



# Motion & Sensing

piezo-based nanopositioners

# 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 ambient & vacuum conditions



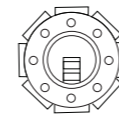
## Ambient & Vacuum Nanopositioners

attocube ambient and vacuum nanopositioners all incorporate a piezoelectric motor to achieve motion with nanometer precision and are available in a variety of different materials depending on the customer's application. Nanopositioners for use in ambient conditions are made of light-weight and strong aluminium, while a stainless steel housing is compatible with vacuum conditions up to  $5 \times 10^{-11}$  mbar and titanium is employed for non-magnetic requirements.

Different sizes and types of positioners are available for versatile needs. The bearing-based ECS series is a more rugged and cost efficient option, while the ANP series is suitable for special requirements such as limited space or non-magnetic demands. Use the product finder on the following pages to identify the most suitable model for your requirements.

1

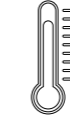
### Extreme Environments



down to  $5 \times 10^{-11}$  mbar  
UHV pressure



up to ISO Class 5  
low particle generation



up to 150 °C  
bakeable



up to 35 T  
magnetic fields

2

### Precise & Powerful



down to 1 nm  
resolution



up to 20 N  
maximum load

3

### Flexible Positioning



linear positioners  
vertical/horizontal



goniometers  
 $\Theta$  &  $\Phi$  positioning



rotators  
up to 360°



stacks  
multi-axis positioning

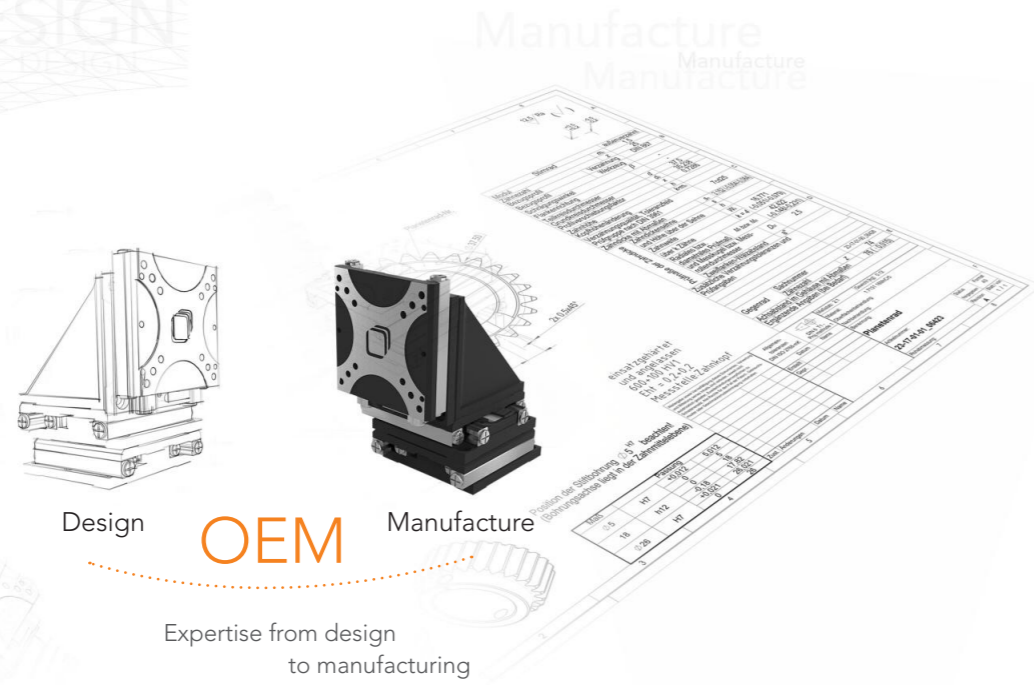


# Customized Nanopositioning Solutions

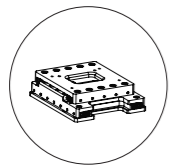
nanopositioning tailored to your application

Many high precision applications have specific requirements concerning e.g. certification, travel range, or clean room compatibility. For these applications, attocube offers a broad range of customized components and sub-modules as well as integrated systems solutions, exactly tailored to the customers specific needs.

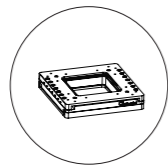
Combining attocubes competencies in nanopositioning and interferometry with years of experience in challenging and extreme environments guarantees highest levels of consulting competence and products that work with highest reliability, pushing the limits of technical feasibility.



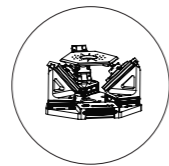
## Customized Solutions Examples



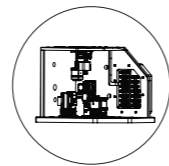
Spectroscopy Stage



Microscopy Stage



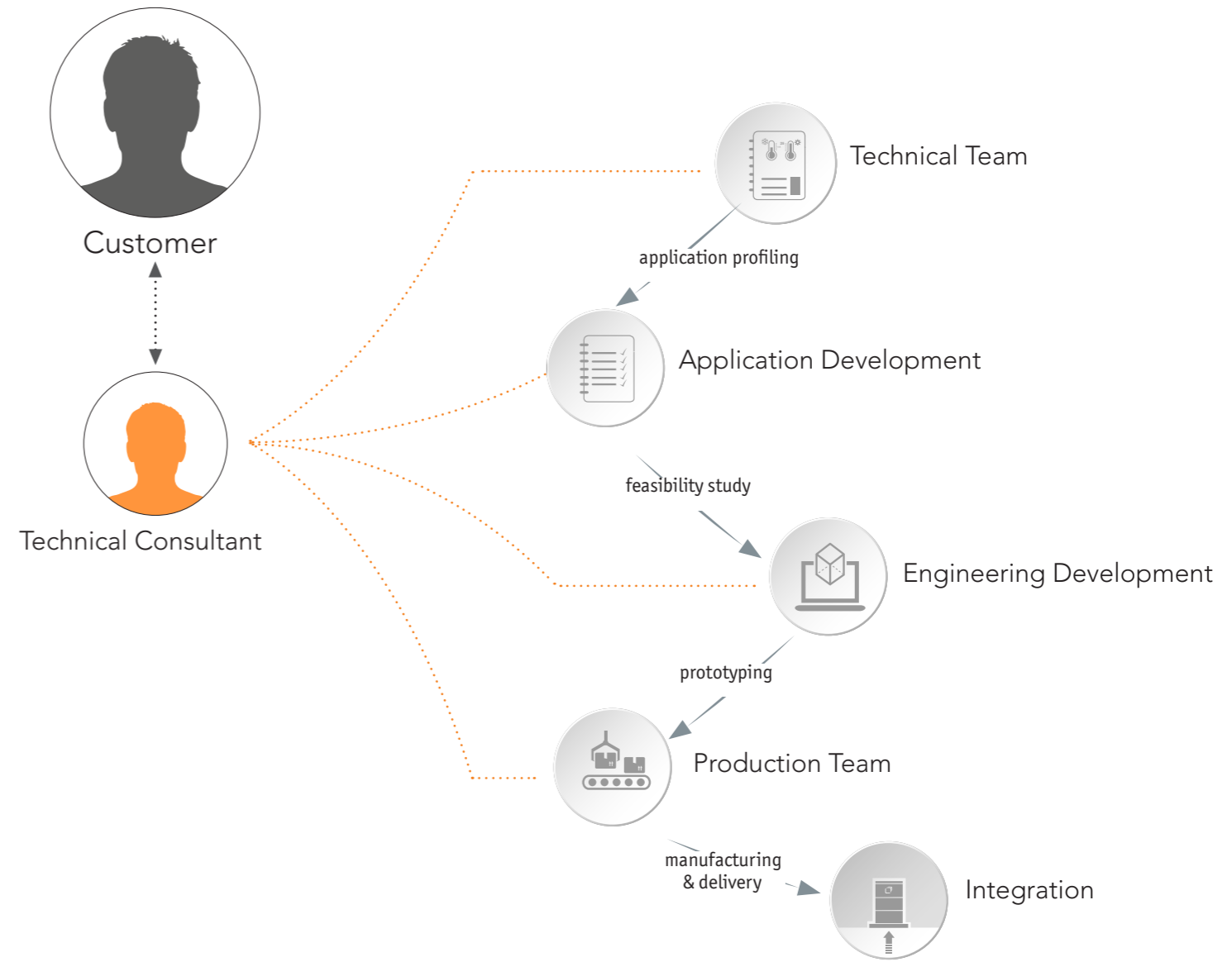
Multiaxis Solution



Imaging System

# How do customizations work at attocube?

where ideas become results



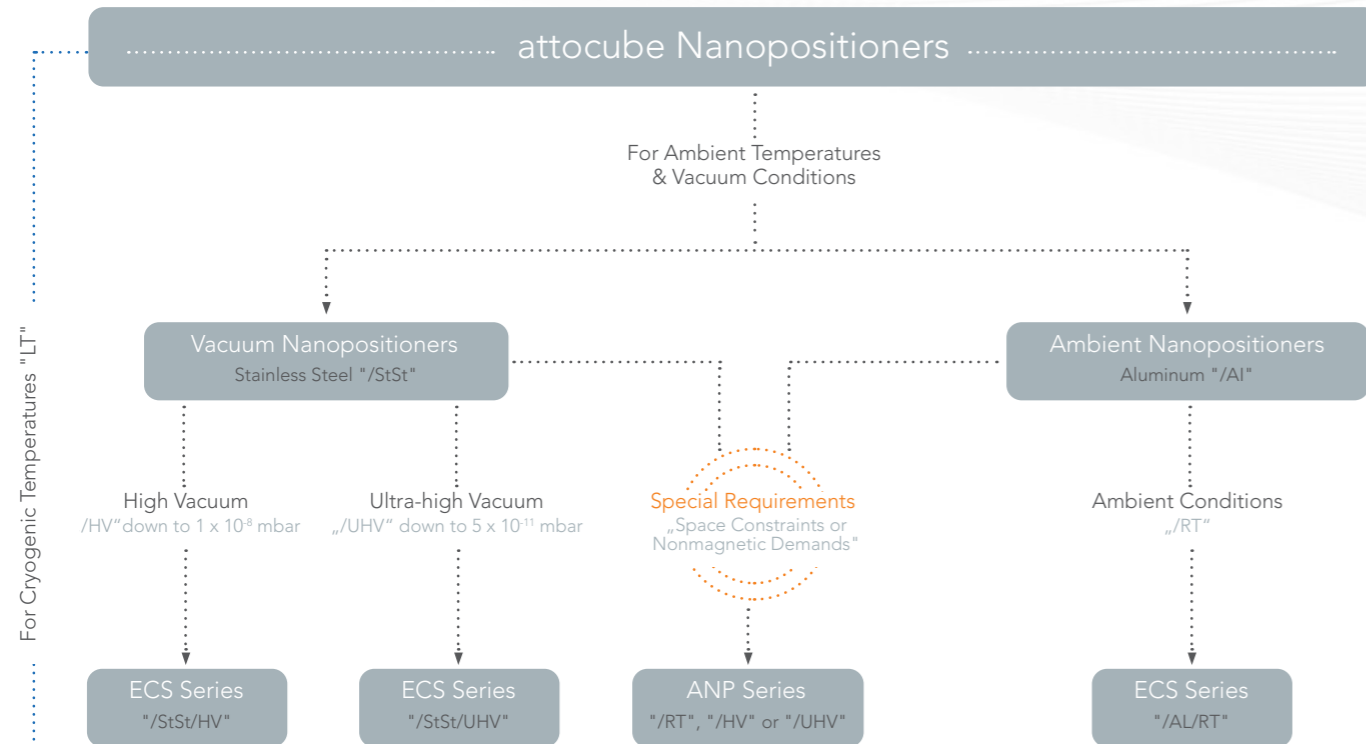
# Product Finder

which positioner fits your application?

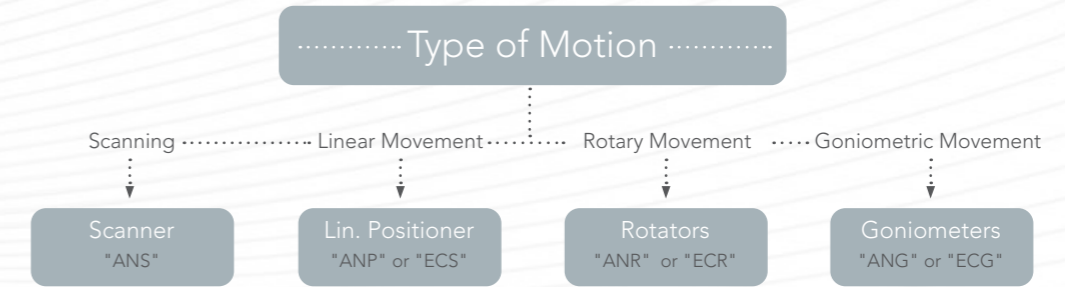
The product finder helps you to identify the most suitable model for your requirements. It indicates the respective positioner series (ECS or ANP) and the suffix in the naming scheme of attocube nanopositioners (e.g. "/StSt" for stainless steel, "/Al" for aluminium etc.).

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.

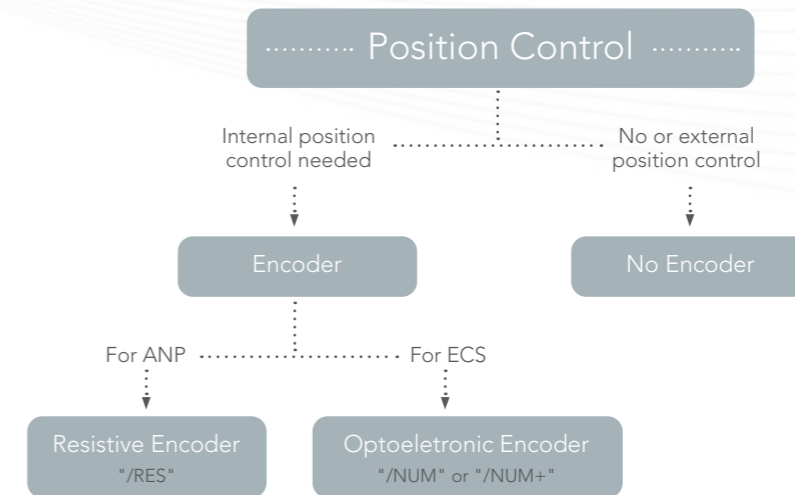
## Step 1



## Step 2



## Step 3



# Linear Positioners



Linear Positioners	ECSx5050	ECSxy5050	ECSz5050
<b>Options</b>			
environment	/RT, /HV, /UHV	/RT	/RT
encoder	/NUM, /NUM+	/NUM	/NUM
high load	/HL(*)	---	---
<b>Dimensions</b>			
footprint; height	50 x 50; 9.5 mm	50 x 50; 16.4 mm	50 x 50; 32 mm
<b>Positioning Mode @ Ambient Conditions</b>			
travel range	30 mm	25 x 25 mm <sup>2</sup>	8 mm
drive velocity	4.5 mm/s	4.5 mm/s	2 mm/s
maximum load	20 N	20 N	8 N
dynamic drive force	1 N <small>(high load *5 N)</small>	2 N	8 N
<b>Closed Loop Features</b>			
resolution /NUM	1 nm	1 nm	1 nm
repeatability /NUM	50 nm	50 nm	100 nm



Linear Positioners	ECSx3080	ECSx3050	ECSx3030	ECSz3030
<b>Options</b>				
environment	/RT, /HV, /UHV	/RT, /HV, /UHV	/RT, /HV, /UHV	/RT
encoder	/NUM, /NUM+	/NUM, /NUM+	/NUM, /NUM+	/NUM
high load	/HL(*)	/HL(*)	---	---
<b>Dimensions</b>				
footprint; height	30 x 80; 9.5 mm	30 x 50; 9.5 mm	30 x 30; 9.5 mm	31 x 30; 31.5 mm
<b>Positioning Mode @ Ambient Conditions</b>				
travel range	50 mm	30 mm	20 mm	5 mm
drive velocity	4.5 mm/s	4.5 mm/s	4.5 mm/s	2 mm/s
maximum load	20 N	20 N	10 N	8 N
dynamic drive force	1 N <small>(high load *5 N)</small>	1 N <small>(high load *5 N)</small>	1 N	8 N
<b>Closed Loop Features</b>				
presolution /NUM	1 nm	1 nm	1 nm	1 nm
repeatability /NUM	50 nm	50 nm	50 nm	50 nm

## Naming Scheme

Type of Positioner	Direction of Movement	Dimension	Options	Environment	Encoder
ECS linear nanopositioner	x enabling movement in x or y direction xy enabling movement in x and y direction z enabling movement in z direction	50xx positioner width in mm xx50 positioner length in mm	/HL high load version	/RT room temperature /HV high vacuum /UHV ultra-high vacuum	/NUM (+) closed loop control based on an optoelectronic encoder

# Linear Positioners



Linear Positioners	ANPx341	ANPx321	ANPx311	ANPz102
<b>Options</b>				
environment	/RT, /HV, /UHV	/RT, /HV, /UHV	/RT, /HV, /UHV	/RT, /HV, /UHV
encoder	/RES	/RES	/RES	/RES
high load	/HL(*)	/HL(*)	/HL(*)	/HL(*)
<b>Dimensions</b>				
footprint; height	40 x 45; 11.5 mm	40 x 41.6; 11.5 mm	30 x 30; 10 mm	24 x 24; 27 mm
<b>Positioning Mode @ Ambient Conditions</b>				
travel range	20 mm	15 mm	6 mm	4.8 mm
drive velocity	3 mm/s	3 mm/s	3 mm/s	3 mm/s
maximum load	20 N	20 N	20 N	2 N
dynamic drive force	2 N <small>(*20N vertical mounting)</small>	2 N <small>(*20N vertical mounting)</small>	2 N	2 N <small>(*3N load and force for /HL)</small>
<b>Closed Loop Features</b>				
resolution /RES	200 nm	200 nm	200 nm	200 nm
repeatability /RES	1-2 μm	1-2 μm	1-2 μm	1-2 μm



Linear Positioners	ANPz101	ANPx101	ANPz51	ANPx51	ANPz30
<b>Options</b>					
environment	/RT, /HV, /UHV	/RT, /HV, /UHV	/RT, /HV, /UHV	/RT, /HV, /UHV	/RT, /HV, /UHV
encoder	/RES	/RES	/RES	/RES	---
high load	---	---	---	---	---
<b>Dimensions</b>					
footprint; height	24 x 24; 20 mm	24 x 24; 11 mm	15 x 15; 13.5 mm	15 x 15; 9.2 mm	ø 11; 12 mm
<b>Positioning Mode @ Ambient Conditions</b>					
travel range	5 mm	5 mm	2.5 mm	3 mm	2.5 mm
drive velocity	3 mm/s	3 mm/s	1 mm/s	1 mm/s	1 mm/s
maximum load	2 N	1 N	0.5 N	0.25 N	0.1 N
dynamic drive force	2 N	2 N	1 N	1 N	0.2 N
<b>Closed Loop Features</b>					
resolution /RES	200 nm	200 nm	200 nm	200 nm	---
repeatability /RES	1-2 μm	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 z enabling movement in z direction	3x positioner series with smallest available footprint 5x positioners designed for a 1" clear bore size 10x positioners designed for a 2" clear bore size 3xx linear positioners with integrated bearings

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

# Scanners



ANSx150



ANSxyz100/std



ANSxy100/std



ANSxy100/lr

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



ANSz100/std



ANSz100/lr



ANSxyz50



ANSxy50



ANSz50

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

## Naming Scheme

Type of Positioner	Direction of Movement	Dimension	Options	Environment
ANS scanner	x enabling movement in x or y direction xy enabling movement in x and y direction z enabling movement in z direction xyz enabling movement in x, y and z direction	5x positioners designed for a 1" clear bore size 10x positioners designed for a 2" clear bore size 150 scanner with extended scan range at cryogenic temperatures	/std standard range option /lr large range option	/RT room temperature /HV high vacuum /UHV ultra-high vacuum

# Goniometers



Goniometers	ECGt5050	ECGp5050	ANGt101	ANGp101	ANGt50	ANGp50
Options						
environment	/RT, /HV, /UHV	/RT, /HV, /UHV	/RT, /HV, /UHV	/RT, /HV, /UHV	/RT, /HV, /UHV	/RT, /HV, /UHV
encoder	/NUM, /NUM+	/NUM, /NUM+	/RES	/RES	---	---
high load	/HL(*)	/HL(*)	---	---	---	---
Dimensions						
footprint; height	50 x 50; 17 mm	50 x 50; 17 mm	24 x 24; 11 mm	24 x 24; 11 mm	15 x 15; 10 mm	15 x 15; 10 mm
Positioning Mode @ Ambient Conditions						
travel range	10°	10°	6.6°	5.4°	7.2°	5.8°
drive velocity	approx. 3°/s	approx. 3°/s	1°/s	1°/s	1°/s	1°/s
maximum load	10 N	10 N	1 N	1 N	0.25 N	0.25 N
dynamic torque around axis	7 Ncm <i>(high load *35 Ncm)</i>	8,7 Ncm <i>(high load *43,5 Ncm)</i>	10 Ncm	10 Ncm	3 Ncm	3 Ncm
Closed Loop Features						
resolution	1 μ° (NUM)	1 μ° (NUM)	0,1 m° (RES)	0,1 m° (RES)	---	---
repeatability	50 μ° (NUM)	50 μ° (NUM)	2 m° (RES)	2 m° (RES)	---	---



## Naming Scheme

Type of Positioner	Direction of Movement	Dimension	Options	Environment	Encoder
ECG goniometer	p enabling angular movement in „phi“	50xx positioner width in mm	/HL high load version	/RT room temperature	/NUM closed loop control based on an optoelectronic encoder
ANG goniometer	t enabling angular movement in „theta“	xx50 positioner length in mm		/HV high vacuum	/RES closed loop control based on a resistive encoder
		5x positioners designed for a 1" clear bore size		/UHV ultra-high vacuum	
		10x positioners designed for a 2" clear bore size			

# Rotators



Rotators	ECR5050hs	ECR4040	ECR3030	ANR240	ANRv220
<b>Options</b>					
environment	/RT, /HV, /UHV	/RT	/RT, /HV, /UHV	/RT, /HV, /UHV	/RT, /HV, /UHV
encoder	/NUM, /NUM+	/NUM	/NUM	/RES	/RES
high load	---	---	---	---	---
<b>Dimensions</b>					
footprint; height	50 x 50; 15 mm	40 x 40; 14.5 mm	30 x 30; 13.5 mm	35 x 35; 13.5 mm	27 x 12; 27 mm
<b>Positioning Mode @ Ambient Conditions</b>					
travel range	360°	360°	360°	360°	360°
drive velocity	approx. 10°/s	approx. 10°/s	approx. 10°/s	30°/s	30°/s
maximum load	20 N	20 N	5 N	2 N	1 N
dynamic torque around axis	1 Ncm	1 Ncm	0,5 Ncm	2 Ncm	1 Ncm
<b>Closed Loop Features</b>					
resolution	0.01 m° (NUM)	0.04 m° (NUM)	0.01 m° (NUM)	6 m° (RES)	6 m° (RES)
repeatability	1 m° (NUM)	4 m° (NUM)	1 m° (NUM)	50 m° (RES)	50 m° (RES)



Rotators	ANR101	ANRv51	ANR51	ANR31
<b>Options</b>				
environment	/RT, /HV, /UHV	/RT, /HV, /UHV	/RT, /HV, /UHV	/RT, /HV, /UHV
encoder	/RES	/RES	/RES	---
high load	---	---	---	---
<b>Dimensions</b>				
footprint; height	24 x 24; 15.2 mm	10 x 20; 21 mm	15 x 15; 9.5 mm	∅ 10; 7.5 mm
<b>Positioning Mode @ Ambient Conditions</b>				
travel range	360 °	360 °	360 °	360 °
drive velocity	30 °/s	10 °/s	10 °/s	3 °/s
maximum load	1 N	0.2 N	0.3 N	0.05 N
dynamic drive torque	0.8 Ncm	0.2 Ncm	0.2 Ncm	0.03 Ncm
<b>Closed Loop Features</b>				
resolution	6 m° (RES)	6 m° (RES)	6 m° (RES)	---
repeatability	50 m° (RES)	50 m° (RES)	50 m° (RES)	---

## Naming Scheme

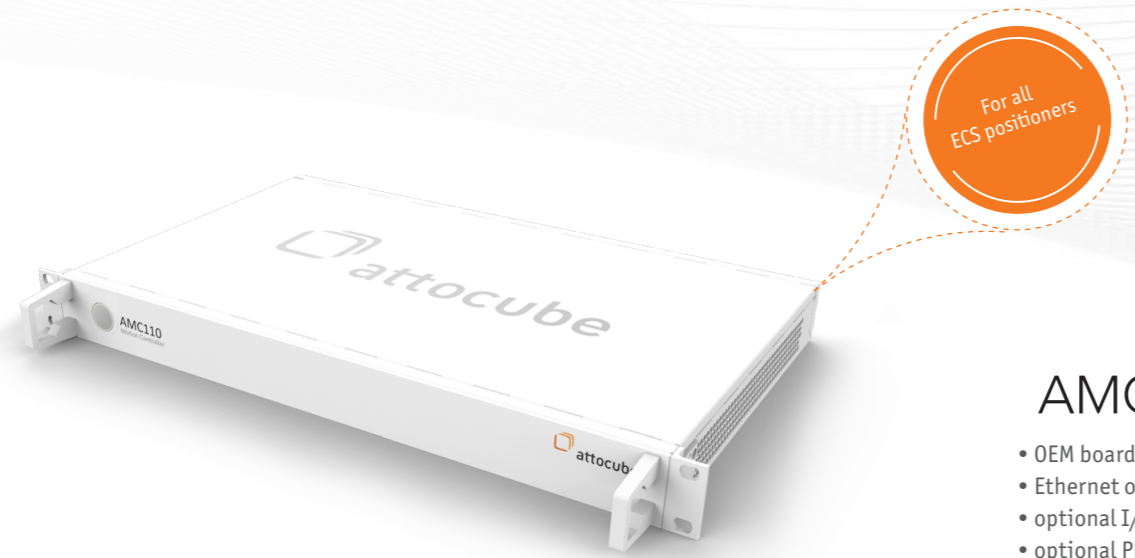
Type of Positioner	Direction of Movement	Dimension	Environment	Encoder
ECR rotator	v horizontal rotation axis	50xx positioner width in mm	/RT room temperature	/NUM closed loop control based on an optoelectronic encoder
ANR rotator		xx50 positioner length in mm	/HV high vacuum	/RES closed loop control based on a resistive encoder
		3x positioner series with smallest available footprint	/UHV ultra-high vacuum	
		5x positioners designed for a 1" clear bore size		
		10x positioners designed for a 2" clear bore size		
		2x0 rotator with ultra-low wobble		

# Controller Overview

piezo positioning electronics and accessories

Highest-precision piezo positioning systems require state-of-the-art control electronics. attocube's FPGA-based motion controllers are adapted to the technical challenges of positioners and scanners dedicated for cutting-edge applications and experiments. The AMC110

table-top controller is the model of choice for applications with ECS series positioners, while the ANP series nanopositioners can be accompanied by 19" rack electronics for laboratory environments. Suitable accessories for attocube's positioners are listed below.



For all ECS positioners

## AMC110

- OEM board available (IMC)
- Ethernet or USB (with adapter) connectable
- optional I/O upgrade
- optional PRO upgrade



For all ANS scanners

## ANC250

- ultra low noise scan voltage amplifier (20  $\mu$ V rms)
- three channels with up to 200 V (differential)

For all open loop ANP positioners & ANS scanners



## ANC300

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



For all closed loop ANP positioners

## AMC300

- position readout
- controlling via display, PC or remote control
- tabletop or 19" rack versions
- pre-implemented libraries as API wrappers

## Accessories

### Adapter Plates AAP & EAP

- for vertical mounting of ANP positioners
- for cross-mounting of differently sized ANP & ECS positioners



### ECS Lift 3030/5050

- suitable for ECSx3030 and ECSx5050
- for lifting high loads exceeding the capabilities of the ECSz3030 or ECSz5050
- ultra-high vacuum compatible



### 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 tweezer
- available as nanopositioning toolbox or as RES toolbox (integration of an ANP/RES)

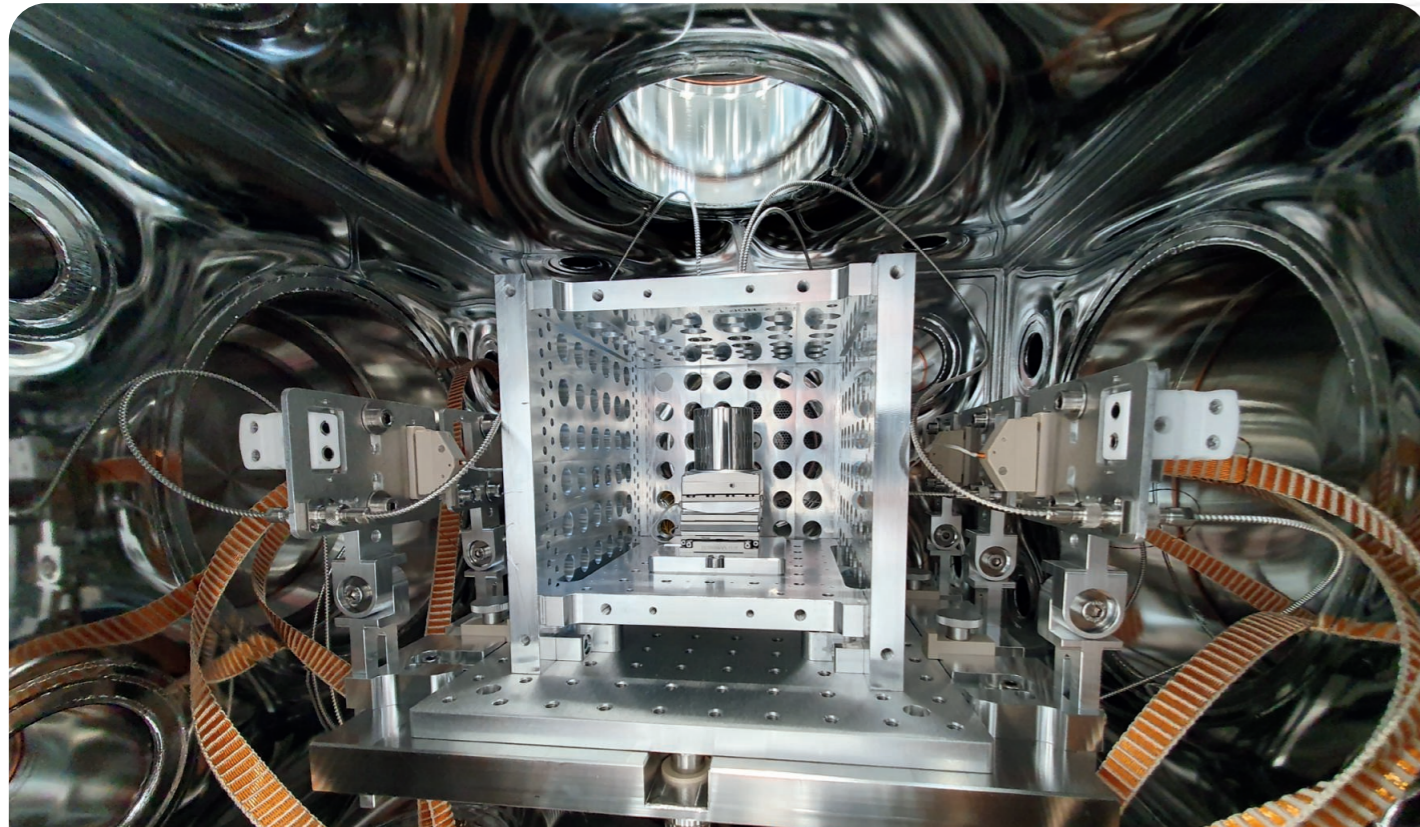
# Applications

pushing precision in motion

High-precision applications in science and industry demand nanopositioning solutions that ensure the highest accuracy, resolution, and stability.

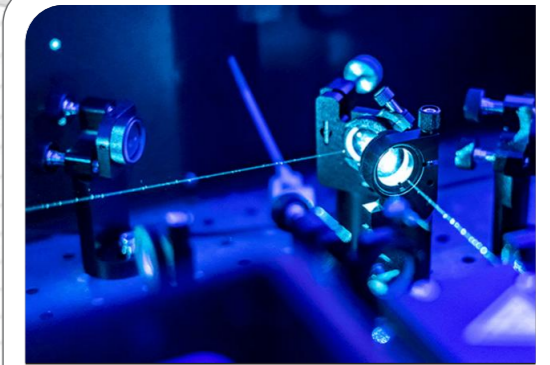
Engineered for extreme conditions, our nanopositioners operate reliably in ultra-high vacuum, radiation harsh environments, and high magnetic fields. Their compact and robust design makes them ideal for OEM applications, enabling tailored solutions for industries that require the utmost precision.

This section provides an overview of key application fields and examples showcasing how our solutions enable cutting-edge advancements. Contact us to discuss your specific requirements.



## Semiconductor Equipment

high precision components for semicon  
equipment



## Optics and Photonics

precision components for optical systems and  
photonics assembly



## Scientific Instruments

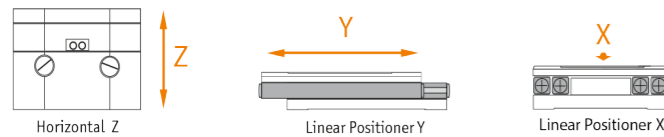
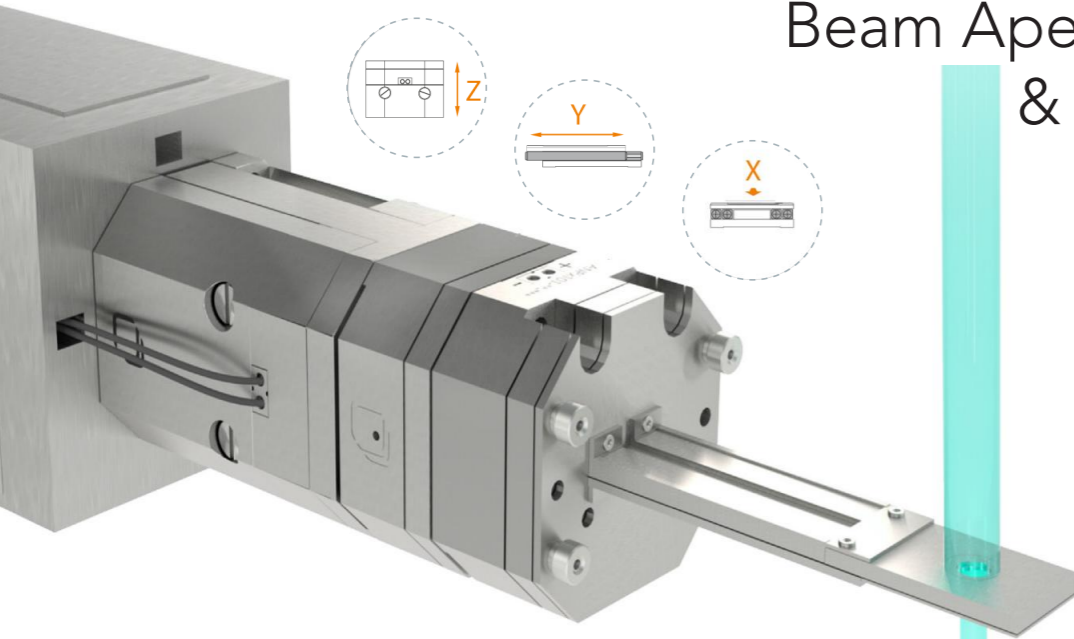
positioner solutions for microscopy and  
analytical systems



## Large Scale Facilities

precision components for particle accelerator  
infrastructure and beamlines

## Beam Aperture & Filter Positioning



### ● Challenge:

In lithography and optical metrology, precise alignment and filtering of EUV light are crucial for wafer quality. High-energy photons from the laser source are collected by a gathering mirror and shaped through apertures and filters to accurately interact with components like the reflection mask. The short wavelength and high energy of EUV light demand exceptional precision to meet semiconductor manufacturing standards.

### ● attocube's solution:

attocube's piezo positioners provide nanometer precision and are fully compatible with UHV and high-temperature environments, making them ideal for the precise alignment and filtering of EUV light. Their reliability under extreme conditions ensures optimal beam control for advanced lithography and metrology applications.

### ● Benefits:

- nanometer precision
- UHV compatibility down to  $5 \times 10^{-11}$  mbar
- coarse & fine movement



## Electron Beam Aperture Positioning

### ● Challenge:

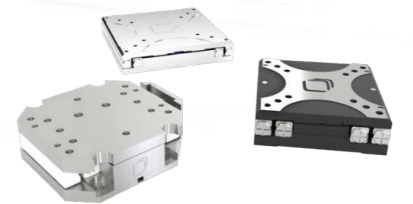
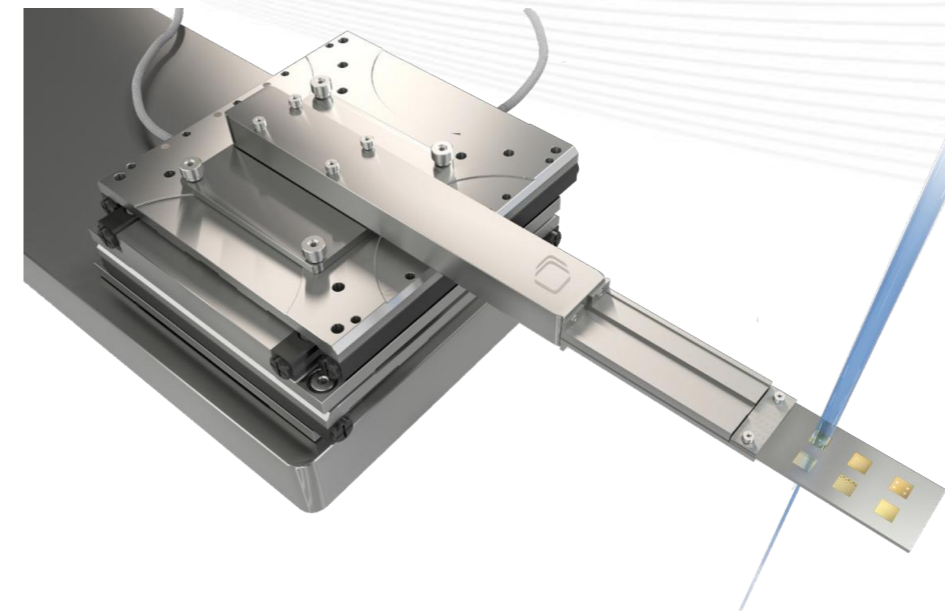
Electron-beam systems are widely used in scientific and industrial applications, particularly in semiconductor lithography and defect inspection. They offer the highest resolution for small structures but suffer from low throughput. Multi-stencil character projection can improve throughput, but its complexity demands nano-precise alignment in ultra-high vacuum and elevated temperatures.

### ● attocube's solution:

Besides highest precision, attocube's nanopositioners fit well with the required harsh environments. The positioners are suitable for pressures down to  $5 \times 10^{-11}$  mbar, extreme temperatures and offer clean room compatibility. Furthermore, the compact design allows facilitated integration of single positioners or multi-axis motion systems.

### ● Benefits:

- nanometer precision
- UHV compatibility up to  $5 \times 10^{-11}$  mbar
- bake out up to  $150^\circ\text{C}$  stability



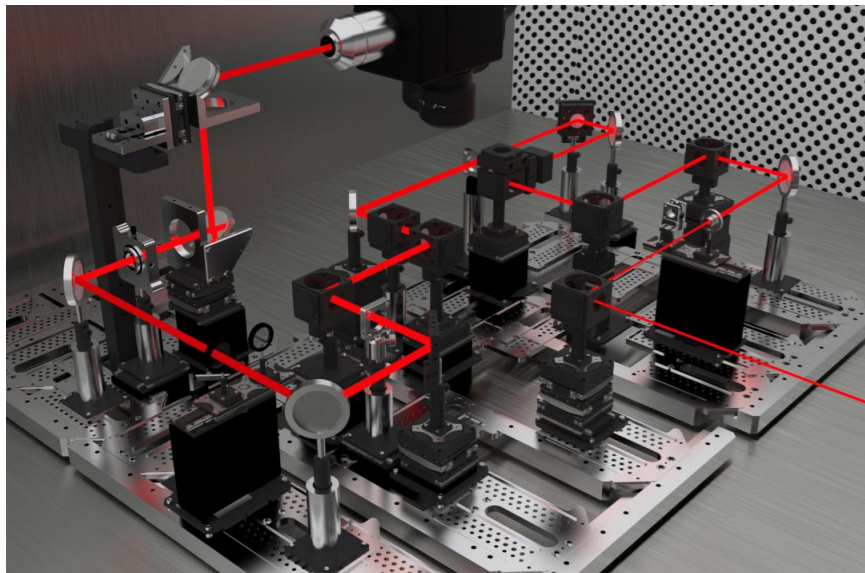
## Laser Beam Adjustment & Optics Alignment

### ● Challenge:

Metrology processes, such as wavefront or optical metrology, rely on light shaping to achieve specific wavelengths or ion selection. Optical components like shutters, apertures, lenses, and mirrors shape and direct the beam. Precise alignment in all orientations is essential to ensure optimal beam quality and accuracy in the desired application.

### ● attocube's solution:

attocube positioners feature a modular design, enabling versatile multi-axis solutions for precise optical component movement. They are UHV compatible without sacrificing precision and offer low particle generation, making them ideal for clean or vacuum environments.

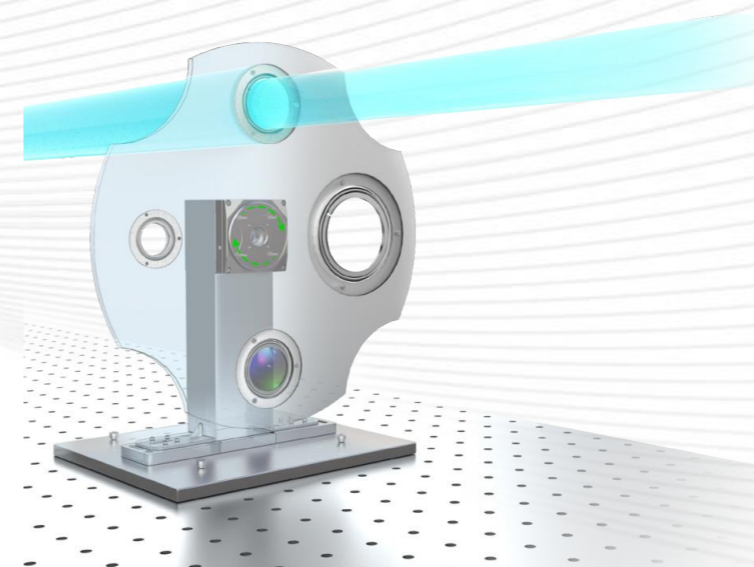


### ● Benefits:

- nanometer precision
- stackable positioners
- UHV compatibility up to  $5 \times 10^{-11}$  mbar



## Filter & Aperture Wheel Rotation



### ● Challenge:

Filter and aperture wheels are essential for compact and automated beam manipulation in optical systems, particularly in microscopy and semiconductor metrology. To resolve nanometer structures, beam properties must not be impacted, requiring precise positioning of filters and apertures over angular ranges exceeding 180°. Advanced systems may also demand multiple in-line filter wheels in vacuum and cleanroom conditions.

### ● attocube's solution:

In addition to cleanroom and vacuum compatibility down to  $1 \times 10^{-9}$  mbar, attocube's rotation stages offer  $\mu^\circ$  angular resolution and a 360° endless travel range. Despite the compact size loads of more than 1 kg are possible and the rotation stage can be easily combined with other piezo positioners for multi-axis movements.

### ● Benefits:

- 1 m° precision
- UHV compatible up to  $1 \times 10^{-9}$  mbar
- 360° endless travel



## Fiber Array Alignment

### Challenge:

With ever-growing data demands, fiber optic transmission enables global communication, cloud applications, and streaming. Increasing bandwidth needs drive mass production and advancements in fiber optics. Precision is crucial in fabricating and assembling microstructured components like fiber arrays. Reliable, multi-axial positioning devices ensure submicron accuracy, minimizing connection loss across various components.

### attocube's solution:

attocube stages excel in micro assembly, offering both coarse and fine positioning. Fibers can be moved across millimeters, then finely adjusted at the nanometer level. Piezo-driven stages ensure long-term stability, maintaining precise positions. Stacking multiple positioners enables versatile multi-axis solutions for high-precision applications.

### Benefits:

- high stability
- stackable positioners
- coarse & fine movement



## Beam Steering for High Power Laser Cutting

### Challenge:

Display manufacturing demands precise, high-power laser cutting for hard glass and OLED screens. Even minor defects are costly, as workpieces may contain expensive materials or millions of sub- $\mu\text{m}$  integrated circuits. Accurate beam steering is crucial, requiring ultra-stable positioning stages to maintain milli-degree optical alignment and compensate for misalignments like thermal expansion.

### attocube's solution:

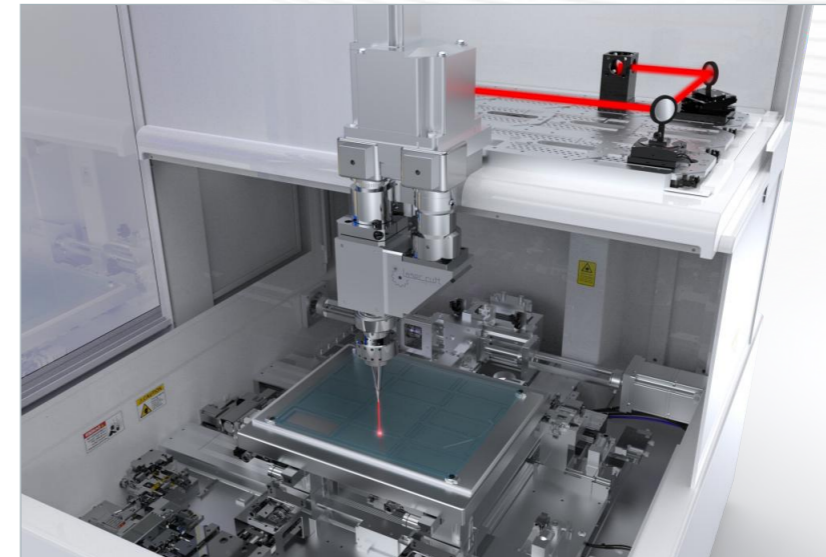
attocube goniometers and rotation stages provide high-precision angular positioning. Goniometers achieve  $\mu^\circ$  accuracy within a limited range, while rotators enable continuous  $360^\circ$  motion. The self-locking piezo slip-stick drive ensures stability, and the modular design allows flexible stacking for multi-degree-of-freedom motion solutions.

### Benefits:

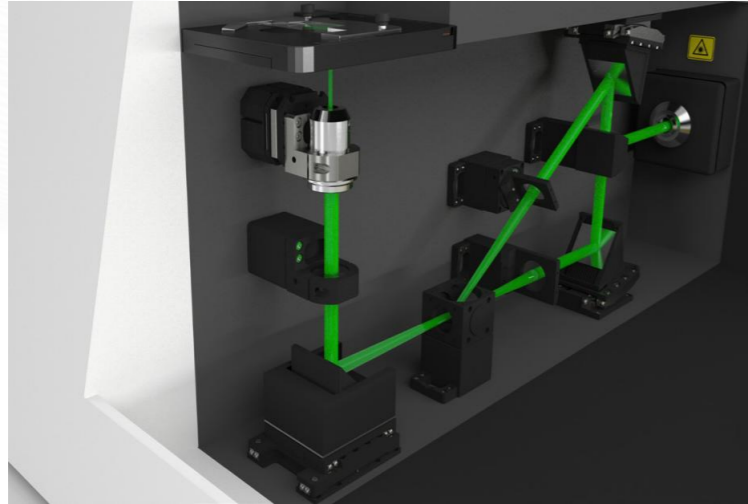
- Rotator: ECR5050hs**
- $1\text{ m}^\circ$  precision
  - self-locking piezo slip-stick drive
  - $360^\circ$  endless travel

**Rotator: ECG5050**

- $\mu^\circ$  precision
- self-locking piezo slip-stick drive
- $10^\circ$  angular range



## Super Resolution Microscopy



### ● Challenge:

As resolution demands rise, microscopy applications require fast, precise sample positioning. This is crucial for optical imaging, super-resolution microscopy, topographical measurements, material analysis, and cell array studies. Accurate sample alignment with objectives or probe heads, like AFM cantilevers, ensures reliable, reproducible measurements, making precision positioning essential for high-quality imaging and analysis.

### ● attocube's solution:

attocube's customizable microscopy stages enable noiseless, fast motion over several centimeters. These piezo-based positioners ensure reliability, precision, and repeatability for high-accuracy microscopy. Monolithic xy-units and assembled xyz stacks enhance stability, precision, and space efficiency, optimizing performance across travel axes while minimizing installation space.

### ● Benefits:

- monolithic positioners
- stackable positioners
- repeatability < 50 nm



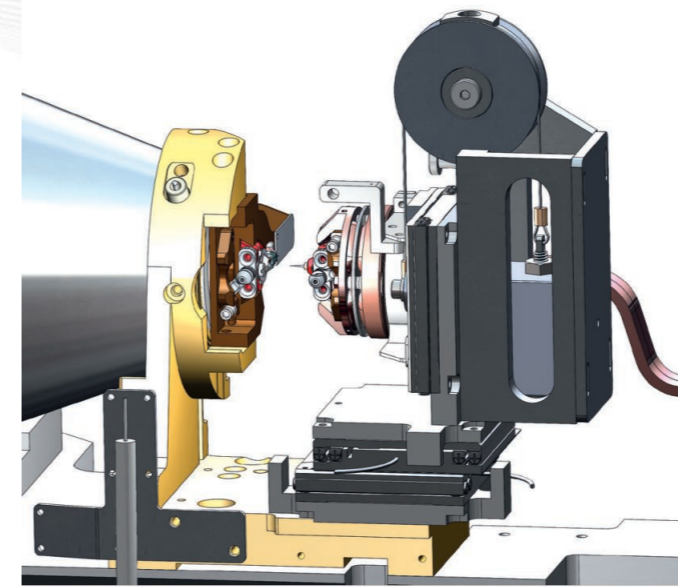
## Atom Probe Tomography

### ● Challenge:

Achieving simultaneous atomic-scale 3D imaging and chemical analysis is extremely challenging. With the unique APT method CAMECA offers this possibility. A frozen specimen tip, just 50–100 nm in radius, must be precisely positioned along three axes in UHV. Laser or voltage pulses evaporate single atoms, requiring nanometer accuracy to ensure 0.1 nm resolution for reliable material analysis.

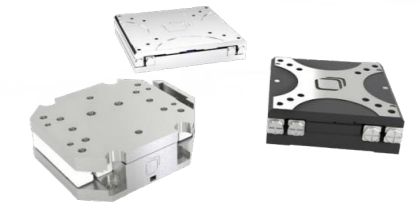
### ● attocube's solution:

attocube's compact and modular nanopositioners can be combined into multi-axis motion systems, offering the highest precision and stability even under challenging environmental conditions. This allows reliable sample or probe positioning in advanced material analysis systems.

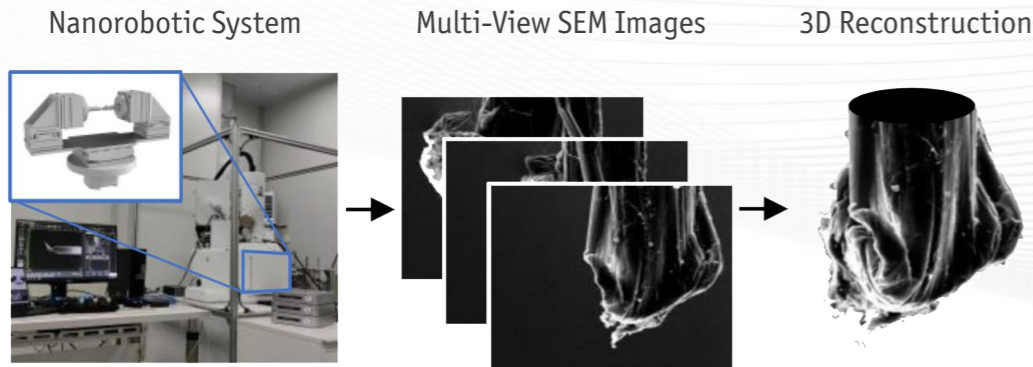


### ● Benefits:

- nanometer precision
- stackable positioners
- UHV compatibility up to  $5 \times 10^{-11}$  mbar
- bake out up to 150° C



# NanoNeRF under a Scanning Electron Microscope (SEM)



## Challenge:

Nanoscale 3D reconstruction under a scanning electron microscope (SEM) requires extreme precision in positioning and stability. Multi-view SEM imaging for neural radiance field (NeRF) reconstruction demands accurate translational and rotational alignment at the sub-nanometer scale. Any drift or misalignment can introduce errors, degrading the quality of the reconstructed model. Additionally, maintaining in-situ stability while capturing high-resolution images presents a major challenge. A reliable nanopositioning system is crucial to ensuring seamless integration of NeRF, enabling high-fidelity nanoscale imaging and overcoming the limitations of traditional SEM-based reconstruction methods.

## attocube's solution:

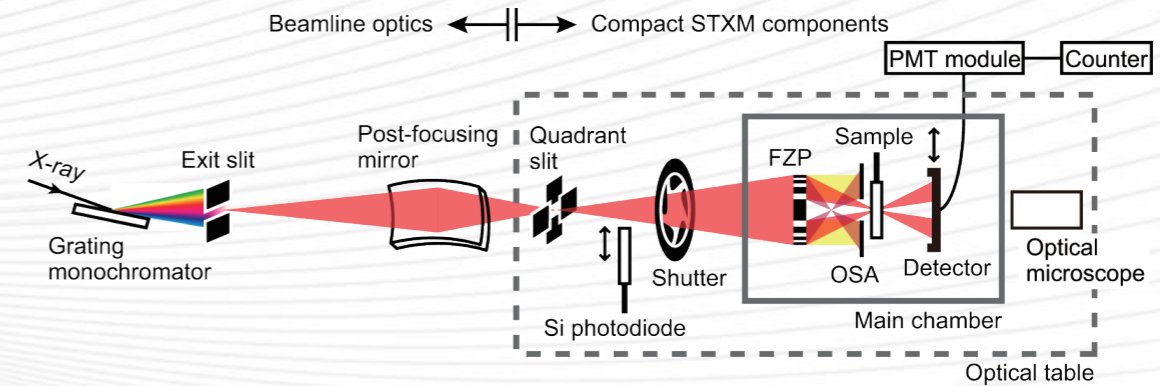
attocube's ECSx3030 and ECR3030 nanopositioners provide sub-nanometer precision and long-term stability for accurate sample alignment under SEM. Their piezo-driven technology ensures smooth, multi-axis motion, enabling precise positioning and rotation essential for high-quality 3D reconstruction with NeRF.

## Benefits:

- nanometer precision
- stackable positioners
- UHV compatibility up to  $5 \times 10^{-11}$  mbar



# Portable X-Ray Microspectroscopy



## Challenge:

In order to perform microscopy and spectroscopy experiments achieving image resolution at the nm level it is necessary to control and maintain temperature, humidity and pressure as stable as possible over time. Mounting a complete system into a controlled environment is often limited by the dimension of the setup itself. Therefore, it is necessary to minimize the footprint and enhance the instrument performance to achieve a nanometer resolution.

## attocube's solution:

A combination of small sized piezo positioners and scanners provides the necessary millimeter travel range for alignment and imaging the sample with the required resolution. Using a laser interferometer as feedback allows the customer to monitor the motion with a resolution of 1pm ensuring nanometer precise closed-loop positioning.

## Benefits:

- nanometer resolution
- harsh environment compatibility (ultra-high vacuum or radiation)
- limited footprint of only several square centimeters



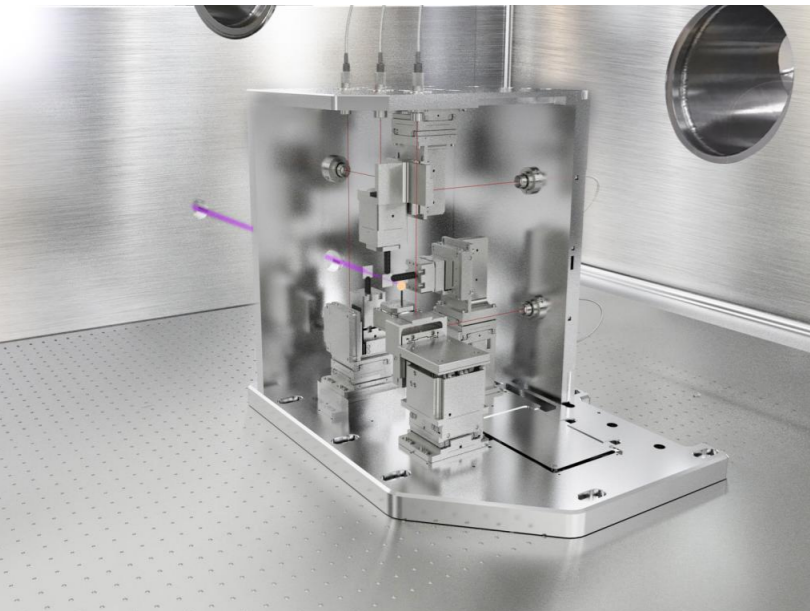
## Optics and Sample Positioning

### ● Challenge:

X-ray microscopes at beamline end stations use synchrotron radiation for ultra-high imaging resolution. These systems require precise alignment of optical components and multi-axis motion solutions for accurate initial alignment and control during imaging. Operating in HV/UHV conditions, they rely on advanced sensors for closed-loop control instead of optical encoders. Components must withstand radiation and offer reliable performance to avoid delays and high costs from replacements.

### ● attocube's solution:

attocube offers precision components and expertise in nanotechnology, enabling combinations of piezo stages like inertia drives or scanners with interferometric readout. All components are designed for radiation-harsh and vacuum environments, with application engineers ready to tailor solutions for your specific needs.



### ● Benefits:

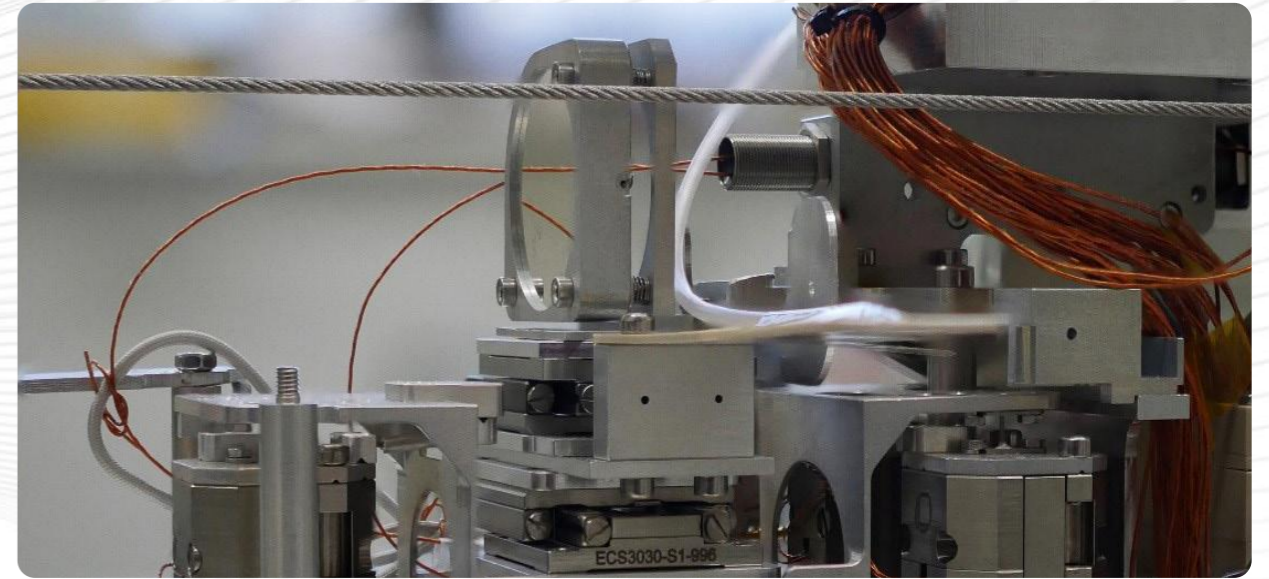
#### Nanopositioners:

- nanometer precision
- stackable positioners
- UHV compatibility up to  $5 \times 10^{-11}$  mbar

#### Interferometer Sensor:

- Dicometer resolution.
- multi-axis measurements
- vacuum, low & high temperature, radiation compatible

## Measurements in Synchrotron Radiation



### ● Challenge:

At large-scale facilities, there are a number of generic nanopositioning tasks to be performed under harsh environments such as ultra-high vacuum or radiation. Undulators are the key assemblies for generating synchrotron radiation in light sources. In order to optimize the resulting photon energy, the magnetic properties of cryogenic undulators need to be characterized precisely at different temperatures by movable Hall probes.

### ● attocube's solution:

attocube's positioners can be combined for multidimensional configurations, and are compatible with variable temperatures, high magnetic fields and radiation. In this particular example, the nanopositioners serve as key elements of the Hall bar bench achieve the necessary accuracy of the Hall-probe orientation relative to the undulator's magnetic axis.

### ● Benefits:

- high size flexibility
- radiation compatibility
- high stability



## Scanners and Stepping Positioners

All attocube scanners and stepping positioners are driven via piezoceramics made from lead zirconite titanate (PZT) for voltages < 150 V. The PZT for cryogenic scanners and steppers is optimized for maximal performance under these conditions.

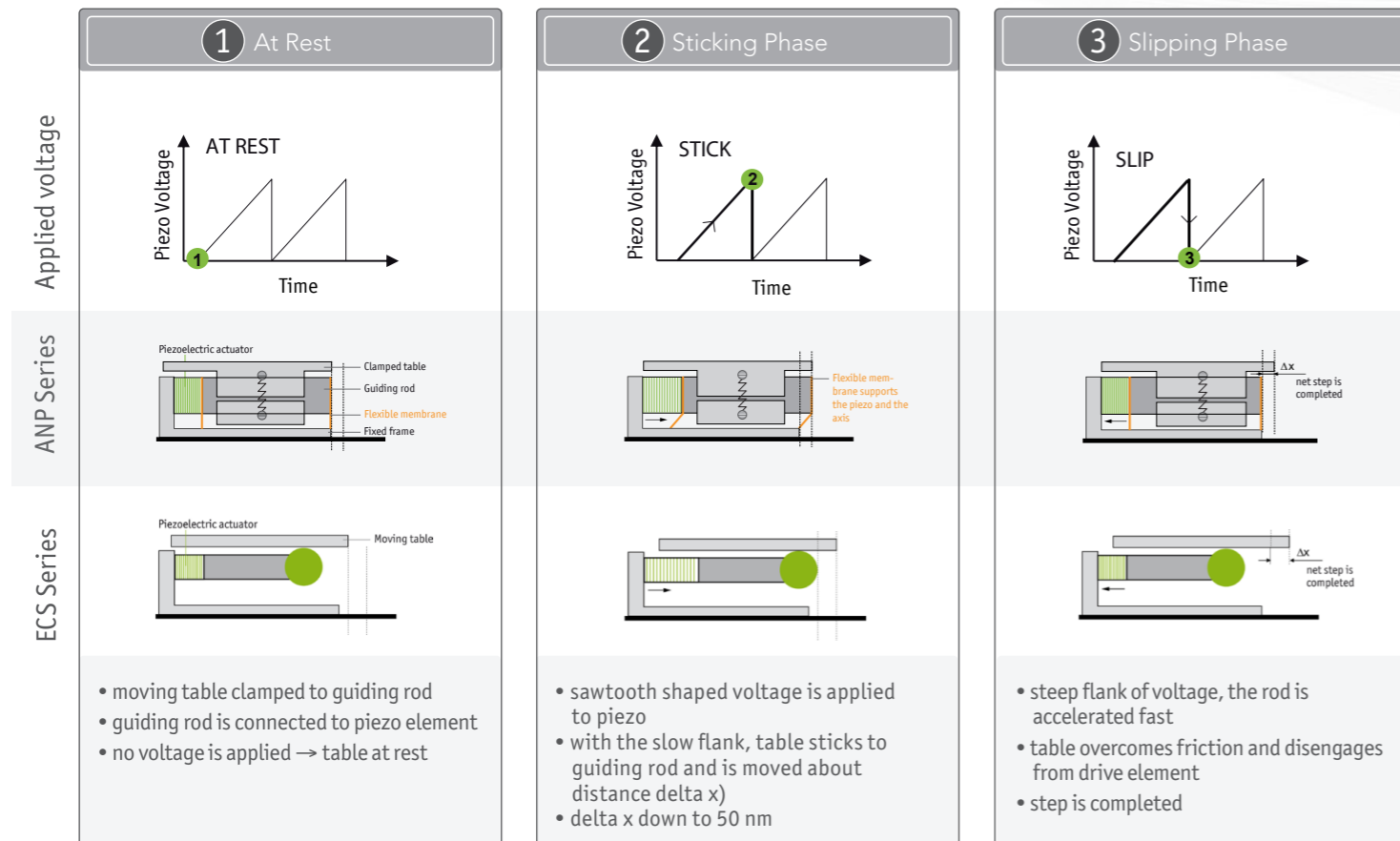
### • Scanners

Scanners are suitable for travel ranges in  $\mu\text{m}$  range and their motion is continuous. Our 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). There are two different positioner series – “ANP” and “ECS”.

## Working Principle of Stepping Positioners



## Environmental Conditions

attocube’s nanopositioners can be used in different environmental conditions such as ultra-high vacuum. One or more suitable suffixes in the article name describe the environment for which a nanopositioner is designed and tested in-house. Moreover, all ANP nanopositioners are suitable for measurements in a magnetic field as they are built of completely non-magnetic materials.

### • /RT – Room Temperature

/RT positioners are manufactured for use at ambient conditions (room temperature, dry atmosphere, ambient pressure).

### • /(U)LT – (Ultra-) Low Temperature

These positioners are suitable for repeated cooling and operation in cryogenic temperatures.

### • /HV – High Vacuum

At attocube the high vacuum range is specified down to  $1 \times 10^{-8}$  mbar.

### • /UHV – Ultra-High Vacuum

The ultra-high vacuum range is specified down to  $5 \times 10^{-11}$  mbar for most of our 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  $1 \times 10^{-9}$  mbar as a precaution (noted in specification sheets). Most of our positioners can be baked up to 150 °C.

## Position Control

Most of attocube’s nanopositioners are available in open and closed loop versions.

### • Open Loop Positioning

In this mode, the positioner is simply driven forward or backward, without an encoder to read back the actual position or a feedback loop to control the desired target position.

### • Closed Loop Positioning

Positioners with an integrated encoder (/RES, /RES+ or /NUM, /NUM+) can be used for closed loop position control. A feedbackloop 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 Resistive encoder (/RES) is used for our ANP 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 repeatability of  $1 \mu\text{m}$  is achieved. For ultra low temperatures ( $T < 1 \text{ K}$ ) a special /RES+ sensor is available which is included in all our /ULT models.

### • Optoelectronic Encoder (/NUM)

The usage of a glass grating and the interpretation of the generated Moiré pattern characterizes the working principle of the /NUM and /NUM+ encoder. The measurement refers to the relative sample position with a position resolution of 1 nm and a repeatability of typically 50 nm for most linear stepping positioners. An absolute position information is also available via a reference mark. The +-version /NUM+ features a reduced thermal dissipation of only 50 mW making it especially suited for /HV and /UHV positioners. The /NUM and /NUM+ encoders are available for our ECS series positioners.

# Terminology

glossary

## Resolution

The measurement resolution is the smallest increment of displacement that the sensor can show.

## Accuracy

Accuracy is the deviation of a device's measured displacement value compared to the true displacement of the target. Accuracy is defined as a percentage of the measured range.

## Repeatability

Repeatability is the standard deviation ( $\sigma$ ) of a set of a device's moving target approach measurements, all made under the same conditions. Approach measurements may be done from one or both sides of a target, specifying a device's uni- or bi-directional repeatability respectively.

## Noise

Noise is the standard deviation ( $\sigma$ ) of all additionally captured random values made during any static or dynamic ongoing measurement at a specific bandwidth.

## Stability

The stability is the change in bias over time.

## Precision

The precision is the standard deviation ( $\sigma$ ) of a measurement. Its value is strongly related to the system's noise level, its repeatability and – over duration – its stability.

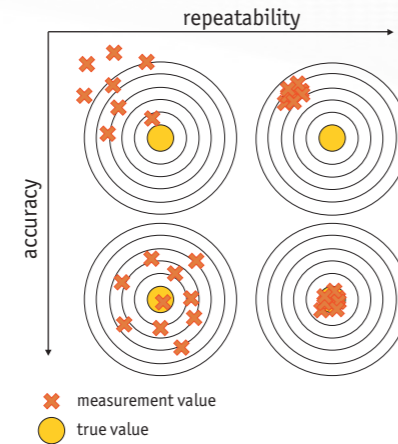


Figure 1:  
Difference between measurement accuracy (trueness) and measurement repeatability.

## Maximum Load

Maximum normal load refers to the maximum amount of weight or force applied perpendicularly to the center of the mounting surface that a positioner can bear without damaging its structure. The positioner needs to be mounted in the intended orientation. Loads around the maximum may influence other specifications.

## Combining Goniometers

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

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

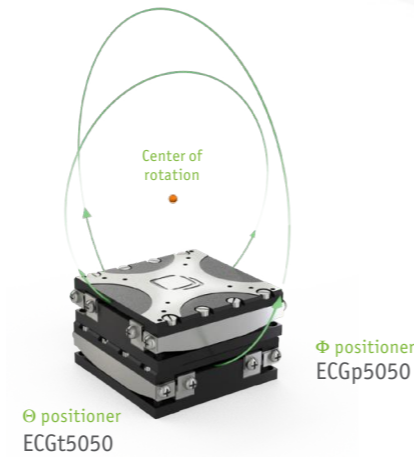


Figure 2:  
Combination of two ECG-goniometers for 2-angle alignment with one center of rotation

## Dynamic Force

This is the force generated by a positioner during its movement along its axis. It is the force that is required to overcome friction and inertia, and to accelerate the device. For positioners that move masses against gravity or against external forces, this property is sometimes referred to as lifting or pushing capability.

## Dynamic Torque

This is the torque generated by a rotary positioner (rotators and goniometers) during its movement around the rotation axis specified. For positioners that rotate masses against gravity or against external inertia, this property is sometimes referred to as lifting or pushing capability. Please note that the moment of inertia that can be induced by a non-centered load on the positioner has to be considered as a significant factor when accelerating with positioners.

## Holding Force

This is the force that a positioner inherently applies maintaining its static position along its axis, even in the absence of an external force or respectively also when powered down. The self-locking mechanism is a main advantage of piezo slip stick inertia drives. In general, the holding force is higher than the dynamic force of a positioner. The holding force is sometimes referred to as the static force.

## Holding Torque

This is the torque that a rotary positioner (rotators and goniometers) inherently applies maintaining its static position around the rotation axis specified, even in the absence of an external force or respectively also when powered down. The self-locking mechanism is a main advantage of piezo slip stick inertia drives. In general, the holding torque is higher than the dynamic torque of a positioner. The holding torque is sometimes referred to as the static torque.



Figure 3:  
Standard ECSxyz-configuration: two x-positioners (one rotated by 90°) and one additional x-positioner mounted vertically on a L-bracket.

# Additional Info

glossary

## 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 differently sized models (e.g. a 51 series positioner on top of a 101 positioner) may necessitate 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 with loads corresponding to the specified dynamic force for the respective positioner.

## Error Motion:

In an ideal scenario, the moving part of the positioner (the carrier) would have only one degree of freedom along the intended positioning direction. However, in reality, the motion of the carriages is not ideal. As a carriage moves, manufacturing imperfections within the stages, improper mounting, and surface quality issues can cause unwanted angular, translational and radial errors. Consequently, variations can occur in all six degrees of freedom during positioner movement.

Key error terms include angular motions such as Pitch, Roll, and Yaw, as well as translational motions like Straightness. According to ASME B.5.64, these error motions are categorized as follows:

- The first letter, E, indicates an error.
- The first subscript denotes the direction or orientation of the error.
- The second subscript represents the intended axis motion.

In this context, rotational axes (A, B, C) are assigned based on the corresponding linear axes (X, Y, Z) (see Figure 4a and 4b).

## Roll ( $E_{AX}$ )

Angular error motion of the YZ-axes of the moving coordinate system (csM) around the X-axis of the fixed coordinate system (csF) as the target position changes, causing side-to-side tilting. The rotational axis A corresponds to rotation around the X-axis (see Figure 5a).

## Pitch ( $E_{BX}$ )

Angular error motion of the ZX-axes of csM around the Y-axis of csF as the target position changes, causing up and/or down tilting. The rotational axis B corresponds to rotation around the Y-axis (see Figure 5a).

## Yaw ( $E_{CX}$ )

Angular error motion of the XY-axes of csM around the Z-axis of csF as the target position changes, causing rotational deviation left or right from the intended path. The rotational axis C corresponds to rotation around the Z-axis (see Figure 5a).

## lateral Z-straightness ( $E_{ZX}$ )

Translational error motion: deviation from a reference straight line of oM in the Z-axis direction of csF as the target position is varied, indicating out-of-vertical-plane motion (see Figure 5a).

## lateral Y-straightness ( $E_{YX}$ )

Translational error motion: deviation from a reference straight line of oM in the Y-axis direction of csF as the target position is varied, indicating out-of-horizontal-plane motion (see Figure 5a).

Note: In specific contexts within the motion industry, lateral straightness is categorized into two distinct parameters: "straightness" and "flatness". According to ASME B.5.64, straightness error motion is divided into two components: Y and Z. Here, "lateral Y-straightness" corresponds to straightness, while "lateral Z-straightness" refers to flatness. We adhere to these terminologies.

## Radial Runout ( $E_{XYC}$ )

Radial runout or radial error is defined as the position-dependent lateral error motion of a rotary stage perpendicular to the axis of rotation (see  $\alpha$  in Figure 5b). The radial runout  $E_{XYC}$  is a combined error in the X and Y direction when rotating around the Z-axis.

Radial runout and wobble are often cyclic in nature and are caused by the imperfect nature of mechanical components. They are defined for one full rotation (360°) and do not include a static offset (eccentricity or tilt) or surface errors of the rotating table.

Note: ASME B.5.64 specifically addresses linear positioners. Since radial runout and wobble are phenomena associated with rotary positioners, we have adjusted the nomenclature for radial errors accordingly. The second subscript 'r' denotes the rotational axis (rotation around the Z-axis).

## Wobble ( $E_{ABC}$ )

Wobble is the position-dependent angular misalignment of the real axis of motion relative to its ideal axis. Wobble  $E_{ABC}$  is a combined tilt deviation around the X and Y-axes when rotating around Z that effects a radial runout that scales with height (see  $E_{XYZ}(z)$  Figure 5b).

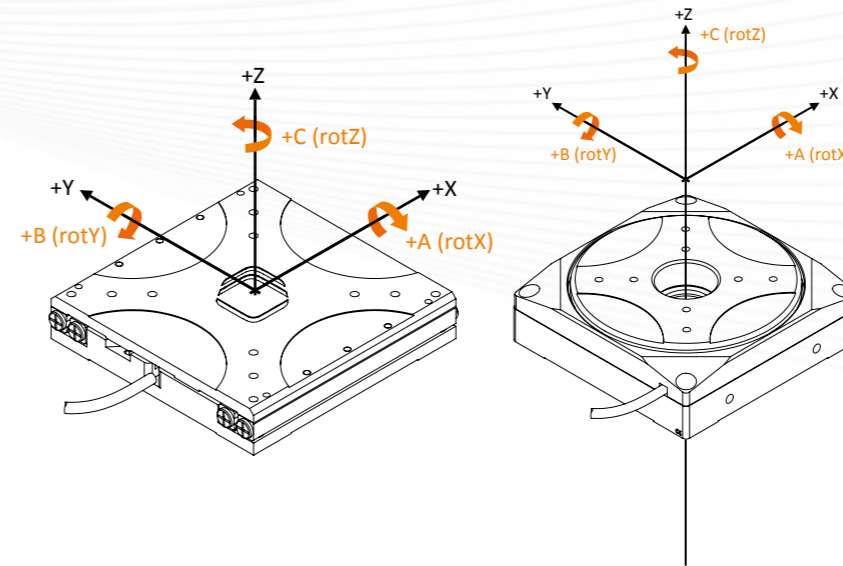
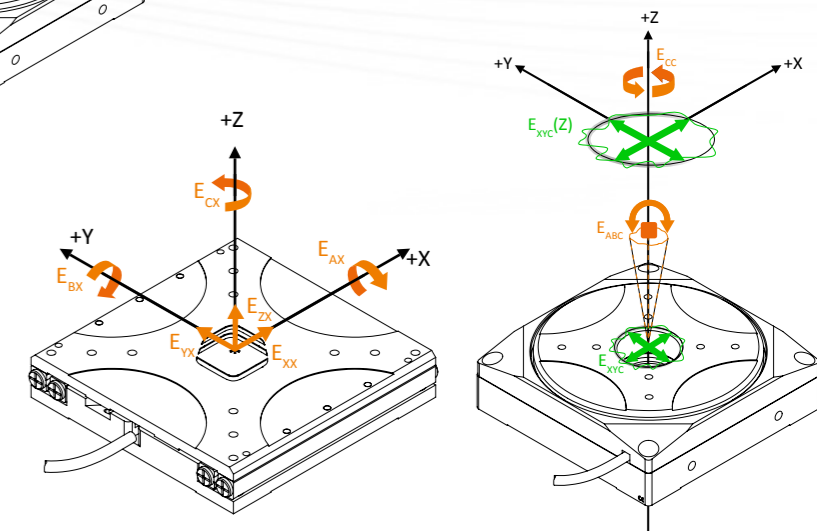


Figure 4a and 4b: Right-handed coordinate system with rotational axes on the corresponding linear axes for a linear positioner (a) and a rotary positioner (b)

Figure 5a and 5b: Nomenclature of errors in the various axes for a linear motion (a) and for a rotary motion (b)





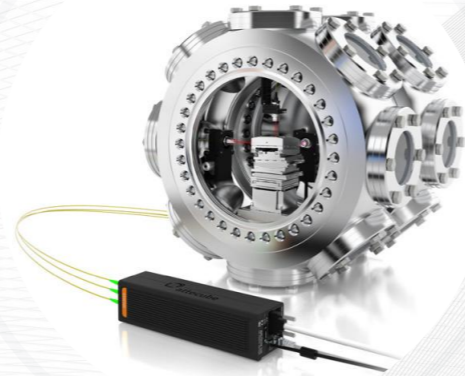
## • Application Engineer Integration Program

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.



## • 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.



## • 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 come to your site to provide the best support to integrate our products into your system and efficiently bring your business to the next level.



## • 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.



### What is the difference between the ANP series and the ECS series?

- The ECS series is a dedicated industrial series which is bearing based, cost efficient and convinces with a rugged design and high load capacities. The ECS/RT models are made out of aluminum and the ECS/(U)HV out of stainless steel. The ANP series is more research focused with smaller footprints and a nonmagnetic positioner body out of titanium.

### 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 /NUM or /RES encoder are driven in "closed loop" mode, which means that a feedback loop integrated into the control electronics minimizes the difference between target position and actual position.

### What is the difference between NUM and NUM+?

- The NUM+ encoder features a reduced thermal dissipation of only 50 mW making it especially suited for /HV and /UHV positioners. The necessary amplifier has been detached from the sensor itself and placed in the connector of the cable outside of the vacuum chamber.

### 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's sales engineers help you to find the suitable motion controller as well as cables. Moreover, there are different kinds of accessories like feedthroughs or adapter plates.

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

- For the /UHV positioners special UHV compatible (i.e. not outgassing) 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  $5 \times 10^{-11}$  mbar. Please note, our ECS series rotators and goniometers are specified for  $1 \times 10^{-9}$  mbar due to a special UHV compatible grease.

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

- All attocube open loop positioners and all closed loop positioners of the ANP series (/RES & /RES+) are specified from 0°C to 100°C (dedicated low temperature positioners are specified down to the mK range). ECS positioners with a /NUM encoder work up to a temperature of 50°C (/NUM+ up to 55°C). All UHV positioners can be baked out up to 150°C.

### What is the load capacity in a specific environment or mounting direction?

- All positioners are specified at ambient conditions. For specific requests please contact attocube's sales engineers.

### There is only limited space available for my setup, are there positioners with a comparatively small footprint?

- Yes, the ANP series positioners all have a relatively small footprint starting at 15 x 15 mm.

### What is the difference between accuracy and repeatability?

- Please refer to the glossary.



# attocube

WITTENSTEIN group

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