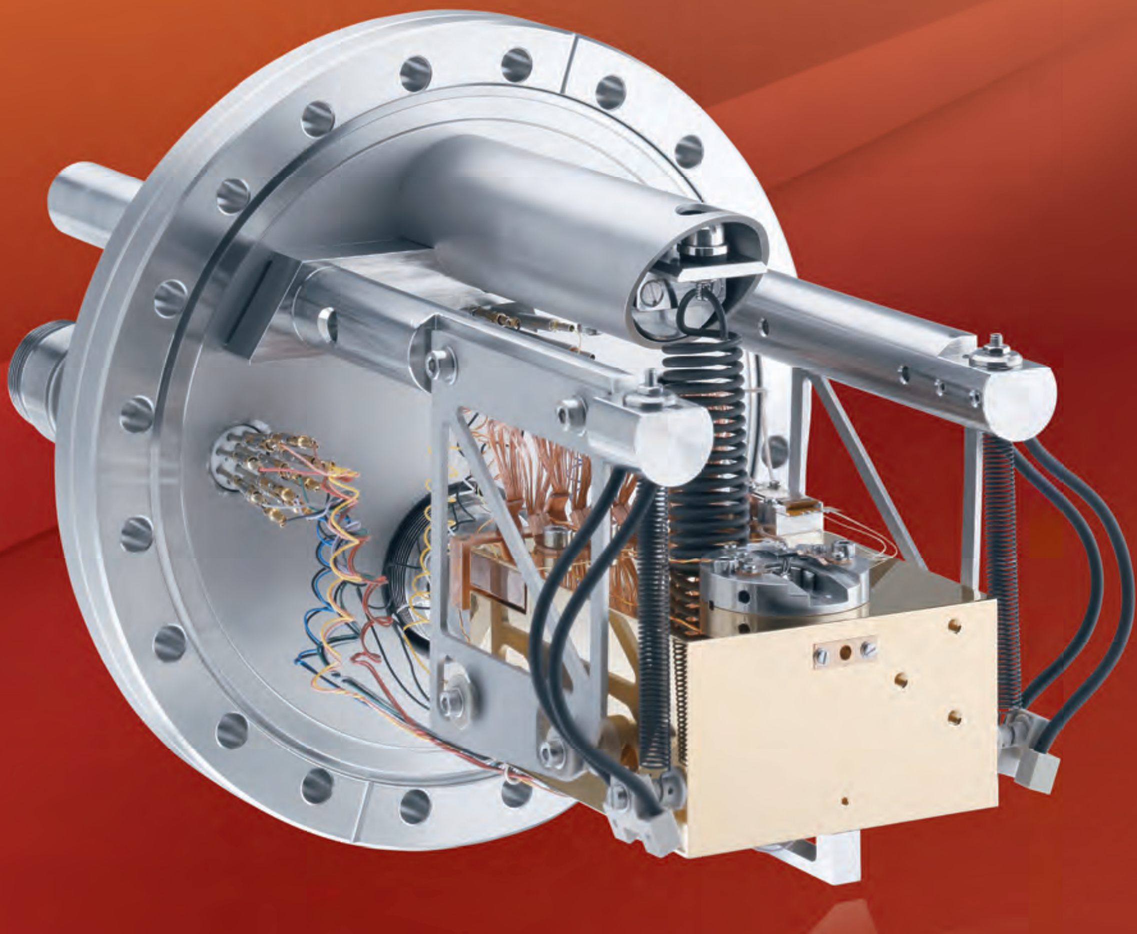
SPM Aarhus Series

SPM AARHUS 150 SCANNING PROBE MICROSCOPES
FOR ADVANCED SPM RESEARCH

KEY FEATURES

- Extreme Stability
- Highest Productivity
- In-situ Tip Preparation
- Video speed STM
- KolibriSensor for combined nc-AFM & STM
- SPC 260 or Nanonis™ Control System

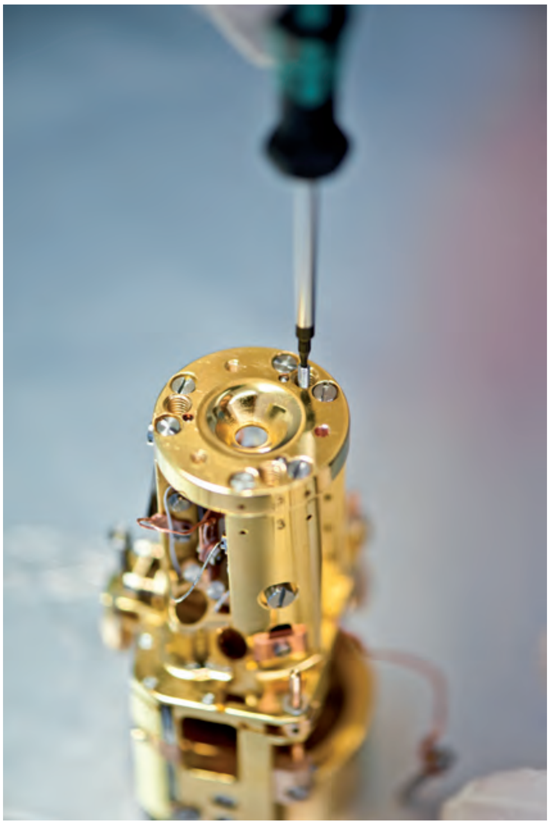


SPECS™

SPECS™

INNOVATION IN SURFACE SPECTROSCOPY AND MICROSCOPY SYSTEMS

SPECS leads the way in state-of-the-art technology for electron spectroscopy and scanning probe microscopy.



State-of-the-art scanning probe microscopy sytems

SPECS Surface Nano Analysis GmbH

SPECS headquarters with more than 150 employees is located in the center of Germany's capital Berlin, with subsidiaries in Switzerland (SPECS Zurich GmbH) and in the USA (SPECS Inc.). Furthermore, we have liaison offices in BeNeLux and Spain and are represented all over the globe by our sales partners.

We are a team of scientists and engineers who have been dedicating their knowledge and experience to the development, design, and production of instruments for surface science, materials research, and nanotechnology since 1983.

Our key to succes is know-how, experience, close contact to scientists from all over the world, customer orientation, reliable quality control, and dynamic research and development.

SPM Method

STATE-OF-THE-ART AFM AND STM TECHNOLOGY

Scanning probe microscopy (SPM)

New dimension in SPM

Over the last decades scanning probe microscopy (SPM) has proven to be one of the most powerful techniques in surface science and nanotechnology since it allows atomic scale investigations of a wide variety of materials like, insulators, semiconductors, metals to superconductors and organic molecules.
In a typical SPM experiment a sharp tip is located close to the surface so that a distance dependent interaction between tip and sample is measured. An image of the surface is recorded by keeping a feedback parameter, typically tunneling current or the resonance frequency shift, constant and taking the interaction parameter vs. position coordinate of the tip. The resolution can at least reach the atomic level.

In scanning tunneling microscopy (STM) the working principle is based on the quantum mechanical tunneling of electrons between two electrodes which are separated by an insulating barrier. When applying a bias voltage between a sharp metallic tip and a conducting sample a distance dependent tunneling current is measured if the tip is positioned a few Ångstrøms above the sample surface. In the constant current mode the tip sample distance is controlled with a feedback circuit which keeps the tunneling current constant. The surface information is reconstructed from tip displacement.

Furthermore, the bias dependence of the tunneling current is proportional to the local density of states (LDOS) and thus contains information of the electronic properties of the sample.

This gives the ability to combine surface structure studies with local spectroscopy on atomic length scales. STM opens up a wide range of applications in nanotechnology: Spectroscopy on single molecules, superconductors, metals and semiconductors, as well as atomic manipulation etc.

In non-contact atomic force microscopy (nc-AFM) a sharp oscillating tip is located close above the sample surface. The distance dependent interacting forces between tip and surface result in a resonance frequency shift of the oscillating tip. By adjusting the tip sample distance such that the resonance frequency shift is constant, information about the surface can be gained on the atomic level. The surface can be reconstructed from tip displacement. The energy to drive the oscillator at constant amplitude allows to determine the non conservative interaction forces between tip and sample.
AFM gives the opportunity to sense interatomic forces and energy dissipation on all kind of surfaces such as metals, semiconductors and insulators. Typical AFM applications are: sample investigation on the atomic scale, force spectroscopy on a single molecule, Kelvin probe measurements and atomic manipulation on insulating surfaces.

With a combined STM/AFM instrument a large variety of surfaces ranging from clean metals, semiconductors, insulators to adsorbate covered materials can be imaged, characterized and manipulated on the atomic level. A recent development of a near ambient pressure instrument with an in-situ reactor cell allows for the bridging of the information and pressure gaps by allowing measurements between UHV and near ambient conditions.

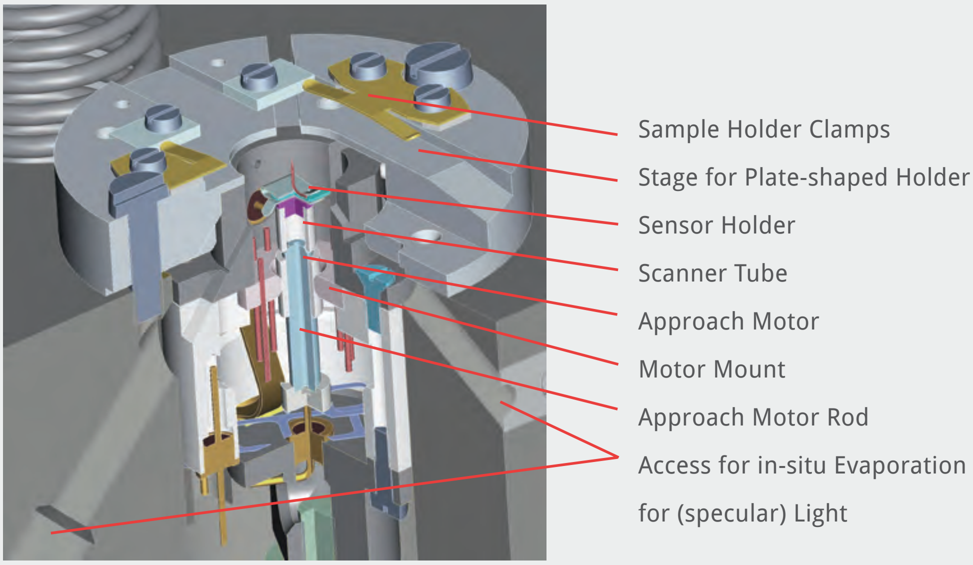
SPM Aarhus series

History

Since its invention in 1981 decades have passed until reliable commercial SPM instruments became available for scientists. Commercial SPM systems were approaching the needs of scientists with a wide variety of SPM techniques, yet neglecting fundamental problems arising from the lack of mechanical stability and from time-consuming operational requirements from its users. SPECS entered the market by licensing the STM system from University of Aarhus, showing ultimate stability and ease of use at the very same time. In doing so SPECS managed to offer STM systems that operate on a daily basis, thereby allowing scientists to spend more time thinking about possible experiments rather than investing valuable time operating the instrument itself.

Mechanical Loop

One of the key features of the SPM Aarhus family members is the smallest possible stiff and stable mechanical loop between sensor and surface using a miniaturized approach mechanism. During operation the coarse approach motor fixes the scanner in such a way that it could carry 1 kg weight without moving. With most other instruments not having such a feature, the SPM Aarhus gains its fundamental stability from this miniaturized mechanical loop.



Scanner Mount and Coarse Approach Motor

In-situ tip preparation by ion sputtering

Another key feature for all SPM Aarhus family members is in-situ tip preparation feasibility by ion sputtering. The probing sensors e.g. a tunneling tip or KolibriSensor™ do not have to be replaced. The lack of instrumental stability, i.e. from sensor damaging contact with the surface ('tip crashes') along with the lack of cleaning possibilities, i.e. removing contaminants and sensor sharpening, made 'in-situ' tip replacement necessary for most other instruments. Within the SPM Aarhus family a different approach is used. By using a protection shield all sensors are left within the instrument and are bombarded with a parallel ion beam. The sensors are not just cleaned but also sharpened in a very reproducible and time-efficient manner so that the same sensor can be used for months or even years.

Advanced Heat Flow Management

Symmetry in the mechanical design as well as highly defined heat flows in the physical arrangement of the SPM Aarhus systems allows variable temperature measurements with the highest thermal and mechanical stability. As a result of this design, thermal equilibrium is reached within minutes even after changing temperatures of several hundreds of Kelvin. This advanced heat flow management allows measurements from cryogenic temperatures to temperatures exceeding 1100K. The massive copper body always acts as a large heat sink and an extremely effective buffer for reducing thermal drift rates to extraordinary low values.

Motor End Position Indicator MEPI

Safe and reliable sample exchange is one of the highest priorities and a prerequisite for long life time of the instrument. The fully automatic approach of the SPM Aarhus 150 makes continuous observation of the tip-sample distance unnecessary. To allow for the safe and reliable sample exchange all SPM Aarhus family members have an integrated safety feature in form of a motor end position indicator. If the motor is fully retracted to its end-position a visual and sound signals will be activated to guide you towards safely removal of the sample plate.

SPM mechanics

For many years most commercial AFM systems had to be modified after purchase and required highly skilled experts to operate them. SPECS took on the challenge of reaching the highest productivity by developing the SPM Aarhus 150 with KolibriSensor™ . The original instrument has been further developed and improved with the highest priority on stability and ease of user operation, resulting in an Aarhus SPM family with unique capabilities being available never before. All of the SPM Aarhus family members have now improved and unified STM/AFM mechanics increasing experimental flexibility without compromising the original mechanical stability.

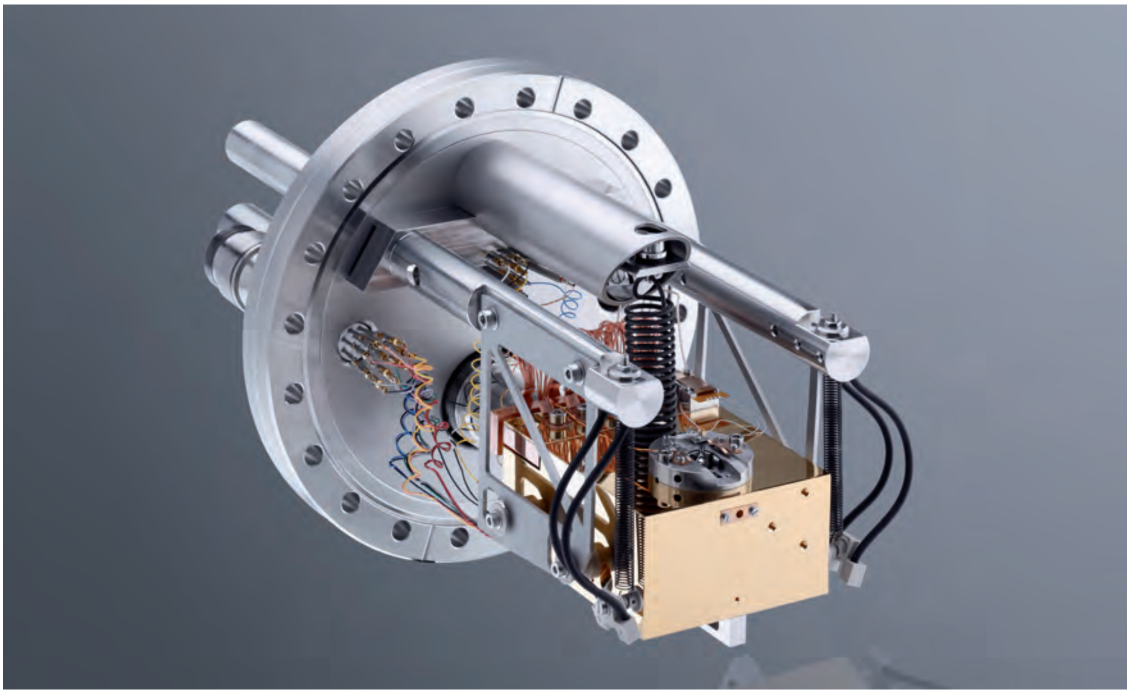
SPM Aarhus 150

With the SPM Aarhus 150 an outstanding stable and time saving instrument became available on the market. A specially designed variable temperature scanner platform of 3kg mass with integrated low noise liquid nitrogen (LN_2) cooling device guarantees the uncompromised superior SPM performance. Special care was taken to decouple the flow cooler from the sample stage and yet ensure permanent cooling connection between them. For this dedicated flexible copper braids are used to couple the extra heavy scanner platform to the flow cryostat without affecting excellent stability of the SPM Aarhus.

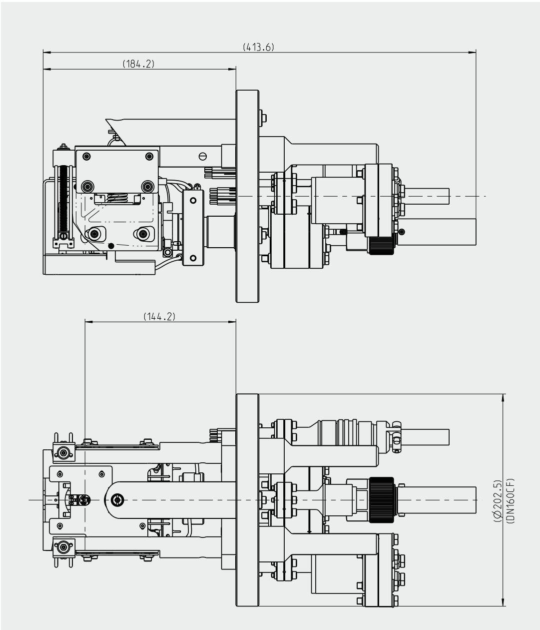
A tight mechanical and thermal contact between sample holder and SPM stage allows for the extremely accurate sample temperature control and stability. A typical cool down times of less than 60 min to the temperatures below 130K are achieved. A typical time span of 20 min from insertion of a sample at room temperature to “ready for SPM” at below 130 K and has been shown. For temperature ramps counter heating of the sample is possible even to elevated temperatures up to 400 K. A comparably low LN_2 consumption can be realized in operation as well as during the fast cool down of the cryostat from room temperature. About 20 l of LN_2 is consumed during initial cool down while the typical LN_2 consumption during operation at 130 K is about 10 litres per hour.

Through the unification of the SPM mechanics into one STM/AFM unit, the SPM Aarhus 150 can easily be upgraded to AFM by using the KolibriSensor™. The SPM Aarhus 150 sets a new standard by showing the highest thermal stability at variable temperatures between 90 and 400K without compromising its original mechanical stability.

A direct in-situ optical access allows for the sample illumination and investigation of light induced processes. Additionally an evaporation port permits in-situ deposition on the sample surface and investigation of the growth processes during scanning.



To reach ultimate long-term temperature stability during measurements using LN_2 cooling an additional heat shield is available. This shield does not compromise the handling and operation of the SPM Aarhus 150 in standard configuration.



SPM Aarhus 150 with cooling shield

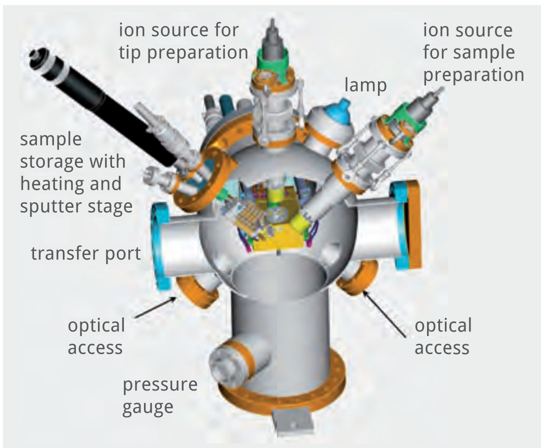
Turn-key UHV System and Easy Integration into Complex Systems

For SPM Aarhus family members special bolt-on UHV chambers are developed allowing easy integration into any existing UHV system via attachment to the existing transfer port. A special care was taken to design dedicated bolt-on chambers to enable the use of the full potential of the SPM Aarhus family members in a most efficient manner. Optical access, in-situ evaporation, in-situ tip/sensor sputtering, as well as sample storage, sputtering and transfer are only some of the standard features integrated in the bolt-on concept. Thanks to its excellent mechanical stability the proven and uncompromised SPM Aarhus performance is still preserved without taking any additional measures even after integration into complex UHV systems designed for demanding applications.

Turn-key SPM Aarhus 150 system

Vacuum Chamber Design and System Integration

A turn-key system is mounted on a solid rigid bench and includes bolt-on chamber with SPM Aarhus, pumping and pressure monitoring system, wobble stick for loading and operating the SPM Aarhus, ion sources for “in-situ” tip/sensor sputtering, sample storage, load lock with turbo pump and transfer rod. If necessary it can also be connected to any existing UHV system via attachment to the existing transfer port.



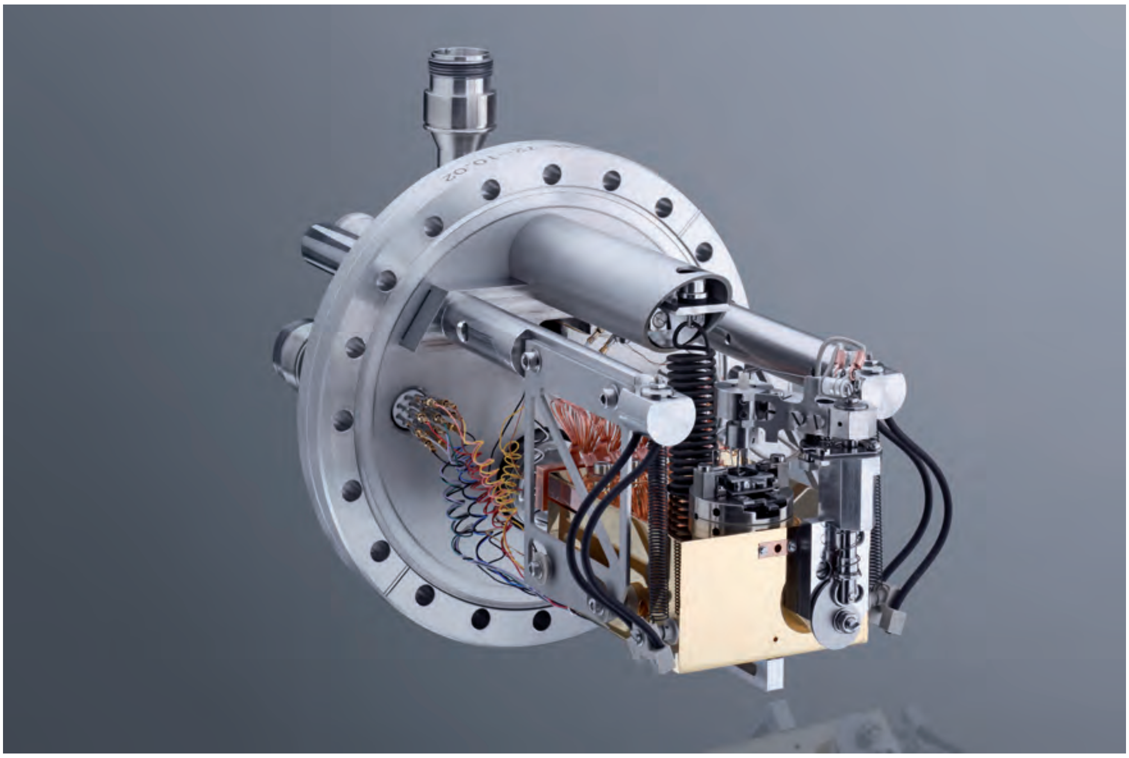
SPM Aarhus 150 bolt-on chamber

SPM Aarhus 150 HT

By adding a radiative heater element with a high stability power supply, the SPM Aarhus 150 allows imaging of all kinds of samples at temperatures exceeding 1300K (650K with KolibriSensor™). SPM Aarhus 150 HT can be used with both STM tips as well as with KolibriSensor™ without any compromises on its stability. Using improved heat flow management it is possible to suppress thermal drift with ultimate mechanical and thermal stability regardless of temperature and duration of the experiment.

The instrument runs in the thermal steady-state condition meaning that sample is the only object that changes its temperature during operation. All other parts of the instrument stay at the constant temperature thus minimizing thermal drift. To achieve this a combination of permanent cooling and counter heating of the scanner platform is used. Special heaters are integrated on the scanner platform and on the scanner itself and are constantly regulated compensating changes in the power flow induced by the change of the sample temperature. Thus the scanner platform acts as a heat sink for the power flow from the hot sample to the scanner ensuring excellent thermal stability and uncompromised SPM performance.

A direct in-situ optical access allows for the sample illumination and investigation of light induced processes. Additionally an evaporation port permits in-situ deposition and investigation of the growth processes during scanning.



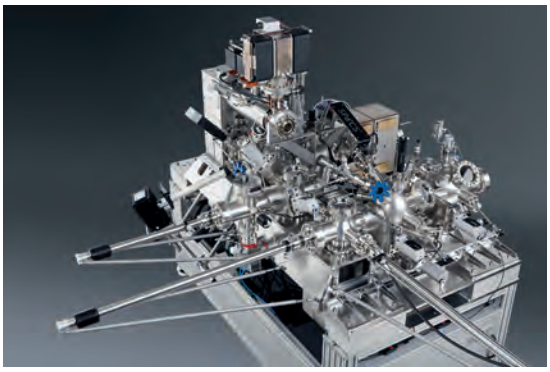
SPM Aarhus 150 MBE

The scientific demand for combined deposition/ MBE-SPM systems has constantly been growing over the last decade. Unless the scientist can afford to work on standard substrates of 10mmx10mm size the larger substrates usually used in deposition are in contradiction to the high stability needed to reach atomic resolution.

The SPM Aarhus 150 HT MBE is bridging this gap. Substrate sizes of up to 1” can directly be transferred from the deposition chamber to the SPM. By using a clamping mechanism the sample holder can be fixed to the SPM. By this the same stability as on 10mmx10mm substrates can be reached. Due to the additional substrate heater the temperature can be set during the measurements from 130 K to 650 K (for SPM with KolibriSensor) or 1000 K (with an STM tip). Thus, SPM studies of freshly grown thin MBE films can be performed without contamination and even at elevated temperature on larger substrates. Refer to the section Sample holder options for details on the special 1” MBE holder used.

SPM Aarhus 150 LEEM

With SPECS offering the low electron energy microscope FE-LEEM P90 with unique lateral resolution, its dedicated sample holder was implemented into the STM 150 Aarhus. Including the HT option, all LEEM/PEEM experiments can also be performed within the STM 150 Aarhus, thereby allowing users the LEEM/PEEM view with atomic resolution.



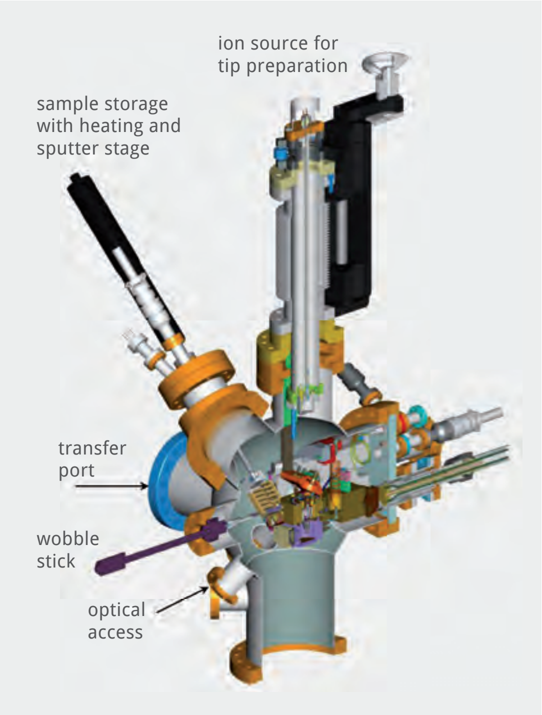
SPM Aarhus 150 NAP

Investigations of catalytic reactions on the surfaces and the attempt to bridge the pressure and material gap between UHV and "real world" applications require an ultra-stable and reliable SPM able to operate in extreme conditions. Once again, the stability and simplicity of the SPM Aarhus design allowes for the extension of the applications in the pressure range between UHV and 100 mbar by developing special near ambient pressure (NAP) design. For this SPM Aarhus head is mounted in side of an in-situ reactor cell made of inert materials (or coated with non-reactive material). By doing so, only the inside of a little reactor cell is flooded with the gas. Easy and fast on-site switch between UHV and near ambient pressure applications is possible by opening a lid on top of the reactor cell. A halogen lamp heater for high temperature applications is mounted directly on the lid allowing imaging of all kinds of samples at temperatures exceeding 850K in UHV and 550K at 10mbar.

In-situ tip/sensor preparation by ion sputtering is still feasible when the lid of the reactor is open. A direct in-situ optical access to the sample during measurements at near ambient pressures can be used for investigation of photo catalytic reactions. Both STM tips as well as the KolibriSensor™ can be used with the system without any compromises on its stability.

SPM Aarhus 150 NAP system with preparation chamber

SPM Aarhus 150 NAP



SPM Aarhus 150 NAP bolt-on chamber

Sensors

Tips

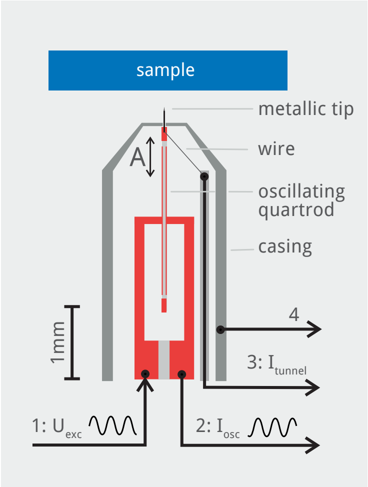
Besides the quality of the SPM mechanics and the controller, the tip (material, geometry and tip preparation prior to the measurement) is important for the quality and resolution of the SPM images. Tungsten is a material widely used for probes in UHV for STM and high resolution nc-AFM. The tips are usually electrochemically etched from a piece of tungsten wire. The solution used, the application of the solution to the tip, the geometry of the counter electrode and the potentials applied to the tungsten wire is essential for the tip geometry. For the STM and KolibriSensor tips SPECS is following a receipe, that has been patented by Eric Laegsgaard (University of Aarhus) and SPECS (WO 2011/015378 A1), leading to small, sharp tips of reproducible shape. In general etched tungsten tips are significantly oxidized at their surfaces. The best suited technique for removing the oxide and further sharpening of the tips after electrochemical etching is Ar^+ ion etching. As already mentioned before, this can be done inside the Aarhus SPM for STM tips and for KolibriSensors.

KolibriSensor™

The KolibriSensor™ plus the Nanonis control system combined with the Aarhus SPM series allows imaging of non-conductive samples in non-contact AFM (nc-AFM) mode. Furthermore, considering the significantly more demanding AFM technology, this Aarhus SPM family member makes atomically resolved imaging of conductive and non-conductive samples possible on a daily basis. By separating the Tungsten tip from the quartz oscillator, tunneling signals can be recorded simultaneously and completely independently. The SPM Aarhus series represents a new generation of UHV systems to examine every possible surface at the atomic scale even at sample temperatures below RT or near ambient pressure conditions.

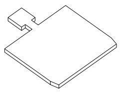
KolibriSensor™ Design

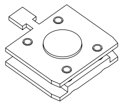
The design of the KolibriSensor™ provides purely electrical excitation and read out of the force signals. For a clear separation of oscillation current Iosc and tunneling current It, the metallic tip is separately connected to a third electrode by a wire. A sputter shield enables in-situ tip cleaning and sharpening within the microscope.

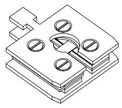


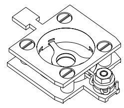
Sample holder options

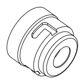
A variety of sample holder options is available for the SPM Aarhus family members providing perfect compatibility with other surface science methods like electron spectroscopy, LEEM or MBE.

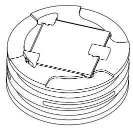

Standard


Hat-shaped Crystals


Direct Current


High Temperature


FE-LEEM P90


MBE

Control System

SPC 260 Control System

SPC 260 control electronics was developed by the University of Aarhus. The SPC 260 now equips the SPM Aarhus family members with control electronics with video frame recording speeds over a USB2.0 Interface. Its acquisition and analysis software is based on the proven concept from University of Aarhus.

Nanonis Control System

The lack of appropriate control systems has always been a challenge for all AFM applications. With Nanonis having found a way to develop extremely advanced and user-friendly control electronics, a new era in SPM technology began, thus letting the users develop mechanical hardware whilst being able to depend on a reliable and powerful control system in their hands.

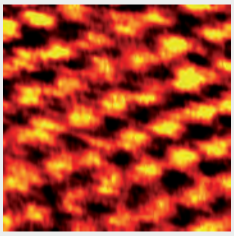
What began as a collaboration between SPECS and Nanonis resulted in the creation of SPECS Zurich. Along with this and the development of KolibriSensor™, SPECS SPM systems now include all the mechanical advantages of the Aarhus base system, and the effectiveness and reliability of SPECS Zurich components. Nanonis electronics can be configured for STM or STM/AFM applications.

SPM Aarhus 150 Results

Live Performances: SPM in Vibrant Environments

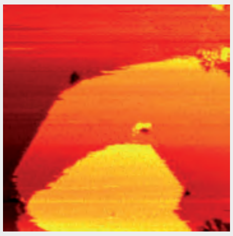
To demonstrate the unique capabilities of the SPM Aarhus family members, a most bold approach was taken: to run all Aarhus SPM Family members at a conference within the exhibition area. Without any consideration of appropriate location, and without any measures to avoid disruptive vibrations, all systems were put to task under this harsh testing environment. To the surprise and delight of many, the Aarhus SPM systems working during the whole exhibition produced the highest quality results that could barely be superseded even under the best of experimental conditions.

DPG 2009 - Dresden



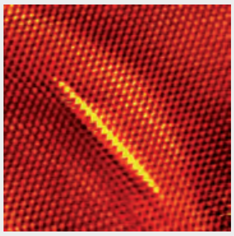
NC-AFM

DPG 2008 - Berlin



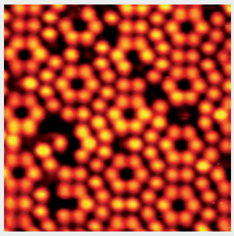
STM rel. 2

AVS 2007 - Seattle



STM rel. 2

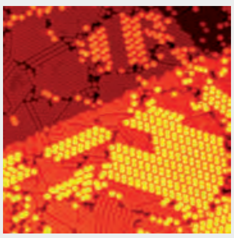
ICN & T 2006 - Basel



STM rel. 1

STM on C60/AA Molecules

Well-patterned molecular templates can be used to control ordering of molecules upon adsorption. Usually supramolecular hosts are used as building blocks for construction of surface confined structures. The pattern of the underlying template is an important factor influencing supramolecular ordering of adsorbed molecules. The following example shows adsorption of C60 on AA molecular template.

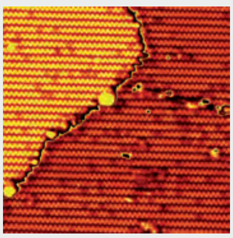


C60 on AA Molecules,
RT, I = 0.23 nA,
U = 1.13 V

Image courtesy of
Bo Xu, Yanshan
University, China

STM on TiO_2(011)-(2x1)

Understanding the interaction of water with oxide surfaces is of crucial importance especially when technologically important materials like TiO_2 are involved. A recent STM study has shown that hydroxyls, which are formed at oxygen vacancies after water exposure, act as nucleation centers for the growth of water clusters. STM image shows atomically resolved TiO_2 surface, bright spots are attributed to O atoms, missing spots are O vacancies.

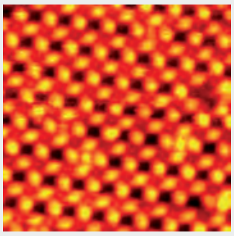


Atomic Resolution on
Rutile
TiO_2 (011)-(2x1), RT,
I = 0.95 nA, U = 1.24 V

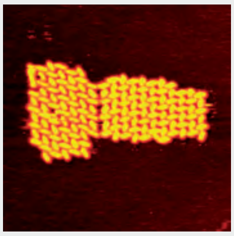
Image courtesy of
U. Diebold, Tulane
University, USA

STM on Organic Molecules

Self-assembly of organic molecules on solid surfaces and formation of 2D networks in controlled way are promising tools towards potential applications in nano electronics. The most important issue is to investigate, understand and manipulate properties of the molecular nano structures in controlled way. The properties of the 2D networks are influenced by the competition between intermolecular interaction and interaction between molecules and substrates. Additionally parameters like adsorption temperature and dipole moments of the molecules can be used to guide the growth processes and influence the properties of 2D networks. Examples shown below are only a small excerpt from the available data obtained with the SPM Aarhus 150.

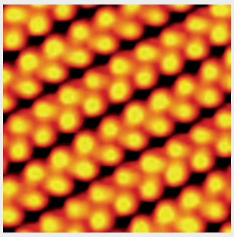


Self assembled DCNQI-Molecules on Cu(111), RT, I = -0.20 nA, U = -0.78 V
Image courtesy of R. Otero, Universidad Autónoma de Madrid, Spain



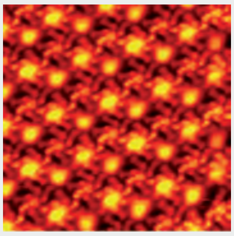
Chiral Assembly of DCSB on Cu(110), RT, I = -0.10 nA, U = -4.8 V

Image courtesy of K. Horn, FHI Berlin, Germany



Self Assembly of Rubrene on Au(111), RT, I = 0.01 nA, U = 3.3 V

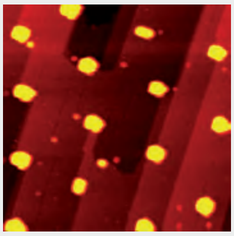
Image courtesy of Li Wang, Nanshang University, China



Linker Molecules coadsorbed with Co Atoms on Ag(111), RT, I = -0.08 nA, U = -1.15 V
Images courtesy of J. V. Barth, Technical University München, Germany

STM on Pt Nanoclusters on TiO_2(110)

Nano particles are new materials systems with unusual structural, magnetic and chemical properties which can be used for applications in catalysis, molecular electronics and plasmonics. The prerequisite for their use in real world conditions is the understanding of their behavior during exposure to extreme conditions like elevated temperatures and pressures as well as their stability in such extreme conditions. STM allows monitoring of their behavior in real time and is perfectly suited for the characterization of such systems. The STM image below shows Pt nanoclusters on TiO_2(110).

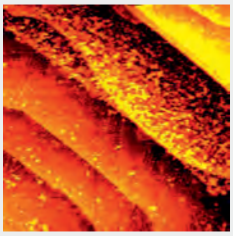


Pt nanoclusters on TiO_2(110), RT, I = 0.15 nA, U = 1.5 V

Image courtesy of B. Roldan, University of Central Florida, USA

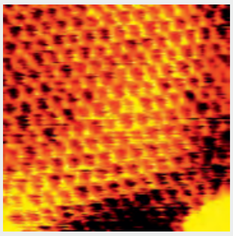
NAP-STM on Gr/Ru(0001) and O(2x2)/Ru(0001)

Graphene, a single layer of carbon atoms is a promising candidate for the use in technological applications like gas sensors, THz transistors, integrated circuits, touch screens and many others. One of the promising systems on the basis of Graphene is its interface with metallic substrates where Graphene can be used as a protection layer for the underlying substrate. Real world applications require understanding of its behavior in extreme conditions like elevated temperatures and pressures. For this topographical changes of Graphene layers have been monitored in a Nitrogen atmosphere of 10 mbar at 500 K by high temperature near ambient pressure STM. Such demanding in-situ measurements in extreme environments are only possible with a dedicated instrument with uncompromised stability and resolution. The STM image shows Graphene (Moire) and O(2x2) structure on stepped Ru(0001) surface along with the adsorbed water clusters.



Graphene and O(2x2) on Ru(0001) imaged at 10 mbar in Nitrogen atmosphere: T=500 K, I=0.7 V, U=0.7 V

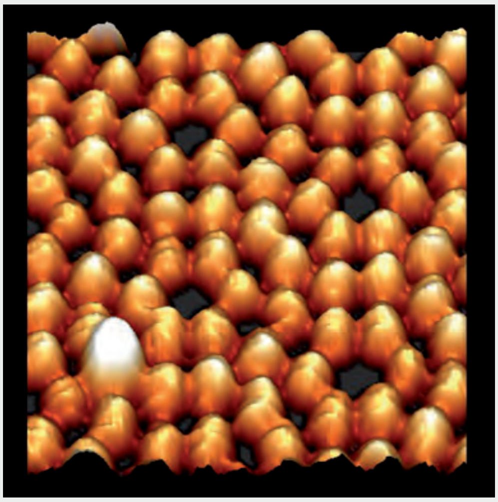
Even atomic resolution can be achieved when working in extreme environments The result below shows atomic resolution of O(2x2) layers on Ru(0001) at 10 mbar in a Nitrogen atmosphere and at the temperature of 500 K.



O(2x2) on Ru(0001) imaged at 10 mbar in Nitrogen atmosphere: T=500 K, I=0.7 V, U=0.5 V

Atomic Resolution nc-AFM on Si(111)

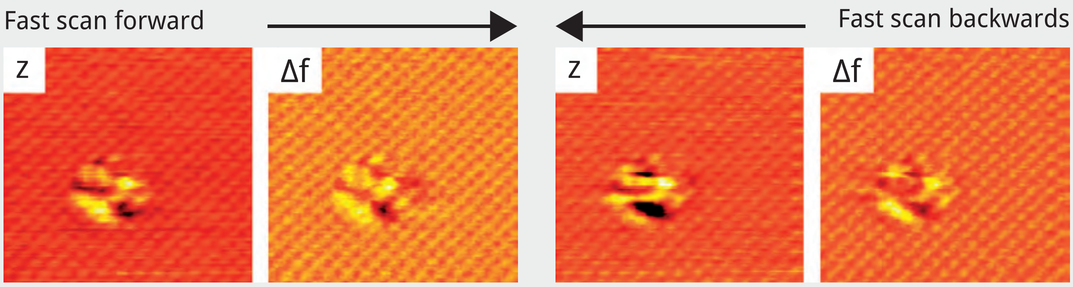
Unique features of the KolibriSensor™ compared to conventional tuning fork-based sensors allow for high quality images that can also display tunneling and force signals completely independently (and yet simultaneously) at the highest speeds and the smallest oscillation amplitudes.



Atomic Resolution on Si (111) -7x7

Atomic Resolution nc-AFM on KBr(001)

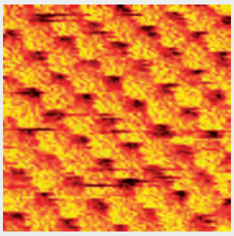
The high stability during operation of the KolibriSensor™ during nc-AFM imaging gives you the possibility to go beyond characterization of clean surfaces. Even atomic size defects on the surface can be imaged routinely whereas atomic resolution is maintained throughout the image. The comparison of forward and backward fast scan direction shows the identical shape of the defect in both directions.



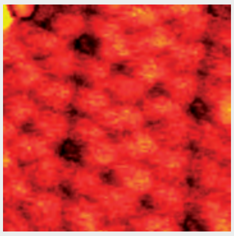
Imaging of atomic size defects on the KBr(001) surface

Imaging at Extremely Small Oscillation Amplitudes with nc-AFM

Application of small oscillation amplitudes in nc-AFM imaging results in enhanced detection of the short range chemical bonding forces. The high stiffness of the KolibriSensor and its excellent signal to noise ratio allows for atomic resolution imaging at extremely small oscillation amplitudes even at room temperature. These low amplitudes have so far been only applicable when working at cryogenic temperatures.



KBr(001), A=30pm

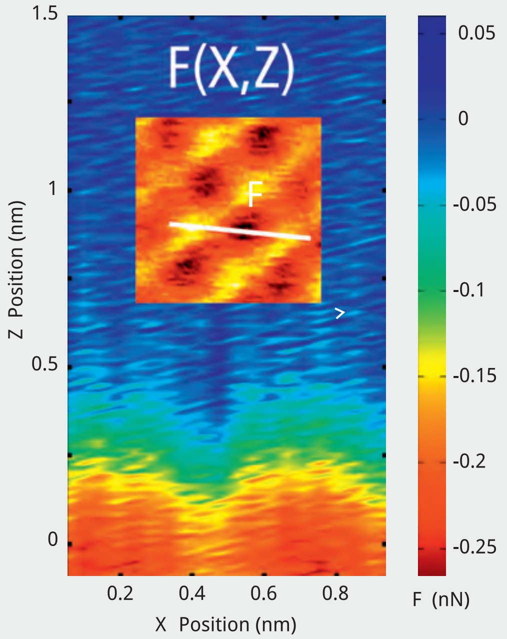


Si(111)(7x7), A=20pm

Atomic resolution topographic images on KBr(001) and Si(111)

Force Mapping and Spectroscopy on KBr(001)

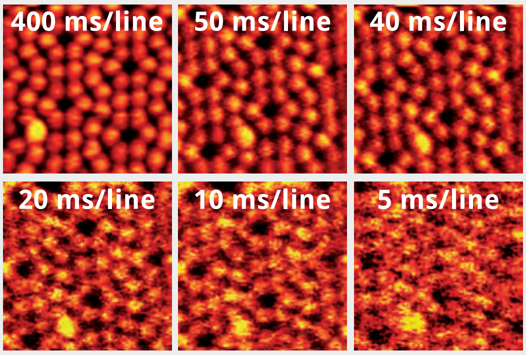
The highly symmetric geometry of the electrically actuated quartz rod ensures that only the rod is excited during oscillation while the sensors' base remains at rest. This allows for precise and stable spectroscopy experiments even at room temperature, due to very low thermal drift rates. The sample can be characterized beyond imaging on a quantitative level by combination of force/tunneling current vs. distance or bias voltage in spectroscopic experiments.



Two-dimensional map of the site specific vertical tip-sample forces F(x,z) on the KBr(001) surface at room temperature

High-speed nc-AFM Atomic Resolution Imaging

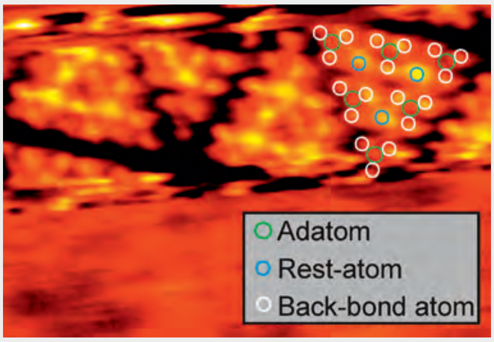
Get to know more about surface dynamics. The extraordinary high resonance frequency of 1 MHz allows for fast nc-AFM atomic resolution imaging at extremely fast scanning speeds. These imaging speeds are not accessible with other piezoelectric force sensors like tuning forks due to their low resonance frequencies.



High-speed nc-AFM atomic resolution maging on Si(111)

Subsurface Atoms of Si(111)(7x7)

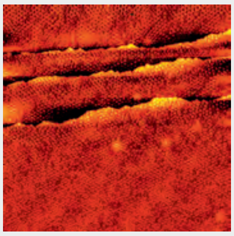
Explore the area beyond the usually visible surface atoms. A special tip termination can be obtained by gentle tip crashes allowing imaging of all rest atoms and back-bond atoms on the Si(111)(7x7) surface, rather than adatoms.



Subsurface atoms of Si(111)(7x7), constant detuning nc-AFM image

High-temperature nc-AFM

The excellent stability of the instrument allows for the nc-AFM imaging even at the high sample temperatures. The Graphene was grown by chemical vapor deposition of ethylene on Ru(0001) and imaged with the high temperature STM instrument at 650 K.

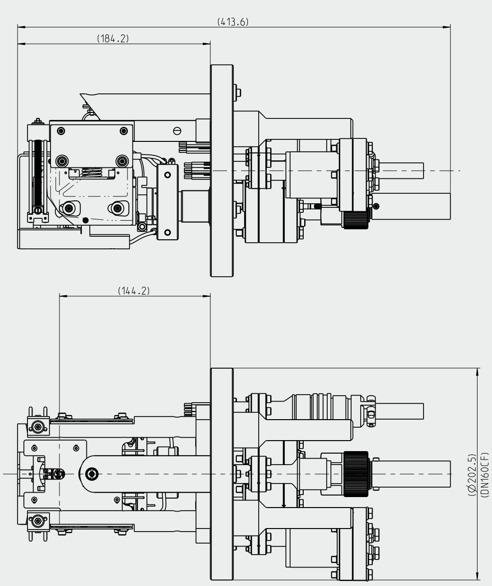


nc-AFM imaging of Graphene on Ru(0001) at 650 K

SPM Aarhus 150

Mounting Flange	DN 150CF
Temperature Stability	Better ± 2 K (150 K ... 400 K)
In-situ Access	Specular and Evaporation
Scan Range	1.500 nm x 1.500 nm
Sensitive Z Range	± 175 nm
Approach Speed	up to 1mm / min
Drift-rate	< 0.05 nm/min (vert), < 0.15 nm/min (lat)
Stability	< 10 pm
Temperature Control	2 controlled subsystems for sample & scanner

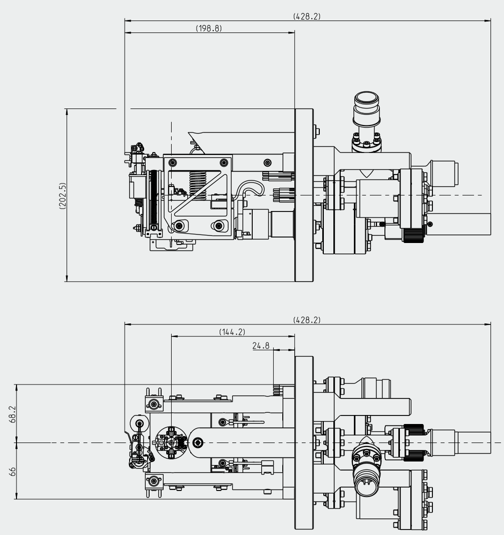
Separate analog heater for STM head and sample, manual or automated, temperature displays, alarm control for both temperatures and external interlock.



SPM Aarhus 150

SPM Aarhus 150 HT

Mounting Flange	DN 150CF
Temperature Range	90 – 650 K (SPM) / 1300 K (STM)
Temperature Stability	Better ± 2 K (150 K ... 1300 K)
In Situ Access	Specular and Evaporation
Scan Range	1.500 nm x 1.500 nm
Sensitive Z Range	±175 nm
Approach Speed	up to 1 mm/ min
Drift-rate	< 0.05 nm/ min (vert), < 0.15 nm/ min (lat)
Stability	< 10 pm
Temperature Control	2 controlled subsystems for sample & scanner



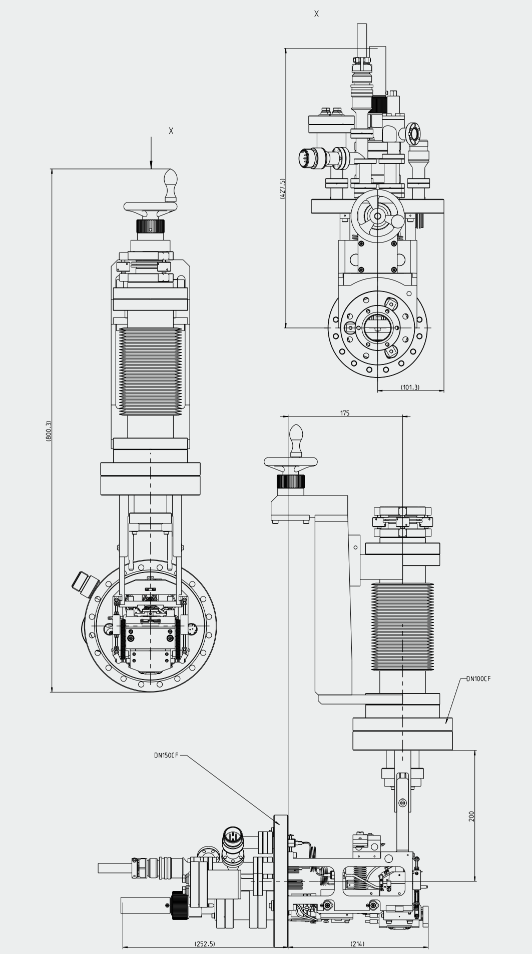
SPM Aarhus 150 HT

KolibriSensor

Resonance Frequency	1 MHz
Q-Factor	> 10,000
Spring Constant	540 kN/m
Noise Floor	< 10 fm/ √Hz
Oscillation Amplitudes	10 pm - 1 nm

SPM Aarhus 150 NAP

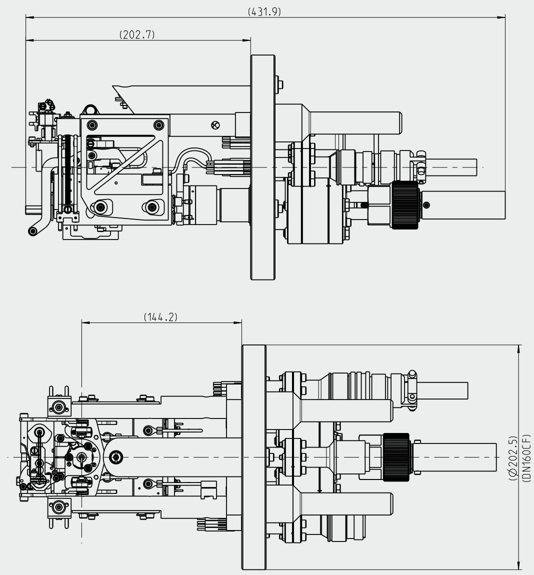
Mounting Flange	DN 150CF
Temperature Range	130 – 650 K (SPM) / 800 K (STM) in UHV, RT
Temperature Stabilty	0.1 K
In Situ Access	Specular
Scan Range	1.200 nm x 1.200 nm
Sensitive Z Range	±175 nm
Approach Speed	up to 1 mm/ min
Drift-rate	< 0.05 nm/min (vert), < 0.15 nm/min (lat)
Stability	< 10 pm
Temperature Control	2 controlled subsystems for sample & scanner



SPM Aarhus 150 NAP

SPM Aarhus 150 MBE

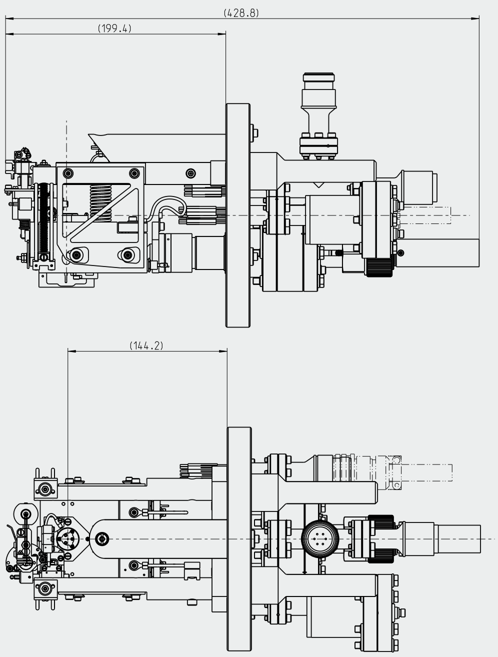
Mounting Flange	DN 150CF
Temperature Range	130 – 650 K (SPM) 1000 K (STM)
Temperature Stability	Better ± 2 K (150K ... 1000 K)
In-situ Access	Specular and Evaporation
Scan Range	1.500 nm x 1.500 nm
Sensitive Z Range	± 175 nm
Approach Speed	up to 1mm / minute
Drift-rate	< 0.05 nm/min (vert), < 0.15 nm/min (lat)
Stability	< 10 pm
Temperature Control	2 controlled subsystems for sample & scanner



SPM Aarhus 150 MBE

SPM Aarhus 150 LEEM

Mounting Flange	DN 150CF
Temperature Range	300 – 1300 K
Temperature Stability	Better 0.2 K
In-situ Access	Specular and Evaporation
Scan Range	1.500 nm x 1.500 nm
Sensitive Z Range	± 175 nm
Approach Speed	up to 1mm / minute
Drift-rate	< 0.05 nm/min (vert), < 0.15 nm/min (lat)
Stability	< 10 pm
Temperature Control	2 controlled subsystems for sample & scanner



SPM Aarhus 150 LEEM

SPC 260 Scan Electronics and Data Acquisition

Tunneling Current	0.001 - 50 nA
Scan Speed	1,000,000 pixels / sec.
Direct Monitoring of It	Remote Headphones (included)
Operating System	Windows 2000/XP
PC Interface	USB 2.0
Diagnostic Features	z(t), I(t) with Fourier transform
Drift Compensation	Fully automated (with feature selection or template matching)
Z-Travel Centering	In-situ, fully automated
Video Recording Mode	260 images/sec. at 64 x 64 pixels
Spectroscopy Modes	dI/dV, dI/dz, dz/dV, dz/dI, ...

- Multi-channel Data Acquisition for various tunneling parameters.
- Multi-scan Mode for forward and backward scans.
- Multiple Manipulation and Lithography features.

Nanonis Control System

SPM Control System Base Package BP5

RC5	
Real-time System	NI PXIe-8115 real-time system with Intel Core i5 CPU 2.5 GHz, 2 GB RAM
Operating System	NI LabVIEW Real-Time OS
Connectivity	3 x SC5 max., 3 x OC4 max. Total of max. 4 frontends

Analog Inputs (all specifications for ±10 V input range)	
Hardware Interface	8 x BNC connectors, differential
Differential Input Voltage Range	±10 V
Analog Bandwidth	DC – 100 kHz (-3 dB), 5th-order Butterworth low-pass filter

Analog Outputs (all specifications for ±10 V output range)	
Hardware Interface	8 x BNC connectors, referenced to AGND
Output Voltage Range	±10 V into 1 kΩ or larger (0 to +10 V with internal jumper per channel)
Analog Bandwidth	DC – 40 kHz (-3 dB), 5th – order Butterworth low-pass filter

Digital Lines	
Ports	4 x 8 lines on four D-sub 9 female connectors
Direction	Input or output for each line
Signal	3.3 V TTL, max. 25 mA per line
Maximum Sampling Frequency	500 kHz

High Speed Digital Lines	
Ports	4 x inputs and 4 x outputs on SMB male connectors
Signal	3.3 V TTL, max. 33 mA per line
Maximum Sampling Frequency	200 MHz

Graphical User Interface	
Operating System	Windows XP/Vista/7/8 Windows 7 64-bit recommended
Recommended Configuration	Intel Core i5 2.5 GHz or equiv., 4 GB RAM, 1 TB HD, two 21” screens with 1600 x 1200 or 1920 x 1200 pixels

Oscillation Controller Module OC4

Functions	
Lock-in	True phase and amplitude and x, y measurements frequency response measurements, Bode- & Nyquist plots phase sweeps, higher harmonics
PLL	Constant phase, with const. excitation or const. amplitude auto PLL setup with perfectPLL™
Kelvin Probe	Frequency modulation & amplitude modulation technique
Oscilloscope	3 channels, triggering, 100 kS/s per channel cont. acquisition

Signal Input	
Analog bandwidth	100 Hz - 5 MHz

Excitation Output	
Bandwidth	100 Hz - 5 MHz

HVA4 – High Voltage Amplifier

Generel	
Mounting	Stackable bentchtop casing, rack mount kit available
Outputs	6 (+X, -X, +Y, -Y, Z, AUX)
Inputs	4 (X, Y, Z, AUX)
Gain	Depending on model, 4 selectable values

Analog Inputs	
Connectors	BNC
Analog bandwidth	2 kHz, 10 kHz optional, 1.2 MHz for fast AUX channel

AMP5 – Audio Monitor

Generell	
Input channels	4
Headphone jacks	2
Analog Input	BNC

- Atom Tracking Module AT4
- Kelvin Probe Controller Module KC4 Includes
- Femto Preamp
- Aarhus Adaptation Kit

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