Dektak XT 2D Profilometer

This document is intended to describe the operation of the Bruker Dektak XT Profilometer and its capabilities. In order to gain access on the tool, formal qualification by staff is required.

The Dektak XT (Fig 1.1) is a 2D contact profilometer used to provide quantitative information about step heights and surface roughness for thin and thick films measurements. This information is collected and analyzed in the Vision 64 application software.

Figure 1.1. Dektak XT within an environmental enclosure.

Advantages

Compatible with a wide range of materials

Measures a wide range of vertical features with high resolution

Easy-to-use

Disadvantages

Stylus head has 12.5 um radius. This is a poor tool for samples with high aspect ratios or narrow trenches

Not suitable for very soft or fragile samples that can warp or break under small amounts of force

Only 2D measurements with simple block stage

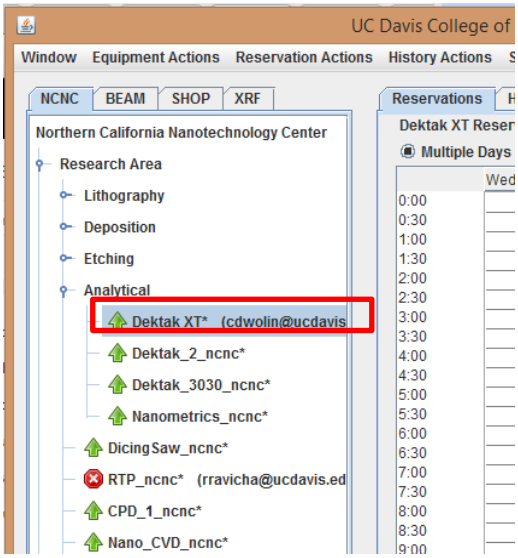
1. **Standard Operating Procedure**
    - 1.1 System Start up
    - 1.2 Adjusting the stage
    - 1.3 Taking a measurement
    - 1.4 Data Analysis
    - 1.5 System shut down

2. **System overview**
    - 2.1 Capabilities
    - 2.2 System mechanism
    - 2.3 Components (Hardware)
    - 2.4 Components (Software)
3. **Factors**
    - 3.1 Scan parameters
    - 3.2 Leveling the stage
    - 3.3 Limitations of the stylus

1.0 Standard Operating Procedure

1.1 System start up

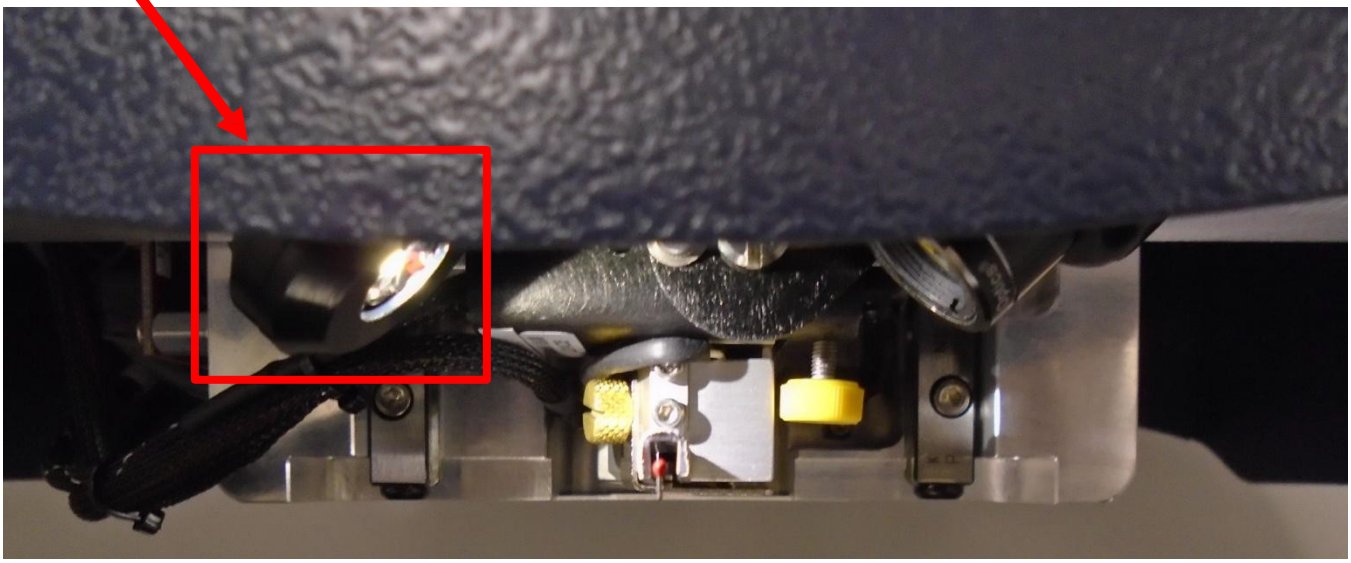
Make sure system is enabled on Badger



Make sure the system is **ON**
If not, press white **power on** button;
button should light up

Turn on Vision 64 software

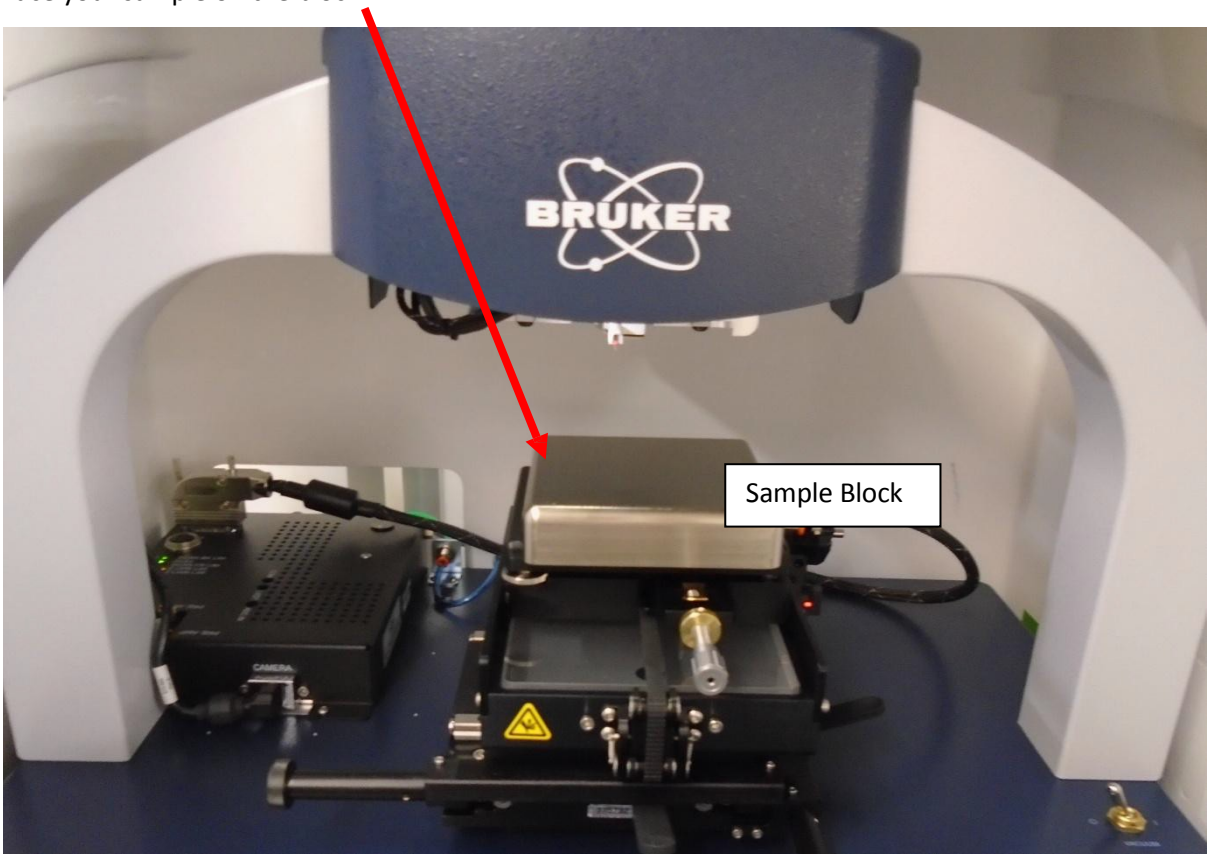
Light within the housing system should turn on to indicate that the system has initialized.



Note: do not open the software without the system on first. Otherwise the software crashes. If this happens, press **abort** on the software error message and start over.

Loading sample

Place your sample on the block



WARNING

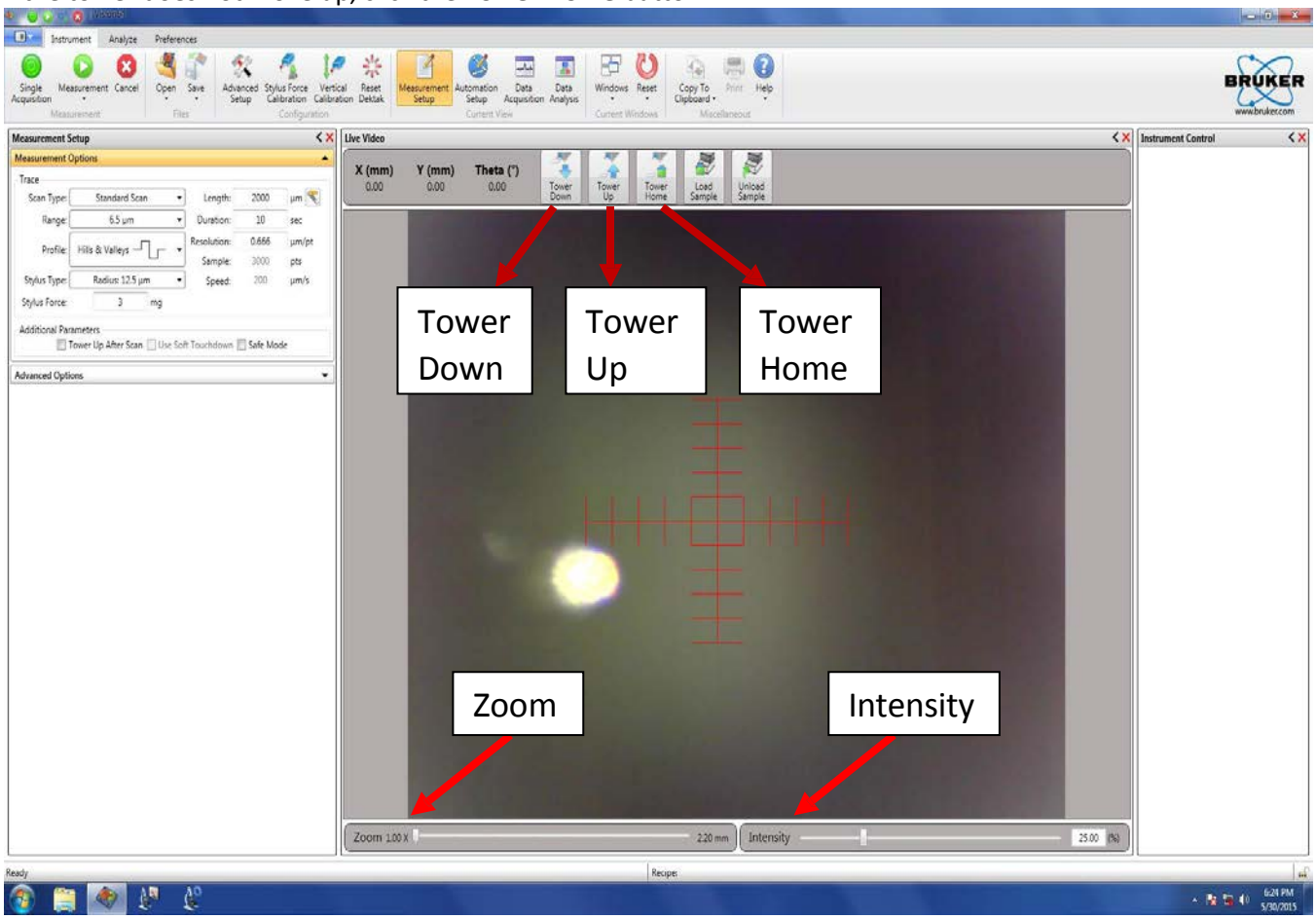
Always raise the tower prior to loading a sample. Failure to do so can damage the stylus and sample.

Lower the stylus towards your sample. If you need to readjust your sample position on the block make sure to raise the tower assembly.

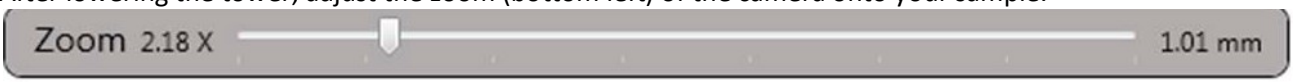
To do lower the assembly, click the **Tower Down** button on the toolbar above the camera's Live Video Display.

To raise the tower assembly, click the **Tower Up** button.

If the tower does not move up, click the **Tower Home** button.



After lowering the tower, adjust the zoom (bottom left) of the camera onto your sample.

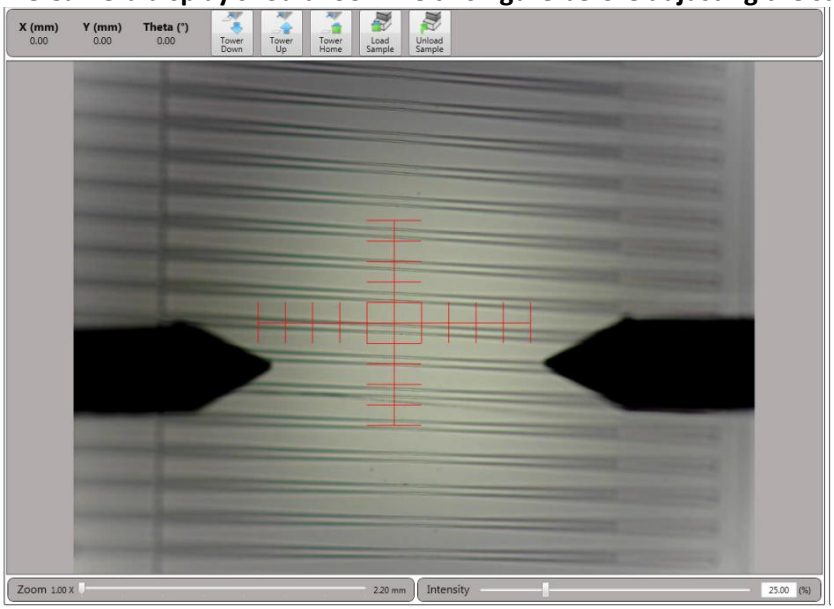


Adjust the illumination level (bottom right) of the video image displayed on the monitor.

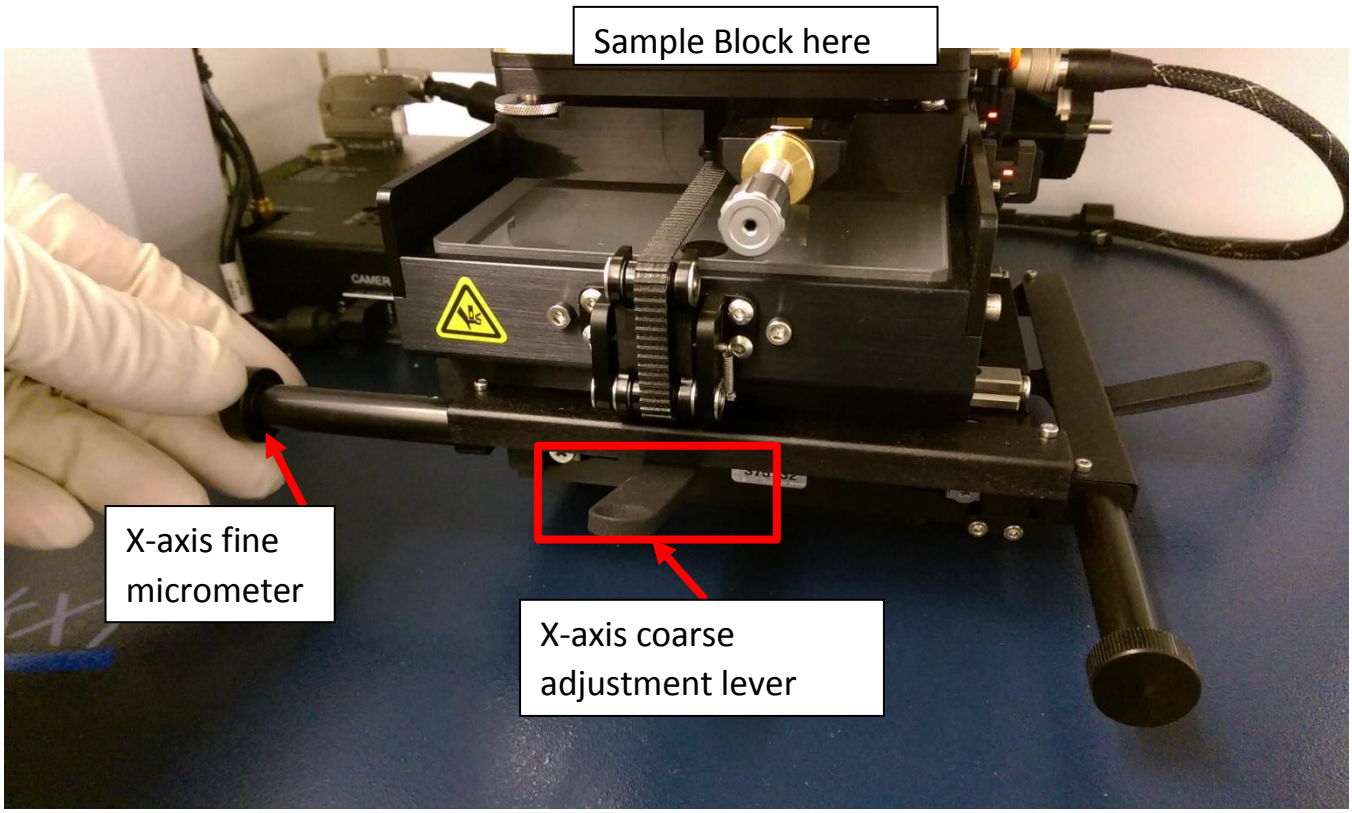
1.2 Adjusting the X-Y Position

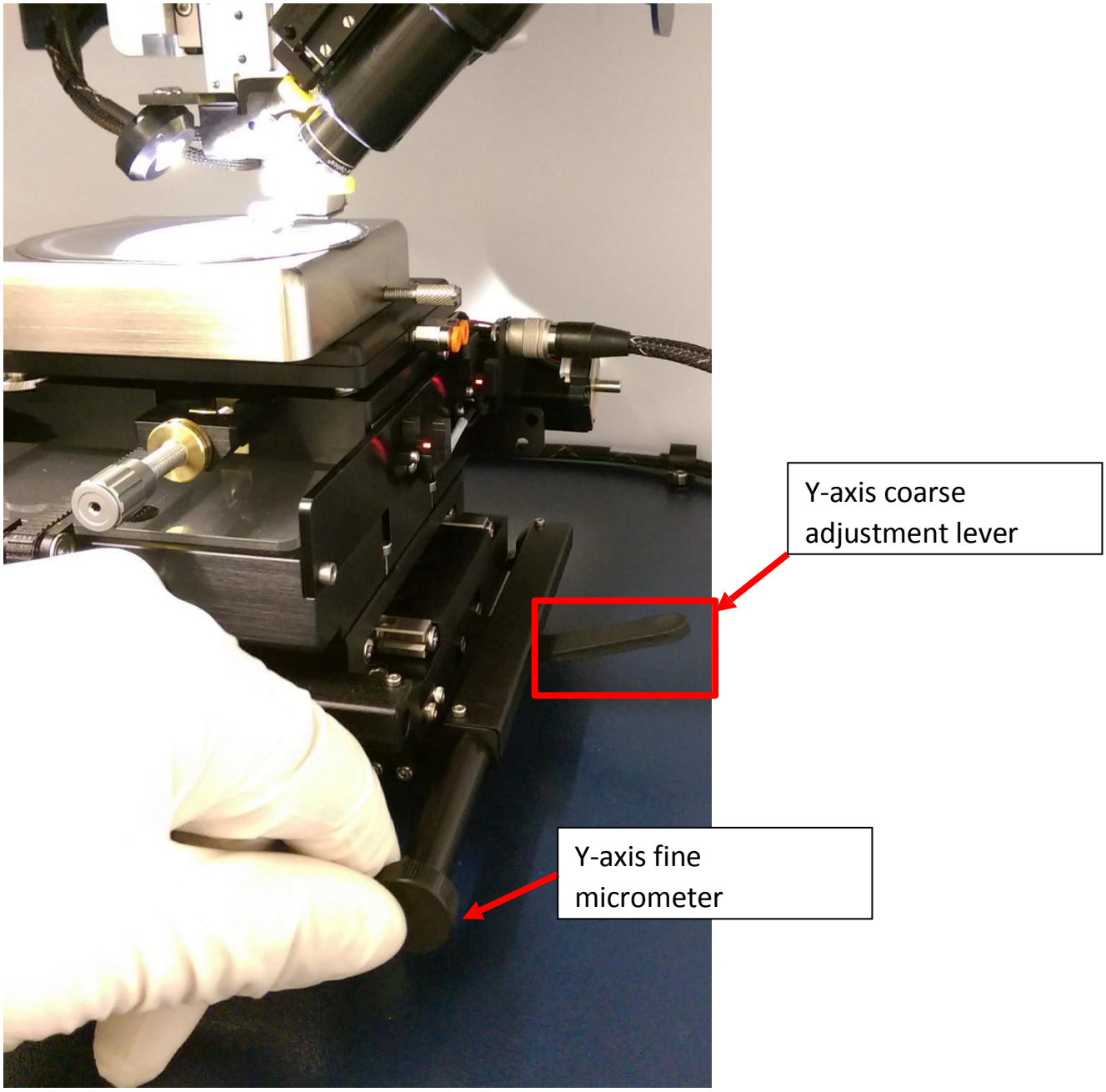
Ensure the stylus is not touching the sample surface, if it is press the **Tower Up** button.

The Camera display should look like this figure before adjusting the sample

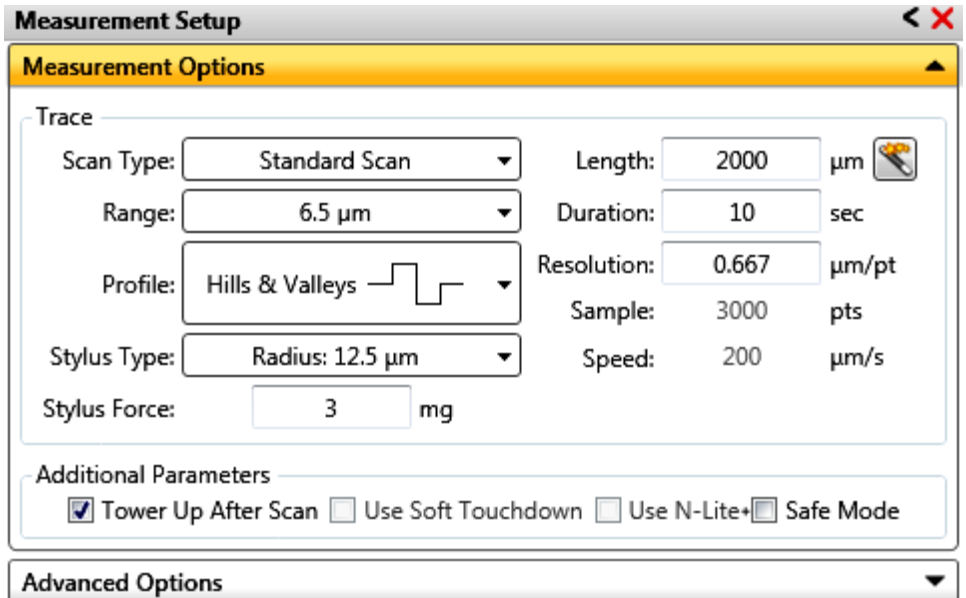


Position the scan start site by using the X-Y positioning levers and micrometers as shown:





Press **measurement set up** and define measurement parameters



Scan Type: Select **Standard Scan**

- **Standard Scan:** A normal scan type in which the scan is performed across the surface of a sample.

  The software has other options, but the machine is limited to the standard scan

Range: Enter a value that indicates vertical resolution of the scan. When measuring extremely fine geometries, the 6.5 um range provides a vertical bit resolution of 0.1 nm. For general applications, the 1.0 nm vertical resolution of the 65.5 um range is usually adequate. When measuring thick films or very rough or curved samples, select the 524 um range with 8.0 nm resolution.

Profile: Select from the following:

- **Valleys:** Provides 90% of the measurement range below the zero horizontal grid line. This option is used primarily for measuring etch depths.
- **Hills and Valleys:** Provides 50% of the measurement range above the zero horizontal grid line and 50% below. This option is used in most applications, especially if the surface characteristics of the sample are not well known, or if the sample is out of level.
- **Hills:** Provides 90% of the measurement range above the horizontal grid line. This option is used primarily for measuring step heights.

Stylus Type: Select the currently installed stylus type: **12.5 um**

Stylus Force: Enter a value between 1 mg and 15 mg. When measuring softer materials (photoresist, pdms, etc) uses the lower values closer to 1mg. When measuring tougher materials use a larger force closer to 15mg to get a more accurate reading of the surface features.

Length: Enter a scan length between 50 um and 55,000 um (55 mm) for a non-stitched measurement.

Duration: Enter amount of time it will take to complete a given scan. Scan duration, in conjunction with scan length, determines the horizontal resolution of a scan. For most applications, a 10 – 20 second scan provides adequate resolution and throughput.

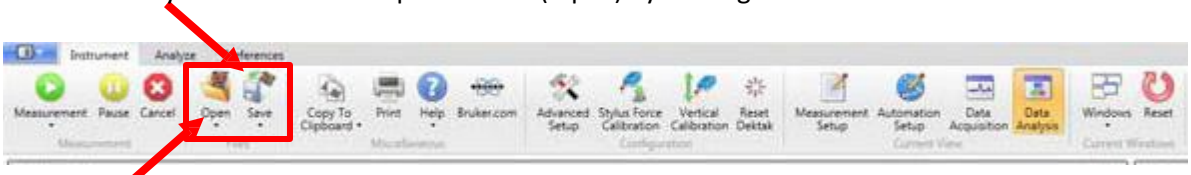
Resolution: Enter the horizontal resolution for the scan length and scan duration. The scan resolution is expressed in um/sample, indicating the horizontal distance between data points.

Sample: Indicates the number of data points that the system should take on the sample during a measurement.

Speed: Indicates the scan speed in units of um/s. A slower scan generally indicates for more accurate results.

Tower Up After Scan: Select this check box to make the DektakXT stylus profiler automatically raise the tower to a safe position after each scan.

You can **save** your measurement parameters (.opdx) by clicking **save**

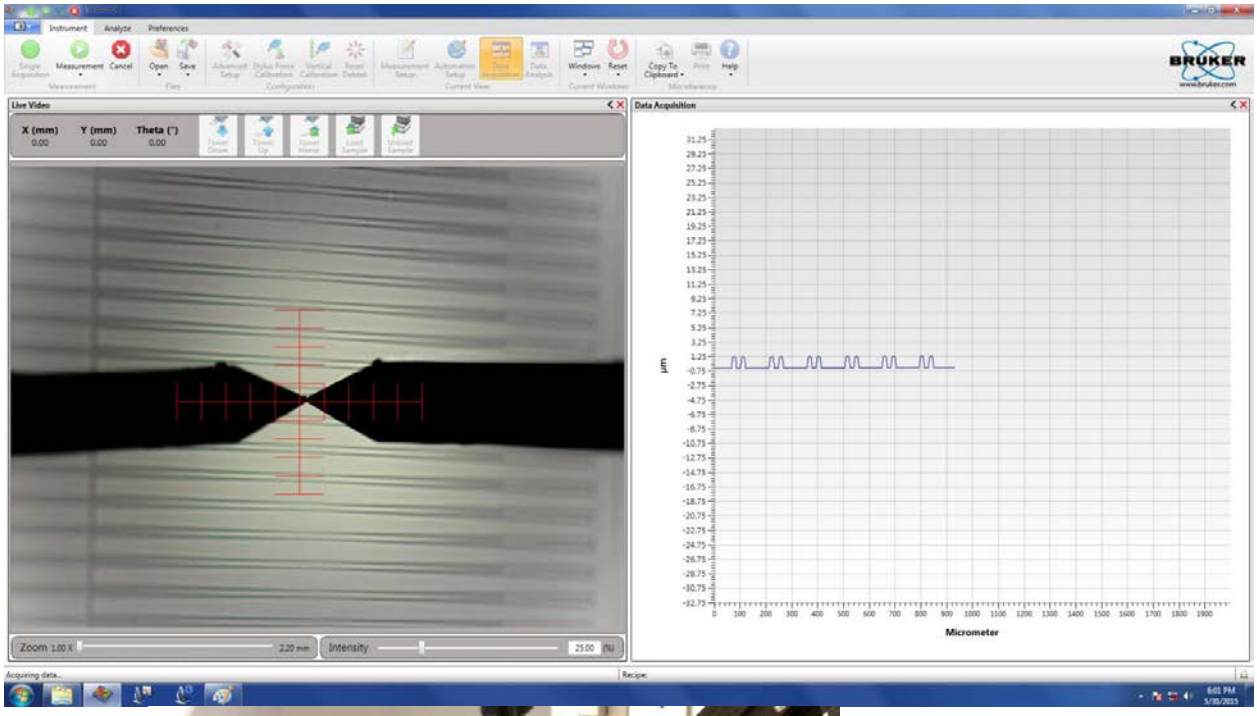


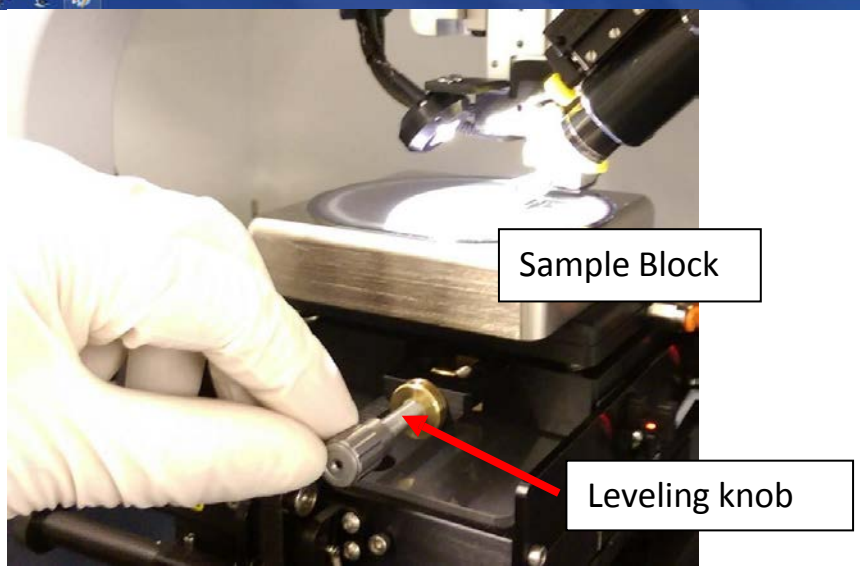
Or **open** an existing recipe

1.3 Taking a measurement

Click on **measurement**

Data acquisition window will appear to show the live progress of the scan. Use this time to level the stage as needed

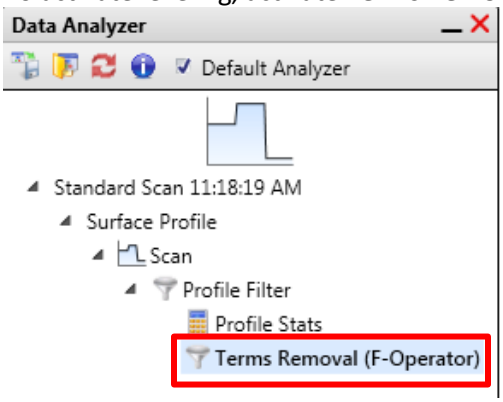




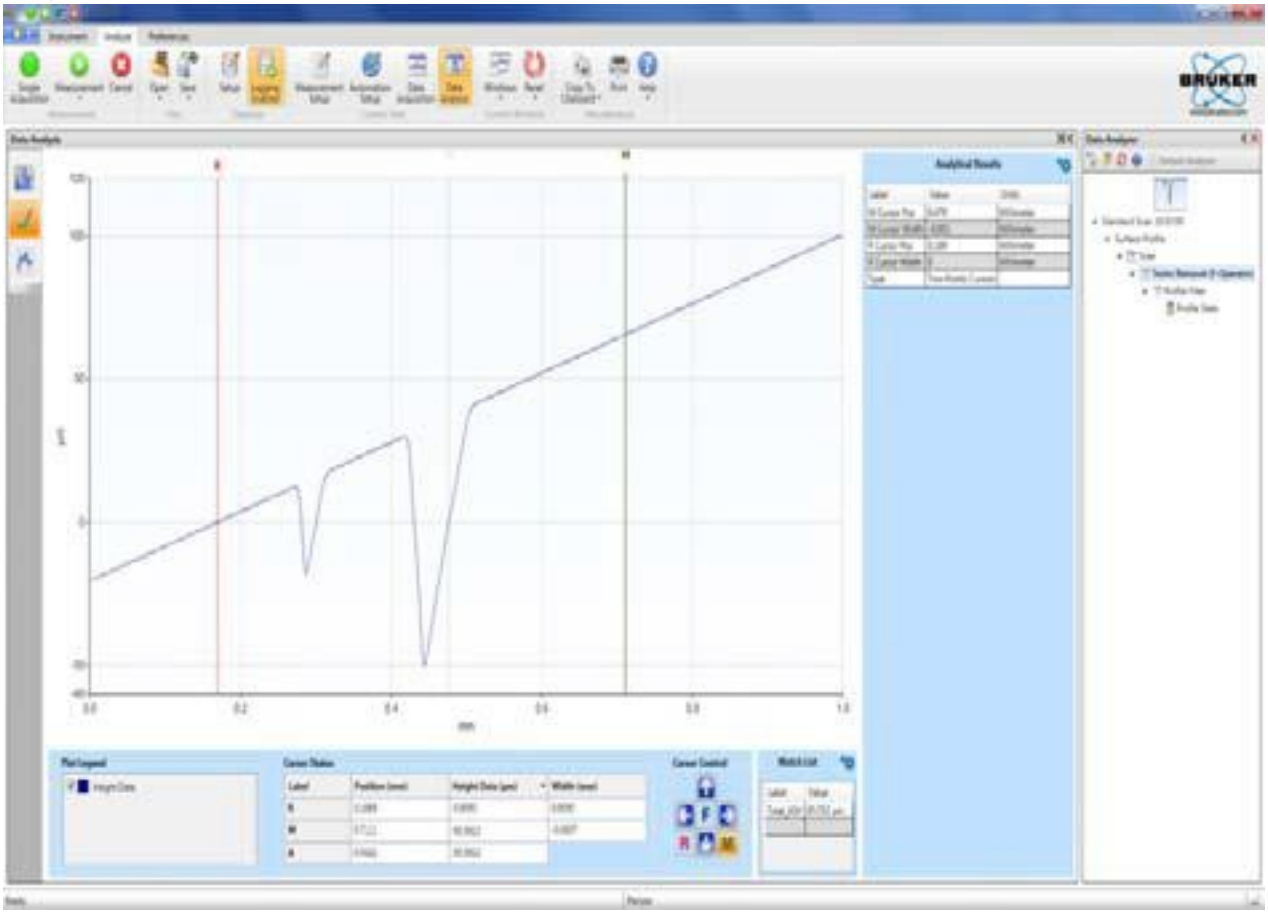
R. Ravichandran 07/2015 v.1

1.4 Analysis

To activate leveling, activate **Terms Removal (F-Operator)** in the Data Analyzer window on the right.



Then place the two cursors (R and M) on two points on the graph that you know to be flat on your sample, right-click, and click **Level Two Point Linear.**



When you proceed to a height measurement, place the cursors (R & M) on the two points you want to measure

Information about the width and depth of the channel is present in the final data analysis page. The red box highlights reference and measurement cursors, as well as the calculated Δ for the step height.

1.5 Shutting down the system

After taking your measurements, click on the icon "**Measurement setup**", click **Tower Home** button**,** and remove your sample from the block.

Leave the system **on** and the Vision 64 Software **open** to the measurement set up menu with the camera display

Disable Dektak XT from Badger

2.0 System Overview

2.1 Capabilities

- Contact profilometer with 12.5um radius diamond tipped stylus
- Manual sample positioning stage with 101.6 x 101.6mm (4 x 4 inches) of X-Y translation
- Manual stage leveling
- Two-point cursor software leveling
- Vertical range 1 mm, with ~5A resolution (may be limited by stylus geometry)
- Scan distances of 55 mm (2.16 inches)
- Force range 0.1 to 3mg
- Compatible with 6'' to wafer pieces up to 50 mm (1.9 inches) thick
- Color camera: 1 to 4mm FOV
- Vision 64 software for operation, measurements, and analysis of the Dektak XT

2.2 System Mechanism

The DektakXT system takes measurements electromechanically by moving a diamond-tipped stylus over the sample surface according to a user-programmed scan length, speed, and stylus force (Fig 1.2). The stylus is linked to a Linear Variable Differential Transformer (LVDT), which produces and processes electrical signals that correspond to surface variations of the sample. After being converted to a digital format, these surface variations are stored for display and analysis. The factors that affect the resulting measurement data will be discussed in more detail in section 2.

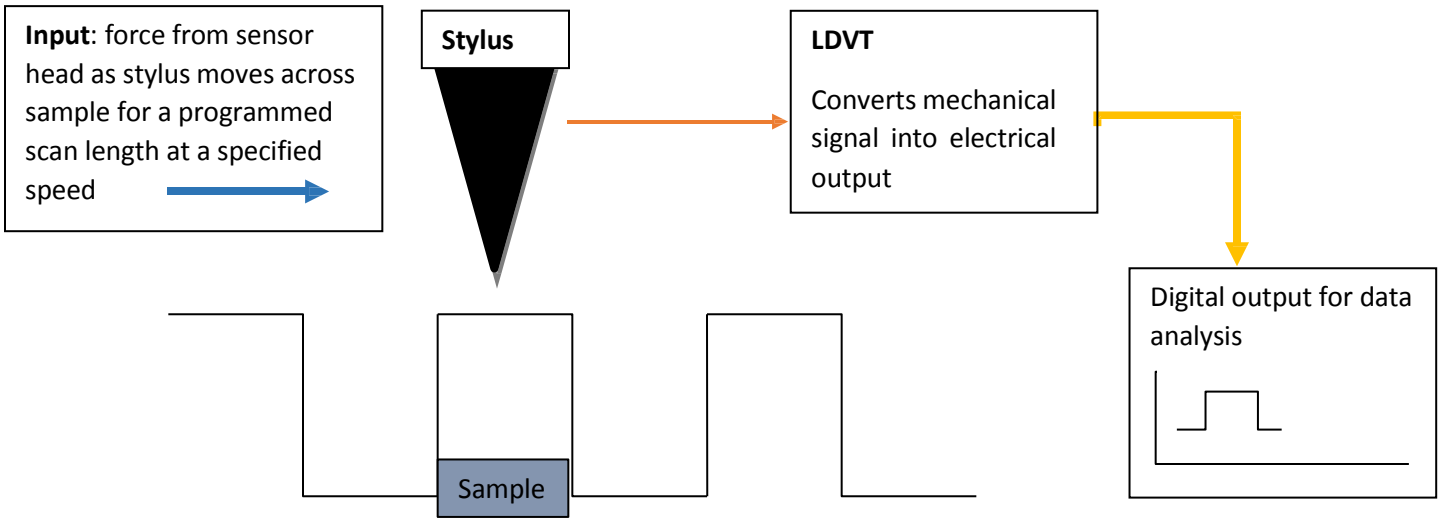


Figure 1.2 Describes an overview of the profilometer measurement mechanism during data acquisition.

The Vision64 application calculates and displays the results of user-selected analytical functions for measuring, step height, surface texture, and other parameters to characterize the profile data. For example, the ASH (Average Step Height) analytical function calculates the step height by taking the difference at two marked points. The features of the Vision64 software will be described in more detail throughout this manual in subsequent sections.

2.3 System Components: Hardware

As shown in Figure 1.3, the DektakXT stylus surface profiler system contains all of the mechanical, electrical, and optical components for sample positioning, sample viewing, and scanning/measurement. The tower assembly of the system is detailed in Figure 1.4: USB video color camera, LED illuminator, and a sensor head that magnetically holds the stylus assembly and contains the feedback mechanisms required to track stylus movements as it rides over the sample surface. Lastly, Figure 1.5 shows the components of the Emergency Machine Off box (EMO box) which includes the power on and power off buttons, along with an emergency off button. After the emergency off buttons has been depressed, the power cannot be returned to the system until it has been released by turned the knob clock-wise by one-eighth turn.

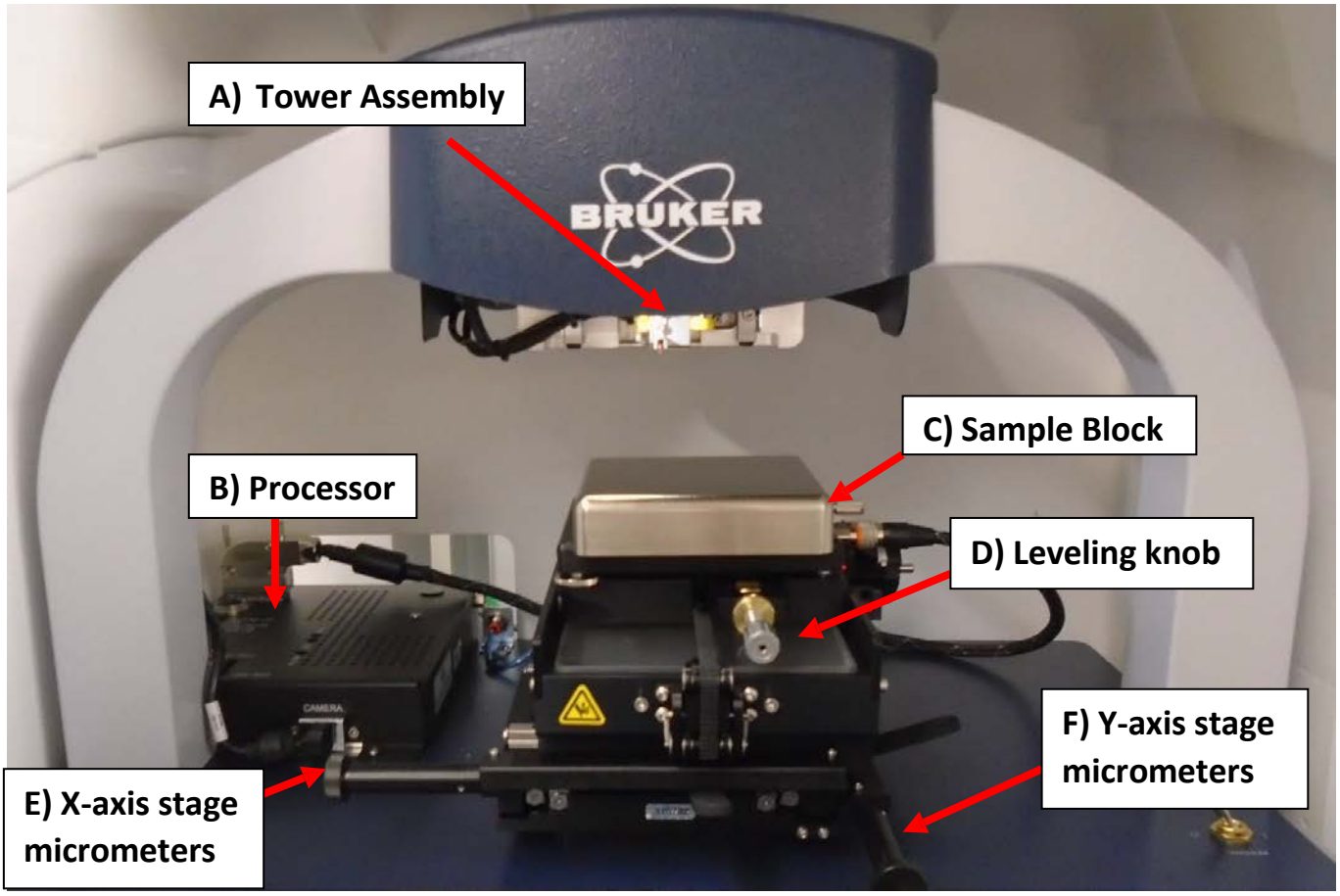


Figure 1.3. Dektak XT hardware components. A) Tower Assembly: contains critical sensor equipment and is currently shown in its home position. B) Processor: houses connections between the tool and the computer C) Sample Block: where the sample is placed D) Leveling Knob: To adjust for any tilt during measurements E&F) Stage Micrometers: To adjust the sample position

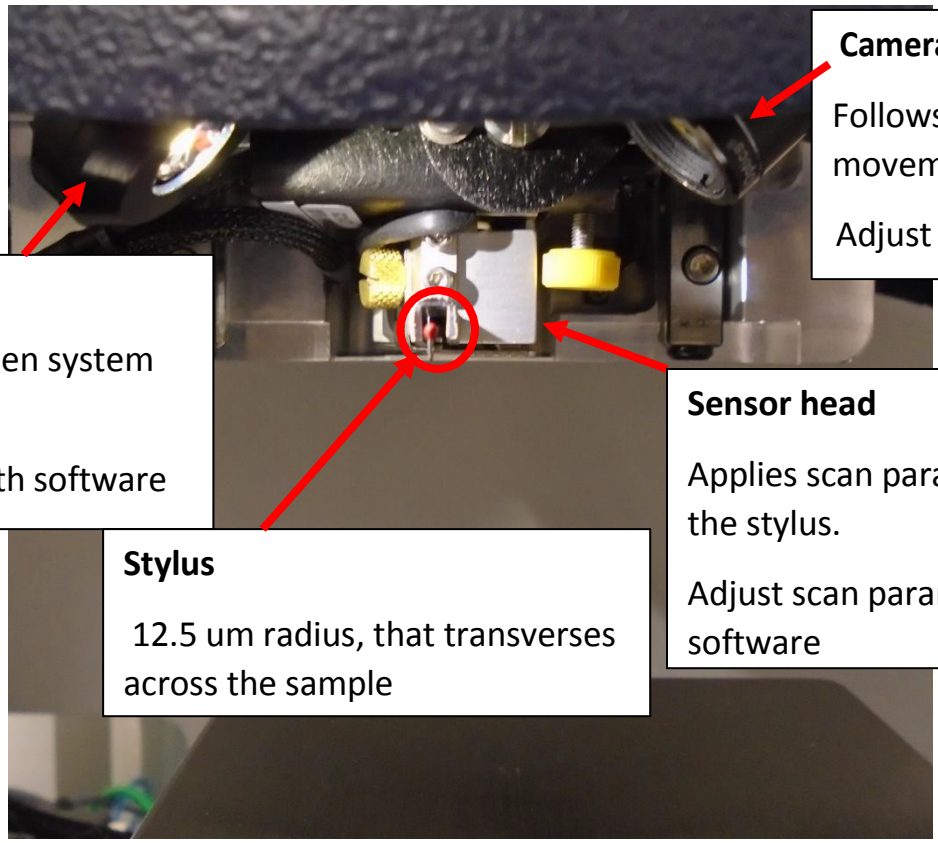


Figure 1.4. Overview of the tower assembly components. The Camera and light are angled to the stlyus, and follow its movements. The sensor head and stylus are the heart of the system as they make contact with the sample on the sample block.

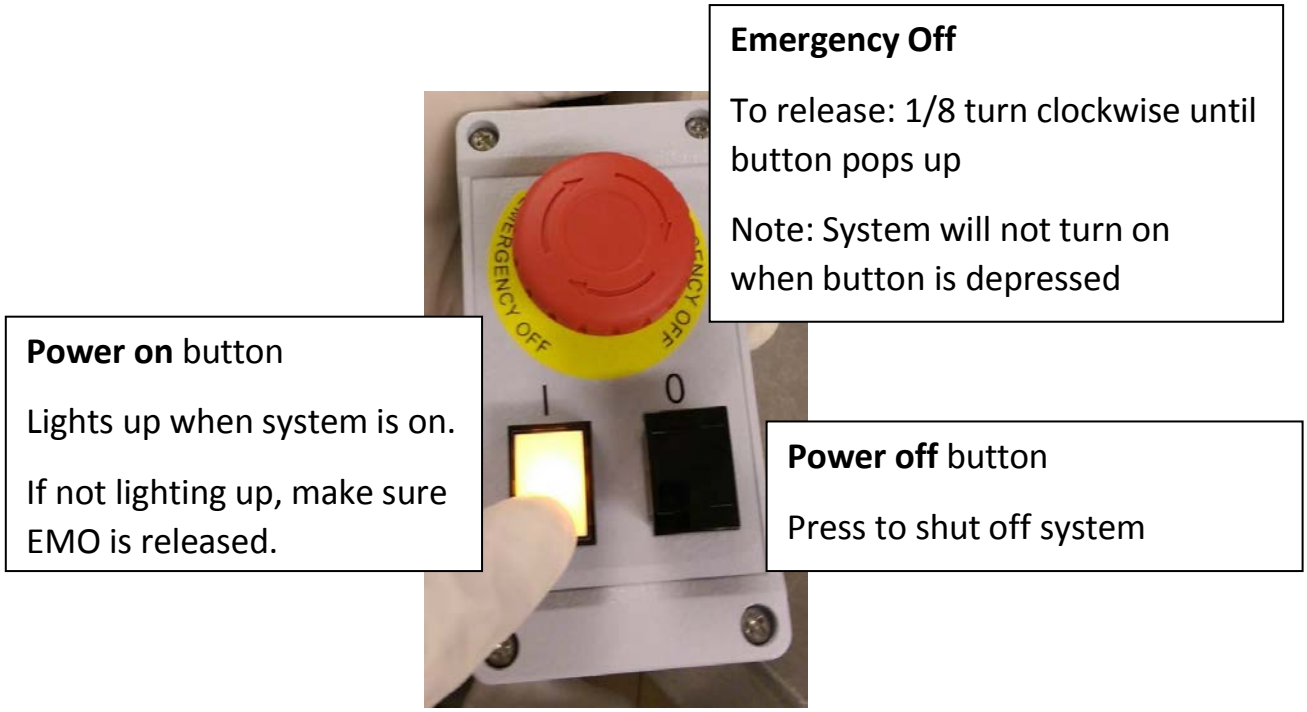


Figure 1.5. EMO box for Dektak XT, also includes the power on and power off buttons for the system

2.4 System Components (software)

The Dektak XT is controlled and calibrated by using Bruker's Vision 64 software on a Windows 7 OS (Fig 1.6). It allows you to adjust the system illumination, position the stylus, program scan parameters, and analyze the results. The main controls to be concerned on the software are the following menus: measurement setup (Fig 1.7), data acquisition (Fig 1.8), data analysis (Fig 1.9). In section 3, for the standard operating procedure of the system, these menus will be discussed in more detail.

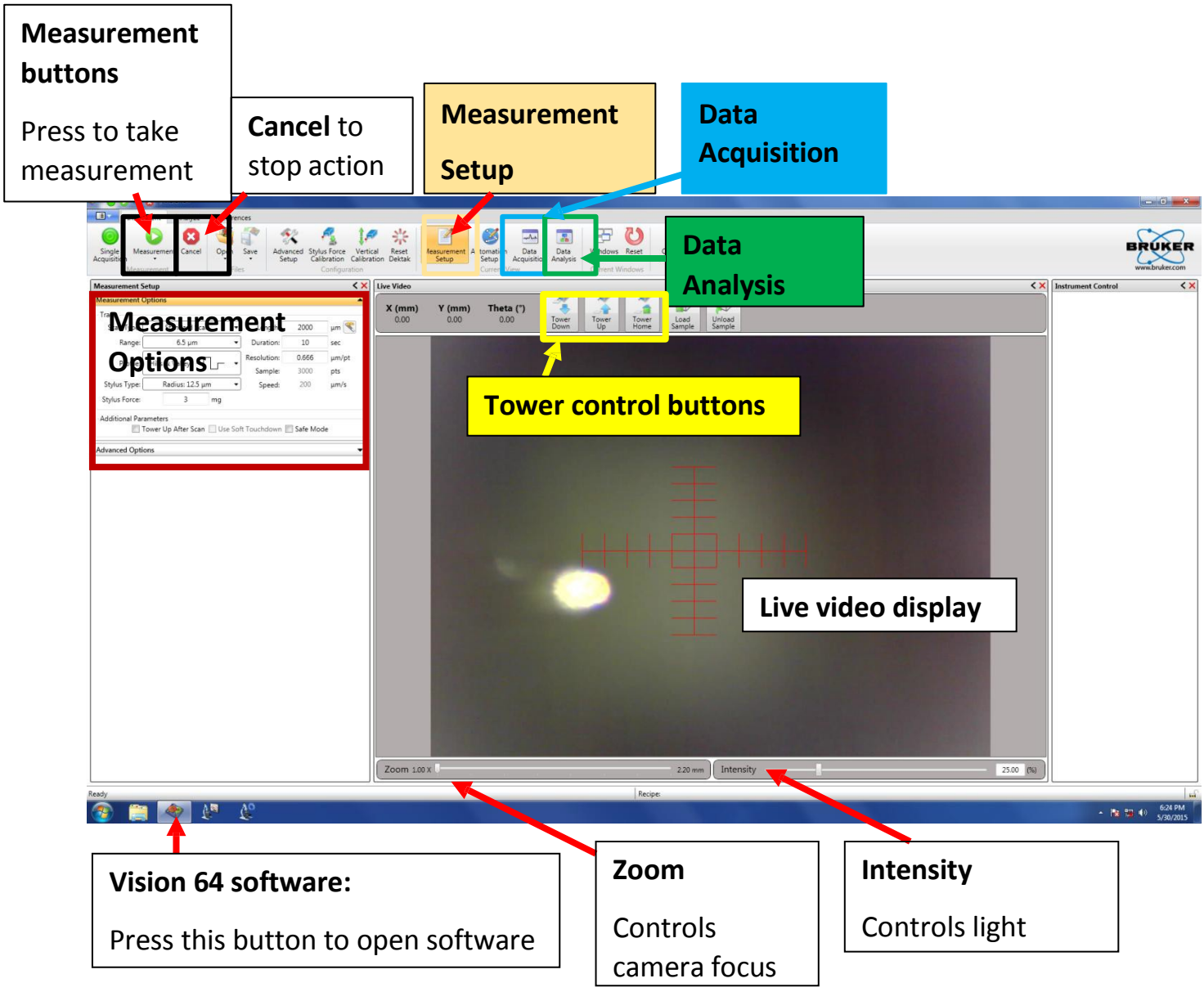


Figure 1.6. An overview of the Vision64 components as the Dektak XT initializes. The tower assembly is in the home position and away from the sample. Highlighted are the key menus of the software.

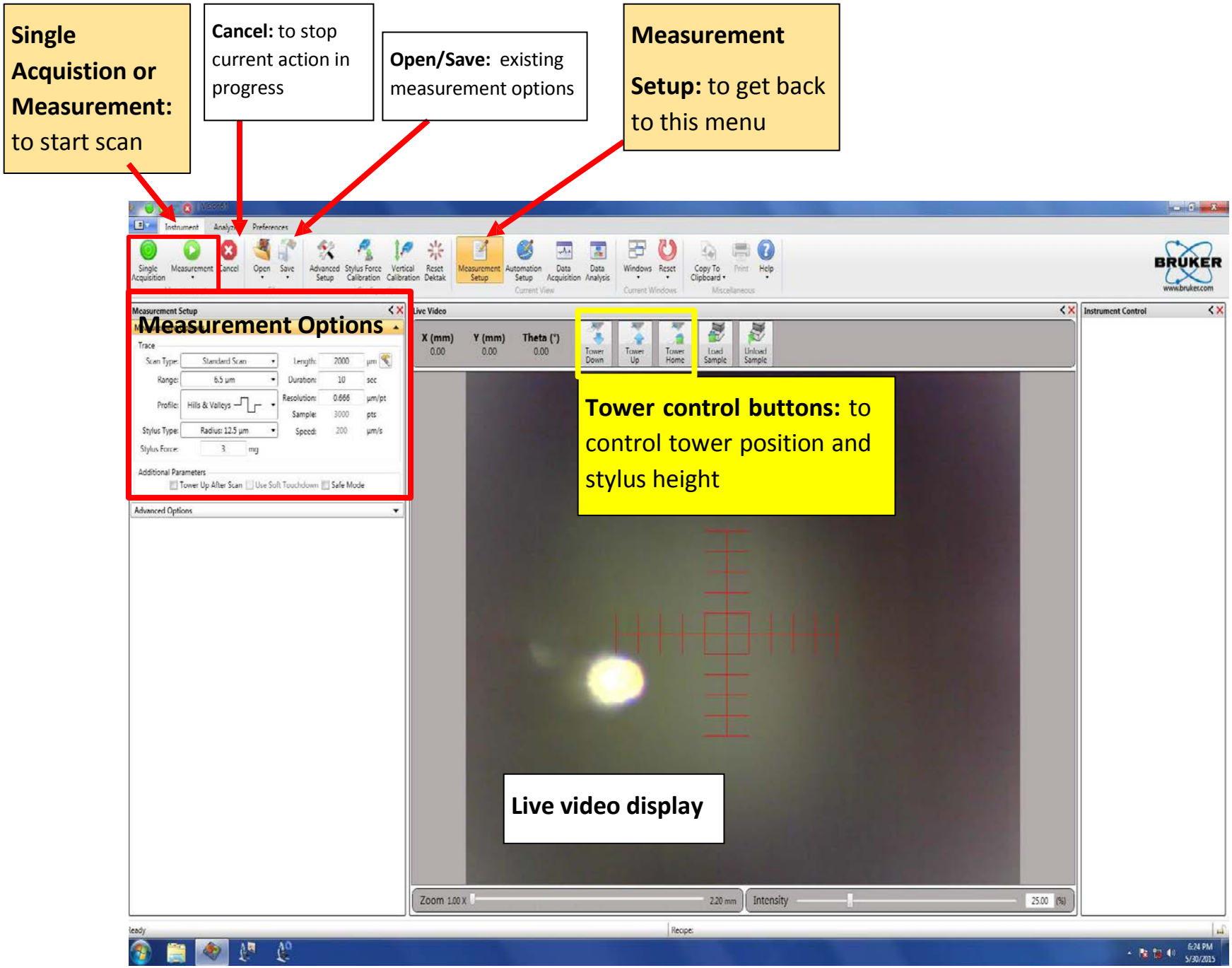


Figure 1.7. The measurement set up menu critical for setting up the measurement options and various scan parameters. Additionally, use the video display to view your features as you adjust the stage position with the micrometers.

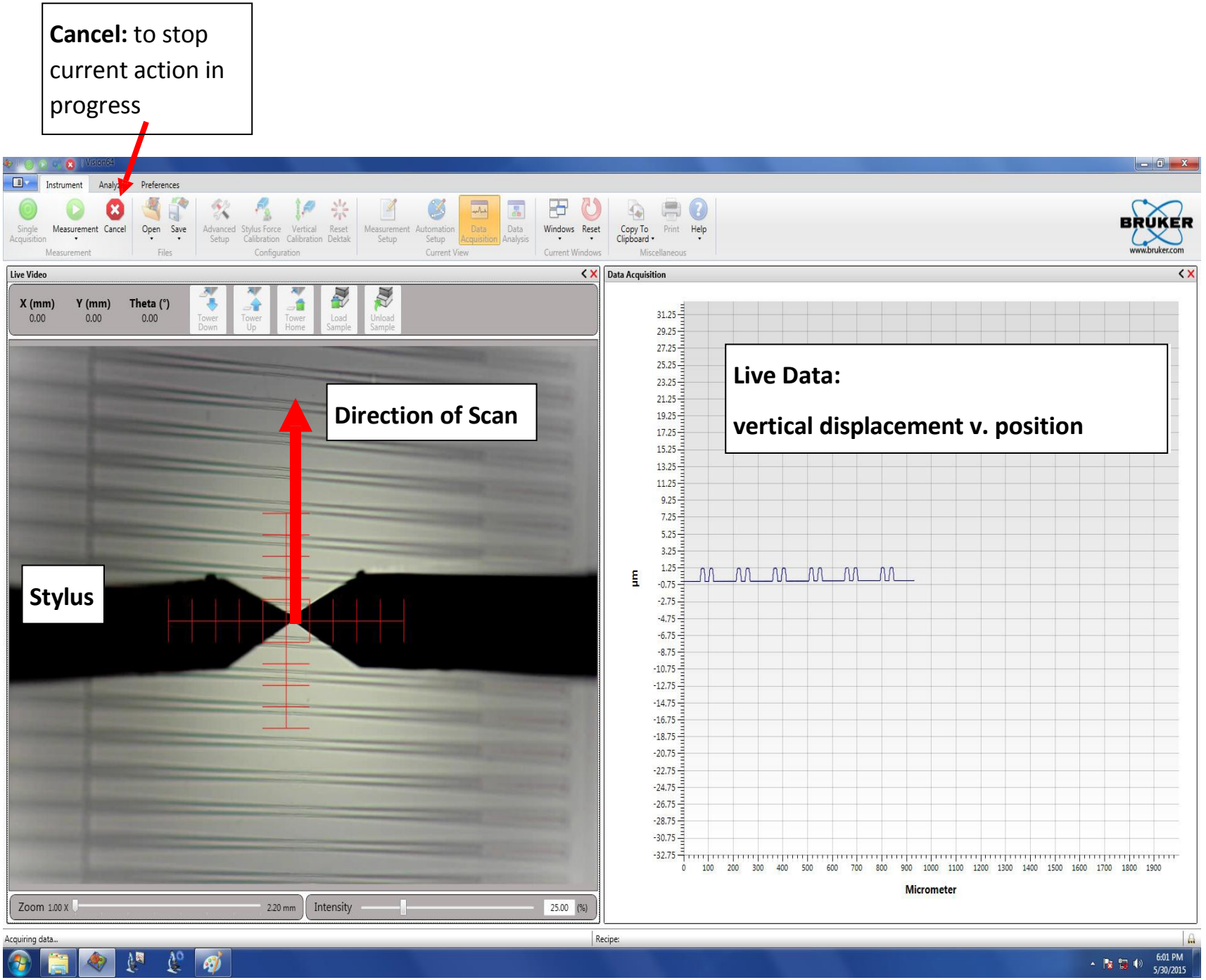


Figure 1.8 The Data Acquisition menu provides live information as the stylus scans across the sample and the measured vertical displacement. The sample measured is leveled.

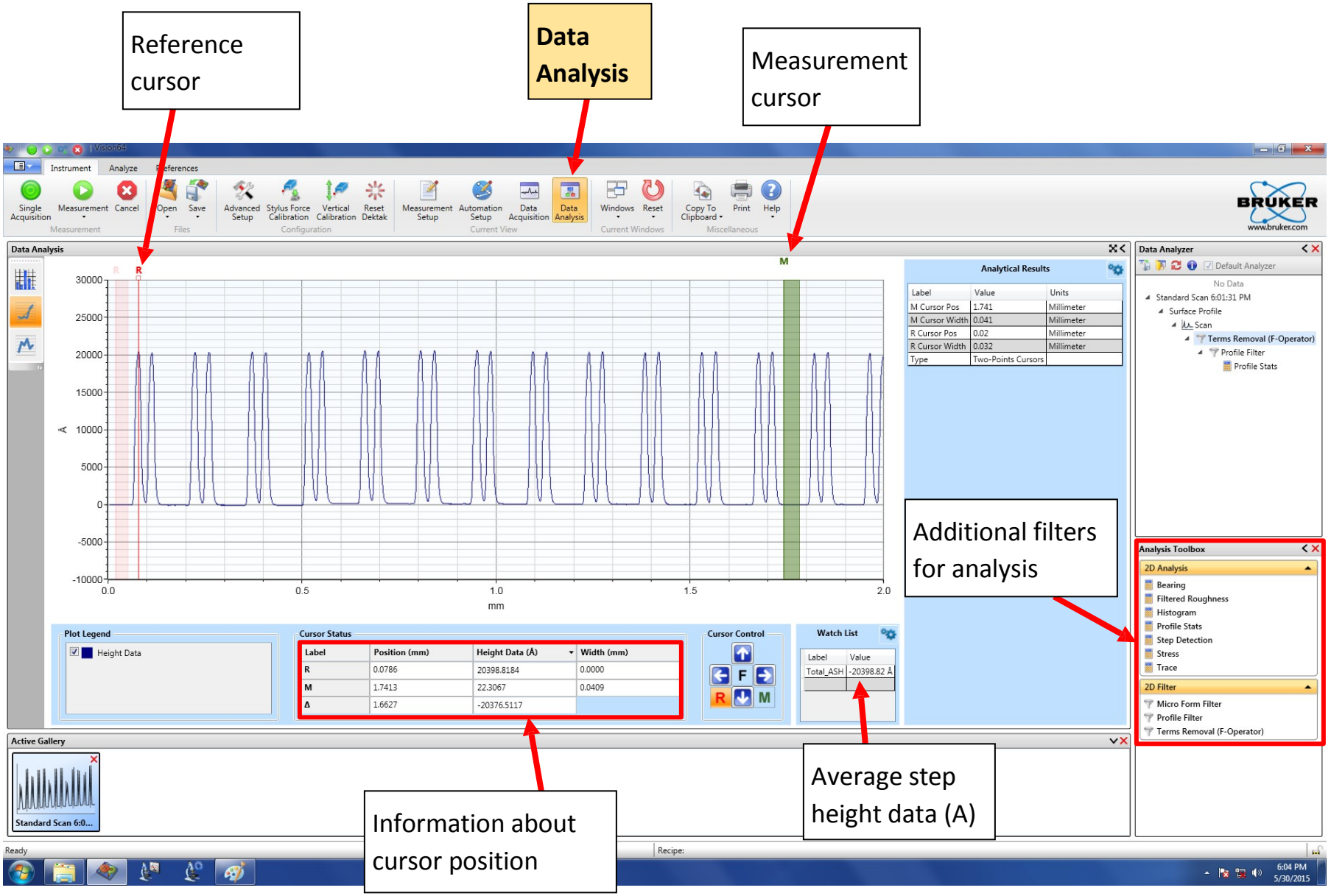


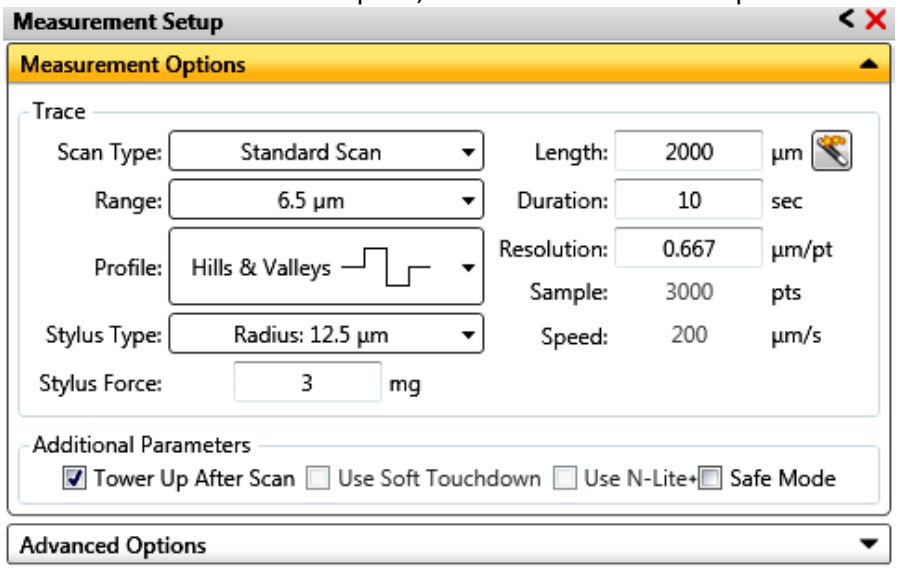
Figure 1.9 The Data Analysis menu appears after a scan has completed. At this point, the data can be leveled via software controls and the step heights can be measured in angstroms under ASH. The horizontal positions of the reference and measuring markers can also be found. Lastly, other filters and software controls can be applied to the data set.

3.0 Mechanism

The Dektak XT is a profilometer that provides quantitative data about the sample's surface (step heights, roughness, etc) by using a contact measurement technique. Measurements are made by a diamond tipped stylus moving laterally in contact with a sample across a specified distance with a specified force. The measurements of these vertical features range from 6.5 microns to 1mm with a resolution of ~0.5 nm across a variety of substrate surfaces. There are key factors that must be considered in order to obtain reliable, consistent, and accurate results. These are more critical but complementary to the software analysis functions: choosing appropriate scan parameters, leveling the stage, and the limitations of the stylus geometry.

3.1 Scan Parameters

Under the Measurement set up tab, there is a Measurement options section on the left-side



Scan Type: Select **Standard Scan**

- **Standard Scan:** A normal scan type in which the scan is performed across the surface of a sample.

Other options are available in the software, but the machine is limited to standard scan

Range: Enter a value that indicates vertical resolution of the scan. When measuring extremely fine geometries, the 6.5 um range provides a vertical bit resolution of 0.1 nm. For general applications, the 1.0 nm vertical resolution of the 65.5 um range is usually adequate. When measuring thick films or very rough or curved samples, select the 524 um range with 8.0 nm resolution.

Profile: Select from the following:

- **Valleys:** Provides 90% of the measurement range below the zero horizontal grid line. This option is used primarily for measuring etch depths.
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Stylus Force: Enter a value between 1 mg and 15 mg. When measuring extremely soft materials (photoresist, pdms, etc) uses the lower values closer to 1mg. When measuring tougher materials use a larger force closer to 15mg to get a more accurate reading of the surface features.

Length: Enter a scan length between 50 um and 55,000 um (55 mm)

Duration: Enter amount of time it will take to complete a given scan. Scan duration, in conjunction with scan length, determines the horizontal resolution of a scan. For most applications, a 10 – 20 second scan provides adequate resolution and throughput.

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Sample: Indicates the number of data points that the system should take on the sample during a measurement.

Speed: Indicates the scan speed in units of um/s. A slower scan generally indicates for more accurate results. When measuring taller features, be sure to choose a slower scan speed.

Tower Up After Scan: Select this check box to make the DektakXT stylus profiler automatically raise the tower ti a safe position after each scan.

Use Soft Touchdown: If your system includes the 3D Mapping Option, select this check box to make the DektakXT stylus profiler increment the stylus force up to the specified value. This causes the stylus to descend more slowly, thus minimizing the possibility of scratching the sample.

3.2 Leveling the Stage

The closest possible **manual** leveling ensures the best profiler performance, and will help gather the most accurate data.

Level the sample-positioning stage by turning the leveling knob below it (Fig 2.1). As you perform manual stage leveling, follow these guidelines:

- To view the effect of leveling on the profile trace in real time, perform stage leveling while a scan measurement is in progress.
- To verify that the maximum possible level has been obtained, position the cursors so that they intersect the same horizontal plane.
- If the profile trace is extremely off-level, change the measurement range to 5240kÅ under the measurement options. Level the trace, change to the intermediate range, and then repeat the procedure until the stage is leveled.

The best level is achieved by using the 6.5kÅ range.

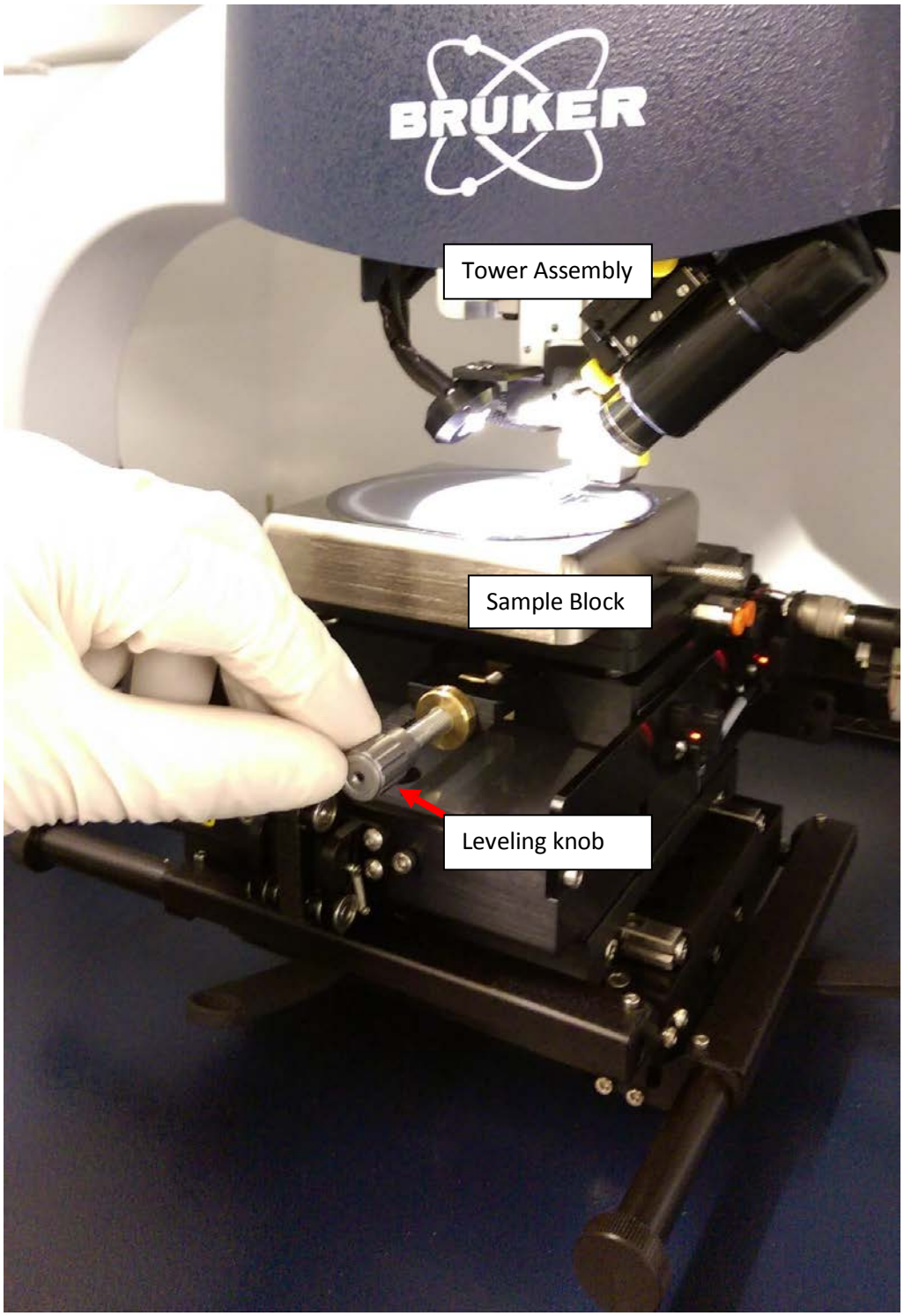

Figure 2.1. Adjust the leveling knob under the sample block to achieve high resolution profilometry

3.3 Limitations of the stylus

The stylus shape may have a significant impact on the measurement data as it is the component that makes direct contact with the sample's surface. The following section provides information from **Bruker** about the geometry of the stylus and its limitations. This stylus tip terminates in a 45˚ cone with an end radius of 12.5um, as seen in Figure 2.2. When measuring samples with narrow trenches (Fig 2.3), the stylus is unable to correctly verify the widths or reach the bottom of the trench. This is because the width of the stylus is caught at the opening. If your sample has many narrow trenches, please measure across a larger more open area to get a more accurate reading of the film thickness.

In order to prevent excess wear or damage to the stylus:

- Use the camera to verify that no features on the surface exceed the height of the stylus. Lateral contact between the stylus and the sample is the primary cause of damage
- When measuring taller features (> 10um), use a slower scan speed to limit sudden forces on the stylus
- For more information, please refer to Bruker's application notes on Stylus Profilometry: **Dektak Stylus Capabilities: How to Choose the Correct Stylus for Any Application**

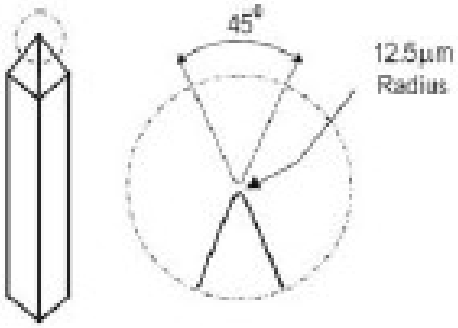

Figure 2.1. Shows the dimensions of the diamond-tipped stylus as it terminates at a 45 cone with 12.5 um radius at the end. **Credit: Bruker**

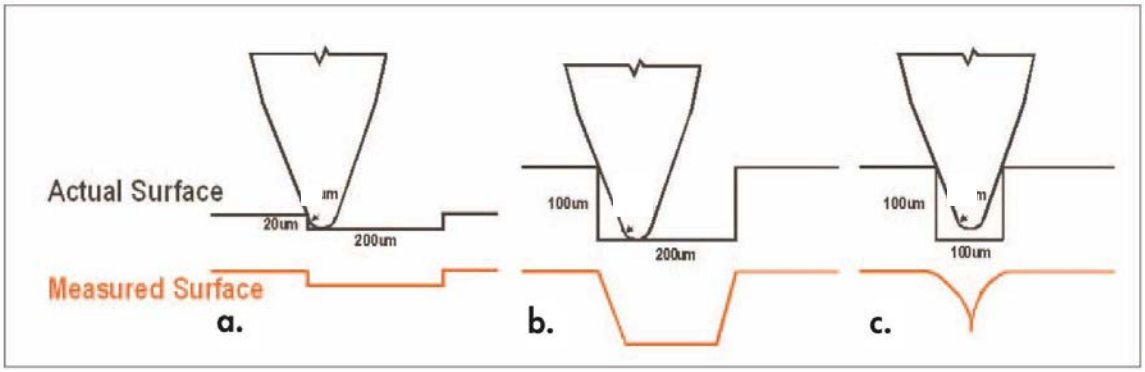

Figure 2.2. The geometry of the stylus must be considered as it creates limitations of the accuracy of the measurements. The 12.5 um stylus can easily measure larger trenches (a) but cannot accurately measure the width (b) and height (c) as the trench aspect ratio increases. **Credit: Bruker**