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Products: Closed Loop Upgrade

Operation Manual

Closed Loop Upgrade for attoAFM

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Disclaimer of Responsibility

This document is meant to be used as a quick use operating manual and does not contain every detail of the described software or hardware. For more detailed information, please refer to the corresponding manuals.

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I. Introduction

This manual covers the closed loop functionality add on for attocube scanning probe microscopy systems. The manuals of the used devices to accomplish the closed loop functionality describe the hardware and software in more detail.

I.1. System Overview

The closed loop upgrade is a high precision position measurement unit for any of attocube's scanning probe microscopy (SPM) systems. It enables the user to track and correct for displacement as well as move to any position on his sample in the measurement plane with nm precision. These features allow for optimal imaging capabilities and high reliability of your attocube scanning probe microscopy system.

Additionally, the SPM controller ASC500 together with the fully automated interferometric displacement sensor FPS3010 can be controlled using the convenient user interface of the delivered software combining the advantages of state of the art interferometry with great usability

I.2. Safety Information

For the continuing safety of the operators of this equipment and the protection of the equipment itself, the operator should take note of the **Warnings, Cautions,** and **Notes** that each manual provides for the respective hardware component!

II. Hard- & Software Description

II.1. Construction & Function

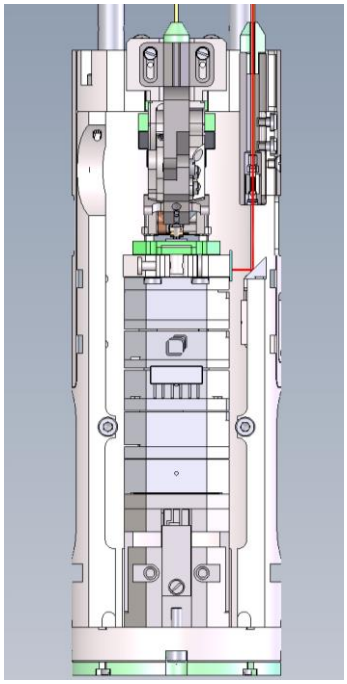

Figure 1: *Cross-section of an AFM housing with closed loop upgrade.*

The closed loop upgrade for attocube's SPMs enables you to read out the sample stage position in lateral direction with (sub) nm precision. It uses interferometric displacement measurement to track the position and allow for a global coordinate system.

In order to track the displacement of the sample stage inside the cryostat, two infrared laser beams are guided to the microscope housing using optical fibers and optical vacuum feedthroughs. Each fiber ends in a sensor head with 8 mm focus distance (see Figure 1). The beams are deflected on 45° mirrors, which are mounted opposing of the sample stage. Another pair of mirrors is attached to the sample stages and reflects the beam back defining the length of the optical cavity.

The reflected infrared laser light is detected with attocube's interferometer, the attoFPS3010 (please refer to manual for further information). It is capable of measuring up to three different axis at once utilizing the interference of the reflected infrared laser light.

II.2. Software Overview

Both devices the attoFPS3010 and ASC500 are operated with their own control software called FPS Daisy and ASC500 daisy respectively (For more details please refer to the ACS500 or attoFPS3010 manual). By default, a link to both is placed on the desktop of the supplied computer. The main measurements and controls such as the movement of the nano-positioners and the readout of the AFM tip are performed in the ASC500 daisy.

In addition, the FPS daisy controls and evaluates solely the signal of the attoFPS3010 and generates an exact position of the sample stage as a main output. The values of the x and y position can in turn be communicated to the ASC500 daisy and serve as new input parameters. They can then be used for example to correct the a priori non-linear motion of the scanners (closed loop scanning) or to track the absolute position of the sample to be able to merge several scans to a bigger picture.

III. Preparation for Closed Loop Measurements

Some preparations have to be made in order to use the closed loop functionality.

III.1. Connection of attoFPS3010 and ASC500

Before the system can be operated, there are several steps that need to be performed. First of all, one needs to set up the communication between the involved electronics and the control software.

Make sure both the attoFPS3010 and ASC500 are connected to the AHC100 via the delivered USB cables. Switch on the attoFPS3010 by pushing the button on the left hand side of the front panel. The button should start flashing. Switch on the ASC500 on the backside of the device by flipping the toggle switch to “I”. Start the ANC500daisy.exe and FPSdaisy.exe.

Also ensure that FPS3010 and ASC500 are connected by HDMI cables on the back side. This connection is used to communicate the position readout to the ASC500.

III.2. Settings for FPS software

To avoid readout errors and guarantee a reliable functionality it is important to set several values for the operation of the software FPS daisy.

To do so, go to the *Alignment* tab of the FPS daisy and open the *Optimisations window* by clicking the *Optimisations* button:

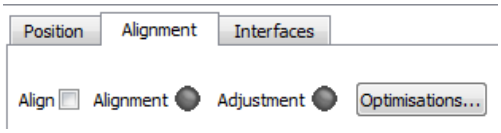

Figure 2: *Optimisations button in the Alignment Tab.*

The working range corresponds to the distance between the sensor head and the sample plate mirror. For a standard AFM+ or CFM+ it is 18 mm.

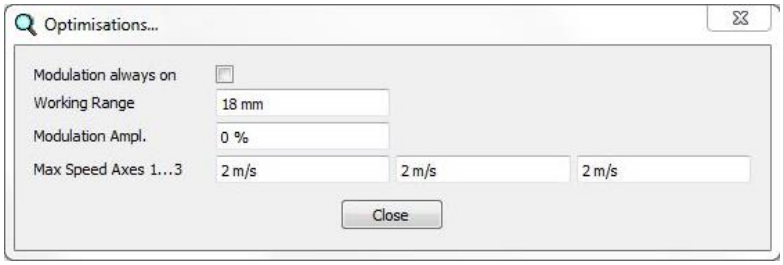

Figure 3: *Recommended settings for the Optimisations window of the FPS daisy. The Modulation Ampl. is a parameter automatically adjusted by the software so it should not be adjusted manually.*

Furthermore, one needs to set the variables for the signal output of the FPS3010 for communication to the ASC500. This is done in the *Interface* tab of the FPS daisy. Make sure, that the values are as depicted in Figure 4.

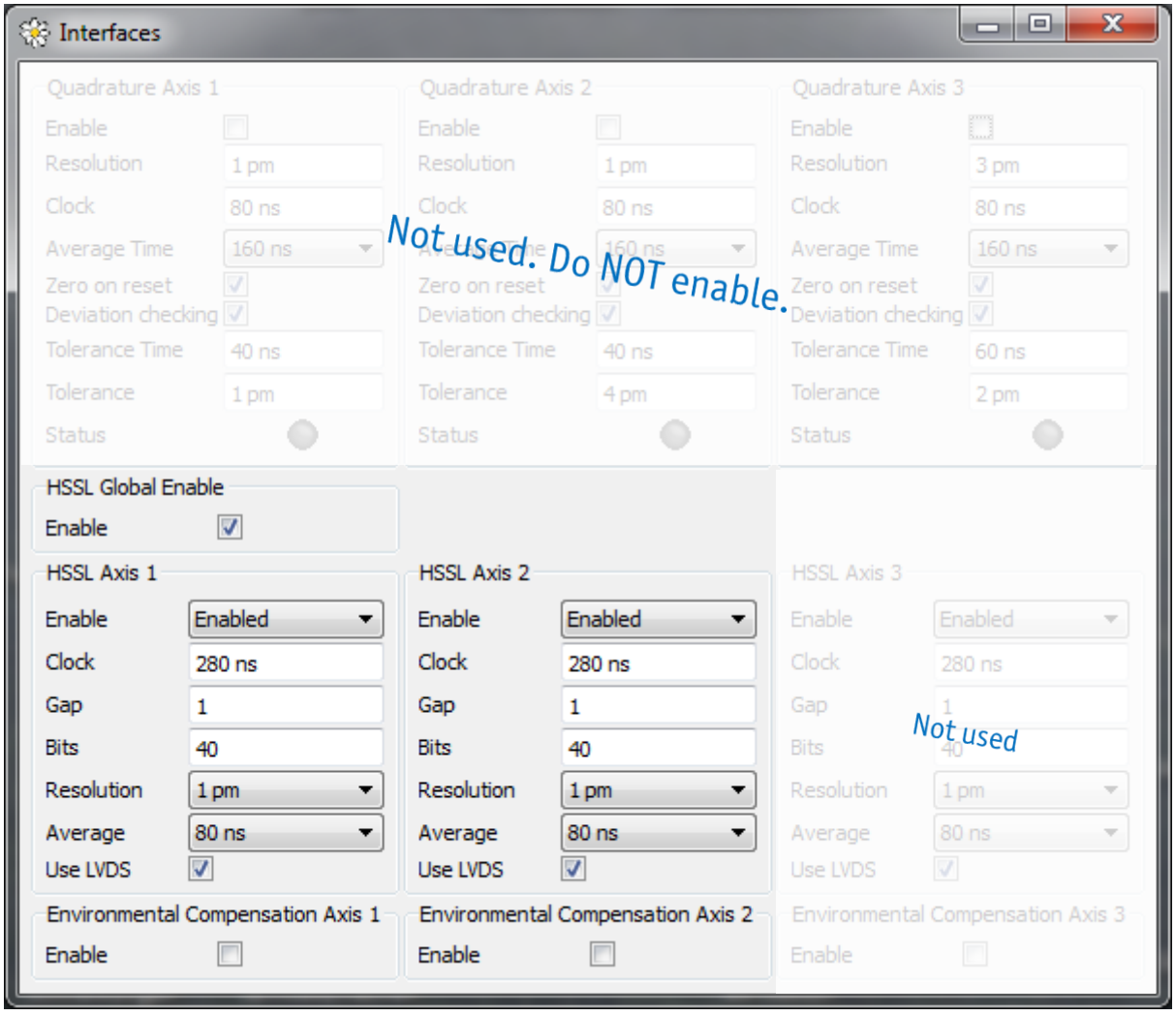

Figure 4: *Recommended interface settings for the FPS3010.*

III.3. Optical Alignment

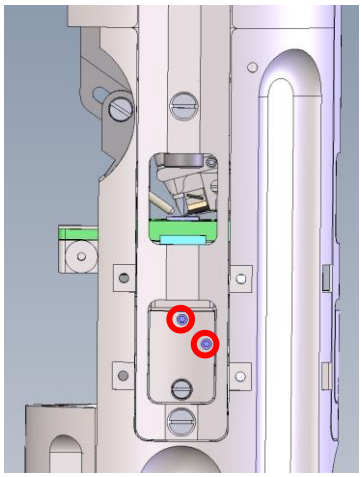

Figure 5: *Position of the adjustment screws of the 45° mirrors.*

At last, the 45° mirrors need to be adjusted such that the detected amplitude is maximized. We recommend doing this by performing the following steps for both axes.

As the light of the FPS laser source is not in the visible spectrum, it is convenient to connect a visible guiding laser to the optical fiber for the coarse adjustment. The aim is to guide the beam of the laser back onto the center of the sensor head. To do so one can use a 0.89mm (M2) hexagonal key to adjust the tilt of the 45° mirrors by tightening or loosening the screws depicted in Figure 5 in an iterative manner.

If the coarse adjustment is done, one can reconnect the output of the FPS3010 to continue with the fine adjustment procedure. To do this open the FPS daisy software and switches to the alignment tab. As you check the alignment box, the signal should become visible as a sinusoidal oscillation of the detected amplitude. Use the hex key again to maximize the signal as depicted in Figure 6. For optimal use the signal has to have an amplitude of about 10-20 µW.

Once the mirrors are set properly they do not need to be realigned within the course of the next few cool-downs.

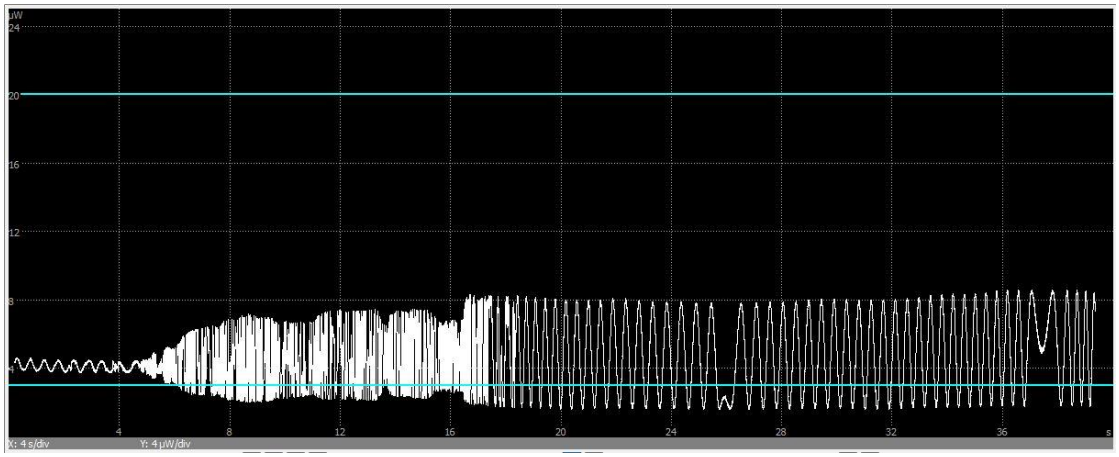

Figure 6: *Signal during fine adjustment.*

IV. Operationg Instructions

IV.1. Initiationg the FPS3010

After switching on the attoFPS3010 and the ANC500, start the FPSdaisy. The light on the power button of the attoFPS3010 will start flashing and in the user interface the indicator light next to “Adjustment” will be red. This indicates, that the internal adjustment processes of the attoFPS3010 are being executed. After approximately 2 minutes the process is done and the light on the attoFPS3010 will be continuously illuminated as well as the indicator light will turn green, indicating the “ready to use” state.

Go to the alignment tab and check the signal amplitude (c.f. Figure 6**Fehler! Verweisquelle konnte nicht gefunden werden.**) by activating the alignment box in the alignment tab. If necessary adjust the position of the mirror, otherwise uncheck the alignment box. The indicator light will again turn red for 2 minutes. After internal procedure adjustment, the position tab shows you the exact position of your sample stage. By pressing “reset all” you may set the origin of your coordinate system to the current location. Move the positioners a few steps to see if it is working properly, especially with respect to the axis orientation.

IV.2. Setting up the ASC500

Open the ASC500 daisy. The software should automatically recognize the closed loop evaluation and offer the X and Y Position (PosX, PosY) as input parameters and show them in the Scan tab of the ASC500 Daisy. Please check the lineview of PosX and PosY and ensure that the signals are transmitted and are consistent with the signal displayed in the FPS3010 (there may be an offset). In case the position is not displayed in the ASC500 Daisy or shows unstable values, make sure the HDMI cables are properly connected on both devices and the communication is set up correctly (see Fig. 4 and 7).

Move the X positioner/scanner in positive direction and check if PosX increases. If this is not the case you can invert the PosX signal in Settings → Experimental Preferences by checking the corresponding box (see Figure 7). Repeat for Y direction.

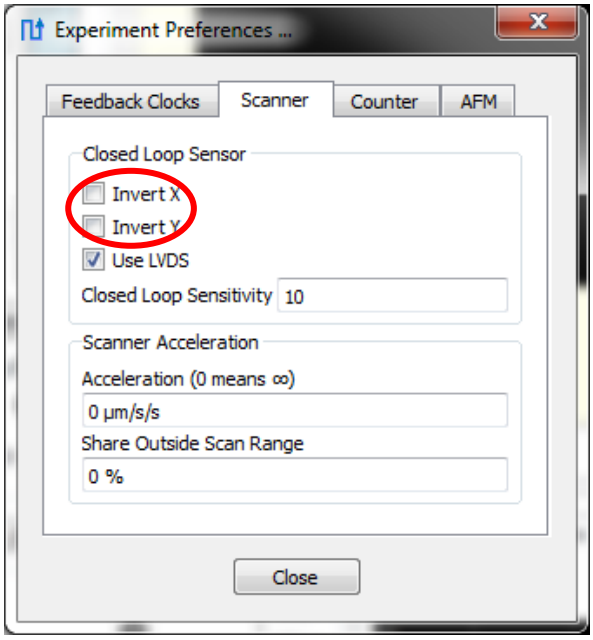

Figure 7: *Experiment Preferences window of the ASC500 settings.*

Always ensure that the output given to the scanners does not exceed the maximum rating at any given temperature!

To activate the closed loop scan control of the sample position ANC500 software, go to the Scan tab and check the "use sensor position" box (see Figure 8). You can only change the checkbox if the outputs are off.

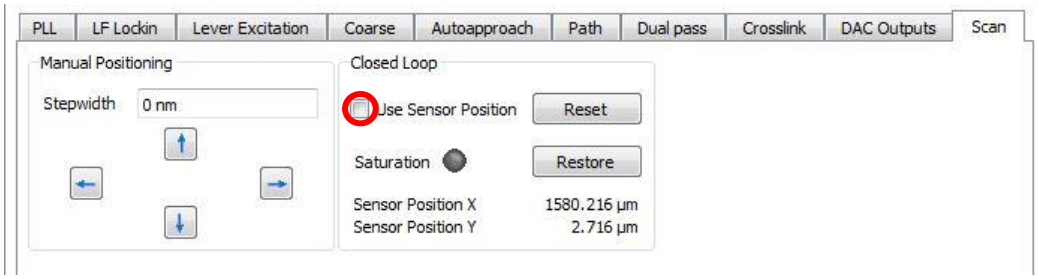

Figure 8: *Scan tab for working closed loop systems.*

When the output is activated, the systems will automatically stabilize the registered motion by adjusting the voltages applied to the scanners. This regulated mode is also indicated by a green light in the scanner ctrl window.

It is not recommended to move the positioners while closed loop scanning is running and the position is being stabilized.

To move the positioners without the system trying to compensate for the displacement, one can either turn off the output or press the stop button in the Scanner Ctrl tab. In the latter case the indication light in the Scanner Ctrl tab will turn yellow (see Figure 9) and can be changed back to green (active closed loop scanning) by pressing the scan button. For a more detailed explanation of the scan engine states please refer to the ASC500 manual.

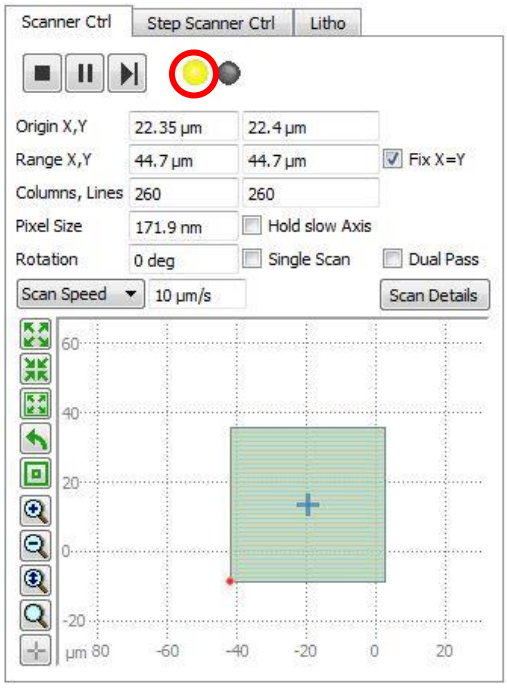

Figure 9: *Scanner Ctrl tab in mode for coarse movement.*

To fine tune the reaction of the closed loop system you can change the closed loop sensitivity paramter (cf. Figure 10). It can take values from 0 to 100 where smaller values mean less reaction to a difference between actual and target position. A typical value for a two inch stack is about 25. To adjust this value increase the parameter until PosX or PosY start to oscillate and thus to “widen up”. Use a value where the operation is still stable.

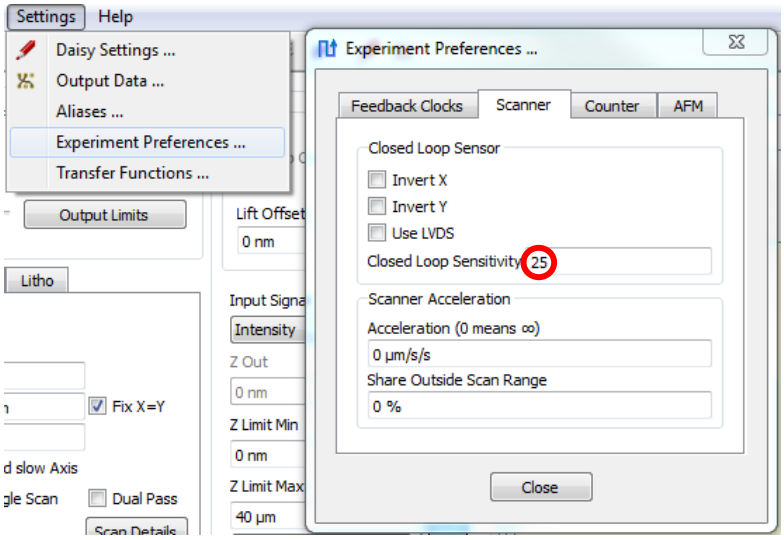

Figure 10: *Setting up the “Closed Loop Sensitivity” which governs the reaction to a difference between target and actual position.*

IV.3. Adjusting the Scan Range

The closed loop upgrade can also be used to precisely calibrate the scan range of the used scanners. To do so first turn the outputs off and deactivate Use Sensor Position. Let a full range 0° scan run and check the x scanner range in PosX. Repeat with a 90° scan and check the y scanner range in PosY.

As the system cannot be operated outside the output limits, there is an option to set a certain percentage of the scan range for correction purposes, which will however decrease your actual scan range. This option can be found in the Output window as seen in Figure 11. Depending on the expected noise and hysteresis of the scanners, values of around 5% are recommended.

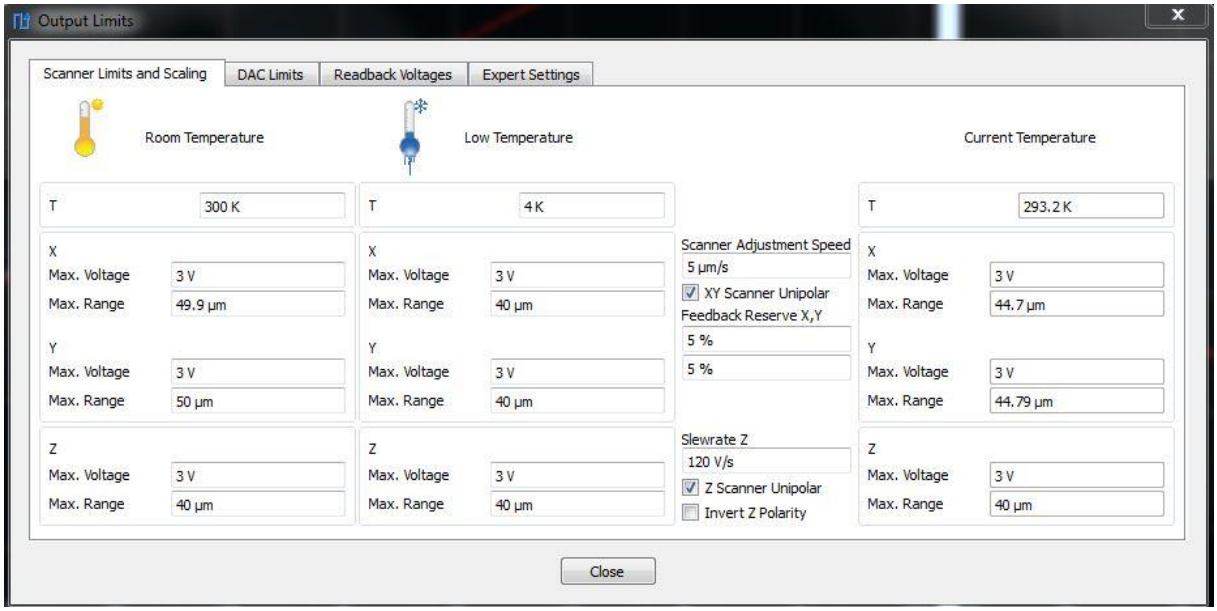

Figure 11: *Output limits window.*

To check the functionality of the closed loop stabilization, one should perform a line scan with a 0 or 90° direction and with the corresponding position as recorded parameter. If the result is a straight line, this is a good indication that the system is performing properly (see Figure 12: ***Linearized scan position for a 0 deg large range scan in x (top) and y (bottom) direction.***Figure 12). If a hysteresis can be seen it is necessary to lower the scan speed (or increase Closed Loop Sensitivity).

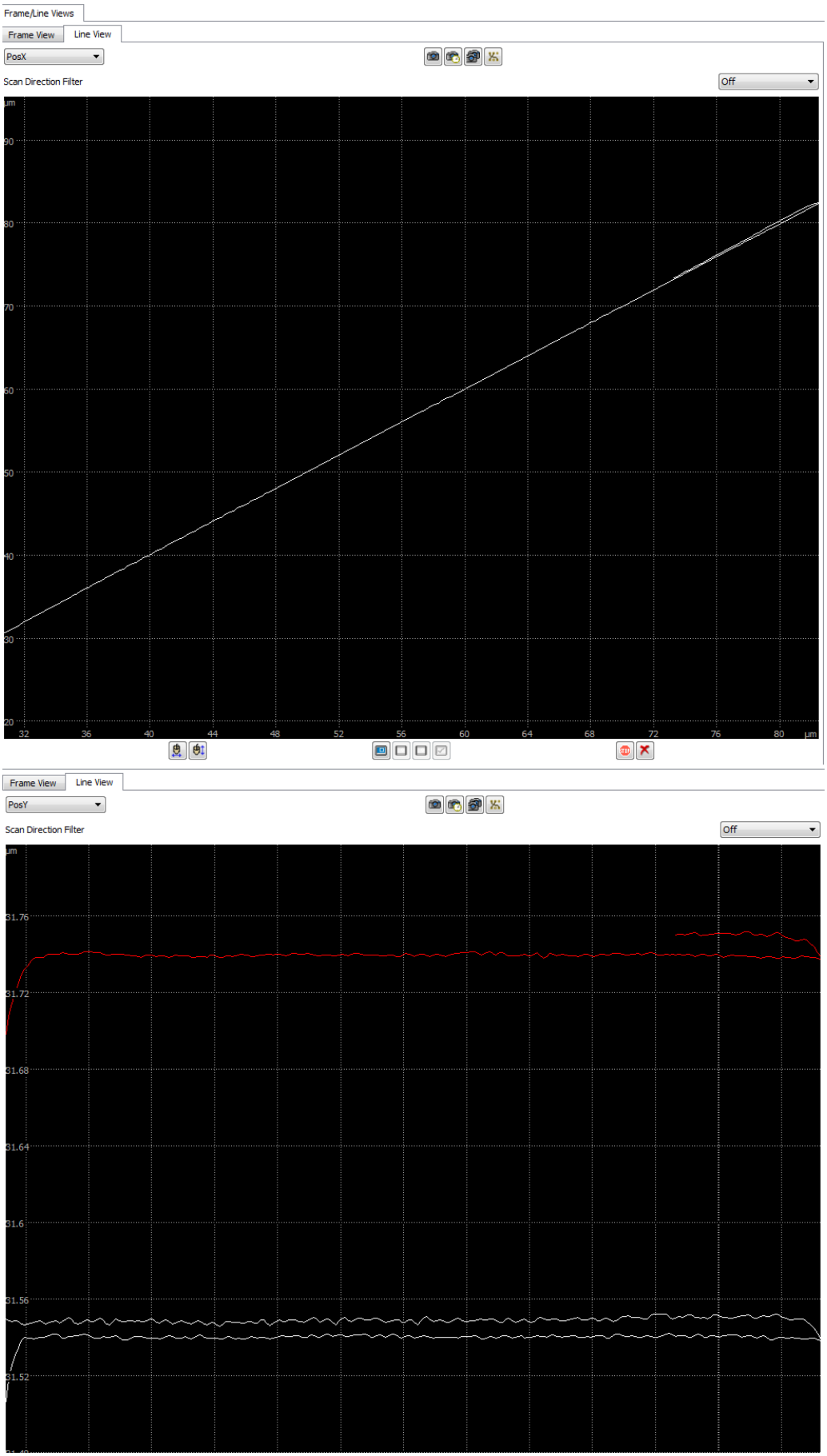

Figure 12: *Linearized scan position for a 0 deg large range scan in x (top) and y (bottom) direction.*

V. Troubleshooting

Signal on the alignment tab looks like summation of two sine signals:
The reason for this error lies in an unwanted partial reflection of the beam at the sensor head leading to a second interference pattern. As the optical cavity for this case is twice as long as the standard cavity, the interference arises with double the frequency of the base interference. Possible reasons for this are a mismatch of the optical path especially of the sensor head, for example an incorrect working distance or a wrong focus distance of the sensor head. In the latter case, a new correctly focused head is needed.

The closed loop option in the scan tab is not available:
This error occurs if the wrong hardware is used. There are two different kinds of ANC500 electronics, one intended as a basic version for standard AFM measurements and one customized for the use with a closed loop upgrade. This error can be fixed by a soft- and hardware update.

Non-linear X(x) scans/ Hysteresis of PosX while scanning:
Decrease the scan speed or increase the closed loop sensitivity (ensure that PosX is still stable). Typical maximum scan speeds for closed loop scanning with no noticeable hysteresis are about 20µm/s. This value can differ depending of the stability and mass of you stack.

No PosX PosY signal displayed in Daisy, or flat line:
Either the communication in the FPS software is turned off or the connection to the ASC500 is not made. Please compare your settings to the settings made in Figure 4; ensure HSSL is enabled for all axis you are using. Please ensure that the HDMI cables connecting ASC500 and FPS are properly plugged in and that the cables are of sufficient quality.

PosX or PosY has discontinuity or jumps:
The communication settings in the FPS software are incorrect. Please compare your settings to the settings made in Figure 4.

PosX or PosY start to widen up as soon as I activate the output/closed loop scanning:
Lower the closed loop sensitivity (cf. Figure 10).

Red lines show up at the edges of the scan range/ the maximum or minimum scanner voltages are reached:
Please reinitiate you scan range, either by going into the “yellow state” (press stop in the scan ctrl several times) and back into the “green state“ (press start in the scan ctrl once), or by turning off and on the ASC500 daisy outputs.
If the problem persists check whether PosX positive corresponds to positive x scanner movement, and vice versa for PosY and y scanner. Check and adjust the scan range of the positioner in open loop mode (cf. Section IV.2).

The position readout in the ASC500 Daisy is unstable for certain values:
Make sure the “Use LVDS” boxes are checked in the ASC500 Daisy’s experimental preferences tabd and the FPS3010 Daisy’s interface window.

VI. Preventive Maintenance and Cleaning

Warning. The equipment contains no user serviceable parts. There is a risk of severe electrical shock if the equipment is operated with the covers removed. Only personnel authorized by attocube systems and trained in the maintenance of this equipment should remove its covers or attempt any repairs or adjustments. Maintenance is limited to safety testing and cleaning as described in the following sections.

Note: Please note that you may lose the warranty for the FPS3100 or ASC500 in case unauthorized persons have opened the housing or unauthorized parts or actions have been employed. This is especially true in case of fuses that have higher specifications than allowed.

Warnings.

- Disconnect the power supply before cleaning the unit.
- Never allow water to get inside the case.
- Do not saturate the unit.
- Do not use any type of abrasive pad, scouring powder, or solvent, e.g. alcohol or benzene.

The front-panel may be cleaned with a soft cloth, lightly dampened with water or a mild detergent.

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