Tunneling Atomic Force Microscopy (TUNA)

293.1 Overview

This support note describes how to perform Tunneling Atomic Force Microscopy (TUNA) on a Dimension™-series microscope. TUNA enables AFM users to accurately measure low currents (sub-picoampere) through highly resistive samples with a lateral resolution of a few nanometers (≤10 nm). This support note includes:

- **Theory of Operation:** Section 293.2
- **Safety Requirements:** Section 293.3
- **TUNA Instrumentation:** Section 293.4
- **Installation/ Setup of the TUNA System:** Section 293.5
- **Collecting Data:** Section 293.6
- **Imaging:** Section 293.6.3
- **IV- Spectra:** Section 293.6.4
- **Offset Correction:** Section 293.7
- **Troubleshooting:** Section 293.8

Document Revision History: Support Note 293

Rev.	Date	Sections	Ref. DCR	Approval
Rev. A	06/15/00	Preliminary Release	0339	K. Slater

112 Robin Hill Rd.
Santa Barbara, CA 93117
(805)967-1400

293.2 Theory of Operation

To perform TUNA measurements on all Dimension™ series microscopes, the user applies a selectable bias between the sample and the conductive SPM tip, with the tip being on virtual ground. As the tip is scanning the sample in contact mode and imaging the topography, a linear amplifier with a range of 80fA to 120pA senses the current passing through the sample. Thus, the sample's topography and current image are measured simultaneously, enabling the direct correlation of a sample location with its electrical properties.

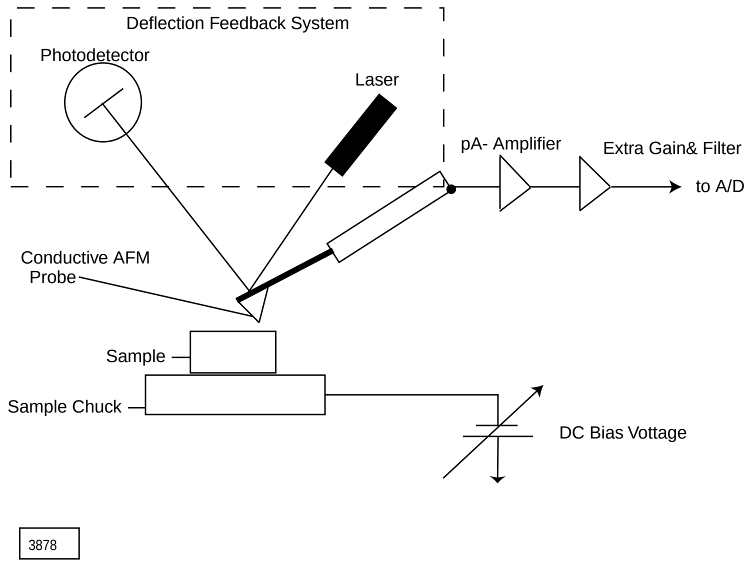
This technique is especially useful for the evaluation of dielectric films with high resistivity and when local electrical properties strongly affect the amount of current passing through the film. An important application is the evaluation of gate oxides for transistors like silicon oxide (SiO_2). The current tunneling from the SPM tip through the oxide strongly depends on film thickness, leakage paths (possibly caused by defects) and charge traps. All of these may significantly affect the properties and the integrity of the whole film, thus compromising an entire device's performance. With its high current sensitivity and high lateral resolution, TUNA helps to identify and characterize in homogeneities like those present in the sample.

TUNA is also very useful for the measurement of other higher resistivity films, such as ferroelectric films and diamond-like-carbon (DLC) films, which find widespread use in data storage. Further examples of application include conductivity measurements on light-emitting conductive polymers or nanotubes, to name a few. Figure 293.2a shows a rough schematic of the tunneling AFM setup.

Note: Make sure to read and understand, or receive training by authorized Digital Instruments Bruker personnel before installing the sensor and attempting a tunneling AFM measurement.

Theory of Operation continued...

Figure 293.2a How Tunneling AFM Works



293.3 Safety Requirements

This section details the safety requirements involved in the installation and operation of the TUNA system. Specifically, these safety requirements include all safety precautions, non-physical conditions and equipment safety applications. Training and compliance with all safety requirements is essential during installation and operation of the Nanoscope SPM.

WARNING: Service and adjustments should be performed only by qualified personnel who are aware of the hazards involved.

ATTENTION: Toute réparation ou étalonnage doit être effectué par des personnes qualifiées et conscientes des dangers qui peuvent y être associés.

WARNUNG: Service- und Einstellarbeiten sollten nur von qualifizierten Personen, die sich der auftretenden Gefahren bewußt sind, durchgeführt werden.

WARNING: Follow company and government safety regulations. Keep unauthorized personnel out of the area when working on equipment.

ATTENTION: Il est impératif de suivre les prérogatives imposées tant au niveau gouvernmental qu’au niveau des entreprises. Les personnes non autorisées ne peuvent rester près du système lorsque celui-ci fonctionne.

WARNUNG: Befolgen Sie die gesetzlichen Sicherheitsbestimmungen Ihres Landes. Halten Sie nicht authorisierte Personen während des Betriebs fern vom Gerät

Safety Precautions continued...

WARNING: Voltages supplied to and within certain areas of the system are potentially dangerous and can cause injury to personnel. Power down everything and unplug from sources of power before doing ANY electrical servicing. (Digital Instruments personnel, *only*.)

ATTENTION: Les tensions utilisées dans le système sont potentiellement dangeureuses et peuvent blesser les Utilisateurs. Avant toute intervention électrique, ne pas oublier de débrancher le système. (Réservé au personnel de Digital Instruments, Bruker seulement.)

WARNUNG: Die elektrischen Spannungen, die dem System zugeführt werden, sowie Spannungen im System selbst sind potentiell gefährlich und können zu Verletzungen von Personen führen. Bevor elektrische Servicearbeiten irgendwelcher Art durchgeführt werden ist das System auszuschalten und vom Netz zu trennen (Nur Bruker Personal).

293.4 TUNA Instrumentation

293.4.1 System Requirements

The minimum system requirements needed to install and operate TUNA are:

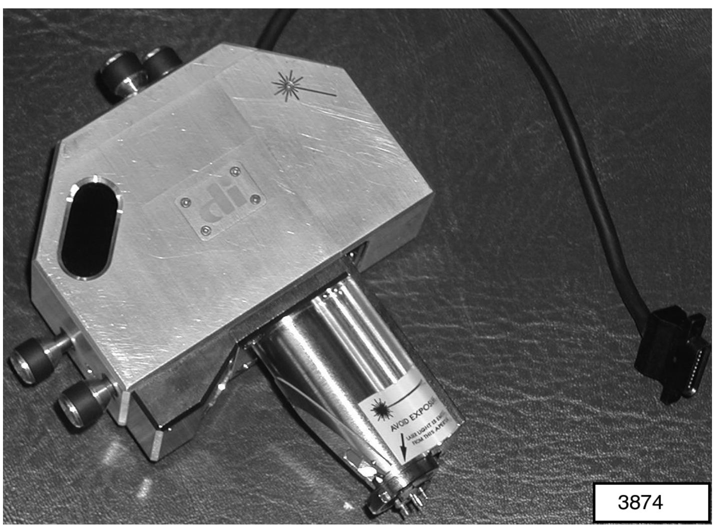
- Software V4.44 or higher, Windows NT
- Application Module System

293.4.2 Hardware Description

The TUNA hardware consists of the following items:

- **Application Module AFM Scanner**: This scanner allows the user to mount the TUNA sensor using two screws (size: 2-56, 1 1/4 inch socket head; See Figure 293.4a).

Figure 293.4a Application Module AFM Scanner



Note: Screws and a matching screwdriver are included in the application module accessory kit.

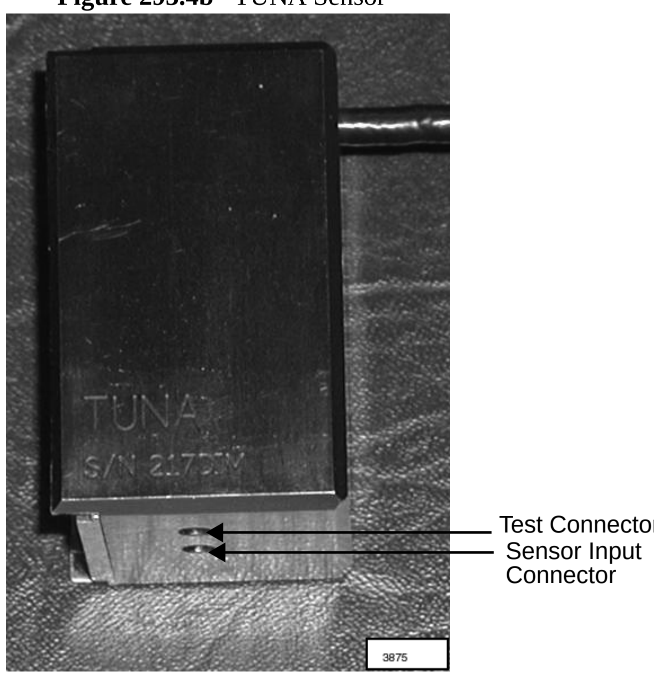
TUNA Instumentation continued...

- **Application Module Electronics Box**: This electronics box contains specialized electronics for standard AFM imaging, extended AFM imaging, TUNA imaging and other application module techniques including: scanning capacitance microscopy (SCM) and scanning spreading resistance microscopy (SSRM).

  Note: Using the application module AFM scanner and electronics box, it is possible to operate other application modules such as SCM and SSRM provided the corresponding sensor and tip holder are available.

- **TUNA Sensor**: The TUNA sensor may be mounted on the application module AFM scanner using the two screws. The TUNA sensor contains the current amplification circuit necessary for the ultra-low current measurements. It connects to the application module electronics box using the subminiature D-15 connector (See Figure 293.4b).

Figure 293.4b TUNA Sensor

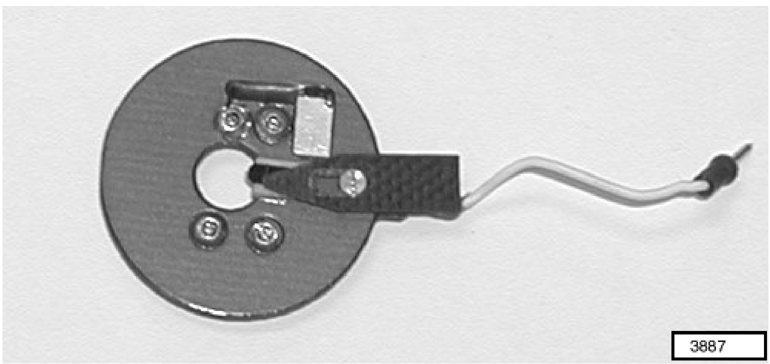


TUNA Instrumentation continued...

- **TUNA Tip Holder**: The TUNA tip holder provides electrical connection from the tip to the TUNA sensor, while maintaining standard features for contact mode and tapping mode imaging (See Figure 293.4c).

Note: This tip holder is used for TUNA and SSRM measurements. It is not intended for general purpose scanning.

Figure 293.4c TUNA Tipholder



293.5 Installation/ Setup of the TUNA System

Installation of the Dimension™ system for tunneling atomic force microscopy differs from a standard Dimension™ system only in the installation of the TUNA module on the SPM head. For other installation issues, see your *Dimension Series Instruction Manual*.

293.5.1 Installation of the TUNA Module

1. Unplug the Dimension head's 21-pin connector. Retract the clamping screw on the right hand side of the dovetail mount by turning it clockwise. Gently remove the head.

2. Place the TUNA sensor flush on the flat part of the piezo guard, and tighten it down using the two screws provided with the sensor.

   Note: Do not overtighten screws. The screws and a matching screwdriver are included in the application module accessory kit.

3. Remove the jumper wire from the input pins of the TUNA module.

WARNING: Remove the jumper wire from the TUNA sensor input *before* connecting its 15-pin connector to the electronics box of the microscope. The jumper wire protects the sensor's input from ESD during transport and storage. However, if the jumper wire is left in place when connecting the sensor to the microscope, previous software settings could damage the sensor.

4. Carefully install the Dimension head on the dovetail mount.

Installation/ Setup of the TUNA System continued...

CAUTION: When installing the Dimension head, carefully check the clearance between the sample/ stage and the tip/ scanner to prevent the tip/ scanner from crashing into the sample/ stage. If it appears that the tip/ scanner may crash when fully inserted into the dovetail mount, remove the Dimension head completely and execute the **Motor/ Withdraw** command or select **Stage/ Focus Surface** and use the trackball to obtain sufficient clearance.

5. Tighten the clamping screw by turning it counter-clockwise until the head is secured.

   Note: It is very important to fasten the clamping screw on the dovetail, and tightly secure the Dimension head. A loose Dimension head causes a large increase in image noise, due to the reduced rigidity of the mechanical support of the SPM head.

6. Plug the head's 21-pin connector and the TUNA module's 15-pin connector into the receptacles on the front of the microscope's electronics box.

Installation/Setup of the TUNA System continued...

293.5.2 Select the Desired Microscope Mode

Prior to any TUNA measurement, first select the proper hardware and software settings. Select the following settings:

1. Toggle the **Analog 2** switch on top of the electronics box of your microscope into the forward position. This enables the application of a bias to the chuck/ sample through the Nanoscope software.

2. Make sure the **STM/ AM** switch is in the **AM** position (See Figure 293.5).

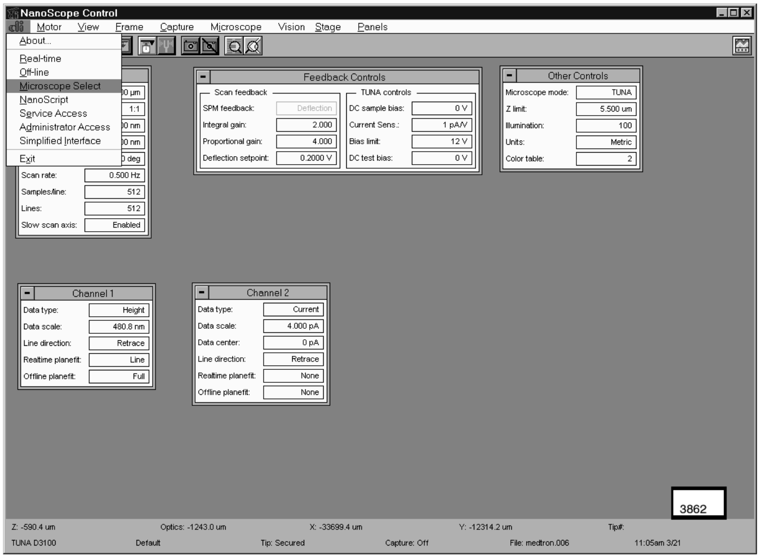
Note: The **STM** position is for STM measurements only.

Figure 293.5a Toggle Switches on Dimension Electronics Box

Installation/Setup of TUNA System continued...

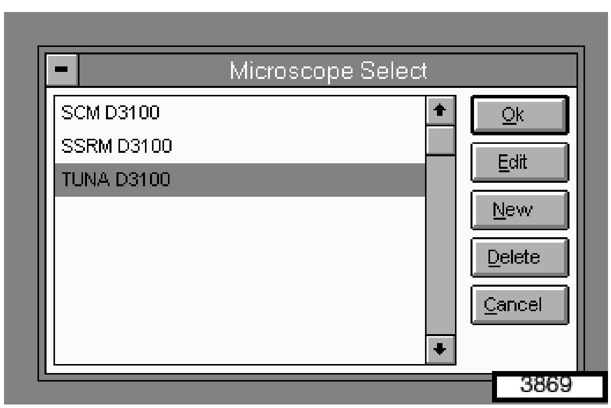
3. Using the mouse, click and hold on the **Digital Instruments** icon located in the upper left hand corner of the control screen (See Figure 293.5b).

Figure 293.5b Digital Instruments Pull-Down Menu/ Microscope Select Panel



4. Single click on **Microscope Select** to open the Microscope Select panel. From the Microscope Select Panel, select the **TUNA D3100** option (See Figure 293.5c).

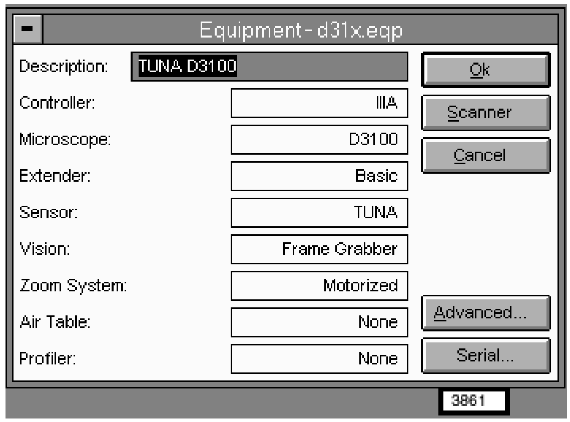
Figure 293.5c Microscope Select Panel



Installation/ Setup of the TUNA System continued...

5. Click **Edit** to open the **Equipment** panel. In the Equipment panel, verify that the **TUNA** module is selected for the option **Sensor** (See Figure 293.5d).

Figure 293.5d Equipment Panel



Note: To enable all sensor options, set the **Extender** option to **Basic**.

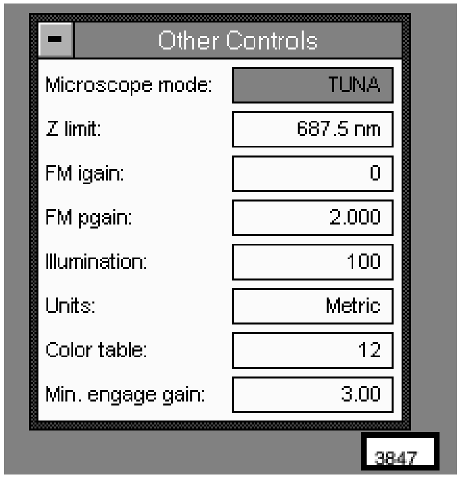
6. Click the OK button to close panels. The system loads the new software configuration.

7. In the **Other Controls** panel, select different Microscope modes: contact, tapping, STM and TUNA.

8. Select **TUNA** as the microscope mode (See Figure 293.5e).

Installation/ Setup of the TUNA System continued...

Figure 293.5e Other Controls Panel

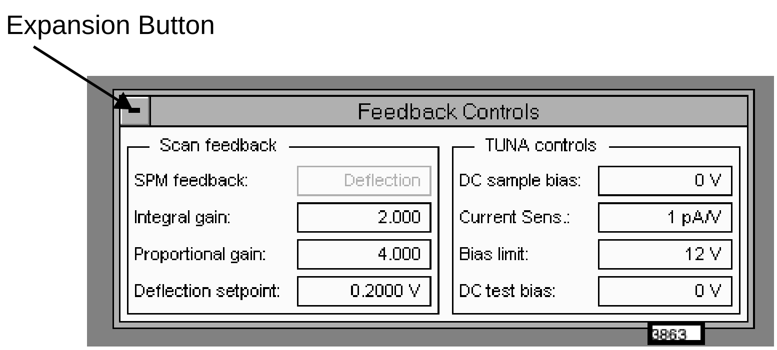


293.5.3 TUNA Controls Panel

Currently the equipment allows TUNA measurements to be performed in open loop mode *only*. The user selects a fixed DC bias and the current passing through the sample is measured. For these standard measurements only a few of the parameters available in the **Feedback Controls- TUNA Controls** panel are necessary. Deselect all other parameters. Table 293.5a summarizes all TUNA controls parameters and their functions. To access these additional parameters, a user must complete the following steps:

1. Select the EXPANSION button in the top left hand corner of the **Feedback Control** parameters (See Figure 293.5f). A pull-down menu appears

Figure 293.5f .Feedback and TUNA Control Panel



2. Select **View All** to view additional parameter options.

Installation/Setup of the TUNA System continued...

Table 293.5a: TUNA Control Parameters

Feedback Mode	Selects between open and closed loop mode. In TUNA, select **open**.	Deselect
DC Sample Bias	Selectable bias to chuck/sample.	Select
Current Setpoint	Selects the current setpoint in closed loop mode.	Deselect
Current Sensitivity	Selects the gain of the TUNA sensor:[a] 1pA/V = gain of 10^{12} 10pA/V= gain of 10^{11}	Select
Bias Lower Limit	Limits the minimum bias applied to the chuck/ sample in closed loop mode.	Deselect
Bias Upper Limit	Limits the maximum bias.	Deselect
Feedback gain	Adjusts the feedback gain in closed loop mode.	Deselect
Bias Limit	Should be set to 12V, which is the maximum bias (± 12V) applied to the chuck/ sample.	Select
DC Test Bias	Provides an additional bias for the purpose of testing the TUNA sensor.	Select

a.1pA/V and 10pA/V refer to the output voltage of the TUNA sensor. If a signal access module is available, the output voltage can be measured at Aux D.

293.6 Collecting Data

293.6.1 Sample Mounting

1. Attach the sample to a magnetic puck provided with the system and place the puck on top of the sample chuck. For larger samples or wafers, use the chuck vacuum to hold the sample in place.

When measuring large samples, the use of the hood is recommended. Depending on the sample's electric properties, large samples can act as an antenna and transmit electrical noise from the environment into the input of the TUNA sensor. As a result, the background noise of the sensor can reach much larger orders of magnitude than the specified noise.

WARNING: The sample chuck and it's surrounding area is electrostatic sensitive. Wear a grounding device at all times.

293.6.2 Tip Mounting

Selection

In TUNA an electrically conductive tip is used. Standard TUNA tips include platinum-iridium coated tips (SCM-PIT, SCM-PIC) and cobalt chromium coated tips (MESP). Alternative tips are diamond coated tips (DCT-ESP) when selecting a tip for TUNA.

Note: When selecting a tip, keep in mind that TUNA is being operated in contact mode.

Mounting

Mount the tip as described in Chapter 5 of your SPM's *Instruction Manual*. Plug the wire attached to the cantilever holder into the TUNA sensor.

Note: Tweezers may be used to plug in the connector.

293.6.3 Imaging

Quick Start

For a quick start, use the TUNA profile.

1. Select **Microscope/ Profile** and the **Profile Select** panel appears.

2. Highlight the profile **Tunneling AFM** (file name TUNA) and click on **Load Master**. The software automatically sets the scan parameters to acceptable values.

Real -time Mode

1. To perform a measurement in Real-time mode, select **DI/Realtime**.

2. In the **Other Controls** panel, select **TUNA** as the Microscope mode (See Figure 293.5e).

3. Set the TUNA Controls parameters to the following, initial settings:

Note: The **Feedback Controls** panel shows the **Scan Feedback** parameters and the **TUNA Controls** parameters simultaneously (See Figure 293.5f).

Table 293.6a: Initial Settings of TUNA Control Parameters

DC Sample Bias	0V
Current Sens.	1pa/V
Bias Limit	12V
DC Test Bias	0V

TUNA is a contact mode technique. For the initial settings of the **Scan Controls** parameters and the **Feedback Controls** parameters in contact mode, refer to Chapter 6 in your *SPM Instruction Manual*.Typically the **Feedback Controls** panel looks similar to what is shown in Figure 293.5f.

Collecting Data continued...

4. Set the **Deflection Setpoint** to no more than a few tenths of a volt above the engagement point. This will keep the contact force sufficiently low, thus not causing any damage to the tip or sample. This is especially important for metal coated tips or soft samples.

5. Once the parameters are set, click on the ENGAGE command and start a measurement.

   Note: It will probably be necessary to make adjustments to a number of parameters (**Integral Gain, Prop. Gain, Def. Setpoint**) before the image is optimized.

6. To view the topography and the current data set the **Data Type** to **Height** in the **Channel 1** panel and set the **Data Type** to **Current** on the **Channel 2** panel (See Figure 293.6a).

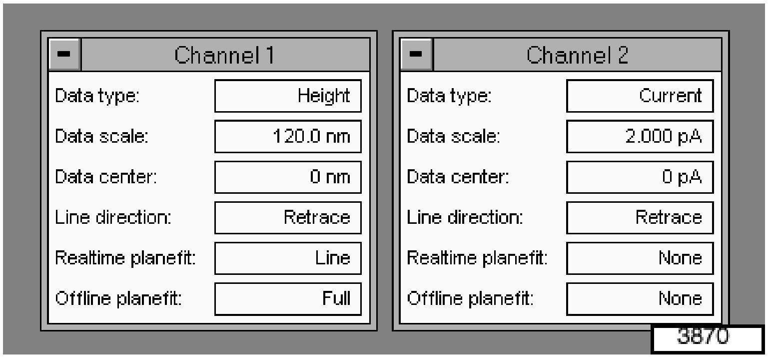
7. Set the current **Real-time Planefit** to **None** and the **Offline Planefit** to **None** or **Full** on the channel that displays the current.

8. The **Highpass** and **Lowpass Filters** should be turned OFF.

   Note: The **Data Center** option is useful for the measurement of small current variations in a sample with an overall larger background current.

Collecting Data continued...

Figure 293.6a Channel 1 and Channel 2 Panels for Initial Set-Up (TUNA)



9. To reduce wear of the tip and sample, decrease the contact forces between the tip and sample as much as possible. This is done in one of the following two ways:

   a. Obtain a force plot and adjust the setpoint to a level just before the pull-off point, thus minimizing force (See Chapter 11 of your *SPM Instruction Manual*).

   b. Click on the **Scope Mode** command and observe the **Height** trace.

   c. Lower the setpoint in small increments by highlighting the **Deflection Setpoint** in the **Feedback Controls** panel and repeatedly clicking on the LEFT ARROW key. This reduces the force applied to the sample until the tip eventually lifts off the surface.

   d. Slowly increase the setpoint by clicking on the RIGHT ARROW key to obtain a focused image.

Note: Adjusting the **Setpoint** to a few tenths of a volt above the engagement point provides a low contact force.

Collecting Data continued...

10. Slowly increase the **DC Sample Bias** while watching the current signal in either **image** or **scope** mode. For many samples, you will find a rapidly increasing current once a certain threshold bias is reached.

Note: It is important not to scan too fast. The sensor's band width is only 160 Hz. The more slowly a sample is scanned, the more variations in current the sensor may detect. Adjust the **Scan Rate** for better current image quality.

CAUTION: When increasing the bias, it is important to proceed carefully in order not to reach overly high current densities. In cases where metal coated tips are being used, the coating may melt if high current densities are used.

Note: Such caution is used to avoid damage to the sample.

CAUTION: When scanning a sample during the application of a bias, keep in mind that the electrostatic forces in most samples causes a strong attraction between the tip and the sample. This electrostatic force does not result in any additional deflection of the cantilever, thus disabling a correction through the SPM feedback system. The increased force causes more wear on the tip, and can be harmful to soft samples like polymers. It is necessary to the force between the tip and the sample by reducing the **Deflection Setpoint** (See Section 293.5). Another option is to apply the bias first before engaging with the AFM. However, this method works only for experiments with a well-defined, known bias. In most cases further adjustment of the setpoint will be necessary.

11. Save the data as described in Chapter 6 of the *Command Reference Manual*.

Collecting Data continued...

293.6.4 IV- Spectra

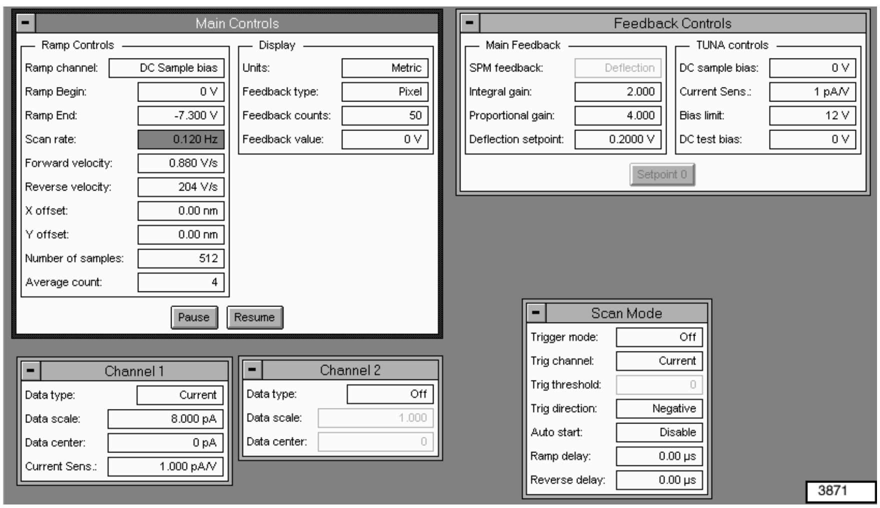
The Nanoscope software permits IV measurements in a specified location on the sample. Typically the SPM tip is placed at the center of an image where an IV-spectrum is captured. By applying X and Y offsets, the tip may be moved to other locations.

Perform an IV Measurement

1. To perform an IV measurement go to **View**/ **Force Mode**/ **Calibrate**.

Note: The command screen appears, displaying the ramping panels (See Figure 293.6b).

Figure 293.6b Ramping Panels



Collecting Data continued...

The following tables (Table 293.6b through Table 293.6f) summarize the ramping parameters and their functions:

Table 293.6b: Main Controls/ Ramp Controls Panel

Ramp Channel	Select **DC Sample Bias** to ramp the bias applied to the chuck/sample
Ramp Begin./Ramp End	Define beginning and ending of ramp, both values may be positive or negative
Scan Rate[a]	All ramps are *begin-end-begin* cycles (V-start-Vend-V-start), and the scan rate refers to one complete cycle.
Forward Velocity [a] **& Reverse Velocity** [a]	Defines the ramp velocity from beginning to end value, and end to beginning value, respectively.
X and Y Offset	Moves the tip to a different location.
Number of Samples	Sets the number of samples per ramp (minimum 16, maximum 64,000).
Average Count	Allows several ramps to be averaged (minimum 1, maximum 1024).

a.**Scan Rate**, **Forward Velocity** and **Reverse Velocity** are interdependent. Changing one of the velocities will affect the overall scan rate and the changing of the scan rate will affect both velocities.

Collecting Data continued...

For proper feedback during the measurement of IV-spectra, adjust the following parameters in the **Main Controls/ Display** Panel:

Table 293.6c: Main Controls/ Display Panel

Units	Select Metric for IV-spectra
Feedback Type	Ensures that deflection feedback is on while ramping the DC sample bias; select **ramp**, **cycle** or **pixel**.. **Ramp**- Enables feedback after each ramp or half cycle ($V_{start-}V_{end-}$feedback). **Cycle**- Enables feedback after each ramp cycle ($V_{start-}V_{end-}V_{start-}$feedback). **Pixel**- Enables feedback after every sample point of the ramp. This might be useful for extremely slow ramps with few sample points.
Feedback Counts	Select 50 for proper feedback.
Feedback Value	This parameter is only relevant to STS in STM mode.

Collecting Data continued...

2. To view IV-spectra, on either the **Channel 1** or the **Channel 2** panel, set the **Data Type** to **Current** (See Table 293.6d).

Table 293.6d: Channel1/ Channel 2

Data Type	For IV Spectra select **current.**
Data Scale[a]	Adjust according to data.
Data Center	Offsets IV-spectrum along the vertical/ current axis.
Current Sensitivity [a]	Displays the sensitivity which has been selected in the **Feedback Controls**/ **TUNA Controls** panel.

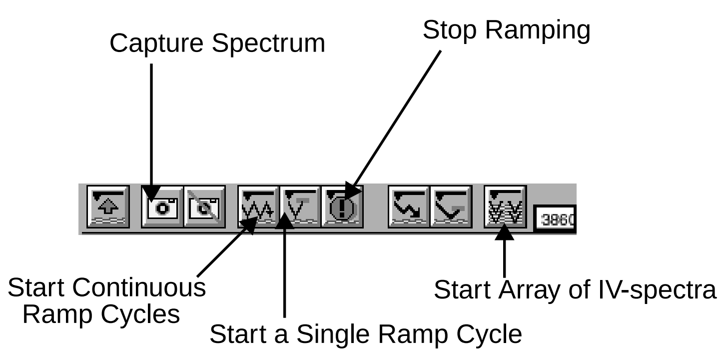
a.**Data Scale** and **Current Sensitivity** parameters automatically adjust to change in the **Current Sensitivity** parameter. The **Current Sensitivity** parameter is located in the **Feedback Controls/ TUNA Controls** panel.

Start and Save IV-spectra

1. To start and stop voltage ramps, select the appropriate icon located in the toolbar (See Figure 293.6c).

Note: In order to take IV-spectra, the AFM must be engaged.

Figure 293.6c Toolbar Buttons Used for Starting, Stopping and Capturing Ramp Curves



Collecting Data continued...

Start Continuous Ramps Icon: This option starts continuous ramps and permits the averaging of several spectra. To select the number of averaged spectra, select the **Average count** parameter in the **Main Controls/Ramp Controls** panel. This measurement continues until the user clicks the stop button (See Figure 293.6c).

Note: The voltage ramp stops at whatever value is applied at the time the stop button is selected. To stop multiple voltage ramps at a specific voltage value, switch to the single ramp cycle icon before pressing the STOP button. This will add a single ramp to the multiple ramps and leave the bias voltage at V-start.

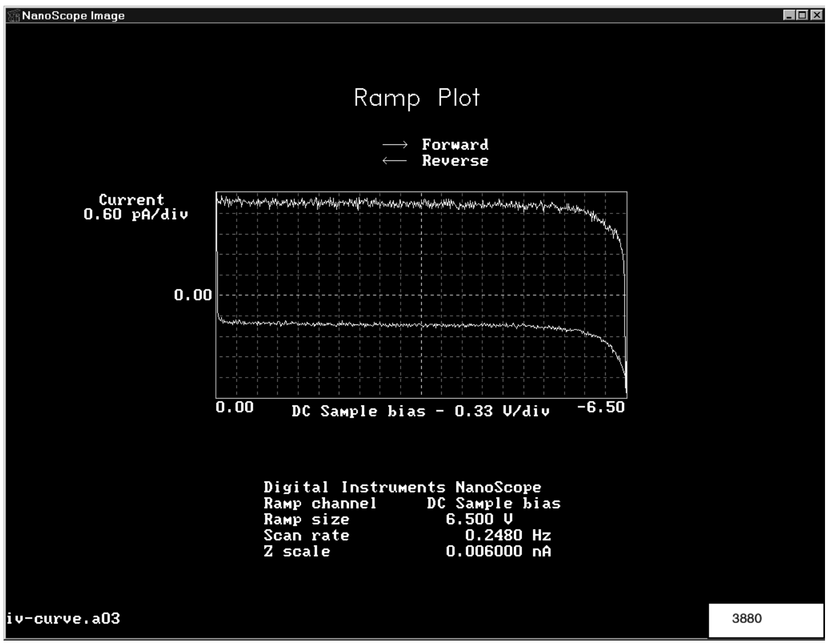
- **Single Ramp Icon**: Starts a single ramp. The voltage ramp starts at the **Ramp Begin** value, is increased or decreased until the **Ramp End** value is reached, and is then ramped back to the **Ramp Begin** level.
- **Stop Icon**: Click this option to stop the ramping process.
- **Start an Array of IV-spectra Icon**: Starts an array of IV-spectra. For a full description of this function see Multiple IV-spectra in Section 293.6.
- **Capture Icon**:0 Saves the spectrum during a measurement.

Note: At the bottom of the **Main Controls** panel there are two buttons, PAUSE and RESUME. PAUSE interrupts the voltage ramp and holds the voltage at the current value until the user continues the measurement. To continued with the measurement select the RESUME button.

Collecting Data continued...

Figure 293.6d shows a typical IV-spectrum measured on a 40Å thick gate oxide. The ramp rate of the spectrum is 0.248Hz, with a forward velocity of 1.63 v/s and a reverse velocity of 181v/s. Forward and reverse currents are offset from the the zero current line due to displacement currents. When comparing IV-spectra, we recommend slowly ramping in one direction, the direction of interest, to reduce the displacement current and rapidly ramping in the reverse direction. The reverse ramp should then be ignored due to artifacts that may occur at high ramp velocities.

Figure 293.6d IV-spectrum of a 40Å Thick Gate Oxide



Collecting Data continued...

Function and Operation of the Trigger Mode

In certain cases it is necessary to limit the current passing through a sample in order to protect it from destruction. The **Trigger Mode** enables the user to limit the current to a selected value. All necessary parameters, and additional parameters, may be found in the **Scan Mode** panel (See Figure 293.6e). The following tables (Table 293.6e and Table 293.6f) describe the individual functions of the parameters.

Figure 293.6e Scan Mode Panel

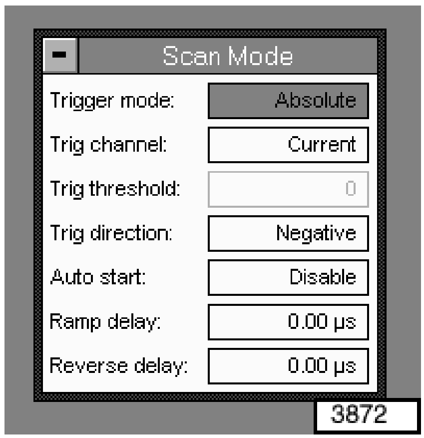


Table 293.6e: Scan Mode Panel Parameters

Trigger Mode	This turns the **Trigger Mode** on and off. For IV-spectra select **Absolute** to turn the trigger on.
Trigger Channel	For IV-Spectra select **Current** for triggering of the current.
Trigger Thresh-old	This sets the trigger value. For a current sensitivity of 1pA/V, select any value between +10pA and -10pA. For a current sensitivity, select any value between +100pA and -100pA.
Trigger Direction	(See explanation below)
Auto Start	Set to **Disable**.

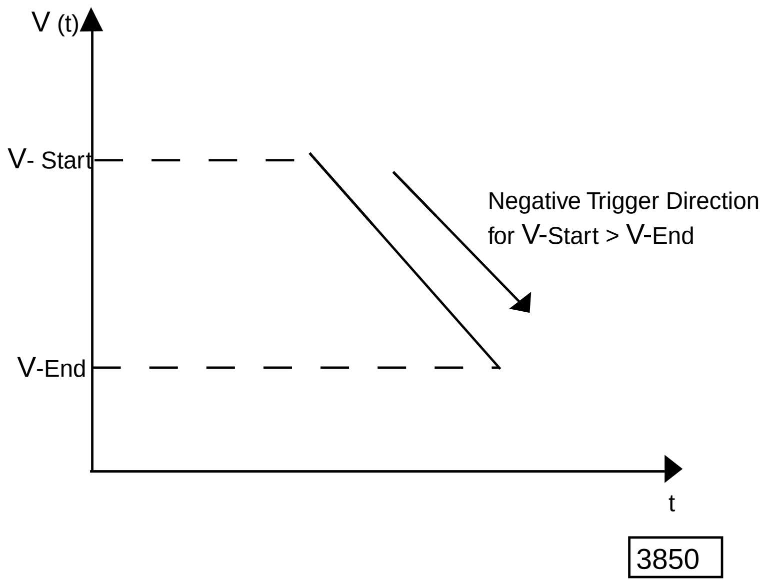
Collecting Data continued...

Explanation of Trigger Direction:

For the **Trigger Mode** to function properly, it is imperative to select the correct trigger direction for a given ramp.

1. When ramping from a larger **Ramp Begin** value to a smaller **Ramp End** value (this means V(t) follows a negative slope), select **Negative** for the **Trigger Direction**.

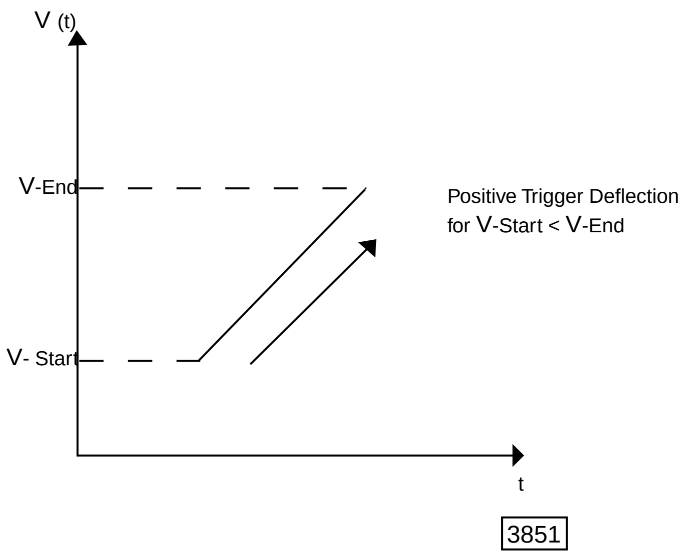
Figure 293.6f Negative Trigger Direction for V- $_{Start}$-V-$_{End}$



Collecting Data continued...

2. When ramping from a smaller **Ramp Begin** value to a larger **Ramp End** value (this means V(t) follows a positive slope), select **Positive** for the trigger direction.

Figure 293.6g Positive Trigger Direction for $V_{Start} > V_{End}$



Note: Trigger values can be either positive or negative, depending on the requirements of a specific experiment.

Note: Select **Trigger Mode/Absolute** when operating in IV-spectra. Parameter options may seem confusing. In addition to IV-spectra parameters, the panel displays parameters relevant only to force curves. Disregard these additional parameters.

CAUTION: It is important to set the **Trigger Mode** to **Absolute** when performing IV-spectra. Since IV-spectra and force curves share parameters on a common control screen, it is very important to closely follow the above instructions. Some parameters are relevant only to force curves, disregard these parameters for TUNA measurements.

Collecting Data continued...

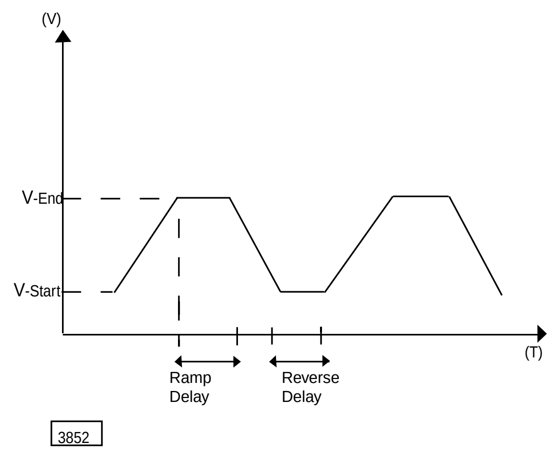
Delaying Ramps

The **Scan Mode** panel offers two more parameters that are used to independently add delay times at the end of a *start-end* ramp, or at the end of a complete *start-end-start* cycle (See Figure 293.6h).

Table 293.6f: Ramp Delays

Ramp Delay	This adds a delay time following each *start-end* ramp.
Reverse Delay	This adds a delay time following each complete *start-end-start* cycle.

Figure 293.6h Delaying Ramps



Note: Delay times are not included in the **Scan Rate** parameter.

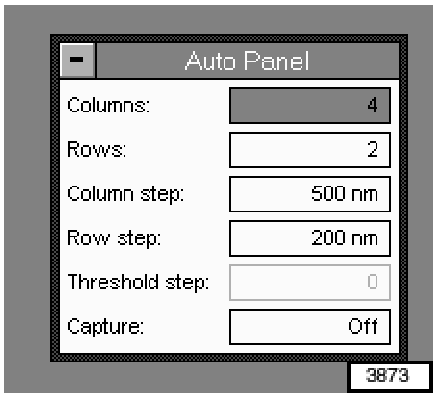
Note: When switching from one start/end value to another, the **Scan Rate** is kept at a protected value. **Forward** and **Reverse Velocity** are automatically adjusted to keep the **Scan Rate** constant.

Collecting Data continued...

Multiple IV- Spectra

1. Open the **Auto Panel** by selecting **Panels/Auto** (See Figure 293.6i).

Figure 293.6i Auto Panel for Multiple IV-Spectra



2. Set the number of IV-spectra in the array using the **Columns** and **Rows** parameters. The **Columns** and **Rows** parameters are the number of IV-spectra to be performed in the X and Y direction, respectively.

3. Set the spacing between the columns and rows in the array using the **Column Step** and **Row Step** parameters. The **Column (Row) Step** parameters define the distance between two neighboring IV-spectra along the X(Y) direction.

Collecting Data continued...

4. Set the trigger threshold currents for the array of IV-spectra using the **Trigger Threshold** parameter (abbreviated **Trig. Threshold**) and the **Threshold Step** parameter.

   Note: The **Trigger Threshold** parameter is located in the **Scan Mode** panel. The **Threshold Step** parameter is located in the **Auto Panel**.

5. For automated IV-spectra, increment the trigger threshold current in the X direction using the **Trigger Threshold** and **Threshold Step** parameters.

   a. Set the **Trigger Threshold** to the initial value for the first IV-spectrum in each row.

   b. Increment the **Trigger Threshold** according to the value of the **Threshold Step** for every subsequent IV-spectrum in each row.

Example:

If a **Trigger Threshold** is 1.0pA and the **Threshold Step** is 0.1pA, then any row of the IV-spectra will use a trigger threshold current varying from 1.0, 1.1, 1.2,... pA. The threshold current is always incremented from the right to the left. To execute an array of IV- spectra with the same trigger threshold current, set the **Trigger Threshold** to the desired threshold and set the **Threshold Step** to 0.0pA.

6. To execute an array of IV-spectra click on the START ARRAY button in the toolbar (See Figure 293.6c).

7. To capture the IV-spectra set the **Capture** parameter (located in the **Auto** panel) to **Enable** before starting the array. Save each spectrum of the array separately.

   Note: If **Capture** is set to **Off**, the IV-spectra will be lost.

Collecting Data continued...

Export IV-Spectra

To export IV- spectra in ASCII or any other format offered by the Nanoscope software, complete the following steps:

1. Save the current data.

2. Export this saved data. The export function is located in the **Utility** menu in the Off-line mode.

293.7 Offset Correction

For proper measurements you must adjust any offset of the TUNA sensor. This is done through a potentiometer, which is covered by the bottom flat head screw on the right hand side of the sensor housing (See Figure 293.4b).

1. Go to **Scope Mode**.

2. Remove the screw on the sensor housing and carefully adjust the potentiometer with the screw driver (provided in the application module accessory kit) until the the signal is along the horizontal zero line.

3. Adjust the **Data Scale** for better alignment.

293.8 Troubleshooting

If a current signal is not received, although you expect the sample to be adequate for this type of measurement, check for several possible problems with the system/ setup:

1. Apply a DC bias to the chuck and measure it with a voltmeter.

    a. If there is no bias, the ANALOG 2 switch on top of the electronics box of your microscope is probably in the wrong position.

    b. If the switch is in the correct position and there is still no bias, reset the microscope by clicking on **Microscope/Reset**.

    c. If the problem persists, please, contact Bruker.

2. Check to see if the sample is in electrical contact with the chuck. If not, establish contact between the sample and the chuck.

3. Verify that the STM/AM switch is in the AM position. If not, toggle the STM/AM switch to the AM position.

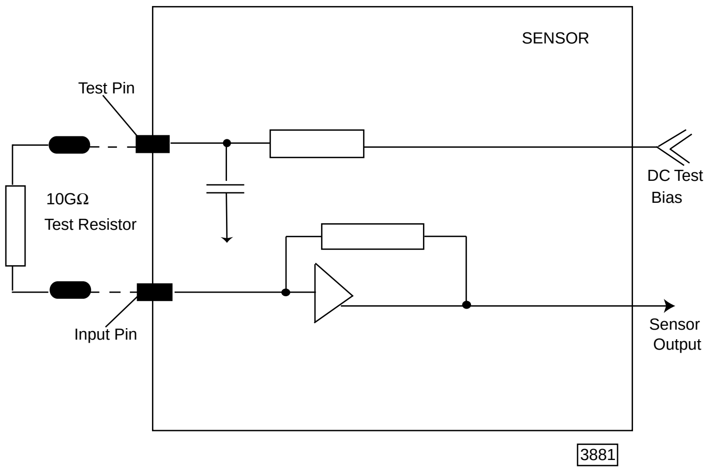
4. If you suspect a problem with the TUNA sensor, complete the following procedure:

    a. Unplug the sensor's 15-pin connector from the electronics box.

    b. Plug a 10GΩ resistor between the input pin and the test pin of the sensor.

Troubleshooting continued..

Figure 293.8a Schematic Test Circuit of TUNA Sensor



CAUTION: Be careful not to touch the resistor with your hands. The resistance of the grease from your hands is much less than 10GΩ and will decrease the resistor’s effective value. Use tweezers.

Troubleshooting continued...

c. Before reconnecting the sensor's 15-pin connector to the electronic box, make sure that the **TUNA Controls** parameters are set to the following values:

Table 293.8a: TUNA Controls Parameters

Feedback Mode	Open	May be deselected
DC Sample Bias	0V	
Current Setpoint	0V	May be deselected
Current Sensitivity	1pA/V	
Bias Lower Limit	0V	May be deselected
Bias Upper Limit	0V	May be deselected
Bias Limit	12V	
DC Test Bias	0V	

Note: Verify that the **DC Test Bias** is set to 0V.

d. Attach the sensor to the scanner head and connect the wire to the 15-pin connector on the front of the electronics box.

Troubleshooting continued...

e. Go to **View/Scope Mode** and select the following parameters for the **Channel 2** panel:

Table 293.8b: Channel 2 Parameters

Data Type	Current
Data Scale	10pA
Data Center	0pA
Line Direction	N/A
Realtime Planefit	None
Offline Planefit	None
Lowpass Filter	Off

f. Apply a **DC Test Bias** of +0.01V and -0.01V respectively. Verify that the current signal increases by +1pA and decreases by -1pA, respectively.

g. Check if current signals scales properly by applying ± 0.01 V, ± 0.02 V, ± 0.03V and ± 0.04V. The current signal should change by ± 1pA, ±2pA, ±3pA up to ± 4pA.

Note: If scanner does not perform according to the previous description, something is wrong. In this case, contact Bruker.

Note: The value of these larger resistors is typically not very accurate and can easily be off by 5% or more. Thus the output signal at a given test bias might differ slightly from the above values.

WARNING: Always handle the 10GΩ resistor with tweezers.

Troubleshooting continued...

293.8.1 External Disturbances

Keep in mind that you are engaging with extremely sensitive equipment. This equipment can measure very small currents, but it also amplifies any external disturbances. Examples of such disruptive electronic equipment include: an oscilloscopes, a fluorescent light in conjunction with certain samples, and other electronic equipment operated in a close vicinity.