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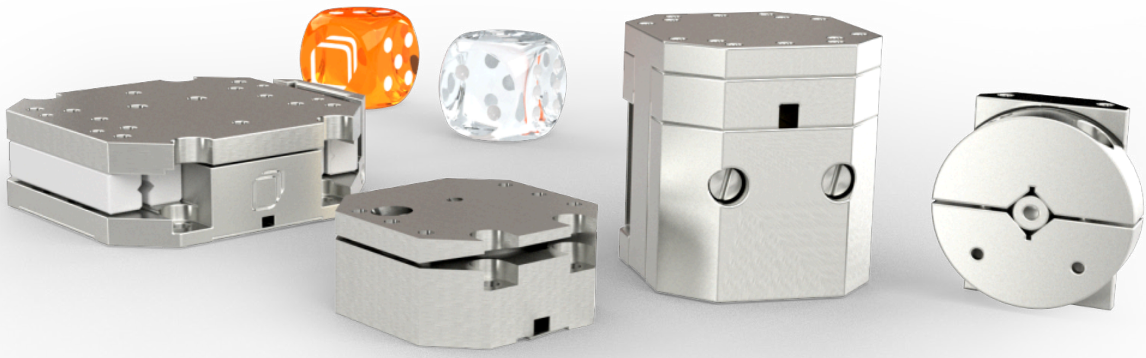


Cryogenic Nanopositioning

piezo-based nanopositioners

low temperature

CRYOGENIC INSTRUMENTS
cool tools for cold science

attocube

WITTENSTEIN Group

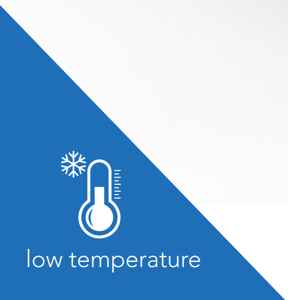
Technology Leader in Nanopositioning

attocube is the technology leader in piezo-based nanopositioning. The company stands out with patented technologies and years of experience in nanopositioning for extreme environments such as ultra-high vacuum, cryogenic to elevated operating temperatures, and high magnetic fields. The nanopositioner division focuses on the design, engineering and manufacturing of piezoelectric motor-driven stages and integrated nanopositioning solutions for applications with the highest requirements on resolution, precision and stability.

The portfolio covers linear, rotary, and goniometric positioners and scanners and combines motion over centimeter ranges with proven nanometer precision. Customized engineering solutions complete the portfolio. All components are developed, manufactured, and tested at the company's headquarters in Germany. Years of experience and a highly skilled team guarantee highest levels of consulting competence and excellent after-sales support.

Nanopositioners

for cyrogenic environments



Cryogenic Nanopositioners

attocube cryogenic nanopositioners are based on a patented piezo drive mechanism and designed for reliable nanopositioning over centimeter ranges with the highest precision under extreme environmental conditions such as cryogenic temperatures, high magnetic fields, and ultra-high vacuum (5×10^{-11} mbar).

Special non-magnetic materials like titanium and beryllium copper are used for operation down to mK temperatures. The dimensions of the positioners are designed for typical bore sizes of strong superconducting magnets. Use the product finder on the following page to identify the most suitable model for your requirements.

1 Extreme Environments

down to 10 mK low temperatures	up to 35 T magnetic fields	down to 5×10^{-11} mbar UHV pressure

2 Compact. Precise. Proven performance.

15x15 mm^2 minimum footprint	down to 1 nm resolution	> 10.000 units installed worldwide

3 Flexible Positioning

linear positioners vertical/horizontal	goniometers Θ & Φ positioning	rotators up to 360°	stacks multi-axis positioning

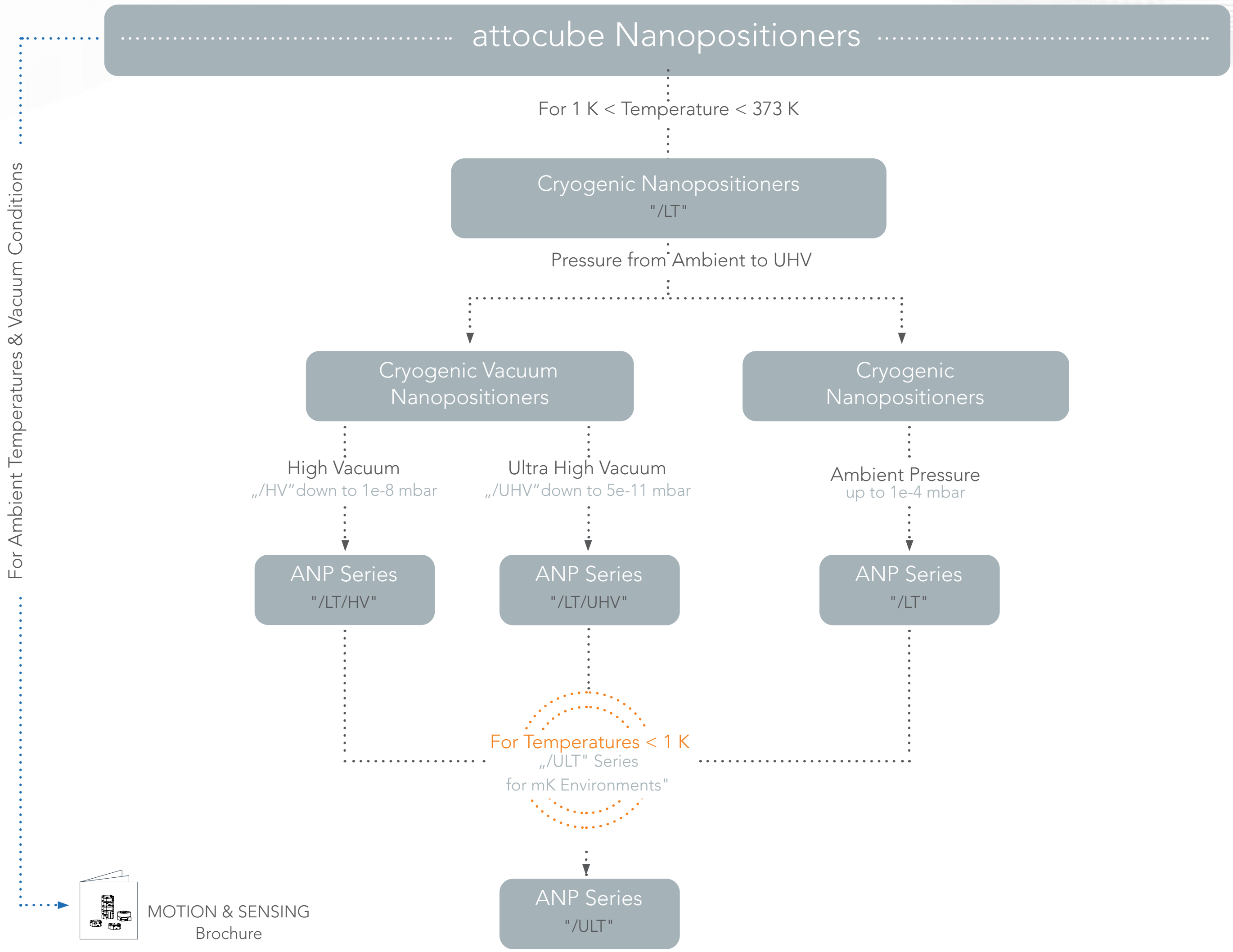
Product Finder

which positioner fits your application?

The product finder helps you to identify the most suitable model for your requirements. It indicates the respective positioner series (ANP) and the suffix in the naming scheme of attocube nanopositioners (e.g. "/LT" for low temperature, "/UHV" for ultra-high vacuum etc.)

In step 1 you can opt for the respective working environment, while step 2 leads you to the desired direction of movement and step 3 indicates whether internal position control is required or not.

Step 1



Step 2

Type of Motion

- Scanning → Scanner "ANS"
- Linear Movement → Lin. Positioner "ANP"
- Rotary Movement → Rotator "ANR"
- Goniometric Movement → Goniometer "ANG"

Step 3

Position Control

- Internal position control needed → Resitive Encoder "/RES"
  - For Temperatures < 1 K → Resistive Encoder "/RES+"
- No or external position control → No Encoder

Linear Nanopositioners

Linear Positioners	ANPz30	ANPx51	ANPz51	ANPx101
Options				
environment	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV, /ULT
encoder	---	/RES	/RES	/RES, /RES+
high load	---	---		---
Dimensions				
footprint; height	ø 11; 12 mm	15 x 15; 9.2 mm	15 x 15; 13.5 mm	24 x 24; 11 mm
Positioning Mode @ Ambient Conditions				
travel range	2.5 mm	3 mm	2.5 mm	5 mm
drive velocity	1 mm/s	1 mm/s	1 mm/s	3 mm/s
maximum load	0.1 N	0.25 N	0.5 N	1 N
dynamic drive force	0.2 N	1 N	1 N	2 N
Closed Loop Features				
resolution /RES	---	200 nm	200 nm	200 nm
precision /RES	---	1..2 µm	1..2 µm	1..2 µm

Naming Scheme

Type of Positioner		Direction of Movement		Dimension	
ANP	linear nanopositioner	x	enabling movement in x or y direction	3x	positioner series with smallest available footprint
		z	enabling movement in z direction	5x	positioners designed for a 1"clear bore size
				10x	positioners designed for a 2" clear bore size

Linear Positioners	ANPz101	ANPz102	ANPz101eXT12
Options			
environment	/LT, /LT/HV, /LT/UHV,	/LT, /LT/HV, /LT/UHV, /ULT	/LT, /LT/HV, /LT/UHV
encoder	/RES	/RES, /RES+	/RES
high load	/HL(*)	---	---
Dimensions			
footprint; height	24 x 24; 20 mm	24 x 24; 27 mm	24 x 24; 32 mm
Positioning Mode @ Ambient Conditions			
travel range	5 mm	4.8 mm	12 mm
drive velocity	3 mm/s	3 mm/s	3 mm/s
maximum load	2 N	2 N	2 N
dynamic drive force	5 N (high load *5 N)	5 N	5 N
Closed Loop Features			
resolution /RES	200 nm	200 nm	200 nm
precision /RES	1..2 µm	1..2 µm	1..2 µm

Options

eXT	extended travel range
/HL	high load version

Environment

/LT	low temperature
/ULT	ultra-low temperature
/HV	high vacuum
/UHV	ultra-high vacuum

Encoder

/RES	closed loop control based on a resistive encoder
/RES (+)	closed loop control based on a resistive encoder for mK temperatures

Linear Nanopositioners

				
Linear Positioners	ANPx311	ANPx312	ANPx321	ANPx341
Options				
environment	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV
encoder	/RES	/RES	/RES	/RES
high load	/HL(*)	---	/HL(*)	/HL(*)
Dimensions				
footprint; height	30 x 30; 10 mm	30 x 30; 12 mm	40 x 41.6; 11.5 mm	40 x 45; 11.5 mm
Positioning Mode @ Ambient Conditions				
travel range	6 mm	6 mm	15 mm	20 mm
drive velocity	3 mm/s	3 mm/s	3 mm/s	3 mm/s
maximum load	20 N	20 N	20 N	20 N
dynamic drive force	2 N (*20N vertical mounting)	2 N	2 N (*20N vertical mounting)	2 N (*20N vertical mounting)
Closed Loop Features				
resolution /RES	200 nm	200 nm	200 nm	200 nm
precision /RES	1..2 µmz	1..2 µm	1..2 µm	1..2 µm

Naming Scheme

Type of Positioner		Direction of Movement		Dimension	
ANP	linear nanopositioner	x	enabling movement in x or y direction	3xx	linear positioners with integrated bearings

Options		Environment		Encoder	
/HL	high load version	/LT	low temperature	/RES	closed loop control based on a resistive encoder
		/HV	high vacuum		
		/UHV	ultra-high vacuum		

Scanner

Scanners	 ANSz50	 ANSxy50	 ANSxyz50	 ANSz100/lr	 ANSz100/std
Options					
environment	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV
Dimensions					
footprint; height	15 x 15; 6 mm	15 x 15; 7 mm	15 x 15; 13 mm	24 x 24; 12 mm	24 x 24; 10 mm
Scan Mode					
fine positioning range @ 300 K	4.3 µm	30 x 30 μm^2	30 x 30 x 4.3 μm^3	50 µm	24 µm
fine positioning range @ 4 K	2 µm	15 x 15 μm^2	15 x 15 x 2 μm^3	30 µm	15 µm
maximum load	0.5 N	0.5 N	0.5 N	1 N	1 N

Naming Scheme

Type of Positioner		Direction of Movement		Dimension	
ANS	scanner	x	enabling movement in x or y direction	5x	positioners designed for a 1”clear bore size
		xy	enabling movement in x and y direction	10x	positioners designed for a 2” clear bore size
		z	enabling movement in z direction	150	scanner with extended scan range at cryogenic temperatures
		xyz	enabling movement in x, y and z direction		

Scanners	ANSxy100/lr	ANSxy100/std	ANSxyz100/hs	ANSxyz100/std	ANSx150
Options environment	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV	LT, /LT/HV, /LT/UHV
Dimensions footprint; height	24 x 24; 10 mm	24 x 24; 10 mm	24 x 24; 10 mm	24 x 24; 10 mm	24 x 24; 9 mm
Scan Mode					
fine positioning range @ 300 K	50 x 50 μm^2	40 x 40 μm^2	40 x 40 x 4.3 μm^3	50 x 50 x 24 μm^3	80 μm
fine positioning range @ 4 K	30 x 30 μm^2	9 x 9 μm^2	9 x 9 x 2 μm^3	30 x 30 x 15 μm^3	125 μm
maximum load	1 N	1 N	1 N	1 N	1 N

Options		Environment	
/std	standard range option	/LT	low temperature
/lr	large range option	/HV	high vacuum
/hs	high stability option	/UHV	ultra-high vacuum

Goniometers & Rotators

Goniometers & Rotators	 ANGt101	 ANGp101	 ANR31	 ANR51	 ANRv51
Options					
environment	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV, /ULT
encoder	/RES	/RES	---	/RES	/RES, /RES+
high load	---	---	---	---	---
Dimensions					
footprint; height	24 x 24; 11 mm	24 x 24; 11 mm	ø 10; 7.5 mm	15 x 15; 9.5 mm	10 x 20; 21 mm
Positioning Mode @ Ambient Conditions					
travel range	6.6°	5.4°	360°	360°	360°
drive velocity	1°/s	1°/s	3°/s	10°/s	10°/s
maximum load	1 N	1 N	0.05 N	0.3 N	0.2 N
dynamic drive torque	10 Ncm	10 Ncm	0.03 Ncm	0.2 Ncm	0.2 Ncm
Closed Loop Features					
resolution /RES	0.1°	0.1 m°	---	6 m°	6 m°
precision /RES	2 m°	2 m°	---	50 m°	50 m°

Naming Scheme

Type of Positioner		Direction of Movement		Dimension	
ANG	goniometer	p	enabling angular movement in „phi“	3x	positioner series with smallest available footprint
ANR	rotator	t	enabling angular movement in „theta“	5x	positioners designed for a 1”clear bore size
		v	horizontal rotation axis	10x	positioners designed for a 2” clear bore size
				2x0	rotator with ultra-low wobble

Goniometers & Rotators	 ANR101	 ANRv220	 ANR240
Options			
environment	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV	/LT, /LT/HV, /LT/UHV
encoder	/RES	/RES	/RES
high load	---	---	---
Dimensions			
footprint; height	24 x 24; 15.2 mm	27 x 12; 27 mm	35 x 35; 13.5 mm
Positioning Mode @ Ambient Conditions			
travel range	360°	360°	360°
drive velocity	30°/s	30°/s	30°/s
maximum load	1 N	1 N	2 N
dynamic drive torque	0.8 Ncm	1 Ncm	2 Ncm
Closed Loop Features			
resolution /RES	6 m°	6 m°	6 m°
precision /RES	50 m°	50 m°	50 m°

Environment

/LT low temperature
/ULT ultra-low temperature
/HV high vacuum
/UHV ultra-high vacuum

Encoder

/RES closed loop control based on a resistive encoder
/RES+ closed loop control based on a resistive encoder for mK temperatures

Controller Overview

piezo postitioning electronics and accessories

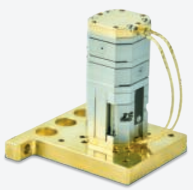
Highest-precision piezo positioning systems require state-of-the-art control electronics. attocube FPGA-based motion controllers are adapted to the technical challenges of positioners and scanners dedicated for cutting-edge applications and experiments.

The cryogenic nanopositioners are accompanied by 19″ rack electronics for laboratory environments. Suitable accessories for attocube positioners are listed below.

ANC250

- ultra low noise scan voltage ampifier (20 µV rms)
- three channels with up to 200 V (differential)

Accessories



ATC – Thermal Coupling Device

- nanoprecise motion with the sample close to the cryostats base temperature
- available with or without heater and temperature sensor

Adapter Plates AAP

- for vertical mounting of ANP positioners
- for cross-mounting of differently sized ANP positiones

ANC350

- position readout
- piezo grounding on target position
- controlling via frontpanel or PC
- combined stepping and scanning possible

ANC300

- modular design
- slots for up to 7 plug-in modules
- combined stepping & scanning possible
- controlling via frontpanel or PC

Vacuum Feedthrough Solution

- for connecting positioners mounted in a vacuum chamber to the motion controller
- different sizes are available
- suitable cabling is available

Toolbox

- including titanium screws, pin plugs, wires, base plates, screwdrivers and a tweezers
- available for ambient or vacuum conditions or as RES toolbox (integration of an ANP/RES)

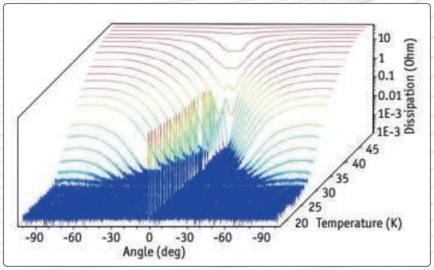
Applications

where ideas become results

Fundamental research in physics and materials science is often conducted at cryogenic temperatures in order to reduce thermal noise, broadening of optical spectra, and to be able to access quantum effects that are per se not observable at ambient conditions. Additionally, increasing precision, resolution, and accuracy are of the utmost importance in nowadays research.

attocube cryogenic positioners are designed for a broad range of applications where highest precision, space constraints, or challenging environmental conditions define the specifications. In this section you will find a snapshot of the main research fields with selected applications examples. Contact us to discuss your special requirements and setups.

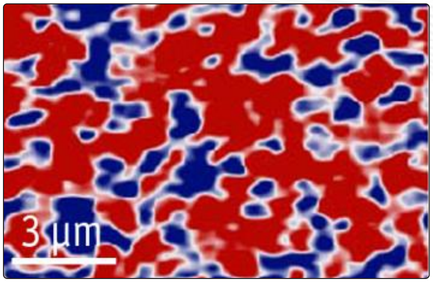
Transport Measurements



Application Examples

- angle-dependent transport measurements at 40 mK
- van der Waals heterostructure under rotation at 40 mK
- rotating transport measurement setup at 25 mK
- angle-dependent characterizations of materials at mK temperatures
- transition from slow Abrikosov to fast moving Josephson vortices
- cryogenic angle-dependent magnetoresistance measurement

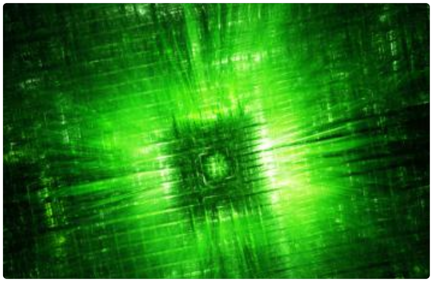
SPM Measurements



Application Examples

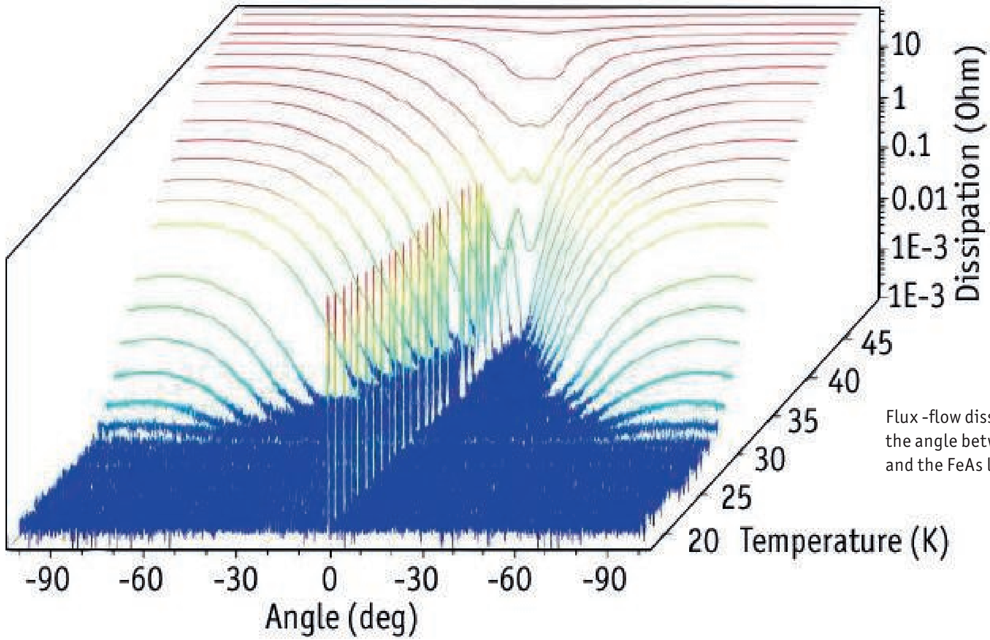
- SPM using attocube nanopositioners in magnetic fields above 30 T
- scanning Hall probe microscopy at 300 mK with ANP positioners
- magnetic resonance imaging of nanoscale virus at 300 mK

Optical Measurements



Application Examples

- single photon generation with controlled polarization from InGaN quantum dots
- Raman measurements on 2D materials at 2 K
- a quantum network node and register based on silicon vacancies in diamond
- automatic mapping of semiconductor QDs
- light-matter coupling in TMD monolayers & heterostructures
- dissipation in optomechanical resonators
- 3D g-factor mapping of single quantum dots
- photoluminescence measurements in fields up to 28 T



Flux -flow dissipation as a function of the angle between the magnetic field (H = 12 T) and the FeAs layers (= 0°) for several temperatures.

Challenge:

With ever increasing varieties of novel anisotropic materials, comprehensive characterization of their transport properties is becoming more demanding and time-consuming, mostly due to the requirement for vector magnets. Vector magnets are not just costly and cumbersome to operate, but also limited in the magnitude of their vector field strength. Yet, the interest in anisotropic materials is growing because of their technological potential.

attocube´s solution:

A compact and cost-efficient solution for studying anisotropic effects is provided by attocube precision rotators, which allow for angle-dependent magneto-transport measurements in 2D or 3D with the full field of a single solenoid.

Benefits:

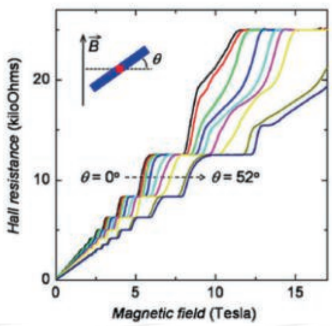
- effective replacement of vector magnets
- precise readout of angular position
- non-magnetic materials
- mK-compatibility

Application Examples

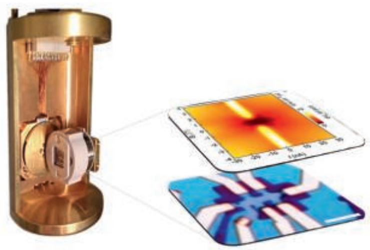
Angle-dependent Transport Measurements at 40 mK

Based on the smallest attocube rotator – ANR30/LT - a rotation stage for angle-dependent transport measurements in magnetic fields up to 33 T and temperatures down to 40 mK was built at the user facility of the High Field Magnet Laboratory in Nijmegen (Netherlands). The mixing chamber of the commercially available dilution refrigerator from Leiden Cryogenics offers only a limited space of 17 mm in diameter.

U. Zeitler, High Field Magnet Laboratory, Nijmegen, Netherlands



Van der Waals Heterostructure under Rotation at 40 mK



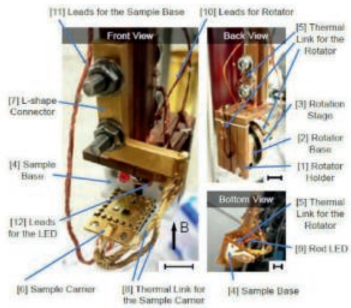
An international collaboration (Berkeley, Stanford, Shanghai, Tsukuba, Seoul) reported signatures of tunable superconductivity in van der Waals heterostructures, detected via a sharp drop in the resistivity and a plateau in the I-V curve below 1 K. For in-plane measurements, the atto3DR double sample rotator was used, which conveniently allows for using the full field of a single solenoid in an arbitrary orientation.

G. Chen et al., Nature 572, 215 (2019)

Rotating Transport Measurement Setup at 25 mK

When designing a setup for mK applications material choice and thermalization are crucial. At Peking University (Beijing, China), Pengjie Wang from Xi Lin group has chosen the ULT version of the ANR101 positioner with resistive readout to realize their low-electron-temperature sample rotation system for transport measurements inside a dilution refrigerator. The deteced elelectron temperature in the setup was measured to be 25 mK.

P. Wang et al., Rev. Sci. Instrum. 90, 023905 (2019)

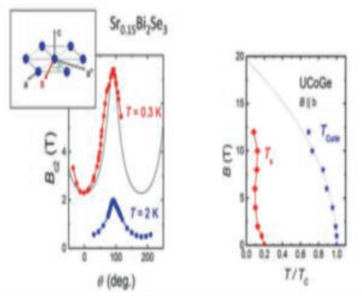


Application Examples

Angle-dependent Characterizations of Materials at mK Temperatures

The group of Anne de Visser at the Van der Waals - Zeeman Institute (University of Amsterdam, Netherlands) used attocubes rotators and benefitted from the “quasi rotation” of a 1D magnet in two different approaches – rotating a small sample within limited space with an ANR51 and rotating a dilatometer inside a dilution cryostat by using an ANRv220.

Y. Pan et al., Sci. Rep. 6, 28632 (2016)
A.M. Nikitin et al., Phys. Rev. B 95, 115151 (2017)



Transition from Slow Abrikosov to Fast Moving Josephson Vortices

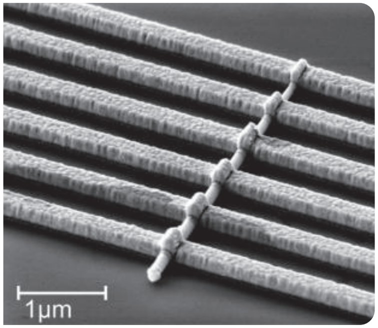
Cutting-edge application using the ANR31 rotator: The group of Bertram Batlogg (ETH Zurich, Switzerland) observed the formation of fast moving Josephson vortices, which depends critically on the angular alignment. Using an ANR31, they were able to rotate the sample below 2 K with better than 0.1° precision and could observe no drifts while sweeping temperature and magnetic field.

P.J.W. Moll et al., Nature Mater. 12, 134 (2013)

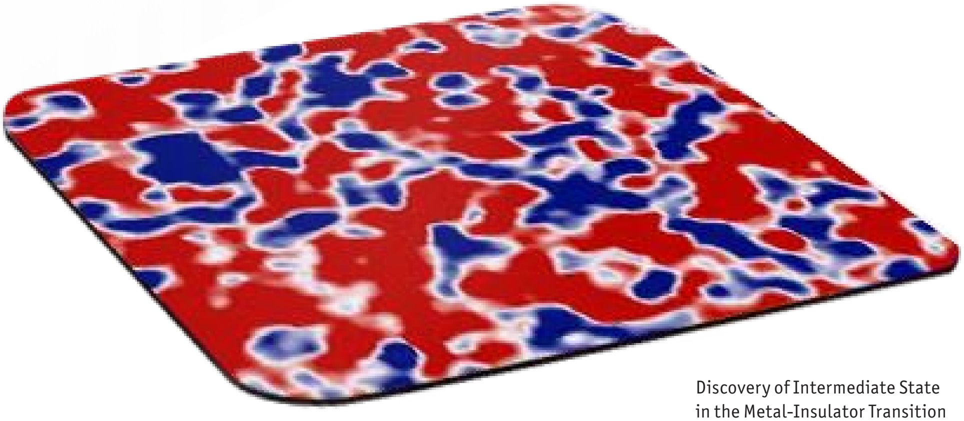
Cryogenic Angle-dependent Magnetoresistance Measurement

Christian Butschkow and co-workers from the group of Dieter Weiss (University of Regensburg, Germany) measured magnetotransport on individual GaAs/(Ga,Mn)As core-shell nanowires. An atto3DR allowed them to align the nanowires exactly to the 1D magnetic field. Their results showed the resistance anisotropy being dominated by the effective magnetic field and a relation between the origin of the NMR and the spin scattering.

C. Butschkow et al., Phys. Rev. B 87, 245303 (2013)




atto3DR



Discovery of Intermediate State
in the Metal-Insulator Transition

Challenge:

In order to be able to access various emergent and quantum phenomena, scanning probe microscopy (SPM) needs to be performed in extreme environmental conditions such as cryogenic temperatures, high magnetic fields, and ultra-high vacuum. Moreover, large scan range, as well as high stability and repeatability are required simultaneously.

Benefits:

- large ranges and high stability
- compact design
- easy retrieval of regions of interest
- small footprint
- mK-compatibility

attocube´s solution:

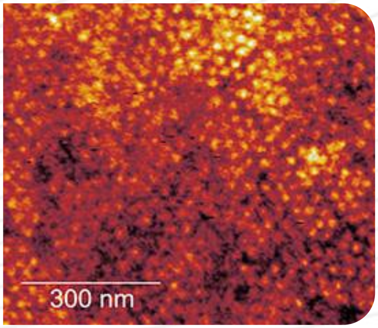
attocube cryogenic nanopositioners offer positioning over centimeter range under extreme conditions and without drift. Easy retrieval of regions of interest is ensured by resistive encoders. These features enable comprehensive surface studies of mesoscopic samples. Furthermore, attocube nanopositioners have a minimal footprint, that makes them compatible with typical bore sizes of strong superconducting magnets.

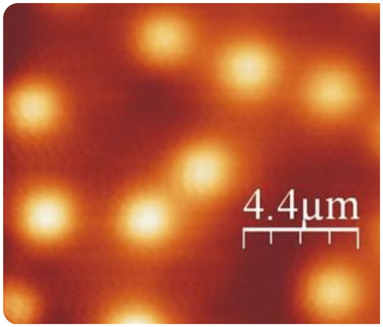
Application Examples

SPM using attocube Nanopositioners in Magnetic Fields above 30 T

In an outstanding setup, Benjamin Bryant and Lisa Rossi together with the SPM group of Alex Khajetoorians (Radboud University, Netherlands), designed a high field scanning probe microscope for operation at cryogenic temperatures and in extreme magnetic fields up to 38 T. An ANPz30 nanopositioner controls the coarse approach of an atomic force microscope cantilever to a scanned sample. Due to the compactness and rigid design of the positioner, the sensitivity to vibrational noise is reduced, which is critical for SPM in the extreme environment of the Bitter magnet.

L. Rossi et al., Rev. Sci. Instrum. 89, 113706 (2018)





Scanning Hall Probe Microscopy at 300 mK with ANP Positioners

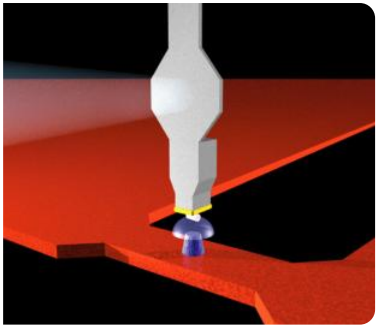
Magnetic properties of superconducting and ferromagnetic materials at ultra-low temperatures represent some of the most interesting contemporary problems in condensed matter physics. These properties are typically investigated using a magnetic force microscope or a scanning Hall probe microscope (SHPM). Such a SHPM was built by the group of Simon Bending (University of Bath, UK) with submicron lateral resolution and a large scanning range.

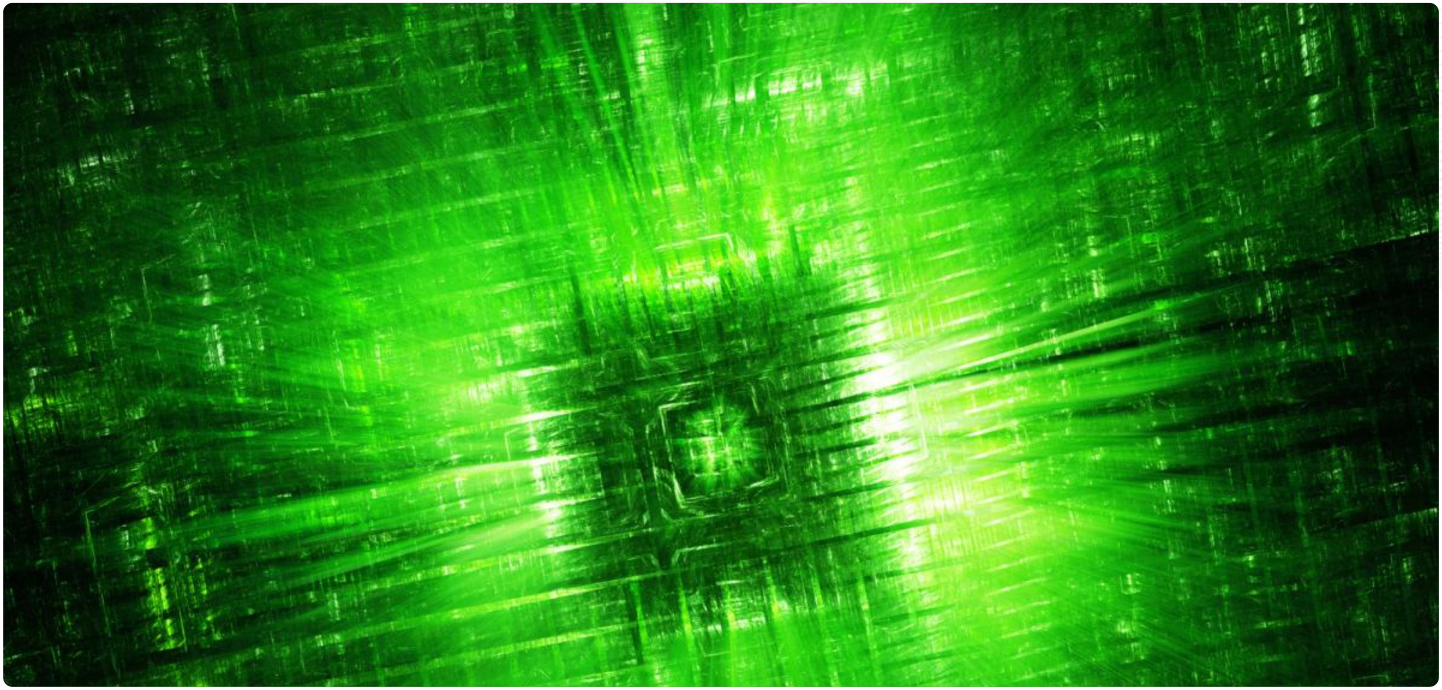
V.V. Khotkevych et al., Rev. Sci. Instrum. 79, 123708 (2008)

Magnetic Resonance Imaging of Nanoscale Virus at 300 mK

Christian Degen (now at ETH Zurich, Switzerland), Martino Poggio (now at University of Basel, Switzerland) and the group of Daniel Rugar at IBM Almaden (USA) demonstrated improvement of magnetic-resonance-force-microscopy imaging resolution to length scales of a few nanometers, representing a 100-million fold increase in volume resolution over conventional MRI. In the setup used for these ground-breaking experiments, two attocube ANPx51 positioners played the crucial role of coarse positioning the sample over the nanoscale magnetic tip.

C. L. Degen et al., PNAS 106, 1313 (2009)





Challenge:

Quantum optics often involve not only low temperatures and high-magnetic fields, but also scarce signals from single photon emitters, which may be randomly scattered across the substrate. Hence, a typical measurement requires repeatable *insitu* motion to locate emitters, and, once there, long-term stability due to long acquisition times. Furthermore, mesoscopic samples like nanowires or 2D materials require large scan ranges in extreme environments.

attocube´s solution:

attocube cryogenic nanopositioners enable in-situ movements over macroscopic distances (cm range) with step size in the range of tens of nm, and without drift (achieving ground positioning). They are thus perfectly suited for selecting best single-photon sources and consequent measurements on them over months.

Benefits:

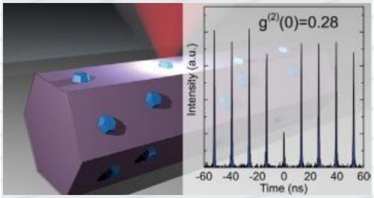
- proven performance (>10^4 units sold)
- suited for extreme environment
- large scan ranges
- high stability and repeatability
- small footprint

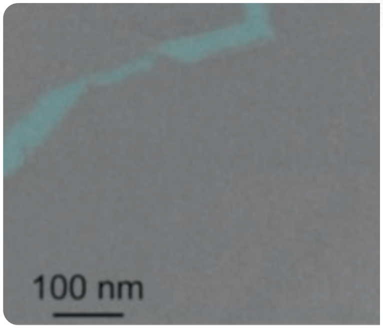
Application Examples

Single Photon Generation with Controlled Polarization from InGaN Quantum Dots

The research group led by Robert Taylor (University of Oxford, UK) has successfully generated single photons with polarized light emission and predefined polarization axis at temperatures spanning from around 5 K to above 200 K using InGaN quantum dots. By using attocube cryogenic nanopositioners inside the optical cryostat attoDRY800, temperature sweeps between 5 K and 300 K were easily possible.

T. Wang et al., Nanoscale 9, 9421 (2017)
T. Wang et al., Nanophotonics 6, 1175 (2017)
T. Wang et al., Phys. Status Solidi B 254, 1600724 (2017)





Raman Measurements on 2D Materials at 2 K

Based on the reliability of attocube nanopositioners the groups of Nathaniel Stern and Vinayak Dravid at Northwestern University, USA used a film of monolayer MoS_2 to present a new *in-situ* electrical biasing technique with transmission electron microscopy. They found that net vacancy flux towards the grain boundaries occurs with an applied electric field.

A.A. Murthy et al., ACS Nano 14, 1569 (2020)

A Quantum Network Node and Register Based on Silicon Vacancies in Diamond

The realization of a quantum network node is a fundamental requirement for a future quantum network or even quantum internet. At Havard University(USA) the groups of Marko Loncar and Mikhail Lukin presented an elementary quantum network node based on a silicon vacancy color center inside a diamond nanocavity. The mm sized travel range with nm resolution of ANP positioners as well as the cryogenic objective are fundamental building blocks in their home-built mK microscope.

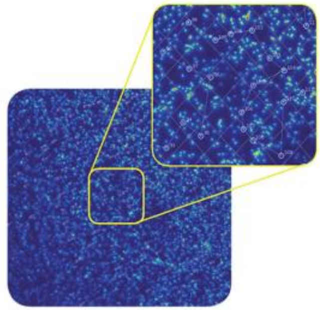
C.T. Nguyen et al, Phys. Rev. B 100, 165428 (2019)

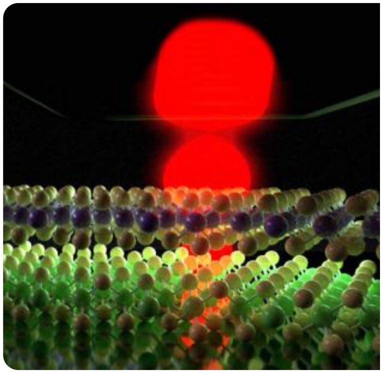
Application Examples

Automatic Mapping of Semiconductor QDs

Returning to interesting sample positions has never been easier: Yves Delley from the Quantum Photonics Group and co-workers at the ETH Zurich (Switzerland) have built a micro-photoluminescence setup and automated it to a great extent. They programmed a fully automated routine for raster-imaging a full sample of up to 4 x 4 mm^2 as well as implemented an auto-focus routine. Once initiated, the positioners are moved frame by frame and a CCD camera takes images of the PL of their semiconductor quantum dot samples. Knowing the coordinates of all individual images, it is easy to put together a complete map of the sample.

(Image kindly provided by Yves Delley, Quantum Photonics Group, ETH Zurich, Switzerland)





Light-Matter Coupling in TMD Monolayers and Heterostructures

Scanning optical micro-cavities has been used in collaboration between the groups of David Hunger (Karlsruhe Institute of Technology, Germany) and Alexander Högele (Ludwig Maximilian University Munich, Germany) to study light-matter coupling phenomena in semiconductor transition metal dichalcogenide (TMD) monolayers and heterostructures. To this end, suitable positioners - ECSx3030 and ANPx101 positioners for ambient and cryogenic conditions respectively - were used to scan a fiber-based micro-mirror across a planar micro-mirror with the sample and couple a WSe_2 monolayer ($MoSe_2$-WSe_2 heterobilayer) to the tuneable cavity.

C. Gebhardt et al., Sci. Rep. 9, 13756 (2019)
M. Frög et al., Nature Commun. 10, 3697 (2019)
(Image courtesy of Christoph Hohmann, NIM and MCQST, Munich, Germany)

Application Examples

Dissipation in Optomechanical Resonators

G.D. Cole and M. Aspelmeyer of the University of Vienna (Austria) have analyzed the acoustic disspiation of microresonators using a cryogenic interferometry setup. In detail, their system utilizes a ^{4}He cryostat as sample chamber equipped with a stack of attocube ANPxyz51 positioners for aligning the sample with respect to an optical fiber. The micro-optomechanical resonator showed resonance frequencies of up to 4 MHz and Q-factors of 8000.

G.D. Cole et al., 23rd IEEE International Conference on Microelectromechanical Systems, Hong Kong SAR, China, 24-28 January 2010, TP133

3D g-Factor Mapping of Single Quantum Dots

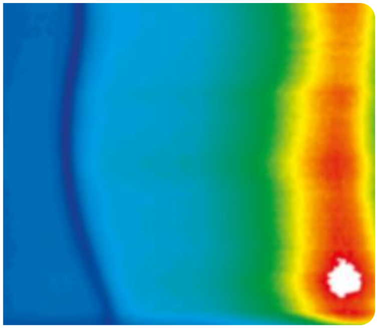
The group of Richard Phillips at the University of Cambridge (UK) used cryogenic nanopositioners of the ANP51 series for their novel fibre-based confocal microscope for magnetophotoluminescence. The design allows them to turn the samples to arbitrary angles of tilt and rotation with respect to a magnetic field of up to 10 T at low temperatures, while maintaining focus on a single quantum dot.

T. Kehoe et al., Rev. Sci. Instrum. 81 013906 (2010)

Photoluminescence Measurements in Fields up to 28 T

The attocube positioners ANPxyz100/LT have been used in a setup for optical measurements at the Grenoble High Magnetic Field Laboratory (France). The authors reported photoluminescence measurments on a single quantum dot in magnetic fields up to 28 T and were able to observe three pairs of Zeeman-split emission lines related to the recombination of a neutral exciton, a biexciton, and a charged exciton.

A. Babinski et al., Physica E 26, 190 (2005)



General Information

glossary

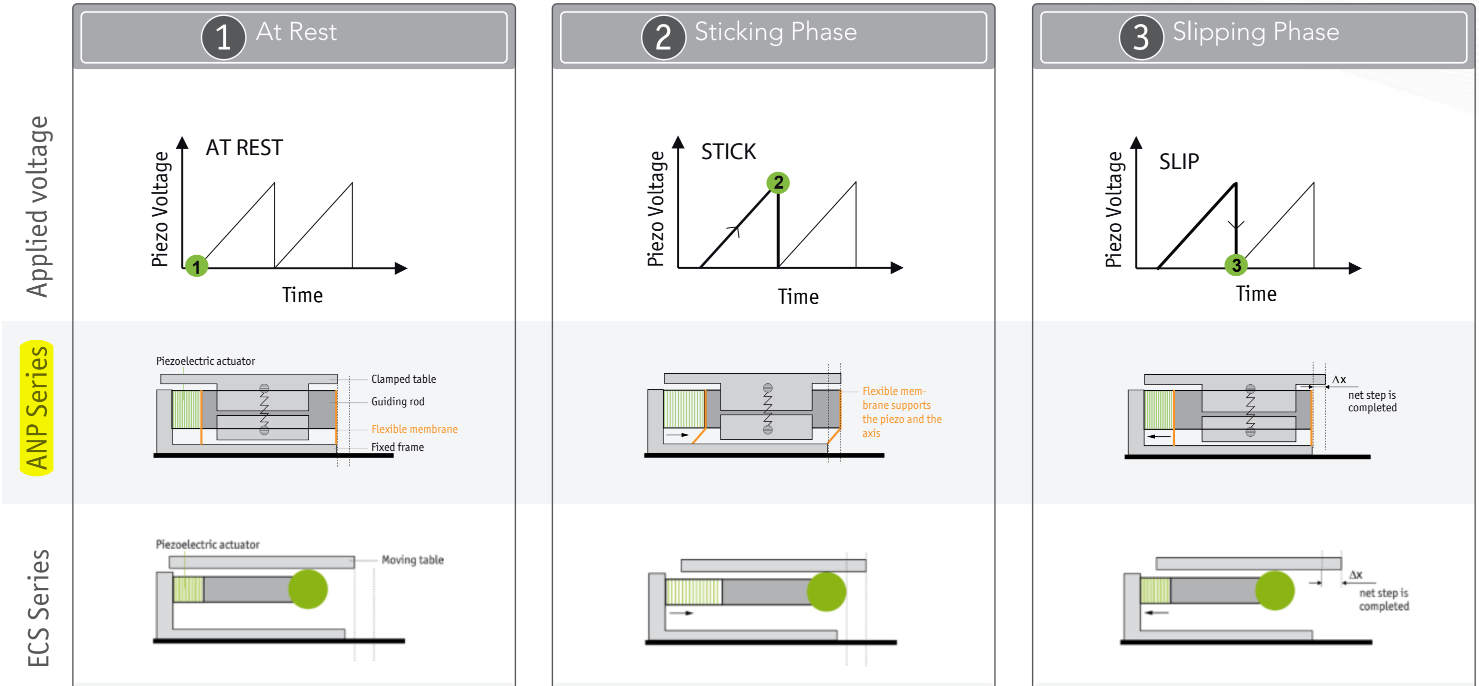
Scanners and Stepping Positioners

The low temperature scanners and stepping positioners are optimized for maximal performance under cryogenic conditions and high magnetic fields (tested up to 35 T).

- **Scanners**
  Scanners are suitable for travel ranges in µm range and their motion is continuous. The scanners are recognizable by the name „ANS“.

- **Stepping positioners**
  Stepping positioners are suitable for travel ranges in mm range. They are driven via slip stick principle (sawtooth voltage with an amplitude up to 70 V at LT).

Working Principle of Stepping Positioners



- moving table clamped to guiding rod
- guiding rod is connected to piezo element
- no voltage is applied → table at rest

- sawtooth shaped voltage is applied to piezo
- with the slow flank, table sticks to guiding rod and is moved about distance delta x)
- delta x down to 50 nm

- steep flank of voltage, the rod is accelerated fast
- table overcomes friction and disengages from drive element
- step is completed

Environmental Conditions

attocube cryogenic nanopositioners are made for different environmental conditions such as ultra-low temperature or ultra-high vacuum. One or more suitable suffixes of the article name describes the environment for which a nanopositioner is designed and tested in-house. Moreover, all cryogenic nanopositioners are suitable for measurements in a magnetic field as they are built of completely non-magnetic materials.

• /LT – Low Temperature

These positioners are suitable for repeated cooling and operation in cryogenic temperatures down to 1 K.

• /ULT – Ultra-Low Temperature

For measurements going beyond 1K: these positioners come (if desired) with a special resistive sensor and are made from berrylium copper (BeCu) instead of titanium.

• /HV – High Vacuum

The high vacuum range is specified down to 10^{-8} mbar.

• /UHV – Ultra-High Vacuum

The ultra-high vacuum range is specified down to $5x10^{-11}$ mbar for most positioners. A few rotators and goniometers use UHV compatible grease. Due to the increased outgassing of these types at elevated temperatures we specify them for 10^{-9} mbar as a precaution (noted in specification sheets). Most of our positioners can be baked out up to 150 °C.

Position Control

Most of the cryogenic nanopositioners are available in open and closed loop versions.

• Open Loop Positioning

The positioner is simply driven forward or backward, without an encoder reading the actual position.

• Closed Loop Positioning

Positioners with an integrated encoder (/RES, /RES+) can be used for closed loop position control. A feedback loop integrated into the control electronics minimizes the difference between target position and actual position. Setpoints can either be defined in a software interface or on the front panel of the electronics.

• Resistive Encoder (/RES)

A resitive encoder used for our cryogenic nanopositioners. The working principle of this encoder type is based on a potentiometer. It is the method of choice for applications at cryogenic temperatures, ultra-high vacuum and highest magnetic fields. The /RES encoder measurement refers to the absolute sample position, for most linear steppers a precision of 1 µm is achieved. For ultra-low temperatures ($T < 1$ K) a special /RES+ sensor is available which is included in all our /ULT models.

Terminology

glossary

Sensor Resolution

The low temperature scanners and stepping positioners are optimized for maximal performance under cryogenic conditions and high magnetic fields (tested up to 35 T).

Sensor Accuracy

Measurement accuracy describes the closeness of agreement of the displacement measurement value of the used sensor compared to the true target displacement value (see Figure 1). A high accuracy of the measured values implies minimized systematic errors. The accuracy of the sensor is dependent on different environmental factors.

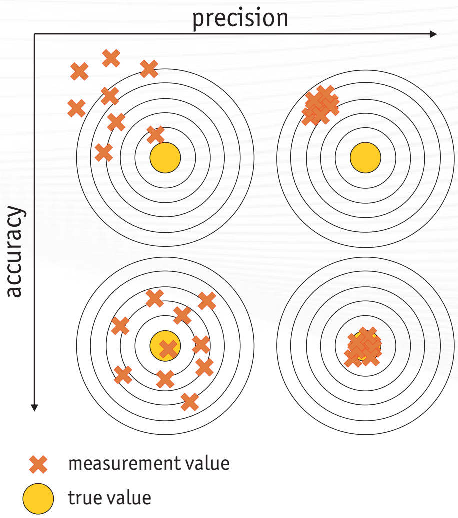
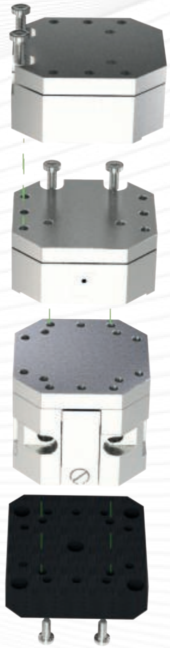


Figure 1: Difference between measurement accuracy (trueness) and measurement precision

Sensor Precision

The sensor precision is the position uncertainty when approaching a certain target value from one side (uni-directional precision, e.g. /RES). At attocube, the sensor precision is specified for a positioner and a measurement bandwith. That means positioner-specific parameters contribute to the sensor precision. The precision is defined as the measurement's standard deviation (σ).



For the standard ANPxyz-configuration, two x-positioners (one rotated by 90°) are mounted on top of a z-positioner.

Merge Nanopositioning Stages to Multi-Dimensional Systems

The modular concept of attocube positioners in combination with a consequent use of similar mounting patterns enables the assembly of multi- axis positioning units composed of (several) different types of nanopositioning stages. By merging several positioning units with distinct travel ranges and motion options, motor assemblies with up to six degrees of freedom can be built.

Cross mounting rules

Following general rules apply for building multi-dimensional setups:

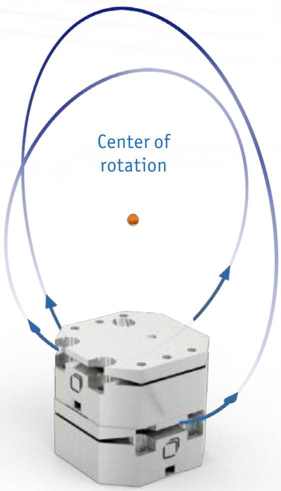
- a positioner with a lower number should not be used to support one with a larger number, e.g. an ANPx51 should not carry an ANPz101.
- cross-mounting between two different sized models (e.g. a 51 series positioner on top of a 101 positioner) may require an adapter plate (see adapter plates overview in accessories section on our webpage).
- all bearing-based positioners (ANPx3*1 series) can be mounted on a L-bracket which enables vertical positioning.

Combining Goniometers

Each size of goniometer is available in two versions which are usually used as a pair for theta (Θ) and phi (Φ) motion. The Θ positioner mounted on top of the Φ positioner form a tip-tilt stage with a common center of rotation. Mounting is done directly with two or four screws.

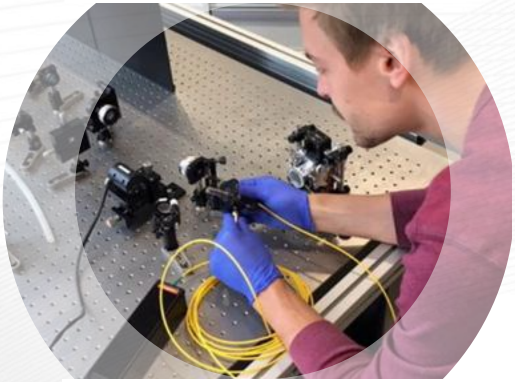
Combinations with other positioners are explained above or in the accessories sections on our webpage.

Combination of two ANG-goniometers for 2-angle alignment with one center of rotation



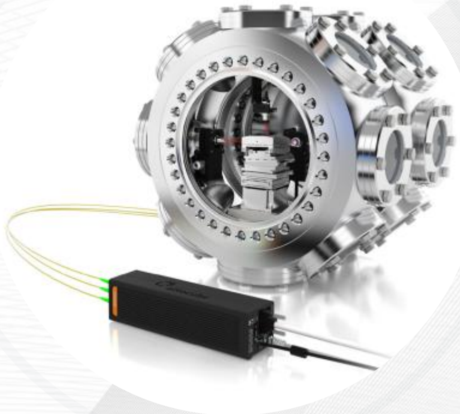
Services

how can we support you?



• Application Engineer Integration Program

attocube supports you to start your project with the best technical knowledge on our products enabling you to perform your experiment with the best output from day 1. Our engineers are available to bring your team through the initial challenges and enhance the experience and time-to-result.



• Application Engineer Initial Training

How to integrate our positioners into your system? Which challenges need to be solved to have them perform at their best? attocube engineers are at your site to provide the best support to integrate our products into your system and efficiently bring your business to the next level.

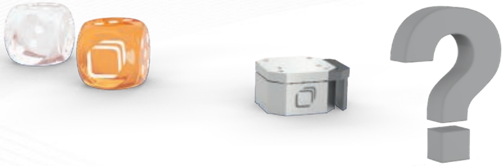
• Test Measurements

Is your lab engaged with other experiments and you don't have capacity to test your samples? Do you want to optimize your resources and time? attocube provides the facility and the service to deliver reliable test results and reports directly to you.

• Positioners Loan Kit

Do you want to verify if your setup performs at its best with our positioners? The Loan Kit with standard 6D positioners is the perfect solution to test our piezo positioners performance directly at your facility and have a first impression on the precision and the simplicity of our system.

FAQ?



Is the travel range dependent on temperature or pressure?

- For the ANP positioners, rotators and goniometers it is not dependent on that.
  The scan range of the ANS scanners is however limited at lower temperatures

Is the maximum load dependent on temperature or pressure?

- Yes, at lower temperatures as well as in vacuum conditions the maximum load capacity is lowered (compared to ambient conditions).

What is the difference between the /HV and /UHV positioners?

- For the /UHV positioners special UHV compatible (i.e. not outgasing) materials are used. Moreover, a test in a baked out UHV environment is performed for all UHV positioners to guarantee full functionality usually down to $5x10^{-11}$ mbar.

What's the maximum pressure and magnetic field ratings?

- attocube /UHV-positioners are specified down to $5x10^{-11}$ mbar and the maximum tested magnetic field is currently 35 T.

What is the temperature range for the positioners? Are they bakeable?

- There are different attocube ANP positioners specified from the mK range up to 373 K. All UHV positioners can be baked out up to 427 K.

Is the controller included with the purchase of a positioner? What else do I need?

- A motion controller is not included with the positioner. attocube sales engineers help you to find the suitable motion controller as well as cables. Moreover, there are different kinds of accessories like feedthroughs or thermal coupling devices.

What is meant with "open loop" and "closed loop"?

- The positioners without an encoder are driven in "open loop" - those positioners can only be driven forward or backward without an actual readout of the position. Whereas the positioners with an encoder are driven in "closed loop" mode, which means that a feedback loop is integrated into the control electronics and minimizes the difference between target position and actual position.

What is the difference between /RES and /RES+?

- Both encoders are based on a potentiometer. The /RES+ encoder is explicitly for our /ULT positioners.

What's the meaning of "fine positioning mode"?

- The fine positioning mode is the "scan"-mode of our positioners. For that, a DC voltage can be applied to obtain sub-step-size resolution.

What's the thermal conductivity of the ATC?

- It mostly depends on the type of link (sheets or braids) between the upper and lower plate and of the length of the link.

What is the difference between accuracy and precision?

- Please refer to the glossary.

attocube

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