



## Veeco Dimension 3100/5000 Procedure Manual



*Illustration 1: Dimension 3100*



*Illustration 2: Dimension 5000*

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## **1.0 Scope**

This document establishes the procedures for the use of the Veeco Dimension SPM systems (3100 & 5000) that are available for use in the Materials Science & Engineering building, room 0071.

## **2.0 Applicable Documents**

Dimension 3100 Logbook

Dimension 5000 Logbook

## **3.0 Materials and Equipment**

Veeco Dimension 3100

Veeco Dimension 5000

Cantilever Holder x2

Cantilever Holder Stand x2

Tweezers

Gloves, cleanroom

Cleanroom wipes

## **4.0 General**

**4.1** There are two standard modes of operation for both of the Dimension tools: Contact Mode and Tapping Mode. If a user needs to use an advanced mode of operation, please contact staff in order to receive the proper training and SOP.

**4.2** Handle samples and probes going into the system with gloves.

**4.3** Load only clean substrates onto the stage.

## **5.0 Operation**

The Operation section of this SOP contains sections from the User's Manual for the Dimension 3100. All of these sections are applicable to both the Dimension 3100 and the Dimension 5000.

The sections are as follows:

### **Chaper 2 - Safety**

- 2.1 Safety Requirements
- 2.2 Safety Precautions
- 2.3 Ergonomics
- 2.9.1 Laser Warning Labels

### **Chapter 5 – Stage System**

- 5.1 Mounting of Samples
- 5.2 Stage Menu Commands

### **Chapter 7 – Head, Probe, & Sample Preparation**

- 7.1 System Information
- 7.2 Basic AFM Operation
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- 8.1 Basic Contact Mode AFM Operation
- 8.2 Advanced Atomic Force Operation
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### **Chapter 9 – TappingMode AFM**

- 9.1 Principles of TappingMode
- 9.2 Basic TappingMode AFM Operation
- 9.3 Withdraw the Tip
- 9.4 Advanced TappingMode Operation
- 9.5 Troubleshooting

## 2.1 Safety Requirements


Figure 2.1a Safety Symbols Key


Symbol	Definition
	This symbol identifies conditions or practices that could result in damage to the equipment or other property, and in extreme cases, possible personal injury.
	Ce symbole indique des conditions d'emploi ou des actions pouvant endommager les équipements ou accessoires, et qui, dans les cas extrêmes, peuvent conduire à des dommages corporels.
	Dieses Symbol beschreibt Zustände oder Handlungen die das Gerät oder andere Gegenstände beschädigen können und in Extremfällen zu Verletzungen führen können.
	This symbol identifies conditions or practices that involve potential electric shock hazard.
	Ce symbole indique des conditions d'emploi ou des actions comportant un risque de choc électrique.
	Dieses Symbol beschreibt Zustände oder Handlungen, die einen elektrischen Schock verursachen können.
	This symbol identifies a laser hazard. Exposure could result in eye damage.
	Ce symbole indique un risque lié à un laser. Une exposition à ce laser peut entraîner des blessures aux yeux.
	Dieses Symbol bedeutet "Gefährliche Laserstrahlung". Laserstrahlung kann zu Beschädigung der Augen führen.
	This symbol identifies a thermal hazard. Touching could result in skin burns upon contact.
	Ce symbole indique un risque lié à de hautes températures. Un contact peut entraîner des brûlures de la peau.
	Dieses Symbol bedeutet "Heiße Oberfläche". Berührung kann zu Hautverbrennungen führen.
	This symbol identifies a mechanical crushing hazard. Moving parts can result in serious injury to hands or fingers.
	Ce symbole indique un risque d'écrasement. Déplacer des pièces de l'appareil peut entraîner des blessures sévères des mains ou des doigts.
	Dieses Zeichen bedeutet "Quetschungsgefahr durch mechanisch bewegte Teile". Bewegliche Teile können zu erheblichen Quetschverletzungen von Fingern oder Händen führen.
	This symbol identifies a heavy object. Improper lifting can cause muscle strain or back injury.
	Ce symbole indique un objet lourd. Soulever cet objet de façon incorrecte peut entraîner des froissements musculaires ou des problèmes de dos.
	Dieses Symbol identifiziert ein schweres Objekt. Falsches Anheben kann Muskelzerrungen und Rückenverletzungen verursachen.
	This symbol identifies a corrosive material hazard. Corrosive material can cause serious damage to the equipment.
	Ce symbole indique un risque de la matière corrosive. La matière corrosive peut causer des dommages sérieux au matériel.
	Dieses Symbol bedeutet "Gefahr durch Korrosive Materialien". Korrosive Materialien können erhebliche Schäden am Gerät oder anderen Gegenständen verursachen.

## 2.2 Safety Precautions

Because the Dimension 3100 SPM features independently motorized components, it is crucial that operators become familiar with precautions to avoid injury to themselves and/or damage to samples. This section of the manual should be read by ALL persons working with or around the system.

### 2.2.1 General Operator Safety

	<b>WARNING:</b>	Service and adjustments should be performed only by qualified personnel who are aware of the hazards involved.
	<b>AVERTISSEMENT:</b>	Tout entretien ou réparation doit être effectué par des personnes qualifiées et conscientes des dangers qui peuvent y être associés.
	<b>WARNUNG:</b>	Service- und Einstellarbeiten sollten nur von qualifizierten Personen, die sich der auftretenden Gefahren bewußt sind, durchgeführt werden.

	<b>WARNING:</b>	Follow company and government safety regulations. Keep unauthorized personnel out of the area when working on equipment.
	<b>AVERTISSEMENT:</b>	Il est impératif de suivre les prérogatives imposées tant au niveau gouvernemental qu'au niveau des entreprises. Les personnes non autorisées ne peuvent rester près du système lorsque celui-ci fonctionne.
	<b>WARNUNG:</b>	Befolgen Sie die gesetzlichen Sicherheitsbestimmungen Ihres Landes. Halten Sie nicht autorisierte Personen während des Betriebs vom Gerät fern.



- CAUTION:** Please contact Veeco before attempting to move the Dimension 3100 SPM system.
- ATTENTION:** Il est impératif de contacter Veeco avant de déplacer le Dimension 3100 SPM.
- VORSICHT:** Bitte kontaktieren Sie Veeco bevor Sie das Dimension 3100 SPM System transportieren.



- WARNING:** Voltages supplied to and within certain areas of the system are potentially dangerous and can cause injury to personnel. Power-down all components and unplug from power sources before doing **any** electrical servicing. (Veeco service personnel, *only*).
- AVERTISSEMENT:** Les tensions utilisées dans le système sont potentiellement dangereuses et peuvent blesser les utilisateurs. Avant toute intervention électrique, ne pas oublier de débrancher le système. (Réservé au personnel de Veeco, seulement.)
- WARNUNG:** Die elektrischen Spannungen, die dem System zugeführt werden, sowie Spannungen im System selbst sind potentiell gefährlich und können zu Verletzungen von Personen führen. Bevor elektrische Servicearbeiten irgendwelcher Art durchgeführt werden ist das System auszuschalten und vom Netz zu trennen. (Nur Veeco Personal.)



- WARNING:** Never alter pneumatics or wiring on the Dimension 3100 SPM.
- AVERTISSEMENT:** Ne jamais toucher les cables et l'installation pneumatique sur le boîtier acoustique du Dimension 3100.
- WARNUNG:** Ändern Sie niemals etwas am pneumatischen System oder der Verdrahtung der Schallschutzhaube.



**WARNING:** The Dimension 3100 SPM contains a diode laser with an output of less than 1.0mW at 670nm.

**AVERTISSEMENT:** Le microscope "Dimension 3100 SPM" est équipé d'une diode laser dont la puissance de sortie est inférieure à 1mW à 670nm.

**WARNUNG:** Das Dimension 3100 SPM ist mit einem Halbleiterlaser ausgerüstet, dessen Ausgangsleistung kleiner ist als 1.0mW bei 670nm.



**WARNING:** Do not use acetone to clean the Dimension 3100 SPM.

**AVERTISSEMENT:** Ne pas utiliser d'acétone pour nettoyer le Dimension 3100 SPM.

**WARNUNG:** Bitte verwenden sie kein Azeton um das Dimension 3100 SPM zu reinigen.





**WARNING:** The Dimension 3100 SPM uses a halogen lamp to illuminate samples. Exposure to non-ionizing radiation from this lamp is well within the current exposure guidelines published by the American Conference of Governmental Industrial Hygienists (ACGIH). Typical IR exposure to the user from the sample illuminator is less than 3 mW/cm<sup>2</sup>. UV radiation is not detectable.

**AVERTISSEMENT:** Le microscope Dimension 3100 SPM est équipé d'une lampe halogène pour illuminer les échantillons. L'exposition aux radiations non-ionisantes de cette lampe est très inférieure aux recommandations publiées par "l' American Conference of Governmental Industrial Hygienists (ACGIH)". Les radiations IR dues à cette lampe sont typiquement inférieures à 3 mW/cm<sup>2</sup>. Les radiations UV ne sont pas détectables.

**WARNUNG:** Das Dimension 3100 SPM System ist mit einer Halogenlampe ausgestattet, um die Probe zu beleuchten. Die von dieser Lampe ausgehende Strahlenbelastung der nichtionisierenden Strahlung liegt weit unter den publizierten Richtwerten der American Conference of Governmental Industrial Hygienists (ACGIH). Die fuer den Benutzer typische IR Strahlenbelastung der Beleuchtungseinheit ist kleiner als 3 mW/cm<sup>2</sup>. UV Strahlung ist nicht nachweisbar.

## 2.2.2 Microscope

To avoid operator injury and equipment damage, observe the following cautions regarding the Dimension 3100 microscope.



**CAUTION:** If you use the equipment in a manner not specified by the manufacturer, you can impair the protection provided by the instrument.



**CAUTION:** Stage microscopes feature an automated X-Y stage and Z-axis capable of programmed movement. The movements of all axes are slow, but are capable of exerting high forces. A hand caught in the stage of a Dimension 3100 SPM could be injured severely.

**ATTENTION:** La platine des microscopes est automatisée dans les directions X, Y et Z, et est programmable. Les mouvements selon ces 3 axes sont lents, but peuvent exercer des forces importantes. La main d'un utilisateur pourrait être sévèrement endommagée si elle se trouvait coincée par cette platine.

**VORSICHT:** Mikroskope mit automatisiertem Probenstisch können programmierte Bewegungen in X-, Y- und Z-Richtung durchführen. Die Bewegungen in allen drei Richtungen sind langsam, können aber sehr große Kräfte ausüben. Eine Hand, die vom Probenstisch des Dimension 3100 SPMs erfaßt wird, kann leicht ernsthaft verletzt werden.



**WARNING:** The internal electronics of the microscope, controllers, and peripheral equipment feature high-voltage components. Because there are no user-serviceable parts, do not attempt system repairs. Disconnect faulty components and ship them to Veeco for repair or replacement.

**AVERTISSEMENT:** Les parties électroniques du microscope, du contrôleur et des équipements périphériques comportent des équipements fonctionnant avec de hauts voltages. Ne pas essayer d'effectuer de réparations, aucune de ces parties n'étant conçue pour être réparée par l'utilisateur. Déconnecter les équipements défectueux et les envoyer à Digital Instruments/Veeco pour réparation.

**WARNUNG:** Die Elektronik des Mikroskops selbst, der Steuergeräte und der externen Geräte ist mit Hochspannungselementen ausgestattet. Diese Elemente dürfen nur von geschultem Personal gewartet werden. Versuchen Sie nicht, das System selbst zu reparieren. Trennen Sie fehlerhafte Komponenten vom System, und schicken sie diese zur Reparatur oder zum Umtausch zu Veeco.



**WARNING:** Do not attempt repairs on electrical components. If it is necessary to enter the electrical chassis for any reason (e.g., to replace a computer card), power-down the entire system and disconnect it from its power source.

**AVERTISSEMENT:** Ne pas essayer de réparer les parties électroniques. Si il est nécessaire d'accéder au boîtier électronique (pour remplacer une carte dans l'ordinateur par exemple), éteindre tout le système et le déconnecter.

**WARNUNG:** Versuchen Sie nicht, elektrische Komponenten selbst zu reparieren. Falls es aus irgend einem Grund notwendig sein sollte, ein Gehäuse mit elektrischen Bauteilen zu öffnen (z.B., um eine Computer-Karte auszutauschen), schalten Sie das gesamte System ab, und trennen Sie es von der Spannungsquelle.





**CAUTION:** Avoid spilling fluids onto the microscope stage or into electrical assemblies, particularly the SPM head. If it is necessary to use fluids, apply only small amounts as needed.

**ATTENTION:** Eviter d'éclabousser la platine du microscope et les assemblages électriques, en particulier la tête du microscope. Si il est nécessaire d'utiliser des liquides, ne les employer qu'en faibles quantités.

**VORSICHT:** Vermeiden Sie es, Flüssigkeiten auf dem Probenstisch oder über elektronische Bauteile, insbesondere den Mikroskopkopf, zu verschütten. Wenn es notwendig ist, Flüssigkeiten zu verwenden, benutzen Sie dem Bedarf entsprechend nur geringe Mengen.

### 2.2.3 Sample Safeguards

	<b>CAUTION:</b>	<b>Do not</b> change samples in the middle of operation. Verify that the stage is clear of tools, objects, and debris at all times. Use alcohol wipes periodically to keep the stage clean of dust. Dispose of wipes in an appropriately labelled solvent-contaminated waste container.
	<b>ATTENTION:</b>	<b>Ne pas</b> changer d'échantillon en cours d'utilisation. Vérifier que la platine n'est pas encombrée, par des outils par exemple. Employer des tampons d'alcool régulièrement pour dépolssiérer la platine.
	<b>VORSICHT:</b>	Tauschen Sie <b>keine</b> Proben aus, während sich das System im Betrieb befindet. Der Probenstisch sollte von Werkzeug, anderen Objekten und Überresten ständig freigehalten werden. Benutzen Sie ein mit Alkohol getränktes Tuch, um den Probenstisch regelmäßig von Staub zu reinigen.

	<b>CAUTION:</b>	All interlocks are provided to ensure operator and sample safety. <b>Do not</b> attempt to bypass interlocks.
	<b>ATTENTION:</b>	Tous les intelocks sont fournis pour assurer toute sécurité à l'utilisateur. <b>Ne pas</b> essayer de ne pas les employer.
	<b>VORSICHT:</b>	Alle Sperrvorrichtungen des Systems sind dazu vorgesehen, Personal und Probe zu schützen. Versuchen Sie <b>nicht</b> , Sperrvorrichtungen zu umgehen.

## 2.3 Ergonomics

The Dimension 3100 SPM design promotes compatibility in the integration of user personnel and equipment within a semiconductor manufacturing environment. Specifically, the ergonomics of the Dimension 3100 SPM design prevent personal injury, equipment damage, and minimizes procedural errors.

## 2.9.1 Laser Warning Labels

### Laser Explanatory Label

The **Laser Explanatory Label** (see [Figure 2.9a](#)) indicates that the area to which the label is affixed is affected by a laser. The Laser Explanatory Label is affixed on the Dimension SPM head.

**Figure 2.9a** Laser Explanatory Label



### Laser Warning Label

The **Laser Warning Label** (see [Figure 2.9b](#)) indicates that the area to which the label is affixed is affected by a laser. The Laser Warning Label is affixed on the Dimension SPM head.

**Figure 2.9b** Laser Warning Label



### Noninterlocked Protective Housing Label

The **Noninterlocked Protective Housing Label** (see [Figure 2.9c](#)) indicates that the area to which the label is affixed is affected by a laser. The Noninterlocked Protective Housing Label is affixed to the manual access door.

**Figure 2.9c** Noninterlocked Protective Housing Label



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# Chapter 5 Stage System

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The Dimension 3100 Scanning Probe Microscope (SPM) features a large sample stage capable of positioning large samples such as silicon wafers and computer hard drive media, as well as small samples. The X-Y stage consists of a pair of stacked, perpendicular slides and uses an open loop (unencoded) architecture with stepper motors to drive the stage to user-specified coordinates.

This chapter details procedures for mounting samples and dedicated stage menu software commands. Specifically, this chapter discusses the following:

- **Mounting of Samples:** [Section 5.1](#)
  - **Vacuum Chucks:** [Section 5.1.1](#)
  - **Magnetic Pucks:** [Section 5.1.2](#)
  - **Axis Orientation—Motorized X-Y Stages:** [Section 5.1.3](#)
- **Stage Menu Commands:** [Section 5.2](#)
  - **Load New Sample:** [Section 5.2.1](#)
  - **Locate Tip:** [Section 5.2.2](#)
  - **Focus Surface:** [Section 5.2.3](#)
  - **Move To (X,Y):** [Section 5.2.4](#)
  - **Set Reference:** [Section 5.2.5](#)
  - **Programmed Move:** [Section 5.2.6](#)
  - **Initialize:** [Section 5.2.7](#)
  - **SPM Parameters:** [Section 5.2.8](#)

## 5.1 Mounting of Samples

There are two methods widely used for mounting samples: vacuum chucks and magnetic pucks. Regardless of the method used, verify that samples are mounted flat and parallel to the stage. This is especially important for larger samples inspected over more than one site. Grossly tilted samples may require raising the head higher whenever the sample is indexed, increasing cycle time and the risk of probe-sample collision. Similarly, large numbers of identical samples should be mounted the same way whenever possible to allow use of the same settings between samples.

### 5.1.1 Vacuum Chucks

Stages are equipped with vacuum chucks which are often employed for securing samples.



**CAUTION:**

Operators should be cautious when handling larger samples with the vacuum chuck — an 8-inch wafer held using 5 psi vacuum sustains a loading of 250 lbs.



**CAUTION:**

If debris is trapped between the stage and wafer, the wafer may become scratched or broken. Keep the stage clean at all times using isopropyl alcohol. Dispose of wipes in an appropriately labelled solvent-contaminated waste container. When cleaning dust from the stage area, use a vacuum cleaner with a soft brush. **DO NOT** clean stages using compressed air.

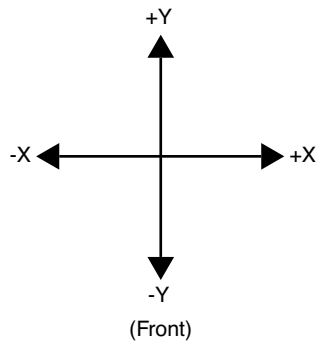
### 5.1.2 Magnetic Pucks

Samples may also be secured to the stage using magnetic pucks. This system allows for easy mounting and removal of small samples. For detailed mounting instructions, see [Chapter 7](#).

### 5.1.3 Axis Orientation—Motorized X-Y Stages

When viewing the Dimension 3100 SPM from the front, stage movements are defined over two axes of motion: X (left-right), and Y (front-back). For X-axis movements, lesser (decreasing) coordinates are located to the left. For Y-axis movements, positive (increasing) coordinates are located toward the rear of the machine, decreasing values are located forward (see [Figure 5.1a](#)).

**Figure 5.1a** Stage X-Y Axis Orientation






## 5.2 Stage Menu Commands

Important stage menu commands are discussed in detail in the following sections:

- **Load New Sample:** [Section 5.2.1](#)
- **Locate Tip:** [Section 5.2.2](#)
- **Focus Surface:** [Section 5.2.3](#)
- **Move To (X,Y):** [Section 5.2.4](#)
- **Set Reference:** [Section 5.2.5](#)
- **Programmed Move:** [Section 5.2.6](#)
- **Initialize:** [Section 5.2.7](#)
- **SPM Parameters:** [Section 5.2.8](#)

### 5.2.1 Load New Sample

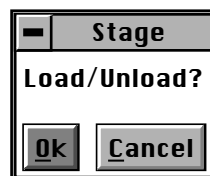
	<b>CAUTION:</b> Do not move the stage while the microscope is scanning.
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Stage software is designed to function between vertical movements of the head. Functions such as **Load New Sample** first lift the head's probe from the sample surface, then index the stage to a preprogrammed location (usually front-center) where samples may be rapidly reloaded.

To load or unload a sample from the stage using the **Load New Sample** function, complete the following:

1. Select **Load New Sample** from the **Stage** pop-down menu. The screen displays a dialog box (see [Figure 5.2a](#)).

**Figure 5.2a** Stage Load/Unload Prompt




2. To load a new sample, click **OK**. The head raises to the Load/Unload height, and the stage indexes to the front-center position.

**Note:** Verify that the tip is still usable. If the tip has been used for a lengthy period, or if damage is suspected, change the tip now per instructions provided in [Chapter 7](#) of this manual.
3. To release the vacuum chuck's hold on a sample, use the pneumatic toggle switch located on the upper-right corner of the electronics box. When the vacuum is released, remove the sample.
4. Verify that the stage and vacuum chuck are clean of debris. If debris is present, clean the stage using a lint-free wipe and isopropyl alcohol. Dispose of wipes in an appropriately labelled solvent-contaminated waste container.
5. Place the new sample on the stage.
6. Verify that the sample is centered and seated flat against the chuck's contact points.
7. Activate the vacuum chuck by toggling the vacuum chuck switch. Select **Stage > Load New Sample** to move the stage back.

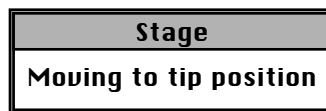
## 5.2.2 Locate Tip

When installing new tips, execute the locate tip function before focusing on the sample surface. This function enables the operator to find the probe tip using the optical system. To locate the tip, complete the following:

1. Verify that a tip is installed in the probe tip holder, then select **Stage > Locate Tip** option or use the tool bar icon 

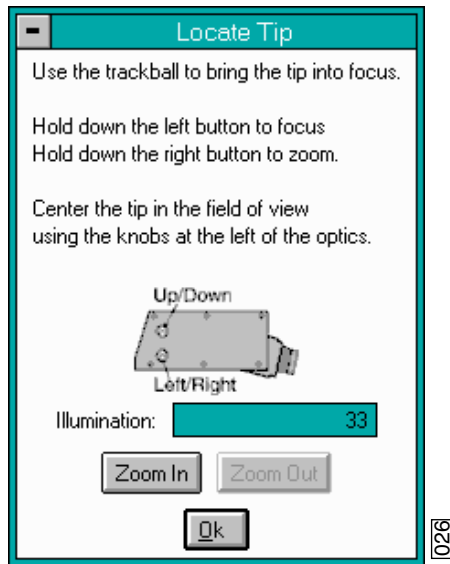
**Note:** The screen displays a caution indicating that the microscope objective is in motion (see [Figure 5.2b](#)).

**Figure 5.2b** Moving to Tip Position Caution



**Note:** As the objective moves positions, the tip should begin to come into focus. When the focus position is attained, the screen displays trackball instructions for achieving a focus (see [Figure 5.2c](#)).

**Figure 5.2c** Locate Tip Prompt



2. Bring the tip into focus by holding down the left trackball button while rolling the trackball.

**Note:** The tip may be off from center in the field of view, particularly if installing a new type of tip. Zooming out may aid in locating the tip.

3. Rotate the small, metal knobs located on the front of the on-axis viewing assembly to center the tip in the field of view as indicated in the screen prompt.
4. When the tip is in focus and centered in the field of view, click **OK** in the **Locate Tip** prompt.

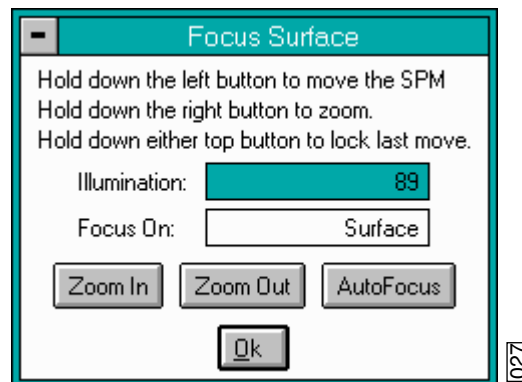
### 5.2.3 Focus Surface

This function focuses the sample surface. The operator may choose to manually focus on the surface using the trackball or allow the optics to focus automatically by choosing the **Autofocus** feature. When the surface is already partially in focus (or close to it), use the **Autofocus** feature.

To use the **Focus Surface** feature complete the following:

1. Select **Focus Surface** from the **Stage** menu. The screen displays trackball instructions for achieving a focus (see [Figure 5.2d](#)).

**Figure 5.2d** Focus Surface Prompt



2. Use the left button on the trackball to focus on the surface (which moves the SPM or Z stage up and down).
3. Use the right button on the trackball to zoom out completely when trying to focus on the surface.
4. If the sample is not already under the microscope, use the trackball (with neither the left nor right buttons pressed) to move the X-Y stage until the sample is in position.
5. If the surface is partially in focus, use the **Autofocus** option to complete the focusing process.
6. To focus on the sample “surface” (normal operation) or the “tip reflection” (for extremely clean samples), change the **Focus On** parameter accordingly.

**Note:** For reflective or semi-reflective samples, the tip reflection is easier to bring into focus than the surface, especially if the sample is very flat or clean.



**CAUTION:**

When moving the SPM stage up and down, it is possible to crash the tip into the surface. To prevent a crash while focusing on the surface, watch the optical image **and** tip-to-sample proximity. The sample should be in focus when the tip is 1mm (1000 $\mu$ m) above the surface.

7. For samples which are difficult to bring into focus, move to an edge of the sample, which is easy to find in the optical image, and bring the top of the edge into focus.
8. Move the sample back to the desired X-Y position.
9. Verify that the surface remains in focus.

## 5.2.4 Move To (X,Y)

This option enables the operator to quickly index the stage to a defined X-Y coordinate. If the origin has not been preset using the **Stage > Set Reference** panel, the stage automatically defaults to the last origin that was previously used. (All subsequent X-Y moves are done from the origin.)

To move the X-Y stage to a specified X-Y coordinate, complete the following:

1. Verify that the stage origin (position 0, 0) is either:
  - At the default, or,
  - Reset to a new position using the **Set Reference** panel under the **Stage** pop-down menu.
2. Select the **Move To (x,y)** panel under the **Stage** pop-down menu. The screen presents a panel with four fields (see [Figure 5.2e](#)).

**Note:** The first two fields define absolute moves relative to the currently set origin (0,0). The third and fourth fields define relative moves from the *current position*.

**Figure 5.2e** Move To Prompt

Move To (xy)	
X position:	-1782.8 μm
Y position:	-96.8 μm
X position change:	0.0 μm
Y position change:	0.0 μm
Quit Move Focus Surface	

3. Enter the X and Y coordinates of the desired move to position, then click **Move**.
4. The stage moves to the new position. Should it become necessary to halt movement, click on the **Pause** button (see [Figure 5.2f](#)).

**Figure 5.2f** Abort Motion Prompt

Stage
Press <Pause> to abort motion



**CAUTION:** Always verify that the tip is off the surface before attempting stage movements. If manual stage movements are attempted during engagement (by turning the leadscrew knobs on the stage's X-Y slide assemblies) the tip and/or sample may be damaged.

**ATTENTION:** Il est impératif de toujours s'assurer que la pointe ne touche pas la surface avant de bouger la platine porte-échantillon. Si la platine porte échantillons est déplacée manuellement (en tournant les vis des moteurs de la platine) la pointe et/ou l'échantillon pourraient être endommagés.

**ATTENTION:** Überprüfen Sie immer zunächst, daß die Meßspitze nicht mehr auf der Oberfläche ist, ehe Sie den XY-Verschiebetisch bewegen. Wenn der XY-Verschiebetisch von Hand bewegt wird (indem die Drehknöpfe an den Gewindestangen des XY-Verschiebetisches gedreht werden), während sich das Mikroskop im Engage-Zustand befindet, können Meßspitze und/oder Probe beschädigt werden.

5. To exit the **Move To (x,y)** dialog box, click the **Quit** button.

## 5.2.5 Set Reference

The **Set Reference** panel is used to set the origin point on the sample surface to be used for all subsequent **Move To** and **Programmed Move** operations. It is important to verify the reference point (0,0) with programmed move sequences, since all moves are relative to the current origin. For example, a program designed to move the stage to the four corners of a square sample when the origin (0, 0) is set to the upper-left corner will *not* probe the same positions if the origin is changed to the lower-right corner. It will avoid confusion to select a standard position as the usual origin reference (e.g., lower-left corner), then reuse the same reference position with all samples.

On samples having a grid-like aspect (e.g., integrated circuits), the reference may be initially defined from a line (two points) rather than a single point. The reference line is defined parallel to some feature on the sample surface (e.g., an electronic trace on an integrated circuit). You may complete this by defining two points: an origin and a second point. Defining the second point compensates for sample rotation. To set a reference on the sample, complete the following:

1. Select the **Focus Surface** function under the **Stage** menu to focus on the sample and move the sample to the desired origin.
2. Select the **Set Reference** option under the **Stage** menu. The screen offers five options to the operator (see [Figure 5.2g](#)).

Figure 5.2g Set Reference Prompt



3. Click **Origin** in the **Set Reference** panel; this is the first of two points to be used for defining a reference line on the coordinate grid.
4. Quit the **Set Reference** menu, and use the **Focus Surface** option and trackball to either move the stage right or upward as necessary.

### Move Stage Right

- a. Move the stage to the right to a second point on the linear feature. (This second point, along with the point of origin, defines the X-axis.)
- b. Quit the **Focus Surface** option, and return to the **Set Reference** option under the **Stage** pop-down menu.
- c. Click on the **X Axis** option. This establishes the ( $Y = 0$ ) reference line.

### Move Stage Upward

- a. Move the stage upward to a second point on the linear feature. (This second point, along with the point of origin, defines the Y-axis.)
- b. Quit the **Focus Surface** option, and return to the **Set Reference** option under the **Stage** pop-down menu.
- c. Select the **Y Axis** option. This establishes the ( $X = 0$ ) reference line.

**Note:** Accuracy improves if the two points defining a reference line are located at some distance to each other. For maximum angular accuracy, the two points should be located at opposite sides of the sample (see [Figure 5.2h](#)). The left image depicts two closely located points to define the X-axis. The right image depicts a more accurate reference line defined by two, widely spaced points.

Figure 5.2h Defining the X-Axis

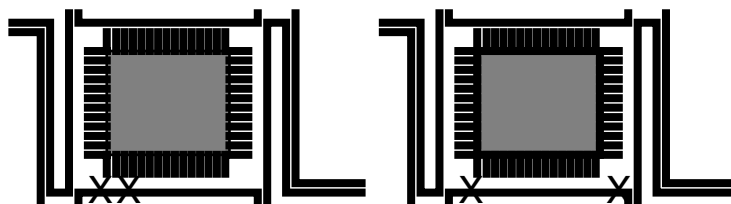
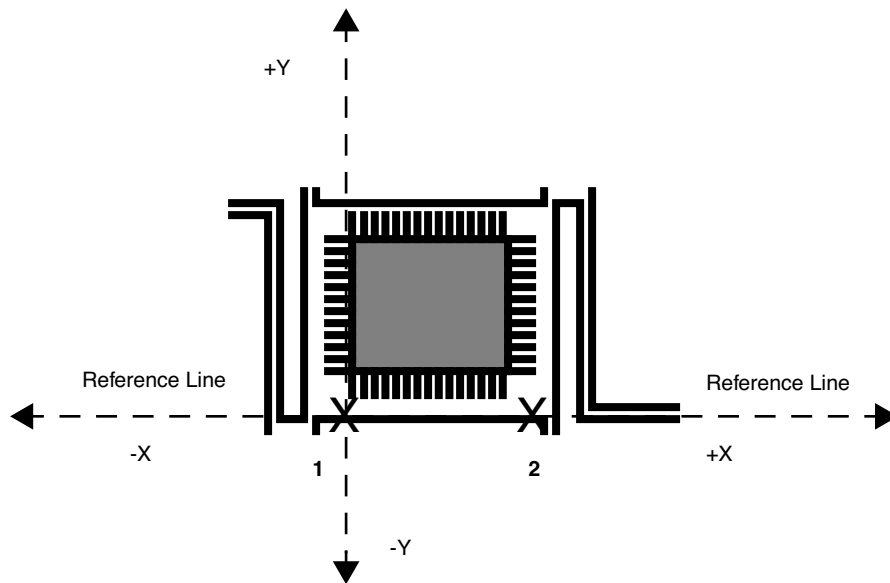


Figure 5.2i Resultant Reference Line



## 5.2.6 Programmed Move

The **Programmed Move** function allows the stage to be automatically positioned using a series of memorized positions. These positions are programmed into the controller's computer, then executed automatically in sequence. This function is particularly useful for statistical quality assurance runs on large numbers of identical samples, and as a basic inspection aid.

To use this option, select the **Programmed Move** function under the **Stage** pop-down menu. The screen displays a panel of options (see Figure 5.2j).

Figure 5.2j Programmed Move Prompt



The name of the move program currently loaded is displayed in the **Program name** panel (in the above example, the program is called "move"). Moves are first programmed using the **Teach** function. Later they may be executed using the **Run** function.



## Teaching a Programmed Move

To program (teach) a series of moves, complete the following:

1. Draw a simple map of the sample, along with each programmed position, before programmed moves are entered. Note the origin point at the time of programming.

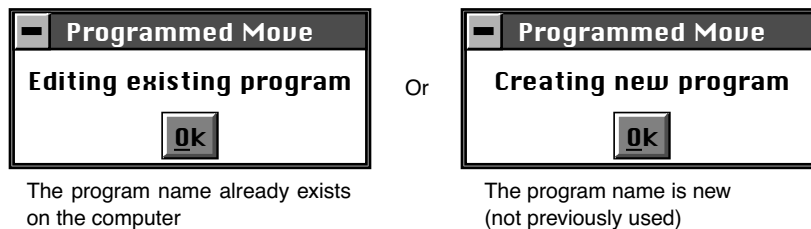
**Note:** If reducing cycle time is important, position order should be optimized to reduce stage travel

2. Click on the **Program name** option in the **Programmed Move** panel (see [Figure 5.2j](#)) and enter the name to be used.

**Note:** Program names must be eight characters or less and follow DOS protocol.

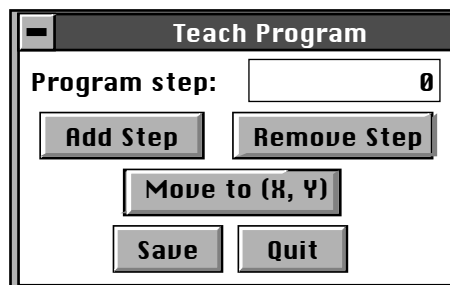
3. From the **Programmed Move** panel, click on **Teach**. The screen prompts with (see [Figure 5.2k](#)):

**Figure 5.2k** Editing or Creating New Program Prompts



4. Click **OK** to proceed with programming moves. A new panel displays, featuring the basic teaching commands (see [Figure 5.2l](#)).
5. To add a first step, click **Add Step** to invoke the **Teach Mode** panel (see [Figure 5.2l](#)).

**Figure 5.2l** Teach Program Prompt

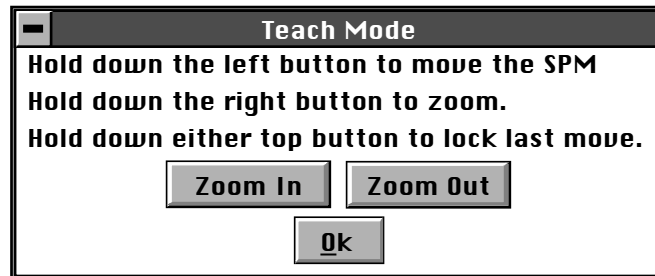


6. Use the controls to position the stage and sample to the desired location(s) to be programmed into the computer.

**Note:** These controls are identical to the **Focus Surface** controls explained in Chapter 5 of this manual.

7. Click on **OK** in the **Teach Mode** panel when the stage has moved to a desired position (see Figure 5.2m).

**Figure 5.2m** Teach Mode Prompt



8. To add another position, repeat [Step 4](#) - [Step 6](#) until all desired positions have been programmed up to a maximum of 100 steps.  
**Note:** Each time the **Teach Program** panel is reentered, the **Program step** increments by another count and automatically assigns a program step number.
9. When all stage positions are entered into the program, click **Save** in the **Teach Program** panel, then click **Quit**. Verify the program is entered and saved under the correct program name.  
**Note:** Save steps before exiting the **Teach Program** panel; otherwise, programmed steps will be lost.
10. Enter additional programs in the same manner, using a separate program name for each.

### Other Information Regarding the Teach Program Option

To remove a step from the programmed sequence:

1. Go to the **Stage** pop-down menu to the **Programmed Move** panel, and select **Teach Program**.
2. Select **Program step** from the **Teach Program** panel.
3. Enter the step number to be removed or drag the mouse to index to the step number. The stage simultaneously moves to the new step position.
4. Select the **Remove Step** option.

**Note:** When individual program steps are removed, all subsequent steps are “moved up” by one count.

5. Click **Save** to save the edited version of program.

To insert a step into an existing program sequence:

6. Go to the **Stage** pop-down menu to the **Programmed Move** panel, and select **Teach Program**.
7. Select **Program step** in the **Teach Program** panel.
8. Enter *one less* than the step number to be added to the sequence, or drag the mouse to index to the desired step number.

**Note:** For example, to add a new program step #7, while leaving all preexisting steps intact, enter “6” in the **Program step** panel. The stage simultaneously moves to the preexisting step position #6.

9. Select the Add Step option. The **Teach Mode** panel appears.
10. Use the trackball to move the stage to the new position to be added.
11. Click **Quit** to exit the **Teach Mode** panel. Verify the new position is now added.

**Note:** When new program steps are added, all preexisting steps beyond the new entry are “moved up” by one count.

12. Click **Save** to save the edited version of program.

## Origin Points

**Programmed Move** positions are memorized relative to the current origin at the time of programming. If the origin has been shifted from its original position since the time of programming, it is necessary to reestablish the original origin point to locate the same positions on the sample. When generating maps of programmed moves, always indicate the origin point.

## Running a Programmed Move

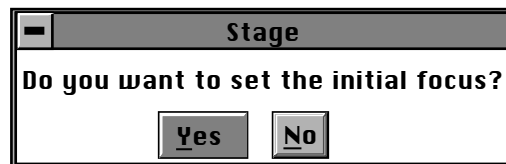
Once a program sequence has been taught to the computer, you may run the program from the **Programmed Move** panel. The stage moves to each position in the same order taught, relative to the current origin point. At each program position, the sample is scanned for 1.5 frames, captured, and then indexed to the next position. The system stores captured data from each position is stored on the hard disk; there should be sufficient memory to record 100 frames at 256 samples each.

To run a series of programmed moves, complete the following:

1. Select **Stage > Programmed Move**.
2. Select the **Program name** field, and enter the name of the program to be run.

3. Select the **Run** option. If you are loading and running the program from the beginning, the screen prompts the operator whether to refocus the screen.
  - a. Clicking **Yes** transfers you to the **Focus Surface** panel; you may then make focusing adjustments to better view the surface.
  - b. Clicking **No** initiates the programmed move from step #1.

**Figure 5.2n** Initial Focus Prompt



**Note:** If the program was previously run without finishing (aborted), the screen requests whether to begin the program sequence at the aborted step.

4. If you wish to run the entire program from its beginning (step #1); click **No**. Otherwise, click **Yes** (see [Figure 5.2n](#)).
5. The screen displays the current program step in progress (see [Figure 5.2o](#)). To initiate the program sequence from another starting point, use the **Teach Program** panel to remove any unwanted step(s), and run the program again from the new “step 1” position.

**Figure 5.2o** Programmed Move Prompt



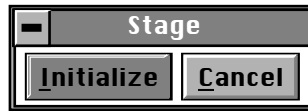
## 5.2.7 Initialize

The **Initialize** option allows the system software to locate the top (positive) limit switches on the SPM axis and optics axis stages. If the NanoScope computer determines that it is unsure of the stage position, it will not allow any functions under the **Stage** menu (except **Initialize**) to be selected.

To initialize the stage, complete the following:

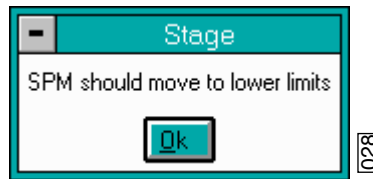
1. Before beginning initialization, verify that the stage is clear of loose items and debris.
2. Select **Stage > Initialize**. The dialog box offers two options (see [Figure 5.2p](#)).

**Figure 5.2p** Stage Initialize/Cancel Prompt



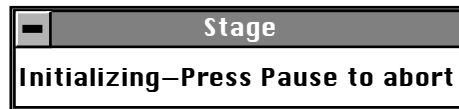
3. To begin initialization, click **Initialize**. As the stage begins a series of motorized movements, the screen indicates operating status (see [Figure 5.2q](#)).

**Figure 5.2q** SPM Move to Lower Limits Prompt



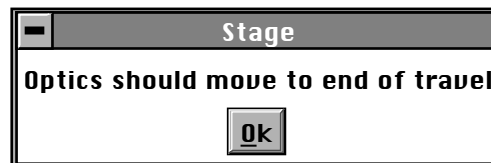
**Note:** The initialization sequence may be aborted at any time by clicking **Pause** (see [Figure 5.2r](#)).

**Figure 5.2r** Stage Initializing Prompt



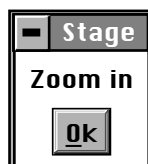
4. The microscope Z-axis moves to the top of its travel. When this is achieved, click **Ok** to continue.
5. The microscope focuses its camera optics to the extent of its travel. When this is achieved, click **Ok** to continue (see [Figure 5.2s](#)).

**Figure 5.2s** Optics Move to End of Travel Prompt



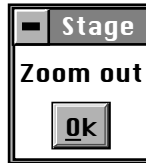
6. Next, the camera zoom optics assembly zooms. When the camera zooms in to the limit of its travel, click **Ok** to continue (see [Figure 5.2t](#)).

**Figure 5.2t** Stage Zoom Prompt



7. Finally, the camera's optics zooms out. When the camera zooms out to the limit of its travel, click **Ok** to complete the stage initialization process (see [Figure 5.2u](#)). The dialog box removes itself from the screen.

**Figure 5.2u** Stage Zoom Out Prompt



### 5.2.8 SPM Parameters

The SPM parameters menu lists the most important Z-axis parameter values for loading/unloading the stage and engaging samples. These values are explained in more detail in [Chapter 7](#).

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# Chapter 7 Head, Probe, & Sample Preparation

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This chapter includes information regarding the Dimension 3100 Scanning Probe Microscope (SPM) setup and operation procedures for Contact Mode and TappingMode. Specifically, this chapter details removal and installation of the microscope head, mounting the cantilever, changing the tip, loading and positioning samples, focusing the optics, and general information regarding engaging and withdrawing the tip.

[Chapter 9](#) discusses SPM operation in TappingMode in more detail, while [Chapter 8](#) reviews SPM operation in Contact Mode AFM. This chapter contains the following:

- **System Information:** [Section 7.1](#)
  - **Mouse versus Trackball:** [Section 7.1.1](#)
  - **Motor Interlock:** [Section 7.1.2](#)
  - **Laser Requirements:** [Section 7.1.3](#)
- **Basic AFM Operation:** [Section 7.2](#)
  - **Select the Microscope:** [Section 7.2.1](#)
  - **Select Mode of Operation:** [Section 7.2.2](#)
  - **Prepare the Cantilever Holder:** [Section 7.2.3](#)
  - **Load the Cantilever Holder:** [Section 7.2.4](#)
  - **Remove the Dimension SPM Head:** [Section 7.2.5](#)
  - **Install the Cantilever Holder:** [Section 7.2.6](#)
  - **Replace the Dimension SPM Head:** [Section 7.2.7](#)
  - **Connect the Dimension Head:** [Section 7.2.8](#)
  - **Align Laser:** [Section 7.2.9](#)
  - **Adjust Photodetector:** [Section 7.2.10](#)
  - **Locate Tip:** [Section 7.2.11](#)

- **Load the Sample:** [Section 7.2.12](#)
- **Focus Surface:** [Section 7.2.13](#)
- **Cantilever Tune (TappingMode only):** [Section 7.2.14](#)
- **Set Initial Scan Parameters:** [Section 7.2.15](#)
- **Engage:** [Section 7.2.16](#)
- **Withdraw:** [Section 7.2.17](#)
- **Advanced AFM Operation:** [Section 7.3](#)
  - **Stage Parameters:** [Section 7.3.1](#)

## 7.1 System Information

### 7.1.1 Mouse versus Trackball

The mouse exclusively operates the NanoScope software with the exception of functions related to direct control of the stage. These commands are only initiated with the trackball. Operator-initiated movement of motors via the Zoom, Focus, Move SPM (Z-stage) and Move XY commands are controlled by the trackball and its buttons. Motor operation is permitted only when the appropriate menu enables movement.

### 7.1.2 Motor Interlock

SPM stage movement is software interlocked against motion if a valid sum (laser signal) is not present. The sum signal must be between 0.5-9.5 volts, otherwise all commands which try to initiate stage motion will not move the SPM X, Y, or Z stages. However, except for upward Z-stage travel. This interlock reduces the possibility of inadvertently crashing the tip and scanner crystal into the sample or stage, minimizing tip and scanner damage. If during the engage sequence the sum signal changes to a value outside the interlocked limits, the downward motion stops, preventing damage to scanners had the Z-stage continued downward.



### 7.1.3 Laser Requirements



**CAUTION:** When the Dimension head is plugged into the microscope control electronics, laser light is emitted.

**CAUTION:** The Dimension head features an internal tilt switch to shut power off to the laser whenever it is inverted, however, heed all precautions below.

This instrument uses a semiconductor laser emitting a maximum 1.0mW beam at 670 nm. The light is emitted down the center of the scanner tube and during normal operation reflects back into the system's optics from the back surface of the cantilever probe.



**WARNING:** During and prior to set up of the laser, it is important to avoid looking directly at the laser beam or at the laser spot. The laser head should never be plugged into the microscope control electronics unless the head is installed in the Z-stage mount. Take care when inserting highly reflective samples on the chuck. Avoid looking at all reflected laser light. Use care to avoid staring into beams that may be reflected from sample surfaces.

**AVERTISSEMENT:** Avant de faire fonctionner le laser, et durant tout le temps pendant lequel il fonctionne, il est impératif de ne pas regarder directement le faisceau du laser ou l'image qu'il réfléchit. La sonde laser ne doit jamais être branchés sur l'électronique de contrôle du microscope, tant que la tête de mesure n'est pas installée dans son support. Il est impératif de faire très attention lorsque des échantillons très réfléchissants sont déposés sur la platine. Eviter toute exposition à la lumière laser. Durant l'utilisation, ne pas fixer les faisceaux laser réfléchis par les surfaces d'échantillons.

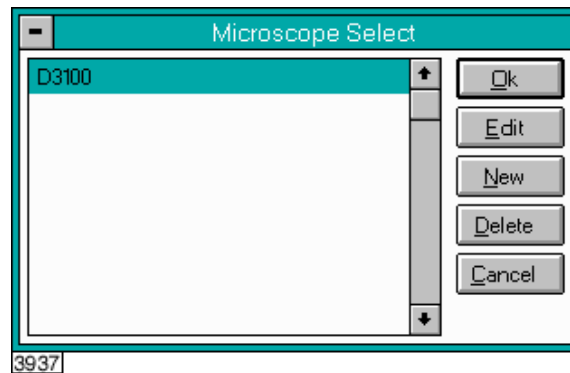
**WARNUNG:** Es ist sehr wichtig, vor und während der Laserjustierung nicht in den Laserstrahl oder auf den Laserpunkt zu schauen. Der Laser sollte niemals an die Mikroskopelektronik angeschlossen werden, wenn er nicht in der Halterung der Z-Verschiebeeinheit installiert ist. Seien Sie bitte sehr vorsichtig, wenn stark reflektierende Proben auf dem Probenteller liegen. Vermeiden Sie unter allen Umständen, in das reflektierte Laserlicht zu schauen. Alle Bediener des Mikroskops sollten größte Vorsicht walten lassen um zu vermeiden, in den von der Probenoberfläche reflektierten Laserstrahl zu schauen.

## 7.2 Basic AFM Operation

### 7.2.1 Select the Microscope

1. Set the microscope configuration by selecting the **Microscope Select** panel from the **Di** pop-down menu (see [Figure 7.2a](#)).
2. Click **OK** to close the **Microscope > Select** dialog box and initiate the Realtime software.

**Figure 7.2a** Microscope Select Prompt



### 7.2.2 Select Mode of Operation

1. Select **Microscope > Profile**.
2. Select the desired mode of operation (Contact Mode, TappingMode, etc.) and click **OK**.

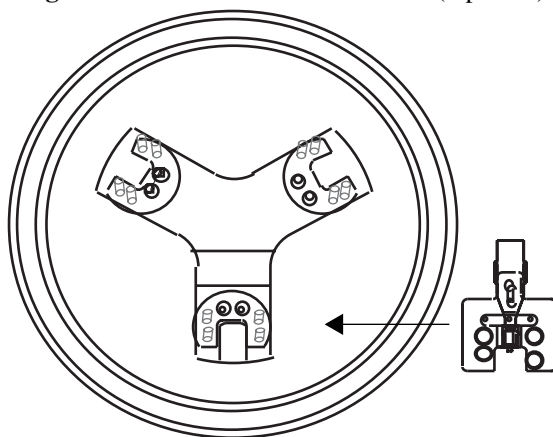
### 7.2.3 Prepare the Cantilever Holder

Before loading the substrate onto the cantilever holder, place the cantilever holder on the cantilever holder stand (see [Figure 7.2b](#)). The cantilever holder stand is a 2.5-inch diameter black anodized aluminum cylinder that ships with the Dimension 3100 SPM for easy installation of the substrate onto the cantilever holder.

The cantilever holder stand has three stations for different tip holders: 1) standard AFM, 2) fluid imaging AFM and 3) STM. A small, raised block in the center of the gold connector identifies the standard AFM load station.

To prepare the cantilever holder, with the AFM cantilever holder's large spring clip face up, mate the standard AFM cantilever holder sockets to the pins of the AFM cantilever holder stand (see [Figure 7.2b](#)).

**Figure 7.2b** Cantilever Holder Stand (top view)



**Note:** You may install the AFM cantilever holder in only one orientation because the pins are asymmetrical.

## 7.2.4 Load the Cantilever Holder

### Contact Mode AFM

Silicon nitride substrates are used for SPM operation in Contact Mode AFM. Silicon nitride substrates consist of a cantilever integrated with a sharp tip on the end. For Contact Mode AFM imaging, the cantilever must be soft enough to deflect very small forces and have a high enough resonant frequency to avoid vibrational instabilities.

**Note:** Install silicon nitride substrates face-up so the tip points away from the AFM cantilever holder. This ensures that the cantilever and tip face toward the sample once the cantilever holder is mounted on the head.

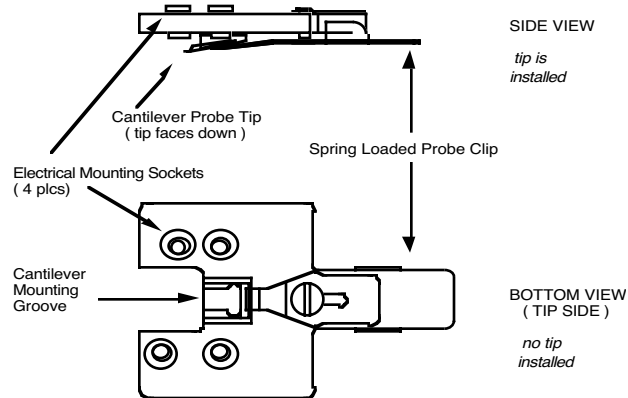
To install a silicon nitride substrate on the AFM cantilever holder, complete the following:

1. Using sharp tweezers, grasp the substrate firmly on the sides and lift to free the substrate from the wafer or gel-pack. In the gel-pack boxes the tip ends are pointing upward and do not need to be turned over before being placed in the cantilever holder.

**Note:** Refer to [Chapter 6](#) for detailed information on how to break out each substrate from the wafer.

2. Many silicon nitride substrates have cantilevers on both ends of the substrate. If this is the case, place the substrate under an optical microscope or magnifier and locate the substrate you want to use.
3. Press down and slide back the spring clip of the standard AFM cantilever holder (see [Figure 7.2c](#)).

Figure 7.2c Standard AFM Cantilever Holder



4. Orient the cantilever intended for imaging away from the cantilever holder, and place the substrate in the AFM cantilever holder groove.
5. Carefully maneuver the substrate until the substrate is flush against the back edge and laying flat in the cantilever holder groove.
6. Press the spring-loaded probe clip down, gently push forward over the substrate, and release the spring clip to hold the substrate in place in the cantilever holder groove.

**Note:** Always orienting the substrate to one side and the back of the cantilever holder groove will improve repeatability of tip location between runs. This will make aligning the laser onto the cantilever quicker and easier when installing new cantilevers.

### TappingMode

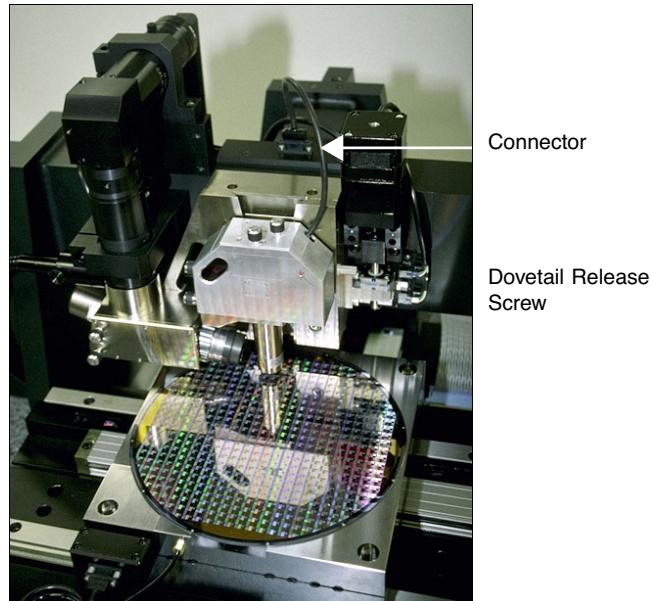
The procedure for installing TappingMode, single crystal silicon substrates is the essentially the same as the procedure for installing silicon nitride substrates in Contact Mode AFM. However, one difference is that silicon substrates usually have only one cantilever per substrate, which can often be identified without an optical microscope.

**Note:** Single crystal silicon substrates are installed face-up so the tip points away from the AFM cantilever holder. This ensures that the cantilever and tip face toward the sample once the cantilever holder is mounted on the head.

## 7.2.5 Remove the Dimension SPM Head

1. Tighten the screw located on the right side of the Dimension SPM head dovetail to release the Dimension SPM head (see [Figure 7.2d](#)).

**Figure 7.2d** SPM Head Dovetail and Signal Connector



**Note:** Dovetail engagement actuates with a spring. Failing to engage the spring-loaded dovetail causes a large increase in image noise due to reduced rigidity of the mechanical support of the SPM head.

2. Unplug the connector wire that runs from the SPM head to the Dimension base.
3. Carefully slide the Dimension SPM head up and out of the dovetail groove.

## 7.2.6 Install the Cantilever Holder

If you are changing cantilevers, we recommend you select **Stage > Load new sample** before removing the old cantilever. The stage moves to the front of the Dimension base, which becomes useful in laser alignment (refer to [Section 7.2.9](#) for laser alignment). Because the laser sum signal will reach zero once the cantilever is removed, the motor interlock will prevent this in the future.



**CAUTION:**

When using the **Stage > Load New Sample** command, be sure there are no objects taller than the height of the cantilever in-between current location of the scanner and the front of the sample chuck. An object in this path could damage the scanner and/or tip.

1. Mate the cantilever holder sockets to the Dimension SPM head pins to install the loaded AFM cantilever holder.
2. Verify the tip points down and away from the head. The end of the cantilever must point in the direction of the optics assembly.
3. Verify the AFM cantilever holder mounts flat against each pin on the end of the head.

### 7.2.7 Replace the Dimension SPM Head

1. Carefully slide the Dimension SPM head down into the dovetail groove of the Z-stage SPM.
2. When sliding the SPM head into the dovetail, make sure that the tip will not touch the sample. If it appears that the tip may touch when the SPM head is fully inserted in the dovetail, raise the Z-stage by selecting **Motor > Withdraw** several times, or by selecting **Stage > Focus Surface** and raising the Z-stage upward.
3. Loosen the screw located on the right side of the Dimension SPM head dovetail to lock the head in place (see [Figure 7.2d](#)).

### 7.2.8 Connect the Dimension Head

Insert the Dimension SPM head black 21-pin connector plug into the socket just behind the Z-stage located on the stage control electronics box (see [Figure 7.2d](#)).

### 7.2.9 Align Laser

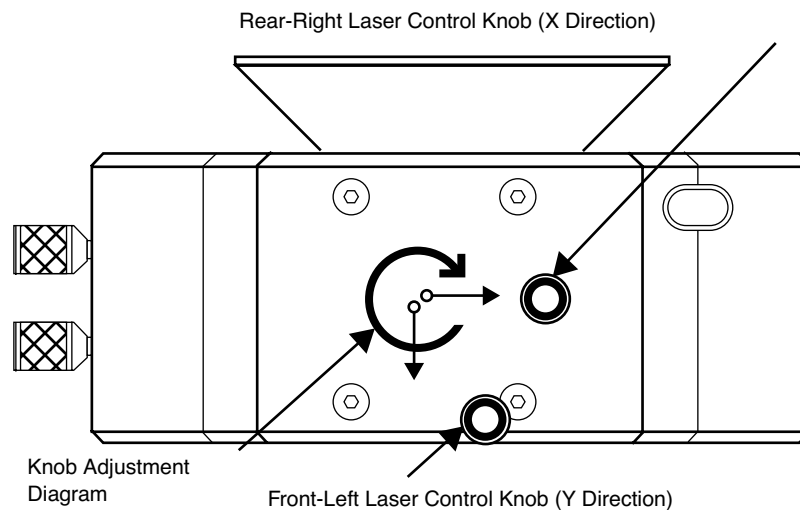


**CAUTION:** Turn down the illuminator intensity before proceeding with laser alignment.

For both TappingMode and Contact Mode AFM, the user aligns the laser by moving the laser beam relative to the cantilever while observing the laser spot on the granite surface (a piece of white paper also works well) below the Dimension head. If the laser is not on the cantilever substrate, the laser appears as a bright red spot on the surface below. When the laser is aligned on the cantilever, a shadow appears on the surface below.

[Figure 7.2e](#) displays the laser control knobs located on the top of the Dimension head. There is a diagram printed on top of the Dimension head illustrating which direction the laser moves when turning the laser control knobs clockwise.

**Figure 7.2e** Dimension Head Laser Control Knobs



The X direction runs along the major axis of the substrate (parallel to the length of the cantilever). The right-rear laser control knob, atop the SPM head, controls the laser beam movement along the X direction. The front-left laser knob, atop the SPM head, moves the beam along the Y direction perpendicular to the cantilever and substrate's major axis. In the vision system display, the X direction is right-to-left across the screen, and the Y direction is top-to-bottom.

The procedure for aligning the laser is slightly different between TappingMode and Contact Mode AFM. The sections below detail the procedures for aligning the laser on the cantilever and tips for each mode respectively.

### Etched Silicon Tips (TappingMode)

In order to place the laser reflection at the end of the cantilever, you must shine a laser beam on either the granite base or a piece of paper.

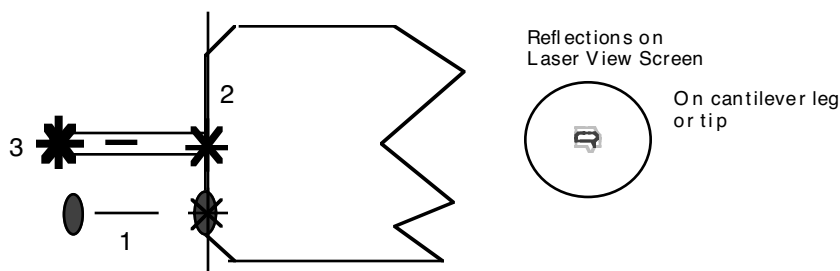
1. You can view the laser spot several different ways:
  - a. If a cantilever is being replaced, first select **Stage > Load New Sample** to reflect the laser off the of the granite base while it is locked in the Z-stage dovetail (as discussed in [Section 7.1.2](#)).
  - b. If the cantilever has already been removed, you may need to raise the Z-stage by selecting **Stage > Focus Surface** or **Motor > Withdraw**.
  - c. You can see the laser spot by removing the SPM head from the dovetail (without unplugging the cable between the SPM head and the Dimension base) and holding the SPM head over the granite or piece of paper.



**CAUTION:** Use extreme caution when removing the SPM head. Hold the head firmly and do not stress the wire between the SPM head and the Dimension base. Dropping the head will likely result in damage and Veeco factory repair.

2. Verify the laser beam is visible on the surface below. If it is not, turn the rear-right laser control knob counter-clockwise until the laser spot appears on the surface below.
3. Turn the rear-right laser control knob clockwise to move the laser in the X positive direction until the laser spot disappears from the surface below. Turn the right-rear laser control knob counter-clockwise until the laser spot just reappears. The laser is now positioned at the edge of the substrate (see Point 1 in Figure 7.2f).

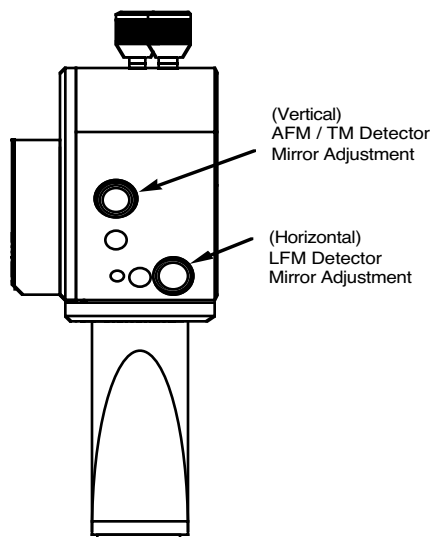
**Figure 7.2f** Etched Silicon Tip Laser Alignment



4. Turn the front-left laser control knob clockwise or counter-clockwise to move the laser in the Y direction (parallel to the substrate edge and perpendicular to the cantilever) until the beam crosses the cantilever and a shadow appears over the laser spot on the surface below. The laser is now positioned over the cantilever (see Point 2 in Figure 7.2f).
5. Verify that the laser is deflecting off the cantilever by moving the laser on, over, and off the cantilever by turning the front-left laser control knob less than 1/8 of a turn.
6. Turn the rear-right laser control knob counter-clockwise to move the laser in the X negative direction on the cantilever until the laser crosses the tip-end of the cantilever and falls on the surface below.
7. Move the laser onto the tip-end of the cantilever by reversing the direction of the rear-right laser control knob clockwise until the spot disappears from the surface below (see Point 3 in Figure 7.2f).
8. Verify that a laser spot appears in the Dimension head filter screen. If there is not laser spot, adjust the photodetector mirror using the photodetector adjustment knobs located on the left side of the SPM head (see Figure 7.2g).



Figure 7.2g Photodetector Adjustment Knobs



**Note:** You may now restore the illuminator lamp to increased intensity for improved video image quality.

### Silicon Nitride Tips (Contact Mode AFM)

In order to place the laser reflection at the end of the cantilever, you must shine a laser beam on either the granite base or a piece of paper.

1. You can view the laser spot several different ways:
  - a. If a cantilever is being replaced, first select **Stage > Load New Sample** to reflect the laser off the of the granite base while it is locked in the Z-stage dovetail (as discussed in [Section 7.1.2](#)).
  - b. If the cantilever has already been removed, you may need to raise the Z-stage by selecting **Stage > Focus Surface** or **Motor > Withdraw**.
  - c. You can see the laser spot by removing the SPM head from the dovetail (without unplugging the cable between the SPM head and the Dimension base) and holding the SPM head over the granite or piece of paper.

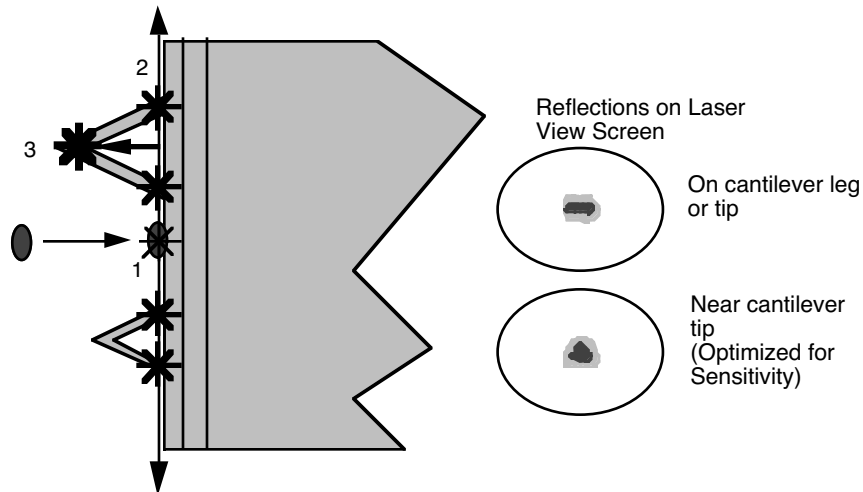


**CAUTION:** Use extreme caution when removing the SPM head. Hold the head firmly and do not stress the wire between the SPM head and the Dimension base. Dropping the head will likely result in damage and Veeco factory repair.

2. Verify the laser beam is visible on the surface below. If it is not, turn the rear-right laser control knob counter-clockwise until the laser spot appears on the surface below.

- Turn the rear-right laser control knob clockwise to move the laser in the X positive direction until the laser spot disappears from the surface below. Turn the right-rear laser control knob counter-clockwise until the laser spot just reappears and stop turning the knob. The laser is now positioned at the edge of the substrate (see Point 1 in [Figure 7.2h](#)).

**Figure 7.2h** Silicon Nitride Laser Alignment



- Once the laser is positioned just off the edge of the substrate, use the front-left laser control knob to move in the Y direction (parallel to the edge of the substrate) until the laser crosses a maximum of four legs on the two V-shaped cantilevers (see Point 2 in [Figure 7.2h](#)).

**Note:** This occurs when moving in one direction (either up or down from end to end). If the laser is close to the substrate, you should detect four distinct occurrences of the laser spot disappearing and reappearing on the surface below.

- If the laser is positioned between a pair of legs of one cantilever (laser spot on surface below) turn the rear-right laser control knob counter-clockwise to move the laser left in the X direction until the laser spot disappears on the surface below (see Point 3 in [Figure 7.2h](#)).
- Verify the laser is located on the portion of the cantilever connecting the two lever arms near the tip location by moving the laser on and off the cantilever, repeatedly, with an 1/8 turn of the back-left control knob. Then, place the laser back on the cantilever.
- Turn the rear-right laser control knob counter-clockwise to move the laser in the X negative direction on the cantilever until the laser crosses the tip-end of the cantilever and falls on the surface below (see [Figure 7.2h](#)).
- Move the laser onto the tip-end of the cantilever by reversing the direction of the rear-right laser control knob clockwise until the spot disappears from the surface below.
- The laser is now on one of the two cantilevers. To determine which cantilever the laser is on:

**Note:** During this step do not adjust the back-right laser knob, or you may accidentally return to the original cantilever. Only use the back-right knob when you need to place the laser on the other cantilever.

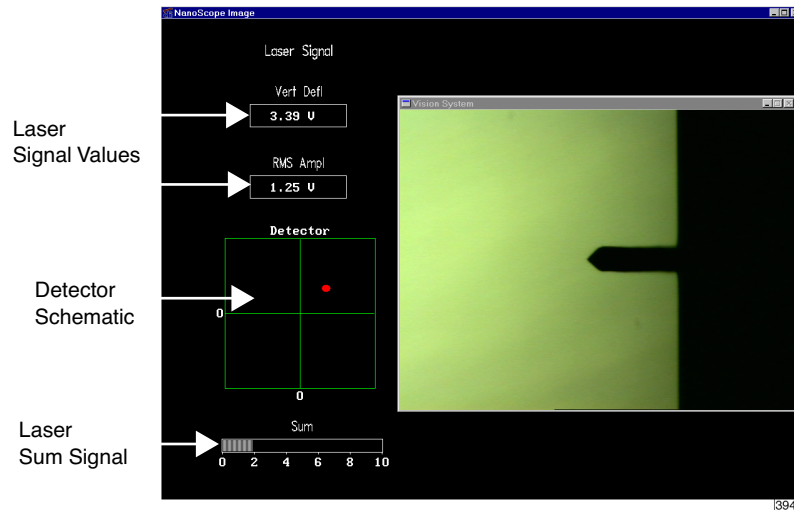
- a. Rotate the back-left laser control knob in either direction until the laser disappears and does not reappear with an 1/8 turn.
  - b. Use the same back-left laser control knob to rotate the laser the opposite direction, past the original cantilever.
  - c. Determine which cantilever you are on:
    - If the laser was on the longer cantilever at then beginning of this step, then the laser will not cross any other cantilever legs during this movement.
    - If the laser was on the small cantilever, then the laser will cross the two longer cantilever legs.
  - d. Select the cantilever for imaging by returning to the original cantilever, or locate the other end of this cantilever.
10. Verify that a laser spot appears in the Dimension head filter screen. If there is not laser spot, adjust the photodetector mirror using the photodetector adjustment knobs located on the left side of the SPM head.

### 7.2.10 Adjust Photodetector

1. Now that the laser is aligned on the cantilever, verify there is a spot visible on the Dimension head filter screen.
2. Verify there is an appropriate laser sum signal displayed on the image monitor (see [Figure 7.2i](#)). Typical laser sum values:
  - Contact Mode AFM: **4 - 6V**
  - TappingMode: **1.5 - 2.5V**

**Note:** If the laser sum signal is low, either the laser is not aligned or the photodetector knob needs adjusting (described in [Step 3](#)).

Figure 7.2i Vision System Window



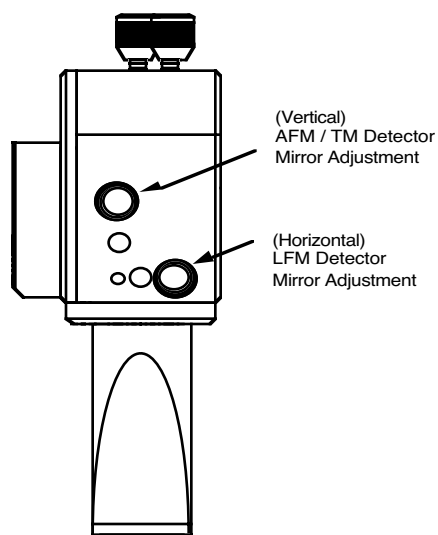
3. Center the laser detector signal using the photodetector adjustment knobs (see [Figure 7.2i](#)) located on the left side of the Dimension head. The image monitor displays the laser signal values and a schematic of the detector quadrants labeled **Detector**. The position of the laser is denoted by a red dot on the detector schematic (see [Figure 7.2i](#)).

- The Vertical Deflection signal is the difference between the top and bottom photodetectors. For TappingMode, adjust this signal to 0. For Contact Mode, adjust this signal to -2 (see [Figure 7.2j](#)).

**Note:** In TappingMode, the **RMS Ampl** is an AC signal and does not have any real magnitude until the cantilever tune has been completed.

**Note:** When the laser is positioned in the center of the detector schematic, the laser is also in the center of the screen on the front of the head. If the laser is severely out of alignment, it may help to first center the laser on the screen on the head using the photodetector adjustment knobs, then use the detector schematic on the image monitor to finish positioning the laser.

**Figure 7.2j** Photodetector Mirror Adjustment Knobs



### 7.2.11 Locate Tip

For initial start-up where the Z-stage and optics have been almost fully retracted (such as when you performed **Stage > Load New Sample**), use the **Focus Surface** command to move the tip closer to the surface. It is easier to focus on the tip with more light reflecting from the surface into the optics.

To locate the tip, complete the following steps:

1. Initiate the **Locate Tip** command in the **Stage** menu by clicking on **Locate Tip**.  
**Note:** This command locates the tip position (Z height) using optical focal distance measurements. When this step completes, the computer records the tip position in memory.
2. Zoom out as far as possible using the trackball or **Zoom Out** button. This helps you locate the cantilever in optical field of view.
3. Once you find the tip, use the optic adjustment knobs (lower-left corner of the zoom optics assembly) to align the optical microscope lens so the tip is centered in the video display window.
4. Focus on the cantilever using the trackball. You can zoom in using the **Zoom** button on the trackball.
5. Quit the **Locate Tip** sequence by pressing **ENTER** on the keyboard or clicking **OK** at the bottom of the **Locate Tip** dialog box.

## 7.2.12 Load the Sample

If it is your first time operating the microscope, we recommend that you first image the calibration sample (a  $10\mu\text{m}$ -pitch grid of 200nm step height) provided with the instrument.

### Small Sample Preparation

Place the calibration sample or other small sample on one of the 1.5cm diameter metal disks used for sample mounting. The Dimension 3100 SPM ships with several steel sample disks that you may attach to a magnetic sample holder located in the Dimension Chuck Spare Parts Kit. Also provided with the instrument are red and white colored double-sided adhesive patches, or “sticky tabs,” designed to hold the sample chip to the disk.

1. Peel off a sticky tab from the provided sheet, and place it on the steel small sample puck (see [Figure 7.2k](#)).
2. Peel off the red-and-white paper to leave a patch of the two-sided adhesive on the steel sample disk holding the sample chip to the disk.
3. Using tweezers, place the small sample to be imaged firmly on the adhesive (see [Figure 7.2l](#)).

**Note:** Alternatively, you may glue a small sample down to the sample puck using cyanoacrylate glue (super glue).

4. Place the small sample disk on the magnetic small sample holder.

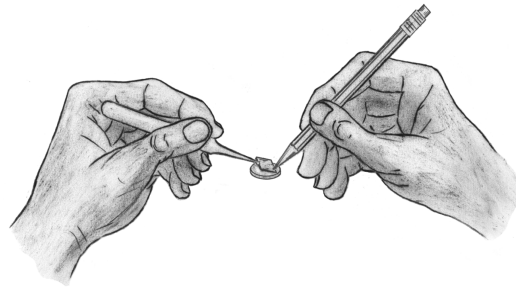
**Note:** The small sample holder provided with the Dimension 3100 is not optimal for imaging soft magnetic materials due to the magnetic hold-down properties. If magnetic imaging is intended, use the vacuum chuck.

**Note:** For small samples with flat backs or samples mounted on metal discs, use the vacuum chuck.

**Figure 7.2k** Securing Double-sided Tape to the Sample Disk



**Figure 7.21** Securing the Sample



5. Secure the sample atop the stage.

### Large Sample Preparation

You may place large, flat samples directly on the vacuum chuck which are held down using vacuum. To engage the vacuum, use the toggle switch labeled **Vacuum** on the front of the black SPM electronics box. The stage has five holes available for holding samples: the center hole, three holes with machined rings for holding wafers and discs, and an isolated hole near the edge of the chuck for small samples. Remove the screw from the hole you will use, and block all unused holes with screws.

### 7.2.13 Focus Surface

1. Select the **Focus Surface** option under the **Stage** pop-down menu, or click on the **Focus Surface** icon.
2. Focus on the sample surface by rolling the trackball up or down while pressing the bottom-left button. This adjustment raises or lowers the vertical engage stage on which the SPM and optics are mounted.
3. To move long distances hold both left trackball buttons down simultaneously and roll the trackball with high speed to lock the peak speed of motion. Release these two buttons to stop the motors. be careful when performing this in the downward direction



**CAUTION:**

Since the command **Focus Surface** moves the scanner vertically, be careful when making this adjustment to ensure that the tip does not hit the sample surface.

### 7.2.14 Cantilever Tune (TappingMode only)


1. Select **Cantilever Tune** from the **View > Sweep** pop-down menu, or click on the **Cantilever Tune** icon.
2. For **Auto Tune Controls**, verify the following:
  - **Start Frequency** is set to **100 kHz**
  - **End Frequency** is set to **500kHz**.
  - **Target Amplitude** is set to **2V**.
3. Click on **AUTO TUNE**.
4. When the procedure ends, click on **QUIT** to exit the function.

### 7.2.15 Set Initial Scan Parameters

1. In the **Scan Controls** panel, set the following:
  - **Initial Scan Size** is set to **1 $\mu$ m** (or desired scan size). Veeco recommends you always initially engage with small scan sizes.
  - **X and Y Offsets** are set to **0**.
  - **Scan Angle** is set to **0**.
2. In **TappingMode**, under the **Feedback Controls** panel, set the following:
  - **Integral Gain** is set to **0.4**.
  - **Proportional Gain** is set to **0.8**.
  - **Scan Rate** is set to **1Hz**.
3. In **Contact Mode AFM**, under the **Feedback Controls** panel, set the following:
  - **Setpoint** is set to **0V**.
  - **Integral Gain** is set to **2.0**.
  - **Proportional Gain** is set to **3.0**.
  - **Scan Rate** is set to **1Hz**.




## 7.2.16 Engage

- Select **Motor > Engage**, or click the **Engage** icon. 
- Once engaged, refer to the appropriate chapter in this manual for further instructions for the mode you are using (e.g. **Contact AFM: Chapter 8**, **TappingMode AFM: Chapter 9**, etc.)

## 7.2.17 Withdraw

When imaging is complete, withdraw the tip by selecting **Motor > Withdraw**, or the click

**Withdraw** icon.  This typically raises the tip 1mm above the sample.

Although the 1mm withdraw distance provides enough clearance to loosen the dovetail and remove the AFM head, if further distance is desired perform one of the following:

- Select **Stage > Focus Surface** to raise the Z-stage with the trackball.
- Execute **Withdraw** multiple times.
- Select **Stage > Load New Sample**.

**Note:** It is impossible to move the Dimension head if the laser sum signal is too low.

## 7.3 Advanced AFM Operation

### 7.3.1 Stage Parameters

The system ships with the following default stage parameters (see [Figure 7.3a](#)). Once you have become familiar with using the system, you may want to adjust the stage parameters to speed up the engage sequence.

1. To access the stage parameters panel, select **SPM Parameters** from the **Stage** pop-down menu.
2. For initial set-up, use the following values. When done, click **OK** to close the **SPM Parameters** window.

Figure 7.3a Default SPM Stage Parameters

SPM Parameters	
Sample clearance:	1000.0 $\mu\text{m}$
SPM safety:	100 $\mu\text{m}$
SPM engage step:	1.00 $\mu\text{m}$
Load/Unload height:	3000 $\mu\text{m}$

Definitions of **Stage > SPM Parameters** fields are as follows:

### Sample Clearance

Defines the height of the probe tip over the sample prior to **Engage** (set up by performing the **Locate Tip** and **Focus Surface** routines). You may change the sample clearance parameter once you are experienced with the system. The default parameter is  $1000\mu\text{m}$ . This parameter also sets the distance that the tip is raised above the sample each time **Withdraw** is executed.

### SPM Safety

Defines the height of the probe tip over the sample where the fast approach changes over to the slow approach. The default parameter is  $100\mu\text{m}$ . You may reduce to  $50\text{--}75\mu\text{m}$  once you are experienced with the system. Reducing this number speeds up the approach sequence, but it increases the risk of the tip reaching the surface during the fast engage if the **Locate Tip** and **Focus Surface** focal points are not properly set. If this happens, the tip has “crashed” and may need replacing.

### SPM Engage Step

Defines the step size of the Z-stage during engage. The default parameter is  $1\mu\text{m}$ . Increasing this increases the speed of the approach.



**CAUTION:**

Do not change this parameter by more than  $0.5\text{--}1\mu\text{m}$  because the step size must be some modest fraction of the total Z range of the scanner (i.e.  $6\text{--}7\mu\text{m}$ ).

### Load/Unload Height

This parameter defines how high the tip moves above the sample when **Stage > Load New Sample** is executed. After the Z-stage is raised, the sample stage moves as far forward in the Y direction (towards you) as possible.

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# Chapter 8 Contact AFM

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This chapter covers procedures for operating the Dimension 3100 Scanning Probe Microscope (SPM) in Contact Mode AFM. It is assumed that the operator has previously prepared a Contact Mode tip and aligned the laser per instructions provided in [Chapter 7](#) of this manual. Specific information regarding tip preparation is also provided in [Chapter 6](#).

- **Basic Contact Mode AFM Operation:** [Section 8.1](#)
  - **Select the Microscope:** [Section 8.1.1](#)
  - **Select Mode of Operation:** [Section 8.1.2](#)
  - **Head, Cantilever and Sample Preparation:** [Section 8.1.3](#)
  - **Align Laser:** [Section 8.1.4](#)
  - **Adjust Photodetector:** [Section 8.1.5](#)
  - **Locate Tip:** [Section 8.1.6](#)
  - **Focus Surface:** [Section 8.1.7](#)
  - **Show All Items:** [Section 8.1.8](#)
  - **Set Initial Scan Parameters:** [Section 8.1.9](#)
  - **Engage:** [Section 8.1.10](#)
- **Advanced Atomic Force Operation:** [Section 8.2](#)
  - **Cantilever Selection:** [Section 8.2.1](#)
- **Optimization of Scanning Parameters:** [Section 8.3](#)
  - **Data Type:** [Section 8.3.1](#)
  - **Gain Settings:** [Section 8.3.2](#)
  - **Scan Size and Scan Rate:** [Section 8.3.3](#)
  - **Setpoint:** [Section 8.3.4](#)

- **Lowpass Filter:** [Section 8.3.5](#)
- **Highpass Filter:** [Section 8.3.6](#)
- **Force Calibration Mode:** [Section 8.4](#)

## 8.1 Basic Contact Mode AFM Operation

The following is a general outline of basic operational procedures involved in Contact Mode AFM. For more detailed instructions, refer to [Chapter 7](#) of this manual.

### 8.1.1 Select the Microscope

1. Set the microscope head configuration by selecting **Di > Microscope Select**.
2. Click **OK** to close the **Microscope Select** dialog box. When enabled, the selected buttons are black.

### 8.1.2 Select Mode of Operation

1. Select **Microscope > Profile**.
2. Select **Contact Mode** as the mode of operation.

### 8.1.3 Head, Cantilever and Sample Preparation

1. Install a silicon nitride tip onto an AFM cantilever holder (see [Chapter 7](#)).
2. Load the cantilever holder with installed tip onto the scanner tube of the Dimension SPM head.


### 8.1.4 Align Laser

1. Align the laser using the laser control knobs.
2. Verify the laser beam is positioned on the back of the cantilever, with a spot visible in the Dimension head filter screen and a sum signal of **4-6V**.


### 8.1.5 Adjust Photodetector

1. Adjust the photodetector so that the red dot moves toward the center of the Dimension head filter screen using the two photodetector adjustment knobs located on the side of the Dimension head.
2. Verify that the red dot is centered and elliptical in shape in the Dimension head filter screen.
3. Set the **Vertical Deflection** to **-2V**.

### 8.1.6 Locate Tip

1. Select **Stage > Locate Tip** or click on the **Locate Tip** icon. 
2. Center the tip end of the cantilever under the cross hairs using the two optics adjustment knobs located left of the optical microscope objective.
3. Use the trackball with the bottom left button depressed to focus on the tip end of the cantilever.

### 8.1.7 Focus Surface

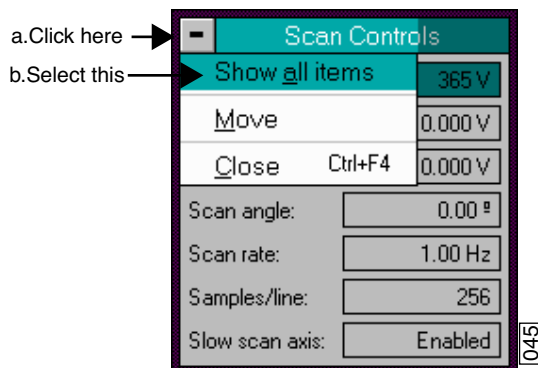
1. Select **Stage > Focus Surface** or click on the **Focus Surface** icon. 
2. Focus on the sample surface using the trackball with the bottom-left button depressed.

### 8.1.8 Show All Items

Before changing any parameters, you should display all of the available parameters. If you cannot view a parameter in a panel, you might need to enable this parameter.

1. Click the “minus box”  in the upper left corner of the panel, and click **Show all items**.

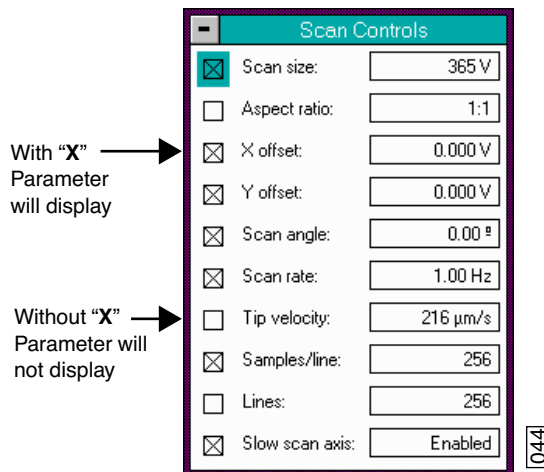
**Figure 8.1a** Select Show All Items



2. Ensure there is a “X” in the check box to the left of all parameters.

**Note:** Those parameters without a X will not display in normal Realtime mode.

**Figure 8.1b** Enable Parameters



3. Click the “minus box”  in the upper left corner of the panel, and click **Show all items**. The panel will once again appear in normal Realtime mode.

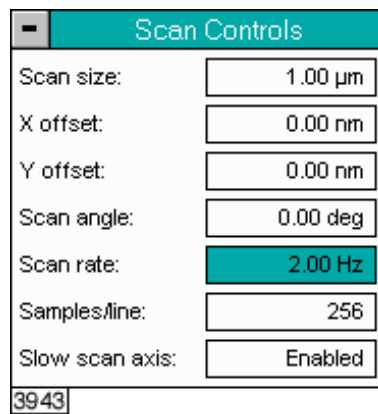
## 8.1.9 Set Initial Scan Parameters

### Scan Controls Panel

In the **Scan Controls** panel, set the following initial scan parameters (see [Figure 8.1c](#)).

1. Set the **Scan Rate** to **2 Hz**.
2. Set the **Scan Size** to **1  $\mu\text{m}$** .
3. Set the **Scan Angle** to **0**.
4. Set **X** and **Y Offsets** to **0**.

**Figure 8.1c** Suggested Scan Controls Settings



The image shows a software window titled "Scan Controls" with a teal header. It contains several input fields with the following values: Scan size: 1.00  $\mu\text{m}$ ; X offset: 0.00 nm; Y offset: 0.00 nm; Scan angle: 0.00 deg; Scan rate: 2.00 Hz (highlighted in teal); Samples/line: 256; Slow scan axis: Enabled. A small box with the number "3943" is located at the bottom left of the panel.

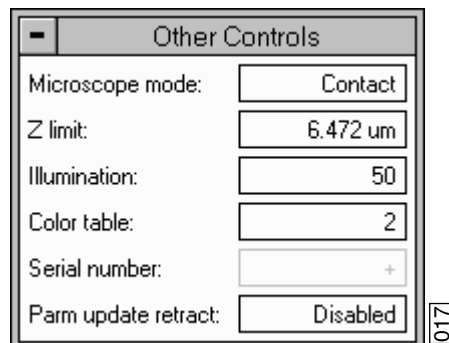
Scan size:	1.00 $\mu\text{m}$
X offset:	0.00 nm
Y offset:	0.00 nm
Scan angle:	0.00 deg
Scan rate:	2.00 Hz
Samples/line:	256
Slow scan axis:	Enabled

3943

### Other Controls Panel

Keep the **Z limit** at its maximum value.

**Figure 8.1d** Suggested Other Controls Settings



The image shows a software window titled "Other Controls" with a grey header. It contains several input fields with the following values: Microscope mode: Contact; Z limit: 6.472  $\mu\text{m}$ ; Illumination: 50; Color table: 2; Serial number: +; Parm update retract: Disabled. A small box with the number "017" is located at the bottom right of the panel.

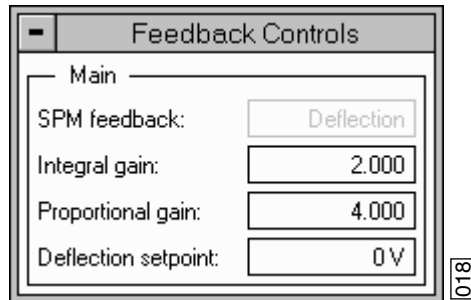
Microscope mode:	Contact
Z limit:	6.472 $\mu\text{m}$
Illumination:	50
Color table:	2
Serial number:	+
Parm update retract:	Disabled

017

### Feedback Controls Panel

1. Set the **Integral gain** to **2.0** and the **Proportional gain** to **4.0** (see Figure 8.1e).
2. Set the **Deflection Setpoint** to **0V**.

Figure 8.1e Suggested Feedback Controls Settings



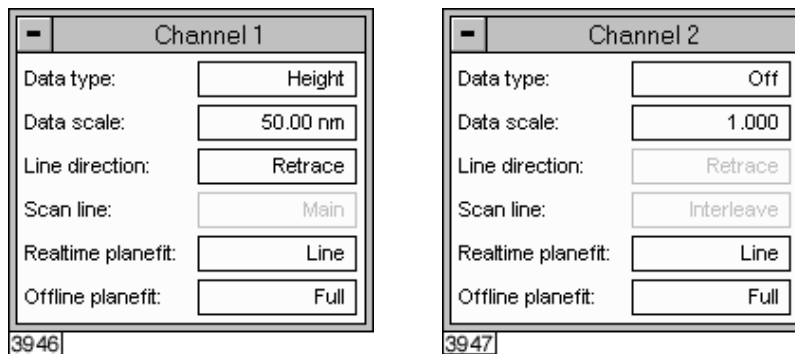
### Channel Panels 1 and 2

1. In the **Channel 1** panel, set **Data type** to **Height** (see Figure 8.1f).
2. Set **Data scale** to a reasonable value for the sample.

**Note:** For example, for a 200nm step height calibration sample, a reasonable Data scale setting is 300nm initially.

3. Set **Line direction** to either **Trace** or **Retrace**.
4. On the **Channel 2** panel, verify **Data type** is set to **Off** to disable the panel.

Figure 8.1f Suggested Channel Controls Settings





### 8.1.10 Engage

1. Select **Motor > Engage**. A pre-engage check begins, followed by Z-stage motor motion.
2. To move to another area of the sample, execute a **Withdraw** command to avoid damaging the tip and scanner.
3. Move the stage using the trackball to the next area of interest on the sample.
4. Select **Motor > Engage**.

**Note:** After the tip engages, adjust the control panel values to provide the desired scan parameters.

## 8.2 Advanced Atomic Force Operation

Although a great deal can be accomplished with basic knowledge of AFM operation, there is far more to operating the AFM.

Cantilever selection is critical and becomes more important as tip and cantilever technology continues to develop. A clear understanding of the parameters in the Realtime control panel allows the user to tune the microscope to accommodate a wide variety of samples. This section provides more detailed information on the operation of the Dimension microscope in Contact Mode AFM.

### 8.2.1 Cantilever Selection

Two basic cantilever styles are available for Contact Mode AFM. Traditional triangular silicon nitride cantilevers have been used successfully for years. They are robust and relatively inexpensive. Etched silicon cantilevers with integral tips provide another scanning option. They have a higher aspect ratio and smaller end radius than the silicon nitride cantilevers (Model ESP).

**Note:** There are a wide variety of tips available for Contact Mode AFM. Check the tip buying guide on the Veeco website ([www.veeco.com](http://www.veeco.com)) for more information.

#### Silicon Nitride Cantilevers

Silicon nitride cantilevers for the Dimension 3100 SPM are available in two process variations: standard and sharpened. Sharpened silicon nitride cantilevers (Model DNPS) are almost identical in appearance to the standard silicon nitride cantilevers, but have a slightly sharper end at the very tip. Sharpened silicon nitride cantilevers are available by mail order through [www.veeco.com](http://www.veeco.com).

Each silicon nitride cantilever substrate includes four cantilever tips with different size and spring-constants. Two of the cantilevers on each substrate measure 115 $\mu$ m from the substrate to the apex of the triangular cantilever (referred to as 100 $\mu$ m cantilevers) while the remaining two cantilevers measure 193 $\mu$ m from the substrate to the apex of the triangular cantilever (referred to as 200 $\mu$ m cantilevers). Both cantilever lengths are available with wide legs and narrow legs; however,

thickness of both cantilevers are equal. The calculated spring-constant for each of the cantilever configurations is listed below in [Table 8.2a](#). These values are approximations and significant variability occurs. The tabulated values are used to approximate contact force unless more accurate values are measured by the user.

**Table 8.2a** Cantilever Spring Constants

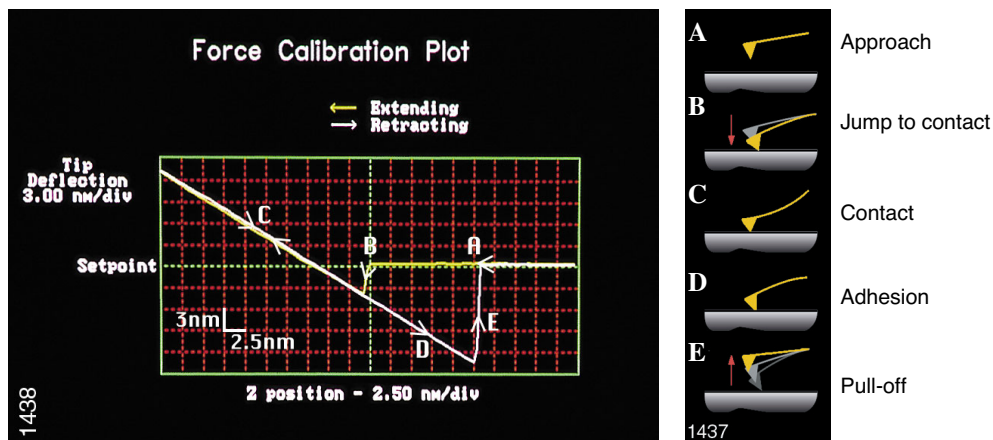
Cantilever Type	k (N/m) Narrow Legs	k (N/m) Wide Legs
100 $\mu$ m (triangular)	0.38	0.58
200 $\mu$ m (triangular)	0.06	0.12

The 100 $\mu$ m wide-legged cantilever are used on most samples. If the image degrades rapidly because the tip damages the sample surface, switch to a cantilever with a lower spring-constant. Cantilevers with smaller spring-constants are used on softer samples which are destroyed by imaging with high-contact forces.

### Etched Silicon Tips

Etched silicon tips have a higher aspect ratio and smaller end radius than the silicon nitride cantilevers. Because they are sharper, etched silicon tips provide better resolution and have less applied capillary forces. Most samples in air are covered by a thin layer of water and other condensed contaminants. These contaminants often form a capillary bridge between the tip and sample, generating large adhesive forces, also referred to as capillary forces (see [Figure 8.2a](#)). For more force curve information, see [Chapter 13](#).

**Figure 8.2a** Force Curve





**CAUTION:** Large offsets are not recommended between engage and disengage (2 volts) with etched silicon cantilevers in Contact Mode AFM (450 $\mu$ m long only) because breakage is likely.

**ATTENTION:** Il est recommandé de ne pas utiliser de forts décentremments pendant l'engagement et le désengagement des céramiques piézo-électriques (2 V) avec des pointes en silicium (longueur: 450 $\mu$ m) sous peine de destruction de celles-ci.

**VORSICHT:** Wir empfehlen, im Kontakt-Modus mit den geätzten Siliziumspitzen (nur mit den 450 $\mu$ m langen) keine großen Offsets zwischen engage und disengage-Zustand (2 Volt) zu haben, da diese sonst leicht brechen könnten.

**Note:** The smaller end radius of etched silicon tips creates greater force between the tip and sample. Therefore, etched silicon tips are not suggested for soft samples.

## 8.3 Optimization of Scanning Parameters

Careful selection of scan parameters is important in the successful application of Contact Mode AFM. In most cases, optimal parameter selection depends on the sample. It is beneficial to experiment with a range of values within each parameter, however, please review discussions of the scan parameters in the Realtime control panels in the *Command Reference Manual* before making bold changes. The following section analyzes the effects of the most important parameters.

### 8.3.1 Data Type

**Data type** is the first parameter set because the settings of other parameters depend on it. The **Data type** parameter in the **Channel** control panels selects the type of data collected by the system. **Height** data corresponds to the change in piezo height needed to keep the cantilever deflection constant. **Deflection** data comes from the differential signal off of the top and bottom photodiode segments relative to the **Deflection Setpoint**.

The scan parameters required to collect accurate height data are different from the optimal parameters for deflection data. To collect height data, the feedback gains must be high so that the tip tracks the sample surface with minimal cantilever deflection. The position of the piezo during the scan reflects the height of the sample. To collect accurate topographical data, set the **Data type** parameter to **Height**. Topographical **Deflection** data is only reasonable on very smooth, flat samples. Topographical **Deflection** data is used infrequently and only for high resolution work.

Collect **Deflection** data with low feedback gains to ensure the piezo remains at a constant position relative to the sample. In this case, the tip and cantilever are deflected by the features on the sample surface. The output fluctuations in the cantilever deflection voltage from the top and bottom photodiode segments are recorded as a measure of the variation in the sample surface. **Deflection** data is not automatically calibrated in units of distance. You must measure the sensitivity using the procedures discussed in [Chapter 13](#).

**Deflection** data collected with high feedback gains essentially equals the derivative of the height. This is commonly referred to as the error-signal. The error-signal provides a sensitive edge-detection technique and can be very helpful in visualizing fine details in topography that are difficult to see in regular height data. Using two channels, you must capture both height and deflection data simultaneously. **Deflection** (error-signal) data alone does not yield quantitative height information.

### 8.3.2 Gain Settings

The **Integral**, **Proportional**, and **LookAhead** gains in the **Feedback Controls** panel determine the feedback on the piezo height. The feedback loop keeps the deflection signal constant by adjusting the height of the piezo tube. If the gains are high, as they should be for **Height** data, the piezo height changes to keep the cantilever deflection nearly constant. If the gains are low, as they should be for topographical **Deflection** data, the cantilever deflects from its nominal position as it encounters features in the sample.

In general, set the gain settings as follows:

1. Set the **Integral** and **Proportional gains** to **2-3** to start scanning.
2. To optimize the gains for **Height** data, increase the **Integral gain** until the piezo begins to oscillate, then eliminate the oscillations by reducing the gain with 2-3 clicks of the left arrow key.
3. Repeat the process for the **Proportional gain**.

**Note:** Piezo oscillations typically cause high frequency wavy lines in the Realtime image. Piezo oscillations are more easily observed in **View > Scope Mode**.

4. For **Deflection** data, engage the microscope with the gains high, then lower them as much as possible without losing contact with the sample once the system begins scanning.
5. Set the **LookAhead gain** to **0.7** initially for samples with step-like features oriented perpendicular to the fast scan direction. Otherwise, it should be left at 0.00.

**Note:** The **LookAhead gain** includes information from the previous scan line to determine the current gain setting.

### 8.3.3 Scan Size and Scan Rate

In general, decrease the **Scan rate** as the **Scan size** increases. Use scan rates of **1.5 - 2.5 Hz** for large scans on samples with tall features. High scan rates help reduce drift, but use high scan rates only on flat samples with small scan sizes. When first using the system, vary the scan rate enough to observe a change in the image quality.

### 8.3.4 Setpoint

The **Setpoint** parameter defines the desired voltage (and, therefore, the desired deflection or force of the cantilever) for the feedback loop. The setpoint voltage constantly compares to the present vertical deflection signal of the photodiode to calculate the desired change in the piezo position. When the gain values are high, and when the **Data type** is set to **Height**, the Z piezo position changes to keep the photodiode output signal close to the **Setpoint**; therefore, the cantilever deflection remains nearly constant.

Adjust the **Setpoint** to increase or decrease the cantilever deflection and, therefore, the contact force of the tip on the sample. The **Force Calibration** command in the **Realtime > View** menu allows you to adjust the setpoint while viewing a graph of the tip position versus the deflection voltage. Using this procedure, described in detail in [Chapter 13](#), minimizes the contact force of the tip on the sample. This is especially important on soft materials such as biological samples.

### 8.3.5 Lowpass Filter

The **Lowpass filter** invokes a digital, one-pole, lowpass filter to remove high-frequency noise from Realtime data. The filter operates on the collected digital data regardless of the scan direction. Settings for this item range from **Off** through **9**. **Off** implies no lowpass filtering of the data, while settings of **1** through **9**, successively, lower the cut-off frequency of the filter applied to the data stream. The standard setting is **Off**.

### 8.3.6 Highpass Filter

The **Highpass filter** parameter invokes a digital, two-pole, highpass filter to remove low frequency effects such as ripples caused by torsional forces on the cantilever when the scan reverses direction. As with the **Lowpass filter**, the **Highpass filter** also operates on the digital data stream regardless of scan direction. This parameter can be **Off** or set from **1** through **9**. Settings of 1 through 9, successively, lower the cut-off frequency of the filter applied to the data stream. Note that in removing low frequency information from the image, the **Highpass filter** distorts the height information in the image. As a result, this filter must be **Off** when accurate height information is desired. The **Highpass filter** is typically used only for atomic images.

## 8.4 Force Calibration Mode

The **Force Calibration** command in the **View > Force Mode > Calibration** menu allows you to check the interaction between the cantilever and the sample surface. For detailed information regarding **Force Calibration**, see [Chapter 13](#).

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# Chapter 9 TappingMode AFM

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This chapter details procedures for operating the Dimension 3100 SPM in TappingMode in air. For information regarding TappingMode in fluids, see [Chapter 10](#). For information regarding loading a TappingMode tip and aligning the SPM laser see [Chapter 7](#) of this manual. Additional information regarding cantilever preparation is provided in [Chapter 6](#).

This chapter addresses the following:

- **Principles of TappingMode:** [Section 9.1](#)
- **Basic TappingMode AFM Operation:** [Section 9.2](#)
  - **Select Mode of Operation:** [Section 9.2.1](#)
  - **Head, Cantilever and Sample Preparation:** [Section 9.2.2](#)
  - **Align Laser:** [Section 9.2.3](#)
  - **Adjust Photodetector:** [Section 9.2.4](#)
  - **Locate Tip:** [Section 9.2.5](#)
  - **Focus Surface:** [Section 9.2.6](#)
  - **Cantilever Tune:** [Section 9.2.7](#)
  - **Show All Items:** [Section 9.2.8](#)
  - **Set Initial Scan Parameters:** [Section 9.2.9](#)
  - **Engage:** [Section 9.2.10](#)
  - **Optimize Scan Parameters:** [Section 9.2.11](#)
- **Withdraw the Tip:** [Section 9.3](#)
- **Advanced TappingMode AFM Operation:** [Section 9.4](#)
  - **Resonating Techniques:** [Section 9.4.1](#)
  - **Cantilever Oscillation:** [Section 9.4.2](#)

- **Decreasing the Cantilever Drive Frequency:** [Section 9.4.3](#)
- **Optimization of Scanning Parameters:** [Section 9.4.4](#)
- **Data Type:** [Section 9.4.5](#)
- **Gain Settings:** [Section 9.4.6](#)
- **Scan Size, Scan Rate, and Setpoint:** [Section 9.4.7](#)
- **Surface Tune:** [Section 9.4.8](#)
- **Troubleshooting:** [Section 9.5](#)
  - **Frequency Response Plot:** [Section 9.5.1](#)
  - **Engaging the Sample:** [Section 9.5.2](#)
  - **Cantilever Will Not Tune:** [Section 9.5.3](#)

## 9.1 Principles of TappingMode

[Figure 9.1a](#) depicts a cantilever oscillating in free air at its resonant frequency. A piezo stack excites the cantilever substrate vertically, causing the cantilever to move up and down. As the cantilever moves vertically, the reflected laser beam, or “return signal,” deflects in a regular pattern over a photodiode array, generating a sinusoidal, electronic signal.

**Figure 9.1a** Tapping Cantilever in Free Air

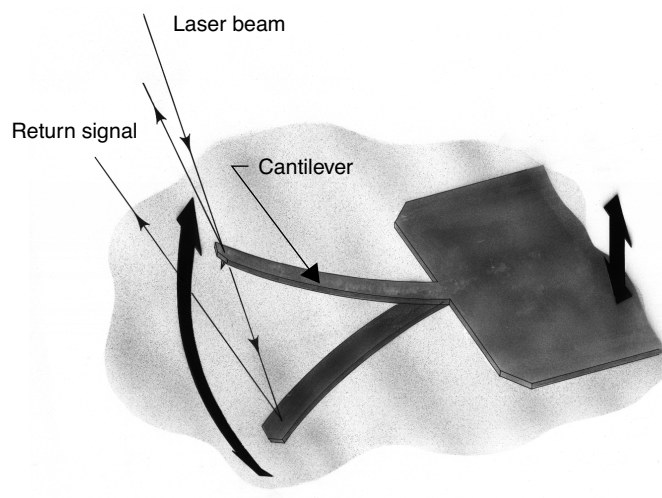
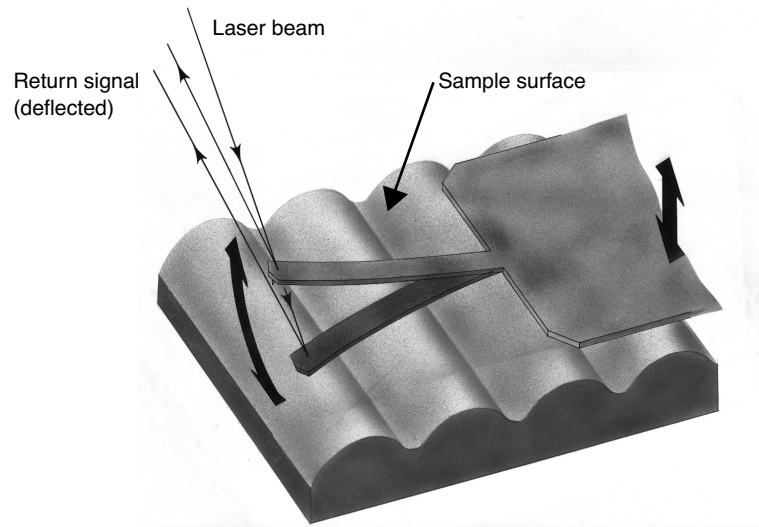




Figure 9.1b represents the same cantilever at the sample surface. Although the piezo stack continues to excite the cantilever substrate with the same energy, the tip deflects in its encounter with the surface. The reflected laser beam reveals information about the vertical height of the sample surface and characteristics of the sample material itself. These material characteristics include elasticity, magnetism, and presence of electrical forces.

**Figure 9.1b** Tapping Cantilever on Sample Surface



**Note:** Deflection of the cantilever and return signal are exaggerated in the figure for illustrative purposes.

## 9.2 Basic TappingMode AFM Operation

The following is a general outline of basic operational procedures involved in TappingMode AFM. For more detailed instructions, refer to [Chapter 7](#) of this manual.

### 9.2.1 Select Mode of Operation

- Select **Microscope > Profile**.
- Select **TappingMode** as the mode of operation.

## 9.2.2 Head, Cantilever and Sample Preparation

- Install an etched single crystal silicon tip onto an AFM cantilever holder (see [Chapter 7](#)).
- Load the cantilever holder with installed tip onto the scanner tube of the Dimension SPM head.


## 9.2.3 Align Laser

- Align the laser using the laser control knobs (see **Align Laser:** [Section 9.2.3](#) for more detailed instructions).
- Verify the laser beam is positioned on the back of the cantilever, with a spot visible in the Dimension head filter screen and a sum signal of at least **1V**.

## 9.2.4 Adjust Photodetector

1. Adjust the photodetector so that the red dot moves toward the center of the Dimension head filter screen using the two photodetector adjustment knobs located on the left side of the Dimension head.
2. Verify that the red dot is centered and elliptical in shape in the Dimension head filter screen.
3. Set the **Vertical Deflection** to **0V**.

## 9.2.5 Locate Tip

1. Select **Stage > Locate Tip** or click the **Locate Tip** icon. 
2. Center the tip end of the cantilever under the crosshairs using the two optics adjustment knobs located left of the optical microscope objective.
3. Use the trackball with the bottom left button depressed to focus on the tip end of the cantilever.


**Note:** You may need to adjust the illumination and zoom to clearly see the probe.

## 9.2.6 Focus Surface



**CAUTION:**


Use caution when focussing on the sample surface. Moving the head too quickly while focussing can cause the tip to crash, which may damage the tip and/or sample.

1. Select **Stage > Focus Surface** or click the **Focus Surface** icon. 
2. In the **Focus On** box, select **Choose either surface** or **Tip reflection**. If the sample is very flat or reflective, choose **Tip reflection**.
3. Focus on the sample surface using the trackball with the bottom left button depressed.

**Note:** You may need to adjust the illumination and zoom to clearly see the probe.

## 9.2.7 Cantilever Tune

This section describes the steps required to find the resonance peak of the cantilever and adjust the oscillation voltage so the cantilever vibrates at an appropriate amplitude. A range of oscillation frequencies are applied to the cantilever to determine the frequency which produces the largest response (the resonant frequency). In most instances, the resonant peak has a sharp Gaussian distribution but at times the peak can be ragged. The system tolerates some deviation in the shape of the peak.

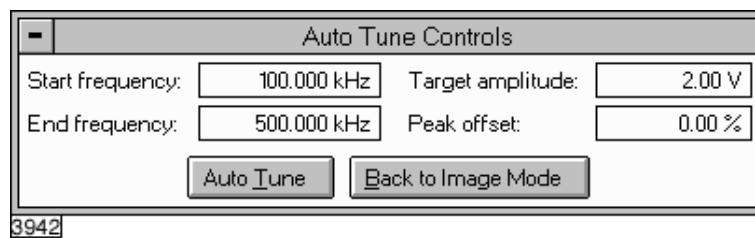
- Select **View > Sweep > Cantilever Tune**, or click on the **Cantilever Tune** icon.  The initial **Cantilever Tune** panel appears with the **Frequency Sweep** (a plot of cantilever response as a function of applied oscillation frequency) on the display monitor.
- Choose either the manual or automatic tuning method (see [Automatic Tuning](#) and [Manual Cantilever Tuning](#)).

## Automatic Tuning

For most purposes, the **Auto Tune** function will suffice.

- Verify the starting parameters. The nominal resonant frequency of a probe can be found on the probe box label. Ensure the start and end frequencies correlate with this value.
- Click **Auto Tune**. The computer and controller begin automatic tuning (see [Figure 9.2a](#)).

**Figure 9.2a** Auto Tune Control Panel



## Manual Cantilever Tuning

With Force Modulation or Fluid Tapping applications, it may be useful to tune the cantilever manually.

**Note:** More than one type of cantilever exists. Cantilevers can have different dimensions and different resonant frequencies. Certain parameter values, particularly the center frequency and the sweep width used in the following example, apply to a particular cantilever type. In the following example, nominal parameter values will vary depending on the actual cantilever used.

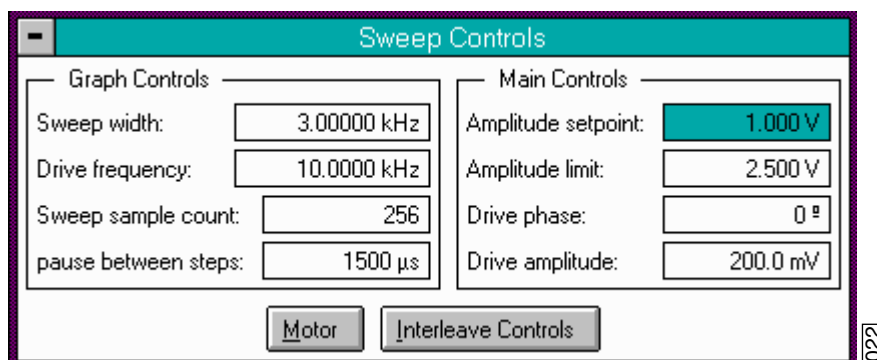
1. In the **Cantilever Tune** panel, set the **Drive frequency** parameter to a value near the center of the resonant frequencies range specified for the wafer. For example, if the frequency range is specified as 240—420 KHz, select a drive frequency of **330 KHz**.
2. Set the **Drive amplitude** to **200 mV**.
3. Set the **Sweep Width** to the same value as the **Center Frequency**.
4. The **Sweep Width** must be large enough to cover the frequency range specified for the wafer.
5. Zero the **Setpoint**.
6. Set the **Amplitude limit** to **2.5V**.
7. Center the peak on the frequency sweep plot shown on the display monitor using the **Zoom In** and **Offset** commands after identifying the maximum amplitude peak with the lowest frequency in the frequency response plot.

**Note:** The **Offset** command sets the center frequency equal to the cursor position to shift the plot. The **Zoom In** command decreases the sweep width and shifts the center frequency value to stretch the plot.

8. Increase the **Setpoint** until the peak appears.
9. Continue to **Zoom In** and center the peak until the peak coincides with the vertical center line within **10 Hz**. The value displayed for center frequency is now used as the resonant frequency of the cantilever.

**Note:** The system works well in TappingMode if the center frequency is at, or below, the peak in the resonance plot. The center frequency can decrease to the point where the oscillation amplitude reaches 90 percent of the maximum value. Operate at a frequency lower than the resonant frequency to avoid shifting the resonant frequency upon approach of the tip to the surface (see [Figure 9.2c](#)).

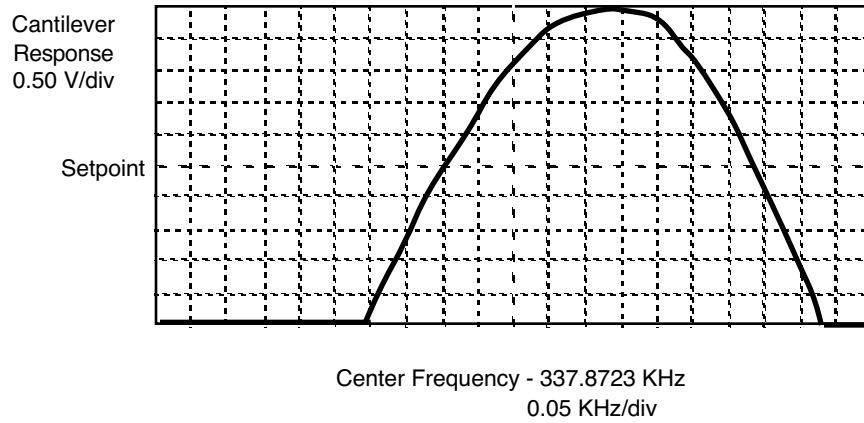
**Figure 9.2b** Cantilever Tune Control Panels for Main Controls



10. Specify the **RMS amplitude** after tuning the cantilever to its resonant frequency. The desired operating amplitude depends on the sample and other scanning conditions.

**Figure 9.2c** Cantilever Tune Frequency Sweep

## Frequency Sweep



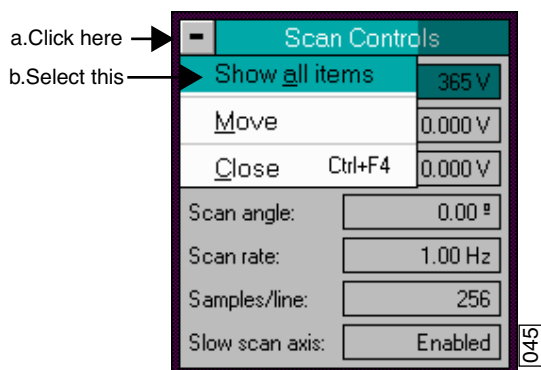
11. Click **OK**. The parameters set in the **Cantilever Tune** control panel appear in the **Realtime** control panel.
12. Click on **CANCEL** to exit the **Cantilever Tune** command and leave the parameters unchanged.

## 9.2.8 Show All Items

Before changing any parameters, you should display all of the available parameters. If you cannot view a parameter in a panel, you might need to enable this parameter.

1. Click the “minus box”  in the upper left corner of the panel, and click **Show all items**.

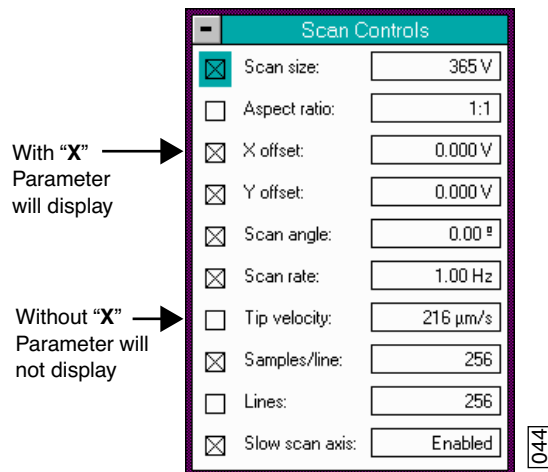
**Figure 9.2d** Select Show All Items



2. Ensure there is a “X” in the check box to the left of all parameters.

**Note:** Those parameters without a X will not display in normal Realtime mode.

**Figure 9.2e** Enable Parameters



3. Click the “minus box”  in the upper left corner of the panel, and click **Show all items**. The panel will once again appear in normal Realtime mode.

## 9.2.9 Set Initial Scan Parameters

### Scan Controls Panel

In the **Scan Controls** panel, set the following initial scan parameters (see [Figure 9.2f](#)).

1. Set the **Scan Rate** to **2 Hz**.
2. Set the **Scan Size** to **1 $\mu$ m**.
3. Set the **Scan Angle** to **0**.
4. Set **X** and **Y Offsets** to **0**.

**Figure 9.2f** Suggested Scan Controls Settings

Scan Controls	
Scan size:	1.00 $\mu$ m
X offset:	0.00 nm
Y offset:	0.00 nm
Scan angle:	0.00 deg
Scan rate:	2.00 Hz
Samples/line:	256
Slow scan axis:	Enabled

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### Other Controls Panel

Verify the **Z Limit** is at the maximum value.

**Figure 9.2g** Suggested Other Controls Settings

Other Controls	
Z limit:	5.104 $\mu$ m
FM igain:	40.00
FM pgain:	60.00
Units:	Metric
Color table:	2
Engage Setpoint:	1.00
Min. engage gain:	3.00

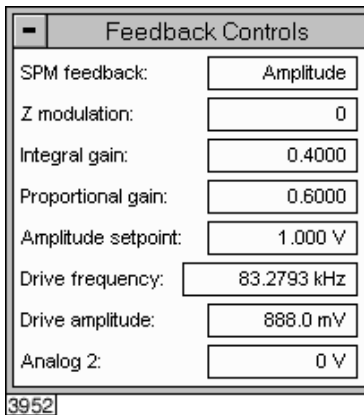
3951



### Feedback Controls Panel

- Set the **Integral gain** to **0.5** and the **Proportional gain** to **0.7** (see [Figure 9.2h](#)).
- Set the **Look Ahead gain** to zero.

**Figure 9.2h** Suggested Feedback Controls Settings



**Note:** The **Drive frequency** and **Drive amplitude** values were determined during the Cantilever Tune procedure. It is not necessary to enter a value for the **Amplitude setpoint**; this will be determined automatically during the engage process.

### 9.2.10 Engage

1. Select **Motor > Engage**. A pre-engage check begins, followed by Z-stage motor motion.
2. To move to another area of the sample, execute a **Withdraw** command to avoid damaging the tip and scanner.
3. Move the stage using the trackball to the next area of interest on the sample.
4. Select **Motor > Engage**.

**Note:** After the tip engages, adjust the control panel values to provide the desired scan parameters. Refer to [Section 9.4.4](#) for scan parameter optimization.

5. After engaging, it may be necessary to recheck the Cantilever Tune parameters. Select **View > Sweep > Cantilever Tune**. In the **Tip Offset** box, enter **200nm** and click **OK**. Adjust the **Drive frequency** if necessary.

### 9.2.11 Optimize Scan Parameters

The procedure to optimize the scan parameters is similar to that of Contact Mode.

1. In the **Scan Controls** panel, set **Slow scan axis** to **Disabled**.
2. Select **View > Scope Mode**.
3. Observe the agreement between the trace and retrace lines. Adjust the **Scan rate**, **Gains**, and **Amplitude setpoint** to bring these two lines in to coincidence. A more detailed discussion of these parameters can be found in [Section 9.4](#).

## 9.3 Withdraw the Tip

1. Select **Withdraw** from the **Motor** menu. The SPM stops scanning, and ascends to the sample clearance height defined in the **SPM Parameters** menu.
2. Select the **Stage > Load New Sample** option to replace or move the sample.
3. Use the **Focus Surface** command to move the SPM up if you desire more clearance between the tip and sample.



**CAUTION:**

Never withdraw samples without verifying that the tip has adequate clearance during the entire sample removal sequence.

## 9.4 Advanced TappingMode AFM Operation

This section discusses the more subtle aspects involved in operating the Dimension 3100 in TappingMode.

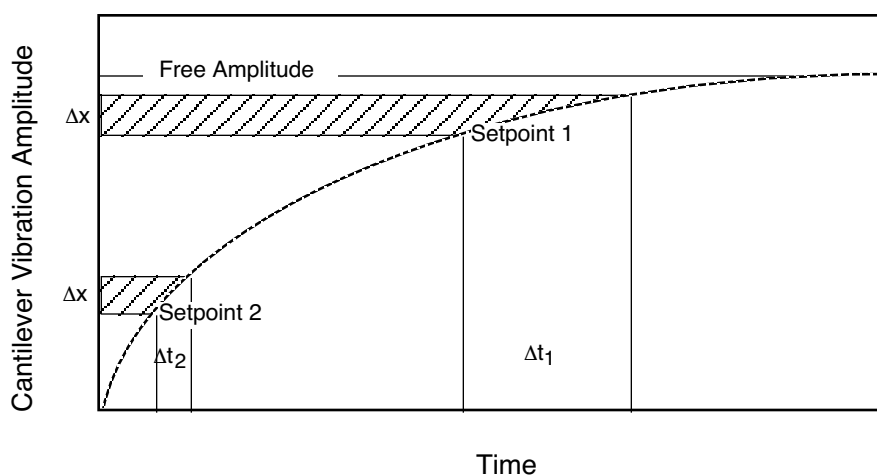
### 9.4.1 Resonating Techniques

Without a thorough understanding of principles associated with cantilever resonating techniques, you may generate distorted data. Understanding the **Cantilever Tune** process and the effects of real-time scan parameters is critical for effective operation of the microscope. It is also important to understand similarities and differences between **Force Calibration Mode in Contact AFM** and **Force Calibration Mode in TappingMode** (see [Chapter 13](#)).

### 9.4.2 Cantilever Oscillation

The response of the cantilever to inputs plays an important role in the operation of the Dimension 3100 SPM while in TappingMode. There is an important trade-off between the response time of the cantilever and the force applied to the sample. The cantilever does not respond instantly to perturbations in oscillation amplitude. The cantilever drive system pumps energy gradually into the cantilever oscillation. [Figure 9.4a](#) illustrates a typical response curve of the cantilever amplitude as a function of time. To demonstrate the conflicting requirements, the performance of the system is analyzed at two operating points.

**Figure 9.4a** Cantilever Response Curve



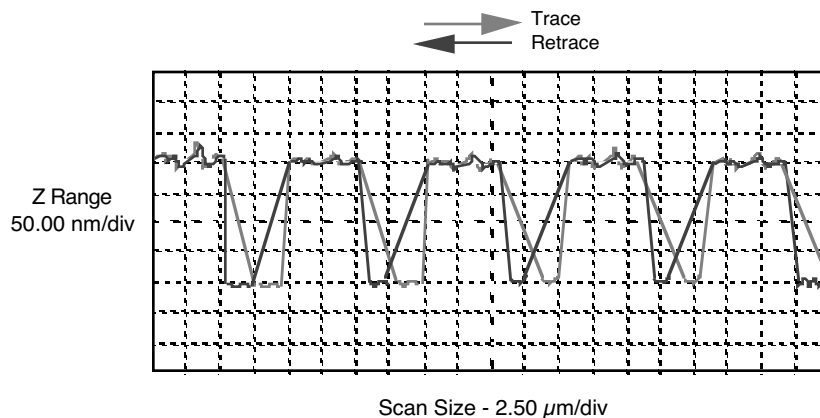
At Setpoint 1 the operating point is only slightly lower than the free oscillation amplitude. This has the advantage of dissipating very little energy to the sample surface. The disadvantage is that the system takes longer to recover from a given perturbation in the amplitude. Consider the situation where the tip travels off a step with a height of  $\Delta x$ . At Setpoint 1 it takes longer for the amplitude of the cantilever oscillation to increase; therefore, the feedback system is slow in responding to the error created by going off of the step. At operating Setpoint 2 the cantilever amplitude builds up

more rapidly. The feedback system senses the error caused by going off of the step and responds more rapidly. Unfortunately, more energy transfers to the sample surface while scanning at this operating point.

The nature of the sample influences the decision between response time and contact force. For example, harder samples can withstand higher contact forces, so the response time improves by lowering the **Setpoint amplitude**. Soft samples that are relatively flat should run with higher **Setpoint** values to reduce the energy imparted to the sample. In general, the solution to the problem is to decrease the scan rate and increase the feedback gains. In some situations, the feedback gains cannot increase without causing piezo oscillations; in such cases there is no choice but to reduce the scan rate.

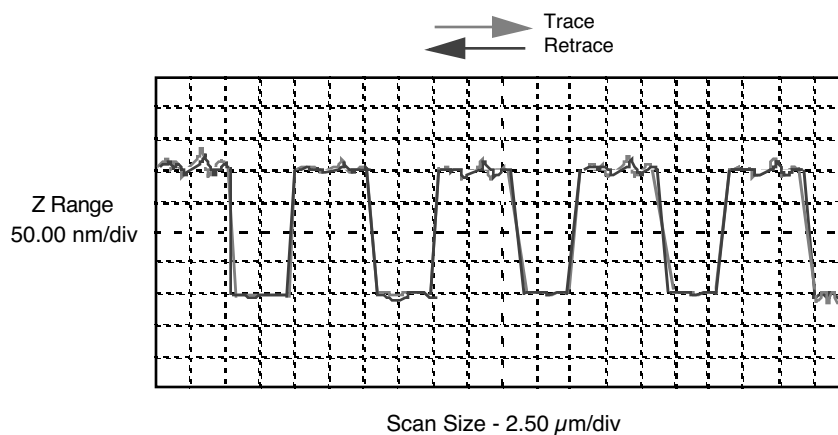
Inadequate response time typically occurs when the tip encounters a low point in the sample. The amplitude of the cantilever oscillation decreases very quickly when taller portions of the sample are encountered. As a result, the system response is markedly different depending on whether the tip is climbing or descending a feature in the sample. For this reason, **Scope Mode** is very useful when setting scan parameters. As the tip descends, features are evaluated by comparing the **Trace** and **Retrace** in **Scope Mode**. **Figure 9.4b** illustrates the effects of poorly selected scan parameters on a calibration standard that includes a series of sharp-walled pits. Regardless of the scan direction, the tip does not track the wall of the pit when the tip encounters a pit. However, it does track the surface closely when moving out of the pit.

**Figure 9.4b** Scope Trace with High Scan Rate



**Figure 9.4c** depicts the same sample with a slight increase in the **Integral gain** and a twofold decrease in the **Scan rate**. The tip now tracks the surface when it descends into the pit as well as when it exits. The **Trace** and **Retrace** lines now coincide closely.

**Figure 9.4c** Scope Trace with Correct Scan Rate

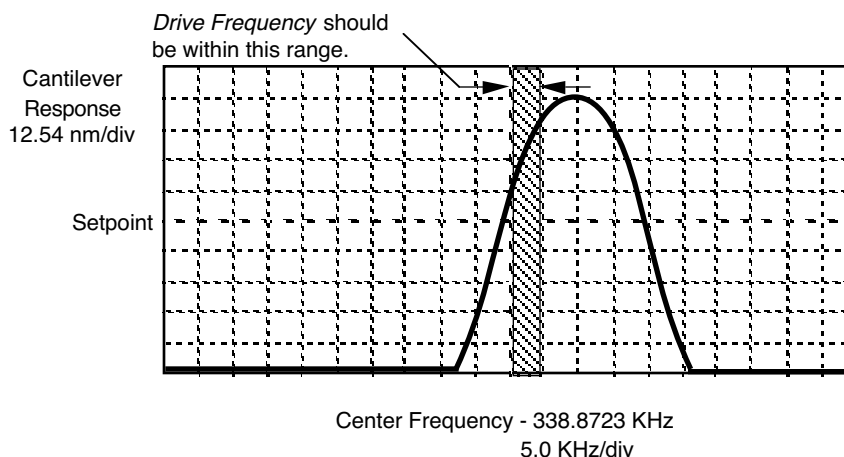


### 9.4.3 Decreasing the Cantilever Drive Frequency

The **Drive frequency** selected to oscillate the cantilever plays an important role in the performance of the microscope while in TappingMode. As a first step it is important to determine the resonant frequency of the cantilever, but the **Drive frequency** could be further tuned to improve scanning performance.

The microscope produces better data in TappingMode when the **Drive frequency** is set lower than the resonant peak of the cantilever. The **Drive frequency** is set such that it coincides with a 1-10 percent decrease in the oscillation amplitude by setting **Peak offset** in the **Auto Tune** controls to the desired percent. [Figure 9.4d](#) shows a suggested operating region. This is a suggestion based on our observations; users are encouraged to experiment with the microscope and decide what produces the best results.

**Figure 9.4d** Suggested Range of Drive Frequencies



#### 9.4.4 Optimization of Scanning Parameters

The user is encouraged to review [Section 8.3](#) which discusses parameter optimization for Contact AFM.

#### 9.4.5 Data Type

**Data type** is the first parameter to set because the values of other parameters depend on it. The **Data type** parameter in the **Channel 1**, **Channel 2** and **Channel 3** panels selects the type of data collected by the system. **Height** data corresponds to the change in piezo height needed to keep the amplitude of the cantilever constant. **Amplitude** data measures the change in amplitude relative to the amplitude setpoint.

The scan parameters required to collect good **Height data** are different than the optimal parameters for **Amplitude data**. To collect **Height data** while tracking the sample surface with minimal change in the tip's oscillation amplitude, the feedback gains must be high.



**CAUTION:**

Do not conduct TappingMode microscopy with low feedback gain values, as this will cause damage to both the tip and sample. The maximum amplitude of the cantilever oscillation is not sufficient to track tall features.

**Amplitude data** collected with high feedback gains is the derivative of the height. **Amplitude mode** provides a sensitive edge detection technique. With the dual screen mode it is possible to capture both **Height** and **Amplitude data** simultaneously.

#### 9.4.6 Gain Settings

The **Integral** and **Proportional gains** on the **Feedback Controls** panel must be high enough to force the feedback system to track the sample surface. When scanning in TappingMode, set the **Integral** and **Proportional gains** to lower values than those values used in Contact mode. The **Proportional gain** can usually be set 30%-100% higher than the **Integral gain**. To optimize the gains, increase the **Integral gain** until the piezo begins to oscillate (feedback oscillation usually occurs with **Integral gains** of 1-2), then eliminate the oscillations by reducing the gain with two or three clicks of the left arrow key. Repeat the process for the **Proportional gain**.

#### 9.4.7 Scan Size, Scan Rate, and Setpoint

The **Scan size**, **Scan rate**, and **Setpoint** values effect data output differently. As in Contact mode, decrease the **Scan rate** as the **Scan size** is increased. Use **Scan rates** of **0.5-1.0 Hz** for large scans on samples with tall features. High scan rates help reduce drift, but only use them on flat samples with small scan sizes.

The **Setpoint** parameter defines the desired voltage for the feedback loop. The **Setpoint** voltage is constantly compared to the present **RMS amplitude** voltage to calculate the desired change in the piezo position. When the gain values are high, as they should be when the **Data type** is set to **Height**, the Z piezo position changes to keep the amplitude voltage close to the **Setpoint**; therefore, the oscillation amplitude remains nearly constant.


As discussed above, changing the **Setpoint** alters the response of the cantilever oscillation and changes the amount of force applied to the sample surface.

The force applied by the tip on the sample increases as the setpoint is decreased. To minimize the force on the sample:

- Increase the setpoint using the right arrow key on the computer keyboard until the tip is no longer interacting with the surface. This can be observed by monitoring the trace and retrace lines in **View > Scope Mode**, and by monitoring the **Z Center Position** display in the Image Monitor. When the tip is no longer interacting with the surface, the Z Center Position will move to the retracted limit.
- Slowly decrease the setpoint using the left arrow key on the keyboard until features appear in the trace and retrace lines in **View > Scope Mode**.

The setpoint can also be adjusted by using **View > Force Mode > Calibrate**. Force calibration mode is used to compare the amplitude of the cantilever oscillation on the surface to the free-air amplitude. Other uses of Force Calibration include characterizing the forces on the cantilever tip, diagnosing the performance, and calibrating the RMS amplitude voltage as a function of the oscillation amplitude of the cantilever. The use of Force Calibration is described in [Chapter 13](#).

## 9.4.8 Surface Tune

It is often desirable to check the cantilever tune after engaging. You will notice that the **Cantilever Tune** icon  is grayed out when the tip is engaged. However, you can still access the **Cantilever Tune** panel by selecting **View > Sweep > Cantilever Tune**.

A warning appears indicating that cantilever tuning while engaged can result in damage to the tip or sample. This warning prompts you to enter a **Tip offset**. This is the distance above the sample that the tip will be raised before displaying the tuning spectrum. Use a minimum **Tip offset** of **100-200nm**.

Observe the plot of amplitude vs. driving frequency to see if the cantilever tuning curve shifted during the engagement. The drive frequency can be adjusted to compensate for such a shift by using the **Offset** command located above the **Cantilever Tune** plot. The phase response curve can be adjusted as well.

## 9.5 Troubleshooting

### 9.5.1 Frequency Response Plot

If a peak in the frequency response plot does not appear, perform the following steps:

1. Increase **Sweep width** to the maximum value.
2. Increase the **Drive amplitude** in intervals of 200-300mV until you have reached 2-3V.
3. If the peak still has not appeared, then increase the **Sweep width** by first increasing the **Center Frequency**, then maximizing the **Sweep width**. If there is still no peak on the response plot, check the laser alignment.

### 9.5.2 Engaging the Sample

If the engage aborts because the tip is still too far away from the surface, return to **Stage/Focus Surface** and use the trackball to relocate the surface. After successful re-engaging, a well formed image appears on the display monitor.

### 9.5.3 Cantilever Will Not Tune

If the Cantilever Tune fails, check the following:

- Ensure the laser is properly aligned at the free end of the cantilever (the end furthest from the substrate).
- Ensure there is good physical coupling between the probe and the probe holder. Make sure the groove the probe is held in is free of debris, and that the probe substrate is in firm contact with the back wall of the groove and is pushed firmly against one side of the groove.