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# NanoScope Software 6.13 User Guide

**Part Numbers**  
**004-132-000 (Standard)**  
**004-132-100 (Cleanroom)**

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Dimension™  
BioScope™  
Atomic Force Profiler™ (AFP™)  
Dektak®

**Software Modes:**

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Tapping™  
TappingMode+™  
LiftMode™  
AutoTune™  
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NanoScript™  
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**Miscellaneous:**

NanoProbe®

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# Chapter 1 New Features in NanoScope v6.13 Software

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## 1.1 Newly Supported Hardware

NanoScope v6.13 supports hardware that was formerly supported only by NanoScope v5.30. This includes:

- Torsion (TRmode).
- Electrochemistry including the Universal Bipotentiostat.
- EnviroScope (not including Auto Programs/recipes).
- Dimension Hybrid XYZ Scanning Probe Microscope Head.

See the appropriate manuals, *Support Note 402 TRmode*, *Support Note 390 Universal Bipotentiostat*, *Electrochemical SPM Manual*, *EnviroScope Manual* and *Support Note 394 Dimension Hybrid XYZ Scanning Probe Microscope Head* for details.

## 1.2 Windows XP Support

NanoScope v6.13 runs on Windows XP in addition to Windows NT and Windows 2000.

## 1.3 Additional New Features

Additional new features, described in the NanoScope v6.13 release notes, are included in this manual. These include:

- Single and batch Bitmap and jpeg export.
- Programmed move.
- Step and width analysis functions.

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New Features in NanoScope v6.13 Software  
**Additional New Features**

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# Chapter 2 Getting Started with NanoScope v6.13 Software

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The focus of this manual is the NanoScope software version 6.13. It is a reference to the tasks related to your NanoScope system. The material provides an overview (i.e., theory and applications), procedures, interface definitions and optimization tips.

Refer to the following sections to begin to understand the NanoScope software:

- **Installing the NanoScope Software:** [Section 2.1](#)
- **Getting to Know the NanoScope Software:** [Section 2.2](#)
- **Setting up the Workspace** [Section 2.3](#)
- **Quick Guide to a 4K Point Image:** [Section 2.4](#)
- **Using Online Help:** [Section 2.5](#)
- **Technical Support at Veeco:** [Section 2.6](#)

## 2.1 Installing the NanoScope Software

### 2.1.1 System Requirements



**CAUTION:**

Contact Veeco Technical Support (see **Contact Information** [Section 2.6.2](#)) before attempting to increase the RAM of your system. Failure to do so could cause irreparable damage to your system.

The 6.13 version of software requires the following:

- A minimum computer configuration of 1.7GHz (2.4GHz recommended)
- 512MB RAM (1GB recommended)
- G450 Video (G550 Video recommended)

### 2.1.2 Before You Install



**CAUTION:** Ensure you have backed up all critical data onto external media before installing the NanoScope 6.13 software.

1. If you are upgrading from a previous version of NanoScope, ensure you are starting with a working version. The settings from the working version will be used for the new version.
2. Note that some of the installation screen views may not appear, or may appear slightly different, depending on your particular system configuration.
3. Make sure you have downloaded and installed NS Toolbox. This is available on the NanoScope 6.13 CD or from the Veeco FTP site (contact Veeco for more information).
4. Make sure you are logged in as Administrator on the local workstation.

### 2.1.3 NanoScope 6.13 Installation

**Note:** Most systems are configured on the microscopes prior to delivery.

1. Insert the NanoScope 6.13 CD-ROM in your CD drive, open the CD-ROM files, open the v613 folder, and select the **Setup.exe** icon.



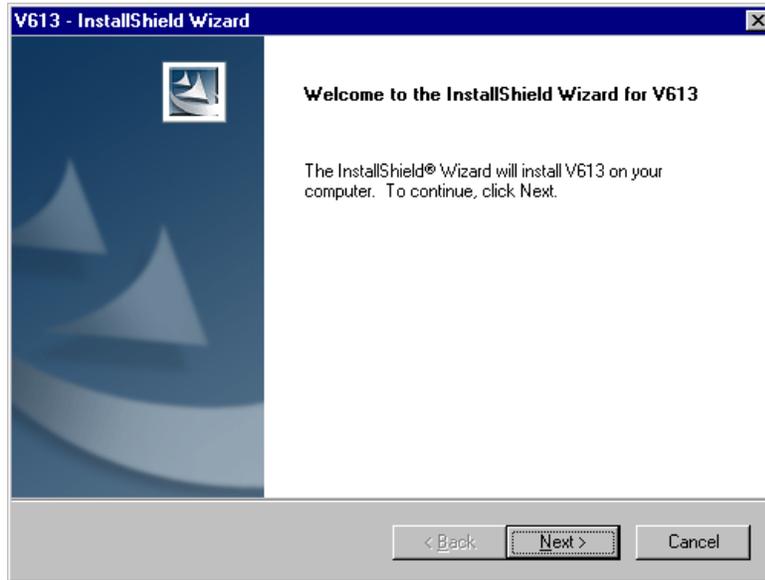
If you do not have Administrator privileges on your workstation, a WARNING will appear on the screen and installation will discontinue (see [Figure 2.1a](#)).

**Figure 2.1a** Administrator Warning



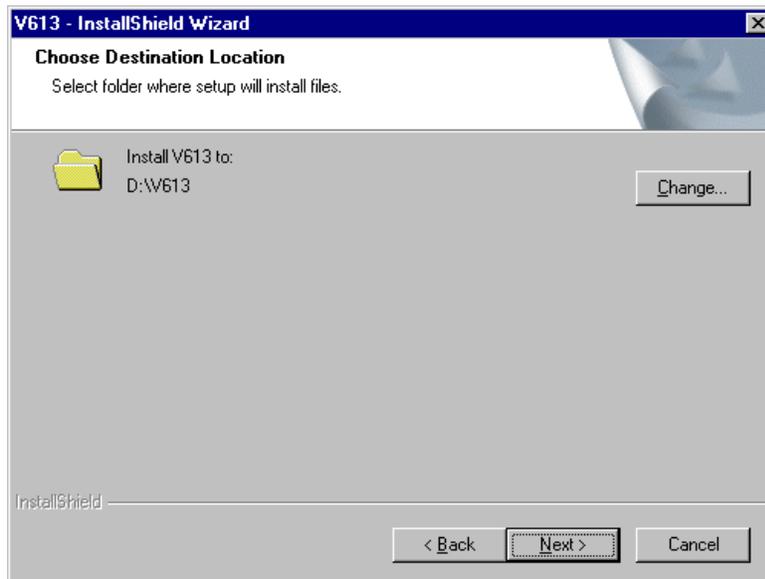
2. The **Welcome to NanoScope 6** dialog box will open (see [Figure 2.1b](#)). Click **NEXT**.

**Figure 2.1b** Welcome to NanoScope 6 Dialog Box



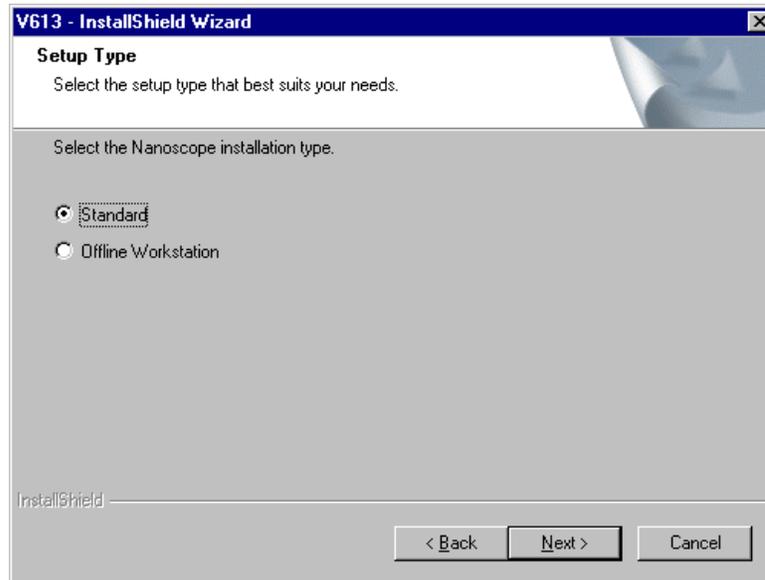
3. After choosing a destination location (see [Figure 2.1c](#)) click **NEXT**.

**Figure 2.1c** Destination Location Dialog Box



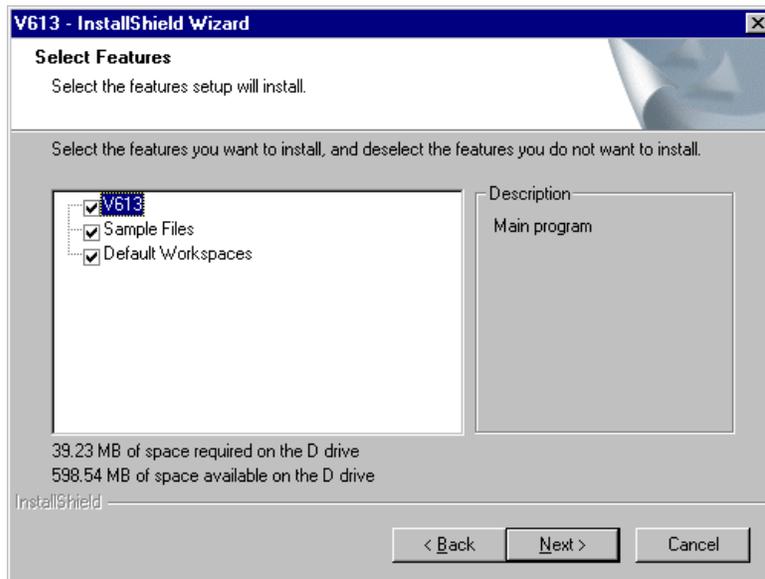
4. The **Installation Type** dialog box will open (see [Figure 2.1d](#)).

**Figure 2.1d** Installation Type Dialog Box



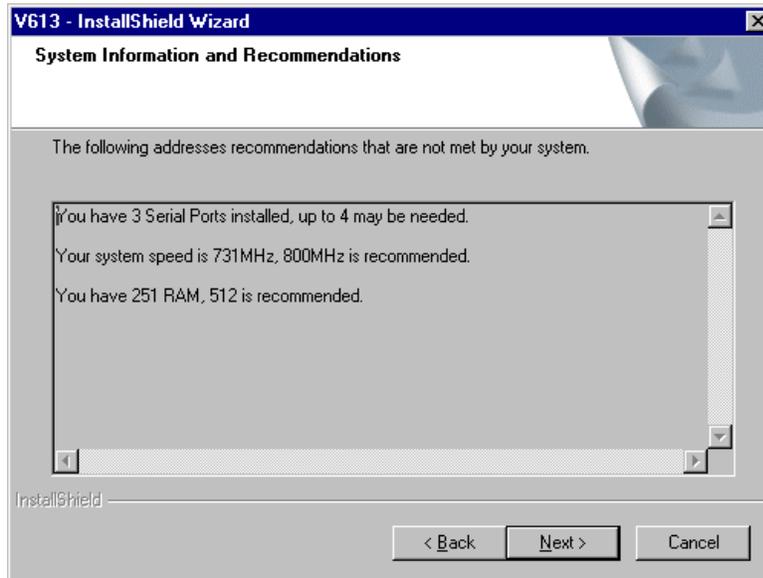
5. Select the features you wish to install:

**Figure 2.1e** Select Features Dialog Box



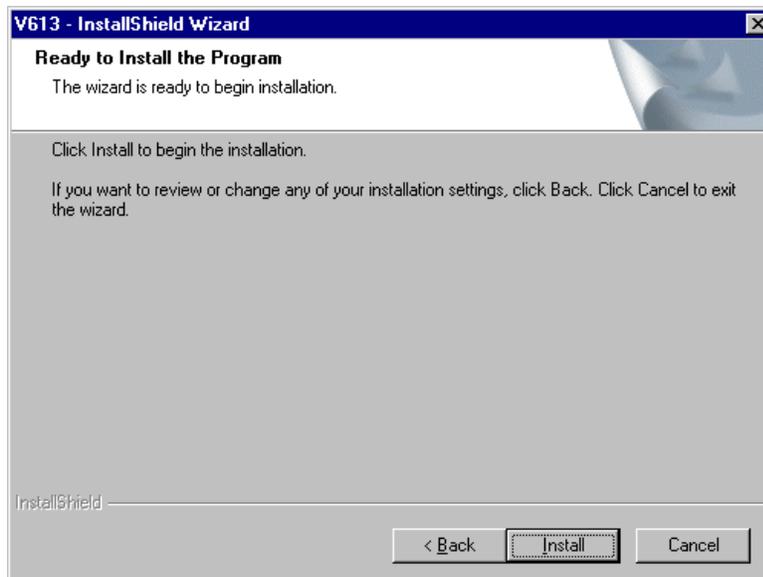
- The Install Shield Wizard will display system configuration and recommendations (see Figure 2.1f). Click **CANCEL** if you wish to change your configuration. Click **NEXT** to proceed.

**Figure 2.1f** System configuration and Recommendations Dialog Box



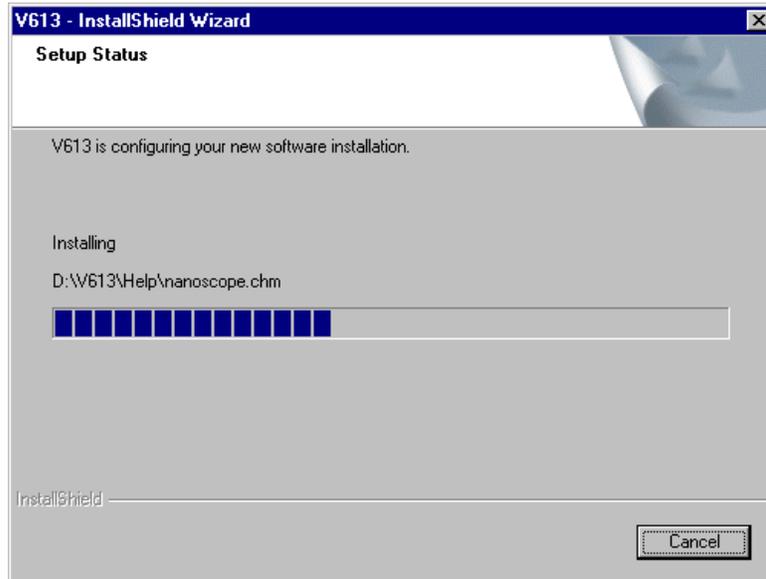
- The Ready to Install dialog box will display:

**Figure 2.1g** Ready to Install Dialog Box



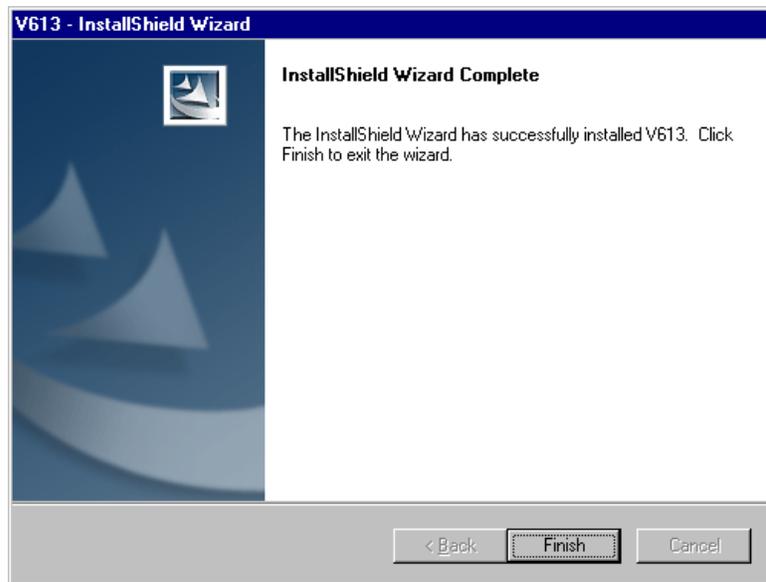
8. Installation of the NanoScope V6.13 software will then continue. A progress box, shown in Figure 2.1h, appears:

**Figure 2.1h** Progress Dialog Box



9. When the NanoScope V6.13 installation is complete, the following dialog box will appear:

**Figure 2.1i** Installation Complete Dialog Box



10. Click **FINISH** to complete the installation.

## 2.2 Getting to Know the NanoScope Software

Start the NanoScope software by double-clicking on the desktop shortcut labeled **NanoScope 6.13**.

### 2.2.1 Software Interface

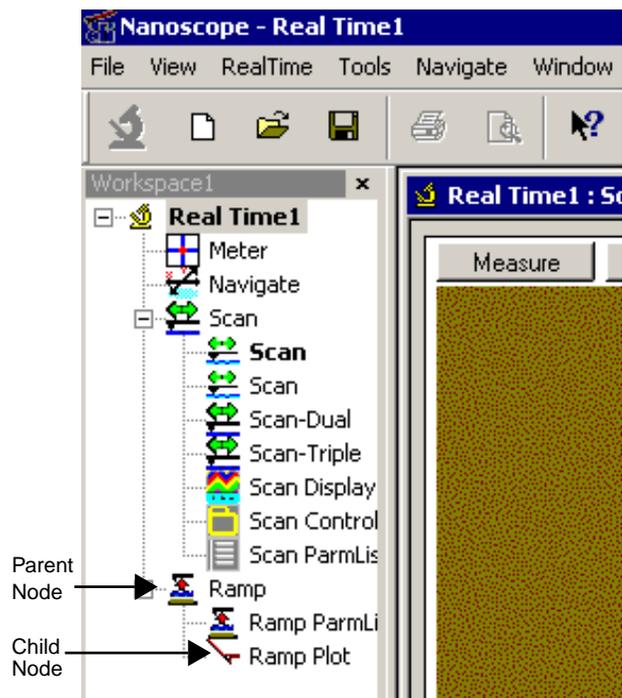
The NanoScope software contains two modes of operation: **Realtime** (i.e., all operations related to controlling of the microscope) and **Image Processing** or **Offline** (i.e., analysis and modification of captured images). In previous versions of NanoScope software, these modes were separate work environments. With version 6.13, both work environments have been combined into a “workspace.”

### 2.2.2 What is a Workspace?

A workspace is a configuration of views and parameters in the NanoScope software. Within the workspace window, the user configures a hierarchy of commands (i.e., nodes) for running the microscope and processing images. Auto programs are run in the order that commands are configured.

The behavior and appearance of the workspace window may be controlled using the **Workspace > Preferences** menu or by right-clicking in the workspace window.

Figure 2.2a Workspace Nodes



## Nodes

The top level node is known as the *parent node* and each node underneath is known as a *child node* (see [Figure 2.2a](#)). Parent nodes are usually the name for the microscope mode (e.g., Realtime) or a file name of an image within the workspace. Parent nodes are the higher level nodes for auto programs. Child nodes, also known as “views,” are typically associated with a window that is used to carry out an analysis, image processing, or Realtime control function of the software.

Each node may be renamed, deleted and grouped. Node names may be preceded by an icon and/or lines indicating the relative positions of nodes in the hierarchy.

### 2.2.3 The Main Screen Elements

<b>Workspace Window</b>	The left pane in the client window for viewing and configuring a series of views.
<b>Client Window</b>	A central window for viewing all Realtime graphical displays, input parameters, results parameters and graphs.
<b>Menu Bar</b>	A group of items for executing commands or viewing files.
<b>Toolbar</b>	A group of icons for executing commands or viewing dialog boxes to configure input parameters.
<b>Status Bar</b>	A read only list that displays the stage X, Y, Z coordinates and enabled functions (e.g., Capture: On).
<b>RT Status Window</b>	A dockable window in the client window displaying information about the sample during Realtime.
<b>Browse Window</b>	A dockable window in the client window for browsing files. Available in list or thumbnail format.
<b>Help Window</b>	A dockable window in the client window for displaying the Help screen.

### Start the NanoScope Software

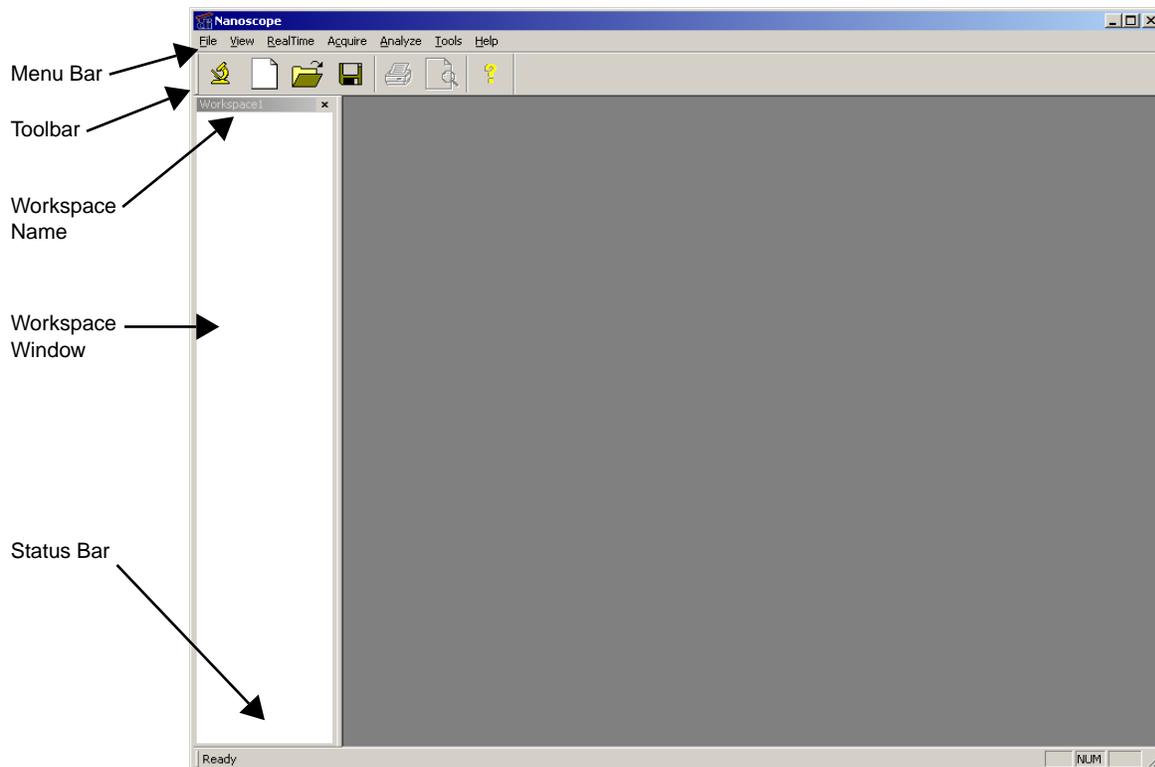
Complete the following to open the NanoScope software:



1. Double-click the desktop shortcut labeled **NanoScope 6.13**.
2. The default screen appears with menu items (**File**, **View**, **Help**, etc.), a blank workspace and a toolbar (see [Figure 2.2b](#)).

**Note:** Select **File > Open Workspace** to open a previously created workspace file.

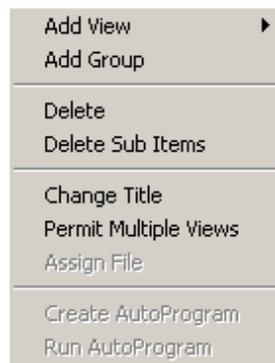
**Figure 2.2b** Screen Elements



## Functions Menu

The **Functions** menu is accessed by right-clicking on a parent node (i.e., Realtime or a filename). It includes specific elements for viewing multiple windows, renaming views, grouping views, and adding and deleting views. This menu also includes the command for running an Auto Program (i.e., **Run AutoProgram**) where the image processing commands may be run in a series on multiple images and results may be saved in a data file (see [Figure 2.2c](#)).

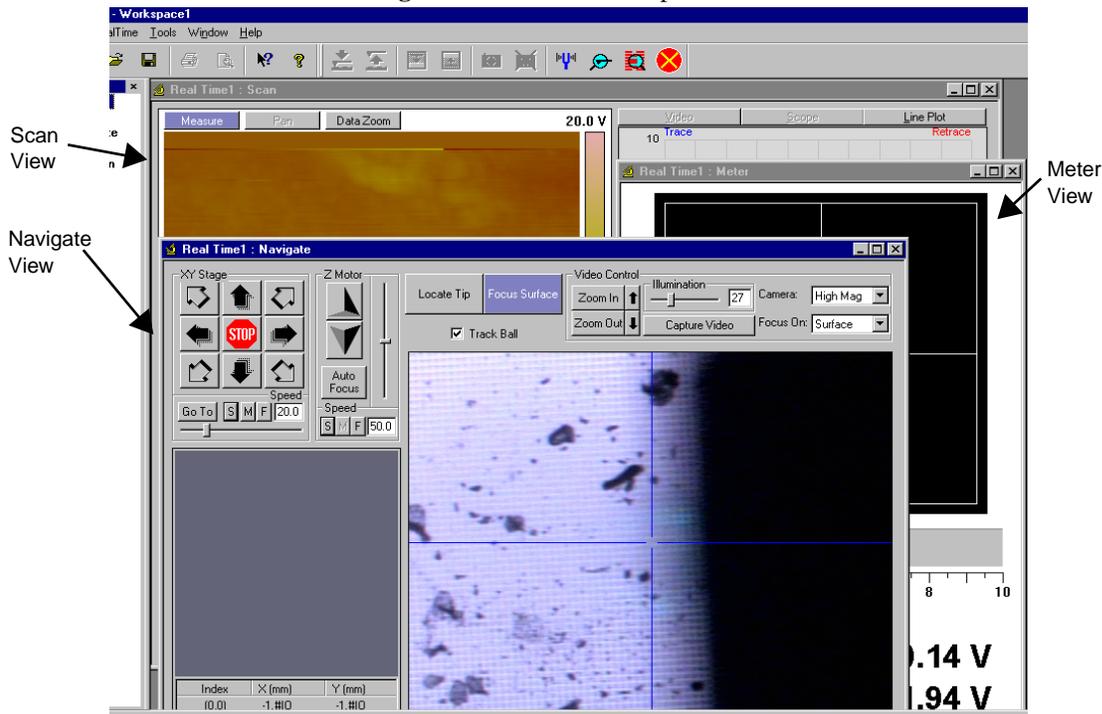
**Figure 2.2c** Functions Menu



## Menu Items

<b>Add View</b>	Accesses a submenu of Realtime or offline commands.
<b>Add Group</b>	Adds a <b>Group</b> node to the workspace for creating a defined set of commands.
<b>Delete</b>	Deletes the currently selected node in the workspace. If changes were made, a prompt appears to save the view.
<b>Delete Sub Items</b>	Deletes the items listed under the currently selected node in the workspace. If changes were made, a prompt appears to save the view.
<b>Change Title</b>	Allows for the selected view title to be changed.
<b>Permit Multiple Views</b>	Selecting this item allows for multiple views to appear in the client window (see <a href="#">Figure 2.2d</a> ).
<b>Assign File</b>	TBD
<b>Create Auto Program</b>	Allows you to create a new Auto Program based on analysis done on a node.
<b>Edit AP Attributes</b>	If the currently selected node is in Auto Program, this parameter allows you to edit the Auto Program properties.
<b>Run Auto Program</b>	Accesses the Auto Program Results view to run the selected image processing commands.

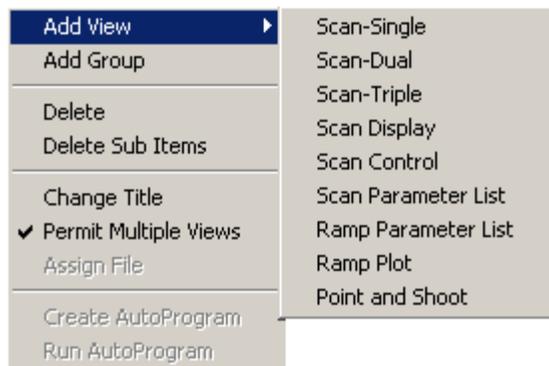
Figure 2.2d Permit Multiple Views



### Functions Submenu

The **Functions** submenu allows for adding new views to the workspace in the **Add View** command (see Figure 2.2e).

Figure 2.2e Realtime Workspace Functions Submenu



## Functions Submenu Items

The **Add View** submenu includes commands for running the microscope, analyzing and reporting. Selecting a command adds the item name and icon as a new child node to the workspace window. Click on a node to invoke the view in the client window.

Depending upon the microscope type and mode (i.e., Realtime, Image Processing and Profiler), each workspace has unique commands in the **Add View** submenu. For the Realtime functions **Add View** submenu, see [Figure 2.2e](#). For more detailed descriptions about the views, see [Chapter 3](#).

## Quick Key Commands

Many commands have **quick key** commands (series of keys to enter in place of using the mouse). You can open menus, access panels and execute commands with the keys or combination of keystrokes. In the NanoScope software, the quick keys are designated by an **underlined letter** in the command name (e.g., **R** is the quick key in Realtime).

To activate a quick key command, press the **Alt** button then the quick key, or select the command with the mouse and press the indicated quick key.

Quick keys only apply when in an *active* box, menu, panel or window that is currently visible on the screen. *Active* panels are designated in color with a highlight on the panel title or with a heavy frame around the panel.

## 2.2.4 Menu Bar Items

The initial menu bar includes: **File**, **View** and **Help** to begin the process of initializing and opening files in the client window. Once a workspace is open an expanded toolbar exists for running and configuring the microscope to scan or process images.

The menu items include:

- **File**—Accesses menu selections for opening, saving and printing files and documents.
- **View**—Accesses menu selections allowing to choose display properties.
- **Format**—Accesses menu selections for modifying NanoScope files.
- **Realtime**—Accesses menu selections to administer commands during data collection.
- **Acquire**—Accesses all Realtime Views.
- **Analyze**—Accesses all Offline Views.
- **Tools**—Accesses menu items for selecting and calibrating various settings.
- **Window**—Accesses menu selections for arranging windows.

- **Help**—Accesses menu items for initializing and displaying the help screen, a **Bug Report** dialog box to submit bugs/requests to Veeco, and NanoScope information about your system.

## 2.2.5 Cursor Types

Within captured images, it may be necessary to do analysis or modification on a selected area or exclude this area from the analysis. Cursors allow for specifying this information.

The cursor types are as follows:

- **Lines**—Selecting specific data (e.g., lengths of features or sectioning features) along the line.
- **Boxes**—Selecting specific areas on the display for including or excluding data.
- **Grid Markers**—Horizontal or vertical line cursors within histograms and spectrum graphs for choosing data ranges or making measurements.

### Using a Slider Cursor

In a graph or histogram, position the mouse with in the blank area between the axis and the edge of the graph and drag the slider along the graph to position the cursor. The mouse cursor will change to .

### Positioning a Line or Box Cursor

- Click and drag the image to draw a line or box cursor.
- To resize an existing line or box cursor, click and drag on a corner edge or end of the object. Cursor will change to  or .
- To move an existing object, click and drag the center of the object to the desired location. The cursor will change to .

## 2.3 Setting up the Workspace

### 2.3.1 Create or Open a Workspace

1. A workspace can be opened or created by selecting the following:

- **File > New Workspace.**
- **File > Open Workspace** and browse to open an existing workspace.
- **File >** Select the **Workspace Name** from the Recent files list.

**Note:** A new blank space will automatically display when version 6.13 is opened.



2. To begin Realtime operations, open a Realtime node. Select **Realtime > Start Realtime** or click the **NanoScope** icon.

A **Realtime** mode appears in the workspace, along with a dialog box allowing you to add views to the **Realtime** node.

### 2.3.2 Add Views and Configure the Workspace

1. Position the mouse on the **Realtime** icon and right-click to view the functions menu (see [Figure 2.3a](#)).
2. If one of the views (**Scan-Single**, **Scan-Dual**, or **Scan-Triple**) does not appear automatically, in the functions menu, select **Add View** and one of the scan views or click the **Scan** button.
3. Add the following views to your workspace to set up the hardware for scanning:
  - **Meter View**—for verifying the laser signal on the cantilever. (If desired, the Realtime Status Window can be opened in place of **Meter View**).
  - **Navigate View**—for setting the tip to sample focus, locate tip and stage alignment (not present for MultiMode).
4. Customize your workspace with any additional views using the same procedure as in [Step 2](#).

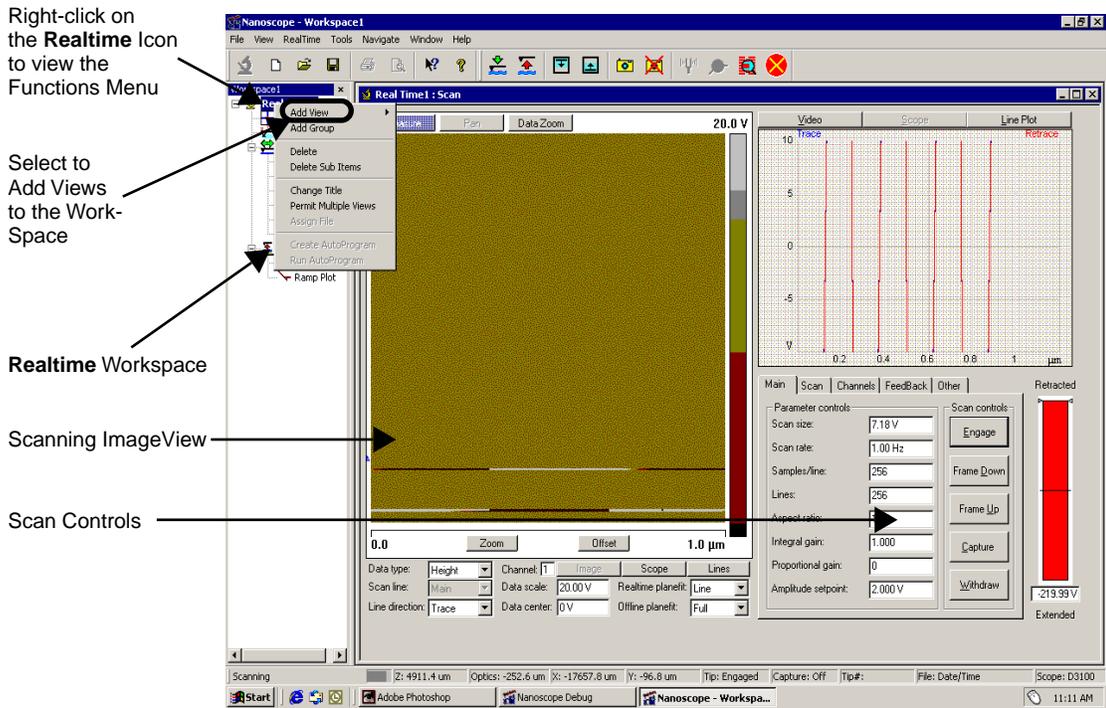
**Note:** In the **Functions** menu, select **Permit Multiple Views** for allowing several windows to display.

### 2.3.3 Multiple Users using NanoScope

The NanoScope computer can save multiple user preferences/settings in the computer registry. Once a user sets up an account on the computer, several settings are automatically saved for the user. These settings include:

- Previous image file type
- Previous directories
- Browse window settings
- Option to disable video while scanning
- Section View results to display
- Location of Abort dialog box
- Review curve settings
- Force Filter settings
- Help settings
- Script directory
- Track ball on
- Default Parameter dialog box location
- Point and Shoot View settings
- Sweep dialog box settings
- Workspace settings
- Image control settings
- Grid control settings
- Meter View control settings
- Color control settings
- Z center control settings

Figure 2.3a New Realtime Screen



## 2.4 Quick Guide to a 4K Point Image

The following procedures provide quick steps for using the NanoScope 6.13 software. Follow these steps to quickly scan a sample and then capture and analyze an image. Along the way, you'll see how the NanoScope 6.13 software works, learn some useful tricks, and find out how to learn more later.

If you have used the “classic” NanoScope software, you'll see that the new interface is Microsoft Windows-based.

**This section is not intended to teach a new user how to run an AFM, but only to introduce experienced users to V6.x.**

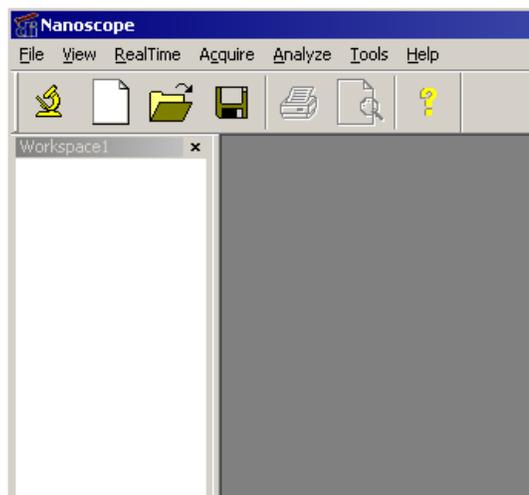
### 2.4.1 Starting the NanoScope Software

After the software installation is complete, you are ready to start the NanoScope software and add some views to the software workspace.



1. To start the NanoScope software, double-click the **NanoScope 6.13** startup icon on the computer desktop. You will see the NanoScope software window (see [Figure 2.4a](#)), which can span one or two monitor displays. This large window will contain all the areas and views you use to control the microscope and analyze your results.

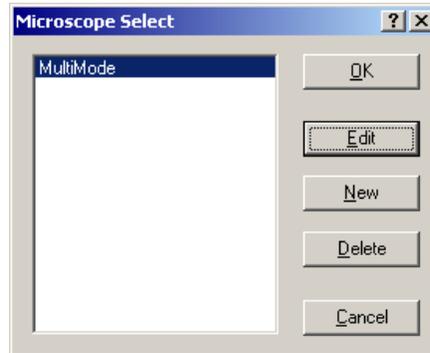
**Figure 2.4a** NanoScope Software Window



2. Notice the white area on the left side of the NanoScope software window. This white area is the “workspace.” This area acts as an organizer for operations you use in the software—including scanning and analysis. Each item in the workspace has a view window that lets you set parameters, perform actions, or view results. The sequence of items in the workspace is important only for Auto Programs that use analysis functions.

3. Select **Tools > Select Microscope** to open the **Microscope Select** dialog box.

**Figure 2.4b** Microscope Select Dialog Box

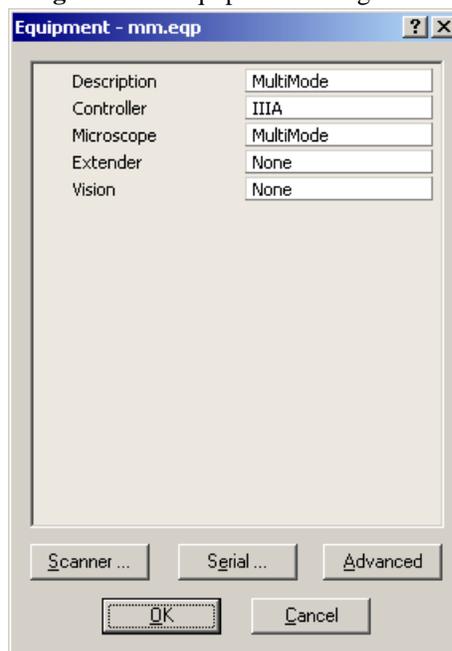


In the **Microscope Select** dialog box:

- a. You can add a new set of hardware configuration parameters by clicking **New**, or edit the parameters of the selected microscope by clicking **Edit**. The parameters include things such as the controller, extender, and vision system.
- b. In the **Equipment** dialog box, choose the microscope you are using (see [Figure 2.4c](#)). If you are using a MultiMode AFM, select the scanner you plan to use (**Scanner** button).

**Note:** Select the **Advanced** button to view all equipment parameters.

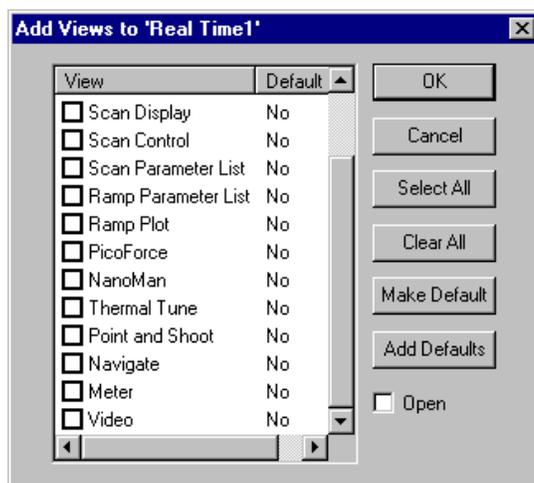
**Figure 2.4c** Equipment Dialog Box





- Click the yellow **Realtime** icon in the toolbar. This adds a “**Realtime**” group and a **Scan View** to the workspace. It may take a moment the first time **Realtime** is added. A dialog box (see [Figure 2.4d](#)) will appear giving you the option to add more views.

**Figure 2.4d** Add Realtime Views Dialog Box



- Right-click on **Realtime** in the workspace and select **Permit Multiple Views** from the pop-up menu. When this item is enabled (that is, has a check mark next to it), you can have several views open at the same time.

**Note:** Areas in the NanoScope software window can be resized and moved to make it easier for you to use. When you reopen the software, it will remember your changes. Drag the edge of an area to resize it. Drag the title bar or double raised lines on an area to move it to another edge of the window or to make it a floating window. (In Microsoft Windows terminology, these areas are “dockable.”) Click the “X” in the upper-right corner to close an area. Use the **View**, **File**, or **Scan** menu to open an area. For details about the areas of the NanoScope software window, see [Section 2.2](#).

If you are using a Dimension Series AFM, continue with the steps in Preparing a Dimension Series AFM for a **Realtime** Scan. If you are using a MultiMode AFM, skip to **Scanning and Scan Parameters** [Section 2.4.4](#).

## 2.4.2 Preparing a Dimension Series AFM for a Realtime Scan

Once you’ve created the workspace, prepare the system to scan. This includes selecting the operation mode, aligning the laser, adjusting the photodetector, locating the cantilever tip with the optical microscope, and focusing the optical microscope on the surface. If you have not yet learned these procedures please refer to your **Dimension Microscope Manual** and/or **SPM Training Notebook**.

For details on using the Realtime **Scan Views**, see [Chapter 3](#).

1. Click the **Scan** group or one of the **Scan** views (**Scan Single**, **Scan Double** or **Scan Triple**) in the workspace to see one of the **Scan Views**. Set the **Microscope mode** parameter to **Tapping** or **Contact**.
2. Mount the probe into the cantilever holder
3. Mount the cantilever holder onto the end of the scanner head.
4. Align laser on cantilever.
5. Click **Meter** in the workspace or check **View -> Real Time Status** to see the **Meter View**. Turn the two screws on the side of the scanner to adjust the laser position in the photodetector. In the **Meter View**, the location of the red dot and the values at the bottom of the display change.
6. Click **Navigate** in the workspace to see the **Navigate View**. This view shows the video and stage controls. Activate the **track ball** by clicking on the **Track ball ON** button inside the **Navigate View**.



7. Click the **Locate Tip** icon in the toolbar or the **Locate Tip** button within **Navigate View**. Using the two adjustment screws to the left of the optical objective of the microscope, center the tip of the cantilever under the crosshairs.
8. Focus on the tip end of the cantilever either by using the trackball while holding down the bottom-left button or by using the **Optical Focus** mouse controls. Click and hold the large arrow keys to move the focus up or down. The speed is controlled by the sliding bar or by typing a value from 0 to 100. Click **OK** to set the focus and enter **Focus Surface** mode.

When you leave **Locate Tip** mode, the optics move to a focus position, typically 1mm below the tip. To set this, select **Tools > Engage Settings > General > Motor**.

9. Focus the optics on the sample surface using either the trackball or the **Z Motor** arrows in the **Navigate View**. To use the track ball, set the **trackball** to **On**, and roll the trackball up or down while holding down the bottom-left button. To use the **Z Motor** arrows, click and hold them down. You can use the speed controls in the **Z Motor** area to adjust the speed. This adjustment raises or lowers the Z stage on which the SPM and optics are mounted.
10. Move the x-y stage to align the desired location on the sample under the crosshairs either by using the trackball without holding down any buttons or by using the **XY Stage** arrows in the **Navigate View**.



11. If you are using TappingMode, click the **Tune** icon. Check your parameters in the **Auto Tune** list.
12. Click the **Auto Tune** button. Notice that the status bar at the bottom of the NanoScope software window says "Cantilever Tuning" during automatic tuning. When tuning is complete, click **Exit** in the **Cantilever Tune** dialog box. Proceed to [Section 2.4.4, "Scanning and Scan Parameters"](#).

### 2.4.3 Preparing a MultiMode AFM for a Realtime Scan

Once you've created the workspace, prepare the system to scan. This includes selecting the operation mode, mounting the probe, selecting the scanner, mounting the sample, aligning the laser, and adjusting the photodetector. If you have not yet learned these procedures, please refer to your **Multimode Manual** and/or **SPM Training Notebook**.

1. Click **Scan** in the workspace to see the **Scan View**. In the **Scan View** parameters area, select the **Other** tab. Set the **Microscope mode** parameter to Tapping or Contact.
2. Change the mode switch on the base of the microscope. Set it to **TMAFM** if you are using TappingMode. Set it to **AFM & LFM** mode if you are using Contact mode.
3. Mount the probe into the cantilever holder.
4. Put the cantilever holder in the optical head. Secure the holder by tightening the screw in the back of the optical head.
5. Choose a scanner (A, E, or J) by clicking on **Tools > Select Scanner**. Mount and plug the scanner into the base. Attach the corresponding springs to the microscope base.
6. Mount sample onto scanner.
7. Place optical head on scanner, making sure there is enough clearance between the tip and the sample.
8. Align laser.
9. Adjust the photodiode signal.
10. If you are using TappingMode, click the **Tune** icon. Check your parameters in the **Auto Tune** list.
11. Click the **Auto Tune** button in the **Cantilever Tune** dialog box. Notice that the status bar at the bottom of the NanoScope software window says "Cantilever Tuning" during automatic tuning. When tuning is complete, click **Exit** in the **Cantilever Tune** dialog box.



### 2.4.4 Scanning and Scan Parameters

Next, you set scan parameters and scan the sample.

1. In the **Scan View**, use the following initial parameter settings in the **Scan** tab. These values may already be set; they are handy starting values.

<b>Scan size:</b>	1 $\mu$ m
<b>Aspect Ratio:</b>	1.00
<b>X offset:</b>	0nm
<b>Y offset:</b>	0nm

**Scan angle:** 0.00 °  
**Scan rate:** 2Hz

- Most of these commonly-used parameters are also shown on the **Main** tab. You can right-click on the field in the **Main** tab to open a dialog box that allows you to change which parameters are shown on the **Main** tab.
- To collect 4K points of data per line, set the following parameters in the **Scan** tab:

**Samples/line:** 4096  
**Lines:** 512 (or 1024)  
**Aspect ratio:** 8.00 (or 4.00 if Lines is 1024) and you want square pixels

**Note:** You can use the mouse to adjust the value in many parameter fields. Click on the value and drag the mouse left to decrease the value or right to increase the value.

The **Aspect ratio** controls the X:Y ratio of the pixels in the displayed image. Since there is a 8:1 ratio between 4096 samples/line and 512 lines using an **Aspect ratio** of 8 causes the pixels displayed in the image to be square.

- For TappingMode, use the following initial parameter settings in the **Feedback** tab:

**SPM feedback:** Amplitude  
**Integral gain:** 0.2  
**Proportional gain:** 0.3

- For Contact mode, use the following initial parameter settings in the **Feedback** tab:

**Integral gain:** 2.0  
**Proportional gain:** 3.0  
**Deflection setpoint:** 0V (vertical deflection = -2V (before engage))



- Click the **Engage** button in the **Main** tab or click the **Engage** icon. Scan lines appear in the **Scan View** once the tip engages and scanning begins.
- Click the **Scope** button. Check to see whether the trace and retrace lines are tracking each other well. They should have a similar shape, but they may not overlap each other horizontally or vertically. Adjust the **Scan rate**, **Integral gain**, **Proportional gain**, and/or **Setpoint** (that is, **Amplitude setpoint** for TappingMode and **Deflection setpoint** for Contact Mode) parameters. Once the trace and retrace are tracking well, your tip is scanning the sample surface.
- At this point, you may want to adjust the **Scan size**, **X offset**, **Y offset**, and **Scan angle (Scan Tab)** parameters to locate the scan over features of interest. If you increase the **Scan size**, remember that the **Scan rate** should be lowered.

**Note:** You can zoom in on the scan image by selecting the **Zoom** button below the image. Then, use your mouse to drag a box outline over the area you want to zoom in on. Click **Offset** to offset the center position of your scan.

9. With a 4K image, it may be useful to zoom in on the scan without changing the scan size. Select the **Data Zoom** button above the image. Use your mouse to drag a box outline on the image (begin by clicking where you want the center of the box to be). When you release the left button, you will be zoomed in (scan size of image display will change) but the scanner will remain scanning the original scan size. At this point you can choose to “pan” over to other areas of the total scan. Select the **Pan** button and click and hold the left mouse button as you move the mouse. The left arrow button above the image allows you to go back to the original scan and the right arrow button allows you to go to more zoomed in scans (if you have done multiple zooms). You may also choose to physically change the scan size or X/Y offsets by using the **Zoom** or **Offset**.

## 2.4.5 Capturing an Image

Once you have adjusted the scan parameters, you can capture a scanned image. Perform these steps once a scan you want to capture is in progress.

1. You can capture a scan in any one of three ways:
  - From the menu bar, select **Realtime > Capture**.
  - From the menu bar, select **Realtime > Capture Now**.
  - On the **Main** Tab in the **Scan View**, click the **Capture** button.
  - Click the **Capture** icon in the toolbar.



The scan will continue. Notice that the status bar at the bottom of the NanoScope window (see [Figure 2.4e](#)) says “Capture: On.” When the current scan is complete, the image will be stored automatically in the Capture Directory with the file name indicated in the status bar. The file name and directory can be changed by selecting **Realtime > Capture Filename** from the menu bar (see [Figure 2.4f](#)).

Figure 2.4e Status Bar

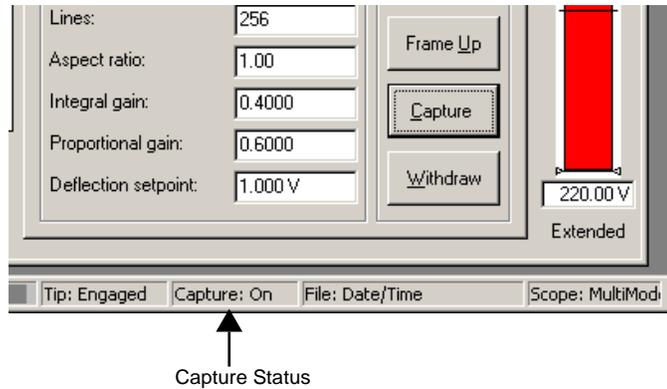
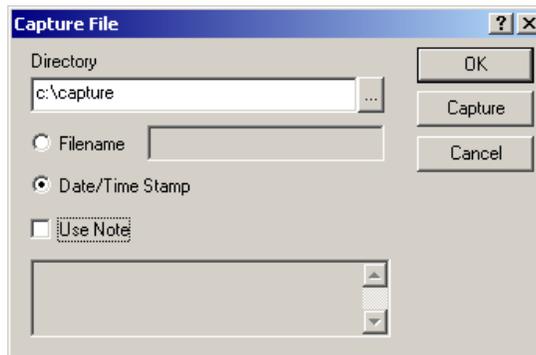
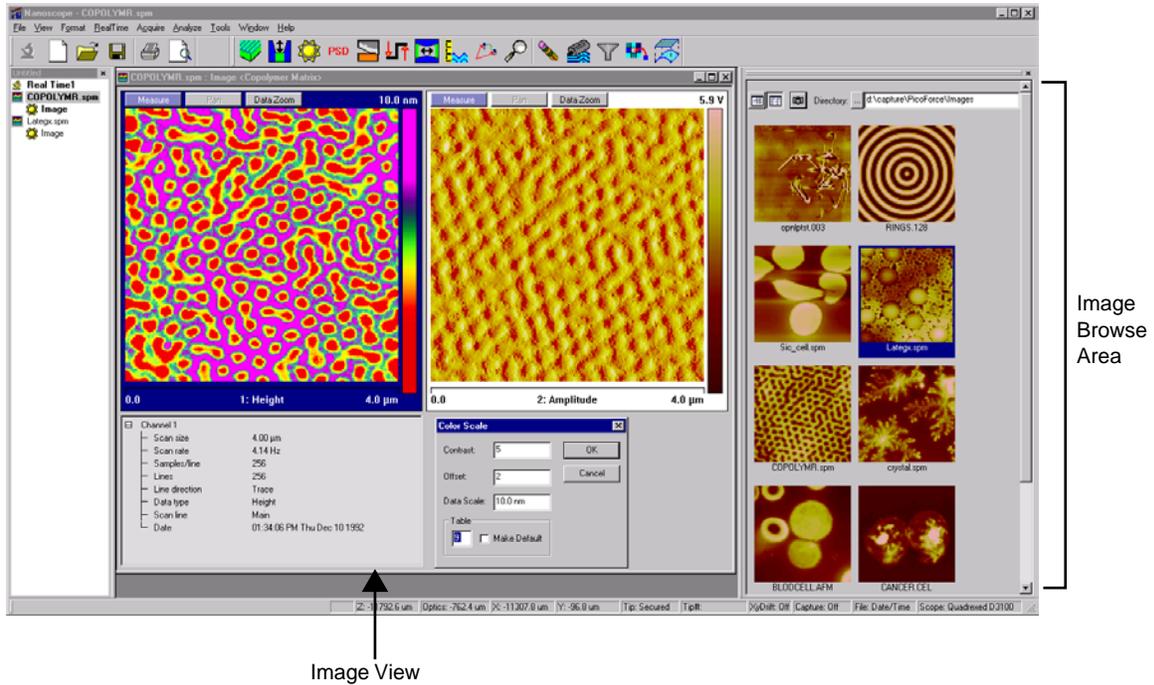


Figure 2.4f Change Filename



2. In the Image Browser area (see Figure 2.4g), check to see if you are looking at the Capture Directory. If not, select the **Capture Directory** icon (or click the “...” button and select the Capture Directory, which is usually **DI > Capture**). If you don’t see the Image Browser, choose **View > Browse**.

Figure 2.4g NanoScope Image View Window

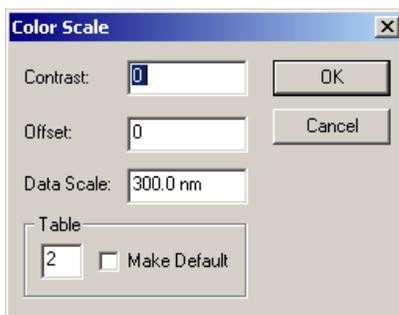


3. Double-click the image you just captured. The image opens in the **Image View** window (see Figure 2.4g). Notice that the image filename and an image view are added to your workspace.

4. If you need to change the **DATA SCALE**, **CONTRAST**, **OFFSET** or **COLOR TABLE**, use **Format > Color Scale** on the menu bar or right-click on the data scale value in the top right corner of the **Image View** window, and change the appropriate values in the **Color Scale** popup window. The **Color Table** may also be changed by clicking and holding the color bar, then dragging the mouse left or right.

**Note:** To rename image files, you can **Save As**, use Explorer to rename the file, or right-click on the image in the image browser and select **Move**.

**Figure 2.4h** Color Scale



## 2.4.6 Analyzing an Image with the Section Analysis

After opening the captured image, you can analyze the image. In this example, the **Flatten** filter and **Section** analysis views are used.



1. Right-click on the name of the image in your workspace. Choose **Add View > Flatten** from the pop-up menu, select **Analyze > Flatten** from the menu bar, or click the **Flatten** icon.

The **Flatten** filter can be used to remove image artifacts due to vertical (Z) scanner drift, image bow, skips, and anything else that may have resulted in a vertical offset between scan lines. Refer to the **Command Reference Manual, 004-122-000** for a detailed description of Flatten.

2. Set the input parameters for the filter. For example, you can choose the order of the polynomial to use to fit scan lines.
3. Click **Execute**.
4. To restore to the original data, click **Reload**. Then change the parameters and click **Execute** again.



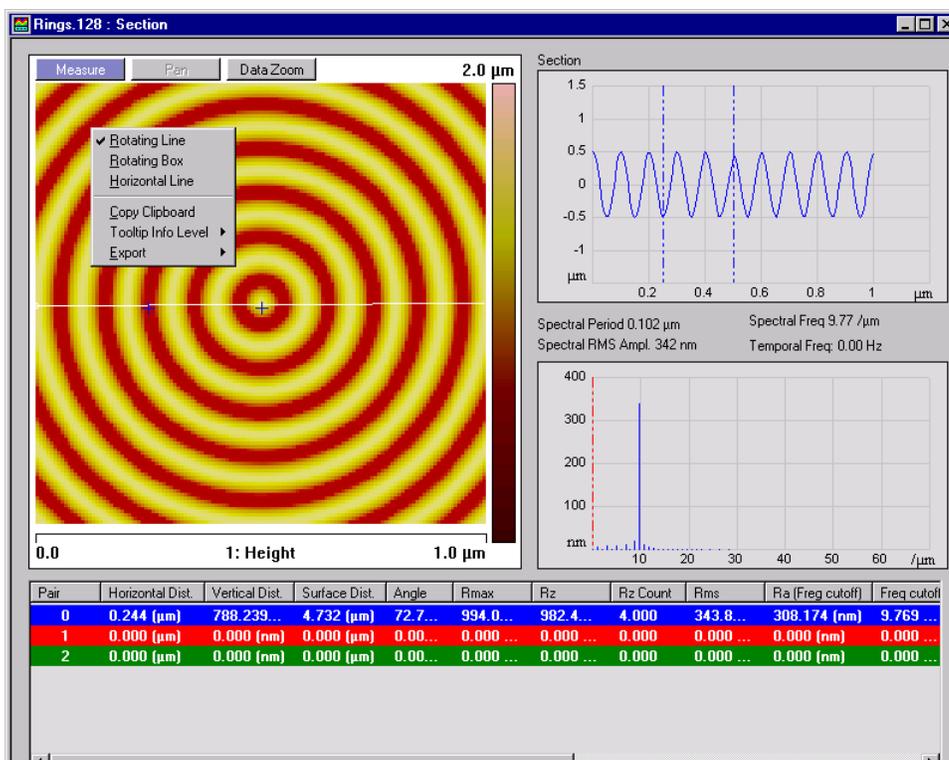
5. Right-click on the name of the image in your workspace again. Choose **Add View > Section** from the pop-up menu, select **Analyze > Section** from the menu bar, or click the **Section** icon. **Section** analysis allows you to easily make depth, height, width, and angular measurements.

6. Drag a line across the image. A vertical cross section along that line is shown in the upper graph area, shown in Figure 2.4i. The lower graph also shown in Figure 2.4i, shows the power spectrum (Fourier Transform) of the cross section.
7. In the upper grid, drag the two cursors around to make measurements. You can grab two or more measurement cursors from the outside of the grid. You will see the cursor change from a  $\perp$  to a  $\leftrightarrow$ , at which point you can grab the measurement cursors. The results area at the bottom of the view shows various measurements at the marker position.

**Note:** Section can have three horizontal lines or 3 rotating lines or one rotating box. It can have three sets of grid markers on one image cursor or one set of grid markers on each image cursor.

8. If you would like to make an Average Section, right-click on the image, select **Rotating Box**. After drawing the box, you can make it rotate by holding down the shift key while grabbing anywhere in the box.

**Figure 2.4i** Section Analysis

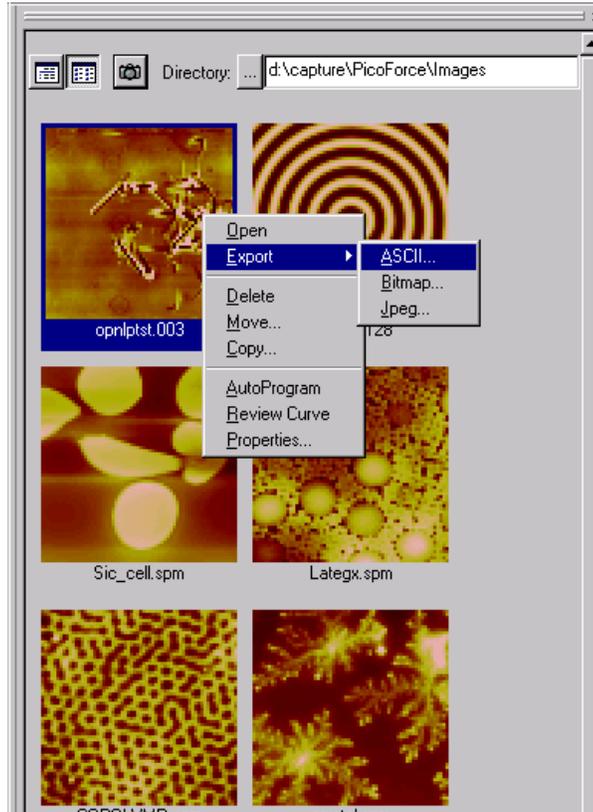


## 2.4.7 ASCII Export

When transporting the results of using NanoScope software to another computing platform, the most generic format is an ASCII text file. The **File > Export > ASCII** command builds such a file.

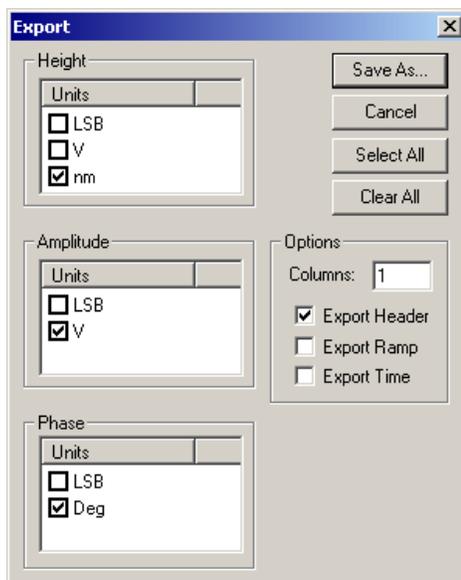
1. Select a directory, then an image file within it, from the file browsing window at the right of the **NanoScope Version 6** main window. Right-click in the thumbnail image to open the menu shown in [Figure 2.4j](#).

**Figure 2.4j** The ASCII Export Command



2. Click **Export** > **ASCII** to open the **Export** dialog box (see [Figure 2.4k](#)).

Figure 2.4k The File Export Dialog Box



3. Select the units in which to record the data in the new file by checking the appropriate boxes. You can also export image header, ramp, or time information by selecting those check boxes.
4. Click **Save As...**, designate a directory path and filename, and click **Save**.

Figure 2.4l shows the start of an exported ASCII image file saved without a header.

Figure 2.4l Sample ASCII Image File

Height(nm)	Amplitude(LSB)
1.581191e+002	5.940000e+002
2.019038e+002	5.860000e+002
1.803088e+002	5.710000e+002
1.795310e+002	5.570000e+002
1.730342e+002	5.280000e+002
1.731715e+002	5.240000e+002
1.653479e+002	5.110000e+002
1.712957e+002	4.830000e+002
1.917468e+002	5.120000e+002

## 2.5 Using Online Help

The NanoScope software now includes complete documentation in online Help, including: Theory, Procedures and Interface references.

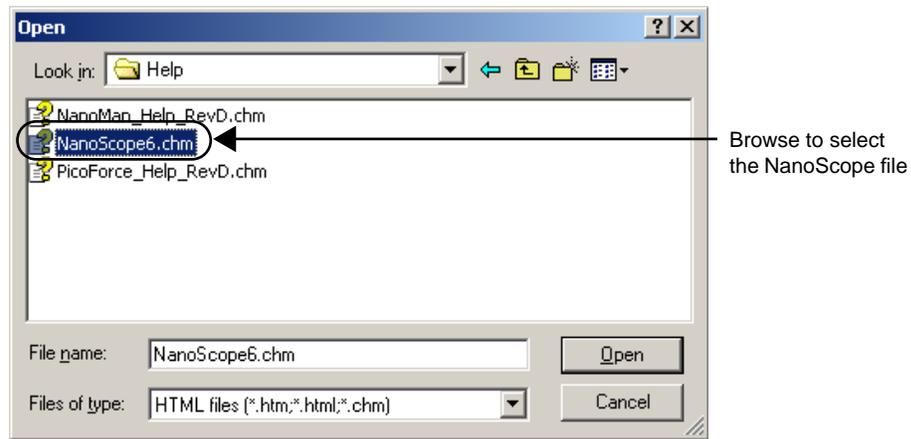
If the help is not open,

- Select **View > Help** or
- Use **Help > Nanoscope Help** to display and hide the Help window.

To manually select the Help file:

1. Select **Tools > Options > Set Help File**.
2. A browse dialog box appears to select the NanoScope 6 help file (see [Figure 2.5a](#)).

**Figure 2.5a** Initialize Help Dialog Box



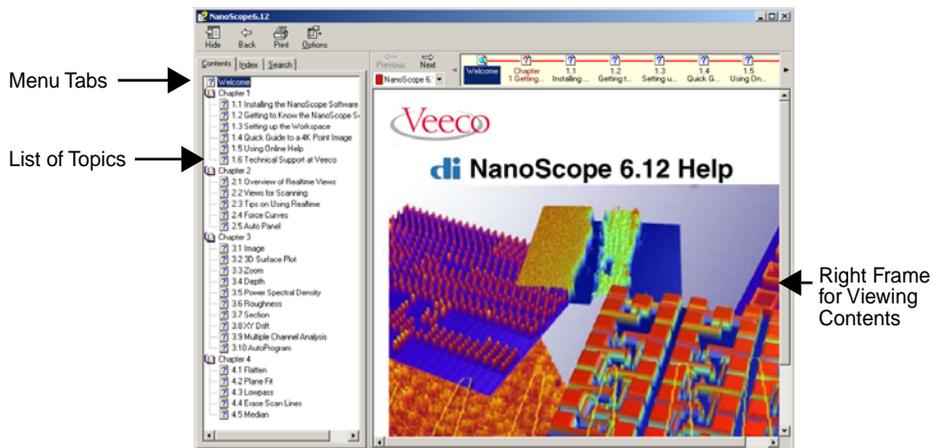
3. Select the NanoScope6.chm file.

## 2.5.1 Help Window

The **Help** window includes three tabs (see [Figure 2.5b](#)):

- **Contents**—Displays a list of topics and subtopics to search.
- **Index**—Allows searching by indexed items in alphabetical order.
- **Search**—Allows for searching the entire online help for a word or phrase.

Figure 2.5b Help Window



## Contents

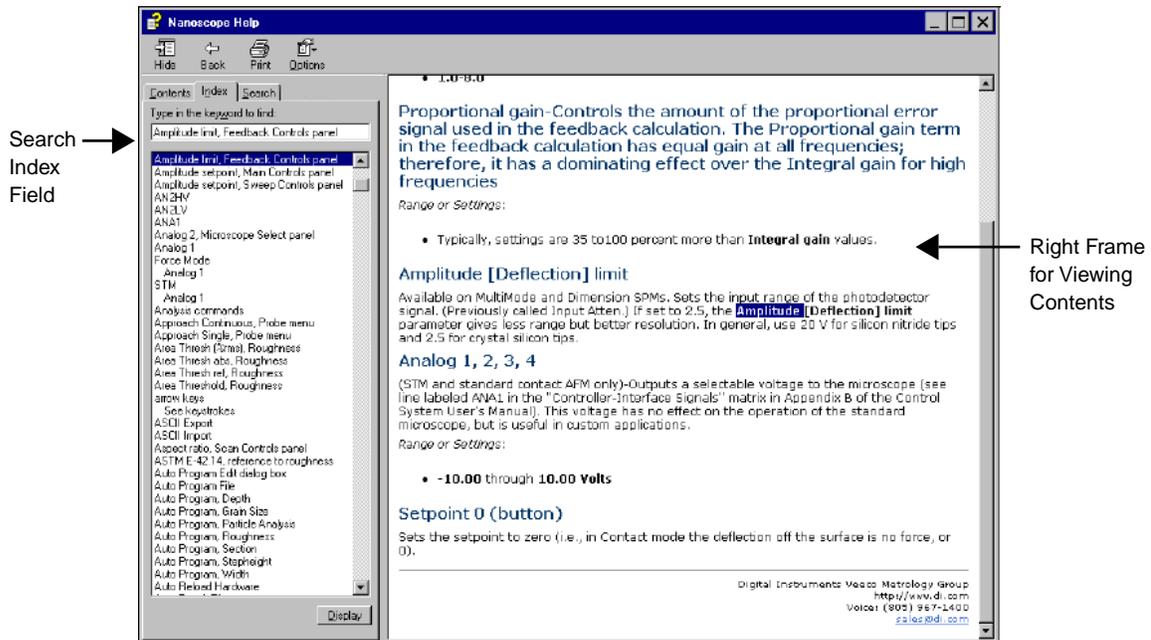
The **Contents** tab allows for scrolling between main topics and subtopics. Click on a topic to view documentation in the right frame (see Figure 2.5b).

## Index Tab

The **Index** tab allows to search the index of items, then select display to view the contents in the right frame (see Figure 2.5c).

**Note:** Often, the indexed item displays the top level help page where the item is found. For viewing the exact location, select the indexed item, display the page, then select the contents tab to view the related topic of the indexed item.

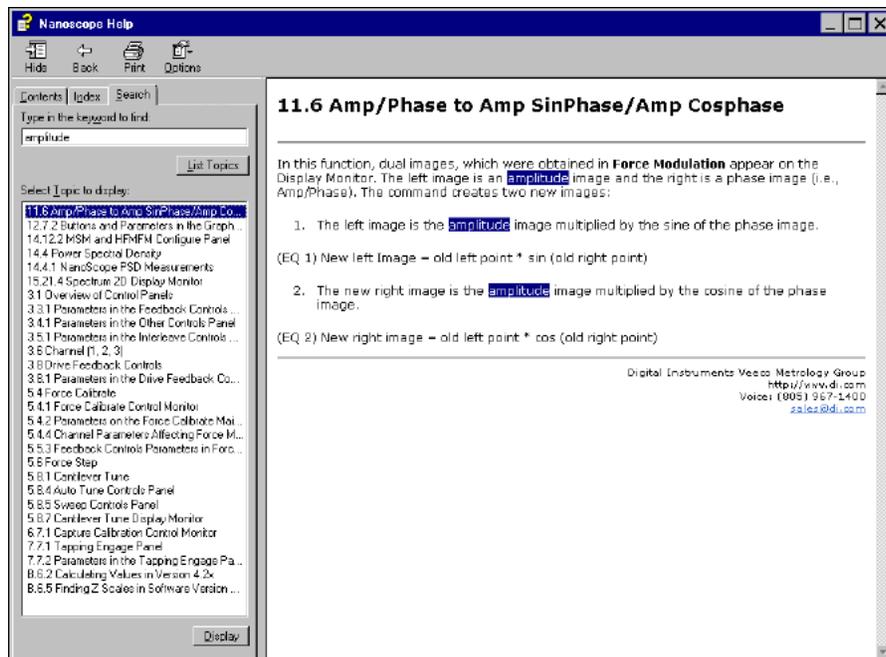
Figure 2.5c Index Tab



Search Tab

The **Search** tab allows to search the entire help text, then view the content in the right frame (see Figure 2.5d).

Figure 2.5d Search Tab



## 2.6 Technical Support at Veeco

Your satisfaction and productivity regarding Veeco products and documentation are absolutely essential.

### 2.6.1 Submitting Bug Reports

The NanoScope software automatically generates a bug report if the system should abort for any reason. This bug report form may help a Veeco programmer correctly analyze the problem that caused the abort.

If the system should abort, the next time the software is initiated a bug report form automatically displays. You can also report a bug by selecting **HELP > BUG REPORT...** For submitting bug reports, complete the following:

1. Enter your name and a brief description of the functions in use when the crash occurred. Please describe the situation as accurately as possible.

**Note:** The form also includes crucial internal coding information for the developer.

2. Select **Ok** to transmit the file.

**Note:** A file labeled `BUG.TXT` will be created in your SPM directory. If another `bug.txt` file exists, the number on the file name is incremented or the information is appended to the previous file.

**Note:** If there is no SPM directory or `bug.txt` file, the software prompts to place the file in another location.

3. Once the file is created, attach the `BUG.TXT` file to an e-mail and send to `bugs@di.com`.

**Note:** You may not get a response to your bug submittal, but be assured that our programmers will analyze the problem and fix it in a future release if necessary.

### 2.6.2 Contact Information

#### Mailing Address

Technical Documents, Technical Support or Bug Reports at Veeco  
Veeco Instruments Inc.  
112 Robin Hill Rd.  
Santa Barbara, CA 93117

E-mail: [help@veeco.com](mailto:help@veeco.com)

**Voice Phone**

(805) 967-1400, (800) 873-9750

**Fax**

(805) 967-7717

**E-Mail (Documentation Feedback only)**

TechPubsSBO@veeco.com

**World Wide Web**

<http://www.veeco.com>

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# Chapter 3 Realtime Views

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The Realtime Views control the Realtime collection of data. Each part of the screen is an integral part of the scanning process. For more information on controlling views and the workspace, reference [Chapter 2](#).

For general procedures in setting the parameters and data definitions, refer to the following sections:

- **Overview of Realtime Views:** [Section 3.1](#)
- **Views for Scanning** [Section 3.2](#)
- **Tips on Using Realtime** [Section 3.3](#)
- **Force Curves** [Section 3.4](#)
- **Auto Panel** [Section 3.4.5](#)

**Note:** If you have never used an AFM before, please refer to your microscope manual or contact Veeco for training.

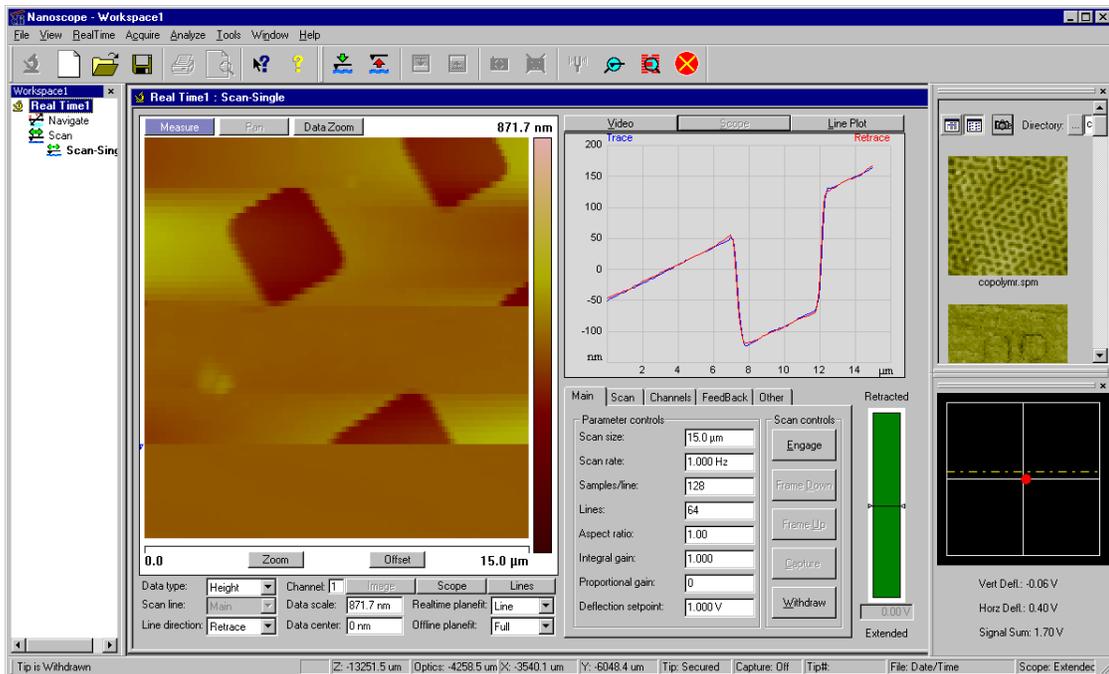
## 3.1 Overview of Realtime Views

The **Scan View** includes all SPM parameters previously found in the Realtime control panels. The settings and parameters configure the microscope and NanoScope controller signals to optimize each scan.

You can access Realtime views such as **Scan-Single**, **Scan-Dual**, **Scan-Triple**, **Meter**, **Navigate**, **Video**, and **Point and Shoot** by any of the following methods (see [Figure 3.1a](#)):

1. Right-click on Realtime in the workspace and select the desired view from the **Add View** menu.
2. Click on the desired view icon in the Realtime button bar.
3. Select a view from the **Acquire** menu.

Figure 3.1a Manual Scanning in Realtime



### 3.1.1 Typical Procedures to Begin to Scan

Set **Scan** parameters to affect piezo movement and data collection. The **Scan** functions control the type of scan to run, how large the scan is, its angle, scan rate, and number of samples per scan line. Prior to scanning a sample, the user must have knowledge of the following:

- Basic SPM processes
- Microscope safety, handling and tip/probe handling procedures (see your system manual)
- Sample handling procedures

## 3.2 Views for Scanning

The general interface views associated with configuring parameters for scanning include:

- **Navigate View** [Section 3.2.1](#)
- **Meter View** [Section 3.2.2](#)
- **Point and Shoot View** [Section 3.2.3](#)
- **Cantilever Tune** [Section 3.2.4](#)
- **Scan View Interface** [Section 3.2.6](#)
- **Scope Trace Plot** [Section 3.2.7](#)
- **Main Tab Interface** [Section 3.2.8](#)
- **Scan Tab Interface** [Section 3.2.9](#)
- **Channels Tab Interface** [Section 3.2.10](#)
- **Feedback Controls Tab Interface** [Section 3.2.11](#)
- **Other Tab Interface** [Section 3.2.12](#)

### 3.2.1 Navigate View

Use the Navigate commands to locate the tip, focus on the surface, enable the trackball and move the stage. Use the **Navigate View** (previously the **Realtime > Stage** menu commands) to position the tip, locate a surface position for referencing Z height and move the stage for scanning the sample surface.

To access the **Navigate View**, click on the **Navigate** icon in the Realtime workspace. If the **Navigate** icon is not present, right-click **Realtime** in the workspace to view the functions menu. Select **Add View > Navigate** and the **Navigate View** appears in the client window.

#### Navigate Commands

The **Navigate** commands allow you to focus surface or locate the tip (see [Figure 3.2a](#)). To view the Navigate commands select **Tools > Stage** or the command icons for **Focus Surface** or **Locate Tip**.

Figure 3.2a Navigate Menu Commands

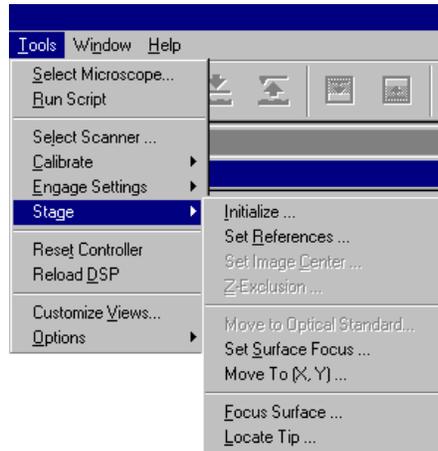
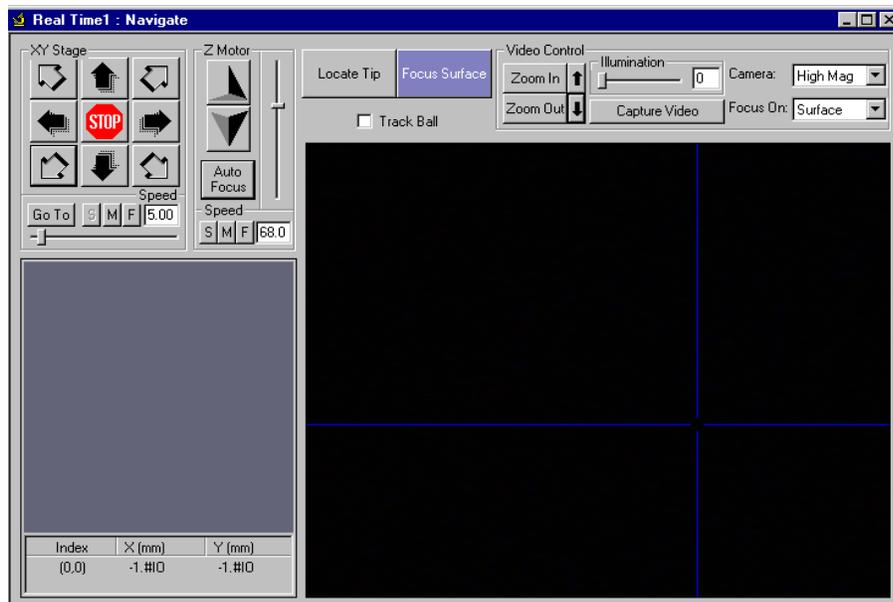


Figure 3.2b Navigate View



## Using the Navigate View



**CAUTION:** If **Tip Focus** is not accomplished before **Focus Surface**, there is a danger of crashing the tip during **Engage**.

Access the **Navigate View** at any time when the stage movement or focus surface and locate tip settings are necessary.

**Note:** Some microscope options, such as **Engage** and **Withdraw**, are unavailable when the **Navigate View** is active. You must select another view, such as the **Scan View**, to enable these options.

1. Access **Locate Tip** and **Focus Surface** in the **Navigate View** or select the appropriate icons.
2. Select the **Locate Tip** button and focus on the tip using the trackball or arrow keys. When finished, click the **Ok** button.
3. For **Focus Surface**, use the trackball or arrow keys to move the stage in X, Y or Z directions.

### Navigate View Parameters:

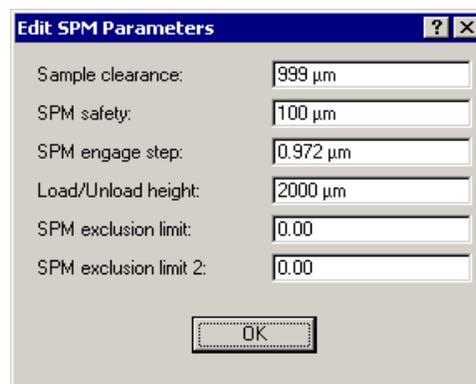
<b>XY Stage Motion</b>	Controls the horizontal, vertical and diagonal movement of the stage.
<b>Speed</b>	Buttons allow for setting slow ( <b>S</b> ), medium ( <b>M</b> ) and fast ( <b>F</b> ) stage speeds by entering a speed value to the right of the buttons or using the scroll bar then select the S, M or F button.
<b>Z Motion</b>	Up and down arrow keys control the height movement of the tip toward or away from the stage.
<b>Auto Focus</b>	Opens an Auto Focus dialog box to set the Z axis focus from vision settings.
<b>Trackball</b>	Enables or disables the X, Y stage and Z cantilever movement by using the trackball.
<b>Camera</b>	Controls the magnification used to view the stage or tip. <i>Range:</i> High Mag, Low Mag.
<b>Illumination</b>	Sets the light intensity in the optics.
<b>Zoom</b>	Changes the optical field of view (i.e., without stage or tip movement).
<b>Vision System</b>	Displays the surface (in focus surface mode) or tip (in locate tip mode) and tip on the surface (in Realtime scanning mode).

## SPM Parameters

To access the SPM Parameter controls, select **Tools > Engage Settings > General** or right-click in **Navigate View** and select **Edit SPM Parameters** (see [Figure 3.2c](#)). Parameter Controls are:

- Sample Clearance
- SPM Safety
- SPM Engage Step
- Load/Unload Height

**Figure 3.2c** Edit SPM Parameters Dialog Box



## 3.2.2 Meter View

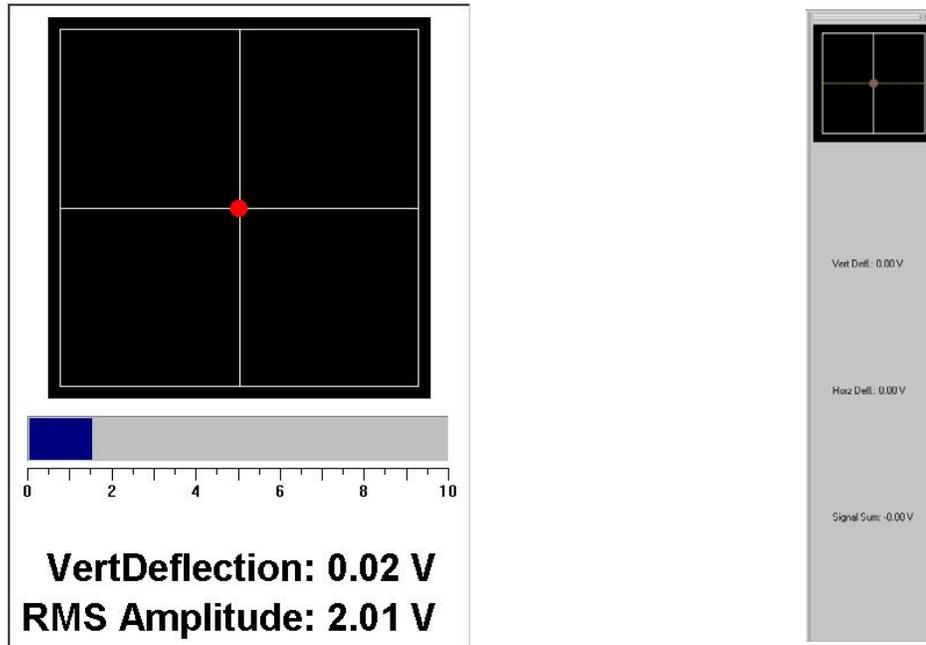
Access the **Meter View** (select **Acquire > Meter**) to view the photodetector signal, RMS amplitude, horizontal and vertical deflection signals, and the signal sum. The meter can also be viewed in the docking RealTime status window.

### Meter View Interface

- **Photodetector Signal**—Corresponds to the positioning of the laser on the photodiode detector.
- **Signal Sum**—Sum of the voltage response from the laser in all 4 sections of the photo detector.
- **Vertical Deflection**—Corresponds to the voltage for vertical displacement of the laser signal. Should be “0” for centering.
- **Horizontal Deflection**—Corresponds to the voltage for the horizontal displacement of the laser signal. Should be “0” for centering.

- **RMS Amplitude**—Root mean square (RMS) signal measured at the detector (TappingMode only).

**Figure 3.2d** Meter View and Docking RealTime Status Window

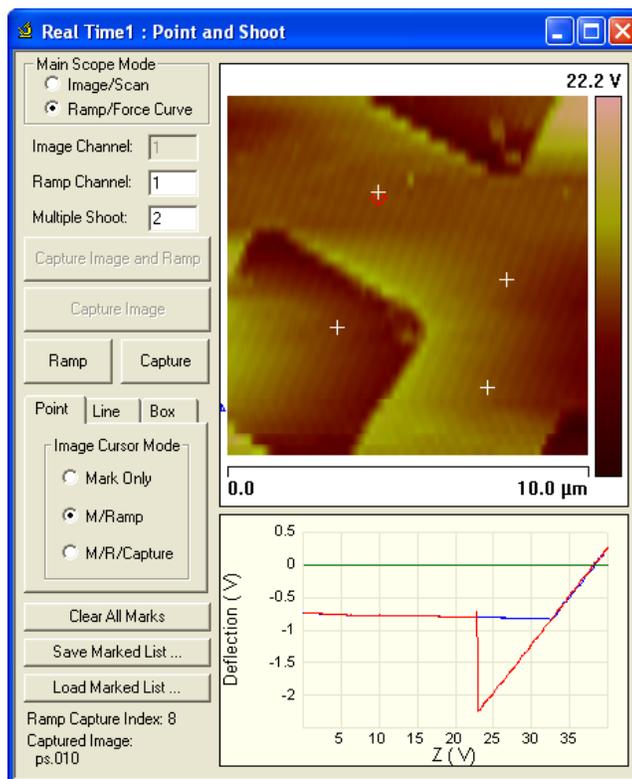


### 3.2.3 Point and Shoot View

The **Point and Shoot View** allows you to select specific points on an image (see [Figure 3.2e](#)). Use **Point and Shoot** to capture an image and/or collect a force curve for every point you designate.

When you click a point on an image, a crosshair (+) marks the location. You can designate individual points, or use the tools in the **Point and Shoot View** to assign multiple points simultaneously.

**Figure 3.2e** Point and Shoot View



#### Controls and Parameters

<b>Image/Scan</b>	Allows you to switch to Image/Scan mode. Use Image/Scan mode to adjust scan parameters in any scan view.
<b>Ramp/Force Curve</b>	Allows you to switch to Ramp/Force Curve mode. Use Ramp/Force Curve mode to adjust the ramp settings. You can select points on an image, ramp each point, and create a force curve for each point.
<b>Image Channel</b>	Select the channel to use for the image.
<b>Ramp Channel</b>	Select the channel to use for the ramp display.
<b>Multiple Shoot</b>	Number of force curves collected at each point, 100 max.

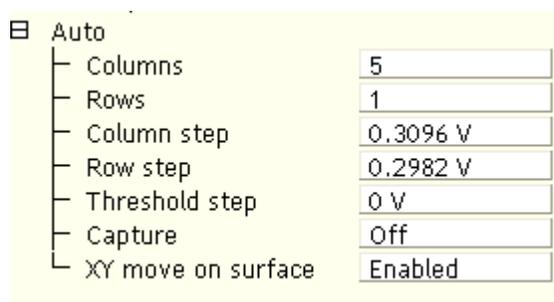
<b>Capture Image and Ramp</b>	Click this button to capture an image and save it in the Capture Directory, and to then capture a force curve at each designated point.
<b>Capture Image</b>	Click this button to capture an image and save it in the Capture Directory. After the capture the software switches to Ramp/Force Curve mode.
<b>Ramp</b>	Click this button to ramp a variable determined from the force curve menu at each point.
<b>Capture</b>	Click this button to ramp each point, capture the ramp/force curve, and save it in the Capture Directory.
<b>Point Parameters</b>	Image Cursor Mode Settings: <b>Mark Only</b> —Select points of interest on the image. <b>M/Ramp</b> —Select points of interest. Software will automatically ramp each point. <b>M/R/Capture</b> —Select points of interest. Software will automatically ramp each point and capture a ramp/force curve.
<b>Line Parameters</b>	Draw a line to select specific points on an image. <b>Point Number</b> —Number of points in the line. <b>Spacing</b> —The distance in nm between each point. All points are equidistant. <b>Clear Path</b> —This button clears the current line and associated points. <b>Convert to Points</b> —Places a + in the location of each point in the line. The line disappears.
<b>Box Parameters</b>	Draw a box in the area you want to place a group of points. You can use the parameters below to create a grid of points. <b>Row Number</b> —Designates the number of rows of points in the grid. <b>Column Number</b> —Designates the number of columns of points in the grid. <b>Row Space (nm)</b> —Designates the distance in nm between each row of the box. <b>Col Space (nm)</b> —Designates the distance in nm between each column of the box. <b>Clear Path</b> —This button clears the current box and associated points. <b>Convert to Points</b> —Places a + in the location of each point in the grid. The box disappears.
<b>Clear All Marks</b>	Removes all user-defined marks from the Point and Shoot image.
<b>Save Marked List...</b>	Save the marks on the image as Path Files (*.psm).

**Load Marked List...** Opens and loads a previously saved Path File (\*.psm) which contains marks on a Point and Shoot image.  
**Note:** If there are points on the image prior to selecting this option, when this button is selected the saved marks will appear *in addition* to the previous marks.

Two options are available for moving, in XY, from one point to another:

1. **XY MOVE ON SURFACE: OFF** - Move with tip at home (lift) height.
2. **XY MOVE ON SURFACE: ENABLED** - Move on surface with Z feedback on See [Figure 3.2f](#).

**Figure 3.2f** Ramp Parameters > Auto > XY move on surface



### 3.2.4 Cantilever Tune

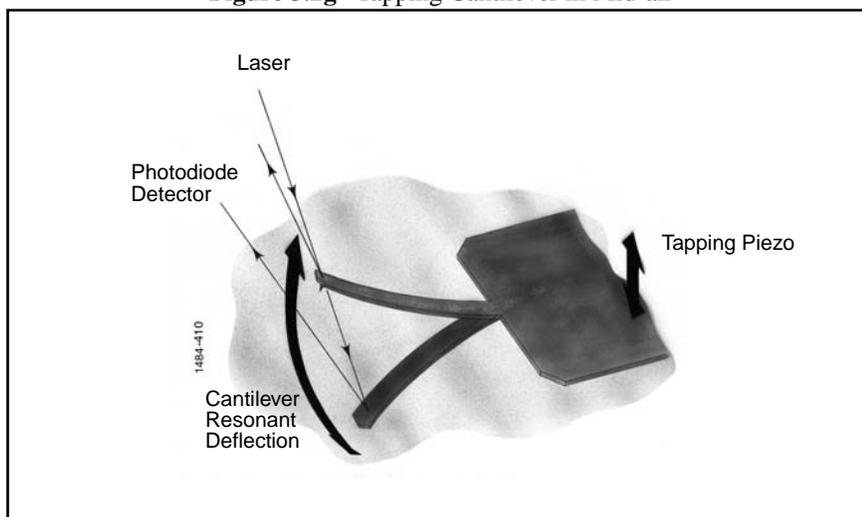
The **Cantilever Tune** command allows determination of the cantilever resonant frequency and the setting of the operating point for TappingMode feedback (see [Figure 3.2g](#)). In addition, it is possible to determine the spring constant of a Contact Mode cantilever quickly and easily.

**Cantilever Tune** sweeps the cantilever drive frequency over a selectable range, then displays a plot of the cantilever amplitude versus drive frequency on the Display Monitor. This command is enabled *only* when the **Microscope mode** parameter on the **Other Controls** panel is set to **Tapping**. On Small Sample MultiMode SPMs, verify that the switch located on the base is toggled to **TM AFM** before selecting the **Cantilever Tune** command.

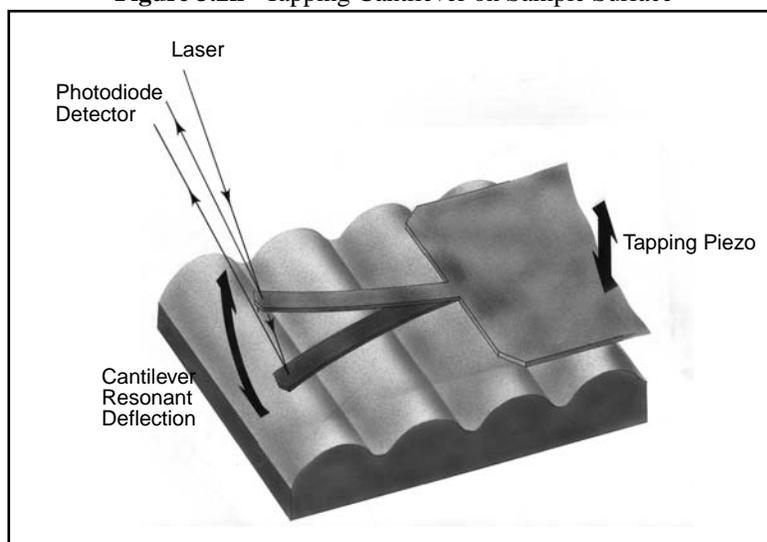
**Note:** The sweep channel is determined by the data selection in the **Channel 1**, **Channel 2**, or **Channel 3** control panels.

[Figure 3.2g](#) shows how the maximum amplitude is attained in air at the cantilever natural resonance. [Figure 3.2h](#) shows the amplitude is reduced when it is in contact with the sample surface.

**Figure 3.2g** Tapping Cantilever in Mid-air



**Figure 3.2h** Tapping Cantilever on Sample Surface

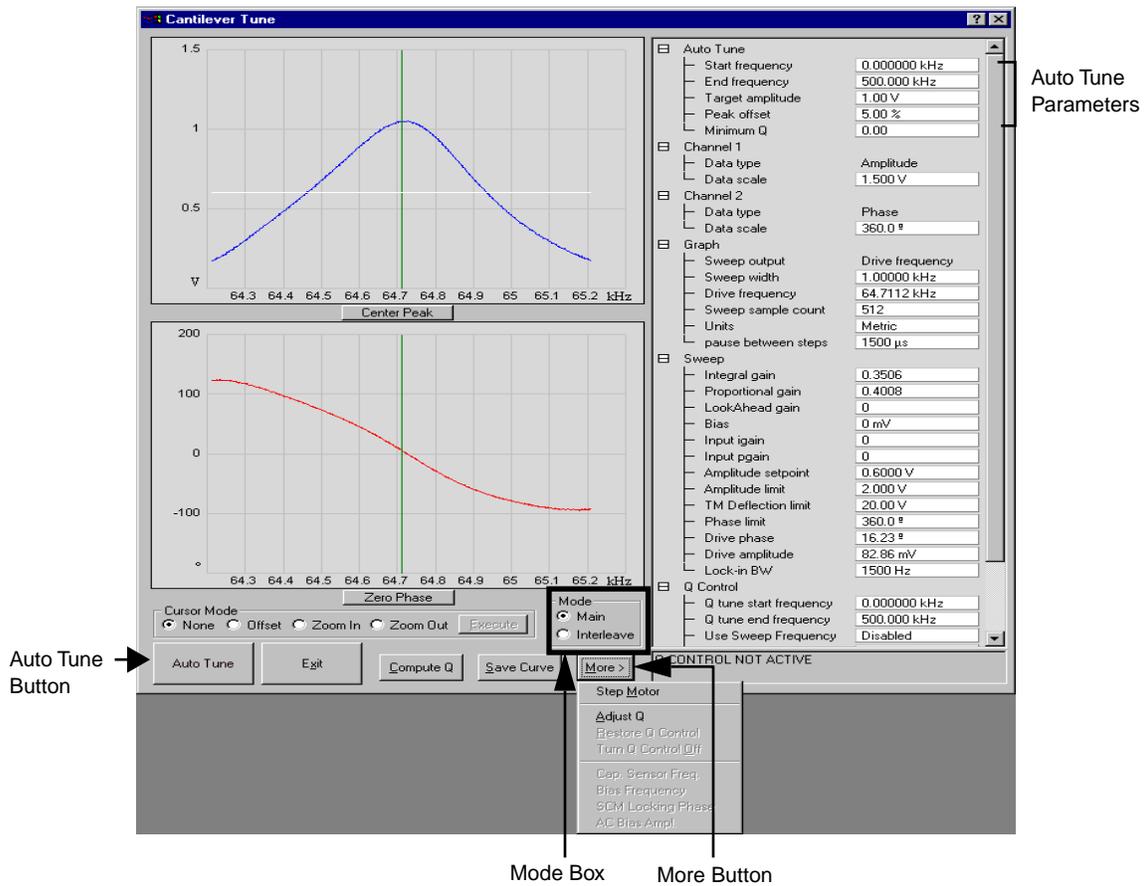


In TappingMode, the optical lever technique reflects a laser beam off the back of the oscillating cantilever, thence to a segmented photodiode. The differential signal between the top and bottom photodiode segments provides a sensitive measure of cantilever deflection. As the sample is scanned, analog circuitry determines the RMS value of the rapidly changing cantilever deflection signal. The RMS value of the cantilever deflection signal corresponds to the amplitude of the cantilever oscillation. Changes in amplitude of the cantilever oscillation is controlled by the feedback system to track the sample surface.



Access the **Cantilever Tune** dialog box by selecting the **Tune** icon or by selecting **Tune...** from the **Realtime** menu.

Figure 3.2i Cantilever Tune Dialog Box



Select Cantilever Tune Dialog Box Definitions:

- Mode box** Toggles the Auto Tune signal from the main to interleave signals.  
*Settings:*  
**Main**— Displays the set of parameters applied to the main scan (see Section 3.2.8).  
**Interleave**—Displays a duplicate set of parameters applied only to the interleaved portions of the scan.
- Auto Tune Button** Executes the automatic tuning procedure: the cantilever is excited through a range of frequencies beginning at the Start frequency and ending at the End frequency.

**Auto Tune Parameters:**

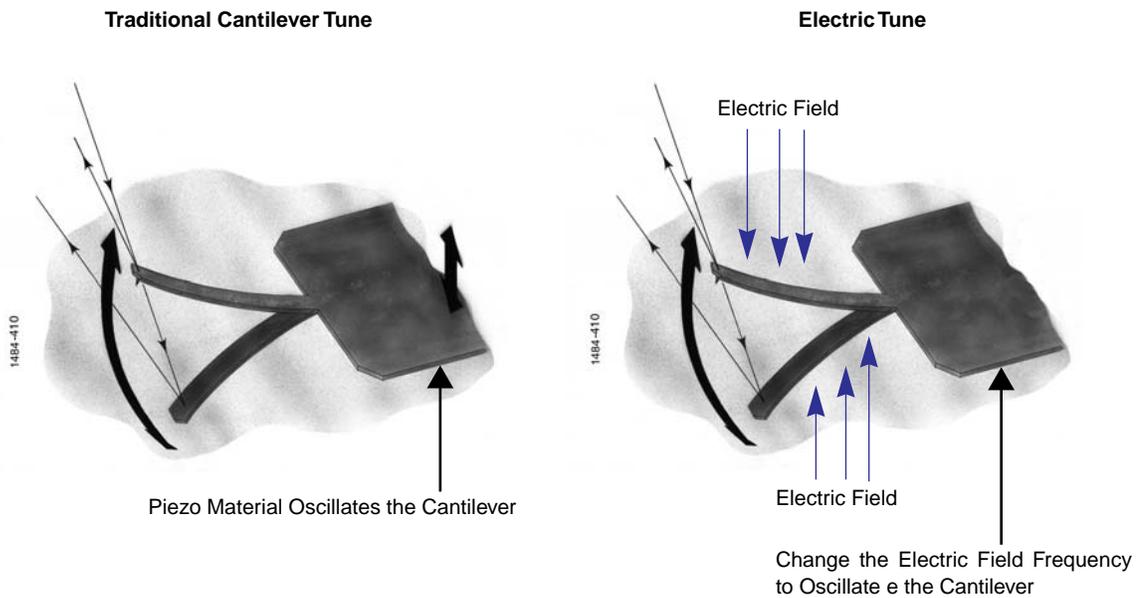
<b>Start Frequency</b>	Starting point of the <b>Auto Tune</b> frequency sweep.
<b>End Frequency</b>	Ending point of the <b>Auto Tune</b> frequency sweep.
<b>Target Amplitude</b>	<p>Targeted output signal amplitude <i>at the photodiode detector</i>. This value should <i>not</i> be confused with Drive amplitude, which is the amplitude applied directly to the cantilever itself (see Drive amplitude).</p> <p><i>Range and Settings: 0.00 to 8.00 V</i></p> <p>Note: Dimension Series SPMs, nominal = 2.00V Small Sample MultiMode SPMs, nominal = 3.00V</p>
<b>Peak Offset</b>	<p>Percentage of cantilever's free-air resonant frequency to be automatically off-set. Peak offset is used to compensate for changes in resonance before engagement due to the tip's interaction with the surface after engagement.</p> <p><i>Range and Settings: 0 to 50%; typical value = 1 to 2%</i></p>
<b>Minimum Q</b>	<p>Q is the value defined by the amount of oscillation it takes for a wave to drop to 1/e (<math>e = 2.718</math>) of its amplitude value (i.e. a wave with an amplitude of ten would have a Q of 10/e, or 3.6788). Minimum Q establishes a minimum "width of peak" value allowed by the AutoTune function. Peaks not meeting the Minimum Q may be ignored by setting the Smash Q factor.</p>
<b>Smash Width Factor</b>	<p>The width of the area beneath the wave <i>smashed</i> (set to zero) when a peak not meeting the Minimum Q requirement is found.</p> <p><b>Note:</b> This parameter does not appear if Minimum Q is 0.</p>

### 3.2.5 Electric Tune

#### Theory

When evaluating Surface Potential, you can now tune the cantilever electrically. Traditional cantilever tune oscillates the cantilever via tapping piezo material (see [Figure 3.2j](#)). Electric Tune sweeps the frequency of the electric field surrounding the cantilever. The force of the electric field moves the cantilever. The cantilever amplitude is then plotted in the **Generic Sweep** dialog box.

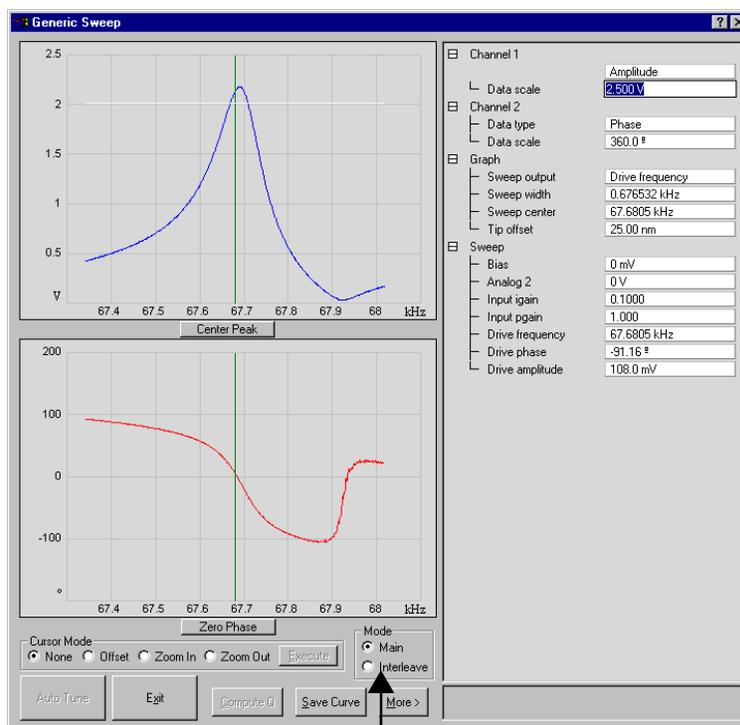
**Figure 3.2j** Cantilever Tune Method Comparison



## Procedure

1. While evaluating Surface Potential in Realtime mode, select **RealTime > Generic Sweep**. The **Generic Sweep** dialog box will display.

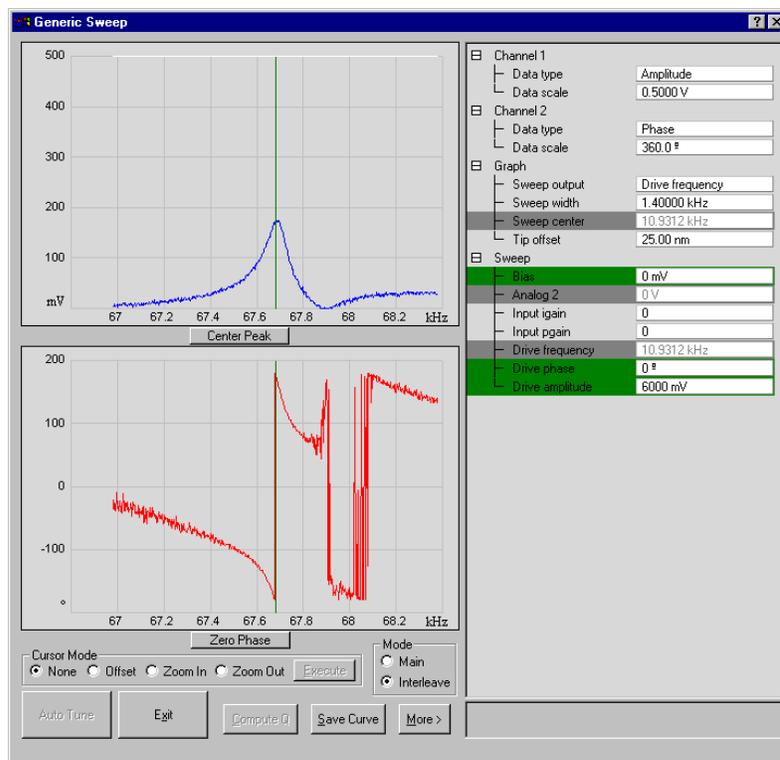
**Figure 3.2k** Typical Generic Sweep



Interleave Mode

2. In the **Generic Sweep** dialog box, set the **Sweep** parameters **Input igain** and **Input pgain** to **0**. This disables the Surface Potential feedback loop, which works to keep the cantilever's amplitude at zero.
3. Select **Interleave** as the **Mode** (see [Figure 3.2k](#)).
4. You can adjust several parameters to acquire interesting data:
  - Try changing the **Data Scale**, **Drive Phase** and **Drive Amplitude** (see [Figure 3.2l](#)).
  - Try changing the channel. For example, the **Data Type** can be changed to **Potential Input**.
  - Try sweeping another channel. For example, set the **Graph** parameter **Sweep Output** to **Bias** (see [Figure 3.2l](#)).

**Figure 3.21** Electric Tune Generic Sweep while adjusting the Drive Amplitude and Drive Phase



**Note:** Remember to re-enable the **Input gains** before collecting further Surface Potential data.

### 3.2.6 Scan View Interface

The **Scan View** display includes an image viewer, color bar, scope viewer, vision control viewer (for systems configured with vision controls), and numerous parameters to configure Realtime data collection. Most SPM operators use only a few of these parameters to obtain images. The parameters within each tab are also microscope-specific or level-access dependent and may be greyed out or hidden, depending on microscope configuration.

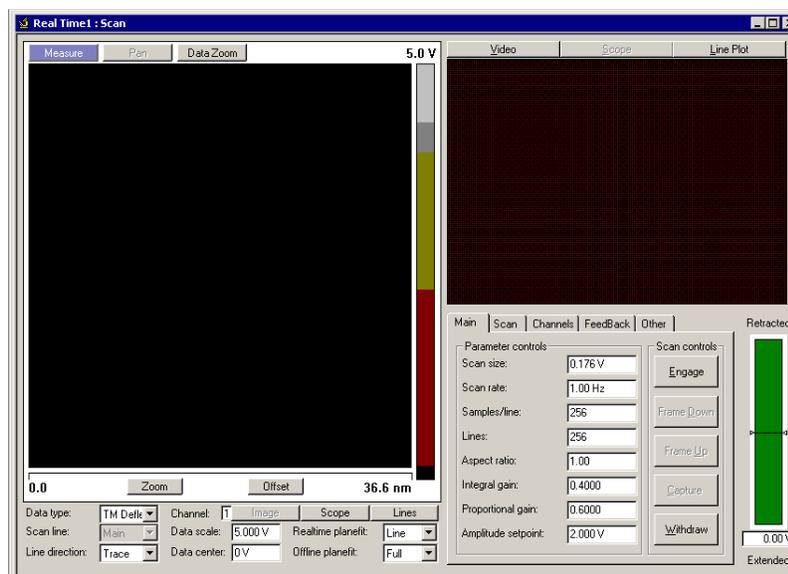
#### Scan View Interface:

##### Image Window

During scanning, the Realtime image of the sample appears along with a cursor. The cursor moves along the image vertically to show the engaged tip position on the surface. The **Measure** button allows you to make line measurements. The **Data Zoom** button allows you to “zoom in” to a smaller view, but doesn’t change the scan size. The **Pan** button allows you to pan over to other areas of the total scan if you are zoomed in.

- Color Bar** Sets the color table for viewing height data in the image window. Left-click on the color bar and drag the mouse left or right.
- Image Parameters** Configure options below the image window to select the channel and image display values, (e.g. **Data type**, **Line direction**, **Data scale**, and so on).
- Vision Window** The Vision window displays the Optics or **Scope** data. Select the **Video** or **Scope** or **Line Plot** button.

**Figure 3.2m** Scan View and Main Controls



### User-Defined Parameters in the Scan View

Clicking on a parameter and then dragging the mouse back and forth increases or decreases a parameter value much like an old analog slider. The significance, range of acceptable values, and specific information about control panel parameters are discussed in this section.

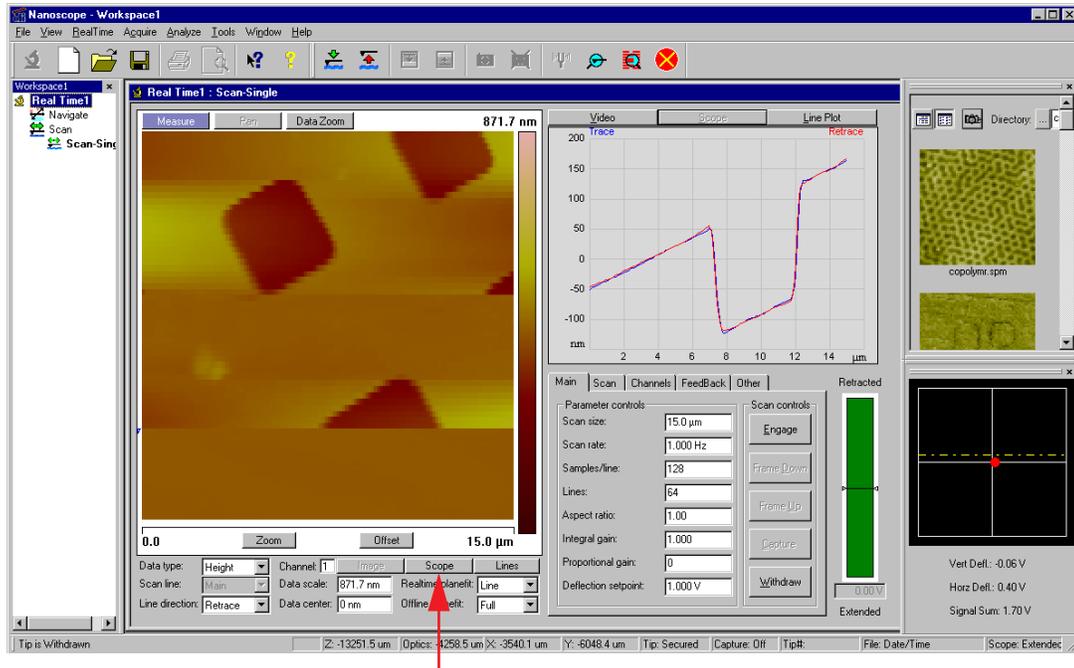
Parameters listed in the **Scan** tabs depend on the microscope selected and the **Show All Items** function (right-click on tab interface > **Show All**). Parameters necessary for one style of microscope are not applicable to another. For example, the **Drive frequency** and **Drive Amplitude** parameters are enabled on the **FeedBack** tab only when the mode is set to TappingMode.

Some users find operating an SPM less confusing if the number of parameters is limited to only the most essential ones. For this reason, The **Main** tab in the **Scan View** contains user specified parameters.

### 3.2.7 Scope Trace Plot

Select the **Scope** button in **Scan View** (see Figure 3.2m) for a scope to display a plot versus the probe position in an oscilloscope-type format on the image display (see Figure 3.2n).

Figure 3.2n Scope Grid



### Scope Trace Interface

By right-clicking the **Scope** grid, you will get a menu of different options (see Figure 3.2o).

**Figure 3.2o** Scope Grid Parameters



These menu options allow you to make the following changes:

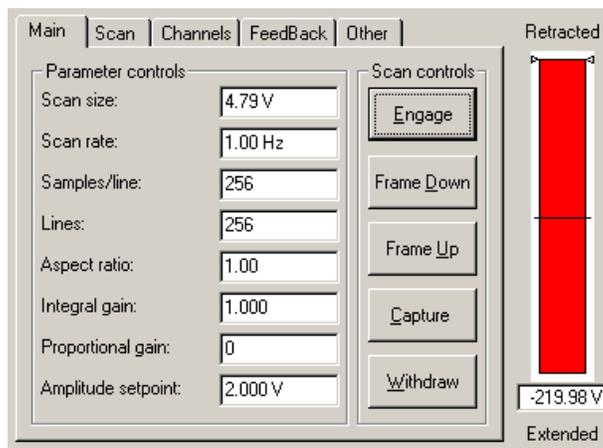
- |                    |  |
|--------------------|--|
| <b>Color</b>       | Allows operator to change color of: <ul style="list-style-type: none"> <li>• Curve (data)</li> <li>• Text</li> <li>• Background</li> <li>• Grid</li> <li>• Minor Grid</li> <li>• Markers</li> </ul>  |
| <b>Filter</b>      | Typically used for a Profiler Scan. <ul style="list-style-type: none"> <li>• <b>Type</b>—Allows the user to plot the mean, maximum or minimum y-value per x-value.</li> <li>• <b>Points</b>—Allows user to plot multiple vertical axis (y-)values at each horizontal axis (x-)value. Select 4K, 8K, 16K or 32K Points to limit the display to 4, 8, 16 or 32 times 1024 points.</li> </ul> |
| <b>Minor Grid</b>  | Places a minor grid in the background of the <b>Vision</b> Window.   |
| <b>Scale</b>       | Allows user to auto scale, set a curve mean, or set their own data range.  |
| <b>Y Translate</b> | Offsets the curve by placement of vertical cursor on the grid. Grab vertical cursor in the black space above the grid and pull down onto grid.   |
| <b>Line Style</b>  | For each curve, operator can choose, connect, fill down, or point.   |

<b>User Preferences</b>	<b>Restore</b> —Reverts to initial software settings <b>Save</b> —Saves all changes operator has made during this session. This becomes the new default settings.
<b>Copy Clipboard</b>	Copies the grid image to the Microsoft Clipboard.
<b>Print</b>	Prints out the current screen view to a physical printer.
<b>Export</b>	Exports data in bitmap, JPEG or XZ data format.
<b>Active Curve</b>	Determines which curve you are analyzing.

### 3.2.8 Main Tab Interface

Figure 3.2p shows an example of parameter controls and settings for scanning in TappingMode.

**Figure 3.2p** Main Controls Panel



- Engage Button**                    The **Engage** command brings the tip into contact with the sample surface and starts the Realtime imaging process.
- Withdraw Button**                The **Withdraw** command stops the scanning process and withdraws the tip from the surface.
- Frame Down Button**            The **Down** command restarts the Realtime scan at the top of the frame. This allows you to go directly to the start of the frame and not have to wait for the previous frame to end.
- Frame Up Button**                The **Up** command restarts the Realtime scan at the bottom of the frame. It is an easy way to begin a view an entire Realtime frame from the bottom. By clicking on this icon, the Realtime scan restarts and moves up at the bottom of the frame. This allows you to go directly to the start of the frame and not have to wait for the previous frame to end.
- Capture Button**                 The **Capture** command stores the image data of the current scan. During the image scanning process, the cursor moves up and down a square image frame. When the cursor moves up or down one complete frame the **Capture** is complete and an image file is saved.
- Capture Cancel Button**        The **Capture Cancel** command stops the capture process.

### Procedures to Set the Main Tab

The parameters in the **Main Control** panel (see [Figure 3.2q](#)) are unique to your specific needs. Configure specific parameters as follows:

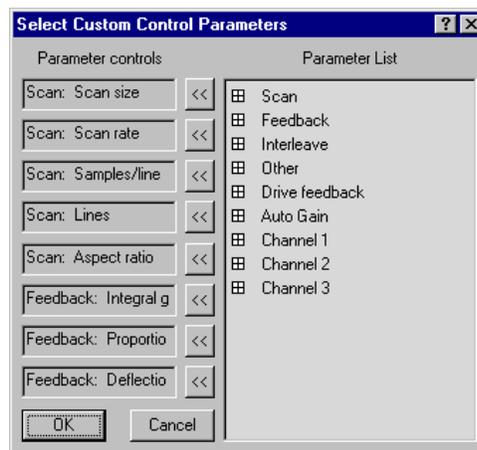
1. Right-click in the **Main Control** panel.
2. In the **Parameter** list, verify each **Scan View** tab name.
3. Expand the desired tab name by clicking on the plus (+) sign next to each name (i.e., Scan, Feedback, Interleave, etc.) to view a list of parameters.
4. Highlight the desired parameters for viewing on the **Main Controls** tab.

**Note:** Only eight parameters may be selected. Therefore, take note of the most used parameters to view in the **Main Controls** tab.

5. With the parameter selected, click the double arrows (<<) to position the selected parameter.
6. Repeat [Step 2 - Step 5](#) for displaying eight main controls parameters for viewing during the scanning process.

Select **Ok** to accept the changes or **Cancel** to revert to the previous view.

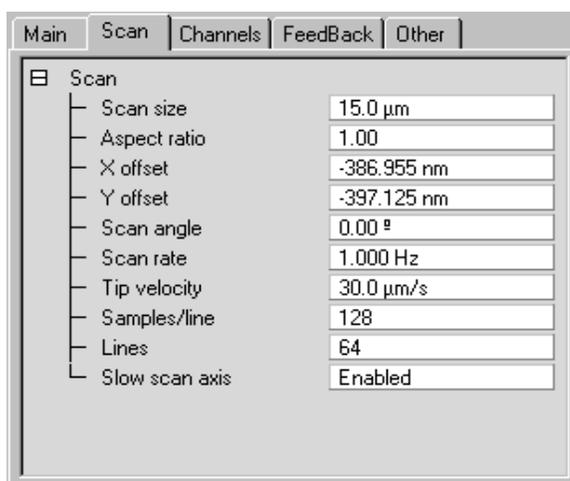
**Figure 3.2q** Select Scan View Controls



### 3.2.9 Scan Tab Interface

The **Scan** tab (see [Figure 3.2r](#)) includes parameters influencing piezo movement and data acquisition, as well as the ability to execute non-square scans. This **Tab** panel is probably the most frequently used panel, as it controls what type of scan to run, how large the scan is, its angle, scan rate, and number of samples per scan line.

**Figure 3.2r** Scan Tab Parameters



#### Scan Tab Parameters

**Scan size** Determines the size of the scan by controlling the voltage applied to the X and Y piezos.

*Range or Settings:*

- 0 to 440V
- 0 to XX $\mu\text{m}$  (scanner-dependent)

The units of this parameter are volts if the **Units** parameter (**Other Controls** panel) is set to **Volts**. The units are linear distance (nm or  $\mu\text{m}$ ) if the **Units** parameter is set to **Metric**.

See also, [Optimizing the Scan Size Parameter](#) on page 85.

**Aspect ratio** Controls the width-to-height size ratio of scans. Set **Aspect ratio** to 1.00 for square scans. An **Aspect ratio** of 2.00 yields scanned images having width equal to twice the height.

*Range or Settings: (depends upon the number of scan lines) 1 to 256.*

Figure 3.2s Aspect Ratio Example

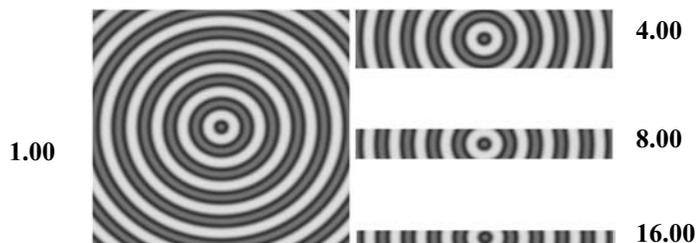
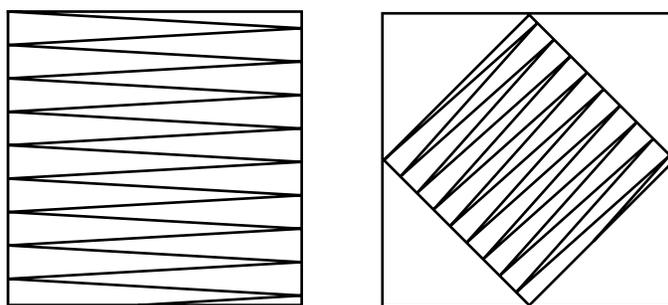


Figure 3.2t Scan Angle Rotated Example.



**X offset, Y offset**

Controls the center position of the scan in the X and Y directions, respectively.

*Range or Settings:*  $\pm 220V$ ;  $\pm XX\mu m$  (dependent on **Scan size** and scanner).

*See also, [Optimizing the X Offset, Y Offset Parameter](#) on page 85.*

**Scan angle**

Controls the angle of the X (fast) scan relative to the sample.

*Range or Settings:* **0** to **359°** (Any angular value can be entered with the keyboard)

Changing this parameter can dramatically affect the quality of images due to tip effects (tip side wall angle).

Setting this parameter to a setting besides 0 or 90° may reduce the maximum allowable **Scan size** 10-20 percent due to corner constraints (see [Figure 3.2t](#)).

**Scan rate**

The **Scan rate** sets the number of fast scan lines performed per second. When the Scan rates are low, it can take a fairly long time to scan an entire frame. For example, With the **Scan rate** set to **0.5Hz** and the **Number of samples** set to **512**, it can take over 17 minutes to capture a single image.

*Range or Settings:* **0.1-237Hz**, depending on the number of **Samples/line**.

*See also, [Optimizing the Scan Size and Scan Rate Parameters](#) on page 85.*

<b>Lines</b>	<p>Selects the number of lines to scan in a frame. The <b>Lines</b> parameter reduces resolution along the Y axis. It also speeds imaging (or frame rate) and reduces the size of the resulting image file.</p> <p><i>Range or Settings:</i> <b>2</b> to <b>1024</b>. The maximum number of lines may be limited by the value for <b>Samples/line</b>.</p>
<b>Tip velocity</b>	<p>Velocity of the tip (in <math>\mu\text{m/s}</math>) as it scans over the surface.</p> <p>When <b>Tip Velocity</b> is changed, the <b>Scan Rate</b> adjusts automatically.</p>
<b>Samples/line</b>	<p>Selects the number of sample data points per scan line.</p> <p>When this parameter is changes, the number of scan lines per image (<b>Lines</b>) are automatically adjusted to maintain the same ratio between the samples/line and lines per image.</p> <p><i>Range or Settings:</i> <b>128</b> to <b>16384</b>. This setting influences the memory size of captured files and image resolution (see <a href="#">Table 3.2a</a>).</p>

**Table 3.2a** File Size/Samples per line

<b>Samples/line value</b>	<b>File size (for square scans, including 8K header)</b>
128	40Kb
256	136Kb
512	520Kb

**Note:** **Samples/line** should be kept at 512 or higher for high resolution scans. To increase the frame rate (rate at which complete images are generated), the **Lines** parameter should be reduced. When the **Lines** parameter is reduced, file sizes in [Table 3.2a](#) are reduced accordingly.

**Slow scan axis** Allows the slow scan to be disabled, causing the fast scan to be repeated continuously at the same position. This means that the image displays the same line continuously. Images may be presented either as “true” X-Y renderings of the sample surface (Enabled), or as “stretched” single-line scans of length equal to the **Scan size** (Disabled).

*Range or Settings:*

- **Enabled**—Sample is scanned in the slow scan direction. (This is the normal setting of this parameter.)
- **Disabled**—No scanning of the sample in the slow direction is performed. The fast scan is repeated at the same position.

**Note:** Disabling the **Slow scan axis** and viewing the **Scope Mode** display is a convenient way of setting the **Feedback Gain** parameters.

The advantage of using the **Slow Scan Axis > Disabled** parameter is to emphasize one area (line) to adjust SPM parameters. For example, an area of the image appears fuzzy (believing SPM parameters are not optimized for the sample). **Disable** the **Slow Scan Axis**, view the image in **Scope** mode, and reconfigure scan parameters to optimize the scan.

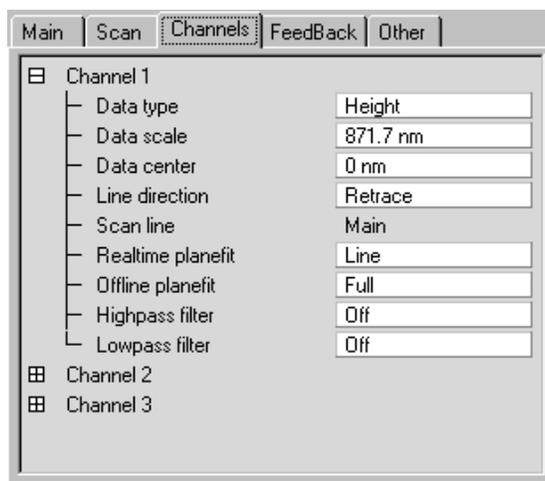
**Note:** Setting the **Slow scan axis** parameter to **Disable** stops the slow scanning of the piezo, but does not stop the movement of the Realtime display in Y. Lines are replicated in the Y direction.

### 3.2.10 Channels Tab Interface

The Channels tab (see [Figure 3.2u](#)) consists of parameters for three channels. Each channel represents a unique scanning image. Up to three data **Channels** may be opened by selecting each channel and choosing a data type to view simultaneously, opening up Realtime 3 times. Channels are numbered **1**, **2** and **3** and feature their own control panels. When a Data type is selected on a Channel, its image appears on the Display Monitor. It is possible to have up to three separate images from each scan. For example, a TappingMode scan might simultaneously present a **Height** image on **Channel 1**, a **Deflection** image on **Channel 2**, and an **Amplitude** image on **Channel 3**.

Parameters shown on each **Channel** control panel vary slightly, depending upon the type of microscope selected and its operating mode.

**Figure 3.2u** Channels Tab



## Channel Tab Parameters

**Data Type** Settings vary, depending upon the microscope selected and operating mode as shown in the field descriptions below. The **Data type** parameter may receive: no data (**Off**); sample-height data (**Height**); cantilever oscillation amplitude data for TappingMode (**Amplitude**); cantilever deflection data (**Deflection**); STM current data (**Current**); phase data (**Phase**).

See also, [Optimizing the Data Type Parameters](#) on page 86.

## Data Type Range or Settings

<b>Amplitude (TappingMode and Force Mode only)</b>	The RMS of the cantilever amplitude signal is displayed and captured.
<b>Current (STM only)</b>	Data displayed and captured is the tunneling current generated by the preamplifier. (When set to <b>Current</b> , the units of the data are <b>nA</b> .)
<b>TM Deflection</b>	Cantilever deflection signal data is displayed and captured. (When set to <b>TM Deflection</b> , the units of the data are in distance or volts.)
<b>Height</b>	The Z piezo voltage set by the feedback calculation in the Digital Signal Processor (DSP) is displayed. (The displayed data comes from the voltage output to the Z piezo.) Units are distance (e.g., <b>nm</b> , <b>μm</b> , etc.). Standard imaging of topography.
<b>Off</b>	Channel is turned off.
<b>Phase (MFM, EFM)</b>	Phase data from oscillating TappingMode tips, generally used with Magnetic Force Microscopy (MFM) and Electrical Force Microscopy (EFM), is displayed and captured. This setting appears when the microscope is configured with an Extender™ Electronics Module.
<b>Potential (EFM)</b>	Surface potential data is displayed. (For detailed information on Surface Potential or EFM features, see Support Note 231, <i>Electric Force Microscopy on the MultiMode Systems</i> .)
<b>Thermal</b>	Temperature data from thermal tips is displayed and captured.
<b>Deflection</b>	Cantilever deflection signal data is displayed
<b>Friction</b>	Torsional deflection signal data is displayed

- Data scale** The Data Scale controls the Z scale corresponding to the full height of the display and color bar.
- Range or Settings:*
- **0.0067 to 440V** (**Data type** set to *height*, **Units** are set to *volts*).
  - **XX to XXX  $\mu\text{m}$**  (Scanner dependent; where **Data type** is set to *height*, **Units** set to *metric*).
  - **XX to XXX  $\mu\text{m}$**  (Sensitivity dependent; where the **Data type** is set to *deflection* or *amplitude*; **Units** are set to *metric*).
  - **0.00003815 to 2.5V or 20V** (**Data type** set to *amplitude*; **Units** set to *volts* or *deflection*)
  - **0.0031 to 200nA** (**Data type** set to *current*; **Units** are set to *metric*).
  - **0.0003052V to 20V** (**Data type** set to *current*; **Units** are set to *volts*).

See also, [Optimizing the Data Scale Parameters](#) on page 86.

- Data center** Offsets centerline on the color scale by the amount entered.
- The **Data Center** offset does *not* become a permanent part of the data.
- Range or Settings:*
- $\pm 220\text{V}$
  - $\pm \text{TappingMode}$

- Line direction** Selects the direction of the fast scan data collection that is displayed in the image.
- The feedback calculation is always performed regardless of the scan direction. This parameter simply selects whether the data is collected on the trace or the retrace. This parameter selects the relative motion of the tip to the sample.
- Range or Settings:*
- **Trace**—Data is collected when the relative motion of the tip is left to right as viewed from the front of the microscope.
  - **Retrace**—Data is collected when the relative tip motion is right to left as viewed from the front of the microscope.

- Scan line** The scan line controls whether data from the **Main** or **Interleave** scan line is displayed and captured.
- Range or Settings:* **Main** or **Interleave**

This parameter is not selectable when the **Interleave mode** parameter is set to **Disable**. The system is locked on the **Main** scan lines whenever the interleaved mode is turned off.

**Realtime Planefit** Applies a software *leveling plane* to each Realtime image, removing up to first-order tilt. Three types of planefit are available to each Realtime image.

*Range or Settings:*

- **None**—Only raw, unprocessed data is displayed.
- **Offset**—Takes the Z-axis average of each scan line, then subtracts it from every data point in that scan line.
- **Line**—Takes the slope and Z-axis average of each scan line and subtracts it from each data point in that scan line. This is the default mode of operation, and should be used unless there is a specific reason to do otherwise.

**Offline Planefit** Applies a software “leveling plane” to each captured image for removing up to first-order tilt. Three types of planefit are available to each Offline image.

*Range or Settings:*

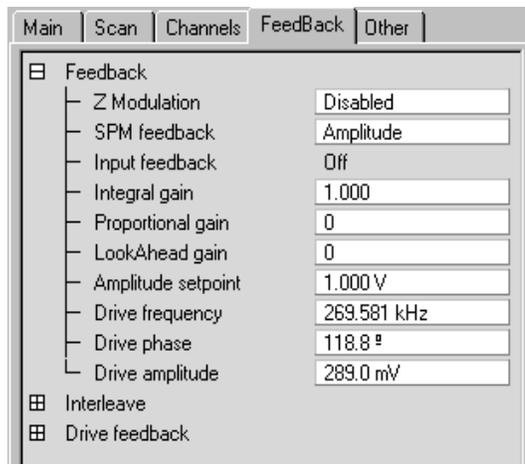
- **None**—Only raw, unprocessed data is displayed.
- **Offset**—Captured images have a DC 21 offset removed, but they are not fitted to a plane.
- **Full**—A best-fit plane which is derived from the data file subtracted from the captured image.

See also, [Optimizing the Offline Planefit Parameter](#) on page 86.

### 3.2.11 Feedback Controls Tab Interface

The **Feedback Controls** parameters allow for monitoring the signals between the **NanoScope Controller** and the cantilever. These signals adjust the setpoint, oscillation frequency, drive voltage, Z response for surface tracking, and output voltages. The purpose of the **Feedback Controls** is to maintain a constant setpoint (deflection, amplitude, or current) in the **Feedback Loop** for tip/sample control and tracking optimization.

**Figure 3.2v** Feedback Controls Tab in TappingMode



## Feedback Control Parameters

### Z Modulation (Fluid TappingMode only)

Allows the user to add the drive oscillation signal to the Z piezo voltage. This parameter is used to set up fluid cell oscillation in any Dimension system for Fluid TappingMode.

*Range or Settings:*

- **Enabled**—Enables Z modulation. Drive oscillation signal (Drive Frequency) is added to Z piezo voltage. **When enabled, the Z limit must be set  $\leq 420\text{V}$ .**
- **0**—Disables the Z modulation (i.e., no additional signal is added to Z piezo voltage).

The desired **Drive amplitude** and **Drive frequency** voltages (**Realtime > View > Sweep > Cantilever Tune**) need to be set for Fluid **TappingMode** operation.

### SPM feedback

Selects the signal to be used for tip feedback according to the selected **Microscope mode** parameter (**Other Controls** panel). For Contact AFM, the choice defaults to **Deflection**; however, for TappingMode, you may select either the **Deflection** or the **Amplitude**. STM offers three choices of feedback: Linear, Log and Boost.

*Range or Settings:*

- **TappingMode—Amplitude, TM Deflection-Phase** (Forcemod only)
- **Contact Mode—Deflection** only
- **STM—Linear, Log, Boost**

***Linear**—The linear difference between the instantaneous tunneling current and the **Setpoint** current is used in the feedback calculation.*

***Log**—The difference between the log of the instantaneous tunneling current and the log of the **Setpoint** current is used in the feedback calculation.*

***Boost**—Optimizes the feedback performance for high **Scan rates** over rough surfaces. This is not intended for atomic images.*

See also, [Optimizing the STM Feedback Parameters](#) on page 87.

### Input Feedback

Controls Frequency Modulation (MFM or EFM) and Surface Potential.

### Integral Gain

Controls the amount of integrated error signal used in the feedback calculation.

*Range or Settings: 0 to 1024*

See also, [Optimizing the Integral and Proportional Gain](#) on page 87.

Gain settings vary, depending upon the scanner used, the sample and scanner sensitivity. See [Table 3.2b](#) for approximate, nominal values (assumes a **Scan rate** of  $\approx 2.5\text{Hz}$ ).

**Table 3.2b** Typical Integral Gain Ranges:

Scanner	Contact AFM and Forcemod	TappingMode	STM
A <sup>a</sup>	1.0 - 8.0	0.2 - 1.0	0.3 - 5.0

- a. For atomic-scale images, scan rate must be increased to approximately 60 Hz.

### Proportional Gain

Controls the amount of the proportional error signal used in the feedback calculation. The **Proportional gain** term in the feedback calculation has equal gain at all frequencies; therefore, it has a dominating effect over the **Integral gain** for high frequencies (scan rates).

*Range or Settings:* **0** to **1024**

(Typical settings for the **Proportional gain** parameter are 35-100% more than **Integral gain** values).

### LookAhead Gain

Adjusts Z-axis tracking of the sample surface by “remembering” previous scan line data, then anticipating adjacent surface features on the current scan line. Look ahead gain is a valuable assist to the Integral gain parameter when scanning regular, steep features such as gratings and integrated circuits (e.g., by decreasing tip overshooting, etc.).

*Range or Settings:* **0** to **1**

See also, [Optimizing the Look Ahead Gain Parameter](#) on page 87.

### Setpoint

The meaning of this parameter depends on the operating mode of the microscope as follows:

**Amplitude Setpoint** (TappingMode)—defines the amplitude of the cantilever oscillation signal to be maintained by the feedback loop. (Range: **0.00** to **10.00V**)

**Deflection Setpoint** (Contact Mode)—Controls the deflection-signal level used as the constant desired voltage in the feedback loop. (Range: **10.00** to **10.00 V**)

**Current Setpoint** (STM)—Controls the constant current maintained by the feedback loop. (Range: **0.0** to **100.0nA**)

<b>Drive frequency (TappingMode and Force Mode only)</b>	<p>Selects the oscillation frequency applied to the piezoelectric crystal that vibrates the cantilever.</p> <p><i>Range or Settings: 0.00 to 250MHz</i></p> <p>The <b>Center frequency</b> is adjusted with the <b>Cantilever Tune</b> command to find the resonance frequency of the cantilever. The maximum cantilever oscillation amplitude occurs at its resonant frequency. The software sets the <b>Drive frequency</b> equal to the current <b>Center frequency</b> value when the <b>Ok</b> button in the Cantilever Tune control panel is pressed.</p>
<b>Drive Phase (TappingMode and Force Mode only)</b>	<p>Selects the phase of the drive voltage applied to the piezoelectric crystal that vibrates the cantilever.</p>
<b>Drive amplitude (TappingMode and Force Mode only)</b>	<p>Selects the amplitude of the drive voltage applied to the piezoelectric crystal that vibrates the cantilever.</p> <p><i>Range or Settings: 0.00 to 20.00V</i></p> <p>The <b>Drive amplitude</b> is also adjusted with the <b>Cantilever Tune</b> command. Increasing the <b>Drive amplitude</b> increases the cantilever-oscillation amplitude. The cantilever-oscillation amplitude is increased to an appropriate level with the <b>Cantilever Tune</b> command. In <b>AutoTune</b>, the <b>Drive Amplitude</b> automatically adjusts to get a cantilever oscillation (rms amplitude) equivalent to the user's <b>Target amplitude</b>.</p>
<b>Bias</b>	<p>Controls the sign and magnitude of the bias voltage applied to the sample.</p> <p><i>Range or Settings: -10.00 to 10.00V</i></p> <p>When used with STM, typical settings for the <b>Bias</b> voltage parameter are <b>20</b> to <b>100mV</b> for conductive samples and up to several volts with poorly conducting samples. Positive settings of the <b>Bias</b> voltage item correspond to negative current (electrons) tunneling from the tip into the sample on heads with the <b>Bias</b> applied to the <b>Sample</b> or <b>Tip</b>.</p>
<b>Analog 1, 3, 4</b>	<p>This voltage has no effect on the operation of the standard microscope, but is useful in custom applications.</p> <p><i>Range or Settings: -10.00 to 10.00V. These settings are only displayed with either NSIV or NSIII A with Quadrex extender.</i></p>
<b>Aux Lockin</b>	<p>Directs an external input signal through the auxiliary lock-in amplifier.</p>
<b>Drive Phase</b>	<p>The phase of the AC bias signal applied to stimulate piezore-sponse.</p>
<b>Lockin BW</b>	<p>The bandwidth of the effective bandpass filter centered on the TTL level reference frequency (i.e., the cantilever drive frequency in the NSIV Controller) used by the main lock-in amplifier.</p>

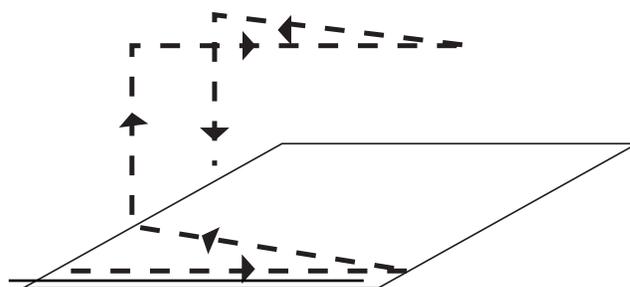
## InterSave Parameters Range or Settings

Several parameters (e.g. Z modulation, SPM Feedback, etc.) are highlighted by dark gray or green background. Dark grey indicates that the parameters are coupled with the equivalent values in the Feedback controls. By selecting (left-click) the Interleave parameters, the grey field turns green, indicating that the Feedback and Interleave parameters are decoupled and the value in those parameters will be used as feedback during the interleave scan line.

## Interleave Mode

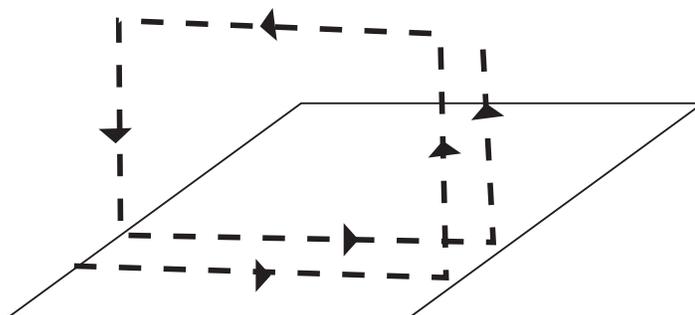
- **Interleave**—Adds a second, interleaved set of lines to the scan, which can be accessed from the Channel panel and captured as data. Invoking Interleave reduces the slow axis speed by one-half and doubles the capture time.
- **Lift**—A variant of Interleave, the Lift option uses the first set of scan lines to detect the surface, then lifts the probe above the sample surface on the interleaved set of scan lines according to the Lift start height and Lift scan height parameter settings. During the Interleaved scan, the tip mimics the surface topography from the previous surface scan line (see Figure 3.2w).

Figure 3.2w Interleave Lift Mode



- **Linear**—Lifts the tip to a predetermined height and runs the interleave scan at that height.
- **Disabled**—Turns off the interleave scanning.
- **Retrace Lift**—Lifts after the trace scan in the retrace direction. This parameter is optimized with the **Rounding** parameter (**Microscope > Calibrate > Scanner > Rounding**). The suggested rounding setting is **0.2**.

Figure 3.2x Retrace Lift Mode

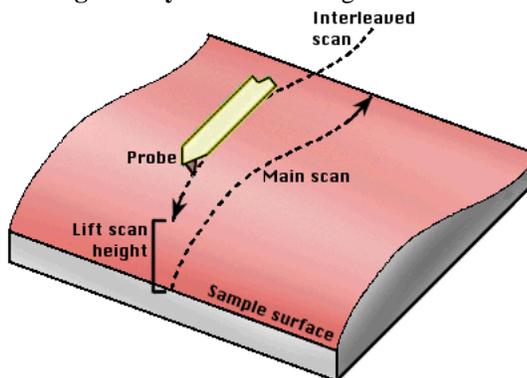


**Lift scan height** Specifies the tip's height above the sample surface during interleaved scans. This parameter is in effect **ONLY** when the Interleave mode parameter is set to **Lift**, **Linear**, and **Retrace Lift** (see Figure 3.2y).

*Range or Settings:* XX $\mu$ m (Scanner dependent)

The maximum meaningful value of the parameter depends on the Z voltages applied in the **Main** scan line and the maximum voltage that the system can output. The maximum voltage that can be applied to the piezo is  $\pm 220$ V. It will be lower if the Z voltage is restricted by the **Z limit** parameter.

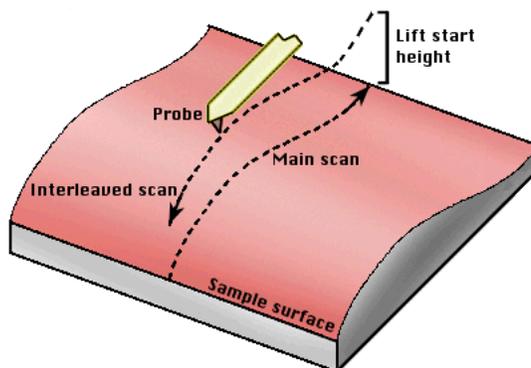
Figure 3.2y Lift Scan Height Illustrated



**Lift start height** Specifies the height that the tip is to be lifted above the sample surface at the start of each interleaved scan. Generally, this parameter serves to lift the tip clear of any contamination layers present on the sample before assuming its Lift scan height during interleaved scans. This parameter is in effect **ONLY** when the **Interleaved mode** parameter is set to **Lift** and **Retrace Lift**. This parameter defines an offset from the Z voltage, or height, applied to the piezo on the **Main** scan line.

*Range or Settings:* XX $\mu$ m (Scanner dependent)

Figure 3.2z Lift Start Height Illustrated



### Tips for Using the Lift Start Height Parameter

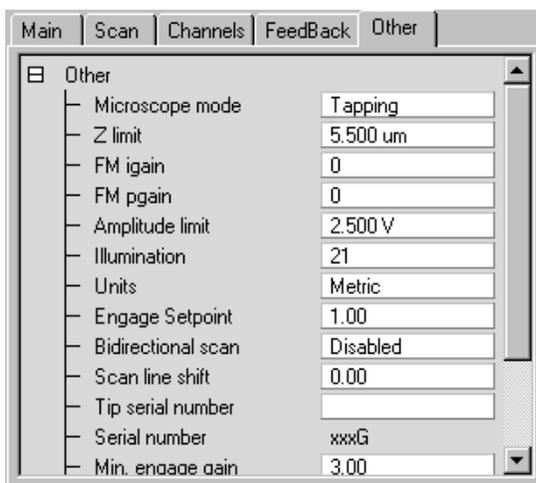
- This value can be left at zero for TappingMode and STM. It is generally only used for Contact AFM to break the tip free of the adhesive force produced by the water layer before settling to the final tip height.
- The maximum meaningful value of the parameter depends on the Z voltages applied in the **Main** scan line and the maximum voltage that the system can output. The maximum voltage that can be applied to the piezo is  $\pm 220\text{V}$ . It will be lower if the Z voltage is restricted by the **Z limit** parameter.

The tip will go through this height at the start of every lifted scan line, then proceeds to the lift scan height for the rest of the scan line.

### 3.2.12 Other Tab Interface

The **Other Controls** parameters set the type of microscopy, Z tracking limits, units to use in measuring and other parameters specific to microscope mode (i.e., the parameters that appear in the **Other Controls** panel will vary from one microscope to another). In the **Workspace** menu, select **R001 Time**. In the **Realtime Scan** window, select the **Other** tab.

Figure 3.2aa Other Tab



#### Parameters in the Other Controls Tab:

- |                        |   |
|------------------------|---|
| <b>Microscope mode</b> | Selects the type of microscopy to be employed. Switching this parameter enables/disables other parameters. Also, on <b>MultiMode SPMs</b> , any change to the <b>Microscope mode</b> must be accompanied by use of the mode selector switch on the microscope's base.<br><i>Range or Settings:</i><br><b>Contact, Tapping or STM</b>      |
| <b>Z limit</b>         | Permits attenuation of maximum allowable Z voltage and vertical scan range for achieving higher resolution (smaller quantization) in the Z direction.<br><i>Range or Settings:</i><br><b>11 to 440V</b> (with Units set to Volts) for the XY Closed loop head<br><b>11 to 330V</b> (with Units set to Volts) for the XYZ Closed loop head |
| <b>FM igain</b>        | Integral gain for Frequency modulation. Controls the feedback loop that uses phase electronics.   |
| <b>FM pgain</b>        | Proportional gain for Frequency modulation. Controls the feedback loop that uses phase electronics.   |

- Deflection Limit** Use this parameter for attenuating the input voltage signal (appears only when performing Contact AFM).  
*Range or Settings:*
- 2.500V to 20.0V for regular imaging
  - 20.00V in **Force Mode only**
- Amplitude Limit** Use this parameter for attenuating the input voltage signal (appears only for TappingMode or STM).  
*Range or Settings:*
- 2.500V for regular imaging
  - 20.00V in **Force Mode only**
- Illumination** Controls the fiber optic illumination of the sample in **Dimension** series microscopes.  
*Range or Settings:* **0** to **100**, recommended range is **20** to **50**
- Units** Selects whether the units of certain scan parameters are in Volts or in units of Metric distance (nm, etc.). Parameters affected include Scan size, X Offset, Lift start height and Lift scan height, Y Offset, Data Scale, Z Limit, Z Scan Start, Ramp Size, Column Step and Row Step.  
*Range or Settings:*
- **Volts**—Parameters are in Volts.
  - **Metric**—Parameters are in units of distance (nm,  $\mu\text{m}$ , etc.)

**Engage Setpoint (TappingMode only)** Allows the user to correct for loss of tracking on engage due to sample differences. The automatic **Engage** procedure establishes the setpoint voltage at the smallest possible value that detects the sample surface, resulting in a value that protects both the sample surface and the cantilever tip. However, this value may not be sufficient for optimal surface tracking on all samples. The setpoint voltage determined by the automatic **Engage** procedure will be multiplied by the **Engage Setpoint** value, increasing or decreasing tapping force.

*Range or Settings:*

**0.5** through **2.0**. A value of **1.0** results in no change to the tapping force. Values less than **1.0** increase the tapping force and values greater than **1.0** decrease the tapping force. A value of **0.9** is nominal for most samples.

#### **Example of Engage Setpoint**

The **Engage Setpoint** for a particular sample may be empirically determined. Procedures are as follows:

1. Set the **Engage Setpoint** to **1.0** and engage on the sample.
2. After engagement, make note of the **Setpoint** parameter.
3. While watching the scan, adjust the **Setpoint** value until the tip tracks the surface correctly. Calculate the following:
  - Setpoint value/ Starting Setpoint value = Engage Setpoint  
(For optimal value, take the average of several engages on a selection of samples or different areas of the same sample).

**Bidirectional scan** When the Bidirectional scan parameter is **Enabled**, data from both Trace and Retrace scans are used to capture frames in half the normal time. Images have alternately shifted lines, which cause features to lose some of their lateral definition; however, data may be used for metrological analysis. Use to save time while capturing images.

*Range or Settings:*

#### **Enabled or Disabled**

When **Enabled**, features shown in images lose some lateral definition, making point-to-point measurements inadvisable. Vertical data, however, is unaffected.

Use the **Scan line shift** parameter to readjust images with the **Bidirectional scan** parameter **Enabled**. This will shift scan lines relative to one another to restore some lateral definition in features.

**Scan line shift** Use the **Scan Line Shift** parameter to shift trace and retrace lines relative to one another by up to 5 pixels in either direction. Units are in pixels and range from -5 to +5. Scan line shift is used for readjusting images captured when the **Bidirectional scan** parameter is **Enabled**.

*Range or Settings:* **-5** to **+5**

This parameter is generally only for images that have been captured with the **Bidirectional scan** parameter set to **Enabled**.

**Tip Serial Number** Saves input in the image header (Ciao Scan List) for users who keep a tip filing system. This is to keep track of the tips used for certain images.

*Serial Number:* **Scanner Calibration** file.

<b>Min. Engage Gain (STM only)</b>	Allows user to engage tip in <i>constant height</i> mode. In constant height mode, the gains (feedback) is disabled. However, the <b>Min. Engage Gain</b> parameter provides for gain during engagement.
<b>Strip Chart Rate</b>	Frequency of (Z-position, deflection) data point acquisition. <i>Range: 32kHz</i> <i>Typical value: 1kHz</i>
<b>Strip Chart Size</b>	Time interval over which (Z-position, deflection) data points are displayed. <i>Typical value: Tens of seconds.</i>  Note: Although the strip chart collects and displays data over the time interval defined by clicking <b>Start</b> , then later, <b>Stop</b> , this data is not saved for subsequent use until the <b>Capture</b> icon is clicked. If <b>Capture</b> is clicked while strip chart data is being taken, what is saved begins at the start of the chart (sooner than the icon is clicked).

## Auto Gain

**Auto Gain** automatically sets the feedback parameters (**Proportional** and **Integral gain**) for a given sample.

**Auto Gain** works by analyzing the difference between **Trace** minus **Retrace (TMR)**. The analysis is used to choose a set of feedback parameters that minimizes the **TMR** value. By specifying the starting value of the **Integral gain** sweep, the ending value, and the size of the increments, Auto Gain may be used to calculate a set of useful feedback parameters.

For the purposes of this analysis, **Proportional gain** operates as a factor of **Integral gain**. The relationship is  $\text{Proportional gain} = F \times \text{Integral gain}$ , where  $F$  is a factor defined as **Pro. Gain factor**.

**Auto Gain** only requires the input of the three **Gain** values in order to calculate an effective **Integral gain**.

### Parameters in the Auto Gain Panel:

<b>Gain start</b>	The starting value of the integral gain sweep. <i>Range or Settings:</i> Recommended settings are <b>0.10</b> for <b>TappingMode</b> , <b>0.5</b> for <b>Contact Mode</b> .
<b>Gain end</b>	The ending value of the integral gain sweep. <i>Range or Settings:</i> Recommended settings are <b>1.0</b> for <b>TappingMode</b> , <b>10.0</b> for <b>Contact Mode</b> .
<b>Gain incr.</b>	The increment step for each integral gain test. <i>Range or Settings:</i> <b>0.0</b> to <b>5.0</b> ; Recommended settings are <b>0.1</b> for <b>Tapping-Mode</b> , <b>0.5</b> for <b>Contact Mode</b> .
<b>Pro. Gain factor</b>	<b>Proportional gain</b> is set to: Pro. Gain factor $\times$ Integral gain <i>Range or Settings:</i> <b>0.0</b> to <b>10.0</b> ; Recommended value is <b>1.50</b>
<b>Max shift</b>	The percentage of pixels to shift the Retrace line to match the trace line during the correlation routine. The more closely the Trace and Retrace lines match, the lower the TMR will be, and the more effective the Auto Gain feature. <i>Range or Settings:</i> <b>0</b> to <b>0.2</b> ; recommended setting is <b>0.02</b> (or <b>2%</b> )
<b>Gain offset</b>	Specifies the number that determines the final, best fit Integral gain. Allows a change in the value produced by Auto Gain. <i>Range or Settings:</i> <b>0.0</b> to <b>2.0</b> ; recommended setting is <b>0.95</b> (or <b>95%</b> )
<b>Lines/gain</b>	The number of lines to test and average for each integral gain step. Optimal settings are between 4 and 8. This, like Max shift, allows for a more accurate determination of TMR. <i>Range or Settings:</i> <b>1</b> to <b>20</b> , with a default setting of <b>8</b>

### 3.3 Tips on Using Realtime

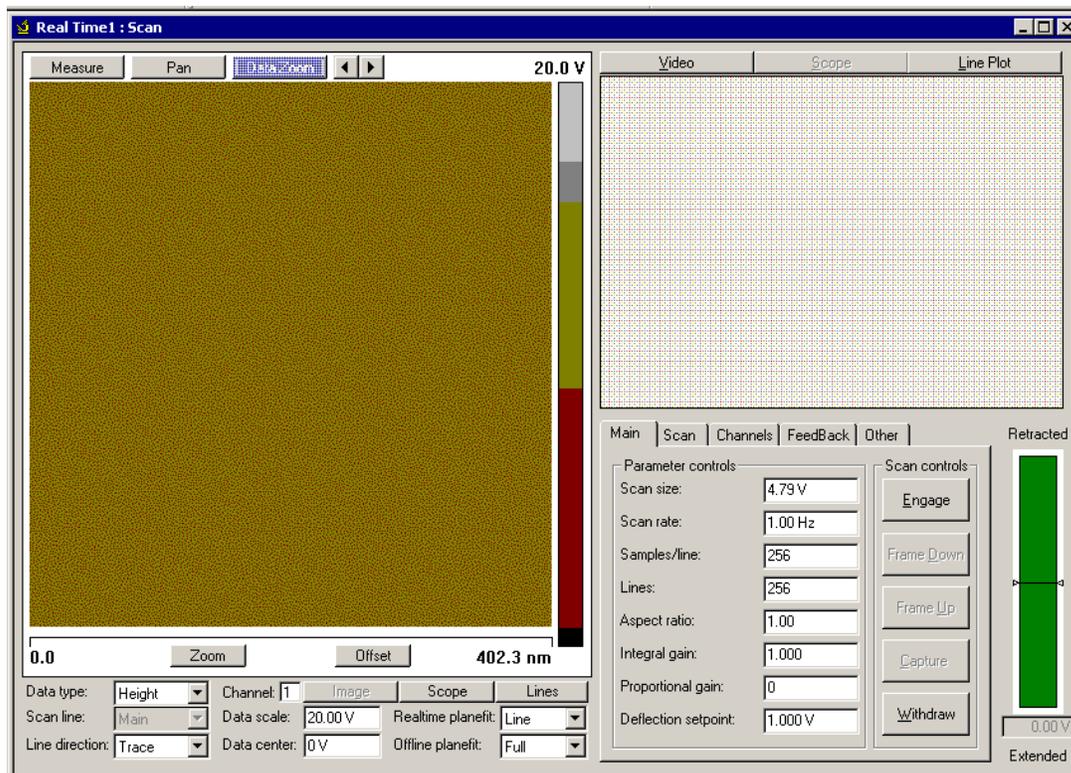
Please refer to the following Realtime commands available on the NanoScope software:

- **Using the Image Interface** [Section 3.3.1](#)
- **Multiple Channels** [Section 3.3.2](#)
- **Hints to Optimize the Engage Button** [Section 3.3.3](#)
- **Scan View Parameters Tips** [Section 3.3.4](#)
- **Channels Parameters Tips** [Section 3.3.5](#)
- **Feedback Parameters Tips** [Section 3.3.6](#)

#### 3.3.1 Using the Image Interface

There are various commands available for use during a Realtime scan. Below is a description of these commands (see [Figure 3.3a](#)).

**Figure 3.3a** Image for Processing



## Buttons

- **Measure:** Allows you to draw a line to make measurements.
- **Pan:** From a zoomed image, the user can pan around to other areas of the original image.
- **Data Zoom:** Left-click, hold, and drag out a box. Release the mouse button and the image will automatically zoom in to the area of the box. The original scan size remains the same.
- **Zoom:** Allows you to zoom in on a region of interest.
  - When you select **Zoom** a bounding box appears on the image display. Left-click on the outer edge of the box to resize.
  - Left-click in the center to reposition.
  - Click the **Execute** button to zoom in. This updates the **Scan size** and **X** and **Y Offset** parameters.
- **Execute:** Executes the **Zoom** and **Offset** commands. You must select the **Zoom** or **Offset** button for the **Execute** button to appear.
- **Offset:** Allows you to center the scan at the region of interest.
  - When you select **Offset** a crosshair displays at the center of the image.
  - Left-click and hold the crosshair to reposition it.
  - Click the **Execute** button to center the scan. This updates the **X** and **Y Offset** parameters.

## Right-Clicking on the Image

By right-clicking on the image, you will get a menu that allows you to perform the following tasks:

- **Copy Clipboard:** Copies the image to the Microsoft™ clipboard.
- **Tooltip Info Level:**
  - Basic
  - Medium
  - Advanced
  - None

## Right-Clicking on the Color Bar

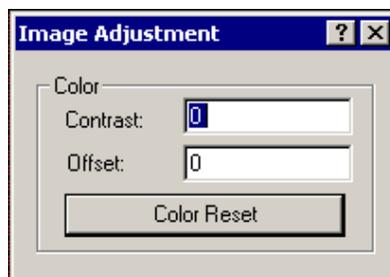
Right-clicking on the color bar along the right side of the image (see [Figure 3.3a](#)) will produce a **Color** button (see [Figure 3.3b](#)). Clicking on this **Color** button will open the **Image Adjust** menu, where you can perform the following image adjustments (see [Figure 3.3c](#)):

**Figure 3.3b** Color Button



- a. You can adjust the color by changing the **Contrast** or **Offset** settings.
  - **Contrast**—Number (-10 to +10) designates contrast of colors in displayed image (e.g., 0 shows little change, while 10 shows highest contrast).
  - **Offset**—Number (-128 to +128) designates offset of colors in displayed image (e.g., 120 shows illuminated background on image).
- b. Clicking the **Color Reset** button will change all the current readings to the default settings.

**Figure 3.3c** Image Adjust Menu



- c. To change the color table, position the mouse over the color bar on the right side of the image. Click and hold the left mouse button, then drag the mouse from left to right to scroll through the different color tables.

## Using the Mouse Within a Captured Image in Measure Mode

- |  |   |
|--|---|
| <b>Left-click anywhere in image window, drag line out, and release</b> | Creates a line of X length, at X° of angle in the image window. |
| <b>Place cursor on line</b>  | Displays length and angle values of line in the image window.   |
| <b>Place cursor on line, click and hold left button, and drag</b>      | Allows you to drag the line anywhere in the image window.       |

- Click and hold on either end of line and drag** Changes length and/or the angle of the line.
- Right-click** Clicking the right mouse button when the cursor is on the line accesses the **Image Cursor** menu (see [Figure 3.3d](#)).
- **Delete**—Deletes the line.
  - **Flip Direction**—Switches the line end to end.
  - **Show Direction**—Adds small arrowhead to the line to indicate its the direction.
  - **Set Color**— Allows you to changes the color of the line.
  - **Clear All**—Deletes the line.

**Figure 3.3d** Image Cursor Menu



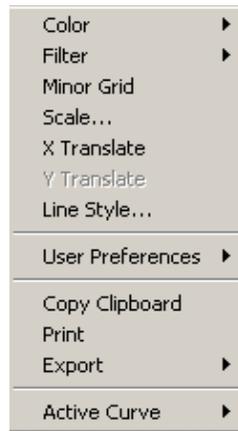
### Using the Grid Display

Measurement cursors for the **Scope View** are provided to the left and right of the Grid Display. You can bring the cursors into the grid by placing the mouse cursor onto the measurement cursors, clicking and holding the left mouse button, and dragging them onto the grid. When you place the mouse cursor onto a measurement cursor, the cursor will change from a plus sign to a horizontal or vertical arrowhead cursor, which indicates you can grab and drag this cursor.

Right-clicking on the grid will bring up the **Grid Parameters** menu (see [Figure 3.3e](#)) and allow you to make the following changes:

<b>Color</b>	Allows operator to change the color of the: <ul style="list-style-type: none"><li>• Curve (data)</li><li>• Text</li><li>• Background</li><li>• Grid</li><li>• Minor Grid</li><li>• Markers</li></ul>
<b>Filter</b>	Typically used for a Profiler Scan. <ul style="list-style-type: none"><li>• <b>Type</b>—Allows the user to plot the mean, maximum or minimum y-value per x-value.</li><li>• <b>Points</b> —Allows user to plot multiple vertical axis (y-)values at each horizontal axis (x-)value. Select 4K, 8K, 16K or 32K Points to limit the display to 4, 8, 16 or 32 times 1024 points.</li></ul>
<b>Minor Grid</b>	Places a minor grid in the background of the Vision Window.
<b>Scale</b>	Allows user to auto scale, set a curve mean, or set their own data range
<b>Translate</b>	Offsets the curve by the placement of a horizontal cursor on the grid
<b>Line Style</b>	For each curve, the operator can choose a connect, fill down, or point line.
<b>User Preferences</b>	<b>Restore</b> —Reverts to initial software settings <b>Save</b> —Saves all changes operator has made during this session. This becomes the new default settings.
<b>Copy Clipboard</b>	Copies the grid image to the Microsoft Clipboard
<b>Print</b>	Prints out the current screen view to a physical printer
<b>Export</b>	Exports data in bitmap, JPEG or XZ data format
<b>Active Curve</b>	Determines which curve you are analyzing

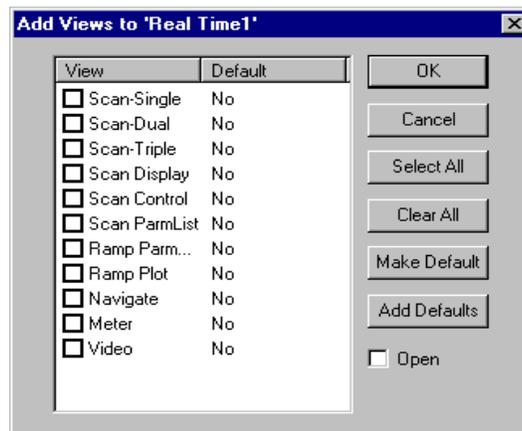
Figure 3.3e Grid Parameters



### 3.3.2 Multiple Channels

It is often helpful to view more than one channel of data simultaneously. **Scan-Dual** and **Scan-Triple** can be selected upon first opening Realtime by clicking on the appropriate check boxes in the **Add Views to Realtime1** dialog box (see Figure 3.3f).

Figure 3.3f Add Views to Realtime1 Dialog Box



If you are already in Realtime, you can also access multiple channel views by right-clicking on the **Realtime** icon in the Realtime workspace (see Figure 3.3g).

- Click **Add View > Scan-Dual** to add a window with two channels displayed.
- Click **Add View > Scan-Triple** to add a window with three channels displayed.

**Note:** To open a single channel, click **Add View > Scan Display**.

Figure 3.3g Add Views to Realtime1 Menu

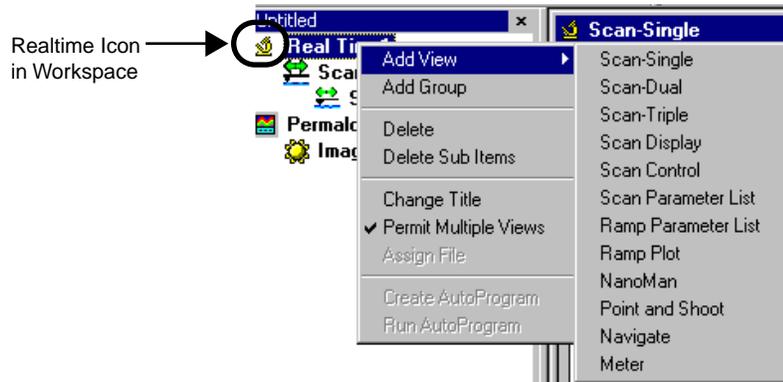
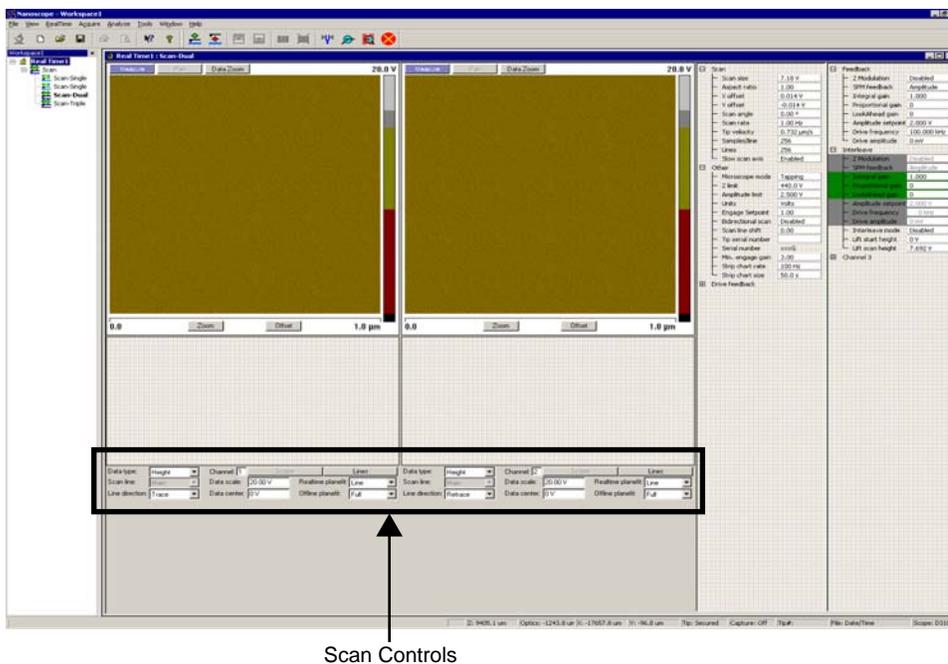


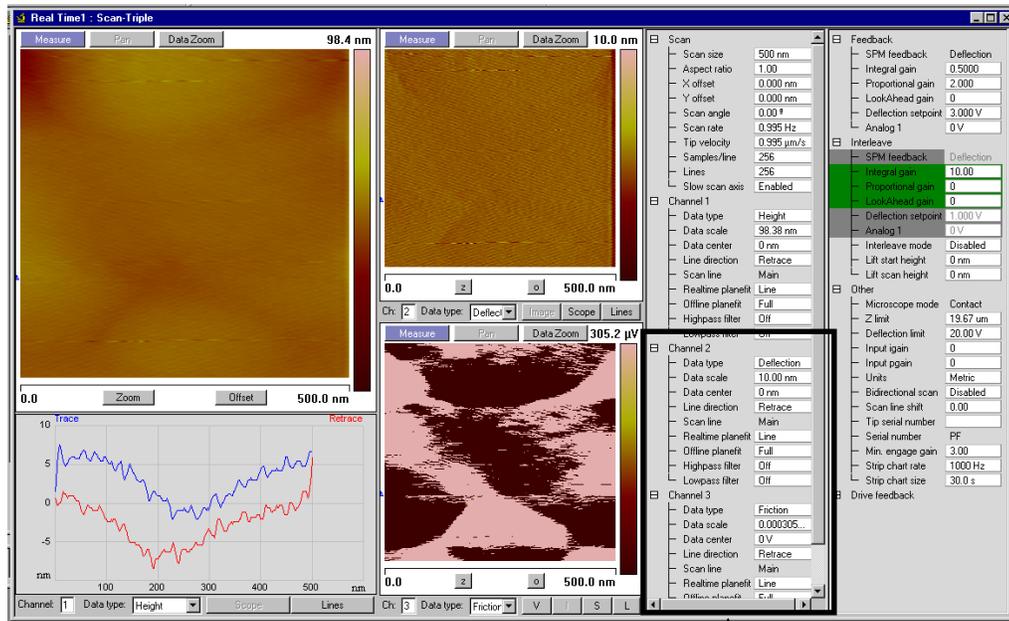
Image controls are displayed beneath each image (see Figure 3.3h).

Figure 3.3h Scan-Dual View



In Scan-Triple, the **Scan Line**, **Scan Direction**, **Data Scale**, **Data Center**, **Realtime Planefit**, and **Offline Planefit** settings are not displayed below the images and must be accessed using the parameters list to the right of the image display (see Figure 3.3i).

Figure 3.3i Scan Triple Dialog Box and Location of Channel 2 and 3 Parameters



Channels 2 and 3 Parameters

**Note:** All three channel display options are included among the Realtime views presented as options to include in the workspace upon first opening the Realtime workspace (see Figure 3.3h).

Typical examples of the use of multiple channels:

- To simultaneously monitor both a TappingMode height image and a phase image of the same region.
- To simultaneously collect a topography and MFM image.

### 3.3.3 Hints to Optimize the Engage Button

- When used with stepper-motor-engagement microscopes, the tip is lowered under program control. While the tip is being engaged, the tip travel distance is shown in the center of the status bar on the Control Monitor. When the surface is detected, the workstation beeps, starts the Realtime imaging process, and displays **Engaged** in the status bar on the Control Monitor.
- During automatic engagement, the tip will travel a preset distance (200μm for Dimension AFMs, 125μm for MultiMode AFMs). If the sample surface is not detected in this distance, an error message will be displayed.
- If the tip is on the surface and the Z center voltage indicates that the piezo is near full extension or retraction, the tip may be withdrawn and re-engaged to center the Z center voltage. Alternatively, the *Tip Up* and *Tip Down* subcommands of the **Motor** command

can be used to center the Z voltage. If the Z center position indicates that the scanner is retracted, click the Tip Up button until Z center is near 0V (0.50V).

- Pressing **Ctrl-F** after the **Engage** command has been executed will cause a false engage to occur after the SPM safety height is recycled for Dimension, causing the Realtime software to start scanning independently of whether the surface has been detected or not.

### 3.3.4 Scan View Parameters Tips

#### Optimizing the Scan Size Parameter

- The **Scan size** and offsets can be set by using the **Zoom** and **Offset** subcommands in **Scan View** or in tabbed panels.
- Non-zero **X** and **Y offsets** reduce the maximum **Scan size**. Each volt of **X** or **Y offset** reduces the maximum scan size by 2V.
- Having a non-zero **Scan angle** will reduce the maximum allowable **Scan size**.
- The maximum **Scan size** will also decrease as the **Scan rate** increases.

#### Optimizing the X Offset, Y Offset Parameter

- These parameters use the sample as the position reference. Therefore, a more negative **X offset** value will move a feature in the current image to the *left* on the Image display. Similarly, a more negative **Y offset** moves a feature in the current image *down* on the Image display.
- Using the left-arrow and right-arrow keys when the cursor is in these parameters will decrement and increment these parameters by 10% of the **Scan size**.
- Using the **Zoom** or **Offset** subcommands on the automatically changes the value of **X** and **Y offsets**.

#### Optimizing the Scan Size and Scan Rate Parameters

- The **Scan size** and height of features on the sample will affect the maximum **Scan rate** that should be used on a given sample. Scan rate should be set to a rate that allows the tip to closely track the sample surface in both trace and retrace. In general, larger scans and taller features require slower scan rates.

### 3.3.5 Channels Parameters Tips

#### Optimizing the Data Type Parameters

- The system can display up to three Realtime images on the Display Monitor.
- The **Data type** parameter does *not* switch the operating mode of the instrument, it simply changes the source of the data displayed.

#### Optimizing the Data Scale Parameters

- Data beyond the setting of the **Data scale** is clipped for the Realtime display. Captured data, however, is not clipped. Independent of the settings of this parameter, the captured data will be correct unless it exceeds the maximum vertical range of the scanner.
- Each **Data type** retains separate settings for **Data scale**.
- **Data Center** is used to manually offset the trace data when Realtime Planefit is set to none.

The conversion of volts to **nm** or **nA**, is dependent on the value **Sensitivity Detector** parameters in the **Tools > Calibrate > Detector** panel.

For example, nanometers of cantilever deflection are calculated using the **Sensitivity** parameter in the **Force Calibrate** panel.

#### Optimizing Realtime Planefit Parameters

The setting of **Realtime Planefit** only affects the displayed data. It does not affect the captured data. The parameters are described below.

- **None** displays the raw data in the scope display.
- **Offset** applies a zero order correction to each line of data so that the average height of the line is centered in the scope display.
- **Line** applies a 1<sup>st</sup> order correction, removing both tilt and offset from each line of data.

**Note:** If features are not evenly spaced along the scan line, using **Realtime Planefit Line** can result in artificial tilting of the scan line.

#### Optimizing the Offline Planefit Parameter

- The **None** option should only be used in special cases. The **Offset** and **Full** options provide greater dynamic range in the data to reduce round-off and other errors in subsequent calculations.
- The **Offline > Modify > Flatten** and **Planefit** commands can also be used to level the data after it has been captured.

### 3.3.6 Feedback Parameters Tips

#### Optimizing the STM Feedback Parameters

- The **Boost** and **Log** modes are preferable for most STM samples, because the tip responds in a more symmetric manner (i.e., the same going up and coming down). **Log** and **Boost** modes tend to linearize the entire feedback loop since  $Z \approx \ln(i)$ . The asymmetric response of the **Lin** setting distorts data.
- Use of **Boost** mode allows the **Proportional gain** and **Integral gain** values to be reduced and is preferable for large scans having high, vertical features (e.g., integrated circuits).
- When **Boost** mode is selected, the **Integral** and **Proportional gains** are often best set to lower values than when **Log** mode is used.

#### Optimizing the Integral and Proportional Gain

- The **Integral gain** is usually the major contributor to the performance of the feedback loop due to its “long term” influence. For this reason, it is usually adjusted before proportional gain.
- The integral term in the feedback calculation has the highest gain at low frequencies, and its effects diminish with increasing frequency.
- A nominal **Integral gain** value may be obtained by slowly increasing the value until the piezo begins to oscillate, then decreasing the value until oscillation ceases. Oscillation effects are best viewed using **Scope Mode** and show up first in error signal (i.e. deflection or amplitude).
- The **Proportional gain** parameter is typically set to 35 to 100% more than the **Integral gain** value.

#### Optimizing the Look Ahead Gain Parameter

- **Look ahead gain** adds information from the previous scan line to the feedback loop calculation, so it is most useful for samples with long features oriented perpendicular to the scanning direction.
- Use **Look ahead gain** discreetly. For many surfaces, **0.5** to **0.8** is nominal.

## 3.4 Force Curves

**Force Curves** ramp tip-sample separation while holding the X, Y position constant in the center of the previous scan. The scanner's vertical position is plotted versus either the cantilever deflection (Contact AFM), or the amplitude of the cantilever oscillation (TappingMode). Alternatively, the cantilever deflection or oscillation amplitude can be plotted relative to a user-designated input signal.

### 3.4.1 Force Curves Procedure

#### Ramp Settings

To obtain force curves, it is necessary to first engage in Scan Mode using one of the **Scan Views** (see **Preparing a Dimension Series AFM for a Realtime Scan** [Section 2.4.2](#)), then switch to Ramp mode. If you want to calibrate deflection sensitivity, use a hard sample in the following procedure.

1. Activate Ramp mode (this causes the system to stop scanning, and the probe to position above the center of the previous image):
  - a. Click the Ramp node in the workspace or any visible ramp plots.

Or

- b. Add the **Ramp Parameter List** and **Ramp Plot(s)** to the workspace. Right-click **Realtime** or click the **Acquire** menu, and select **Ramp Parameter List** and **Ramp Plot**. It is possible to view three **Ramp Plots** at a time by adding ramp plots to the workspace. Arrange the **Ramp Plot(s)** and **Ramp Parameter List** so that all are viewable.

**Note:** See **Ramp Parameter List** [Section 3.4.2](#) - **Feedback Panel** [Section 3.4.7](#) for a thorough discussion of the **Ramp Parameter List** Parameters. When in **Ramp** mode, a ramp-specific menu also displays, the **Ramp** menu. See **Ramp Menu** [Section 3.4.8](#) for more information.

2. Enter the following parameter settings in the designated panels of the **Ramp Parameter List**:
  - a. In the **Ramp** panel select:

Parameter	Setting
Ramp output	Z
Ramp size	1.00 $\mu$ m

Parameter	Setting
Z scan start	0nm
Scan rate	1.00Hz
Number of samples	512

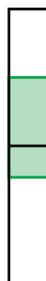
b. In the **Channel 1** panel select:

Parameter	Setting
Data Type	Deflection
X Data Type	Z
Display Mode	Deflection vs. Z

### Gather Force Curves

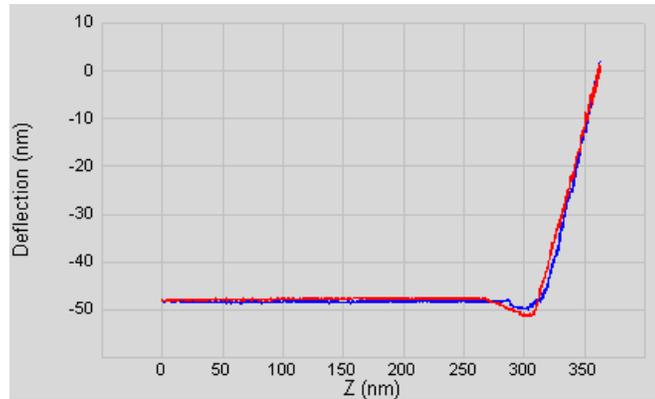
1. Select **Ramp** > **Run continuous** from the menu bar.
2. While watching the **Ramp View** and the Display Monitor's bar graph (see [Figure 3.4a](#)), increase the **Z Scan Start** to move the tip closer to the sample.

**Figure 3.4a** Bar Graph



3. When the force curve suddenly rises, the tip has reached the surface (see [Figure 3.4b](#)).

**Figure 3.4b** Force Curve



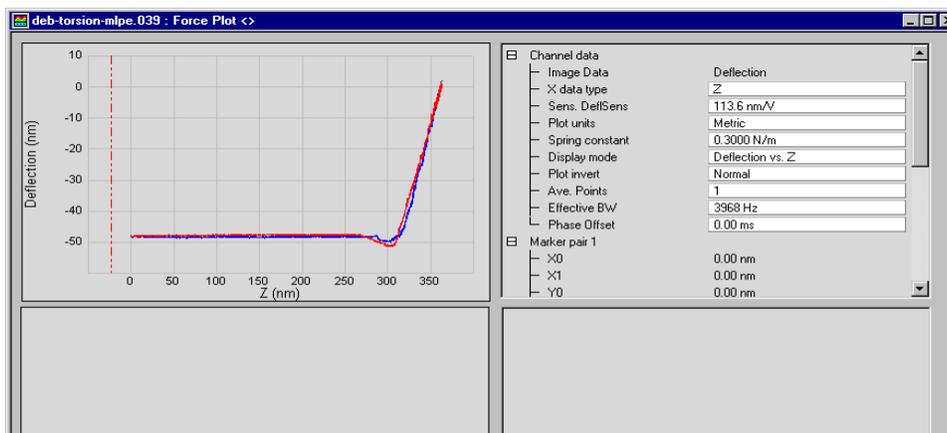
4. Click the **Capture** icon to save the force curve. Make note of the file name in the status bar (lower right corner of the window).

### Calibrate Deflection Sensitivity

It is often necessary to calibrate the deflection sensitivity of a force curve. The deflection sensitivity depends upon several factors, such as the position of the laser spot on the cantilever, so it needs to be calibrated each time you change the probe. Use the following procedure to determine the deflection sensitivity:

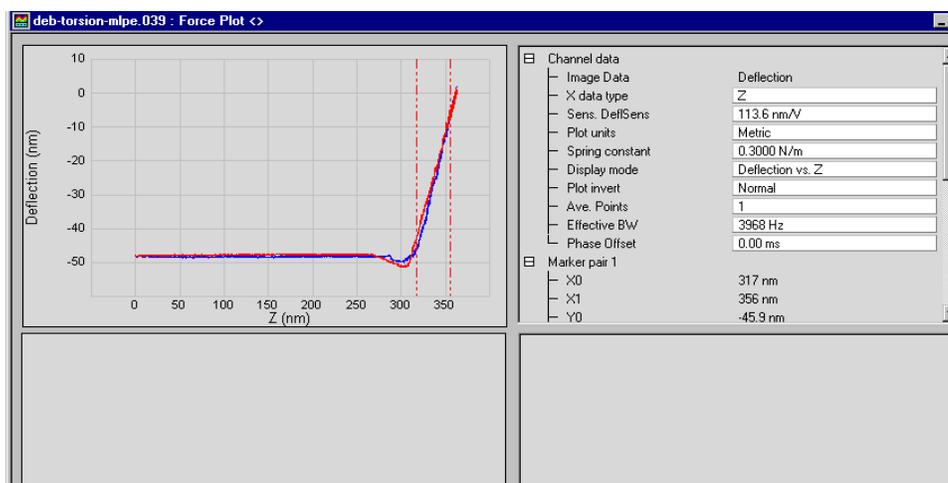
1. Move two cursors onto the Deflection vs. Z plot (see [Figure 3.4c](#)).

**Figure 3.4c** Realtime Force Curve



2. Arrange the cursors so that they surround the contact (steepest) portion of the graph (see [Figure 3.4d](#)).

Figure 3.4d Force Curve Cursors



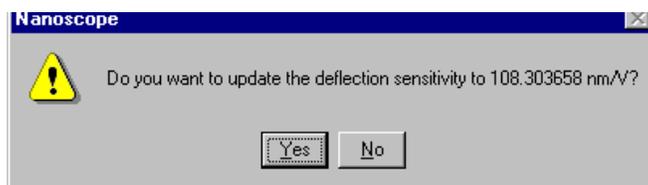
3. Select **Force > Update Sensitivity**. The software will automatically calculate the deflection sensitivity.

Figure 3.4e Update Sensitivity



4. Click **OK** to accept this deflection sensitivity in the dialog box that displays, and it will automatically be entered into the **Sens. DeflSens** parameter in the **Channel Data** panel to the right of the plot (see Figure 3.4c).

Figure 3.4f Deflection Sensitivity Dialog Box



5. Replace the hard sample with the sample you wish to analyze. The deflection sensitivity will remain applicable as long as the position of the laser spot on the cantilever does not change.

### 3.4.2 Ramp Parameter List

When you open **Ramp Parameter List**, the **Ramp Parameter List** box displays (see [Figure 3.4g](#)). All force curve parameters can be set in the **Ramp Parameter List**. The **Ramp Parameter List** is sectioned into seven panels. The parameters in each panel are defined in the following sections:

- [Ramp Panel on page 94](#)
- [Mode Panel on page 96](#)
- [Auto Panel on page 97](#)
- [Channel \(1, 2 or 3\) Panels on page 98](#)
- [Feedback Panel on page 99](#)

Figure 3.4g Ramp Parameter List

Real Time1 : Ramp ParmList	
[-] Ramp	
Ramp output	Z
Ramp size	1.000 $\mu$ m
Z scan start	0 nm
Scan rate	1.00 Hz
Forward velocity	2.01 $\mu$ m/s
Reverse velocity	2.01 $\mu$ m/s
X offset	0.000 nm
Y offset	0.000 nm
Number of samples	512
Spring Constant	0.3000 N/m
Plot units	Metric
Display mode	Both
X Rotate	11.0 °
[-] Mode	
Trigger mode	Off
Data type	Deflection
Trig threshold	0 V
Trig direction	Positive V
Start mode	Calibrate
End mode	Retracted
Z step size	0 nm
Auto start	Enable
Surface delay	0.00 s
Retracted delay	0.00 s
Auto offset	Off
Center plot	Off
Strip chart rate	100 Hz
Strip chart size	5.00 s
[-] Auto	
Columns	5
Rows	1
Column step	100 nm
Row step	100 nm
Threshold step	0 V
Capture	Off
[-] Channel 1	
Data type	Deflection
X data type	Z
Data scale	5.000 V
Data center	0 V
Deflection Sens.	1.000 V/V
Plot invert	Normal
Ave. Points	1
Effective BW	1027 Hz
Phase Offset	0.00 ms
Display mode	Deflection vs. Z
[-] Channel 2	
Data type	Off
X data type	Z
Data scale	1.000
Data center	0
Plot invert	Normal
Ave. Points	1
Effective BW	1027 Hz
Phase Offset	0.00 ms
Display mode	Off vs. Z
[-] Channel 3	
Data type	Off
X data type	Z
Data scale	1.000
Data center	0
Plot invert	Normal
Ave. Points	1
Effective BW	1027 Hz
Phase Offset	0.00 ms
Display mode	Off vs. Z
[-] Feedback	
SPM feedback	Deflection
Tip Bias Ctl	Ground
Sample Bias Ctl	Ground
Integral gain	2.000
Proportional gain	3.000
LookAhead gain	0
Bias	0 V
Analog 1	0 V
Analog 2	0 V
Analog 3	0 V
Analog 4	0 V
Deflection setpoint	2.000 V
Deflection limit	20.00 V
Lateral limit	20.00 V

### 3.4.3 Ramp Panel

**Ramp Output:** Specifies the **Ramp Channel**.

**Ramp Size:** Specifies the range of the **Ramp Channel**. Visible only if the Ramp Channel parameter is set to Z. Settings depend on the specified units.

**Z Scan Start:** Visible only if the **Ramp Channel** parameter is set to **Z** and **TRIGGER MODE** is **OFF**. **Z scan start** is the bottom position of the Z-axis scan as represented on the Display Monitor's bar graph. When the **Force Calibrate** command is first accessed during imaging, this value is automatically set to the **Z Center Position**.

**Note:** The value of this parameter will need to be increased to move the sample closer to the cantilever in the case where there is no deflection of the cantilever for a displacement of the sample.

- *Range and Settings:* The range of this parameter depends on the scanner. The units of this parameter are volts or nanometers, depending on the setting of the **Units** parameter.

**Note:** While the user is ramping Z in **Force Calibrate**, the feedback parameters (i.e., type, count and value) are inactive.

**Scan Rate:** The **Scan Rate** sets the ramping rate. Changing this value effects the Forward and Reverse Velocities.

**Forward Velocity:** **Forward Velocity** of the tip (in  $\mu\text{m/s}$ ) as it approaches the surface. Increasing this value increases the **Scan Rate**.

**Reverse Velocity:** **Reverse Velocity** of the tip (in  $\mu\text{m/s}$ ) as it retracts from the surface.

**X Offset:** Controls the position of the range in the X direction.

**Y Offset:** Controls the position of the range in the Y direction.

**Number of samples:** Number of data points collected during each upward (retraction) and downward (extension) travel cycle of the piezo. The Number of samples parameter sets the pixel density of the force curve. This parameter does not change the Z scan size.

- *Range or Settings:* **4** to **64,000** data points displayed per extension and retraction cycle.

**Spring Constant:** Records the spring constant of the cantilever that is currently being used. This parameter is input by the user and is recorded along with each force plot captured. It is used for Offline analysis of the force plot. It is not critical to set the **Spring constant** in Realtime, since it can be altered in the Offline analysis of the captured force plot. The Spring constant is necessary to display a graph of force vs. separation if **UNITS** is set to **FORCE**.

**Plot Units:** Switches parameters in the control panels between units of Volts (V), Metric (nm or  $\mu\text{m}$ ), or Force (nM). Changing this parameter also changes the setting of the **Units** parameter on the AFM control panel.

- *Range or Settings:* **Volts (V)**, **Metric (nm)** or **Force (nN)**

**Display Mode:** The portion of a tip's vertical motion to be plotted on the force graph.

- *Range or Settings:*
  - **Extend**—Plots only the extension portion of the tip's vertical travel.
  - **Retract**—Plots only the retraction portion of the tip's vertical travel.
  - **Both**—Plots both the extension and retraction portions of the tip's vertical travel.
  - If a channel other than Z is chosen, **Display mode** will not be available in Offline view.

**X Rotate:** Allows the user to move the tip laterally, in the X direction, during indentation. This is useful since the cantilever is at an angle relative to the surface. One purpose of **X Rotate** is to prevent the cantilever from plowing the surface laterally, typically along the X direction, while it indents in the sample surface in the Z direction. Plowing can occur due to cantilever bending during indentation or due to X movement caused by coupling of the Z and X axes of the piezo scanner. When indenting in the Z direction, the **X Rotate** parameter allows the user to add movement to scanner in the X direction. X Rotate causes movement of the scanner opposite to the direction in which the cantilever points. Without **X Rotate** control, the tip may be prone to pitch forward during indentation. Normally, it is set to about 22.0°.

- *Range or Settings:* **0** to **90°**; most effective values are between 15 and 25°.

### 3.4.4 Mode Panel

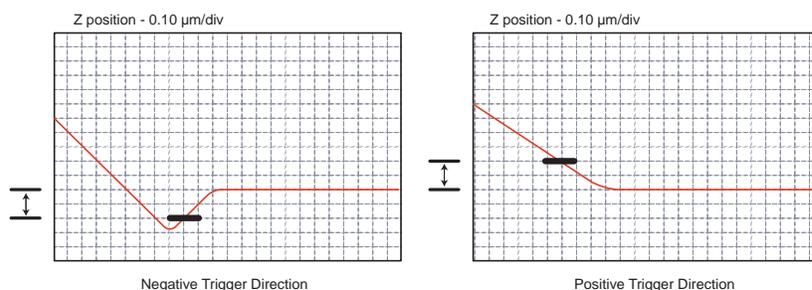
**Trigger Mode:** Limits the amount of force exerted by the tip upon the sample. It is possible to operate the trigger independent of drift (Relative) or at some arbitrarily fixed point (Absolute) depending on the trigger settings.

**Data Type:** Channels may be assigned for triggering to any input signal available including: **Deflection, Amplitude, Phase** or **Friction** data.

**Trig Threshold:** The value of the cantilever deflection, as measured by the photodetector, desired for the indentation or scratch. The **Trigger threshold** defines the maximum force applied to the sample corresponding to the upper right-most point on the force plot.

- *Range or Settings:* **-10V** to **+10V**, depending on the **Deflection Limit**. Try 0.5V to 1.0V.

**Trig Direction:** Determines the direction of the trigger and allows for a Positive, Negative, or Absolute trigger slope. In this way, the trigger may be configured to activate on either the positive or negative direction of the force curve.



**Start Mode:** Start mode allows you to switch between the various force modes without returning to image mode.

- *Range or Settings:*
  - **CALIBRATE**—Produces standard Force Mode force plots. Includes the ability to continuously cycle the tip up and down.
  - **STEP**—Produces standard **Force Mode** force plots, with added control to step the tip towards the surface.
  - **MOTOR STEP**—Tip is stepped towards surface using the motor.

**End Mode:** Determines the location of the tip when the microscope is returned to Image mode. Choices include **Extended, Retracted,** or **Surface**.

**Z Step Size:** The change in tip height per step when using force step.

**Auto Start:** When enabled, autostarts **Force mode** when entering from **Image mode**. If off, you must start ramping by clicking the **Continuous** or **Single** icon, or by selecting the proper menu selection under the **Ramp** menu.

**Surface Delay:** Specifies a delay when the tip reaches the point closest to the sample.

- *Range or Settings:* **0 to 200 seconds**

**Retracted Delay:** Similar to **Surface delay**, this value specifies the duration of the delay when the piezo is at the top of the cycle (farthest away from the sample).

- *Range or Settings:* **0 to 200 seconds**

**Auto Offset:** Because of Z drift (thermal drift, piezo drift, etc.), the sample will sometimes drift out of Z range. When enabled, **Auto Offset** uses the Setpoint value from Image mode to Feedback and find the surface and resume Force imaging. The **Auto Offset** feature is a form of drift correction.

**Strip Chart Rate:** Frequency of (Z-position, deflection) data point acquisition for strip chart (only available for Picoforce and Nanoman).

- *Range:* **20kHz to 0.01Hz**. Typical value: 1kHz

**Strip Chart Size:** Time interval over which (Z-position, deflection) data points are displayed in strip chart.

- Typical value: **10 to 10,000 sec.**

**Note:** Although the strip chart collects and displays data over the time interval defined by clicking **Start**, then later, **Stop**, this data is not saved for subsequent use until the **Capture** icon (shown) is clicked. If **Capture** is clicked while strip chart data is being taken, what is saved begins at the start of the chart (sooner than the icon is clicked).

### 3.4.5 Auto Panel

The Auto Panel parameters are only available when Autoramping.

**Columns:** Number of points in the Y axis.

**Rows:** Points in the X axis.

**Column Step:** Offset distance between points in the X direction.

**Row Step:** Offset distance between points in the Y direction.

**Threshold Step:** The trigger point at which the deflection or the current activates the position change.

**Capture:** State is either enabled or disabled. When enabled, the software records and stores the ramp data for each data point in the matrix of rows and columns.

### 3.4.6 Channel (1, 2 or 3) Panels

**Data Type:** Channels may be assigned to any input signal available including: **Deflection, Amplitude, Phase, Friction** and so on. Any channel may be switched to Off, however, *at least one channel* is always on.

**X Data Type:** Type of data that the channel data is being compared to. This data displays on the X-Axis of the scope grid.

**Data Scale:** Voltage range for the vertical axis of the force curve plot.

**Note:** This can be overridden by setting **Autoscale** On for the plot.

**Data Center:** Offsets centerline of scan by the amount entered.

**Note:** The Data center offset does *not* become a permanent part of the data.

- *Range or Settings:* Depends upon the input signal, generally  $\pm$  one-half of **data scale** maximum.

**Deflection Sens.:** Defines the conversion factor from cantilever deflection signal voltage to nanometers of cantilever displacement (in nm/V) using data in the contact region of a force plot.

**Plot Invert:** Inverts data along the Y-axis, effectively turning valleys into mounds and vice versa.

**Ave. Points:** Averages multiple points to smooth the curve.

**Effective BW:** A display (you cannot input a value to it) representing the sampling frequency with display averaging taken into account:

$$\text{Effective BW} = (\text{force plot sampling rate})/(\text{Ave. Points})$$

**Phase Offset:** Shift horizontal position of plot to compensate for averaging of endpoint data.

**Note:** The numerical values of the two **Phase Offset** parameters can be ignored; set them to whatever values minimize the apparent hysteresis. Particularly when **Forward Velocity** and **Reverse Velocity** are unequal, the same numerical value for each **Phase Offset** may not correspond to an identical displacement on each axis.

**Display Mode:** The portion of a tip's vertical motion to be plotted on the force graph.

*Range or Settings:*

- **Extend**—Plots only the extension portion of the tip's vertical travel.

- **Retract**—Plots only the retraction portion of the tip's vertical travel.
- **Both**—Plots both the extension and retraction portions of the tip's vertical travel.
- If a channel other than Z is chosen and the force curve is captured Offline, **Display mode** may not be available in Offline view.

**X Rotate:** Allows the user to move the tip laterally, in the X direction, during the ramping of Z. This is useful because the cantilever is at an angle relative to the surface. One purpose of **X Rotate** is to prevent the cantilever from plowing the surface laterally, typically along the X direction, while it indents in the sample surface in the Z direction. Plowing can occur due to cantilever bending during indentation or due to X movement caused by coupling of the Z and X axes of the piezo scanner. When indenting in the Z direction, the **X Rotate** parameter allows the user to add movement to scanner in the X direction. **X Rotate** causes movement of the scanner opposite to the direction in which the cantilever points. Without **X Rotate** control, the tip may be prone to pitch forward during indentation. Normally, it is set to about 22.0°.

*Range or Settings:* **0 to 90 degrees**; most effective values are between **15** and **25°**.

### 3.4.7 Feedback Panel

Only the Force Curve-applicable menu parameters are described below:

**Deflection Setpoint:** Defines the deflection signal, and therefore the tip-sample force, maintained by the feedback loop.

- *Range or Settings:* **± 10.0V** maximum

**Deflection Limit:** Use this parameter for attenuating the input voltage signal (appears only when performing Contact AFM).

- *Range or Settings:* **2.500V** for regular imaging and 20.00V in **Force Mode only**

### 3.4.8 Ramp Menu

While the microscope is engaged and in Realtime mode, opening the **Ramp** parameters will display the **Ramp** Menu.

**Figure 3.4h** Ramp Menu



### Ramp Menu Definitions

**Run Continuous:** The tip is continuously lowered and raised by a distance equal to the **Ramp size**. This is the normal, default motion during **Force Calibrate**. “Raising” and “lowering” are relative to your system (e.g., On Dimension Series SPMs, the tip is raised and lowered to the surface; however, other SPMs raise and lower the sample beneath the tip).

**Run Single:** Lowers and raises tip *once* by a distance equal to the Z scan size, then halts.

**External Trigger:** (Not available)

**Stop:** Halts all tip movement.

**Retract:** The Z-axis piezo retracts to its limit in preparation for **Approach Continuous**. This command does *not* initiate motor movements.

**Approach Continuous:** The tip lowers to the surface and raises in a controlled series of steps, then indexed by the Z step size (see Scan Mode panel) distance. This process continues downward until the tip encounters the surface. When tip deflection exceeds the **Threshold Step** amount, **Approach Continuous** halts and the resulting force curve displays.

**Approach Single:** The tip is lowered to the surface and raised in a single, controlled step. This process is halted if the surface is encountered by the tip, causing deflection exceeding the Step threshold amount. The resulting force curve is displayed.

**Note:** For both **Approach Continuous** and **Approach Single**, if **Start mode** = **MOTOR STEP**, the motor is stepped towards the surface, not the Z piezo.

**Auto ramp:** Begins auto ramping as defined by the parameters specified in the **Auto Panel**.

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# Chapter 4 Analysis Commands

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The **Analysis** commands relate to analyzing the surface behavior of materials on images captured in Realtime mode. These commands are known as image processing or analysis commands. The commands contain views, options and configurations for analysis, modification, and storage of the collected data. The analysis may be automated (i.e., in autoprogams) or completed manually. In general, the analysis commands provide methods for quantifying the surface properties of samples.

Please refer to the following analysis commands available in **Analyze** menu of the NanoScope software:

- **Image:** [Section 4.1](#)
- **3D Surface Plot:** [Section 4.2](#)
- **Zoom:** [Section 4.3](#)
- **Depth:** [Section 4.4](#)
- **Power Spectral Density:** [Section 4.5](#)
- **Roughness:** [Section 4.6](#)
- **Section:** [Section 4.7](#)
- **Step:** [Section 4.8](#)
- **Width:** [Section 4.9](#)
- **XY Drift:** [Section 4.10](#)
- **Multiple Channel Analysis:** [Section 4.11](#)
- **AutoProgram:** [Section 4.12](#)

## 4.1 Image



The term **Image** refers to the data captured in Realtime mode. The current image processing capabilities include data analysis, modification, presentation and storage of the images. The source of the image includes:

- Data captured in Realtime scanning mode
- New image files created using modification or analysis commands

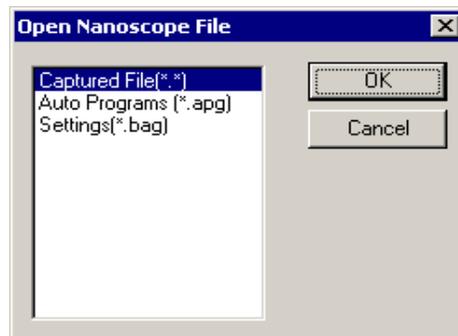
For general information on the interface and basic functions in image processing, see **Using the Image Interface:** [Section 4.1.1](#).

### 4.1.1 Using the Image Interface

To process an image, you must open an image file. This can be done by:

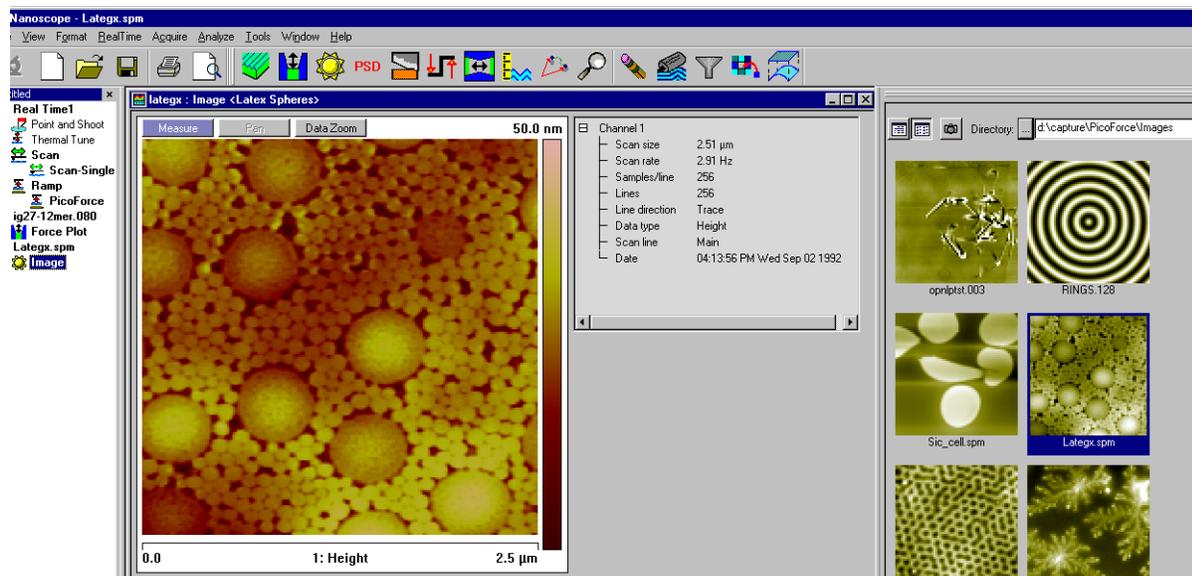
- Clicking **File > Open**. When the **Open NanoScope File** dialog box opens (see [Figure 4.1a](#)), select **Captured File (\*.\*)** and click the **Ok** button.

**Figure 4.1a** Open NanoScope File Dialog Box



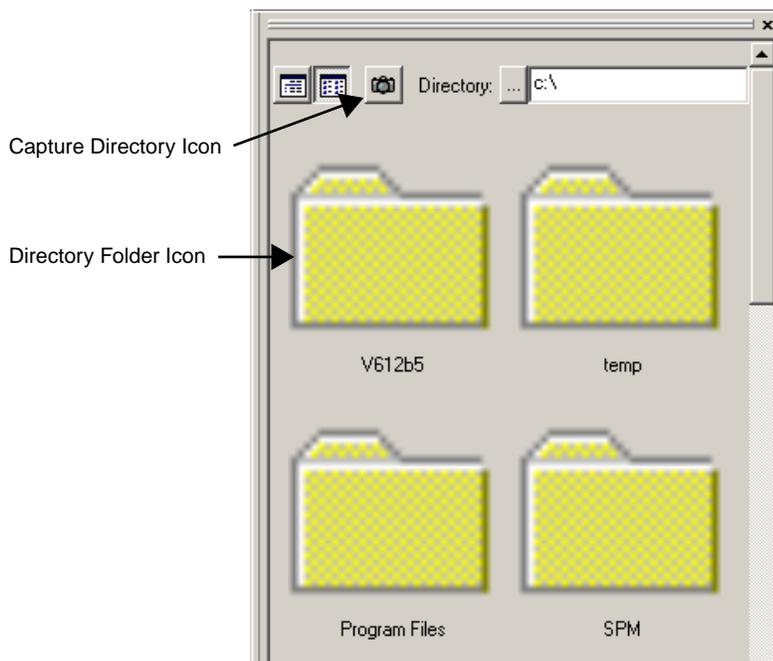
- Double-click an image in the **Browse** dialog box. The new image appears in the client window (see [Figure 4.1b](#)).

Figure 4.1b Image for Processing



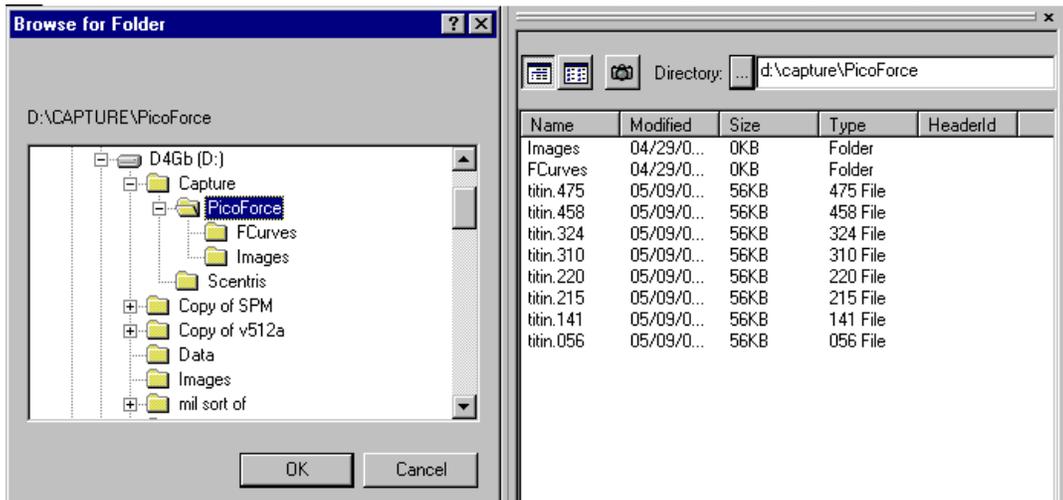
Directory icons appear in the browse window. Double-click a folder icon to browse that directory (see Figure 4.1c).

Figure 4.1c Directory Icons



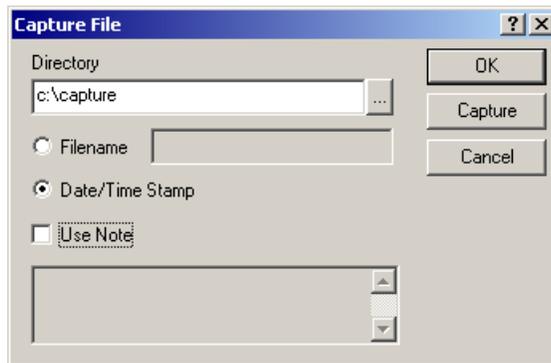
Selecting the first icon in the upper left of the file browsing window initiates a text presentation of file information (as in Figure 4.1d). The second icon in the upper left of the file browsing window causes thumbnail presentation of image files as illustrated in Figure 4.1b (the icon has been scrolled out of view at the top of the window of images). Click on a thumbnail to open the image for further analysis. The **Capture Directory** icon  in the upper left of the file browsing window displays file information, in either text or thumbnail presentations, of the capture directory (default is D:\capture).

**Figure 4.1d** Browse for Folder Window Open Upon Clicking Directory



You can change the current capture directory in the **Capture File** dialog box by selecting **REALTIME > CAPTURE FILENAME**, shown in Figure 4.1e.

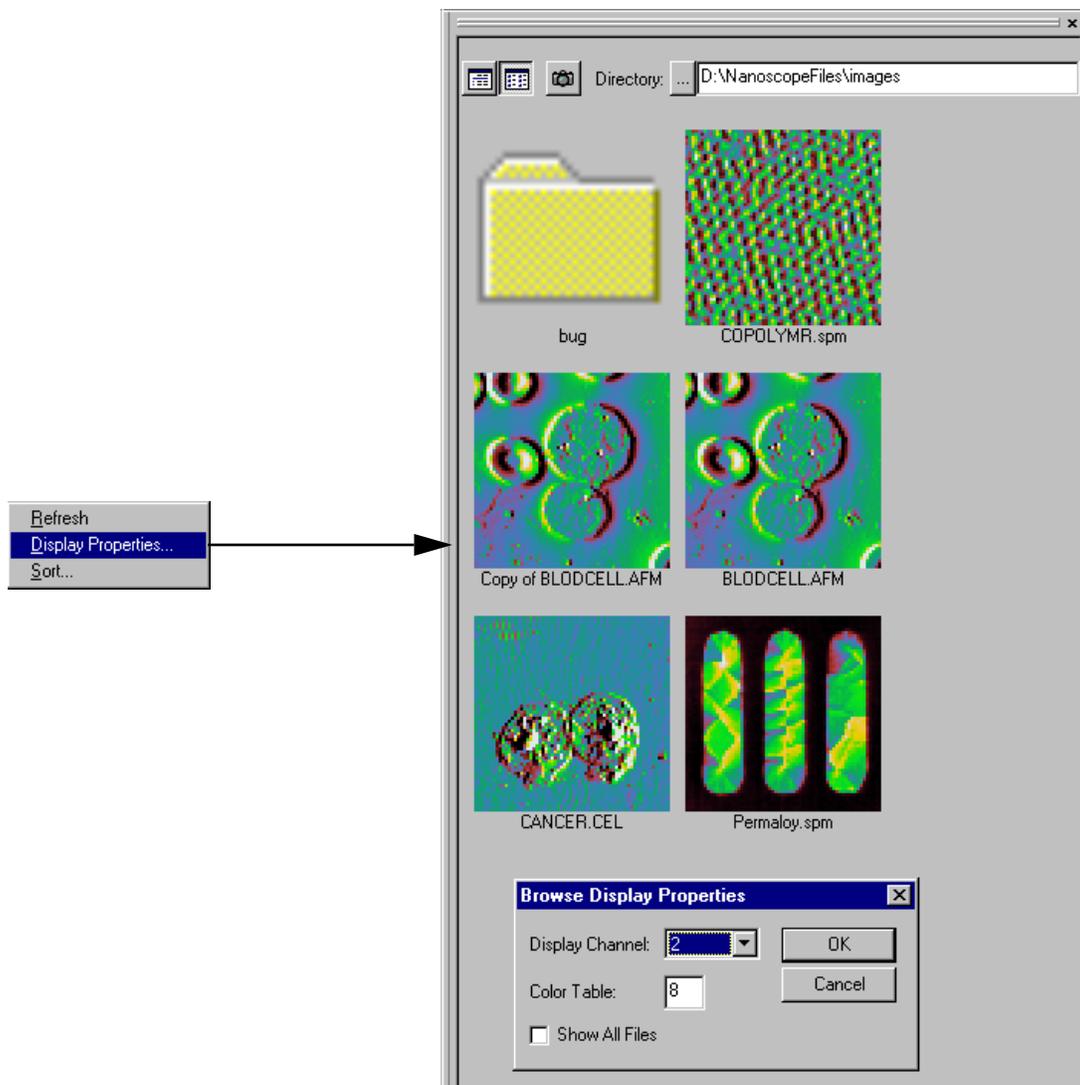
**Figure 4.1e** Capture File Dialog Box



### Image Display

If no images are selected, right-clicking in the image browse window (but not on an image icon) allows you to select a display channel and a color table for the image icons in the browse window. See [Figure 4.1f](#).

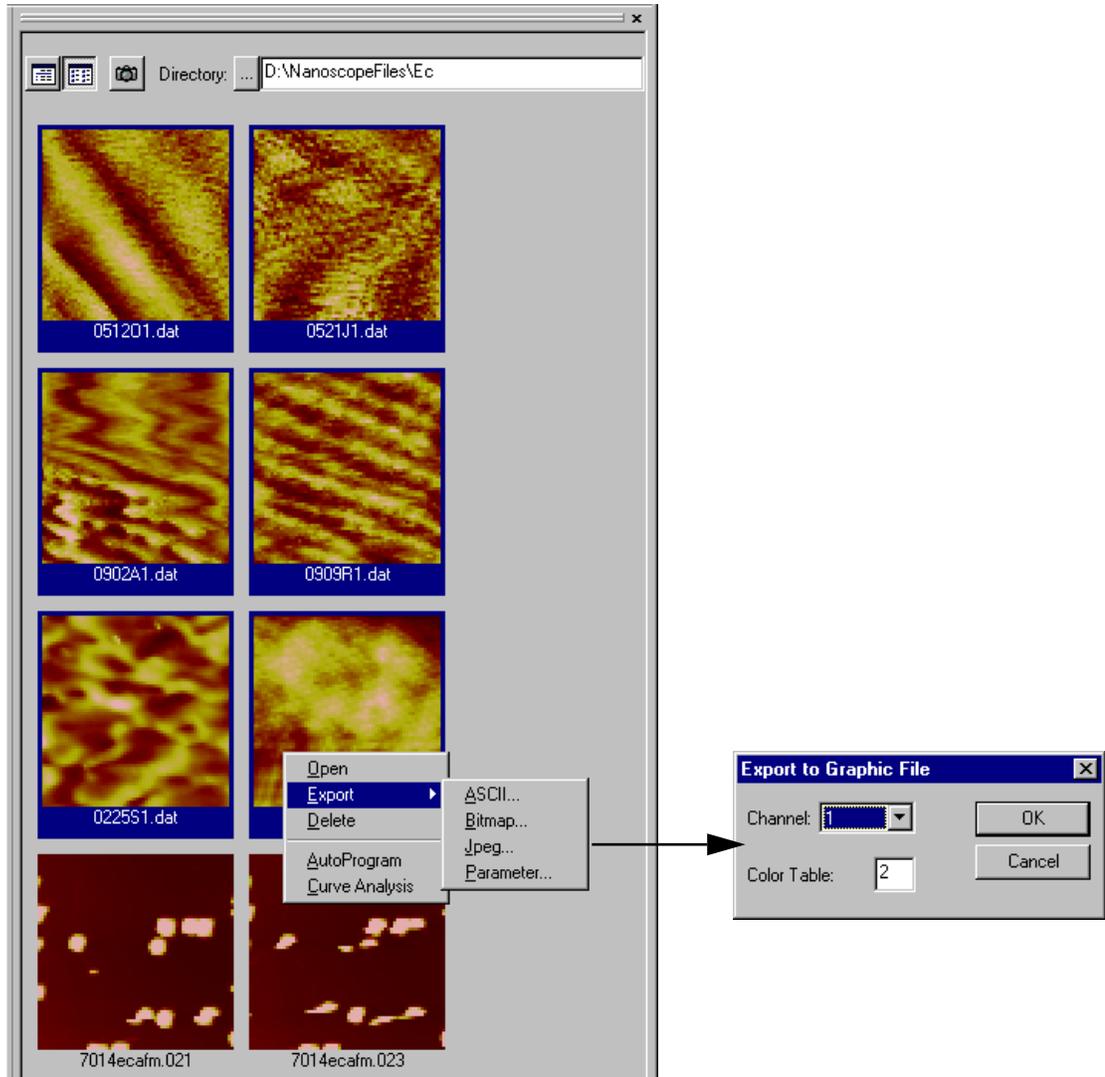
**Figure 4.1f** Selecting the Display Channel and Color Table for the Icons



## Exporting Images

You may export images, in either bitmap or JPEG formats, from the image browse window by right-clicking single or multiple images, shown in [Figure 4.1g](#). You may select the channel and a color table.

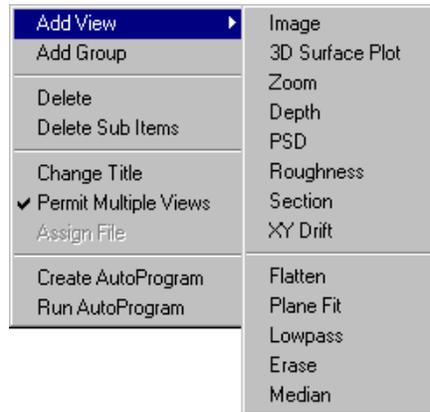
**Figure 4.1g** Exporting Multiple Images from the Image Browse Window



### Image Processing Add View Commands

The Offline **Add View** menu for image processing differs from the Realtime **Add View** commands. The commands include measurement, analysis and modification commands (see [Figure 4.1h](#)).

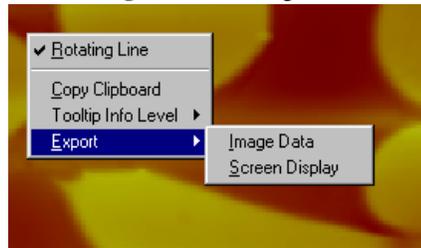
**Figure 4.1h** Image Processing Functions Menu



### Right-Clicking on the Image

By right-clicking on the image, you will get a menu (see [Figure 4.1i](#)) that allows you to perform the following tasks:

**Figure 4.1i** Image Click



- **Rotating Line**—Left-click, hold, and drag out a line. Release the mouse button to end the line.
- **Box** (for some analyses)—Left-click, hold, and drag out a box and release the mouse button.  
**Note:** Left-clicking in the center of the box allows you to translate. Left-clicking on edges allows you to change the box size.
- **Copy Clipboard**—Copies the image to the Microsoft clipboard.
- **Tooltip Info Level:**
  - Basic
  - Medium
  - Advanced
  - None
- **Export**—Exports the image as a bitmap or JPEG (WYSIWYG), or Full Image (pixel by pixel data).

## Image Buttons

Clicking the **Image** buttons above the captured image (see [Figure 4.1j](#)) performs the following functions:

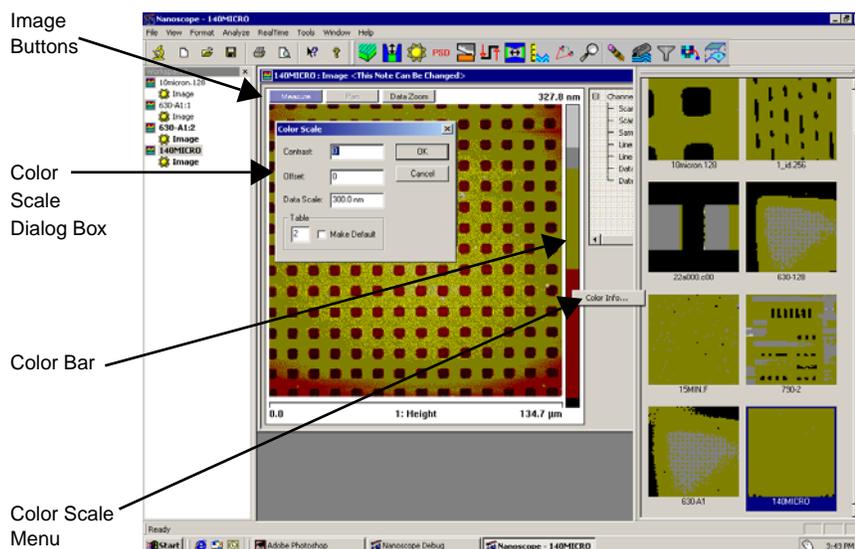
- **Data Zoom**—Left-click, hold, and drag out a box. Release the mouse button and the image will automatically zoom in to the area of the box.
- **Pan**—From a zoomed image, the user can pan around to other areas of the original image.
- **Measure**—Left-click, hold, and drag out a line. Length of line appears in a box near the line any time cursor is on the line.

## Right-Clicking on the Color Bar

Right-clicking on the color bar along the right side of the image (see [Figure 4.1j](#)) will produce a **Color Scale** button. Clicking on this **Color Scale** button will open the **Color Scale** dialog box, where you can perform the following image adjustments:

- **Contrast**—Number (-10 to +10) designates contrast of colors in displayed image (e.g., 0 shows little change, while 10 shows highest contrast).
- **Offset**—Number (-128 to +128) designates offset of colors in displayed image (e.g., 120 shows illuminated background on image).
- **Data Scale**—Designates the vertical range of the image, corresponding to the full extent of the color table.
- **Table**—Designates the **Color Table** number.

**Figure 4.1j** Image Adjustment Controls



### Using the Mouse Within a Captured Image

<b>Left-Click anywhere in image window, drag line out, and release</b>	Creates a line of X length, at X° of angle in the image window
<b>Place cursor on line</b>	Displays length and angle values of line in the image window
<b>Place cursor on line, click and hold left button, and drag</b>	Allows you to drag the line anywhere in the image window
<b>Click and hold on either end of line and drag</b>	Changes length and/or the angle of the line
<b>Right-Click</b>	Clicking the right mouse button when the cursor is on the line accesses the Image Cursor menu (see <a href="#">Figure 4.1k</a> ) <ul style="list-style-type: none"><li>• <b>Delete</b>—deletes the line.</li><li>• <b>Flip Direction</b>—switches the line end to end.</li><li>• <b>Show Direction</b>—Adds small arrowhead to the line to indicate direction.</li><li>• <b>Set Color</b>—Allows you to change the color of the line.</li><li>• <b>Clear All</b>—Deletes all lines.</li></ul>

**Figure 4.1k** Image Cursor Menu



## 4.2 3D Surface Plot



The **3D Surface Plot View** displays the selected image with color-coded height information in a three-dimensional, oblique perspective. You can select the viewing angle and illumination angle for a modeled light source.

You can view the **3D Surface Plot View** using *one* of the following methods:

- Right-click on the image name in the **Workspace** and select **Add View > 3D Surface Plot** from the popup menu.

Or

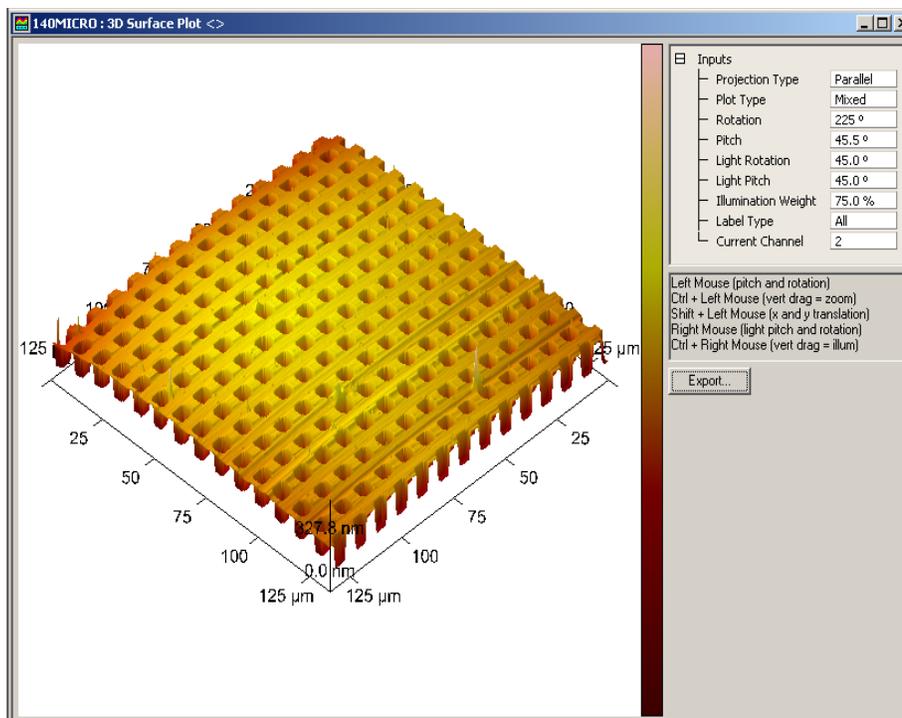
- Select **Analyze > 3D Surface Plot** from the menu bar.

Or

- Click the **3D Surface Plot** icon in the upper toolbar. 

The **Surface Plot** panel appears and allows formatting of image data on the Display Monitor (see [Figure 4.2a](#)).

**Figure 4.2a** 3D Surface Plot Window



### 4.2.1 Parameters in the 3D Surface Plot Inputs

The **Projection Type**, **Plot Type**, and **Label Type 3D Surface Plot** parameters can be changed by clicking on the related window and selecting from the drop-down menus. The remaining parameters may be changed by typing the desired information in the related window or by use of the keyboard and mouse keys.

- To zoom in or out on the image, hold the control key down and slide the mouse up and down on the image while holding the left mouse button.
- To pan, hold the shift key down and move the mouse up, down, left, or right on the image while holding the left mouse button.
- Clicking and holding the right mouse button down while moving the mouse left and right changes the light rotation on the image. This is only available when plot type is set to mixed
- Clicking and holding the right button while moving the mouse up down changes the light pitch. This is only available when **Plot Type** is set to **Mixed**.

The function of the **Input** parameters are:

<b>Projection Type</b>	Select either <b>Parallel</b> or <b>Perspective</b> <ul style="list-style-type: none"><li>• In parallel mode, the viewing volume does not change, which has the affect keeping objects the same size as they are projected. This is useful for maintaining the size and angle of objects between the front and back of the view.</li><li>• In perspective mode, objects appear to get smaller the further away they are from the eye. This is how the objects are perceived in the real world.</li></ul>
<b>Plot Type</b>	Select <b>Height</b> , <b>Wire</b> , or <b>Mixed</b> <ul style="list-style-type: none"><li>• Height displays image with the height values encoded according to the color table.</li><li>• Wire displays image as a line representation of the scanned data.</li><li>• Mixed displays a combination of height and illumination encoding which is used on the displayed image.</li></ul>
<b>Rotation</b>	The <b>Rotation</b> parameter in the <b>Surface Plot Inputs</b> changes as the viewing angle in changed by rotating the displayed image about the Z axis relative to its captured orientation.
<b>Pitch</b>	The <b>Pitch</b> parameter in the <b>Surface Plot Inputs</b> changes as the viewing angle by manually changing the pitch of the Y axis in the three-dimensional Surface Plot image.

<b>Light Rotation</b>	The <b>Light Rotation</b> parameter in the <b>Surface Plot Inputs</b> rotates the light source in the horizontal plane (along the Z axis). This is only available when the <b>Plot Type</b> is set to <b>Mixed</b> .
<b>Light Pitch</b>	The <b>Light Pitch</b> parameter in the <b>Surface Plot Inputs</b> changes the viewing angle by selecting the pitch of the Y axis in the three-dimensional Surface Plot image. This is only available when the <b>Plot Type</b> is set to <b>Mixed</b> .
<b>Illumination Weight</b>	Selects the percentage of the imaginary light source mixed with the color-encoded height information when the <b>Plot type</b> is set to <b>Mixed</b> .
<b>Label Type</b>	The <b>Label Type</b> parameter in the <b>Surface Plot Inputs</b> selects whether labels, axes, and the view/illumination controller are displayed with the image.
<b>Current Channel</b>	Displays the current channel of multichannel scan displays.

The **Export** button allows the operator to export the image in the window to either JPEG or bitmap format. The graphic will be stored in the Capture folder.

## 4.3 Zoom



Use the **Zoom** function to extract an image from a large Version 6 image for Version 5 analysis. NanoScope Version 5 software features a number of **Analysis** functions currently not available in Version 6 software. Zoom will produce the largest Version 5 image size possible within the bounded region (128 x 128, 256 x 256 or 512 x 512).

**Note:** 512 x 512 is the most common image size, and will be used as the example throughout the rest of this section.

**Note:** The image produced by this analysis is Version 5 compatible, however, if the image is later processed by a Version 6 analysis, the image may no longer be Version 5 compatible.

### 4.3.1 Zoom Procedure

Use the Zoom analysis to isolate a 512 x 512 portion of a high resolution image.

1. Open a large Version 6 image (larger than 512 x 512).
2. You can view the **Zoom View** using *one* of the following methods:
  - Right-click on the image name in the **Workspace** and select **Add View > Zoom** from the popup menu.

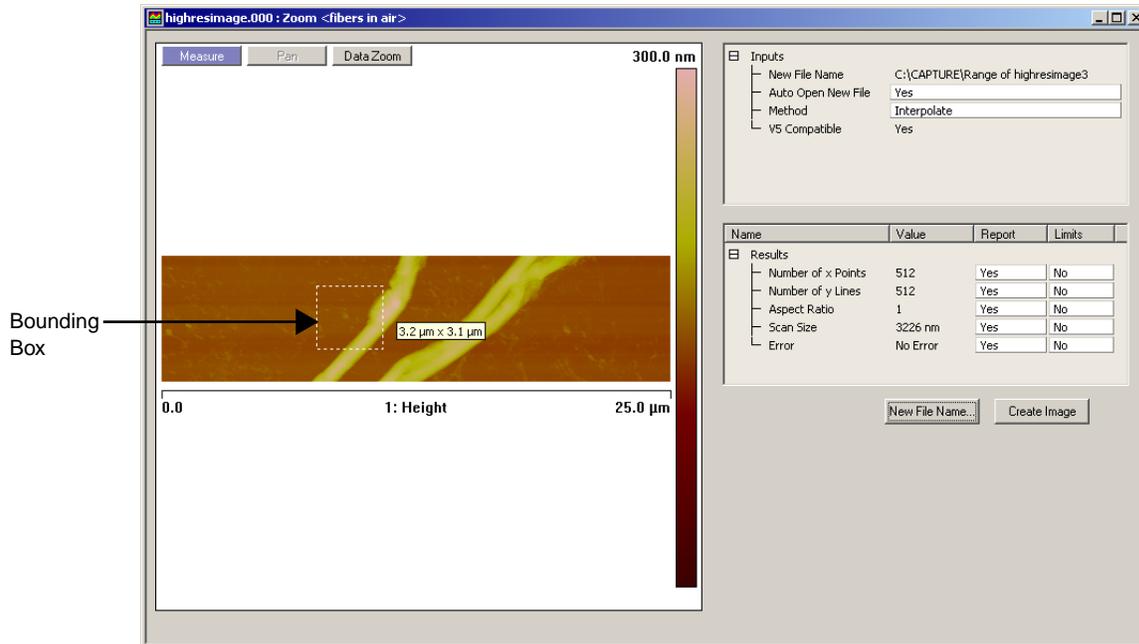
Or

  - Select **Analyze > Zoom** from the menu bar.

Or

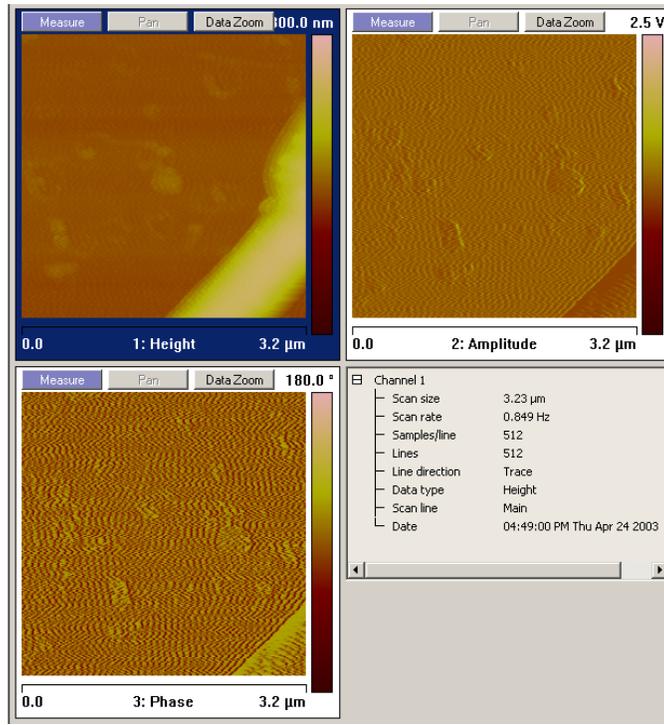
  - Click the **Zoom** icon in the upper toolbar. 
3. The selected image opens in the **Zoom** dialog box (see [Figure 4.3a](#)).

Figure 4.3a Initial Zoom Dialog Box



4. A bounding box appears in the image (see Figure 4.3a). Place the cursor inside the box, and while holding the mouse button, move the box to the location of interest. The box is restricted to the largest possible Version 5-compatible image size (usually 512 x 512).
5. Once the box is in place, select the **New File Name** button. Select a location and name for the new image.
6. Select the **Create Image** button.
  - a. If the **Auto Open New File** parameter under **Inputs** is set to **Yes**, the image opens in the default image view (see Figure 4.3b).

Figure 4.3b New Zoom Image Dialog Box



- b. If the **Auto Open New File** parameter under **Inputs** is set to **No**, The new image will be saved in the designated directory but will not automatically display.
7. Use this new image for Version 5 analysis.

---

## 4.3.2 Zoom Interface

### Input Parameters

<b>New File Name</b>	Displays the path of the extracted image file.
<b>Auto Open New File</b>	Settings: <ul style="list-style-type: none"><li>• If <b>Yes</b> is selected, after selecting the <b>Create Image</b> button the newly extracted image open.</li><li>• If <b>No</b> is selected, the new file will be created and saved in the designated directory, but will not automatically display.</li></ul>
<b>Method</b>	Settings: <ul style="list-style-type: none"><li>• <b>INTERPOLATE</b>—Data points will be interpolated to create new image.</li><li>• <b>Replicate</b>—Data points will be used as is to create a new image.</li></ul>
<b>V5 Compatible</b>	<b>Yes</b> . The largest possible V5 compatible file (512 x 512) is created from the image.

### Results Parameters

<b>Number of x Points</b>	Number of x points in the new image.
<b>Number of y Points</b>	Number of y points in the new image.
<b>Aspect Ratio</b>	Aspect ratio of the new image.
<b>Scan Size</b>	Scan size of the new image. The units of this parameter are volts if the <b>Units</b> parameter ( <b>Other Controls</b> panel) is set to <b>Volts</b> . The units are linear distance (nm or $\mu\text{m}$ ) if the <b>Units</b> parameter is set to <b>Metric</b> .
<b>Error</b>	Possible errors: <ul style="list-style-type: none"><li>• <b>No Error</b>—(Default)</li><li>• <b>Not Enough X Points</b>—Original image has less than 512 points/line.</li><li>• <b>Invalid Aspect Ratio</b>—Zoomed image results in an aspect ratio greater than 256:1.</li><li>• <b>File Write</b>—A disk error occurred.</li><li>• <b>Unknown</b>—An unknown error has occurred.</li></ul>

### Zoom Buttons

<b>New File Name</b>	Browse for the location to save the new image.
<b>Create Image</b>	A Version 5 compatible image is created from the portion of the high resolution image that is contained in the bounding box.

## 4.4 Depth



To analyze the depth of features you have numerous choices which measure the height difference between two dominant features that occur at distinct heights. **Depth** was primarily designed for automatically *comparing* feature depths at two similar sample sites (e.g., when analyzing etch depths on large numbers of identical silicon wafers).

Refer to the following sections on **Depth** analysis:

- **Depth Theory:** [Section 4.4.1](#)
- **Depth Procedures:** [Section 4.4.2](#)
- **Depth Interface:** [Section 4.4.3](#)

### 4.4.1 Depth Theory

The **Depth** command accumulates depth data within a specified area, applies a Gaussian low-pass filter to the data to remove noise, then obtains depth comparisons between two dominant features. Although this method of depth analysis does not substitute for direct, cross-sectioning of the sample, it affords a means for comparing feature depth between two similar sites in a consistent, statistical manner.

The display screen includes a top view image and a histogram; depth data is displayed in the results window and in the histogram. The mouse is used to resize and position the box cursor over the area to be analyzed. The histogram displays both the raw and an overlaid, Gaussian-filtered version of the data, distributed proportional to its occurrence within the defined bounding box.

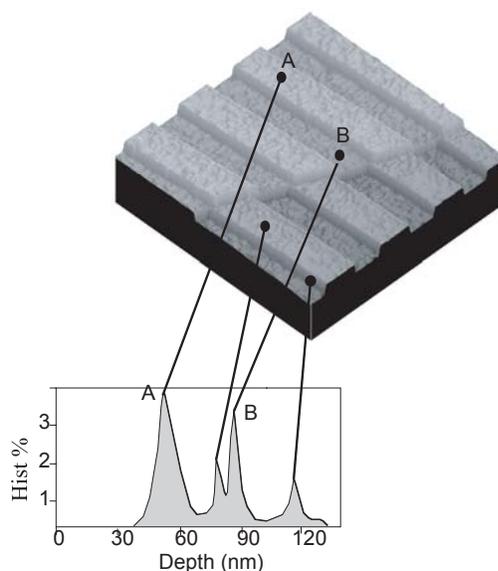
#### Histogram

##### Raw Data

[Figure 4.4a](#) (bottom graph) displays a histogram from raw depth data. Data points A and B are the two most dominant features, and therefore would be compared in Depth analysis. Depending upon the range and size of depth data, the curve may appear jagged in profile, with noticeable levels of noise.

**Note:** Color of cursor, data, and grid may change if user has changed the settings. Right-click on the graph and go to **Color** if you want to change the default settings.

Figure 4.4a Depth Histogram



### Correlation Curve

The **Correlation Curve** is a filtered version of the **Raw Data Histogram** and is located on the **Raw Data Histogram** represented by a red line. Filtering is done using the **Histogram filter cutoff** parameter in the **Input** parameters box. The larger the filter cutoff, the more data is filtered into a Gaussian (bell-shaped) curve. Large filter cutoffs average so much of the data curve that peaks corresponding to specific features are unrecognizable. On the other hand, if the filter cutoff is too small, the filtered curve may appear noisy.

The **Correlation Curve** portion of the histogram presents a lowpass, Gaussian-filtered version of the raw data. The low-pass Gaussian filter removes noise from the data curve and averages the curve's profile. Peaks which are visible in the curve correspond to features in the image at differing depths.

Peaks do not show on the correlation curve as discrete, isolated spikes; instead, peaks are contiguous with lower and higher regions of the sample, and with other peaks. This reflects the reality that features do not all start and end at discrete depths.

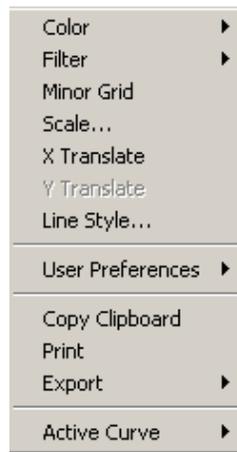
When using the **Depth View** for analysis, each peak on the filtered histogram is measured from its statistical centroid (i.e., its statistical center of mass).

### Using the Grid Display

Measurement cursors for histogram are automatically positioned based on the numerical values selected in the **Input** fields. Right-clicking on the grid will bring up the **Grid Parameters** menu (see [Figure 4.4b](#)) and allow you to make the following changes:

<b>Color</b>	Allows operator to change the color of the: <ul style="list-style-type: none"><li>• Curve (data)</li><li>• Text</li><li>• Background</li><li>• Grid</li><li>• Minor Grid</li><li>• Markers</li></ul>
<b>Filter</b>	Typically used for a Profiler Scan. <ul style="list-style-type: none"><li>• Type—Select None, Mean (default), Maximum, or Minimum</li><li>• Points—Select 4k, 8k (default), 16k, or 32k</li></ul>
<b>Minor Grid</b>	Places a minor grid in the background of the <b>Vision</b> window.
<b>Scale</b>	Allows user to auto scale, set a curve mean, or set their own data range
<b>Line Style</b>	For each curve, the operator can choose a connect, fill down, or point line.
<b>User Preferences</b>	Restore—Reverts to initial software settings Save—Saves all changes operator has made during this session. This becomes the new default settings.
<b>Copy Clipboard</b>	Copies the grid image to the Microsoft Clipboard
<b>Print</b>	Prints out the current screen view to a printer
<b>Export</b>	Exports data in bitmap, JPEG or XZ data format
<b>Active Curve</b>	Determines which curve you are analyzing

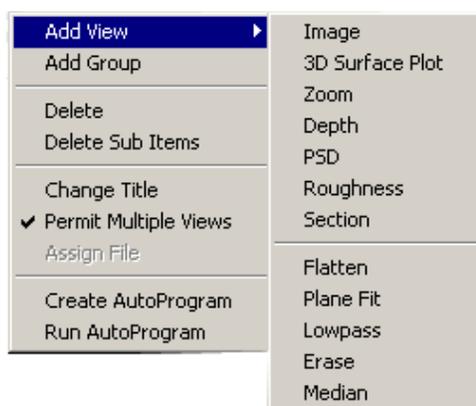
**Figure 4.4b** Grid Parameters Menu



## 4.4.2 Depth Procedures

1. If no workspace is present, open a new workspace (**File > New Workspace**).
2. Open the image you wish to analyze (**File > Open > Captured Data File**) or double click on the browse view image.
3. In the workspace, position the cursor on the file name and right-click to access a functions pop-up menu.

**Figure 4.4c** Functions Menu



4. In the pop-up menu, select **Add View > Depth**.
5. You can view the **Depth View** using *one* of the following methods:
  - Right-click on the image name in the **Workspace** and select **Add View > Depth** from the popup menu.

Or

  - Select **Analyze > Depth** from the menu bar.

Or

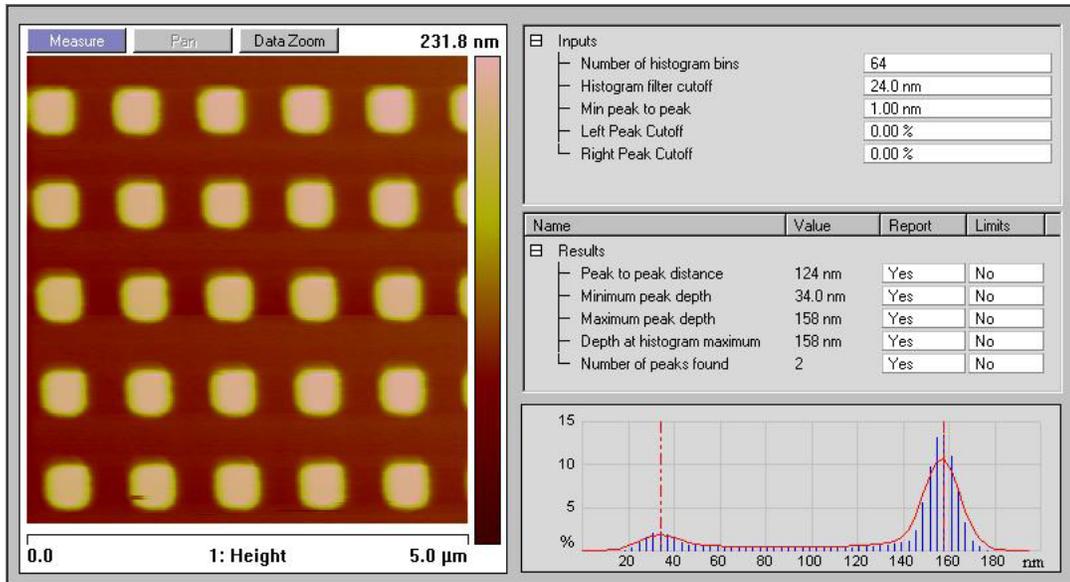
  - Click the **Depth** icon in the upper toolbar. 
6. Using the mouse, left-click and drag a box on the area of the image to analyze. The Histogram displays the depth correlation on this specified area.

**Note:** If no box is drawn, by default, the entire image is selected.
7. Adjust the **Minimum Peak to Peak** to exclude non relevant depths.
8. Adjust the **Histogram Filter Cutoff** parameter to filter noise in the histogram as desired.

9. Note the results.

**Note:** To save or print the data, run the analysis in an **Auto Program** (see [Section 4.11](#)).

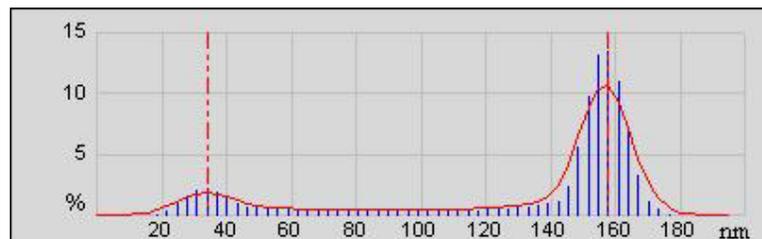
**Figure 4.4d** Depth Interface



### 4.4.3 Depth Interface

The **Depth** interface includes a captured image, **Input** parameters, **Results** parameters and a correlation histogram (see [Figure 4.4e](#)).

**Figure 4.4e** Depth Histogram



## Depth Input Parameters

The depth input parameters below define the slider cursor placement for determining the exact depth of a feature.

<b>Number of Histogram Bins</b>	The number of data points, ranging from 4 to 512, which result from the filtering calculation.
<b>Histogram Filter Cutoff</b>	Lowpass filter which smooths out the data by removing wavelength components below the cutoff. Use to reduce noise in the Correlation histogram.
<b>Min Peak To Peak</b>	Sets the minimum distance between the maximum peak and the second peak marked by a cursor. The second peak is the next largest peak to meet this distance criteria.
<b>Left Peak Cutoff</b>	The left (smaller in depth value) of the two peaks chosen by the cursors. Value used to define how much of the left peak is included when calculating the centroid. At 0 percent, only the maximum point on the curve is included. At 25 percent, only the maximum 25 percent of the peak is included in the calculation of the centroid.
<b>Right Peak Cutoff</b>	The right (larger in depth value) of the two peaks marked by the cursors. Value used to define how much of the right peak is included when calculating the centroid. At 0 percent, only the maximum point on the curve is included. At 25 percent, only the maximum 25 percent of the peak is included in the calculation of the centroid.

## Results Parameters:

<b>Peak to Peak Distance</b>	Depth between the two data peak centroids as selected using the line cursors.
<b>Minimum Peak Depth</b>	The depth at which the smaller of the two peaks occurs.
<b>Maximum Peak Depth</b>	The depth at which the larger of the two peaks occurs.
<b>Depth at Histogram Max</b>	Depth at the maximum peak on the histogram.
<b>Number of Peaks Found</b>	Total number of peaks included within the data histogram.

## 4.5 Power Spectral Density

### PSD

The **Power Spectral Density** (PSD) function is useful in analyzing surface roughness. This function provides a representation of the amplitude of a surface's roughness as a function of the spatial frequency of the roughness. Spatial frequency is the inverse of the wavelength of the roughness features.

The **PSD** function reveals periodic surface features that might otherwise appear “random” and provides a graphic representation of how such features are distributed. On turned surfaces, this is helpful in determining speed and feed data, sources of noise, etc. On ground surfaces, this may reveal some inherent characteristic of the material itself such as grain or fibrousness. At higher magnifications, **PSD** is also useful for determining atomic periodicity or lattice.

Refer to the following **Power Spectral Density** sections:

- **NanoScope PSD Measurements:** [Section 4.5.1](#)
- **PSD and Surface Features:** [Section 4.5.2](#)
- **PSD and Flatness:** [Section 4.5.3](#)
- **Performing a Spectral Density Analysis:** [Section 4.5.4](#)
- **Changing Parameters of the Spectrum Plot:** [Section 4.5.5](#)

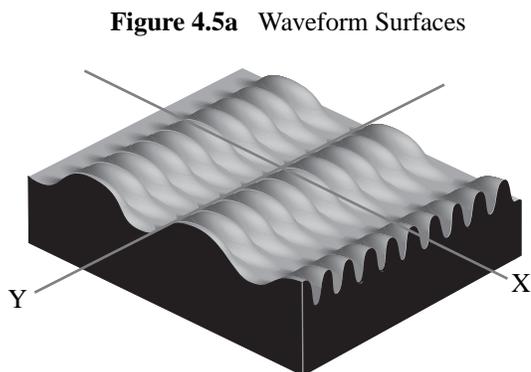
### 4.5.1 NanoScope PSD Measurements

The **Power Spectral Density** function computes the following information for the image:

- **Total power spectrum**—Power is roughness amplitude squared, so power is in units of length squared for a topographic image. Power spectrum is a plot of power as a function of spatial wavelength or frequency.
- **1D PSD**—A one dimensional power spectral density. Power spectral density is a plot of the density, in spatial frequency space, of the power spectrum. Its units are length squared divided by a one dimensional frequency, or 1 over length, which is length cubed. A 1D PSD can be calculated in either the X direction of the data or in the Y direction.
- **1D isotropic PSD**—A different version of a one dimensional power spectrum.
- **2D isotropic PSD**—A two dimensional power spectral density. Its units are length squared divided by a two dimensional frequency, or 1 over length squared, which is length to the fourth power. This is isotropic in the sense that it is an average taken over all directions in the data.
- **RMS roughness values**—Since the RMS roughness is the square root of the integral of the PSD, over some wavelength or frequency interval, this calculation can be conveniently done when one has the PSD.

## 4.5.2 PSD and Surface Features

Consider the image in [Figure 4.5a](#).



**2D Spectrum**

This synthetic surface consists of essentially two dominant wave forms: a long period waveform along the X-axis, and a shorter period waveform along the Y-axis. A 2 dimensional power spectral density plot consists of two dominant spikes (one for each dominant wavelength), plus some number of extra wavelengths inherent within the image. (These extra wavelengths may appear due to fine surface features and/or side bands of the dominant wave forms.) Because of the sinusoidal nature of the composite wave form, a relatively small set of spectral frequencies suffices to describe the entire surface. By contrast, an image comprised of angular (saw-toothed or square) waveform contains more spatial frequency components.

Over a given range of spatial frequencies the total power of the surface equals the RMS roughness of the sample squared.

The frequency distribution for a digitized profile of length  $L$ , consisting of  $N$  points sampled at intervals of  $d_0$  is approximated by:

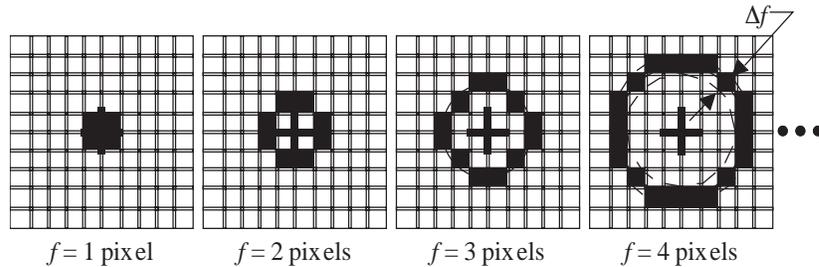
$$\text{PSD}(f) = \frac{2d_0}{N} \left| \sum_{n=1}^N e^{i \frac{2\pi}{N}(n-1)(m-1)} z(n) \right|^2 \quad \text{for } f = \frac{m-1}{Nd_0}$$

Where  $i = \sqrt{-1}$ , and frequencies,  $f$ , range from  $\frac{1}{L}$  to  $\frac{N/2}{L}$ . Practically speaking, the algorithm used to obtain the PSD depends upon squaring the FFT of the image to derive the power. Once the power,  $P$ , is obtained, it may be used to derive various PSD-like values as follows:

$$\begin{aligned} \text{1D PSD} &= \frac{P}{\Delta f} \\ \text{1D isotropic PSD} &= \frac{P}{2\pi f} \\ \text{2D isotropic PSD} &= \frac{P}{2\pi f(\Delta f)} \end{aligned}$$

The terms used in the denominators above are derived by progressively sampling data from the image's two-dimensional FFT center (see [Figure 4.5b](#)).

**Figure 4.5b** Progressive Data Sampling



Each sampling swings a “data bucket” of given frequency  $f$ . Since samples are taken from the image center, the sampling frequency,  $f$ , is limited to  $\frac{N/2}{L}$ , where  $N$  is the scan size in pixels. This forms the upper bandwidth limit (i.e., the highest frequency or Nyquist frequency) of the PSD plot. The lower bandwidth limit is defined at  $1/L$ .

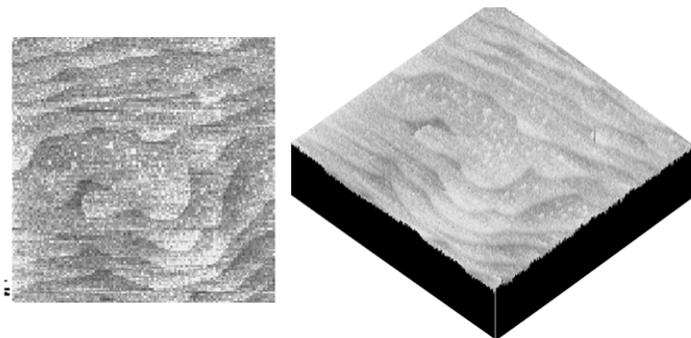
### 4.5.3 PSD and Flatness

**PSD** is used increasingly as a metrology tool for evaluating extremely flat surfaces, such as polished or epitaxial silicon. Generally, the desired surface is expected to adhere to certain **PSD** thresholds, signifying it meets a specified flatness criterion.

The main advantage gained over traditional RMS specifications is that **PSD flatness** is qualified through the full spectral range of interest. For example, one may specify spectral thresholds at frequencies measured on the atomic scale, thus ensuring surfaces consist largely of uniform lattices. Setting the precise thresholds for various materials remains a matter of debate.

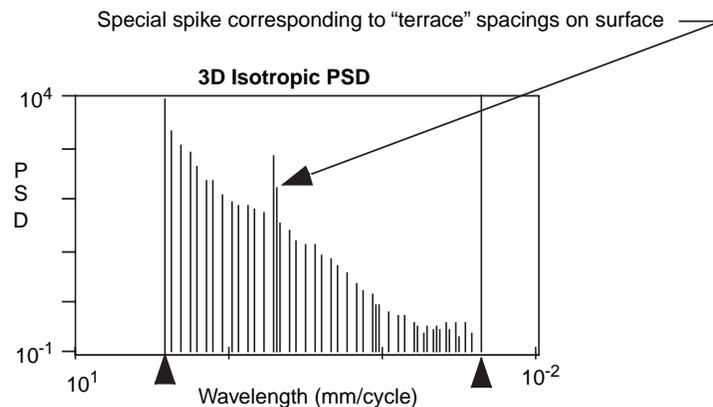
Consider the image of epitaxial gallium arsenide in [Figure 4.5c](#).

**Figure 4.5c** Epitaxial Gallium Arsenide Image



This surface is comprised of “terraces” formed from the material’s natural lattice structure; each terrace is one atomic monolayer thick and is spaced at fairly regular intervals. This degree of flatness is handily evaluated with PSD, as the terraces produces a spectral spike corresponding to their spacing wavelength. A PSD plot for this type of surface generally takes the form shown in Figure 4.5d.

**Figure 4.5d** PSD Plot for Terraced Sample



This tapered PSD plot is characteristic of flat, isotropic surfaces. Longer wavelengths are present up to the scan width, and are accompanied by uniformly decreasing powers of shorter wavelengths down to 2 pixels. On the plot shown above a spike stands out, corresponding to the wavelength spacing of the terraced features. Depending upon the qualitative standards of the person evaluating such a plot, this spike may exceed a threshold standard of flatness.

#### 4.5.4 Performing a Spectral Density Analysis

To use the **PSD Analysis** function, perform the following procedures:

1. Select **View > Browse** from the menu bar, then open the image you wish to analyze by double-clicking it.
2. You can view the **PSD Analysis View** using *one* of the following methods:
  - Right-click on the image name in the **Workspace** and select **Add View > PSD** from the popup menu.

Or

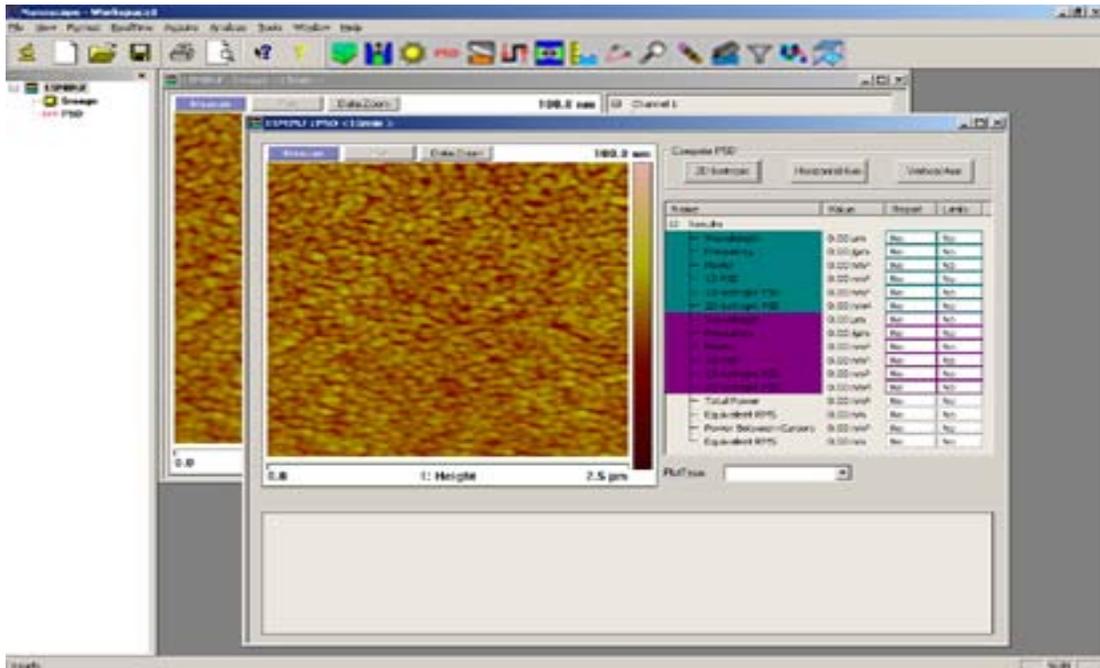
  - Select **Analyze > PSD** from the menu bar.

Or

  - Click the **PSD** icon in the upper toolbar. 

The PSD window opens to allow spectral density plotting on the Display Monitor (see Figure 4.5e).

Figure 4.5e PSD Analysis



### Compute PSD Buttons

Once the **PSD analysis** window is opened, select the type of spectral density analysis you wish to perform by clicking the appropriate button above the **Results** window.

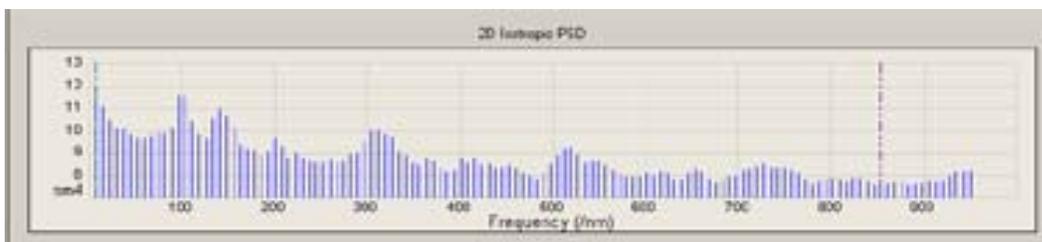
**2D Isotropic**—Executes a two-dimensional **Power Spectral Density** analysis.

**Horizontal Axis**—Executes a one-dimensional **Power Spectral Density** analysis along the X-axis.

**Vertical Axis**—Executes a one-dimensional **Power Spectral Density** analysis along the Y-axis.

The calculation begins as soon as the button is selected. The **PSD** and a table of values from the graph are shown in the **Results** window. Completion of the analysis will also result in a topographical histogram in the spectrum plot window (see Figure 4.5f).

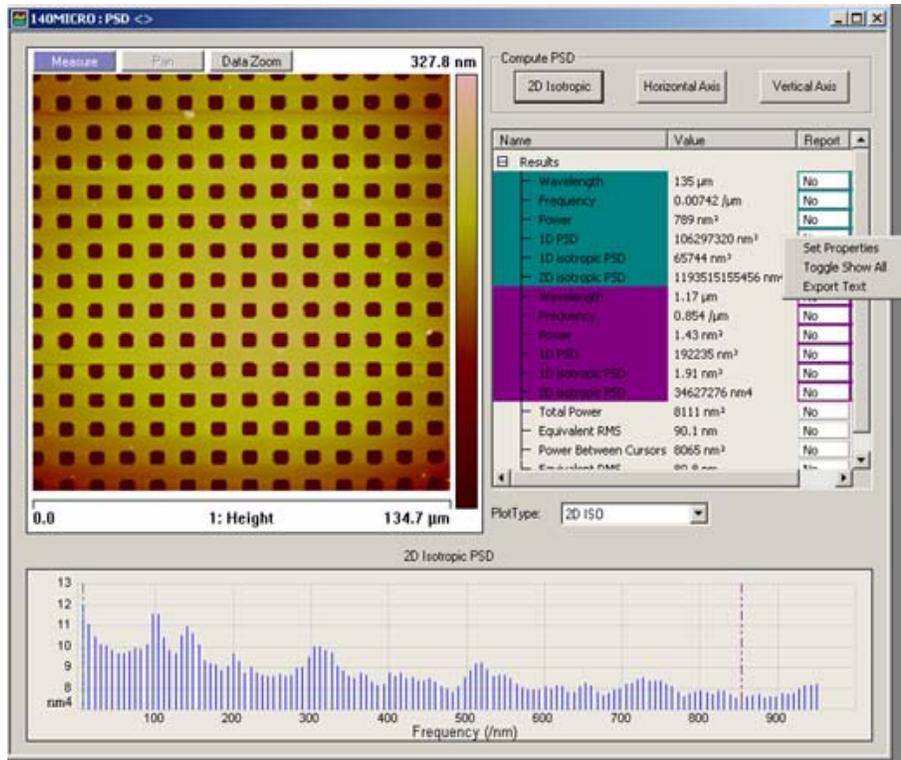
Figure 4.5f Power Spectral Density Histogram



### Results Display

The **Results** window displays the **Name** and **Value** of the procedures performed during a **PSD** analysis. The teal shaded area in the display window corresponds to the area designated by the teal cursor on the **Power Spectral Density** histogram, and the purple shaded area corresponds to the purple cursor. The operator can select to have a report generated for each **Result** displayed by toggling the **Report** window between **Yes** and **No**. Right-clicking in the **Results** window will open a popup menu (see Figure 4.5g) that allows you to set the result properties, select the parameters that will be displayed, and export the results data to the clipboard as a text file.

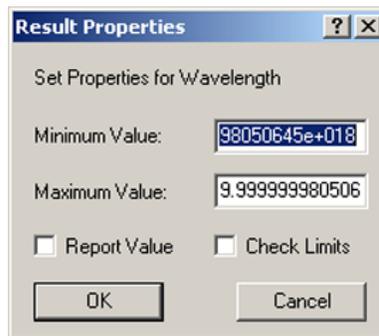
Figure 4.5g Power Spectral Density Display



### Set Properties

The operator can select the wavelength properties for each **Results** window parameter by selecting **Set Properties** from the **Results** popup menu, which opens the **Result Properties** window (see [Figure 4.5h](#)), and entering the a **Minimum Value** and a **Maximum Value**. Checking the **Report Value** check box will change the **Report** window from **No** to **Yes** for that particular parameter. When **PSD** is being used as part of an **AutoProgram** (see **AutoProgram**: [Section 4.12](#)), Checking the **Check Limits** box will cause the analysis to fail if the results are not within designated limits.

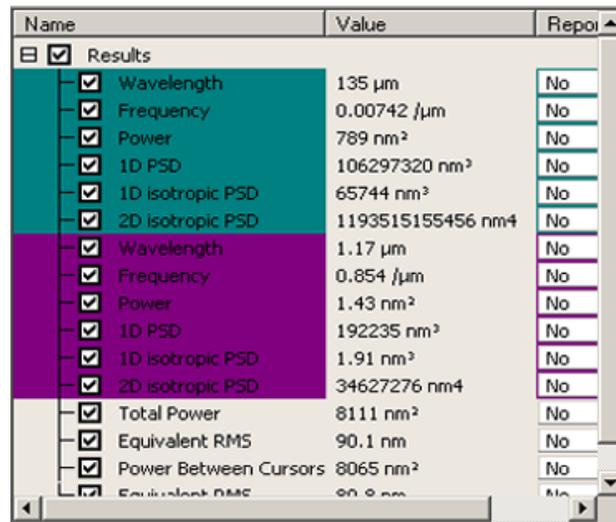
**Figure 4.5h** Result Properties Window



### Select Displayed Parameters

The operator can select which **Results** will or will not be displayed in the **Results** window by Right-clicking in the **Results** window, selecting **Toggle Show All** from the popup menu, and checking or unchecking the appropriate boxes (see [Figure 4.5i](#)).

**Figure 4.5i** Select Show All On/Off Check Boxes



## Export Text

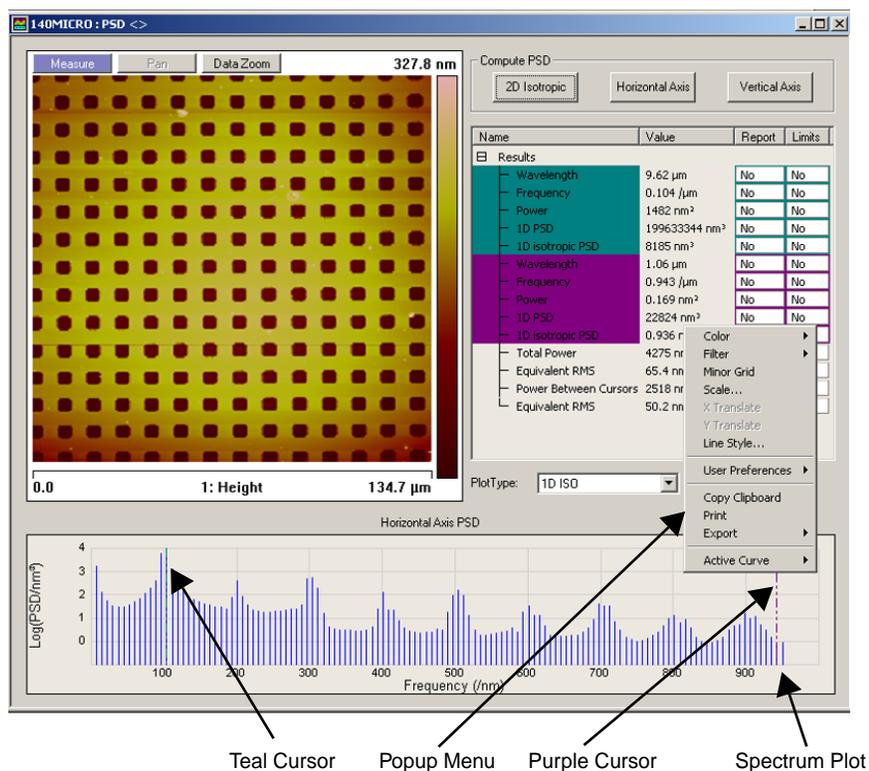
Selecting **Export Text** from the popup menu will copy the text from the **Results** window, in tab-delimited text format, to the Windows clipboard. You may then paste it into a text or word processing program.

## 4.5.5 Changing Parameters of the Spectrum Plot

The **Spectrum Plot** window displays results of the **PSD** analysis (see [Figure 4.5j](#)). The window has two cursors whose color corresponds to the shaded areas in the **Results** window. You can move either of these cursors within the **Spectrum Plot** window by placing the cross hair cursor directly over the cursor, clicking and holding the left mouse button, and dragging the mouse to the left or right. You can also move both cursors simultaneously by left-clicking the mouse with the cross hair cursor anywhere between the two cursors and dragging to the left or right.

To change the parameters of the **Spectrum Plot**, right-click in the **Spectrum Plot** window at the bottom of the display and choose from the popup menu.

**Figure 4.5j** Spectrum Plot Parameter Menu



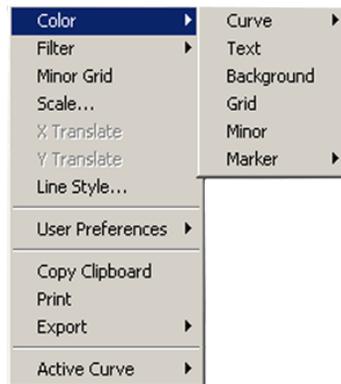
### Spectrum Plot Popup Menu Items

**Color**—Changes the colors of the curves, text, background, grid lines, minor grid lines (if selected), and the marker pairs (see [Figure 4.5k](#)).

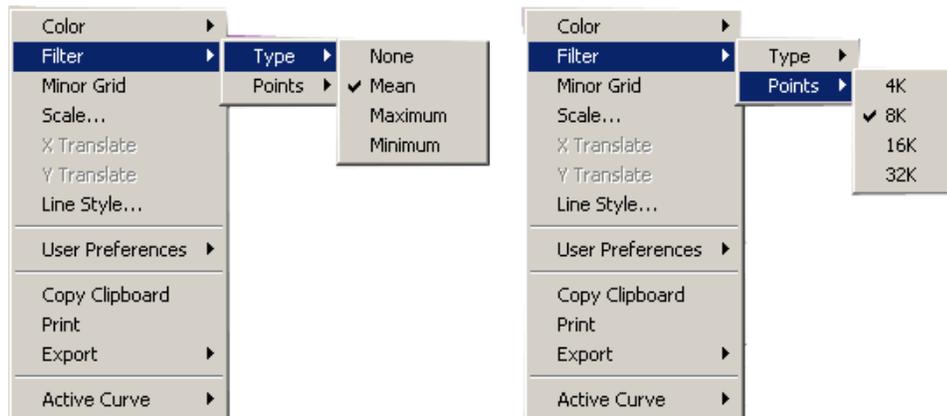
**Filter**—Selects Filter type and points (see [Figure 4.5l](#)).

**Minor Grid**—Shows/hides minor grid lines

**Figure 4.5k** Color Menu Items



**Figure 4.5l** Filter Menu Items



**Scale**—Sets the vertical axis range, the center of the range, or allow the software to autoscale (see [Figure 4.5m](#)).

**Line Style**—Changes the line style of the Spectrum Plot graphical display (see [Figure 4.5n](#)).

**User Preferences**—You can either save all changes made to the graphical display, or restore previously saved settings (see [Figure 4.5o](#)). **Save** will result in all graphical displays maintaining any design changes made to this display.

**Copy Clipboard**—Copies the graphical display only to the Windows clipboard, allowing it to be pasted into any compatible Windows program.

**Print**—Prints the graphical display only to a printer.

**Export**—Saves the graphical display as a JPEG graphic, a Bitmap graphic, or as an XZ Data file text, which can be read in a database program (i.e. Excel).

**Active Curve**—Changes the curve displayed when more than one curve has been plotted. (Does not occur in PSD).

Figure 4.5m Scale Settings Dialog Box

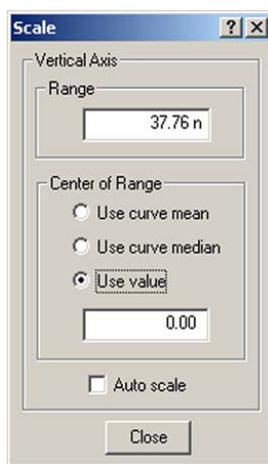
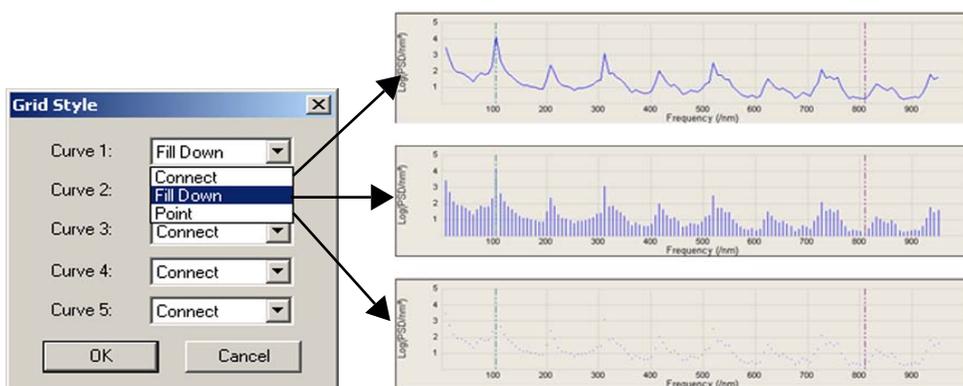


Figure 4.5n Line Style Display



**Figure 4.5o** User Preferences Menu



## 4.6 Roughness



The **Roughness** command generates a variety of statistics on surfaces, including classical roughness values, and peak and zero crossing data. “Image” statistics are reported for the entire image. “Box” statistics are reported only for the region you define within a cursor box. In addition, the data can be augmented with *stopbands*, (excluding features) to isolate desired analysis.

Refer to the following sections on **Roughness**:

- **Roughness Theory:** [Section 4.6.1](#)
- **Roughness Procedures:** [Section 4.6.2](#)
- **Roughness Interface:** [Section 4.6.3](#)

Most industrial standards for roughness measurement call for planefitting data *before* calculating values. Planefitting applies a temporary, first-order planefit before calculating statistics. On many surfaces, especially those which are tilted, this yields different values from those seen in raw (unplanefitted) data. Moreover, peripheral features included within the analyzed region may produce cumulative results uncharacteristic of the feature(s) of interest. To ensure the best results, you should observe the following rules when using **Roughness** analysis:

- If the image shows signs of second- or third-order distortion (e.g., bow due to large scans on large scanners), apply a second- or third-order **Flatten** and **Planefit** to the image *before* using **Roughness** analysis.
- Isolate your analysis to specific areas of the image. This may be accomplished by using the box cursor in **Roughness** to analyze only select portions of the image.

### 4.6.1 Roughness Theory

Regarding the effects of **Planefitting** on **Roughness** statistics—When **Roughness** analysis is applied to an image, statistical values are calculated according to the relative heights of each pixel in the image. **Planefitting** (used to correct images for tilt and bow) reorients these pixels in a manner which can affect roughness statistics dramatically on some surfaces. This is especially true of surfaces having broad, coplanar features. Planefitting can be applied at the time of file capture using **Offline planefit** from a **Channel** panel, or via the **Analyze > Plane Fit** function.

When **Roughness** analysis is applied to an image, the image data is automatically planefit beforehand. This is done to accord with ASME and ISO metrological standards. (Only the **Raw mean** parameter is exempt from this operation, being calculated from raw data only.) To avoid unexpected results due to planefitting, be certain to apply **Roughness** analysis only to the surface(s) of interest by utilizing a cursor box, or by scanning just the specific site of interest. Including peripheral features within an analyzed area may produce cumulative results uncharacteristic of the feature(s) of interest.

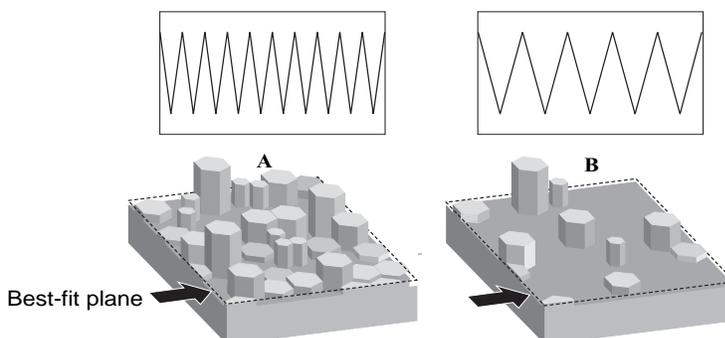
The relationship between the zero plane and the data also changes according to the setting of the **Offline planefit** parameter. If the **Offline planefit** parameter is set to **None** the offset is not removed from the data and it is very possible that the zero plane does not intersect the data. The other settings of the parameter subtract the average Z value from every point in the image so the data varies around the zero plane.

Regarding Basic Roughness Measurements—Average roughness ( $R_a$ ) is one of the most commonly used roughness statistics. [Figure 4.6a](#) represents two surfaces having the same average roughness.

Similarly, a number of other roughness values are based upon least-squares calculations (e.g., RMS roughness, or  $R_q$ ), and their algorithms are more concerned with a best fit of all height points than with the spatial frequency of features.

The surface of image **A** is represented as having a high frequency profile of features. Image **B** represents a separate surface having the same average feature height, but distributed at wider (lower-frequency) intervals. In terms of average and RMS roughness, both surfaces are equally rough. If you are interested in differentiating between the two, you must rely upon other statistical parameters such as Power Spectral Density.

**Figure 4.6a** Basic Roughness Measurements



## 4.6.2 Roughness Procedures

### Example of Using Roughness Analysis

For general **Roughness Analysis**, complete the following procedures:

1. Select an image file from the file browsing window at the right of the main window. Double click the thumbnail image to select and open the image.
2. You can view the **Roughness View** using *one* of the following methods:
  - Right-click on the image name in the **Workspace** and select **Add View > Roughness** from the popup menu.

Or

  - Select **Analyze > Roughness** from the menu bar.

Or

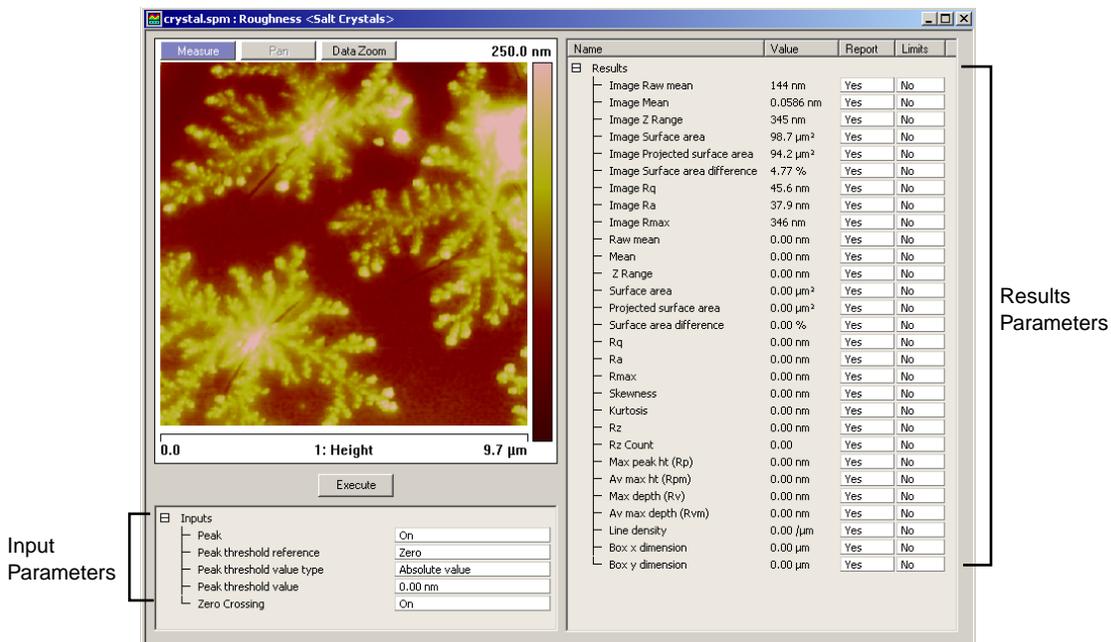
  - Click the **Roughness** icon in the upper toolbar. 
3. The **Roughness View** appears showing results for the entire image.
4. To perform **Roughness** measurements within an area, left-click and move the mouse to draw a measurement box. Click on the **Execute** button to calculate the **Roughness** inside the box.
5. To exclude an area, right-click in the image to access a pop-up menu and select **Stop band**. Using the mouse, draw a box around the area to be excluded by the stop band command. Click on the **Execute** button to calculate the **Roughness** outside the box.

### 4.6.3 Roughness Interface

The **Roughness View** shows the image along with **Input** parameters and a **Results** window.

**Note:** Some parameters are reported only when certain subroutines are turned on.

**Figure 4.6b** Roughness Display



## Input Parameters

### Peak

The **Peak** feature, when switched **On**, isolates specified height portions of the image (peaks) from background data. Peaks are specified using the **Peak Threshold** parameters, either in terms of their absolute height or their deviation from the RMS value of all surface data, and relative to either the highest data point (Peak) or the mean (Zero). When **Peak** is turned **On**, portions of the image contained within the box cursor and falling within the specified boundaries are retained; all other data is removed.

**Range or Settings**—When **Peak** is turned **On**, the following subcommands are activated (see [Figure 4.6c](#)):

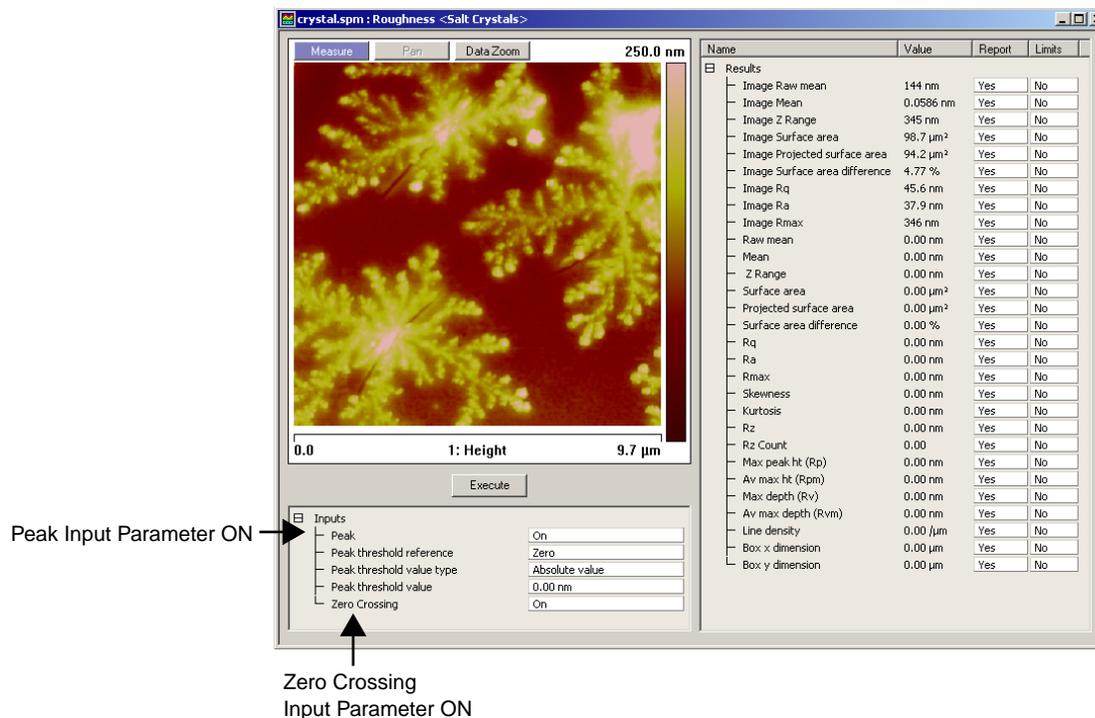
<b>Peak Threshold Reference</b>	The <b>Reference</b> buttons select whether the threshold is defined relative to the <b>Zero</b> (lowest) value, or the tallest <b>Peak</b> in the selected region.
<b>Peak Threshold Value Type</b>	The <b>Value Type</b> determines whether the threshold is defined as an absolute distance from the reference point in nanometers ( <b>Absolute value</b> ) or a percentage of the root-mean-square ( <b>Rms %</b> ) of the Z values.
<b>Peak Threshold Value</b>	The <b>Value</b> is an absolute distance from the reference point in nanometers (Absolute value) or a percentage of the root-mean-square (Rms %) of the Z values.

When **Peak** is turned **On**, the following statistical parameters are turned on. All **Peak** parameters are calculated from the thresholds you define with the **Peak** subcommands.

- **Rz**
- **Rz count**
- **Max peak ht (Rp)**
- **Av. Max ht (Rpm)**
- **Max depth (Rv)**
- **Av. max depth (Rvm)**

When **Peak** is turned **Off**, statistics are not calculated.

Figure 4.6c Input On Parameters



### Zero Crossing

A zero crossing is a point where the Z values go through zero regardless of slope. This value is the total number of zero crossings along both the X and Y center lines divided by the sum of the box dimensions.

**Range or Settings**—When **Zero crossing** is turned **On** and you click the **Execute** button, the number of zero crossings along the X and Y center lines of the box cursor is determined (see [Figure 4.6c](#)). The number of zero crossings is divided by the sum of the lengths of the X and Y center lines and reported as the **Line density**.

When **Zero crossing** is turned **Off**, the zero crossing determination is not performed.

### Results Parameters

Statistics used by the Roughness routine are defined in this section. The terms are listed *alphabetically*. Most are derived from ASME B46.12 (“Surface Texture: Surface Roughness, Waviness and Lay”) available from the American Society of Mechanical Engineers, which should be consulted.

<b>R<sub>z</sub></b>	This is the average difference in height between the five highest peaks and five lowest valleys relative to the <b>Mean Plane</b> . In cases where five pairs of peaks and valleys do not exist, this value is based on fewer points.
<b>Av max Depth (R<sub>vm</sub>)</b>	Average distance between the five lowest profile points and the mean data plane.
<b>Av max ht (R<sub>pm</sub>)</b>	Average distance between the five highest profile points and the mean data plane.
<b>Box x Dimension</b>	The width of the <b>L<sub>x</sub></b> box cursor you define.
<b>Box y Dimension</b>	The length of the <b>L<sub>y</sub></b> box cursor you define.
<b>Image Mean</b>	Mean value of data contained within the image.
<b>Image Projected surface area</b>	Area of the image rectangle (X x Y).
<b>Image R<sub>a</sub></b>	Arithmetic average of the absolute values of the surface height deviations measured from the mean plane.

$$R_a = \frac{1}{N} \sum_{j=1}^N |Z_j|$$

<b>Image Raw mean</b>	Mean value of image data without application of plane fitting.
<b>Image R<sub>max</sub></b>	Maximum vertical distance between the highest and lowest data points in the image following the planefit.
<b>Image R<sub>q</sub></b>	Root mean square average of height deviations taken from the mean image data plane, expressed as:

$$\sqrt{\frac{\sum Z_i^2}{N}}$$

<b>Image Surface area</b>	The three-dimensional area of the entire image. This value is the sum of the area of all of the triangles formed by three adjacent data points.
<b>Image Surface Area Difference</b>	Difference between the image’s three-dimensional <b>Surface area</b> and two-dimensional projected surface area.
<b>Image Z range</b>	Maximum vertical distance between the highest and lowest data points in the image prior to the planefit.

**Kurtosis** This is a non-dimensional quantity used to evaluate the shape of data about a central mean. It is calculated as

$$R_q = \frac{1}{N} \sqrt[N]{\sum_{j=1}^N Z_j^4}$$

Graphically, kurtosis indicates whether data are arranged flatly or sharply about the mean.

**Line Density** The number of zero crossings per unit length on the X and Y center lines of the box cursor. A zero crossing is a point where the Z values go through zero regardless of slope. This value is the total number of zero crossings along both the X and Y center lines divided by the sum of the box dimensions.

**Max Depth (R<sub>v</sub>)** Lowest data point in examined region.

**Max Height (R<sub>max</sub>)** Maximum vertical distance between the highest and lowest data points within the cursor box.

**Max Peak ht (R<sub>p</sub>)** Maximum peak height within the analyzed area with respect to the mean data plane.

**Mean** The average of all the Z values within the enclosed area. The mean can have a negative value because the Z values are measured relative to the Z value when the microscope is engaged. This value is not corrected for tilt in the plane of the data; therefore, plane fitting or flattening the data changes this value.

**Mean Roughness (R<sub>a</sub>)** Arithmetic average of the absolute values of the surface height deviations measured from the mean plane within the box cursor:

$$R_a = \frac{1}{N} \sum_{j=1}^N |Z_j|$$

**Projected Surface Area** Area of the selected data.

**Raw Mean** Mean value of image data within the cursor box you define without application of plane fitting.

**Rms (R<sub>q</sub>)** This is the standard deviation of the Z values within the box cursor and is calculated as:

$$R_q = \sqrt{\frac{\sum (Z_i)^2}{N}}$$

where Z<sub>i</sub> is the current Z value, and N is the number of points within the box cursor. This value is not corrected for tilt in the plane of the data; therefore, plane fitting or flattening the data changes this value.

**Rz Count** Number of Surface peaks taller than the threshold.

<b>Skewness</b>	Measures the symmetry of surface data about a mean data profile, expressed as: $\text{Skewness} = \frac{1}{R_q^3} \frac{1}{N} \sum_{j=1}^N Z_j^3$ where $R_q$ is the Rms roughness. Skewness is a non dimensional quantity which is typically evaluated in terms of positive or negative. Where <b>Skewness</b> is zero, an even distribution of data around the mean data plane is suggested. Where <b>Skewness</b> is strongly non-zero, an asymmetric, one-tailed distribution is suggested, such as a flat plane having a small, sharp spike ( $> 0$ ), or a small, deep pit ( $< 0$ ).
<b>Surface Area</b>	The three-dimensional area of the region enclosed by the cursor box. This value is the sum of the area of all of the triangles formed by three adjacent data points.
<b>Surface Area Diff</b>	Difference between the analyzed region's three-dimensional <b>Surface area</b> and its two-dimensional, footprint area.
<b>Z Range</b>	Peak-to-valley difference in height values within the analyzed region.

## 4.7 Section



The **Section** command displays a top view image, upon which a single reference line may be drawn. The cross-sectional profiles and fast Fourier transform (FFT) of the data along the reference line is shown in separate windows. Roughness measurements are made of the surface along the reference line you define.

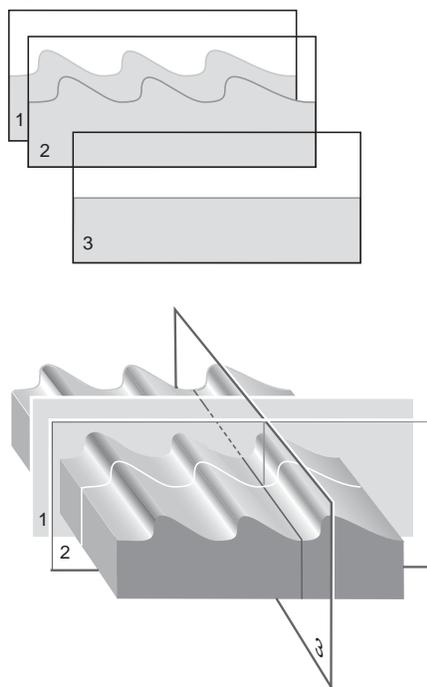
**Section** is probably the most commonly used **Analyze** command; it is also one of the easiest commands to use. To obtain consistently accurate results, ensure your image data is corrected for tilt, noise, etc. *before* analyzing with **Section**.

- **Sectioning of Surfaces: Overview:** [Section 4.7.1](#)
- **Section Procedures:** [Section 4.7.2](#)
- **Section Interface:** [Section 4.7.3](#)

### 4.7.1 Sectioning of Surfaces: Overview

Samples are sectioned to learn about their surface profiles. The **Section** command does not reveal what is *below* the surface—only the profile of the surface itself. When sectioning samples, you should first ascertain surface topology. Depending upon the topology and orientation of the sample, the results of **Section** analysis may vary tremendously.

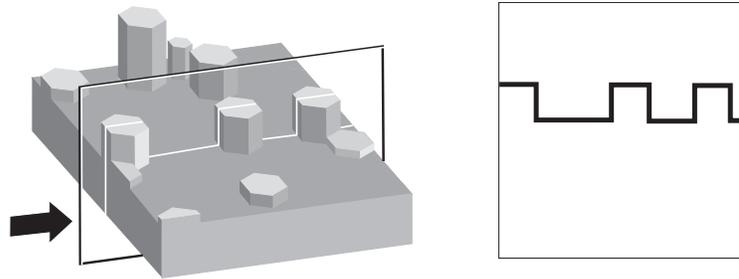
**Figure 4.7a** Section Analysis Orientation



In [Figure 4.7a](#), the sample surface (a diffraction grating) is sectioned along three axes. Sections 1 and 2 are made perpendicular to the grating's rules, revealing their blaze and spacings. (Sections 1 and 2 may be compared simultaneously using two fixed cursor lines, or checked individually with a moving cursor.) Section 3 is made parallel to the rules, and reveals a much flatter profile because of its orientation.

The **Section** command produces a profile of the surface, then presents it in the **Section** grid (see [Figure 4.7b](#)).

**Figure 4.7b** Section Command Profile



Generally, **Section** analysis proves most useful for making direct depth measurements of surface features. By selecting the type of cursor (fixed, moving, or average), and its orientation to features, you may obtain:

- Vertical distance (depth), horizontal distance and angle between two or more points.
- Roughness along section line: RMS,  $R_a$ ,  $R_{max}$ ,  $R_z$ .
- FFT spectrum along section line.

Features are discussed below. Refer to **Roughness: Section 4.6** for additional information regarding roughness calculations.

### Using the Grid Display

Measurement cursors for histogram and cross section views in depth and section are provided to the left and right of the **Grid Display**. You can bring the cursors into the grid by placing the mouse cursor onto the measurement cursors, clicking and holding the left mouse button, and dragging them onto the grid. When you place the mouse cursor onto a measurement cursor, the cursor will change to a horizontal or vertical double-arrow cursor  $\leftrightarrow$ , which indicates you can grab and drag this cursor.

Right-clicking on the grid will bring up the **Grid Parameters** menu (see [Figure 4.4b](#)) and allow you to make the following changes:

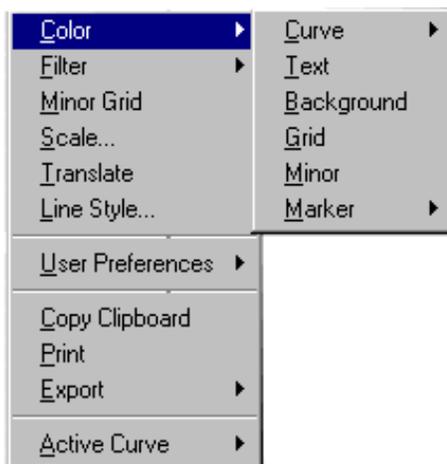
#### **Color**

Allows operator to change the color of the

- Curve (data)
- Text
- Background
- Grid
- Minor
- Marker

<b>Filter</b>	Typically used for a Profiler Scan. <ul style="list-style-type: none"> <li>• Type—Select None, Mean (default), Maximum, or Minimum</li> <li>• Points—Select 4k, 8k (default), 16k, or 32k</li> </ul>
<b>Minor Grid</b>	Places a minor grid in the background of the Vision Window.
<b>Scale</b>	Allows user to auto scale, set a curve mean, or set their own data range
<b>Line Style</b>	For each curve, the operator can choose a connect, fill down, or point line.
<b>User Preferences</b>	<p><b>Restore</b>—Reverts to initial software settings</p> <p><b>Save</b>—Saves all changes operator has made during this session. This becomes the new default settings.</p>
<b>Copy Clipboard</b>	Copies the grid image to the Microsoft Clipboard
<b>Print</b>	Prints out the current screen view to a printer
<b>Export</b>	Exports data in bitmap, JPEG or XZ data format
<b>Active Curve</b>	Determines which curve you are analyzing

**Figure 4.7c** Grid Parameters Menu



## 4.7.2 Section Procedures

1. Select an image file from the file browsing window at the right of the main window. Double click the thumbnail image to select and open the image.
2. You can view the **Section View** using *one* of the following methods:
  - Right-click on the image name in the **Workspace** and select **Add View > Section** from the popup menu.

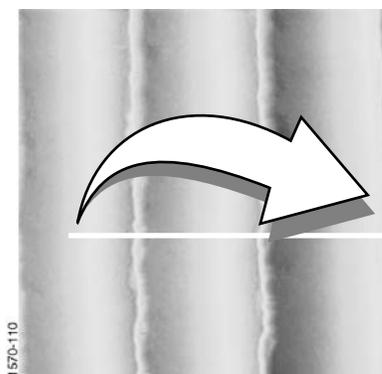
Or

  - Select **Analyze > Section** from the menu bar.

Or

  - Click the **Section** icon in the upper toolbar. 
3. Before doing a section analysis, ensure that the image is properly oriented by removing any tilt or bow. This is especially important if a high level of precision is to be employed in measuring the blaze angle.
4. To remove any tilt which might be present, select **Analyze > Plane Fit**. Set the **Planefit Order** parameter in the panel to **1st**, then click the **Execute** button. The image is fitted to a plane (“leveled”) by fitting each scan line to a first-order equation, then fitting each scan line to others in the image. At this point, the image has not been appreciably altered, it has only been reoriented slightly.
5. In Section Analysis, to make a single-line section of the image, use the mouse to draw a line through the image, as in [Figure 4.7d](#), and note the results.
6. Move the grid cursors along the section to make measurements.

**Figure 4.7d** Mouse Drawing Line



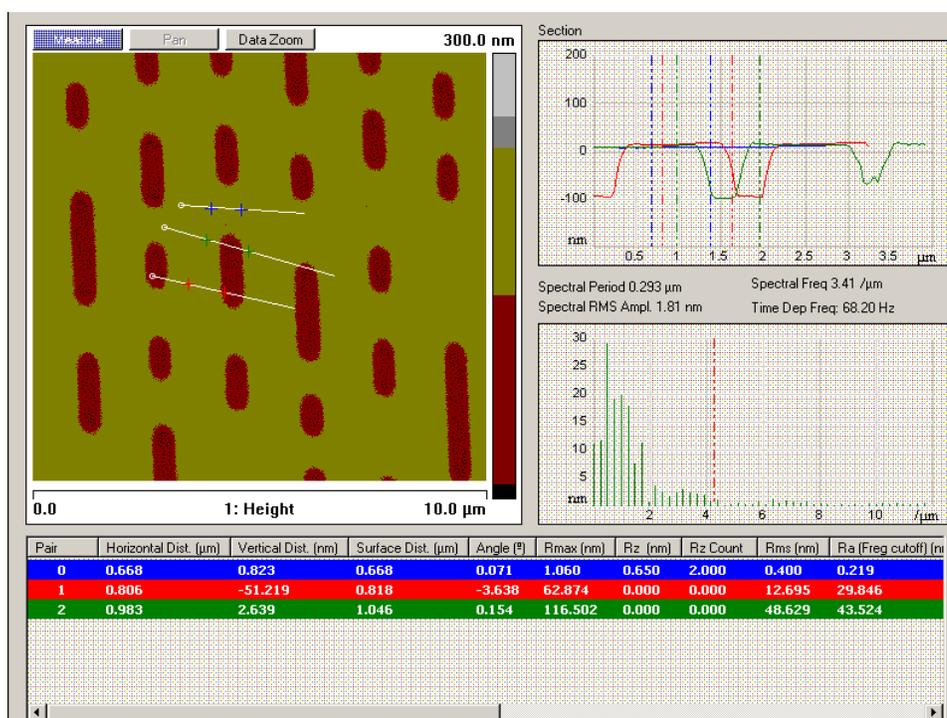
Use the mouse to drag a line cursor across the image.

### 4.7.3 Section Interface

When a line is drawn on the image, the cross-sectional profile is displayed in the upper right window, and the FFT spectrum along the line is displayed directly below it (see Figure 4.7e). More detail about the FFT algorithm used may be found at <http://www.fft.org>.

The markers may be positioned in the profile and FFT spectrum. The results window at the bottom of the display lists roughness information based on the position of the presently selected reference markers. Each marker pair is color coordinated with the data in the results window.

Figure 4.7e Section View



#### Grid Markers:

A pair of markers in the section grid and a single marker in the spectrum grid will automatically be drawn. Place the mouse cursor on the desired marker and left-click to move.

**Marker pair 0** Default display color is blue. Slide the markers into the grid from the left or right side by clicking and holding the left mouse button. Data between the two markers will be displayed in the results window at the bottom of the display screen in blue.

**Marker pair 1** Default display color is red. Slide the markers into the grid from the left or right side by clicking and holding the left mouse button. Data between the two markers will be displayed in the results window at the bottom of the display screen in red.

- Marker pair 2** Default display color is green. Slide the markers into the grid from the left or right side by clicking and holding the left mouse button. Data between the two markers will be displayed in the results window at the bottom of the display screen in green.
- Spectrum Marker** Displays the third slider cursor location along the spectral data (e.g., FFT Spectrum).

### Results Parameters:

The standard deviation RMS ( $R_q$ ), mean roughness ( $R_a$ ), the maximum height ( $R_{max}$ ), and the 10-point roughness ( $R_z$ ) for the segment between the reference markers are also listed in the **Results** parameter grid.

### Results Parameters:

- Length** Length of the roughness curve.
- RMS (Standard Deviation)** Standard deviation of the Z values between the reference markers, calculated as:

$$RMS = \sigma = \sqrt{\frac{\sum (Z_i - Z_{ave})^2}{N}}$$

where  $Z_i$  is the current Z value,  $Z_{ave}$  is the average of the Z values between the reference markers, and  $N$  is the number of points between the reference markers.

- $R_a$  (Mean Roughness)** Mean value of the roughness curve relative to the center line, calculated as:

$$R_a = \frac{1}{L} \int_0^L |f(x)| dx$$

where  $L$  is the length of the roughness curve and  $f(x)$  is the roughness curve relative to the center line.

- $R_{max}$  (Maximum Height)** Difference in height between the highest and lowest points on the cross-sectional profile relative to the center line (not the roughness curve) over the length of the profile,  $L$ .

- $R_z$  (Ten-Point Mean Roughness)** Average difference in height between the five highest peaks and five lowest valleys relative to the center line over the length of the profile,  $L$ . In cases where five pairs of peaks and valleys do not exist, this is based on fewer points.

- Freq. Cutoff ( $\Omega_m$ )** **Frequency Cutoff** measured in terms of a percentage of the root mean square.

Changing the cursor on the FFT changes  $l_c$ , the cutoff length of the high-pass filter applied to the data. The filter is applied before the roughness data is calculated; therefore, the position of the cutoff affects the calculated roughness values.

- **RZ Count**—number of peaks used for rz computation

- **Radius**—radius of circle fitted to the data between the cursors
- **Radius Sigma**—mean square error of radius calculation
- **Surface Distance**—distance measured along the surface between the cursors
- **Horizontal Distance**—horizontal distance between the cursors
- **Vertical Distance**—vertical distance between the cursors
- **Angle**—angle of the imaginary line drawn from the first cursor intercept to the second cursor intercept
- **Spectral Period**—spectral period at the cursor position
- **Spectral Frequency**—spectral frequency at the cursor position
- **Spectral RMS Ampl.**—amplitude at the cursor position

#### **Mouse Operations for a Line Cursor:**

- Mouse down, drag—Anchors the origin of a line segment and expands from the selected position, allowing a line segment to be drawn in any direction.
- Mouse up—Anchors the terminal point of the first (dashed) line segment and draws a moving reference line perpendicular to the fixed-line segment. The cross-sectional profile and the FFT along the reference line are displayed at this time. The position of the moving reference line tracks the movements of the mouse. When the mouse is stationary, the cross-sectional profile and the FFT of the data along the moving reference line is updated on the Display Monitor.
- Clicking on the center of the line and dragging moves the line on the image.
- Clicking on either end of the line rotates the line.

### Mouse Operations for Box Cursor (Right-Click Selection):

- 1st click—Anchors the origin of a box and “rubber bands” out from the center of the selected position.
- As a reference, the cursor positions show up on the center line in the box.
- Clicking on the box—Allows the box to be moved (cursor inside box), or resized (cursor on edge of box). Clicking on the corner allows the box to be resized in two directions.
- Holding the **Shift** button down while clicking on the box and dragging in a circular direction rotates the box.

## 4.8 Step



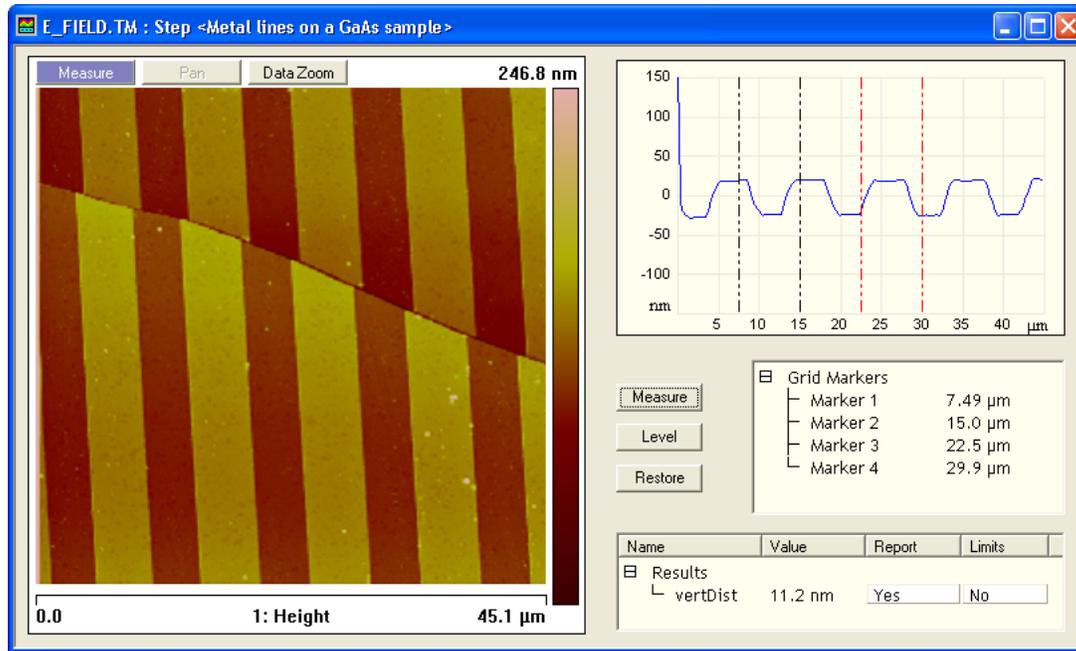
The **Step** command makes relative height measurements between two regions (steps) on sample surfaces. Typical applications include measuring film thickness and etch depths. **Step** works similarly to a **Section** command with an averaging box cursor, but its operation is simplified.

**Step** displays a top view of the image, then a reference line is drawn across the regions to be measured. A height profile is generated from averaged data on either side of the reference line. Cursors—which are moved along the profile—define specific regions (steps). These may be measured (**Measure** button) relative to each other, with or without data leveling (**Level** button).

### 4.8.1 Step Interface

The Step interface, shown in [Figure 4.8a](#), includes a captured image and a graph of averaged height within a selected box. Two pairs of cursors (one black and one red) can be moved across this profile to define the steps to be measured. The region between each cursor defines a “step.” The marker position is shown below the height graph.

Figure 4.8a Step Interface

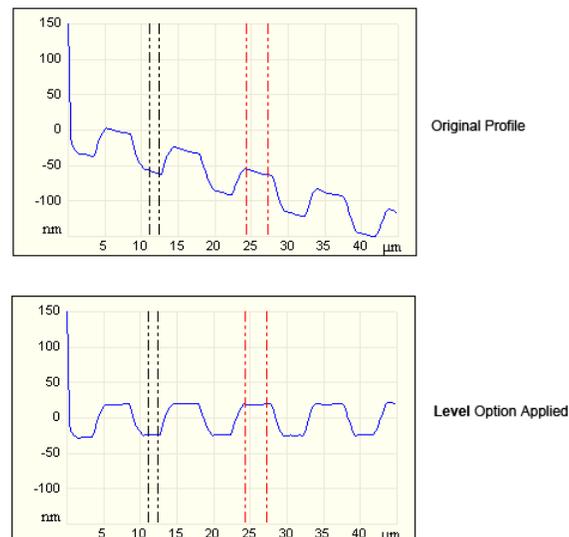


### Stepheight Display Menu Commands

#### Level

Reorients the profile so that the average height of each step region (between cursor pairs) is equal.

Figure 4.8b Level Option Profile



### Measure

Displays the relative height between steps.

### Restore

Returns the profile to its original, unleveled form. (Deselects the Level option.)

## Results

### vertDist

Displays the difference between the average height of each region (between cursor pairs).

## Mouse Operation (within image)

- 1st click—Anchors the origin of a line segment and “rubberbands” from the selected position, allowing the line segment to be drawn in any direction.
- 2nd click—Anchors the terminal point of the first line segment and draws a box along the fixed-line segment. The average profile of the lines perpendicular to the segment and confined by the box is displayed.
- As a reference, the cursor positions also show up as red and green lines in the box.
- 3rd click—Allows the box to be moved (cursor inside box), or resized (cursor on edge of box). Clicking on the corner allows the box to be resized in two directions.
- 4th click—Fixes the box position or size.

## Using the Grid Display

Measurement cursors for histogram are automatically positioned based on the numerical values selected in the **Input** fields. Right-clicking on the grid will bring up the **Grid Parameters** menu (see [Figure 4.9b](#)) and allow you to make the following changes:

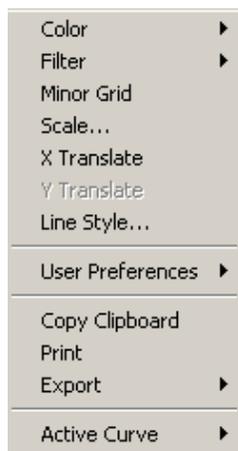
### Color

Allows operator to change the color of the:

- Curve (data)
- Text
- Background
- Grid
- Minor Grid
- Markers

<b>Filter</b>	Typically used for a Profiler Scan. <ul style="list-style-type: none"> <li>Type—Select None, Mean (default), Maximum, or Minimum</li> <li>Points—Select 4k, 8k (default), 16k, or 32k</li> </ul>
<b>Minor Grid</b>	Places a minor grid in the background of the <b>Vision</b> window.
<b>Scale</b>	Allows user to auto scale, set a curve mean, or set their own data range
<b>Line Style</b>	For each curve, the operator can choose a connect, fill down, or point line.
<b>User Preferences</b>	Restore—Reverts to initial software settings Save—Saves all changes operator has made during this session. This becomes the new default settings.
<b>Copy Clipboard</b>	Copies the grid image to the Microsoft Clipboard
<b>Print</b>	Prints out the current screen view to a printer
<b>Export</b>	Exports data in bitmap, JPEG or XZ data format
<b>Active Curve</b>	Determines which curve you are analyzing

Figure 4.8c Grid Parameters Menu



## 4.9 Width



To analyze the width of features you have numerous choices which measure the height difference between two dominant features that occur at distinct heights. **Width** was primarily designed for automatically *comparing* feature widths at two similar sample sites (e.g., when analyzing etch depths on large numbers of identical silicon wafers).

The **Width** command is designed to automatically measure width between features distinguished by height, such as trenches and raised features.

This algorithm utilizes many of the same functions found in **Depth** analysis by accumulating height data within a specified area, applying a Gaussian low-pass filter to the data (to remove noise), then

rapidly obtaining height comparisons between two dominant features. For example, 1) the depth of a single feature and its surroundings; or, 2) depth differences between two or more dominant features. Although this method of width measurement does not substitute for direct, cross-sectioning of the sample, it does afford a means for comparing feature widths between two or more similar sites in a consistent, statistical manner.

The **Width** command is best applied when comparing similar features on similar sites. Width measurement on dissimilar sites is better performed using the **Section** command.

Refer to the following sections on **Width** analysis:

- **Width Theory:** [Section 4.9.1](#)
- **Width Procedures:** [Section 4.9.2](#)
- **Width Interface:** [Section 4.9.3](#)

### 4.9.1 Width Theory

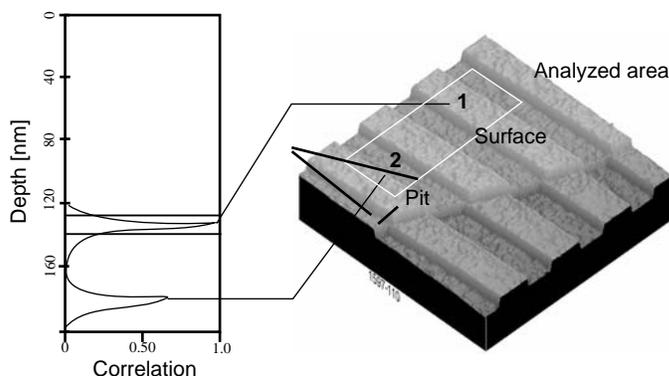
The **Width** command accumulates width data within a specified area, applies a Gaussian low-pass filter to the data to remove noise, then obtains width comparisons between two dominant features. Although this method of width analysis does not substitute for direct, cross-sectioning of the sample, it affords a means for comparing feature width between two similar sites in a consistent, statistical manner.

The display screen includes a top view image and a histogram; depth data is displayed in the results window and in the histogram. The mouse is used to resize and position the box cursor over the area to be analyzed. The histogram displays both the raw and an overlaid, Gaussian-filtered version of the data, distributed proportional to its occurrence within the defined bounding box.

#### Histogram

##### Raw Data

Histograms for depth data are presented on the bottom of the **Width** window. The histogram peaks correspond to the different parts of the image (see [Figure 4.9a](#)).

**Figure 4.9a** Width Histogram Analysis

**Note:** Color of cursor, data, and grid may change if user has changed the settings. Right-click on the graph and go to **Color** if you want to change the default settings.

### Correlation Curve

The **Correlation Curve** is a filtered version of the **Raw Data Histogram** and is located on the **Raw Data Histogram** represented by a red line. Filtering is done using the **Histogram filter cutoff** parameter in the **Input** parameters box. The larger the filter cutoff, the more data is filtered into a Gaussian (bell-shaped) curve. Large filter cutoffs average so much of the data curve that peaks corresponding to specific features are unrecognizable. On the other hand, if the filter cutoff is too small, the filtered curve may appear noisy.

The **Correlation Curve** portion of the histogram presents a lowpass, Gaussian-filtered version of the raw data. The low-pass Gaussian filter removes noise from the data curve and averages the curve's profile. Peaks which are visible in the curve correspond to features in the image at differing widths.

Peaks do not show on the correlation curve as discrete, isolated spikes; instead, peaks are contiguous with lower and higher regions of the sample, and with other peaks. This reflects the reality that features do not all start and end at discrete depths.

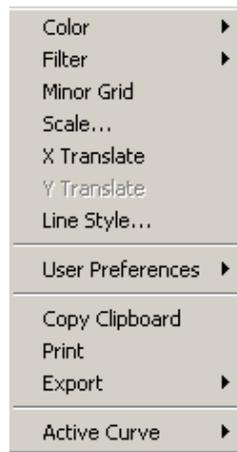
When using the **Width View** for analysis, each peak on the filtered histogram is measured from its statistical centroid (i.e., its statistical center of mass).

### Using the Grid Display

Measurement cursors for histogram are automatically positioned based on the numerical values selected in the **Input** fields. Right-clicking on the grid will bring up the **Grid Parameters** menu (see [Figure 4.9b](#)) and allow you to make the following changes:

<b>Color</b>	Allows operator to change the color of the: <ul style="list-style-type: none"><li>• Curve (data)</li><li>• Text</li><li>• Background</li><li>• Grid</li><li>• Minor Grid</li><li>• Markers</li></ul>
<b>Filter</b>	Typically used for a Profiler Scan. <ul style="list-style-type: none"><li>• Type—Select None, Mean (default), Maximum, or Minimum</li><li>• Points—Select 4k, 8k (default), 16k, or 32k</li></ul>
<b>Minor Grid</b>	Places a minor grid in the background of the <b>Vision</b> window.
<b>Scale</b>	Allows user to auto scale, set a curve mean, or set their own data range
<b>Line Style</b>	For each curve, the operator can choose a connect, fill down, or point line.
<b>User Preferences</b>	Restore—Reverts to initial software settings Save—Saves all changes operator has made during this session. This becomes the new default settings.
<b>Copy Clipboard</b>	Copies the grid image to the Microsoft Clipboard
<b>Print</b>	Prints out the current screen view to a printer
<b>Export</b>	Exports data in bitmap, JPEG or XZ data format
<b>Active Curve</b>	Determines which curve you are analyzing

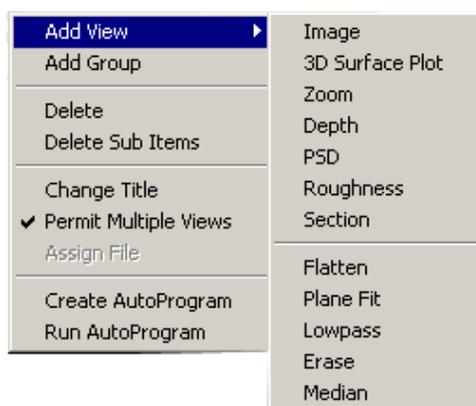
**Figure 4.9b** Grid Parameters Menu



## 4.9.2 Width Procedures

1. If no workspace is present, open a new workspace (**File > New Workspace**).
2. Open the image you wish to analyze (**File > Open > Captured Data File**) or double click on the browse view image.
3. In the workspace, position the cursor on the file name and right-click to access a functions pop-up menu.

**Figure 4.9c** Functions Menu



4. In the pop-up menu, select **Add View > Width**.
5. You can view the **Width View** using *one* of the following methods:
  - Right-click on the image name in the **Workspace** and select **Add View > Width** from the popup menu.

Or
  - Select **Analyze > Width** from the menu bar.

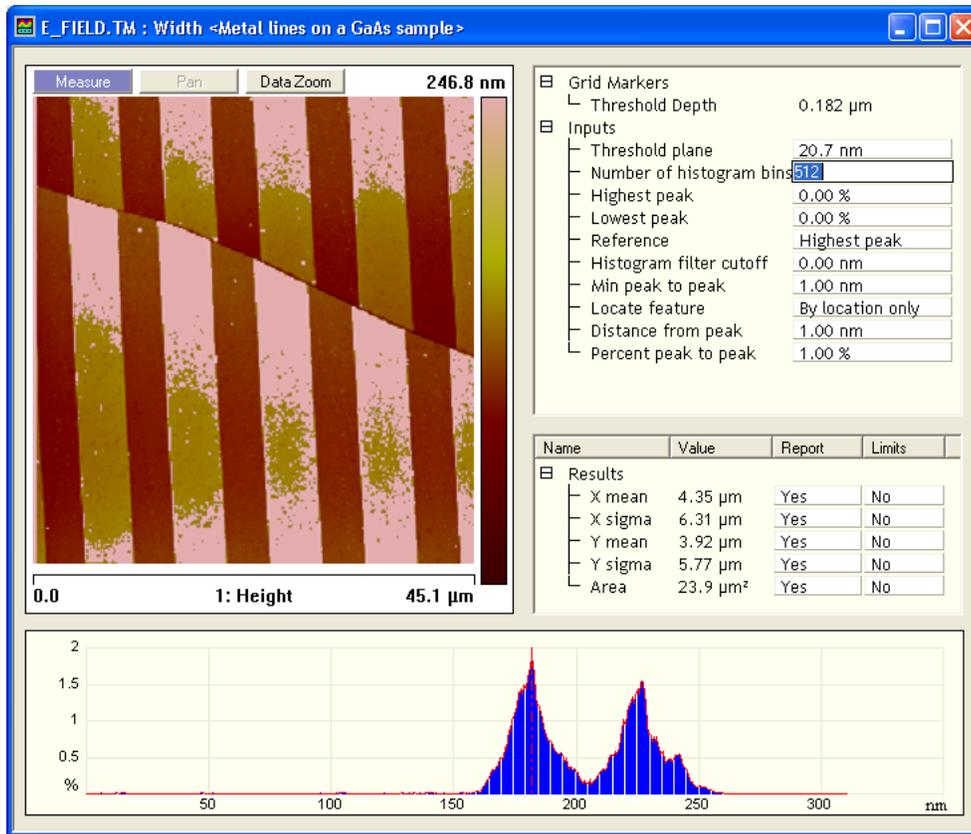
Or
  - Click the **Width** icon in the upper toolbar. 
6. Using the mouse, left-click and drag a box on the area of the image to analyze. The Histogram displays the depth correlation on this specified area.

**Note:** If no box is drawn, by default, the entire image is selected.
7. Adjust the **Minimum Peak to Peak** to exclude non relevant depths.
8. Adjust the **Histogram Filter Cutoff** parameter to filter noise in the histogram as desired.

9. Note the results.

**Note:** To save or print the data, run the analysis in an **Auto Program** (see Section 4.11).

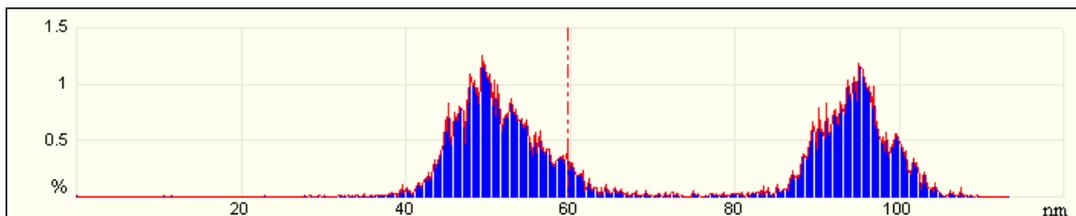
**Figure 4.9d** Width Interface



### 4.9.3 Width Interface

The **Width** interface includes a captured image, **Input** parameters, **Results** parameters and a correlation histogram, shown in Figure 4.9e.

**Figure 4.9e** Depth Histogram



## Width Input Parameters

The depth input parameters below define the slider cursor placement for determining the exact depth of a feature.

<b>Threshold Plane</b>	The z height which is used as a minimum for the higher peak. This can be adjusted by moving the cursor in the correlation histogram.
<b>Number of Histogram Bins</b>	The number of data points, ranging from 4 to 512, which result from the filtering calculation.
<b>Histogram Filter Cutoff</b>	Lowpass filter which smooths out the data by removing wavelength components below the cutoff. Use to reduce noise in the Correlation histogram.
<b>Min Peak To Peak</b>	Sets the minimum distance between the maximum peak and the second peak marked by a cursor. The second peak is the next largest peak to meet this distance criteria.
<b>Lowest Peak</b>	The left (smaller in depth value) of the two peaks chosen by the cursors. Value used to define how much of the left peak is included when calculating the centroid. At 0 percent, only the maximum point on the curve is included. At 25 percent, only the maximum 25 percent of the peak is included in the calculation of the centroid.
<b>Highest Peak</b>	The right (larger in depth value) of the two peaks marked by the cursors. Value used to define how much of the right peak is included when calculating the centroid. At 0 percent, only the maximum point on the curve is included. At 25 percent, only the maximum 25 percent of the peak is included in the calculation of the centroid.
<b>Reference</b>	You may specify a reference point for the cursor. This feature is useful for repeated, identical measurements on similar samples. After moving the cursor to a specific point on the correlation histogram, that point is saved as a distance from whatever reference peak you choose. These reference peaks include: <b>HIGHEST PEAK</b> , <b>LOWEST PEAK</b> , <b>MIN PEAK</b> and <b>MAX PEAK</b> .
<b>Distance from peak</b>	Cursor distance from the <b>REFERENCE</b> peak
<b>Percent peak to peak</b>	Cursor position/(peak-to-peak distance)

### Results Parameters:

<b>X mean</b>	The average of the highlighted X values within the enclosed area.
<b>X sigma</b>	The standard deviation of the measured X values.
<b>Y mean</b>	The average of the highlighted Y values within the enclosed area.
<b>Y sigma</b>	The standard deviation of the measured Y values.
<b>Area</b>	The area below the threshold in the selected region.

## 4.10 XY Drift



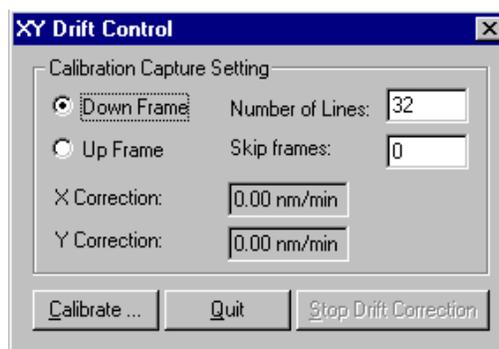
Due to temperature differences, thermal lateral drift can occur between two successive images while scanning. Using Offline **XY Drift** analysis, the software can calculate the lateral shift between two images. You can also manually enter the drift.

### 4.10.1 Realtime XY Drift

You can capture two images in Realtime mode for later **XY Drift** analysis in Offline mode.

1. You must be in Realtime mode and engaged (**Realtime > Engage**).
2. Select **Realtime > XY Drift**. The **XY Drift Control** dialog box displays (see [Figure 4.10a](#)).

**Figure 4.10a** XY Drift Control Dialog Box



3. Enter the appropriate capture calibration settings and select **Calibrate**. Two images are captured with the number of lines designated, then the Offline **XY Drift View** opens (see **Offline XY Drift Analysis:** [Section 4.10.2](#)).

**Note:** Both images must have the same microscope configuration and scanner calibration settings currently in use.

### Calibration Capture Settings

<b>Down Frame</b>	Captures lines from the top of the image to the bottom. ↑
<b>Up Frame</b>	Captures lines from the bottom of the image to the top. ↓
<b>Number of Lines</b>	Designates the number of lines to capture. This number must be less than or equal to the Lines parameter in the <b>Scan View &gt; Scan</b> tab panel.
<b>Skip Frames</b>	Designates the number of frames to skip at the beginning of the scan.
<b>X Correction</b>	Reports the current X correction value.
<b>Y Correction</b>	Reports the current Y correction value.

### XY Drift Control Dialog Box Buttons

<b>Calibrate</b>	Stops any current drift correction and captures 2 images. After capturing the images, the Offline <b>XY Drift View</b> automatically displays.
<b>Quit</b>	Closes the <b>XY Drift Control</b> dialog box.
<b>Stop Drift Correction</b>	Stops any current drift correction.

## 4.10.2 Offline XY Drift Analysis

### Requirements

Two images from the same capture directory captured within 1 day of each other are required. The capture direction must be the same for both images (up or down), and the images must have the same microscope configuration and scanner calibration properties.

### Procedure

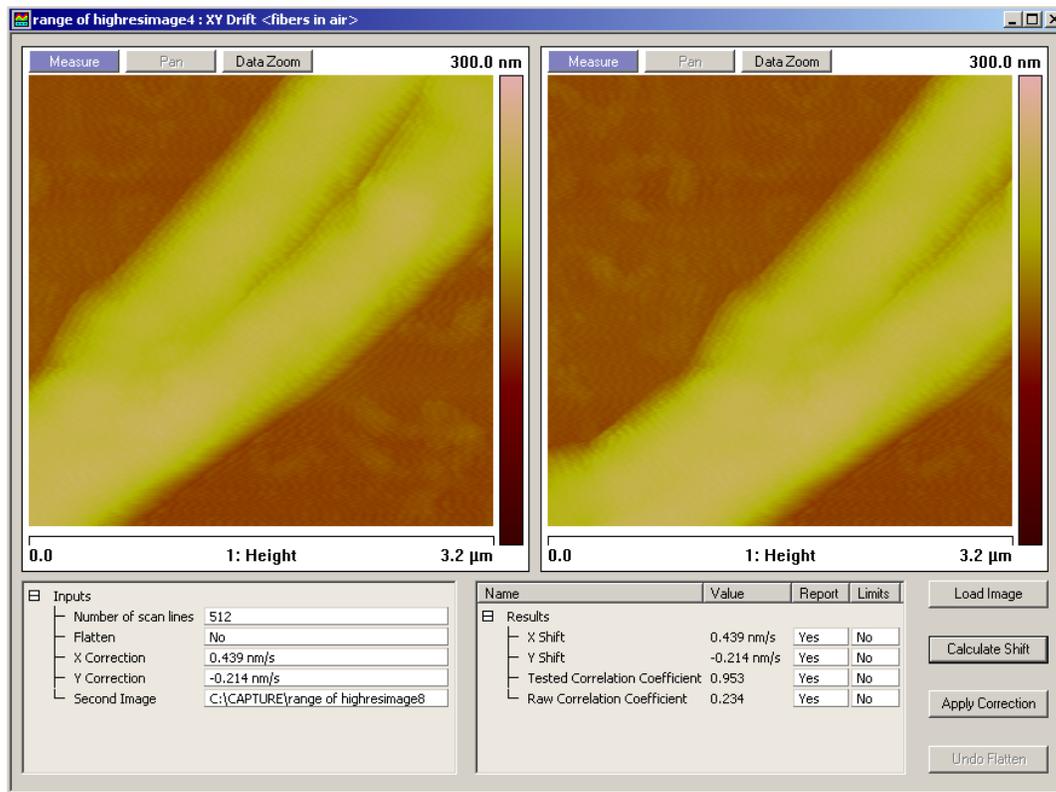
To calculate XY Drift using the software:

1. Start with the earliest image and use *one* of the following methods to open the **XY Drift Analysis View** (see [Figure 4.10b](#)).
  - Right-click on the image name in the **Workspace** and select **Add View > XY Drift** from the popup menu.

Or
  - Select **Analyze > XY Drift** from the menu bar.

Or
  - Click the **XY Drift** icon in the upper toolbar. 

Figure 4.10b XY Drift View



2. Use the **Load Image** button to browse for the subsequent image.
3. Click the **Calculate Shift** button. The software will calculate the shift of the second image relative to the first image.
4. The results display in the **Results** box.
  - a. To apply the corrections in the **Inputs** box, click the **Apply Correction** button.

Or

- b. You can also manually enter the correction values in the **Inputs** box. Click the **Apply Correction** button.

**Note:** **Apply Correction** effects Realtime by applying a drift correction to the Realtime images. Do not use **Apply Correction** if this is not your intent.

### Input Parameters

Statistics used by the **XY Drift** analysis are defined in this section.

<b>Number of scan lines</b>	Specifies the number of lines to calculate.
<b>Flatten</b>	Flattens both images before the shift is calculated. (Use the <b>Undo Flatten</b> button to reverse the flatten).
<b>X Correction</b>	Specifies the amount of correction to apply to the X-axis of the scanner.
<b>Y Correction</b>	Specifies the amount of correction to apply to the Y-axis of the scanner.
<b>Second Image</b>	Defines the location of the second image used in the analysis.

### Results Parameters

Results of the **XY Drift** analysis are presented in this section.

<b>X Shift</b>	Specifies the amount of calculated shift along the X-axis of the second image relative to the first.
<b>Y Shift</b>	Specifies the amount of calculated shift along the Y-axis of the second image relative to the first.
<b>Tested Correlation Coefficient</b>	Reports the correlation coefficient after correcting for the detected shift. A perfect correlation is 1.0. If the tested correlation coefficient is too low, then the calculation is not valid and should not be applied. You may need features that have more distinct contrast.
<b>Raw Correlation Coefficient</b>	Reports the correlation coefficient between the two images prior to processing.

### XY Drift Buttons

<b>Load Image</b>	Browse to open the second image in the right box.
<b>Calculate Shift</b>	Compares left image to right image, and reports the shift statistics in the <b>Results</b> box.
<b>Apply Correction</b>	Applies the correction in the <b>Inputs</b> box to the second image.
<b>Undo Flatten</b>	<b>Undo Flatten</b> restores the image to its original form.

## 4.11 Multiple Channel Analysis

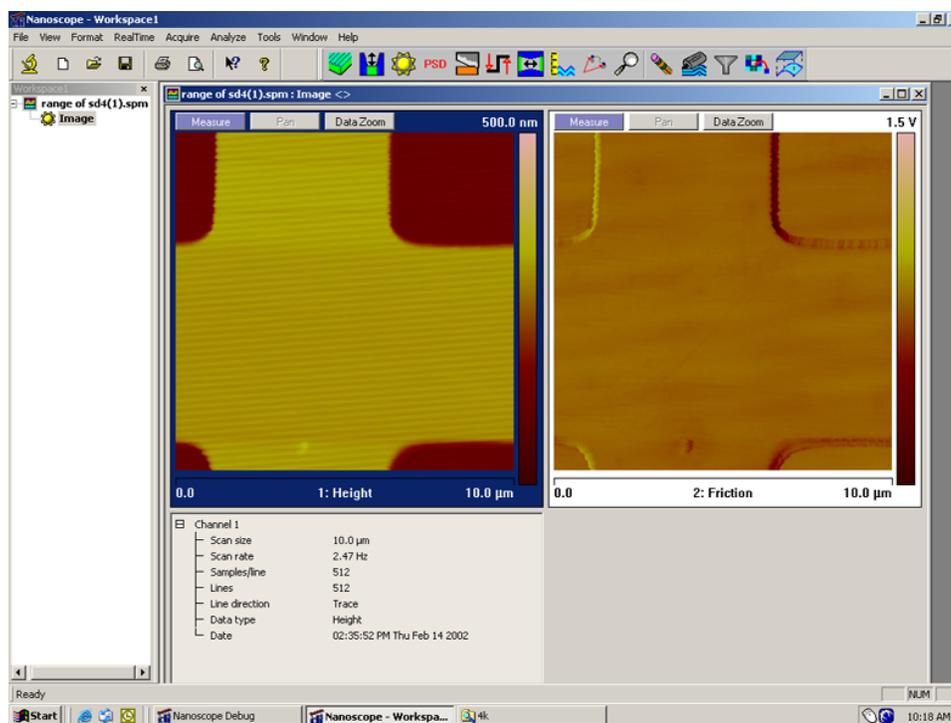
It is often necessary to analyze more than one channel of data from the same scan. This can be done by opening a captured dual-scan or triple-scan image Offline.

### 4.11.1 Dual-Scan Image

When you open a dual-scan image, the **Channel 1** and **Channel 2** images will appear side by side, with **Channel 1** on the left and **Channel 2** on the right, and the channel data will typically be shown below the left image. Click on the desired image to select the channel and the corresponding channel data will appear (see [Figure 4.11a](#)).

**Note:** The location of the Channel data may vary depending on window proportions.

**Figure 4.11a** Captured Dual-Scan Image

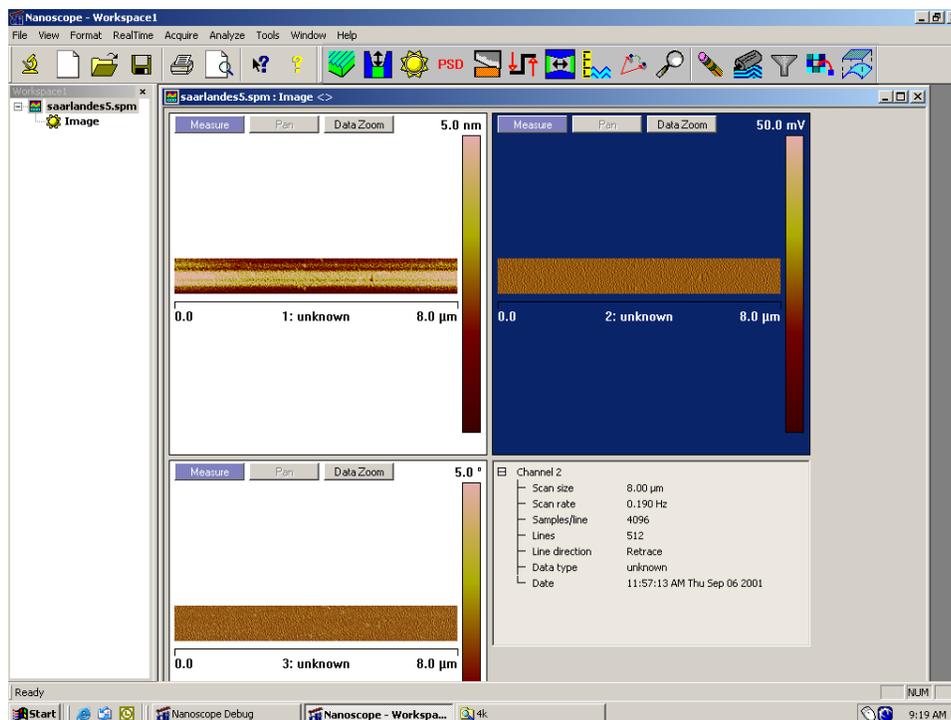


### 4.11.2 Triple-Scan Image

When you open a triple-scan image, the **Channel 1** and **Channel 2** images will typically appear side by side, with **Channel 1** on the left and **Channel 2** on the right, and the **Channel 3** image will typically appear below the **Channel 1** image. Channel data is now shown to the right of the **Channel 3** image. Click on the desired image to select the channel and the corresponding channel data will appear (see Figure 4.11b).

**Note:** The location of the Channel data may vary depending on window proportions.

Figure 4.11b Captured Triple-Scan Image



### 4.11.3 Analyzing Captured Multichannel Images

When performing any analysis of a multichannel scan, you may only analyze one channel at a time. Highlight the appropriate channel image by clicking on it, then select the desired **Analysis View** by any one of the following:

- Right-clicking on the image file name in the **Workspace**, selecting **Add View**, and clicking on the desired view.
- Selecting **Analyze** from the menu bar and clicking on the desired view.
- Clicking on the appropriate button in the button bar.

Once you select the desired channel, and the appropriate view, a new window will open with only the image of the selected channel and you may start your analysis in accordance with the instructions in [Section 4.1](#) through [Section 4.3](#). If the image display in the view is not the desired channel, you can right-click on the image, go to **Channel**, and select the appropriate channel from the pop-up menu.

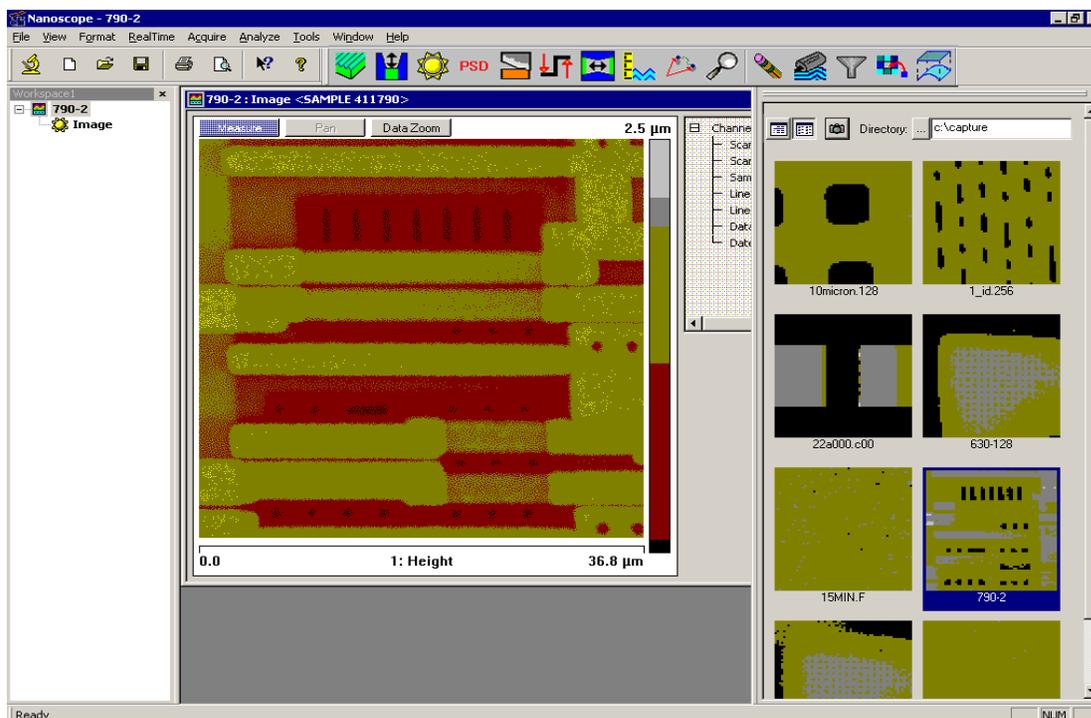
You can also print multichannel images simultaneously. All channels must be open in the same view, then select **File > Print**.

## 4.12 AutoProgram

An AutoProgram is a sequence of operations that may be applied automatically to at least one previously captured image. Typically, an AutoProgram is created to rapidly analyze a large number of images taken under similar conditions. Any image **Modify** or **Analyze** command may be included in an AutoProgram. Do the following to create an AutoProgram:

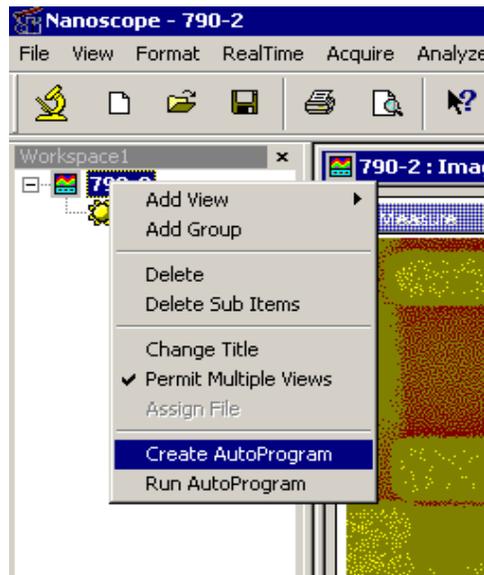
1. Select a directory, then an image file within it, from the file browsing window at the right of the **NanoScope** main window. Double-click its thumbnail to select and open the image. The image file name and the **Offline** icon, as well as a **sunburst** icon and the word “**Image**” are added to the **Workspace**, and the image opens in the viewing window (see [Figure 4.12a](#)).

Figure 4.12a Open Image



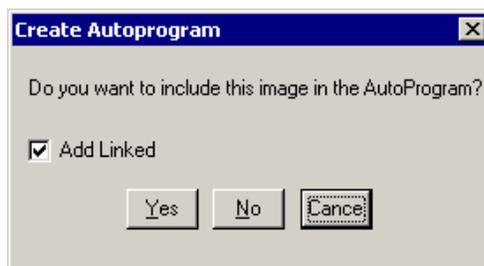
2. In the **Workspace**, right-click on the image file name or its **Offline** icon and select **Create AutoProgram** (see Figure 4.12b).

Figure 4.12b Create AutoProgram



3. You are asked if you want to include the selected image to define the AutoProgram among the images processed by the AutoProgram (see Figure 4.12c). (Typically: "Yes.") The **Add Linked** box should also be checked. When linking, any changes made to the currently active view will then alter any linked views.

Figure 4.12c Include Selected Image Box

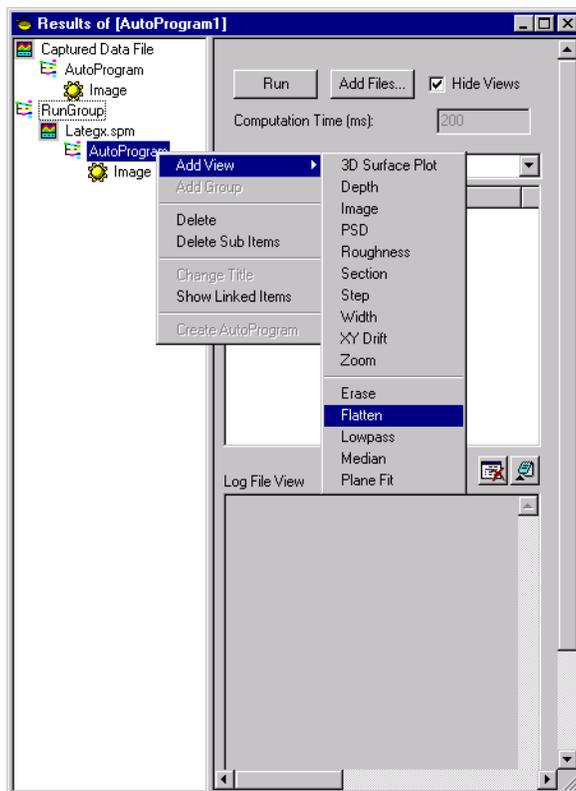


4. In the **AutoProgram Results View** (see Figure 4.12d):
  - a. Right-click on **Autoprogram**, under the file name or icon appearing on the line under **Run Group**.
  - b. Click **Add View** to add a view to the Autoprogram. This view will then be added to all files in the Autoprogram if they are linked.

- c. Click the view of an **Analyze** or **Modify** command to be performed first by the AutoProgram.
- d. Repeat for additional views (in [Figure 4.12a](#), **Flatten**, **Depth** then **Roughness** operations will be performed).

**Note:** Example specifications of the **Flatten**, **Depth** and **Roughness** commands for inclusion in an AutoProgram are described next. Similar actions apply to include other Offline **Analyze** and **Modify** commands in an AutoProgram.

**Figure 4.12d** Add Views to be Included in an AutoProgram



### 4.12.1 Example command: Flatten

To open the **Flatten View**:

1. Click the command name or icon that has been added to the **Run Group** Autoprogram.
2. Click in the image and drag open a box over features in the image that are to be excluded from the polynomial fit calculations (see [Figure 4.12e](#)). Typically, only featureless areas are used for flattening an image.

3. On the right of the **Flatten View**, set parameter values to apply for all images operated on by the AutoProgram.
4. Close the **Flatten View**.

#### 4.12.2 Example command: Depth

To open the **Depth View**:

1. Click the command name or icon that has been added to the **Run Group** Autoprogram.
2. Click in the image and drag open a box over an area that contains a height step (see [Figure 4.12g](#)).
3. On the right of the **Depth View**, set parameter values that will apply for all images operated on by the AutoProgram.
4. Close the **Depth View**.

Figure 4.12e Specify a Flatten Operation

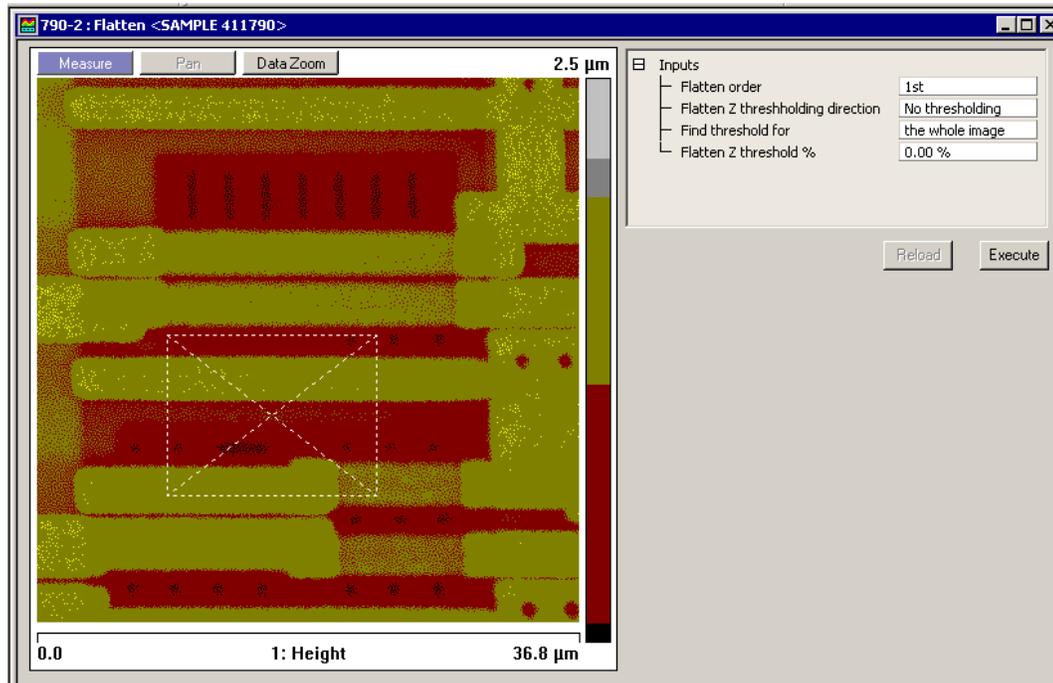
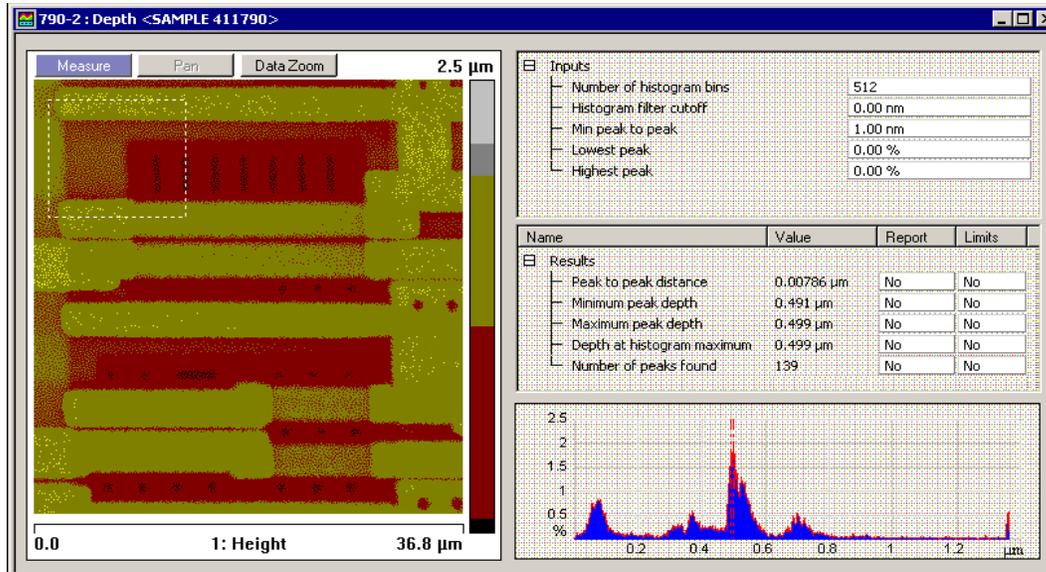


Figure 4.12f Specify a Depth Measurement

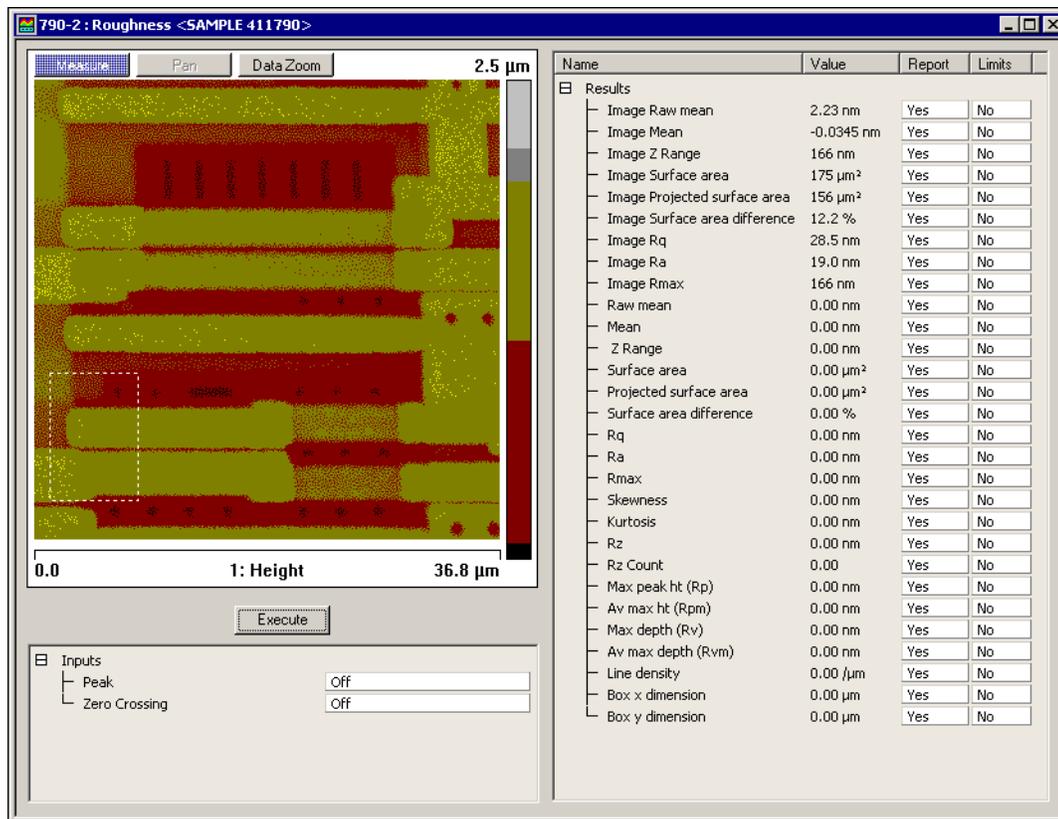


### 4.12.3 Example command: Roughness

To open the **Roughness View**:

1. Click the command name or icon that has been added to the **Run Group** Autoprogram.
2. Click in the image and drag open a box over an area where you would like the sample surface condition analyzed (see [Figure 4.12g](#)).
3. On the upper right of the **Roughness View**, set parameter values that will apply for all images operated on by the AutoProgram.
4. On the lower right of the **Roughness View**, select what measurements to report.
5. Close the **Roughness View**.

**Figure 4.12g** Specify a Roughness Measurement for Inclusion in an AutoProgram

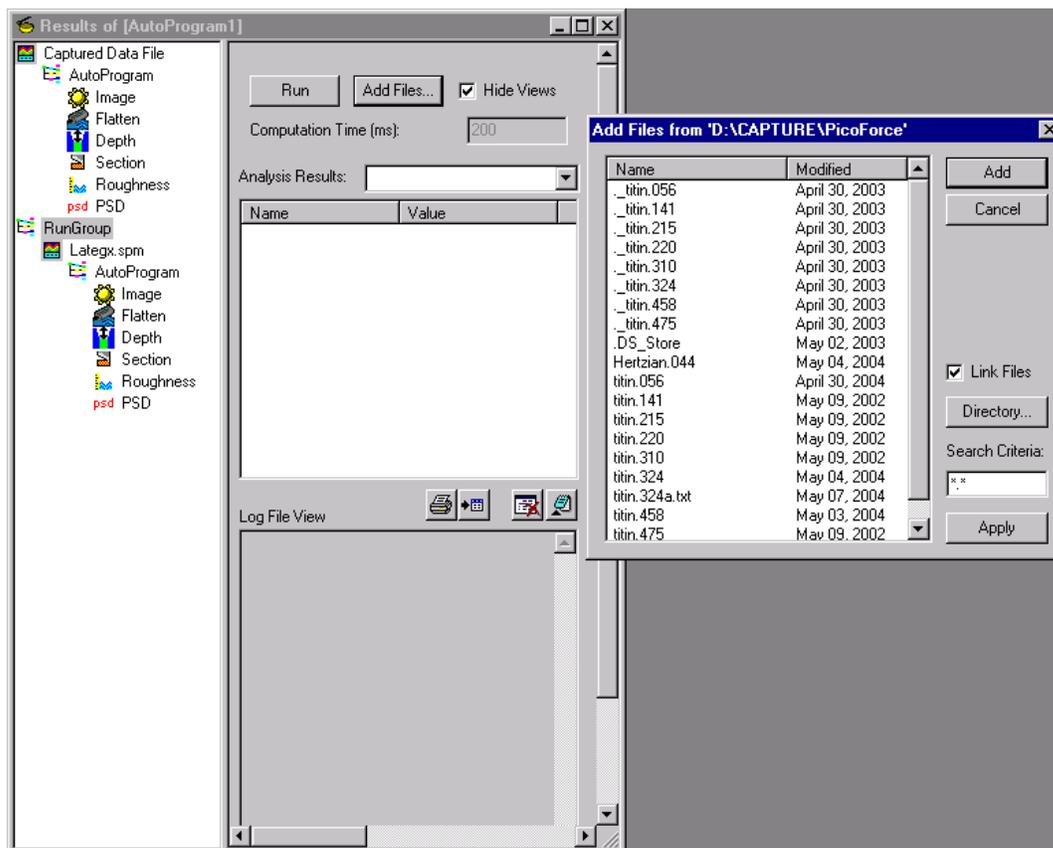


## 4.12.4 Running AutoProgram

Once all commands are included in the AutoProgram list and their action specified, you are ready to run AutoProgram.

1. Click the **Add Files** button in the **AutoProgram Results View** (see Figure 4.12h). The **Add Files** dialog box appears.
2. In the **Add Files** dialog box, select the **Link Files** box to have the same **AutoProgram** instructions apply to each file. Select files of interest and click **Add** to have the selected files included when the **AutoProgram** is run. Hold down the **Shift** key to select a consecutive group of files or the **Control** key to select more than one individual file.
3. In the **AutoProgram Results View**, check the **Hide View** box if you don't want the images displayed, as they are automatically analyzed by the **AutoProgram**. If you want to see the images processed during **AutoProgram** execution, leave **Hide View** unchecked. Increasing the value in **Computation Time** allows more time to view operations during Autoprogram execution.

Figure 4.12h Add Files Dialog Box

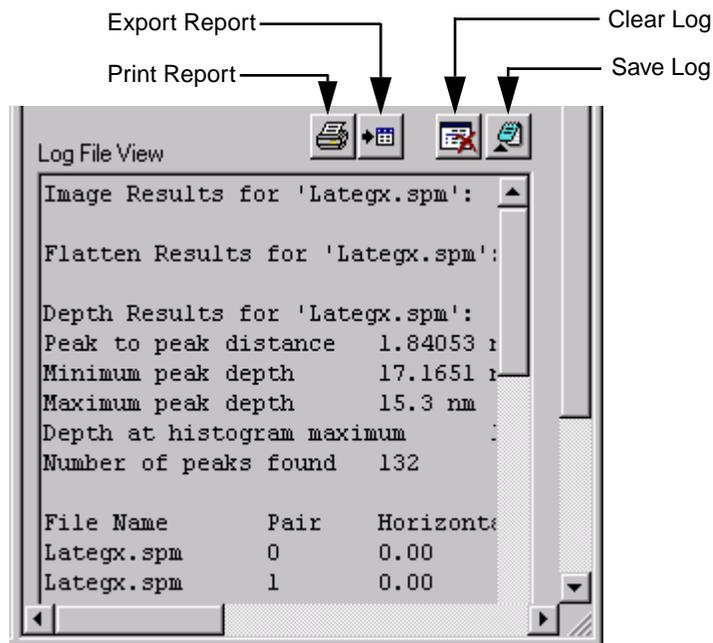


- Click the **Run** button in the **AutoProgram Results View** to start the **AutoProgram**.

**Note:** The **RUN** button toggles to display **Stop** while the AutoProgram is running. Click it if you need to stop the process before it is completed. Clicking the **Run** button again restarts the **AutoProgram** at the first image.

- Upon completion, the data appears in the **Log File View** property sheet (see [Figure 4.12i](#)).

**Figure 4.12i** Log File View Property Sheet



- If you close the **Autoprogram Results View** without saving the Autoprogram, you will be prompted to save the Autoprogram as an .apg file.
- To save the log file, select the **SAVE LOG** button in the **Log File View**.
- To clear the log file, select the **CLEAR LOG** button in the **Log File View**.
- Autoprogram results, with statistical analysis (termed reports), can be printed or exported as tab delimited text using the **PRINT REPORT** or **EXPORT REPORT** buttons.

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# Chapter 5 Modify Commands

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The **Modify** commands are in the lower portion of the **Analyze** menu. **Analyze** appears in the menu bar once an image is open/active. It also appears in the **Add View** submenu and is accessible with a right-click on the image name in the workspace. **Modify** commands are used to eliminate noise, and correct for bow and tilt. These operations process the captured/stored image, then produce another (modified) version.

Please refer to the following analysis commands available on the NanoScope software:

- **Flatten:** [Section 5.1](#)
- **Plane Fit:** [Section 5.2](#)
- **Lowpass** [Section 5.3](#)
- **Erase:** [Section 5.4](#)
- **Median:** [Section 5.5](#)

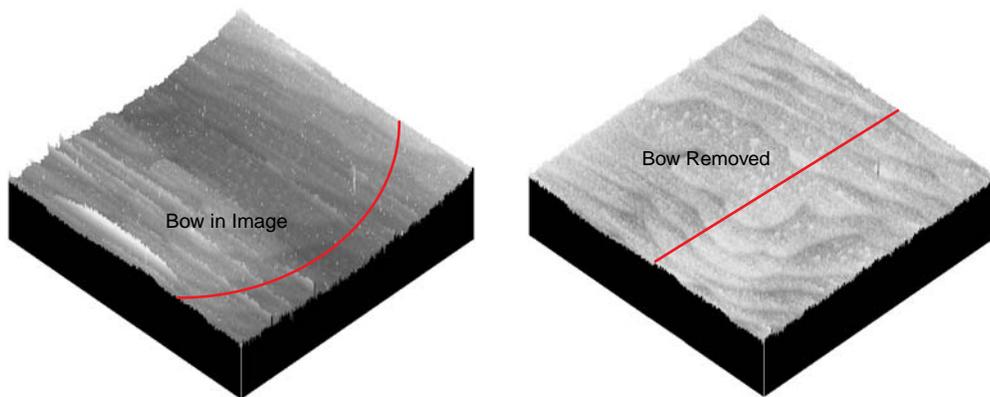
## 5.1 Flatten



The **Flatten** command eliminates unwanted features from scan lines (e.g., noise, bow and tilt). It uses all unmasked portions of scan lines to calculate individual least-square fit polynomials for each line.

**Flatten** is useful prior to image analysis commands (e.g., **Depth**, **Roughness**, **Section**, etc.) where the image displays a tilt, bow or low frequency noise, which appear as horizontal shifts or stripes in the image.

**Figure 5.1a** Image Flattened



### 5.1.1 Flatten Theory

The **Flatten** command is a filter that modifies the data to delete low frequency noise and remove tilt from an image. Each line is fit individually to center data (0th order) and remove tilt (1st order), or 2nd or 3rd order bow. A best fit polynomial of the specified order is calculated from each data line and then subtracted out. In some cases, the stopband (box cursor to exclude features) can be used to remove regions of the image from the data set used for the polynomial fits. Click on the image to start drawing a stopband box. Right-click on a box to delete it or change its color.

#### Flatten Polynomials

The polynomial equations calculate the offset and slope, and higher order bow of each line for the data (see [Table 5.1a](#)).

**Table 5.1a** Flatten Polynomials

Order	Polynomial	Explanation
<b>0</b>	$z = a$	Centers data along each line.
<b>1</b>	$z = a + bx$	Centers data and removes tilt on each line [i.e., calculates and removes offset (a) and slope (bx)].
<b>2</b>	$z = a + bx + cx^2$	Centers data and removes the tilt and bow in each scan line, by calculating a second order, least-squares fit for the selected segment then subtracting it from the scan line.
<b>3</b>	$z = a + bx + cx^2 + dx^3$	Centers data and removes the tilt and bow in each scan line, by calculating a third order, least-squares fit for the selected segment then subtracting it from the scan line.

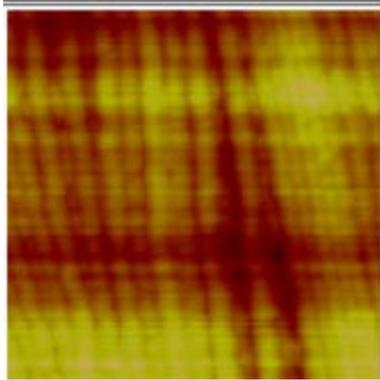
### 5.1.2 Flatten Procedures

For an image that contains a number of noisy scan lines, use the **Flatten** command to correct the problem.

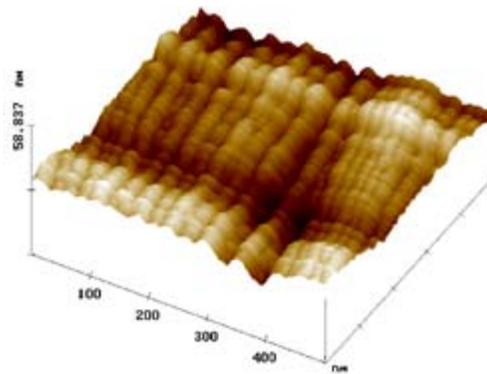
1. Open the image. Note disjointed scan lines which are misaligned along the Z-axis (some are high and some are low). This effect somewhat resembles an unshuffled deck of cards when viewed on-edge or appears as horizontal streaks or bands. The image may have bow along its Y-axis.

[Figure 5.1b](#) shows an image file in its original, raw form as an example for the **Flatten** command. Many of the image's scan lines are disjointed along the Z-axis.

**Figure 5.1b** Raw Image of Syndiatatic Polystyrene (500nm)



Top View of Image to Flatten



Surface Plot of Image showing Bow

- You can view the **Flatten View** using *one* of the following methods:
  - Right-click on the image name in the **Workspace** and select **Add View > Flatten** from the popup menu.

Or

- Select **Analyze > Flatten** from the menu bar.

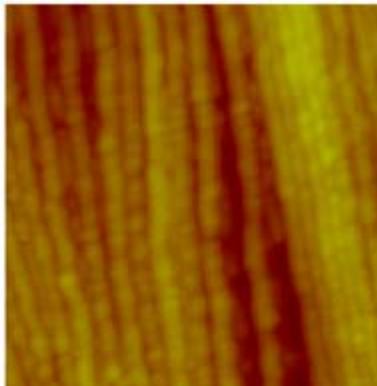
Or

- Click the **Flatten** icon in the upper toolbar. 

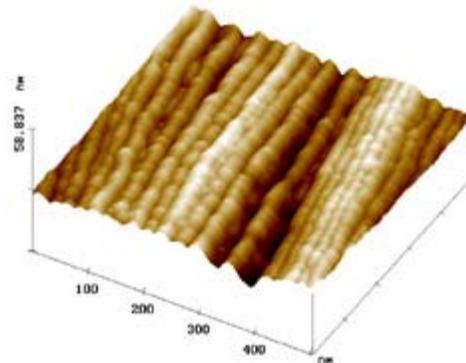
- Set the **Flatten order** value to **0**. This removes the scan line misalignment.
- Click on **Execute** to initiate the **Flatten** command. The flattened image appears on the display screen.

**Note:** [Figure 5.1c](#) shows the same image file after using a zero-order **Flatten** (Flatten order = 0). The scan lines are now aligned.

**Figure 5.1c** Flattened Image of Syndiotactic Polystyrene (500 nm)



Top View of Flattened Image



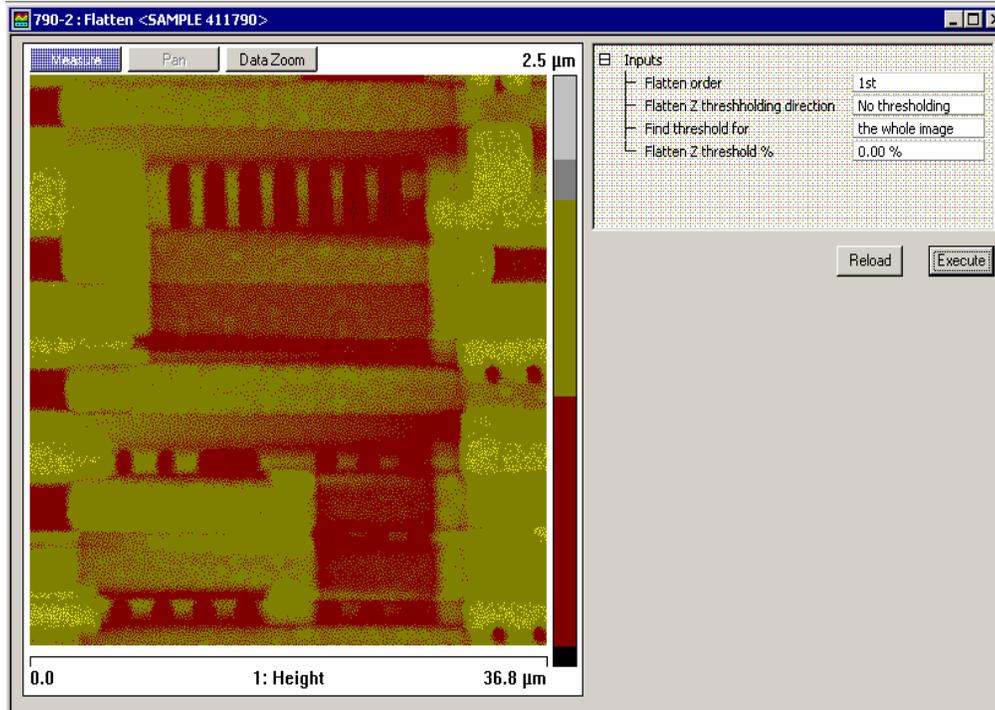
Surface Plot View of Flattened Image

- To see a variety of effects using the **Flatten** command, enter different **Flatten order** values. Each new change may be undone by clicking on the **Reload** button.

### 5.1.3 Flatten View Interface

Click **Analyze** in the menu bar and select **Flatten**, or click on the **Flatten** icon in the button bar. A series of parameters appear in the **Flatten View**, allowing the order of the equation to be selected and display parameters to be adjusted to your preference.

Figure 5.1d Flatten View



**Input Parameters:**

**Flatten Order**

**Flatten Order** selects the order of the polynomial calculated and subtracted from each scan line.

**Range and Settings:**

**Flatten Order**

**Flatten Order** selects the order of the polynomial calculated and subtracted from each scan line.

Range and Settings:

- **Zero Order (0)**—Removes the Z offset between scan lines by subtracting the average Z value for the unmasked segment from every point in the scan line.
- **First Order (1)**—Removes the Z offset between scan lines, and the tilt in each scan line, by calculating a first order, least-squares fit for the unmasked segment then subtracting it from the scan line.
- **Second order (2)**—Removes the Z offset between scan lines, and the tilt and bow in each scan line, by calculating a second order, least-squares fit for the unmasked segment then subtracting it from the scan line.
- **Third order (3)**—Removes the Z offset between scan lines, and the tilt and bow in each scan line, by calculating a third order, least-squares fit for the unmasked segment then subtracting it from the scan line.

**Flatten Z Thresholding Direction**

Specifies the range of data to be used for the polynomial calculation based on the distribution of the data in Z:

Range or Settings:

- **Use Z >=** —Uses the data whose Z values are greater than or equal to the value specified by the Z thresholding %.
- **Use Z <**—Uses the data whose Z values are less than the value specified by the Z thresholding %.
- **No thresholding**—Disables all thresholding parameters.

**Flatten Threshold for**

Applies the Thresholding values for the **whole image** or each line independently.

Range or Settings:

- The whole image
- Each line

**Flatten Z Threshold %**

Defines a Z value as a percentage of the entire Z range in the image (or data set) relative to the lowest data point.

**Buttons on the Flatten Panel**

**Execute**

Initiates the command, based on the order selected.

**Reload**

Restores the image to its original form.

## 5.2 Plane Fit

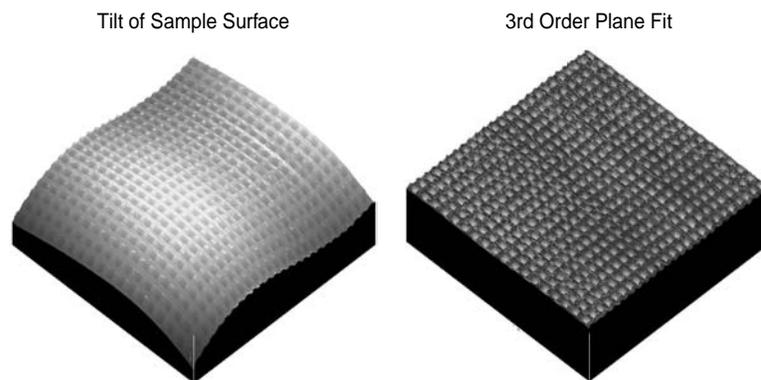


The **Plane Fit** command calculates a single polynomial of a selectable order for an image and subtracts it from the image. The **Plane Fit** operation can be applied to either or both of the XY directions.

Box cursors, or passbands, allow specific points to be used in the calculation of the polynomial. Click on the image to start drawing a passband box. Right-click on a box to delete it or change its color.

[Figure 5.2a](#) illustrates an image with tilt and bow which could affect the analysis of the surface data.

**Figure 5.2a** Visual Representation of Plane Fit



## 5.2.1 Fitted Polynomials

Refer to [Table 5.2a](#) to view the polynomials that calculate the best plane fit for the images in the Plane Fit Auto function.

**Table 5.2a** Plane Fit Auto Equations

Order	Variable	Polynomial Equation
<b>0</b>	X	$z = a$
	Y	$z = a$
	XY (Add Higher Order Cross Terms for XY OFF)	$z = a$
	XY (Add Higher Order Cross Terms for XY ON)	$z = a$
<b>1</b>	X	$z = a + bx$
	Y	$z = a + by$
	XY (Add Higher Order Cross Terms for XY OFF)	$z = a + bx + cy$
	XY (Add Higher Order Cross Terms for XY ON)	$z = a + bx + cy + dxy$
<b>2</b>	X	$z = a + bx + cx^2$
	Y	$z = a + by + cy^2$
	XY (Add Higher Order Cross Terms for XY OFF)	$z = a + bx + cy + dxy + ex^2 + fy^2$
	XY (Add Higher Order Cross Terms for XY ON)	$z = a + bx + cy + dxy + ex^2 + fy^2 + gxy^2 + hx^2y + ix^2y^2$
<b>3</b>	X	$z = a + bx + cx^2 + dx^3$
	Y	$z = a + by + cy^2 + dy^3$
	XY (Add Higher Order Cross Terms for XY OFF)	$z = a + bx + cy + dxy + ex^2 + fy^2 + gxy^2 + hx^2y + jx^3 + ky^3$
	XY (Add Higher Order Cross Terms for XY ON)	$z = a + bx + cy + dxy + ex^2 + fy^2 + gxy^2 + hx^2y + ix^2y^2 + jx^3 + ky^3 + lxy^3 + mx^2y^3 + nx^3y^3 + ox^3y + px^3y^2$

## 5.2.2 Plane Fit Procedures

Use **Plane Fit** to correct the image distortion as follows:

1. Open an image file from the menu bar (**File > Open > Image**) or through Browse (**View > Browse**), then double click on the image.
2. You can view the **Plane Fit View** using *one* of the following methods:
  - Right-click on the image name in the **Workspace** and select **Add View > Plane Fit** from the popup menu.

Or

- Select **Analyze > Plane Fit** from the menu bar.

Or

- Click the **Plane Fit** icon in the upper toolbar. 

**Note:** The **Plane Fit** input parameters appear along with the top view image.

3. Select **X**, **Y**, or **XY**.
4. Select the **Order**.
5. Select **Execute**.
6. Notice that the image distortion is removed, reflecting a flat, planar profile.

**Figure 5.2b** Saddle Image Before Plane Fit

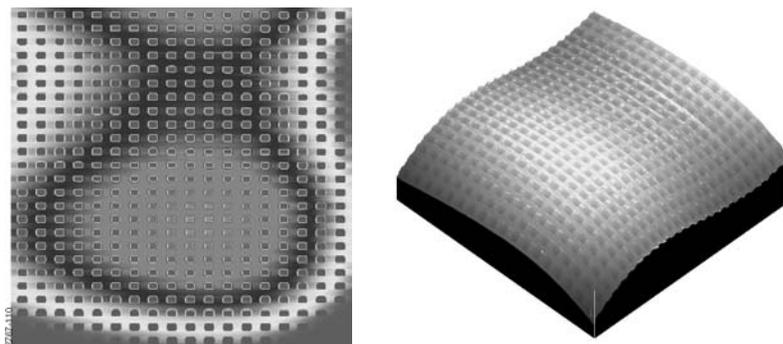


Figure 5.2c Plane Fit View

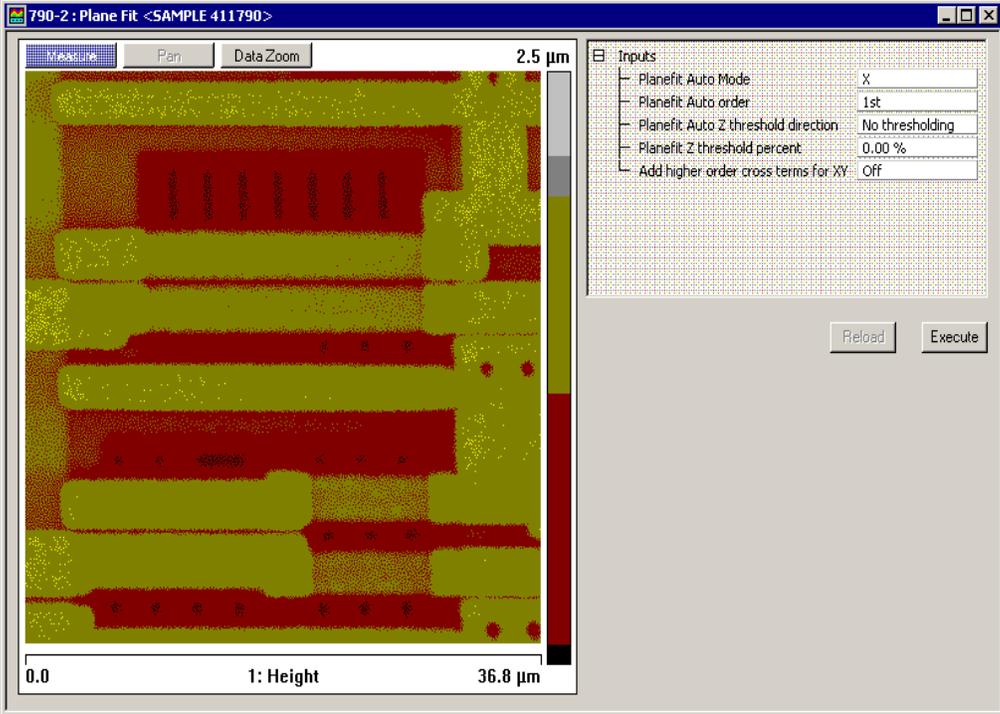
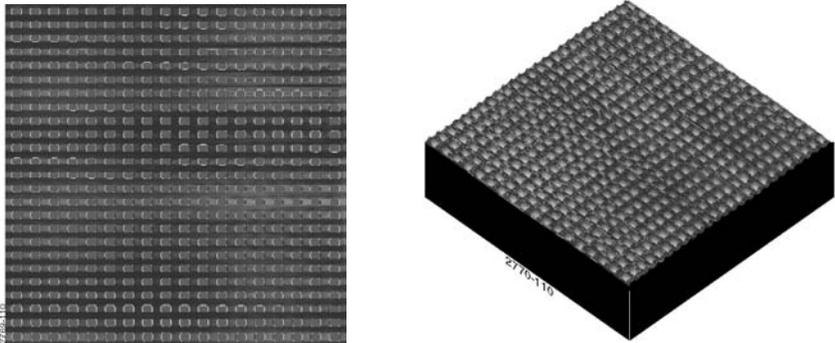


Figure 5.2d Plane Fit Image



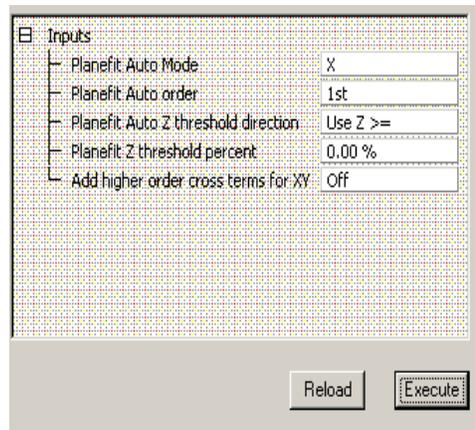
Now, experiment with this image to explore the range of **Plane Fit** capabilities. Try the following:

- Change the **Planefit order** value to see its effects. Notice that there is a vast difference between a value of **1**, **2** or **3**.
- Try plane fitting in one axis (for example, **X**), but not the other. This generally keeps whatever distortions are presently oriented along the unused axis. For example, the image can be straightened along its **Y** axis, while leaving the **X** axis strongly bowed.
- Try using a different **Planefit order** for the **X** and **Y** axis (for example, a setting of **3** for **X**, but a setting of **1** for **Y**.) This is similar to using one axis, but not the other.
- Compare the effect of **Plane Fit** with **Flatten**. Notice that each command has a significantly different impact upon this image; although, the difference is less noticeable for some other types of images.

### 5.2.3 Plane Fit Interface

The **Plane Fit** dialog box (see [Figure 5.2e](#)) allows the display parameters and the Planefit order to be adjusted to your preferences.

**Figure 5.2e** Plane Fit Inputs Dialog Box



**Buttons on the Plane Fit Window:**

<b>Execute</b>	Initiates the plane fit operation.
<b>Reload</b>	Restores the image to its original form.

**Input Parameters:**

<b>Planefit order</b>	Selects the order of the plane calculated and subtracted from the image.
<b>Z Thresholding direction</b>	<p>Specifies the range of data to be used for the polynomial calculation based on the distribution of the data in Z:</p> <p>Range or Settings:</p> <ul style="list-style-type: none"><li>• <b>Use Z &gt;=</b> —Uses the data whose Z values are greater than or equal to the value specified by the Z thresholding %.</li><li>• <b>Use Z &lt;</b> —Uses the data whose Z values are less than or equal to the value specified by the Z thresholding %.</li><li>• <b>No Thresholding</b> —Disables all thresholding parameters.</li></ul>
<b>Z Thresholding Percent</b>	Defines a Z value as a percentage of the entire Z range in the image (or data set) relative to the lowest data point.
<b>Add Higher Order Cross Terms</b>	Turning this on adds higher order cross terms to the polynomial fit when XY is chosen (see <a href="#">Table 5.2a</a> ).

## 5.3 Lowpass

The **Lowpass** modify command applies spatial filtering to a captured image, suppressing high spatial frequency components. Each pixel in an image is replaced with the average value of the  $3 \times 3$  pixels centered on it.

1. Select an image file from the file browsing window at the right of the main window. Double-click the thumbnail image to select and open the image.
2. You can view the **Lowpass View** (see Figure 5.3a) using *one* of the following methods:
  - Right-click on the image name in the **Workspace** and select **Add View > Lowpass** from the popup menu.

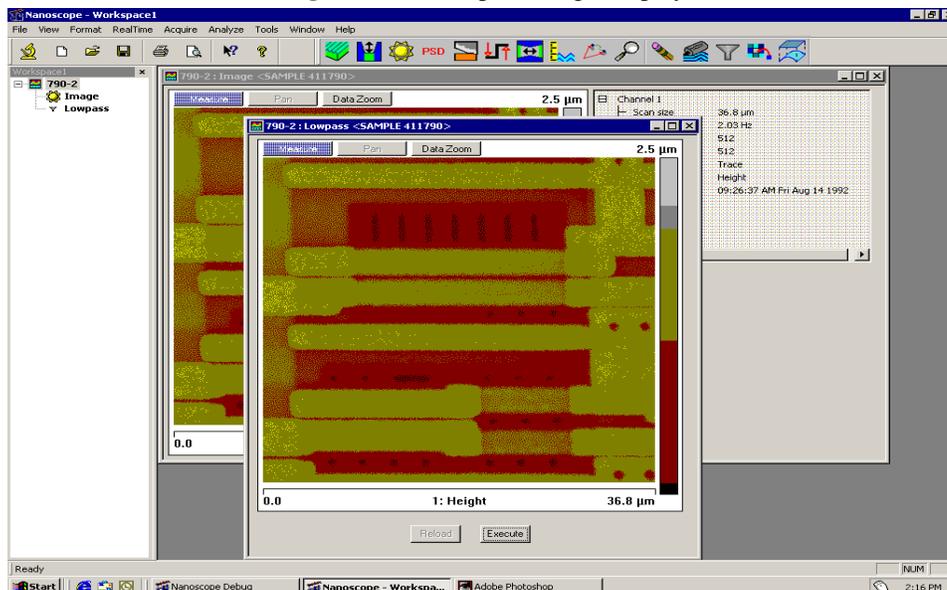
Or

  - Select **Analyze > Lowpass** from the menu bar.

Or

  - Click the **Lowpass** icon in the upper toolbar. 

Figure 5.3a Lowpass Image Display



3. Click the **Execute** button in the **Lowpass** window to apply the low pass function to the copy of the image in both windows.
4. To restore the unprocessed image, click the **Reload** button.

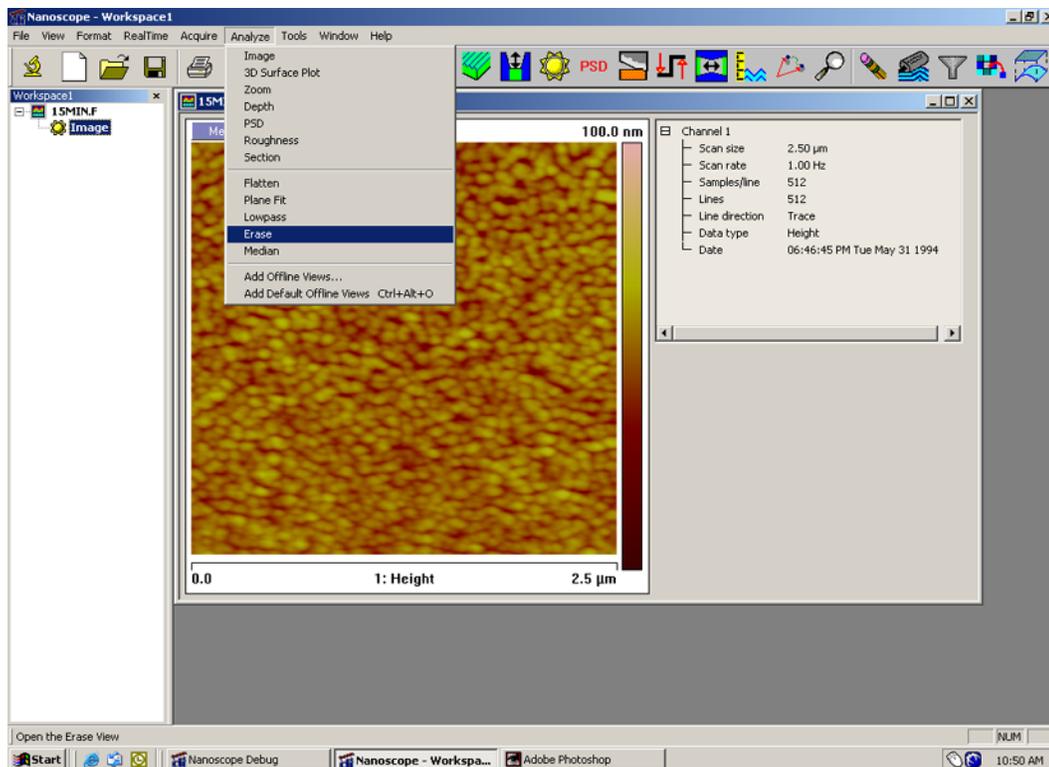
**Note:** There are no parameter controls for the **Lowpass** modify command.

## 5.4 Erase

The **Erase** modify command is a retouching function for editing images. Previously, horizontal lines could be replaced with an interpolation from the adjacent lines. In Version 6, the capability is extended to rectangular areas as well.

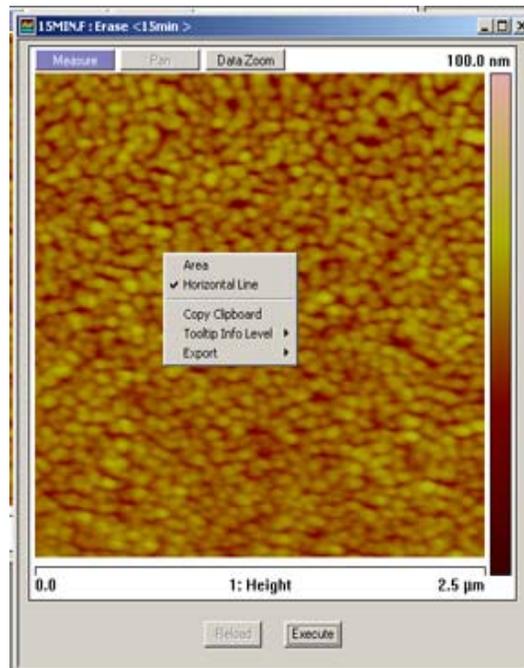
1. Select an image file from the file browsing window at the right of the main window. Double click the thumbnail image to select and open the image.
2. Open the **Erase View** (see [Figure 5.4a](#)) using *one* of the following methods:
  - From the menu bar, click **Analyze > Erase**.
  - Or
  - Right-click on the Image file name in the **Workspace** and select **Add View > Erase** from the menu.
  - Or
  - Click the **Erase** icon in the upper toolbar. 

**Figure 5.4a** The Erase Option in the Analyze Menu



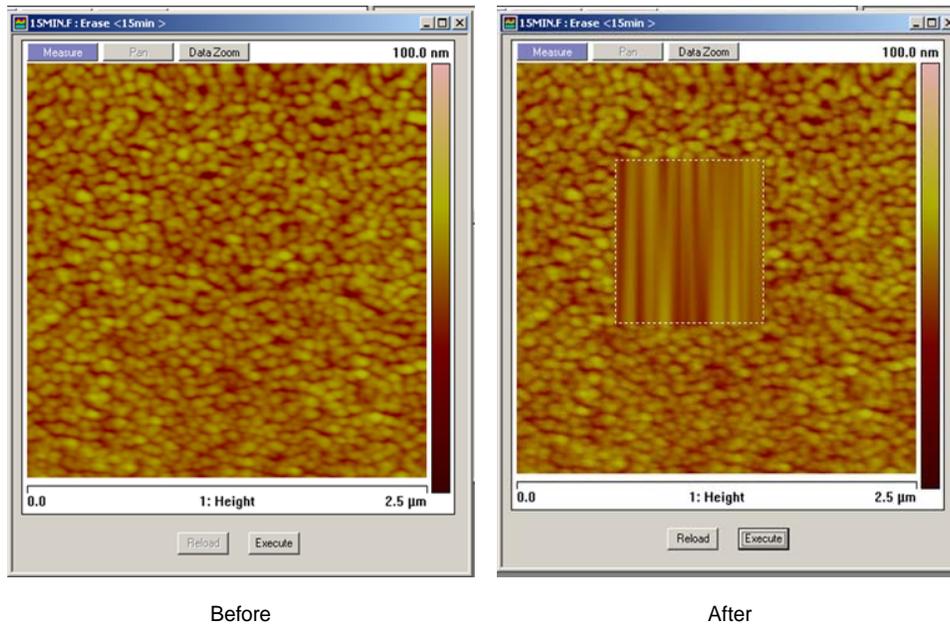
3. A separate window opens, also displaying the image. Right-click in the image to display the **Erase** options menu (see [Figure 5.4b](#)). Select either **Horizontal Line** or **Area** and a check mark will appear. The option chosen will remain checked until another selection is made.
4. Click anywhere within the image to define a horizontal line, or click and drag in the image to define a box to be replaced.

**Figure 5.4b** Erase Options Menu



5. Click the **Execute** button to perform the interpolation.

**Figure 5.4c** Effect of the Erase Interpolation on a Rectangular Area

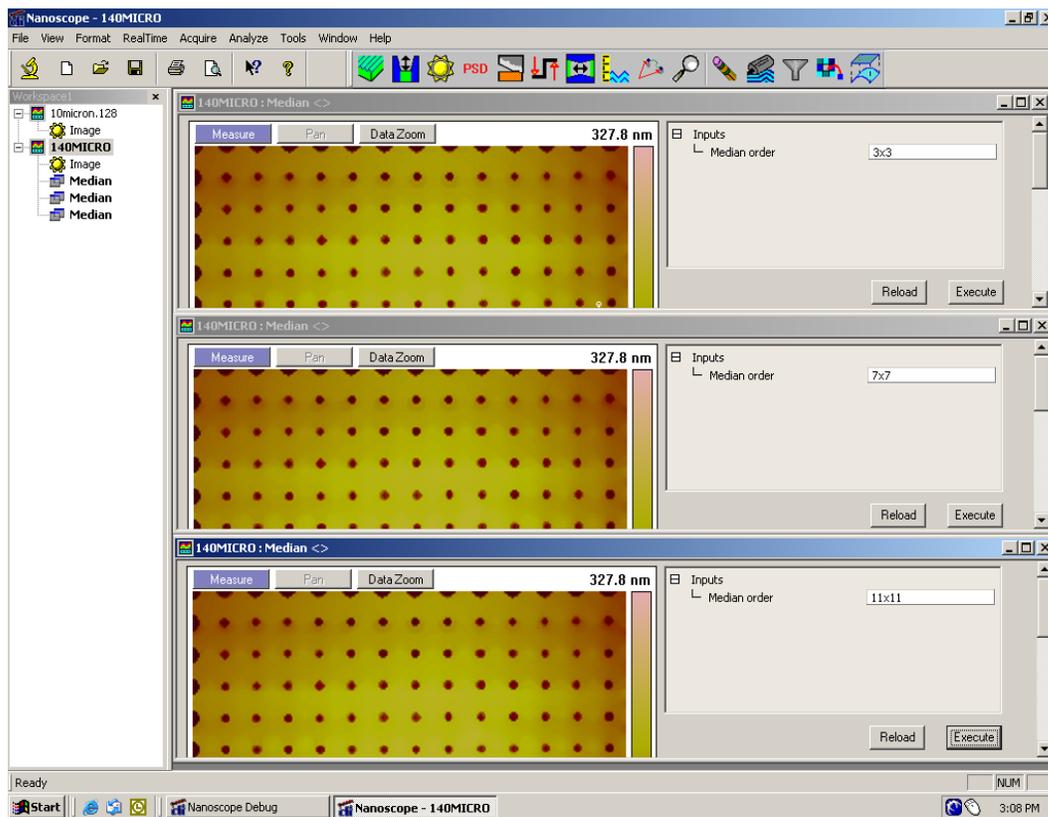


6. Right-click on an **Erase** feature of a modified image (either line or box) for options to complete the operation. Click **Delete** to erase the dashed construction lines from the display of the selected feature. Click **Clear All** to eliminate all construction lines from the display, while retaining the modifications to the image.
7. To eliminate all trace of **Erase** activity to an image, click the **Reload** button while the image is still open in the **Erase** panel.

## 5.5 Median

The **Median** modify command is similar to **Lowpass**; it reduces the contributions of high spatial frequency, reducing contrast in regions of high contrast. For each pixel in an image, **Median** substitutes with the median pixel value of the  $n \times n$  array of pixels centered around that pixel. The size of the filter's sliding window pixel array is set under **Inputs > Median order**. [Figure 5.5b](#) illustrates the effect of three different size pixel arrays applied to the same image.

**Figure 5.5a** # Different Pixel Arrays of the Same Image



---

## Modify Commands

### Median

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1. Select an image file from the file browsing window at the right of the main window. Double-click the thumbnail image to select and open the image.
2. Open the **Median View** using *one* of the following methods to open a separate window which also displays the image (see [Figure 5.5b](#)):
  - From the menu bar, click **Analyze > Median**.

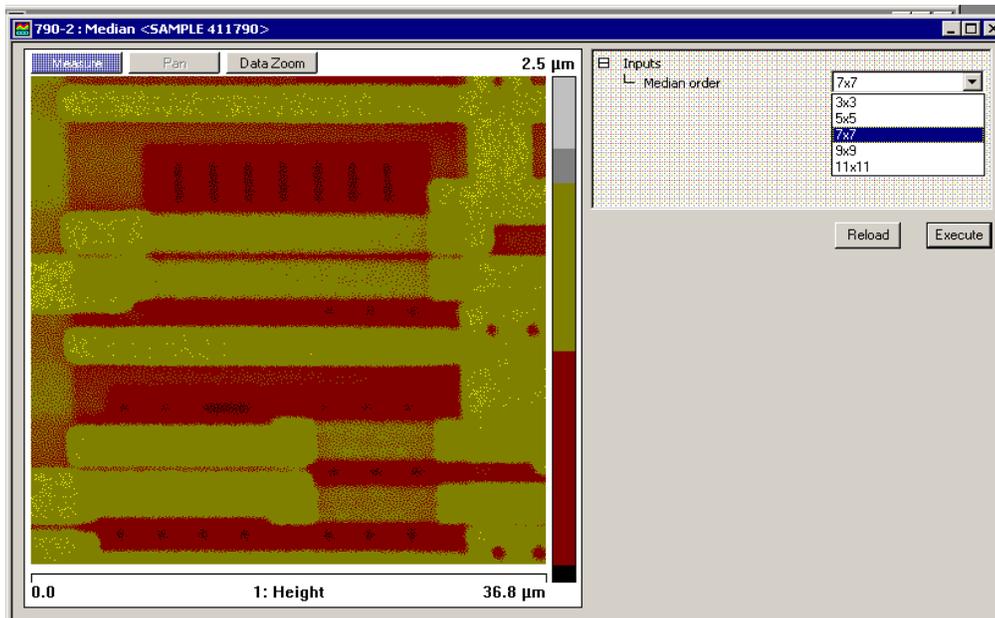
Or

  - Right-click on the Image file name in the **Workspace** and select **Add View > Median** from the menu.

Or

  - Select the **Median** icon. 
3. Select the **Median Order** from the **Inputs** menu: 3×3, 5×5, 7×7, 9×9, or 11×11.
4. Click **Execute** to apply the **Median** filter.
5. Click **Reload** to start over.

**Figure 5.5b** Median View



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# Chapter 6 Tools

---

The **Tools** commands are in the right portion of the menu bar.

Please refer to the following analysis commands available on the NanoScope software:

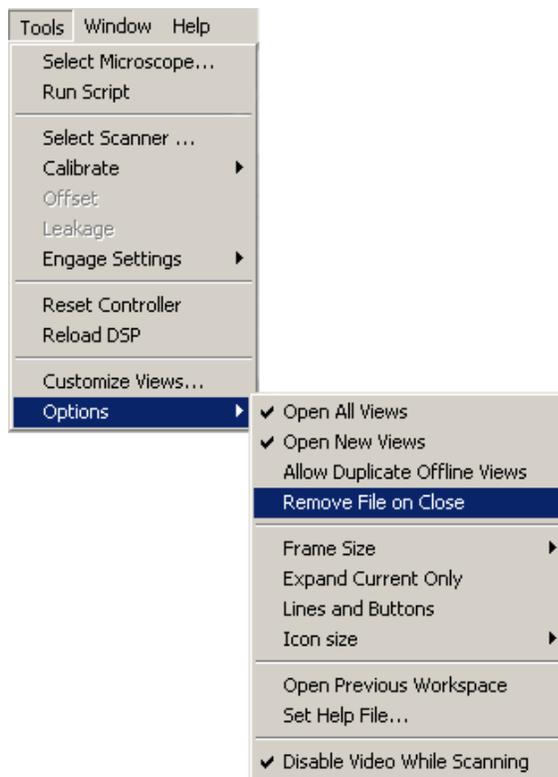
- **Options:** [Section 6.1](#)
- **Programmed Move (Dimension Series Only):** [Section 6.2](#)

## 6.1 Options

### 6.1.1 Remove File on Close

Select **Tools > Options > Remove File on Close** menu item (see [Figure 6.1a](#)). You can also right-click the workspace and select **Remove File on Close**. When selected, this option removes the workspace item of the offline file when all views on that file are closed.

**Figure 6.1a** Remove File on Close Menu Item



**Note:** The entire **Tools > Options** menu, with the exception of **Set Help File...**, is available when you right click in the workspace (not on a node).

## 6.2 Programmed Move (Dimension Series Only)

The **Stage > Programmed Move** function allows the stage to be automatically positioned at a series of memorized positions. These positions are programmed into the controller's computer, then called out automatically in sequence. The operator may run either the entire memorized sequence, or skip positions, as desired. This function is particularly useful for statistical quality assurance runs on large numbers of identical samples, and as a basic inspection aid.

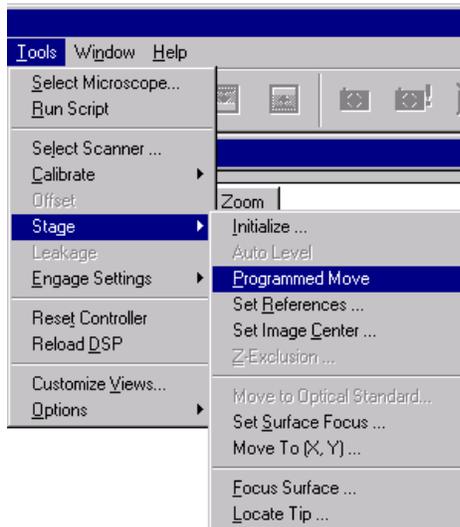
Refer to the following sections:

- **Programmed Move Panels** [Section 6.2.1](#)
- **Procedure for Teaching a Programmed Move** [Section 6.2.2](#)
- **Procedure to Remove a Programmed Option** [Section 6.2.3](#)
- **Procedure to Insert a Step into an Existing Program Sequence** [Section 6.2.4](#)
- **Procedure To Run a Series of Programmed Moves** [Section 6.2.5](#)

## 6.2.1 Programmed Move Panels

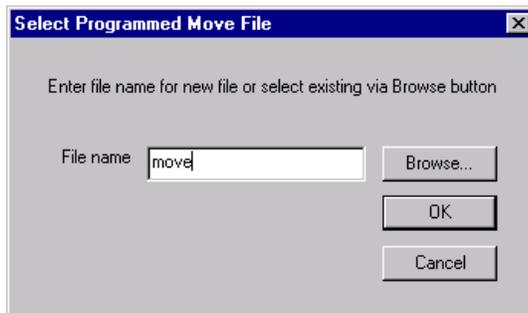
To access this option, select on **Stage > Programmed Move**, shown in [Figure 6.2a](#).

**Figure 6.2a** Selecting Programmed Move



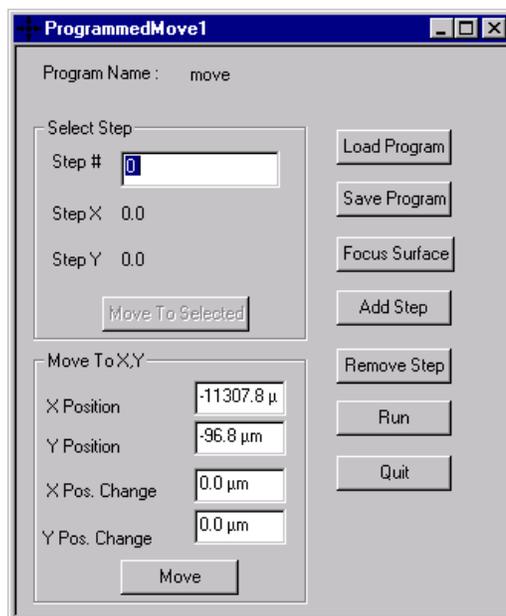
You will be prompted for a new file name or an existing file:

**Figure 6.2b** Programmed Move File Name Selection



After clicking **OK**, the main **Programmed Move** panel, shown in [Figure 6.2c](#), will appear:

**Figure 6.2c Programmed Move Window**



## Definitions

- **Program Name Field**—Provides the name of the move program currently loaded (in this example, the program is called “move”). Moves are first programmed using the **ADD** and **REMOVE STEP** functions. Later they may be executed using the **Run** option.
- **QUIT** (button)—Exits the **Programmed Move** panel.
- **RUN** (button)—Executes the specified program name.  
 Once a program sequence has been taught to the computer, the program can be run from the **Programmed Move** panel. The stage will move to each position in the same order it was taught, relative to the current origin point. At each program position, the sample will be scanned for 1.5 frames, captured, then indexed to the next position. Captured data from each position is stored on the hard disk; there should be sufficient memory to record 100 frames at 256 samples each.
- *Origin Points*—*Current origin at the time of programming.*  
 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 will be necessary to reestablish the original origin point to locate the same positions on the sample. When generating maps of programmed moves, the origin point should always be indicated.

## 6.2.2 Procedure for Teaching a Programmed Move

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

1. Select a file name for a new or existing **Programmed Move** file. See [Figure 6.2b](#).
2. Click **OK** to proceed with programming moves. A new panel, shown in [Figure 6.2c](#), will be displayed.
3. Make a stage move using either the trackball or the **Move To X,Y** panel (i.e. enter **X** and **Y POSITION** or **POSITION CHANGE** and click **MOVE**).
4. Click **ADD STEP**.
5. This procedure may be repeated until all the desired positions have been programmed up to a maximum of 100 steps. Each position will be automatically assigned a program step number.

It may prove helpful to draw a simple map of the sample, along with each programmed position, before programmed moves are entered. If reducing cycle time is important, position order should be optimized to reduce stage travel. Also, note the origin point at the time of programming.

6. When all stage positions have been entered into the program, click **SAVE PROGRAM**, then **QUIT**.
7. Additional programs are entered in the same manner, using a separate program name for each.

## 6.2.3 Procedure to Remove a Programmed Option

To remove a step from the programmed sequence:

1. Select a file name for an existing **Programmed Move** file. See [Figure 6.2b](#).
2. Click **OK** to proceed with programming moves. A new panel, shown in [Figure 6.2c](#), will be displayed.
3. Click in the **Step #** field in the **Select Step** sub-panel.
4. Enter the step number to be removed into the keyboard, or drag the mouse to index to the step number. The stage will simultaneously move to the new step position.
5. Click the **REMOVE STEP** button. When individual program steps are removed, all subsequent steps are “moved up” by one count. (For example, after removing step #2 from a program, step #3 would become the new step #2, step #4 would become the new step #3, etc.)
6. Click the **SAVE PROGRAM** button to save the edited version of program.

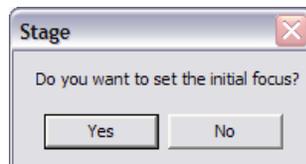
## 6.2.4 Procedure to Insert a Step into an Existing Program Sequence

1. Select a file name for an existing **Programmed Move** file. See [Figure 6.2b](#).
2. Click **OK** to proceed with programming moves. A new panel, shown in [Figure 6.2c](#), will be displayed.
3. Click in the **STEP #** field in the **Select Step** sub-panel.
4. Enter *one less* than the step number to be added to the sequence, or drag the mouse to index to the desired step number. (For example, if the operator wishes to add a new program step #7, while leaving all preexisting steps intact, they would enter “6” in the **STEP #** field. The stage will simultaneously move to the preexisting step position #6.)
5. Make a stage move using either the trackball or the **Move To X,Y** panel (i.e. enter **X** and **Y POSITION** or **POSITION CHANGE** and click **MOVE**).
6. When new program steps are added, all preexisting steps beyond the new entry are “moved up” by one count.
7. Click **SAVE PROGRAM** to save the edited version of program.

## 6.2.5 Procedure To Run a Series of Programmed Moves

1. Select a file name for an existing **Programmed Move** file. See [Figure 6.2b](#).
2. Click on **OK** to proceed with programming moves. A new panel, shown in [Figure 6.2c](#), will be displayed.
3. Click the **RUN** button. If the program is being loaded and run from the beginning, the screen will prompt the operator whether to refocus the screen:

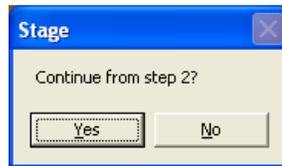
**Figure 6.2d** Stage Panel



4. Clicking on **Yes** will transfer the user to the **Focus Surface** panel; the user may then make focusing adjustments to better view the surface. Clicking on **No** will initiate the programmed move from step #1.

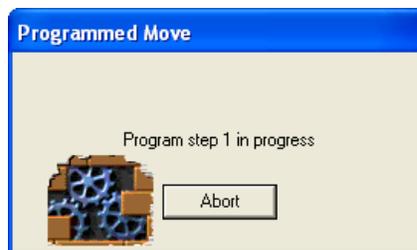
If the program was previously run without finishing (aborted), the screen will request whether to begin the program sequence at the aborted step; for example, if the operator left off at step #2:

**Figure 6.2e** Stage Panel



5. The operator may wish to run the entire program from its beginning (step #1); if this is the case, click **No**. Otherwise, click **Yes**. The screen will display the current program step in progress:

**Figure 6.2f** Programmed Move Panel



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