

SNOM Contact Configuration

This document describes the principles of Scanning Nearfield Optical Microscopy (SNOM) in contact mode followed by the WITec Control software configuration for Scanning Nearfield Optical Microscopy (SNOM) in contact mode. The beam path and the step by step alignment procedure can be found in Sections 3 and 4.

1 Principles of Scanning Near-field Optical Microscopy

The resolution in classical (as well as confocal) microscopy is limited by the wavelength of the excitation light. This was investigated in detail by ABBE around 1890. According to him, at least the first diffracted order of an object (e.g. a grating) has to be captured by the lens system to resolve the object in image space. This is the reason for the importance of the numerical aperture for the resolution of an optical system.

In a perfect lens system with circular aperture, the image of a point object will be an Airy-pattern. On integrating the irradiance, one finds that 84% of the light arrives within the central spot and 91% within the bounds of the second dark ring.

If one brings two point objects close together, so that the maximum of the first Airy pattern is at the first minimum of the second, we are still able to resolve the two spots. This is the Rayleigh limit and the resolution defined by this (arbitrary) criterion is:

$$\Delta x = 0.61 \cdot \frac{\lambda}{NA}$$

where λ is the wavelength of the light and $NA = n \cdot \sin \alpha$, the numerical aperture of the lens system, while n is the index of refraction of the surrounding medium.

The maximum NA for commercially available objectives is about 0.95 when working in air and about 1.4 for oil immersion objectives (sample immersed in oil).

From this formula, one can see that the maximum resolution for conventional microscopy is

- $2/3 \cdot \lambda$ in air and
- $1/2 \cdot \lambda$ using immersion oil.

Using confocal microscopy this resolution can be further improved to

- $1/2 \cdot \lambda$ in air and
- $1/3 \cdot \lambda$ using immersion oil.

These values are only valid for optimum conditions, e.g. thin samples.

The only way to overcome the diffraction limit is to observe very close to the sample in the near-field regime (observer \leftrightarrow sample distance $\lambda/5$).

The idea was first proposed by SYNGE in 1928. He suggested using a metal plate with holes much smaller than the wavelength of light, to illuminate this with light from the back side and then scan this plate in close proximity across a sample. If the plate-sample distance is much smaller than the diameter of the holes, the resolution is limited by the diameter of the light source (holes) and not by the wavelength of light.

It was not possible at that time to prove this idea and it took until 1972 before ASH and NICOLLS could verify the theory with electromagnetic waves in the microwave range (3 cm wavelength, 0.5 mm resolution $\Rightarrow \lambda/60$). The first results in the optical regime were obtained by POHL and BETZIG (1986), who used pulled optical fibers and shear-force feedback for distance control.

The *alpha300 S* goes a step further and uses microstructured, cantilever sensors and beam deflection feedback (well known from AFM) for distance control. To take advantage of the high resolution obtainable with SNOM, one should consider the following points:

The maximum resolution is given by the aperture of the sensor, but this resolution is only possible in the near-field. Therefore, the distance between tip and sample should be less than the radius of the aperture (<50 nm for a 100 nm aperture), otherwise the resolution decreases. This resolution can only be obtained at the surface of a sample (one can not look inside the sample as in confocal microscopy).

As a result of the small distance between tip and sample there is always an interaction between topographic features and light emitted by the aperture, which gives rise to artifacts. The user should always be aware that these artifacts might be present. On the other hand, the importance of these artifacts should not be exaggerated.

A careful comparison of the optical image with the simultaneously obtained topographic image can help to identify artifacts. If one finds an optical feature at exactly the same position as a topographic step, one should be sceptical. Particularly if the change in optical contrast is only a few percent of the overall intensity.

If there is a topographic step, the distance between tip and sample changes as does the coupling of the electrical field (near-field) between them, which may cause a change in detected intensity.

Usually, the optical aperture is slightly shifted (50-150 nm) from the point of contact. This is due to the fact that the mechanical contact is somewhere at the rim

of the optical aperture. The hollow aperture is surrounded by a 100-150 nm thick layer of aluminium providing the mechanical contact. Therefore, a genuine optical contrast should show a shift between the optical and topographic images of 50-150 nm.

The preferable mode for near-field optical microscopy is transmission. In this mode, the light transmitted through the transparent (or fluorescing / luminescing) sample is collected by the detector and topographic artifacts are usually a minor problem.

In reflection mode, the light transmitted through the aperture and reflected from the sample surface is collected with auxiliary optics. In this mode, topography-induced artifacts are most likely and can even dominate the image. The reflection mode is most often used when the sample does not transmit the excitation light. In this case, the light transmitted through the aperture must cross the extremely small gap between tip and sample. If the tip is scanned across a topographic step, it is very likely that the detected light intensity would change and give rise to topography-induced artifacts. Here again, a careful comparison between topography and optical images is very helpful in distinguishing actual sample features from artifacts.

With the *alpha300 S*, the following near-field optical modes are possible:

- near-field transmission
- near-field fluorescence/luminescence transmission (using additional filters)
- near-field reflection (with the reflection mode upgrade)
- near-field reflection fluorescence/luminescence (with the reflection mode upgrade and additional filters)

All the above mentioned modes are described in this document. Additional modes are possible if the respective hard- and software extensions are added. These include:

- near-field spectroscopy in transmission and reflection configuration
- near-field in AC mode in transmission and reflection configuration
- confocal Raman microscopy
- atomic force microscopy (AFM) in contact, AC and (Digital) Pulsed Force Mode ([D]PFM)

2 WITec Control SNOM Contact configuration description

This description is intended to be used in combination with the WITec Control manual. The WITec Control manual contains the description of the full functionality of WITec Control, whereas this section indicates only which functionalities are included in this configuration. Please refer to the WITec Control manual for further details. The configuration-specific speed buttons, as well as the layout of the Control Window, will also be illustrated below.

The *SNOM Contact* configuration is used to perform SNOM contact mode measurements. During a SNOM contact mode measurement, data can be acquired using the following sequencers:

- Oscilloscope: displays the output channel of a photon counting device as a function of time similar to the display of an oscilloscope.
- Image Scan: acquisition of SNOM contact mode images.
- Line Scan: acquisition of distance curves along a line.
- Distance Curve: acquisition of distance curves at the current position.

The characteristics of the SNOM contact configuration are described in the following sections. The typical layout of the SNOM contact configuration is shown in Fig. 1.

2.1 Speed Buttons

The main menu contains, in addition to the standard WITec Project speed buttons, several speed buttons which provide quick access to microscope and controller functions used in this configuration. A short description of these speed buttons is given below.

Stop

This speed button is used to stop any sequencer.

Start Scan

With this button, the *Image Scan* sequencer is started.

Oscilloscope

Clicking with the mouse on this speed button starts the oscilloscope sequencer (WITec Control manual Section 3.5.11). A graph viewer showing the variation of the selected data source (channel) as a function of time is displayed.

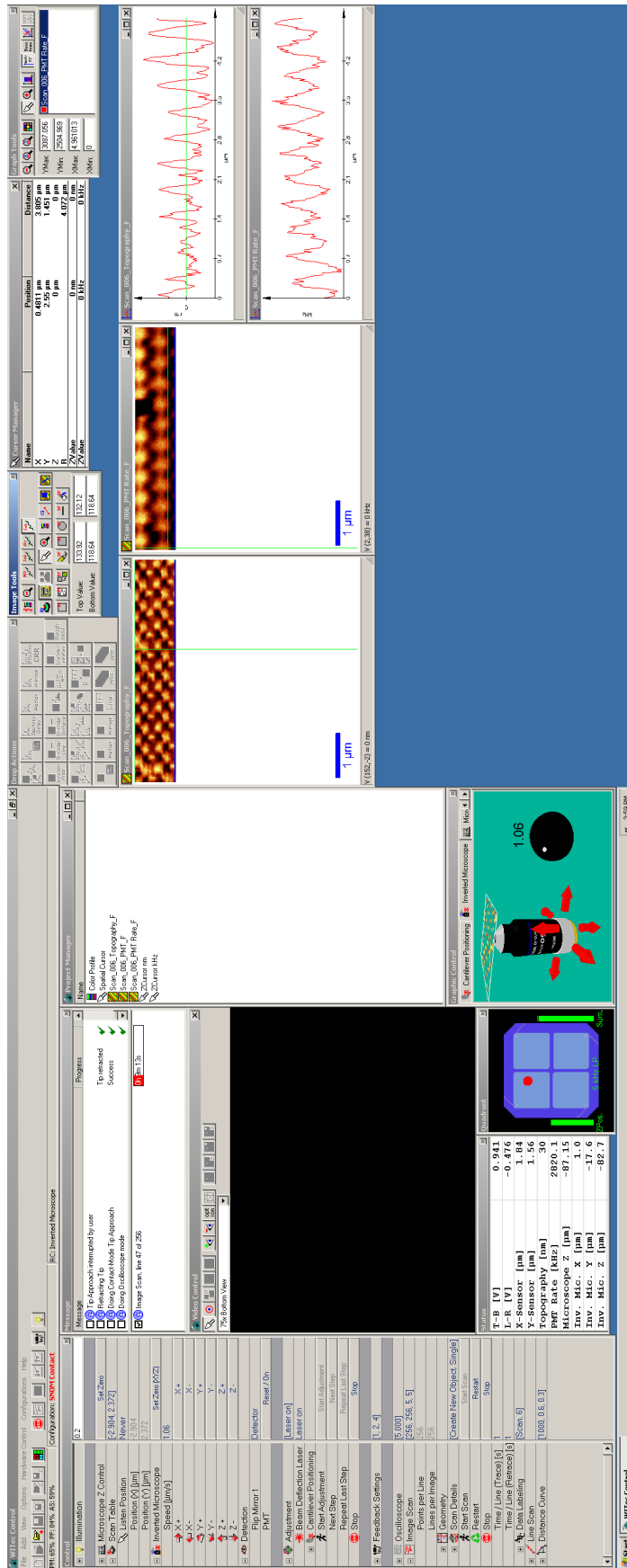


Fig. 1: Typical layout of the SNOM contact configuration.

In SNOM contact measurements, the readout of the photon counting device is typically displayed as a function of time. This signal is mainly used for the alignment of the system.

Tip Approach

This button is used to start the *Tip Approach* sequencer.

Retract Tip

A mouse-click on this speed button causes the tip to retract from the sample by the distance defined in the *Microscope Z Control* device under the parameter *Retract Distance* [μm].

P-I Control

Clicking with the mouse on this speed button will open the *Feedback Settings* in the Control Window.

Illumination

With this speed button, the white light illumination can be switched on and off. The brightness of the illumination is defined in the Control Window using the illumination device.

2.2 Control Window

The Control Window described in Chapter 3 of the WITec Control manual is customized for SNOM contact mode measurements. The reduced tree structure of the Control Window in the SNOM contact configuration is shown in Fig. 2.

Devices and sequencers are grouped in this configuration based on functionality. Each device and sequencer contains the list of parameters which are used during a SNOM contact mode measurement. The following devices and sequencers are accessible in the SNOM contact configuration.

2.2.1 Setup and Control

In this section, the software controls for the hardware components (called devices in WITec Control) and the software controls for data acquisition processes (called sequencers) are listed and briefly described. These controls are used for microscope setup and measurement control.

Illumination

This device is used to control the white light illumination of the tip/sample video image. A detailed description of the parameters used to control the white light illumination is given in the WITec Control manual Section 3.4.2.

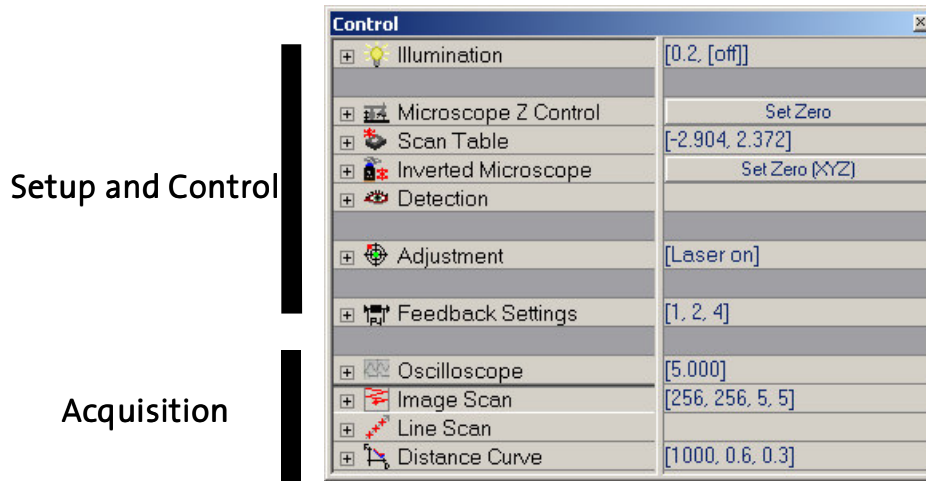




Fig. 2: Control Window for SNOM contact configuration.


The illumination speed button located in the main menu uses the brightness parameter set here.


Microscope Z Control

The microscope Z control is part of the scan table device (WITec Control manual Section 3.4.3). In this configuration, the *Move Mode* is automatically set to *Z for Feedback*, allowing the control of the Z-axis of the scan table through the PI controller. Therefore, Microscope Z control refers only to the movement of the microscope Z-stage.

HINT The microscope Z-stage can be controlled via the remote control (see WITec Control manual Section 3.4.1), the Graphic Control Window (see WITec Control manual Chapter 8) or using the parameters *Speed*, *Move Up* , or *Move Down*  listed in the Control Window.

In addition, the microscope Z-stage is used for the safe tip approach (WITec Control manual Section 3.5.8). All parameters of the tip approach sequencer are preset to appropriate values to guarantee a safe tip approach in this configuration.

HINT The speed button from the main menu () can be used for safe tip approach.

The *Retract Distance* [μm] parameter defines the distance of the upward movement of the microscope Z-stage if the *Retract Tip* button () is activated.

Scan Table

In this configuration, the manual movement of the scan table is reduced to a planar movement (X-Y) to allow precise positioning within the scan-range. For a detailed description of the scan table, please see also the WITec Control manual Section 3.4.3.

Inverted Microscope

The parameters required to control the inverted microscope of the alpha300 S are listed in this group. A detailed description of each parameter can be found in the WITec Control manual Section 3.4.9.

HINT The inverted microscope can be controlled via the remote control (see WITec Control manual Section 3.4.1), the Graphic Control Window (see WITec Control manual Chapter 8) or using the parameters listed in the Control Window.

Detection

In this group, all parameters required to control the optical devices of the inverted microscope are listed. These devices are:

Flip Mirror

The flip mirror of the inverted microscope can guide the light signal either to the video camera or to the photon counter (typically a PMT). The position of this mirror can be selected from a drop down menu with this parameter.

PMT

The PMT can be switched on using the button. Generally this will only be necessary if the system has shut down the PMT due to excessive count rates. In normal operation, the system automatically turns the PMT on and off as required by the measurement.

Filter Wheel

This menu entry will only be visible if the filter wheel has been included in the configuration of the instrument.

From the drop down menu, the filter which is to be positioned in the transmitted beam can be selected. A detailed description of the filter wheel is given in WITec Control manual Section 3.4.8.

Adjustment

All devices and sequencers required for the cantilever alignment are summarized in this section. These include controls of the beam deflection laser (see the WITec Control manual Section 3.4.5) and the cantilever positioning (see the WITec Control manual Section 3.4.7). Additionally, the control elements for

the computer guided alignment of the system can be found here (see WITec Control manual Section 3.5.10 for a detailed description of these elements).

Feedback Settings

The feedback settings provide access to the parameters used in conjunction with the PI control of the scan table Z axis. A detailed description of the parameters is given in the WITec Control manual Section 3.4.5.

2.2.2 Acquisition

The sequencers used to acquire data in this configuration are listed and briefly described below.

Oscilloscope

The parameters used to display measured values in a similar way as is done through an oscilloscope are described in WITec Control manual Section 3.5.11. If the microscope is operated in this configuration, the counter output of a photon counting device (PMT) will be integrated for the integration time set by the user. The recorded values will then be displayed in a graph viewer.

Image Scan

The parameters used to perform an image scan are described in WITec Control manual Section 3.5.2. In this configuration, all parameters required to perform an image scan in SNOM contact mode are listed here.

Line Scan

The parameters used to perform a line scan are described in WITec Control manual Section 3.5.3. In standard SNOM contact mode, force-distance curves and light intensity as a function of distance can be recorded along a line. The parameters used to record each distance curve are the actual parameters defined in the distance curve sequencer (see below).

Distance Curve

The parameters used to generate a distance curve are described in WITec Control manual Section 3.5.7.

2.3 Data Sources and Status Window

The data sources (WITec Control manual Section 3.6) used during a SNOM contact mode measurement are summarized in Tab. 1 along with the default data labeling of the acquired channel. The data sources used for adjustment and control of the measurement are displayed in the Status Window (WITec Control manual Chapter 5) or the Quadrant Window (WITec Control manual Chapter 7).

Channel	Oscilloscope	Image Scan	Distance Curve	Channel Caption	Unit	Display Window
Photon Counter		✓	✓	PMT	[cts]	
Count Rate	✓	✓	✓	PMT Rate	[kHz]	
T-B			✓	T-B	[V]	Status
L-R				L-R	[V]	Status
Sum						Quadrant
X-Sensor					[μm]	Status
Y-Sensor					[μm]	Status
Z-Sensor		✓	✓	Topography	[nm]	Status Quadrant
Microscope Z					[μm]	Status
Inv. Mic. X					[μm]	Status
Inv. Mic. Y					[μm]	Status
Inv. Mic. Z					[μm]	Status

Table 1: Output channels and their sequencers.

2.4 Quadrant Window

The Quadrant Window is used for the alignment and display of the beam deflection system. A detailed description of this window is given in the WITec Control manual Chapter 7.

In SNOM Contact, the Quadrant Window shows the position of the beam deflection laser on the four quadrant photo diode as the red spot on the display (see Fig. 3).

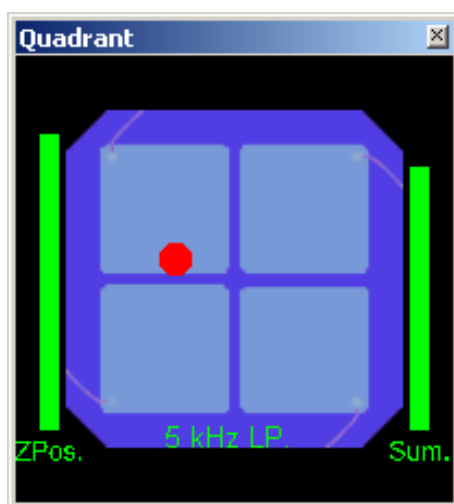


Fig. 3: The Quadrant Window in SNOM Contact mode.

3 Beam Path

In this section, the beam path is illustrated schematically. The parts common to all instruments are displayed in dark grey. Parts not common to all instruments, but necessary for the described measurement mode are indicated in blue. Optional parts which may be present with the instrument, but are neither common to all instruments nor are necessary for the described measurement mode are displayed in light grey. The parts indicated are listed below the figure where an *alpha300* system is shown exemplarily. Detailed descriptions of the parts indicated can be found in the *alpha300/alpha500/alpha700* system description. The beam paths are represented in green for the excitation laser and in red for the beam deflection laser in the following figures.

3.1 SNOM in transmission configuration

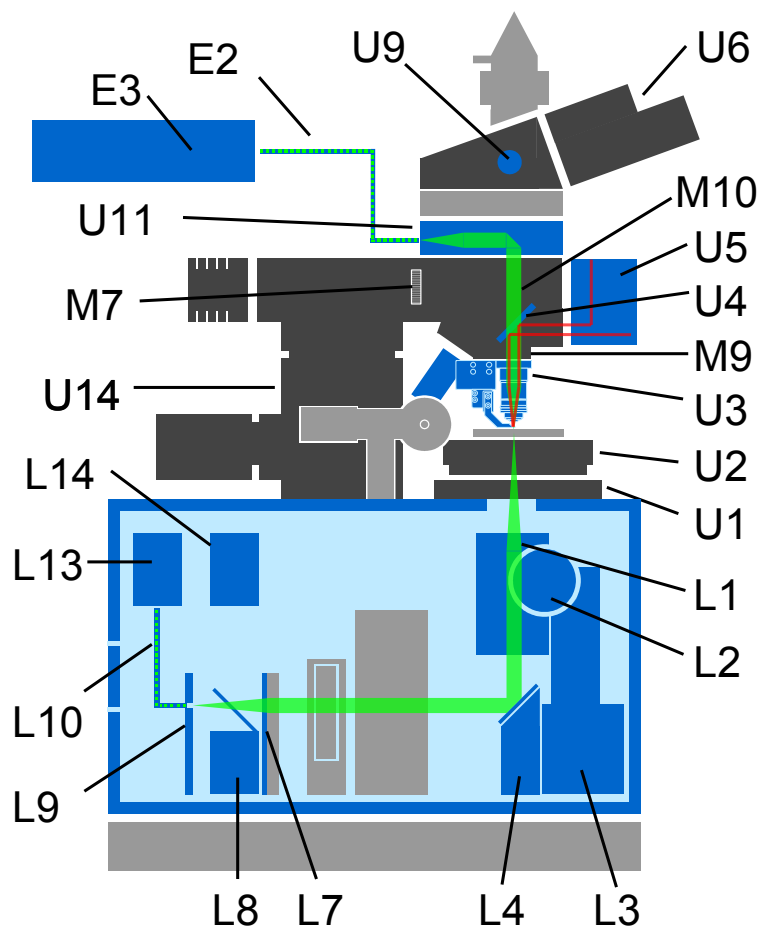


Fig. 4: Schematic illustration of the beam path for Scanning Near-field Optical Microscopy in transmission mode.

- U1** XY positioner (alpha300 system description manual Section 2.1.1)
- U2** Scan stage (alpha300 system description manual Section 2.1.2)
- U3** Objective turret with objectives including the inertial drive and the SNOM cantilever tip (alpha300 system description manual Section 2.1.3)
- U4** Dichroic mirror (alpha300 system description manual Section 2.1.4)
- U5** Beam deflection unit (alpha300 system description manual Section 2.1.5)
- U6** Binocular tube with ocular camera (alpha300 system description manual Section 2.1.6)
- U9** Pushrod (alpha300 system description manual Section 2.1.6)
- U11** Laser coupling unit optical input (alpha300 system description manual Section 2.1.10)
- U14** Microscope Z stage with stepper motor (alpha300 system description manual Section 2.1.13)
- M9** Objective turret (alpha300 system description manual Section 2.1.11)
- M10** Reflector slider (alpha300 system description manual Section 2.1.11)
- L1** Collection objective of the inverted microscope (alpha300 system description manual Section 2.2.1)
- L2** Manual adjustment knob for the Z-Position of the inverted microscope (alpha300 system description manual Section 2.2.1)
- L3** Motorized X, Y, Z positioning unit of the inverted microscope (alpha300 system description manual Section 2.2.1)
- L4** Deflection mirror (alpha300 system description manual Section 2.2.2)
- L7** Tube lens (alpha300 system description manual Section 2.2.5)
- L8** Flip mirror (alpha300 system description manual Section 2.2.6)
- L9** SMA fiber connector (alpha300 system description manual Section 2.2.7)
- L10** Multi-mode optical fiber (alpha300 system description manual Section 2.2.8)
- L13** Single photon counting detector (PMT or optional APD) (alpha300 system description manual Section 2.2.11)
- L14** High sensitivity b/w video CCD camera (alpha300 system description manual Section 2.2.12)
- E2** Single-mode optical fiber
- E3** Laser (alpha300 system description manual Section 2.6)

3.2 SNOM in reflection configuration

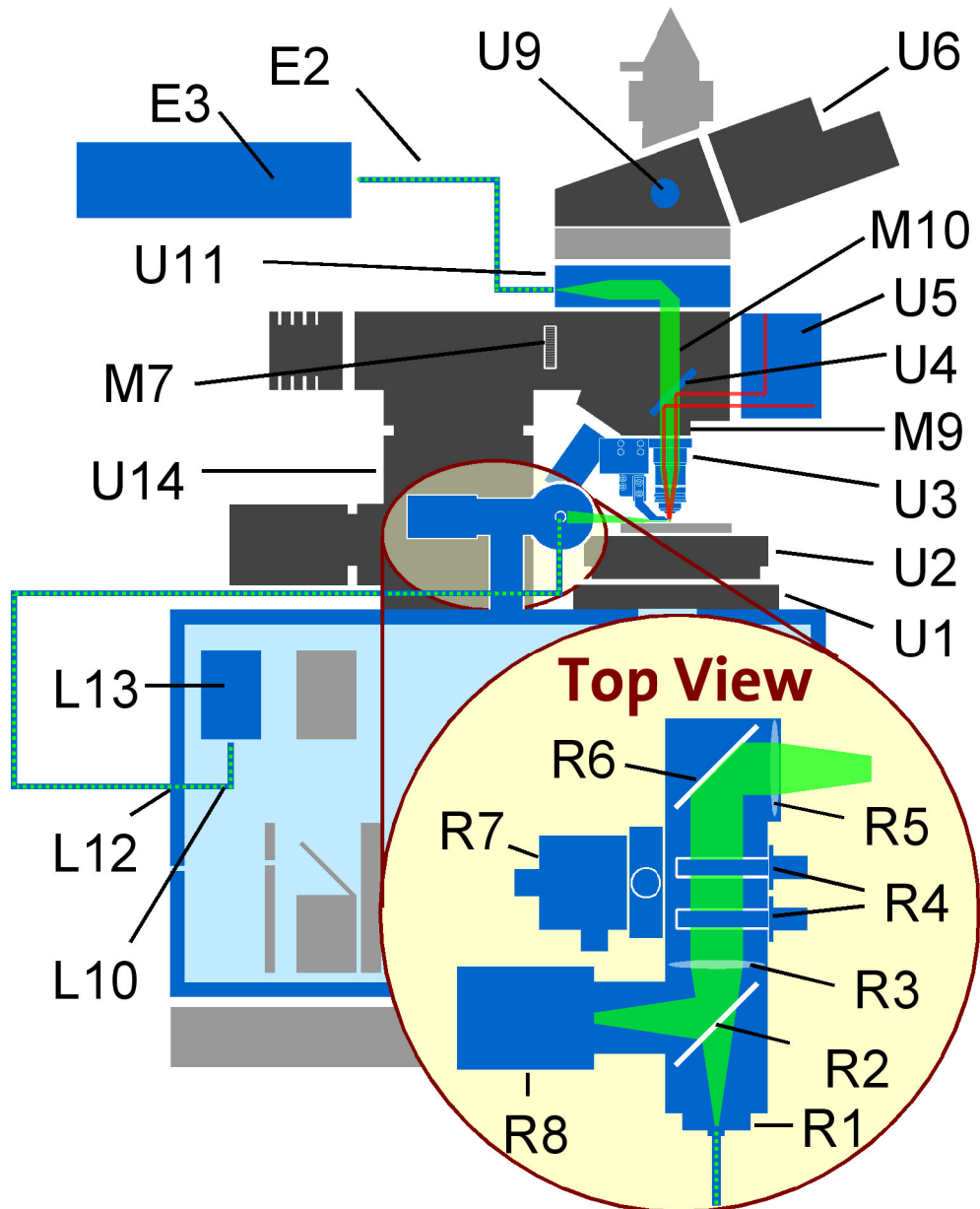


Fig. 5: Schematic illustration of the beam path for Scanning Near-field Optical Microscopy in reflection mode.

- U1** XY positioner (alpha300 system description manual Section 2.1.1)
- U2** Scan stage (alpha300 system description manual Section 2.1.2)
- U3** Objective turret with objectives including the inertial drive and the SNOM cantilever tip (alpha300 system description manual Section 2.1.3)
- U4** Dichroic mirror (alpha300 system description manual Section 2.1.4)
- U5** Beam deflection unit (alpha300 system description manual Section 2.1.5)
- U6** Binocular tube with ocular camera (alpha300 system description manual Section 2.1.6)
- U9** Pushrod (alpha300 system description manual Section 2.1.6)
- U11** Laser coupling unit optical input (alpha300 system description manual Section 2.1.10)
- U14** Microscope Z stage with stepper motor (alpha300 system description manual Section 2.1.13)
- M9** Objective turret (alpha300 system description manual Section 2.1.11)
- M10** Reflector slider (alpha300 system description manual Section 2.1.11)
- L10** Multi-mode optical fiber (alpha300 system description manual Section 2.2.8)
- L12** SMA fiber connector feedthrough (alpha300 system description manual Section 2.2.10)
- L13** Single photon counting detector (PMT or optional APD) (alpha300 system description manual Section 2.2.11)
- R1** SMA fiber coupling unit (alpha300 system description manual Section 2.1.14)
- R2** 50/50 beam splitter cube (alpha300 system description manual Section 2.1.14)
- R3** Focusing lens (alpha300 system description manual Section 2.1.14)
- R4** Filter holders (alpha300 system description manual Section 2.1.14)
- R5** Collimating lens (alpha300 system description manual Section 2.1.14)
- R6** High reflection mirror (alpha300 system description manual Section 2.1.14)
- R7** XYZ positioning stages (alpha300 system description manual Section 2.1.14)
- R8** CCD video camera (alpha300 system description manual Section 2.1.14)
- E2** Single-mode optical fiber
- E3** Laser (alpha300 system description manual Section 2.6)

4 Step by step alignment

The following listing describes the alignment of the *alpha300* system in order to obtain a scanning near-field optical microscopy image, to perform a line scan or to capture a distance curve. The first of the two following sections describes the alignment for SNOM contact mode measurements in transmission configuration. The second part describes the alignment for SNOM contact mode measurements in reflection configuration.

In each of the sections, the first steps describe the procedure for focusing the microscope on the sample using white light illumination followed by the focusing of the excitation laser beam. The inverted microscope is then aligned with the laser beam followed by the cantilever alignment procedure. The fine positioning of the inverted microscope (the XYZ positioning stage and the SMA Fiber coupling unit in the case of the reflection mode) is then described before the automatic tip approach.

Parts of the alignment procedure are computer guided through the adjustment procedure. The procedure can be started using the corresponding **Start Adjustment** button located in the adjustment menu. The computer guided steps of the alignment procedure below are marked with a yellow bar on the left.

4.1 SNOM contact mode measurements in transmission configuration

1. Switch on the alphaControl. This is usually done using the switch on the multi-plug.
2. Power up the computer and start WITec Control . Select the SNOM contact mode from the **Configurations**-menu.
3. Mount either a glass slide or the Aluminum Latex projection pattern included with the instrument on the scan stage.
4. Remove the magnetically fixed cantilever arm from the inertial drive of the SPM objective (see the *alpha300/alpha500/alpha700* system description for details).
5. Rotate the microscope turret until the SPM objective is in the working position.
6. Push in the pushrod (U9) of the sliding prism and direct the beam to the eyepiece color video camera (U6).

7. Move the reflector slider (M10) to the illumination position (M11; see the *alpha300/alpha500/alpha700* system description for details). The beam splitter is mounted in the left position of the three position reflector slider. Therefore, move the reflector slider to the right.
8. Adjust the illumination to the required level using the illumination menu item in the Control Window.
9. Observe the image of the eyepiece color video camera on the computer monitor using the Video Control Window in the WITec Control software. Using the drop down menu in the Video Control Window, select the appropriate view (top view with the correct objective).
10. Focus on the surface of your sample with the Microscope Z stage (U14). This can be done in three different ways:
 - Using the Z microscope control in the Graphic Control Window. Clicking on the arrows will start the movement in the indicated direction and using the virtual potentiometer, the speed can be adjusted from 0.01 to 500 $\mu\text{m/s}$.
 - Using the remote control with the Z Microscope selected as the controlled device. Using the **+Z** and **-Z** buttons, the Z-focusing-stage can be moved up or down and the potentiometer allows the selection of speeds between 0.01 and 500 $\mu\text{m/s}$.

HINT The remote control needs to be activated if the controlled device has changed or if it was idle for more than two minutes. To activate the remote control turn the potentiometer fully anticlockwise.

- Using the **Move Up** and **Move Down** buttons, which can be found in the Microscope Z Control menu of the Control Window. The speed can be adjusted between the minimum and maximum values using the corresponding field.

If possible, move the objective initially away from the sample to avoid a collision between the objective and the sample.


It can sometimes be very difficult to focus on flat and clean surfaces. The field stop diaphragm (M7) can help to overcome these difficulties as outlined in the following. To focus, close the field stop diaphragm (M7) to a value of 1-3. Make sure to move in the 50:50 beam splitter (M11) using the reflector slider (M10) to illuminate the sample. Approach the sample until the edge of the field stop appears focused. At this point, the sample is also in focus. This is due to the fact that the field stop is positioned at the back focal plane of the objective. If the field stop is not in the middle of the field of view, move it to this position with the centering screws (M7; see the *alpha300/alpha500/alpha700* system description for details).

11. Change the view in the Video Control Window to the bottom view with the corresponding objective.
12. Move the inverted microscope (in which the collection objective is mounted) in X,Y, and Z until you see the field stop focused and in the center of the Video Control window. This procedure aligns the optical axis of the inverted microscope with the optical axis of the microscope. The inverted microscope can be moved in three ways:
 - Using the inverted microscope control in the Graphic Control Window. Clicking on the arrows will start the movement in the indicated direction and using the virtual potentiometer, the speed can be adjusted from 0.1 to 200 $\mu\text{m/s}$.
 - Using the remote control with the inverted microscope selected as the controlled device. Using the corresponding buttons, the inverted microscope can be moved in all three directions and the potentiometer allows the selection of speeds between 0.1 and 200 $\mu\text{m/s}$.

HINT The remote control needs to be activated if the controlled device has changed or if it was idle for more than two minutes. To activate the remote control turn the potentiometer fully anticlockwise.

- Using the , , , , and buttons which can be found in the inverted microscope menu of the Control Window. The speed can be adjusted between the minimum and maximum values using the corresponding field.

HINT Even at a reading of 1 for the field stop (field stop as small as possible), the illuminated field on the detection monitor can be larger than the field of view. This depends on the combination of the objectives. Using a 10x objective in the upper microscope and a 60x in the inverted microscope, the image of the field stop is larger than the field of view. If, however, a 20x objective is used in the upper microscope, the field stop will become visible within the field of view. However, in either case, the shadow edge of the field stop can be used as a guide for focusing and as an indicator where the optical axis is located.
It is also possible to focus on dust particles on the glass slide or the Aluminum Latex projection pattern. Care should be taken to ensure that the correct sample surface is in focus.

13. Switch on the excitation laser at low power.
14. Change the view in the video control to the top view with the corresponding objective.
15. Turn off the white light illumination (using the  speed button or the button), move out the 50:50 beam splitter (move the re-

flector slider (M10) into its middle position) and fine focus the microscope until the excitation laser is focused on the sample. You will observe several spots on the video screen, but only one of them changes during focusing. This is the spot that hits the sample while the other spots are reflections inside the microscope. Make sure that the other spots are as small as possible. Since the video camera is in the focal plane of the tube lens, these spots will be minimal if the beams are parallel inside the microscope. If they appear out of focus, rotate the micrometer screw at the laser coupling unit optical input (U11) until they are perfectly focused.



16. Change the view in the video control to the bottom view with the corresponding objective.

17. Fine-adjust the inverted microscope until the excitation beam is in focus and centered in the middle of the circle in the video image.

HINT If the video screen over-saturates (i.e. displays only white) reduce the laser power further.

18. Move the microscope up, switch on the bright field illumination again and move in the 50:50 beam splitter (move the reflector slider (M10) to the right).

19. Attach a SNOM-cantilever to the cantilever arm and mount it to the inertial drive.

20. Select the start adjustment sequencer () from the Control Window, which is located in the adjustment menu (). This will guide you through the alignment procedure. The requested user input is displayed in the Message Window. The following steps (indicated by the yellow bar on the left) are automatically requested and/or performed by the software.

21. Rotate the SPM objective into the working position and position the cantilever centrally and in focus in the top view video image. A coarse positioning (until the cantilever is somewhat visible in the video image) can be performed manually by gently moving the bottom part of the inertial drive in X, Y and Z. Once the cantilever is visible within the video image, the inertial drive should be used to position the cantilever correctly. The inertial drive can be driven in three different ways:
- Using the cantilever positioning control in the Graphic Control Window. Clicking on the arrows will start the movement in the indicated direction and using the virtual potentiometer, the speed can be adjusted from 1 to 1500.
 - Using the remote control with cantilever position selected as the controlled device. Using the corresponding buttons, the cantilever can be moved in all three directions and the potentiometer allows the selection of speeds between 1 and 1500.
 - Using the , , , , and buttons, which can be found in the Adjustment⇒Cantilever Positioning menu of the Control Window. The speed can be adjusted between the minimum and maximum values using the corresponding field.



The cantilever is in its correct position once the excitation laser is pointing into the inverted hollow pyramid at the end of the cantilever. The focus of the beam deflection laser can then be seen about 50 μm above the pyramid. If the beam deflection laser is not visible, try reducing the illumination brightness.

HINT If the cantilever is angled significantly relative to the video image, check the position of the video camera. It should be oriented so that the connecting cable is pointing horizontally to the right. If the camera seems to be rotated significantly, this should be adjusted. Note that the video calibrations will be lost if the camera is rotated.
If the video camera seems approximately correctly oriented and the cantilever still shows a significant tilt in the video image (more than approximately 10°), the cantilever should be re-mounted.


22. Using the T-B and L-R adjustment screws on the front of the beam deflection unit, center the reflected beam deflection laser on the four quadrant photo diode. Use the Quadrant Window in the WITec Control software (see WITec Control manual Chapter 7) to observe the changes as you turn the screws. The red spot indicates the position of the beam deflection laser on the diode.

If it is on one of the edges of the field of view, observe the Σ -signal on the right hand side of the Quadrant Window. Turning the screw in the wrong direction will cause the sum signal to decrease whereas it will maximize if the screw is turned in the correct direction and the red spot will then move toward the center of the screen. If the Σ -signal is below 3 V, the bar representing the Σ -signal will turn red, which indicates that the Σ -signal is critically low.

The correct position has been reached when the red spot is in the center of the Quadrant Window (note that the display is non-linear and more sensitive toward the center), the T-B signal as indicated in the Status Window (see WITec Control manual Chapter 5) is 0 ± 0.05 V and the L-R signal is 0 ± 0.1 V. The bar on the left hand side of the Quadrant Window (indicating the Z-position of the scan stage) should be fully extended at this point.

23. The feedback settings are preset upon loading the configuration. However, they should be checked before starting the approach. The recommended settings are a setpoint of 1.0 V, a proportional gain of 2.0 and an integral gain of 4.0.
24. Move the microscope down using the microscope Z stage (as described in step 10) until the cantilever is close to the sample, but be careful to not hit the sample.
25. Check the position of the beam deflection laser in the Quadrant Window again and correct it if necessary.
26. Press the Auto-Approach speed button () or select the Start Approach button from the Microscope Z Control menu. The Message Window (see WITec Control manual Chapter 6) displays the message: *Doing Contact-Mode Tip Approach ; Moving fast* in the initial stages of the Auto-Approach.
27. As soon as the tip is in contact with the surface, the message in the Message Window changes to: *Doing Contact-Mode Tip Approach ; Moving slowly*, the T-B signal in the Status Window will show 1.0 V (if that is the setpoint selected) and the red spot in the Quadrant Window will have moved up. If you hear a noise from the stage during contact, the feedback is too aggressive. In this case, reduce the I and P-gains until the noise stops. At this point the automatic approach can be stopped using the Stop speed button () or any other Stop button.

The automatic approach may fail and/or be interrupted if one of the following problems occur. The solutions for the respective problems are indicated by the blue bars in the following.

- The approach is interrupted by the user clicking on the  button. In the Message Window, the message *Tip Approach interrupted by user* is displayed.

■ Approach again.

- Instability of the sum signal. If the sum-signal increases by 10% or decreases by 20%, the automatic approach is interrupted. In the Message Window, the message *Dangerous Sum-Signal while approaching* is displayed.


■ Check the alignment of the beam deflection system and try the automatic approach again.

- No contact was registered after the microscope moved 2 mm down. In the Message Window, the message *Tip Approach stopped. Drove 2 mm down.* is displayed.

■ Check the alignment of the beam deflection system as well as the Microscope Z position and approach again.

- The setpoint has been altered by the user during the approach. In the Message Window, the message *Tip Approach interrupted by user* is displayed.

■ Restart the automatic approach using the desired setpoint.

28. After double-checking that the *Retract Distance* [μm] is set to 50 μm in the Microscope Z Control menu, press the Retract Tip speed button () or choose the **Retract Tip** button from the Microscope Z Control menu. This procedure ensures that the tip is close to, but not touching the surface. If a collection objective with a short working distance is used, this is particularly important.


29. Increase the white light illumination. Carefully move the inverted microscope up without touching the sample. Looking at the video image of the inverted microscope (bottom view with the corresponding objective in Video Control Window), you should be able to see the shadow of the cantilever and the pyramid. Focus on the tip of the pyramid. If you are not able to see the tip of the pyramid, focus on the edge of the cantilever and then move the inverted microscope 10 μm down.

HINT If the camera oversaturates, reduce the white light intensity. This can happen particularly if a highly sensitivity UV camera is used.


30. Slide out the 50:50 beam splitter (move the reflector slider (M10) to its middle position) and turn off the white light illumination. Increase the excitation laser and fine adjust the cantilever position in X and Y using the inertial drive as described in point 21 until you see some of the excitation light power trans-

mitted through the aperture in the Video Control Window. Focus the inverted microscope on this spot.

The new user might have difficulties in positioning the the cantilever in order to obtain light through the cantilever. The following steps can be performed if no light can be obtained through the cantilever:

- The laser intensity can be increased. This is only possible up to a certain point since the scattered light will start to dominate the image if the laser intensity is too high. Note also, that by increasing the laser power the power dissipated into the cantilever increases. Since it acts similar to a bi-metal strip this will change the bending of the cantilever. Again move the cantilever position in X and Y in order to find the transmitted light.
 - Focus with the inverted microscope on the edge of the cantilever (or the bottom edge of the pyramid) and then move the inverted microscope 8-10 μm down. This ensures the proper focusing onto the tip of the pyramid. Again move the cantilever position in X and Y in order to find the transmitted light.
 - Using the inertial drive control move the cantilever to the side in order to allow the laser beam to hit the inverted microscope directly. You most likely will have to decrease the laser intensity in order to locate the exact position of the laser spot. Then verify that this position is where the red circle on the video screen is. Adjust the position of the inverted microscope in X and Y if necessary. Check the collimation of the laser beam to verify that the collimation is optimal. This is the case if the the size of the laser spot is minimal. Use the micrometer on the back of the laser coupling unit optical input (see WITec Control manual Section 2.1.10) to adjust the collimation of the beam inside the microscope. Once this is optimized, move the cantilever back and move the cantilever in X and Y in order to find the transmitted light.
31. Fine adjust the cantilever position using the inertial drive in order to maximize the throughput through the cantilever. The collimation of the laser can also be adjusted to optimize the throughput.
 32. Reset the position of the inverted microscope (by pressing the Set Zero (XYZ) button in the Inverted Microscope menu) and the position of the Microscope Z Stage (by pressing the Set Zero button in the Microscope Z Control menu).
 33. Check the position of the beam deflection laser in the Quadrant Window again and correct it if necessary.
 34. Press the Auto-Approach speed button () or select the Start Approach button from the Microscope Z Control menu. The Message Window (see WITec Control manual Chapter 6) displays the message: *Doing Contact-Mode Tip Approach ; Moving fast* in the initial stages of the Auto-Approach.

35. As soon as the tip is in contact with the surface, the message in the Message Window changes to: *Doing Contact-Mode Tip Approach ; Moving slowly*, the T-B signal in the Status Window will show 1.0 V (if that is the setpoint selected) and the red spot in the Quadrant Window will have moved up. If you hear a noise from the stage during contact, the feedback is too aggressive. In this case, reduce the I and P-gains until the noise stops. The scan table will now start to retract, which can be seen in a decrease of the height of the bar on the left hand side of the Quadrant Window and from the topography value in the Status Window. Once it has reached its middle position, the approach was successful and a corresponding message will be displayed in the Message Window. The automatic approach may fail and/or be interrupted if one of the following problems occur. The solutions for the respective problems are indicated by the blue bars in the following.

- The approach is interrupted by the user clicking on the  button. In the Message Window, the message *Tip Approach interrupted by user* is displayed.
| Approach again.

- Instability of the sum signal. If the sum-signal increases by 10% or decreases by 20%, the automatic approach is interrupted. In the Message Window, the message *Dangerous Sum-Signal while approaching* is displayed.

| Check the alignment of the beam deflection system and try the automatic approach again.


- No contact was registered after the microscope moved 2 mm down. In the Message Window, the message *Tip Approach stopped. Drove 2 mm down.* is displayed.

| Check the alignment of the beam deflection system as well as the Microscope Z position and approach again.

- The setpoint has been altered by the user during the approach. In the Message Window, the message *Tip Approach interrupted by user* is displayed.

| Restart the automatic approach using the desired setpoint.

36. Move the inverted microscope down to focus on the tip of the pyramid and the transmitted light again. The position indication of the Microscope Z Stage in the Status Window is a good indicator of how far the inverted microscope must be moved down.

37. If necessary, make fine adjustments in the position of the inverted microscope to focus the transmitted light and to move it into the red circle on the video screen. If the inverted microscope is positioned that way, the light collected through it will hit the multimode fiber (L10) connected to the PMT (L13).
38. Reduce the laser power until it is barely visible on the monitor.
39. Start the oscilloscope in WITec Control using either the  speed button or the **Start Oscilloscope** button in the oscilloscope menu of the Control Window. The integration time as well as the time displayed in the oscilloscope window can also be adjusted in the oscilloscope menu of the Control Window.
40. Watch the oscilloscope reading and make fine corrections in the X, Y and Z axes of the inverted microscope until the count rate is maximized. Make sure the counter board and the detector are not overloaded. If the count rate exceeds 4×10^6 counts per second (cps), the photon counting device will be turned off automatically for protection. In this case, reduce the laser power and press the **Reset / On** button in the detection menu, then continue the optimization.
41. Once the optimum signal intensity is achieved, stop the oscilloscope with any **Stop** button or icon.
42. The measurement parameters in the image scan (or line scan or distance curve) menu of the Control Window should be adjusted next (see WITec Control manual Section 3.5.2 (or 3.5.3 or 3.5.7) for a description of the individual parameters).
 If the (X) and (Y) positions indicated in the Scan Table menu of the Control Window differ from the position entered as *Center (X)* and *Center (Y)* in the image scan menu, the scan table will move to a different position before starting the scan. This might then lead to data acquisition at the wrong position/area. Use the **Center at Current Pos.** button in the image scan menu of the Control Window to avoid this displacement.

HINT Typical values for an image scan in this mode are:
 Points per line: 256-512
 Lines per image: 256-512
 Width: 2-30 μm
 Height: 2-30 μm
 Time per line: 0.5-2 s


43. You may now start your measurement.


4.2 SNOM contact mode measurements in reflection configuration


In order to align the microscope for a SNOM measurement in reflection mode, the cantilever has to be aligned in the same way as in transmission mode. Therefore perform steps 1 to 31 from section 4.1 using a 0.17 mm glass slide as a sample before continuing as described below.

1. Change the view in the Video Control Window to the REAR VIEW to observe the video image of the reflection mode.
2. Move the reflection microscope in the X, Y, and Z axes using the XYZ positioning stages (R7) until you see the light emitted from the cantilever. Adjust the focus (Y direction) and make corrections in X and Z until the light emitted from the cantilever is in the red circle of the video image. If this is the case the light is hitting the SMA feedthrough (R1) correctly.

Do NOT alter the positions of the SMA fiber coupling unit(R1).

3. Ensure that the fiber is connected to the reflection mode SMA fiber coupling unit (R1) and to the SMA fiber connector feedthrough (L12) on the *alpha300* body. Additionally, inside the *alpha300* body, the short SMA fiber needs to be connected from the SMA fiber connector feedthrough to the photon counting device (L13).
4. Start the oscilloscope in WITec Control using either the  speed button or the **Start Oscilloscope** button in the oscilloscope menu of the Control Window. The integration time as well as the time displayed in the oscilloscope window can also be adjusted in the oscilloscope menu of the Control Window.
5. Watch the oscilloscope reading and make fine corrections using the XYZ positioning stages (R7) until the count rate is maximized. Make sure the counter board and the detector are not overloaded. If the count rate exceeds 4×10^6 counts per second (cps), the photon counting device will be turned off automatically for protection. In this case, reduce the laser power and press the **Reset / On** button in the detection menu, then continue the optimization.
6. Once the optimum signal intensity is achieved, stop the oscilloscope with any **Stop** button or icon.
7. Move the microscope up and replace the cover slip with your sample.
8. Check the position of the beam deflection laser in the Quadrant Window again and correct it if necessary.

9. Press the Auto-Approach speed button () or select the Start Approach button from the Microscope Z Control menu. The Message Window (see WITec Control manual Chapter 6) displays the message: *Doing Contact-Mode Tip Approach ; Moving fast* in the initial stages of the Auto-Approach.

10. As soon as the tip is in contact with the surface, the message in the Message Window changes to: *Doing Contact-Mode Tip Approach ; Moving slowly*, the T-B signal in the Status Window will show 1.0 V (if that is the setpoint selected) and the red spot in the Quadrant Window will have moved up. If you hear a noise from the stage during contact, the feedback is too aggressive. In this case, reduce the I and P-gains until the noise stops. The scan table will now start to retract, which can be seen in a decrease of the height of the bar on the left hand side of the Quadrant Window and from the topography value in the Status Window. Once it has reached its middle position, the approach was successful and a corresponding message will be displayed in the Message Window. The automatic approach may fail and/or be interrupted if one of the following problems occur. The solutions for the respective problems are indicated by the blue bars in the following.
 - The approach is interrupted by the user clicking on the  button. In the Message Window, the message *Tip Approach interrupted by user* is displayed.
 Approach again.

 - Instability of the sum signal. If the sum-signal increases by 10% or decreases by 20%, the automatic approach is interrupted. In the Message Window, the message *Dangerous Sum-Signal while approaching* is displayed.
 Check the alignment of the beam deflection system and try the automatic approach again.

 - No contact was registered after the microscope moved 2 mm down. In the Message Window, the message *Tip Approach stopped. Drove 2 mm down.* is displayed.
 Check the alignment of the beam deflection system as well as the Microscope Z position and approach again.

 - The setpoint has been altered by the user during the approach. In the Message Window, the message *Tip Approach interrupted by user* is displayed.
 Restart the automatic approach using the desired setpoint.

11. Check to see if the laser light transmitted through the cantilever is located in the circle on the monitor. If not, carefully correct the position of the reflection microscope. An adjustment of the position in the Z axis (R7) should now be sufficient.

■ When the tip is in contact, try to avoid any vibrations of the microscope body.

12. The measurement parameters in the image scan (or line scan or distance curve) menu of the Control Window should be adjusted next (see WITec Control manual Section 3.5.2 (or 3.5.3 or 3.5.7) for a description of the individual parameters).

■ If the (*X*) and (*Y*) positions indicated in the Scan Table menu of the Control Window differ from the position entered as *Center (X)* and *Center (Y)* in the image scan menu, the scan table will move to a different position before starting the scan. This might then lead to data acquisition at the wrong position/area. Use the **Center at Current Pos.** button in the image scan menu of the Control Window to avoid this displacement.

HINT Typical values for an image scan in this mode are:

Points per line: 256-512

Lines per image: 256-512

Width: 2-30 μm

Height: 2-30 μm

Time per line: 0.5-2 s

13. You may now start your measurement.