaller value; then repeat the measurement.

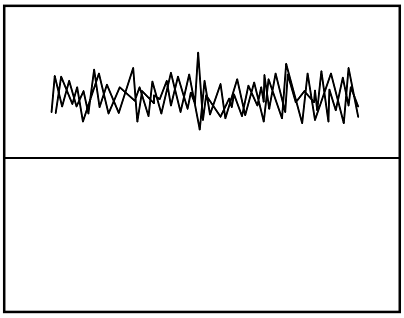



- The relationship between “Tip Displacement/nm” and “Reference/V” is shown in the figure below.




Therefore, when the “Reference/V” value is set to 0 V, feedback is carried out at the point where the Force Curve crosses the 0 V line.

- If the Force Curve is not obtained correctly, it usually means that approaching has not been properly performed. If curves such as the one shown below are obtained, check whether approaching has been properly performed according to Subsection 6.5.4 “Approaching.”



If the data obtained is something like the above, that means that the cantilever tip has not approached the specimen surface yet.

### 6.5.9 Caution for Image Observation

In the Contact mode, the setting of the repulsive force acting between the specimen surface and the cantilever tip plays an important role in obtaining a quality image. If this setting is inappropriate, not only can a quality image not be obtained, but also the specimen and the cantilever may be damaged. The repulsive force between the specimen surface and the cantilever tip is set with “Reference/V.” The more negative “Reference/V” is set, the smaller does the repulsive force become. The more positive “Reference/V” is set, the larger does the repulsive force become. If approaching is performed while the “Reference/V” value is set to –2 V, changing “Reference/V” to the repulsive force side in excess of –2 V might sometimes makes the cantilever tip separate from the specimen surface, thus resulting in forming no image.

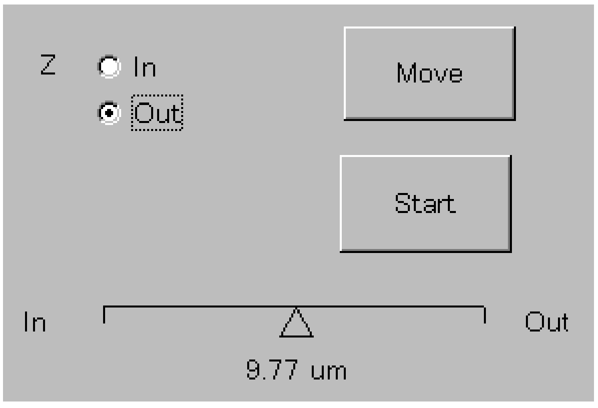
In the Contact mode, generally, scanning is performed in a small repulsive force domain to avoid damaging the specimen. Then, set “Reference/V” to the position where the cantilever tip and the specimen surface become closest to each other. However, in the case of a specimen having large unevenness or a specimen having a low contrast due to materials attached to the specimen surface, scanning in a little larger repulsive force domain (on the plus (+) side of “Reference/V”) would produce a good result.

Change the “Reference/V” value gradually from the value for approaching toward 0 V (closer to the specimen surface) while watching the image and set it to the value that produces the best quality image.

### 6.5.10 Completing Observation

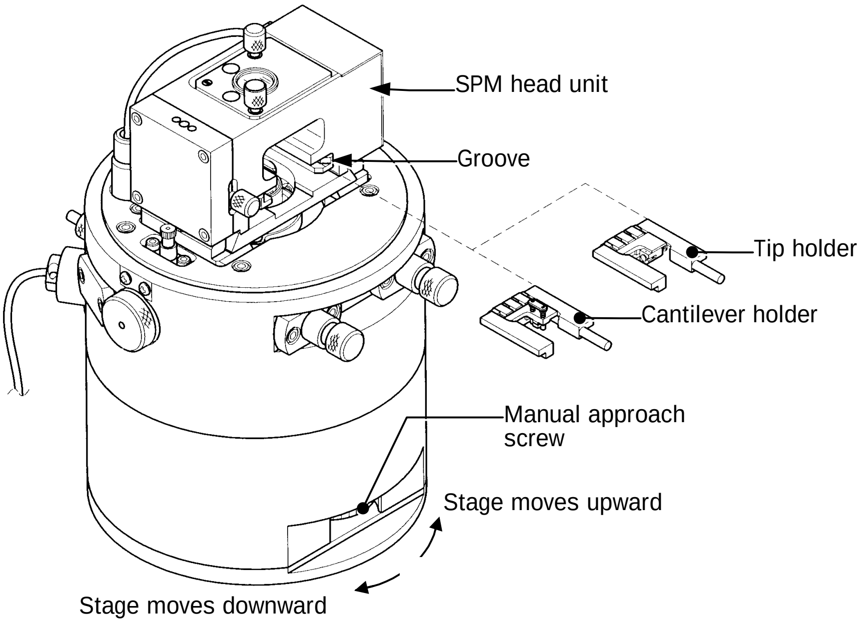
Complete the observation according to the following procedure.

1. Stop scanning.
2. Click on the “Retract” button to retract the cantilever tip.
3. Click on “Out” for “Z” and press the “Start” button.



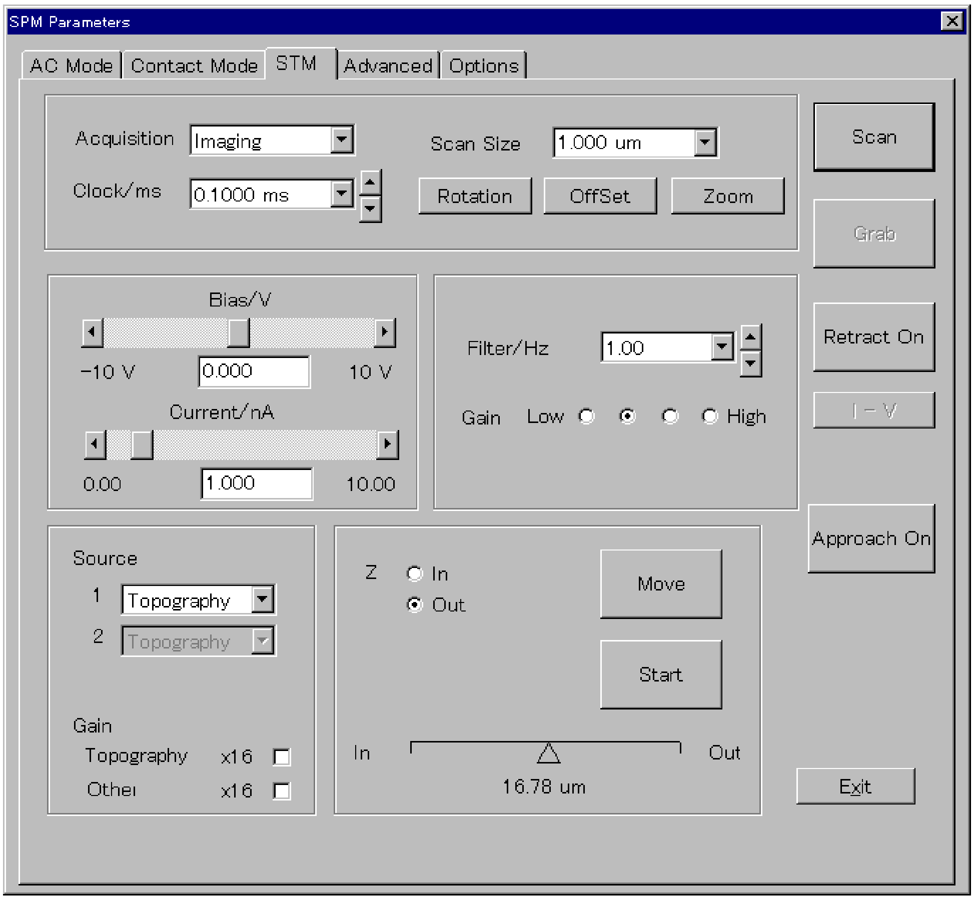

4. When the cantilever has moved 0.1 to 0.2 mm away from the specimen, click on the “Stop” button to stop the movement.

**5.** Turn the manual approach thumbscrew to move the specimen stage down.



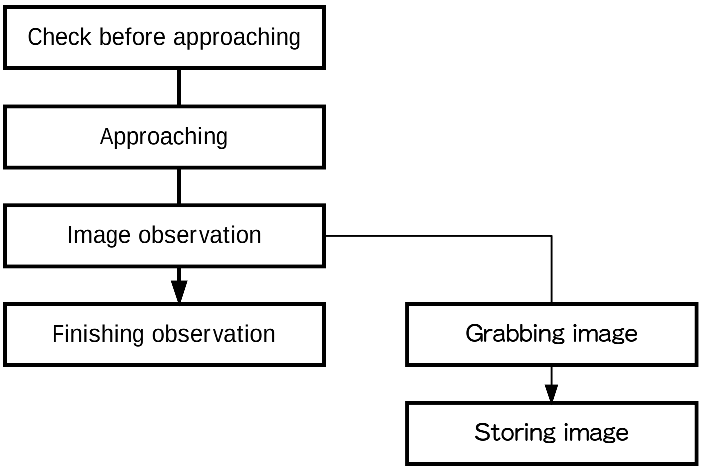
# 6.6 OBSERVATION (TINY MODE) USING STM MODE CONTROL PANEL

The SPM head unit with a tip holder is used for STM (Scanning Tunneling Microscope) observation. Described in this Section is the procedure for observing an STM image using the STM mode control panel.




**STM mode control panel**

The following is the flow chart of the operation in the contact mode.



## 6.6.1 Check Before Approaching

Before performing approaching, check whether the preparation has been completed according to the procedures in Section 6.3.

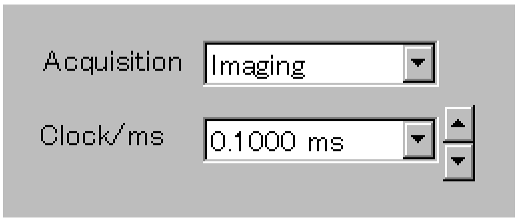
- Has rough approaching been executed in such a way that the distance between the cantilever and the specimen surface is within 0.3 mm or less ?
- Is the Z stage position in the approaching possible range ?

## 6.6.2 Setting Scanning Parameters

Before carrying out approaching, set the scanning parameters such as the scanning range. These parameters vary according to the kinds of specimens and the purpose of observation, but generally, set the parameters as follows.

- **Acquisition**

◆ Click on the “ ” mark in the “Acquisition” selection box and select “Imaging.”
Then, the system enters the image observation mode.

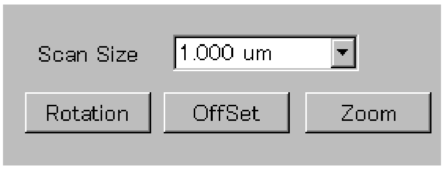



- **Clock/ms**

◆ Click on the “ ” mark in the “Clock/ms” selection box and select “0.100 ms.”
This is the parameter that determines the scan speed. Naturally, this parameter should be changed according to the observation area and the unevenness of the specimen.

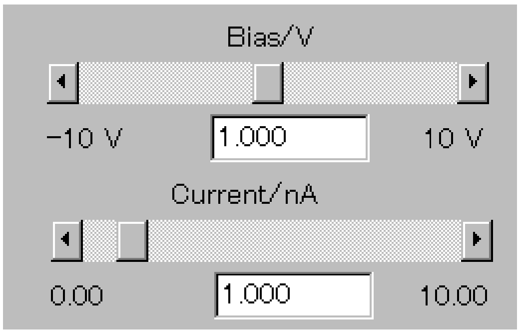
- **Scan size**

◆ Click on the “ ” mark in the “Scan Size” selection box. When the numerical value is highlighted, enter 1 um using the keyboard and fix the numerical value by pressing the “TAB” key. Or, click on the “ ” mark in the “Scan Size” selection box and select a numerical value near 1,000 nm from the pull-down menu.




Note: Here, it is assumed that the standard scanner (scanning range is 10 μm×10 μm) is installed. In practice, set an appropriate value according to the observation area.

- **Click on “Sample/V”. When the numerical value is highlighted, enter 1 using the keyboard and finalize the numerical value by pressing the “TAB” key**




“Sample” has to be changed according to the kind of specimen to be observed. If the specimen is a high-conductivity specimen such as a metal, set it to a small numerical value (0.2 V or less). If the sample is a semiconductor or a sample having an oxide film, set it to a large numerical value (1.0 V or more).

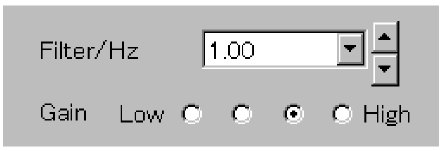
- **Double-click on “Current/nA.” When the numerical value is highlighted, enter 1 using the keyboard. Then, finalize the numerical value by pressing the “TAB” key on the keyboard.**

“Current/nA” is used to specify the tunneling current flowing between the specimen surface and the cantilever tip. The value must be changed while watching the image, but now set it to “1.000” provisionally.

- **Filter/Hz**

◆ Click on the “ ” mark in the “Filter/Hz” selection box and select “1.00” from the pull-down menu.

“Filter/Hz” is the parameter that determines the response speed of the feedback circuit. The larger the set value is, the faster the response speed becomes, thus producing a sharp image, but the feedback circuit easily oscillates. Usually, set the highest speed at which the feedback circuit does not oscillates while watching the image during scanning.



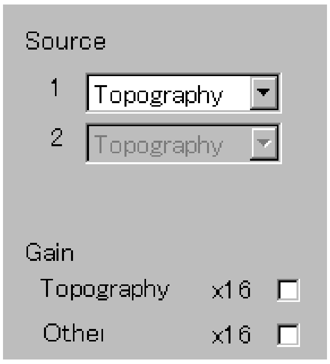

- **Gain**

◆ Set “Gain” to the third value by clicking on the third radio button from the left; then the button changes to “⁄.”

The setting determines the gain of the feedback circuit. If it is set to “High,” the response gain increases, thus causing an uneven specimen surface to be easily observed, but the feedback circuit easily oscillates.

● **Source**

◆ Click on the " ▼ " mark in the "Source 1" selection box and select "Topography."




● **Gain**

◆ Click on the "×16" check box of "Topography" to remove the check mark.

When the check mark is removed, the check box changes to "☐."

Now you have completed the parameter setting for observing a topography image in the STM mode.

## 6.6.3 Approaching

**1.** Click on the "Approach On" button.

Automatically, approaching starts. When approaching finishes, the "Auto Approach Stopped" window is displayed in the center of the screen.

**2.** When this window is displayed, click on "OK."


### ■ Considerations for Using "Approach"

● **When the "Approach On" button is displayed in gray**

◆ Click on the "Retract Off" button. Regarding the meaning of "Retract," refer to Sub-section 6.14.1 "Tip Retract."

● **Speed of approaching**

◆ Set the speed of approaching on the "Advanced" control panel. In the JSPM-4200 it is set at the time of shipment from the factory.

For further details, refer to Subsection 7.1.11 "Tip."

- **Judgement of approaching conditions**

  Whether approaching has finished or not is judged by measuring the voltage applied to the Z scanner. The voltage is set to ±0 V at the time of shipment from the factory. For further details, refer to Subsection 7.1.1l “Tip.”

- **Halt of approaching**

  When approaching has begun, the “Approach On” button changes to the “Approach Off” button. If you click on this button, you can stop the approaching.

## 6.6.4 Image Observation

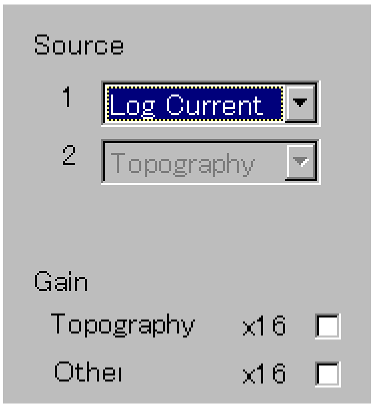
To observe an image, click on the “ ” mark in the “Acquisition” selection box, select “Imaging” and click on the “Scan” button. Scanning will start and an image will be displayed on the Display Window.

## 6.6.5 Current Image Observation

The operation procedures for image observation in the STM mode that have been explained so far in this Section are for the constant current STM mode used to observe the topography of a specimen while keeping the tunneling current constant. In this mode it is also possible to observe a current image by obtaining the change of the current as an image while keeping the tip height constant. The following is the procedure for observing a current image.

1. Carry out approaching according to the procedures in Subsections 6.5.1 through 6.5.4.

   Note: If approaching has already been completed, this operation is not necessary.
2. Click on the “ ” mark in the “Source 1” selection box in the control panel and select “Log Current” from the pull-down menu.




3. Click on the “ ” mark in the “Fback Filter/Hz” selection box and select “0.5” from the pull-down menu.

   Usually, a current image is observed by applying a very slow feedback while keeping the height constant. Use a slower response for the feedback than that used for observing a topography image.
4. Carry out current observation according to the procedure in Subsection 6.6.4 “Image Observation.”

### 6.6.6 I-V Measurement

The following is the procedure for measuring the I-V characteristic of the specimen surface.

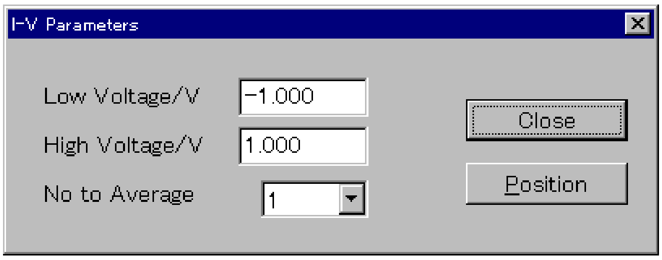
1. Carry out approaching according to the procedures in Subsections 6.6.1 through 6.6.3.

   Note: If approaching has already been completed, this operation is not necessary.

2. Observe a current image according to Subsection 6.6.5 “Current Image Observation” and grab it.

3. Click on the “Acquisition” selection box and select “I-V” from the pull-down menu. Click on the “I-V” button.

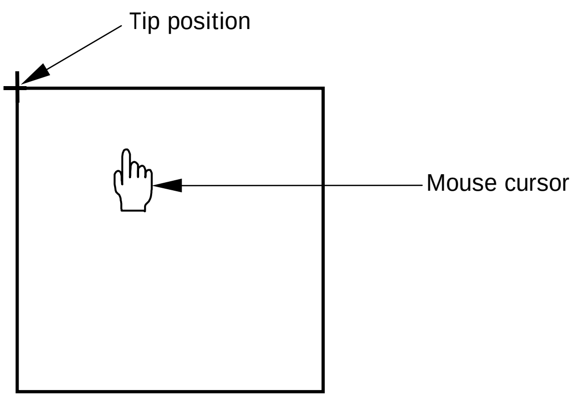
   The “I-V Parameters” window is displayed.



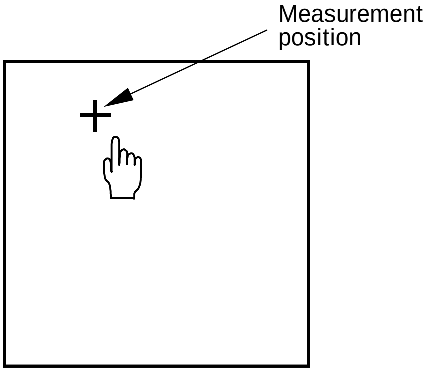

4. Click on the “Retract” button.

5. Click on the “Position” button.

   The “I-V Parameters” window will be closed and the “Tip position” window will be displayed. Move the mouse cursor to the current image in the “Display Window”; then the cursor will change to a hand mark. The present position of the cantilever is displayed with a + mark. Usually, the initial position of the cantilever is the top left corner as shown below.




6. Move the cursor to the position of the tip; press the left mouse button and drag it (while holding down the mouse button) to the point where an I-V measurement is to be performed.




Be careful not to drag the cantilever very fast because the cantilever is actually moving in real time.

**7.** After placing the “+” mark at the measurement point, press the right mouse-button.

The “I-V Parameters” window will be displayed.

**8.** Deselect “Tip Retract” by clicking on the “Tip Retract” check box; the box will change to “☐.”

**9.** Set the I-V measurement parameters according to the following procedures.

**a.** Set the voltage to measure I-V.

- Double-click on the input box for “Low Voltage/V” and enter a voltage using the keyboard. Here, we will explain how to set the I-V measurement range to the range from –1.0 V to +1.0 V. Enter –1 using the keyboard.
- Double-click on the input box for “High Voltage/V” and enter a voltage using the keyboard. Here, enter 1.

Note: In this system, the offset current is capacitance-corrected in such a way that when the input voltage is 0 V, the current is 0 nA. Therefore, the Low and High Voltages must be entered so that they encompass 0 V.

**b.** Click on the “ ” mark in the “No to Average” selection box and select “1” from the pull-down menu.

This specifies the number of I-V measurements for data averaging. Increasing the number of measurement is effective particularly when data is noisy or when a very small current must be measured.

**10.** Click on “Repeat.”

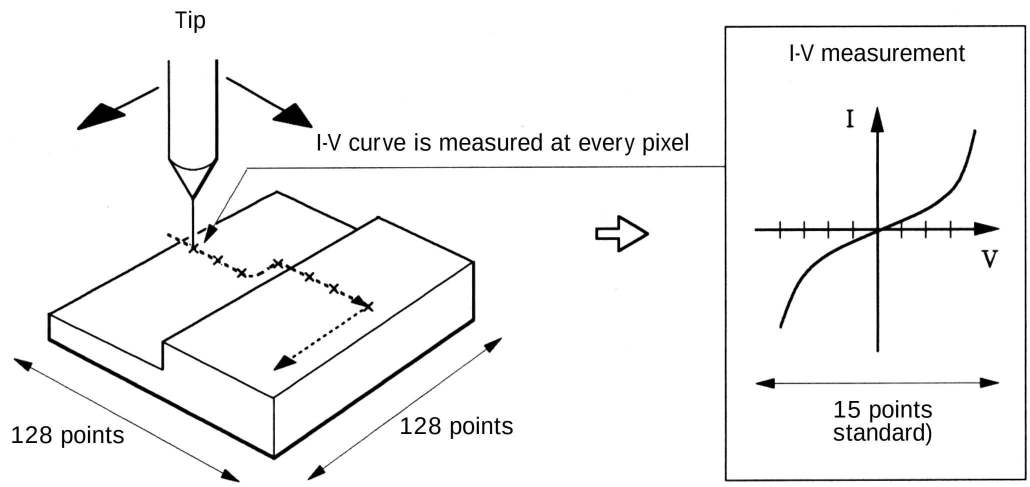
The I-V measurement will start.

When you want to change the I-V display method, change it on the “Plot parameters” after grabbing the data.

Note: If the measurement position is changed with this method, the changed position becomes the initial position. Therefore, when scanning has been finished or “Abort” has been performed, the tip is at the initial position.

## 6.6.7 CITS Image Observation

A CITS (Current Imaging Tunneling Spectroscopy) image is a tunneling-current image produced when applying an optionally designated bias voltage while keeping the distance between the tip and the specimen surface (determined by the topographic-image observation conditions such as tunneling current and bias voltage) constant. I-V curves and data averaging at designated points on the specimen can also be obtained from the image captured in the CITS menu. In the case of CITS, unlike STS, I-V data is measured and an image is created at each pixel during tip-scanning, so there is no influence of specimen drift or hysteresis so that the I-V curve at an arbitrary point of the image perfectly corresponds to the image points.



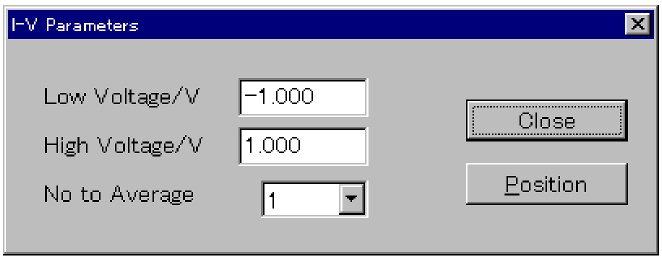

One method of determining the bias voltage is as follows.
Select a point where the image contrast varies greatly on an STM image and measure an I-V curve at that point once; then select the bias voltage of the position where the I-V curve varies greatly.
CITS measurement parameters such as “Low voltage” and “High voltage” are the same as those set in the I-V Parameters.
The following is the procedure for observing a CITS image.

1. Perform approaching according to the procedures in Subsections 6.6.1 through 6.6.3.

   Note: If approaching has already been completed, this operation is not necessary.

2. Click on the “ ” mark in the “Acquisition” selection box and select “CITS” from the pull-down menu. Then, click on the “I-V” button.

   The “I-V Parameters” window will be displayed.



**3.** Set the parameters for I-V measurement according to the following procedures.
Set the voltages at which to measure I-V as follows.

- Double-click on the input box for “Low Voltage/V” and enter a voltage using the keyboard. Here, we will explain how to set the I-V measurement range from −1.0 V to +1.0 V. Enter −1 using the keyboard.
- Double-click on the input box for “High Voltage/V” and enter a voltage using the keyboard. Here, enter 1.

  Note: In this system, the offset current is capacitance-corrected in such a way that when the input voltage is 0 V, the current is 0 nA. Therefore, the Low and High Voltages must be entered so that they encompass 0 V.

**4.** Click on “Repeat.”
Scanning is performed and the following will be displayed.

| | | | |
|---|---|---|---|
| Topo image | Current image | " | " |
| Current image | " | " | " |
| " | " | " | " |
| " | " | " | " |

## 6.6.8 Caution for Image Observation

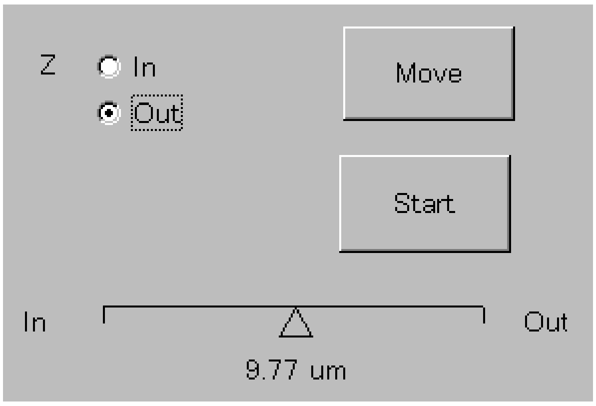
In the case of the STM mode, an important factor for obtaining a quality image is the setting of Bias Voltage and Current . If this setting is inappropriate, not only can a quality image not be obtained, but also the specimen and the tip may be damaged.

The distance between the specimen surface and the tip is controlled by adjusting Bias/V and Current/nA. If Sample Bias is set to a small value and Current/nA to a large value, the distance between the specimen surface and the tip becomes short. Theoretically, the resolving power improves, but the tip could easily collide with the specimen.

## 6.6.9 Finishing Observation

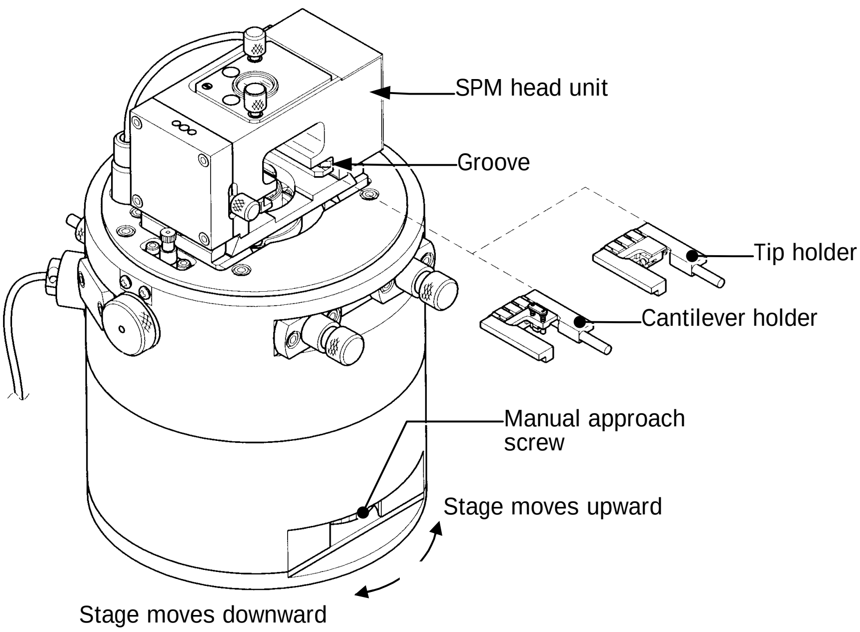
The following is the procedure for finishing the observation.

**1.** Stop the scanning.
**2.** Click on the “Retract” button to retract the cantilever tip.
**3.** Click on “Out” for “Z” and click on the “Start” button.




**4.** When the cantilever has moved 0.1 to 0.2 mm away from the specimen, press the “Stop” button to stop the movement.

**5.** Turn the manual approach screw to move the specimen stage down.



# 6.7 OPTION MODE CONTROL PANEL

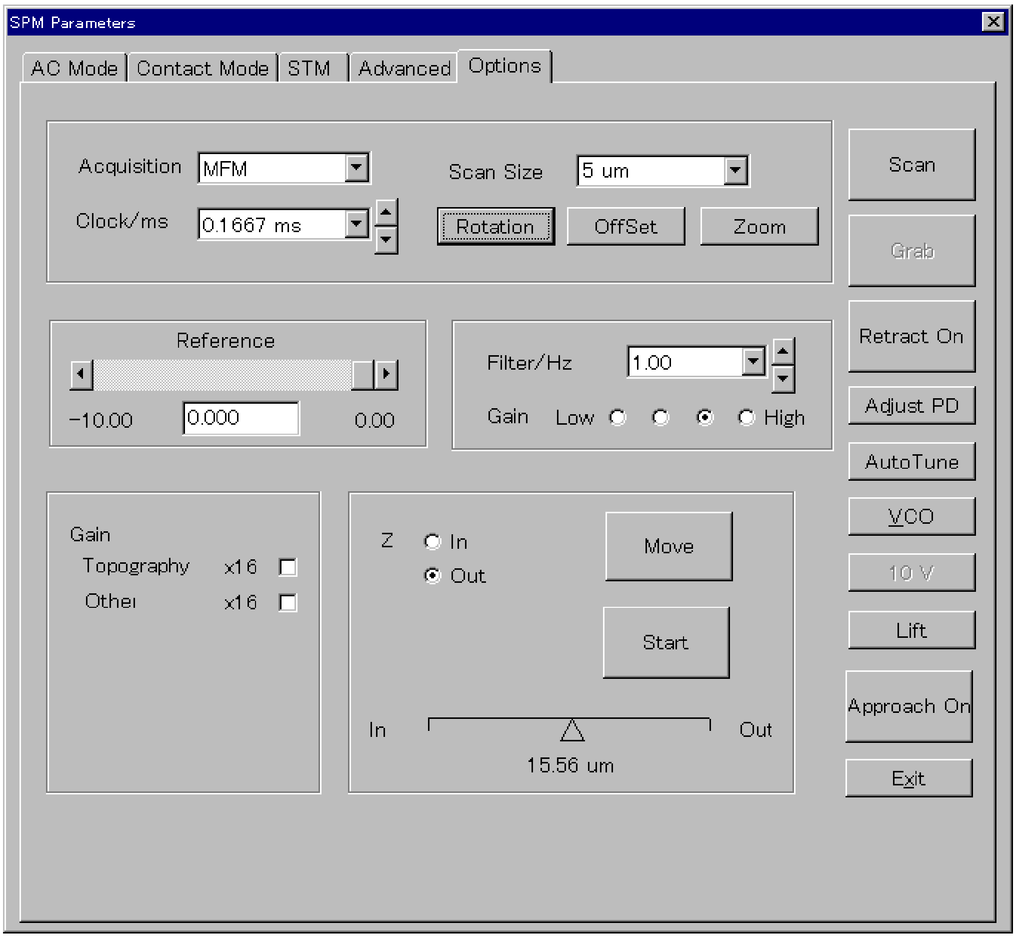
The JSPM-4200, if provided with optional attachments, is capable of performing

Viscoelasticity measurement
Lateral-modulation FFM measurement
Kelvin Force Microscope measurement
MFM (Magnetic Force Microscope) measurement

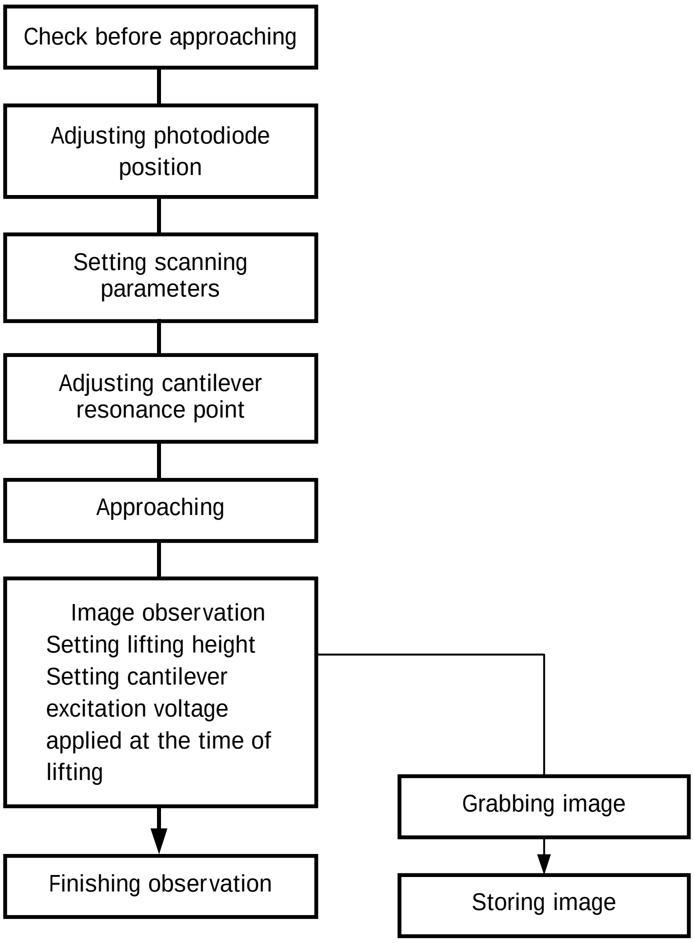
Regarding the installation and handling of the optional attachments for viscoelasiticity measurement, lateral-modulation FFM measurement and Kelvin force microscope measurement, refer to the instruction manual of each optional attachment. MFM measurement can be carried out using the cantilever for MFM measurement.

## 6.7.1 MFM Observation

MFM observation is usually performed using the AC mode. To separate a topographic image from an MFM image, the cantilever is moved away (lifted) from the specimen at the position where a topographic image is acquired and the phase difference of the cantilever is displayed as an MFM image. The following is the procedure for observing an MFM image.




**Option Mode control panel**




## 6.7.2 Check Before Approaching

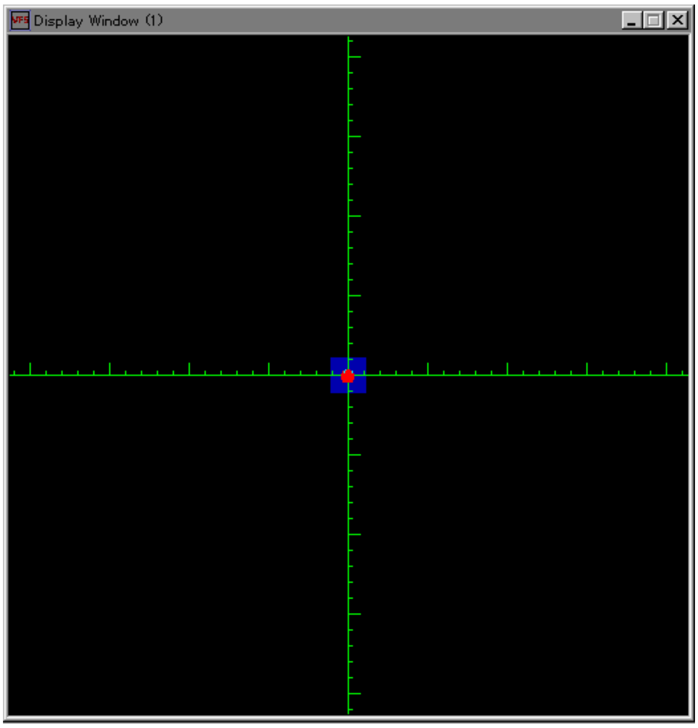
Before carrying out approaching, check whether the preparation has been completed according to the procedures in Section 6.3 “Preparation for Approaching.”

- Has the cantilever for the AC mode been mounted in the cantilever holder ?
- Has coarse approaching been done so that the distance between the specimen surface and the cantilever is 0.3 mm or less ?
- Is the Z stage position in the approaching-possible range ?
- Is the “SUM” value for the AFM AMP unit as negative as possible (–5.0 V or more) ?

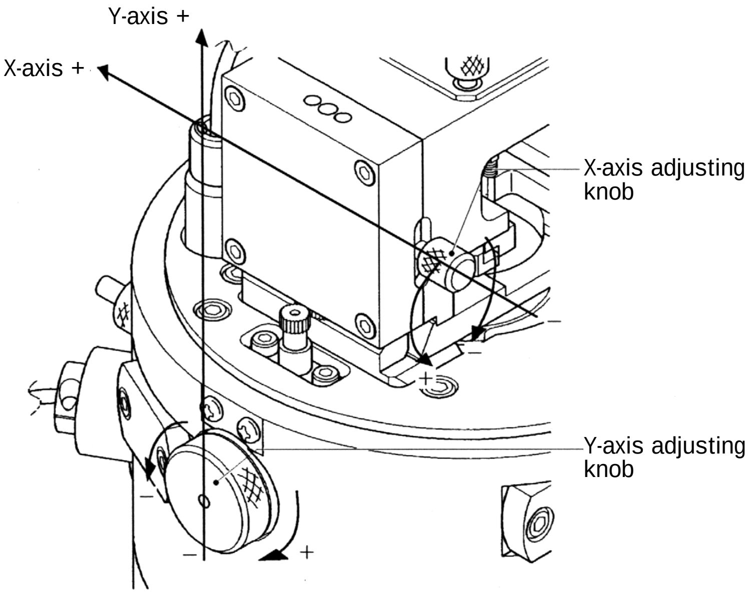
Note: After checking these points, set the indicator selection knob to “RMS.”

## 6.7.3 Adjusting Photodiode Position

◆ Click on the “Adjust PD” button on the right-hand side of the control panel. The following display will appear on “Display Window.”




Turn the X- and Y-axis adjusting knobs so that the red spot goes into the blue area in the center.



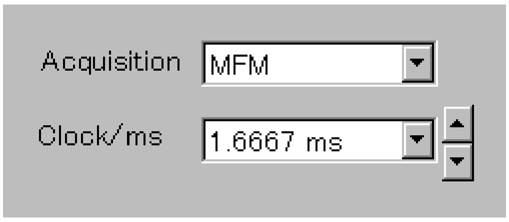
## 6.7.4 Setting Scanning Parameters

Before carrying out approaching, set the scanning parameters such as scanning range. These parameters vary according to the kinds of specimens and the purpose of observation, but generally, set the parameters as follows.

### ● Acquisition

◆ Click on the “ ” mark in the “Acquisition” selection box and select “MFM.”

Then, the SPM CONTROL unit enters the MFM image-observation mode.



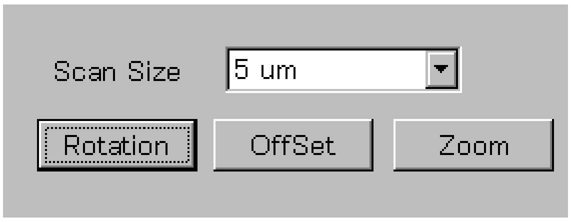

### ● Clock/ms

◆ Click on the “ ” mark in the “Clock/ms” selection box and select “1.6667 ms.”

This is the parameter that determines the scan speed. Naturally, this parameter should be changed according to the observation area and the unevenness of the specimen.

### ● Scan size

◆ Click on “Scan Size”. When the numerical value is highlighted, enter 5 um using the keyboard and finalize the numerical value by pressing the “TAB” key. Or, click on the “ ” mark in the “Scan Size” selection box and select a numerical value near “5,000 nm.”

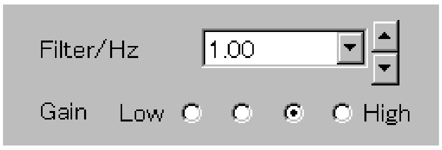



Note: Here, it is assumed that the standard scanner (scanning range is 10 μm×10 μm) is installed. In practice, set an appropriate value according to the observation area.

### ● Filter/Hz

◆ Click on the “ ” mark in the “Filter/Hz” selection box and select “1.00” from the pull-down menu.

“Filter/Hz” is the parameter that determines the response speed of the feedback circuit. The larger the set value is, the faster the response speed becomes, thus producing a sharp image, but the feedback circuit easily oscillates. Usually, set the highest speed at which the feedback circuit does not oscillate while watching an image during scanning.




- **Gain**

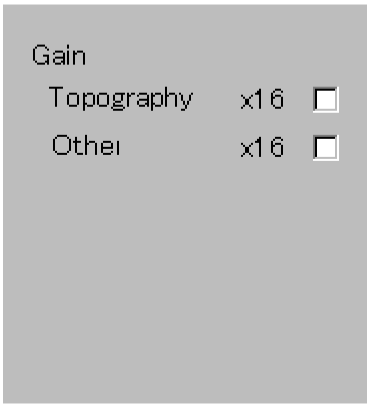
  ◆ Set “Gain” to the third value by clicking on the third radio button from the left; then the “○” mark changes to “⁄.”

  The setting determines the gain of the feedback circuit. If it is set to “High,” the response gain increases, thus causing an uneven specimen surface to be easily observed, but the feedback circuit easily oscillates.

- **Gain**

  ◆ Click on the “×16” check box of “Topography” to remove the checkbox.

  When the check box is removed, the check box changes to “□.”




Now you have completed the parameter setting for observing a topography image in the AC mode.

## 6.7.5 Adjusting the Cantilever Resonance Point

◆ Click on the “Auto Tune” button on the right-hand side of the control panel.

The cantilever resonance point will be adjusted, and the excitation frequency and voltage to be applied to the cantilever and the value of Reference will be automatically set.

### ■ Caution for Using “Auto Tune”

- **Voltage to be applied to cantilever**

  In this system there is a switch that changes over the voltage to be applied to the cantilever to High or Low. When, in observing a specimen under vacuum by installing the optional evacuation system, you set the voltage to “High,” the cantilever might break. Generally, the voltage to be applied to the cantilever is set as follows.

| | | |
|---|---|---|
| Under atmospheric pressure | ☑VCO | High Output |
| Under vacuum | ☐VCO | High Output |

- **Usable cantilever resonance frequency**

  The range of cantilever resonance frequencies that can be adjusted using the "Auto Tune" function is 50 kHz to 500 kHz.

- **If "Auto Tune" fails**

  If the message "Auto Tune Failed" is displayed, carry out the operations described in Subsection 6.4.1 "Check Before Approaching" and in Subsection 6.4.2 "Adjusting Photodiode Position." If the "Auto Tune Failed" message still does not disappear, adjust the resonance frequency manually, referring to Subsection 6.8.5 "Setting VCO."

## 6.7.6 Approaching

**1.** Click on the "Approach On" button.

Automatically, approaching starts. When approaching finishes, the "Auto Approach Stopped" window is displayed in the center of the screen.

**2.** When this window is displayed, click on "OK."


### ■ Considerations for Using "Approach"

- **When the "Approach On" button is displayed in gray**

  ◆ Click on the "Retract Off" button. Regarding the meaning of "Retract," refer to Sub-section 6.14.1 "Tip Retract."

- **Speed of approaching**

  ◆ Set the speed of approaching on the "Advanced" control panel. In the JSPM-4200 it is set at the time of shipment from the factory. For further details, refer to Sub-section 7.1.1l "Tip."

- **Judgement of approaching conditions**

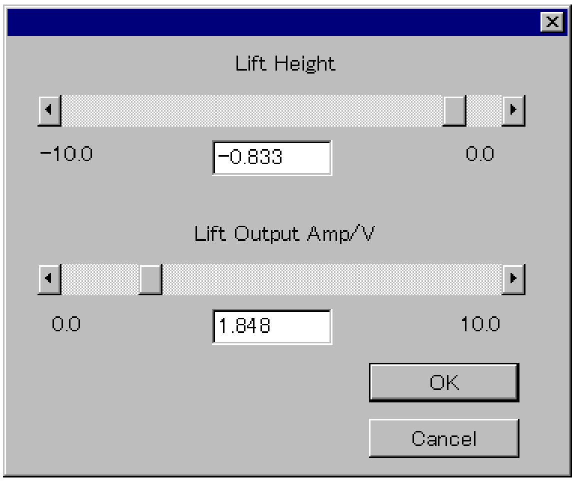
  Whether approaching has finished or not is judged by measuring the voltage applied to the Z scanner. The voltage is set to $\pm$0 V at the time of shipment from the factory. For further details, refer to Sub-section 7.1.1l "Tip."

- **Halt of approaching**

  When approaching has begun, the "Approach On" button changes to the "Approach Off" button. If you click on this button, you can stop the approaching.

## 6.7.7 Image Observation and Setting Lift Height

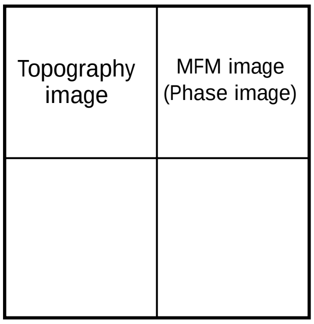
**1.** Click on the “Lift” button and the “Lift” window will be displayed.




**2.** Double-click on “Lift Height” and enter 100 nm using the keyboard. Press the “TAB” key to finalize the value.

**3.** Click on “Scan” to scan the specimen.

Then, the following display will appear.




**4.** Decrease the “Lift Output Amp/V” value gradually so that an MFM image can be better seen.

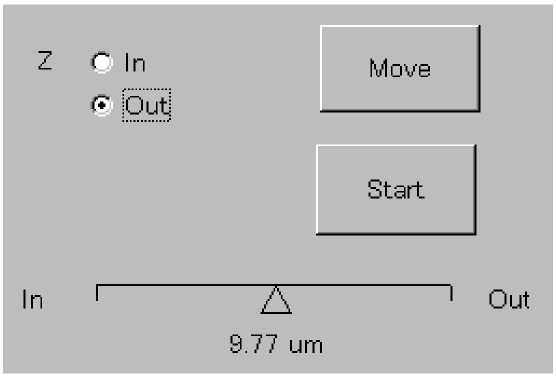
## 6.7.8 Caution for Image Observation

In the MFM mode, it is necessary that a high-quality topographic image in the AC mode can be observed. At first, observe an image in the AC mode only; it is necessary to find parameter values with which a high-quality image can be observed in the AC mode. Next, determine the “Lift Height” and perform scanning, and gradually decrease the “Lift Output Amp/V” value and find the point where a high-quality image can be obtained. It is suggested that the cantilever for MFM image observation should be magnetized in advance using a permanent magnet so as to obtain a good result.

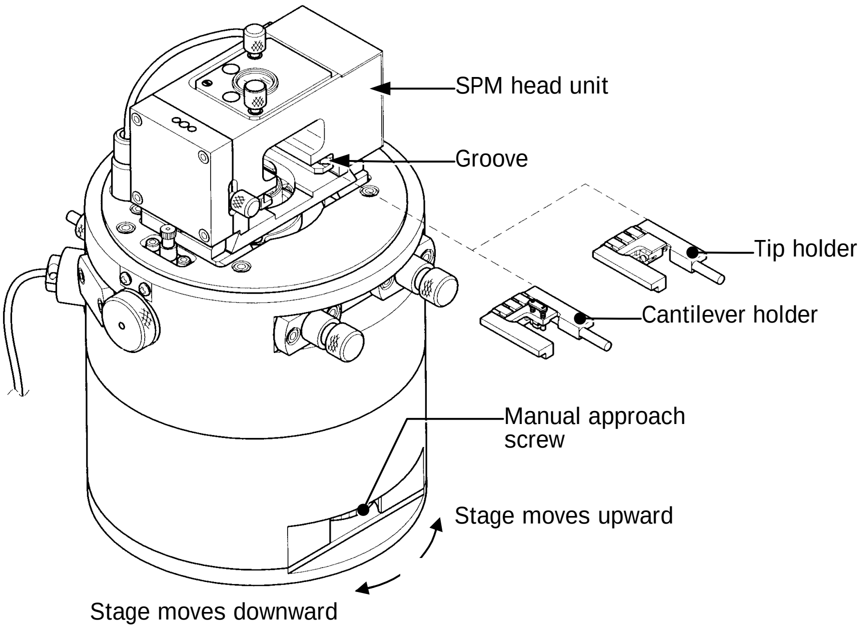
## 6.7.9 Completing Observation

Complete the observation according to the following procedure.

1. Stop scanning.
2. Click on the “Retract” button to retract the cantilever tip.
3. Click on “Out” for “Z” and click on the “Start” button.




4. When the cantilever has moved 0.1 to 0.2 mm away from the specimen, click on the “Stop” button to stop the movement.
5. Turn the manual approach thumbscrew to move the specimen stage down.



# 6.8 OBSERVATION IN AC MODE (ADVANCED)

In the AC mode AFM, a cantilever is vibrated in the vicinity of its characteristic frequency, and the Z scanner is controlled so that the amplitude and phase of the cantilever remain constant during scanning. Using the AC mode, AFM observation in the attractive force range and attraction-repulsion critical range becomes possible. In this section the procedure for AFM observation using the "Advanced" control panel is described. It is possible to set parameters in detail on the "Advanced" control panel but every parameter must be set.

## 6.8.1 Check Before Approaching

Before performing approaching, check whether the preparation has been completed according to the procedure in Section 6.3.

- Is a cantilever for AC mode AFM properly mounted on the cantilever holder ?
- Has rough approaching been executed in such a way that the distance between the cantilever and the specimen surface is 0.3 mm or less ?
- Is the Z stage position in the approaching-possible range ?
- Is the "AFM" value of the AFM amplifier unit about 0 V ?
- Is the "FFM" value of the AFM amplifier unit about 0 V ?

Note: After checking these points, set the indicator selection knob on the AFM amplifier unit to "RMS."

## 6.8.2 Setting Oscilloscope (option)

After setting the optional oscilloscope according to Subsection 6.3.4, set CH2 as follows.

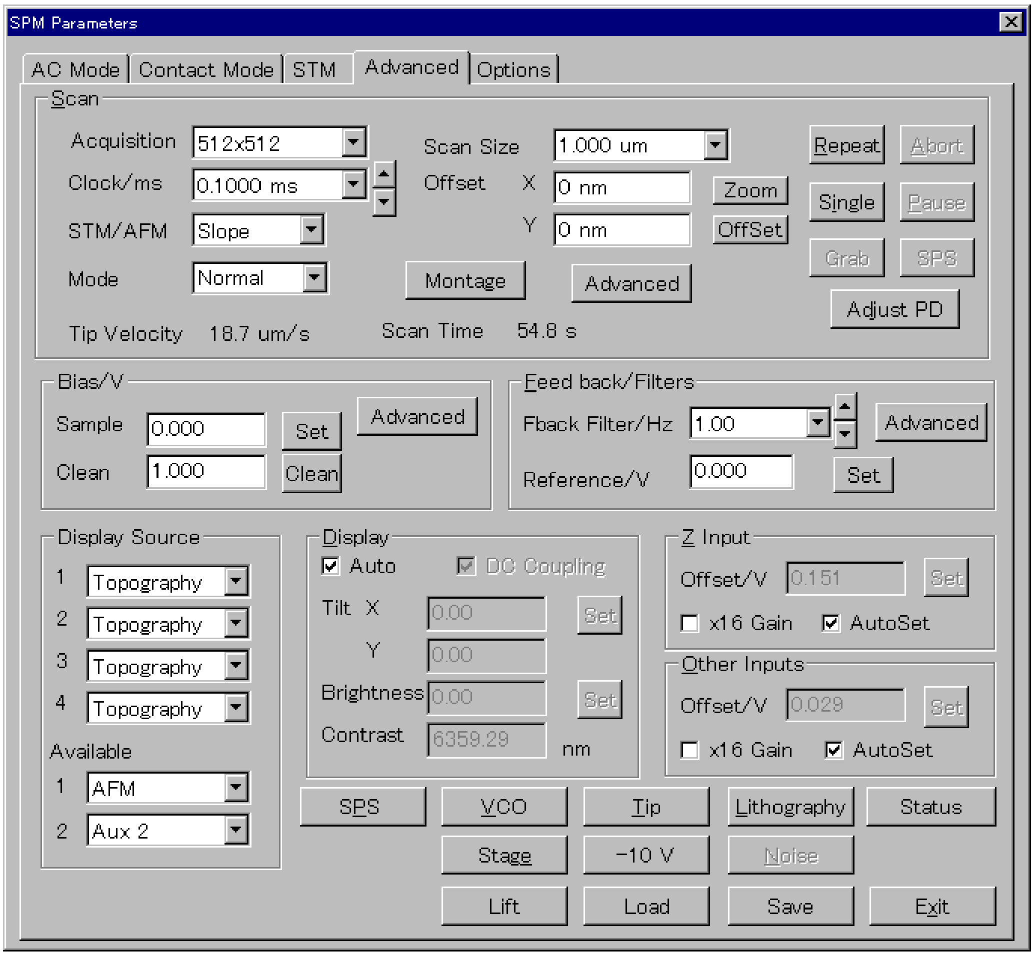
◆ Set the SELECT knob on the SPM CONTROL unit to AUX1.

The A–B signal is monitored. When the cantilever is vibrated in the AC mode, the state of the vibration can be monitored.

## 6.8.3 Setting Control Panel

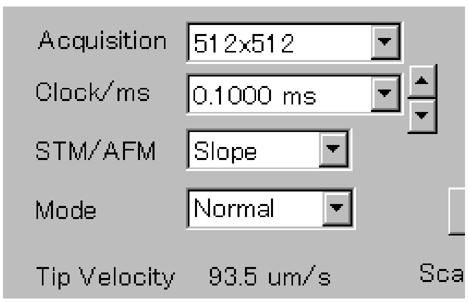
**1.** Click on "SPM Scan" on the main menu and select "Scan···" from the pull-down menu.

The "SPM Parameters" window will be displayed. Click on the "Advanced" tab.




**2.** Set each parameter according to the following procedures.

**a.** Click on the " " mark in the "Acquisition" selection box and select "512×512" from the pull-down menu.

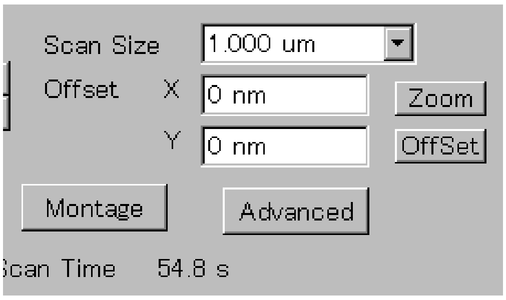


**b.** Click on the “▼” mark in the “Clock/ms” selection box and select “0.1000 ms” from the pull-down menu.
This is the parameter that determines the scan speed. Naturally, this parameter should be changed according to the observation area and the unevenness of the specimen. Here, set it to “0.1000 ms” provisionally.

**c.** Click on the “▼” mark in the “STM/AFM” selection box and select “Slope” from the pull-down menu.
This changes the SPM CONTROL unit to the AC mode.

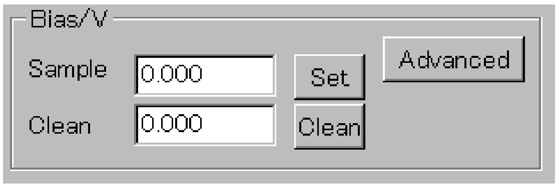
**d.** Click on the “▼” mark in the “Mode” selection box and select “Normal” from the pull-down menu.

**e.** Click on “Scan Size”. When the numerical value is highlighted, enter 1 um using the keyboard and finalize the numerical value by pressing the “TAB” key. Or, click on the “▼” mark in the “Scan Size” selection box and select a numerical value near 1,000 nm.

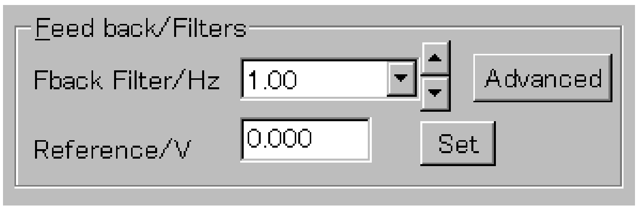



Note: Here, it is assumed that the standard scanner (scanning range is 10 μm×10 μm) is installed. In practice, set an appropriate value according to the observation area you want to observe.

**f.** Click on “Bias/V.” When the numerical value is highlighted, enter 0 using the keyboard and finalize the numerical value by pressing the “TAB” key.

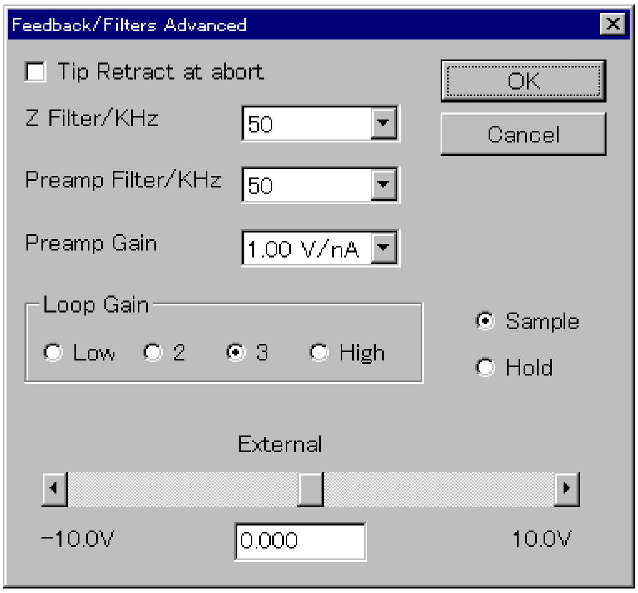



**g.** Click on the “▼” mark in the “Fback Filter/Hz” selection box and select “1.00” from the pull-down menu.



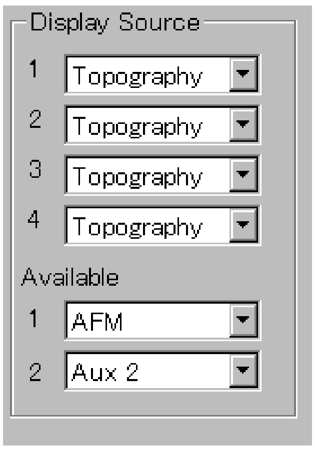
"Filter/Hz" is the parameter that determines the response speed of the feedback circuit. The larger the set value is, the faster the response speed becomes, thus producing a sharp image, but the feedback circuit easily oscillates. Usually, set the highest speed at which the feedback circuit does not oscillate while watching an image during scanning.

**h.** Click on the "Advanced" button in the "Feedback/Filters" frame.
The "Feedback/Filters Advanced" window is displayed.




Select "3" of "Loop Gain." To select "3," click on the radio button to the left of "3." When this mark is selected, the button changes to ⁄. The setting determines the gain of the feedback circuit. If it is set to "High," the response gain increases, thus causing an uneven specimen surface to be easily observed, but the feedback circuit easily oscillates.

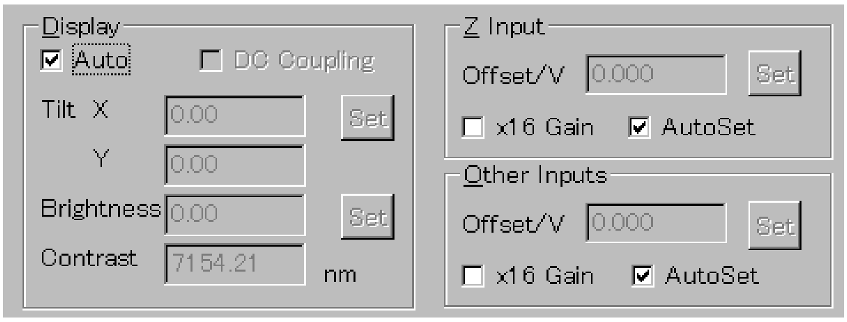
**i.** Click on the " ▼ " mark in the "Available Source 1" selection box and select "AFM" from the pull-down menu.



**j.** Click on the “ ▼ ” mark in the “Available Source 2” selection box and select “Aux2” from the pull-down menu.
These two parameters are for selecting the signal input to the A/D board. Here, set the parameters as shown above.

**k.** Click on the “ ▼ ” mark in the “Display Source 1” selection box and select “Topography” from the pull-down menu.

**l.** Click on “Auto” in the “Display” frame to change “☐ Auto” to “⌡ Auto.”




**m.** Click on “×16 Gain” in the “Z Input” frame to remove the setting.
When the setting is removed, the ⌡ mark changes to ☐.

**n.** Click on “AutoSet” in the “Z Input” frame to change “☐ AutoSet” to “⌡ AutoSet.”
The check boxes, ☐ and ⌡, are toggle boxes. Each time the mouse is clicked on these boxes, the settings are changed. When the ⌡ mark is displayed, the parameter item to which this mark is attached is selected.

The setting of various parameter items required for image observation in the AC mode (Advanced) has so far been explained. It is summarized as shown below. If any of the settings differs from the default setting, the normal functions may be disturbed. Check the parameter referring to the parameter setting below.

| | | | |
|---|---|---|---|
| Acquisition: 512×512 | | Scan Size: lum | |
| Clock/ms: 0.1000ms | | Offset X: 0nm | |
| | | Y: 0nm | |
| STM/AFM: Slope | | | |
| Sample: 0.000 | | Fback Filter/Hz: 1.00 | |
| Clean: 0.000 | | | |
| Display Source | Display | Z Input | |
| 1: Topography 2: Topography | ☑ Auto | ☐x16 Gain | ☑ Auto Set |
| 3: Topography 4: Topography | | Other Inputs | |
| Available Source 1: AFM | | ☐x16 Gain | ☑ Auto Set |
| 2: Aux2 | | | |

| Scan Advanced | |
|---|---|
| Image Angle: 0.0 | |
| ☐Add External X Signal | Scan Filter |
| ☐Add 〃 Y 〃 | ⦿4 High frequency |
| ☐ 〃 〃 Z 〃 | |
| ☐ 〃 〃 Bias 〃 | |

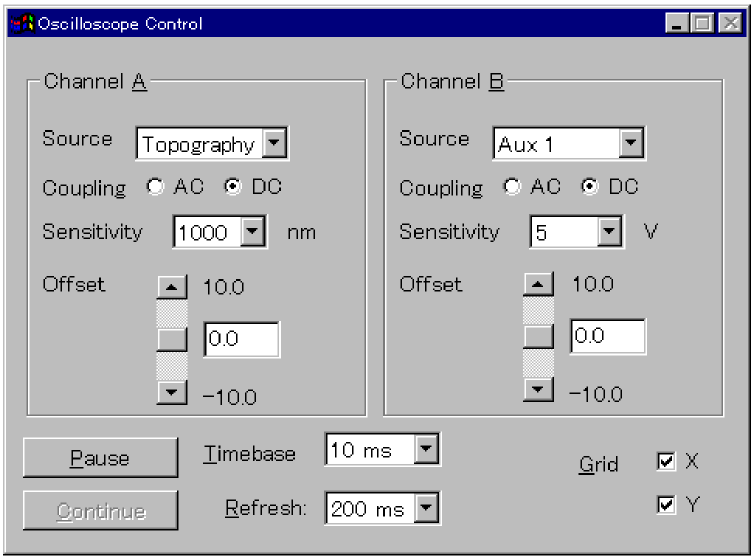
| Bias Advanced | |
|---|---|
| Back Scan: | 0.000 |
| Offset: | 0.000 |

| Feedback/Filters Advanced | | |
|---|---|---|
| ☐ Tip Retract at abort | | ⦿Sample |
| Z Filter/kHz: | 50 | ○Hold |
| Loop Gain: | ⦿3 | |
| External Offset: | 0.000 | |

## 6.8.4 Setting Software Oscilloscope

Set the software oscilloscope according to Subsection 6.3.3; then set CH2 as follows.

1. Click on the "🗗" mark in the "Oscilloscope···" button. The "Oscilloscope Control" window will open.



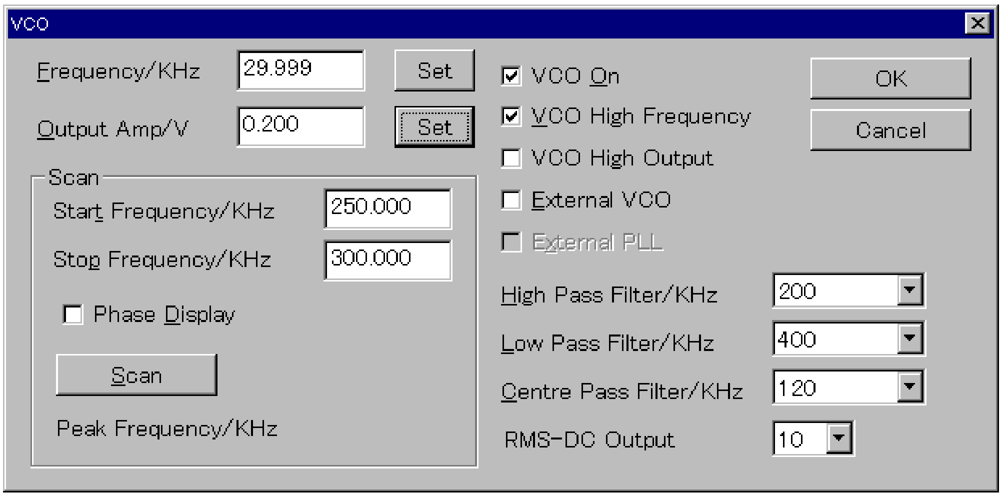
2. Click on the “ ” mark in the “Source” selection box in the “Channel B” frame; then select “Aux1” from the pull-down menu.
3. Click on the “ ” mark in the “Sensitivity” selection box in the “Channel B” frame; then select “5” from the pull-down menu.

## 6.8.5 Setting VCO (Voltage-Controlled Oscillator)

Set the frequency and excitation voltage at which to vibrate the cantilever. When the JSPM-4200 is used in the atmospheric-pressure environment, select “VCO High Output” (✓). If a specimen is observed under vacuum (after installing the optional evacuation system), the Q value of the cantilever becomes high; the cantilever amplitude becomes large even with a small excitation voltage. Therefore, if a large excitation voltage is carelessly applied to the cantilever, the cantilever might break. At first, use “☐ VCO High Output” as it is without clicking on the check box.

Described here in this Section is the parameter-setting procedure for a Si cantilever (resonance frequency: about 300 kHz) for the AC mode, which is used in the atmospheric-pressure environment. First of all, carry out a frequency sweep and locate the resonance point of the cantilever. Continue the operation according to the following procedure.

1. Click on the “VCO” button on the “SPM Parameters” window.
   The “VCO” window will open.




2. Click on the check box for “VCO High Frequency” in the “VCO” window. The box will change to “✓.”
   The excitation frequency has two frequency bands as shown below.

| | | |
|---|---|---|
| VCO High Frequency | ☐ | 3 kHz to 50 kHz |
| 〃 | ☑ | 30 kHz to 500 kHz |

3. Double-click on “Start Frequency/kHz” in the “Scan” frame and enter 250 using the keyboard.
4. Double-click on “Stop Frequency/kHz” in the “Scan” frame and enter 350 using the keyboard.
   This sets the frequency sweep range to 250 to 350 kHz.

**5.** Click on the " " mark in the "High Pass Filter/kHz" selection box and select "200" from the pull-down menu.

**6.** Click on the " " mark in the "Low Pass Filter/kHz" selection box and select "400" from the pull-down menu.

"Low Pass Filter" and "High Pass Filter" are used to cut off other frequency components which come into the A–B signal.

High Pass Filter/kHz<Start Frequency/kHz<Stop Frequency/kHz<Low Pass Filter/kHz
(200 kHz) (250 kHz) (350 kHz) (400 kHz)

**7.** Click on the " " mark in the "Gain" selection box and select "10" from the pull-down menu.

**8.** Double-click on "Output Amp/V" and enter 0.2 using the keyboard.

**9.** Double-click on "Frequency/kHz" and enter 250 using the keyboard.

The reason "250" is entered is that, if this "Frequency/kHz" is in the vicinity of the resonance point when frequency sweep is begun, some amplitude might still remain at the resonance point even though the frequency is set to "Start Frequency/kHz," so the resonance point might not be measured correctly. Set "Frequency/kHz" to the same value as "Start Frequency/kHz."

Parameter setting for VCO is summarized as follows.

| | |
|---|---|
| Frequency/kHz: 250<br>Output Amp/V: 0.2 | VCO On<br>VCO High Frequency |
| Start Frequency/kHz: 250<br>Stop Frequency/kHz: 350 | High Pass Filter/kHz: 200<br>Low Pass Filter/kHz: 400<br>Gain: 10 |

"Center Pass Filter/kHz" is not used for the Slope detection method.

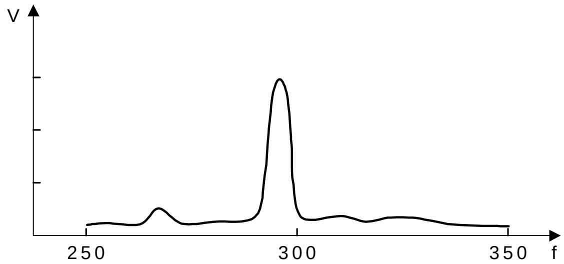
**10.** Click on the check box for "VCO On"

The box will change to "√." Then, the cantilever starts vibrating.

**11.** Click on the "Scan" button in the "Scan" frame.

Frequency sweep is actually performed, and the frequency sweep data is displayed in the Display Window. As the "Enter image title" window will appear, click on the "OK" button if you want to save the data. However, usually, click on the "Cancel" button.

The frequency sweep data roughly looks like the figure shown below.



The value of the peak frequency is indicated in “Peak Frequency/kHz” in the “Scan” frame in the “VCO” window. If no correct data is obtained, check the following points.

- “STM/AFM” in the “Scan” frame on the “SPM Parameters” window is set to “Slope.”
- The “1” and “2” selection boxes for “Available Source” in the “Display Source” frame are set to ”AFM” and “Aux2” respectively.
- “High Pass Filter/kHz” and “Low Pass Filter/kHz” in the “VCO” window are set correctly.
- “VCO On” is checked (√).
- The “SUM” value for the AFM AMP unit is set to about 5 V, and “AFM” and “FFM” are both set to about 0 V.
- When the AUX1 (A–B) waveform is observed while increasing the CH2 gain of the optional oscilloscope, the waveform is a sine waveform.

After obtaining a frequency-sweep result, repeat the frequency sweep in a narrower frequency range according to the following procedure.

**12.** Perform frequency sweep in the frequency range of ±10 kHz of the obtained “Peak Frequency/kHz.”

For example, if the obtained “Peak Frequency/kHz” is 290 kHz, perform frequency sweep again by setting “Start frequency” and “Stop frequency” to 280 kHz and 300 kHz respectively.

**13.** After performing this frequency sweep, set the excitation frequency of the cantilever according to the following procedure.

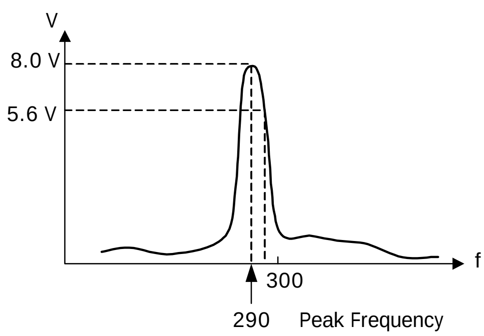
**a.** Set the indicator selection knob on the AFM AMP unit to “RMS.”

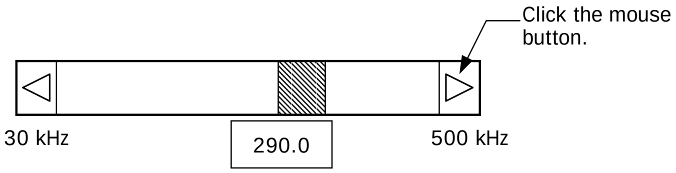
**b.** Click on the “Set” button for “Frequency/kHz” in the “VCO” window; the “VCO Frequency/kHz” window will appear.

**c.** Enter the frequency indicated in “peak frequency” in the input box in the “VCO Frequency/kHz" window using the keyboard.

**d.** Adjust the frequency using the bar chart in the “VCO Frequency/kHz” window on the higher frequency side so that the “AFM ALIGNMENT” indicator on the AFM AMP unit indicates about 70% of the maximum output voltage at the “Peak Frequency” obtained in the frequency sweep.

“AFM ALIGNMENT” indicates the RMS value as a negative number. For example, if the following data is obtained, set the RMS value to 8.0 V×0.7 = 5.6 V.






Click on the "increase button" (arrow mark at right) while watching the indicator on the AFM AMP unit until –5.6 V is indicated. Then, click on the "OK" button to close the "VCO Frequency /kHz" window.

**14.** Set "Reference/V" in the "Feedback Filters" frame on the "SPM Parameters" window.

Set "Reference/V" to 50% of the maximum output voltage at the peak frequency obtained in an ordinary frequency sweep. For example, if the data shown in the above figure is obtained, set "Reference/V" so that it is 8.0 V×0.5 = 4.0 V.

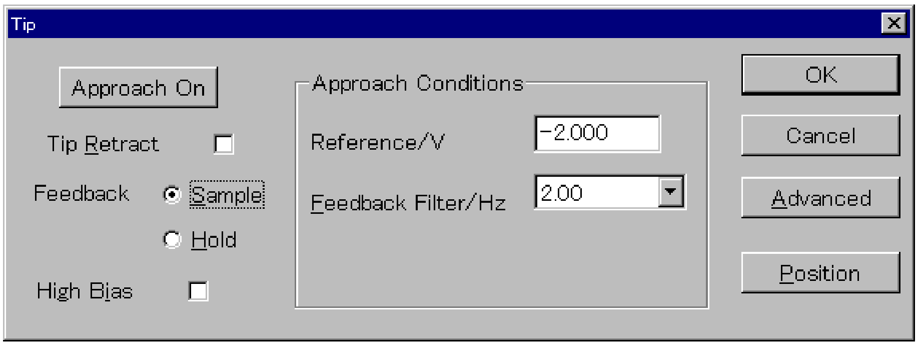
Note: "Reference/V" is set as a negative number. The value obtained in frequency sweep is indicated as a positive number. For example, when the voltage at the peak frequency is +8.0 V, set "Reference/V" to –4.0 V.

## 6.8.6 Approaching

Move the cantilever closer to the specimen until the RMS voltage becomes the voltage specified in "Reference/V." The cantilever movement automatically stops when the RMS voltage reaches the "Reference/V" voltage. The following is the procedure for approaching.

**1.** Click on "SPM Scan" in the main menu and select "Scan···" from the pull-down menu. The "SPM Parameters" window will appear.

**2.** Click on the "Tip" button on the "SPM Parameters" window. The "Tip" window will appear.




**3.** Set each parameter according to the following procedure.

**a.** Double-click on the "Reference/V" input-box. When the numerical value in the box is highlighted, enter the setting value using the keyboard. Press the "TAB" key on the keyboard to finalize the value.

For the value to be given to "Reference/V," refer to Subsection 6.8.5-Step 14.

**b.** Click on the " ▾ " mark in the "Feedback Filter/Hz" selection box and select "2.00" from the pull-down menu.

Now, the Reference/V voltage and the response speed of the feedback circuit, which are used for approaching, have been determined. To prevent the cantilever from colliding with the specimen, set “Feedback Filter/Hz” to a value higher than that for image observation.

**c.** Confirm that “Sample” in the “Feedback” line is selected (marked “⁄”). If “Hold” is selected (marked “⁄”), click on the radio button for “Sample.”

**d.** Click on the “⌋” mark for “Tip Retract” to deselect Tip Retract (the mark changes to “☐”).

**4.** Confirm the following points before performing approaching.

- The voltage applied to the Z scanner is +150 V.
  Check the voltage applied to the Z scanner using CH1 of the optional oscilloscope or Channel A (red) of the software oscilloscope. When checking it with the oscilloscope, read the CH1 voltage as 10 times the voltage displayed. For example, if the displayed voltage is +15 V with the 5 V/div scale, the actual voltage is +150 V. When it is checked with the software oscilloscope, the vertical axis indicates not voltage but scanner displacement in nm depending upon the Z sensitivity of the scanner. With the standard scanner 3 μ m corresponds to 1500nm or more.

If the voltage applied to the Z scanner does not reach +150 V, it is judged that the approaching has already been completed. So, approaching will not start even if the “Approach On” button is clicked on. In such a case, check the following points.

- Make sure that “Loop Gain” is not set to “Low.”
  “Loop Gain” must be set to the 2nd position or higher. If it is set to “Low,” the gain of the feedback circuit is so small that the feedback voltage is not supplied until it reaches +150 V.
- Make sure that “Feedback” is not set to “Hold.”
  “Sample” on the “Feedback/Filters Advanced” window (opened when you click on the “Advanced” button in the “Feedback Filters” sub-frame on the “SPM Parameters” window) must be selected (“⁄”). If “Hold” is selected, the feedback circuit is fixed with a certain voltage and does not function.
- Make sure that the RMS value indicated on the AFM AMP unit is not near the value set in “Reference/V.”
  If the RMS value is near that set in “Reference/V,” it is judged that approaching has already been completed. The following two reasons can be considered.
  1. The amplitude of the cantilever vibration has become small.
     If the cantilever tip is fairly close to the specimen surface, the cantilever amplitude could become small due to the attracting force of the specimen or the electrostatic force acting between the specimen surface and the cantilever tip, thus resulting in decreasing the RMS value down to nearly the “Reference/V” value. In such a case, change the “Reference/V” value to an even smaller value (nearly 0 V), or try to readjust VCO (Subsection 6.8.5) under the “Retract Off” condition.
  2. Approaching has already been completed, or the cantilever tip has collided with the specimen.
     Retract the cantilever tip from the specimen using the manual approach screw. Then, try to readjust according to Subsection 5.2.3 “Rough Approaching.” In this case, the Z voltage indicates –150 V even under the “Retract Off” condition.

**5.** Click on the “Approach On” button on the “Tip” window.

The motor for approaching starts to rotate and automatically stops when the RMS value becomes the same as the value set in “Reference/V.” Confirm if approaching has completed, using the indicator of the AFM AMP unit, the oscilloscope or the software oscilloscope.

- When confirming the completion of approaching with the indicator of the AFM AMP unit, check whether the AFM value has become a value near to the “Reference/V” value (the AFM value does not necessarily become exactly the same as the “Reference/V” value).
- When confirming it with the oscilloscope or the software oscilloscope, check that the Z voltage (CH1 or Channel A (red)) has come closer to 0 V than the position where it was when approaching started, and also check, using the software oscilloscope, that the RMS voltage (Channel B (blue)) has become near the “Reference/V” value.

**6.** Click on the “Approach Off” button in the “Tip” window.

## 6.8.7 Image Observation

When approaching has completed, carry out scanning.

### ■ Starting scanning

◆ Click on the “Repeat” button in the “Scan” frame in the “SPM Parameters” window.

Scanning will start and an image will appear in the Display Window.

In the Contact mode, an important factor for obtaining a high-quality image is the distance between the specimen surface and the cantilever tip. If this setting is inappropriate, not only can a quality image not be obtained, but also the specimen and the cantilever may be damaged. The distance between the specimen and the cantilever tip is set with “Reference/V.”

Generally, the scanning speed for the AC mode is one step slower than that for the contact mode, even for the same scanning range.

### ■ Setting Reference/V

Usually, change the “Reference/V” value little by little from the value for approaching toward 0 V (closer to the specimen surface) while watching the image, and set it to the value that produces the best quality image. During scanning, the RMS indication may vary. If the RMS value indicates –5.6 V, it means that the cantilever tip is too far from the specimen surface. If the RMS value indicates 0 V, it means that the cantilever tip has collided with the specimen surface.

Other general cautions, grabbing, storing and processing of an image are detailed later in this manual.

Note: When changing the observation mode from the AC mode to other modes such as contact mode or STM, be sure to deselect “VCO On” in the “VCO” window. If “VCO On” is selected, the cantilever excitation voltage (sine wave) is continuously applied, thus possibly causing unexpected noise.

## 6.8.8 FM Detection Method

In the JSPM-4200, image observation in the AC mode is usually performed by the Slope detection method (RMS-DC), but the FM detection method can be also used for it. In the FM detection method, vibration of the cantilever is driven by positive feedback oscillation, so image observation must be performed in a vacuum environment. Therefore, it is necessary to use the optional Vacuum Evacuation System. The Q-value becomes high enough in a vacuum environment so that the cantilever can be oscillated with positive feedback. The FM method has higher sensitivity and higher resolution for a flat specimen having a narrow observation area, but has less stability, than the Slope detection method.
The following is the procedure for image observation by the FM detection method.

### 6.8.8a Cantilever characteristic frequency peak search

1. Click on the " ▾ " mark in the "STM/AFM" selection box in the "Scan" frame on the "SPM Parameters" window and select "Slope" from the pull-down menu.
2. Click on the " ▾ " mark in the "Available Source 1" selection box in the "Display/Source" frame on the "SPM Parameters" window and select "AFM" from the pull-down menu.
3. Click on the "VCO" button in the "SPM Parameters" window. The "VCO" window will open.
4. Double-click on "Output Amp/V" and enter 0.1 using the keyboard.

   Note: Confirm that the OSC switch on the rear of the AFM AMP unit is set to "L." When it is, the amplitude of the actual excitation voltage becomes 1/10 of the set value. Therefore, the excitation voltage becomes 0.01 V.
5. Set "High Pass Filter" and "Low Pass Filter" according to the characteristic frequency of the cantilever, and set "Gain" to 10.

   Note: If "High Pass Filter" is set to 10 kHz and "Low Pass Filter" to 600 kHz, there would be no inconvenience in performing routine measurement. "Gain" is the gain of the RMS value. Set it to 10 (that is, 10 times) for routine measurement.
6. Check the check box of "VCO High Frequency" according to the characteristic frequency of the cantilever.

   Note: Low Frequency (there is no check mark ("□")) → 3 kHz to 50 kHz
   High Frequency (there is a check mark ("√")) → 30 kHz to 500 kHz
7. Set "Start Frequency/Hz" and "Stop Frequency/Hz" in the "Scan" frame.

   Note: A span of about 100 kHz centering around the characteristic frequency of the cantilever is an appropriate range to input.
8. Check the check box of "VCO On" and click on the "Scan" button.

   The frequency-dependence curve of cantilever vibration amplitude by forced oscillation will be displayed and the peak frequency will be indicated under "Stop Frequency/Hz" in the "Scan" frame. For image observation by the FM detection method, remove the check mark from the check box of "VCO On."

It is possible to check the cantilever resonance frequency for the FM detection method and set the center frequency for the FM detection method, using the curve and the peak value obtained through the operations described above. Moreover, it is possible to determine the forced frequency for the Slope detection method.

The forced frequency in the Slope detection method is the value obtained when shifting the frequency from the peak value to a slightly higher value (the frequency at which the amplitude becomes about a half of the amplitude at the peak frequency; however, it cannot be set in a vacuum environment). For image observation by the Slope detection method, set the forced frequency in the input box of “Frequency/kHz.” Then, set “Output Amp/V” to an appropriate value while watching the RMS value of the AFM AMP unit or the Aux 1 (A–B/A+B) signal. Set the value of “Output Amp/V” in such a way that the “Output Amp/V” waveform does not become triangular, taking it into account that the RMS value (Gain × 10) is about –5 V or less.

### 6.8.8b Adjustment of Positive Feedback Oscillation (FM Detection Method)

In the case of image observation by the FM detection method, if you already know the characteristic frequency of the cantilever, you can omit the operation in Subsection 6.8.8a “Cantilever characteristic frequency peak search” and can proceed directly to the following operation.

1. Turn the OSC AMP knob on the AFM AMP unit counterclockwise (down to 0 (zero) on the dial).
2. Click on “STM/AFM” in the “Scan” frame on the “SPM Parameters” window. The “STM/AFM” window will open. Click on the “ ” mark in the “STM/AFM” selection box and select “FM” from the pull-down menu.
3. Set the SELECT knob of the SPM CONTROL unit to “AUX1” and monitor the (A–B) signal using CH2 on the oscilloscope.

   Note: Set the vertical-axis range of the oscilloscope to a small value such as 50 mV/ div.
4. Slowly turn the OSC AMP knob on the AFM AMP unit clockwise and stop turning it when the (A–B) signal begins to oscillate.

   Note: If no oscillation is observed even with three revolutions of the OSC AMP knob, turn the knob back to its original position (turn it counterclockwise to “0”) and change the POLARITY switch to the opposite side (NORMAL or INVERSE); then repeat this step.
5. After confirming that the (A–B) signal is oscillating, turn the PHASE knob on the AFM AMP unit so that the oscillation amplitude becomes a maximum.

   Note: If the maximum amplitude is likely to exceed 2 Vp-p, turn the OSC AMP knob counterclockwise so as to reduce the amplitude.

**CAUTION**

**The waveform will change from sine to triangular when the amplitude exceeds about 2 Vp-p. If you maintain this triangular waveform for a long time, the cantilever might break.**

6. Adjust the oscillation amplitude with the OSC AMP knob to the minimum level at which the (A–B) signal oscillates even when the POLARITY switch is turned to its original position after changing it to the opposite side to stop the oscillation.

   Note: The purpose of this operation is to minimize the damage to the specimen that might occur during tip approach.

7. Click on the “VCO” button on the “SPM Parameters” window, and the “VCO” window will open.
8. Click on the “ ” mark in the “FM Center Frequency/kHz” selection box and select the value nearest to the cantilever characteristic frequency from the pull-down menu.
9. Set the indicator selection knob on the AFM AMP unit to “FMD” and adjust the FMD knob so that the indicator on the AFM AMP unit displays about –6 V.

   Note: When you turn the FMD knob clockwise, the numerical value on the indicator increases. However, the range within which the numerical value changes is so small that it only changes in about ten revolutions of the knob.
10. Turn the SELECT knob on the SPM CONTROL unit back to “AFM.”

    Note: Since the oscillation amplitude on the oscilloscope is very small, noise of about 1 V may be observed on the oscillation waveform.

### 6.8.8c Parameter setting for image observation

Parameter setting for the FM detection method is almost the same as that for the Slope detection method. In the FM detection method, the scanning speed is slower and the setting range of “Reference/V” is narrower (–5.5 to –6.0 V) than those for the Slope detection method. Parameter setting for the FM detection method is summarized as follows.

| | | | | | |
|---|---|---|---|---|---|
| Acquisition: | 512×512 | Scan Size: | 1um | | |
| Clock/ms: | 0.1667ms | Offset X: | 0nm | | |
| | | Y: | 0nm | | |
| STM/AFM: FM | | | | | |
| Sample: | 0.000 | Fback Filter/Hz: | 1.00 | | |
| Clean: | 0.000 | Reference/V: | -5.5 | | |
| Display Source | | Display | Z Input | | |
| 1: Topography 2: Topography | | ☑ Auto | ☑x16 Gain | ☑ Auto Set | |
| 3: Topography 4: Topography | | | Other Inputs | | |
| Available Source 1: AFM | | | ☐x16 Gain | ☑ Auto Set | |
| 2: Aux2 | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Scan Advanced | | | | | |
| Image Angle: 0.0 | | | | | |
| ☐Add External X Signal | | | | | Scan Filter |
| ☐Add | 〃 | Y | 〃 | | ⊙4 High frequency |
| ☐ 〃 | 〃 | Z | 〃 | | |
| ☐ 〃 | 〃 | Bias | 〃 | | |

| Bias Advanced | |
|---|---|
| Back Scan: | 0.000 |
| Offset: | 0.000 |

| Feedback/Filters Advanced | | |
|---|---|---|
| ☐ Tip Retract at abort | | ⦿Sample |
| Z Filter/kHz: | 50 | ○Hold |
| Loop Gain: | ⦿3 | |
| External Offset: | 0.000 | |

# 6.9 OBSERVATION IN CONTACT MODE (ADVANCED)

In the contact-mode AFM, observation is performed in a range where a repulsive force acts between a cantilever tip and a specimen.
Described in this Section is the procedure for AFM observation using the “Advanced” control panel. It is possible to set parameters in detail on the “Advanced” control panel but every parameter must be set.

## 6.9.1 Check Before Approaching

Before performing approaching, check whether the preparation has been completed according to the procedure in Section 6.3.

- Has rough approaching been executed in such a way that the distance between the cantilever and the specimen surface is 0.3 mm or less ?
- Is the Z stage position in the approaching-possible range ?
- Is the “AFM” value of the AFM amplifier unit about –2.0 V ?
- Is the “FFM” value of the AFM amplifier unit about 0 V ?

After checking these points, set the indicator selection knob on the AFM amplifier unit to “AFM.”

## 6.9.2 Setting Up Oscilloscope (option)

After setting up the optional oscilloscope according to Subsection 6.3.4, set CH2 as follows.

◆ Set the SELECT knob on the SPM CONTROL unit to “AUX1.”
Then, the (A–B) signal can be monitored.

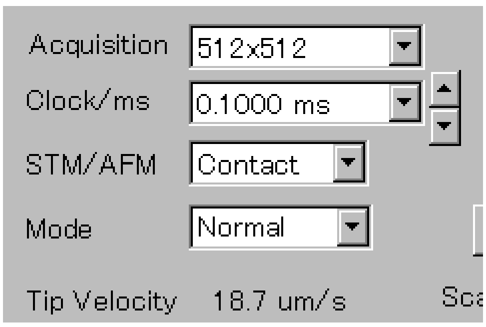
## 6.9.3 Setting Control Panel

Start the system according to the starting procedure in Subsection 6.2.1 “System Startup.”

**1.** Click on “SPM Scan” on the main menu and select “Scan···” from the pull-down menu.
The “SPM Parameters” window will be displayed. Click on the “Advanced” tab.

**2.** Set each parameter according to the following procedures.

**a.** Click on the “  ” mark in the “Acquisition” selection box and select “512×512” from the pull-down menu.

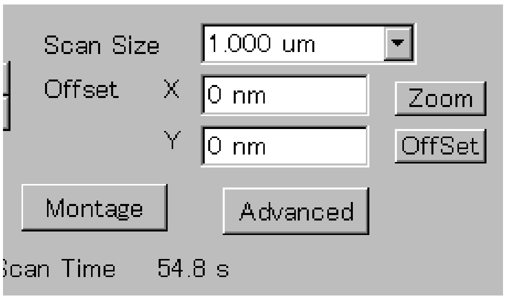


**b.** Click on the " " mark in the "Clock/ms" selection box and select "0.1000 ms" from the pull-down menu.
This is the parameter that determines the scan speed. Naturally, this parameter should be changed according to the observation area and the unevenness of the specimen. Here, set it to "0.1000 ms" provisionally.

**c.** Click on the " " mark in the "STM/AFM" selection box and select "Contact" from the pull-down menu.
This changes the SPM CONTROL unit to the Contact mode.

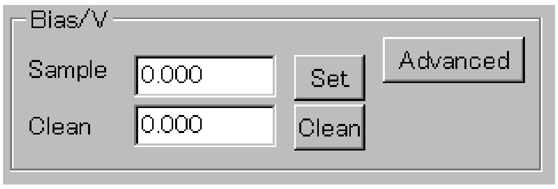
**d.** Click on the " " mark in the "Mode" selection box and select "Normal" from the pull-down menu.

**e.** Click on "Scan Size". When the numerical value is highlighted, enter 1 um using the keyboard and finalize the numerical value by pressing the "TAB" key. Or, click on the " " mark in the "Scan Size" selection box and select a numerical value near "1,000 nm."

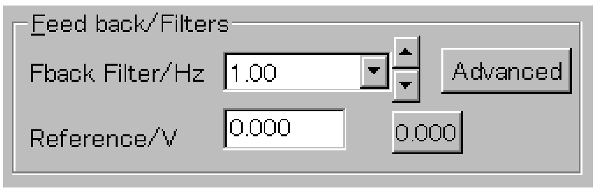



Note: Here, it is assumed that the standard scanner (scanning range is 10 μm×10 μm) is installed. In practice, set an appropriate value according to the observation area you want to observe.

**f.** Double-click on "Bias/V." When the numerical value is highlighted, enter 0 using the keyboard and finalize the numerical value by pressing the "TAB" key.



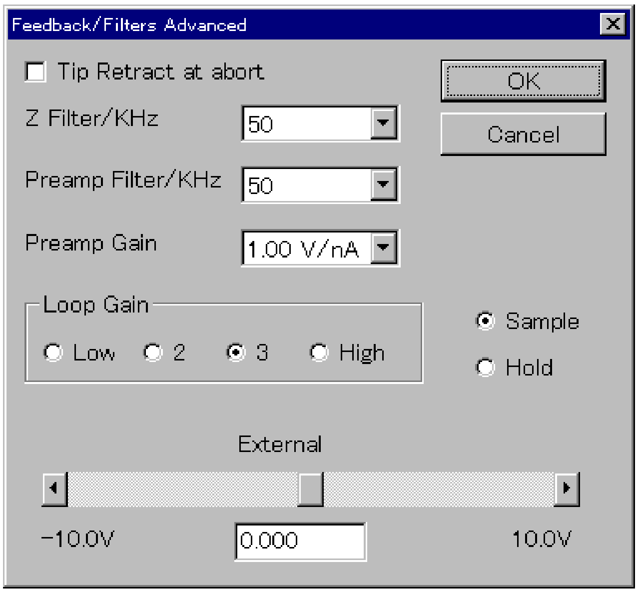

**g.** Click on the " " mark in the "Fback Filter/Hz" selection box and select "1.00" from the pull-down menu.




"Filter/Hz" is the parameter that determines the response speed of the feedback circuit. The larger the set value is, the faster the response speed becomes, thus producing a sharp image, but the feedback circuit becomes prone to oscillation. Usually, while watching an image during scanning, set the highest speed at which the feedback circuit does not oscillate.

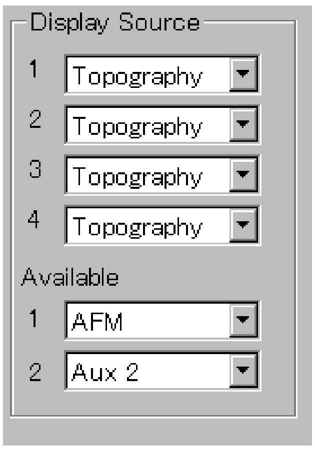
**h.** Double-click on “Reference/V.” When the numerical value is highlighted, enter 0 using the keyboard and finalize 0 by pressing the “TAB” key.
The force acting between the specimen surface and the cantilever tip is set with “Reference/V.” You have to change the “Reference/V” value while watching an image during scanning. Here, set it to “0.000” provisionally.

**i.** Click on the “Advanced” button in the “Feedback/Filters” frame.
The “Feedback/Filters Advanced” window is displayed.




Select “3” for “Loop Gain.” To select “3,” click on the radio button to the left of “3.” When this mark is selected, the button changes to ⁄. The setting determines the gain of the feedback circuit. If it is set to “High,” the response gain increases, thus causing an uneven specimen surface to be easily observed, but the feedback circuit becomes prone to oscillation.

**j.** Click on the “ ▾ ” mark in the “Available Source 1” selection box and select “AFM.”

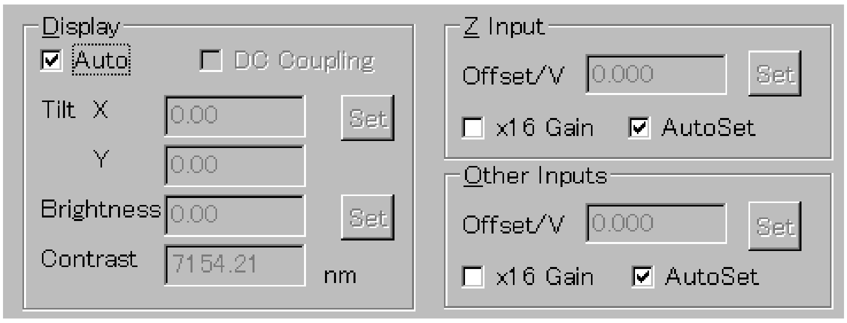



**k.** Click on the “ ▾ ” mark in the “Available Source 2” selection box and select “Aux2.”

These two parameters are for selecting the signal to be input to the A/D board. Here, set the parameters as shown above.

**l.** Click on the " ▼ " mark in the "Display Source 1" selection box and select "Topography."

**m.** Click on "Auto" in the "Display" frame to change "☐ Auto" to "」 Auto."




**n.** Click on "×16 Gain" in the "Z Input" frame to deselect the setting.
When the setting is deselected, the 」 mark changes to ☐.

**o.** Click on "Auto Set" in the "Z Input" frame to change "☐ Auto Set" to "」 Auto Set."
The check boxes, ☐ and 」, are toggle boxes. Each time the mouse is clicked on these boxes, the settings are changed. When the 」 mark is displayed, the parameter item to which this mark is attached is selected.

The setting of various parameter items required for image observation in the Contact mode (Advanced) has so far been explained. It is summarized as shown below. If any of the settings differs from the setting shown in the table, the normal functions may be disturbed. Check the parameters referring to the parameter setting below.

| | | | |
|---|---|---|---|
| Acquisition: 512 x 512 | | Scan Size: | lum |
| Clock/ms: 0.1000ms | | Offset X: | 0nm |
| | | Y: | 0nm |
| STM/AFM: Contact | | | |
| Sample: 0.000 | | Fback Filter/Hz: | 1.00 |
| Clean: 0.000 | | Reference/V: | 0.000 |
| Display Source | Display | Z Input | |
| 1: Topography 2: Topography | ☑ Auto | ☐x16 Gain | ☑ Auto Set |
| 3: Topography 4: Topography | | Other Inputs | |
| Available Source 1: AFM | | ☐x16 Gain | ☑ Auto Set |
| 2: Aux2 | | | |

Scan Advanced

Image Angle: 0.0

☐Add External X Signal

☐Add 〃 Y 〃

☐ 〃 〃 Z 〃

☐ 〃 〃 Bias 〃

Scan Filter

⦿4 High frequency

Bias Advanced

Back Scan: 0.000

Offset: 0.000

Feedback/Filters Advanced

☐ Tip Retract at abort

Z Filter/kHz: 50

Loop Gain: ⦿3

External Offset: 0.000

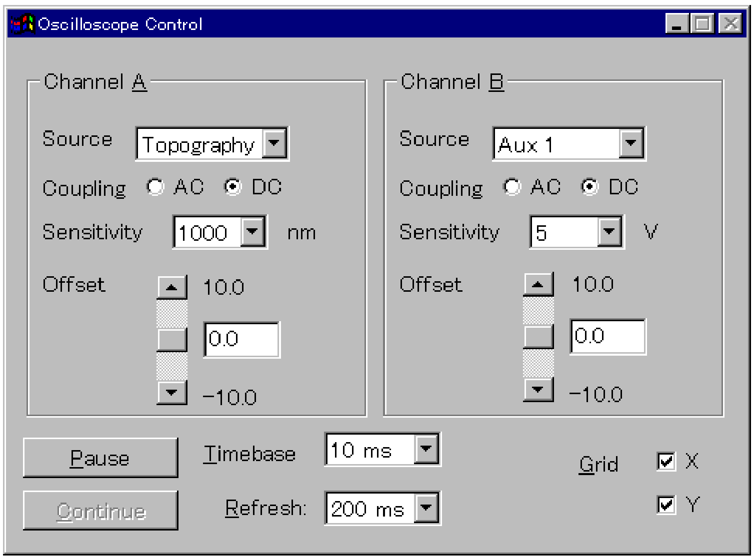
⦿Sample

○Hold

## 6.9.4 Setting Software Oscilloscope

Set the software oscilloscope according to Subsection 6.3.3; then set CH B as follows.

**1.** Click on the "🗗" mark in the "Oscilloscope···" button. The "Oscilloscope Control" window will open.



**2.** Click on the “ ” mark in the “Source” selection box in the “Channel B” frame; then select “Aux1” from the pull-down menu.

**3.** Click on the “ ” mark in the “Sensitivity” selection box in the “Channel B” frame; then select “5” from the pull-down menu.

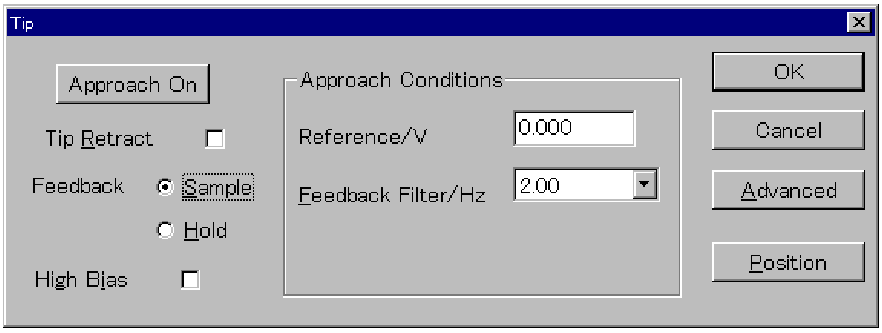
Then, the (A–B) signal can be monitored. The (A–B) signal output can be up to ±15 V maximum.

## 6.9.5 Approaching

Move the cantilever closer to the specimen until the A–B (AFM) voltage becomes the voltage specified in “Reference/V.” The cantilever movement automatically stops when the A–B voltage reaches the “Reference/V” voltage. The following is the procedure for approaching.

**1.** Click on “SPM Scan” in the main menu and select “Scan···” from the pull-down menu. The “SPM Parameters” window will appear.

**2.** Click on the “Tip” button on the “SPM Parameters” window. The “Tip” window will appear.




**3.** Set each parameter according to the following procedures.

**a.** Double-click on the “Reference/V” input box. When the numerical value in the box is highlighted, enter 0 using the keyboard. Press the “TAB” key on the keyboard to finalize the value (“0”).

**b.** Click on the “ ” mark in the “Feedback Filter/Hz” selection box and select “2.00” from the pull-down menu.

Now, the Reference/V voltage and the response speed of the feedback circuit, which are used for approaching, have been determined. To prevent the cantilever from colliding with the specimen, set “Feedback Filter/Hz” to a value higher than that for image observation.

**c.** Confirm that “Sample” on the “Feedback” line is selected (marked “⁄”). If “Hold” is selected (marked “⁄”), click on the radio button for “Sample.”

**d.** Click on the “⌡” mark for “Tip Retract” to deselect Tip Retract (the mark changes to “□”).

**4.** Confirm the following points before performing approaching.

- The voltage applied to the Z scanner is +150 V.

  Check the voltage applied to the Z scanner using CH1 of the optional oscilloscope or Channel A (red) of the software oscilloscope. When checking it with the oscilloscope, read the CH1 voltage as 10 times the voltage displayed. For example, if the displayed voltage is +15 V with the 5 V/div scale, the actual voltage is +150 V.

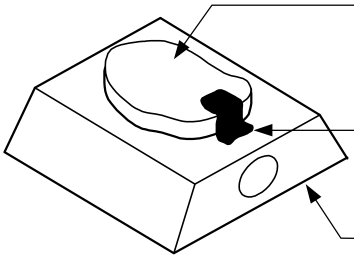
When it is checked with the software oscilloscope, the vertical axis indicates not voltage but scanner displacement in nm depending upon the Z sensitivity of the scanner. With the standard scanner, 3 μ m corresponds to 1500nm.

If the voltage applied to the Z scanner does not reach +150 V, it is judged that the approaching has already been completed. So, approaching will not start even if the "Approach On" button is clicked on. In such a case, check the following points.

- Make sure that "Loop Gain" is not set to "Low."
  "Loop Gain" must be set to the 2nd position or higher. If it is set to "Low," the gain of the feedback circuit is so small that the feedback voltage is not supplied until it reaches +150 V.
- Make sure that "Feedback" is not set to "Hold."
  "Sample" on the "Feedback/Filters Advanced" window (opened when you click on the "Advanced" button in the "Feedback Filters" subframe on the "SPM Parameters" window) must be selected ("✓"). If "Hold" is selected, the feedback circuit is fixed with a certain voltage and does not function.
- Make sure that the AFM value indicated on the AFM AMP unit is not near 0 V.
  If the AFM value is near 0 V, it is judged that approaching has already been completed. The following two reasons can be considered.
  1. The photodiode position has changed.
     Readjust the photodiode position according to the procedure in Subsection 5.2.2 "Adjusting Photodiode Position."
  2. Approaching has already been completed, or the cantilever tip has collided with the specimen.
     Retract the cantilever tip from the specimen using the manual approach thumbscrew. Then, try to readjust according to Subsection 5.2.3 "Rough Approaching."

When the cantilever tip gets fairly close to the specimen surface, the electrostatic force acting between the specimen surface and the cantilever tip might affect the cantilever, thus sometimes making approaching impossible. Most of such cases are due to an electrostatic force. Try the following steps.

- Change the cantilever to a hard one (a cantilever with a high resonance frequency).
- Change the cantilever to a conductive one (a Si cantilever or a cantilever with both sides gold-coated), and use a non-contact cantilever holder. A non-contact cantilever holder is virtually-grounded via the operational amplifier in the SPM head unit.
- Add a bias voltage to "Sample."
- Try to change the bias voltage to be added to "Sample" from 0 V to both positive and negative values.
- Make sure that good conductivity is kept between the specimen and the specimen stub. Affix the specimen to the specimen stub using a conductive tape or conductive paste (Dotite). If possible, apply the conductive paste not only to the surface but to the side of the specimen as well.




If the specimen is an insulating material, make the specimen smaller or coat the masked observation area of the specimen with gold or any other suitable metal. Then, stick the specimen onto the stub as shown in the above figure.

**5.** Click on the “Approach On” button on the “Tip” window.

The motor for approaching starts to rotate and automatically stops when the RMS value becomes approximately the same as the value set in “Reference/V.” Confirm if approaching has completed, using the indicator of the AFM AMP unit, the oscilloscope or the software oscilloscope.

- When confirming the completion of approaching with the indicator of the AFM AMP unit, check whether the AFM value has become near the “Reference/V” value (the AFM value does not necessarily become exactly the same as the “Reference/V” value).
- When confirming it with the oscilloscope or the software oscilloscope, check that the Z voltage (CH1 or Channel A (red)) has come closer to 0 V than the position where it was when approaching started, and also check that the Aux1 voltage (the (A–B) voltage: CH2 or Channel B (blue)) has become a value near the “Reference/V” value (0 V).

**6.** Click on the “Approach Off” button in the “Tip” window.

When approaching has completed, the indicator on the AFM AMP unit suddenly changes from the value during approaching (–2.0 V) to the “Reference/V” value (0 V). This phenomenon is called “Jump-in.” If approaching finishes as the indicator on the AFM AMP unit slowly changes to 0 V, approaching may not have been correctly performed. In such a case, even though you try to measure a force curve (described later), you cannot obtain the force curve data, nor can you obtain the force curve image, either.

The possible reasons for this are the electrostatic force and interference of laser beams reflected on the specimen surface. For the former, take remedial measures as described in step 4 above. For the latter, readjust the photodiode position according to the procedure in Subsection 5.2.2 “Adjusting Photodiode Position”; click on the “Approach Off” button in the “Tip” window; then, click on the “Approach On” button in the “Tip” window again.

If approaching stops before the indicator on the AFM AMP unit indicates the “Reference/V” value (0 V), it is judged that the seeming state of approaching having completed occurred due to unexpected electrical noise or something like that. In this case, click on the “Approach Off” button in the “Tip” window; then, click on the “Approach On” button again.

You may hear an oscillation sound coming from the instrument when approaching is completing. This is because the setting of the feedback filter is so fast that it oscillates. To stop the oscillation sound, click on the "Approach Off" button in the "Tip" window. Then, the feedback filter value is returned to normal scanning specified in the "Feedback/Filter" frame in the "SPM Parameters" window. If the sound continues, click on the " ▼ " mark in the "Feedback Filter/Hz" selection box and select a slow filter (a smaller value) from the pull-down menu.

### 6.9.6 Image Observation

When approaching has completed, carry out scanning.

#### ■ Starting scanning

◆ Click on the "Repeat" button in the "Scan" frame in the "SPM Parameters" window. Scanning will start and an image will appear in the Display Window.

Note: In the Contact mode, the setting of the repulsive force acting between the specimen surface and the cantilever tip plays an important role in obtaining a quality image. If this setting is inappropriate, not only can a quality image not be obtained, but also the specimen and the cantilever may be damaged. The repulsive force acting between the specimen surface and the cantilever tip is set with "Reference/V."

#### ■ Setting Reference/V

The more negative "Reference/V" is, the smaller the repulsive force become. The more positive "Reference/V" is, the larger the repulsive force becomes. If approaching is performed under the condition of the "Reference/V" value set to –2 V, changing "Reference/V" to the repulsive force side in excess of –2 V might sometimes make the cantilever tip go away from the specimen surface, thus resulting in forming no image.

In the case of the Contact mode, generally, scanning is performed in the domain of a small repulsive force to avoid damaging the specimen. Then, set "Reference/V" to the position where the cantilever tip and the specimen surface become closest to each other. However, in the case of a specimen having large unevenness or a specimen having a low contrast due to materials attached to the specimen surface, scanning with a little larger repulsive force (on the plus (+) side of "Reference/V") would produce a good result.

Change the "Reference/V" value gradually from the value for approaching toward 0 V (closer to the specimen surface) while watching the image, and set it to the value that produces the best-quality image.

Other general cautions, grabbing, storing and processing of an image are detailed later in this manual.

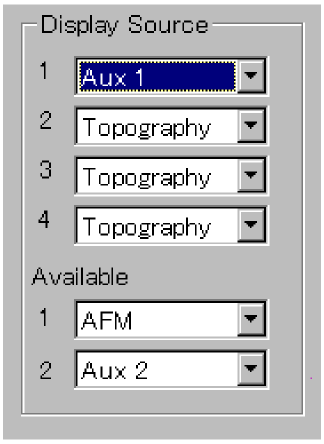
### 6.9.7 Force Image Observation

The image observation in the contact mode that has been explained so far in this Section is the constant-force mode used to observe the topography of a specimen while keeping the repulsive force constant. In this mode it is also possible to observe a Force image (an atomic-force image) by obtaining the movement of the cantilever as an image while keeping the distance between the cantilever and the specimen constant. The following is the procedure for observing a Force image.

1. Carry out approaching according to the procedures in Subsections 6.4.1 through 6.4.5.

   Note: If approaching has already been completed, this operation is not necessary.

2. Click on the “ ” mark in the “Display Source 1” selection box in the control panel and select “Aux1” from the pull-down menu.




3. Click on the “ ” mark in the “Fback Filter/Hz” selection box and select “0.5” from the pull-down menu.

   Usually, a Force image is observed by applying a very slow feedback while keeping the height constant. Use a slower response for the feedback than that used for observing a topography image.

4. Carry out phase observation according to the procedure in Subsection 6.4.6 “Image Observation.”

# 6.10 FORCE CURVE MEASUREMENT (ADVANCED)

A force acting between the specimen surface and the cantilever tip is measured from the bending of the cantilever while varying the distance between the specimen surface and the cantilever tip in the contact mode. This measurement is called “Force Curve” measurement. The following is the procedure for Force Curve measurement.

## 6.10.1 Measurement Method

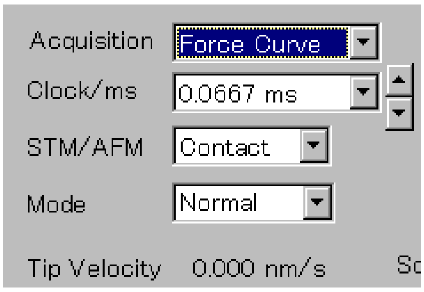
The procedure up to approaching is exactly the same as that for the measurement method in the contact mode.

**1.** Perform approaching according to the procedures in Subsections 6.5.1 to 6.5.4.
Confirm that approaching has been properly performed.

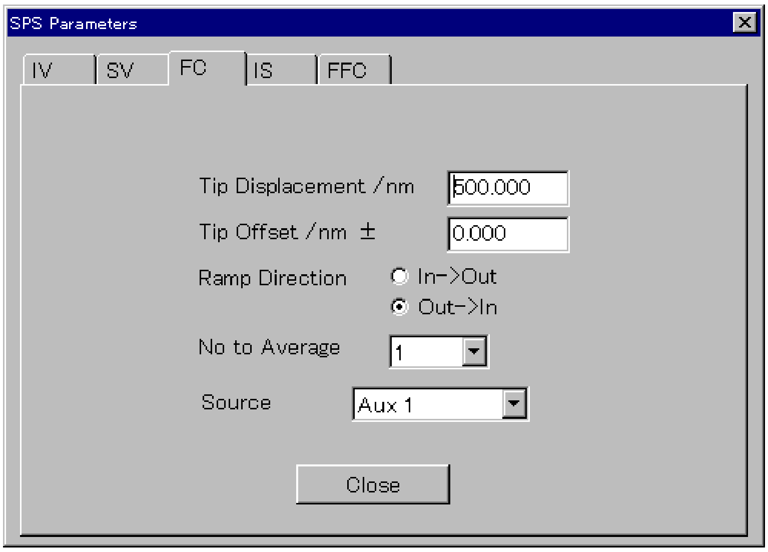
**2.** Click on the “ ▼ ” mark in the “SPM Scan” selection box in the main menu and select “Scan···” from the pull-down menu.
The “SPM Parameters” window will open.

**3.** Set each parameter according to the following procedures.

**a.** Click on the “ ▼ ” mark in the “Acquisition” selection box and select “Force Curve” from the pull-down menu.




**b.** Click on “SPS Param.”
The “SPS Parameters” window will be displayed. Click on the “FC” tab.



**c.** Double-click on “Tip Displacement/nm” on the “F-C” window and enter the maximum value of the scanner Z scanning range using the keyboard.
When the standard scanner (10 μm×10 μm×3 μm) is installed, enter about 1,500 nm (the total scanning range in Z direction is 3,000 nm, because the value input is the limit of the scan in both the positive and negative directions). In practice, however, eve if a value exceeding the scanner Z scanning range is entered, the software automatically calculates and indicates the maximum possible value.

**d.** Double-click on “Tip Offset/nm±” and enter 0 using the keyboard.

**e.** Set “Ramp Direction” to “Out→In” (/).

**f.** Click on the “ ” mark in the “No to Average” selection box and select “1” from the pull-down menu.

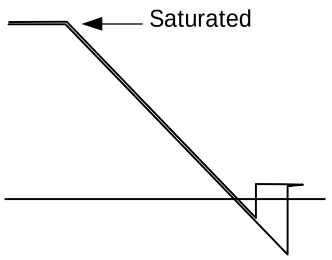
**g.** Click on the “ ” mark in the “Source” selection box and select “Aux1” from the pull-down menu.

The setting of various parameter items required for image observation in the Contact mode (Advanced) has so far been explained. It is summarized as follows.

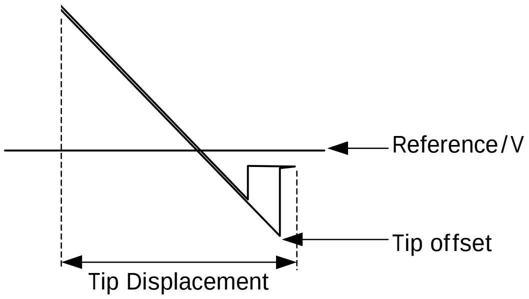
| Acquisition: Force Curve | |
|---|---|
| Tip Displacement/nm: | Maximum value |
| Tip Offset/nm ±: | 0 |
| Ramp Direction: | Out → In |
| No to Average: | 1 |
| Source | Aux1 |

**4.** Click on “Repeat” on the “SPM Parameters” window.
The Force Curve will be measured and displayed on the Display Window.

- To grab the measured Force Curve, click on the “Grab” button during the measurement.
- To change the display style of the Force Curve, change it on the “Plot Parameters” menu of “Display” after grabbing the Force Curve.
- If the Force Curve goes out of the linear region and becomes saturated in the repulsive-force domain, as shown below, it means that the measurement has been attempted outside the measurable range of the detector and the A/D converter (±10 V). In such a case, change the “Tip Displacement/nm” value in the “SPS Parameters” window to a smaller value.

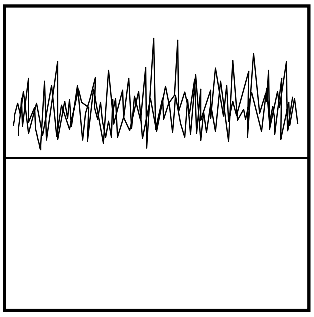


- The relationship among "Tip Displacement/nm," "Tip Offset/nm" and "Reference/V" is shown in the figure below.




Therefore, when the "Reference/V" value is set to 0 V, feedback is carried out at the point where the Force Curve crosses the 0 V axis.

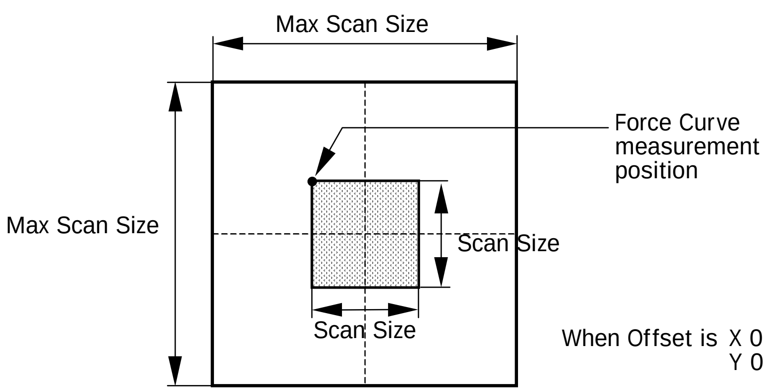
- If the Force Curve is not obtained correctly, it usually means that approaching has not been properly performed. If curves such as the one shown below are obtained, check whether approaching has been properly performed according to Subsection 6.4.5 "Approaching."



If the data obtained is something like the above, that means that the cantilever tip has not yet approached the specimen surface.

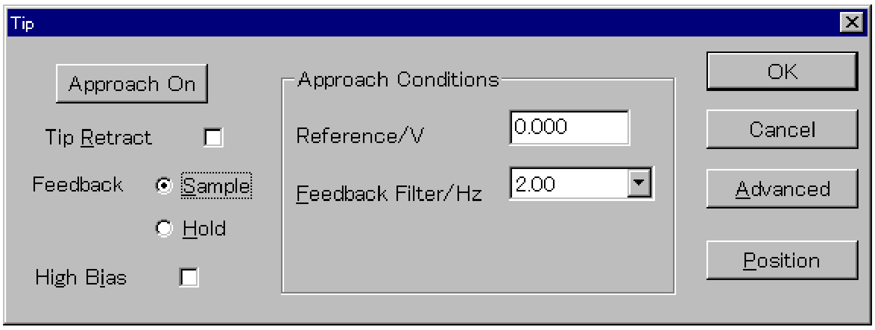
### 6.10.2 Measuring Force Curve at Specified Position

The Force Curve measurement described in Subsection 6.10.1 is carried out at the top-left corner of the image.

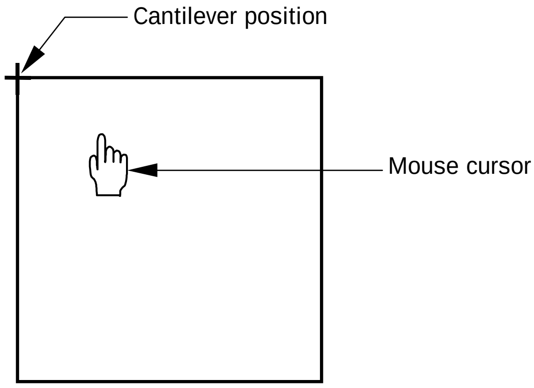


In practice, however, the Force Curve measurement is often carried out at a certain specified point in an observed image, when image observation is performed in the contact mode. The following is the procedure for specifying the Force Curve measurement point.

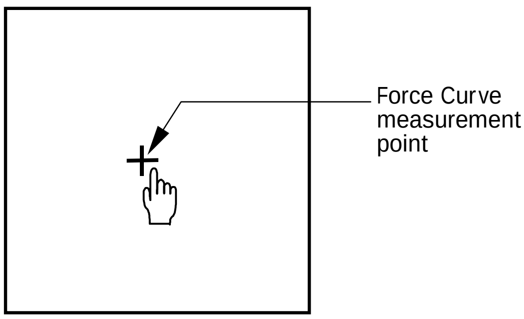
1. Observe an image and grab it according to Section 6.5 “Observation by Contact Mode (Advanced).”
2. Set the parameters according to Subsection 6.10.1 “Measurement Method.”
3. Click on the “Tip” button in the “SPM Parameters” window.
   The “Tip” window will open.




4. Click on the check box for “Tip Retract” (√).
5. Click on the “Position” button in the “Tip” window.
   The “Tip” and “SPM Parameters” windows will close and the “Tip position” window will open. Move the cursor to “Display Window”; then, the cursor changes to a hand mark.




6. Move the cursor to the cantilever position (“+”); press the left mouse button; drag it to the point where the Force Curve is to be measured while pressing the mouse button.



The cantilever is actually moving in real time during the cursor dragging, so be sure to drag the "+" mark slowly enough.

**7.** After placing the "+" mark at the measurement point, press the right mouse-button.

The "SPM Parameters" and "Tip" windows will appear again.

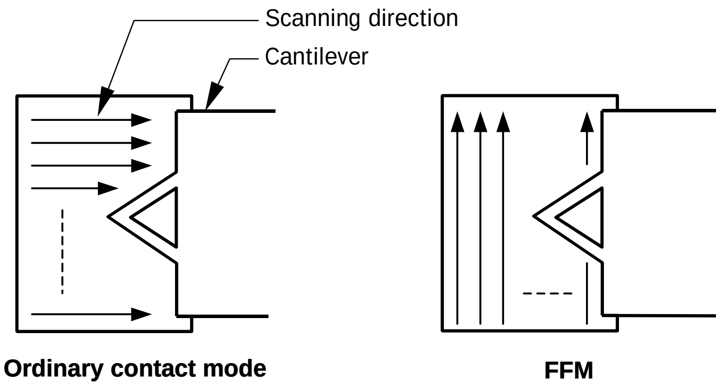
**8.** Release "Tip Retract" by clicking on the ⌋ mark for "Tip Retract"; the mark changes to "□."

**9.** Click on the "Repeat" button on the "SPM Parameters" window.

Note: If the measurement point is changed by this method, the changed point becomes the initial position for the cantilever. So, when the measurement has been completed or "Abort" has been performed, the cantilever tip returns to this initial position.

# 6.11 FFM OBSERVATION (ADVANCED)

In the ordinary contact mode AFM, the scanning direction is parallel to the cantilever axis as shown in the left figure below. In the FFM image observation, on the other hand, the scanning direction is orthogonal to the cantilever axis as shown in the right figure below. The cantilever is twisted during scanning due to the friction force acting between the specimen surface and the cantilever tip. The FFM measures the friction force of the specimen surface from this torsion of the cantilever.

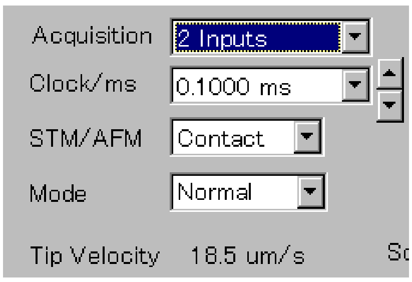



The following is the procedure for observing an FFM image in the contact (advanced) mode.

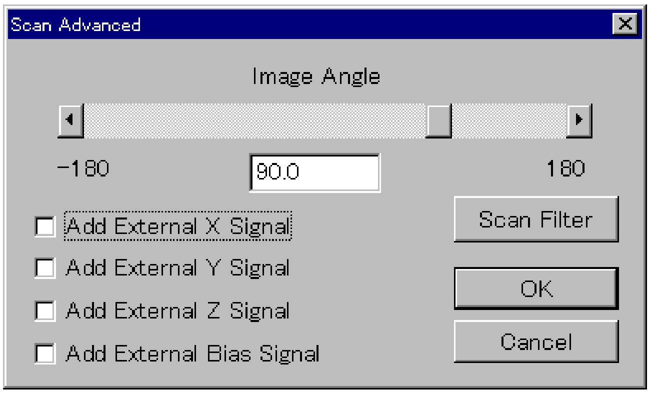
**1.** Carry out the procedures in Subsections 6.5.1 through 6.5.5.

**2.** Set the parameters for observing an FFM image according to the following procedure.

**a.** Click on the “ ▼ ” mark in the “Acquisition” selection box in the “Scan” frame and select “2 Inputs” from the pull-down menu.
Two images are acquired and displayed simultaneously with this operation. When an FFM image is observed, a topography image is also acquired so as to be compared with an FFM image.

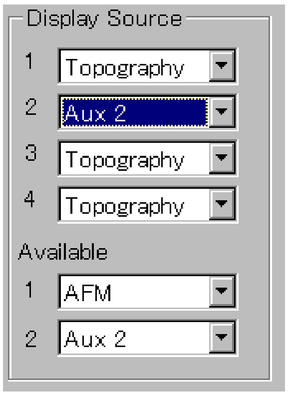



**b.** Click on the “Advanced” button in the “Scan” frame to display the “Scan Advanced” window. Double-click on the input box for “Image Angle” and enter 90 using the keyboard.



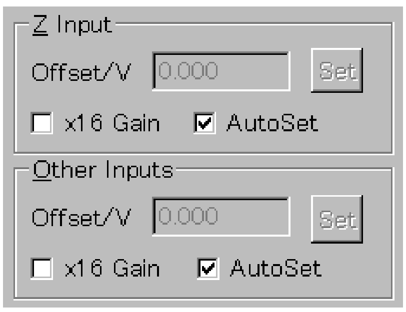

Now, the specimen is scanned in a direction orthogonal to the cantilever axis.

**c.** Click on the “ ” mark in the “2” selection box in the “Display Source” frame and select “Aux2” from the pull-down menu.




If “Aux2” is not selected from the pull-down menu, confirm that “AFM” and “Aux2” have been selected in the “Available Source 1” selection box and in the “Available Source 2” selection box respectively.

**d.** Click on the check box for “×16 Gain” in the “Other Inputs” frame to make it checked (√).




The setting of various parameter items required for FFM image observation in the Contact mode (Advanced) has so far been explained. It is summarized as shown below.

| | | | |
|---|---|---|---|
| Acquisition: Inputs | | Scan Size: | 1 µm |
| Clock/ms: | 0.1000ms | Offset X: | 0nm |
| | | Y: | 0nm |

STM/AFM: Contact

| | | | |
|---|---|---|---|
| Sample: | 0.000 | Fback Filter/Hz: | 1.00 |
| Clean: | 0.000 | Reference/V: | 0.000 |

| | | | |
|---|---|---|---|
| Display Source | Display | Z Input | |
| 1: Topography 2: Aux2 | ☑ Auto | ☐x16 Gain | ☑ Auto Set |
| 3: Topography 4: Topography | | Other Inputs | |
| Available Source 1: AFM | | ☐x16 Gain | ☑ Auto Set |
| 2: Aux2 | | | |

Scan Advanced

| | |
|---|---|
| Image Angle: 90.0 | |
| ☐Add External X Signal | Scan Filter |
| ☐Add 〃 Y 〃 | ⦿4 High frequency |
| ☐ 〃 〃 Z 〃 | |
| ☐ 〃 〃 Bias 〃 | |

Bias Advanced

Back Scan: 0.000

Offset: 0.000

Feedback/Filters Advanced

| | | |
|---|---|---|
| ☐ Tip Retract at abort | | ⦿Sample |
| Z Filter/kHz: | 50 | ○Hold |
| Loop Gain: | ⦿3 | |
| External Offset: | 0.000 | |

**3.** Click on the “Repeat” button on the “SPM Parameters” window.

Scanning starts and images are displayed on the Display Window as shown below.


The images are displayed in a range of 256×256 pixels. The white locations in the FFM image represent areas of large friction force on the specimen surface.

## ■ Notice on FFM Image Observation

Since the cantilever torsion is observed statically, unevenness of the specimen surface affects the friction force image. Therefore, a topography image must also be observed simultaneously in order to properly evaluate the FFM image. To reduce the effect of the unevenness of the specimen surface, it is recommended that the Viscoelasticity, Lateral Modulation FFM (50)/(60) (an optional attachment) be used.
The contrast of an FFM image is affected by the scanning speed (“Clock/ms”) and the repulsive force between the specimen surface and the cantilever tip (“Reference/V”). For a specimen with less contrast, try changing “Reference/V” a little to the positive side to make the repulsive force larger. In addition, the brightness of a grabbed image can be adjusted using the image processing function (“Adjust LUT”).

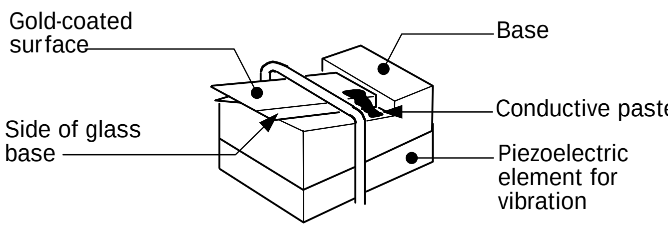
Other general cautions, grabbing, storing and processing of an image are detailed later in this manual.

# 6.12 CURRENT IMAGE OBSERVATION IN CONTACT MODE (ADVANCED)

An amplifier for current detection is built into the AFM head unit. A contact current image as well as a Topography image can be acquired using a conductive cantilever. Moreover, an I-V image can be observed at a specified point of the specimen.

## ■ Cantilever Mounting

Use a conductive cantilever (such as a conductive Si cantilever or a cantilever with both sides coated with gold). Mount a cantilever on a non-contact cantilever holder. Make sure that good conductivity is kept between the cantilever and the cantilever holder. Use conductive paste (Dotite) especially for a gold-coated cantilever as the conductivity between the front face and the rear face is not so good.



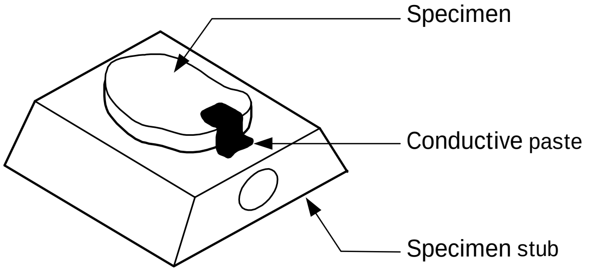

> **CAUTION**
>
> **When applying conductive paste to the cantilever and the cantilever holder, be sure not to touch the conductive paste to the cantilever piezoelectric element. When replacing a cantilever, be sure to confirm that no previously used conductive paste remains on the holder. Otherwise, the cantilever will tilt, causing the reflected laser beam not to irradiate the right position.**

## ■ Cantilever holder setting

After mounting a cantilever on a cantilever holder, insert the cantilever holder into the head unit until it touches the innermost wall.

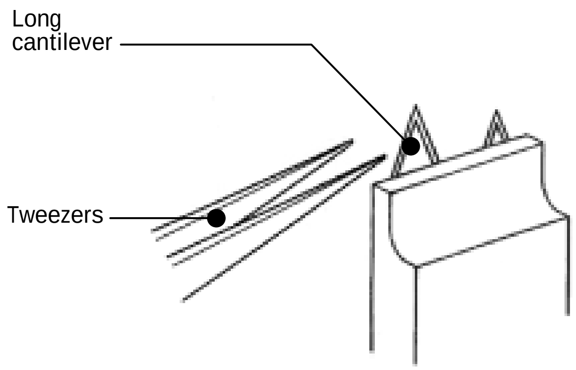
## ■ Specimen setting

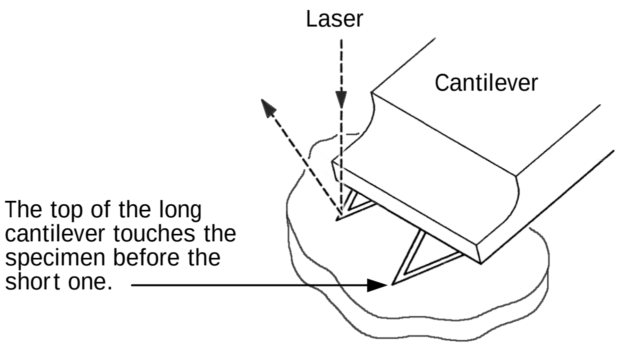
In order to observe a current image correctly, it is essential that good conductivity be kept between the specimen and the specimen stub. Attach the specimen to the specimen stub with conductive tape or conductive paste (Dotite). If possible, apply the conductive paste not only to the surface but to the side of the specimen as well.




## ■ Cantilever selection

Usually, a short cantilever is used for image observation. If there are two cantilevers, long and short, as shown in the figure below and the short cantilever is used for image observation, be sure to remove the long one using a pair of tweezers.



**CAUTION**

**When you select and use a short cantilever out of two cantilevers, long and short, be sure to remove the long one with a pair of tweezers. Otherwise, the top of the long cantilever touches the specimen before the short one does.**

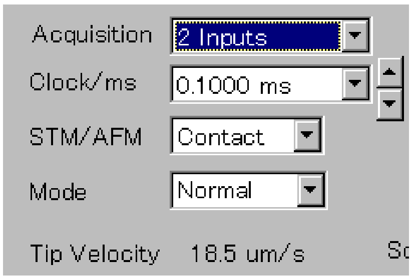
## 6.12.2 Current Image Observation

The following is the procedure for observing a current image.

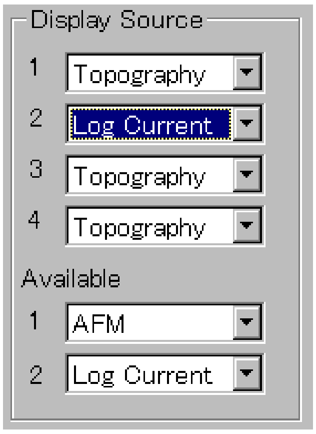
**1.** Carry out the contact-mode procedures in Subsections 6.5.1 through 6.5.5.

**2.** Set the parameters for observing a current image according to the following procedure.

**a.** Click on the “ ” mark in the “Acquisition” selection box in the “Scan” frame and select “2 Inputs” from the pull-down menu.
Two images are acquired and displayed simultaneously as a result of this operation. When a current image is observed, a topography image is also acquired to allow comparison with the current image.

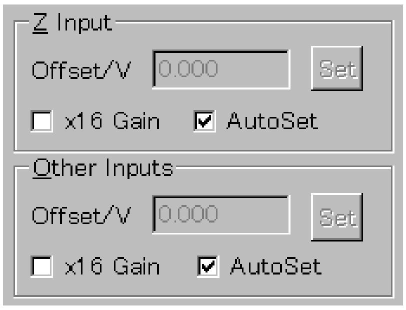



**b.** Click on the “ ” mark in the “2” selection box in the “Available Source” frame and select “Log Current” from the pull-down menu.

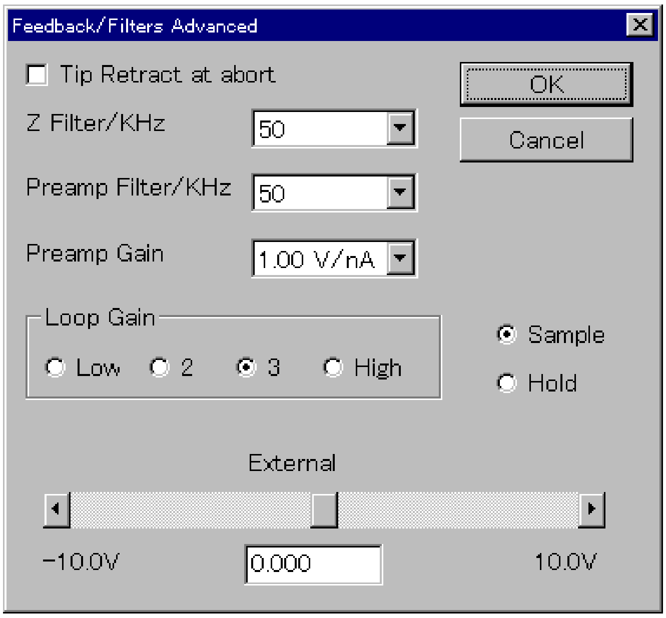



**c.** Click on the “ ” mark in the “2” selection box in the “Display Source” frame and select “Log Current” from the pull-down menu.

**d.** Click on the ⌋ mark for "×16 Gain" in the "Other Inputs" frame to remove the check mark ("☐"). Click on the check box for "Auto Set" in the "Other Inputs" frame to make it checked ("⌋").




**e.** Click on the "Advanced" button in the "Feedback/Filters" window to open the "Feedback/Filters Advanced" window.




**f.** Click on the "▼" mark in the "Preamp Gain" selection box and select "1.00 V/nA" from the pull-down menu.

**g.** Click on the "▼" mark in the "Preamp Filter/kHz" selection box and select "50" from the pull-down menu.

**h.** Double-click on the "Sample" input box in the "Bias/V" frame and enter 1 using the keyboard.

The settings for the above bias voltage and preamplifier gain differ depending upon the conductivity of the specimen to be observed. Here, it is supposed that a +1.0 V bias voltage is to be applied to the specimen. In practice, when scanning the specimen, adjust these values so that the current image and the CH2 input signal value indicated in the top right on the "SPM Parameters" window are not saturated.

Parameter setting is summarized as follows.

Acquisition: Inputs　　Scan Size: lum
Clock/ms: 0.1000ms　　Offset X: 0nm
　　Y: 0nm

STM/AFM: Contact

Sample: 1.000　　Fback Filter/Hz: 1.00
Clean: 0.000　　Reference/V: 0.000

Display Source　　Display　　Z Input
1: Topography 2: Log Current　　☑ Auto　　☐x16 Gain　☑ Auto Set
3: Topography 4: Topography　　Other Inputs
Available Source 1: AFM　　☐x16 Gain　☑ Auto Set
2: Log Current

Scan Advanced

Image Angle: 0.0
☐Add External X Signal　　Scan Filter
☐Add 〃 Y 〃　　⦿4 High frequency
☐ 〃 〃 Z 〃
☐ 〃 〃 Bias 〃

Bias Advanced

Back Scan: 0.000
Offset: 0.000

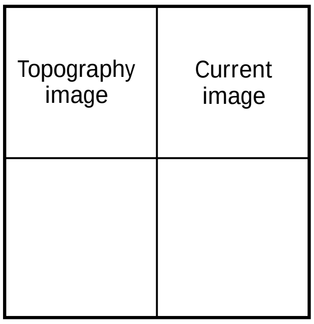
Feedback/Filters Advanced

☐ Tip Retract at abort
Z Filter/kHz: 50　　⦿Sample
Preamp Filter/kHz: 50　　○Hold
Preamp Gain: 1.00V/nA
Loop Gain: ⦿3
External Offset: 0.000

After setting the parameters and completing the approaching, perform scanning.

**3.** Click on the “Repeat” button on the “SPM Parameters” window.

Scanning starts and images are displayed on the Display Window as shown below.

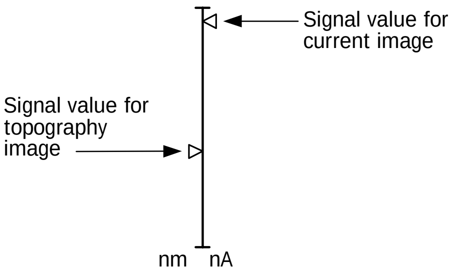



The images are displayed in a range of 256×256 pixels. The white locations in the Current image represent high-conductance (large current flow) areas on the specimen surface.

## ■ Notice on current-image observation

- The current measured in the contact mode is larger than that in the STM observation (for a conductive specimen). If the bargraph displayed in the “Status” frame in the “SPM Parameters” window exceeds the maximum on the scale, reduce the setting of “Preamp Gain” in the “Feedback/Filters Advanced” window.

  Note: If the arrow shown at right in the figure below is positioned at the top of the bar, that means that the current exceeds the maximum on the scale.

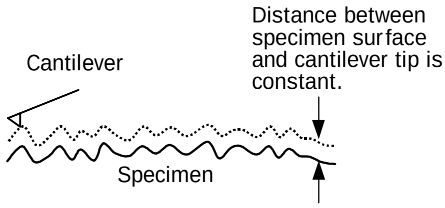



The maximum detectable current for each preamplifier gain is shown below.

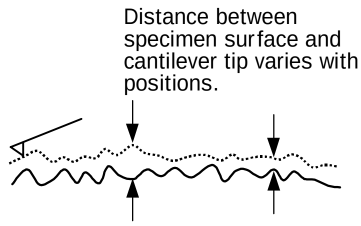
| Preamp gain | Maximum detectable current |
|---|---|
| 0.01 V/nA | 1 μA |
| 0.1 V/nA | 100 nA |
| 1 V/nA | 10 nA |

- If the specimen has low conductivity like an insulating material, or the surface of the specimen is oxidized, the current changes little and the image contrast is poor. In such a case, click on the check box for “×16 Gain” in the “Other Inputs” frame (to make it checked) in order to increase the sensitivity to 16 times.

- "Linear current" instead of "Log current" can be used to observe a current image. When the contrast does not increase with "Log current," the apparent sensitivity can be increased with "Linear current." When observing a current image, click on the " ▾ " mark in the "2" selection box in the "Available Source" frame and select "Linear current" from the pull-down menu; also select "Linear current" in the "2" selection box in the Display Source" frame.
- In order to correctly observe a current image, a topography image must be acquired correctly. If the feedback filter setting is too slow, the cantilever response to the specimen surface topography becomes very slow, thus resulting in incorrect current measurement.




**Appropriate feedback speed**




**Too slow feedback speed**

## 6.12.3 I-V Measurement with Conductive Cantilever

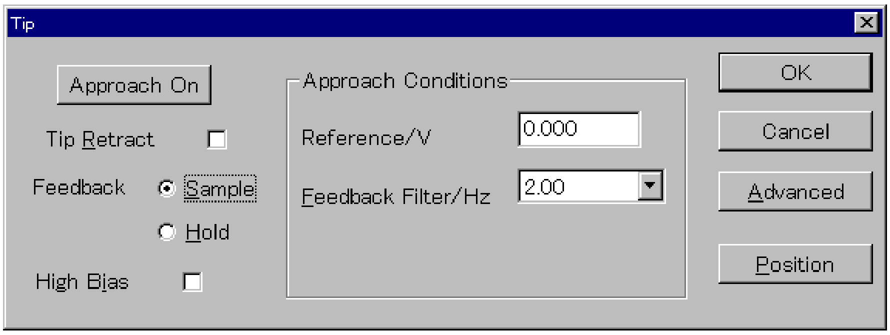
The I-V measurement on the surface of a specimen is as commonly used as the observation of a current image.

### ■ Notice on cantilever

The same type conductive cantilever as for the current image observation is used for the I-V measurement. Be sure that there is sufficient conductivity in the cantilever, the cantilever holder and the specimen stub, and among them. In the I-V measurement, a bias voltage is scanned, so an electrostatic force is applied to the cantilever. Therefore, if a soft cantilever is used, it may be bent by the electrostatic force during the bias voltage scanning, thus possibly resulting in incorrect I-V measurement. A hard cantilever (such as a silicon cantilever) should be used for accurate I-V measurement.
The following is the procedure for I-V measurement.

1. Perform the current-image observation according to Subsection 6.12.2 and grab the image.

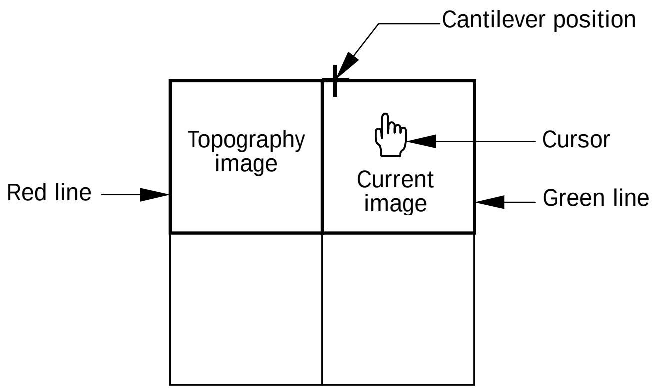
   Both a topography image and a current image are usually acquired to determine a point for measurement, but it is easier to determine the measurement point on a current image because there are points where no current flow is observed on some specimens.
2. Click on the "Tip" button in the "SPM Parameters" window to open the "Tip" window.




**3.** Click on the check box for “Tip Retract” to make it checked.

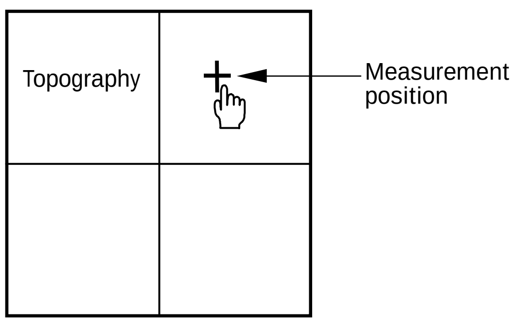
**4.** Click on the “Position” button in the “Tip” window.

The “Tip” and “SPM Parameters” windows will close and the “Tip position” window will open. Move the cursor to the current image in the Display Window; then the cursor changes to a hand mark. The present cantilever position is indicated by the “+” mark. Usually, the initial position is the top-left corner of the frame.




The cursor is in effect only within the active window (the image surrounded by a green line). The image surrounded by a red line is not active now. If the current image is acquired according to Subsection 6.12.2, the image is grabbed later and becomes an active window.

**5.** Move the cursor to the cantilever position (“+”); press the left mouse button and drag it, while holding down the left mouse button, to the point where I-V measurement is to be performed.




The cantilever is actually moving in real time during the cursor dragging, so be sure to drag the “+” mark slowly.

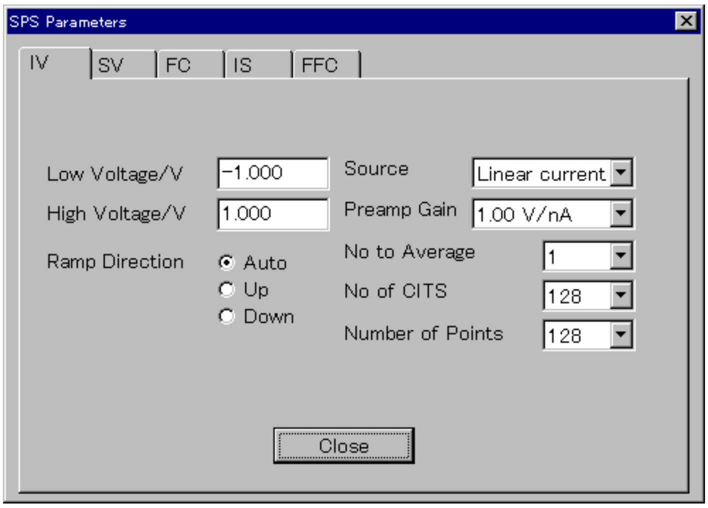
**6.** After placing the "+" mark at the measurement point, press the right mouse button.

The "SPS Parameters" and "Tip" windows will be displayed.

**7.** Deselect "Tip Retract" by clicking on the ⌡ mark for "Tip Retract"; the mark will change to "☐."

**8.** Click on "SPS Param" on the "SPM Parameters" window.

The "SPS Parameters" window will appear. Click on the "I-V" tab.



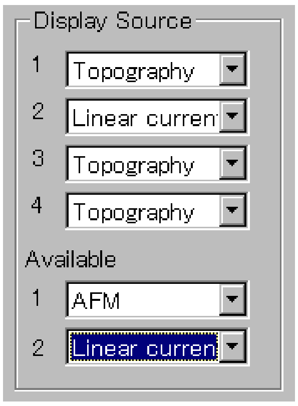

**9.** Set the parameters for I-V measurement according to the following procedure.

**a.** Set the voltage at which to measure I-V.

- Double-click on the input box for "Low Voltage/V" and enter a voltage using the keyboard. Here, it is assumed that the I-V measurement range is to be from –1.0 V to +1.0 V. So, enter –1 using the keyboard.
- Double-click on the input box for "High Voltage/V" and enter a voltage using the keyboard. Here, enter 1 based upon the same assumption as above.

Note: In this system, the offset current is capacitance-corrected in such a way that when the input voltage is 0 V, the current is 0 nA. Therefore, the Low and High Voltages must be entered so that they encompass 0 V.

**b.** Click on the "▼" mark in the "Available Source 2" selection box on the "SPM Parameters" window and select "Linear current" from the pull-down menu. Click on the "▼" mark in the "Source" selection box in the I-V frame on the "SPS Parameters" window and select "Linear current" from the pull-down menu.



**c.** Click on the “ ” mark in the “Preamp Gain” selection box in the I-V frame on the “SPS Parameters” window and select “1.00 V/nA” from the pull-down menu. This value determines the preamplifier gain for I-V measurement. If the measured current gets saturated, decrease this setting value.

**d.** Select “Auto” by clicking o the radio button for “Ramp Direction”; the button changes to “⁄.”

“Ramp Direction” determines the scanning direction of the bias voltage for I-V measurement. If “Auto” is selected, scanning is performed from a voltage near the voltage set in the “Bias/V” on the “SPM Parameters” window.

**[Example]**: If “Bias/V” is set to 1.0 V, and “Low Voltage/V” and “High Voltage/V” are set to –1.0 V and 1.0 V respectively, the scanning is performed from +1.0 V to –1.0 V.

If the selection is “Up,” the scanning is performed from a low voltage to a high voltage regardless of the value set in “Bias/V.” If “Down” is selected, the scanning is performed from a high voltage to a low voltage.

**e.** Click on the “ ” mark in the “No to Average” selection box and select “1” from the pull-down menu.

This specifies the number of I-V measurements for data averaging. Increasing the number of measurements is effective particularly when data is noisy or when a very small current must be measured.

**f.** Click on the “ ” mark in the “Number of Points” selection box and select “128” from the pull-down menu.

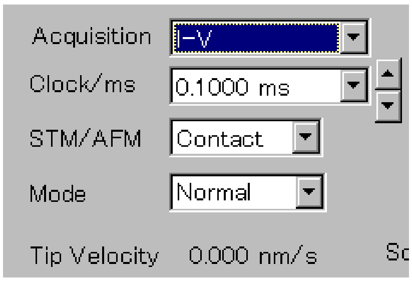
This specifies the number of points for I-V measurement. The maximum number is 2048 points.

Note: “No of CITS” on the “SPS Parameters” window has nothing to do with the I-V measurement.

The above procedures are a typical example of parameter setting in the “SPS Parameters” window. Summarized below is an example of parameter setting to perform I-V measurement in the scanning range between –1.0 V and +1.0 V.

| I-V | | | |
|---|---|---|---|
| Low Voltage/V: | –1.0 | Source: | Linear current |
| High Voltage/V: | 1.0 | Preamp Gain: | 1.00V/nA |
| Ramp Direction: | ⦿Auto | No to Average: | 1 |
| | | No of Points: | 128 |

**10.** Click on the “ ” mark in the “Acquisition” selection box and select “I-V” from the pull-down menu.



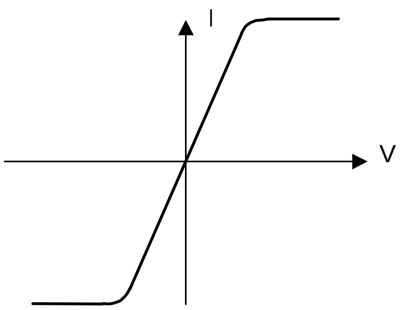

**11.** Click on the “Repeat” button on the “SPM Parameters” window.

The I-V measurement will start.

When you want to change the I-V display method, change it on the “Plot parameters” after grabbing the data.

Notes: 1. If the measurement position is changed with this method, the changed position becomes the initial position. Therefore, when scanning has been finished or “Abort” has been performed, the tip is at the initial position.

2. If the I-V measurement data is saturated as shown in the figure below, decrease the value set in “Preamp Gain” on the “SPS Parameters” window.




3. If no stable data is obtained at the same measurement point or unreasonable data is obtained, the cantilever might be irregularly bent due to an electrostatic force during the measurement. In such a case, try to reduce the I-V scanning voltage range.

4. Parameter change during I-V measurement might cause incorrect data. Parameter change must be done while the measurement is suspended.

# 6.13 OBSERVATION IN STM MODE (ADVANCED)

The SPM head unit with a tip holder is used for STM (Scanning Tunneling Microscope) observation. Described in this Section is the procedure for observing an STM image using the STM mode "Advanced" control panel. It is possible to set parameters in detail on the "Advanced" control panel, but every parameter must be set.

## 6.13.1 Check Before Approaching

Before performing approaching, check whether the preparation has been completed according to the procedures in Section 6.3.

- Has rough approaching been executed in such a way that the distance between the cantilever and the specimen surface is 0.3 mm or less ?
- Is the Z stage position in the approaching-possible range ?

## 6.13.2 Setting Oscilloscope (option)

After setting the optional oscilloscope according to Subsection 6.3.4, set CH2 as follows.

◆ Set the SELECT knob on the SPM CONTROL unit to "LOG."

Then, the LOG I signal can be monitored.

## 6.13.3 Setting Control Panel

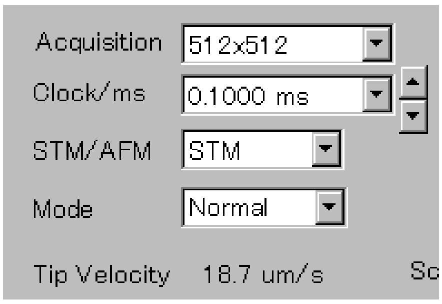
Start the system according to the start-up procedure in Subsection 6.2.1 "System Startup."

**1.** Click on "SPM Scan" on the main menu and select "Scan···" from the pull-down menu.

The "SPM Parameters" window will be displayed. Click on the "Advanced" tab.

**2.** Set each parameter according to the following procedures.

**a.** Click on the " " mark in the "Acquisition" selection box and select "512×512" from the pull-down menu.




**b.** Click on the " " mark in the "Clock/ms" selection box and select "0.1000 ms" from the pull-down menu.

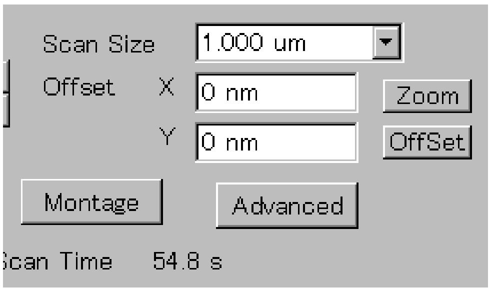
This is the parameter that determines the scan speed. Naturally, this parameter should be changed according to the observation area and the unevenness of the specimen. Here, set it to "0.1000 ms" provisionally.

**c.** Click on the " " mark in the "STM/AFM" selection box and select "STM" from the pull-down menu.

This changes the SPM CONTROL unit to the STM mode.

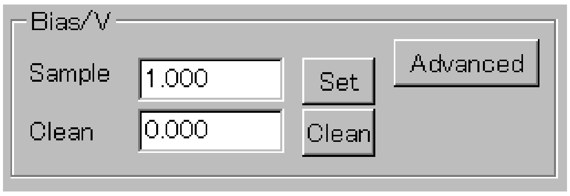
**d.** Click on the “ ▼ ” mark in the “Mode” selection box and select “Normal” from the pull-down menu.

**e.** Click on “Scan Size”. When the numerical value is highlighted, enter 1 um using the keyboard and finalize the numerical value by pressing the “TAB” key. Or, click on the “ ▼ ” mark in the “Scan Size” selection box and select a numerical value near “1,000 nm.”



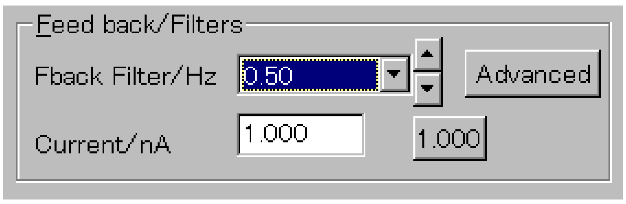

Note: Here, it is assumed that the standard scanner (scanning range is 10 μm×10 μm) is installed. In practice, set an appropriate value according to the observation area you want to observe.

**f.** Click on “Sample.” When the numerical value is highlighted, enter 1 using the keyboard and finalize the numerical value by pressing the “TAB” key.




The “Sample” value should be changed according to the specimen to be observed. If it is a conductive specimen like a metal specimen, set a small numerical value (0.2 V or less), and set a large numerical value (1.0 V or more) for a semiconductor specimen or a specimen having an oxidized film.

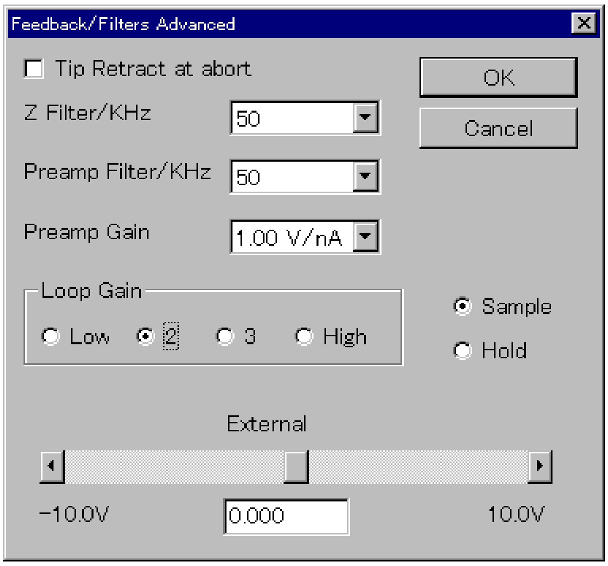
**g.** Click on the “ ▼ ” mark in the “Fback Filter/Hz” selection box and select “0.5” from the pull-down menu.




“Filter/Hz” is the parameter that determines the response speed of the feedback circuit. The larger the set value is, the faster the response speed becomes, thus producing a sharp image, but the feedback circuit becomes prone to oscillation. Usually, set the highest speed at which the feedback circuit does not oscillate while watching an image during scanning.

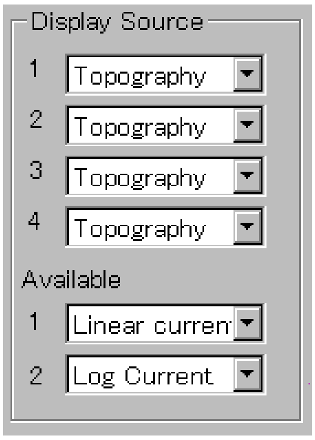
**h.** Double-click on “Current/nA.” When the numerical value is highlighted, enter 1 using the keyboard and finalize 1 by pressing the “TAB” key.
“Current/nA” specifies the tunneling current flowing between the specimen surface and the cantilever tip. You have to change the “Current /nA” value while watching an image during scanning. Here, set it to “1.000” provisionally.

**i.** Click on the “Advanced” button in the “Feedback/Filters” frame.
The “Feedback/Filters Advanced” window is displayed.




Select “2” of “Loop Gain.” To select “2,” click on the radio button located on the left of “2.” When this button is selected, the button changes to ⁄. The setting determines the gain of the feedback circuit. If it is set to “High,” the response gain increases, thus causing an uneven specimen surface to be easily observed, but the feedback circuit becomes prone to oscillation.

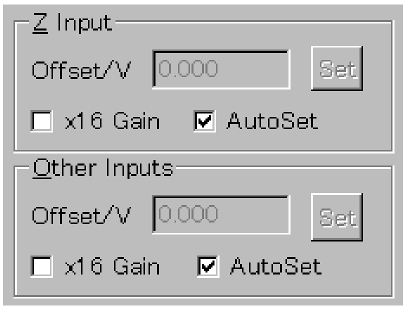
**j.** Click on the “ ” mark in the “Available Source 1” selection box and select “Linear current” from the pull-down menu.



**k.** Click on the “ ” mark in the “Available Source 2” selection box and select “Log Current” from the pull-down menu.
These two parameters are for selecting the signals input to the A/D board. Here, set the parameters as shown above.

**l.** Click on the “ ” mark in the “Display Source 1” selection box and select “Topography” from the pull-down menu.

**m.** Click on “Auto” in the “Display” frame to change “☐ Auto” to “⌋ Auto.”




**n.** Click on “×16 Gain” in the “Z Input” frame to deselect the setting.
When the setting is deselected, the ⌋ mark changes to ☐.

**o.** Click on “Auto Set” in the “Z Input” frame to change. “☐ Auto Set” to “⌋ Auto Set.”
The check boxes, ☐ and ⌋, are toggle boxes. Each time the mouse is clicked on these boxes, the settings are changed. When the ⌋ mark is displayed, the parameter item to which this mark is attached is selected.

The setting of various parameter items required for image observation in the Contact mode (Advanced) has so far been explained. It is summarized as shown below. If any of the settings differs from the setting shown in the table, the normal functions may be disturbed. Check the parameters referring to the parameter setting below.

| | | | |
|---|---|---|---|
| Acquisition: 512×512<br>Clock/ms: 0.1000ms | | Scan Size: 1um<br>Offset X: 0nm<br>Y: 0nm | |
| STM/AFM: STM | | | |
| Sample: 1.000<br>Clean: 0.000 | | Fback Filter/Hz: 0.5<br>Current/nA: 1.000 | |
| Display Source<br>1: Topography 2: Topography<br>3: Topography 4: Topography<br>Available Source 1: Linear current<br>2: Log Current | Display<br>☑ Auto | Z Input<br>☐x16 Gain<br>Other Inputs<br>☐x16 Gain | <br>☑ Auto Set<br><br>☑ Auto Set |

| Scan Advanced | |
|---|---|
| Image Angle: 0.0 | |
| ☐Add External X Signal | Scan Filter |
| ☐Add 〃 Y 〃 | ⊙4 High frequency |
| ☐ 〃 〃 Z 〃 | |
| ☐ 〃 〃 Bias 〃 | |

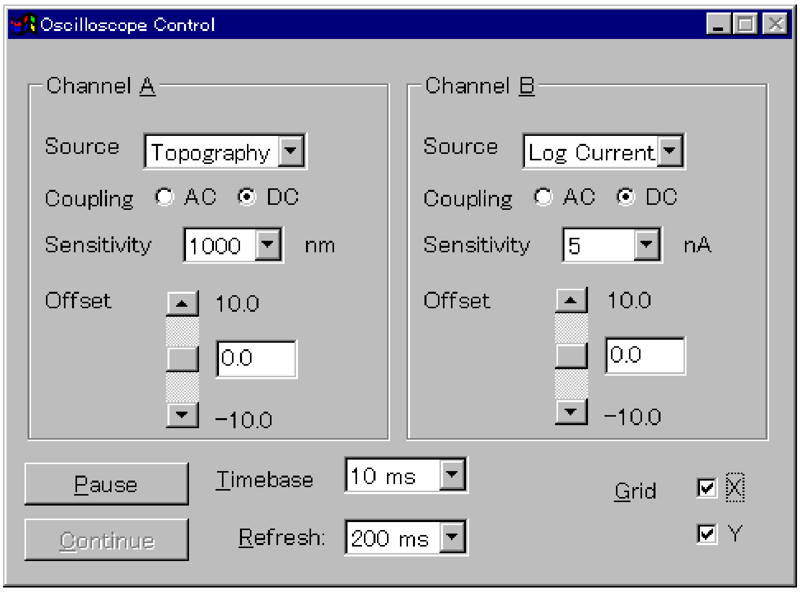
| Bias Advanced | |
|---|---|
| Back Scan: | 0.000 |
| Offset: | 0.000 |

| Feedback/Filters Advanced | | |
|---|---|---|
| ☐ Tip Retract at abort | | ⊙Sample |
| Z Filter/kHz: | 50 | ○Hold |
| Preamp Filter/kHz: | 50 | |
| Preamp Gain: | 1.00V/nA | |
| Loop Gain: | ⊙2 | |
| External Offset: | 0.000 | |

### 6.13.4 Setting Software Oscilloscope

Set the software oscilloscope according to Subsection 6.3.3; then set CH B as follows.

1. Click on the “🗗” mark in the “Oscilloscope···” button. The “Oscilloscope Control” window will open.



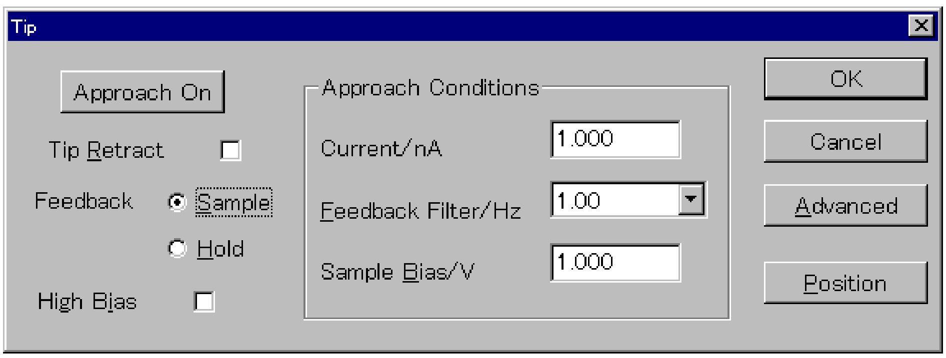

2. Click on the “▼” mark in the “Source” selection box in the “Channel B” frame; then select “Log Current” from the pull-down menu.
3. Click on the “▼” mark in the “Sensitivity” selection box in the “Channel B” frame; then select “5” from the pull-down menu.

Then, the Log I signal can be monitored.

### 6.13.5 Approaching

Move the cantilever closer to the specimen until the value of the tunneling current becomes the value specified in “Current/nA.” The cantilever movement automatically stops when the tunneling current reaches the value set in “Current/nA”. The following is the procedure for approaching.

1. Click on “SPM Scan” in the main menu and select “Scan···” from the pull-down menu. The “SPM Parameters” window will appear.
2. Click on the “Tip” button on the “SPM Parameters” window. The “Tip” window will appear.



**3.** Set each parameter according to the following procedures.

**a.** Double-click on the “Current/nA” input box. When the numerical value in the box is highlighted, enter 1 using the keyboard. Press the “TAB” key on the keyboard to finalize the value (“1”).

**b.** Click on the “ ▼ ” mark in the “Feedback Filter/Hz” selection box and select “1.00” from the pull-down menu.

Now, the Current/nA value and the response speed of the feedback circuit, which are used for approaching, have been determined. To prevent the cantilever from colliding with the specimen, set “Feedback Filter/Hz” to a value higher than that for image observation.

**c.** Confirm that “Sample” in the “Feedback” line is selected (marked “✓”). If “Hold” is selected (marked “✓”), click on the radio button for “Sample.”

**d.** Click on the “⌋” mark for “Tip Retract” to deselect Tip Retract (the mark changes to “☐”).

**4.** Confirm the following points before performing approaching.

- The voltage applied to the Z scanner is +150 V.

  Check the voltage applied to the Z scanner using CH1 of the optional oscilloscope or Channel A (red) of the software oscilloscope. When checking it with the oscilloscope, read the CH1 voltage as 10 times the voltage displayed. For example, if the displayed voltage is +15 V with the 5 V/div scale, the actual voltage is +150 V. When it is checked with the software oscilloscope, the vertical axis indicates not a voltage but a scanner displacement in nm depending upon the Z sensitivity of the scanner. With the standard scanner, 3 µ m corresponds to 1500nm.

  If the voltage applied to the Z scanner does not reach +150 V, it is judged that the approaching has already been completed. So, approaching will not start even if the “Approach On” button is clicked on. In such a case, check the following points.

- Make sure that “Loop Gain” is not set to “Low.”

  “Loop Gain” must be set to the 2nd position or higher. If it is set to “Low,” the gain of the feedback circuit is so small that the feedback voltage is not supplied until it reaches +150 V.

- Make sure that “Feedback” is not set to “Hold.”

  “Sample” on the “Feedback/Filters Advanced” window (opened when you click on the “Advanced” button in the “Feedback Filters” sub-frame on the “SPM Parameters” window) must be selected (“✓”). If “Hold” is selected, the feedback circuit is fixed with a certain voltage and does not function.

- Make sure that the tunneling current is already flowing.

  If “Current/nA” is set to a small value near 0 V, noise or a similar component may be mistaken for a tunneling current, thus resulting in performing no approaching (the computer judges that approaching has been completed). In such a case, select “Approach Off”; set a larger value for “Current/nA”; then try to find a “Current/nA” where the Z voltage becomes +150 V.

**5.** Click on the “Approach On” button on the “Tip” window.

The motor for approaching starts to rotate and automatically stops when the tunneling current becomes the same as the value set in “Current/nA.” Confirm if approaching has completed, using the oscilloscope or the software oscilloscope.

- When confirming it with the oscilloscope or the software oscilloscope, check that the Z voltage (CH1 or Channel A (red)) has come closer to 0 V than the value it had when approaching started.

**6.** Click on the “Approach Off” button in the “Tip” window.

You may hear an oscillation sound coming from the instrument when approaching is completing. This is because the setting of the feedback filter is so fast that it oscillates. To stop the oscillation sound, click on the “Approach Off” button in the “Tip” window. Then, the feedback filter value is returned to normal scanning specified in the “Feedback/Filter” frame in the “SPM Parameters” window. If the sound continues, click on the “  ” mark in the “Feedback Filter/Hz” selection box and select a slow filter (a smaller value) from the pull-down menu.

## 6.13.6 Image Observation

When approaching has completed, carry out scanning.

### ■ Starting scanning

◆ Click on the “Repeat” button in the “Scan” frame in the “SPM Parameters” window.

Scanning will start and an image will appear in the Display Window. In the case of the STM mode, an important factor for obtaining a quality image is the setting of Bias Voltage and Current . If this setting is inappropriate, not only can a quality image not be obtained, but also the specimen and the tip may be damaged.

### ■ Setting Sample Bias and Current

The distance between the specimen surface and the tip is controlled by adjusting Bias/V and Current/nA. If Sample Bias is set to a small value and Current/nA to a large value, the distance between the specimen surface and the tip becomes short. Theoretically, the resolving power improves, but the tip could easily collide with the specimen.

**CAUTION**

**If the Sample Bias is set by using the bar-chart during image observation, be careful not to move the bar-chart button across 0 V. The tip would collide with the specimen surface if the bias voltage became 0 (zero).**

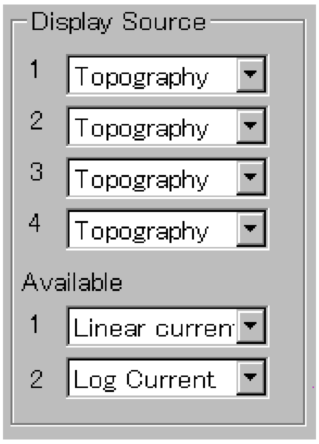
## 6.13.7 Current Image Observation

The operation procedures for image observation in the STM mode that have been explained so far in this Section are for the constant-current STM mode used to observe the topography of a specimen while keeping the tunneling current constant. In this mode it is also possible to observe a current image by obtaining the change of the current as an image while keeping the tip height constant. The following is the procedure for observing a current image.

**1.** Carry out approaching according to the procedures in Subsections 6.13.1 through 6.13.5.

Note: If approaching has already been completed, this operation is not necessary.

**2.** Click on the “ ” mark in the “Display Source 2” selection box in the “SPM Parameters” window and select “Log Current” from the pull-down menu.



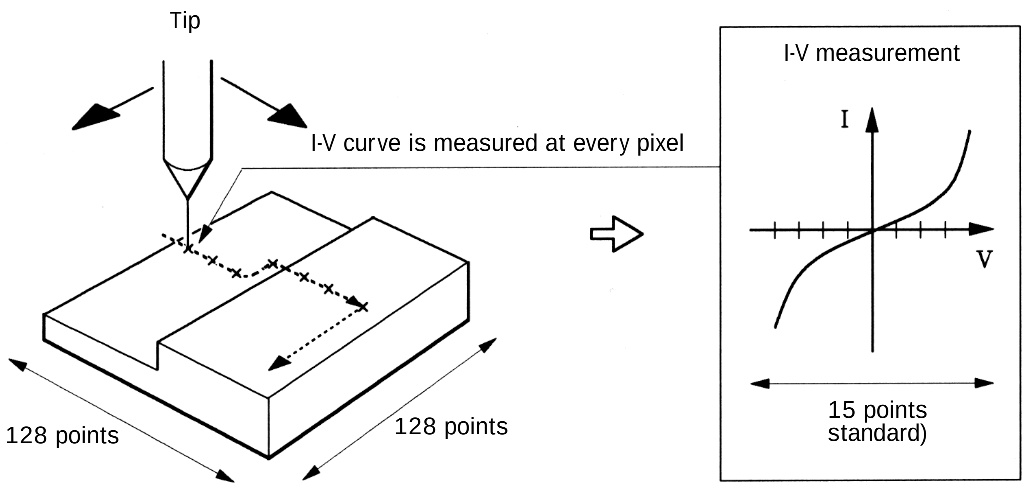

**3.** Click on the “ ” mark in the “Fback Filter/Hz” selection box and select “0.5” from the pull-down menu.

Usually, a Force image is observed by applying a very slow feedback while keeping the height constant. Use a slower response for the feedback than that used for observing a topography image. For current-image observation, use “Log Current” instead of “Linear Current.”

**4.** Carry out current-image observation according to the procedure in 6.13.6 “Image Observation.”

## 6.13.8 CITS Image Observation

A CITS (Current Imaging Tunneling Spectroscopy) image is a tunneling current image produced when applying an optionally designated bias voltage while keeping the distance between the tip and the specimen surface (determined by the topographic image observation conditions such as tunneling current and bias voltage) constant. I-V curves and data averaging at designated points on the specimen can also be obtained from the image captured in the CITS menu. In the case of CITS, unlike STS, I-V data is measured and an image is created at each pixel during tip-scanning, so there is no influence of specimen drift or hysteresis and the I-V curve at an arbitrary point of the image perfectly corresponds to the image points.




One method of determining the bias voltage is as follows.
Select a point where the image contrast varies greatly on an STM image and measure an I-V curve at that point once; then select the bias voltage of the position where the I-V curve varies greatly.
The values set for CITS measurement parameters such as “Low voltage” and “High voltage” are the same as those set for SPS Parameters.
The following is the procedure for observing a CITS image.

1. Click on the “SPS Param” button in the “SPM Parameters” window; set the I-V parameters using the same parameters set for I-V measurement. Click on the “ ▼ ” mark in the “No of CITS” selection box in the “I-V” frame and select “128.”
2. Perform the operations for STM observation according to Subsections 6.13.1 through 6.13.6 to observe an STM image.

   Note: Since a CITS image is scanned in a range of 128×128 pixels, specify “128×128” for STM observation too so that a quality image can be obtained.
3. Click on the “ ▼ ” mark in the “Acquisition” selection box in the “Scan” frame in the “SPM Parameters” window and select “CITS” from the pull-down menu.
4. Click on the “Repeat” button in the “SPM Parameters” window.

   The CITS measurement will start. The acquired CITS images will be displayed on the Display Window.

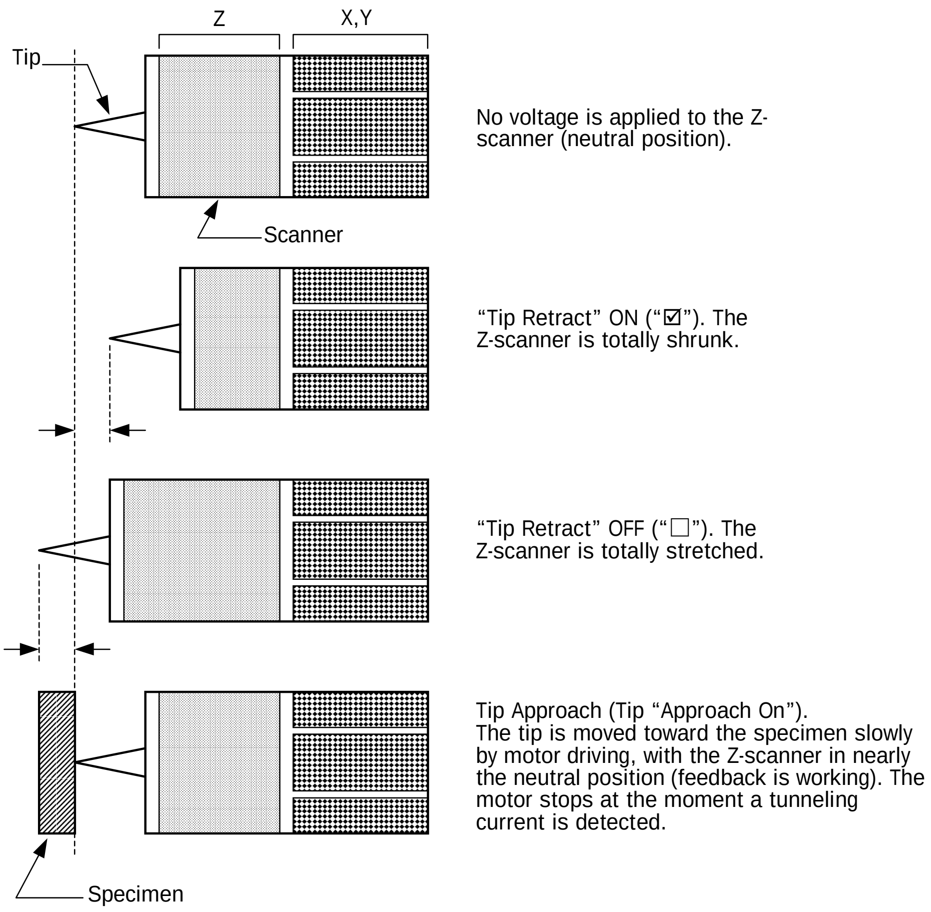
   Note: CITS images are displayed on one screen with divided frames. During scanning, the imaging on each divided frame progresses simultaneously in real time. Watch the progressing images on the screen, and if you are satisfied with the quality of the images, grab the images before the present frame scan is completed. Otherwise, the next frame scan starts automatically without storing the data when the present scan finishes.

# 6.14 GENERAL NOTES ON IMAGE ACQUISITION

Described in this Section are the scanning method for image acquisition and other notes.

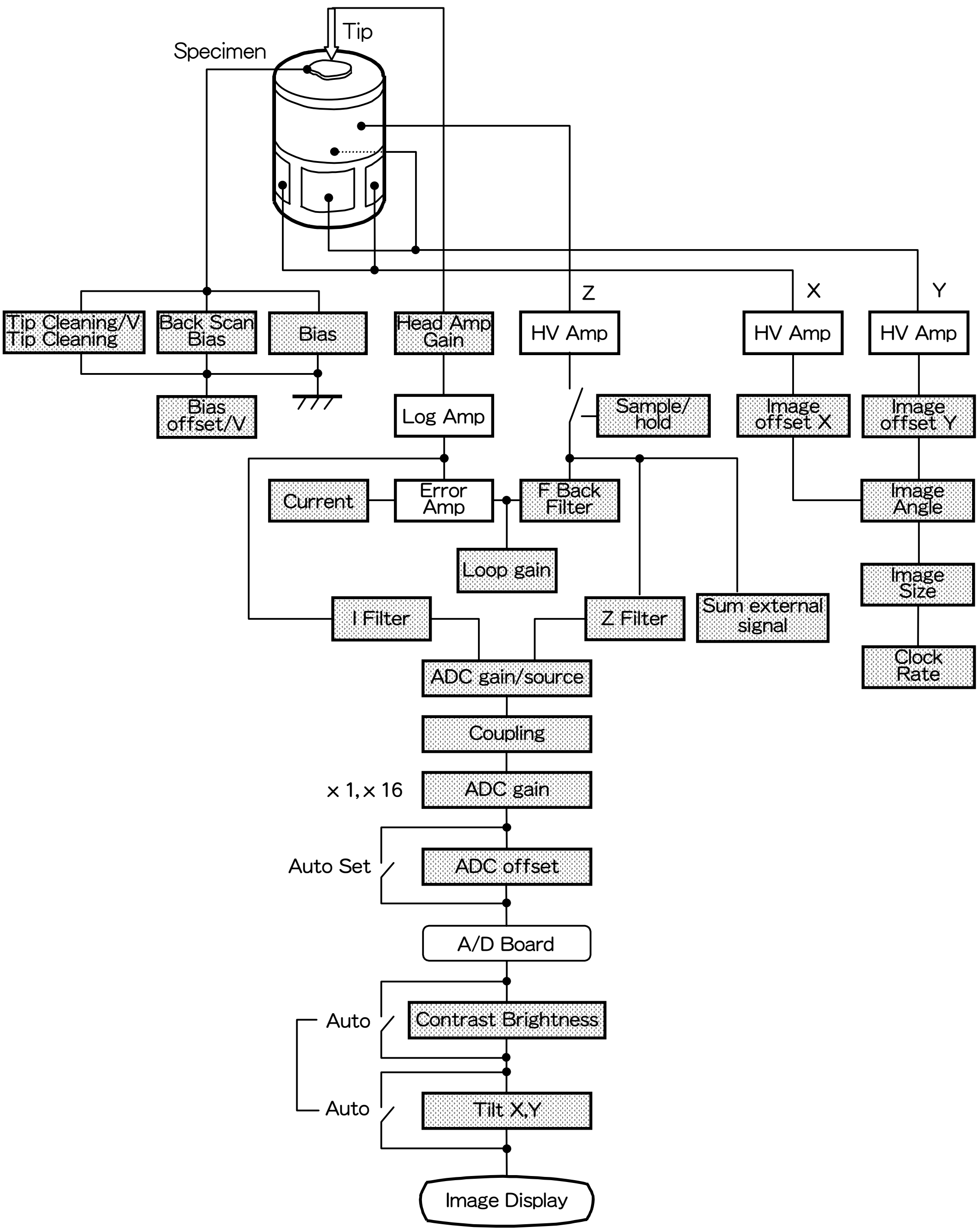
## 6.14.1 Tip Retract

The tip positions in the Z direction at neutral, tip retract on, tip retract off and approach are shown below. “Tip Retract On” is used when the tip must be retracted temporarily.



## 6.14.2 Block Diagram of Software Parameters

A block diagram of each software parameter is shown below.

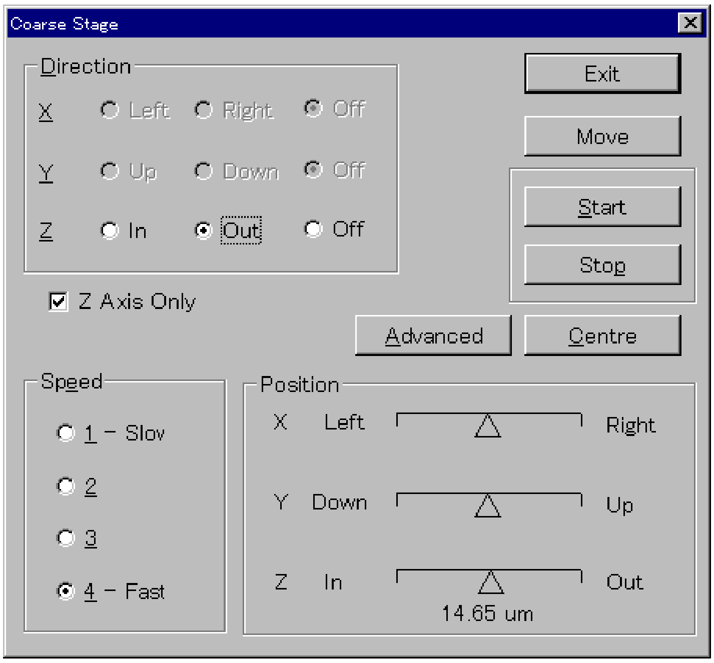



**Block diagram of the control system**

### 6.14.3 Z Position Readjustment

During scanning, stage drift may cause the tip position to change along the Z-axis (the Z/10 value on the oscilloscope may deviate greatly from 0). In such a case, you can move the tip while performing approaching. Readjust the Z position according to the following procedures.

1. Click on the “Abort” button in the “Scan” frame in the “SPM Parameters” window to stop scanning.
2. Click on the check box for “Tip Retract” in the “Tip” window to make it checked (“√”).
   The tip will be retracted. The purpose of this operation is to prevent the tip from colliding with the specimen during motor driving.
3. Click on the “Coarse Stage” button in the “SPM Parameters” window to open the “Coarse stage” window.




4. If the tip is too close to the specimen, click on the radio button for “Out” in the “Direction” frame (“⁄”), or if the tip is too far from the specimen, select “In.”
   Note: For the JSPM-4200 series, “Z Axis Only” and “4-Fast” for “Speed” selection are in effect.
5. Click on the √ mark for “Tip Retract” in the “Tip” window to remove the check mark (“☐”).
   Confirm with the oscilloscope that Z/10 is close to 0. If not, repeat steps 2 and 5 above.
   Note: The specimen-stage Z-axis motor-driving mechanism can be mechanically dismounted to shut out external disturbances such as vibration and noises. When the motor-driving mechanism is rotated backward for dismounting, there is a backlash of about 3/10 of a revolution.

### 6.14.4 Shifting Observation Field (Large Shift)

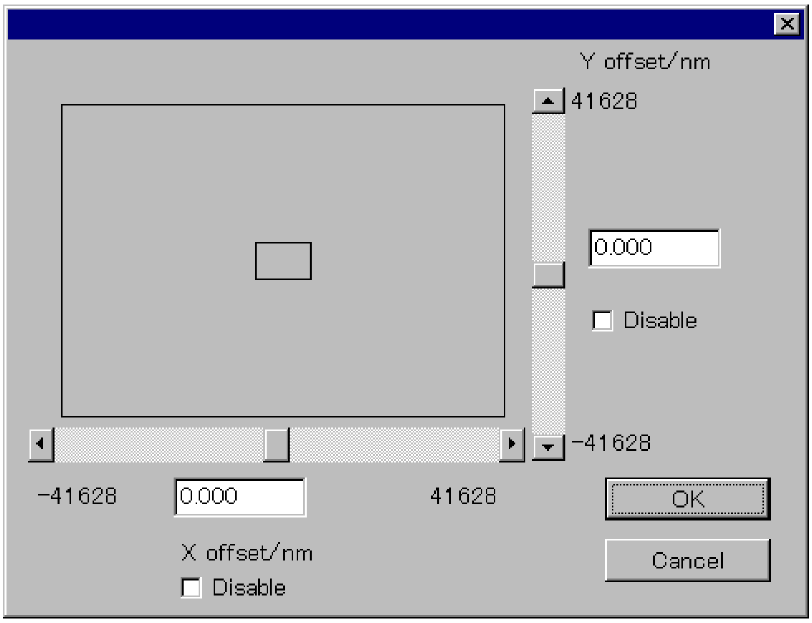
When you want to greatly shift the observation field, retract the tip or cantilever according to the procedure in Section 6.15 “Cantilever/Tip Retraction”; then shift the specimen stage manually.

### 6.14.5 Shifting Observation Field (Small Shift)

When you want to shift the observation field a little within the scanner movement range, shift it according to the following procedures.

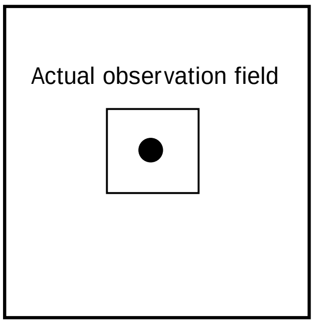
**1.** Click on the “Offset” button in the “Scan” frame in the “SPM Parameters” window.

The Offset window will be displayed.




**2.** Shift the observation field using the X and Y scroll bars or drag the field directly.

The correspondence between the actual observation field and the maximum observation field is shown below.




Maximum observation field

Note: Shift the observation field very slowly.

### 6.14.6 Storing Data in Computer Memory (Grab)

The image that is being scanned and I-V data are cleared when the next scan is started. The following is the procedure for grabbing the data in the computer memory.

Note: This operation is used to store data in the RAM of the computer temporarily. The stored data is cleared when the SPM software is terminated. If you want to save the data for later use, the data must be saved on the disk using the image-saving operation.

1. When data that you want to save is obtained, click on the “Grab” button in the “Scan” frame in the “SPM Parameters” window.

   Be sure to click on the button while the scan is in progress, as the acquired data in the frame memory is cleared at the beginning of the next scan.
2. When the “Grab” button has been clicked on, the image data is normalized after scanning of one image completes, and the “Title” dialogue box will open, prompting you to enter an image name (title). Enter the title using the keyboard.

   Note: The title is not a file name used for transferring the data to and from the disk, but is simply a title of the image used for identification and selection of the data. Therefore, an easily understandable name is preferable.
3. The image data will be stored in the computer memory. If you want to continue the scanning, click on the “Repeat” button in the “Scan” frame again.
4. Then, the next image will be scanned. Grab (store) the image data in the computer memory following steps 1 to 3 above.
5. After finishing the observation and retracting the tip, save the image data on a disk, if necessary.

- Difference between an image displayed during scanning and a grabbed image

  An image displayed during scanning is sometimes very different from a grabbed image. This is because

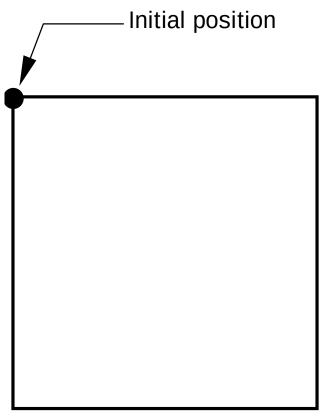
  During scanning: The brightness and contrast are adjusted at the highest and lowest signal levels within one scanning line.

  Grabbed image: The brightness and contrast are adjusted at the highest and lowest signal levels within the entire image.

  Therefore, if the specimen surface has a difference in level or the Z-axis shifts unexpectedly, the brightness and contrast may differ greatly between the two images. This phenomenon often occurs during observation in the contact mode at high magnifications. This is supposed to occur due to the bending of the cantilever during scanning. To avoid this phenomenon, you should carefully make a fine adjustment of “Reference/V.”

## 6.14.7 Notice for Auto Set

If “Auto Set” is selected for “Offset/V” in the “Z Input” and “Other Inputs” frames in the “SPM Parameters” window, the offset is measured before an image is acquired. The offset of the Z-axis voltage is measured at the initial position as shown in the figure below, and an offset is automatically set so that this value becomes zero.




If the specimen height level at the initial position, where the offset was measured, is high (protruding) or low (hollow), or the specimen surface is extremely inclined, the image may become black or white during scanning, thus resulting in no image contrast. In such a case, change the observation area or deselect “Auto Set” by clicking on the “✓” mark for “Auto Set” and set “Offset/V” manually.

## 6.14.8 Saving Image

Image data stored in the computer memory should be saved on a disk for later use. Of course, you can save processed data (such as those output after image processing and data processing), but do not forget to save the original data. For convenience’s sake, it is suggested that you make a data directory and write a comment for each data.

Note: Usually, the data are saved on a magneto-optical disk.

### ● Preparing Directory

1. Click on the Windows95™ “Start” button and select “Explorer” from “Program.”

   Note: For operational convenience, it is recommended that the SPM software be iconized by clicking on the  mark at the top-right corner of the SPM software window.

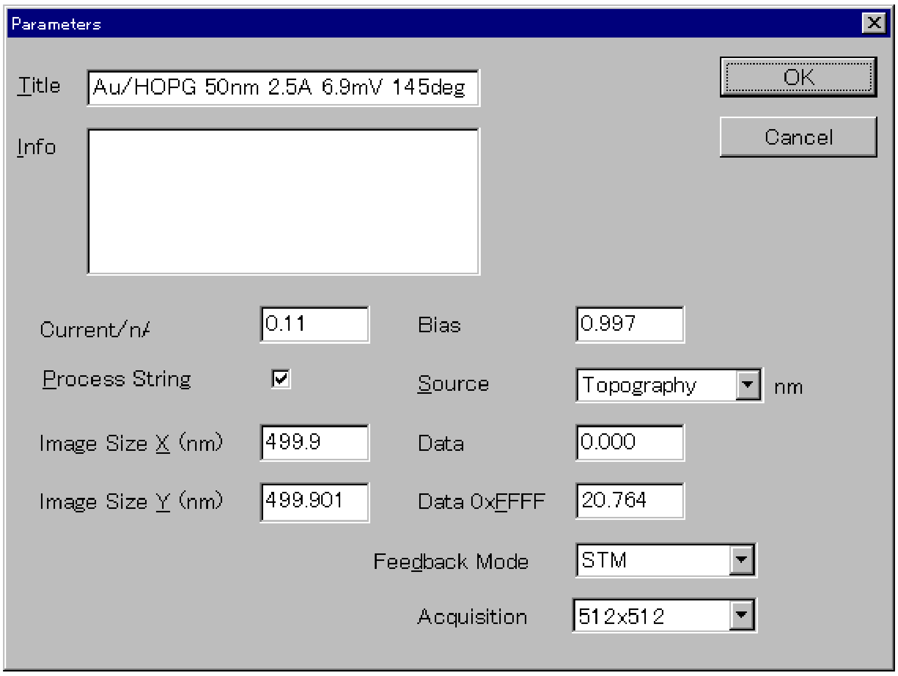
2. Create a directory using the “Explorer” function (“New Folder” in the “File” menu).

### ● Inputting comment

1. Display the image to be saved on the screen.

   Select the image from the list displayed by “Select” in the block menu.

2. Return to the menu; select “Display”; then select ”Change Para⋯.”




**3.** Enter the specimen name and observation conditions in the "Info" block in the "Parameters" window using the keyboard. After confirming the parameters, click on the "OK" button.

Note: You can freely enter any comment such as measurement conditions, which will be very convenient for later use.

**4.** Select "File" from the menu; then select "Save AS···" from the pull-down menu.

**5.** The "Save AS···" window will appear.

Enter a file name for the image to be saved and designate the directory in which the data is to be saved. Then, click on the "OK" button. The image data will be saved on the disk.

**6.** Repeat the procedures of this Subsection, as necessary.

# 6.15 RETRACTING CANTILEVER OR TIP AND TERMINATING MEASUREMENT

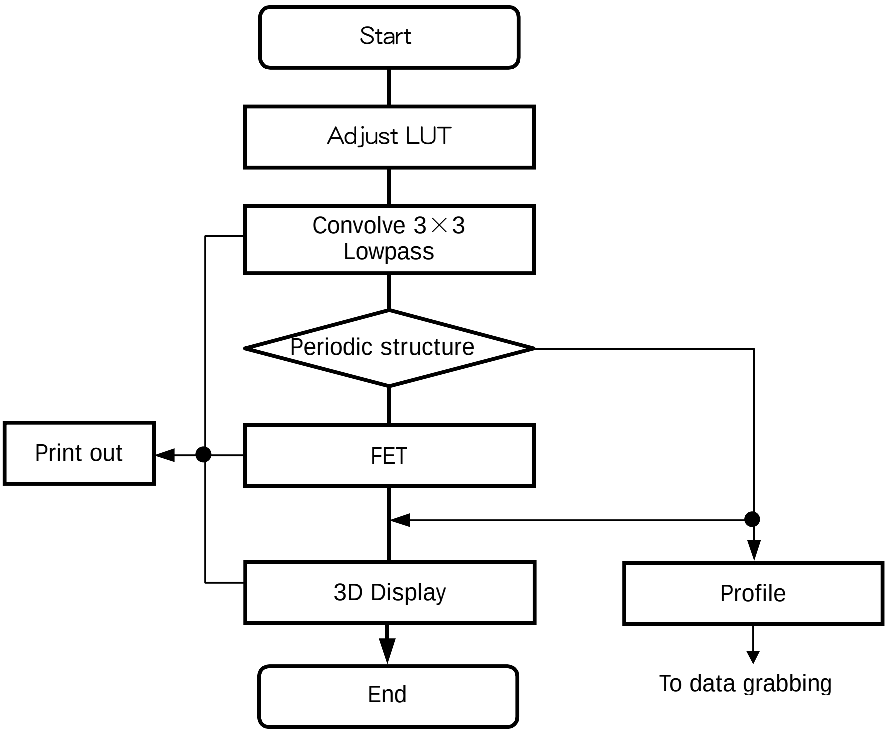
Described in this Section is the procedure for terminating the instrument operation after a series of operations has been completed.

1. Stop scanning by selecting the “Abort” button in the “Scan” frame in the “SPM Parameters” window.
2. Click on the “Tip” button in the “SPM Parameters” window to open the “Tip” window. Click on the check box for “Tip Retract” to make it checked (“✓”). The tip will be retracted.
3. Click on the “Coarse Stage” button to open the “Coarse Stage” window.
   The “Coarse Stage” window will appear.
4. Select “Out” for “Z” in the “Direction” frame (“⁄”); then click on the “Start” button in the “Coarse Stage” window. Retract the cantilever or tip far enough from the specimen surface.
   Note: In the JSPM-4200 series, “4-Fast” is the only “Speed” in effect.
5. Confirm that the cantilever or tip has retracted far enough from the specimen surface. Then, retract the cantilever or tip far away manually.

# 6.16 IMAGE PROCESSING

This system is provided with more than 100 image processing and analysis functions. In this Section, several of them are explained. For details, refer to Chapter 7 “REFERENCE.”

The following is the general flow of image processing.



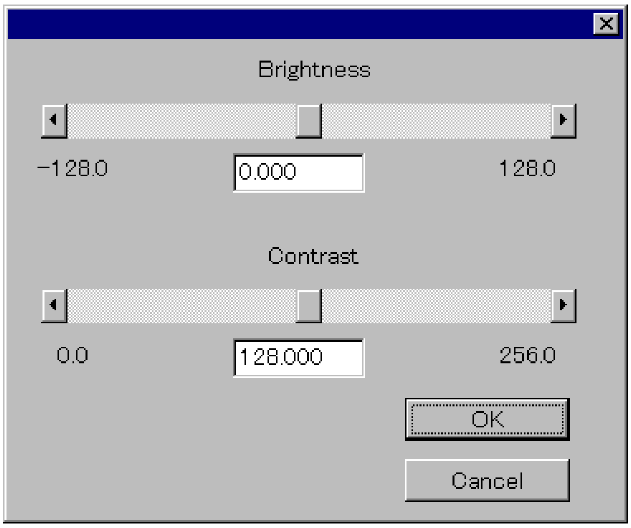

**General Image Processing Flow**

### 6.16.1 Adjust LUT

This function adjusts the brightness and contrast of a displayed image.

**1.** Select “LUT” from the menu bar of the SPM initial window “WINSPM.” Then, select “Adjust LUT” from the pull-down menu displayed just below “LUT.”

The image is displayed in the image-display window with 400×400 pixels, and bar charts for brightness and contrast adjustment are displayed in the “LUT Adjust” window.




**2.** While watching the displayed image, use the mouse to slide the buttons in the “Brightness” and “Contrast” bar charts so that the optimum image brightness and contrast are obtained.

**3.** After the optimum brightness and contrast are obtained, click on the “OK” button.

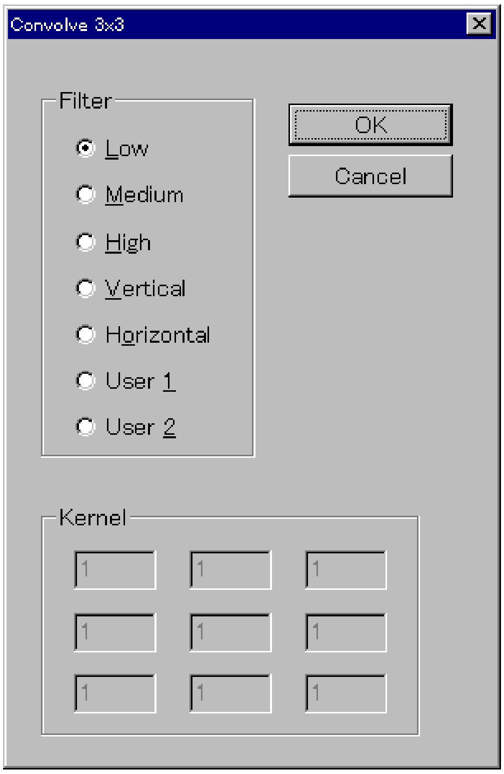
The displayed image will return to the original size (number of pixels) with the adjusted brightness and contrast.

### 6.16.2 Convolve 3×3 Low Pass Filter

This function eliminates unnecessary noise included in an image.

1. Select “Convolve 3×3” from the pull-down menu displayed just below “Process.”

   The “Convolve 3×3” window will be displayed.
2. Select “Low” in the “Filter” frame (“⁄”) and click on the “OK” button.




3. The selected filter function (low-pass filter) is applied to the image data and the filtered image will be displayed on the image-display window.

### 6.16.3 FFT

Apply FFT (Fast Fourier Transform) to periodic-structure images such as crystal or rearranged-structure images to obtain a diffraction pattern of the image. After masking the obtained diffraction pattern, apply inverse FFT to it to obtain a corresponding real image.

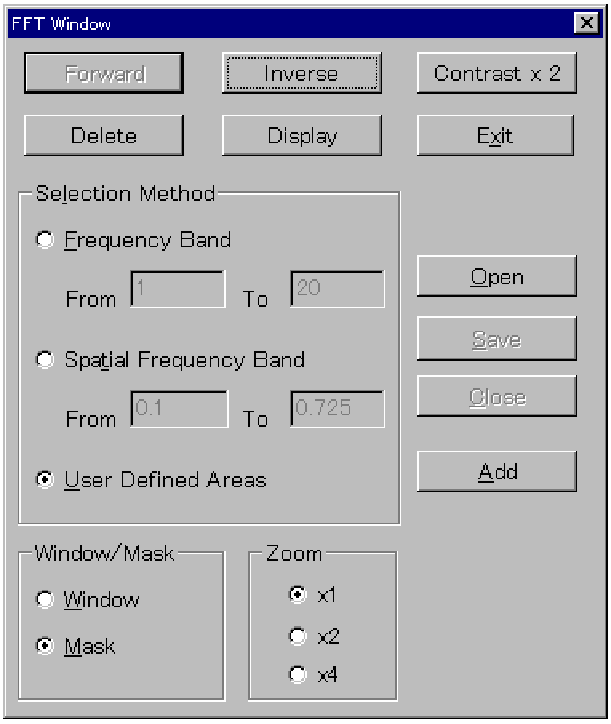
1. Select “FFT” from the pull-down menu displayed below “Analyze” to open the “FFT” window. Select “Forward” by clicking on the “Forward” button.

   FFT is executed, and when it stops, the diffraction pattern of the image will be displayed in the image-display window.
2. If the displayed diffraction-pattern spots are too dark for observation, select “Contrast×2” to enhance the contrast.

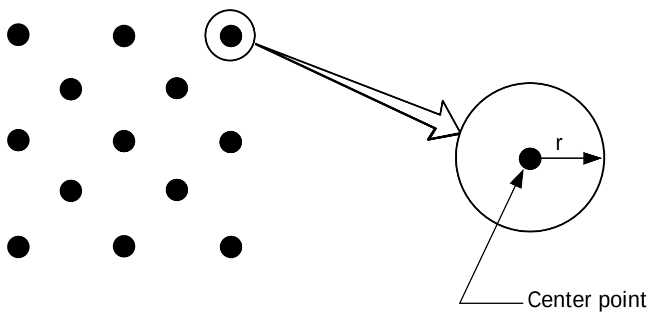
   Note: If you select “Contrast×2” once, the contrast increases to twice the original brightness, but you can select “Contrast×2” many times to further increase the contrast.

When you execute inverse FFT on a spot after eliminating other unnecessary spots, continue according to steps 3 through 6 below.

**3.** Select “Add.”




**4.** Apply a mask window on an effective spot.




Notes: 1. To set the mask window, move the cursor to the center of the spot to be masked and click the left mouse button. Then, move the cursor to a point at the distance of the masking area and click the left mouse button; the mask window will be displayed.

2. To delete the window, select “Window” (“⁄”) from the “Window/Mask” frame, and after designating the center of the masking area, move the cursor to a point at the desired distance and click the left mouse button. The circle with that radius will be erased.

3. To continuously designate or erase masking areas, select the “Add” button in the “FFT Window.”

**5.** Select the “Apply” button in the “FFT Window”; then select the “Exit” button in the same window.

Note: If this step is not performed, the masking can not be applied to the inverse FFT.

**6.** Select “Analyze” from the “WINSPM” menu bar and then “FFT” and “Inverse” from the pull-down menus successively displayed. A real image that is inversely transformed from the diffraction pattern will be displayed on the image-display window.

**7.** The message “Erase Mask ?” will appear in the dialogue box. If you do not want to keep the current masking in effect, click on the “OK” button.

## 6.16.4 3D Display

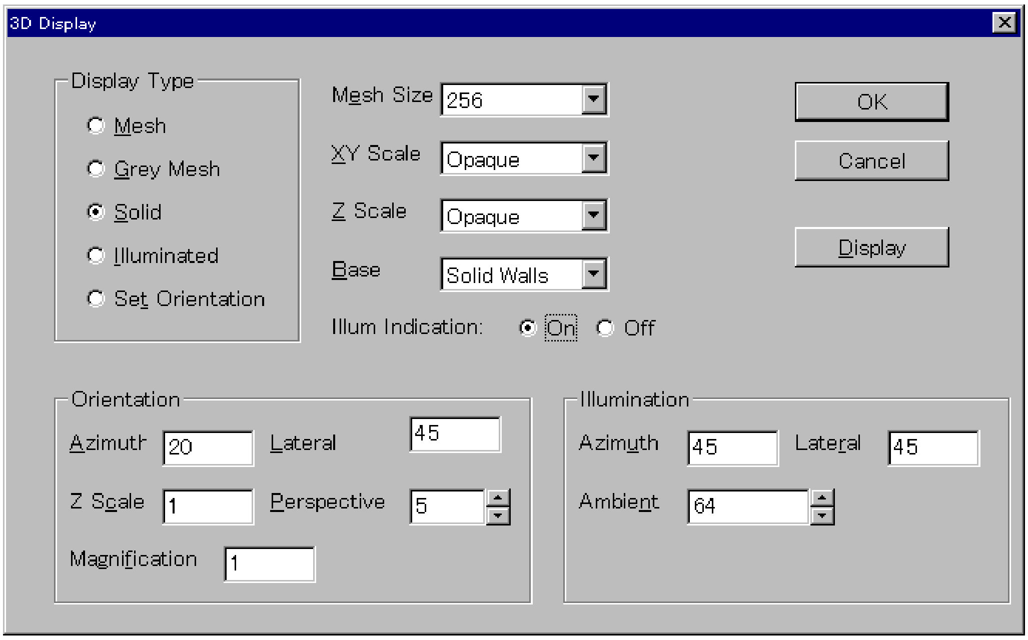
Three-dimensional display of an image is a simple and effective way to understand the surface structure of a specimen. This function can easily display an obtained image three-dimensionally.

In performing 3D display, pay attention to the following points.

Notes: 1. To make the mesh used for the 3D function small, a 512×512 pixel image must be used. If it is a 256×256 pixel image or one of a similar size, change it to a 512×512 pixel image using the “Resize” function in the “Geometry” pull-down menu.

2. If the surface structure of a specimen is too fine, enlarge the part of the image you want to display with the “Zoom” function in the “Analyze” pull-down menu. A clear three-dimensional image can be seen.

**1.** Select “Display” from the menu bar of the SPM initial window. Then, select “3D Display···” from the pull-down menu displayed just below “Display.” The “3D Display” window will appear.



**2.** Select “Set Orientation” by clicking on the radio button for “Set Orientation” in the “Display Type” frame (“⁄”), and click on the “Display” button.

The image will be displayed in the wire-frame mode.

**3.** Designate the viewing angle using the mouse.

Left-right movements of the mouse change the lateral angle, and up-down movements change the azimuth angle. When a suitable angle is obtained, click the right mouse button.

**4.** Set the display parameters in the “3D Display” window.

Ordinary values are shown below.

```
Display Type
  ⦿Solid
                    Mesh size           512
                    XY Scale            Opaque
                    Z Scale             Opaque
                    Base                Solid Walls
                    Illum Indication    ⦿off
Orientation
  Z                 1~5
  Magnification     1
```

Note: “Lateral” and “Azimuth” are set to the values selected in step 3 above.

**5.** Select “Display” by clicking on the “Display” button in the “3D Display” window.

A three-dimensional image will be displayed in the image display window.

## 6.16.5 Profile

For SPM it is often important to obtain information about the height of an image acquired. The profile function is used to obtain this height information.

Note: When you interpret the obtained height information, you should take it into consideration that the relation between the cantilever or tip shape and the specimen surface structure could sometimes produce deformed data.

**1.** Select “Analyze” from the menu bar of the SPM initial window. Then select “Profile” from the pull-down menu displayed just below “Analyze.”

The “+” mark will appear in the display window.

**2.** Designate the starting point of the line profile you want to measure, using the “+” mark.

Move the “+” mark to the starting point of the line profile you want to measure, and click the left mouse button.

**3.** Move the “+” mark to the end point and press the left mouse button.

A cross sectional profile along with the designated line will be displayed on the top left corner of the screen. The message “Keep profile ?” will be displayed.

**4.** If you want to process the obtained data, click on the “Yes” button.

Note: Data-processing functions available for “Profile” are distance measurement between two points in the profile, relative height difference measurement and enlarging of the profile.

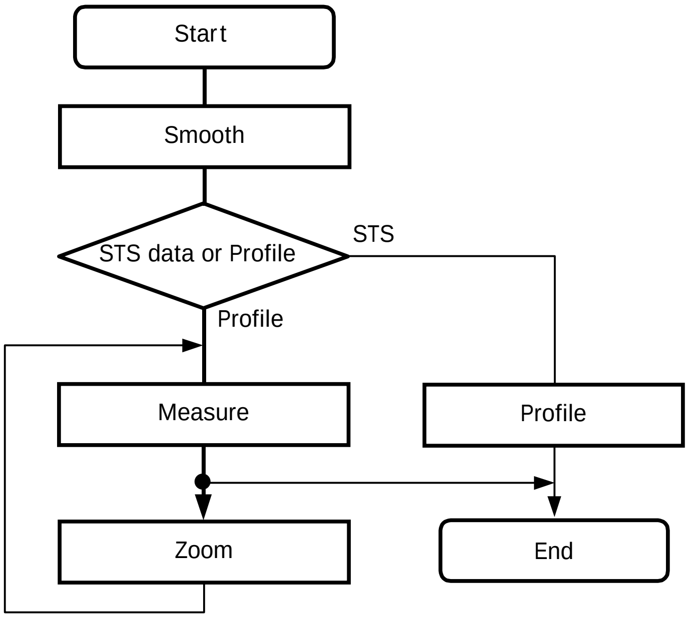
### 6.16.6 Image Printout

To print the displayed image, select “File” from the menu bar of the SPM initial window. Select “Print” from the pull-down menu displayed just below “File.”

Note: A video printer is available as an option. Since parameter setting for printing differs according to the type and model of the printer used, refer to the instruction manual for your printer.

# 6.17 DATA PROCESSING

More than 30 data-processing functions are provided in this system. Several typical examples of them are explained in this Section. For details of each function, refer to Chapter 7 “REFERENCE.”

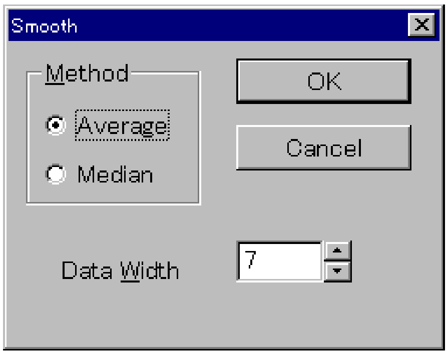



General data processing

## 6.17.1 Smooth

Smoothing is a useful function for eliminating noise from original data. When small noise exists over the entire image (data), the “Average” function is effective. If there is spike-shaped noise, the “Median” function may be effective.

1. Select “Process” from the menu bar of the SPM initial window. Select “Smooth” from the pull-down menu displayed just below “Process.”



2. Select “Average” in the “Method” frame by clicking on the radio button for “Average” (“⁄”), designate the number of data points to be used for smoothing in the input box for “Data Width” and click on the “OK” button in the “Smooth” window.

   Note: Usually, five or seven points are used. Several points on both extreme edges of the data are not smoothed.

3. Smoothing begins and the processed data is displayed in the image display window.

## 6.17.2 Measure

The position (coordinates) of a point in an image and the relative distance between two points in an image can be obtained with this processing function. This function can also be used to obtain an exact distance or height on the specimen surface after performing “Profile” processing.

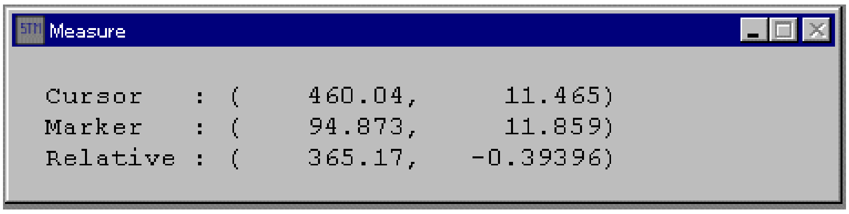
1. Select “Analyze” from the menu bar of the SPM initial window. Select “Measure” from the pull-down menu displayed just below “Analyze.”

   The “+” mark will be displayed in the image-display window.

2. Move the “+” mark to the starting point of the area you want to measure and click the left mouse button.

3. Move the “+” mark to the next measurement point and click the left mouse button again.

   The relative distance between this point and the previous point is indicated in the window.




## 6.17.3 Zoom

By using the Zoom function, an area of interest on the data can be enlarged.

1. Select from the menu bar of the SPM initial window. Select “Zoom” from the pull-down menu displayed just below “Analyze.”

   The “+” mark will be displayed.

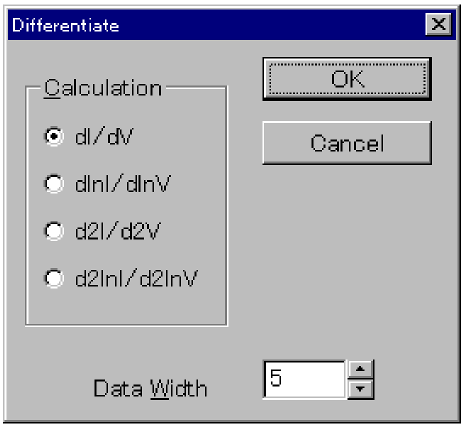
2. Designate the rectangular part of the data to be enlarged by moving the “+” cursor to the opposite corner of the rectangle.

   The enlarged part of the data or image is displayed on the image display screen.

## 6.17.4 Differentiate

An I-V curve, for example, is often processed by differentiating it. In this system, differentiation can be performed with one command.

**1.** Select "Analyze" from the menu bar of the SPM initial window. Select "Differentiate" from the pull-down menu displayed just below "Analyze."



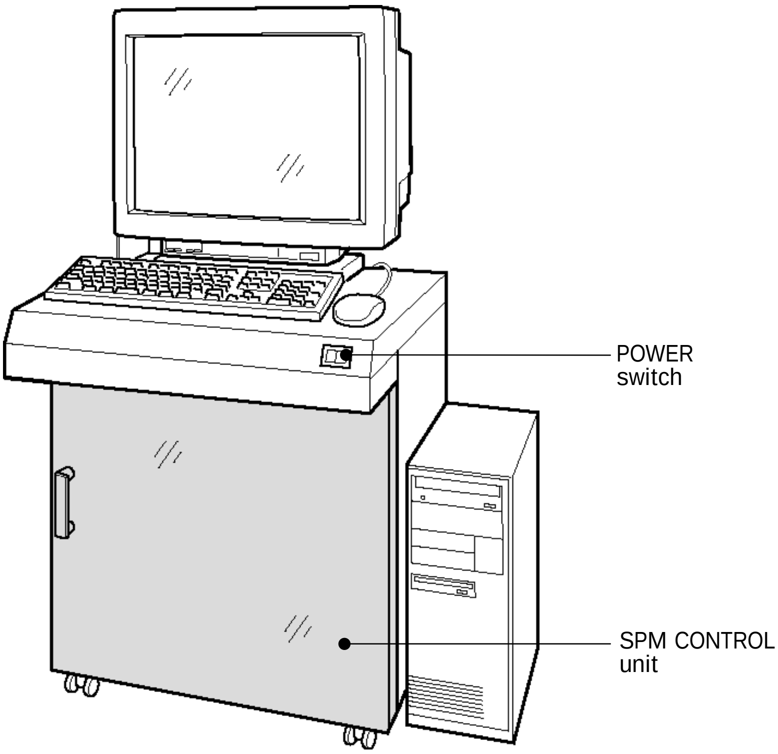

**2.** Click on the radio button for "dI/dV" ("⁄") and select the number of data points for differentiation in the "Data Width" input box.

If "5" is selected , the derivative coefficient is calculated at a point of interest and two other points on its right and left sides (a total of 5 points).

## 6.18 TERMINATION OF OPERATION

After saving data on a disk upon completing image observation, you can terminate the system. The following is the termination procedure.

1. Select “File” from the menu bar of the SPM initial menu and select “Exit” from the pull-down menu displayed just below “File.” If data is still in the computer memory, a warning message appears in the window. Confirm that all necessary data has been saved on a disk, and click on the “OK” button.
2. Confirm that the SPM software has been terminated and the screen has returned to Windows95™.
3. Move the cursor to the bottom-left corner of the screen and click on the “Start” button; then click on the “Shut Down” button from the pop-up menu.
4. Select “Shut down the computer ?”; then click on the “YES” button.
   The computer is turned OFF.
5. Turn off the POWER switch of the SPM CONTROL unit.




6. Confirm that the power to all the units is completely OFF.

**CAUTION**

- **Wait 10 seconds or more before restarting the system.**
- **The software must be terminated before the power is turned off. Never turn off the power while the software is in operation.**

CONTENTS

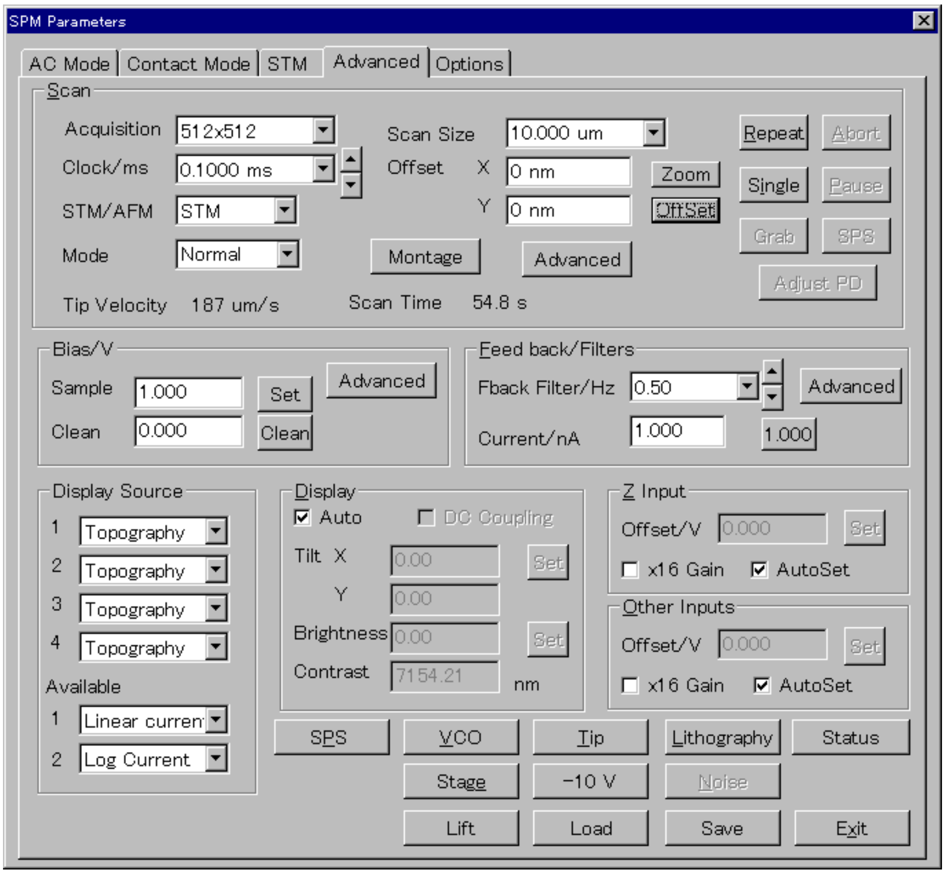
# 7

# REFERENCE

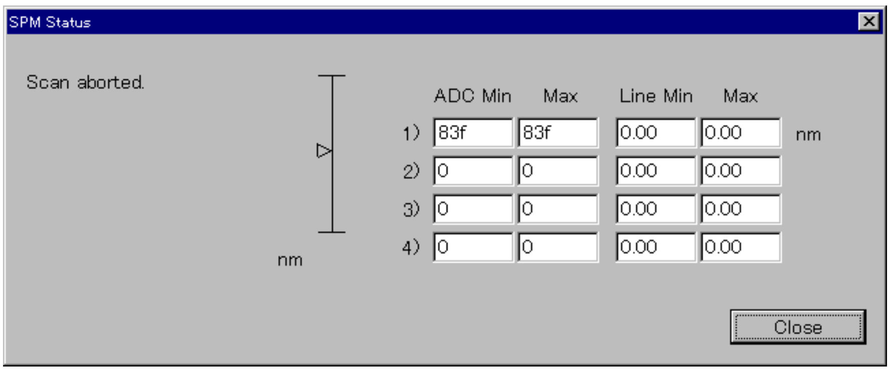
# 7.1 SCAN (CONTROL OF THE SPM CONTROL UNIT)

## 7.1.1 Scan···, Scan Parameters

Click on “SPM Scan” in the main menu, and select “Scan” in the pull-down menu. Then, the “SPM Parameters” window is opened. The operation conditions of the SPM CONTROL unit are specified in this window.




### 7.1.1a Status frame




The present state during scanning is indicated in this frame.

## ■ Status indication

The present state is indicated by the following messages:

### ● SPM inactive at present

This message shows that the SPM CONTROL unit is ready to operate (not in scanning at present). When this message is displayed, you can start scanning by clicking on the “Repeat” or “Single” button.

### ● Scan in progress

This message shows that scanning is in progress.

### ● Scan aborted

This message shows that the “Abort” button has been clicked on during scanning and scanning has been forced to stop. You can restart Scanning from the beginning by clicking on the “Repeat” or “Single” button even while this message is displayed.

### ● Scan Paused

This message shows that the “Pause” button has been clicked on during scanning and scanning has been stopped temporarily. Scanning will restart from the present point if you click on the “Repeat” or “Single” button.

### ● Grab frame

This message shows that the “Grab” button has been clicked on so that the image under scanning is grabbed in the computer memory.

### ● Subtract background

This message shows that the image has been grabbed and the signal level has been normalized.

### ● Processed Line

In this system, the analog image signal sent from the SPM CONTROL unit is converted to a digital signal and the converted signal is sent to the computer. The computer normalizes the received signal, line by line; then it displays the normalized signal on the screen. Therefore, the number of scanning lines under the receiving signal is not always the same as that of scanning lines under the displaying signal because the data processing does not catch up with the image displaying. The actual scanning line is indicated with “Received Line” and the displayed scanning line with “Processed Line.”

## ■ Bar chart

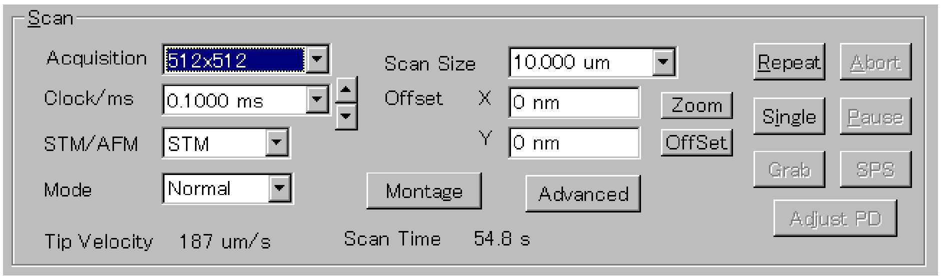
The triangle arrow marks, which show the voltage values to be input to the A/D converter, indicate the signal levels averaged line by line. The positions of the arrow marks are shown as the values obtained after both the “×16” values and the “Offset /V” values in “Z input” and “Other Inputs” have already been calculated. If the marks are positioned at top (positive) or bottom (negative), it means that the input voltages to the A/D converter (±10 V or about±0.6 V for “×16”) are outside the range of the A/D converter and the image on the Display Window becomes only white or black, showing the fact that the data (image) has not been correctly acquired.

The input signal of the arrow mark indicated on the left side is specified in “Display Source 1” and the input signal of the arrow mark indicated on the right side is specified in “Display Source 2.” Only the left arrow mark is shown when inputs other than “2 Inputs” or “4 Inputs” are selected in the “Acquisition” selection box.

- **ADC Min, Max; Line Min, Max**

The input values designated in “1” to “4” of “Display Source” are indicated.
ADC Min Max: The minimum and maximum signals in each scanning line are input to the A/D converter, and the minimum and maximum values from among the converted values are directly indicated in hexadecimal notation.
Line Min Max: The values indicated in ADC Min Max are converted into the actual unit and displayed in the same manner.

## 7.1.1b Scan




### ■ Acquisition

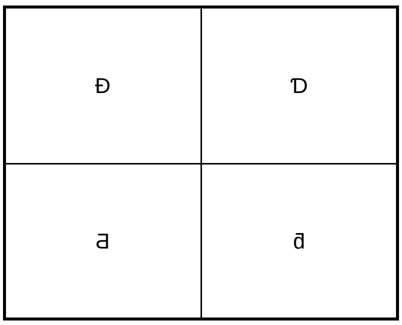
The scanning method is specified in this selection box. The following methods are provided in the pull-down menu displayed when you click on the “▼” mark.

- **512×512**

Scanning is performed in a range of 512×512 pixels. One image frame is displayed in the Display Window. When one frame’s scanning completes, the displayed image is gradually replaced from the top by a new image with the next scan.

- **256×256**

Scanning is performed in a range of 256×256 pixels. Four image frames are displayed in the Display Window as shown in the figure below in the order of ①→②→③→④.



After four image frames are displayed in the Display Window, the displayed image frames are updated with subsequent scanning in the order of ①→②→③→④→①→② ⋯.

## ● 128×128

Scanning is performed in a range of 128×128 pixels. Sixteen image frames are displayed in the Display Window as shown in the figure below in the order of ①→②→③→④.

| | | | |
|---|---|---|---|
| Đ | Ɗ | ɘ | ƌ |
| ƍ | Ǝ | ə | ɛ |
| Ƒ | ƒ | Ɠ | Ɣ |
| ƕ | Ɩ | Ɨ | Ƙ |

After sixteen image frames are displayed in the Display Window, the displayed image frames are updated with subsequent scanning in the order of ①→②→③···⑮→⑯→①→②→③→.

## ● CITS

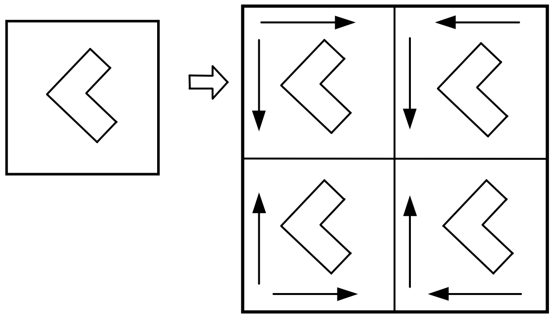
Scanning is performed in a range of 128×128 pixels in the CITS (Current Imaging Tunneling Spectroscopy) mode. In the CITS mode, the I-V measurement is performed at every pixel in one frame (Topography) scan. Usually, the I-V characteristics are measured while an STM image is being scanned. Parameters for the I-V measurement, such as a bias voltage and measurement points, are specified in “I-V” in the “SPS Parameters” window. Images displayed during scanning are as follows.

| | | | |
|---|---|---|---|
| Topo image | Current image | ” | ” |
| Current image | ” | ” | ” |
| ” | ” | ” | ” |
| ” | ” | ” | ” |

In this system, the I-V measurement not only during scanning in the CITS mode but also during scanning in the Contact mode can be performed by combining necessary parameter items.

## ● Mirror

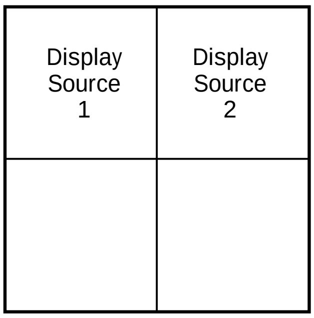
Scanning is performed in a range of 256×256 pixels.  Images are displayed in the forward and backward directions, that is, in the left → right → left directions. The images are scanned, first, downward from top to bottom and then, upward from bottom to top.



When the Mirror scanning is specified, the sample bias voltage in forward and backward scanning automatically changes. In the case of the images displayed on the left side in the Display Window the bias voltage specified in “Sample” is applied. In the case of the images displayed on the right side the bias voltage specified in “Back Scan” is applied. If the same voltage is specified for “Sample” and “Back Scan,” scanning hysteresis and tip shape can be checked in forward and backward scanning. If a different voltage is specified for “Sample” and “Back Scan” in the STM mode, STM images with two different bias voltages can be observed by one scanning.

## ● 2 Inputs

Scanning is performed in a range of 256×256 pixels.  Two different kinds of data are acquired and displayed simultaneously. The input signals are specified in “1” and “2” of “Display Source.”  Two image frames are displayed in the following order in the Display Window.




When the images are grabbed after being scanned, they are separately grabbed as different images. The gain and offset for an image designated as “Topography” in “Display Source” are specified in the “Z Input” frame in the “SPM Parameters” window, and the gain and offset for other images are specified in the “Other Inputs” frame (if “Auto Set” is selected). If both images are other kinds than “Topography,” the offset is calculated by the signal specified in “1” of “Display Source.”

## ● 4 Inputs

Scanning is performed in a range of 256×256 pixels. Two different kinds of data are acquired and displayed simultaneously. The input signals are specified in “1” to “4” of “ Display Source.” Four image frames are displayed in the following order in the Display Window.

| | |
|---|---|
| Display Source 1 | Display Source 2 |
| Display Source 3 | Display Source 4 |

When the four images are grabbed after being scanned, they are separately grabbed as different images. The gain and offset for an image designated as “Topography” in “Display Source” are specified in the “Z Input” frame in the “SPM Parameters” window, and the gain and offset for other images are specified in the “Other Inputs” frame (if “Auto Set” is selected). The same gain and offset are applied for the second to third (or fourth) other images (if “AutoSet” is checked). If other images are displayed in black or white (saturated) due to greatly different offset values, remove the check mark of “AutoSet”; enter 0 to “Offset/V” manually; grab the image; then adjust the brightness and contrast using the “Adjust LUT” function.

## ● I-V

The I-V characteristic between the tip and the specimen is measured. The I-V measurement is performed only once and the data is grabbed when the “Single” button is clicked on. When the “Repeat” button is clicked on, the I-V measurement is continuously performed, and the data is grabbed when the “Grab” button is pressed. The I-V measurement is possible in the STM and Contact modes with an STM tip or with a conductive cantilever mounted on a non-contact cantilever holder. The I-V is also available with the Slope-mode AFM and FM-mode AFM, but these are not generally used.
In this I-V measurement, the tunneling current (I) is measured while keeping the distance between the tip and the specimen surface constant and scanning the bias voltage (V). Parameters for the I-V measurement such as “Bias voltage scanning range” and “Preamp gain” are set in the “SPS Parameter” window, and the point at which the I-V measurement is performed is specified using the “Position” function in the “Tip” window.

## ● S-V

The S-V characteristic is measured. In this mode, the distance between the tip and the specimen surface (S) is measured while keeping the tunneling current constant and scanning the bias voltage (V). The S-V measurement is performed only once and the data is grabbed when the “Single” button is clicked on. When the “Repeat” button is clicked on, the S-V measurement is continuously performed, and the data is grabbed when the “Grab” button is pressed. Parameters for the S-V measurement such as “Bias voltage scanning range” are set in the “SPS Parameter” window, and the point at which the I-V measurement is performed is specified using the “Position” function in the “Tip” window.

### ● I-S (available only in the STM mode)

The I-S characteristic is measured. In this mode, the tunneling current (I) is measured while keeping the bias voltage constant and scanning the distance between the tip and specimen surface (S). This measurement is possible only in the STM mode with an STM tip or with a conductive cantilever mounted on a non-contact cantilever holder. Parameters for the I-S measurement such as “Scanning range” and “Preamp gain” are set in the “SPS Parameters” window, and the point at which the I-V measurement is performed is specified using the “Position” function in the “Tip” window.

### ● Force Curve (available only in the AFM mode)

The Force Curve characteristic is measured. In this mode, the atomic force acting between the cantilever tip and the specimen surface is measured while scanning the distance between the cantilever tip and the specimen surface. This measurement is possible for modes other than the STM mode. Parameters for the Force Curve measurement such as “Scanning range” and “Offset” are set in the “SPS Parameter” window, and the point at which Force Curve measurement is performed is specified using the “Position” function in the “Tip” window (refer to Section 7.1.1i and Section 7.1.1m).

The Force Curve measurements are performed by scanning in both the forward and backward directions and the measured data are displayed in different colors in the Display Window.

### ● Line Scan 128, Line Scan 256, Line Scan 512

In these modes, data are acquired only in the X-direction scanning by keeping the Y-direction position constant, and data are displayed in the Display Window with X- and Y-direction scanning. These modes are used for dynamic observation of time-varying phenomena on the specimen surface such as step edge swaying. The numbers of pixels for one scan line and the numbers of scans (number of lines for display) are the same, and these are 128, 256 and 512 for Line Scan 128, Line Scan 256 and Line Scan 512, respectively.

The line position on which the data is measured is specified using the “Position” function in the “Tip” window, and scanning is performed from this position only in the X direction.

### ● SPS

The SPS (Scanning Probe Spectroscopy) measurement is performed. In this mode, the I-V, S-V, I-S or Force curve measurement is performed at the designated point during the normal image scanning. The following is the procedure for the SPS measurement.

1. Set the parameters for the normal image scanning in the “SPM Parameters” window.
2. Set the parameters for each SPS measurement in the “SPS Parameters” window. Designate the kind of mode in “SPS Mode.”
3. Click on the ▼ mark in the “Acquisition” selection box in the “SPM Parameters” window and select “SPS” from the pull-down menu.
4. Click on the “Repeat” button on the “SPM Parameters” window to start scanning.

Scanning is performed in a range of 512×512 pixels according to the conditions set in the “SPM Parameters” window and the image is displayed on the Display Window.

5. Click on the “SPS” button.

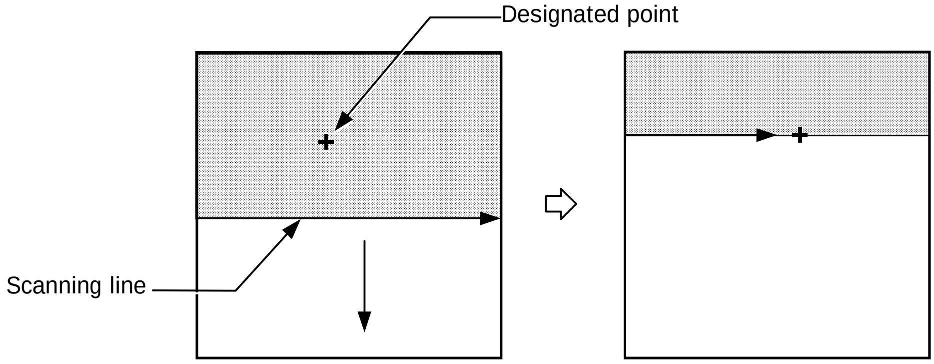
The “SPM Parameters” window will disappear. If you move the cursor to any point of the displayed Display Window, the cursor mark changes to a “+” mark.

6. Move the cursor to the position where measurement is to be performed and click the left mouse-button on that position to determine the measurement position.

The “SPM Parameters” window will appear again.

7. When scanning is performed up to the designated position, measurement is performed; then the measured data is displayed.

- If you do not want to save the data, press the “Cancel” button.
- If you designate, in the image that is being scanned, the position where scanning has already been performed, measurement begins there in the next scan.




8. When scanning of one image frame has been completed, the image is normalized and displayed.

Enter the title of the image and press the “OK” button. If you do not want to save the data, press the “Cancel” button.

## ● Montage

In this measurement, a specified observation area on a specimen surface is divided into many small scanning areas and the obtained images are montaged as one image. Parameters for montaging are specified in the “Montage” window which is opened by clicking on the “Montage” button in the “Scan” frame in the “SPM Parameters” window. After setting montage parameters and selecting “Montage” in the “Acquisition” selection box, click on the “Repeat” button; then, scanning starts and a montaged image can be grabbed.

## ● Friction F-C (available only in the Contact mode)

In this measurement, the friction force acting between the cantilever and the specimen surface is measured while scanning the cantilever in the Y direction over the specimen surface and the measured data is displayed as a graph. This measurement is possible when “Contact” is selected in the “STM/AFM” selection box. The friction force measurement is performed by scanning in both forward and backward directions and the measured data are displayed in different colors in the Display Window. Parameters for the friction force measurement such as “Scanning range” and “Offset” are set in the “SPS Parameter” window.

- **Imaging**

Like the scanning in the “Tiny Tab” mode, in this measurement, scanning is performed downward from top to bottom and then upward from bottom to top.

## ■ Clock/ms

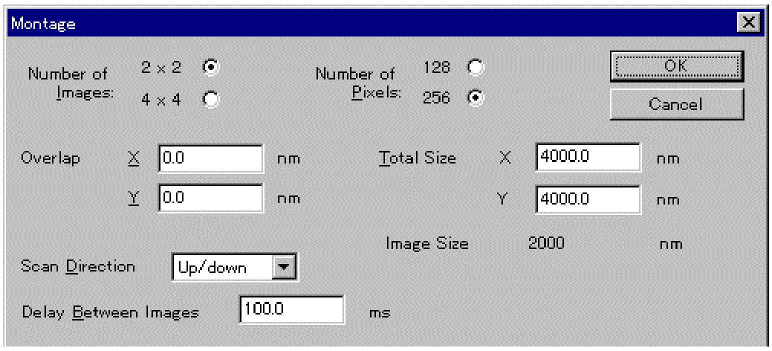
Scanning speed is specified in this selection-box as the unit of time per step (pixel). Thirteen speeds, from 0.01 ms/step to 10 ms/step, are provided in the pull-down menu displayed when you click on the “▼” mark.

Note: Scanning in the X direction is performed in 512 steps regardless of the number of pixels. Certain scanning speeds can not be changed during scanning because they are indicated by average values at one or two points. When you click on the “Clock/ms” selection box during scanning in progress, only the changeable speeds are displayed in the selection box. When you want to select speeds other than the displayed changeable speeds, first, stop scanning by clicking on the “Abort” button and then select other speeds.

The actual tip speed and the time required to scan one frame are indicated in “Tip Velocity” and “Scan Time” in the “Scan” frame in the “SPM Parameters” window.

## ■ Montage

Clicking on the “Montage” button opens the “Montage” window.

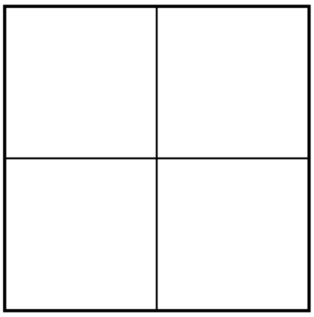



Click on the “▼” mark in the “Acquisition” selection box and select “Montage.” Set the parameters for montage in the “Montage” window.

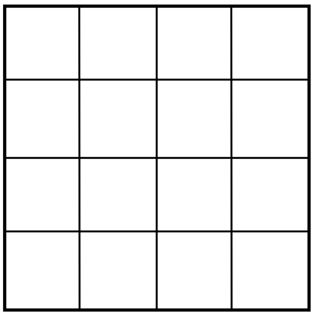
Note: Be sure that the total scanning area never exceeds the maximum scanning range for the scanner in use.

● **Number of Images**

This specifies the number of frames composing the total montaged image. The selections “2×2” and “4×4” are provided. Select one of them by clicking on the “○” mark. The frame arrangement for each selection is shown below.



2×2



4×4

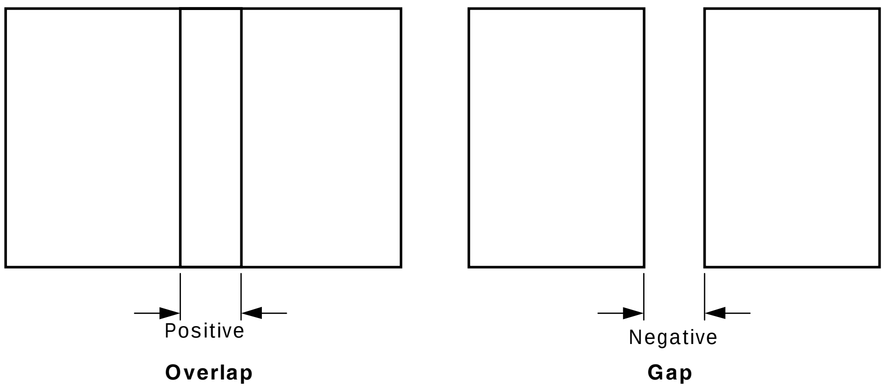
● **Number of Pixels**

This specifies the number of pixels per frame.
The selections “128” and “256” are provided. Select one of them by clicking on the “○” mark. When “128” is selected, one unit frame is composed of 128×128 pixels, and when “256” is selected, one unit frame is composed of 256×256 pixels.

Note: If “4×4” is selected for “Number of Images” and “256” is selected for “Number of Pixels,” an image is displayed on the screen as 128×128 pixels, but the data is stored in the memory as 256×256 pixels.

● **Overlap**

Continuity between unit frames is not perfect due to hysteresis and creep of the scanner. Overlap or gap between frames may occur. The “Overlap” input boxes specify the edge-to-edge distance between frames in “X” and “Y” directions in nm. Positive and negative values can be entered for overlap and gap as shown below.

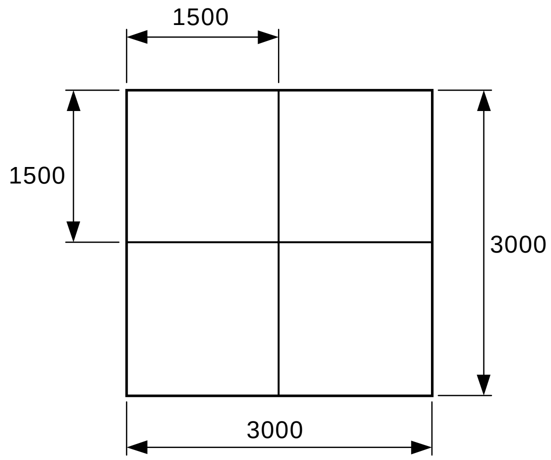



## ● Total Size

The “Total Size” input boxes specify the total scanning area in nm. The area specified in these input boxes is the total size of scanning.

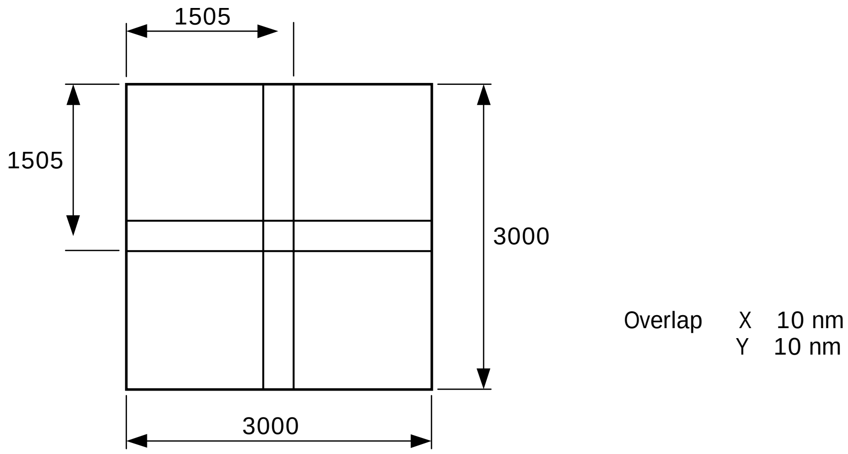
**[Example 1]**

“Number of Images” 2×2 “Total Size” “X” 3000 nm “Y” 3000 nm
“Overlap” “X” 0 nm “Y” 0 nm




**[Example 2]**

“Number of Images” 2×2 “Total Size” “X” 3000 nm “Y” 3000 nm
“Overlap” “X” 10 nm “Y” 10 nm



In the “Montage-scan” mode, this “Total Size” has priority in determining the scanning range of one frame that is specified in “Image Size.”

Note: During montage scanning, “Scan Size” in the “SPM Parameters” window cannot be used.

## ● Scan Direction

This selection box specifies the direction of the unit frame scanning. “Up/down” and “Left/right” are provided in the pull-down menu. The actual frame scanning order is shown below for the “4×4” case.

- Up/down

| | | | |
|---|---|---|---|
| Đ | ǫ | Ƒ | ƕ |
| Ɗ | ∃ | ƒ | ı |
| ɘ | ə | Ɠ | ɨ |
| ƌ | ɛ | ɣ | ĸ |

**4×4**

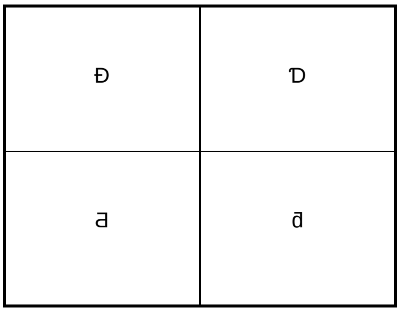
| | |
|---|---|
| Đ | Ɗ |
| ɘ | ƌ |

**2×2**

- Left/right

| | | | |
|---|---|---|---|
| Đ | Ɗ | ɘ | ƌ |
| ǫ | ∃ | ə | ɛ |
| Ƒ | ƒ | Ɠ | ɣ |
| ƕ | ı | ɨ | ĸ |

**4×4**



2×2

- **Delay Between Images**

The waiting time between one frame scan and the next frame scan is specified in this input box. Just after a large shift (frame to frame) of the scanner, drift may occur due to the creep characteristic of the scanner. In order to decrease the effect of this phenomenon, a waiting time is taken.

Note: For a good montage image, an appropriate setting of “Overlap” and “Delay Between Images” is important and necessary. As these values depend upon “Total Size” and “Clock/ms,” try to perform scanning as many times as needed to find appropriate values.

## ■ STM/AFM

Specify the scanning mode. Strictly speaking, you have to specify the kind of signal to be used for the Z-direction feedback in this selection box.

- **STM**

This is the STM mode. The logarithmic value of the tunneling current is designated for the feedback signal.

- **Contact**

This is the contact mode AFM. The (A−B)/(A+B) signal is designated for the feedback signal.

- **Slope**

This is the AC mode AFM. The RMS (Root-Mean-Square) of (A−B)/(A+B) is designated for the feedback signal.

- **FM**

This is the FM detection mode of the AC mode AFM. The PLL (Phase-Locked Loop) output signal is used for the feedback signal.

- **Phase**

This is the mode used when the AC mode AFM (Slope detection method) is selected. The Phase output signal is used for the feedback signal.

## ■ Mode

The following modes can be used when optional attachments are used to perform viscoelasticity measurement, lateral-modulation FFM measurement, Kelvin Force Microscope measurement and MFM (Magnetic Force Microscope) measurement.

### ● Normal

This mode is used when ordinary measurement is performed.

### ● VE-AFM, LM-FFM

These modes are used when an optional attachment, TM-26010/26020 Viscoelasticity and Lateral-Modulation FFM (50)/(60), is used.

### ● KFM

This mode is used when an optional attachment, TM-26030 Kelvin Force Microscope, is used.

### ● MFM

This mode is used when MFM measurement is to be performed.

## ■ Scan Size

Specify the scanning area in this selection box. Two methods are provided.

- Click on the "▼" mark in the box and select a scanning area from the pull-down menu showing some scanning areas.
- Enter a value using the keyboard. Then, the nearest scanning area is selected.

Notes: 1. The selected scanning area is not always the same as the entered value because the value is rounded.

2. The following units can be used for the entered value:

   pm: $10^{-12}$ m
   nm: $10^{-9}$ m
   um: $10^{-6}$ m
   mm: $10^{-3}$ m

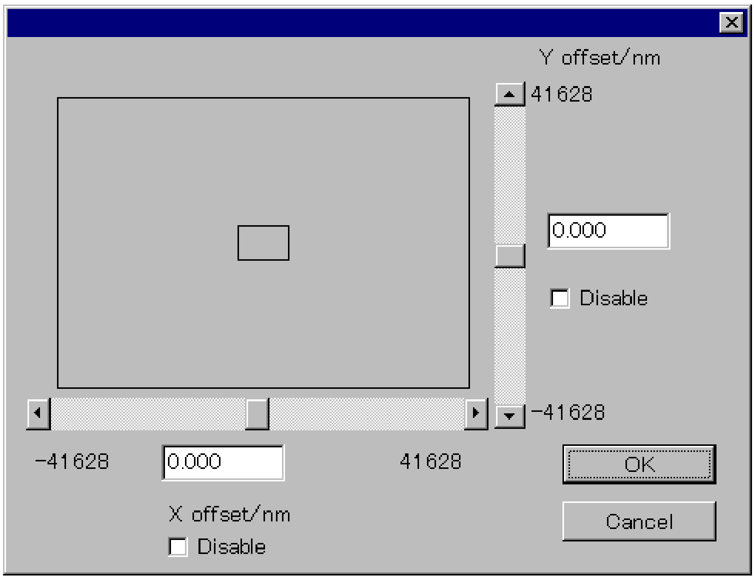
   For example, when "3.000um" is entered, the scanning area is 3.0 µm. If a unit is not entered, the previously entered unit is applied.

3. The maximum scanning area depends on the scanner calibration value selected in the "SPM Calibration•••" window.

## ■ Offset

The coordinates of the center point of scanning area are shifted within the scanning area. Enter the shift values directly in the "Offset" input window using the keyboard or click on the "Offset" button to open the "Offset" window and specify them in the "Offset" window.

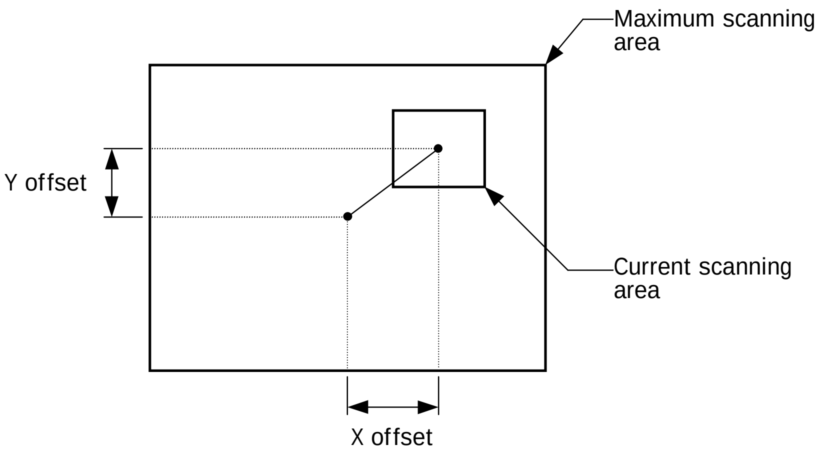
## ● When Specifying the Center Point in the Offset Window




In this window, the current scanning area is displayed. There are three methods for specifying the shift values (the coordinates of the center point) as follows.

**1.** Dragging
Move the cursor to the current scanning area. The cursor will change to the "+" mark. Then, drag the cursor to a desired position.

**2.** Scroll bar
The current scanning area can be moved by using the scroll bar. This method is useful for a tiny scanning area such as for observing an atomic image.



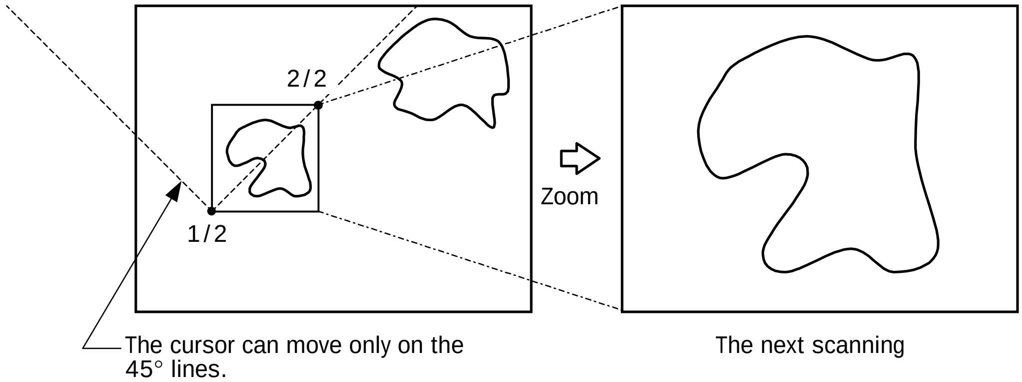

**3.** Input boxes
The offset values can be entered directly into the input boxes for the X and Y axes in the "Offset" window using the keyboard.

- **Disable (check boxes)**

When a "Disable" check-box is checked, the scanning area cannot be moved in this direction. For example, when "Disable" for the Y axis is checked, the scanning area can be moved only in the X direction.

## Zoom

A new scanning area can be designated in the displayed image.
Click on the "Zoom" box; then move the cursor to the Display Window. The cursor will change to the "+" mark. Then, designate a new scanning area by diagonal points as shown below.

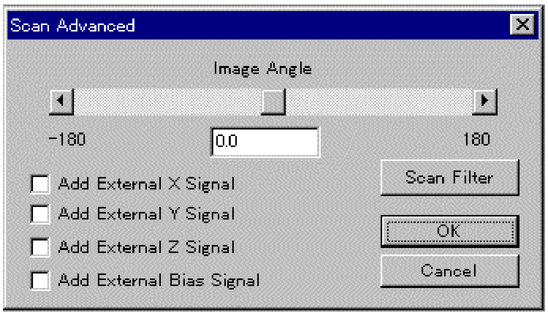



The new scanning area is indicated in "Scan Size" and "Offset."

Note: This function is not in effect during scanning. Stop scanning by clicking on the "Abort" button; then specify the new scanning area.

## Scan Advanced

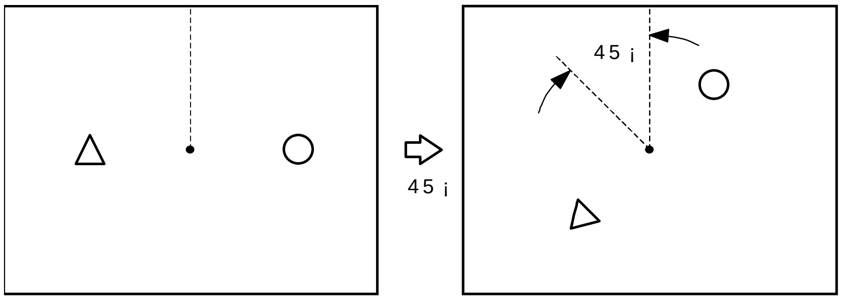
When the "Advanced" button is clicked on, the "Scan Advanced" window is opened.




- **Image Angle**

This scroll bar specifies the scanning angle within the range of −180° to +180°. A positive angle means counterclockwise rotation.

Note: Usually, "0" is specified.




- **Add External X Signal**

When this check box is clicked on, the signal input from the ADX terminal on the rear of the SPM CONTROL unit is added to the X-axis scanning signal. Unless this check box is checked, the signal input from the ADX terminal is not added. Actually, a signal 15 times larger in amplitude is added. That is, inputting a ±1 V sine-wave to the ADX terminal outputs ±15 V.

Note: The maximum input rating of the ADX terminal is ±10 V. However, as the maximum X-axis scanning voltage is ±150 V, the total added scanning voltage is saturated at ±150 V even if the signal input to the ADX terminal exceeds ±150 V.

- **Add External Y Signal**

When this check box is clicked on, the signal input from the ADY terminal on the rear of the SPM CONTROL unit is added to the Y-axis scanning signal. Unless this check box is checked, the signal input from the ADY terminal is not added. Actually, a signal 15 times larger in amplitude is added. That is, inputting a ±1 V sine-wave to the ADY terminal outputs ±15 V.

Note: The maximum input rating of the ADY terminal is ±10 V. However, as the maximum Y-axis scanning voltage is ±150 V, the total added scanning voltage is saturated at ±150 V even if the signal input to the ADY terminal exceeds ±150 V.

- **Add External Z Signal**

When this check box is clicked on, the signal input from the ADZ terminal on the rear of the SPM CONTROL unit is added to the Z-axis scanning signal. Unless this check-check box is checked, the signal input from the ADZ terminal is not added. Actually, a signal 15 times larger in amplitude is added. That is, inputting a ±1 V sine-wave to the ADX terminal outputs ±15 V.

Note: The maximum input rating of the ADZ terminal is ±10 V. However, as the maximum Z-axis scanning voltage is ±150 V, the total added scanning voltage is saturated at ±150 V even if the signal input to the ADZ terminal exceeds ±150 V.

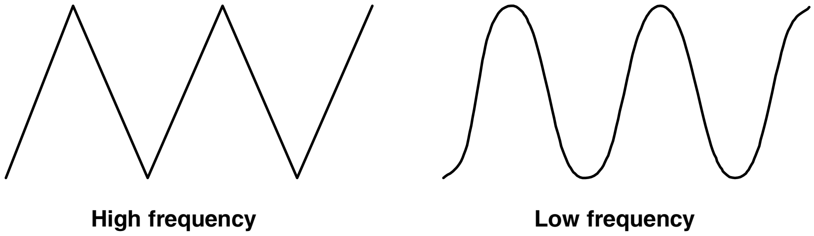
- **Add External Bias Signal**

When this check box is clicked on, the signal input from the ADB terminal on the rear of the SPM CONTROL unit is added to the bias voltage. Unless this check box is checked, the signal input from the ADB terminal is not added. The signal input from the ADB terminal is added as it is. That is, inputting a $\pm 1$ V sine-wave to the ADB terminal outputs $\pm 1$ V.

Note: The maximum input rating of the ADB terminal is $\pm 10$ V. However, as the maximum bias voltage is about $\pm 12$ V, the total added scanning voltage is saturated at $\pm 12$ V even if the signal input to the ADB terminal exceeds $\pm 12$ V.

- **Scan Filter**

The filter for the scanning signal is designated by this button. Clicking on the "Scan Filter" button opens the "Scan Filter" window. When "High Frequency" or "Low Frequency" is selected, the scanning signal waveform becomes as shown below.




When a high scanning speed is selected, vertical streaks sometimes appear on an image. This is because vertical streaks are created by mechanical vibration of the scanner due to the acceleration at the top point of the triangular waveform. If such a phenomenon occurs, the most effective remedy is to change the scanning speed to a low speed. If the image quality deteriorates due to the change of the scanning speed, set this "Scan Filter" to "Low Frequency."
Usually, "High Frequency" is used.

## ■ Repeat

When this button is clicked on, scanning starts with the mode specified in "Acquisition." Since scanning repeats continuously, this function is usually used for image observation. If you want to store an image, click on the "Grab" button during scanning. Then the data which is being scanned when the "Grab" button is pressed is stored in the computer memory.

## ■ Single

When this button is clicked on, scanning is performed only once with the mode specified in "Acquisition" and the image is automatically stored (grabbed) in the computer memory. This function is used to acquire data only once, and is useful in cases such as Force Curve measurement where repeated scanning might damage the specimen.

## ■ Grab

When this button is clicked on during scanning, "Grab Frame" is indicated in the "Status" frame and the image data is stored in the computer memory when the scanning is completed. As "Enter image title" will be displayed at this moment, enter a title for the image from the keyboard; then click on the "OK" button. This title is used only for data storing in the memory and not for image saving in the disk. If you do not want to save the image in the disk, click on the "Cancel" button. Then the image data is cleared.

Note: After the “Grab” button is clicked on, the scanning remains in suspension. To restart the scanning, click on the “Repeat” button. If the “Grab” button is clicked on again during the scanning, the “Grab” function is canceled and the following scanning continues.

## ■ Abort

When this button is clicked on, the scanning is stopped and the tip returns to the initial position.

## ■ Pause

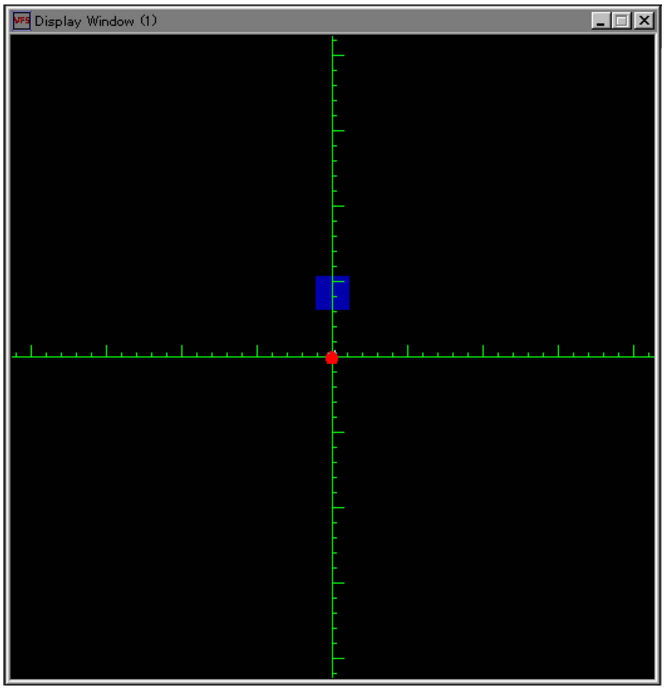
When this button is clicked on, the scanning is temporarily stopped and the tip stays at the present position. Clicking on the “Repeat” or “Single” button restarts the scanning from that position.

## ■ SPS

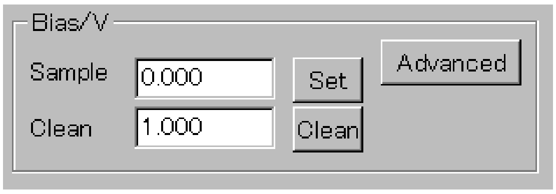
When the “SPS (Scanning Probe Spectroscopy)” mode is designated in “Acquisition,” the point where the SPS measurement is to be performed is specified with this “SPS” button.
When the “SPS” button is clicked on, the “SPM Parameters” window disappears. Move the cursor to the Display Window; then the “+” mark will appear on the image. Position the cursor at the point where the SPS measurement is to be performed; and click the left mouse-button. The point is specified and the “SPM Parameters” window will appear again.

## ■ Adjust PD

Clicking on this button indicates the position of the laser beam illuminated on the photodiode. The red spot shows the laser beam illumination position. Adjust the photodiode position so that the red spot goes into the region indicated in blue.



### 7.1.1c Bias/V




#### ■ Sample

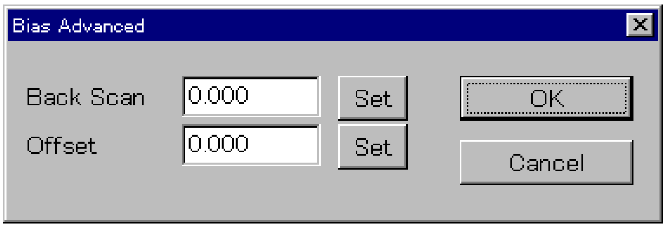
The bias voltage is specified in this input box. In the JSPM-4200 the voltage specified in the “Sample” input box is always applied to the sample. When the “Set” button is clicked on, a bias voltage can be specified with the bar chart in the “Status” frame. A bias voltage of up to ±10 V can be specified.

#### ■ Clean

When STM image quality becomes worse during observation, applying a different bias voltage for a short time may make the quality better, because it cleans the tip. The “Clean” input box specifies a cleaning voltage, and this voltage is applied while the “Clean” button is clicked on. The voltage is entered using the keyboard.
This function, however, is not used in the JSPM-4200. For the tip cleaning, refer to Subsection 7.1.1l “High Bias.”

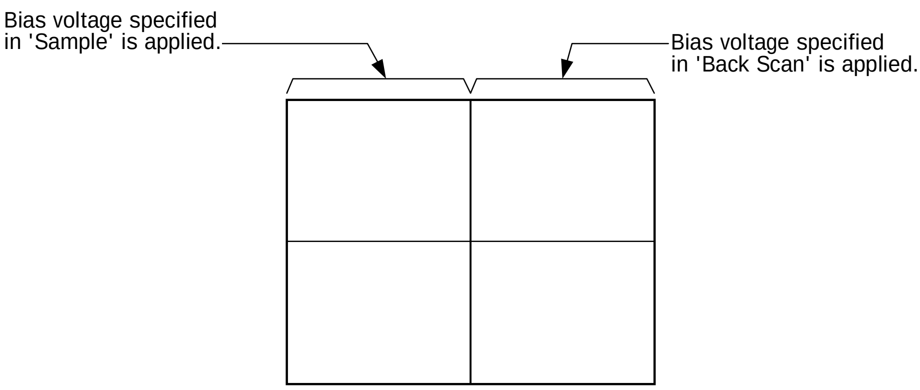
#### ■ Bias Advanced

Clicking on the “Advanced” button opens the “Bias Advanced” window.

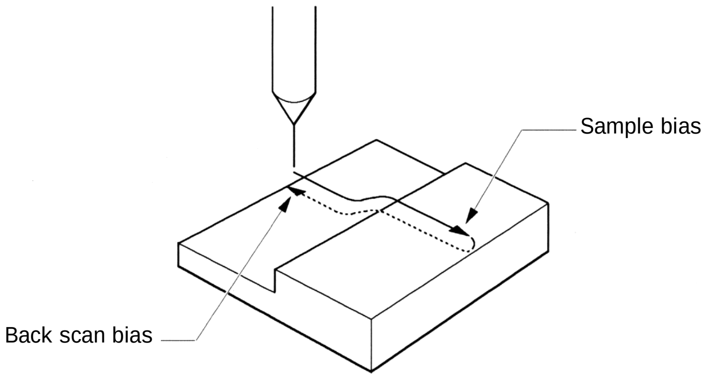



##### ● Back Scan

This input box specifies the bias voltage to be applied in backward scanning when “Mirror” is selected in the “Acquisition” selection box.



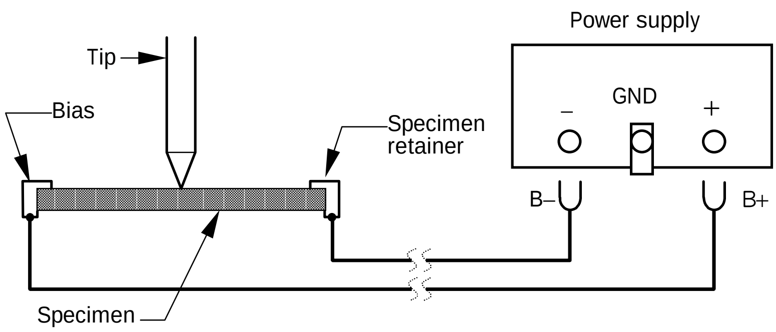
Note that this function is in effect only when “Mirror” is selected. If any other scanning method is specified in the “Acquisition” selection box, the bias voltage that is specified in “Sample” is applied in both forward and backward scanning, even though different voltages are specified in “Sample” and “Back Scan.”




Note: A simple CITS can be performed using this function. This is a useful method to determine the bias voltage for CITS measurement.

## ● Offset

When STM observation is performed while directly heating a specimen with the optional 4-terminal Specimen Holder [TM-21010], the power supply for heating is used with an electrically floating condition as shown in the figure below.



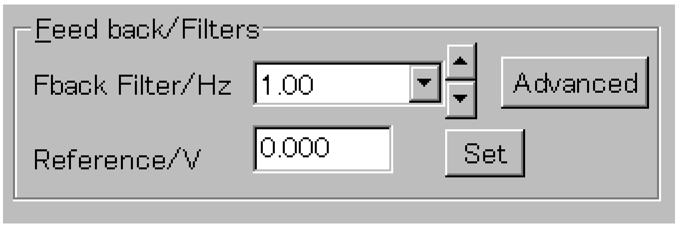

When the STM tip positions just in the center of the specimen, the actual bias voltage is;

Voltage specified in the “Sample” input box – heating-power voltage/2

Therefore, if you input a numerical value in the “Offset” input box so that you may not mistake the bias voltage actually applied, the bias voltage between the sample and the tip can be indicated by the voltage of [the “SPM Controller bias voltage” – the “Offset” voltage].

Note: This “Offset” function is used only for the sake of indication. The voltage output from the SPM control unit is the same as the “Sample” voltage indicated when the “Offset” voltage is set to 0 V.

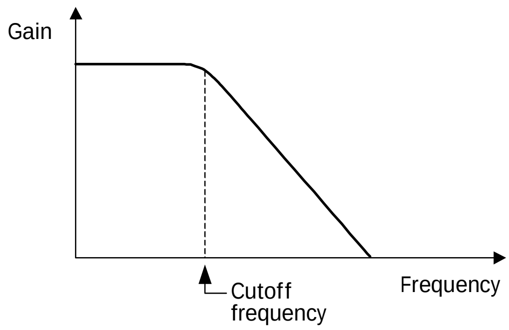
### 7.1.1d Feedback/Filters




## ■ Fback Filters/Hz

The cutoff frequency of the feedback loop is specified in this selection box. Eight frequencies from 0.01 Hz to 10 Hz are provided in the pull-down menu which is displayed when the "▼" mark is clicked on. Response of the feedback loop becomes slower when a smaller frequency is selected, and vice versa. In ordinary topography observation, as high a frequency as possible is selected, but too high a frequency causes the feedback circuit to be prone to oscillating . In the cases of the current image and force image, on the other hand, a lower frequency than that for topography observation is selected.

Note: The filter used in this system is a low-pass filter, and the cutoff frequency means the beginning frequency of gain decrease.




## ■ Current/nA (can be used in the STM mode)
## Reference/V (can be used in the AFM mode)

### ● Current/nA

"Current/nA" is displayed when "STM" is selected in the "STM/AFM" selection box. The tunneling current flowing between the tip and the specimen is specified in this input box, and the feedback circuit acts so that the tunneling current becomes the specified value.

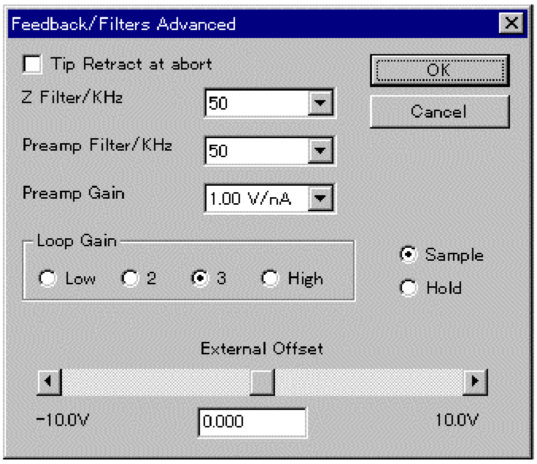
### ● Reference/V

"Reference/V" is displayed when "Contact," "Slope," "FM," or "Phase" is selected in the "STM/AFM" selection box. The reference voltage is specified in this input box, and the feedback circuit works so that the reference voltage becomes the specified value.

Note: Regarding the feedback signal for "Contact," "Slope," "FM" or "Phase," refer to Subsection 7.1.1b "STM/AFM."

## ■ Feedback/Filters Advanced

When the ‘Advanced’ button is clicked on, the “Feedback/Filters Advanced” window is opened.




### ● Tip Retract at abort

When the “Abort” button is clicked on during scanning, the scanning stops and the tip immediately returns to the initial position. Therefore, when a rough-surface specimen is observed, the tip is likely to collide with the specimen surface (when the “Abort” button is clicked on, the feedback is functioning, but the tip movement is too fast to avoid such collision). If the “Tip Retract at abort” check box is checked, the tip first is retracted and then returns to the initial position, the tip thus being prevented from colliding with such an uneven-surface specimen

Note: Usually, the “Tip Retract at abort” button is not checked. If this function is applied to an even-surface specimen, the obtained image might become bright or dark at the beginning of the next scan due to the creep characteristic of the Z scanner. For tip retract, refer to Subsection 7.1.1m “Tip Retract.”

### ● Z Filter/kHz

The cut-off frequency of the low-pass filter for the input voltage of the topography image signal is specified in this selection box. Four frequencies from 2 kHz to 50 kHz are provided in the pull-down menu which is displayed when the “▼” mark is clicked on. This filter, having nothing to do with the feedback, is added as a low-pass filter for filtering the noise component of the topography-image signal before A/D conversion. If a strong high-frequency noise component is included in the image even after “Fback Filter,” “Loop Gain” and “Current/Reference” are adjusted, a lower frequency should be selected. Remember that this filter is used just as an auxiliary function.

Note: Usually, 50 kHz is selected.

### ● Preamp Filter/kHz

The cutoff frequency of the low-pass filter for the detected tunneling current is specified in this selection box. Four frequencies from 2 kHz to 50 kHz are provided in the pull-down menu which is displayed when the “▼” mark is clicked on. This filter, having nothing to do with the feedback, is added as a low-pass filter, when “Linear Current” or “Log Current” is specified in “Display Source,” for filtering out the noise component before A/D conversion. This filter is in effect only when “Linear Current” or “Log Current” is selected in “Display Source.” If a strong high-frequency noise component is included in the image, a lower frequency should be selected. Remember that this filter is used just as an auxiliary function (as the noise largely depends on the tip condition).

Note: Usually, 50 kHz is selected.

## ● Preamp Gain

The gain for the tunneling current preamplifier is specified in this selection box. Three gains are provided as shown below.

| Gain | Tunneling current |
|---|---|
| 1 V/nA | 0 to 10 nA |
| 0.1 V/nA | 0 to 100 nA |
| 0.01 V/nA | 0 to 1 μA |

Usually, 1 V/nA is selected for the ordinary STM mode, but if a tunneling current exceeds 10 nA in the I-V measurement, or if a contact current exceeds 10 nA in the contact current measurement in the AFM Contact mode, 0.1 V/nA or 0.01 V/nA can be selected.

Note: In the contact current measurement, if the current is too large, the cantilever tip and the specimen surface could be damaged by Joule heating. Be careful not to set too large a bias voltage.

## ● Loop Gain

The loop gain of the feedback circuit is selected with these radio buttons. The gain becomes larger with the button number. Usually, “3” or “High” is selected for the AFM mode, and “2” or “3” is selected for the STM mode. “Loop Gain” and “Fback Filter/Hz” are closely related to each other. Even if “Loop Gain” is small, a large “Fback Filter/Hz” (faster response) causes the feedback circuit to be prone to oscillating. Even if “Loop Gain” is large, a small “Fback Filter/Hz” (slower response) causes the feedback circuit not to be prone to oscillating. During image observation, select “2” or “3” for “Loop Gain”; adjust “Fback Filter/Hz”; then select a “Loop Gain” one step larger if no oscillation occurs. When setting “Loop Gain” to “1,” make sure that the Z-voltage is near zero volt. If the Z-voltage is far from zero, the tip may collide with the specimen or go far away from the specimen surface, because the Z-voltage can follow only within ±20 V to ±30 V when ‘Loop Gain’ is “1.”

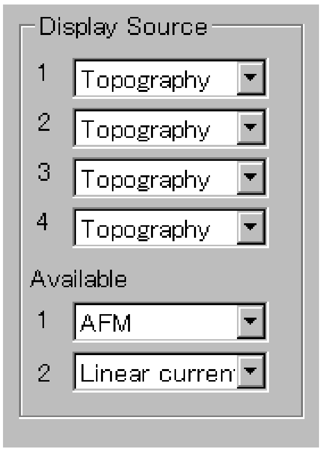
## ● Sample/Hold

The feedback is set to ON or OFF with these radio buttons. When “Sample” is selected, the feedback functions, and when “Hold” is selected, the Z voltage is held at the present position. Select “Sample” for image observation. Since the software automatically selects “Sample” or “Hold” when I-V or Force-curve is measured, you can usually leave “Sample” selected.

## ● External Offset

Offset voltage is added to the ((C–D)/(C+D)) of the AFM AMP unit using this scroll box. When the optional Vacuum Evacuation System [TM-24060] is used, the cantilever may bend due to the vacuum, and the bending of the cantilever is corrected by this function. Since the FFM value can not be corrected mechanically from outside of the vacuum, it must be corrected electrically (with “External Offset”). First, adjust the AFM value ((A−B)/(A+B)) to zero volt using the Y-axis adjusting knob; then adjust the FFM value to zero volt using this scroll bar. If the shift of the FFM value is larger than ±10 V even after the AFM value is adjusted, no correct data can be expected even if it is seemingly corrected with “External Offset.” In such a case, vent the vacuum and adjust the FFM value again.

### 7.1.1e Display Source




### ■ Available Source

This system has four image-input and display channels. However, the system provides the following seven signals:

Topography: Topography signal. Voltage applied to the Z-scanner after feedback
Aux1: Signal corresponding to the cantilever deflection. AFM ((A−B)/(A+B)) signal
Aux2: Signal corresponding to the cantilever twist. FFM ((C−D)/(C+D)) signal
Aux3: Phase signal
AFM: Feedback signal in the AFM mode.

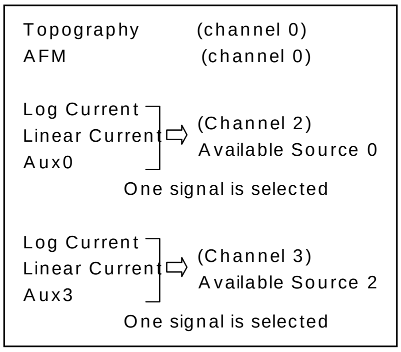
| | |
|---|---|
| Contact mode: | (A−B)/(A+B) signal |
| AC mode (Slope): | RMS value |
| AC mode (FM): | PLL value |
| AC mode (Phase): | Phase value |

Log Current: Logarithm of tunneling current
Linear Current: Tunneling current

The Topography and Aux1 signals are always allocated to two channels. Two of the other five signals (Aux2, Aux3, AFM, Log Current, Linear Current) are allocated to the remaining two channels. Click on the “▼” mark in each selection-box, and select an appropriate signal from the pull-down menu. The signals allocated to “Display Source 1 to 4” are the usable signal sources.

## For STM Mode

Two signals out of three (Log Current, Linear Current and Aux2) are selected. Usually, Log Current and Linear Current are selected.




## For Other Modes

Two signals out of five (Log Current, Linear Current, AFM, Aux2 and Aux3) are selected.
AFM is selected in "Available Source 1."
Aux2 and Aux3 are selected in "Available Source 2."

## Display Source 1, 2, 3, 4

The images to be displayed on the Display Window are designated in these selection boxes. The selectable images are Topography, Aux1 and two other images selected in "Available Source 1 and 2."
For ordinary scanning, the signal to be displayed is designated in "Display Source 1." When "Inputs" or "4 Inputs" is selected in the "Acquisition" selection-box, the signals to be displayed are designated as follows.

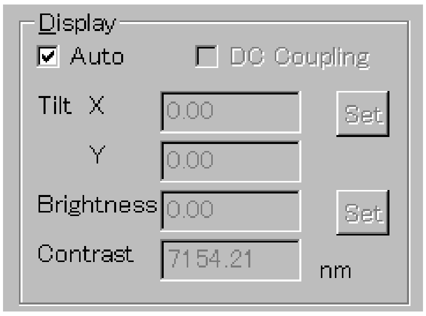
| | |
|---|---|
| Display Source 1 | Display Source 2 |
| | |

**Inputs**

| | |
|---|---|
| Display Source 1 | Display Source 2 |
| Display Source 3 | Display Source 4 |

**4 Inputs**

## 7.1.1f Display




### ■ Auto

When this check-box is checked, the image signal is normalized line by line and displayed. Therefore, image brightness and contrast are automatically corrected. Usually, this check-box is checked.
When this check-box is not checked, image brightness and contrast can be manually adjusted. These adjustments, however, are applied only to an image display process. So, when the "Grab" operation is performed, the original normalized image is stored in the computer memory. When the image is recorded directly from the frame memory (not grabbed), the manually adjusted image (with "Auto" not checked ) is recorded. For the output from the frame memory, refer to Subsection 7.2.7b "Framegrabber Mode."

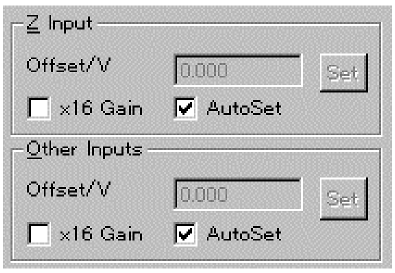
### ■ Tilt X, Y

The software corrects for tilt. "Tilt Y" is in effect only when the "DC Coupling" check box is checked.

### ■ Brightness, Contrast

Image brightness and contrast can be corrected.

## 7.1.1g Z Input



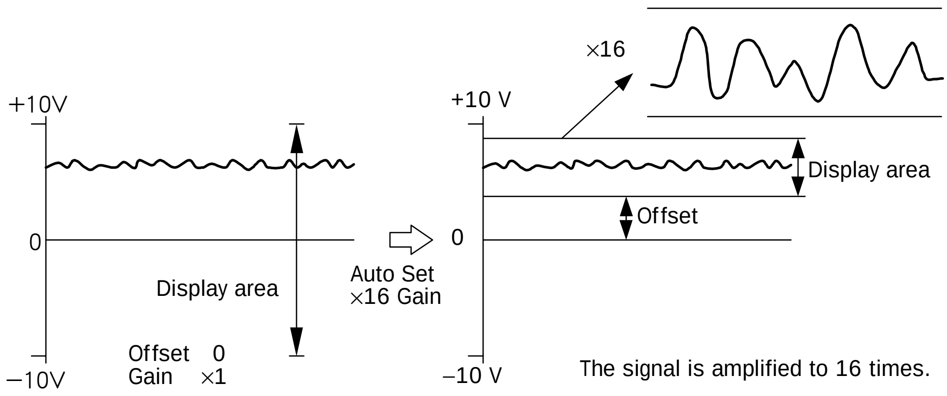

"Gain" and "Offset" are set for the input signal of topography (1/15 of the voltage applied to the Z scanner after feedback).

### ■ Offset/V

The offset voltage to be added to the Topography signal is specified in this input box. This function is in effect only when the "AutoSet" check box is not checked.

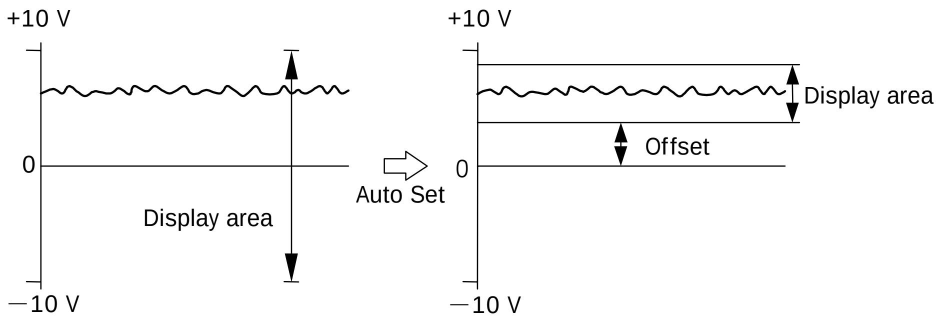
## x16 Gain

When this check box is checked, the amplifier gain for the Topography signal becomes 16 times. This function is useful for a very low contrast specimen such as an atomic image. If this "×16 Gain" function is used for observing a wide area or an uneven-surface specimen, the image contrast may become saturated. Usually, images are observed without checking this check box. Be sure to use this function only for specimens whose image contrast is very poor.

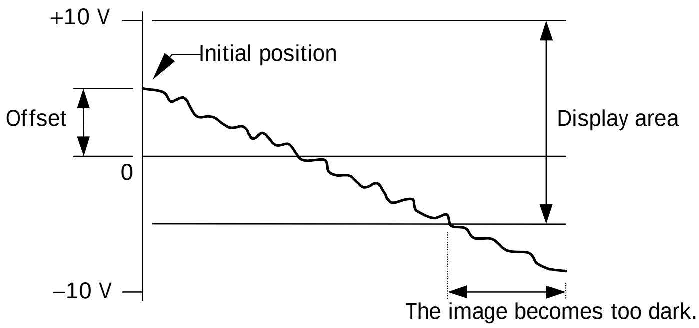



## AutoSet

When this check box is checked, the offset voltage is automatically set so that the signal at the initial position becomes zero volt. If the voltage applied to the Z scanner is positive (+), an offset voltage is added so that the voltage at that positive position becomes 0 V.




Because of this, the display area starting from the initial position (usually, the upper-left corner of the image) becomes a maximum. If the initial position is extremely high or low, or if the specimen is tilted, the image could become white or black during scanning. In such a case, set "Offset/V" manually.



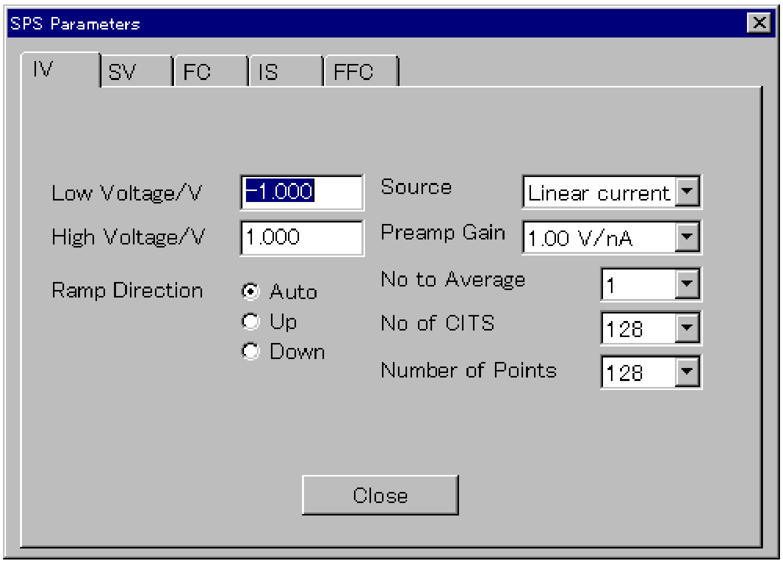

Usually, the “AutoSet” check box is checked.

### 7.1.1h Other Inputs

The offset and gain specified in this sub-frame are applied to all image signals other than Topography. When “AuotSet” is checked and “Inputs” (two images) or “4 Inputs” (four images) is selected in the “Acquisition” selection box, the offset value is determined for the image signal to be displayed in the lowest number other than Topography. If offset values are different among the other signals, deselect “AutoSet”; set “Offset/V” to 0 V manually; grab the image; then try to obtain the optimum image contrast for each image using the “Adjust LUT” function. The “×16 Gain” setting is seldom used for “4 Inputs.”

### 7.1.1i SPS Parameters

Clicking on the “SPS Param” button displays the “SPS Parameters” window.



## ■ IV

When “IV” or “CITS” is selected in the “Acquisition” selection box, parameters for the bias voltage scanning are specified in this frame.

Low Voltage/V: The minimum voltage for the bias scanning is specified in this input box.

High Voltage/V: The maximum voltage for the bias scanning is specified in this input box.

Ramp Direction: The direction for scanning is selected with radio buttons.

- Up: The bias voltage is scanned from the minimum voltage to the maximum voltage.
- Down: The bias voltage is scanned from the maximum voltage to the minimum voltage.
- Auto: The bias voltage is scanned from the maximum or minimum voltage, whichever is nearer to the “Sample” (in “Bias/V” frame) voltage.

No to Average: The number of data to be averaged is selected in this selection box.

Preamp Gain: The preamplifier gain is specified in this selection box.

Source: An input signal is designated from the pull-down menu.
Topography···Voltage applied to the Z scanner
Log Current···Logarithm of tunneling current
Linear Current···Tunneling Current
Aux1···AFM ((A–B)/(A+B)) value
Aux2···FFM ((C–D)/(C+D)) value
The kinds of signals to be displayed are specified in “Available Source” on the “SPM Parameters” window.
Usually, “Linear Current” is selected for the IV measurement.

No of CITS images: The number of CITS images (16, 32, 64 or 128) is selected in this selection box [only for CITS]. The bias voltage scanning range is by this number, and the tunneling current is measured at each resulting bias voltage.

Number of Points: The number of bias voltages (128, 256, 512, 1024 or 2048) at which the tunneling current is measured is selected in this selection box [only for IV]. The bias voltage scanning range is divided into equal intervals by this number, and the tunneling current is measured at each resulting bias voltage.

## ■ SV

When “SV” is selected in the “Acquisition” selection box, the parameters for the bias voltage scanning are specified in this frame.

Low Voltage/V: The minimum voltage for the bias scanning is specified in this input box.

High Voltage/V: The maximum voltage for the bias scanning is specified in this input box.

Ramp Direction: The direction for scanning is selected with radio buttons.

- Up: The bias voltage is scanned from the minimum voltage to the maximum voltage.

Down: The bias voltage is scanned from the maximum voltage to the minimum voltage.

Auto: The bias voltage is scanned from the maximum or minimum voltage, whichever is nearer to the “Sample” (in “Bias/V” frame) voltage.

No to Average: The number of data to be averaged is selected in this selection box.

ADC Source: An input signal is designated from the pull-down menu.
Topography···Voltage applied to the Z scanner
Log Current···Logarithm of tunneling current
Linear Current···Tunneling Current
Aux1···AFM ((A–B)/(A+B)) value
Aux2···FFM ((C–D)/(C+D)) value
Usually, “Topography” is selected for the SV measurement.

Number of Points: The number of bias voltages (128, 256, 512, 1024 or 2048) at which the gap between tip and specimen surface is measured is selected in this selection box. The bias voltage scanning range is divided into equal intervals by this number, and the gap is measured at each resulting bias voltage.

## ■ FC (can be used in the AFM Mode)

When “Force Curve” is selected in the “Acquisition” selection box, parameters for force curve measurement are specified in this frame. This item is in effect only for the AFM mode.

Tip Displacement/nm: The range of the cantilever height (Z direction) scanning is specified in this input box.

Tip Offset/nm±: The offset value of the cantilever scanning (Z direction) is specified in this input box. Usually, 0 (zero) is specified.

Ramp Direction: The direction for specimen movement is selected with radio buttons.

In->Out: Specimen surface moves away from the cantilever; then approaches to the cantilever.

Out->In: Specimen surface approaches to the cantilever; then moves away from the cantilever.

Usually, “Out->In” is selected for the Force Curve measurement.

No to Average: The number of data to be averaged is selected in this selection box. Usually, “1” is selected.

ADC Source: An input signal is designated from the pull-down menu.
Topography···Voltage applied to the Z scanner
AFM···Feedback signal
Aux1···AFM ((A–B)/(A+B)) value
Aux2···FFM ((C–D)/(C+D)) value
Usually, “Aux1” is selected for the FC measurement.

Note: The number of measurement points is always 64 for both forward and backward scanning, giving a total of 128 points.

## ■ IS (can be used in the STM mode)

When “IS” is selected in the “Acquisition” selection box, the parameters for IS measurement are specified in this frame. This item is in effect only for the STM mode.

| | |
|---|---|
| Tip Displacement/nm: | The range of the cantilever height (Z direction) scanning is specified in this input box. |
| Tip Offset/nm±: | The offset value of the cantilever scanning (Z direction) is specified in this input box. Usually, 0 (zero) is specified. |
| Ramp Direction | The direction for scanning the tip is selected with radio buttons.<br>In->Out: The tip moves away from the specimen.<br>Out->In: The tip apptoaches to the specimen. |
| No to Average: | The number of data to be averaged is selected in this selection box. |
| Preamp Gain: | The gain of the preamplifier is specified in this selection box. |
| Source: | An input signal is designated from the pull-down menu.<br>Log Current···Logarithm of tunneling current<br>Linear Current···Tunneling Current<br>Aux1···AFM ((A–B)/(A+B)) value<br>Aux2···FFM ((C–D)/(C+D)) value<br>Usually, “Linear Current” is selected for the IS measurement. |

## ■ FFC (can be used in the AFM mode)

When “Friction F-C” is selected in the “Acquisition” selection box, the parameters for the bias voltage scanning are specified in this frame.

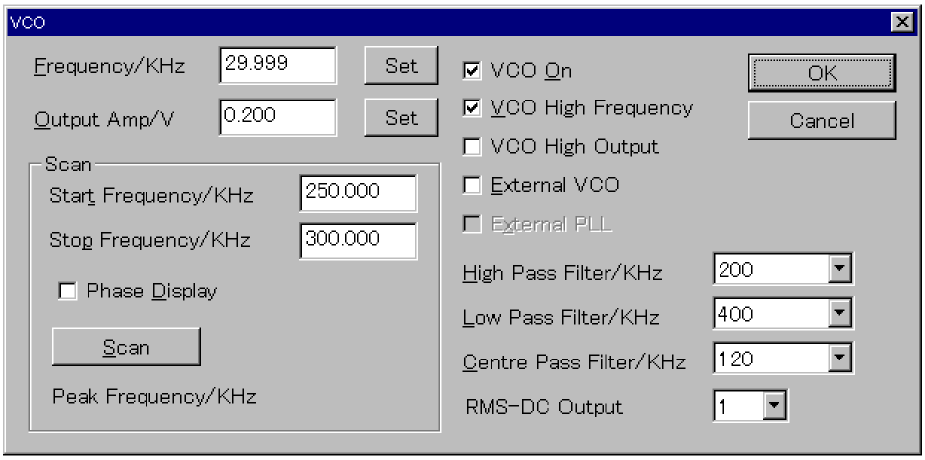
| | |
|---|---|
| Tip Displacement/nm: | The range of the cantilever lateral scanning is specified in this input box. |
| Offset/nm±: | The offset value of the cantilever lateral scanning is specified in this input-box. Usually, 0 (zero) is specified. |
| Ramp Direction | The direction for scanning the tip is selected with radio buttons.<br>Up···The tip moves from bottom to top.<br>Down···The tip moves from top to bottom. |
| No to Average: | The number of data to be averaged is selected in this selection box. |
| Feedback: | Whether feedback is to be performed during scanning is specified in this selection box.<br>“Sample”···Feedback is on.<br>“Hold”···Feedback is off. |
| ADC Source: | An input signal is designated from the pull-down menu.<br>Topography···Voltage applied to the Z scanner<br>AFM···Feedback signal<br>Aux1···AFM ((A–B)/(A+B)) value<br>Aux2···FFM ((C–D)/(C+D)) value<br>Usually, “Aux2” is selected for the Friction F-C measurement. |

## ■ SPS Mode

When ‘SPS’ is selected in the “Acquisition” selection box, the measurement mode is designated in this selection box. Select a desired measurement mode from among “IV,” “SV,” “Force Curve” (only for AFM) and “IS” (only for AFM). Measurement conditions for the designated measurement mode are specified in the “IV,” “SV,” “FC” or “IS” frame.

## 7.1.1j VCO

Clicking on the ‘VCO’ button displays the ‘VCO’ window.




A non-contact cantilever is vibrated in the AC mode AFM observation. The cantilever vibrating parameters are specified in this window.

## ■ Frequency/kHz

The vibrating frequency is specified in this input box. The frequency range depends on whether or not “VCO High Frequency” is checked.

| VCO High Frequency Off ☐ | VCO High Frequency On ☑ |
|---|---|
| 3 kHz to 50 kHz | 30 kHz to 500 kHz |

Note: The waveform of the output signal is sinusoidal.

## ■ Output Amp/V

The voltage to be applied to the piezoelectric element is specified in this input box. The range of the voltage to be set is 0 to 10 V (±10 V).

## ■ VCO On

When this check box is checked, the vibrating voltage is applied to the Piezoelectric element.

## ■ VCO High Frequency

This check box specifies the range of the vibrating frequency (Regarding the frequency range, refer to "■ Frequency/kHz" in this section).

## ■ VCO High Output

This check box specifies the range of the vibrating voltage.
☐ VCO High Output··· 0 to ±1.0 V
☑ VCO High Output··· 0 to ±10 V

## ■ External VCO

When you want to use an external oscillator without using the internal oscillator, check this check box. Connect the external oscillator to the EXT terminal on the rear of the AFM AMP. Set the output of the oscillator to ±1.0 V. Adjust the frequency of the oscillator using the oscillator, but adjust "VCO High Output" and "Output Amp/V" using the software.

## ■ External PLL

When you want to measure the resolution of the internal PLL, check this check box. In the JSPM-4200 this "External PLL" is not used.

## ■ Scan

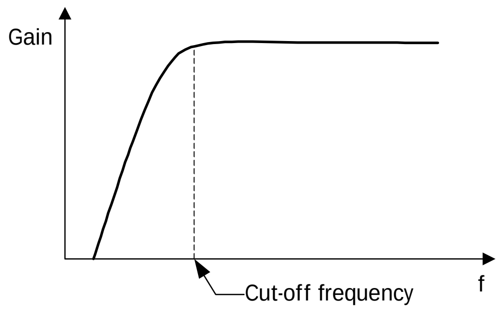
The parameters in this frame are used for searching for the resonance frequency of the cantilever.

- Start Frequency/kHz
  The start frequency of the frequency sweep is specified in this input box.
- Stop Frequency/kHz
  The stop frequency of the frequency sweep is specified in this input box.
- Scan
  Clicking on this button starts the frequency sweep. The measurement result is displayed on the Display Window, and the frequency at which the peak is observed is indicated in "Peak Frequency/kHz" just below the "Scan" button.

Note: Before performing scanning, you must set the following parameters in the "SPM Parameters" window.
STM/AFM: Slope
Available Source 1: AFM

## ■ High Pass Filter/kHz

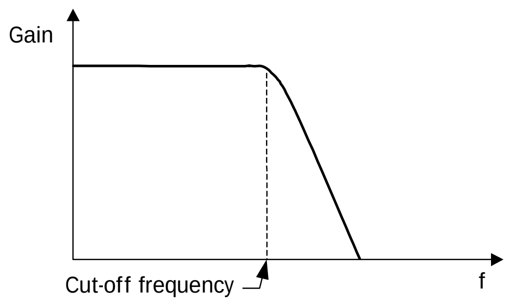
The cut-off frequency of the high-pass filter for the input AFM ((A–B)/(A+B)) signal is specified in this selection box. When the frequency sweep is started by clicking on the “Scan” button, the cutoff frequency must be lower than “Start Frequency/kHz.” After the vibrating frequency is finally determined, you must set the cutoff frequency to the value nearest but lower than the “Frequency/kHz” value.




**Frequency characteristic of high pass filter**

## ■ Low Pass Filter/kHz

The cutoff frequency of the low-pass filter for the input AFM ((A–B)/(A+B)) signal is specified in this selection-box. When the frequency sweep is started with “Scan,” the cutoff frequency must be higher than the “Stop Frequency/kHz” value. After the vibrating frequency is finally determined, you must set the cutoff frequency to the value nearest but higher than the “Frequency/kHz” value.



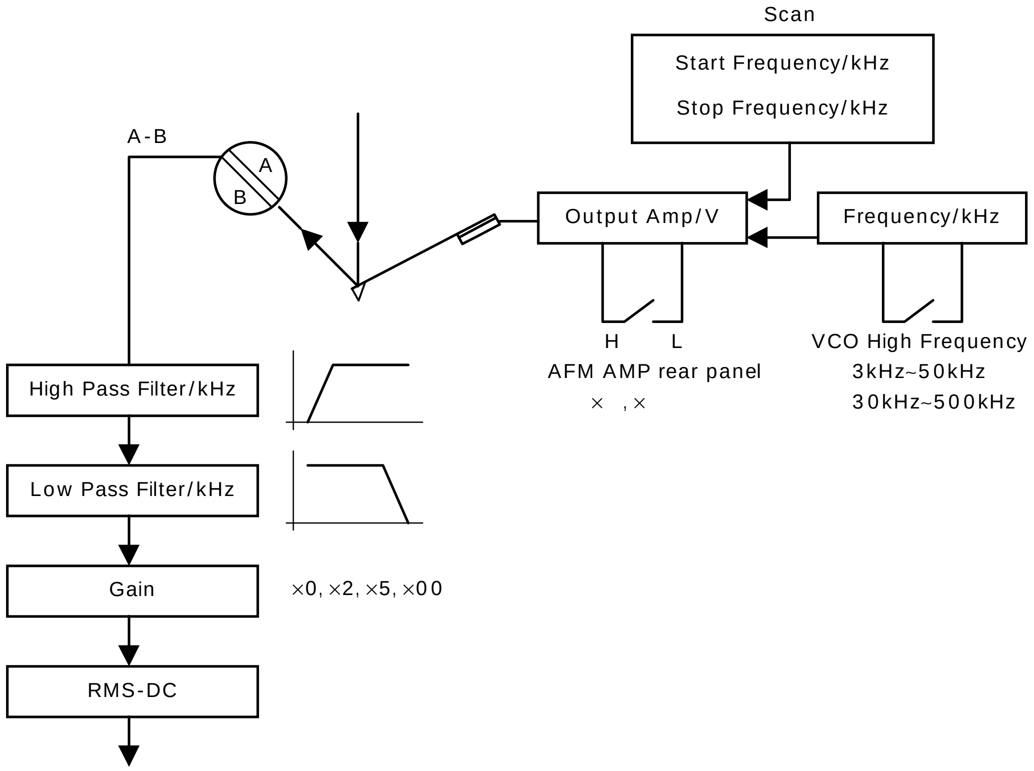

**Frequency characteristic of low pass filter**

## ■ Centre Pass Frequency/kHz

When the FM detection method is used, set the frequency to the frequency nearest to the cantilever resonance frequency.

## ■ RMS-DC Output

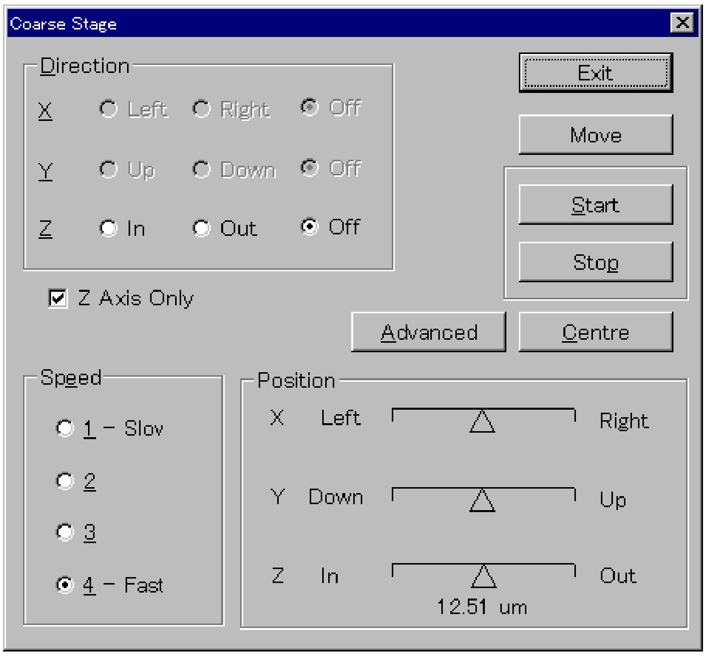
Amplifier gain for the signal that has passed through the high-pass and low-pass filters is specified. Usually, it is set to 10.




**Block diagram of the VCO system**

## 7.1.1k Stage

Clicking on the “Coarse Stage” button displays the “Coarse Stage” window.



The Z-axis motor drive is controlled with this window. In the JSTM-4200 series, only the Z axis is in effect.

## ■ Direction

These radio buttons designate the direction of Z movement.
Z-In: Specimen surface approaches to the tip.
Z-Out: Specimen surface moves away from the tip.
Z-Off: Specimen stage does not move.

**CAUTION**

**When the tip is moved close to the specimen in the "Coarse Stage" window, the tip never stops even if a tunneling current or atomic force is actually detected.**

## ■ Z Axis Only

Check this check box when you do not want to use the X and Y motor drive. In the case of the JSTM-4200 this check box should always be checked.

## ■ Speed

In the case of the JSTM-4200, only "4-Fast" is in effect.

## ■ Position

In the case of the JSTM-4200, only "Z" is in effect.
This bar-chart indicates the Z position in the z movement range. If the "△" mark is at the "In" end or "Out" end, the Z driving motor does not move any more.

## ■ Move

The Z driving motor works while this button is being held down.

## ■ Start/Stop

Once you click the mouse on the "Start" button, the motor continuously works even if you release the mouse button. To stop the motor, click on the "Stop" button.

## ■ Centre

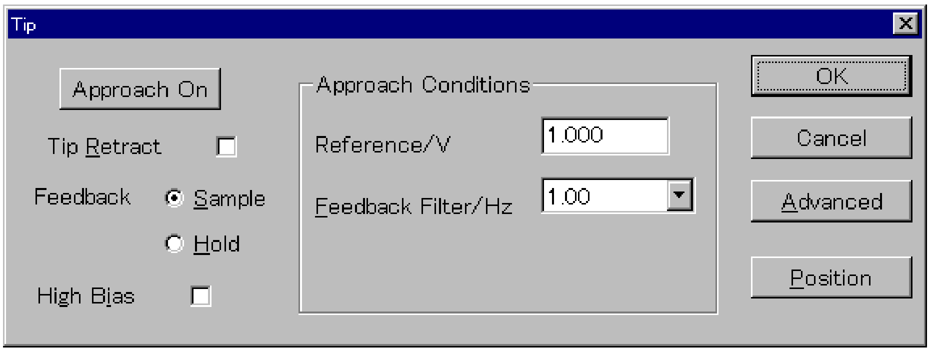
In the JSTM-4200, this button is not used.

## ■ Advanced

Calibration of the Z-stage position is set using this button. The calibration value is set before shipment from the factory. For the calibration value set at the time of shipment, refer to Chapter 9 "APPENDIX."

### 7.1.1l Tip

Clicking on the “Tip” button displays the “Tip” window.



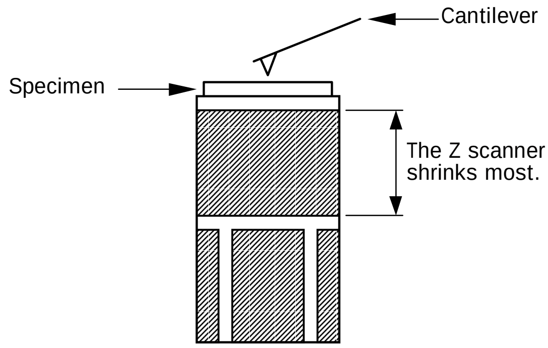

This window is used to move the tip or cantilever close to the specimen.

## ■ Approach On/Approach Off

Clicking on the “Approach On” button starts approaching with the conditions specified in the “Approach Conditions” frame in this window.
When the approaching finishes, the “Approach Off” button must be clicked on.
If the check box for “Auto Approach Stop” which is opened by clicking on the “Advanced” button is not checked, the system conditions remain the same as those specified in “Approach Conditions” even after approaching finishes.
Even if the check box for “Auto Approach Stop” is not checked, approaching automatically stops, but to stop the software, the “Approach Off” button must be clicked on. When the “Approach On” button is clicked on, the system parameters are set to the values specified in the ‘SPM Parameters’ window.
The SPM CONTROL unit recognizes the completion of approaching by the voltage applied to the Z scanner. If the voltage applied to the Z scanner changes due to unexpected electrical noise or any other similar event at the start of approaching or during approaching, that would cause the approaching to stop. Even though the Z scanner voltage returns to the previous voltage (+150 V), approaching is not automatically resumed. In such a case, click on the “Approach Off” button; then click on the “Approach On” button again.

## ■ Tip Retract

When this check box is checked, the Z-piezoelectric element shrinks the most. This check box is used to retract the tip from the specimen temporarily when, for example, the observation field or stage moving is to be changed. While the “Tip Retract” check box is checked, approaching cannot be performed (the “Approach On” function is not in effect).




## ■ Feedback

These radio buttons turn the feedback function on or off.

- Sample: When the radio button for “Sample” is clicked on, the “Feedback” function is on.
- Hold: When the radio button for “Hold” is clicked on, the “Feedback” function is off. The Z scanner voltage is held at the present Z position.

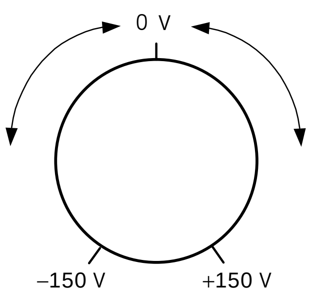
When performing approaching, select “Sample.”

## ■ High Bias

When the “High Bias” check box is checked on, a specimen high bias voltage (−150 to +150 V) is applied. Applying a high bias voltage between the tip and the specimen in the STM mode allows the tip to be cleaned. The conditions for tip cleaning greatly differ, depending upon the tip material and tip condition.

1. Select “Hold” for “Feedback.”
2. Check the check box for “High Bias.”

   The confirmation window will appear; then click on the “OK” button.
   The applied voltage is adjusted with the High Bias knob on the SPM CONTROL unit.




High Bias

3. To deselect “High Bias,” click on the “High Bias” check-box again to erase the check mark in the box.

## Approach Conditions

The conditions for approaching are specified in this frame. When the "Approach On" button is clicked on, approaching is performed according to the conditions specified in this frame.

| STM mode | AFM mode |
|---|---|
| Current/nA | Reference/V |
| Feedback Filter/Hz | Feedback Filter/Hz |
| Sample Bias/V | |

Select either the STM mode or the AFM mode in the "STM/AFM" selection-box in the "Scan" frame of the "SPM Parameters" window. Select the desired mode before opening the "Tip" window.

## ■ Position

The "Position" button is used to move the tip to a desired point referring to the image displayed in Display Window. This function is useful for specifying an I-V or Force Curve measurement point on an image. The following is the procedure for the "Position" setting.

**1.** Perform image observation and grab the image.

Unless the image is grabbed, an error message will appear.

**2.** Click on the "Position" button, and move the cursor to the Display Window in which the image is displayed.

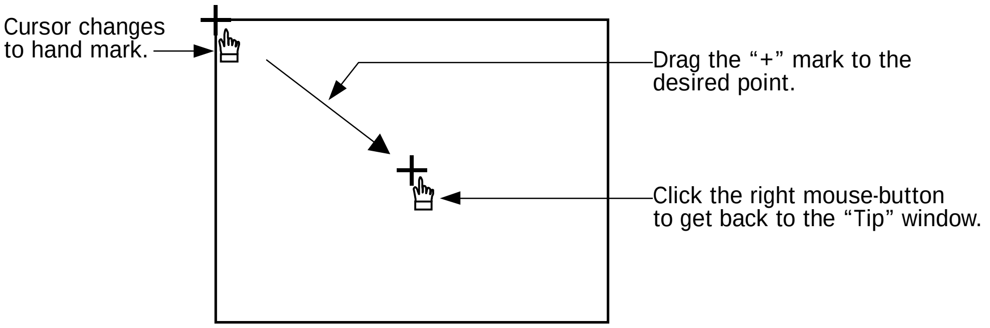
The cursor mark will change to a hand mark.

**3.** Move the cursor to the present tip position indicated by the "+" mark; click the left mouse button; drag the "+" mark to the desired point where the I-V or Force Curve is to be measured.

Note: The tip moves in real time with the "+" mark in the image. Drag the "+" mark very slowly. Otherwise, the tip and the specimen might be damaged.

**4.** When the position has been determined, click the right mouse-button to get back to the "Tip" window.

Note: The position determined as described above does not necessarily correspond accurately to the position in the image because the obtained image might be distorted due to hysteresis and creep of the scanner.



Note: The position to which the “+” mark is dragged by using the “Position” function becomes the initial position for the measurement. When scanning is stopped with the “Abort” operation, the tip is held at this position. Since the new scanning starts from the origin point (top left), the obtained image may be distorted due to hysteresis and creep of the scanner. In such a case, position the tip to the origin point again.

### ■ Tip Advanced

Clicking on the “Advanced” button displays the “Tip Advanced” window.
In this window, the tip speed for approaching is specified. In the case of the JSTM-4200 series, only “4 Fast” is available. Select “4 Fast” for both “Step 1” and “Step 2.”

### ■ Auto Approach Stop

If this check box is checked, approaching automatically stops when the voltage applied to the Z scanner reaches the voltage specified in “Reference/V.” Even if it is not checked, approaching automatically stops, but it is the hardware that stops approaching, so the Z voltage cannot be specified in “Reference/V.” Usually, the check box for “Auto Approach Stop” is checked.

### ■ Reference/V

This function is used to specify a Z voltage for stopping approaching when the check box for “Auto Approach Stop” is checked. Usually, 0 V is set.

## 7.1.1m Lock-in

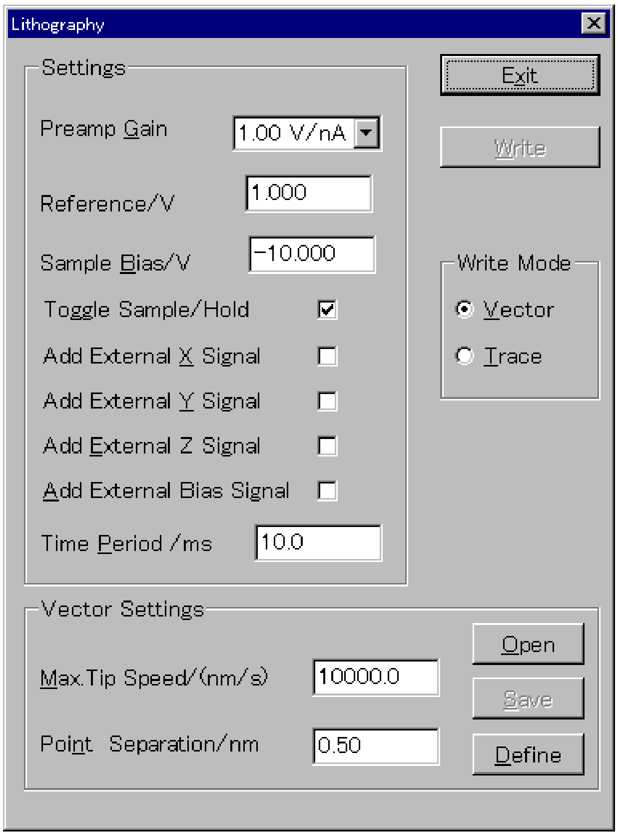
This button is used to control the lock-in amplifier when the optional accessory, TM-26010/TM-26020 Viscoelasticity, Lateral Modulation FFM (50)/(60) or TM-26030 Kelvin Force Microscope is attached. For the operational details of these accessories, refer to each instruction manual.

### ■ Other Options

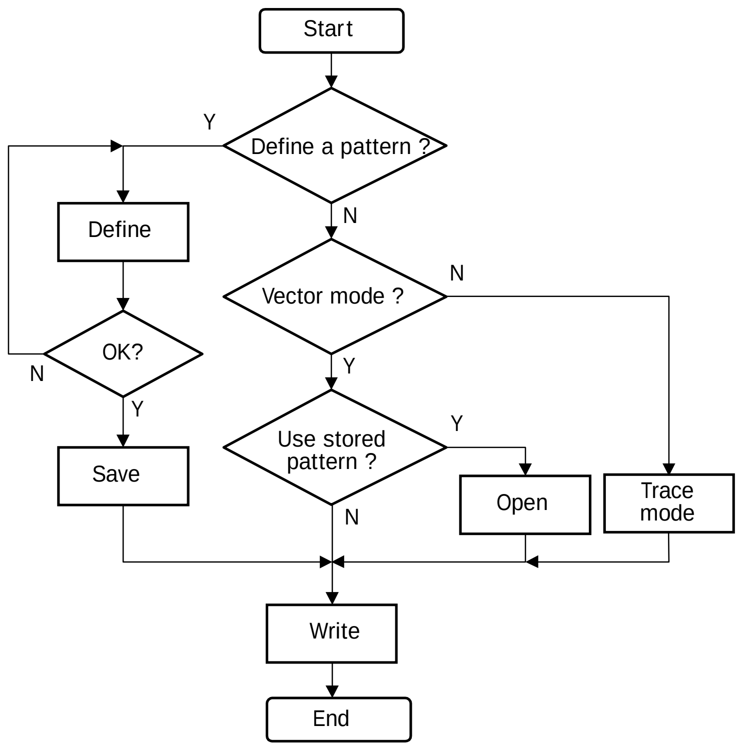
This function is not used in the JSPM-4200.

### 7.1.1n Lithography

Clicking on the “Lithography” button displays the “Lithography” window.




When certain values are given to the bias voltage and tunneling current, the specimen surface structure may change due to displacement or adsorption of atoms. “Lithography” is the function to lithograph (write on) the specimen surface by using this phenomenon. The procedure for lithography is shown in the flow-chart below.




## ■ Settings

Conditions for lithography are specified in this frame.

| Parameter | Description |
|---|---|
| Preamp Gain | Gain for preamplifier is selected in this selection box. |
| Current/nA (for STM mode) | Tunneling current is specified in this input box. |
| Reference/V (for AFM mode) | Reference voltage is specified in this input box. |
| Sample Bias/V | Sample bias voltage is specified in this input box. |
| Toggle Sample/Hold | Whether or not the feedback circuit should be turned on is designated in this check box. When the radio button for “Sample” is clicked on, the “Feeddback” function is on. When the radio button for “Hold” is clicked on, the “Feedback” function is off. |
| Add External ** Signal | Whether or not the external AD**signal should be added is designated in this check box. |
| Time Period/ms | The duration for applying “Current/nA” or “Reference/V” is specified in this inputbox. If “0.0” is specified, “Current/nA” or “Reference/V” is applied while the left mouse button is being pressed. This function is in effect only for the Trace mode. |

## Vector Settings

Lithography conditions for the Vector mode are specified in this frame.

| Parameter | Description |
|---|---|
| Max. Tip Speed/(nm/s) | Speed of movement of the tip is specified in this input box. |
| Point Separation/nm | The step gap for the tip movement is specified in this input box. |
| Open | A pattern is defined and the data stored in the file is loaded when you click on this button. |
| Save | The defined pattern is saved in the file when you click on this button. |
| Define | A designed pattern is defined when you click on this button. |

## Write Mode

These radio buttons designate writing modes.

| Parameters | Description |
|---|---|
| Writing mode | Used to specify a writing mode.<br>Trace: When this radio button is selected, lithography is performed by manual operation of the mouse.<br>Vector: When this radio button is selected, the tip moves along the pattern that has already been defined. |

- Trace mode

  After selecting "Trace," click on the "Write" button; then execute lithography by moving the mouse on the Display Window while pressing the mouse button.

  Notes: 1. If "0" is specified in "Time Period/ms," the same condition is retained while the left mouse-button is being pressed.

  2. The trajectory (pattern) of the mouse movement is displayed on the Display Window.

**CAUTION**

**In order to prevent the tip from colliding with the specimen surface, the speed of the tip movement must not be faster than 200 nm/s.**

- Vector mode

  After selecting "Vector," click on the "Write" button; then the tip moves along the pattern that has already been defined.

  Note: The pattern must be defined prior to the lithography execution with "Open" or "Define" operation.

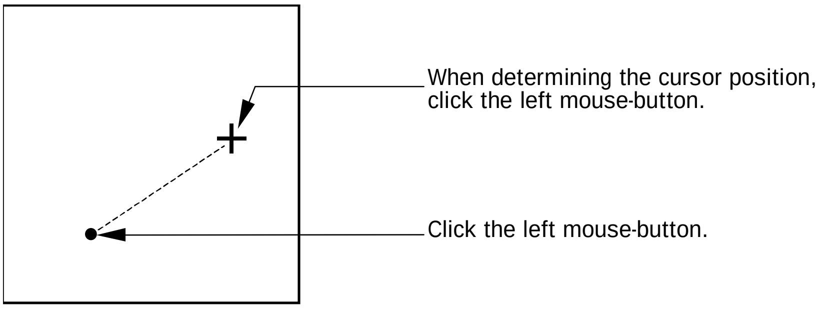
## ■ Lithography in Trace mode

The following is the procedure for performing lithography in the Trace mode.

1. Observe an image as usual and grab it.
2. Specify the lithography conditions in the “Settings” frame.
3. Select “Trace” in the “Write Mode” frame; then click on the “Write” button.
   Move the cursor to the Display Window. The cursor will change to the “+” mark.
4. Execute lithography by moving the mouse while holding the left mouse-button.
   Press the right mouse-button to stop the lithography.
5. Confirm the written pattern by the ordinary image-observation procedure.

## ■ Lithography in Vector Mode

1. Observe an image as usual and grab it.
2. Specify the lithography conditions in the “Settings” frame.
3. Select “Vector” in the “Write Mode” frame; then click on the “Define” button in the “Vector Settings” frame.
   Move the cursor to the Display Window. The cursor mark changes to the “+” mark.
4. Move the “+” mark to the initial point of the pattern to be written by holding the left mouse-button; then click the left mouse-button again to determine the initial point. Move the “+” mark to the next point of the pattern and click the left mouse-button. The second point is fixed.




   You can continuously define the pattern as described above. To stop the pattern definition, click the right mouse-button.
5. Click on the “Write” button. Lithography will be performed along the defined pattern.

## ■ Form of File

A pattern-definition file is saved in ASCII (American Standard Code for Information Interchange) form, as shown below. This file itself can be edited using the Note pad of Windows95™.

```
WinSPM Version 4.04
Vector saved on 9/9/1997 at 16:43:15
Vector created on 9/9/1997 at 16:26:02
*
*Start comment lines with a '*'
*
 x1    y1  -  x1    y1:    Bias    Feedback   Gain   Hold   External
165   355    349   250   -10.000    1.000     1.00    1        0
252   437    430   344   -10.000    1.000     1.00    1        0
```

## 7.1.1o Noise

Clicking on this button indicates the minimum, maximum and average voltages of the ADC input signal. The signal is sampled 5,000 times per second.

1. Click on the “Noise Analysis” button.
   The measurement result of the signal designated in the “Display Source” is indicated in the “Status” frame in the “SPM Parameters” window.
2. To stop the noise analysis, click on the “Abort’ button.”

## 7.1.1p Save

This function is used to save the present settings specified in the “SPM Parameters” window in a file.

## 7.1.1q Load

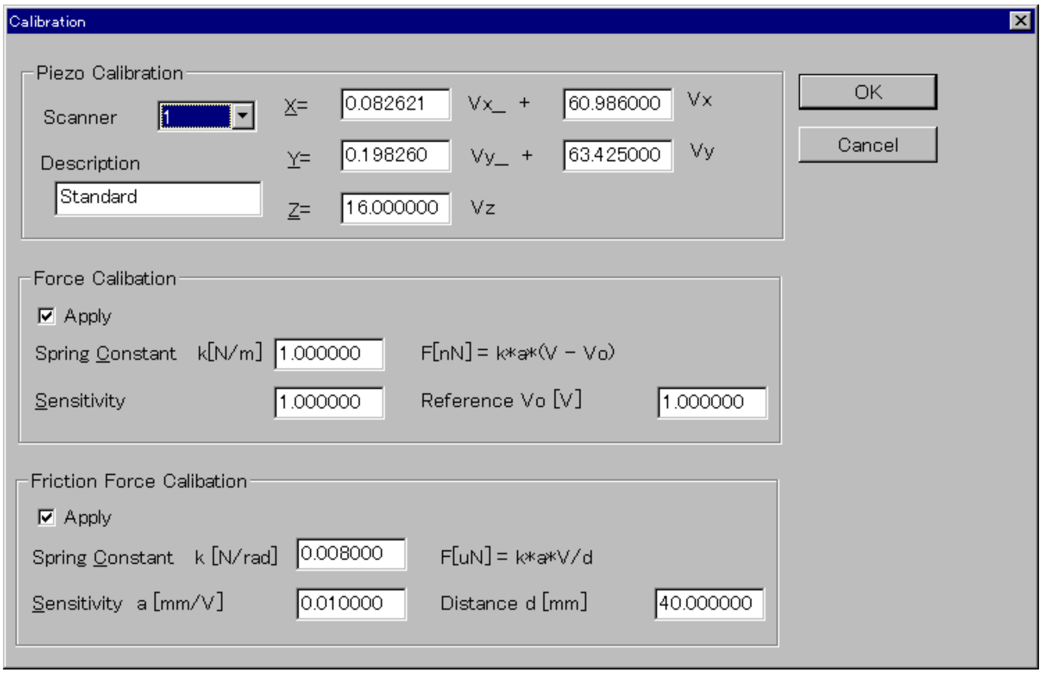
This function is used to recall the parameter settings saved using the “Save” button and initialize the SPM CONTROL unit with them.

## 7.1.1r Exit

Clicking on the “Exit” button terminates the “SPM Parameters” window.

## 7.1.2 SPM Calibration

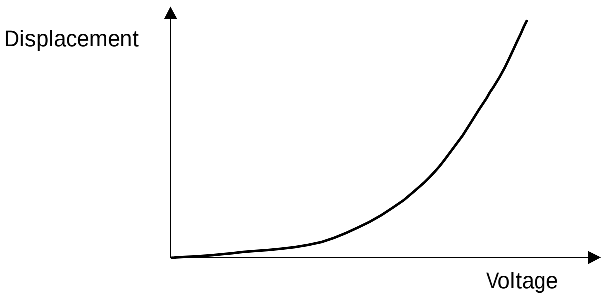
Click on “SPM Scan” in the main menu, and select “SPM Calibration” from the pull-down menu. Then, the “Calibration” window is opened. The scanner sensitivity is set in this window.




### ■ Piezoelectric Scanner Calibration

A tube-shaped piezoelectric scanner is used in the JSTM-4200. This type of piezoelectric element has a nonlinear displacement-voltage as shown below. So, some corrections must be applied to the displacement-voltage characteristic.

These corrections have been done in the factory before shipment. These data are listed in Chapter 9 “APPENDIX.”



## Force Calibration

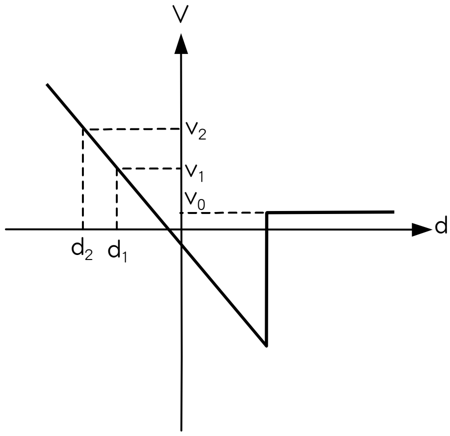
The cantilever is calibrated in this frame.

- Apply

  When the check box for “Apply” is checked, a force image or a force curve is indicated with an atomic-force value calculated from the applied voltage.
- Spring Constant

  The spring constant of the cantilever is input in this input box.
- Sensitivity [nm/V]
- Reference[V]

  This value differs according to the instrument or cantilever used. Click on the check box to remove the check mark; acquire a force curve; then calculate it. When the following force curve is obtained, each parameter value is calculated as follows.




$$\text{Sensitivity} = \frac{d_2 - d_1}{V_2 - V_1}$$

## Friction Force Calibration

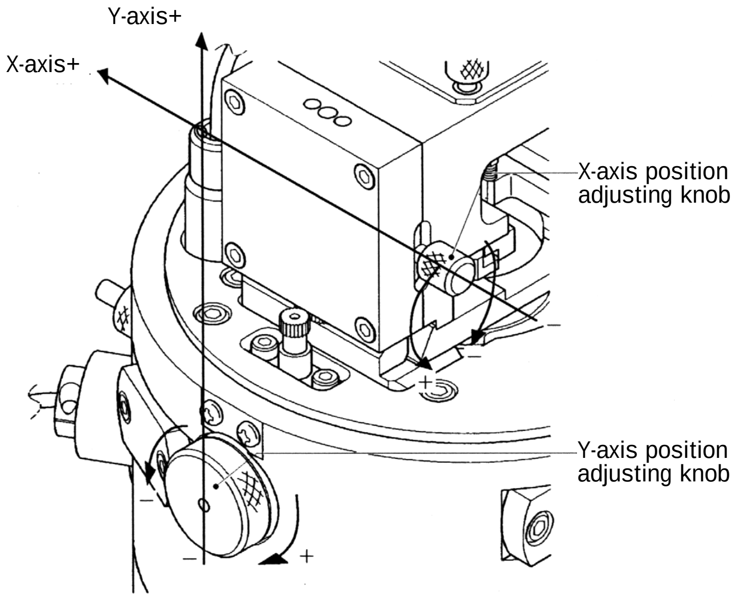
The cantilever for friction force is calibrated in this frame.

- Apply

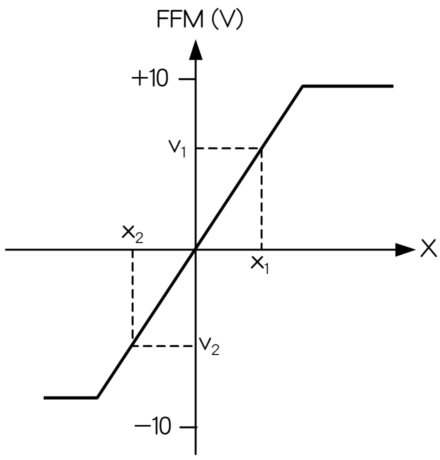
  When the “Apply” check box is checked, a friction force image is indicated with a friction-force value calculated from the applied voltage.
- Spring Constant

  The torsional spring constant of the cantilever is input in this input box.
- Sensitivity [nm/V]

  This value differs according to the instrument used. The sensitivity is calibrated with the FFM value shown on the AFM AMP indicator while the photodiode position (in the X-axis) is changed.




The X-axis position adjusting knob shifts 0.5 mm per revolution, and the Y-axis position adjusting knob shifts 0.25 mm per revolution. When the following result is obtained, the calibration value is calculated from this graph.




$$\text{Sensitivity} = \frac{x_1 - x_2}{V_1 - V_2}$$

- Distance

  The distance between the cantilever and the photodiode is input in this input box. In the case of the JSPM-4200, the distance is 40 mm.

### 7.1.3 Reset SPM

Click on “SPM Scan” in the main menu, and select “Reset SPM” in the pull-down menu. Then, the “Reset SPM” window is opened. When the “OK” button in the “Reset SPM” window is clicked on, the SPM CONTROL unit is initialized by the conditions specified in the “SPM Parameters” window.
This operation must be carried out when the scanner or the SPM head is replaced, or the SPM CONTROL unit is switched OFF, then ON while the computer system is at work.

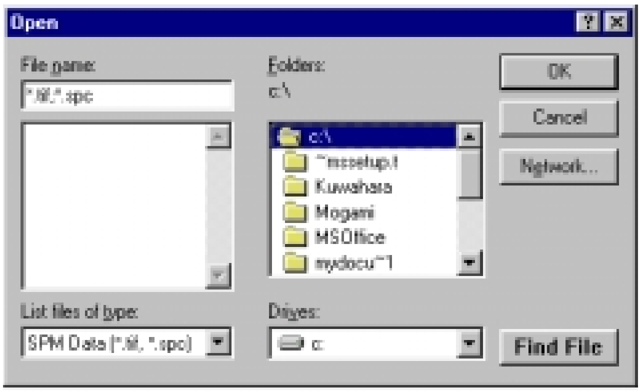
# 7.2 IMAGING (IMAGE PROCESSING FUNCTIONS)

## 7.2.1 File

### 7.2.1a Open

Click on “File” in the main menu, and select “Open” in the pull-down menu. Then, the “Open” window is opened. Data saved on the disk is loaded into the computer memory in this window.

- **File name**




The name of the file to be loaded into the computer memory is specified in this input box.

Note: You can enter the drive name, directory name and wild cards (* and ?) instead of a specific file name. The wild-cards are as follows:
*: Substitutes for a character string
?: Substitutes for one character

**[Example]**

| | |
|---|---|
| *. * | Any file |
| *.TIF | Any file with an extension “TIF” |
| SI*.TIF | Any file starting with “SI” and having an extension “TIF” (for example, “SIABC.TIF”) |
| SI111_?.TIF | Any file starting with “SI111” following any one character, and having an extension “TIF” For example, “SI111_1” and “SI111 A. TIF” match “SI111_?.TIF,” but “SI111_AB” does not. |

When you click on the “OK” button, the applicable file names are displayed in the selection box below. Double-click on the desired file name; then the specified file is loaded. If you want to load several successive files at a time, drag the mouse to highlight the desired file names, and click on the “OK” button. If you want to load several files that are not successive at a time, drag the mouse while pressing the ‘ctrl’ key on the keyboard to highlight the desired files names, and click on the “OK” button.

Note: If so many files have been continuously specified that the buffer memory can not accept them all, no file is loaded.

- **List files of type**

The types of files to be listed are designated in this selection box. The following seven types are provided:

| Type | Description |
|---|---|
| SPM Data (*.tif, *.spc) | Image file and graph file such as I-V data<br>File normally saved with this software |
| SPM Image (*.tif) | Image file only |
| Binary Image (*.bin) | Image file saved in binary with “Save As” |
| Binary FFT (*.bft) | Diffraction image file which is FFT-processed spectrum data in binary |
| ASCII Image (*.asc) | Image file saved in ASCII code with “Save As” |
| ASCII FFT (*.aft) | Diffraction image file which is FFT-processed spectrum data in ASCII code |
| Spectrum (*.spc) | Graph file such as I-V data |

- **Folders**

The folder in which the file is to be saved is specified in this box.

- **Drives**

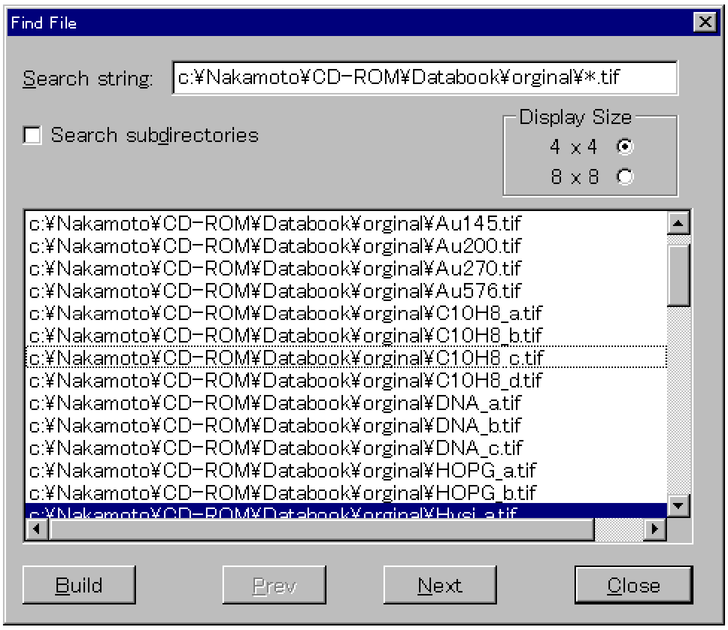
The drive in which the file is to be saved is specified in this box.

- **Find file**

A list of saved files is displayed in this window. The same function as “Find” in Subsection 7.2.1b.

## 7.2.1b Find

A list of saved files is displayed in this window. This function is used to find out a desired file by searching for it among saved images displayed in the window. Click on "File" in the main menu, and select "Find" in the pull-down menu. Then, the "Find File" window is opened.




### ● Search String

Enter the folder name and file name to be searched for in this input box. Enter:

Drive name:Folder name¥folder nme¥··¥File name

Wild-cards can be used for file name.

### ● Search Subdirecrories

If this check box is checked, folders contained in the folder specified in "Search String" are automatically searched if any exist.

### ● Display Size

The number of images to be displayed in the Display Window is designated in this frame.

- 4 × 4: 16 images are to be displayed in the Display Window.
- 8 × 8: 64 images are to be displayed in the Display Window.

### ● Build

Clicking on this button starts searching for the file(s) specified in "Search String" from the folder(s); and the file names found are listed in the "Find File" window.

### ● Prev

When this button is clicked on, the previously displayed page (16 or 64 images) of the image list is displayed in the Display Window.

- **Next**

If the number of the files found exceeds the designated number of frames (16 or 64), the first 16 or 64 images are initially displayed in the Display Window. When this button is clicked on, the next page of the image list (the next 16 or 64 images) is displayed in the Display Window.

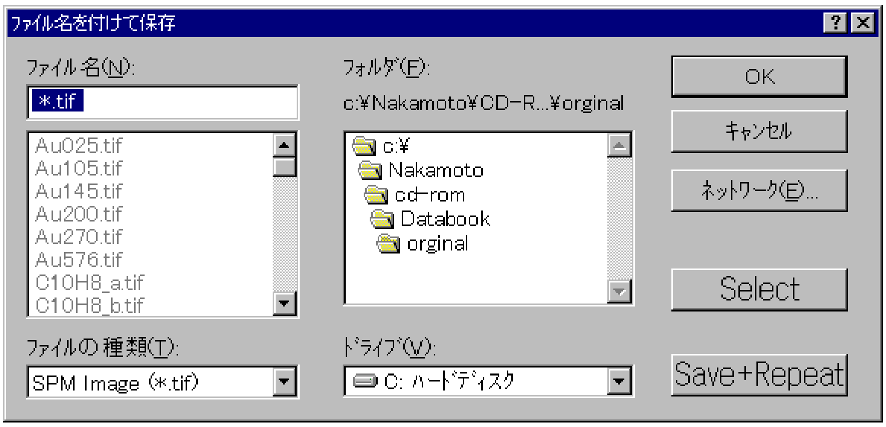
Note: To load data that are displayed in the Display Window into the computer memory using the “Find” function, move the cursor to the image to be loaded and double-click on the image. You can continuously load data by continuing this operation.

## 7.2.1c Close

This function is used to erase the image data currently displayed in the Display Window from the computer memory. If some more data still remains, the next image listed in “Select” is displayed in the Display Window. If there is no more data in the memory, the image displayed in the Display Window still remains in the window, but the indication of the main menu bar changes to gray.

## 7.2.1d Save As...

The data currently displayed in the Display Window is saved on the disk with this function.
Click on “File” in the main menu, and select “Save As...” in the pull-down menu. Then, the “Save As” window is opened.




- **File name:**

The file name for the data to be saved is entered in this input box. The extension corresponding to the currently displayed image is already displayed in the box. If the data type is changed using “Save file as type:”, the corresponding extension is automatically displayed in the “File name:” input box.
After entering a file name, click on the “OK” button to save the data on the disk.

## ■ Save file as type:

When saving data, designate the type of data. The following nine types are provided in this selection box:

| Type | Description |
|---|---|
| SPM Image (*.tif) | 16-bit TIFF format |
| Compressed Image (*.tif) | 8-bit TIFF format.<br>This type has compatibility with other application software which cannot handle the 16-bit TIFF format. |
| Binary Image (*.bin) | 16-bit binary |
| Binary FFT (*.bfc) | FFT spectrum in 16-bit binary<br>Note: This is in effect only for the FFT-processed spectrum data. |
| ASCII Image (*.asc) | ASCII code |
| ASCII FFT (*.aft) | FFT spectrum in ASCII code<br>Note: This is in effect only for FFT-processed spectrum data. |
| Header (*.hdr) | Contents of the “Data Information” window in ASCII code |
| SPM spectram (*.spc) | Graph data, such as I-V data<br>Note: In effect only for graph data |
| ASCII spectrum (*.dat) | Graph data in ASCII code<br>Used for other commercial data processing software.<br>Note: This is in effect only for graph data |

### ● Folders:

The folder in which the file must be saved is specified in this box.

### ● Drives:

The drive in which the file must be saved is specified in this box.

### ● Select

When two or more data sets are grabbed in the computer memory, the data to be saved on the disk is selected with this function.
Clicking on the “Select” button displays a list of data sets stored in the computer memory. When you select the data set to be saved from the list by double-clicking on the name of the data, the selected data set is displayed in the Display Window. Then, enter a file name to be added and click on the “OK” button. The displayed data set is saved on the disk with the file name.

### ● Save+Repeat

When two or more data are grabbed in the computer memory, and when you want to save two or more data successively in the disk memory, this function is useful. Select the first data with the “Select” button; enter a file name; then click on the “Save+Repeat” button. The selected and displayed data is saved on the disk with the file name, and the list of data stored in the computer memory is displayed again.
Then, repeat the same procedure as you like. In this case, however, a letter is added on as the last letter of each file name, first ‘a,’ then ‘b,’ and so forth. If you want to change the added letter or file name, change it and click on the “Save+Repeat” button.

Note: The listed data displayed when you click on the “Select” and “Save+Repeat” buttons are either image data or graph data depending on the current data obtained when “Save As···” was selected.

### 7.2.1e Close All But Current

This function is used to erase all data other than the current data displayed in the Display Window from the computer memory.

### 7.2.1f Close All

This function is used to erase all the data from the computer memory.
Click on “File” in the main menu, and select “Close All” from the pull-down menu. Then, all the data are erased from the computer memory.

### 7.2.1g Print

The displayed data can be printed.
Click on “File” in the main menu, and select “Print” from the pull-down menu. Then, the “Print” window is opened. For the setup of the printer to be used, refer to the instruction manual of the printer.

- **Include Data Information**

If “Include Data Information” is checked, the data displayed in the “Data Information” window is printed together with the data displayed in the Display Window, on one sheet.

- **2 Windows/Page**

If “2 Window/Page” is checked, two data displayed in two Display Windows are printed out on one sheet. Needless to say, two Display Windows must be opened in the screen using the “New Window” function. First, the data displayed in Display Window (1) is printed; then the data displayed in Display Window (2) is printed.

### 7.2.1h Store Configuration

Various parameters set in this software are saved on the disk with this function. Click on “File” in the main menu, and select “Store Configuration” in the pull-down menu. Then, the parameters are saved on the disk. The saved parameters are automatically set at the next startup. If parameters are changed during measurement or during image observation, these changed parameters are saved only when the “Store Configuration” function is used. Otherwise, the previously saved parameters are automatically set again at the next startup.

### 7.2.1i Retrieve Configuration

The parameters saved with the “Store Configuration” function are set in the computer.
Click on “File” in the main menu, and select “Retrieve Configuration” in the pull-down menu. Then, the parameters saved in the disk memory are set in the computer. The parameters set in the computer take effect only after the “Reset SPM” function is executed.

### 7.2.1j Exit

The software is terminated when you click on “File” in the main menu, and select “Exit” in the pull-down menu.

## 7.2.2 Edit

### 7.2.2a Copy

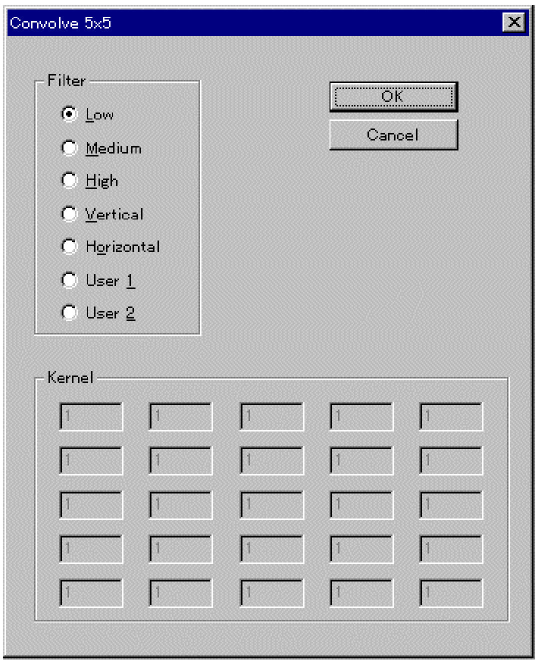
This function is used to paste the data displayed in the Display Window onto other application software with the Copy & Paste function.
Click on “Edit” in the main menu, and select “Copy” in the pull-down menu. Then, the data displayed in the Display Window is copied in the computer memory. This copied data can be pasted onto other application software as an image if the application software is already started up and the Paste function in the application software is executed.

Note: A copied image is all of the 512×512 pixel data in the Display Window.

## 7.2.3 Process

### 7.2.3a Convolve 3×3/5×5

Function: The current image is smoothed by filtering.
Click on “Process” in the main menu; then select “Convolve 3×3” or “Convolve 5×5” in the pull-down menu. The following window will be displayed.

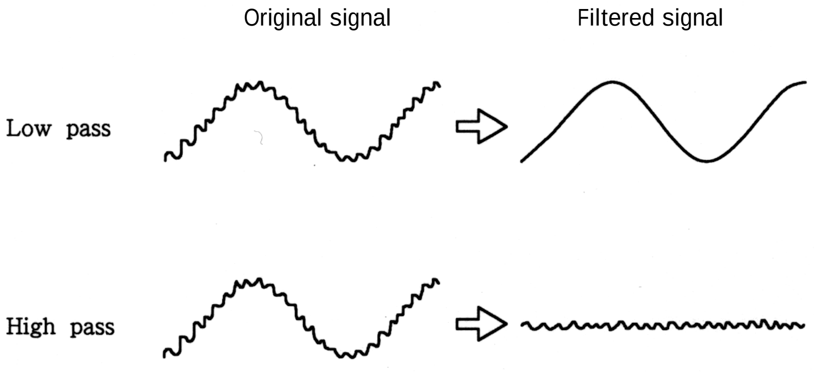



The following filter functions are provided.

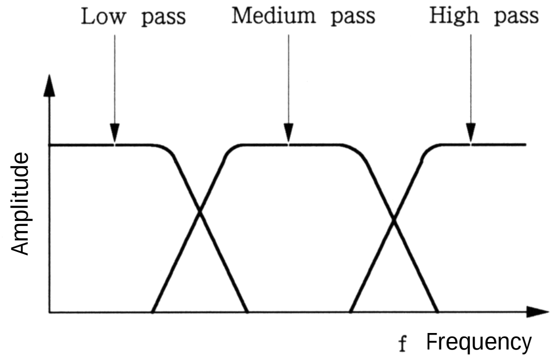
| Filter | Description |
|---|---|
| Low | Low-pass filter |
| Median | Median-pass filter |
| High | High-pass filter |
| Horizontal | Horizontal smoothing |
| Vertical | Vertical smoothing |
| user1, user2 | User defined filter |

Noise having a certain frequency component is eliminated by the filtering function.

**[Example]** For one line signal in an image:




The transfer function of each filter is shown below.

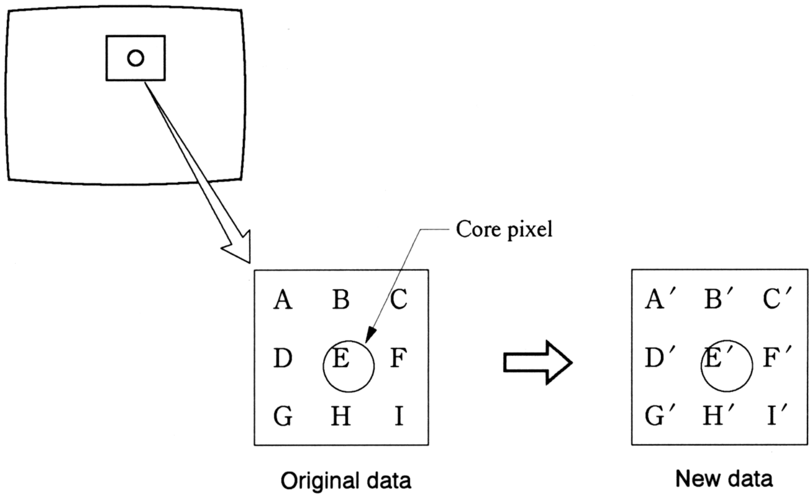



The filter can be represented by a matrix. Convolve 3×3 and Convolve 5×5 mean a matrix of three columns and three rows, and five columns and five rows, respectively. The matrix element for each filter is as follows.

| Filter | convolve 3×3 | convolve 5×5 |
|---|---|---|
| Low | $\begin{vmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{vmatrix}$ | $\begin{vmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{vmatrix}$ |
| Median | $\begin{vmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{vmatrix}$ | $\begin{vmatrix} 1 & 2 & 4 & 2 & 1 \\ 2 & 4 & 8 & 4 & 2 \\ 4 & 8 & 16 & 8 & 4 \\ 2 & 4 & 8 & 4 & 2 \\ 1 & 2 & 4 & 2 & 1 \end{vmatrix}$ |
| High | $\begin{vmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{vmatrix}$ | $\begin{vmatrix} -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 25 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \end{vmatrix}$ |
| Horizontal | $\begin{vmatrix} 0 & 0 & 0 \\ 1 & 1 & 1 \\ 0 & 0 & 0 \end{vmatrix}$ | $\begin{vmatrix} 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{vmatrix}$ |
| Vertical | $\begin{vmatrix} 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 1 & 0 \end{vmatrix}$ | $\begin{vmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{vmatrix}$ |

Actual filtering is carried out by a weighted average with the filtering operator for the core pixel. For example, if the 3x3 median filter is applied to core pixel E, the following calculation is carried out for the new image data E'.

$$E' = \begin{vmatrix} A & B & C \\ D & E & F \\ G & H & I \end{vmatrix} \times \begin{vmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{vmatrix} \equiv \frac{A+2B+C+2D+4E+2F+G+2H+I}{1+2+1+2+4+2+1+2+1}$$

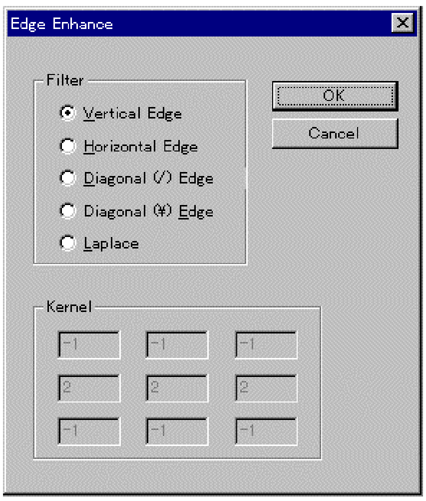



When "User 1" or "User 2" is selected in the "Filter" frame, the matrix element definition frame "Kernel" becomes effective, and you can enter matrix elements by using the keyboard.
The method of entering is as follows.

- Enter an integer between −128 and +128 (the total sum of the matrix elements must not exceed 128) using the keyboard.
- Press the TAB key. Then the highlighted matrix element is defined and the next element will be highlighted.
- The matrix elements defined in "User 1" or "User 2" can be saved using the "Store Configuration" function. Clicking on the 'OK' button executes the designated filter function.

## 7.2.3b Edge Enhance

Function: The current image is edge-enhanced.
Click on "Process" in the main menu; then select "Edge Enhance" in the pull-down menu. The following window will be displayed.




The following edge enhancement functions are provided.

| Filter | Description |
|---|---|
| Vertical Edge | Enhancement in the vertical direction |
| Horizontal Edge | Enhancement in the horizontal direction |
| Diagonal [╱] Edge | Enhancement in the diagonal (╱) direction |
| Diagonal [╲] Edge | Enhancement in the diagonal (╲) direction |
| Laplace | Enhancement of perimeter out-line by Laplace transformation |

The following filtering operation is applied in the same manner as the Convolve 3×3 function.

| Filter | Matrix element |
|---|---|
| Vertical Edge | $\begin{vmatrix} -1 & 2 & -1 \\ -1 & 2 & -1 \\ -1 & 2 & -1 \end{vmatrix}$ |
| Horizontal Edge | $\begin{vmatrix} -1 & -1 & -1 \\ 2 & 2 & 2 \\ -1 & -1 & -1 \end{vmatrix}$ |
| Diagonal [╱] Edge | $\begin{vmatrix} -1 & -1 & 2 \\ -1 & 2 & -1 \\ 2 & -1 & -1 \end{vmatrix}$ |
| Diagonal [╲] Edge | $\begin{vmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{vmatrix}$ |
| Laplace | $\begin{vmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{vmatrix}$ |

Clicking on the “OK” button executes the designated edge-enhancement function.

### 7.2.3c Differentiate

Function: The current image is differentiated at a certain angle.
The following filtering operation is applied in the same manner as the Convolve 3×3 function.

$$\begin{vmatrix} 0 & \sin\theta & 0 \\ 0 & -\sin\theta - \cos\theta & \cos\theta \\ 0 & 0 & 0 \end{vmatrix}$$

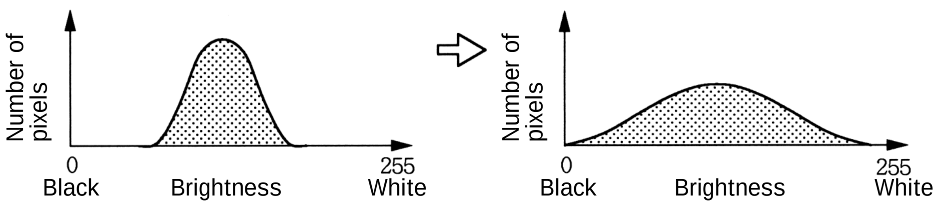
Here is the angle at which the differentiation is to be carried out. Enter an angle (in degree, as an integer between −90 and +90) using the keyboard. Clicking on the "OK" button executes the differentiation function.

### 7.2.3d Normalise

Function: The contrast range for the current image is broadened.
Click on "Process" in the main menu; then select "Normalise" in the pull-down menu. The function is immediately executed.

The "Normalise" function changes the image contrast so that the darkest part of the image becomes 0, and the brightest part of the image becomes 255. In other words, the brightness range of an acquired image is expanded to the full brightness range of the display (0 to 255).

Notes: 1. This function is applied only to the displayed image. The original data is not normalized.
2. When acquired data is grabbed, this function is automatically applied.




**Histogram of the original image** **Histogram of the processed image**

### 7.2.3e Normalise S.D.

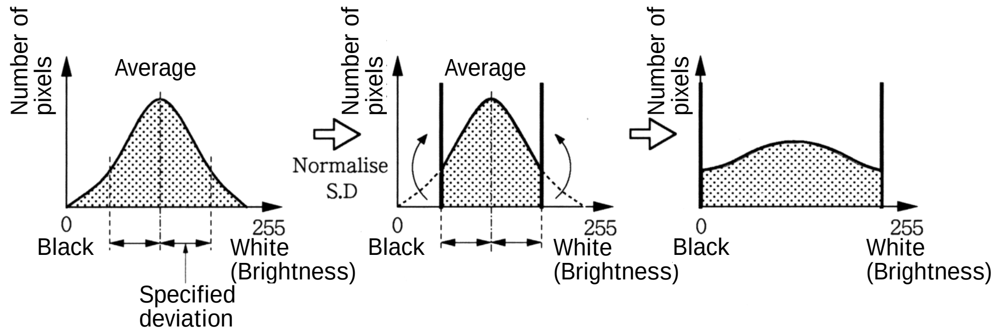
Function: One of the contrast-enhancement methods carried out by expanding the brightness range.

1. Click on "Process" in the main menu; then select "Normalise S.D." in the pull-down menu.

   A histogram of brightness will be displayed on the image display, and the "Enter s.d.'s range to keep data" window will be displayed.

2. Specify the range of deviation.

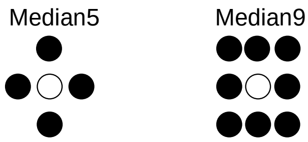
   The "Normalise S.D." function is executed. First, a histogram of brightness of the acquired image, then an average and deviation scale is displayed. When a deviation value is specified, the brightness range within the specified deviation value is expanded to the full brightness range of the display (0 to 255). The brightness range outside of the designated deviation value is displayed in black (0) or white (255).



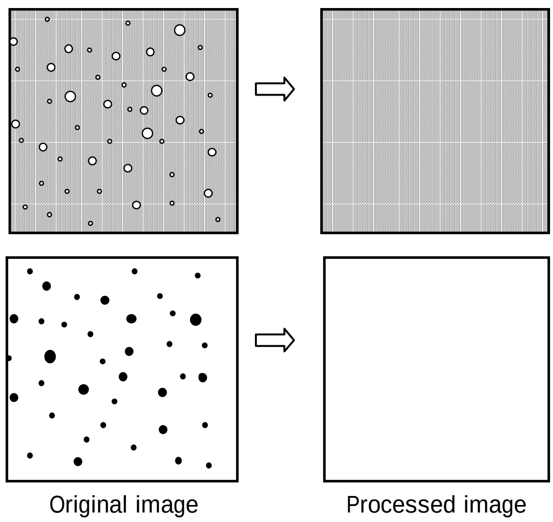

## 7.2.3f Median

Function: Electric spot noise (spike noise) on an image is eliminated.
Click on "Process" in the main menu; then select "Median 5" or "Median 9" in the pull-down menu. The function is immediately executed.

In this function, the data of the center pixel and the surrounding 4 or 8 pixels are selected, and the value of the center pixel is replaced with the middle value of the selected 5 or 9 pixels.

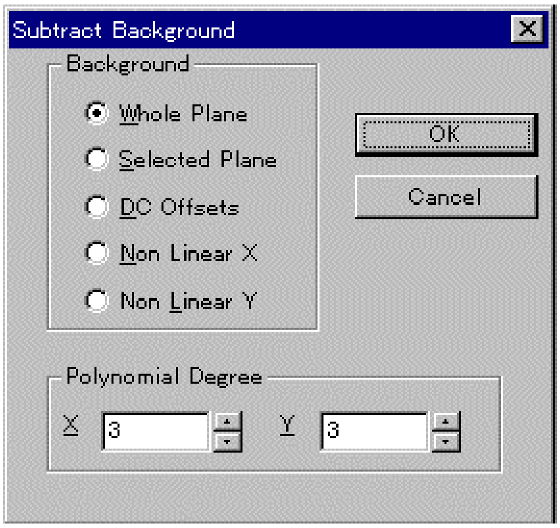



The "Median" filter can eliminate spike-shaped electric noise in an image.



### 7.2.3g Subtract Background...

Function: Background brightness variation of an image is corrected.
Click on “Process” in the main menu; then select “Subtract Background...” in the pull-down menu. The following window will be displayed.




The following four kinds of background correction are provided.

| Correction | Description |
|---|---|
| Whole Plane | Background brightness is subtracted assuming that the image brightness has an inclined but flat background plane in the whole image. |
| Selected Plane | Background brightness is subtracted assuming that the image brightness has an inclined but flat background plane within the selected square area (designated with the mouse) in an image. |
| DC Offset | Background brightness is subtracted assuming that the image brightness has a uniform flat background plane in the whole image. In other words, the offset value of brightness in the whole image is calculated and subtracted. |
| Non Linear X | Background brightness is subtracted assuming that the background plane can be approximated to a polynomial equation in the X-direction. |
| Non Linear Y | Background brightness is subtracted assuming that the background plane can be approximated to a polynomial equation in the Y-direction. |

When “Non Linear X” or “Non Linear Y” is selected, enter a polynomial degree in the “Polynomial Degree” frame using the keyboard. An integer from 3 to 9 can be entered.
After designating conditions, clicking on the “OK” button executes the function.

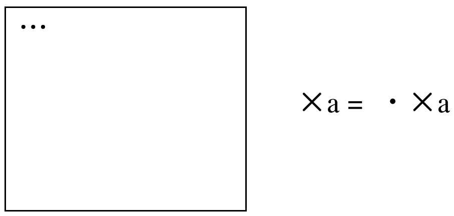
## 7.2.3h Single Math

Function: A mathematical operation is performed for each pixel of the current image.
Click on “Process” in the main menu; then select “Single Math” in the pull-down menu.
The following eight mathematical operations are provided.

| Operation | Description | Effective value |
|---|---|---|
| Invert | Brightness-inverted image display | — |
| Multiply | Product of pixel data and a constant | The same image if 1.0 |
| Divide | Pixel data divided by a constant | The same image if 1.0 |
| Bitwise AND | Logical multiplication of pixel data and a constant in each bit | Integer 0 to 65535 |
| Bitwise OR | Logical sum of pixel data and a constant in each bit | Integer 0 to 65535 |
| Bitwise XOR | Exclusive OR of pixel data and a constant in each bit | Integer 0 to 65535 |
| Add | Sum of pixel data and a constant | Integer 0 to 65535 |
| Subtract | Difference of pixel data and a constant | Integer 0 to 65535 |

Here, pixel data does not mean the display brightness data (0 to 255) but the acquired 16 bit raw data (0 to 65535). Although an integer from 0 to 65535 can be entered for Bitwise AND, OR, XOR, Add and Subtract, the result is converted to the range 0 to 255 for display. If the resultant of the mathematical operation is negative, it is replaced with 0. If the resultant of the mathematical operation exceeds 255, it is replaced with 255.

A mathematical operation is performed for each pixel, as follows.




【Example】
Invert

| Original image | Calculated value |
|---|---|
| 0 (0000 0000) | → 255 (1111 1111) |
| 128 (1000 0000) | → 127 (0111 1111) |

Multiply

| Original image | Constant | Calculated value |
|---|---|---|
| 20 | 3.0 | 60 |
| 128 | 3.0 | 255 |

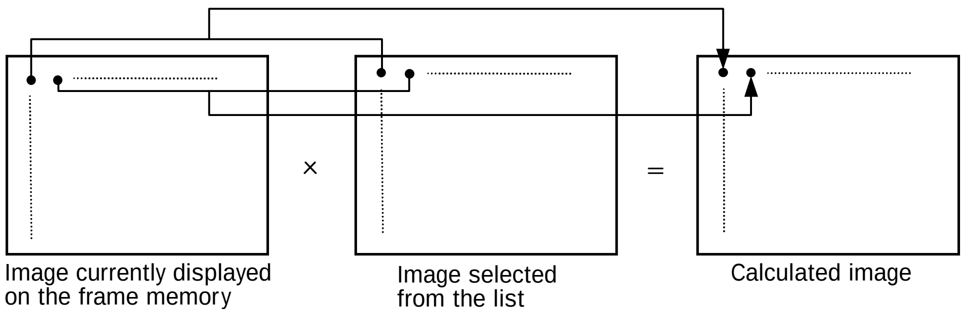
### 7.2.3i Double Math

Function: A mathematical operation is performed for each pixel of the current image and any desired image in the computer memory.

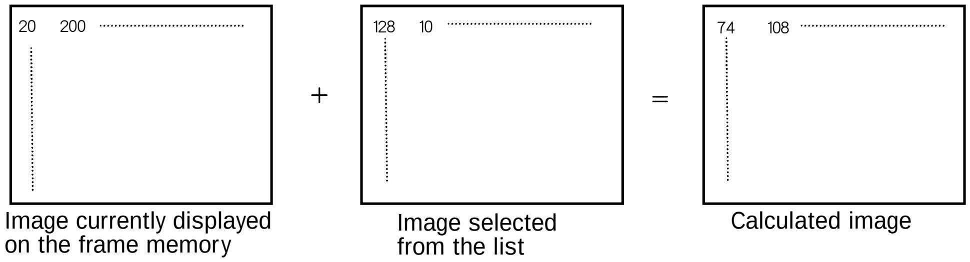
Click on “Process” in the main menu; then select “Double Math” in the pull-down menu.
The following ten mathematical operations are provided.

| Operation | Description |
|---|---|
| Add | Average of the data; (a+b)/2 |
| Subtract | Difference of the data; (a–b+255)/2, that is, [a+(255–b)]/2 |
| Difference | Difference of absolute value of the data; \|a\|–\|b\| |
| Multiply | Product of the data; (a*b)/255 |
| Divide | Quotient of current image data divided by selected image data (a/b)<br>Note: If ‘b’ is zero, resultant set to ‘a’. |
| Bitwise AND | Logical multiplication of the two data in each bit (a AND b) |
| Bitwise OR | Logical sum of the two data in each bit (a OR b) |
| Bitwise XOR | Exclusive OR of the two data in each bit (a XOR b) |
| Minimum | The smaller of the two data |
| Maximum | The larger of the two data |

Here, ‘a’ shows the current image data and ‘b’ shows the selected image data.




【Example】 When “Add” is selected,



## 7.2.4 Analyze

### 7.2.4a Profile

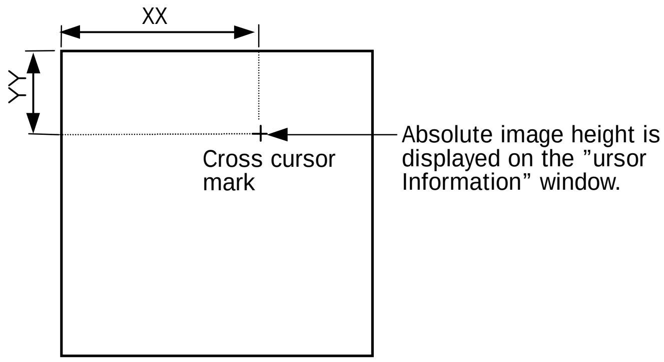
Function: Height data along the straight line between two designated points on an image is displayed in a line profile.

**1.** Click on “Analyze” in the main menu; then select “Profile” in the pull-down menu.

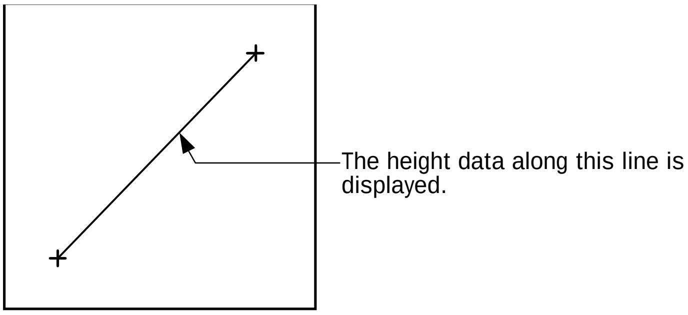
A cross cursor ‘+’ appears on the Display Window, and the following information is displayed on the “Cursor Information” window.

- Coordinates of the cursor location
- Absolute image height at the cursor location

**2.** Move the cursor to the starting point of the measurement origin point with the mouse; click the left mouse-button. A‘+’ mark will be fixed at the point.




**3.** Move the cursor to the end point with the mouse; click the left mouse-button again. Then the height data along the line between the two designated points is displayed in a line profile in the Display Window.




**4.** The message “Enter Image title” is displayed on the window. Enter a title and click on the “OK” button; then the displayed height profile data is stored in the computer memory.

Note: Stored data can be processed with the “Spectroscopy” functions.

## 7.2.4b Measure

When you click on “Analyze” in the main menu and select “Measure” in the pull-down menu, a pulldown sub-menu will be displayed.

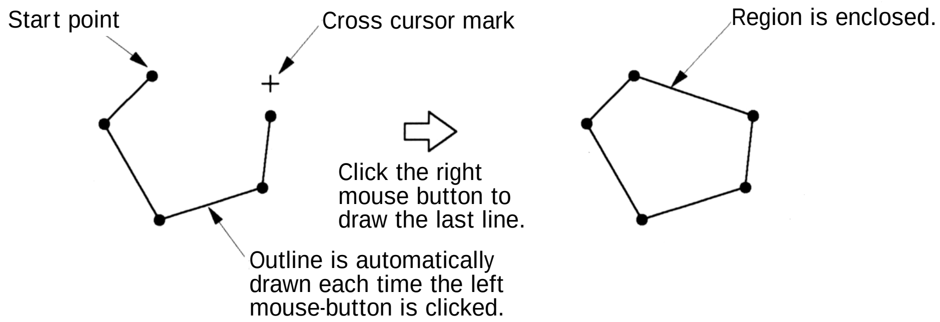
### ■ Area

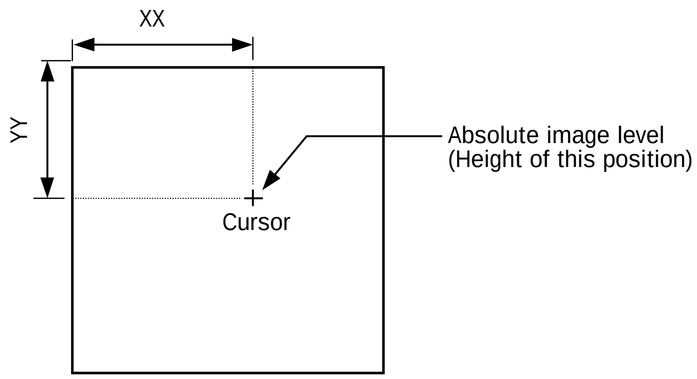
Function: Number of pixels, area, averaged specimen height and root-mean-square value of specimen height within a designated region are measured.

1. Click on “Analyze” in the main menu and select “Measure” in the pull-down menu. Then select “Measure Area” in the pulldown sub-menu. A cross cursor ‘+’ appears on the image.
2. Move the cursor to the starting point of the desired region to be measured with the mouse; click the left mouse-button. The cursor will be fixed at the point.

   Move the cursor to the next corner of the region and click the left mouse-button; then a line will be drawn between the points. Continue the same operation until the desired region is completely enclosed.

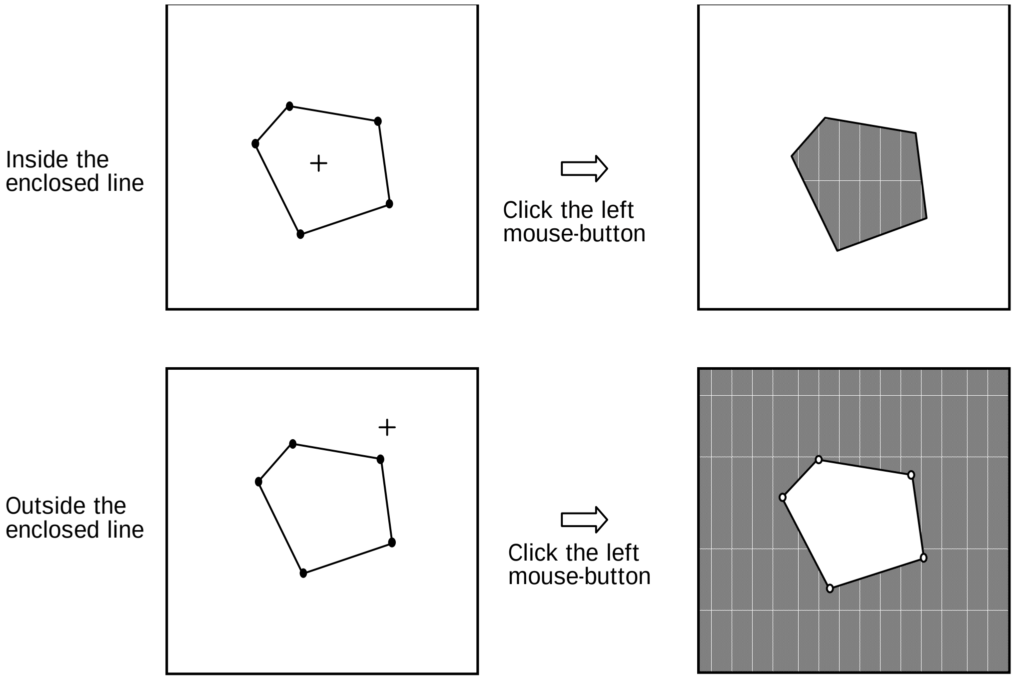
   The last line is drawn by clicking the right mouse-button.




Note: The cursor coordinates (origin is the top-left corner) are indicated in “Cursor position (XX, YY),” and the absolute image level is indicated in “image height XX nm.”

**3.** Designate the region to be measured by placing the cursor inside or outside of the enclosed line and click the left mouse-button. The designated region is displayed in black.




**4.** The number of pixels, area, averaged specimen height and root-mean-square value of specimen height within the designated region are indicated in the window.

## ■ Point

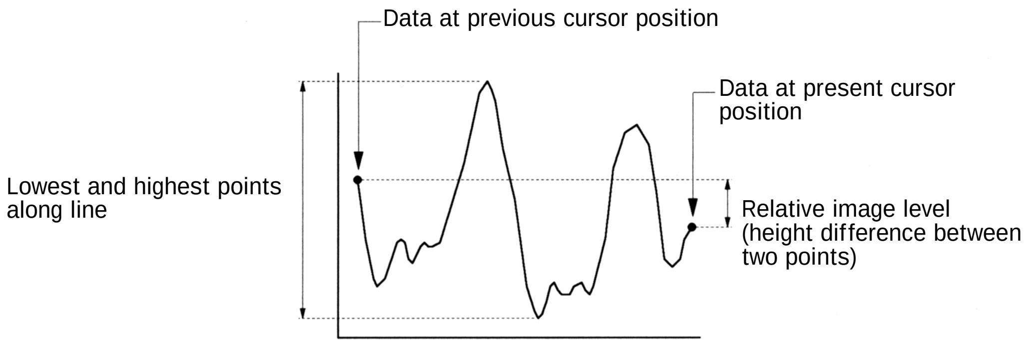
Function: The distance and a relative image-height between two designated points on an image are measured.

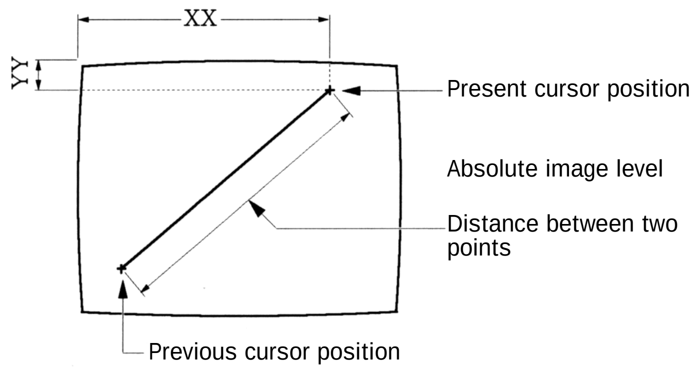
**1.** Click on “Analyze” in the main menu and select “Measure” in the pull-down menu. Then select “Point” in the pulldown sub-menu. A cross cursor ‘+’ appears on the image.

**2.** Move the cursor to the starting point of the measurement with the mouse; click the left mouse-button. The cursor will be fixed at the point.

**3.** When the cursor is moved, the following information is indicated in the window:

- Present coordinates of the cursor
- Image height at the present cursor position
- Relative image height between the present cursor and previous cursor positions
- Distance between the present cursor and previous cursor positions
- The highest and lowest image level on the straight line between the present cursor and previous cursor positions




4. When you click the left mouse-button, the present cursor position is fixed as a new origin point. Repeat Steps 3 and 4 above.
5. Clicking the right mouse-button terminates this measurement.

## ■ Roughness

Function: The mean value and root-mean-square value of the height of the entire current image are measured.

◆ Click on “Analyze” in the main menu and select “Measure” in the pull-down menu. Then, select “roughness” in the pulldown sub-menu.

The mean value and root-mean-square value of the height of the entire image are indicated in the window.

Mean (RMS) height: XXXX.XX YYYY.YY

## ■ Surface Area

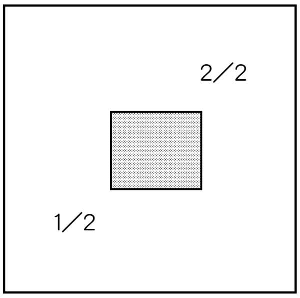
The surface area of the image currently displayed is indicated by this function.

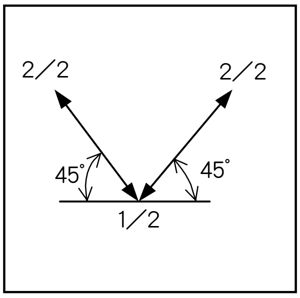
## 7.2.4c Zoom

Function: The designated region of the current image is enlarged. With “Rectangle” you can designate an optional rectangular region, and with “Square” you can designate a square region.

1. Click on “Analyze” in the main menu and select “Zoom” in the pull-down menu. Then select “Rectangle” or “Square” in the pulldown sub-menu. A cross cursor ‘+’ appears on the image.
2. Designate two diagonal points of an area to be magnified. The designated region is enlarged at the moment the second point is designated.

   Note: If you select “Square”, the cursor can move only in a 45° line.




**Cursor movement in “Square”**

The relation between the designated image size and the enlarged image size is as follow.

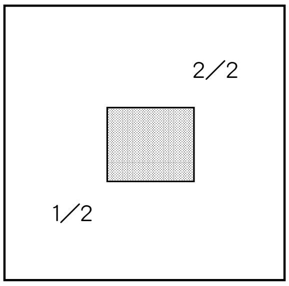
| Designated area | | Enlarged area |
|---|---|---|
| Smaller than 128×128 | → | 128×128 |
| Smaller than 256×256 | → | 256×256 |
| 256×256 or larger | → | 512×512 |

## 7.2.4d Trim

Function: The image outside of a designated region on the current image is erased. With "Rectangle" you can designate an optional rectangular region, and with "Square" you can designate a square region.

**1.** Click on "Analyze" in the main menu and select "Trim" in the pull-down menu. Then select "Rectangle" or "Square" in the pulldown sub-menu. A cross cursor '+' appears on the image.

**2.** Designate two diagonal points of a region to be trimmed.
When you select "Square," the cursor can move only in a 45° line.

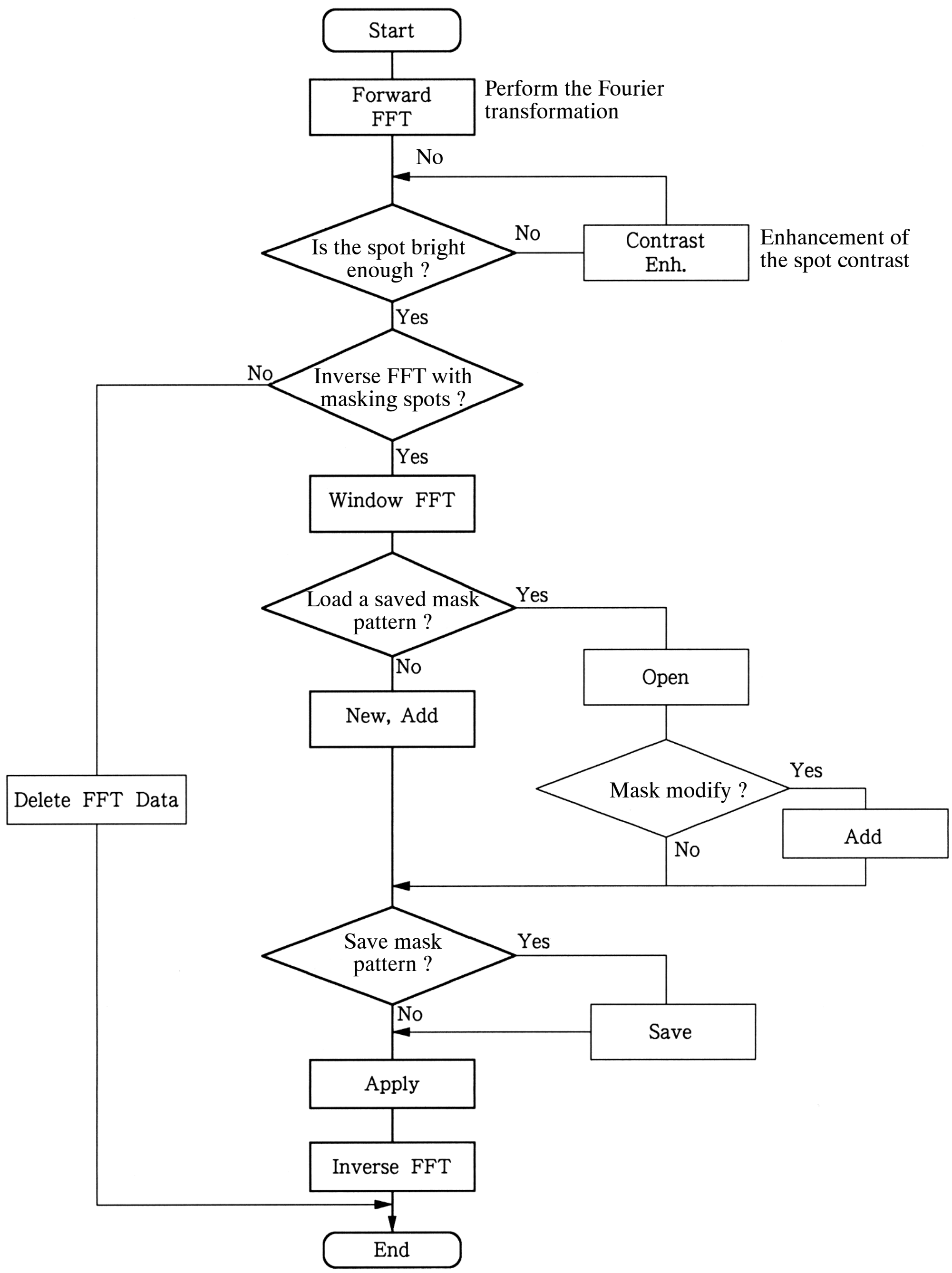


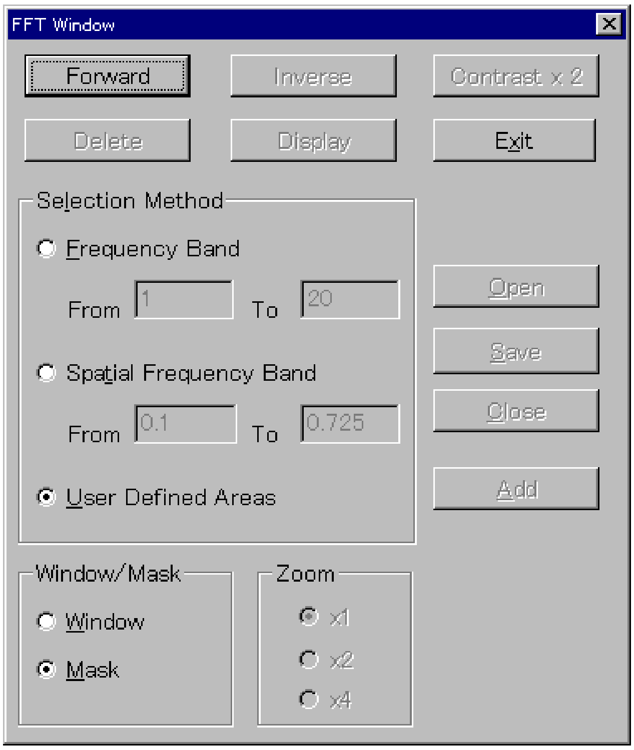

**3.** The image outside of the designated region is erased at the moment the second point is designated.
The data in the erased region are set to 0 (black).

### 7.2.4e FFT (Fast Fourier Transformation)

The two-dimensional FFT is applied to a real image to obtain a spot image (a diffraction pattern of the real image). Also, the inverse transformation is applied to a spot image to obtain the real image. This function is useful to abstract and display a periodic structure of the obtained image.

Click on "Analyze" in the main menu and select "FFT" in the pull-down menu. The "FFT" window will be displayed. The procedure for the FFT function processing is shown below.






## ■ Forward

Function: The current image is Fourier-transformed, and the transformed spots (the diffraction pattern of the image) are displayed on the Display Window.

1. Click on "Analyze" in the main menu and select "FFT" in the pull-down menu. Then select "Forward' in the "FFT Window."
2. Fourier transformation will be executed, and the resultant spot image (diffraction pattern of the image) will be displayed.

   Note: If the displayed spots are too dark, the contrast can be enhanced with the "Contrast × 2" function in the same pulldown sub-menu.

## ■ Inverse

Function: Inverse Fourier transformation is applied to a diffraction pattern (spot data) to display its real image on the Display Window.

1. Display a Fourier-transformed spot image in the Display Window using the "Display" button. Then click on "Analyze" in the main menu and select "FFT" in the pull-down menu. Then select "Inverse" in the "FFT Window."
2. Inverse Fourier transformation will be executed, and the resultant real image will be displayed.

   Note: In order to apply "Inverse FFT" to a spot image (a diffraction pattern) that is previously Fourier-transformed and stored in the computer memory, you must display the spot image on the screen using the "Display" button. If instead the "Select" button is used to display the spot image on the screen, the computer treats it as a real image. Therefore, the inverse FFT cannot be executed.

## ■ Contrast ×2

Function: The contrast of a Fourier-transformed spot image is enhanced.

1. Display a Fourier-transformed spot image on the Display Window. Click on "Analyze" in the main menu and select "FFT" in the pull-down menu. Then select "Contrast ×2" in the "FFT Window."
2. The contrast (brightness) of the spots will be doubled.

Notes: 1. The contrast enhancement is performed only on the displayed image and has nothing to do with the original data itself.
2. The "Contrast×2" operation can be repeated as many times as needed until a good enough contrast is obtined. The contrast is doubled each time.

## ■ Delete

Function: Fourier-transformed data is deleted from the computer memory.

◆ Click on "Analyze" in the main menu and select "FFT" in the pull-down menu. Then select "Delete" in the "FFT Window."

The FFT data is deleted from the computer memory.

## ■ Display

Function: A Fourier-transformed spot image is displayed on the Display Window.

◆ Click on "Analyze" in the main menu and select "FFT" in the pull-down menu. Then click on the "Display" button in the "FFT Window." A Fourier-transformed spot image will be displayed.

Note: If no Fourier-transformed data is in the computer memory, an error message will appear.

## ■ Zoom

Function: When a Fourier-transformed spot image is so small that the setting of the "FFT Window" is very difficult, the "×2" or "×4" zooming function and the "Add" function are used to enlarge the image.

## ■ Add

Function: A masking window is set to specify the spots to be used for inverse FFT.

Note: The words "Masking Window" are used to distinguish it from "Display Window."

1. Display a Fourier-transformed spot image on the Display Window. Click on the "Add" button in the "FFT Window." Then, a '+' cursor will appear on the spot image.

   Note: When you want to define a new masking window, select "New." When you want to modify or edit a previously defined masking window, select "Add."
2. Setting Masking Window
   - a. Select "Mask" in the "Window/Mask" frame.
   - b. Move the cursor to the center of the masking window to be set, and press the left mouse button.
   - c. Specify the radius of the masking window by moving the cursor and pressing the left mouse button.

**d.** The area specified as a masking window is displayed by a circle.

**3.** Deleting Masking Window

**a.** Select “Window” in the “Window/Mask” frame.

**b.** Move the cursor to the center of the circle, and press the left mouse button.

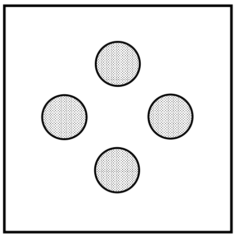
**c.** Specify the radius of the circle to be deleted by moving the cursor, and press the left mouse button.

The specified circle area will be deleted.

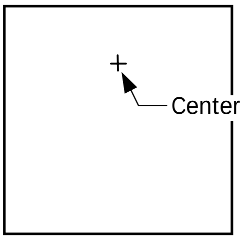
Note: This function is used only to create a masking window. To perform the inverse FFT by actually applying a masking window to a spot image, you must select “Apply.”

**Setting of Masking Window**

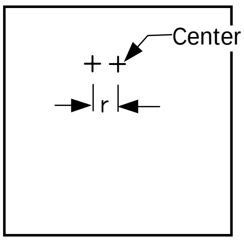
【Example 1】



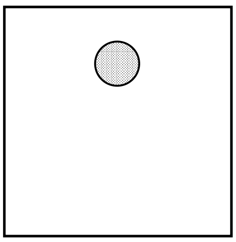
When creating four masking windows. Spots within these circles are used for inverse FFT.




Select “Mask” in the “Window/Mask” frame ; position the cursor at the center of the desired masking window; then click the left mouse-button.

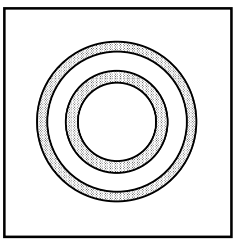



Move the ‘cursor to set the radius r; then click the left mouse button.

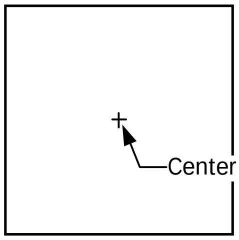


A masking window with a radius r is created. Repeat this procedure as many times as necessary.

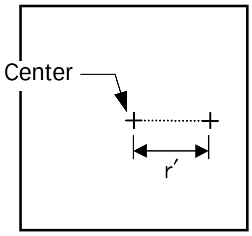
【Example 2】



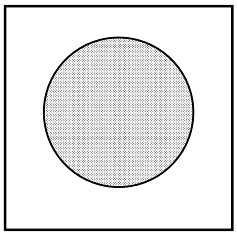
When creating coaxial rings. Spots within these rings are used for the inverse FFT.



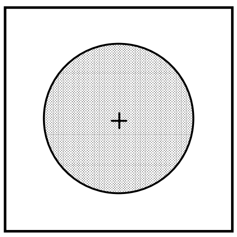

Select “Mask” in the “Window/Mask” frame; position the ‘cursor at the center of the desired masking window; then click the left mouse-button.



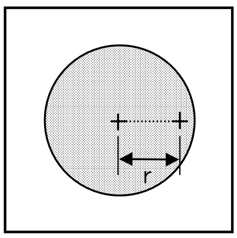

Move the cursor to set the outer radius r’; then click the left mouse button.



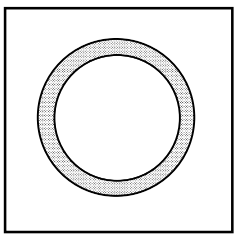
A masking window having radius r’ is displayed.



Select “Window” in the “Window/Mask”frame; position the cursor at the center of the desired masking window; then click the left mouse-button.




Move the cursor to set the inner radius r; then click the left mouse button.



The circle having radius r is erased. A ring-type masking window is specified. Repeat this procedure as many times as necessary.

## ■ Close

Function: The current masking window is erased, or canceled.

◆ Click on the "Close" button in the "FFT Window."

Note: When this function is performed, the masking window on the "Display Window" is still displayed, but the masking window applied to the spot image in the computer memory is erased. In order to display the spot image to which a masking window is not applied, operate "Display FFT."

## ■ Open

Function: A masking window saved on disk is loaded into the computer memory.

1. Display a spot image (diffraction pattern) and click on the "Open" button in the "FFT Window."
2. Enter the file name to be loaded using the keyboard; and click on the "Load" button.

Then the file is loaded and the masking window is displayed on the spot image.

Note: If the sizes of the displayed spot image and the loaded masking window are different (for instance, the displayed spot image is 128×128, and the loading masking-window is 512×512), it causes an error.

## ■ Save

Function: A created masking window is saved on disk.

1. Display the masking window to be saved on the Display Window and click on the "Save" button in the "FFT Window."
2. Enter the file name under which to save it using the keyboard; and click on the "Save" button.

Then the masking window is saved on disk.

Note: A file name must be 8 characters or less. If an extension is omitted, "MSK" is automatically added.

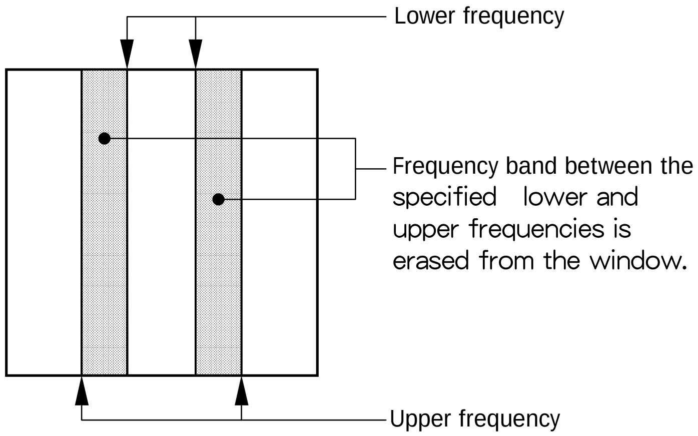
## ■ Selection Method

### ● Frequency band

Function: A vertical strip masking window is defined. The masking window is applied to a specified frequency band.

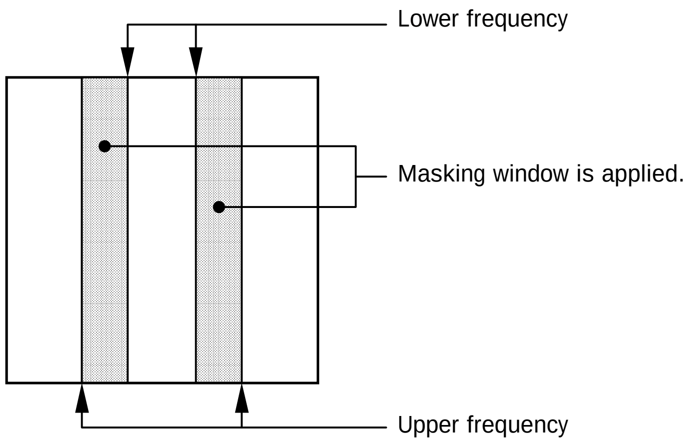
Enter the lower frequency in the "From" input box and the upper frequency in the "To" input box. Select "Mask" or "Window" in the "Window/Mask" frame. Then, click on the "Add" button in the "FFT Window."

[Window]: The frequency band between the specified lower and upper frequencies will be erased from the window.




Note: To eliminate electric noise of 50 Hz—60 Hz, input as follows.
Enter lower frequency 50
Enter upper frequency 60

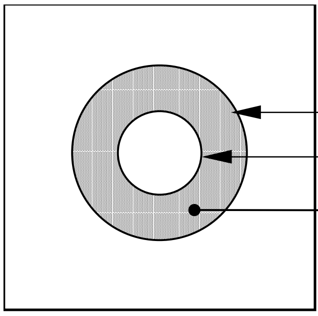
[Mask]: A masking window is applied to the frequency band between the specified lower and upper frequencies.



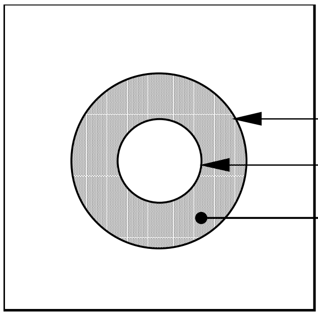

## ● Spatial Frequency Band

Function: A coaxial ring masking window is easily defined as a spatial frequency band. This type of masking window can emphasize the image structure within the specified spatial frequency band. Enter the lower frequency in the “From” input box and the upper frequency in the “To” input box. Select “Mask” or “Window” in the “Window/Mask” frame. Then, click on the “Add” button in the “FFT Window.”

[Window]: The frequency band between the specified lower and upper frequencies will be erased from the window.

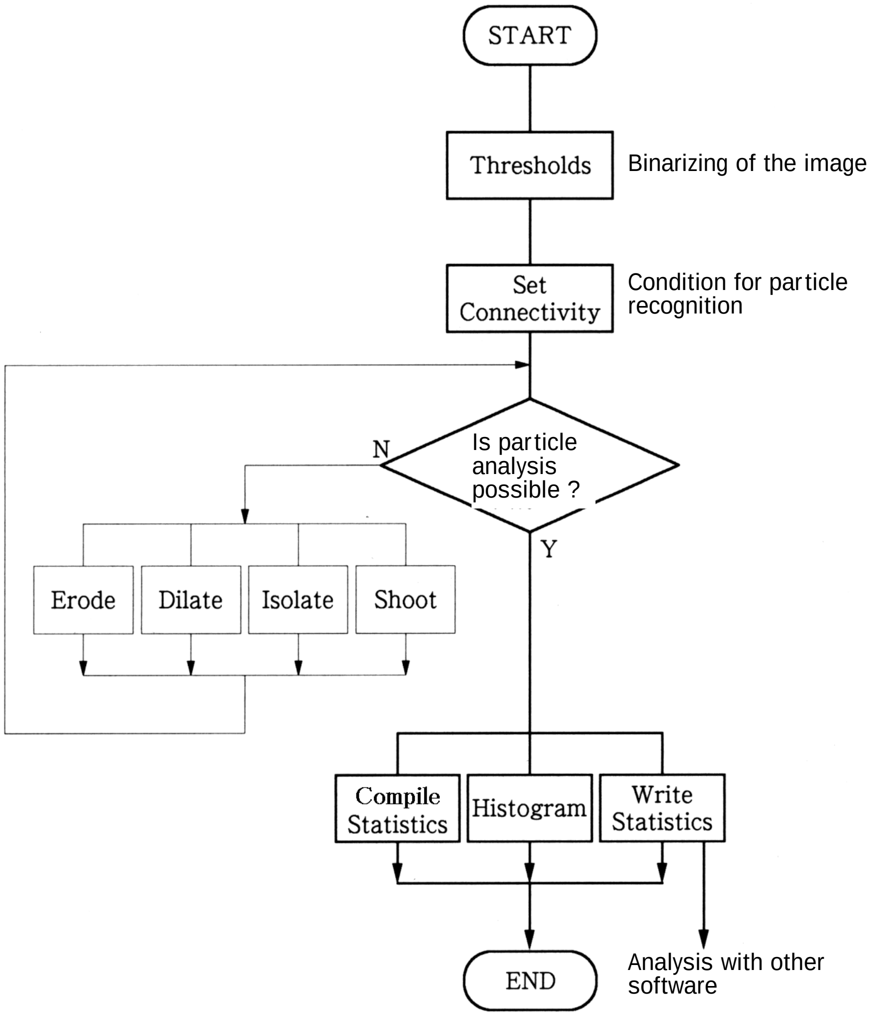


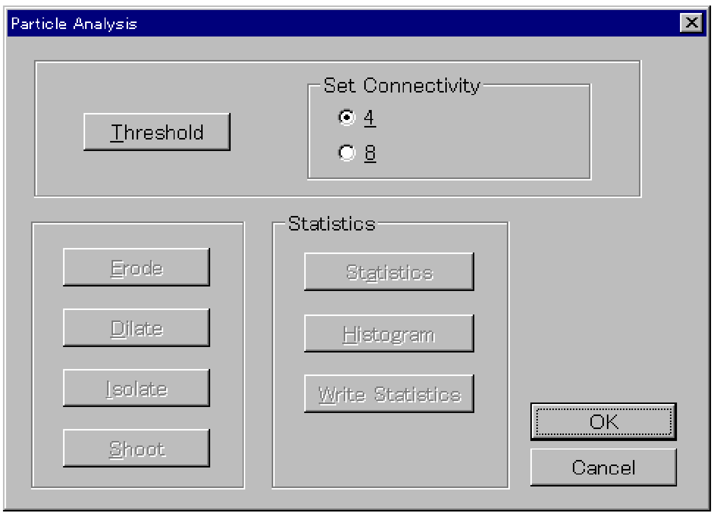

[Mask]: A masking window is applied to the frequency band between the specified lower and upper frequencies.



## 7.2.4f Particle

The Particle analysis function includes measurements of the number of particles and the area of each particle in an image. The procedure for the particle analysis is shown below.

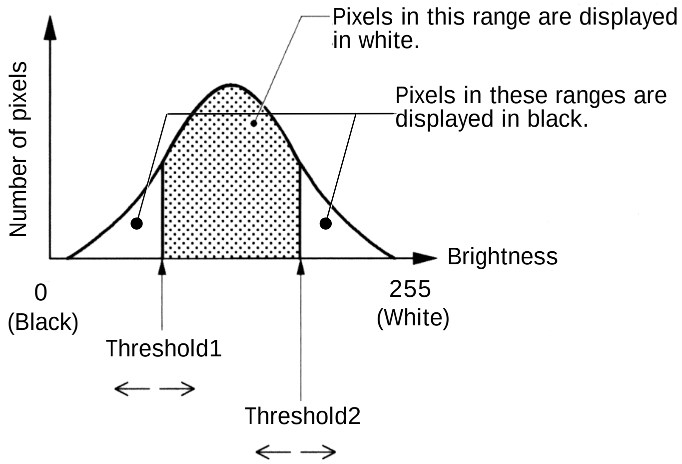


## ■ Thresholds

Function: The threshold values for performing binarization of image data are set.

1. Click on the “Threshold” button.
   An image with a size of 400×400 pixels will be displayed.
2. First, specify the lower threshold value “Threshold 1”; then specify the upper threshold value “Threshold 2” by using the bar chart.
3. Click on the “OK” button for setting.

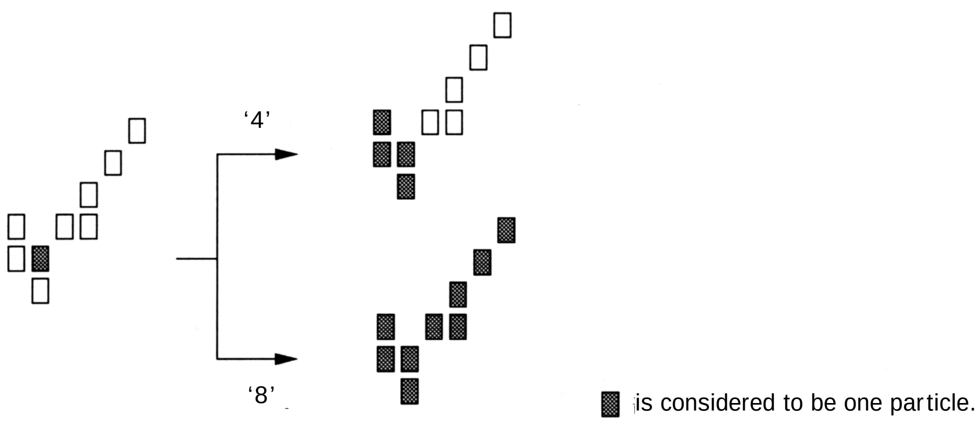



## ■ Set Connectivity

Function: The condition for judging a pixel as being connected to a particle is selected from “4” and “8.”


The pixels connected to a point of interest are judged to be the same particle.

**[Example]**

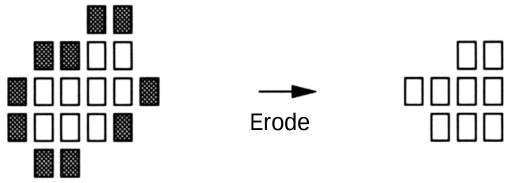


## ■ Erode

Function: Excludes one pixel layer from the area around particles.

◆ Click on the “Erode” button in the “Particle Analysis” window. Immediately, one pixel layer will be taken away from the area around particles.

**[Example]**



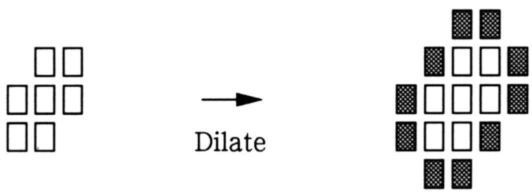

■ show the pixels to be taken away.

## ■ Dilate

Function: Adds one pixel layer to the area around particles.

◆ Click on ‘Dilate’ in the sub-pull-down menu. Immediately, one pixel layer will be added to the area around particles.

**[Example]**




## ■ Isolate

Function: Excludes from the display any particles composed of a specified number of pixels or fewer.

1. Click on the “Isolate” button in the “Particle Analysis” window.” “Enter smallest particle size/pixels” will be displayed.
2. Enter the number of pixels.
   For example, if ‘10’ is entered, all particles, each of which is composed of 9 pixels or fewer, are excluded.

## ■ Shoot

Function: Deletes a designated particle.

1. Click on the “Shoot” button in the “Particle Analysis” window.
   A ‘+’ cursor will appear in the Display Window.
2. Move the cursor onto the particle to be excluded and click the left mouse-button.
   The selected particle will be erased.

## ■ Statistics

Click on the “Statistics” button in the “Statistics” frame in the “Particle Analysis” window. A pull-down menu will be displayed.

### ● Compile Statistics

Function: Information on all particles is listed.

**1.** Click on “Compile Statistics” in the pull-down menu.
**2.** Information about area, diameter and area/diameter$^2$ (showing circularity) of all particles will be displayed in the Display Window.

Notes: 1. Moving the cursor in the window allows the data to be scrolled.
2. The particle pointed to by the cursor in the window is shown with the □ mark surrounding it.
3. Data displayed in the listing window can be sorted according to the followingctiteria:
- To be displayed in the order of particle position (position is given to each particle when recognized)
- To be displayed in the order of area from small to large
- To be displayed in the order of diameter from short to long
- To be displayed in the order of area/diameter$^2$ from small to large (The larger area/diameter$^2$ is, the more completely round the circle is.)

### ● Histogram

Function: A histogram of designated information on all the particles is displayed.

**1.** Click on the “Histogram” button in the “Statistics” frame.
**2.** Click on “Histogram type” to select the information for which a histogram is to be created from among area, diameter and area/diameter$^2$.
**3.** Enter the number of bars in “Number of bins.” Click on “Display.”

A histogram will be displayed.

Note: The number of bars means the number of segments for the histogram. For example, if 50 is entered, the range between the minimum value and the maximum value is divided into 50 segments, and the number of particles in each segment is indicated in the height of the corresponding bar.

### ● Write Statistics

Function: The “Compile Statistics” data is saved on disk.

The relationship between the format and the parameters is as follows.

End of line

Delimiter

| Title→Number | X1 | Y1 | X2 | Y2 | Area/nm$^2$ | Area/pix | Perimeter |
|---|---|---|---|---|---|---|---|
| 1 | 245 | 0 | 250 | 3 | 3.337860E−002 | 14 | 4.198683E−001 |
| 2 | 202 | 3 | 206 | 7 | 3.099442E−002 | 13 | 4.698625E−001 |

⋮

### 7.2.4g Draw mesh

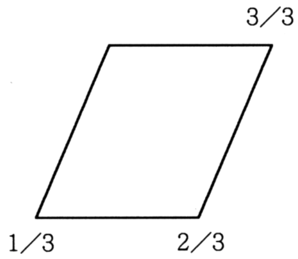
Function: A mesh is overlaid on the displayed image.

**1.** Click on "Analyze" in the main menu and select "Draw Mesh" in the pull-down menu.

A cross cursor '+' appears on the image.

**2.** Designate 3 corners of a parallelogram.

Designate the starting point (1/3), the 1st vector endpoint (1/3 → 2/3), and the 2nd vector endpoint (2/3 → 3/3).

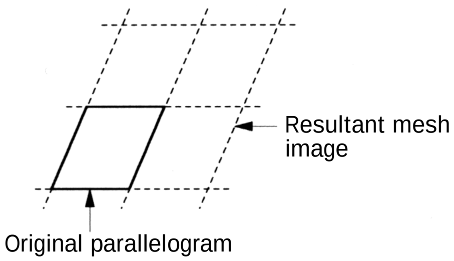



**Unit cell designation method**

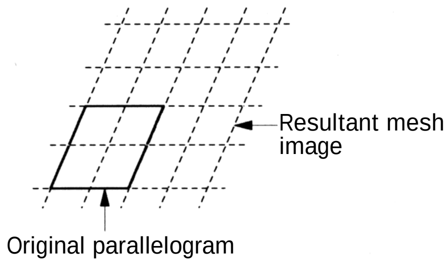
This operation designates the shape of the unit cell of the mesh.
The message "Enter integral factor to scale vectors down by" is displayed on the window.

**3.** Input a numerical value—the denominator of division of the designated parallelogram—to scale down the parallelogram to the actual unit cell of the mesh (each side of the displayed parallelogram is divided by the entered number).

**[Example]**
If 1 is input, the designated parallelogram becomes the unit of the mesh image. If 2 is input, a parallelogram whose size is half the four sides of the designated parallelogram becomes the unit of the mesh image.




**If '1' is entered**




**If '2' is entered**

**4.** Click on the "OK" button; then the mesh is overlaid on the entire image.

## 7.2.5 Geometry

### 7.2.5a Translate

Function: Shifts the current image parallel to itself on the screen.

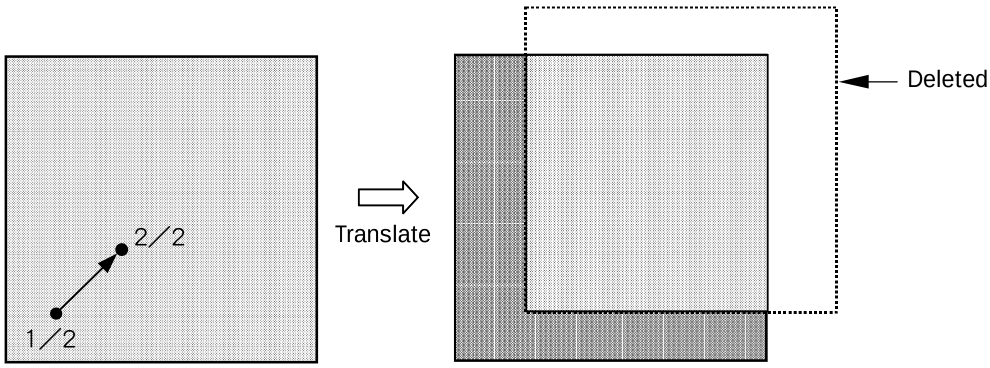
1. Click on “Geometry” in the main menu; then select “Translate” in the pull-down menu.

   A cross cursor ‘+’ appears on the image, and the message “Select point 1/2” is displayed.
2. Designate the starting point of image shift with the mouse.

   The message “Select point 2/2” is displayed on the window.
3. Designate the ending point of image shift.

   The whole image will shift in parallel from the first point to the second.

   Note: The part of the original image that lies outside the screen is deleted. Also, the vacant part of the current image is displayed in black (‘0’).




**After ‘Translate’**

### 7.2.5b Rotate

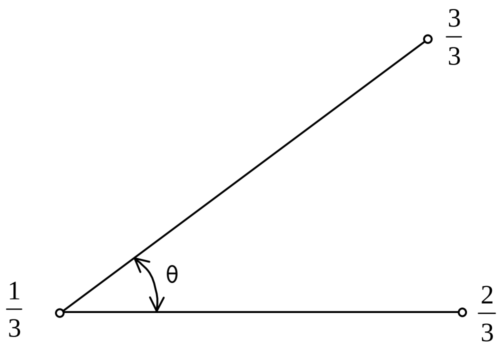
Function: Rotates the current image on the screen.
The following four rotations are provided:

| Rotation | Description |
|---|---|
| 90 | The image is rotated 90° clockwise around the image center. |
| 180 | The image is rotated 180° clockwise around the image center. |
| 270 | The image is rotated 270° clockwise around the image center. |
| theta | The image is rotated to a specified angle in a designated direction around the designated point on the image. |

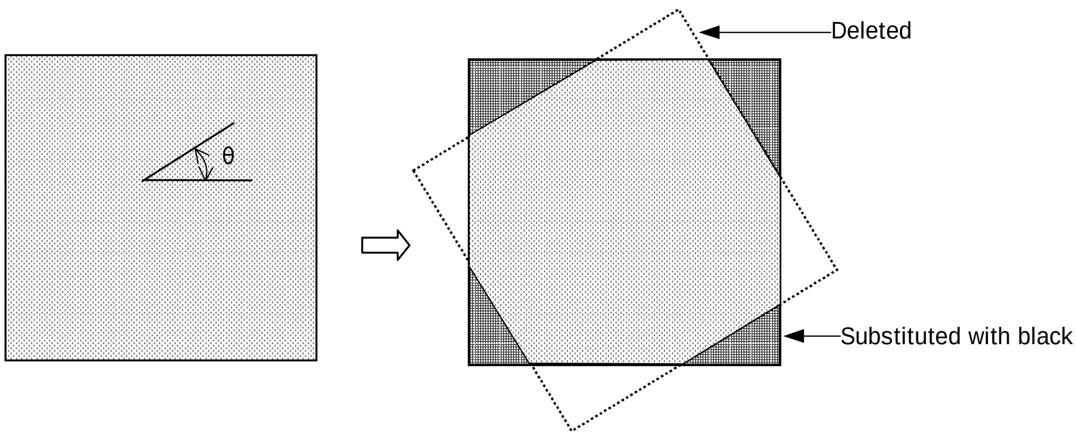
1. Click on “Geometry” in the main menu; then select “Rotate” in the pull-down menu.
2. When “Rotate 90,” “Rotate 180” or “Rotate 270” is selected, image rotation is immediately executed.

**3.** When “Rotate theta” is selected, a cross cursor ‘+’ appears on the image. Then designate the rotation center (1/3), the rotation starting line (2/3), and the rotation end line (3/3) in accordance with the guidance displayed on the window.

Note: Data of the parts of the original image lying outside the screen is deleted. Also, the vacant parts of the current image are displayed in black (‘0’).




**Designation of the rotation angle**



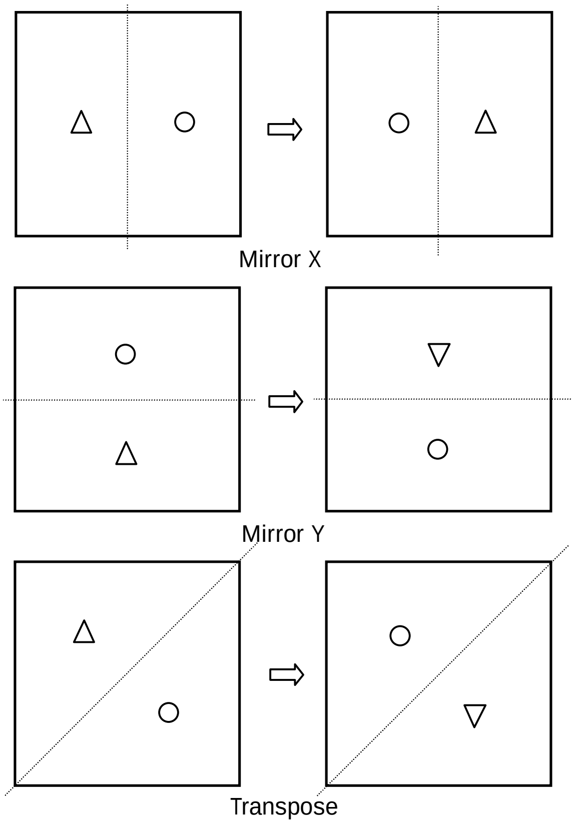

**Rotation angle** **After the “Rotate” operation**

## 7.2.5c Mirror

Function: A mirror image of the current image is displayed.
The following three mirror functions are provided:

| Mirror | Description |
|---|---|
| Mirror X | Reverse the image from left to right |
| Mirror Y | Turn the image upside-down |
| Transpose | Reverse the image from left to right and turn it upside-down |

1. Click on “Geometry” in the main menu; then select “Mirror” in the pull-down menu.
2. Select “Mirror X,” “Mirror Y” or “Transpose” on the pulldown sub-menu. The designated mirror image will be displayed.

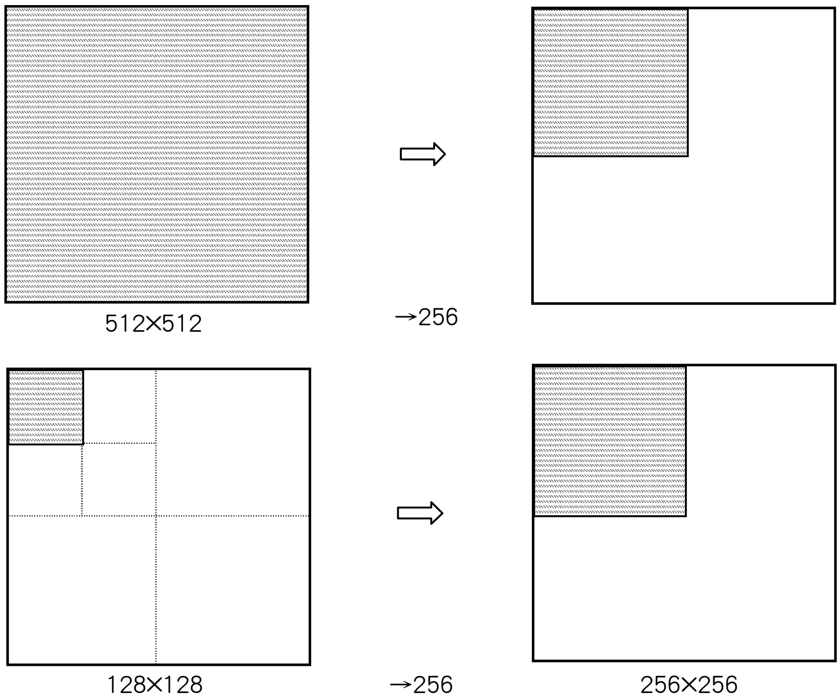



### 7.2.5d Resize

Function: The size of the current image is changed.
The following three changes are provided:

| Resize | Description |
|---|---|
| 128 | Change to 128×128 pixels |
| 256 | Change to 256×256 pixels |
| 512 | Change to 512×512 pixels |

1. Click on “Geometry” in the main menu; then select “Resize” in the pull-down menu.
2. Select “128,” “256” or “512” on the pulldown sub-menu. The resized image will be displayed.
   Note: Selecting the same size as the current image causes an error.




## 7.2.5e Pad Points

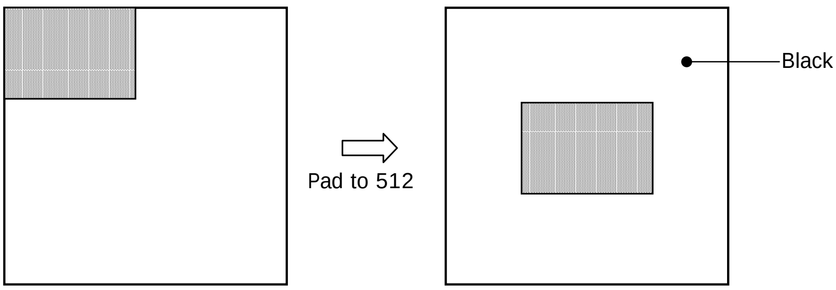
Function: The current image is shifted to the center of a larger frame.
The following three paddings are provided:

| Current image | Padded image size |
|---|---|
| 128×128 | 256, 512 |
| 256×256 | 512 |
| 512×512 | — |

1. Click on “Geometry” in the main menu; then select “Pad Points” in the pull-down menu.
2. Select “256” or “512” on the pulldown sub-menu. Then the current image will be shifted to the center.

   The surrounding area of the image is replaced by black (‘0’).

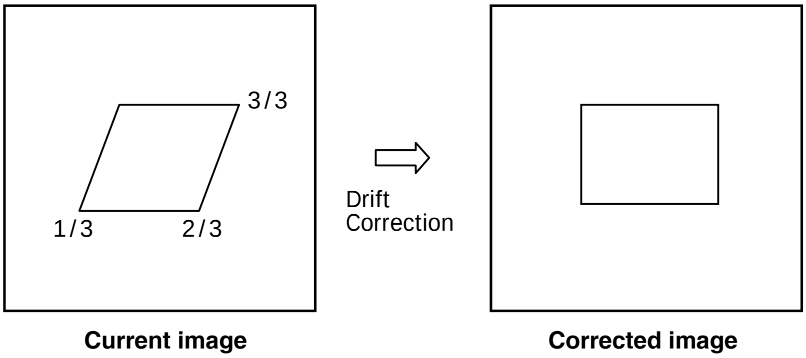
   Note: Selecting any frame size other than those listed in the table above would cause an error.



### 7.2.5f Drift Correction

Function: Corrects the distortion (drift) of the current image.

1. Click on “Geometry” in the main menu; then select “Drift Correction” in the pull-down menu. A cross cursor ‘+’ appears on the image.
2. Designate an image distortion at 3 corners of a parallelogram—the starting point (1/3), the 1st vector endpoint (2/3), and the 2nd vector endpoint (3/3)—in accordance with the guidance displayed on the window. Then the image within the designated parallelogram frame is converted to a square frame image and displayed in the center of the original image.



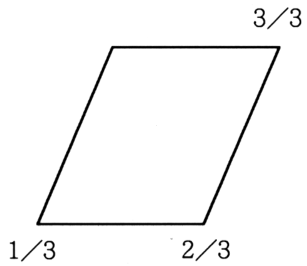

If the parallelogram used for designation is small, the corrected image is also small. The size relation between the designated parallelogram frame and the converted square frame is as follow:

| Designated parallelogram | Corrected image |
|---|---|
| Less than 128×128 | 128×128 pixels |
| Less than 256×256 | 256×256 pixels |
| 256×256 or more | 512×512 pixels |

### 7.2.5g Average Unit Cell

Function: The entire image is reconstructed with a designated unit cell.

1. Click on “Geometry” in the main menu; then select “Average Unit Cell” in the pull-down menu. A cross cursor ‘+’ appears on the image.
2. Designate 3 corners of a parallelogram as a unit cell.
   Designate the starting point (1/3), the 1st vector endpoint (2/3), and the 2nd vector endpoint (3/3) in accordance with the directions displayed on the window. This operation designates the shape of the unit cell of the mesh.
   The message “Enter integral factor to scale vector down by” is displayed on the window.

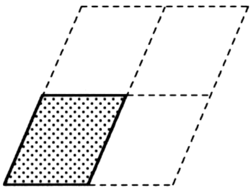



**Method for designating a unit cell**

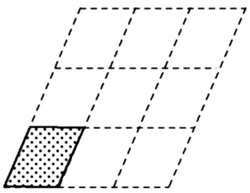
**3.** Input a numerical value—the denominator of division of the designated parallelogram—to scale down the parallelogram to the actual unit cell of the mesh (each side of the displayed parallelogram is divided by the entered number).

**[Example]**

If 1 is entered, the size of unit cell is the same as the displayed parallelogram.
If 2 is entered, the actual size of unit cell becomes 1/2 in each direction.



**If '1' is entered.**



**If '2' is entered.**

**4.** Click on the "OK" button; then the mesh frame with the actual unit cell is overlaid on the original entire image; all unit cell images are averaged and the resultant unit cell image is displayed in the top left corner of the image display screen.

**5.** The message "Select reduction factor" is displayed. The following four selections are provided:

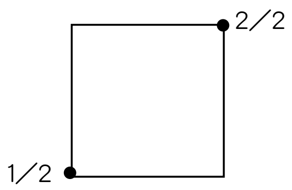
| Reduction | Description |
|---|---|
| Reduction 1 | The image is reconstructed with a cell whose size is the same as the designated unit cell. |
| Reduction 2 | The image is reconstructed with cells whose size is 1/2 the four sides of the designated unit cell. |
| Reduction 4 | The image is reconstructed with cells whose size is 1/4 the four sides of the designated unit cell. |
| Repeat | Return to step 2 (repeat the designation of unit cell). |

**6.** Select one of the reduction factors. The reconstructed image is displayed.

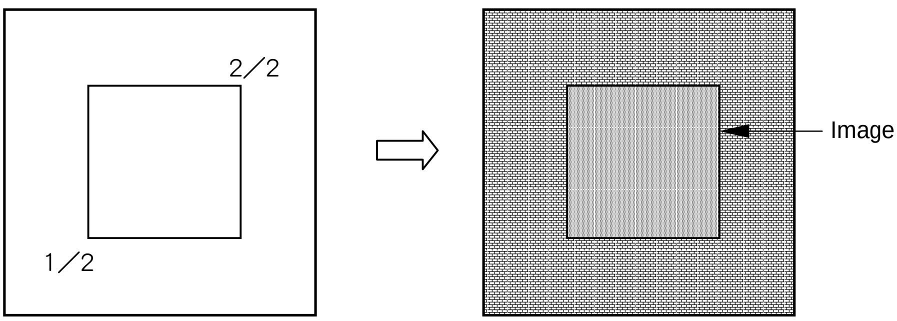
### 7.2.5h Extract Area

Function: The region outside of the designated area on the current image is substituted with black ('0'). This black area can be replaced by another image using the "Replace Area" function.

1. Click on "Geometry" in the main menu; then select "Extract Area" in the pull-down menu. A cross cursor '+' appears on the image.
2. Designate a rectangle by specifying two diagonal points, 1/2 and 2/2. Then, the area outside of the designated rectangle changes to black ('0').




**Area designation**



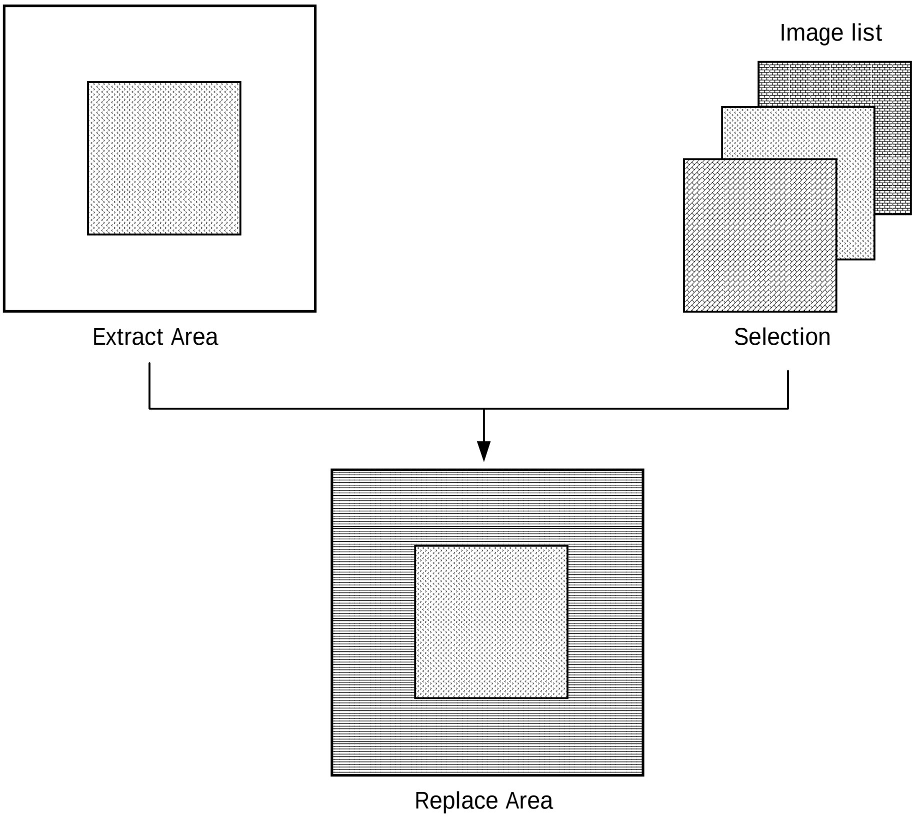

**Original image** **Processed image**

### 7.2.5i Replace Area

Function: The black area made with the "Extract Area" operation is replaced by another image.

1. After the "Extract Area" operation, click on "Geometry" in the main menu; then select "Replace Area" in the pull-down menu.

   Then a list of images stored in the computer memory is displayed on the window.
2. Select an image to be inserted into the black area.
3. The black area of the current image is replaced by the selected image.



## 7.2.6 LUT

### 7.2.6a Adjust LUT

Function: Adjusts brightness and contrast of the current image.

**1.** Click on "LUT" in the main menu; then select "Adjust LUT" in the pull-down menu.

An image is displayed with a size of 400×400 pixels, and bar charts for the brightness and contrast adjustment are displayed.

**2.** Adjust the brightness and contrast of the image by operating the bar charts. Click on the "OK" button.

Note: The "Adjust LUT" function can be applied only to a displayed image. The image data in the computer memory is not changed with this function. In order to change the image data in the computer memory, "Transform Image Data" must be executed.

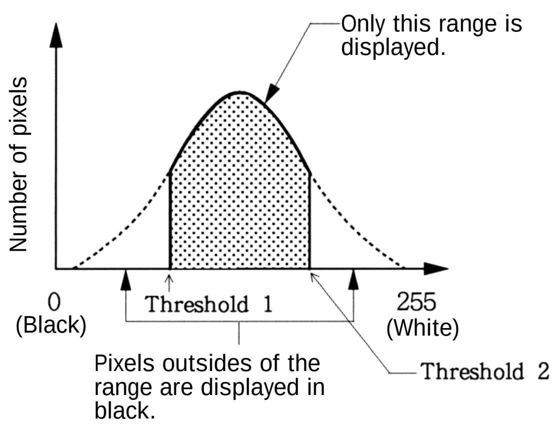
### 7.2.6b Set Window

Function: Pixels whose brightness is within a designated range are displayed, and other pixels are substituted with black ('0').

**1.** Click on "LUT" in the main menu; then select "Set Window" in the pull-down menu.

The "Threshold1" and "Threshold2" windows are displayed.

**2.** Adjust the "Threshold1" and "Threshold2" values and click on the "OK" button.




### 7.2.6c Histogram

Function: A pixel histogram of the current image is displayed and equalized.

◆ Click on "LUT" in the main menu; then select "Histogram" in the pull-down menu.

The following menus will be displayed in the Display Window.

Display Hist ··· A histogram is displayed.

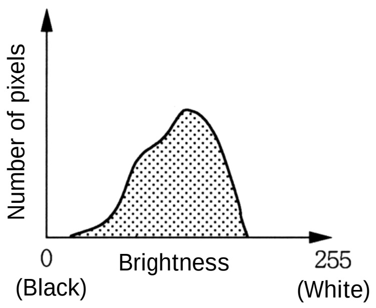
Equalize········· Image contrast is equalized

## ■ Display Hist

Function: The brightness histogram of the current image is displayed.

◆ Select "Display Hist" in the Display Window.

The brightness histogram of the current image is displayed on the image display screen.



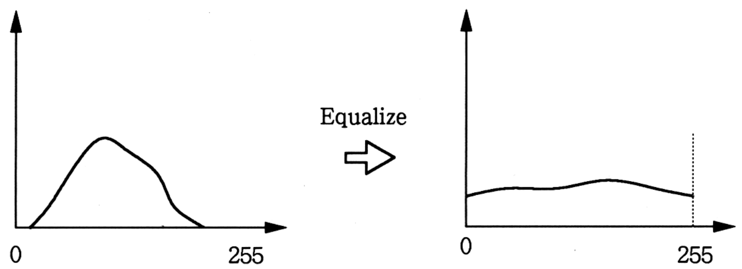

## ■ Equalize

Function: The image contrast is reconstructed so that the brightness histogram of the new image becomes almost flat between 0 (black) and 255 (white).

◆ Select "Equalize" in the Display Window.

The image contrast is equalized as shown in the figure below.

Note: The "Equalize" function is applied only to the displayed image. The image data in the computer memory is not changed with this function. In order to change the image data in the computer memory, "Transform Image Data" must be executed.



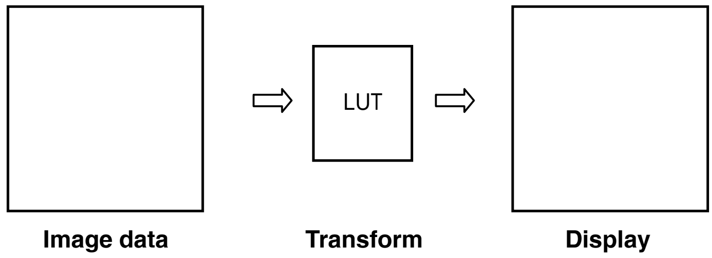
## 7.2.6d Display image LUT

Function: The current LUT (Look Up Table) is displayed on the image as a graph.

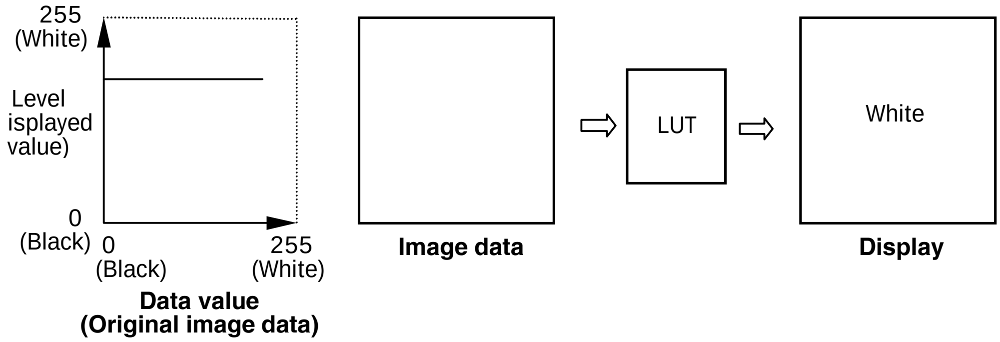
◆ Click on “LUT” in the main menu; then select “Display image LUT” in the pull-down menu.

Then, the current LUT is displayed on the image.

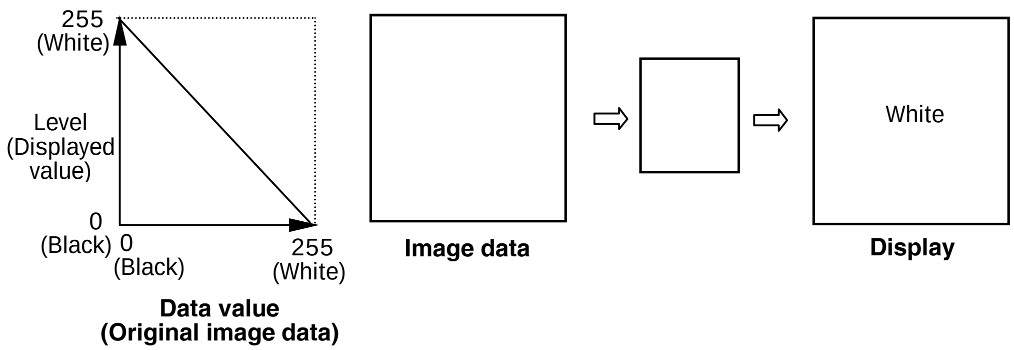
Note: The LUT is a data-transform function for displaying the original data on the image display screen.



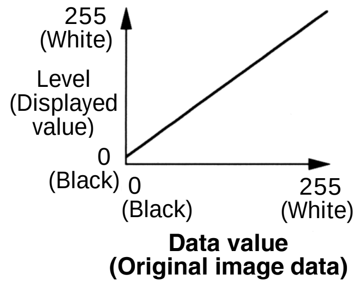

For example, if the LUT is like the one shown below, the displayed image is all white (255).




Or, if the LUT is like the one shown below, an inverse-video image is displayed.

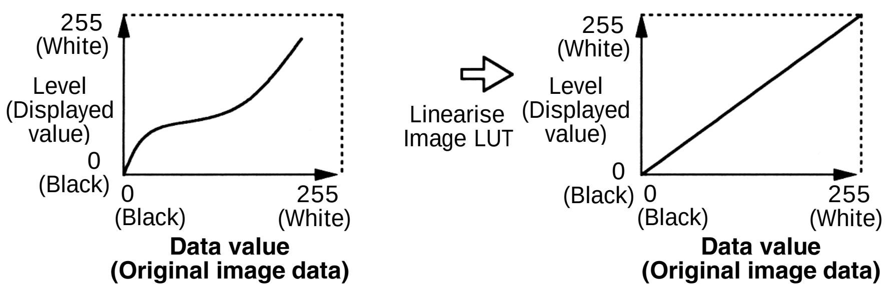



Each image has its own LUT. Usually, the LUT is defined as shown below as a default, but the LUT is changed after “Adjust LUT,” “Set Window” or a similar operation is executed.




### 7.2.6e Linearise Image LUT

Function: The LUT of the current image is changed to a linear function (its default).
When the LUT of the current image is changed to a linear function, the image brightness and contrast are also changed. This function is to force the LUT to a linear function (its default). Therefore, if "Linearise Image LUT" is operated for the following LUT, the LUT is linearised as shown in the figure below (right).




◆ Click on "LUT" in the main menu; then select "Linearise Image LUT" in the pull-down menu.

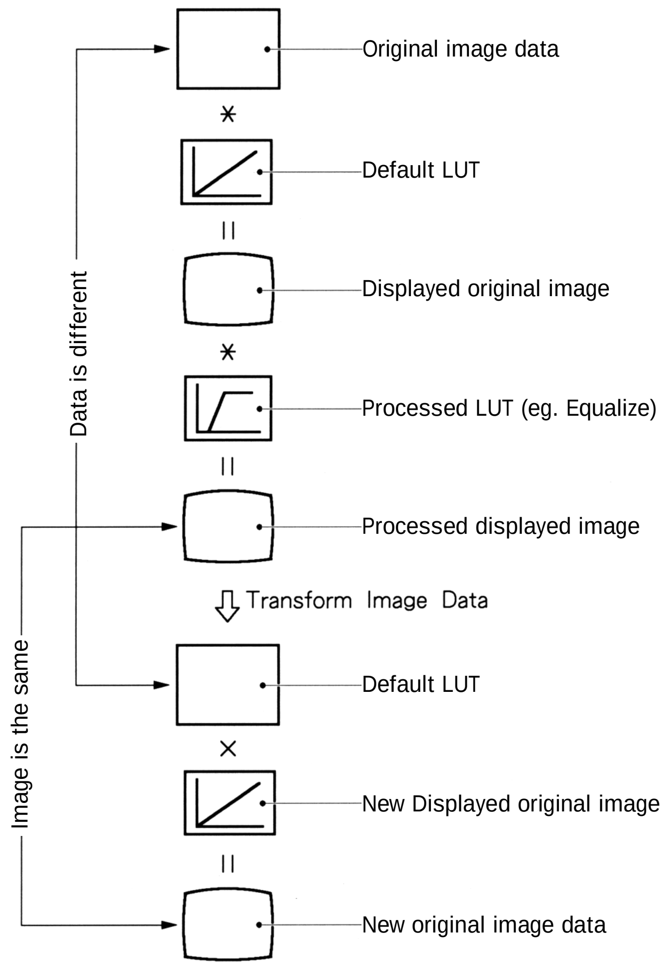
Then the current LUT is linearized. The image is displayed with the linearized LUT.

Note: Whether the LUT has been linearized with this function or not can be confirmed with the "Display Image LUT" function.

### 7.2.6f Transform Image Data

Function: The displayed image, which is processed with an LUT, is stored in the computer memory as new original image data.

The following transforms are performed.




1. Click on “LUT” in the main menu; then select “Transform Image Data” in the pull-down menu.
2. Then, the displayed image, which is processed with an LUT, is transformed to new original image data. In other words, the displayed image data is stored in the computer memory as new original image data.

Notes: 1. After this operation, the current LUT becomes a linearised default LUT.
2. After the “Adjust LUT,” “Set Window” or “Equalize” function is used, the image must be transformed with this function.

### 7.2.6g Remove LUT colours

Function: Color information specified in an LUT (Look Up Table) is erased.

◆ Click on “LUT” in the main menu; then select “Remove LUT color” in the pull-down menu.

Then, the colors specified with the “Display Colours...” function (refer to Subsection 7.2.7f) are removed from the image, and it turns into a normal image.

Notes: 1. When “yes” is selected in reply to the message “keep colours ?” of the “Grab from FS” function (refer to Section 7.2.7h), the color information in the LUT is stored on the computer memory together with the image data.
2. If no color information exists in the stored LUT, this operation causes an error.

### 7.2.6h LUT Math

Function: An LUT is mathematically operated on with addition, multiplication or other operation.

◆ Click on “LUT” in the main menu; then select “LUT Math” in the pull-down menu.

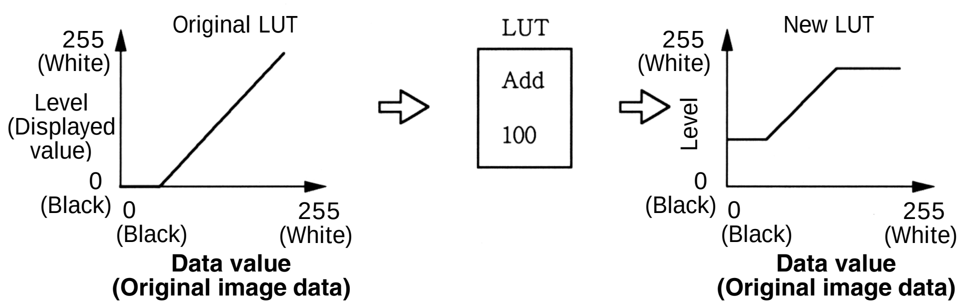
The following eight operations are provided:

| Operation | Description |
|---|---|
| Inverse | Level axis of LUT is inverted. |
| Reverse | Data axis of LUT is reversed. |
| Add | A constant is added to LUT. |
| Bitwise And | AND operation with a constant for each bit |
| Bitwise Or | OR operation with a constant for each bit |
| Bitwise Xor | XOR operation with a constant for each bit |
| Multiply | LUT is multiplied by constant. |
| Divide | LUT is divided by constant. |

Note: If the resultof a numerical operation is outside the range of 0 to 255, the data is set to 0 or 255.

**[Example]**

If 100 is added to a current LUT with the “Add” operation, the image is displayed with the new LUT shown below.

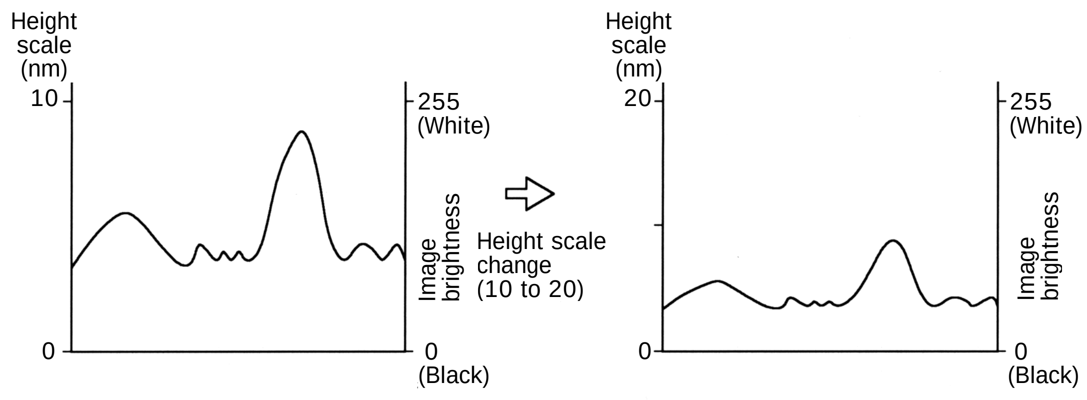



**LUT Math**

### 7.2.6i Fix Z scale

Function: The height scale of the current image is changed.
"Fix Z Scale" changes the scale of the image brightness (height of specimen-surface unevenness).
For instance, in the case of a height profile displayed with the "Profile" function as shown below (left), the scale of height (brightness) is 0 to 10 nm for image brightness of 0 (black) to 255 (white). If the scale is changed to 0 to 20 nm, the displayed height (brightness) profile changes as shown below (right). The contrast of the displayed image is also changed.
This function is used to compare two images whose height scales differ from each other, by converting them to the same height scales.

Note: The LUT is changed by this function, but the original data remains unchanged in the computer memory.




**1.** Click on "LUT" in the main menu; then select "Fix Z Scale" in the pull-down menu.

Then, the window indicates the existing height scale, and asks you about a new scale.

**2.** Enter the new scale using the keyboard, and click on the "OK" button.

## 7.2.7 Display

### 7.2.7a Display

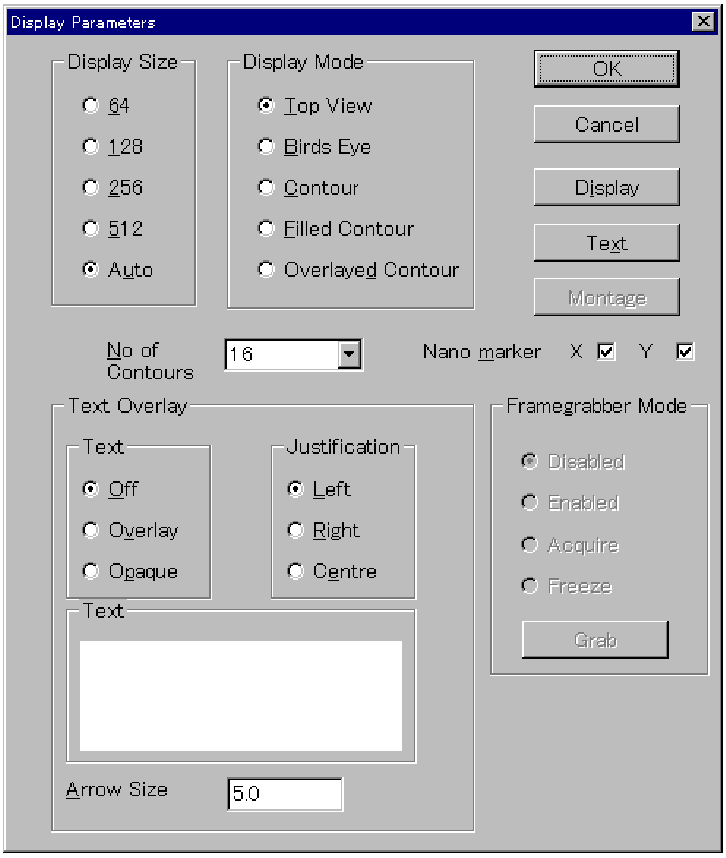
Function: From among the image data stored in the computer memory, the current image data is displayed in the Display Window. This function is used to display an image again after clearing the display with the "Clear FS" function (refer to Section 7.2.7g).

◆ Click on "Display" in the main menu; then select "Display" in the pull-down menu. The current image stored in the computer memory is displayed in the Display Window.

### 7.2.7b Display Param...

Function: Parameters for displaying an image are set in this window.

◆ Click on "Display" in the main menu; then select "Display Param..." in the pull-down menu. The "Display Parameters" window will open.




Note: Parameters set in this window are in effect regardless of the parameters set for scanning as long as they are not changed. For example, if "Display Size" is 64, an image is displayed as 64×64 when loaded from a disk, even if the original image was scanned at 512×512.

## ● Display Size (64,128, 256, 512, Auto)

The image display size is specified in this frame by selecting a radio button. The choices "64," "128," "256," "512" and "Auto" are provided. When a button is selected from among "64," "128," "256" and "512", an image is displayed in the selected pixel size regardless of the original image size. When "Auto" is selected, an image is displayed in the original image size.

## ● Display Mode

The display mode is selected in this frame.

| Radio button | Description |
|---|---|
| Top View | This mode is the normal display mode. Height (signal level) corresponds to brightness. Conversion of signal level to image brightness is performed by LUT. Usually, a higher signal level (height) is displayed at higher brightness. |
| Bird's Eye | An image is displayed as a shaded image. The eye point is the same as in the "TopView." Illuminating brightness and direction can be designated with "3D Display" (refer to Section 7.2.7d). |
| Contour | Contour lines are displayed. Density of contour lines can be set in the "No. of Contours" selection-box in this window. |
| Filled Contour | Areas between the contour lines are filled with a brightness corresponding to the image level. |
| Overlaid Contour | Contour lines are overlaid onto the "Top View" image. |

## ● No of Contours

The number of contour lines for the "Contour" mode is specified in this selection-box.

## ● Nano Marker

A scale marker can be displayed to show the size of an image. When the "X" or "Y" check box is checked, the marker is shown. The marker length and unit are automatically calculated.

## ● Text Overlay

Text and an arrow mark can be overlaid on the image in the Display Window.

- "Text" frame

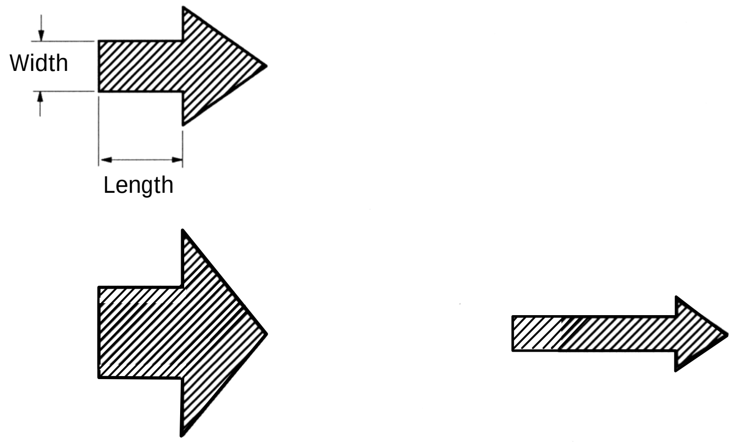
| Radio button | Description |
|---|---|
| Off | An arrow mark is displayed, but no text is overlaid. |
| Overlay | Text is overlaid directly on the image. |
| Opaque | Text is displayed on black background. |

• "Justification" frame

| Radio button | Description |
|---|---|
| Left | Text lines are left-justified. |
| Right | Text lines are right- justified. |
| Centre | Text lines are centered. |

• "Text" frame
Text is entered in this input box using the keyboard. To change to a new line, use the mouse cursor, not the Enter key.

• Arrow Size
The length and width of the arrow mark are specified in this input box. When you click on the "Text" button, a '+' cursor will appear on the image. Designate the starting and ending points of the arrow mark using the cursor.




[Example] "Arrow Size" = 1 "Arrow Size" = 5

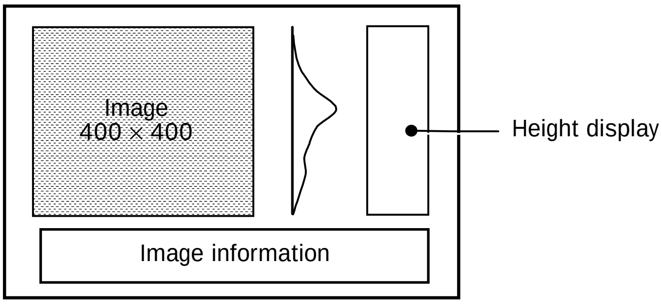
## ● Framegrabber Mode (option)

An externally attached VTR (Video Tape Recorder) is controlled in this frame. An image displayed in the Display Window is output in an S-VHS signal through a video converter. An NTSC video signal is displayed in the Display Window.

| Radio button | Description |
|---|---|
| Disabled | The video signal input/output is stopped. |
| Enabled | The video signal is output to a VTR. |
| Acquire | The video signal from a VTR is displayed in the Display Window. |
| Freeze | The video signal from a VTR isstopped, and the displayed image is frozen temporarily. |
| Grab | An image received from a VTR is grabbed. |

## 7.2.7c Full Display

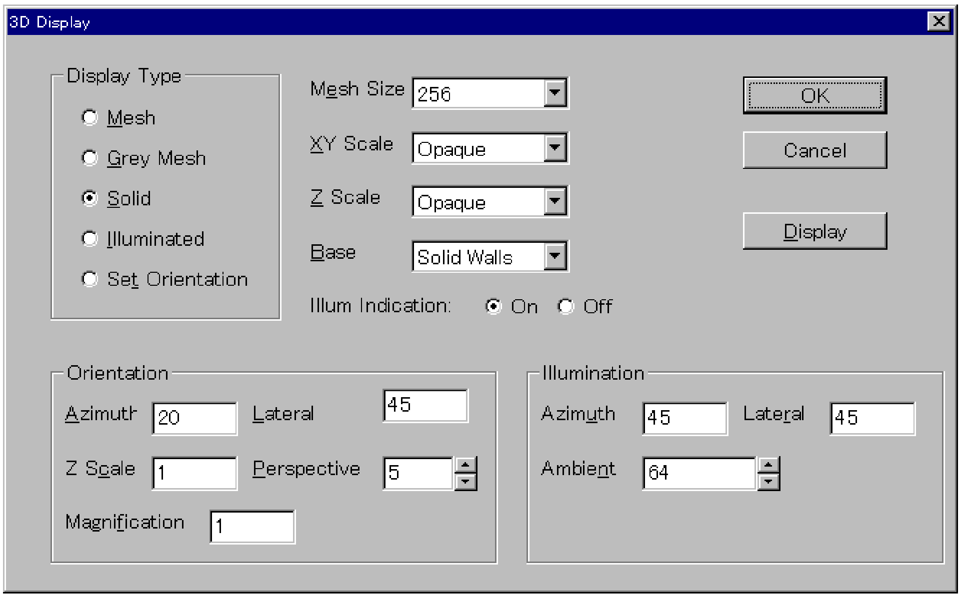
Function: An image with a size of 400×400, the gray scale for the displayed image and information on the image are displayed in the full display screen as shown in the figure below.




## 7.2.7d 3D Display

Function: Parameters for 3-D (three-dimensional) display of an image are set in this window.

The “3D Display” window will be displayed.



## ● Display Type

A type of 3-D display is selected using these radio buttons.

| Radio button | Description |
|---|---|
| Mesh | A 3D wire-frame image is displayed. |
| Solid | A solid 3D image is displayed. |
| Gray Mesh | A 3D wire-frame image is displayed with higher brightness for a higher image level. |
| Illuminated | A solid 3D image is displayed with an illuminating light applied from one direction. |
| Set Orientation | You can adjust the 3D display angle to the optimum condition while watching the 'Mesh' image. After this operation select 'Solid' to display a solid 3D image in this orientation. |

## ● Mesh Size

| | |
|---|---|
| {8,16,32,64,128,256,512} | Number of mesh nodes for 3D construction is specified in this input box. Specify the number of meshes for the X and Y axes.<br>Note: Selecting a larger number of meshes than the number of pixels of the original image would cause an error. Selecting a larger number results in a finer image, but it takes a longer time to construct a 3D image. When selecting "Mesh" or "Gray Mesh," select a rather small number. |

## ● XY Scale, Z Scale

A display type for the X, Y or Z scale is designated in these selection boxes.

| Type | Description |
|---|---|
| Overlay | Scales are overlaid directly on the image. |
| Opaque | Scales are displayed on black background. |

## ● Base

A display type for the foundation of the 3D display is designated in this selection box.

| Type | Description |
|---|---|
| Off | No foundation or side wall is displayed. |
| Base Only | Foundation is displayed, but side walls is not displayed. |
| Solid Walls | Side walls are displayed, but foundation is not displayed. |
| Illuminated Walls | Side walls are illuminated by the same light source as that for the 3D image. |

## ● Illum Indication

When "Illuminated" is selected in the "Display Type" frame, the illumination direction can be indicated by an arrow mark. Select 'On' or 'Off' with the radio-buttons.

## ● Orientation

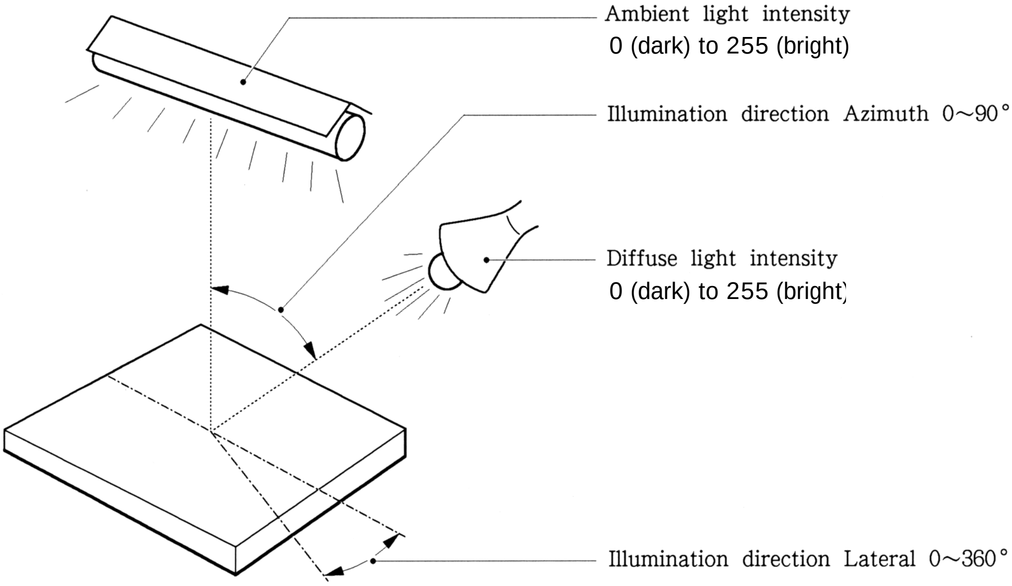
The viewing angle of a 3D image is designated in this frame.

| Item | Description |
|---|---|
| Magnification | Magnification of 3D display is specified. The image size on the screen is always 400×400. This function changes the size of the 3D image displayed on this screen. |
| Lateral | Lateral angle for viewing the 3D image is specified. |
| Azimuth | Azimuth angle for viewing the 3D image is specified. |
| Z Scale | Display magnification in the Z-axis is specified. A smaller magnification produces a plainer image. |
| Perspective | The distance between the eye point and the object is specified. A larger number moves the eye point backward. |

## ● Illumination

An illuminating angle for 3D display is designated in this frame.

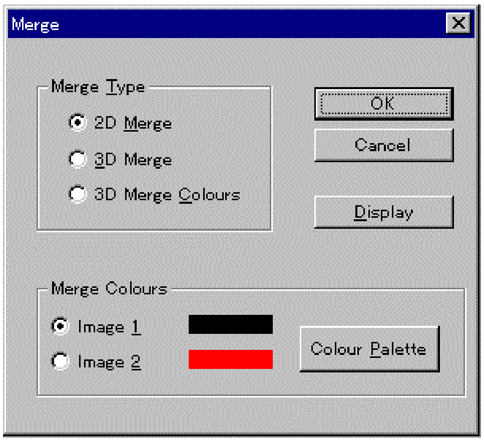
| Item | Description |
|---|---|
| Lateral | Lateral angle of the illuminating source is specified. |
| Azimuth | Azimuth angle of the illuminating source is specified. |
| Ambient | Intensity of the ambient lighting is specified as a number between 0 and 255. |




After completing the parameter setting, click on the "Display" button. A 3D image will be displayed.

## 7.2.7e Merge

Function: The current image and another selected image are merged and displayed.

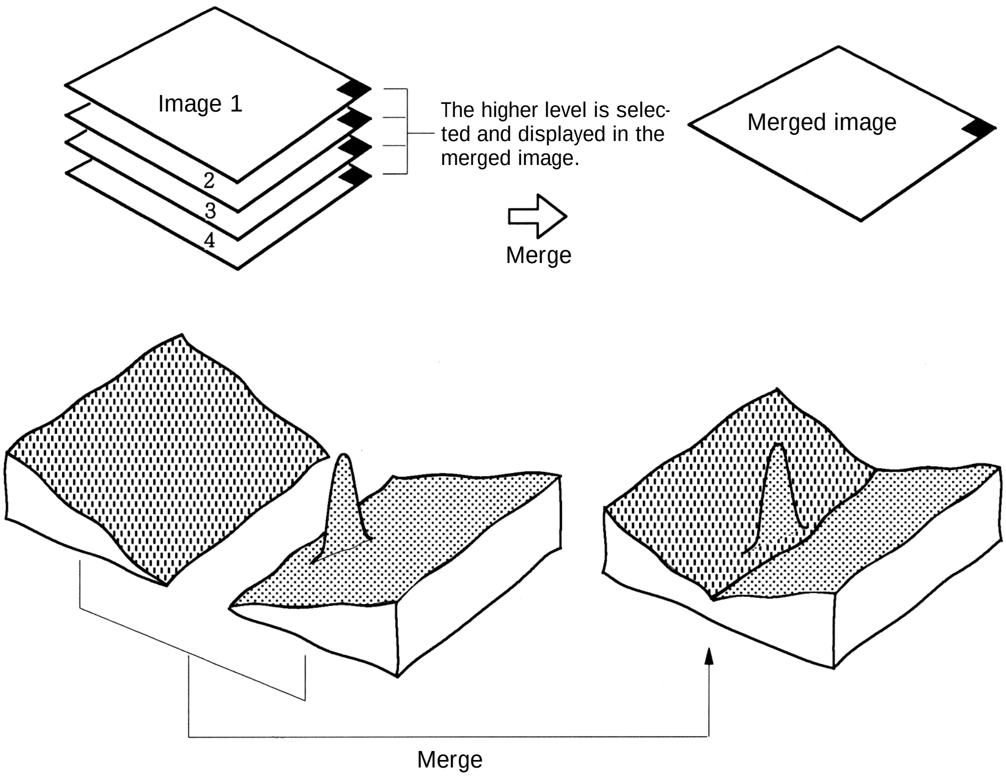



### ● Merge Type

Type of merging is designated in this frame.

| Type | Description |
|---|---|
| 2D Merge | Two images are merged and displayed two-dimensionally. |
| 3D Merge | Two images are merged and displayed three-dimensionally. |
| 3D Merge Colours | Two images are merged and displayed three-dimensionally with colors. Each image is displayed in a different color designated in the “Merge Color” frame. |

The parameters for “3D Merge” and “3D Merge Colours” are specified in the “3D Display” window.
The signal levels of the images to be merged are compared for each corresponding pixel, and the larger level is selected for the merged image to be displayed.

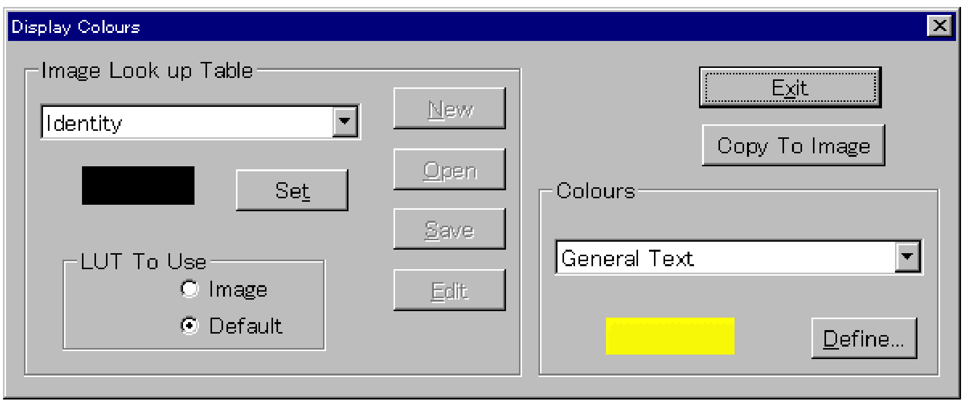



## ■ Merge Colours

The colors of the images to be merged are designated in this frame. "Image 1" designates the color for the current image and "Image 2" designates the color for another image to be merged. Select the "Image 1" radio button and click on the "Color Palette" button. The color of "Image 1" is designated. Then, designate a color for "Image 2" in the same manner. For color setting with the "Color Palette" function, refer to the instruction manual for Windows95™.

## 7.2.7f Display Colours...

Function: The color for displaying an image and colors for displaying other data in the screen are designated.



## ● Image Look up Table

The color for displaying an image is selected in this frame.

| Color table | Description |
|---|---|
| Identity | Linear gray scale (High: White, Low: Black) |
| Inverse | Inverse linear scale (High: Black, Low: White) |
| Logarithmic | Logarithmic gray scale |
| Pseudo colour | High: Red, Middle: Green, Low: Blue |
| Blue | Blue mono-color (linear scale) |
| Yellow | Yellow mono-color (linear scale) |
| User 1, User 2 | User-defined color |

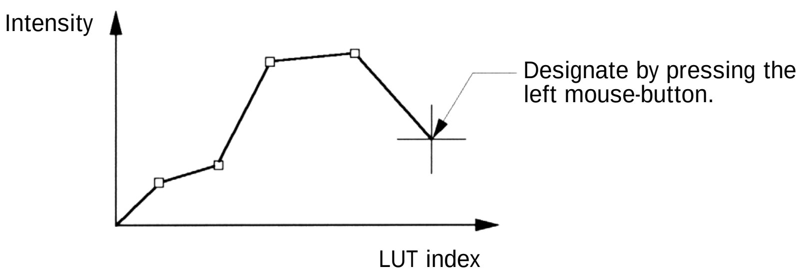
- Open: A saved color table is loaded from the disk.
- Save: The current color table is saved on the disk.
- Edit: The current user-defined color table can be changed (refer to the Note below).
- Set: Image color is defined as displayed in the above box.

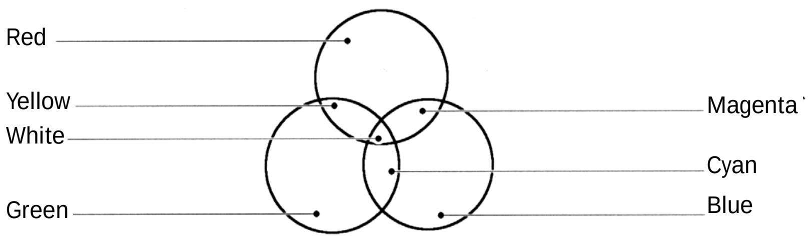
Note: The procedure for making or modifying a color table with “Edit” is as follows:

**1.** Select “User 1” or “User 2” and click on the “Edit” button.

Red, green and blue color table definition windows will appear.

**2.** Define the “R” (red), “G” (green) and “B” (blue) tables using the mouse.



● **Colours**

Colors for displaying other parts than images are selected in this frame.

| Part | Description |
|---|---|
| Old Image Boundary | Frame of an image which is not the current image |
| Current Image Boundary | Frame of the current image |
| Overlay Text | Characters displayed on an image |
| General Text | Image data displayed on the screen |
| 3D Display Base | Foundation of the 3D display |
| 3D Surrounding Colour | Background of the 3D display |
| 3D Sides 1 | Side wall of the 3D display |
| 3D Sides 2 | Side wall of the 3D display |
| Selected Points | A '+' mark when designated |
| Axes Colour | Axes of the graph |
| Axes Title Colour | Axis titles of the graph |
| Plot Title Colour | Title of the graph |
| Plot Colour | Data in the graph |
| Reverse Plot Colour | The second data in the graph when two graphs are plotted on the same graph |
| Grid Colour | Grid of the graph |
| CITS Border Colour | Frame of the CITS image |
| Framestore Background | Background in the window |

For color setting with the "Define" function, refer to the instruction manual of Windows95™.

## 7.2.7g Clear FS

Function: The displayed image is cleared.

1. Click on "Display" in the main menu; then select "Clear FS" in the pull-down menu.
2. Then, The image displayed on the Display Window is erased.

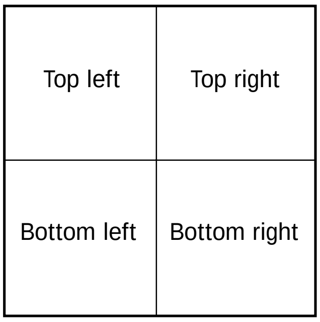
   Note: This function clears only the displayed image or data. Image data in the computer memory are not erased. To do this, use "Close" in "File" (refer to Section 7.2.1c).

## 7.2.7h Grab from FS

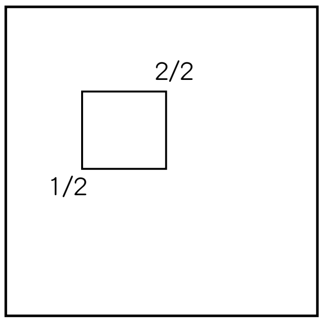
Function: An image displayed on the Display Window is stored in the computer memory with a title name given to it.

1. Click on "Display" in the main menu; then select "Grab from FS" in the pull-down menu. Then, a sub-pull-down menu is displayed.
2. Select a part of the image to be stored from the sub-pulldown menu.

| Item | Description |
|---|---|
| Whole | Whole image in the Display Window |
| Top left | Top left 1/4 of the Display Window |
| Top right | Top right 1/4 of the Display Window |
| Bottom left | Bottom left 1/4 of the Display Window |
| Bottom right | Bottom right 1/4 of the Display Window |
| Center | Center 1/4 of the Display Window |
| Selected | A designated area of the Display Window (refer to the Note below) |




Note: When “Select” is selected, a ‘+’ cursor appears in the image. Then, designate two diagonal points by pressing the left mouse button. The designated image is grabbed in the computer memory.




**Designation of area**

**3.** The message “Keep colours ?” is displayed on the window. If you want to keep the color data, select “Yes.”

The message “Enter image title” is displayed on the window.

Note: Regarding the “Keep colours ?” message, refer to Sub-section 7.2.6g “Remove LUT colours.”

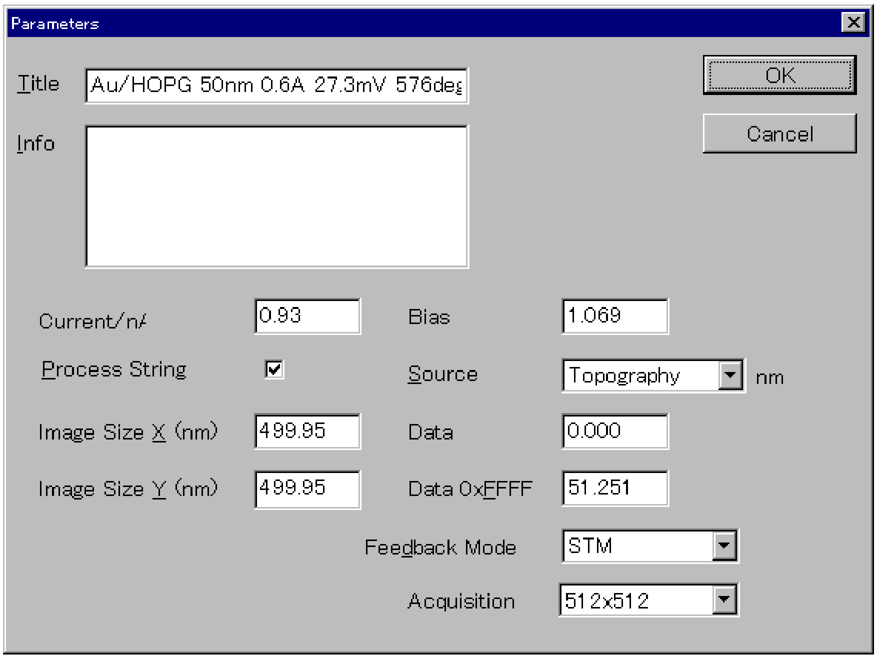
**4.** Input the title using the keyboard.

Note: This title is not the file name saved on the disk, but is listed by the “Select” function (refer to Section 7.2.9).

## 7.2.7i Change Param...

Function: The contents of the “Data Information” window are changed.

◆ Click on ‘Display’ in the main menu; then select ‘Change Param...’ in the pull-down menu. Then, the ‘Parameters’ window will appear.

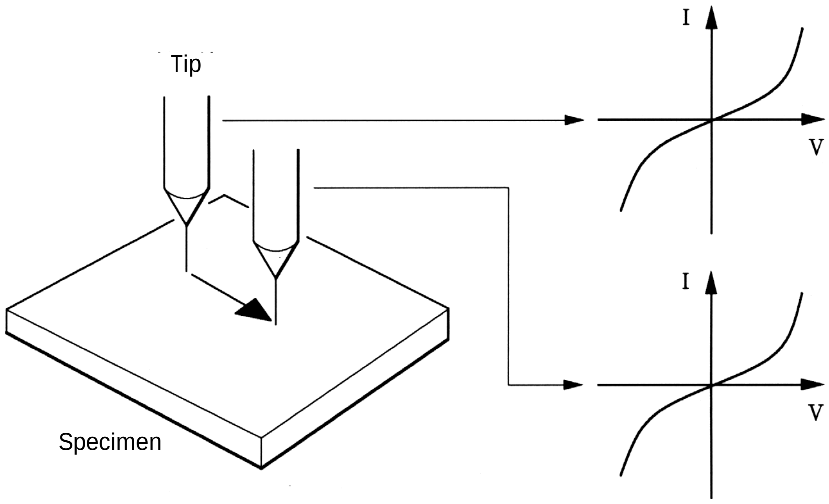



The items that can be changed are as follows:

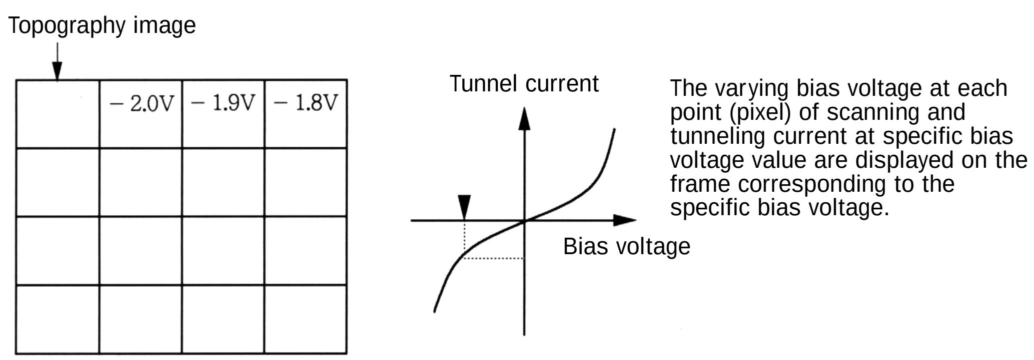
| Item | Description |
|---|---|
| Title | 40 characters or less |
| Info | 39 characters×5 lines, or less |
| Reference/V/Current/nA | Optional |
| Sample Bias (V) | Optional |
| Process string | Whether or not the history of ON, OFF, image processing , etc. is displayed |
| Image Type | Topography, Current image, Log current image, External ADC image, CITS current image, CITS log current image, Force image |
| Image Size X (nm) | Optional |
| Image Size Y (nm) | Optional |
| Data value 0 | Absolute image level (height) to be displayed in black (0) |
| Data value 255 | Absolute image level (height) to be displayed in white (255) |
| Data Type | STM, Contact, Slope, FM, FMS |

## 7.2.8 CITS

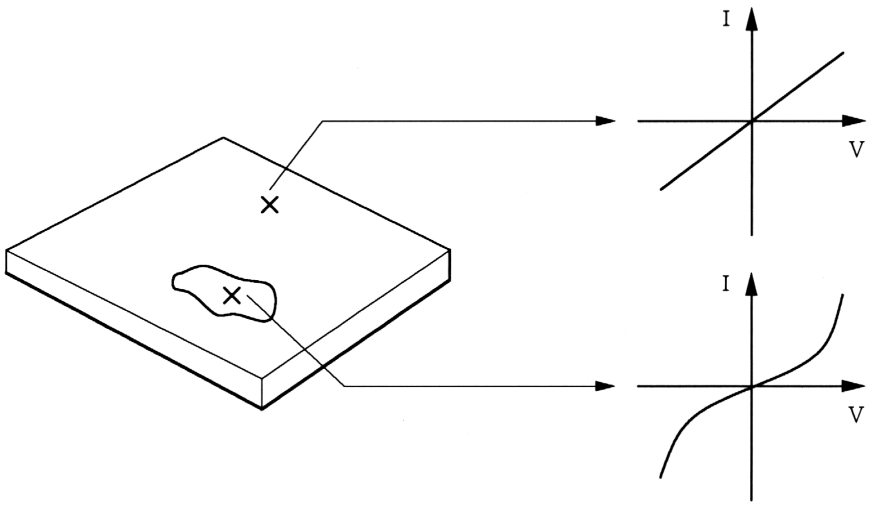
The CITS (Current Imaging Tunneling Spectroscopy) function measures I-V characteristics at each point of scanning. That is, I-V data is obtained at each pixel.




The top left image on the screen is a topographic image obtained under the parameters specified in the “SPM Parameters” window. The next (right-hand side) image and all others show tunneling current images obtained at various bias voltages without changing the tip height at which the topography image was obtained.



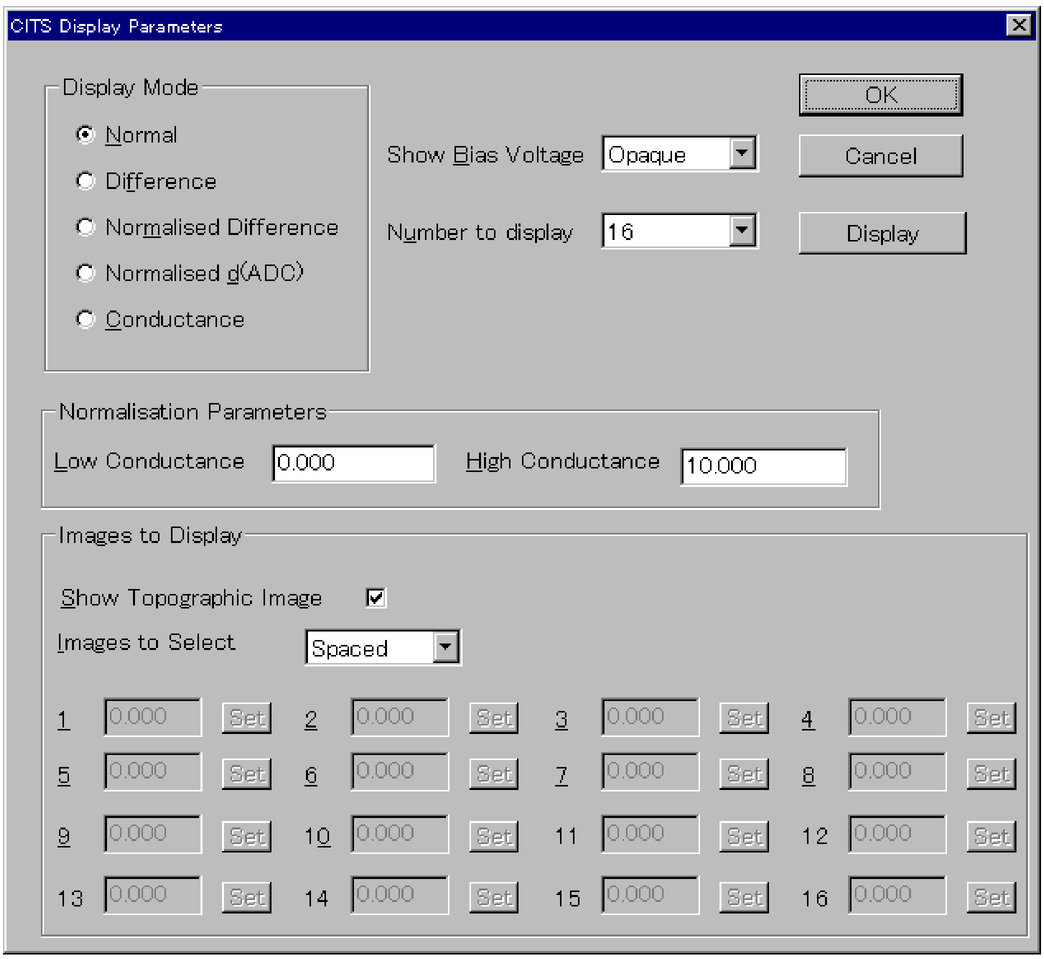

Since I-V data and a topographic image are measured at the same time, there is a perfect position correspondence between the topographic image and tunneling current. It is possible to select, using the mouse, an arbitrary point on the specimen while watching its topographic image and accurately display the I-V characteristics of the selected point.




### 7.2.8a Display Parameters

Function: The display parameters for CITS images are specified in this window. CITS images are displayed in a size of 128 × 128 pixels.

The parameters to be set are as follows.



## ● Display Mode

Display modes are selected with these radio buttons.

| Display mode | Description |
|---|---|
| Normal | Current images are displayed directly. |
| Difference | Images of the current difference between neighboring frames are displayed. |
| Normalized Difference | Images of the normalized current difference between neighboring frames are displayed. |
| Normalized d (ADC) | Images of the normalized current difference between neighboring frames based on the original AD values are displayed. |
| Conductance | Derivative (dI/dV) images are displayed. |

## ● Show Bias Voltage

A display type for bias voltages is selected in this selection-box.

| Type | Description |
|---|---|
| Off | Bias voltages are not indicated. |
| Overlay | Bias voltages are directly overlaid on the images. |
| Opaque | Bias voltages are displayed on a black background. |

## ● Number to display

The number of image frames to be displayed is selected in this selection box.

## ● Normalization Parameters

The range for normalization is specified in this frame. This frame is used only when "Conductance" is selected in the "Display Mode" frame.

| Item | Description |
|---|---|
| Low Conductance | Value to be displayed in black is specified in this input-box. |
| High Conductance | Value to be displayed in white is specified in this input-box. |

## ● Images to Display

Show Topographic Image: When this check-box is checked, a topography image is displayed in the top left frame of the Display Window.

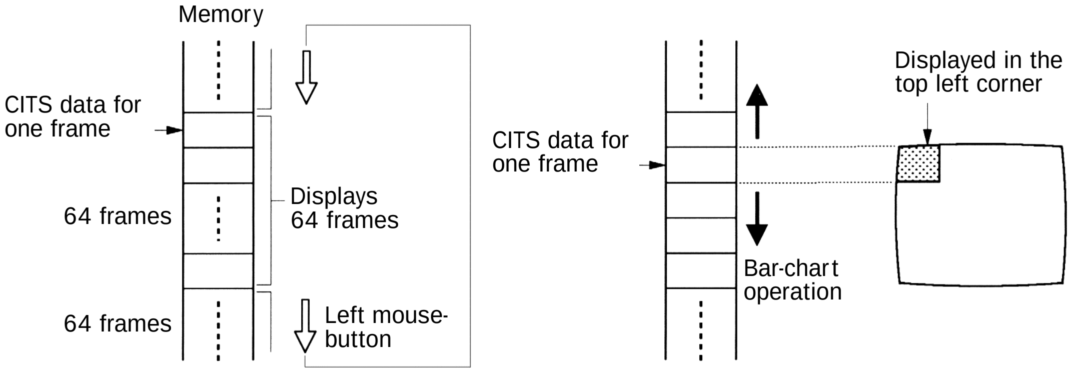
Images to Select: The current image series to be displayed is selected in this selection box.

| Item | Description |
|---|---|
| None | Nothing is displayed. |
| Spaced | Images are displayed in equal voltage intervals. |
| First | Designated number of images starting with the first voltage value are displayed. Number is designated in “Number to display.” |
| Last | Designated number of images starting with the last voltage value are displayed. Number is designated in “Number to display.” |
| Mixed | Images for designated voltages are displayed. Voltages are designated in boxes “1” to “16.” |

## 7.2.8b Special Displays

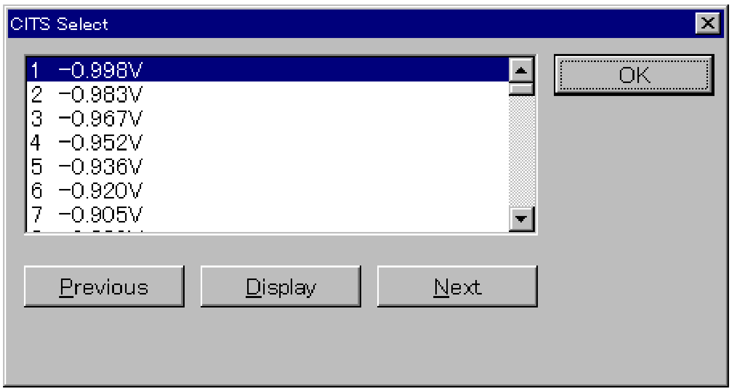
Since one CITS consists of a lot of data, special display modes are provided to display CITS images.

| Display Mode | Description |
|---|---|
| Paged display | Sixteen frames, beginning with the first one, are displayed. |
| 64×64 display | Sixty-four frames are displayed at a time with a size of 64×64 pixels for each frame. If the number of images is 16 or less, these images are displayed at a size of 128×128 pixels. When the ‘+’ cursor is moved to any of the sixty-four image frames, the information of the image is displayed on the “Data Information” window. |
| Rapid display | All the CITS images are sequentially displayed in real time as a moving picture on the top left 128×128-pixel frame with scroll bar operation. |



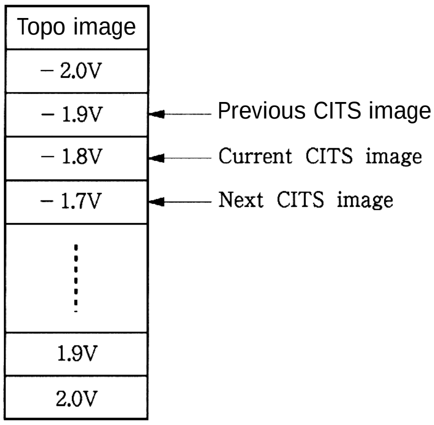

**Paged display (64 × 64 display)**     **Rapid display**

## 7.2.8c Select CITS Image




Function: The active CITS image is designated, and always the current CITS image is displayed in the frame next to it.

Note: “Current CITS image” means the image that is currently designated in the computer program.




**CITS image**

For example, when the tunneling current image with a –1.8 V bias voltage is the current CITS image and each command is executed, the following CITS images will be displayed.

| Button | Description |
|---|---|
| Display | The CITS image with a –1.8 V bias voltage is displayed in colored frame. |
| Previous | The CITS image with a –1.9 V bias voltage is displayed and this image becomes the current image. |
| Next | The CITS image with a –1.7 V bias voltage is displayed and this image becomes the current image. |

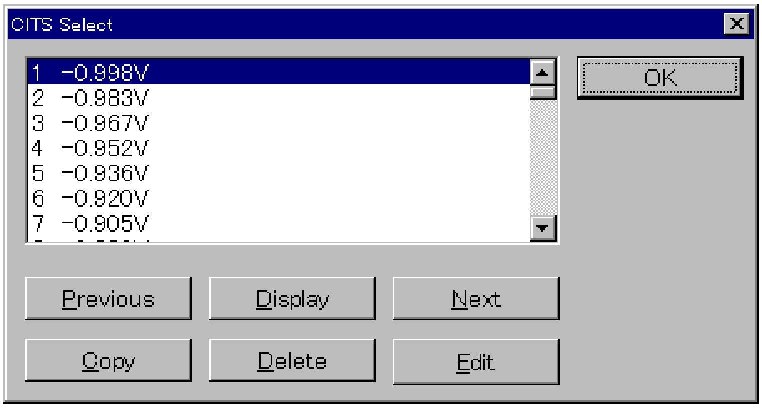
## 7.2.8d Edit CITS Data Set

### ■ Edit

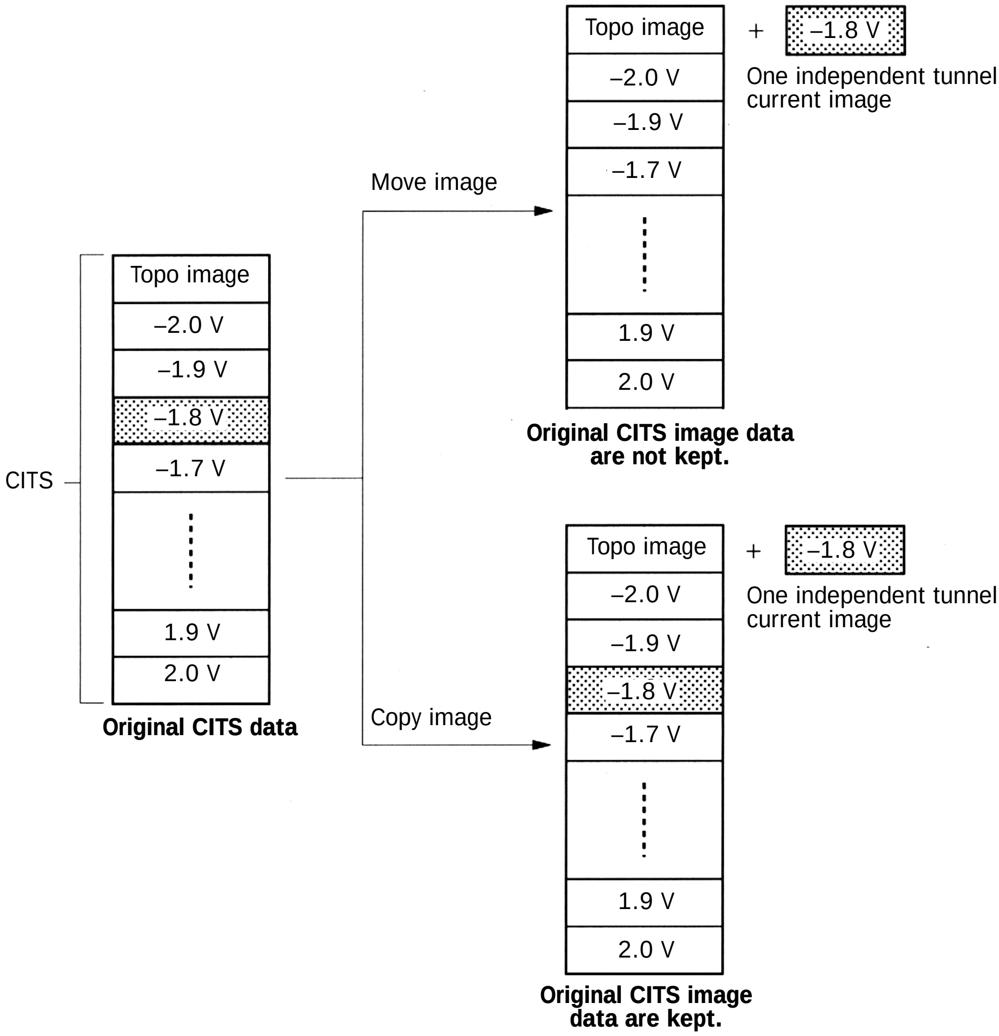
Function: Copy or delete the designated CITS image, or add a comment or title on a designated bias voltage image in the CITS bias voltages.

◆ Click on “CITS” in the main menu; then select “Edit CITS Data Set” in the pull-down menu. Then, select “Edit” in the sub-pulldown menu.

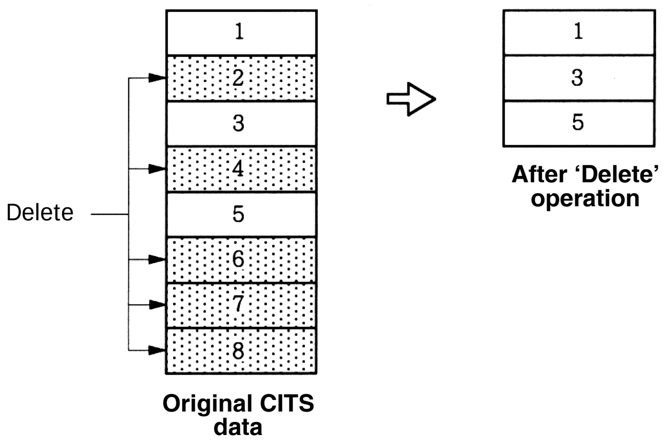
The “CITS Select” window will appear. The following operations can be performed.




- Previous
  The CITS image with the bias voltage prior to the current one is displayed.
- Display
  The current CITS image is displayed again.
- Next
  The CITS image with the next bias voltage after the current one is displayed.
- Copy
  A tunneling current image with an optional bias voltage extracted as an independent image from among the CITS images is stored in the computer memory.
  For example, the extracted –1.8 V image is treated as an independent image. Therefore, image processing can be performed for this image in the same manner as for an ordinary tunneling current image.




- Delete
  CITS images are deleted.



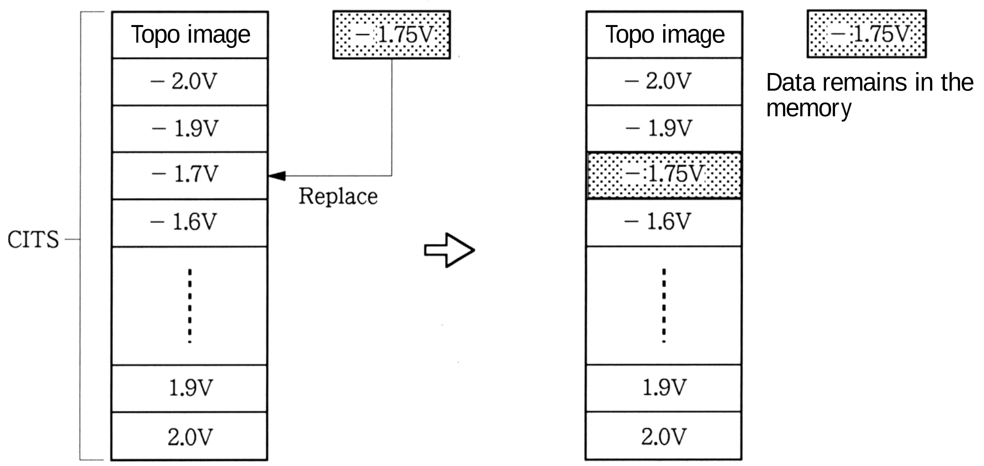

- Edit
  A title is input for the CITS image displayed as the current image.

## ■ Replace image, Insert image

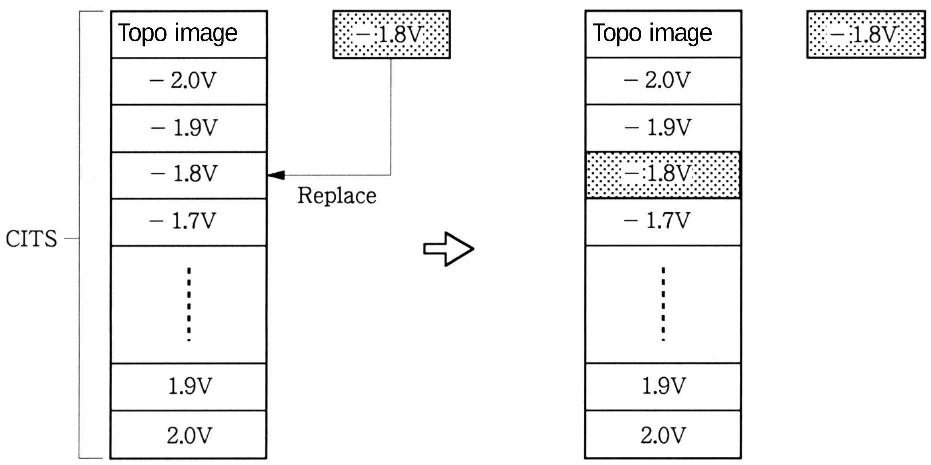
Function: A current image that was stored in the computer memory with the "Copy" operation is inserted again into the original CITS image data.

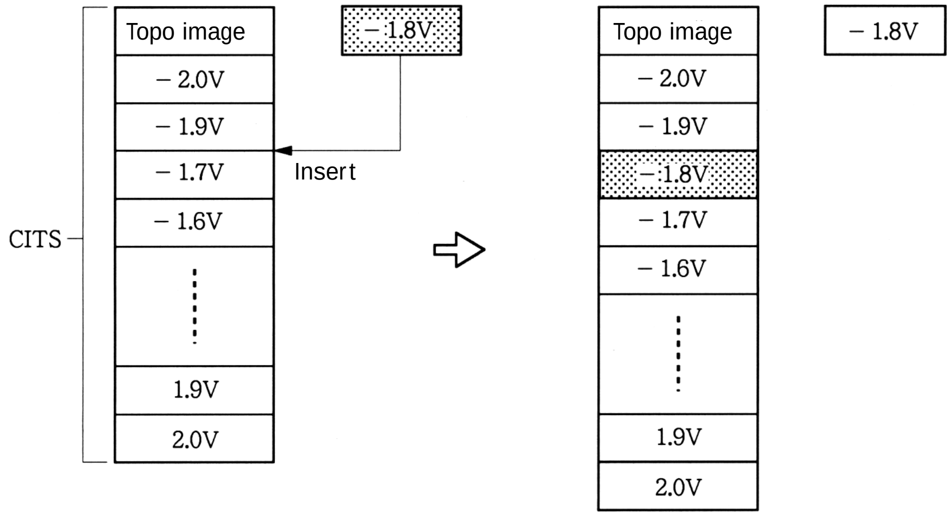
Note: If there is no tunneling current image that was stored in the computer memory with the "Copy" operation, selecting this function would cause an error.

**[Example]**




'–1.7' is replaced by '–1.75'






## ■ Copy I over Topog.

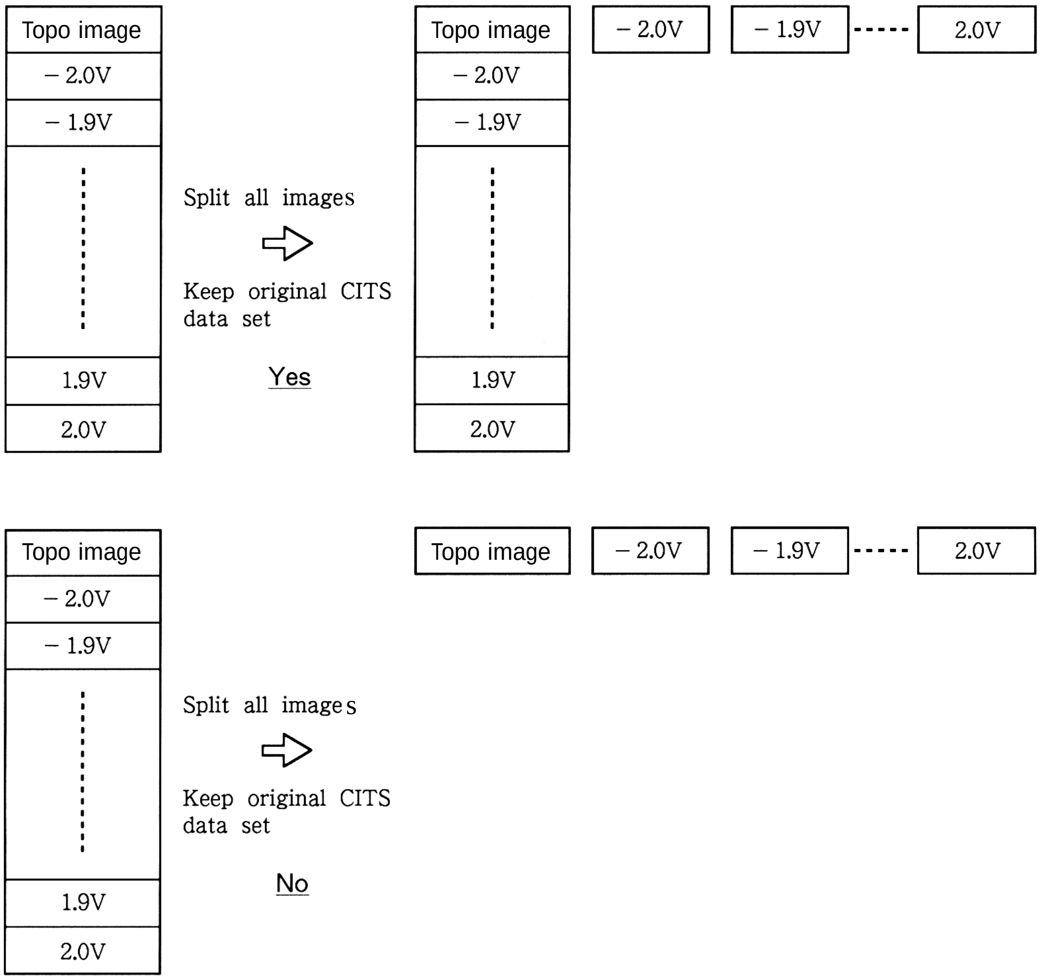
Function: A current CITS image is overlaid on a topography image displayed in the top left frame.

## ■ Split all images

Function: All images comprising of a CITS image are separated, and each split image is stored in the computer memory as an independent current image data.

1. Click on "CITS" in the main menu; then select "Edit CITS Data Set" in the pull-down menu. Then, select "Split all images" in the pulldown sub-menu.
2. The message "Keep original CITS data?" is displayed. If "Yes" is selected, the original CITS image is kept in the computer memory. If "No" is selected, the original CITS image is erased

**[Example]**



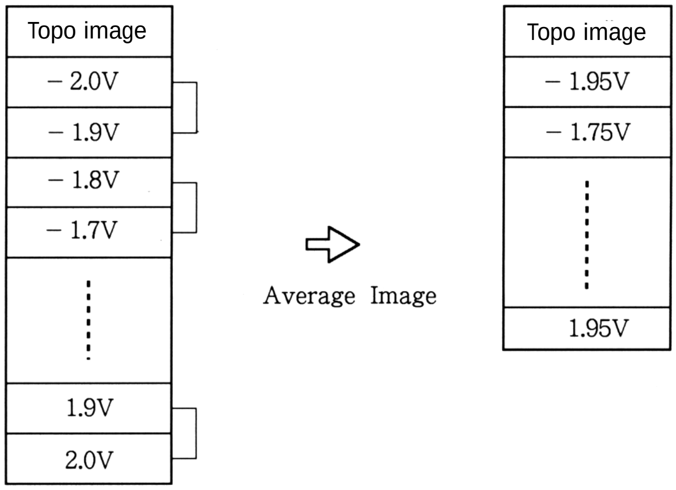
### 7.2.8e Average Images

Function: The designated number of CITS images are averaged.

1. Click on “CITS” in the main menu; then select “Average Images” in the pull-down menu.
   Then, a pop-up window “Number of images to average over” will appear.
2. Select a number from 2, 4, 8, 16 and 32. The designated number of Images are averaged, and the averaged images will be displayed.

**[Example]**

When ‘2’ is selected:




### 7.2.8f Duplicate Data Set

Function: All images in the CITS data series are duplicated in the computer memory.

1. Click on “CITS” in the main menu; then select “Duplicate Data Set” in the pull-down menu.
2. Then the whole data series will be duplicated in the computer memory.

### 7.2.8g Extract Spectra...

Function: The I-V data is derived from the CITS image and is data-processed. Then the processed data is displayed as a graph.

The display method is as follows.

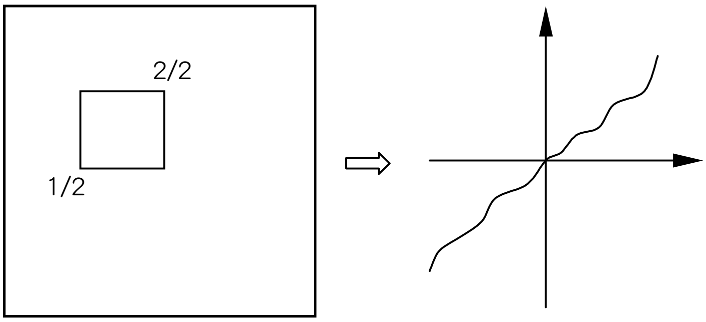
| Display on CRT | Description |
|---|---|
| I-V | Normal I-V data |
| dI/dV | Derivative of the I-V data |
| dLnI/dLnV | Derivative of V-normalized I-V data |
| d_I/d_V | Second derivative of the I-V data |
| d_LnI/d_LnV | Second derivative of V-normalized I-V data |

## ■ Selection Type

When “Object” is selected, an area can be designated by pointing to particles with the ‘+’ cursor and pressing the right mouse button. Then, the I-V curves at the points within the designated particles are averaged and displayed. This function is in effect when the “Particle” function is applied to a binarized image.

## ■ Select

The region in which I-V curves are to be averaged is designated by pointing to two diagonal points with a ‘+’cursor.




**Topographic image**
**Designate two diagonal points**

**I-V curves within the area are averaged and displayed.**

# 7.2.9 Select

The list of data in the computer memory is displayed. A check mark is shown at the left of the current data.
The following functions are provided in the pull-down menu:

### ● Previous Image

Function: When “Previous Image” is selected in the pull-down menu, the nearest image data above the current data is displayed.

### ● Next image

Function: When “Next Image” is selected in the pull-down menu, the nearest image data below the current data is displayed.

### ● Previous Data

Function: When “Previous Data”’ is selected in the pull-down menu, the data listed just above the current data is displayed regardless of whether it is an image or a graph. You can press the Page Up key on the keyboard instead of using the mouse to display the data listed above the current data.

### ● Next Data

Function: When “Next Data” is selected in the pull-down menu, the data listed just below the current data is displayed regardless of whether it is an image or a graph. You can press the Page Down key on the keyboard instead of mouse operation to display the data listed below the current data.

## 7.2.10 Window

Functions for handling windows on the screen are provided. The following handling functions are provided in the pull-down menu:

- **New Window**

Function: When “New Window” is selected in the pull-down menu, a new Display Window is opened. When two or more Display Windows are opened, a check mark is shown at the left of the active window in the list.

- **Close Window**

Function: When “Close Window” is selected in the pull-down menu, the active window is closed. It is impossible to close all the Display Windows. At least one Display Window must be displayed on the screen.

Note: This function is applied to windows which are actually displayed on the screen. The data stored in the computer memory remains there even if its window is closed.

- **Arrange Icons**

Function: When “Arrange Icons” is selected in the pull-down menu, windows on the screen can be iconized and arranged.

- **Cascade**

Function: When “Cascade” is selected in the pull-down menu, the displayed windows are arranged in cascade (overlapped with a small shift).

### 7.2.11 Help

Online help is provided in this software. When you are not aware of the operation or meaning of some functions, this “Help” function is useful.

- **Contents**

Function: When “Contents” is selected in the pull-down menu, the online help is displayed. For an underlined item, you can see a more-detailed description by clicking on the item. Once a help window is set to a convenient size, the help window will be displayed in this size afterwards. If the “Help” window setting is “Options”–“Keep Help on Top” – “On Top,” the help window is always on top. This is convenient especially when you operate while referring to the help window.

- **Search for Help on**

Function: When “Search for Help on” is selected in the pull-down menu, online-help items can be searched for by clicking on the keyword.

- **How to Use Help**

Function: When “How to Use Help” is selected in the pull-down menu, instructions for the usage of the online help are displayed.

Note: Some items are not supported by this function.

- **About**

Function: When “About” is selected in the pull-down menu, the version number of this software is indicated.

# 7.3 DATA PROCESSING

Data processing functions for graph data such as I-V data are provided. The pull-down menus automatically change, depending upon whether the displayed data is an image or a graph.

Here, processing of graph data is described. The following items are the same as those for the Image Processing functions.

File
Edit
Select
Window
Help

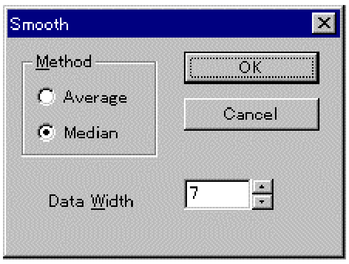
## 7.3.1 Process

### 7.3.1a Smooth

Function: A displayed graph data is smoothed.

◆ Click on "Process" in the main menu; then select "Smooth" in the pull-down menu.

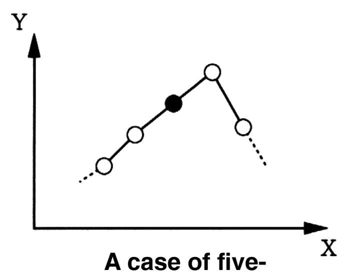
The "Smooth" window will be displayed.




● **Average**

The designated number of neighbor data points are averaged.

Note: The data at the two edges of the graph cannot be processed.



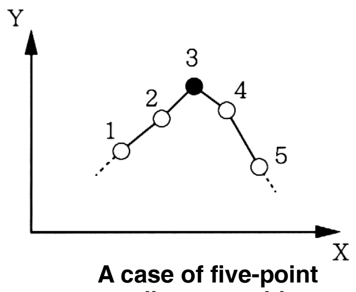

**A case of five-point averaging**

The average of five points is substituted for by the central data point.

## ● Median

Function: A noise spike is eliminated. The designated number of data points are compared with neighboring data, and the middle value of these data is taken as the new data value.

Note: The data at the two edges of the graph cannot be processed.




The Y values of the five points are sorted, and the value of Y3 is replaced by the middle of those five values (Y2, in this example).

**A case of five-point median smoothing**

## ● Data Width

Function: The number of data points to be averaged or compared is specified in this input box.

## 7.3.1b Math X, Math Y

Function: A mathematical operation with a constant is carried out on the X axis (Math X) or the Y axis (Math Y) data.

The following seven mathematical operations are provided.

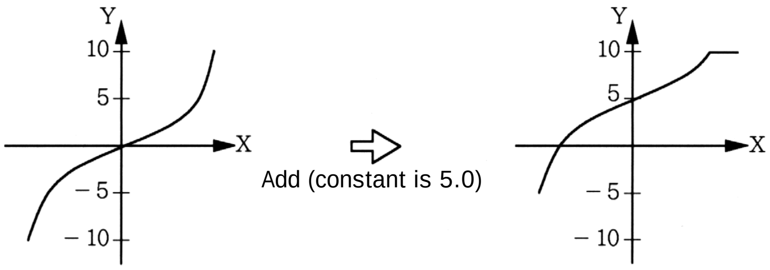
| Operation | Description |
|---|---|
| Add | Addition of a constant |
| Multiply | Multiplication with a constant |
| Divide | Division by a constant |
| Natural Log | Natural logarithm |
| Inverse | Invert the sign of value |
| Absolute Value | Absolute value |
| Reciprocal | Reciprocal of the value |

1. Click on “Process” in the main menu; then select “Math X” or “Math Y” in the pull-down menu.
2. Select the desired operation in the sub-pulldown menu. If “Add,” “Multiply” or “Divide” is selected, the “Enter constant” window will appear. Enter a constant in the window.

   The designated mathematical operation is performed for the graph data, and displayed.

   Note: If “Reciprocal” or “Natural Log” is selected and the result of the reciprocal or natural log overflows, it is set to the maximum or minimum value in the graph data.

**[Example]**




**Original graph** **Processed graph**

## 7.3.1c 2 Spec Math

Function: A mathematical operation is carried out between the Y axis data of the current graph (displayed graph) and Y axis data of another graph (stored in the computer memory).

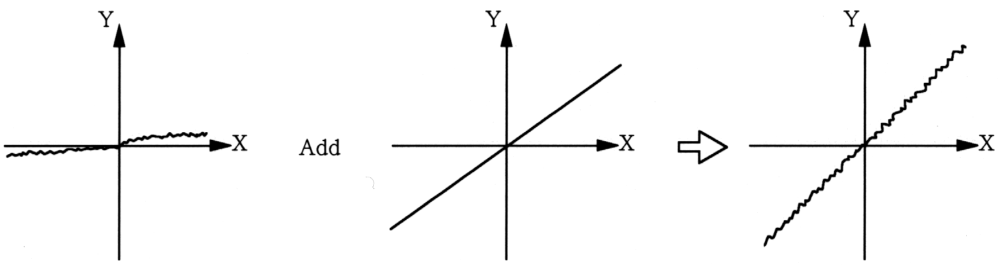
The following mathematical operations are provided.

| Operation | Description |
|---|---|
| Add | A + B |
| Subtract | A – B |
| Average | (A+B)/2 |
| Difference | \|A – B\| |
| Multiply | A×B |
| Divide | A/B |

A: Data of the current graph
B: Data of the selected graph

1. Click on “Process” in the main menu; then select “2 Spec Math” in the pull-down menu. Select the desired operation in the sub-pulldown menu.
2. The list of graph data recorded in the computer memory will be displayed. Then, select a graph to be operated on.
3. The designated mathematical operation is performed between the two graph’s data, and the results are displayed.

**[Example]**



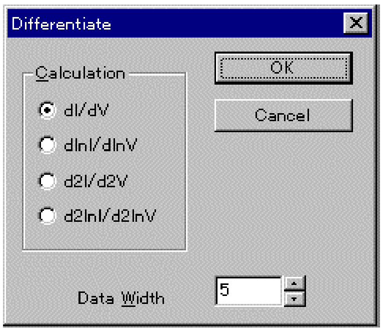

**Current (displayed) graph** **Selected graph** **Processed graph**

## 7.3.1d Differentiate

Function: The displayed graph data is differentiated.

◆ Click on “Process” in the main menu; then select “Differentiate” in the pull-down menu.

The “Differentiate” window will be displayed.




### ● Calculation

A differentiation method is selected in this frame. The available differentiations are as follow:

| Operation | Description |
|---|---|
| dI/dV | 1st derivative by the Savitzky-Golay method |
| dlnI/dlnV | Resultant of the dI/dV is normalized by V/I. |
| d2I/d2V | 2nd derivative by the Savitzky-Golay method |
| d2lnI/d2lnV | Resul of $d^2 lnI/d(lnV)^2$ is normalized by V/I. |

### ● Data Width

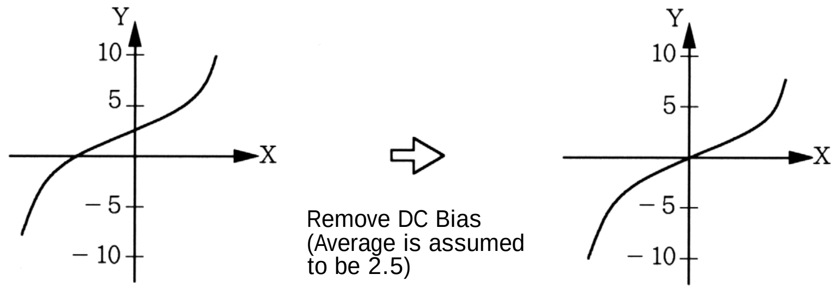
The number of data to be used for the Savitzky-Golay method is specified in this input-box.

### 7.3.1e Remove DC Bias

Function: All the Y values are averaged, and the result is subtracted from each Y value.

1. Click on “Process” in the main menu; then select “Remove DC Bias” in the pull-down menu.
2. The operation is performed, and the processed result is displayed.

**[Example]**




**Current (displayed) graph**    **Tip offset**

## 7.3.2 Analyse

### 7.3.2a Fit Polynomial

Function: A graph is approximated by an n[th]-degree polynomial.

**1.** Click on “Analyse” in the main menu; then select “Fit Polynomial” in the pull-down menu.

The “Enter Polynomial degrees” pop-up window will appear.

**2.** Enter the degree using the keyboard.

If the number ‘n’ is entered, the following polynomial is used for approximation.

$$A_nX^n + A_{n-1}X^{n-1} + \cdots + A_1X^1 + A$$

In the case of cubic polynomial approximation,

$$A_3X^3 + A_2X^2 + A_1X + A_0$$

is applied.

After completion of the approximation, the resultant curve is overlaid on the original graph, and the resultant polynomial formula is displayed on the “Display Information” window.

### 7.3.2b Zoom

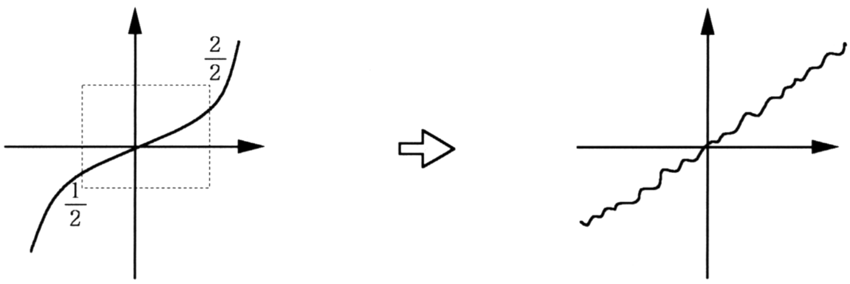
Function: A part of a graph is enlarged.

**1.** Click on “Analyse” in the main menu; then select “Zoom” in the pull-down menu.

A ‘+’ cursor will appear on the graph.

**2.** Designate two diagonal points of the area to be enlarged with the ‘+’ cursor.

Then the designated area will be enlarged to the full frame size.




Designate the area with two diagonal points

Enlarged graph

### 7.3.2c Measure

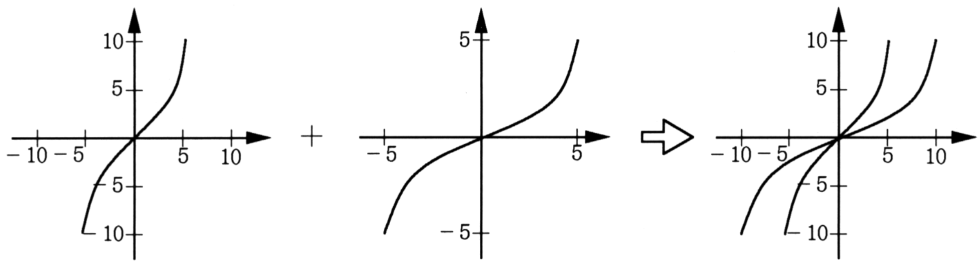
Function: The coordinates of the present cross-cursor position, and the relative distance between the present cross-cursor coordinates and the previous cross-cursor coordinates, are indicated.

1. Click on “Analyse” in the main menu; then select “Measure” in the pull-down menu.
   A ‘+’ cursor will appear on the graph, and the coordinates of the cursor are displayed.
2. Position the ‘+’ cursor at a point on the curve; then click the left mouse-button. The ‘+’ cursor will be fixed at the point.
3. Move the ‘+’ cursor to a desired point. The present coordinates of the ‘+’ cursor position and the distance between the present and previously fixed ‘+’ cursor coordinates are indicated in the “Measure” window.

### 7.3.2d Group Plot

Function: A selected graph is overlaid on the current (displayed) graph.

1. Click on “Analyse” in the main menu; then select “Group Plot” in the pull-down menu.
   The list of graph data stored in the computer memory will be displayed on the console display window.
2. Select a graph to be overlaid with the mouse operation. The selected graph will be overlaid on the current graph.
   Note: The cursor is displayed on the graph already displayed on the display window.
3. The graph list will be displayed again. Continue the operation as necessary.
   Clicking the right mouse button finishes the operation.




**Current graph** **Graph to be overlaid** **Overlaid graph**
(The scale of the original graph is applied to the overlaid graph.)

### 7.3.2e Show FFT

Function: The FFT is applied to the data of a displayed graph.

1. Click on “Analyse” in the main menu; then select “Show FFT” in the pull-down menu. The names of the FFT windows will be displayed in the pulldown sub-menu. The following FFT windows are provided:

| FFT window | Description |
|---|---|
| No window | FFT without window |
| Cosine window | W (n) = 0.5–0.5cos (10n π /N) |
| Parzen window | W (n) = 1–{n–0.5 (N–1)}2/0.5 (N+1) |
| Cosine arch | W (n) = 1–n–0.5 (N–1)/0.5 (N+1) |
| Hamming | W (n) = 0.54+(1–0.54) cos (2 π n/N) |

2. Select a desired FFT window. Then, the FFT is performed and the result is displayed.

   Note: The DC bias component is automatically eliminated before the FFT execution.

## 7.3.3 Display

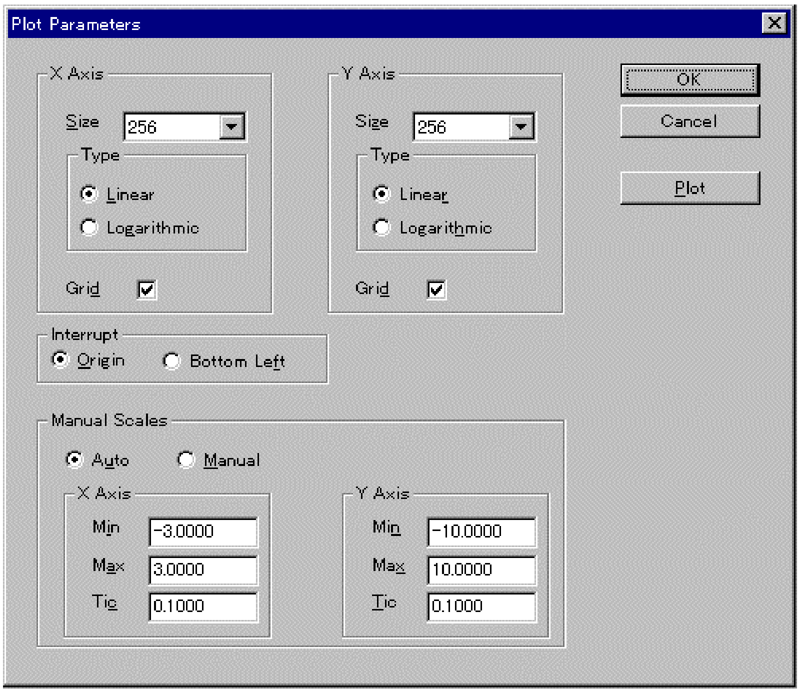
### 7.3.3a Plot

Function: A graph is displayed again.

◆ Click on “Display” in the main menu; then select “Plot” in the pull-down menu.
Then the last-displayed graph is displayed again.

### 7.3.3b Plot Parameters

Function: Parameters for displaying a graph with the “Plot” function are specified in this window.



The following parameters are provided.

| Parameter | Description |
|---|---|
| X Axis Size | Size of graph along X axis is specified. Available sizes are 256 and 512. |
| Y Axis Size | Size of graph along Y axis is specified. Available sizes are 240, 256, 480 and 512. |
| X Axis/Y axis Type | Types of scales are specified in these frames. Select "Linear" or "Logarithmic." |
| Intercept | The point where the X and Y axes cross is specified in this frame. Select "Origin" or "Bottom Left." |
| X Axis/Y Axis Grid | Whether or not grid lines are to be added is specified. The check mark shows that the grid lines are to be added. |
| Manual scales | Whether the X and Y axis scales are to be set automatically or manually is specified with these radio buttons. When "Auto" is selected, the scale is to be automatically set to fit the data value. |
| X Axis Min | The minimum value on the X axis scale is specified. |
| Y Axis Min | The minimum value on the Y axis scale is specified. |
| X Axis Max | The maximum value on the X axis scale is specified. |
| Y Axis Max | The maximum value on the Y axis scale is specified. |
| X Axis Tic | The tick mark interval on the X axis is specified. |
| Y Axis Tic | The tick mark interval on the Y axis is specified. |

CONTENTS

# 8

# MAINTENANCE

# 8.1 STORAGE

## 8.1.1 Instrument

When the instrument is not in use, put the provided glass bell-jar on the top of the SPM base.

If the ambient humidity is very high, dehumidify the room or evacuate the system if the optional vacuum evacuation system is installed.

Head units, scanners, cantilevers, specimen holders and similar parts must be stored in a desiccator when they are not in use.

**WARNING**

**When storing the instrument, avoid high humidity. There is a risk of deterioration of insulation at the tunneling current detector unit and scanner units, causing insufficient instrument performance or electric shock.**

## 8.1.2 Cantilever

**CAUTION**

**Cantilevers must be stored in a desiccator when they are not in use. If they are stored in high humidity, the cantilevers could bend and irregular reflection of the laser beam may occur.**
**Especially, a gold-coated $Si_3N_4$ cantilever is prone to deteriorate with humidity.**

## 8.1.3 Handling of the Instrument

When handling the instrument, be sure to wear Nylon gloves. Never handle with your naked hands. Especially, when you observe a specimen under vacuum using the optional Vacuum Evacuation System, take care so that hand grease does not stick to the parts.

If hand grease stains the parts, wipe off the hand grease with ethanol-soaked lint-free paper or cloth.

**CAUTION**

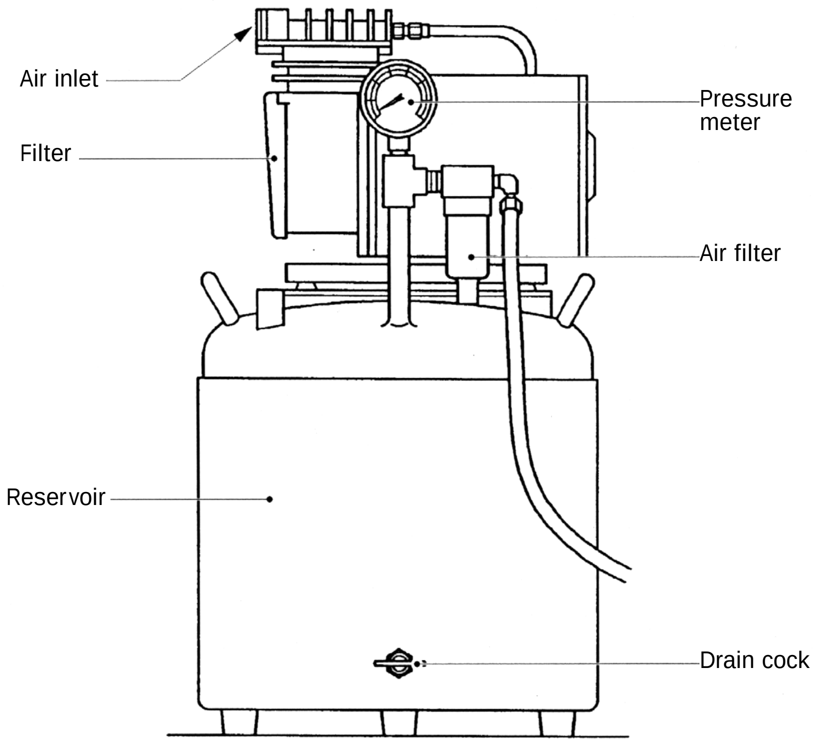
**When handling the instrument, be sure to wear nylon gloves. Hand grease may cause deterioration of the vacuum. Also, there is a risk of deterioration of insulation at the tunneling current detector unit and scanner unit, causing insufficient instrument performance or electric shock.**

# 8.2 VIBRATION ISOLATOR

## 8.2.1 Compressor

The compressor should be inspected periodically and the filter should also be cleaned periodically.

- Drain:
  Shut down the entire instrument and loosen the drain cock at least once a month. Do not forget to tighten the cock after draining off the water.
- Filter cleaning:
  At least once or twice a year, shut the entire instrument down, remove the air inlet using a screwdriver, take the filter out and either replace it with a new one, or wash and dry the filter and remount it.
- Air filter:
  When water collects in the glass container of the air filter, push up the pin at the bottom of the container to drain the water off.



# 8.3 SPM HEAD

## 8.3.1 Laser Beam Focusing

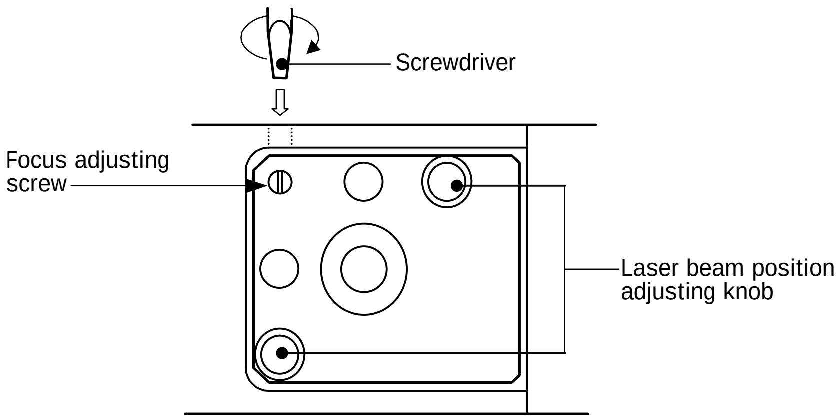
**WARNING**

**Be sure to turn OFF the power to the SPM CONTROL unit before mounting or dismounting the scanner, specimen holder or head unit. There is a risk of electric shock due to the high voltage applied to the connector pins from the SPM CONTROL unit.**

The laser beam has been adjusted in the factory before shipment so that it is focused on the top edge of the cantilever. If, however, the beam becomes out of focus for some reason, re-adjust the focus according to the following procedures:

Note: Due to such processes as scattering, the spot size of the illuminated laser beam looks larger than its real size. If you feel any abnormality with focusing, check the cantilever setting position and angle again before carrying out the focus adjustment.

1. Mount a cantilever as usual and illuminate the laser beam on the tip of the cantilever.
2. Place a piece of white paper on the specimen stub and observe the shadow of the cantilever projected on the white paper. The optional Optical Microscope [TM-24011] may be useful for this observation.
3. Loosen the locking screw of the focus adjusting screw using the provided screw- driver.

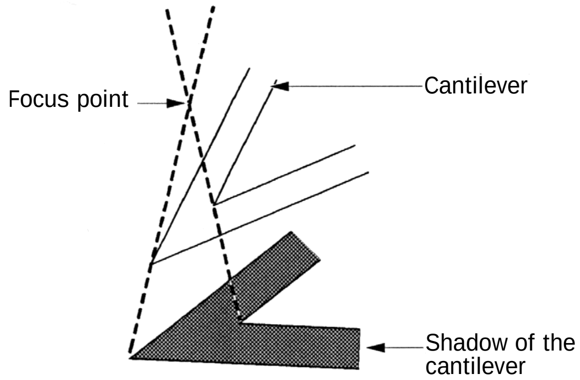



4. Turn the focusing screw and the two beam position adjusting knobs through one revolution in the same direction. Then, observe the shadow again.
5. Adjust these three adjusting elements by turning them in the same direction, so that the shadow of the cantilever becomes the smallest.
6. Tighten the locking screw after adjustment.

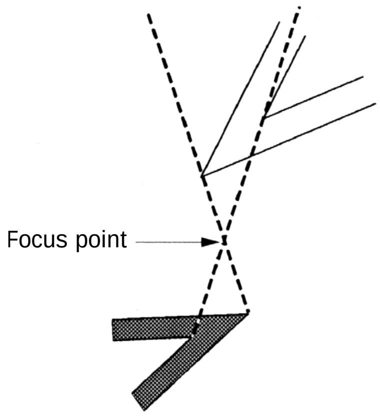
**[Main point for focus adjustment – 1]**

Observe the shadow of the cantilever projected on the specimen stub.

- When the laser beam is focused above the cantilever, the shadow of the cantilever appears on the specimen stub as shown in the figure below.




- When the laser beam is focused below the cantilever, the shadow of the cantilever appears on the specimen stub as shown below. While watching the shadow, adjust the focus point and beam spot position so that the laser beam focuses just at the top of the cantilever.




**[Main point for focus adjustment – 2]**

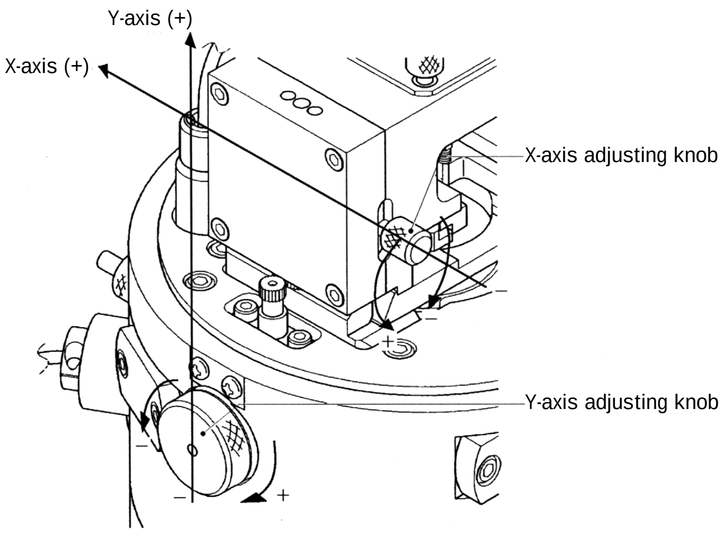
If it is difficult to observe the shadow of the cantilever on the specimen stub, carry out the focus adjustment by removing the scanner and putting a piece of white paper on the specimen stage directly.

## 8.3.2 Mirror Angle Adjustment

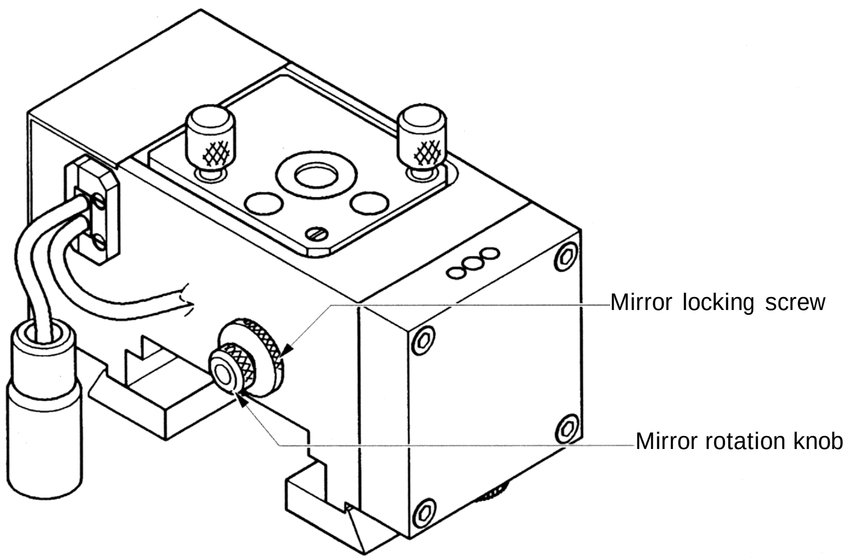
There are some cantilevers whose inclination may differ slightly from that of other cantilevers, depending upon their production lot. If the detector photodiode can not be aligned correctly, adjust the mirror angle according to the following procedure:

1. Mount a cantilever as usual and illuminate the cantilever with the laser beam.
2. Adjust the photodiode position adjusting knobs so that the photodiode is positioned at the center point.

   Note: The total number of revolutions of the X-axis adjusting knob is 20 and that of the Y-axis knob is 52. Therefore, the center position is at 10 (X-axis) and 26 (Y-axis) revolutions back from the fully rotated positions.




3. Loosen the mirror locking screw; then adjust the mirror angle so that the indication of “SUM” on the AFM amplifier unit becomes the maximum negative value and the indication of “AFM” becomes $\pm$0 V.

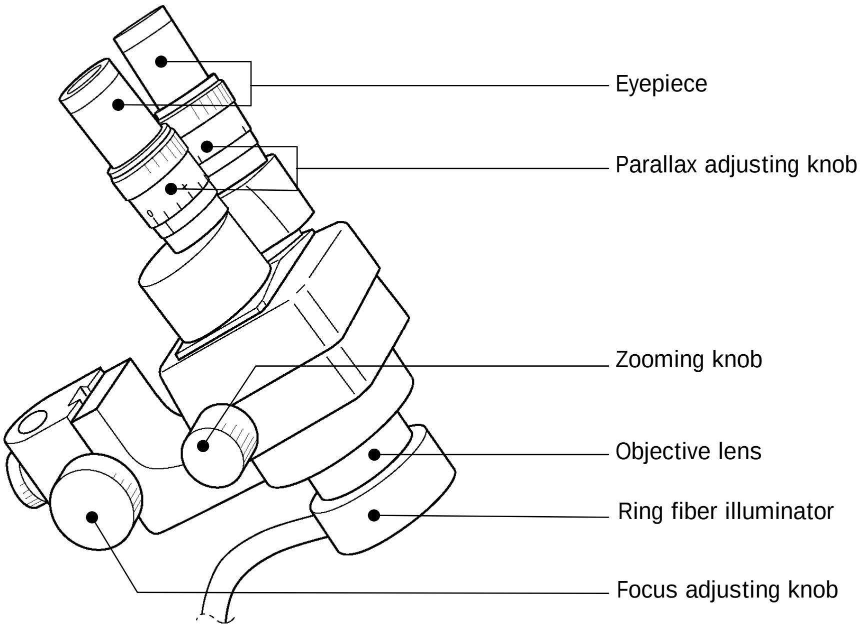



4. Tighten the mirror locking screw to fix the mirror angle.

# 8.4 OPTICAL MICROSCOPE (OPTION)

## 8.4.1 Handling Optical Microscope

It is recommended that the optional optical microscope (TM-24011) be used to adjust the laser-beam focusing position and perform the coarse approaching to the specimen surface. Since parallax is different among individuals, the microscope must be adjusted so as to comply with the parallax of the operator before it is used.




Adjust the microscope according to the following procedure.

1. Turn both the parallax adjusting knobs to 0.
2. Set up the microscope as usual and observe the cantilever or tip with it.
   Then, turn the zooming knob to the maximum magnification and adjust the focus with the focus adjusting knob.
3. Turn the zooming knob to the minimum magnification.
   However, do not turn the focus adjusting knob.
4. Observe the cantilever or tip while closing each eye in turn and adjust the focus by turning the parallax adjusting knob.

After this operation, usually the adjusted focus point does not change even if the zooming knob is turned. If the adjusted focus point still changes, however, try to repeat steps 2 to 4 above a couple of times.

## 8.4.2 Cleaning Lenses of Optical Microscope

The eye lenses and objective lens must be cleaned periodically once or twice a month. Be careful not to attach hand grease to the lenses. For cleaning the lenses, wipe the lenses gently with a piece of soft cloth with an alcohol + ether (70%+30%) solvent soaked in it.

## 8.4.3 Exchanging Lamp

When the filament of the light-source lamp has burnt out, exchange it according to the following procedure. Please ask our service man as to how the replacement lamps can be procured.

**1.** Turn OFF the power to the instrument.

Wait for 30 minutes or longer after the lamp is turned off. Then, exchange the lamp.

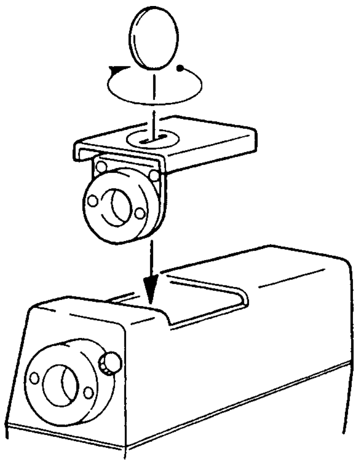
> **WARNING**
>
> **Exchange the lamp more than 30 minutes after it is turned off. Do not touch the lamp immediately after it is turned off. If you do, you might get burnt.**

**2.** Remove the left-side panel of the basic unit using a hexagonal wrench.

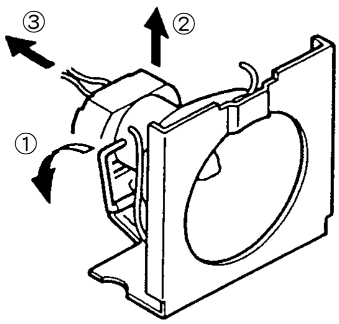
> **WARNING**
>
> **Be careful not to put your hand(s) under the surface plate. Your hand(s) might be pinched.**

**3.** Turn the turntable of the lamp exchange door to “OPEN” using a coin.

**4.** Remove the lamp exchange door.

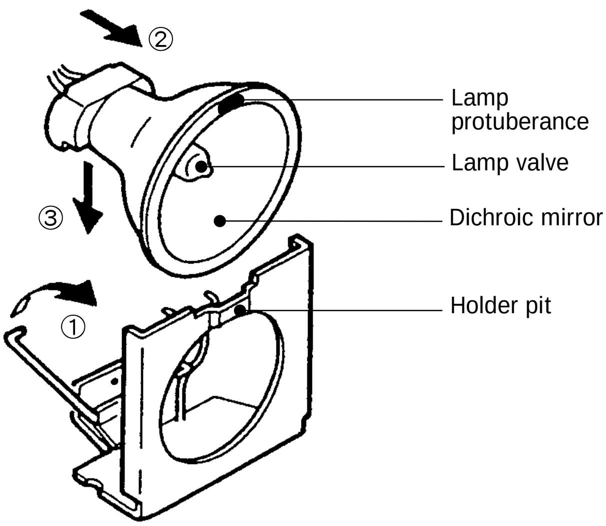


**5.** Throw the lever down, take out the lamp and remove it from the lamp socket.

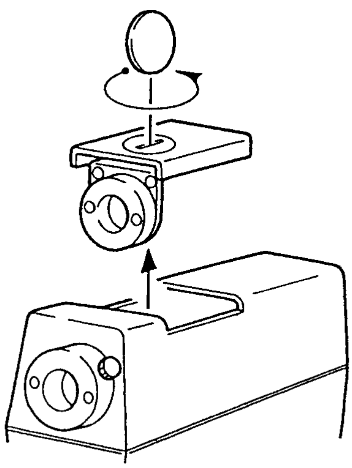



**6.** Set up a new lamp in the lamp socket and insert it into the lamp holder.

Insert the lamp socket deeply into the lamp holder so that the lamp protuberance gets into the pit in the lamp holder.




**7.** Mount the lamp exchange door on the basic unit and turn the turntable to "CLOSE" using a coin.



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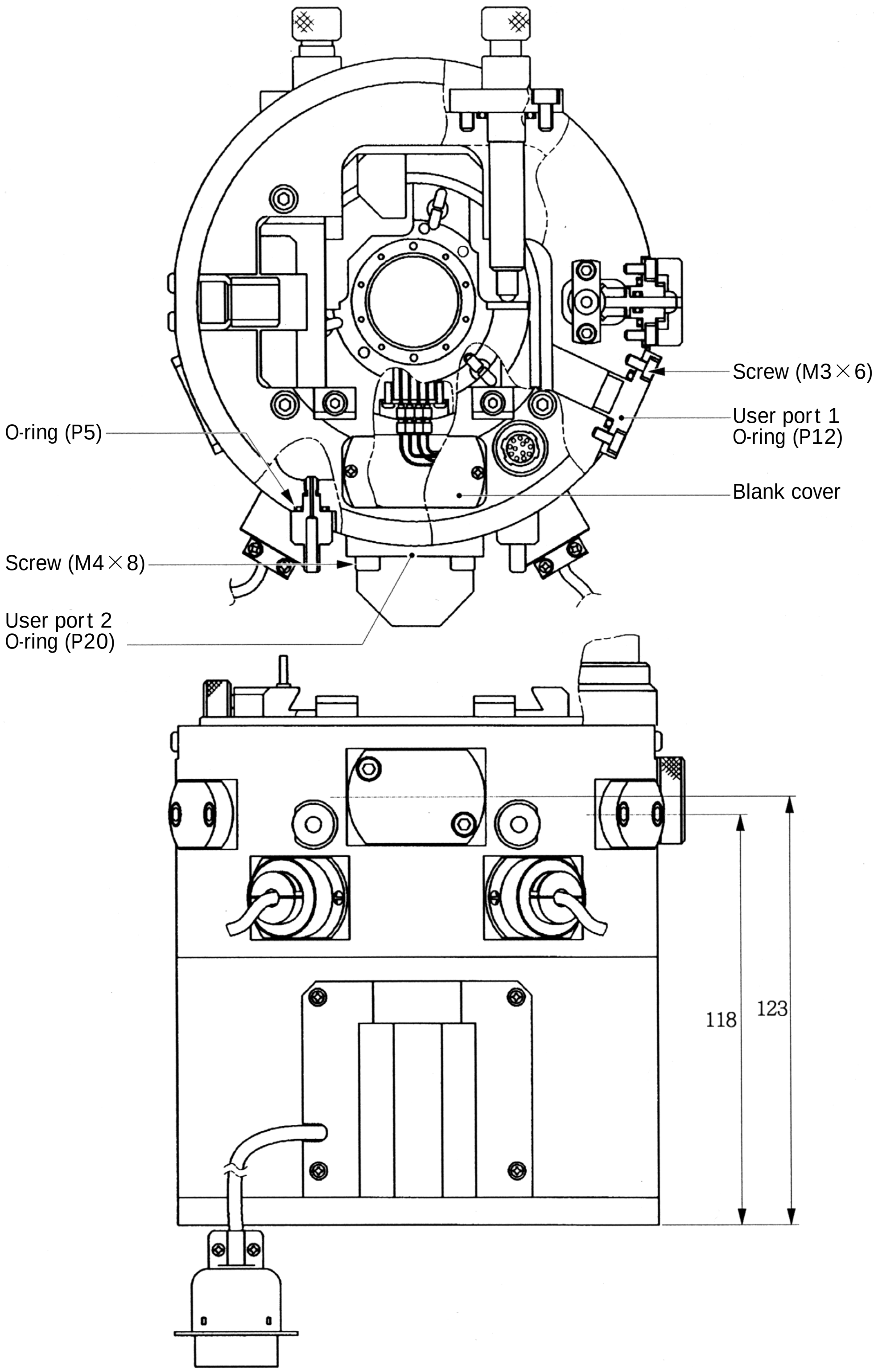
# 9

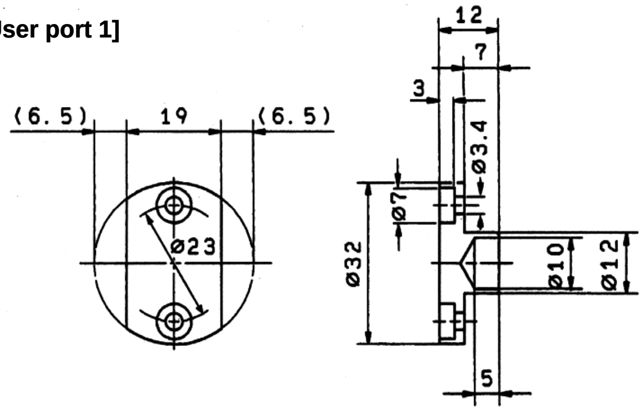
# APPENDIX

## 9.1 POSITIONS OF PORTS

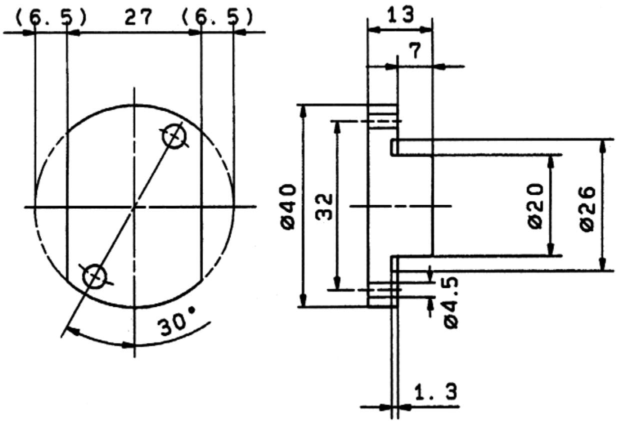


# 9.2 USER PORTS

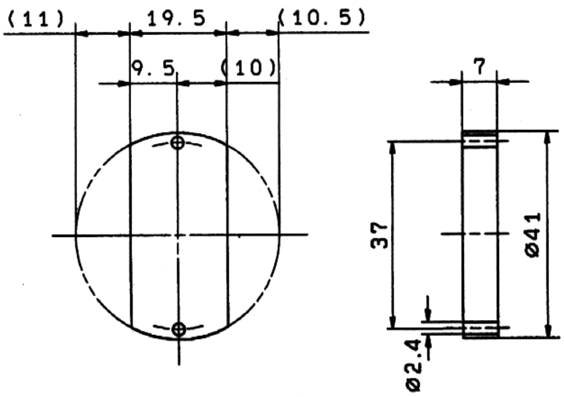
[User port 1]




[User port 2]




[Blank cover]



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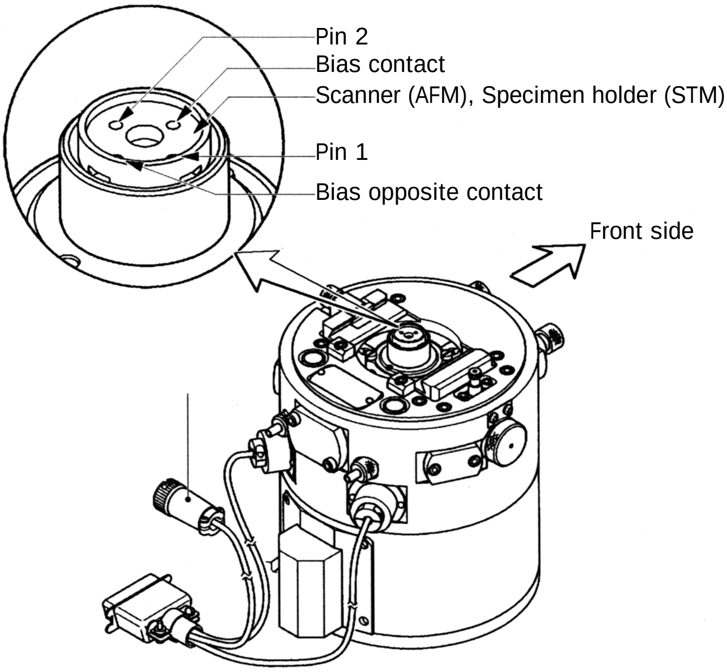
## 9.3 PIN CONNECTION

Heating cable terminal
B+ : Bias contact
B– : Bias opposite contact
H+ : Pin 1
H– : Pin 2



# 9.4 CANTILEVER

The cantilever is a consumable item. Select an appropriate cantilever according to the measurement mode and purpose.

The following are the specifications for the cantilevers manufactured by ORYMPUS, NANOPROBE and MDT. Please consult your local JEOL office for purchasing.

**[OLYMPUS]**

| Mode | Model | Lever shape | Length (μm) | Width (μm) | Thickness (μm) | Tip shape | Tip length (μm) | Spring constant (N/m) | Resonance frequency (kHz) | Metal film coat | Tip diameter | Number of tips |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AC mode | OMCL-AC120TS-1 | Strap | 120 | 30 | 4 | Tetrahedral | 10 | 57 | 300 | Single-side | < 10 | 15 |
| | OMCL-AC120TN-1 | Strap | 120 | 30 | 4 | Tetrahedral | 10 | 57 | 300 | None | < 10 | 15 |
| | OMCL-AC240TS-1 | Strap | 240 | 30 | 4 | Tetrahedral | 10 | 7.2 | 65 | Single-side | < 10 | 15 |
| Contact mode | OMCL-TR400PS-1 | Triangle | 100<br>200 | — | 0.4 | Pyramidal | 2.9 | 0.09<br>0.02 | 40<br>13 | Single-side | < 20 | 35 |
| | OMCL-TR400PS-2 | Triangle | 100<br>200 | — | 0.4 | Pyramidal | 2.9 | 0.09<br>0.02 | 40<br>13 | Single-side | < 20 | 35 |
| | OMCL-TR800PS-1 | Triangle | 100<br>200 | — | 0.8 | Pyramidal | 2.9 | 0.68<br>0.16 | 86<br>27 | Single-side | < 20 | 35 |
| | OMCL-TR800PS-2 | Triangle | 100<br>200 | — | 0.8 | Pyramidal | 2.9 | 0.68<br>0.16 | 86<br>27 | Single-side | < 20 | 35 |
| | OMCL-TR400PB-1 | Triangle | 100<br>200 | — | 0.4 | Pyramidal | 2.9 | 0.10<br>0.025 | 36<br>11 | Double-side | < 20 | 35 |
| | OMCL-TR800PB-1 | Triangle | 100<br>200 | — | 0.8 | Pyramidal | 2.9 | 0.77<br>0.18 | 78<br>25 | Double-side | < 20 | 35 |
| FFM | OMCL-RC800PS-1 | Strap | 100<br>200 | 20<br>40 | 0.8 | Pyramidal | 2.9 | 0.37,0.05<br>0.75,0.09 | 88<br>22 | Single-side | < 20 | 35 |
| | OMCL-RC800PB-1 | Strap | 100<br>200 | 20<br>40 | 0.8 | Pyramidal | 2.9 | 0.37,0.05<br>0.75,0.09 | 88<br>22 | Double-side | < 20 | 35 |

* The above specifications are nominal and are subject to change. The spring constant and resonance frequency were determined by simulation.

## [NANOPROBE]

| Mode | Part name | Thick -ness (µm) | Width (µm) | Length (µm) | Spring constant (N/m) | Reso-nance frequency (kHz) | Tip di-ameter (nm) |
|---|---|---|---|---|---|---|---|
| Contact mode | CONT | 1–3 | 23–28 | 450 | 0.2 | 13 | 15 Guaran-teed value |
| Contact mode | CONTR | 1–3 | 23–28 | 450 | 0.2 | 13 | 15 |
| AC mode (High frequency) | NCH | 3–5 | 23–38 | 125 | 42 | 330 | 15 |
| AC mode (High frequency) | NCHR | 3–5 | 23–38 | 125 | 42 | 330 | 15 |
| AC mode (Low frequency) | NCL | 6–8 | 30–45 | 225 | 48 | 190 | 15 |
| AC mode (Low frequency) | NCLR | 6–8 | 30–45 | 225 | 48 | 190 | 15 |

* Material is N-type silicon single-crystal. Resistivity is 0.01 to 0.025 Ωcm.
* The parts with “R” at the end of the name are aluminum-coated (on the pack side) items. The thickness of the coated film is about 30 nm.
* Number of cantilevers in one package is 16, 50 or 385.
* The nominal value of the tip diameter is 10 nm.

| Mode | Part name | Thick -ness (µm) | Width (µm) | Length (µm) | Spring constant (N/m) | Reso-nance frequency (kHz) | Tip di-ameter (nm) |
|---|---|---|---|---|---|---|---|
| Magnet mode | MFMR | 2–4 | 20–35 | 225 | 2.8 | 75 | 15 (Before bein coated) |

* Magnetic film: Co-Cr-Ta/Random/50 nm thickness

| Parts name | Thick-ness (µm) | Width (µm) | Length (µm) | Spring constant (N/m) | Resonance frequency (kHz) |
|---|---|---|---|---|---|
| EFM sensor *1 | 2–4 | 20–35 | 225 | 28 | 75 |
| SUPER SHARP sensor<br>SSS-NCH<br>SSS-SEIH *2 | 3–5<br>4–6 | 23–38<br>30–35 | 125<br>225 | 42<br>15 | 330<br>130 |
| HIGH ASPECT RATIO sensor *3 | 3–5 | 23–38 | 125 | 42 | 330 |
| DIAMOND coat sensor *4 | 2–4 | 20–35 | 225 | 28 | 75 |

*1 Cr (1st layer) and PtIr5 (2nd layer) coated conductive sensor
*2 A sharp sensor with the tip radius of 2 nm (TYP)
*3 Suitable for the side measurement with the aspect ratio of 1:7 (TYP)
*4 A hard diamond-coated sensor with the resistivity of 0.1 to 0.2Ωcm

**[MDT]**

| Model | Contact or Non-contact | Number of Tips | Coating |
|---|---|---|---|
| NSCS11 | Non-contact | 15 | Nil |
| NSCH11 | Non-contact | 200 | Nil |
| NSCF11 | Non-contact | 400 | Nil |
| NSCS11/“Coating” | Non-contact | 15 | Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni |
| NSCH11/“Coating” | Non-contact | 200 | Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni |
| NSCF11/“Coating” | Non-contact | 400 | Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni4 |
| CSCS11 | Contact | 15 | Nil |
| CSCH11 | Contact | 200 | Nil |
| CSCF11 | Contact | 400 | Nil |
| CSCS11/Si3N4 | Contact | 15 | Si3N4 |
| CSCH11/Si3N4 | Contact | 200 | Si3N4 |
| CSCF11/Si3N4 | Contact | 400 | Si3N4 |
| CSCS11/“Coating” | Contact | 15 | W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni |
| CSCH11/“Coating” | Contact | 200 | W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni |
| CSCF11/“Coating” | Contact | 400 | W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni |
| NSC21 | Non-contact | 15 | Nil |
| NSCH21 | Non-contact | 200 | Nil |
| NSCF21 | Non-contact | 400 | Nil |
| NSC21/“Coating” | Non-contact | 15 | Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni |
| NSCH21/“Coating” | Non-contact | 200 | Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni |
| NSCF21/“Coating” | Non-contact | 400 | Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni4 |
| CSCS21 | Contact | 15 | Nil |
| CSCH21 | Contact | 200 | Nil |
| CSCF21 | Contact | 400 | Nil |
| CSCS21/ Si3N4 | Contact | 15 | Si3N4 |
| CSCH21/ Si3N4 | Contact | 200 | Si3N4 |
| CSCF21/ Si3N4 | Contact | 400 | Si3N4 |
| CSCS21/“Coating” | Contact | 15 | W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni |
| CSCH21/“Coating” | Contact | 200 | W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni |
| CSCF21/“Coating” | Contact | 400 | W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni |
| NSCS21 | Non-contact | 15 | Nil |
| NSCH21 | Non-contact | 200 | Nil |
| NSCF21 | Non-contact | 400 | Nil |
| NSCS21/“Coating” | Contact | 15 | Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni |

| Model | Contact or Non-contact | Number of Tips | Coating |
|---|---|---|---|
| NSCH21/“Coating” | Contact | 200 | Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni |
| NSCF21/“Coating” | Contact | 400 | Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni4 |
| CSCS12 | Contact | 15 | Nil |
| CSCH12 | Contact | 200 | Nil |
| CSCF12 | Contact | 400 | Nil |
| CSCS12/“Coating” | Contact | 15 | Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni |
| CSCH12/“Coating” | Contact | 200 | Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni |
| CSCF12/“Coating” | Contact | 400 | Si3N4,W2C,TiO,TiN,W,Cr,Au,Pt,Co,Ni4 |

# 9.5 SOFTWARE RE-INSTALLATION

## 9.5.1 Setup Procedure

In this chapter, procedure for re-setup of the computer after an abnormal computer stop is described.

### 9.5.1a A/D Board Installation onto the computer

1. Confirm that the jumper switches of the AD board (DT2827) are set in the positions shown in the table below.
   Note: Check the switch position for all switches.
2. Insert the A/D board into the 3rd slot from the front edge.
   Fix the board at the rear top using an M3×12 bolt, a nut and a toothed lock washer.

| Switch | Position | Switch | Position | Switch | Position | Switch | Position |
|---|---|---|---|---|---|---|---|
| W1 | OUT | W11 | OUT | W21 | IN | W31 | OUT |
| W2 | IN | W12 | OUT | W22 | OUT | W32 | IN |
| W3 | OUT | W13 | IN | W23 | IN | W33 | OUT |
| W4 | IN | W14 | IN | W24 | OUT | W34 | IN |
| W5 | OUT | W15 | IN | W25 | IN | W35 | OUT |
| W6 | OUT | W16 | IN | W26 | OUT | W36 | OUT |
| W7 | OUT | W17 | OUT | W27 | IN | W37 | OUT |
| W8 | OUT | W18 | IN | W28 | OUT | W38 | OUT |
| W9 | IN | W19 | IN | W29 | OUT | W39 | IN |
| W10 | IN | W20 | OUT | W30 | OUT | W40 | IN |

### 9.5.1b Connections of Peripheral Devices

◆ Connect the display monitor, keyboard and mouse to the computer.
In this stage, any other peripheral devices than the above are not connected.

### 9.5.1c Setup of the Computer

After starting up Windows98, setup Windows98 and computer as follows:

● **Setup of Windows98**

1. Double click on the ‘Display’ icon in the ‘Control Panel’ window to open the ‘Display Properties’ window.
   Set the items as follows:
   ‘Background’ tag
   Wall paper: None
   ‘Screen Saver’ tag
   Screen Saver: Text
   Wait: 60 minutes
   Setting
   Position: Random

| | |
|---|---|
| Background color: | Black |
| Text: | JEOL Winspem System |
| Speed: | Center |
| Font Text | |
| Font: | Times New Roman |
| Font style: | Italic |
| Size: | 72 |
| Color: | (Default Setting) |
| Effects: | (Default Setting) |
| Scripts: | (Default Setting) |
| ‘Setting’ tag | |
| Color pallet: | High Color (32 bit) |
| Desktop area: | 1280×1024 |
| Font Size: | Large Fonts |

2. After setting the above items, select ‘Apply’.
   The ‘Compatibility Warning’ window will be displayed.
3. Select ‘Restart the computer with the new setting’, and click on ‘OK’.
   The computer will restart with the set conditions.

## ● Setup of hardware

**• Setup of BIOS**

Startup the BIOS setup utility, and check the CPU, memory and VRAM of the computer. Set the sound controller to OFF. Because, the computer (DELL Optiplex GX1) is equipped with an onboard sound controller, but this sound controller interferes with an A/D board (DT2827) in the system.

1. Restart the computer.
2. In the first displayed screen (DELL logo mark), depress the Ctrl+Alt+Enter (or Ctrl+Alt+Delete) keys to startup the BIOS setup utility.
3. Check whether the CPU, memory and VRAM displayed on the bottom right of the first page of the BIOS setup utility are the followings:

| | |
|---|---|
| CPU: | PentiumIII Processor 450 MHz |
| System Memory: | 128 MB ECC SDRSAM |
| Video Memory: | 8 MB SGRAM |

4. Switchover ‘Sound’ in ‘Integrated Device’ on the second page from ‘On’ to ‘Off’.
5. Depress the ESC key to complete the setup utility.
   Windows98 automatically starts up after completion of setup utility.

**• Reservation of IRQ channel**

When installing other boards (SCSI board, etc.) than the A/D board, system interference between those boards and the A/D board may occurs. Inorder to avoid this interference, the IRQ channel (system call channel for interrupt control for devices) must be reserved for the A/D board.

1. Double click on the ‘System’ icon in the ‘Control Panel’ window of Windows98 to open the ‘System Properties’ window.
2. Select the ‘Device Manager’ tag in the ‘System Properties’ window; click on the ‘Properties’ to open the ‘Computer Properties’ window.
3. Select the ‘Reserve Resources’ tag in the ‘Computer Properties’ window.

4. Select the ‘Interrupt request (IRQ)’ checkbox; click on ‘Add’.
5. The ‘Edit Resource Setting’ window will open. Enter 10 in the ‘Value’ box and clicj¥k on the ‘OK’ button (reservation of IRQ 10).
6. Click on ‘OK’. All windows will close.

### 9.5.1d Installation of DT2827 Related Software

Install the attached device driver (DT2821Device Driver for Microsoft Windows 3.1 and Windows95) for Windows.

- **Installation of device driver**

1. Double click on the ‘Add New Hardware’ icon in the ‘Control Panel’ window to display ‘Add New Hardware Wizard’; select ‘Next’.
2. Screen will change to ‘Plug & Play Device’; select ‘Next’ to continue.
3. Answer ‘No’ for the question ‘Do you want Windows to search for your new hardware ?’; select ‘Next’.
4. Select ‘Other device’ for the kind of device; select ‘Next’.
5. A window listing hardware manufacturers and model names will be displayed. Select ‘Have Disk’.
6. The ‘Install From Disk’ window will be displayed. Then, insert the CD-ROM and select ‘Browse’.
7. The ‘Open’ window will be displayed. Set ‘Drive’ to f:CD-ROM drive.
8. Set ‘Folder’ to driver–>win95 and select ‘OK’.
9. Select ‘Install From Disk’ and ‘OK’.
10. After the model name ‘DT-Open Layers DT2821 Series’ is displayed, select ‘Next’.
11. Select ‘Done’ to install the driver.

When the installation has been completed, window ia automatically closed.

- **Setting of device driver**

1. Double click on ‘Multimedia’ in ‘Control Panel’ to open the ‘Multimedia Properties’ window.
2. Select the ‘Advanced’ tag in the ‘Multimedia Properties’ window.
3. The multimedia device list will be displayed. Click on ‘Media Control Devices’; then double click on ‘DT-Open Layers DT2821 Series Device Driver’.
4. The ‘DT-Open Layers DT2821 Series Device Driver Properties’ window will be displayed.
   Check whether ‘Use this media control device’ is selected in the ‘General’ tag.
5. Select ‘Setting’.
6. The ‘‘DT-Open Layers DT2821 Series Device Driver Properties’’ will be displayed. Select ‘New’ and set the board.
7. The ‘DT2821 Series Installation’ window will be displayed. Enter as the followings:

   Board Address: 0×240
   Board Name: DT2827 (If DT2821 is displayed, change it to DT2827.)
   Then select ‘Add’. A verification window will be displayed; select ‘Yes’.

8. Set the items in the 'DT-Open Layers DT2821 Series Device Driver Configuration' window as follows:

| | |
|---|---|
| Board Name: | DT2827 |
| General Configuration | |
| Model: | DT2827 |
| IRQ: | 10 |
| DMA Ch1: | 5 |
| DMA Ch2: | 6 |
| A/D Configuration | |
| Channel: | DI |
| Range: | +/–10 V |
| Output: | twos Complement |
| D/A Configuration | |
| DAC1: | +/–10 V |

9. After completion of setting, click on 'Update' to store the setting.
10. Click on 'Close' to end the device driver setting.
11. Return to 'DT-Open Layers DT2821 Series Device Driver Properties' window; click on 'OK'.
12. The screen informs that Windows must be restarted, but do not perform restart and install SDK successively.
13. Terminate the restart window by entering 'OK'.
14. Terminate the 'Multimedia Properties' window by selecting 'OK'.

- **Installation of the SDK file**

Install the SDK file using the exclusive installer.

1. Open the 'Sdk' folder of the CD-ROM; then setup by double clicking 'Setup'.
2. A verification window will be displayed; select 'Continue'.
3. Select 'Install' staying in the standard setting.
4. After completion of installation, restart Windows according to message displayed.

### 9.5.1e Installation of Winspm Software

After the above setting, install the Winspm Software.

- **Installation of the Winspm software**

1. First, change the file display setting so that the system file such as the dll file can be displayed.
2. Select 'Option' in the 'View' menu of the 'My Computer' window.
3. The 'Option' window will be displayed. Select the 'View' tag.
4. Set 'Hidden files of these types' in the items of 'Hidden files' to 'Show all files'.
5. Delete the check mark of 'Hide MS-DOS file extensions for file types that are registered'.
6. After completion of setting, click on 'Apply' to store the setting; and click on 'OK' to close the window.
7. Double click on (C:) in 'My Computer' to open the window.
8. Create a new folder in C: drive and name it 'Winspm'.
9. Copy all contents in the 'Executable' folder in the CD-ROM to this directory (Executing file).

10. Also copy the contents in the ‘English’ folder to this folder (online help file).
11. Check the properties of all installed file, and if ‘Attribute’ and ‘Read-only’ are checked, delete them.

### ● Installation of Winspm system file

1. Open the ‘Windows’ folder on the C: drive.
2. Since the contents of the folder is not displayed when ‘Windows’ was opened, click on ‘View’ in the properties window to display them.
3. Copy the DLL file for the system in the ‘Dlls’ folder of the CD-ROM to the ‘System’ folder of ‘Windows’.
4. “Would you like to replace the existing file with this one ?’ is displayed.
5. Select ‘Yes to All’.

### ● Setup of Winspem software

Define the Winspm software as the startup file with the following procedure:

1. Click on the ‘Start’ button at the bottom left corner of the screen with the right mouse button; then click on ‘Open’ to open the ‘Start Menu’ window.
2. Open the ‘Start Up’ folder in the ‘Program’ folder.
3. Open the ‘Winspm’ folder in which the Winspm software is installed.
4. Create a shortcut of ‘Winspm32.exe’ in Winspm in the ‘Start Up’ folder.
5. Modify the name of created shortcut file to ‘Winspm32’.
6. Single click on the ‘Winspm32’ icon with the right mouse button to open the option menu: then select ‘Properties’ in the menu.
7. Select ‘Short Cut’ tag in displayed ‘Properties’ window; and enter the following string in ‘Target’:

   C:¥winspm¥WINSPM32.EXE/F450/nofg/lineaverage
8. Click on ‘Apply’ to store the setting: then click on ‘OK’ to end.

   Notes: 1. Three-digit numeric /Fxxx enters the CPU clock frequency.
   2. /nofg means no frame memory.
   3. /lineaverage means enabling the line average correction function of measurement image.
9. Close all windows; then restart the computer.

   As Winspm is defined as the startup file, Winspm is automatically started up when restarting.
10. To startup the software, enter ‘Default’ in ‘User name’ in the ‘WINSPM Login’ window; then click on the ‘OK’ button without entering in ‘Password’.

    Confirm that the software starts up without error.

    Notes: 1. For the scanner calibration values, stage values, etc., enter values after logging in to Winspm with default; then store the set values with ‘Store Configuration’.
    2. For the next new user, this values become the default values.

## 9.6 SCANNER SENSITIVITY

The scanner sensitivities are calibrated with the software. For later use, record the sensitivities shown in the table below on your notebook.

| | |
|---|---|
| Scanner1 | X=____$Vx^2$+____Vx |
| [Standard] | Y=____$Vy^2$+____Vy |
| | Z=____Vz |
| Scanner2 | X=____$Vx^2$+____Vx |
| [ ] | Y=____$Vy^2$+____Vy |
| | Z=____Vz |
| Scanner3 | X=____$Vx^2$+____Vx |
| [ ] | Y=____$Vy^2$+____Vy |
| | Z=____Vz |
| Scanner4 | X=____$Vx^2$+____Vx |
| [ ] | Y=____$Vy^2$+____Vy |
| | Z=____Vz |
| Scanner5 | |
| [ ] | X=____$Vx^2$+____Vx |
| | Y=____$Vy^2$+____Vy |
| | Z=____Vz |
| Scanner6 | |
| [ ] | X=____$Vx^2$+____Vx |
| | Y=____$Vy^2$+____Vy |
| | Z=____Vz |

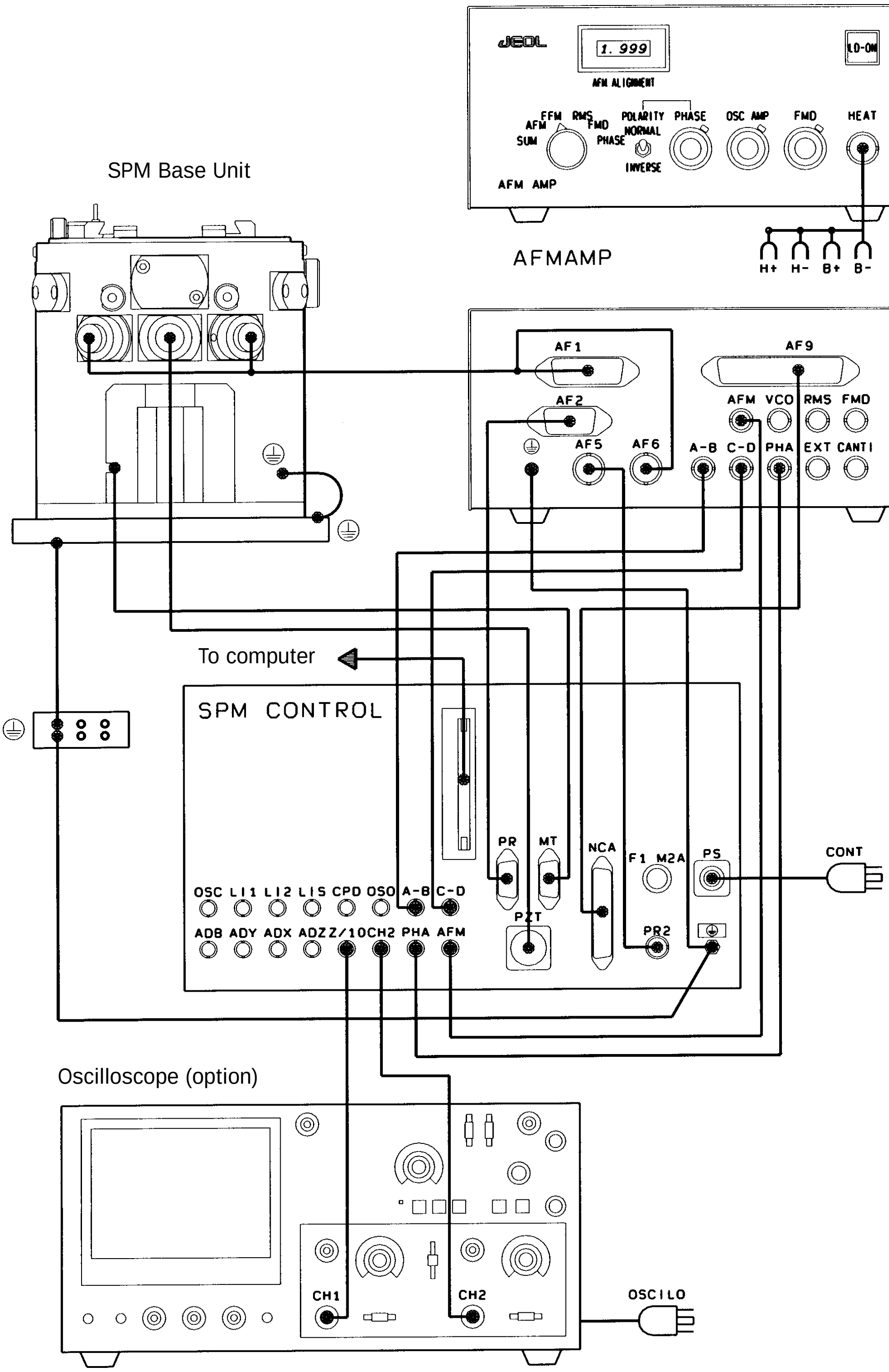
### [Coarse Stage]

The positions of the motor drive are also calibrated with the software. For later use, record the positions shown below.

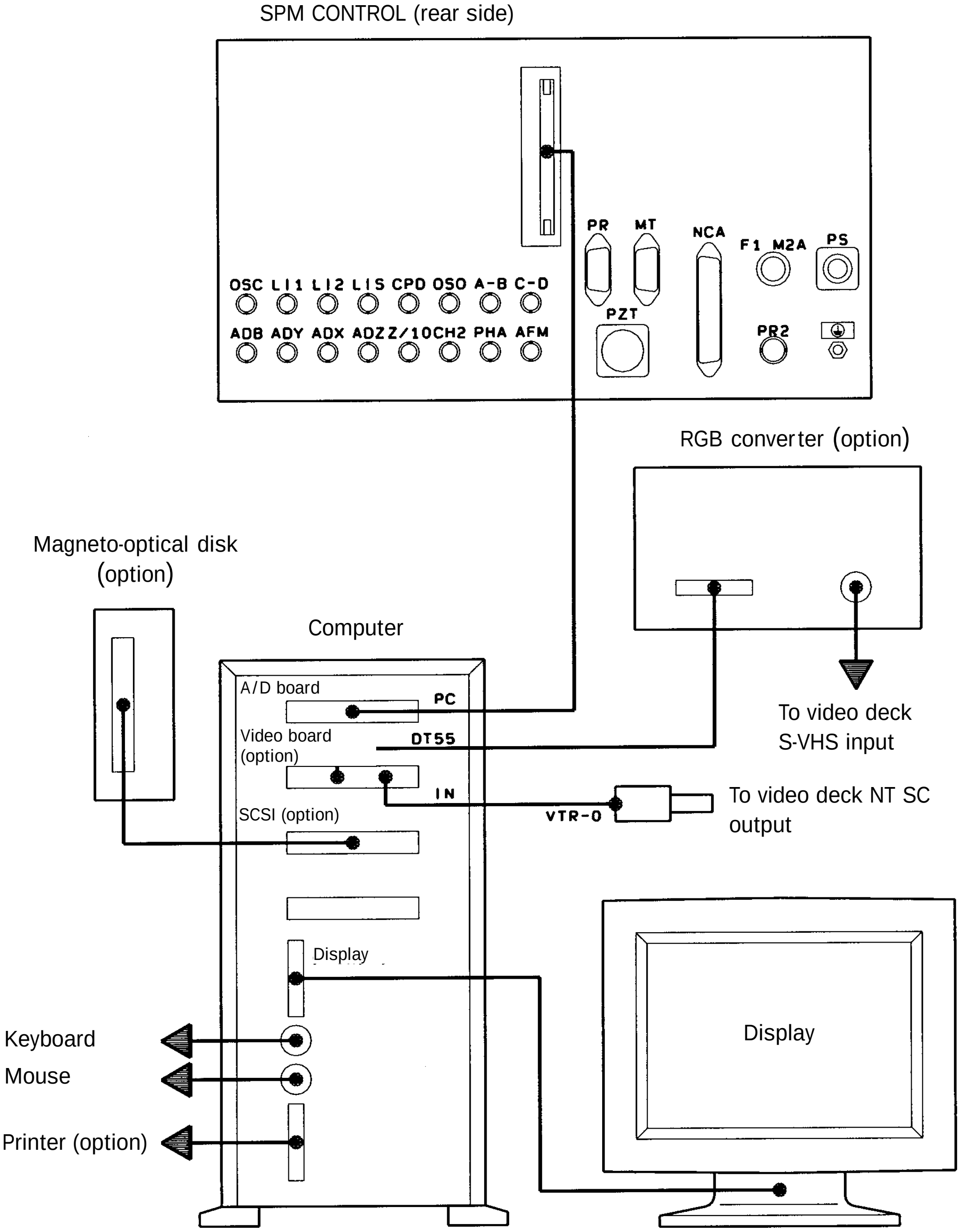
Z In_____V Out_____V Range_____mm

# 9.7 CABLE CONNECTION

## 9.7.1 Cable Connection between Basic Unit and Controller



### 9.7.2 Cable Connection between Computer and Controller




Note: Regarding the details of the cable connections for keyboard, mouse, printer and display, refer to the instruction manual for the computer*.

* Cable connections on the computer rear side may be different according to the types of computers.

## 9.8 TOOLS FOR MAINTENENCE

The following tools for maintenance are provided to the JSPM-4200.

| Item | Quantity |
|---|---|
| Tool box | 1 |
| Precise screwdriver set | 1 |
| L-type Allen wrench | 1 |
| Tweezers | 1 |
| Single-ended wrench | 1 |
| Open-ended adjustable wrench | 1 |
| Philips screwdriver | 1 |
| Flat-bladed screwdriver | 1 |