NeaSNOM

Scanning Near-field Optical Microscope

User Manual

Version 1.1
January 2011

see the nanoworld
neaspec

EC-Declaration of Conformity

in accordance with the EEC low-voltage directive 2006/95/EG

Manufacturer:	**Neaspec GmbH**	CE
Manufacturer`s Address:	**Bunsenstr.5 82152 Martinsried Germany**	

The manufacturer hereby declares that those corresponds to below designated product in its conception and design as well as in circulation the execution the fundamental safety and health requirements of the Community directive low-voltage brought by us.
In the case of a change of the product not co-ordinated with us this explanation loses its validity .

NeaSNOM

(Scattering - type Scanning Near-field Optical Microscope)

2011

The harmonised standard certifying the conformity is

Safety: DIN EN 61010-1

Martinsried, den 03.01.2011

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User Manual

Content:

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NeaSNOM

System

Description

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NeaSNOM System Description

January 2011

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1. General information

1.1. About

NeaSNOM System Description provides important technical details and hardware information for the Neaspec Scanning Near-field Optical Microscope.

All users should read this manual prior working with the NeaSNOM System for the first time.

Software elements including the NeaSNOM user interface are described in the second Section of this manual. The System Description is neither intended to introduce near-field microscopy in general nor to provide a comprehensive review about the physics involved in near-field microscopy and spectroscopy.

The first section provides general setup, usage and safety information. Later sections describe NeaSNOM System in more detail and provide technical details on individual components.

1.1.1. Symbol explanation

During operation, care should be taken to avoid accidents or injury to users or damage to the NeaSNOM System.

The symbols explained below mark areas where special attention is required. They are used both throughout this System Description and at appropriate hardware components of the NeaSNOM System.

	Indicates presence of visible or invisible, hazardous laser radiation.
	Indicates hazardous voltages.
	Indicates potentially dangerous operations.
	Indicates sensitivity against electrostatic discharge. Ground or use a ground bracelet to minimize the risk of damaging the components.

1.2. Safety instructions

This section provides an overview of important safety aspects for the operation of the NeaSNOM System. For the optimal protection of users as well as for the safe and failure-free operation of the System the safety guidelines must be observed. Substantial risks can arise if the instructions and safety notes of this Description are not observed.

1.2.1. Declaration of conformity

The NeaSNOM concept, construction and marketed design satisfy the basic safety requirements of the EU low voltage directive 2006/95/EC, including its changes effective at the date of declaration. NeaSNOM declaration of conformity is enclosed in the delivery documentation. Neaspec GmbH certifies that this product meets its published specifications at the time of shipment.

CE	This product is fully CE-approved.

1.2.2. Customer and personnel responsibility

The NeaSNOM System is intended for laboratory use in the scientific or industrial environment. The customer institution operating the System is subject to legal requirements for the occupational safety. In general, the safety instructions given in this System Description, the laser safety instructions, the rules of accident prevention and the environmental protection codes apply. The institution operating the equipment is obliged to:

- Inform personnel about the current occupational health and safety regulations
- Determine additional hazards resulting from the specific operational conditions at the installation site, in the scope of risk assessment
- Implement necessary requirements for adequate equipment operation at the installation site

- Verify regularly, during the entire operation, that all operational instructions listed in this Description and any additional operational instructions defined by the institution are abided
- Adapt the operational instructions to any the new and applicable legislative rules, regulations and installation site conditions
- Define personnel responsibilities for the installation, operation, maintenance and cleaning of the equipment
- Ensure all personnel working with the equipment or in its immediate vicinity has read and understood the safety regulations contained in this System Description, including general safety regulations, laser safety regulations and high-voltage safety regulations
- Ensure the equipment is operated in an adequate environment and kept in good condition according to the specified maintenance intervals

Only trained personnel is allowed to operate the System. To minimize risks:

- Untrained or unauthorized personnel should not be involved in any NeaSNOM operation
- NeaSNOM operation should be delayed as long as untrained or unauthorized personnel is present
- Lasers and other optical radiation sources of other suppliers should be switched off as long as untrained or unauthorized personnel is present

1.2.3. Special risks

The following section describes risks determined through the risk assessment procedures.

1.2.3.1. Laser safety

The NeaSNOM Systems may utilize sources of hazardous laser radiation. Note, the NeaSNOM microscope itself contains only a laser class II product, which is not dangerous to users in normal use of the microscope.

NeaSNOM Systems are often operated with additional, external laser sources. Users must follow the safety instructions provided by the corresponding laser supplier. Users must read the manual and/or safety instructions for laser sources of other suppliers used in combination with the NeaSNOM System.

	**Warning** **Danger of hazardous laser radiation!**

Lasers or other sources for optical ratiation used in combination with NeaSNOM microscope can generate visible and invisible radiation that can be hazardous to users that do not follow the safety guidelines. The above symbol indicates sources of hazardous laser radiation in the NeaSNOM System. The symbol alerts personnel to the danger of exposure to hazardous laser radiation. Provided that the personnel adheres to all safety regulations, the lasers are safe to operate. All personnel operating the System or working in its immediate vicinity must read and understand this System Description and the safety instructions for any external laser sources from other suppliers. Extreme care should be taken for work where the personnel or bystanders can be subjected to dangerous laser radiation. The work should be performed by trained and authorized personnel only. Personnel operating the NeaSNOM is responsible for implementing the laser safety regulations. Users working with potentially dangerous lasers sources in combination with the NeaSNOM microscope must contact their local laser safety officer for additional laser safety guidelines.

In general:

- Never look directly into the laser source or at laser light scattered from any reflective surface. Laser light can cause permanent eye damage. Never look directly towards the laser source, and use the appropriate safety equipment, such as safety goggles to protect your eyes

- Set up NeaSNOM System at low height from the surface to prevent inadvertent laser beam eye contact

- When the laser is running and the beam is not in use, block the beam. Avoid direct exposure of the laser beam to the skin or eyes

- Ensure limited or restricted access to rooms or laboratories where dangerous laser sources are used. Grant access for trained and authorized personnel only

- Contact your local safety officer for advice on how to implement the required laser and other safety regulations

<table>
<tr><td>
</td><td rowspan="2">These or similar signs indicate sources of hazardous laser radiation. The signs specify laser class (e.g. III or IV) and its potential danger level. NeaSNOM System users must be familiar with the safety requirements imposed by the laser classification.</td></tr>
<tr><td>
</td></tr>
<tr><td>
</td><td>This sign indicates openings where hazardous laser radiation is emitted from the laser sources.</td></tr>
</table>

1.2.3.2. High voltages

Warning

Danger of hazardous voltage!

The NeaSNOM System is safe to be operated in the delivered and installed configuration, and as long as the applicable safety regulations are implemented. In unsafe or improper conditions, the voltage supplied to the NeaSNOM System may cause injury. Do not remove or open any parts of the NeaSNOM System. Removal of covers and servicing of parts should be done by authorized Neaspec personnel only! No user-serviceable parts or components are inside the System. Should you encounter any technical problems, please contact Neaspec GmbH.

Do not install any additional electronic boards or components into the NeaSNOM microscope, controller, or user workstation. Do not connect any 3rd party cables to the NeaSNOM microscope or controller, and connect Neaspec-supplied cables only as instructed in this System Description. On request, Neaspec GmbH may provide institutions with specific, detailed information on how to use other equipment with the NeaSNOM System. Any damage to the NeaSNOM resulting from unauthorized installation or use of additional electronic components from other suppliers will void the product warranty.

1.2.3.3. Spare parts

Warning

Risk of injury or malfunction caused by inadequate spare parts!

Wrong or faulty spare parts can lead to damage, malfunction or complete failure of the NeaSNOM System, and they can significantly affect operational safety. Use only original spare parts and components supplied by Neaspec GmbH.

1.2.3.4. Additional safety information

NeaSNOM Systems are often operated in combination with the equipment from other suppliers that requires e.g. liquid nitrogen for cooling. In contact with skin or eyes, liquid nitrogen can cause serious injury. Please contact equipment suppliers for safety instructions regarding liquid nitrogen handling and necessary safety equipment.

Do not use the NeaSNOM System in an electromagnetically sensitive environment.

1.3. Warranty conditions

1.3.1. Warranty

This Neaspec product is covered by warranty against defects in materials and System components for a period of one year, except if specified otherwise in the purchase contract. Neaspec GmbH guarantees the functionality of the equipment and the declared performance parameters. The warranty period starts from the date of successful acceptance. During the warranty period, Neaspec will, at its option, either repair or replace products which prove to be defective.

Neaspec GmbH assumes warranty only for original and unmodified products, installed by the Neaspec personnel. Any unauthorized modifications or 3rd-party spare parts will void warranty. Particularly, warranty void in case of:

- Improper use of the System (not following regulations listed in this System Description)
- Operation by untrained or unauthorized personnel
- Unauthorized reconstruction
- Unauthorized technical modifications
- Damage caused by the customer's own or 3rd-party electronics or other products
- Opening of delivered boxes by the user (and not by Neaspec personnel)

Neaspec GmbH does not warrant the customer’s electronic components against malfunction that could result from use in combination with the NeaSNOM.

1.3.2. Disclaimer of responsibility and limitations of liability

As a result of special design requirements, customer requests, additional order options or recent technical modifications introduced by Neaspec GmbH, the actual delivery scope, technical details and images used in this System Description may differ from the System installed at the customer's location. Neaspec GmbH does not assume any responsibility for the use of any circuitry described in this reference. Neaspec GmbH reserves the right to change the product specifications and functionality or this System Description at any time, without prior notice. Neaspec GmbH assumes no responsibility or liability for any misinformation, errors or inaccuracies that may unintendedly appear in this manual.

1.4. Installation

1.4.1. Transportation, packaging and delivery

Neaspec will provide own, trained personnel at each customer's site to assist with the initial NeaSNOM installation, acceptance test and usage.

Only Neaspec personnel, or customer's personnel instructed directly by Neaspec GmbH, is authorized to open the packages that comprise the NeaSNOM System.

Upon parcel receipt, the consignment must be checked for completeness and potential transport damages. If there are any visible transport damages, the customer **must** note the extent of the damage in the transport documentation or on the delivery receipt of the carrier.

If the tilt or shock indicators are colored in red:

- Do not refuse the shipment
- Inspect the damage and describe it and its extent on the delivery note
- Leave the components in their original containers and packaging, and request immediate inspection from the carrier within 3 days from the delivery
- Immediately inform Neaspec GmbH with shipment and damage details

The individual components have been packaged according to the expected transportation conditions. For packaging, only environment-friendly materials have been used. The packaging is to protect the individual components from transport damages, corrosion and other damages, until the product assembly by Neaspec personnel. Do not unpack the components and do not discard any packaging material yourself.

Until the assembly by Neaspec personnel, store the packages indoors, in a dry and dust-free environment, at temperatures from 15 to 45 °C and max. 60% humidity. Do not expose the packages to aggressive media, protect them against direct sunlight and keep them prevented from mechanical shocks. In case the products are stored for longer than 3 months, regularly verify the overall condition of the packages.

After installation separate the packaging materials according to category and dimensions, and dispose them in an environment-friendly way. Abide the local disposal regulations.

1.4.2. Installation and commissioning

The NeaSNOM System will be installed and commissioned exclusively by Neaspec personnel or customer personnel explicitly authorized in written form by Neaspec GmbH!

Warning

Risk caused by faulty installation and initial operation! NeaSNOM installation, initial operation and testing must be carried out by Neaspec personnel or customer personnel explicitly authorized by Neaspec GmbH only!

Improper installation can cause significant damage to the System.

- All installation work and initial operation should be performed by Neaspec GmbH personnel or customer personnel explicitly authorized by Neaspec GmbH
- Should the System be transferred for repeated installation or recommissioning, please contact Neaspec GmbH

Regular use of NeaSNOM is restricted to the location where Neaspec personnel has installed and commissioned it. Transfer of this equipment to another location and its installation there without a written consent of Neaspec GmbH will void warranty.

Installation requirements

Neaspec GmbH strongly recommends an air-conditioned room or laboratory for the NeaSNOM installation. The air conditioning and ventilation should not produce air flow directed to or around the NeaSNOM System. The location should have a low level of vibrations and noise (see below). The installation place should be protected against heat, direct sunlight, air draft, moisture and dust.

The NeaSNOM System should be placed on an vibration isolated platform, e.g. an optical table, in order to guarantee the NeaSNOM System specifications. In order to avoid any System vibrations caused by the microscope controller or the user workstation, these components should not be placed together with the NeaSNOM microscope on the optical table. The cables between the NeaSNOM microscope and the controller have a limited length of approx. 1.5m. The cable between the controller and the user workstation is a standard Ethernet cable. The workstation can either be connected directly to the controller, or via an existing Gigabit Local Area Network.

1.4.3. Acceptance test

After installation, the NeaSNOM system will be tested by Neaspec personnel. Full NeaSNOM functionality and performance will be verified. The customer will receive a detailed test report. By accepting the test report, the customer formally verifies that Neaspec GmbH has installed the NeaSNOM System according to the technical specifications stated in the customer's order.

2. Introduction

The NeaSNOM scattering-type Scanning Near-field Optical Microscope is an innovative ultrahigh-resolution optical microscopy and spectroscopy System, based on the Atomic Force Microscope (AFM) technology.NeaSNOM Systems rely on light scattering by the metalized probing tip of an AFM with nanoscale dimensions, enabling near-field optical imaging and spectroscopy at extreme sub-wavelength scale spatial resolution independent of the wavelength of light.

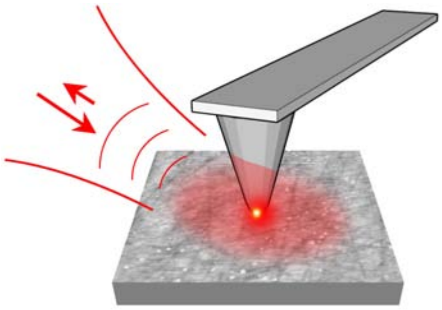


Figure 1: Basic principle of scattering-type Scanning Near-field Optical Microscopy (s-SNOM or ANSOM). The metalized probing tip of an AFM is illuminated by focused light and the back-scattered light is detected.

Scattering-type Scanning Near-field Optical Microscopy (s-SNOM or ANSOM) employs the enhanced electro-magnetic field existing close to the sharp, tip-like metal structures when they are illuminated by light. Figure 1 shows an illustration of the fundamental s-SNOM principle. A sharp metal tip scans a sample surface and simultaneously acts as a mechanical and optical probe, where light is focused onto the tip by an objective. The tip functions as an optical antenna concentrating the incident optical field at its apex to a small spot of only a few tens of nanometers in diameter, which is used as nanoscopic light source for illuminating the sample. When the tip is brought close to a sample surface, the highly confined field at the apex optically interacts with the sample. Because of the optical near-field interaction between the tip and the sample, the tip-scattered light contains information about the local optical properties (e.g. refractive index) of the sample surface. The light back-scattered from the tip can be recorded by a distant detector. Near-field optical images are obtained by raster-scanning the sample surface below the tip. The optical resolution of the images depends only on the geometrical size of the probing tip, but not on the wavelength of light.

The NeaSNOM System is specifically designed to provide optical access to the probing tip in order to illuminate the tip by external light sources and to interferometrically detect the elastically scattered light from the tip by two independent optical axes. The use of patented reflecting optics to focus light to the tip and to detect the tip-scattered light allows to apply the System in a wide spectral range, from visible to terahertz frequencies. In order to keep the probing tip in the focus of an external light source the sample is scanned during the imaging process. The highly flexible System employs individual modules for the interferometrical detection of the tip-scattered light, which are tailored for signal detection of single frequency lasers (e.g. gas lasers) or broadband laser sources. Due to the modular design of the microscope the installed version of the NeaSNOM System can vary according to customer's specific requirements. Naturally, also inelastically scattered light (e.g. Raman scattered) from the probing tip can be detected by appropriate detection schemes.

In Section 3 of the System Description the Atomic Force Microscope components forming the basis of the NeaSNOM System are described. This includes microscope components used to adjust the position of the cantilever on which the probing tip is mounted, the readout mechanism of the cantilever deflection and the sample positioning.

Section 4 outlines the available modules to focus light to the probing tip and to detect the tip-scattered light. A pseudoheterodyne detection unit can be installed for interferometric detection enabling fast near-field image acquisition in single frequency measurements. A broadband detection module can be used for spectroscopic near-field measurements allowing to analyze the tip-scattered light within a given (by the light source) spectral range, similar to Fourier-Transform spectroscopic techniques. Further, a transmissive illumination mode module (used to illuminate the probing tip from below) and a side camera module are available for the NeaSNOM System.

Section 5 contains the listing of technical specifications and Section 6 additional information of other suppliers.

3. NeaSNOM - Scanning Near-field Optical Microscope

3.1. General information about the microscope

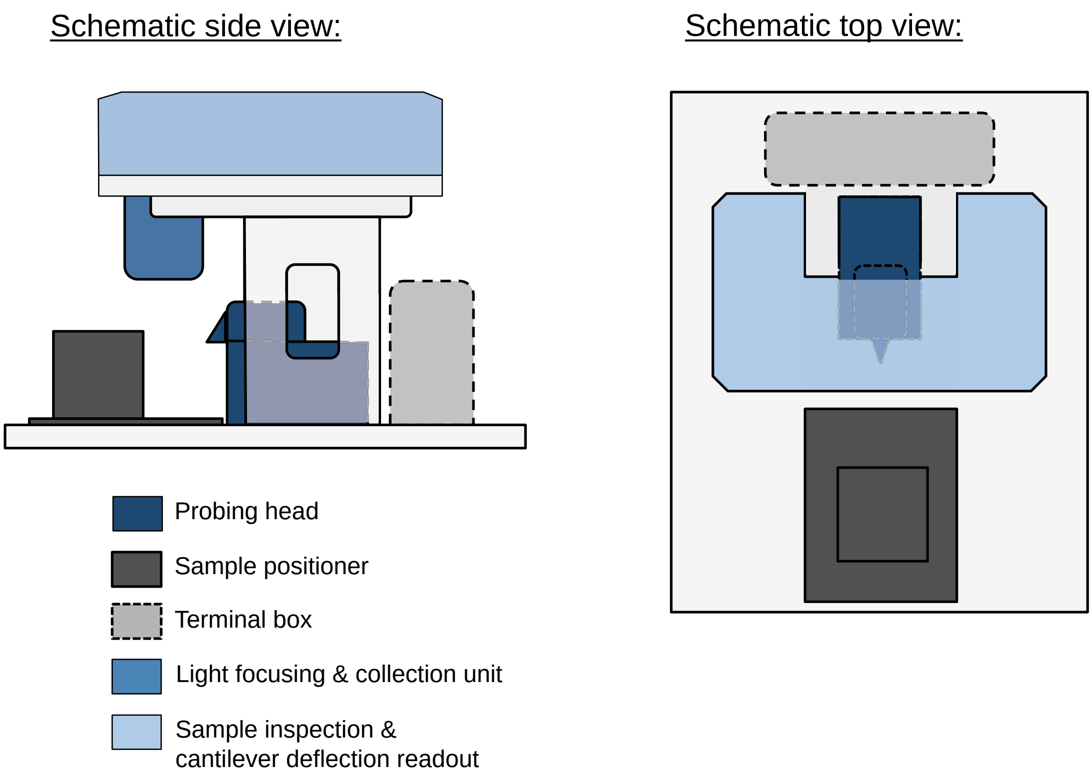


Figure 2: Side and top view (sketch) of the NeaSNOM microscope with the different units labeled.

The NeaSNOM Scanning Near-field Optical Microscope is based on an Atomic Force Microscope (AFM) operated in intermittent contact mode. The AFM consists of different units which are described in the following. In Section 3.2, the probing head is described where the cantilever chip with the probing tip is mounted and positioned. Section 3.3 describes the optical system of the far-field (diffraction limited) sample inspection unit as well as the readout mechanism of the cantilever deflection. The sample positioner which is also used to perform the scanning process is outlined in Section 3.4. The microscope controller including the signal access (Terminal box) and the workstation used to operate the microscope are depicted in Section 3.5. Figure 2 shows schematically the different units of the NeaSNOM System.

3.2. Probing head

The NeaSNOM System employs cantilever based probing tips. Most commercially available cantilevers fabricated on cantilever chips can be used with the NeaSNOM System. The vertical deflection of the cantilever and thus the position of the probing tip is detected by reflecting a laser beam at the backside of the cantilever and monitoring the deflection. The deflection laser (laser class 2) operated at 790nm wavelength is focused by a high-NA objective to the cantilever backside (see also Section 3.3). The laser beam reflected at the cantilever backside is collected by the same objective. The mounting of the objective is stationary and therefore the cantilever position has to be adjusted in all three space coordinates to the focus of the deflection laser. Figure 3 shows a sketch of the AFM head where the chip holder with the cantilever chip is mounted. Linear motors are used to position the assembly of the cantilever holder. The adjustment range for the head motors is 3 and 4mm in y- and z-direction, respectively. The travel range in x-direction is 30mm (required for tip exchange, see below). Positioning resolution down to <200nm can be achieved with the motors in all three directions over the entire positioning range, allowing the precise positioning of the cantilever in the focus of the deflection laser.

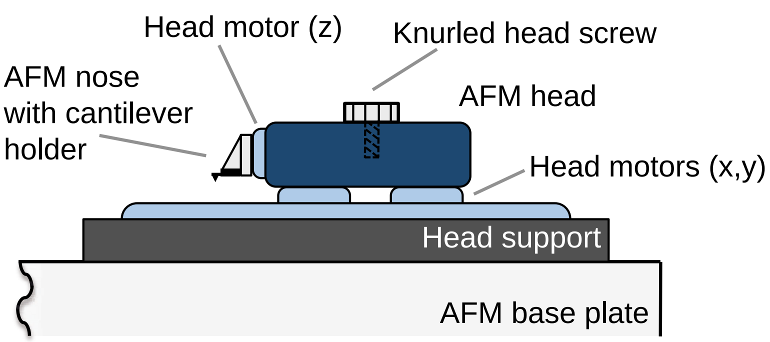


Figure 3: Schematic representation of the NeaSNOM probing head.

All linear motors can be controlled by the user within the Neaspec scan software NeaSCAN. The software includes a module "coarse positioning" where all motors can be driven at selected speeds. Details about the NeaSCAN software are described in the second section of this manual.

In order to replace the probing tip the complete AFM head has to be detached. To achieve this, the head has to be brought in the end position of the x-motors (close to the terminal box, see Fig. 2), the connector for the electrical connections unplugged and the knurled head screw loosened (see Fig. 3). This allows to remove the complete AFM head. In the NeaSNOM System, cantilever chips are mounted to the holder by means of thermal glue. The glue provided by Neaspec GmbH has a melting temperature of approx. 80-100°C, which means that the chip holder has to be heated in order to replace the cantilever chip. The chip holder has to be unmounted before heating. It can be unmounted from the AFM nose by the screw indicated in Figure 4. The position of the chip holder on the AFM nose is determined by an additional alignment pin. Beneath the pin the ring-shaped piezo is located used to excite the cantilever oscillation to operate the AFM in intermittent contact mode. To replace a used or worn-down probing tip a new cantilever chip has to be glued to the holder. The position of the chip on the holder is determined by a repositioning system.

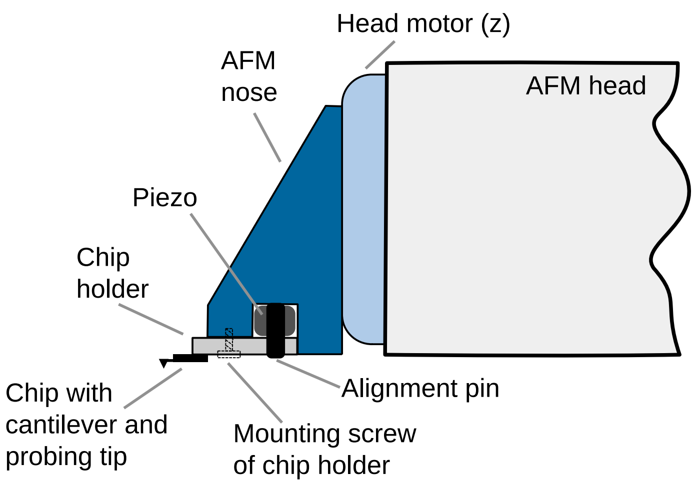


Figure 4: Sketch AFM nose with the cantilever chip holder.

Tip

Only very tiny amounts of thermal glue should be used to fix the cantilever chip on the holder. The screw used to mount the holder on the nose should be fixed tightly but care should be taken not to apply too much torque on the thread.

Caution

Care should be taken not to breake or damage the electrical connections of the AFM head when the chip holder is mounted or unmounted.

Warning

Piezo positioners and linear motors described in this manual are high voltage devices which may cause serious injuries if used improperly. Do not ever touch components that might be connected to high voltages!

3.3. Sample inspection and cantilever deflection readout

An upright optical microscope with an apochromatic objective lens is used in the NeaSNOM System to inspect the sample at diffraction-limited resolution. The same objective is used to focus a laser beam onto the cantilever backside for the cantilever deflection readout (see previous Section). Figure 5 shows the optical beam path for the sample inspection and the cantilever deflection unit. As can be seen in Figure 2, all optical components required for this unit are located in the microscope module above the AFM head and the sample positioner.

Important

Do not open any cover of the NeaSNOM System. Warranty for the System is no longer valid if the cover was opened or the seals are damaged. Any costs for possible realignment work that might be necessary are not covered by Neaspec GmbH.

Caution

Visible or invisible laser radiation is used in the NeaSNOM System (laser class II). Do not remove any cover of the microscope and do not look directly into any laser beam. Severe damage to your eyes may result. Do not look directly in the high-NA objective. If a highly reflective sample is present, laser radiation may occur by refelection of light from the sample surface. Do not look directly in the scattered light from the sample surface below the high-NA objective.

The objective used for the upright optical microscope has a numerical aperture of NA=0.42 at an extra long working distance of ca. 20mm. The resolution that can be achieved with the upright microscope is <0.7µm and the diagonal field of view of the inspection system is >0.8mm. The characteristic properties of the upright microscope can be modified on customer request to increase e.g. the field of view. The image generated by the objective is recorded by a 5MPix CMOS camera where the region of interest (ROI) can be selected in the control software. The resolution and field of view of the displayed image can be adjusted by a three-step digital zoom. The optical beam path for the sample inspection is infinity corrected allowing the introduction of custom filters and polarizers. The focus of the upright optical microscope can be moved along the optical axis of the objective by means of a motorized lens (see Fig. 5). The travel range of the lens is adjusted by Neaspec GmbH such that the focus can be moved from the position of the deflection laser focus (which is fixed) to a plane approx. 200-300µm below. As the cantilever with the probing tip is located at the focus of the deflection laser (see Sect. 3.2), the adjusted travel range of the lens allows to inspect the sample surface before getting into contact with the probing tip.

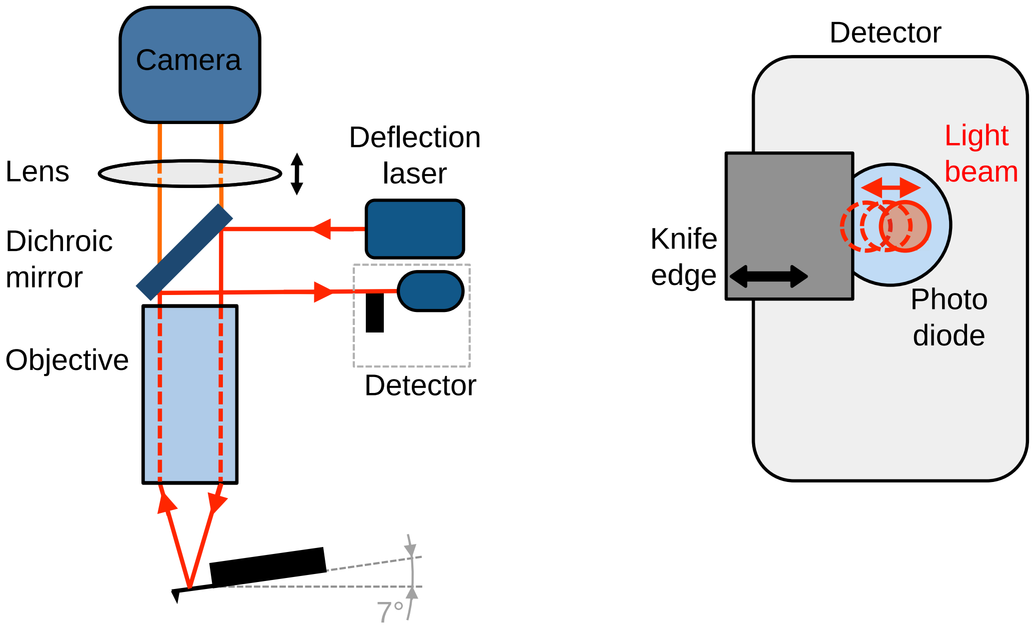


Figure 5: Optical beam path of the NeaSNOM sample inspection and cantilever deflection readout. The sketch on the right side shows the basic principle of the knife-edge detection method: the horizontally moving (oscillating) deflection beam is partly blocked, which results in a modulated electrical signal of the photodiode (see text for details).

To be able to generate an optical image by the camera the sample has to be illuminated. To this end the beam of a high intensity white LED is coupled to the beam path of the upright optical microscope and the sample is illuminated in the Köhler illumination configuration.

To monitor the mechanical tip-sample interaction, a laser beam is focused to the backside of the cantilever (see Fig. 5). Any force applied normal to the tip causes a bending of the cantilever and consequently a translation of the reflected laser beam. The NeaSNOM System employs a low-noise, cw laser diode operated at 790+/-9nm wavelength as deflection laser. The output power of the laser module is <1mW resulting in the classification of the NeaSNOM System as a laser class 2 product. As can be seen in Figure 5 the deflection laser beam is coupled into the optical beam path of the upright optical microscope with the help of a dichroic mirror. The objective is used to focus the laser onto the backside of the cantilever at normal incidence and to collect the reflected beam. Since the cantilever chip is mounted under an angle of 7° the reflected beam is translated, resulting in the spatial separation of the illuminating and reflected deflection laser beam. The dichroic mirror is used again to reflect the deflection signal to the detector. Figure 6 shows an image taken by the upright optical microscope where the elliptical spot of the deflection laser can be seen on the cantilever backside.

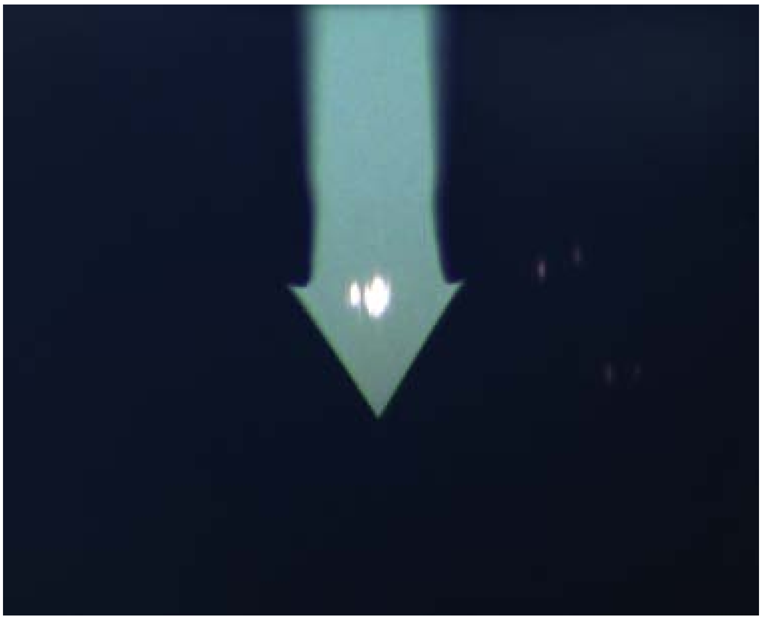


Figure 6: Image taken by the upright optical microscope showing a slightly elliptical focus of the deflectiion laser on a cantilever (Nanoworld, type ARROW™).

In the AFM imaging process of the NeaSNOM System the probing tip is vertically vibrating close to its resonance frequency at an amplitude of approx. 10-100nm (intermittent contact mode). This results in a small movement (oscillation around a center position) of the laser beam reflected at the cantilever backside. In order to monitor the cantilever oscillation the reflected laser beam is detected by an intensity-sensitive photodiode where the incident beam is partly blocked (knife-edge principle). As shown in Figure 5, a knife-edge is placed in front of the detector leading to an intensity modulation of the reflected laser beam at the photodiode. The amplified photodiode signal at the frequency of the cantilever oscillation is used as feedback signal for the tip-sample distance regulation (see following Section).

Tip

The position of the knife-edge has to be adjusted to maximize the ratio between modulated and unmodulated (DC) intensity of the laser beam reflected from the cantilever backside.

3.4. Sample positioner

In order to keep the probing tip in the focus of an external laser source (see Section 4.1) the probing tip is located at a fixed position, as described in the previous Section. The scanning movement for the imaging process of the sample is performed by an integrated sample positioning unit which is used for the sample coarse positioning, performing the xy-scan process and the fine-positioning for the tip-sample distance regulation (z-direction).

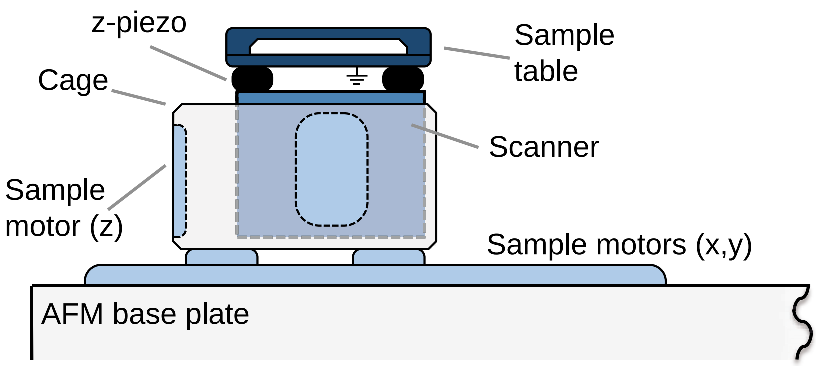


Figure 7: Sketch of the NeaSNOM sample positioner showing the coarse and fine positioning elements.

Figure 7 shows a schematic representation of the sample positioner including the individual positioning elements. Coarse positioning of the sample is done by linear motors with a travel range of >15mm along the x,y-directions and >6mm along the z-direction. The linear motors for the x,y-positioning are mounted on the AFM base plate, whereas the motors for the coarse z-positioning are mounted inside a cage-like construction. The positioning resolution of the motors is <200nm. Optionally the absolute positions of the motors can be read-out by sensor modules at the same resolution. In order to load a sample the positioning unit should be driven to its outer end position.

In the construction shown in Figure 7, the sample x,y-scanner is integrated with a maximum scan range of 100µm x 100µm (closed-loop operation). Integrated capacitive sensors allow to position the scanner with a resolution of 0.4nm in closed-loop operation (open-loop 0.2nm). More specific information about the scanner including a test protocol verifying the linearity of the installed scanner can be provided by Neaspec GmbH on request. On top of the scanner the piezo elements for the fine positioning along the z-direction are mounted (see Fig. 7). The positioning range for the z-piezos is approx. 3µm.

On top of the sample positioning unit the sample table is mounted consisting of a base plate and a top plate. The maximum sample size supported by the sample table is about 40x50mm. In case that high (> ca. 8mm) samples should be imaged the top plate can be unmounted. To fix a sample holder on the top plate clamps or magnetic holders can be used which are provided by Neaspec GmbH. In order to avoid electrostatic charging of the sample the sample table is connected to ground by default.

Important

Care should be taken not to interrupt the ground connection of the sample table when the original construction is modified. This may lead to electrostatic charging of samples and inability to perform near-field optical measurements.

In the AFM imaging process of the NeaSNOM System the distance between the tip and the sample has to be controlled in order to compensate for different heights of surface features. When the probing tip contacts the surface of a sample the oscillation amplitude is reduced. This allows to exploit the cantilever oscillation amplitude as a feedback signal to regulate the distance between probing tip and sample surface. In the NeaSNOM System the oscillation amplitude is monitored and the tip-sample separation is automatically adjusted to keep the amplitude constant by means of an amplitude-based feedback distance regulation. The distance regulation uses the z-piezos as actuators. The piezos allow a fine-positioning of the sample along the z-direction at a noise-limited resolution of <0.2nm (RMS). When the probing tip scans across topographic features during the imaging process the oscillation amplitude changes (in-/decreases at depressions/heightenings) and the tip-sample separation is readjusted by the z-piezos to reach the default value (set-point) of the oscillation amplitude. Thus, deviations from the default value are compensated by the feedback and the oscillation amplitude is ideally kept constant during the imaging process. The map of the amplitude signal represents a measure for the quality of the AFM imaging process and the adjustment of the imaging parameters (e.g. feedback parameters). Note that strong signal variations (> ca. 10-15%) of the oscillation amplitude must be avoided as this may lead to artifacts in the near-field optical images.

Tip

The AFM imaging process requires the adjustment of the oscillation amplitude as well as of the scanning speed and the feedback parameters according to the topographic features on the sample surface. High quality AFM and near-field optical images can be obtained only with optimized imaging parameters!

Caution

Heavy loads on the sample table may modify the properties of the automatic tip-sample distance regulation.

The NeaSNOM System features a software-based automatic approach routine that can be used to bring the probing tip in contact with the surface of a sample. The routine controls an interplay between a step-wise movement of the z-motors and a continuous extraction of the z-piezos. In the control software of the microscope (described in Chapter 2 of this document) a target value for the oscillation amplitude of the cantilever (set-point) can be given (usually between 80-95% of the free oscillation amplitude) and the automatic approach moves the sample towards the probing tip until the setpoint value is obtained. The control software is also used to adjust the scan area, pixel number, scanning speed and the AFM imaging parameters (oscillation amplitude, feedback parameters, etc.).

3.5. Microscope controller and workstation

The NeaSNOM System features a controller that is used to actuate and regulate the imaging process of the microscope as well as to analyze the optical signals. Required electrical signals are delivered to the microscope via a terminal box located at the backside of the microscope. A separate workstation is used to adjust necessary microscope settings and to display all available signals in the microscope control software NeaSCAN. The features of the controller, the workstation and the terminal box are described in this Section together with the necessary electrical connections between microscope and controller as well as available signal outputs.

3.5.1. Controller

The Neaspec microscope controller is specifically designed to support Scanning Probe Microscopy (SPM) imaging in the intermittent contact mode and to analyze the optical signal of the tip-scattered light. Both tasks have to be synchronized which is one of the key features of the NeaSNOM System. The controller supports cantilevers with resonance frequencies of up to 500kHz. It performs the demodulation process of the pseudoheterodyne modulated optical signal (for single wavelength measurements) as well as the analysis and (Fourier-) transformation of the optical signals in broadband near-field spectroscopic measurements. It allows for simultaneous demodulation of up to 4 signal harmonics at a highest input signal frequency of f>1MHz (at -3dB). More information about the demodulation process can be found e.g. in the reference "Ocelic N. et al., APL 89, 1010124 (2006)". Alternatively, Neaspec GmbH can be contacted directly for further information.

Details about what kind of information can be extracted from the tip-scattered light as well as models describing the optical near-field interaction between probing tip and sample are beyond the scope of this System Description. On request Neaspec GmbH can provide references presenting a theoretical framework for the physics involved in scattering-type Scanning Near-field Optical Microscopy.

The controller supports 11 independent coarse positioning axes for linear motors as well as up to 4 independent fine positioning axes (piezo actuators). In combination with the scan software NeaSCAN, 1D, 2D or 3D scans with arbitrary offsets and rotations can be performed where the scan size is limited only by the range of the piezo actuators. The image size is limited only by the available memory of the System. As outlined in Section 3.4, the AFM imaging process requires the regulation of the tip-sample separation. For this purpose the Neaspec controller features a software-based feedback employing a proportional and integral controller.

The microscope controller is a 19'' rackmount computer containing components from other manufacturers as well as electronic boards designed and fabricated by Neaspec GmbH. On the frontside of the controller a ON/OFF button is located together with a reset button and some indicators. Pressing the ON/OFF button for >3s forces the controller to shut off. The frontside of the controller also provides signal access to the individual boards of the controller. Figure 8 shows a sketch of the controller frontside layout with the individual boards labeled. Table 1 lists all the required electrical connections of the controller. Neaspec GmbH reserves the right to modify the layout of the controller together with the electrical connections in order to tailor the controller functionality according to requested specifications or keep the microscope controller at the most sophisticated level of available electronic equipment. Red LED signal lights at the controller backside indicate overload of electronic boards.

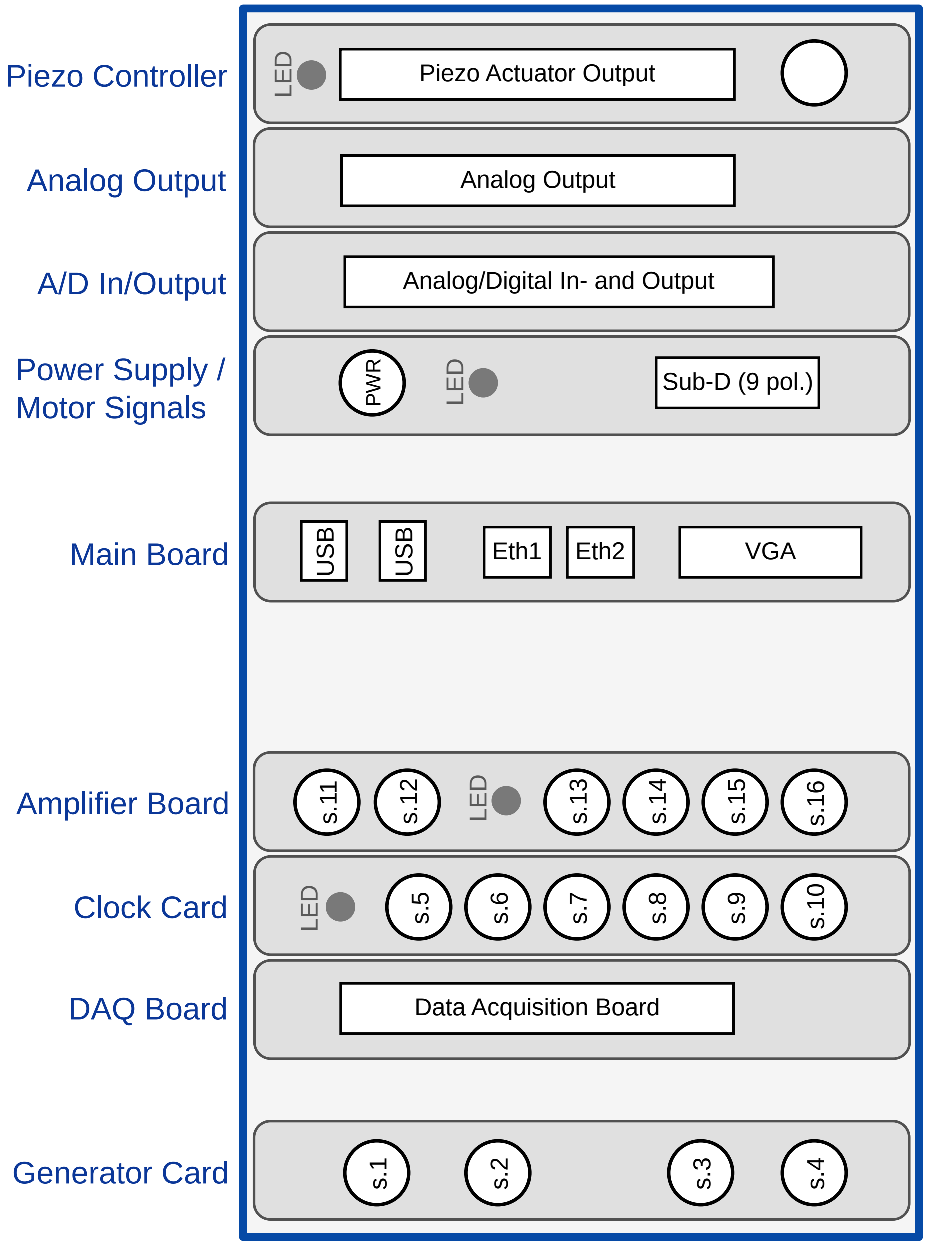


Figure 8: Sketch of the controller frontside with the individual boards and connectors labeled.

Table 1: Controller connections

Card:	**Connector:**	**Signal:**	**Connected to:**
Generator card	s.1	Cantilever oscillation excitation	Terminal box, Head Piezo, f.2
	s.2	Oscillation signal phase modulation	Controller, amplifier board, s.15
	s.3	-	-
	s.4	Synchronization signal	Controller, clock card, s.7
DAQ board		Detector signal	Terminal box, DAQ connector
Clock card	s.5	-	-
	s.6	-	-
	s.7	Synchronization signal	Controller, Generator card, s.4
	s.8	-	-
	s.9	-	-
	s.10	Synchronization signal	Controller, connection to inside
Amplifier board	s.11	Sync. IN	Info: generates a TTL signal from arbitrary signal forms for synchronization purposes
	s.12	Sync. OUT	

Card:	Connector:	Signal:	Connected to:
	s.13	Monitor of phase modulation signal	Info: 1/100 of Ch. s.16 output voltage
	s.14	ext. offset to phase modulation signal	Info: allows to apply an external offset voltage to phase modulation signal
	s.15	INPUT of phase modulation signal	Controller, Generator card, s.2
	s.16	OUTPUT of phase modulation signal (amplified)	Piezo actuator of phase modulation unit
Main board	Eth1	Ethernet connection to LAN	
	Eth2	Ethernet connection to workstation	
Power supply	PWR	Power supply of microscope	Terminal box, s.7
	Sub-D	Motor signals	Terminal box, f.11
A/D In/Output	68-pol. connector	Analog/Digital In- and Output signals	Terminal box, f.12 (A/D In- and Output)
Analog Output	37-pol. connector	Analog Output signals	Terminal box, f.13 (Analog Output)
Piezo Controller	Sub-D special connector	High voltage signals for piezo actuators	Piezo actuators

3.5.2. Terminal box

Electrical signals provided by the controller are delivered to the microscope via the terminal box. Further, the optical detectors are directly connected to the terminal box. Several signal in - and outputs are provided at the box, where the signal of the analog output channels 1-4 can be adjusted in the NeaSCAN software. Figure 9 shows a sketch of the terminal box and Table 2 lists the connectors and elements including their signals or usage. Note that for security reasons the high voltage output of the Piezo Actuator Output (compare Fig. 8) is connected directly to the actuators (not via the terminal box).

	**Warning** **Do not unplug or modify the electrical connections to the piezo actuators. Do not use the connections for other purposes. Danger of high voltage!**

	**Warning** **Maximum output power of detector power supply (+/-15V, GND) is 1.5W. Do not allow high higher power consumption. Higher power consumption will cause malfunction of the NeaSNOM System! Damage to the NeaSNOM System resulting from detector power supply overload will not be covered by Neaspec GmbH.**

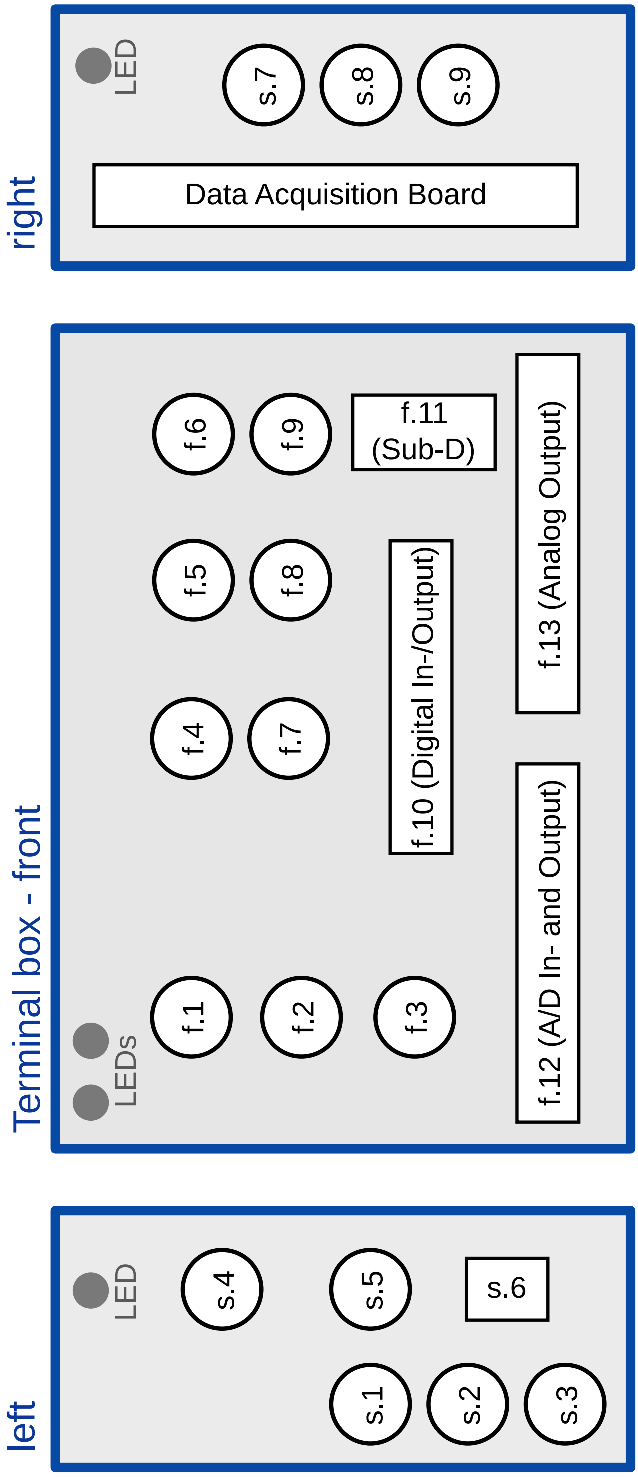


Figure 9: Sketch of the terminal box connectors.

Table 2: Terminal box

Side:	Channel:	Signal:	To:
left	s.1	Detector power supply: + 15V (red)	Detector
	s.2	Detector power supply: GND (black)	Detector
	s.3	Detector power supply: - 15V (blue)	Detector
	s.4	Interlock	Info: Interlock for deflection laser
	s.5	Power supply of microscope	Controller, PWR
	s.6	ON/OFF of +/-15V	Switch for detector power supply
front	f.1	Tapping out	Info: output signal of photo diode (oscillation signal)
	f.2	Cantilever oscillation excitation	Controller, Generator card, s.1
	f.3	Potential tip	Info: electrical connection to tip, can be used to bias tip. Should be grounded in normal use!
	f.4	Analog Input 1	-
	f.5	Analog Input 2	-

Side:	Channel:	Signal:	To:
	f.6	Analog Output 1	Info: can be adjusted in NeaSCAN software
	f.7	Analog Output 2	Info: can be adjusted in NeaSCAN software
	f.8	Analog Output 3	Info: can be adjusted in NeaSCAN software
	f.9	Analog Output 4	Info: can be adjusted in NeaSCAN software
	f.10	Digital In- and Output	Info: details on request
	f.11	Motor signals	Controller: power supply, Sub-D
	f.12/13	Analog/Digital In-Output signals to microscope	Controller, A/D In- and Output (68-pol. and 37-pol. connectors)
right	s.7	Optical input channel 1	Detector (output signal)
	s.8	Optical input channel 2	Detector (output signal)
	s.9	Optical input channel 3	Detector (output signal)
	DAQ	Detector and deflection signal	Controller, Data Acquisition Board

3.5.3. Workstation

The microscope is operated with the help of the scan software NeaSCAN, which is pre-installed on the workstation. The station has a quad-core CPU and uses three 22" displays to present all available information. The operating system of the station (Ubuntu Linux) and the state-of-the-art open source SPM image analysis software (Gwyddion) are installed by Neaspec GmbH. The workstation can be connected to the microscope controller directly or via a local network. Latter option allows to use several workstations at different locations to operate the microscope.

All functions of the microscope can be controlled in the scan software NeaSCAN. Dedicated windows are used to display signals and to adjust the individual functions of the different microscope units. Details about the software can be found in Chapter 2 of this manual. In general, the software is tailored to a large number of input channels (standard configuration up to 24 channels) and the adjustable image size is limited only by the free memory of the system. The standard configuration of the system allows to perform up to 4MPix scans. Ruby scripting language is integrated in the scan software which allows to automate specific tasks or easily extend the software for additional features. NeaSCAN software source code is installed on the workstation. Modification of the NeaSCAN software voids the warranty.

4. NeaSNOM microscope modules

This Chapter describes the modules of the NeaSNOM System used to focus light to the probing tip and to interferometrically detect the tip-scattered light. The flexible design of the microscope allows to use the modules individually or in different combinations according to customer requirements. The NeaSNOM System employs reflective optics to focus light to the tip and to collect the tip-scattered light, which allows to use the focusing optics in a wide spectral range, from visible to infrared to terahertz frequencies.

Scattering-type Scanning Near-field Optical Microscopy suffers in general from an unfavorable signal to background ratio. In order to enhance the near-field signal compared to background signal, AFM imaging is performed in intermittent contact mode and the optical signal is detected at higher harmonics of the cantilever oscillation frequency (see previous Sections). The background interferences can be even further reduced by interferometric detection schemes. A special patented interferometric detection scheme that is used in the NeaSNOM System enables the complete suppression of the background interference. Moreover, interferometric detection enables the determination of a near-field amplitude and phase signal from the complex scattering signal, which can provide complementary information about the local optical properties of a sample.

Interferometric detection schemes tailored for single frequency or broadband spectroscopic measurements are used in the NeaSNOM System. The basic configuration of the optical beam path and the characteristic properties of the interferometric detection schemes are outlined in the following.

4.1. Light focusing and collection unit

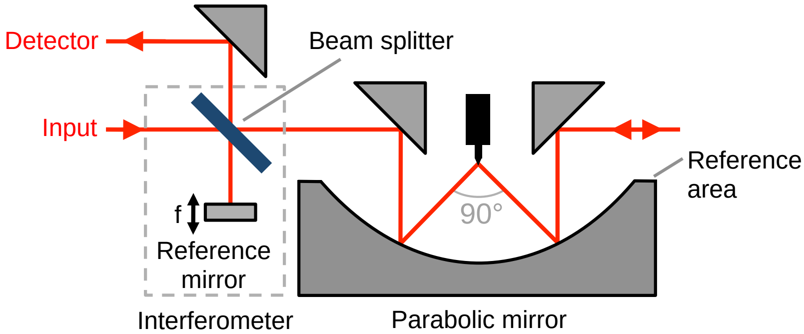


Figure 10: Optical beam path of the NeaSNOM microscope in the standard configuration.

Figure 10 shows the basic optical beam path of the NeaSNOM microscope. Interferometric detection of the tip-scattered light is enabled by the configuration of a Michelson interferometer. The beam path used to illuminate the probing tip represents one arm of the Michelson interferometer. Incoming light is partly transmitted through a beam splitter and then focused onto the probing tip by a parabolic mirror. Ideally, the transmission-reflection ratio of the beam splitter is 50:50 for the application in the NeaSNOM System. Note that the beam splitter has to be selected according to the spectral range where the microscope is operated. Figure 10 shows that the incoming light is directed to the parabolic mirror by a 45° deflection mirror. The use of the deflection mirror allows to provide two optical pathways to illuminate the probing tip. Both pathways use the same parabolic mirror to illuminate the tip. The tip-scattered light is collected by the same parabolic mirror.

Tip

The beam splitter used as the central element in the interferometric detection scheme of the NeaSNOM has to be selected according to the spectral range where the microscope is operated.

Light reflected at the beam splitter serves as reference arm in the Michelson interferometer. In the NeaSNOM System the reference arm mirror represents a full microscope module which can be selected according to the desired application. In the following Sections the properties of the available modules for the interferometric detection are outlined in more detail. The interferometric detection modules are designed to keep the length of the interferometer arms as short as possible in order to achieve a high mechanical stability. If necessary the detection modules exhibit the ability to adjust the length of the interferometer arm to the same length as of the tip arm enabling the use of light sources with short coherence lengths (adjustment to white light position). Suitable attenuators can be used to adjust the intensity of the reference arm.

A patented broadband parabolic mirror, specifically designed for the use in the NeaSNOM system is used to focus light to the probing tip. The mirror can be used in the spectral range from visible to terahertz frequencies and supports dual-beam operation, as outlined above. The available optical aperture of the mirror covers 2x45° with a mirror height of approx. 15mm. The maximum numerical aperture of the parabolic mirror in the plane perpendicular to the beam axis is NA=0.37. The parabolic mirror exhibits a reference area which is oriented perpendicular to the optical axis of the mirror. For alignment purposes a pilot laser can be reflected at the reference area facilitating the adjustment of the interferometer.

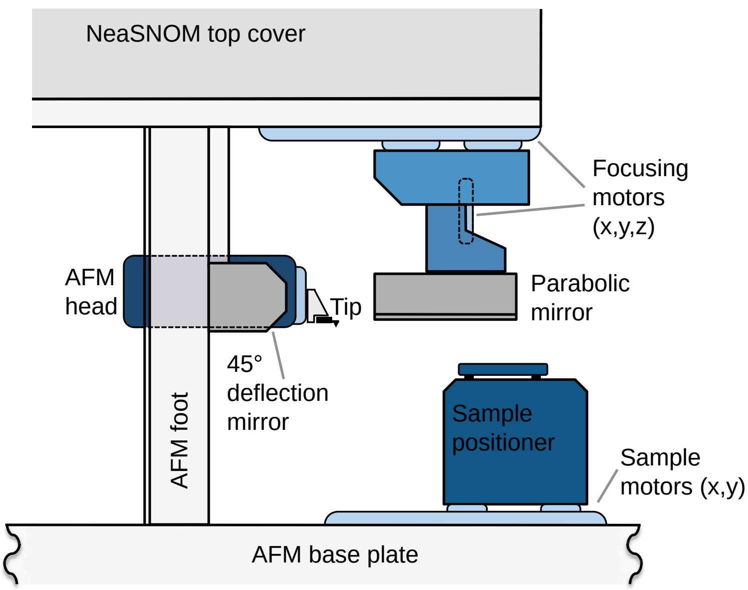


Figure 11: Sketch of the NeaSNOM light focusing module.

Figure 11 shows that the parabolic mirror is mounted on a x,y,z-translation stage. The travel distance of the mirror is >4mm in all three directions. The smallest step size of the linear motors is <100nm. This allows to adjust the position of the parabolic mirror in such a way that the probing tip is located in focus of the incident light. Note that the position of the probing tip is fixed, as outlined in Section 3.2. The position of the mirror can be determined by sensors at a resolution of <100nm. The microscope control software allows to save arbitrary mirror positions and to monitor the mirror movement according to the sensor signals.

4.2. Pseudoheterodyne detection module

Operation of the NeaSNOM System with single frequency laser sources allows for fast near-field image acquisition. For single frequency measurements in the visible to terahertz spectral range the pseudoheterodyne detection module should be used. The patented pseudoheterodyne detection method is based on a phase-modulated reference which is obtained by vibrating the reference mirror of the interferometer at a frequency f. The modulation frequency can be adjusted in pre-defined intervals from 0Hz to a maximal frequency of approx. 2kHz. Note that the amplitude of the mirror oscillation has to be adapted to the wavelength of light, which also limits the maximal modulation frequency. The adaption of the oscillation amplitude to the wavelength of light is a prerequisite for the correct determination of the near-field amplitude and phase signal. In the sketch of the module, shown in Figure 12, it can be seen that the reference mirror of the Michelson interferometer is fixed on top of a piezo actuator. The piezo actuator is mounted vertically in the module in order to reduce the excitation of mechanical vibrations in the complete System by the mirror oscillation. Details about the pseudoheterodyne detection method can be found e.g. in reference "Ocelic N. et al., APL 89, 1010124 (2006)". An additional voltage offset can be applied to the piezo actuator to control the center position of the mirror oscillation. The microscope software allows to select the integration time for the detection of the optical signal in the range from 2.8ms to 1.5s.

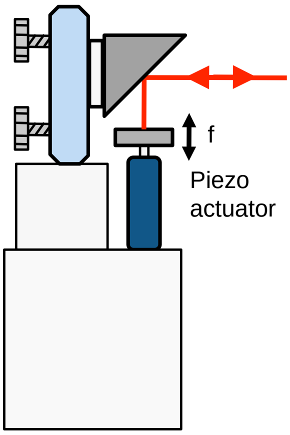


Figure 12: Sketch of the pseudoheterodyne detection unit.

Warning

Danger of hazardous laser radiation! Do not look into the laser beam. Use appropriate safety equipment.

4.3. Broadband detection module

To enable spectroscopic near-field measurements based on light sources that cover a wider spectral range, a broadband near-field signal detection module was developed by Neaspec GmbH. The patented broadband detection module includes a Fourier-Transform spectrometer that operates from visible to terahertz frequencies. This module employs a Michelson interferometer and the spectroscopic measurement is based on the linear movement of the reference mirror over a given distance. To be able to detect an interferogram also for light sources with short coherence lengths the reference arm and the tip arm of the interferometer need to have about equal lengths. Acceptable deviations from the optimal situation of equal interferometer arm lengths are determined by the coherence length of the light source. To achieve the adjustable interferometer arm length and to linearly move the reference mirror an integrated unit was developed. This unit consists of a fine-positioning element containing a piezo actuator and a 1-dimensional translation stage for coarse positioning (see Fig. 13). The high-linearity piezo actuator has maximum a travel range of d=800µm at a positioning resolution of 1.8nm. Resulting interferograms of the near-field signal can be Fourier transformed to obtain spectral information, analogous to FTIR spectroscopy. The module allows to record up to 5 spectra per second at a spectral resolution of up to 6cm^{-1}. On request the spectral resolution can be increased by the use of an actuator with larger travel distance.

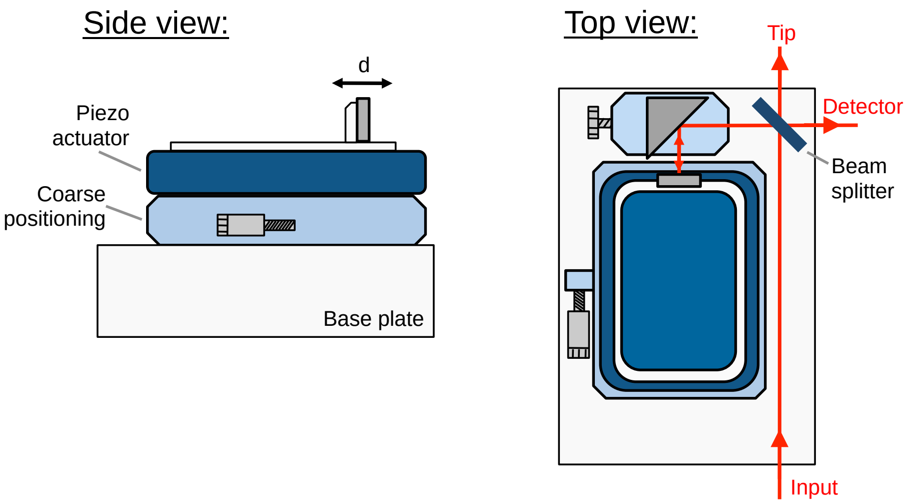


Figure 13: Schematic side and top view of the NeaSNOM broadband detection module.

	Warning **Danger of hazardous laser radiation! Do not look into the laser beam. Use appropriate safety equipment.**

4.4. Transmissive illumination mode module

The NeaSNOM System offers the possibility for transmission mode measurements, where the probing tip is illuminated through a sample from below or the incident light is focused from below to a fixed position of the sample. Figure 14 shows two available illumination configurations of the transmissive illumination mode module. In both configurations the ground plate of the microscope must be modified and mounted on small posts in order to enable bottom-side illumination of a sample.

The additional space between ground plate and optical table is required to place necessary optical elements like mirrors below the microscope ground plate.

Figure 14 (left) shows the configuration where the focus of the light incident from below is fixed to the location of the probing tip. A long working distance objective mounted close to the sample positioner is used to focus light to the probing tip. Note that the objective must be selected according to the spectral range where the transmission measurements should be performed. In this configuration the objective is mounted stationary and, if necessary, the focal point can be slightly re-adjusted by translating the incident beam. As a result the focus of the tip-illuminating light is kept fix in this configuration at the position of the probing tip during the imaging process. On request the transmission mode module can be configured to enable plane wave illumination of the tip/sample. With the help of a specifically designed sample table the sample is positioned on the optical axes of the incident light (from below). The imaged sample surface is illuminated through the sample, which makes at least partly transmissive sample substrates mandatory. The parabolic mirror of the standard configuration (compare Section 4.1) is used to collect the tip-scattered light.

Instead of the long working distance objective an broadband parabolic mirror can be used to focus light to the probing tip from below.The parabolic mirror can be adjusted in xyz-directions in order to align the focus to the probing tip. Another benefit of the use of the parabolic mirror is thaht the AFM base plate does not need to be elevated.

In another configuration, the objective of the transmission mode module is replaced by a Fresnel lens mounted close to the sample on the sample positioner (Fig. 14, right). This allows to keep the focus of the incident light fixed at a specific position of the sample during the imaging (scan) process. As a result, the focus moves together with the sample during the imaging process. The Fresnel lens has to be selected according to the specific requirements (e.g. spectral range) of the measurements.

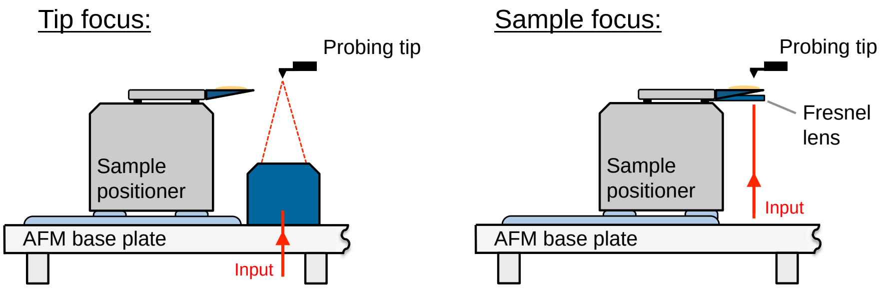


Figure 14: Transmission mode module of the NeaSNOM microscope with a fixed focal point at the position of the probing tip (left) or at a specific sample position (right).

4.5. Side camera module

The flexible design of the NeaSNOM System allows to generate an optical image with the help of the parabolic mirror that is used to focus light to the probing tip (patent pending). Figure 15 shows an representative image recorded by an imaging system (side camera module) which includes the parabolic mirror as an optical element. This allows to acquire an optical image of the probing tip and the sample surface along the optical axis of the illuminating light. Thus, an alternative perspective for the sample inspection additional to the optical image recorded by the upright optical microscope is available. Prerequisite to generate an image by the side camera module is that the focus of the parabolic mirror is adjusted to the probing tip. In Figure 15 it can be seen that due the high NA of the parabolic mirror only the probing tip appears focused on the recorded image. Already the cantilever is out of focus and appears blurred. In Figure 15 a strongly attenuated red HeNe laser beam focused to the probing tip indicates the position of the focal point. The sample shown in Fig.15 is a structured Au film (yellow) on a Si substrate (gray).

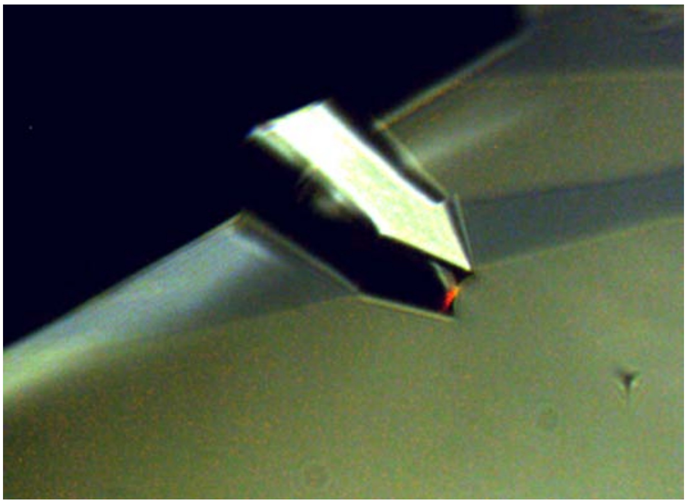


Figure 15: Image recorded by the side camera module

In order to generate an optical image of the probing tip by the side camera module a beam splitter is placed in the detector arm of the interferometer. In combination with some moveable mirrors the beam splitter allows to generate an optical image on a 2.5MPix CCD camera. A lens adjustable along the optical axis is mounted in front of the camera to focus the image on the camera. A lens tube system is used to mount the lens, which also allows to introduce additional filters or polarizers in the beam path. Note that the beam splitter reduces the intensity that can be focused on the detector used for the near-field measurement. To avoid this drawback the beam splitter is mounted on a repositioning plate and can be removed if necessary.

5. Technical data

General

Dimensions: microscope	400x300x290 mm
Dimensions: controller	450x450x180 mm
Dimensions: workstation (excl. displays, etc.)	450x220x450 mm
Weight: microscope	approx. 25 kg
Weight: controller	approx. 20 kg
Weight: workstation	approx. 15kg
Operating temperature range	+15...+25 °C (stabilized)
Humidity	<70% relative humidity, non-condensing
Altitude	< 2000 m
Storage temperature	-10...60 °C

Input / Output voltage	In: 230 / 110 V (47-63 Hz)
	Out: -40...140 V, depending on output channel (see individual Sections of System Description for details)
Microscope fuses	2x F2A microfuse

Warning

Intense voltage spikes may damage the System electronics.

Warning

Only Neaspec personnel or specifically instructed users may change System fuses.

Warning

Danger of hazardous voltage! The voltage supplied to the NeaSNOM System may cause injury of the user.

Warning

Danger of hazardous voltage! The NeaSNOM System uses high voltages which my cause injury of the user in case of improper usage. Do not open or disassemble the System.

Upright optical microscope

Integrated optical microscope with apochromatic objective lens.

Numerical Aperture	NA = 0.45
Working distance	19 mm
Field of view	>0.8 mm
Resolution, min.	<0.7 µm
Digital Camera resolution	5 MPix
Vertical focusing range, min.	approx. 250 µm
Slots for custom filters / polarizers	
Gig E Vision compliant	
Region-of-interest (ROI) selection	

Sample positioning

Coarse positioning range, x-direction	>60 mm
Coarse positioning range, y-direction	>15 mm
Coarse positioning range, z-direction	>8 mm
Resolution coarse positioning, x,y,z-directions	<200 nm
Coarse positioning speed, max.	approx. 3 mm/s
Fine positioning range, z-direction	approx. 4 µm
Fine positioning range, x,y-directions	100x100 µm
Resolution fine positioning, z-direction	<0.2 nm (RMS), 0.15 to 150 Hz
Resolution fine positioning, x,y-directions	0.4 nm (closed loop)

Probing head

Optical access to tip (horizontal x vertical)	180 x 60°
Coarse positioning range, x-direction	>30 mm
Coarse positioning range, y-direction	>3 mm
Coarse positioning range, z-direction	>4 mm
Resolution coarse positioning, x,y,z-directions	<200 nm
Coarse positioning speed, max.	approx. 3 mm/s
Cantilever oscillation frequency	16 - 500 kHz
Automatic detection of cantilever resonance frequency	
Deflection laser wavelength	790 +/- 10 nm
Deflection laser optical output power	<1 mW
Deflection laser class	2
Deflection laser HF-modulated	

Focusing and collection unit

Spectral range	Vis...THz
Optical pathways	2
Usable aperture	2x45°
Numerical aperture	NA=0.37
Coarse positioning range, x,y,z-directions	>4 mm
Resolution coarse positioning, x,y,z-directions	<100 nm

Pseudoheterodyne detection unit

Spectral range	Vis...THz
Modulation frequency range	0...2000 Hz
Integration time	0.0065...1.5 ms

Broadband detection unit

Spectral range	Vis...THz
Spectral resolution	>6 cm^{-1}
Data acquisition speed	up to 5 spectra/s

Pilot Laser

Wavelength	633 nm
Optical output power	>1 mW
Power stability	+/-5%
Linear polarization	

Control unit

Support of intermittent contact scanning probe microscopy mode	
Demodulation of pseudoheterodyne modulated signal	
Analysis of broadband near-field signals	
Demodulation of up to 4 optical signal harmonics simultaneously	
Number of independent coarse positioning axes, max.	11
Number of independent fine positioning axes	4
Max. cantilever resonance frequency	500 kHz
Max. signal input frequency (at -3dB)	1.0 MHz

Workstation

Quad core CPU
3 x 22" displays
Pre-installed Ubuntu Linux OS
Pre-installed state-of-the-art open-source SPM image analysis software (Gwyddion)

NeaSCAN Software Description

NeaSCAN Software Description

May 2010

Table of Contents

1. General information

1.1. About

NeaScan Software Manual provides software usage information for the Neaspec Scanning Near-field Optical Microscope, NeaSNOM.

All NeaSNOM users should read this manual prior to working with the system.

For technical specifications of the NeaSNOM system please refer to the NeaSNOM hardware documentation.

2. Introduction

NeaScan Software Manual documents all available NeaScan features.

Sections 1 to 3 provide general information applicable to the NeaScan software.

Later sections provide detailed information on the individual components. This manual hierarchically organizes the components and their features in a tree of subsections, with each leaf subsection describing one element of the user interface. This allows for quick location of any specific element, such as a button or a value input field, by performing a look-up in the Table of Contents.

2.1. Supported platforms

NeaScan is a cross-platform control and signal-display program for the NeaSNOM near-field optical microscope.

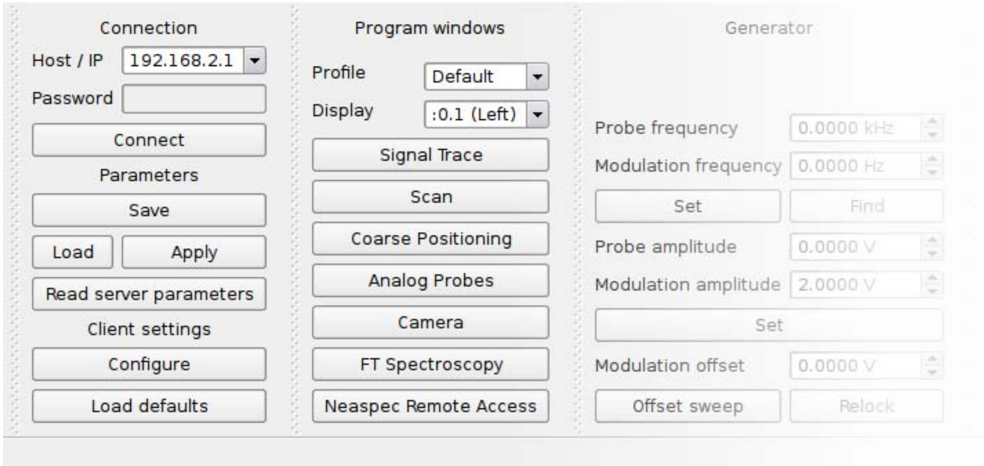
NeaScan is officially supported on the NeaSNOM workstation running Ubuntu Linux, installed and tested by the Neaspec GmbH personnel.

The documentation for installing and running NeaScan on computers running other GNU/Linux distributions, Microsoft Windows and Apple MacOS X is in preparation.

2.2. Software components

NeaScan user interface is designed to support personalized and efficient working environments for all NeaSNOM users.

The complete functionality of the NeaScan user interface is divided into components and each component is represented by a separate window.



The following components (program windows) are available:

Control component contains the NeaSNOM server connection parameters and is used as a starting point for launching other components. It is also used for setting the operational NeaSNOM system parameters.

Signal Trace component displays continuously running plots of the demodulated mechanical vibration and optical signals, along with specialized spectrum and frequency sweep plots.

Scan component performs all scanning-related operations and displays the acquired images.

Coarse Positioning component controls the coarse movement of the edge, head, lens, sample and mirror positioners.

Analog Probes component controls the signals available at the NeaSNOM auxiliary analog outputs.

Camera component allows control and display of live video from all built-in NeaSNOM cameras.

FT Spectroscopy component performs all operations related to the optional Fourier-transform spectroscopy module.

2.3. Common keyboard shortcuts

All NeaScan windows share a common set of keyboard shortcuts, defined in addition to any of the usual shortcuts provided by the operating system or the desktop environment:

F8	Display current connection password
F9	Display NeaScan version information
F11	Show / hide built-in NeaScan command line interface (expert feature)
F12	Connect to / disconnect from the NeaSNOM server
Ctrl+W	Close current window
Ctrl+Q	Close all windows in the current NeaScan process Note: In the default setup, NeaScan opens one window per process and so this shortcut equals Ctrl+W

2.4. Application settings and state

NeaScan saves and restores the complete application state across program or workstation restarts.

The "state" of the application comprises the window visibility, size and position, along with the states and values of all of the contained control elements, i.e. buttons, dropdown menus, spinboxes and text inputs.

Every time a program component connects to the NeaSNOM server, it will also retrieve the values of the variable parameters from the server and override the restored or default parameters accordingly.

2.4.1. Profiles

NeaScan profiles represent independent sets of saved application states. They allow multiple configuration sets to coexist under the same system user name.

This feature supports a wide range of usage scenarios, including:

- Different configuration settings for one user on a single workstation, e.g. running two Signal Trace windows, each with its own size, position, set of signals and other preferences
- Different configuration settings for one user on multiple workstations with a shared home directory
- Multiple users on the same workstation under the same system user name

The complete NeaScan state and all of its settings are always saved to a certain settings profile. When no named profile is specified, data is saved to the default, top-level profile.

All options are saved and loaded according to the active profile and no options affect settings in other profiles.

NeaScan may read and use profile settings in runtime, but it reads and uses most of them during the corresponding component window startup. Likewise, NeaScan may modify and save profile settings in runtime, but it reads and saves most of them during the corresponding program window shutdown.

Incompatible changes in the saved state are sometimes introduced as a consequence of NeaScan software improvements from version to version. To gracefully handle such conditions, a component started with an incompatible profile for the first time will silently discard the saved state and reset the profile to default settings.

For more information, please see Section 3.4.1, “Profile”.

2.5. Common interface behavior

2.5.1. Status messages

All NeaScan components contain a status bar, located at the bottom of the window area.

```
Position:  F=0233- S=0041 V=0000  (+008.2500/-039.7500/+000.0000 µm)
```

To minimize work flow interruptions, all informational and error messages, including status of actions in progress and user interface hints, are conveniently displayed in the corresponding status bar, requiring no user interaction.

The messages are formatted and adjusted to the one-line nature of the status bar. In windows where the status bar is used for displaying structured information, e.g. the scanner progress or pixel values, fixed format and fixed-width font are used for easier reading.

Status bar messages do not have time-limited duration and stay visible until another, more recent or more relevant message is displayed. When the mouse pointer is moved quickly between various options, individual messages could stay displayed for only a short period of time and thus be overlooked.

To be able to read all status and error messages, users getting familiar with the system are advised not to move the mouse pointer immediately after clicking program buttons and options. That way, there will be no new events that could overwrite status information displayed as a result of the previous action.

Successfully executed actions generally do not emit a status message.

Error messages always emit a status message containing information useful in identifying and correcting the problem. If the status bar is missing or the user interface element cannot locate the appropriate status bar in which to display the error message, the message is displayed in a pop-up window. The pop-up window will contain an option to disable further pop-up messages.

2.5.2. Context menus

NeaScan offers standard context menu functionality as supported by the Qt toolkit and the underlying graphics environment. Context menus are available via a right mouse button (RMB) click.

In all places where the context menu implements a non-standard behaviour, the corresponding usage hints are displayed in the status bar.

The most important custom context menus are defined on the Signal Trace and Scan window plots and images.

2.5.3. Color indicators

Where applicable, NeaScan marks user interface elements involved in the most recent action with a distinct color: green indicating success, and red indicating an error condition.

The color changes apply mostly to text input fields, dropdown menus and spinboxes. Widgets whose values apply indirectly or widgets whose standard behavior consists in running an action, e.g. buttons, keep their default behavior and are generally not subject to custom color changes.

2.5.4. Interactive behavior

Certain NeaScan widgets send new values to the server as soon as they are updated using a keyboard, mouse or mouse wheel. They are easily identified by the described color changes that will follow any modification to their value.

In widgets whose values are not suitable for an automatic update to the server, but which are still meaningfully applied on an individual basis, one can press the **Enter** key to send new value to the server. The update will be followed by the appropriate color change. The same functionality is often provided by the nearby Set buttons, with the difference being that clicking Set may update more values at once.

2.5.5. Mouse wheel

NeaScan offers standard mouse wheel functionality as supported by the Qt toolkit and the underlying graphics environment.

In places where the mouse wheel can be used as a non-standard feature, e.g. in the corners of the Signal Trace plots, the appropriate usage hints are displayed in the status bar.

In addition, on all numerical input fields and spinboxes, the following functionality is available:

Mouse wheel	Adjust value by `1.0`
Ctrl + mouse wheel	Adjust value by `0.1`
Shift + mouse wheel	Adjust value by `0.01`

2.5.6. Concurrent access

NeaSNOM supports multiple NeaScan instances connected to the server at the same time, operating autonomously and concurrently.

This feature is intended primarily for individual users accessing the NeaSNOM from multiple locations, and not for an uncoordinated, simultaneous work by multiple users.

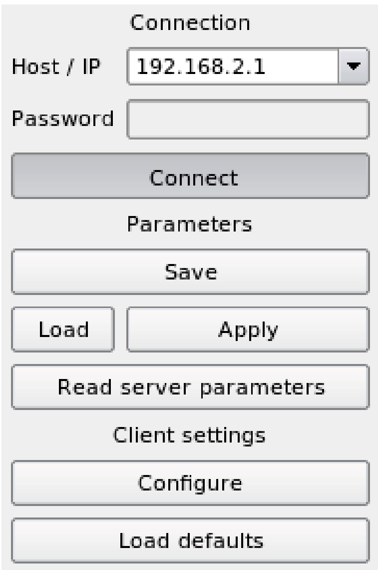
The state of all active NeaScan program windows is kept in sync. On every change, the NeaSNOM server sends callback information to the connected NeaScan clients. In case of just a single NeaScan instance, one callback will be issued.

This behavior is easily observed, even from the local workstation. Starting any program window multiple times and setting a parameter in one instance will cause parameter update in all instances.

3. Control window

Control window is the primary NeaScan component. It contains the NeaSNOM server connection parameters and is used as the starting point for launching other NeaScan components. It is also used for setting the operational NeaSNOM system parameters.

3.1. Connection



3.1.1. Host / IP

Host name or IP (Internet Protocol) address of a NeaSNOM server with an optional port number.

The default IP address, `192.168.2.1`, is valid for any workstation connected directly to the NeaSNOM server. If the NeaSNOM server and the workstation are connected to the existing Local Area Network, the IP address must be changed to the address assigned to NeaSNOM by the local network's DHCP server.

If a host name is used, the local DNS server must be able to resolve the host name into the appropriate IP address.

The NeaSNOM port number defaults to `4044` and should generally not be changed. A specific port number can be specified by using syntax *`host:port`*.

3.1.2. Password

An optional password for the connection.

The connection password is currently unused, but in the future it will serve as a protection against inadvertent concurrent access to the NeaSNOM.

3.1.3. Connect

Toggle connection to the NeaSNOM server using the specified connection information.

The functionality of the Connect button is also accessible by pressing **Enter** in the host and password fields or by using keyboard function F12.

3.2. Parameters

3.2.1. Save

Save currently visible parameter values to the current profile.

This option saves parameter values displayed in the corresponding input fields. These values may differ from the actual values in the NeaSNOM server if they were manually edited (but not applied to the server) prior to saving.

3.2.2. Load

Replace displayed parameter values with the last saved state.

The loaded values are not automatically applied to the NeaSNOM server.

3.2.3. Apply

Apply (transfer) the displayed parameter values to the NeaSNOM server.

3.2.4. Read server parameters

Replace displayed parameter values with their actual, current settings read from the NeaSNOM server.

3.3. Client settings

3.3.1. Configure

Invoke graphical user interface configuration program.

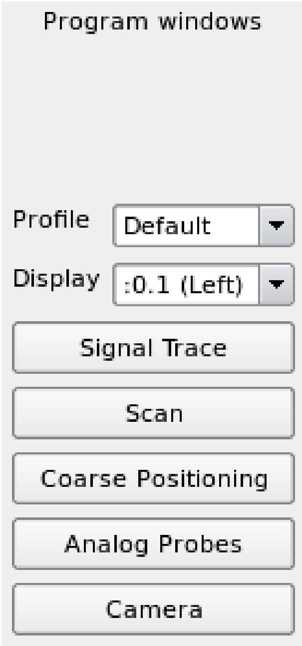
NeaScan uses the Qt GUI toolkit and this option invokes the Qt settings manager. The settings are applied per-user on all supported platforms and do not affect other system users.

3.3.2. Load defaults

Remove all GUI settings and the saved application state, and reset to the built-in defaults.

NeaScan restart is required to reinitialize the application.

3.4. Program windows



3.4.1. Profile

Name of the existing or new settings profile.

NeaScan will run program windows using the selected profile.

To define a new profile that does not yet exist in the profile dropdown box, a new profile name should be typed in, followed by pressing **Enter**.

The NeaScan startup icon, found on the user's desktop, always starts the Control window using the same, default profile. Changing the Control window profile is rarely, if ever, needed. To change profile of the Control window, the desktop icon should be duplicated and then its preferences should be edited to use a different profile.

To prevent accidental loss of newly defined profile settings, e.g. due to quick application crash or improper program shutdown, NeaScan periodically saves all profile settings. The default interval is 5 minutes.

The profile name can be specified when starting NeaScan or any of its components using command line option --profile {name}.

Autosave interval can likewise be specified using command line option --autosave-interval | --autosave {*ms*}.

3.4.2. Display

X11 display device.

NeaScan running on Unix and GNU/Linux workstations will show program windows on display hardware pointed to by the "display" setting.

In the default setup, the NeaScan workstation is delivered with three LCD displays. The rightmost display is known as display `:0`. The remaining two displays on its left are jointly known as the display `:0.1`.

Display `:0 (Right)` is served by the embedded graphics card and should be used for displaying the camera image and other low-intensity graphics work, e.g. displaying the Control Window. Display `:0.1 (Left)` is served by the high-performance graphics card and should be used for heavy-duty graphics work, e.g. displaying the Signal Trace and Scan windows.

Defining a new display is rarely, if ever, needed. To define a new display that does not yet exist in the display dropdown box, the new display location should be typed in, followed by pressing **Enter**. The basic syntax is `:`*`number`*, but the remote host name and a symbolic description can be specified as well using syntax *`host`*`:`*`number description`*.

3.4.3. Signal Trace

Start the corresponding NeaScan component. The Signal Trace component displays continuously running plots of the demodulated mechanical vibration and optical signals, along with specialized spectrum and frequency sweep plots.

3.4.4. Scan

Start the corresponding NeaScan component. The Scan component performs all scanning-related operations and displays the acquired images.

3.4.5. Coarse Positioning

Start the corresponding NeaScan component. The Coarse Positioning component controls the coarse movement of all positioners in a NeaSNOM system.

3.4.6. Analog Probes

Start the corresponding NeaScan component. The Analog Probes component controls the signals available at the NeaSNOM auxiliary analog outputs.

3.4.7. Camera

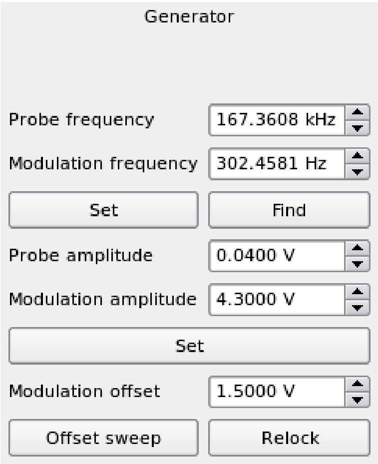
Start the corresponding NeaScan component. The Camera component allows to control and display live images from all cameras built into the NeaSNOM systems.

3.4.8. FT Spectroscopy

Start the corresponding optional NeaScan component. The FT Spectroscopy component performs all operations related to the optional Fourier-transform spectroscopy module.

3.5. Generator

The Generator section of the NeaScan Control component controls the built-in 2-channel signal generator.



3.5.1. Probe frequency

The frequency at which to excite the probe cantilever.

For best results, the probe excitation frequency should be slightly lower than its resonance frequency.

3.5.2. Modulation frequency

For systems with the pseudoheterodyne detection module installed, this setting changes the vibration frequency of the interferometer reference mirror.

In the standard configuration, the modulation frequency can be changed only in discrete steps of about `300` Hz. It can be set to `0` to disable the pseudoheterodyne detection system and use the NeaSNOM demodulation subsystem as an ordinary lock-in amplifier tuned to the parameter 3.5.1, “Probe frequency”.

3.5.3. Find

Find the resonance frequency of a cantilevered probe and adjust the parameter 3.5.1, “Probe frequency” accordingly.

This function is available when Deflection laser is enabled.
The Z-actuator will automatically retract during Find.

The Probe frequency will be raised to `21` kHz during Find if the current value is lower. The probe amplitude will be temporarily increased to `0.5` V during Find if the current value is smaller.

To see the probe frequency response, the Tuning plot in the Signal Trace window should be enabled prior to running this function.

3.5.4. Probe amplitude

Amplitude of the sine signal for exciting the cantilevered probe vibration.

3.5.5. Modulation amplitude

Amplitude (voltage) of the driving signal for vibrating the reference mirror in the pseudoheterodyne detection module. Differently from the standard input field behavior, when changing the value using the mouse wheel, the new value will be applied immediately, and not only after pressing the Enter key or clicking the corresponding "Set" button.

This setting has an effect only if the optional pseudoheterodyne detection module is installed.

3.5.6. Modulation offset

Voltage offset to apply to the reference mirror in the optional pseudoheterodyne detection module. It must be set to a value larger than zero prior to switching the feature 3.5.7, “Offset sweep” on. Differently from the standard input field behavior, when changing the value using a mouse wheel, the new value will be applied immediately, and not only after pressing the Enter key or clicking the corresponding "Set" button.

This setting has an effect only if the optional pseudoheterodyne detection module is installed.

3.5.7. Offset sweep

Switch the modulation offset sweep on or off. When on, the modulation offset voltage will be linearly changed from the value of the parameter 3.5.6, “Modulation offset” to 0 and back. Only the modulation offset value prior to starting the offset sweep is relevant, later changes will not change the sweep amplitude. The linear voltage sweep will be repeated until turned off, and the last sweep cycle will always be fully completed. This feature is useful in combination with the Signal Trace component for determining the correct value of the parameter 3.5.5, “Modulation amplitude”. In particular, the modulation amplitude should be adjusted such that the offset sweep is only seen in the optical signal phase, affecting the optical signal magnitude by less then 5% for a 45° phase sweep.

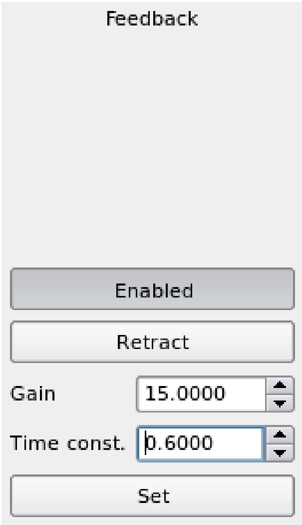
Offset sweep may also be useful while adjusting the pseudoheterodyne interferometer for the first time. A slight phase modulation of the reference beam achieved with this feature can highlight the pattern of interference between the measurement and the reference beams.

3.5.8. Relock

The pseudoheterodyne signal detection unit in NeaSNOM performs a phase modulation of the interferometric reference beam and demodulates the resulting photodetector output signal to simultaneously recover the amplitude and phase of the measured optical signal. To stabilize the phase output from the pseudoheterodyne signal demodulation unit, it is necessary to use the Relock feature. It is possible to Relock the signal components repeatedly, and it is also recommended to execute the Relock after changing either the probe or the modulation frequency.

Please note that relock may change the sense of the demodulated signal phase rotation of some or all of the demodulated optical signal harmonics (O1-O4). It is therefore recommended to check for this effect using the feature 3.5.7, “Offset sweep” in combination with the Signal Trace component and note which optical signal phases, if any, need to be reversed afterwards.

3.6. Feedback



3.6.1. Enabled

Enable or disable the tip-sample distance regulation system, also known as the Z-position regulator or closed-loop feedback.

When disabled, the Z-position actuator (Z-piezo) voltage will remain frozen at the value it had prior to disabling the feedback.

The Z-position feedback (regulator) should normally be enabled at all times because it is a prerequisite for a proper operation of the NeaSNOM system.

3.6.2. Retract

When switched on, the Z-actuator (Z-piezo) voltage will be tied to its minimum value (-20V). This will have the effect of completely retracting the sample, i.e. moving the sample away from the probe.

It is recommended to retract the sample prior to changing the parameters 3.5.1, “Probe frequency” or 3.5.4, “Probe amplitude”, as well as commencing the coarse motion of the head or the sample.

This function is available when the feature 3.6.1, “Enabled” is on. It needs to be switched off to start the automatic sample approach (cf. Section 3.7, “Approach”).

3.6.3. Gain

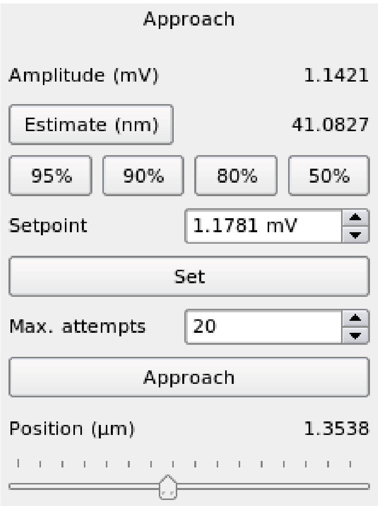
Gain of the Z-position feedback loop, affecting both the proportional and the integral part of the PI regulator. This is the only parameter to control the proportional part of the PI regulator, whereas the integral part is additionally controlled by the parameter 3.6.4, “Time const.”.

3.6.4. Time const.

Time constant of the integral part of the Z-position regulator.

The integral gain Gi can be calculated as Gi=G/T where G is the overall feedback loop gain (Section 3.6.3, “Gain”) and T is the time constant entered into this field.

3.7. Approach



3.7.1. Amplitude (mV)

Measured amplitude of the cantilevered probe oscillations in mV.

3.7.2. Estimate (nm)

Show an estimate of the probe vibration amplitude in nm.

Clicking the button will initiate the measurement of the absolute probe vibration amplitude in nm and calculate the correction factor for the estimate such that the displayed amplitude corresponds to the measured value (in nm). The measured correction factor should normally remain valid until the probe is replaced or the Edge positioner is moved.

This function is available when Feedback is enabled and the Z-actuator is not retracted.

Please note that the estimated value in nm may be wrong by more than an order of magnitude before clicking the Estimate button.

3.7.3. 95%, 90%, 80%, 50%

Adjust the parameter 3.7.4, “Setpoint” to the corresponding percentage of the current amplitude reading (Section 3.7.1, “Amplitude (mV)”).

A nonstandard right mouse button functionality is available here consisting of changing the setpoint to the current amplitude reading divided by the button value, i.e. to 105%, 111%, 125% and 200% respectively.

3.7.4. Setpoint

Current set point value. This is the desired probe vibration amplitude that the Z-position regulator should reach and maintain.

The setpoint can be adjusted by entering and confirming the value in this field directly, or through the setpoint percentage buttons (Section 3.7.3, “95%, 90%, 80%, 50%”). Please note that in the latter case the change will applied immediately, without having to click the Set button.

3.7.5. Max. attempts

Maximum number of coarse motion steps to make when attempting an automatic approach of the sample to the probe.

Set to 0 for no limit.

3.7.6. Approach

Commence the automatic approach of the sample to the tip. The automatic approach will stop when the sample comes into contact with the tip, or the maximum number of attempts has been exceeded (cf. Section 3.7.5, “Max. attempts”). It is also possible to stop the approach manually by clicking the Approach button again while it is running.

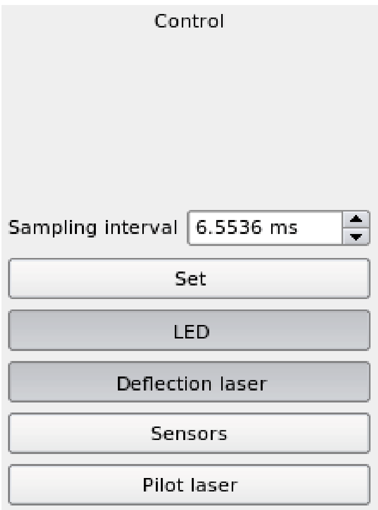
This function is available when Feedback is enabled and not retracted.

3.7.7. Position

The Z-actuator position in a textual and graphical representation.

This value is derived from the voltage applied to the Z-actuators. Due to the inherently nonlinear relationship between the voltage applied to a piezoelectric actuator and its actual extension, the Z position is only an approximate value.

3.8. Control



3.8.1. Sampling interval

Averaging interval for all mechanical and optical signals displayed in the Signal Trace and Scan windows.

This parameter can be incremented in multiples of the base sampling interval, defaulting to about `6.5` ms. NeaSNOM will always update the demodulated signal values once per base interval, i.e. with a rate of about 150Hz. The length (time duration) of the applied moving average for each update can be adjusted with this parameter.

When comparing the NeaSNOM Sampling interval to the time constant of a lock-in amplifier, it is important to bear in mind that the lock-in time constant relates to the angular frequency of the signal. Any lock-in time constant should therefore be multiplied by 6.28 for a meaningful comparison to the NeaSNOM sampling interval.

3.8.2. LED

Switch the sample illumination LED on or off.

3.8.3. Deflection laser

Switch the deflection laser on or off. The deflection laser is a prerequisite for operating the NeaSNOM, and should therefore always be on when the NeaSNOM is in use.

3.8.4. Sensors

Turn the sensors in the coarse positioners on or off.

The sensor readings are displayed in the Mirror section of the Coarse Positioning window.

For more information, please refer to the Section 6.5.1, “Sensors”.

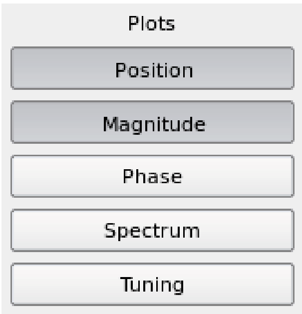
3.8.5. Pilot laser

Toggle the pilot laser in systems where this optional hardware feature is installed.

4. Signal Trace

Signal Trace component displays continuously running plots of the demodulated mechanical and optical signals, along with the specialized spectrum and frequency sweep plots.

4.1. Plots



4.1.1. Position

Switch the sample Z-axis position plot on or off. The Z-position plot displays the Z-axis position of the sample in meters. It is derived from the voltage applied to the sample Z-axis piezoelectric actuators and is always the opposite of the topography signal.

Due to the nonlinear voltage-extension curve of piezoelectric actuators and their inherent hysteresis, the displayed position should be understood only as an approximation of the actual sample position.

Please note that after every large step in the Z position, an exponentially decreasing position drift will follow because of the nature of the piezoelectric actuators.

4.1.2. Magnitude

Toggle the demodulated signal magnitude plot. It contains the absolute values of the complex numbers resulting from the demodulation of the mechanical (M) and optical (O) input signals at different multiples of the probe vibration frequency.

4.1.3. Phase

Toggle the demodulated signal phase plot, containing the arguments of the complex numbers resulting from the demodulation of the mechanical and optical input signals at different multiples of the probe vibration frequency. Please note that the signal M0 is just a real number with constant phase.

The displayed plot range of 0..1 corresponds to the full circle, i.e. 0..360° (2 Pi) phase range.

4.1.4. Spectrum

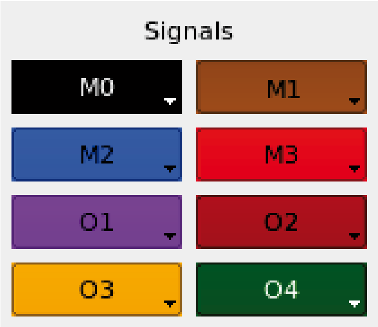
Toggle the spectrum plot, containing the spectra of the demodulated signals in the frequency range of about +/-18 kHz around the central frequency for each of the signals. The central frequency for each of the signals can be derived from its name, whereby the number in the signal name gives the multiple of the probe vibration frequency it is centered on. For example the signal M2 is centered on twice the fundamental probe vibration frequency, i.e. this is the second (or the first higher) harmonic signal.

4.1.5. Tuning

Toggle the frequency sweep plot.

To display the frequency sweep, enable the plot and use the Find button in the Control window. When the sweep is complete, the plot will update with data points revealing the frequency response of the cantilevered probe.

4.2. Signals



4.2.1. M0, M1, M2, M3

Toggle the demodulated mechanical vibration signals.

The signals correspond to the deflection monitoring photodiode output, demodulated at the frequency f=0 (M0), f= f0 (M1), f= 2 f0 (M2) and f= 3 f0 (M3), with f0 being the parameter Section 3.5.1, “Probe frequency”.

Right-clicking the signal buttons allows changing signal properties, i.e. color.

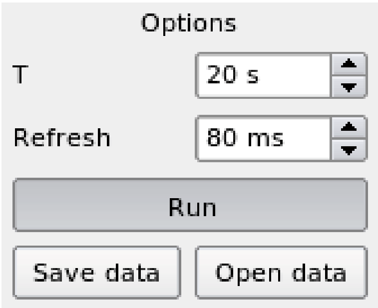
4.2.2. O1, O2, O3, O4

Toggle the demodulated optical signals.

The signals O1 to O4 correspond to the optical signal demodulated at the fundamental frequency, 2nd, 3rd and 4th harmonic of the probe frequency, respectively.

Right-clicking the signal buttons allows changing signal properties, i.e. color.

4.3. Options



4.3.1. T

Total displayed length of the signal traces in seconds.

This option influences the number of the most recent data points displayed in the Position, Magnitude and Phase plots. The number of points is calculated as `N=T/S`, `S` being the NeaSNOM base sampling interval (`6.5` ms by default).

4.3.2. Refresh

Screen update interval in milliseconds.

The NeaSNOM generates a new value for each of the demodulated signals once per base interval (`6.5` ms by default).

The Refresh parameter determines the time interval at which the workstation should poll the NeaSNOM server for new data points.

The setting applies fully only to the Position, Magnitude and Phase plots. Spectrum plot updates one complete spectrum in each pass. Tuning plot updates all of its data points in a single pass as soon as the data is available, i.e. after completing the frequency sweep.

4.3.3. Run

Start or stop tracing the signals. The parameters T and Refresh are read only when starting the run, i.e. they do not affect the running traces.

4.3.4. Save data, open data

Save the visible signal traces to text (ASCII-encoded) files or open the folder containing the last saved traces.

A screenshot of the Signal Trace window will be saved along with the data in the same folder.

4.4. Plot area

In addition to the functionality listed in Section 2.5.5, “Mouse wheel”, the following features are supported in the Signal Trace plots:

4.4.1. Mouse buttons

Clicking the left mouse button (LMB) displays values under cursor in the plot info box.
Clicking the right mouse button (RMB) displays the plot context menu.
Where applicable, clicking the middle mouse button (MMB) resets any scaling and translation applied to the plot view area.

4.4.2. Group scaling

Using the mouse wheel in the upper left or lower left corner of the plot area adjusts the optical signals minimum or maximum values, respectively. Likewise, using the mouse wheel in the upper right or lower right corner of the plot area adjusts the mechanical signals minimum or maximum.

If the plot contains only one type of signal, any plot corner can be used to affect the minimum or maximum values.

Note

This feature works by directly routing the mouse wheel events to the appropriate signals info box. It means that the standard wheel modifiers (Control, Shift) listed in Section 2.5.5, “Mouse wheel” can be used for a finer adjustment.

4.4.3. Selection-based autoscaling

Where applicable, holding **Shift** in combination with LMB and moving the mouse horizontally selects a range. Minimum and maximum values from the range become the plot signals' upper and lower bounds.

4.4.4. View scaling and translation

Where applicable, holding the **Alt** key produces a local zoom effect around the mouse pointer.

Where applicable, holding **Alt** and LMB and moving the mouse horizontally affects view translation, i.e. it moves the view left or right.

Note

The **Alt** key may be reserved by the operating system or the desktop environment and not available for use in the application. On the NeaSNOM workstation running Ubuntu GNU/Linux and the Xfce graphics environment, this key assignment can be changed under the desktop menu "Menu -> Settings -> Window Manager Tweaks -> Accessibility -> Key used to grab and move windows. We recommend changing it from `Alt` to `Super`".

On plots that support view scaling and translation, the view can be conveniently reset to default state using the middle mouse button.

4.4.5. Context menu

All plots offer a standard plot context menu, available by clicking the right mouse button, consisting of the following items that apply to a plot or, where applicable, to all signals contained in it:

4.4.5.1. Scale all

Autoscale upper and lower bounds of all signals to fit all data points into the displayed area.

4.4.5.2. Scale top

Automatically adjust the upper bound of all traces in the plot to the maximum values of the corresponding signals.

4.4.5.3. Scale bottom

Automatically adjust the lower bound of all traces in the plot to the minimum values of the corresponding signals.

4.4.5.4. Autoscaling, top

Choose the upper bound autoscaling method to be automatically applied on every signal update. The available choices are `On` (always), `Up` (expand only) and `Off` (no autoscaling).

4.4.5.5. Autoscaling, bottom

Choose lower bound autoscaling method to be automatically applied on every signal update. The available choices are `On` (always), `Up` (expand only) and `Off` (no autoscaling).

4.4.5.6. Round min./max.

Round minimum and maximum values when performing automatic scaling.

4.4.5.7. Lock group scaling ratios

Maintain group scaling ratios for the two signal groups, mechanical (M) and optical (O).

When this option is enabled and the automatic scaling adjusts one of the signals' minimum or maximum value, all other signals in the group are adjusted proportionally.

4.4.5.8. Log scale

Toggle the logarithmic scale.

This option is available on the Magnitude, Spectrum and Tuning plots.

4.4.5.9. Equalize scales

Equalize the upper and lower plot bounds among the signals belonging to each of the two signal groups, mechanical and optical.

4.4.5.10. Balance plot heights

Choose uniform height for all displayed plots, constrained only by the minimal height requirements and the total plot space available.

4.4.5.11. Show history

Toggle background display of the previous set of data points.

This option is available on the Spectrum plot.

4.4.5.12. Reset view

Reset any scaling and translation applied to the plot view.

This option is available on the Spectrum and Tuning plots.

4.5. Plot info box

Plot info box shows signals contained in the plot, along with each signal's minimum and maximum value, their absolute difference and the current value.

		Magnitude			
Sig	Min	Max	Δ	Val	
M0	0.0	1.417	1.417,5	1.402	E- 1
M1	0.0	1.363	1.363,7	1.177	E- 3
M2	0.0	1.254	1.254,2	1.065	E- 5
M3	0.0	8.679	8.679,0	1.457	E- 7
O1	0.031	7.586	7.554,7	7.002	E- 8
O2	0.090	8.395	8.305,4	1.073	E- 8
O3	0.008	2.248	2.240,1	2.357	E- 7
O4	0.046	7.083	7.037,5	7.469	E- 8

The current value is updated every 2 seconds for easier readout. While the LMB is pressed, this field will be showing value under cursor and will update on mouse move without a delay.

The individual signals' minimum and maximum values displayed in the info box can be adjusted manually by using the mouse wheel over the corresponding values or by typing the new values in and pressing **Enter**.

Note

When using the mouse wheel, the extended functionality is available as described in Section 2.5.5, “Mouse wheel”.

4.6. Comment box

The comment box allows for one-line or multi line comment to be saved along with the trace data.

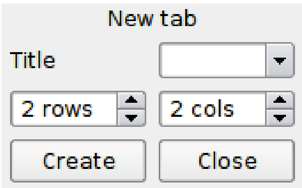
By default, the comment box is sized to accept one line of input. Multi line comments can be inserted but are not as convenient in such a narrow space, so the box can be resized by clicking and dragging the handle above it.

The "Comment:" prefix at the beginning is used only as a visual hint to the purpose of the box. When the data is being saved and the comment contains the "Comment: " prefix at its beginning, this prefix is stripped.

5. Scan

The Scan component performs all scanning-related operations and displays the acquired images.

5.1. Views



5.1.1. New view

Scan images and profiles are displayed in views, contained in tabs. Each tab contains the views in a grid-like structure and may have an optional title.

It is possible to monitor the same channel in multiple views, each with its own display options.

5.1.1.1. Title

Optional title for the new tab.

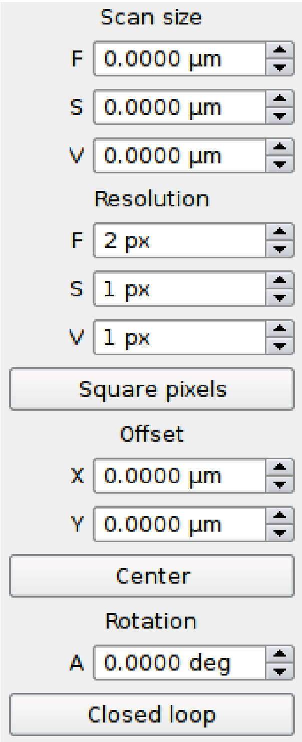
5.1.1.2. Rows, cols

Size of the grid to be created in the new tab.

5.1.1.3. Create, close

Create a new tab or close the current one.

5.2. Scan size



5.2.1. F, S, V

Physical scan sizes for the fast (F), slow (S) and vertical (V) axis in um.

The fast and slow axes are logical axes with their origin given by the parameters from Section 5.4, “Offset” and with rotation in respect to the physical axes given by the angle defined in Section 5.5, “Rotation”. The fast axis is scanned more often than the slow axis. If enabled, the vertical axis is scanned more often than the fast axis, i.e. in the innermost loop.

5.3. Resolution

5.3.1. F, S, V

Fast (F), slow (S) and vertical (V) axis resolutions in pixels.

5.3.2. Square pixels

Adjust the resolution to form square pixels. The adjustment will be made such that the higher of the fast and slow axes resolutions is applied to both axes.

5.4. Offset

5.4.1. X, Y

Scan offset along the physical X and Y axes.

Please note that this offset is applied before the rotation.

5.4.2. Center

Move the sample scanner to the offset position.

If in contact with the tip, the sample will be retracted before the movement and then brought into the contact again after the movement.

5.5. Rotation

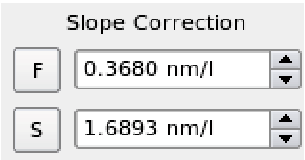
Rotation angle of the logical coordinate system (F-S) relative to the physical coordinate system (X-Y).

5.6. Closed loop

Toggle closed-loop mode of the X-Y sample scanner.

In the closed-loop mode, the X-Y scanner holds the commanded position with the aid of position sensors. This results in much lower positional drift and significantly better linearity of the scan. However, the positional noise is larger in this mode. It may also be impossible to operate the NeaSNOM scanner in the closed-loop mode with samples heavier than about 50g.

5.7. Slope correction



5.7.1. F, S

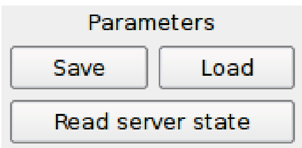
Perform the sample slope correction along the fast and slow axes of the topography channel `MT`.

Clicking the buttons F and S performs automatic slope correction and displays updated correction factors in the corresponding input fields.

Input fields can be adjusted manually to perform slope correction with the specified factors.

The slope-corrected data is displayed in a separate channel, `CT` (Corrected Topography).

5.8. Parameters



5.8.1. Save

Save currently visible parameter values to the current profile.

This option saves parameter values displayed in the corresponding input fields. These values may differ from the actual NeaSNOM server values if they were manually edited (but not applied to the server) prior to saving.

5.8.2. Load

Replace displayed parameter values with the last saved state.

The loaded values are not automatically applied to the NeaSNOM server.

There is no explicit Apply button. The parameter values are transferred to the server when a new scan is started.

5.8.3. Read server parameters

Replace displayed parameter values with the actual values read from the NeaSNOM server.

5.9. Scan and profile view

5.9.1. Free aspect ratio

Free or lock the aspect ratio in scan images.

This feature is useful for maximizing scan view area, especially when selecting offsets in otherwise narrow scans or displaying images whose pixels are not square or do not represent physical 2D areas.

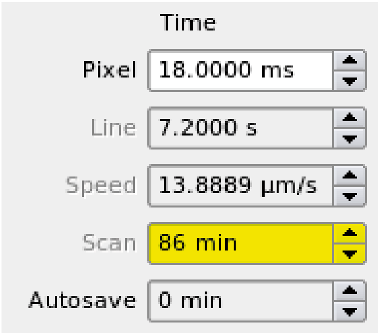
5.9.2. Hide profiles

Toggle displaying of the scan profiles.

This feature is useful for maximizing scan view area.

This is a global option, affecting all views in all tabs. Individual profiles can be toggled by using the right mouse button context menus in the parent image area.

5.9.3. Time



5.9.3.1. Pixel

Scan time per pixel. This value influences the line time and the scan speed which are both calculated from the pixel time.

The Pixel time can be changed at any time, even while the scan is in progress. If it is set to less than the NeaSNOM base interval (6.5s by default), the position signal Trace will go out of the sync with the magnitude and phase traces.

5.9.3.2. Line

Scan time per line (read-only), calculated from the pixel time and the number of pixels per line. The number of pixels per line equals the vertical resolution if it is higher than 1 pixel. Otherwise it is equal to the fast axis resolution.

5.9.3.3. Speed

Scan speed (read-only), calculated from the line time and the scan size along the same axis as for calculating the line time (vertical or fast).

5.9.3.4. Scan

Time left to complete the scan (read-only).

While scanning, this field is colored yellow.

5.9.3.5. Autosave

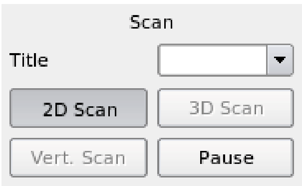
Autosave interval.

While scan is in progress, scan data will be saved periodically using the specified interval. Value of `0` deactivates this feature.

Note

Scan data is always automatically saved at the end of the scan.

5.9.4. Scan



5.9.4.1. Title

Optional title used in saving scan data.

The title is included in folder and file names created during the scan, allowing easier file browsing and identification later.

5.9.4.2. 2D scan

Start or stop a 2D scan. A 2D scan only observes the settings for the fast (F) and the slow (S) axes. Any setting for the vertical (V) axis will be ignored and the V resolution will be set to 1 pixel.

Stopping the scan manually will leave the sample where the stop command is issued. If the scan finishes regularly, the sample will be left centered in the middle of the last scanned area.

5.9.4.3. 3D scan

Start or stop a 3D scan. A 3D scan is performed by scanning all 3 logical axes in the V-F-S order.

Stopping a 3D scan manually will finish the currently running vertical scan line and leave the sample at the last visited F-S position.

5.9.4.4. Vert. scan

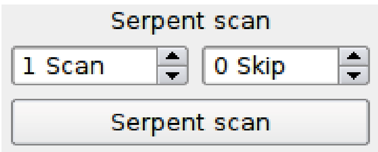
Start or stop a vertical scan. A vertical scan performs only vertical motion (the logical V axis, always coinciding with the physical Z axis). Any settings for the F and S axes will be ignored, but not changed in the Scan window.

This scan mode is intended for recording the distance-dependence curves, also known as the approach or retract curves.

5.9.4.5. Pause

Pause or resume an ongoing scan.

5.9.5. Serpent scan



Serpent scan allows for coarse mapping of the specimen surface by performing a quick scan using a serpent-like pattern.

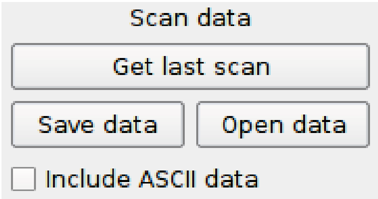
5.9.5.1. Scan, skip

Specify the serpent scan's "duty cycle", i.e. the number of lines to scan and the number of lines to skip before repeating the pattern.

For the most time-efficient scanning, the "scan" parameter should be an odd, and the "skip" parameter an even number.

For example, a scan=3, skip=4 serpent scan will be approximately 4 times faster than a full 2D scan, but will cover only about a half of the scan area.

5.9.6. Scan data



5.9.6.1. Get last scan

Retrieve the data from the last scan performed on the NeaSNOM server.

This option can be used to retrieve completed scans as well as to display data from scans in progress and to continue tracking them to their completion.

5.9.6.2. Save data, open data

Save or view previously saved scan data.

5.9.6.3. Include ASCII data

Toggle the inclusion of the ASCII-encoded (plain text) files in the saved data.

Note

Depending on the size of the scan, saving ASCII data could take a significant amount of disk space and time to complete.

5.9.7. Comment box

The comment box shares functionality with the comment box in the Signal Trace window. For more information, please refer to Section 4.6, “Comment box”.

5.9.8. Scan area

In this area the recorded data is displayed as 2D images. For a 3D scan, the vertical and slow axes are interlaced in such a way that the displayed 2D image consists of series of F-V 2D profiles, stacked below each other according the S-axis position.

5.9.8.1. Mouse buttons

Clicking the LMB displays value and position under cursor in the window status bar.
Holding **Ctrl** and clicking the RMB selects new scan center point.
Holding **Shift** and RMB while moving the mouse selects new scan region and center point.
Clicking the RMB displays the view context menu.

5.9.8.2. Context menu

Scan images support a custom context menu, allowing selection of the data to display in the scan view:

5.9.8.2.1. Channel

Select NeaSNOM channel.

In the standard NeaSNOM setup, the available channels are `MT`, `CT` (slope-corrected channel `MT`), `M0`, `M1`, `M2`, `O1`, `O2`, `O3` and `O4`. Option `No channel` can be used to not display any data.

5.9.8.2.2. Direction

Select channel direction.

The available directions are `F` (forward or trace) and `B` (backward or retrace).

5.9.8.2.3. Function

Select the mathematical function to be applied to the channel data.

In the standard NeaSNOM setup, the available functions are `Magnitude`, `Phase`, `Real` and `Imag`. They correspond to the absolute value, argument, real and imaginary part of the complex values received from the NeaSNOM server.

5.9.8.2.4. Profile plot

Toggle the line profile plot.

In a 3D or a vertical scan, one line profile corresponds to one scan along the vertical axis. In a 2D scan, one profile line corresponds to one fast axis line.

5.9.9. Scan profile area

Scan profiles share the common behavior and the RMB context menu with the Signal Trace plots.

For more information, please refer to Section 4.4.5, “Context menu”.

5.9.9.1. Profile info box

Profile info box is located below the scan profile and shows compact, one-line information about the corresponding channel.

Its shares the elements and the functionality with the Signal Trace info box. For more information, please see Section 4.5, “Plot info box”.

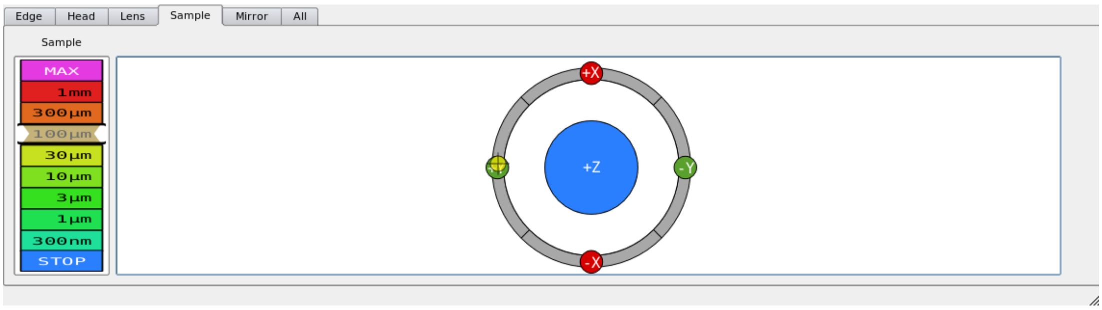
5.10. Image analysis

Scan images can be analyzed and processed using Gwyddion, the state-of-the-art open source SPM data analysis software. Gwyddion comes pre-installed with every NeaSNOM workstation.

To conveniently open an image in Gwyddion, save the scan data, then open the containing folder and double-click the image (.dump) files.

6. Coarse Positioning

Coarse positioning of all motorized parts of a NeaSNOM system can be controlled from the Coarse positioning window. The list of moveable parts is provided in the following subsections.



After selecting the tab with the part to be positioned, the motion speed needs to be adjusted. This can be done by rolling the mouse wheel or by clicking the desired speed indicator.

For parts with single-axis positioning, clicking the speed indicator will immediately start the movement until the mouse button is released.

For parts with multi-axis positioning, the movement can be started by pressing the LMB or RMB inside the colored direction disk. The motion will stop when the mouse button is released.

Wherever pressed, the LMB will move the selected part in the direction indicated, whereas the RMB will move in the direction opposite to the indicated one.

6.1. Edge

Positions the "knife edge" (an opaque screen) which blocks a part of the deflection laser beam reflected off the probe cantilever towards the deflection sensing photodiode.

After replacing the probe, it should be adjusted twice:
In the first pass, the `M0` signal should be brought to about 30% of its maximum attainable value.

In the second pass, after finding the cantilever resonance frequency, the `M1` signal should be maximized using the Edge positioner.

6.2. Head

Moves the probing head including the cantilevered probe.

The motion of the head can be observed in the Camera window.

6.3. Lens

Moves the imaging lens in front of the camera, intended for bringing the probe cantilever or the sample in focus.

6.4. Sample

Moves the sample.

Pressing the LMB in the "z+" (blue) field moves the sample up, i.e. closer to the probe.

Motion of the sample in all directions except "Z-" is disabled when the sample is in contact with the probe. It is nevertheless advisable not to attempt moving the sample or the probing head when the sample is in contact with the probe.

6.5. Mirror

Moves the focusing mirror.

For successful near-field optical measurements, the focusing mirror has to be focused onto the apex of the probing tip.

6.5.1. Sensors

Display the actual measured position of the focusing mirror.

Each time the sensors are first enabled, the position is relative to the position of the focusing mirror. Manual movement of the focusing mirror or motorized movement at the highest speed cannot be properly tracked by the sensors.

Sensor values are displayed when Sensors are enabled in the Control window.

7. Analog Probes

The Analog Probes component configures and monitors signals available on the NeaSNOM analog output channels.

7.1. Probe

Switch the corresponding analog probe (analog output channel) on or off.

7.2. Device

Virtual (digital) device to attach the probe to.

7.3. Output

The output channel (digital signal) of the selected virtual device to monitor.

7.4. Function

Mathematical function to apply to the complex digital signal value.

7.5. Bipolar

When off: analog output range is `0` - `10` V

When on: analog output range is `-10` - `10` V

7.6. Minimum, maximum

Range of the digital signal values to map to the full analog output range.

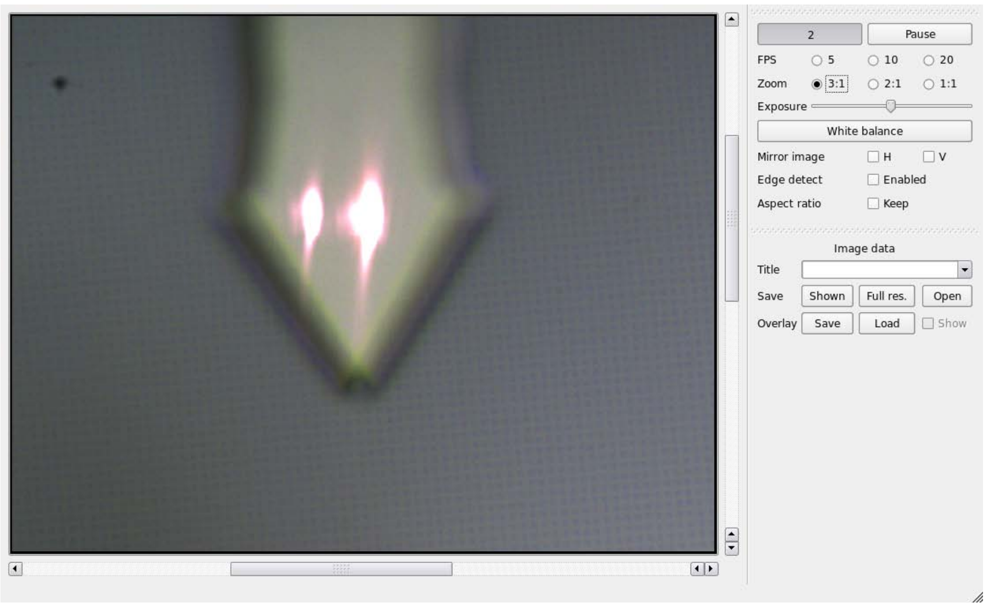
7.7. Value

Current digital signal value after the selected Function has been applied.

7.8. Relative

Relative position of the current Value between the Minimum and Maximum values.

8. Camera



8.1. Selection buttons, pause

Start or stop the selected camera.

Video from the selected camera is displayed at all times. Button Pause can be used to pause the current camera display.

Switching between cameras requires stopping the current camera and initializing the new one, a process that may take up to a few seconds.

Pausing and resuming video from the same camera does not reinitialize the device and is performed without the delay.

8.2. FPS

Frames per second.

Available frame rates are `5`, `10` and `20`.

8.3. Zoom

Subsampling factor.

Available factors depend on the camera resolution, but are usually `3:1`, `2:1` and `1:1` for 3x zoom, 2x zoom and no zoom respectively.

8.4. Exposure

Frame exposure in range `1` - `100` ms.

Increasing exposure results in a brighter image. Increasing the exposure past the sensor limit (in respect to the current FPS) will have no effect.

8.5. White balance

Perform one-time white balancing.

8.6. Mirror image

Toggle video mirroring along the horizontal or vertical axis.

8.7. Edge detect

Toggle the edge-refinement feature of the camera.

8.8. Aspect ratio

Toggle free aspect ratio.

8.9. Image data

8.9.1. Title

Optional title used in saving the camera images.

The title is included in folder and file names, allowing easier file browsing and identification later.

8.9.2. Save shown, save full res., open

Save shown or full resolution image.

Open the containing data folder.

8.9.3. Overlay save, load, show

Save, load and toggle image overlay.

Overlays are static images that can be loaded and displayed on top of the camera video image. Their primary purpose is serving as "visual templates" and assisting in repositioning the new probes.

8.10. Video area

8.10.1. Mouse functionality

Clicking the LMB and moving the mouse adjusts the region of interest displayed by the camera.

Using the mouse wheel scrolls visible video area along the vertical axis.
Holding **Shift** and using the mouse wheel scrolls visible video area along the horizontal axis.

Note

The above functions are available on zoom levels greater than `1:1`.

9. FT Spectroscopy

The FT Spectroscopy component shares many similarities with the Scan component. Only FT-specific elements are described here. For other information, please refer to Section 5, “Scan”.

9.1. Scan size

9.1.1. F, S, E

Fast (F), slow (S) and Fourier (E) axis scan size.

9.2. Resolution

9.2.1. F, S, E

Fast, slow and Fourier axis scan resolution.

9.3. Offset

9.3.1. X, Y, E

Scan offset along X, Y and E axis.

9.4. SFE scan

Start or stop a SFE scan.

A SFE scan is a 3-dimensional scan over slow, fast and Fourier axes. The Fourier axis is scanned in the innermost loop, i.e. most often.

A. Supported command line options

Option name	Abbrev.	Default
--[no-]state	--[no-]s	yes
Description: Load state on startup, save state on shutdown?		
--[no-]state-load	--[no-]sl	yes
Description: Load saved state on startup?		
--[no-]state-save	--[no-]ss	yes
Description: Save state on shutdown?		
--all-windows	--all	context-dependent
Description: Open all windows, regardless of any specific options and saved state? This option defaults to yes when the combination of command line options and saved or default state is such that no windows would be displayed.		
--[no-]antialiasing	--[no-]aa	yes
Description: Use graphics anti-aliasing?		
--[no-]autoconnect	--[no-]connect	yes
Description: Auto-connect to the NeaSNOM server unconditionally?		
--[no-]autoreconnect	--[no-]reconnect	no
Description: Auto-connect to the NeaSNOM server if the password is supplied?		
--autosave-interval	--autosave	300000 (5 min.)
Description: Interval in milliseconds at which the current profile settings will be automatically saved.		
--[no-]disable-offline	--[no-]disable	yes

Option name	Abbrev.	Default
Description: Disable program buttons and functions while not connected to the NeaSNOM server?		
--file-manager	--fm	`thunar`
Description: File manager binary. Can be full pathname or a command in user's PATH.		
--[no-]garbage-collector	--[no-]gc	yes
Description: Disable garbage collector? (Debug feature)		
--help	-h	
Description: Display command line options summary and exit.		
--image-analyzer	--analyzer	`gwyddion`
Description: Image analyzer binary. Can be full pathname or a command in user's PATH.		
--main-rb	--main	`main.rb`*
Description: Full pathname to NeaScan file main.rb. *The default is `/usr/lib/ruby/1.9.1/nfc/main.rb`		
--[no-]stress-collector	--[no-]stress	no
Description: Run garbage collector at every memory and object allocation? (Expert debug feature)		
--[no-]opengl	--[no-]gl	yes
Description: Use OpenGL hardware graphics acceleration?		
--only	--just	no

Option name	Abbrev.	Default
Description: Show only windows specified on the command line, ignoring saved or default setting?		
--password	--pw	
Description: Connection password consisting of 3 uppercase characters. After connection is established, the current connection password is displayed in the password field of the Control window. It can also be displayed in NeaScan by using keyboard function F8 in any window. (Connection password is currently not enforced and can be ignored)		
--profile	-p	context-dependent
Description: Profile name. By default no profile (global profile) is used. Program windows started from the Control window all run in a separate profile, possibly hashed by the user-defined profile.		
--refresh-interval	--refresh	175
Description: Standard refresh interval for all features requiring periodic update or data polling from the NeaSNOM server.		
--server-host	--host	192.168.2.1
Description: NeaSNOM server host name or IP address. The default IP address is valid for any workstation connected directly to the NeaSNOM server.		
--server-port	--port	4044
Description: NeaSNOM server port number. The default port number is valid for all standard NeaSNOM installations.		
--version	-v	
Description: Display version information and exit. This functionality is also available in NeaScan by using the keyboard function F9.		

Option name	Abbrev.	Default
--[no-]control	yes	
Description: Display Control window?		
--[no-]NFC::TraceWindow	--[no-]trace	yes
Description: Display Signal Trace window?		
--[no-]NFC::ScanWindow	--[no-]scan	yes
Description: Display Scan window?		
--[no-]NFC::FourierWindow	--[no-]fourier	yes
Description: Display FT Spectroscopy window?		
--[no-]NFC::MotorsWindow	--[no-]motors	yes
Description: Display Coarse Positioning window?		
--[no-]NFC::CameraWindow	--[no-]camera	yes
Description: Display Camera window?		
--[no-]NFC::ProbeWindow	--[no-]probe	yes
Description: Display Analog Probes window?		
--[no-]NFC::RemoteWindow	--[no-]remote	context-dependent
Description: Display Neaspec Remote Access window? This window is created by default, but not shown unless this option is enabled.		
--[no-]NFC::ShellWindow	--[no-]shell	context-dependent
Description: Display Shell window? This window is created by default, but not shown unless this option is enabled or keyboard function F11 is used. (Expert feature)		

NeaSNOM User Guide

see the nanoworld
neaspec

NeaSNOM User Guide

April 2010

This document provides basic guidelines for users of the Neaspec Scanning Near-field Optical Microscope (NeaSNOM) about necessary operation procedures or recommended preparations for near-field measurements. Section 1 describes a routine how to load a sample to the NeaSNOM System and how to bring the probing tip in contact with the sample surface without damaging the tip. Section 2 provides a guide how to exchange the probing tip of the NeaSNOM System. In Section 3 a procedure is given how the optical beampath should be aligned for near-field measurements.

The lists of this document should be regarded as basic guides for users. Experienced users can change the order of the individual steps or even omit some of the mentioned points. In case this guide provides inadequate assistance Neaspec GmbH can be contacted for more detailed support via email (support@neaspec.com) or phone (+49 89 78793978).

Table of Contents

1. How to bring the probing tip in contact with a sample surface

1. Starting point:

   - sample table at outer end position, moved completely down
   - new (or usable) probing tip
   - adjusted cantilever readout mechanism, e.g. cantilever oscillation frequency, edge position, oscillation amplitude (see Section 2)
   - aligned optics to focus light to the probing tip and to detect the tip-scattered light (described in Section 3)

2. Load sample. Note that the sample should be somehow fixed to the sample holder, e.g. by magnetic sample holder, clamp, etc..

3. Bring focus of upright optical microscope to a plane far below cantilever, e.g. drive lens motor with left mouse button to end position.

4. Bring sample to position below probing tip.

   Hint: the bright area resulting from the sample illumination indicates the region below the probing tip.

5. Drive sample slowly towards the probing tip.

   Hint: characteristic patterns can be observed during the approach allowing the experienced user to estimate the tip-sample distance. Stop when the sample surface is in focus of the upright optical microscope.

6. Readjust lens so that the focus of the upright optical microscope moves towards cantilever, e.g. to an intermediate position between sample surface and cantilever.

7. Select setpoint (e.g. 90-80% of free oscillation amplitude), disable "retract" function. Z-piezos should fully extract now.

8. Start automatic approach. This starts an automatic software routine controlling an interplay between a stepwise movement of the sample z-motors and a continuous extraction of the z-piezos to reduce the tip-sample distance until the oscillation amplitude of the cantilever is reduced as selected.

9. When probing tip is in contact with sample surface, readjust focus of upright optical microscope to sample surface.

10. Retract tip for a few tens of µm to bring the sample to the area of interest. Bring the tip in contact with the sample surface again with the help of the automatic approach.

11. Optimize imaging parameters like oscillation amplitude, feedback settings, etc.

2. How to replace the probing tip

1. Move sample table completely down. Focus upright optical microscope to cantilever at largest field of view.

2. Drive AFM head to outer end position (towards the terminal box).

3. Unplug head connector.

4. Loose knurled head screw.

5. Detach AFM head.

6. Unscrew mounting screw of cantilever holder.

7. Place cantilever holder on heating plate.

8. Replace cantilever chip. Place the new chip as good as possible to the position of the old/used chip.

   Hint: only very tiny amounts of thermal glue should be used to fix the cantilever chip.

9. Cool down the cantilever holder and mount it again to the AFM nose.

   Hint: care should be taken not to damage any electrical connection of the AFM nose.

10. Place AFM head in microscope, tighten knurled head screw and plug in connector.

11. Drive AFM head towards sample table and monitor camera image to see when the cantilever chip is in position. Note that it can be difficult to see the cantilever chip in the camera image when the position of the AFM head z-motor is too far away from the former position (of the old tip). Do not readjust the lens but move only the z-motor of the AFM head to find the cantilever chip in the camera image.

12. Adjust position of cantilever in all three coordinates.

Hint: the position of the deflection laser focus is fixed. Bring the cantilever into a position where the deflection laser is focused on the backside of the cantilever.

13. If necessary readjust the focus of the deflection laser.

    When the deflection laser spot on the cantilever backside appears in the camera image too large the cantilever is not positioned in the focus of the deflection laser. To bring the cantilever in the deflection laser focus the AFM nose has to be moved slowly up or down. Note that during the z-movement of the cantilever the camera image becomes blurred. To check the deflection laser focus on the cantilever backside the lens has to be readjusted. By iterative movements of the AFM head z-motor and the lens motor the cantilever can be placed into a height where the deflection laser spot has a minimal diameter on the cantilever backside.

14. Monitor M0 signal. Adjust edge motor to approx. 1/3 of its maximum value.

15. Start "Find" routine to determine the resonance frequency of the cantilever. Monitor spectrum of M1 in the "Trace window".

16. Readjust edge motor to maximize M1 signal.

17. The "Find" routine automatically selects the frequency where the M1 signal is highest. Reduce the driving frequency so that the M1 signal is between 60-80% of its maximum value.

18. Adjust tapping amplitude when the tip is on contact with the sample surface (see previous Section). Note that the "Estimate value" of the tapping amplitude is strongly dependent on the probing tip and the oscillation amplitude. It should be determined for each probing tip.

3. How to align the optical beampath for near-field measurements

1. Overlap of light source with a pilot laser.

   Hint: check overlap at two positions, close to the beam combiner and further away (e.g. 2-3m).

2. Adjust pilot laser such that light reflected from the reference area of the parabolic mirror is directed back to the light source.

   Hint: position of the reflected light can be monitored nicely with the help of an iris.

3. Align interferometer to reflect incident light back to light source. The use of e.g. a HeNe laser as pilot laser allows to observe an interference pattern (at the position of the detector) between light reflected from the reference area and the interferometer (in case of proper alignment).

4. Block tip-illuminating pathway (but not the interferometer).

5. Optimize detector and lens position (the lens used to focus light to the detectors sensitive element) by maximizing the detector signal. If necessary, modulate light source by means of a chopper.

6. Unblock tip-illuminating pathway and focus light to probing tip. The focus can be adjusted with the help of the characteristic diffraction pattern.

7. O1 signal should be observable now.

   Hint: reduce the free oscillation amplitude such that only O1 signal can be detected and no signal at higher harmonics (e.g. O2 or O3).

8. If applicable, adjustment of the pseudoheterodyne detection unit:

   Adjust modulation amplitude of pseudoheterodyne detection unit. Start offset sweep routine to continuously change the phase signal of O1 for approx 90°

(corresponding to an offset amplitude between approx. 2-10V, depending on the wavelength of light).

9. Maximize O1 signal by adjustment of reference mirror and lens position. Do not move the parabolic mirror used to focus light to the probing tip.
10. Bring probing tip in contact with sample surface (see Section 1).
11. When focused correctly to probing tip, O2 signal should be observable when the tip gets in contact.
12. Maximize O2 by readjusting parabolic mirror.
13. Maximize signal by iterative readjusting the interferometer, lens position and parabolic mirror.

Read the User Manual before operation.

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