SmarAct

High Precision Positioning and Metrology

SmarAct

Catalog 20

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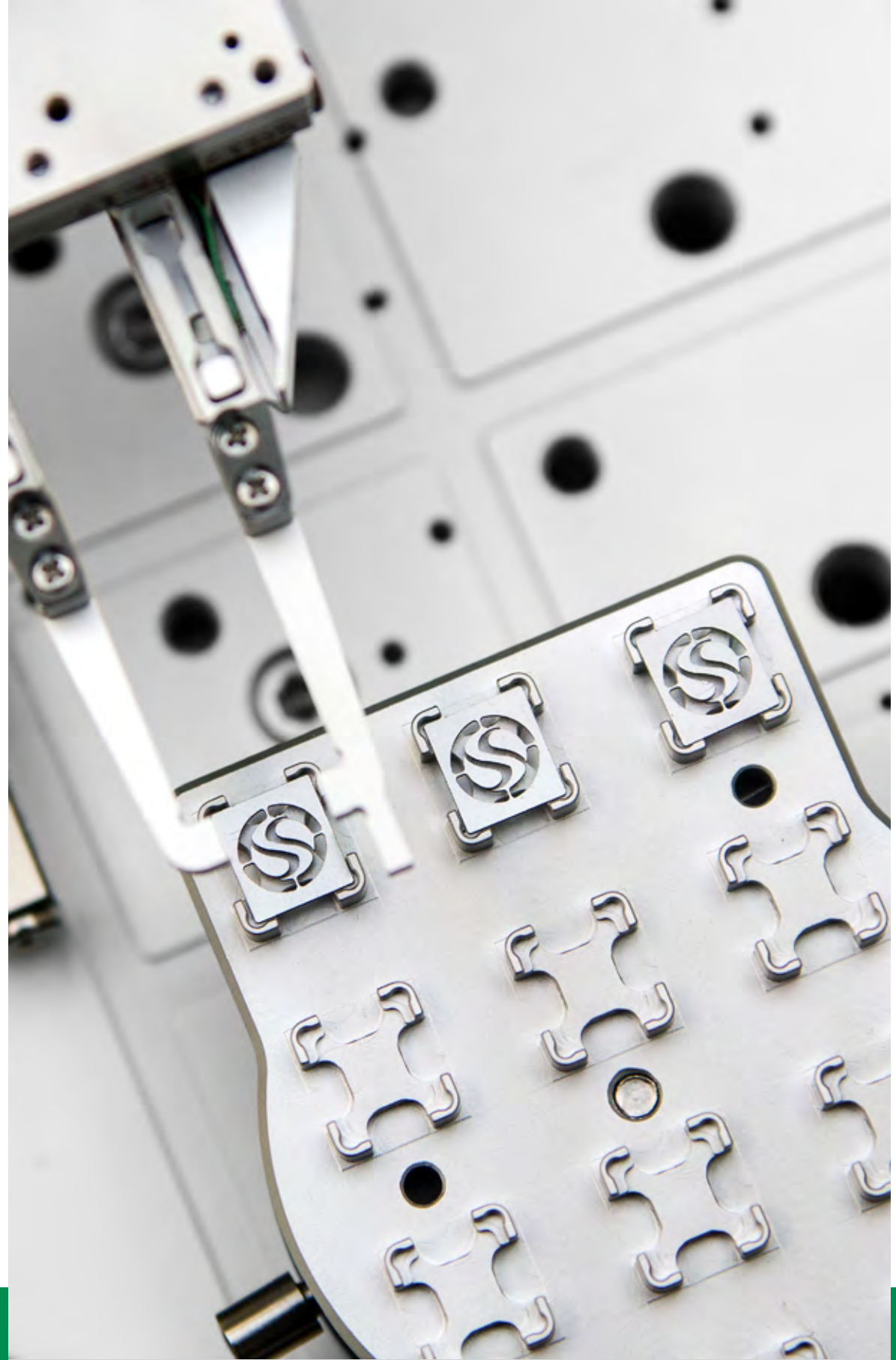


Introduction

Introduction
Preamble

Dear Customer,

SmarAct's mission is to develop and manufacture devices in the sector of high-precision technology and to supply our customers with innovative solutions also for the most demanding applications. As experts in the fields of positioning technology and metrology we have the ambition to be and stay the technology leader. Therefore we tackle daring requests with an open mind for new approaches. Thus, we often stun our customers with innovative solutions surpassing the requested performance. We are glad that our products and services help our customers in science and industry to achieve their goals in very different fields of technology and integration levels like in lab research, product development or OEM product integration.

Since SmarAct has been founded in 2005 as an independent and privately owned company we have been continuously growing from a small team of highly skilled engineers to a business with more than 170 employees in 2019. To ensure a high level of flexibility, product and service quality, we have established subsidiaries and cooperative partnerships to be able to supply products and solutions to customers and all over the world.

In the beginning, we started with the development of piezo-based high-resolution positioning solutions for electron microscopes. Over the years we have broadened our portfolio with many new products like the unmatched parallel kinematic positioning system **SMAR**POD and the miniaturized, high-performance interferometer **PICO**SCALE. With the wide variety of our products we are able to serve customers in the fields of research, photonics, microscopy as well as microassembly & automation – and many others.

SmarAct systems offer unique performance. Our stages are optimized for compactness and high stiffness and combine sub-nanometer-resolution with centimeter-travel ranges. The systems are robust and simple to use. The **PICO**SCALE *Interferometer* is a powerful tool for displacement measurements with picometer resolution whereas the **PICO**SCALE *Vibrometer* allows high-resolution imaging of vibrational modes of mechanical systems. With SmarAct's powerful control electronics and software you can easily integrate our nanopositioning systems and our metrology equipment into your existing setups.

Research & Development is the foundation of our success. With our experts in diverse fields such as physics, material science, mechanical engineering, optics, electrical engineering and computer science we are able to develop all parts of our products in-house, ranging from motor technology, controller, measurement technology to firmware and application software, leading to ever increasing performances of our products and thus strengthening our position as the technology leader.

The dedication to our customers is unrivaled. A team of highly skilled application scientist is ready to support you right from the beginning. Starting with the selection of the perfect solution for your project, supporting you during integration and setup of the stages and systems and of course whenever technical support is required.

Even if you are looking for a high-precision positioning or a high-resolution measurement solution that is not available yet, please contact us – we may already be working on it or it may spark a new development. project.

I hope that this catalog will inspire you and I would be proud if SmarAct can contribute to the success of your next project.

Axel Kortschack
Managing Director

SmarAct

HIGH QUALITY
MADE IN GERMANY

SmarAct Services
Help & Support

Your Partner for High Precision in Positioning and Metrology.

Customer Service

Our sales team consists of experts with technical backgrounds in fields such as physics, material science, optics and life science and are looking forward to support you in selecting the best solution for your positioning and measurement task. We have an unrivaled speed and flexibility in developing and building custom solutions according to your specific requirements – no matter whether it is a highly complex or a recurrent high-volume OEM positioning system.

Service and Support

As part of a fully customer oriented company the SmarAct Sales and Support Team is pleased to help and support you during the installation and setup of your newest positioning system. The team also offers immediate and comprehensive technical support to minimize downtime of your application.

Customization and Engineering Service

You have a new challenging task within the field of positioning or metrology? Parts and components presented in this catalog generally caught your attention but did not quite match your specific criteria? Just involve us. We are eager to hear about your project and design the perfect solution for it.

Equipment Rental Service

You only need a certain SmarAct product for a short period of time? Many of our positioning and metrology systems can be rented. Please check with our technical sales team for rental terms and conditions and product availability.

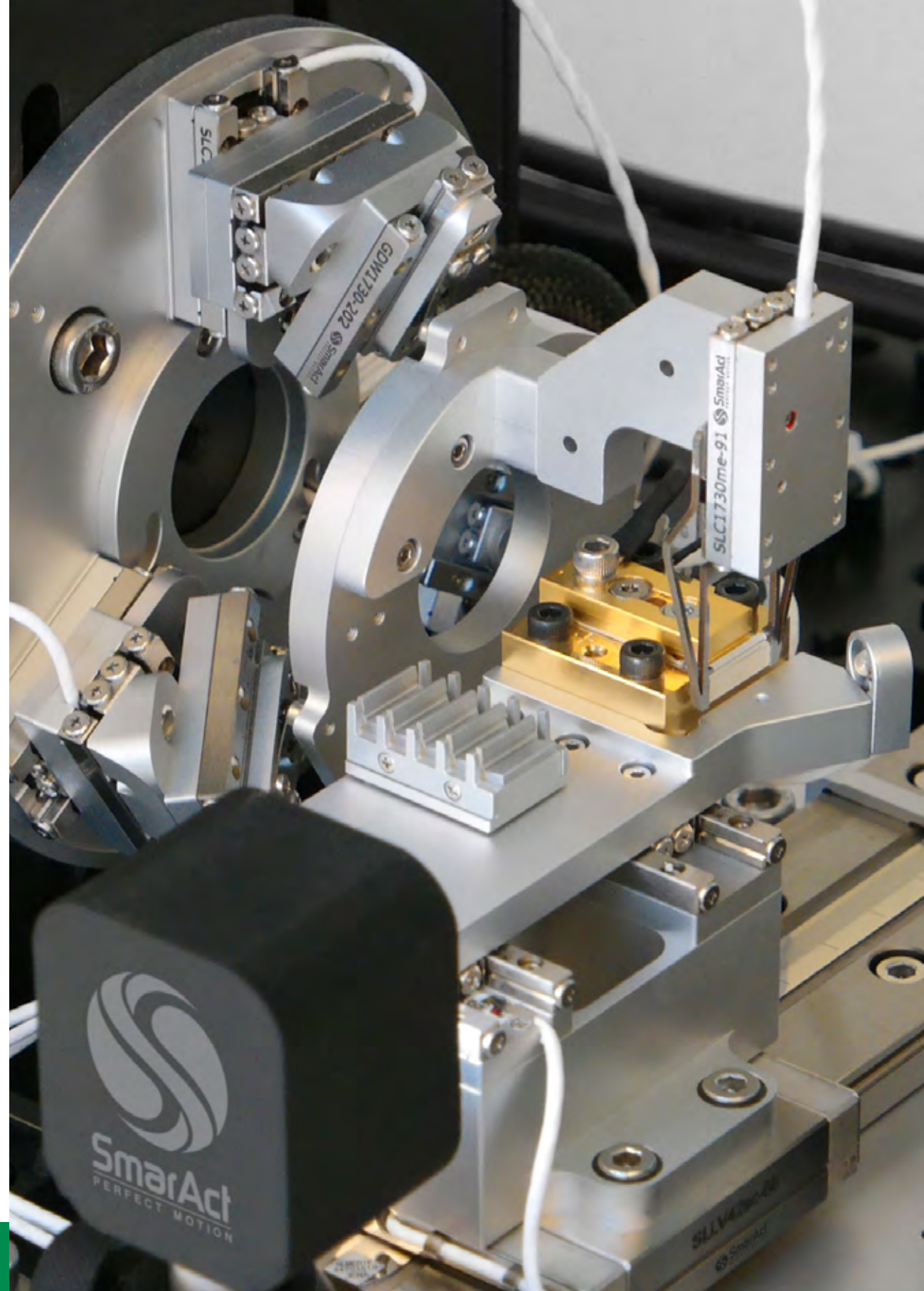
Laboratory Services

You want us to perform measurements or to examine components for you in general? Please do not hesitate to consult our technical sales team to discuss viability, conditions and availability.

Commitment to Quality

We are certified according to the ISO standard 9001:2015 and eager to deliver the best solutions and products for laboratory and industry applications.

Certified ISO 9001



*The **SMAR**POD os a hexapod-like positioning system which uses linear stages of the SLC Series in a parallel kinematic design to create a positioning system with six degrees of freedom.*

High Precision Positioning

High Precision Positioning
Linear, Rotation and Goniometer Stages

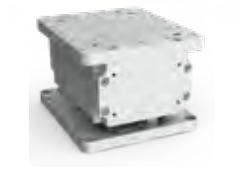
Miniaturization in all fields of application increases the demand and requirements for compact and high-resolution positioning solutions.

Typical areas of application for our stages demand highest accuracy and flexibility. Our stick-slip technology combines resolution in the sub-nanometer range with macroscopic travel of up to 1.5 meters. A large range of standard components consisting of linear, rotation and goniometer stages is supplemented by microgrippers for handling small components like lenses or electrical contacts and probes. Our versatile control systems and comprehensive software development kits enable easy and efficient integration into your own control environment.

Please feel free to start a discussion about your specific requirements with the specialist of our sales team. If our standard product range does not fit to your requirements we are pleased to offer customized versions of our products as well as the development of complete systems and applications according to your specifications. This includes mechanical and electrical components, as well as software.

Become inspired by the wide variety and high modularity of our positioning solutions.

The modular design of the SmarAct stages and the availability of a high number of sensor, material, control and application specific options lead to a wide variety of individually configurable setups. Here we present an overview about the product series, available sensors types, different control electronics and other possible material and mechanical options. Due to our dedication to create the highest quality products not all stages, options, sensors and control electronics can be combined. Please consult the specification tables of each series in this chapter of the catalog or feel free to contact us whenever questions about possible combinations or requirements arise.



Linear Piezo Stages

SLC Series
The SLC Series covers linear stages equipped with linear crossed roller slides.

SLS Series
The robust linear stages of the SLS Series can be easily combined to create completely new multi axis setups due to the high mechanical versatility, compatibility and modularity.

SL Series
The SL Series features ultra-compact linear stages equipped with ball slides.

SLL Series
The SLL Series is based on a different concept compared to the to our other product lines. Here motorized carriages are moved on top of rail that can be mounted to an optical table or a mechanical setup. Several carriages can share the same rail allowing to set up fully motorized optical benches, for example.

SHL Series
Based on the SLC series, the SHL series is designed for the handling of heavy loads up to several kilograms.

Rotation Stages

SR Series
The SR series covers all rotation stages with and without appertures.

Goniometer Stages

SGO Series
The SGO Series features high precision goniometers.

Options

Cryogenic
For applications that require very low temperatures down to the mK range specialized versions of our SLC and SR stages are available. Please consult page 66 for further information about cryogenic applications.

Vacuum
Standard stages are configured to work in atmospheric pressure only. For high vacuum (HV, 10^{-6} mbar) and ultra-high vacuum (UHV, 10^{-11} mbar) applications specialized versions of our components are available. As SmarAct is a complete solution provider we deliver complete single or multi-axis systems including vacuum compatible cabling and HV or UHV electrical feedthroughs.

Non-Magnetic Materials
Especially stages of the SLC, SLS and SR Series are available as complete non-magnetic versions. In most cases their outer dimensions remain unchanged.

Sensors
Optical and inductive sensors can be integrated into our stages for closed-loop position control allowing you to define the desired travel distance or the target position and the velocity of the stage.

Higher Blocking Force
The blocking force is the maximum external force a stage can withstand without changing its position. It corresponds to the maximum force that can be applied by the stage to another object. For certain applications when the required blocking force is higher than specified in the tables below the stages can be modified in a way that the force can be increased by 1.5 Newton without changing the outer dimensions.

Constant Force Spring
When the application requires the stage to lift a constant load mounted in a vertical arrangement a constant force spring can be integrated to act as a counterbalance.

U-Shaped Base
The stages of the SLC Series are also available as versions with a U-shaped base instead of the rectangular standard bases. This special shape increases the mechanical strength of the stage significantly. Due to the different dimensions of the U-shaped base the width of the stage itself will be increased by 6mm. Nevertheless the mounting hole pattern remains the same as for the standard bases.

Sensor Type	S	SC	L	I
Working Principle	Optical			Inductive
Resolution [nm]	1		4	300
Reference Positions	Single reference mark	Multiple reference marks	Endstop or multiple reference marks	Endstop
Control System Compatibility	**MCS**2, **SDC**2		**MCS**2, **SDC**2, CU	EMS, CU
Vacuum Compatibility	Down to 10^{-11} mbar		Atmospheric pressure only	Down to 10^{-6} mbar

MCS2

The **MCS**2 is our most versatile and modular control system. For multi-axis systems with up to three stages it is available in a compact tabletop housing or as a rack mountable module or as an OEM single board controller. More than three channels can be driven with interconnected rack mountable modules, a compact tabletop enclosure and a handheld controller. Ethernet and USB interfaces guarantee easy integration into your setup.

The modular concept of the **MCS**2 control system does not only include enclosures, the number of channels and optional input and output modules but also firmware modules that increases the functional scope even further. For example, the optional *Low-Vibration Mode* firmware module was especially developed for ultra-high precision applications like Scanning Probe Microscopy and life science experiments. This algorithm reduces the vibrations which inevitably occur by the stick-slip driving principle. The result is a smooth motion which enables the usage of our stick-slip piezo stages even in the most demanding applications.

CU

The CU product line of control systems include one and three channel controllers with optional support of closed-loop positioners. All control systems of this product line are equipped with a USB connection. In addition the three channel systems allow also for external control via an RS232 interface. Beside the availability as fully integrated hand-held controllers for desktop usage, the three channel version is also available as an OEM single board controller to be exclusively computer controlled.

SDC2

The Step-Direction Control System **SDC**2 is a low-level control system which allows to drive our piezo stages in a stepper motor like fashion with very high resolution. Controllers of this product line are available as rack mountable modules, as tabletop devices enclosures or as OEM single board controllers for integration into existing electronics.

EMS

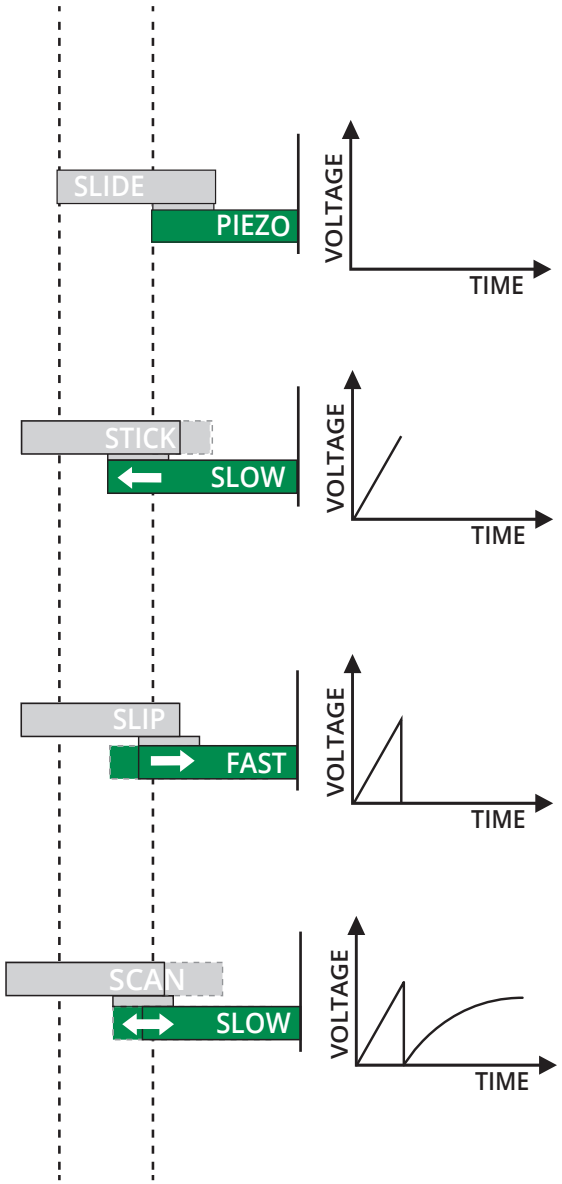
The EMS product line is defined by two OEM single board controllers exclusively for integration into existing electronics. The board dimensions and connectors differ whether the two channel or three channel version is required. External communication is realized via a Two Wir Interface (TWI).

AVC

The AVC OEM single board control system was exclusively designed to be integrated into existing electronics to drive a single stage. Analog inputs (-10V to +10V) allow external selection of driving direction and speed.

MCS2 *system controllers are available in different enclosures, also in tabletop enclosures like the one depicted here.*

All SmarAct piezo stages are equipped with a patented Stick-Slip drive, thus combining macroscopic travel with sub-nanometer resolution and high velocities of several millimeters per second. The working principle of a Stick-Slip piezo drive is explained in the following drawings:

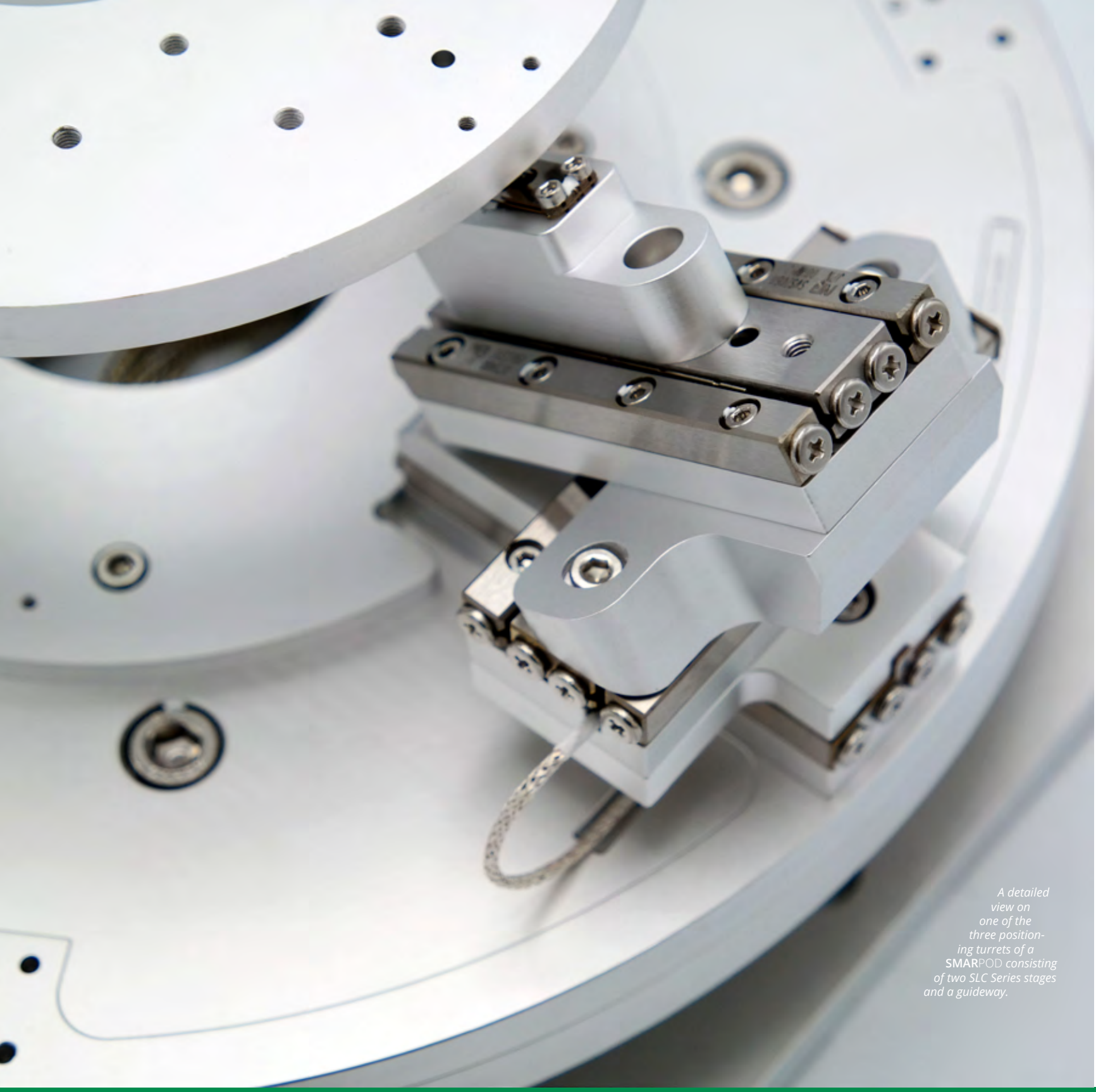


A piezo actuator is coupled to the slide of the guideway by a friction element that is permanently fixed to the actuator. The piezo actuator itself is fixed at the stationary base of the stage.

The piezo actuator is changing its length proportional to the applied voltage. Because of the controlled ramp-up of the applied voltage to the piezo, it will enlarge and the friction coupled slide will follow the movement of the friction element. This phase is called stick-phase.

A sharp decrease of the applied voltage will cause a shortening of the piezo on a very short time scale which yields to a very fast movement of the friction element. Because of the mass inertia of the slide the friction element slips across the slides' surface. As a result, the friction element is changing its position, while the slide does not follow. This phase is called slip phase. By repeating this sequence a macroscopic travel of the slide can be achieved. This mode is called step mode.

During the stick-phase the slide can be moved by slowly enlarging the piezo actuator with sub-nanometer resolution. This mode is called scan mode.



A detailed view on one of the three positioning turrets of a **SMAR**POD *consisting of two SLC Series stages and a guideway.*

Piezo Stages
Unique Features

Future-Proof and Modular
The highly modular design and the variety of available options allow custom-specific solutions of highest quality while ensuring future upgradability.

Robust
Moving the slide by hand will not harm the stage or the piezo drive.

Cost-Effective
Due to the in-house development and manufacturing of all core components SmarAct is able to provide positioning systems of the highest quality, precision and reliability at a reasonable price.

All-In-One Solution
Each stage consists of a high quality guideway, a SmarAct piezo drive and an optional high-resolution position sensor.

High Resolution and Long Travel Range
SmarAct stages provide closed-loop positioning resolution of 1 nanometer with tens of nanometer positioning repeatability even over long travel ranges.

Versatile
All stages are independent of their mounting orientation and therefore present the perfect match even for the most complex and space constrained setups.

Extreme Miniaturization
SmarAct stages are the perfect selection for miniaturized applications and setups. For example our SLC-1720 stage with a size of 22 x 17 x 8.5 mm^3 is the world's smallest closed-loop piezo stage with nanometer resolution and macroscopic travel range.

Guided Motion
SmarAct stages are mechanically designed to reduce wobble and other parasitic motions to a minimum and to guide the motion of the piezo drive in the desired direction effectively.

Backlash-Free
Since the movable part of the stage is permanently coupled to the piezo drive via a friction element the SmarAct piezo stages are backlash-free by design.

Self-Clamping
Even with switched-off or disconnected control electronics the stages will keep their position.

Low Thermal Drift and High Resonance Frequencies
A high level of miniaturization in conjunction with a perfect choice of materials, our sophisticated design and optimized control modes assures low thermal drift and high resonance frequencies.

Vacuum Compatibility
Nearly all stages and positioning systems are available in vacuum compatible versions for use in high vacuum (HV) or ultra-high vacuum (UHV) applications down to 10^{-11} mbar.

Non-magnetic Materials
Most of the stages are also available as complete non-magnetic versions.

Nanometer Precision Linear Piezo Stages

SmarAct's product portfolio includes different product lines of linear stages. Each line was designed with your requirements in mind and allows us to deliver the highest performance for your specialized positioning project. Full compatibility between components of different product lines allow you to select stages with special key features to combine them into multi-axis systems.

SLC Series
Linear stages of the SLC Series are based on linear slides with crossed roller bearings and are characterized by their high rigidity and straightness. They are ideally suited for positioning systems where stability and high accuracy have top priority.

SLS Series
Linear stages of the SLS Series are the best choice for multi axis setups that require to be highly modular and mechanically robust.

SL Series
Linear stages of the SL Series are ultra-compact and are the perfect match for setups with space constraints or demands for extreme miniaturization.

SLL Series
Linear stages of the SLL Series are especially useful in applications where parts or components need to be placed on the same optical axis and moved in conjunction with each other over long ranges up to 1.5 m.
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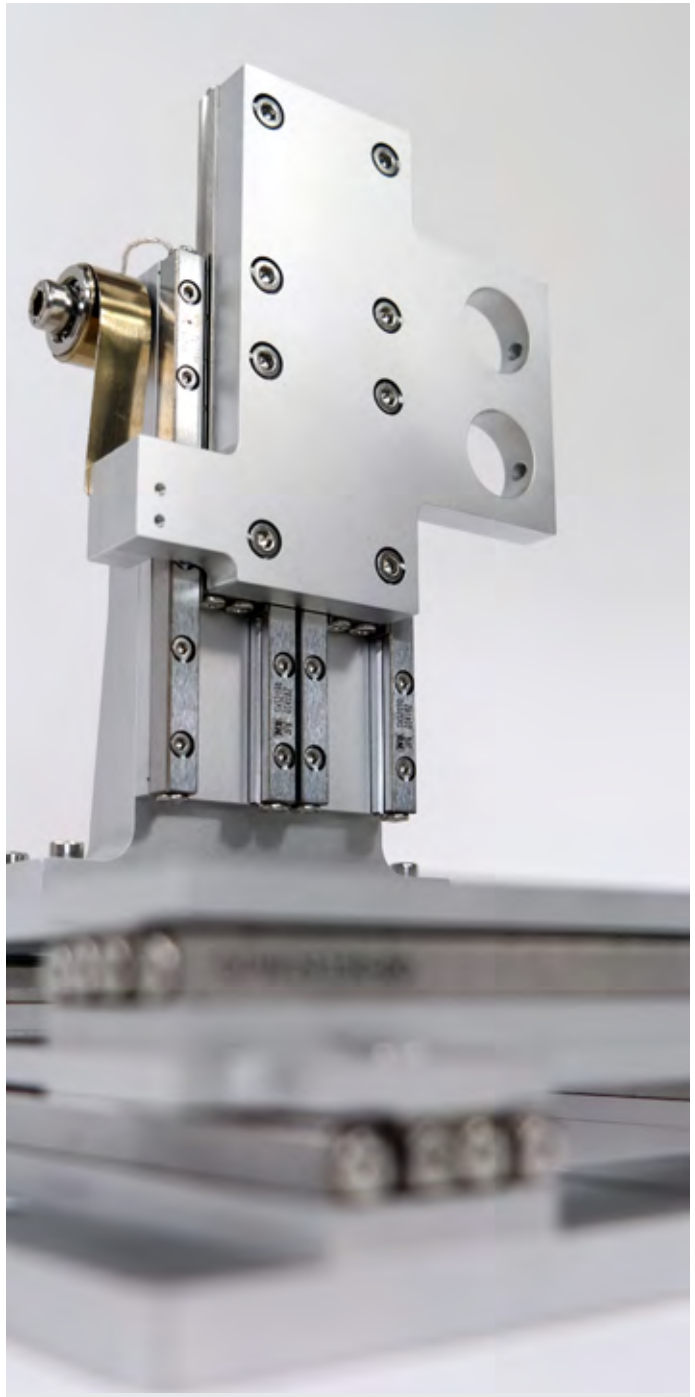
SHL Series
Linear stages of the SHL Series are the best solution for applications where high mechanical loads need to be moved.



For lifting stages that need to handle heavy payloads constant force springs are available for weight compensation

Even long travel SLC Series stages can be mounted on top of each other to create gantries or large XY platforms.

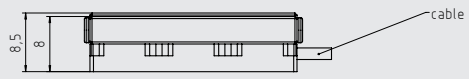
		SLC		SLS			SL	SLL		SHL
	Series	SLC-17	SLC-24	SLS-32	SLS-52	SLS-92	SL-06	SLL12	SLL V42	SHL-20N-10
Mechanical	Travel [mm]	12 .. 51	16 .. 123	21 .. 51	31 .. 51	63..103	4.5 ..16	35 .. 460	10 .. 1410	10
	Blocking Force [N]	≥ 3.5					≥ 1	≥ 3	≥ 5	--
	max. Normal Force [N]	20 .. 30	20 .. 30	20			1	30		20
	max. Lift Force [N]	1.5	1.5	1.5	1.0	--	0.35	1	--	5 .. 20
	Cross Section W x H [mm]	17 x 8.5	24 x 10.5	32 x 11	52 x 14	92 x 17	5.2 x 11	27 x 10	60 x16	65 x 50
Open-Loop	Velocity [mm/s]	> 20	> 20	> 20			> 10	> 15		> 5
	Resolution [nm]	< 1								
Closed-Loop	Sensor Types	S, L, I		S, L			--	S		S, L
	Resolution [nm]	1 (S), 4 (L), 500 (I)		1 (S), 4 (L)			--	1 (S)		1 (S), 4 (L)
Vacuum Compatibility		HV (10^{-6} mbar); UHV (10^{-11} mbar)								

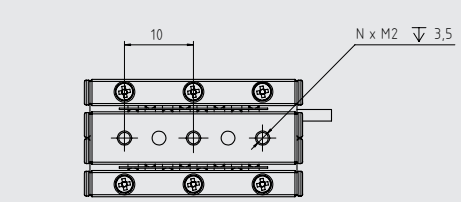
Linear stages of the SLC-17 Series are very rigid and therefore ideally suited for micro- and nanopositioning systems where stability and high accuracy are top priority.
Despite their small size of only 17 mm in width and 8.5 mm in height a position sensor for closed-loop operations can be optionally integrated into each stage without affecting its outer dimensions. Optionally the stages are available in specialized versions for use in high vacuum and ultra-high vacuum environments or can be manufactured in different material combinations.
Please consult the following table for more details and feel free to contact us whenever questions about compatibility, specification and customization arise.

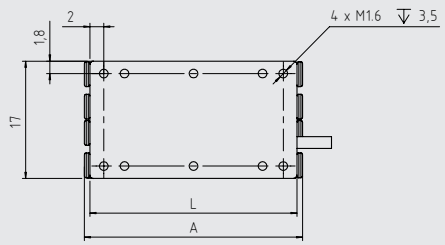
Linear Piezo Stages
SLC-17 Series

		SLC-1720	SLC-1730	SLC-1740	SLC-1750	SLC-1760	SLC-1770	SLC-1780
Mechanical	Travel [mm]	12	21	26	31	41	46	51
	Blocking Force [N]	≥ 3.5						
	max. Normal Force [N]	20	30					
	max. Lift Force [N]	> 1.5						
	Dimensions [mm], L x W x H	22 x 17 x 8.5	30 x 17 x 8.5	40 x 17 x 8.5	50 x 17 x 8.5	60 x 17 x 8.5	70 x 17 x 8.5	80 x 17 x 8.5
	Weight [g]	13	20	26	32	38	45	51
Open-loop	Velocity [mm/s]	> 20						
	Resolution [nm]	< 1						
Closed-Loop	Resolution **MCS**2 [nm]	1 (S) 4 (L)						
	Repeatability, Full Stroke **MCS**2 [nm]	± 25 (S) ± 50 (L)	± 30 (S) ± 60 (L)	± 40 (S) ± 80 (L)	± 50 (S) ± 100 (L)	± 60 (S) ± 120 (L)	± 70 (S) ± 140 (L)	± 80 (S) ± 160 (L)
	Resolution (H)CU [nm]	50 (L)						
	Repeatability, Full Stroke (H)CU [nm]	± 1000 (L)						
Material Options		Aluminum base as standard; steel base (-ST); titanium base (-TI); black anodized (-BK)						
Mechanical Options		U-shaped base for higher mechanical strength (-W) increases width to 23 mm; increased lifetime (-Z)						
Performance Options		Higher blocking force (-D): +1.5 N						
Cryogenic Option		Yes					--	--
Vacuum Options		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)						
Non-Magnetic Option		Yes, changes of the slide hole pattern apply: all threaded holes M 1.6, no dowel holes. We also recommend to opt for the U-shaped base (-W).						

XYZ Stage built with three SLC-1730 stages





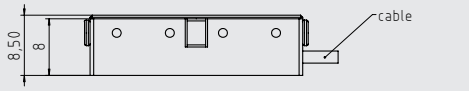


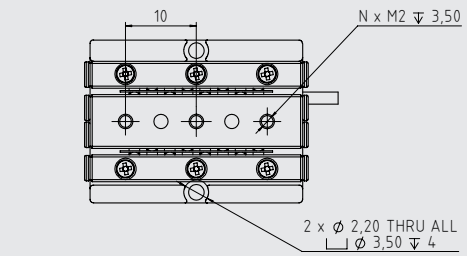
Parameterized example drawing. Visit us online to get technical drawings for each stage or contact our technical sales team.

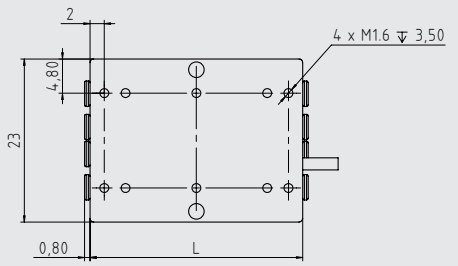
XYZ Stage built with three SLC-1730 stages with a U-shaped base for higher mechanical strength

The U-shaped base resembles the same mounting hole pattern but adds 6 mm to the width of the stage itself. As a result the width of a SLC-17 stage enlarges to 23 mm .

This option is highly recommended if the system needs to be baked for operation in ultra-high vacuum. Thus, waiving the U-shaped base option is only advisable if compactness is the top most requirement.







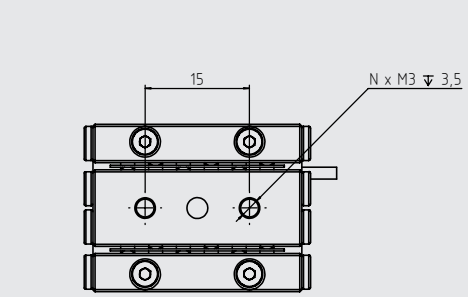
Shown in reference position.
For information purposes only.
All linear dimensions are given in millimeters.

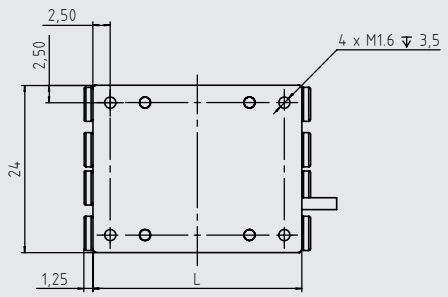
Linear stages of the SLC 24 Series are – analogous to the SLC 17 Series – also very rigid and therefore ideally suited for micro- and nanopositioning systems where stability and high accuracy are top priority.
With dimensions of 24 mm in width and 10.5 mm in height they are wider but even more rigid than their SLC 17 counterparts. Their high straightness allows for an excellent positioning accuracy even over long travel ranges. Nevertheless a position sensor for micro- and nanopositioning tasks can be optionally integrated into each stage without affecting its outer dimensions. Optionally, the stages are available in specialized versions for use in high vacuum and ultra-high vacuum environments or can be manufactured in different material combinations.
Please consult the following table for more details and feel free to contact us whenever questions about compatibility, specification and customization arise.

		SLC-2430	SLC-2445	SLC-2460	SLC-2475
	Travel [mm]	16	29	35	49
Open-loop	Blocking Force [N]	≥ 5			
Open-loop	max. Normal Force [N]	20	30		
Open-loop	max. Lift Force [N]	1.5			
Mechanical	Dimensions [mm], L x W x H	30 x 24 x 10.5	45 x 24 x 10.5	60 x 24 x 10.5	75 x 24 x 10.5
Mechanical	Weight [g]	36	54	72	90
Open-loop	Velocity [mm/s]	> 20			
Open-loop	Resolution [nm]	< 1			
Closed-loop	Resolution **MCS**2 [nm]	1 (S) 4 (L)			
Closed-loop	Repeatability, Full Stroke **MCS**2 [nm]	± 30 (S) ± 60 (L)	± 45 (S) ± 90 (L)	± 60 (S) ± 120 (L)	± 75 (S) ± 150 (L)
Closed-loop	Resolution (H)CU [nm]	50 (L)			
Closed-loop	Repeatability, Full Stroke (H)CU [nm]	± 1000 (L)			
Material Options		Steel base (-ST); titanium base (-TI); black anodized (-BK)			
Mechanical Options		U-shaped base for higher stiffness (-W) increases width to 30 mm			
Performance Option		Higher blocking force (D): +1.5 N			
Cryogenic Option		Yes			--
Vacuum Options		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)			
Non-Magnetic Option		Yes. Changes of the slide hole pattern apply: all threaded holes M 1.6, no dowel holes. We also recommend to opt for the U-shaped base (-W) for higher stiffness.			

		SLC-2490	SLC-24105	SLC-24120	SLC-24150	SLC-24180
	Travel [mm]	63	69	83	103	123
Open-loop	Blocking Force [N]	≥ 3.5				
Open-loop	max. Normal Force [N]	30				
Open-loop	max. Lift Force [N]	1.5				
Mechanical	Dimensions [mm], L x W x H	90 x 24 x 10.5	105 x 24 x 10.5	120 x 24 x 10.5	150 x 24 x 10.5	180 x 24 x 10.5
Mechanical	Weight [g]	108	126	144	180	216
Open-loop	Velocity [mm/s]	> 20				
Open-loop	Resolution [nm]	< 1				
Closed-Loop	Resolution **MCS**2 [nm]	1 (S) 4 (L)				
Closed-Loop	Repeatability, Full Stroke **MCS**2 [nm]	± 90 (S) ± 180 (L)	± 105 (S) ± 210 (L)	±120 (S) ± 240 (L)	±150 (S) ± 300 (L)	± 180 (S) ± 360 (L)
Closed-Loop	Resolution (H)CU [nm]	50 (L)				
Closed-Loop	Repeatability, Full Stroke (H)CU nm]	± 1000 (L)				
Material Options		Aluminum base as standard; steel base (-ST); titanium base (-TI); black anodized -(BK)				
Mechanical Option		U-shaped base for higher mechanical strength (-W) increases width to 30 mm				
Performance Option		Higher blocking force (-D): +1.5 N				
Cryogenic Option		--				
Vacuum Options		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)				
Non-Magnetic Option		Yes. Changes of the slide hole pattern apply: all threaded holes M 1.6, no dowel holes. We also recommend to opt for the U-shaped base (-W)				

SLC-2430 linear piezo stage

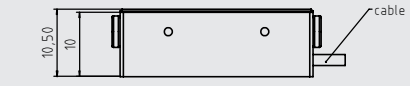


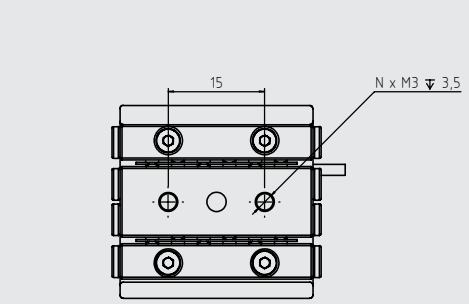


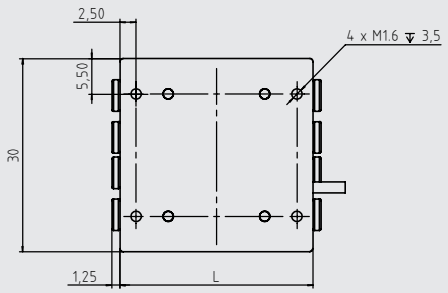
SLC-2430 linear stage with a U-shaped base (option -W) for higher mechanical strength

The U-shaped base resembles the same mounting hole pattern but adds 6 mm to the width of the stage itself. As a result the width of a SLC-24 stage enlarges to 30 mm.

This option is highly recommended if the system needs to be baked for operation in ultra-high vacuum. Thus, waiving the U-shaped base option is only advisable if compactness is the top most requirement.







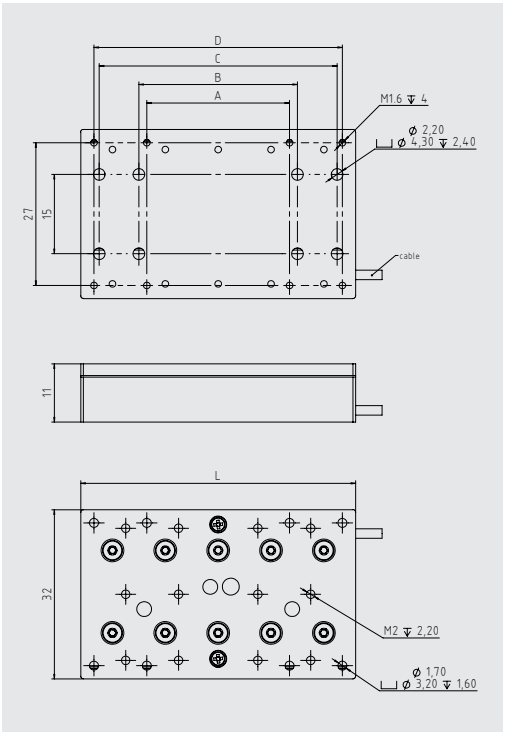
Linear Piezo Stages
SLS Series

Linear stages of the SLS Series were consistently designed to allow for easy integration into multi-axis systems: Their mounting hole pattern is perfectly matched to mount our rotation stages and goniometers. They are the perfect option when modularity and easy configuration are the top level requirements.
Example setups of multi-axis systems and an overview about the range of mechanical components like adapter plates, breadboard adapters and brackets to easily setup multi-axis systems can be found on page 74 and following.

Here we are presenting stages of the SLS Series in standardized length. If your specific application requires other length and travel please feel free to contact us to discuss possible configurations.

Stages of the SLS Series can be easily combined with SHL, SGO and SR stages to form complex positioning systems.

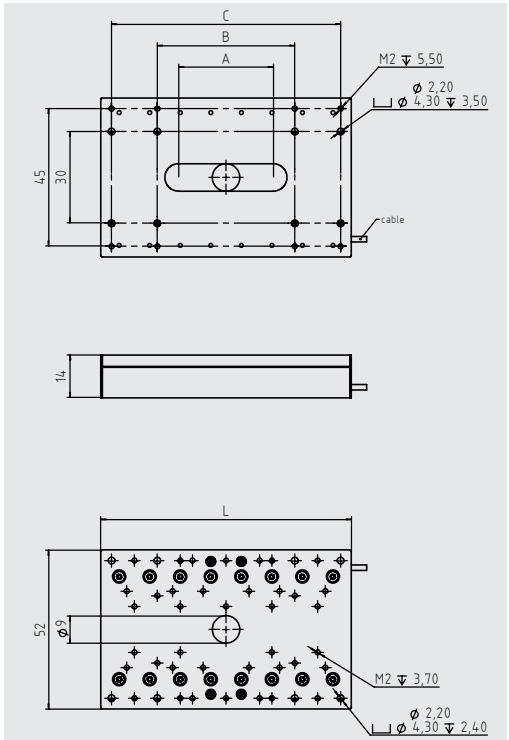
SLS-3232 linear stage with a travel range of 21 mm.



		SLS-3232	SLS-3252	SLS-3282
Mechanical	Travel [mm]	21	31	51
	Blocking Force [N]	≥ 3.5		
	max. Normal Force [N]	20		
	max. Lift Force [N]	> 1.5		
	max. Lift Force with Constant Spring [N]	> 3.5		
	Dimensions [mm], L x W x H	32 x 32 x 11	32 x 52 x 11	32 x 82 x 11
	Weight [g]	32	54	87
Open-loop	Velocity [mm/s]	> 20		
	Resolution [nm]	< 1		
Closed-Loop	Resolution **MCS**2 [nm]	1 (S) 4 (L)		
	Repeatability, Full Stroke, **MCS**2 [nm]	± 50 ± 100		
	Resolution SCU [nm]	4 (L)		
	Repeatability, Full Stroke, SCU [nm]	± 1000 (L)		
Material Options		Aluminum base as standard; steel base (-ST); titanium base (-TI); black anodized -(BK)		
Vacuum Options		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)		
Non-Magnetic Option		Yes (-NM)		

Linear Piezo Stages
SLS-52 Series

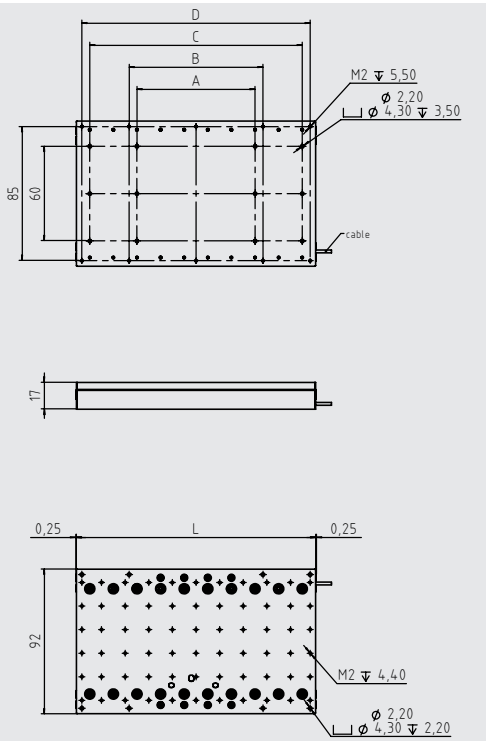
SLS-5282 linear piezo stage



		SLS-5252	SLS-5282
Mechanical	Travel [mm]	31	51
	Blocking Force [N]	≥ 3.5	
	max. Normal Force [N]	20	
	max. Lift Force [N]	> 1.0	
	max. Lift Force with Constant Spring [N]	5	
	Dimensions [mm], L x W x H	52 x 52 x 14	52 x 82 x 14
	Weight [g]	90	140
Open-loop	Velocity [mm/s]	> 20	
	Resolution [nm]	< 1	
Closed-Loop	Resolution **MCS**2 [nm]	1 (S) 4 (L)	
	Repeatability, Full Stroke, **MCS**2 [nm]	± 50 ± 100	
	Resolution SCU [nm]	4 (L)	
	Repeatability, Full Stroke, SCU [nm]	± 1000 (L)	
Material Options		Aluminum base as standard; steel base (-ST); titanium base (-TI); black anodized -(BK)	
Vacuum Options		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)	
Non-Magnetic Option		Yes (-NM)	

Linear Piezo Stages
SLS-92 Series

SLS-9292 linear piezo stage

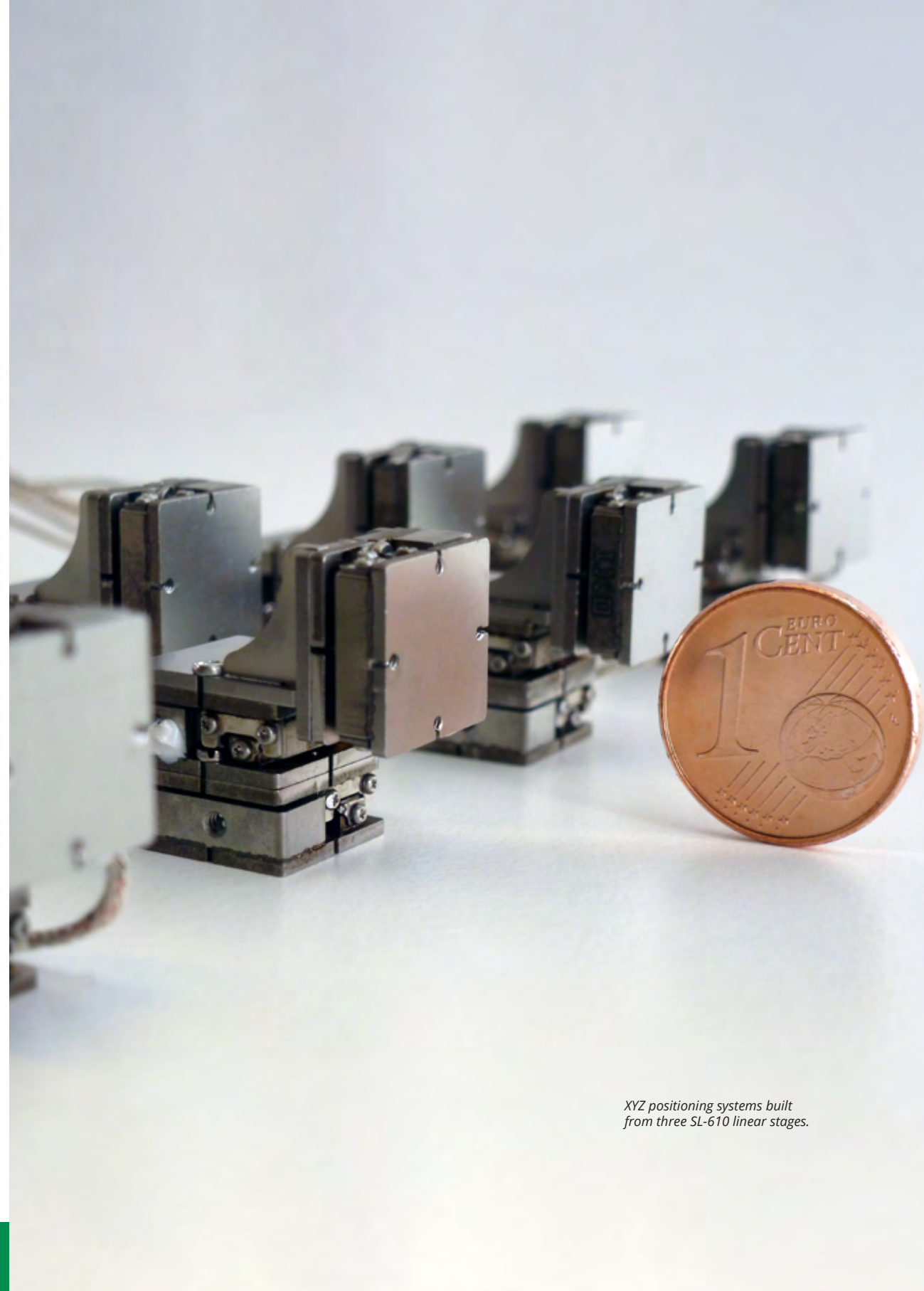


		SLS-9292	SLS-92152
Mechanical	Travel [mm]	63	103
	Blocking Force [N]	≥ 3.5	
	max. Normal Force [N]	20	
	Dimensions [mm], L x W x H	92 x 92 x 17	92 x 152 x 17
	Weight [g]	339	558
Open-loop	Velocity [mm/s]	> 20	
	Resolution [nm]	< 1	
Closed-loop	Resolution **MCS**2 [nm]	1 (S) 4 (L)	
	Repeatability, Full Stroke, **MCS**2 [nm]	± 50 ± 100	
	Resolution SCU [nm]	4 (L)	
	Repeatability, Full Stroke, SCU [nm]	± 1000 (L)	
Material Options		Aluminum base as standard; steel base (-ST); titanium base (-TI); black anodized -(BK)	
Vacuum Options		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)	
Non-Magnetic Option		Yes (-NM)	

Linear Piezo Stages
SL Series

Linear stages of the SL Series are based on miniature ball slides and are very small and light. Therefore, it is an interesting solution for precise positioning within limited space. The smallest and lightest stage of the series has a footprint of only 11 x 11 mm and an overall height of only 5.2 mm.

		SL-0610	SL-0620	SL-0630
	Travel [mm]	4.5	11	16
Mechanical	Blocking Force [N]	≥ 1.6		
	max. Normal Force [N]	1		
	max. Lift Force [N]	0.35		
	Dimensions [mm], L x W x H	11 x 11 x 5.2	21 x 11 x 5.2	31 x 11 x 5.2
Open-loop	Velocity [mm/s]	> 10		
	Resolution [nm]	< 1		
Material Options		Steel base (-ST) as standard		
Vacuum Options		HV (10^{-6} mbar); UHV/ UHVT (10^{-11} mbar)		



XYZ positioning systems built from three SL-610 linear stages.

Linear stages of the SLL Series are based on recirculating ball slides. The slide or carriages in combination with rails of different length make it an optimal solution either for precise long range positioning or large travel ranges within limited space. SLL stages can be operated by any of our control systems.

It is also possible to put multiple carriages on the same rail and move them independently to create fully motorized optical bench setups.

The components of the SLL Series are available for two different rail widths. The rail of the compact SLL12 product line has a width of 12 mm and the compatible carriages a width of 27 mm. The larger versions of the SLL 42 product line include 42 mm wide rails and 60 mm wide carriages. The SLL42 product line is also available in a high-vacuum version.

SLL12 linear stage

SLLV42 linear stage

SLL Accessories Line

Different accessories are available to allow you to mount existing equipment to the rails of the SLL Series or to combine SLL stages with your existing optical setups on optical tables or breadboards.
Due to the diversity of possible fields of application for SLL stages the number of available and customizable accessories is beyond the scope of this catalog. Please do not hesitate to contact our application scientists to discuss specialized accessories or fully customized solutions.

For the application of SLL stages as optical benches for example the following accessories are available.

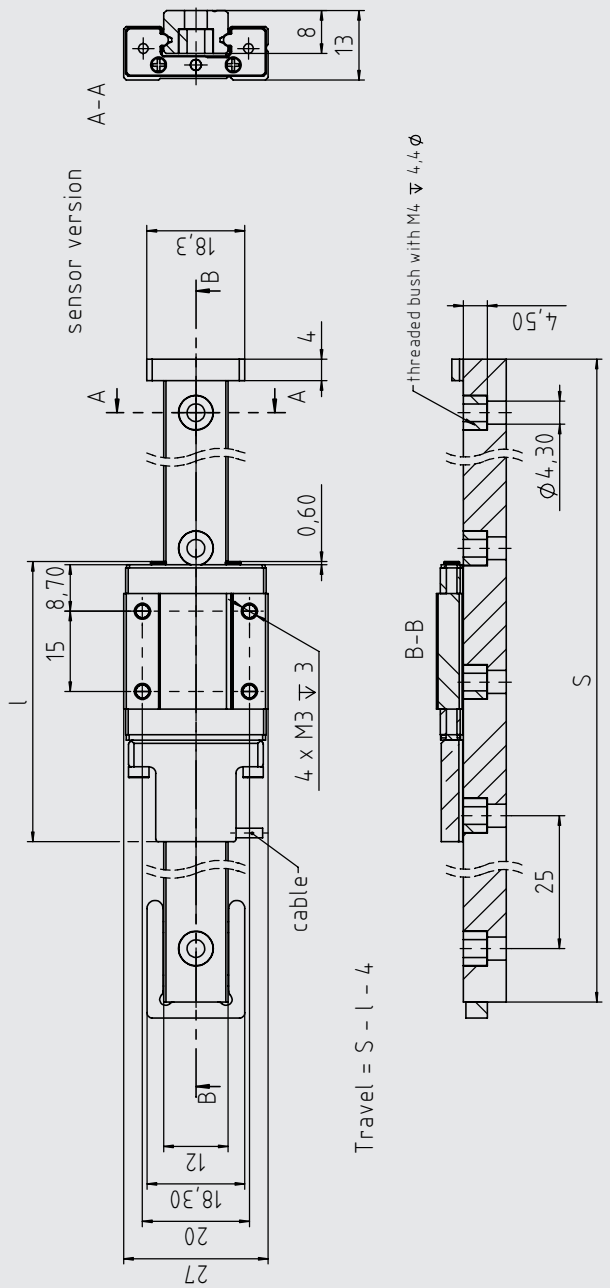
Passive Carriages
Passive carriages are perfectly suited as a mounting platform for existing optical equipment. They are also equipped with a clamping screw locking mechanism to securely fix their position on the rail.

Mechanical End Stop
Mechanical end stops allow to mechanically limit the travel range of a motorized carriage along the rail.

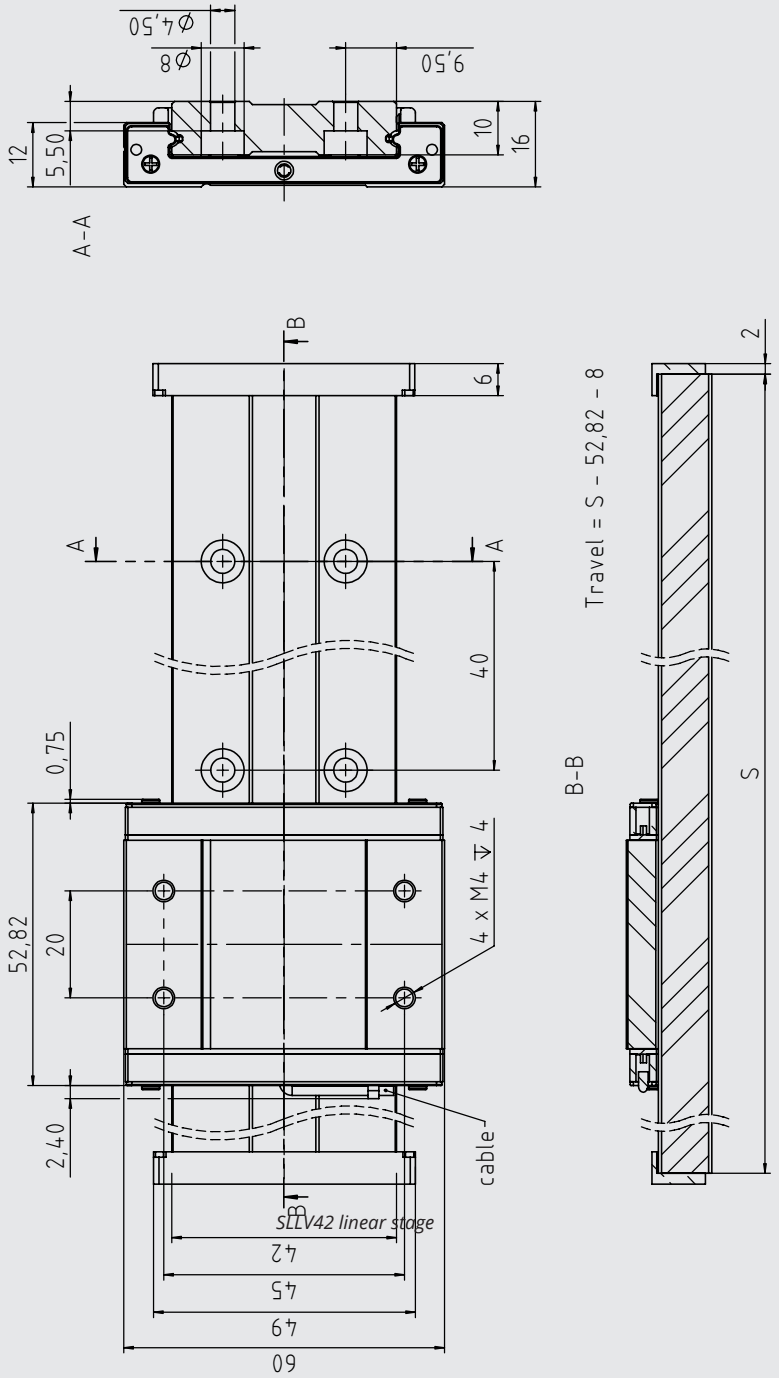
Breadboard Adapter
To mount the rail to an existing breadboard or optical table mounting adapters are available for every common hole pattern.

Opto-mechanical Mounts
To attach opto-mechanical components to the rails, various mounts and adapters are available.

		SLL12	SLLV42
	Travel [mm]	35 .. 460	10 .. 1410
Mechanical	Blocking Force [N]	≥ 3	≥ 5
	max. Normal Force [N]	30	
	max. Lift Force [N]	1	--
	Dimensions [mm], L x W x H	27 x 13	60 x 16
	Weight [g]	Length-dependent	
Open-Loop	Velocity [mm/s]	> 15	
	Resolution [nm]	< 1	
Closed-Loop	Resolution **MCS**2 [nm]	1 (S) 4 (L)	
	Repeatability, Full Stroke, (**MCS**2) [nm]	± 70 .. 450 (S)	
Material Options		Multiple carriages; counterbores; tapped holes (M4)	
Vacuum Options		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)	



SLL12 linear stage



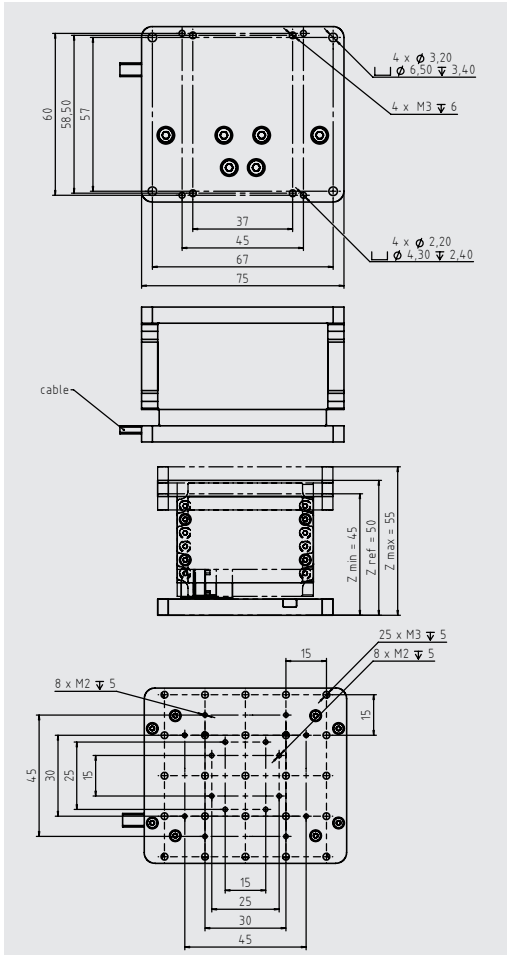
SLLV42 linear stage

Linear Piezo Stages
SHL-Series

Linear stages of the SHL Series are specially designed to handle heavy loads. The mechanical design is based on an actuated wedge which guarantees highest resolution of the stages motion. A separate guideway assures a straight movement along the load direction and allows an integration of a position sensor for direct position feedback and closed loop operation. Stages which are intended for pure vertical motion to lift components or equipment can be equipped with an additional constant force spring to offset the payload to even higher values. Accordingly, nano-encoded stages which can lift up to 10 kilogramms over several millimeter are possible as well as multi-axis systems based on linear stages of the SHL Series which offer high blocking forces in all three dimensions.
While offering high payloads, SmarAct SHL stages remain very compact and are suitable also for setups with space contraints.

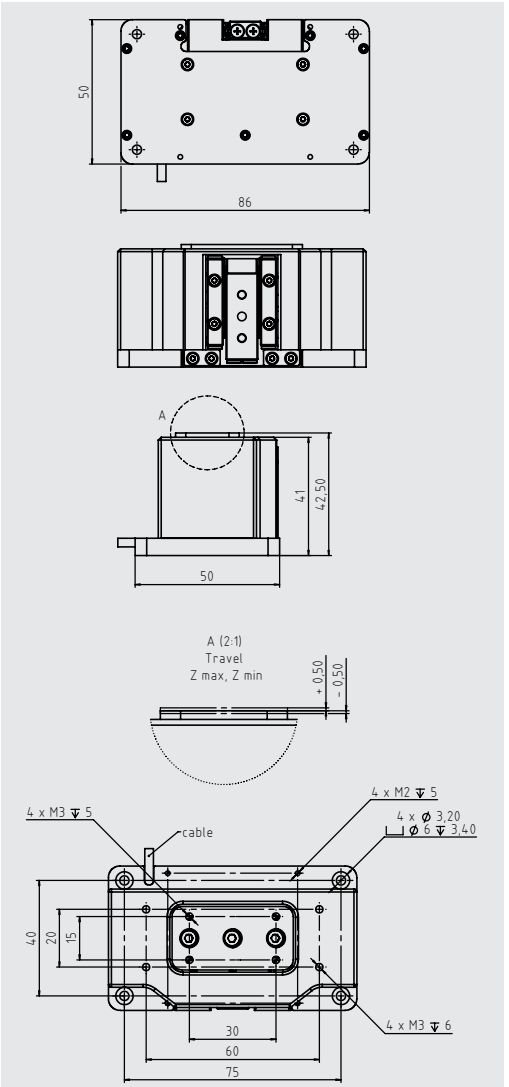
		SHL-1D20N-10	SHL-1D80N-1	SHL-3D5N-5	SHL-5237-1D10N-10
	Degrees of Freedom	1	1	3	1
Mechanical	Travel [mm]	10	1	5	10
	max. Lift Force [N]	20	80	5 (in all directions)	10
	Dimensions [mm], L x W x H	65 x 75 x 50	41 x 86 x 50	100 x 140 x 40	52 x 52 x 37
	Weight [g]	400	340	650	460
Open-loop	Velocity [mm/s]	> 5	> 1	> 5	> 4
	Scan Resolution [nm]	< 1			< 1
Closed-Loop	Resolution **MCS**2 [nm]	1 (S) 4 (L)			
	Repeatability, Full Stroke, **MCS**2 [nm]	100 (S) 200 (L)			
	Resolution (H)CU [nm]	500 (L)			
	Repeatability, Full Stroke , (H)CU [nm]	± 1000 (L)			
Material Options		Aluminum as standard; steel base (-ST); titanium base (-TI); black anodized (-BK)			
Vacuum Options		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)			

SHL-1D20N-10 linear stage



		SHL-1D20N-10
	Degrees of Freedom	1
Mechanical	Travel [mm]	10
	max. Lift Force [N]	20
	Dimensions [mm], L x W x H	65 x 75 x 50
	Weight [g]	400
Open-loop	Velocity [mm/s]	> 5
	Scan Resolution [nm]	< 1
Closed-Loop	Resolution **MCS**2 [nm]	1 (S) 4 (L)
	Repeatability, Full Stroke, **MCS**2 [nm]	100 (S) 200 (L)
	Resolution (H)CU [nm]	500 (L)
	Repeatability, Full Stroke , (H)CU [nm]	± 1000 (L)
Material Options		Aluminum as standard; steel base (-ST); titanium base (-TI); black anodized (-BK)
Vacuum Options		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)

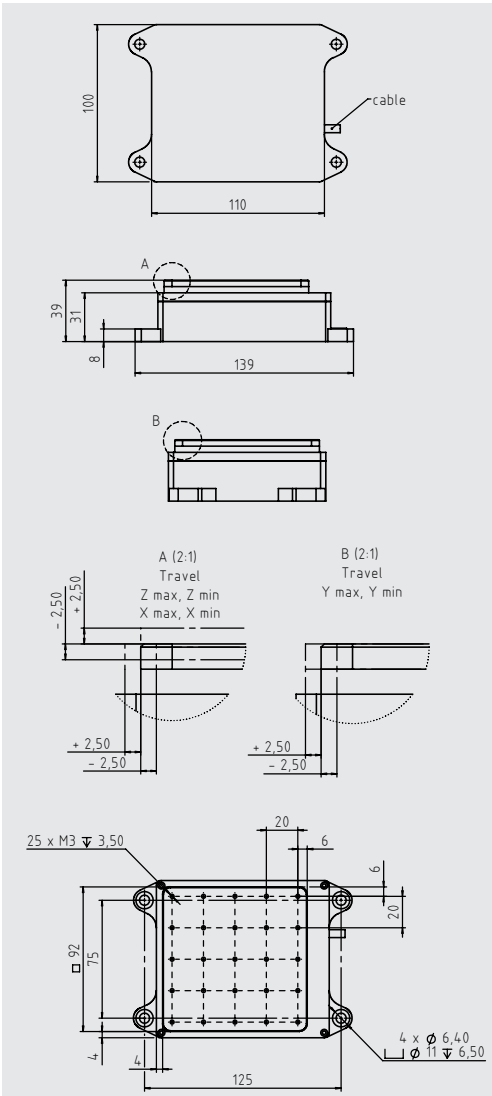
SHL-1D80N-1 linear stage



		SHL-1D80N-1
	Degrees of Freedom	1
Mechanical	Travel [mm]	1
	max. Lift Force [N]	80
	Dimensions [mm], L x W x H	41 x 86 x 50
	Weight [g]	340
Open-loop	Velocity [mm/s]	> 1
	Scan Resolution [nm]	< 1
Closed-Loop	Resolution **MCS**2 [nm]	1 (S) 4 (L)
	Repeatability, Full Stroke, **MCS**2 [nm]	100 (S) 200 (L)
	Resolution (H)CU [nm]	500 (L)
	Repeatability, Full Stroke , (H)CU [nm]	± 1000 (L)
Material Options		Aluminum as standard; steel base (-ST); titanium base (-TI); black anodized (-BK)
Vacuum Options		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)

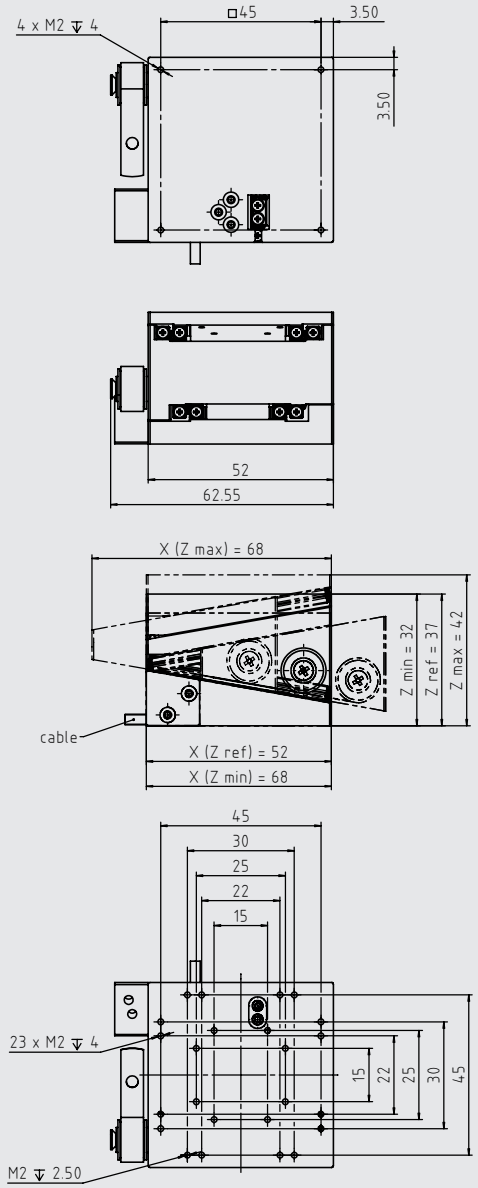
SHL-3D5N-5 linear stage

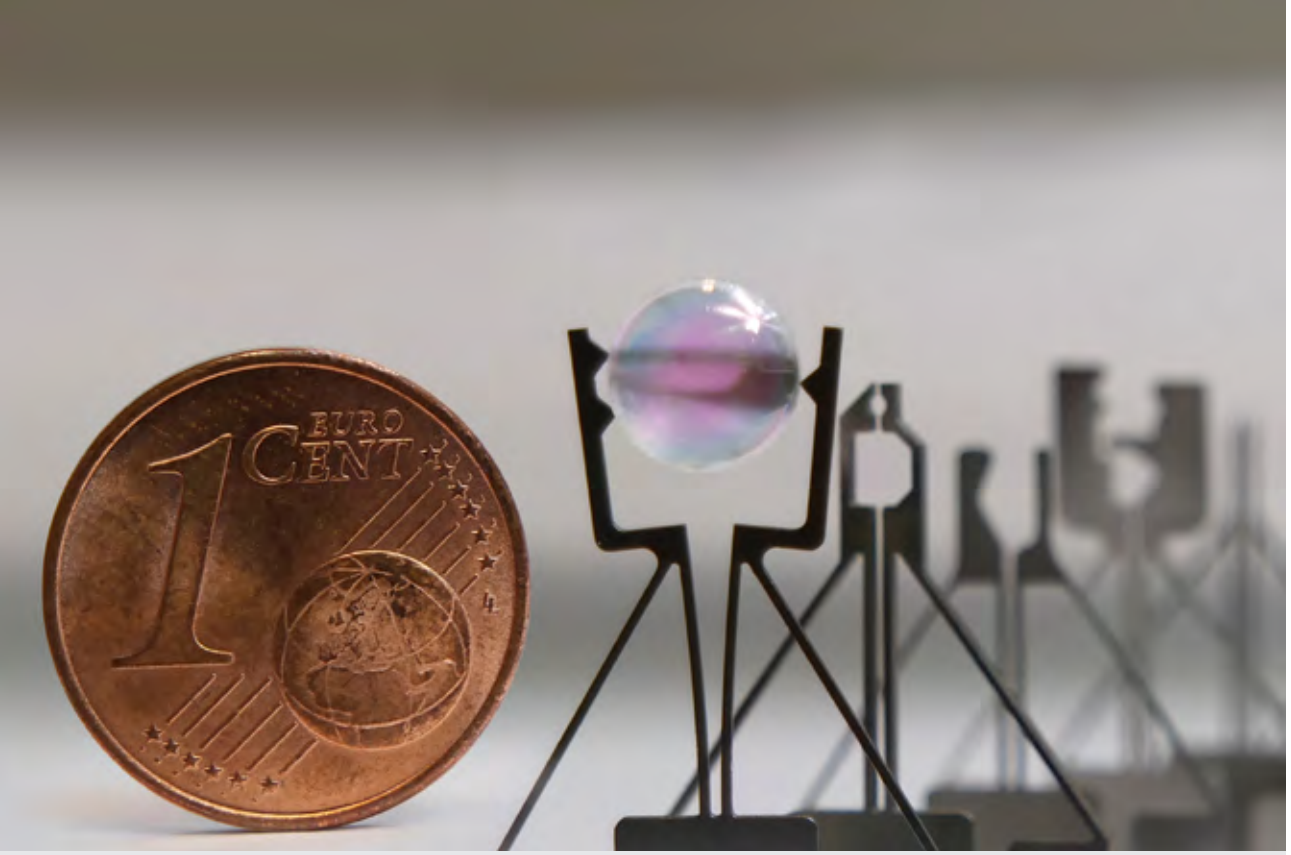
		SHL-3D5N-5
	Degrees of Freedom	3
Mechanical	Travel [mm]	5
	max. Lift Force [N]	5 (in all directions)
	Dimensions [mm], L x W x H	100 x 140 x 40
	Weight [g]	650
Open-loop	Velocity [mm/s]	> 5
	Scan Resolution [nm]	< 1
Closed-Loop	Resolution **MCS**2 [nm]	1 (S) 4 (L)
	Repeatability, Full Stroke, **MCS**2 [nm]	100 (S) 200 (L)
	Resolution (H)CU [nm]	500 (L)
	Repeatability, Full Stroke , (H)CU [nm]	± 1000 (L)
Material Options		Aluminum as standard; steel base (-ST); titanium base (-TI); black anodized (-BK)
Vacuum Options		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)



SHL-5237-1D10N-10 linear stage

		SHL-5237-1D10N-10
	Degrees of Freedom	1
Mechanical	Travel [mm]	10
	max. Lift Force [N]	10
	Dimensions [mm], L x W x H	52 x 52 x 37
	Weight [g]	460
Open-loop	Velocity [mm/s]	> 4
	Scan Resolution [nm]	< 1
Closed-Loop	Resolution **MCS**2 [nm]	1 (S) 4 (L)
	Repeatability, Full Stroke, **MCS**2 [nm]	100 (S) 200 (L)
	Resolution (H)CU [nm]	500 (L)
	Repeatability, Full Stroke , (H)CU [nm]	± 1000 (L)
Material Options		Aluminum as standard; steel base (-ST); titanium base (-TI); black anodized (-BK)
Vacuum Options		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)





SmarAct gripper jaws are available in different designs optimized for specific applications.

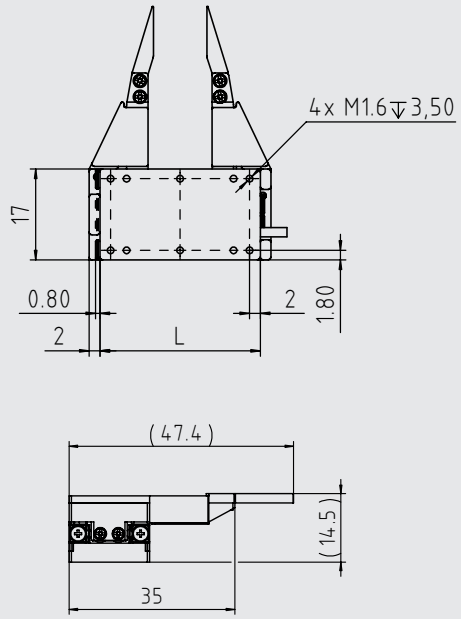
Micro-Grippers
Overview

Precise handling of components, parts and tools at automated opto-electronic assembly lines and sample handling and manipulation in life science are most crucial positioning tasks. To address the growing demand to control tweezers, pincers and grippers with very high precision we have complemented our product portfolio with versatile gripping solutions based on miniaturized positioning stages.

Modularity is one of the key features of our products. All of our grippers consist of a linear piezo stages and a gripping jaw which can be easily exchanged and customized if required. Several different and specialized designs of gripper jaws are available.

When equipped with a position sensor the grippers allow full closed-loop control about the gripping process and the opening of the jaw. In addition, force sensors integrated into our parallel micro-gripper SGP-17F allow to control not only the jaw opening but also the gripping force when handling fragile or highly delicate objects. If your specific application requires a dedicated design, do not hesitate to contact our application specialist to discuss possible solutions or fully customized designs.

SGP-17F Micro-Gripper with force sensors and exchangable jaws.

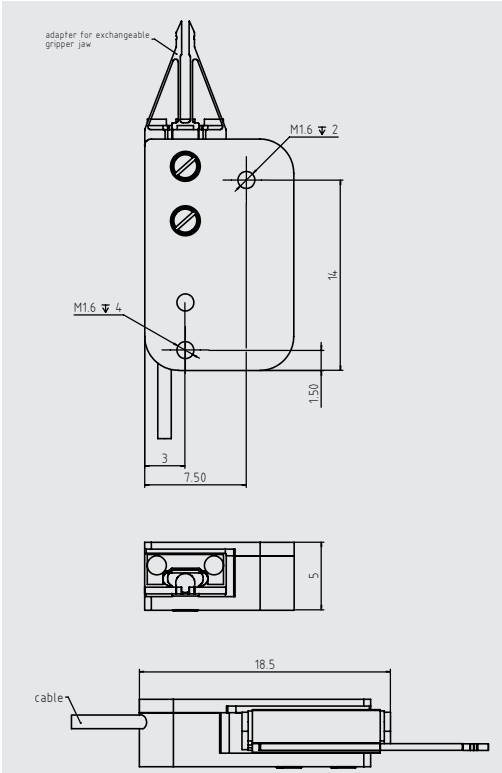


The SGP-17F micro-gripper is the perfect solution when it comes to applications in the field of opto-electronics like the active alignment of optics or sub-components or the parallel gripping of larger objects. Due to the integrated force sensors it doubles as a sensitive force detection system that can be used in a variety of applications as for example in the monitoring of UV-curing processes. The micro-gripper is equipped with one biaxial load cell per jaw, allowing to measure gripping force and orthogonal contact force individually. Gripping force orientation is constant and jaw movement is fully parallel over the whole gripping range. The jaws itself can be easily exchanged, adapted or fully customized to address the requirements of specific applications.
As force and position are measured by individual sensors independently the gripping tool is ideal for handling of lightweight and fragile objects without the risk of damage by applying unnecessary high forces. Utilizing the force feedback signals, collision warning and handling can be implemented via software.

		SGP-17F
Mechanical	Opening [mm]	< 10
	Gripping Force [N]	3,5
	Dimension [mm], L x W x H	30 x 35 x 14
	Weight [g]	40
Closed-loop	Sensor Types	S, L
	Gripping Time [ms]	< 10
	Gripping Resolution [nm]	< 10
Material Options		Aluminum aus standard; black anodized (-BK)

Micro-Grippers
SG-06

SG-06 Micro-Gripper with receptacle for click in place gripper jaws

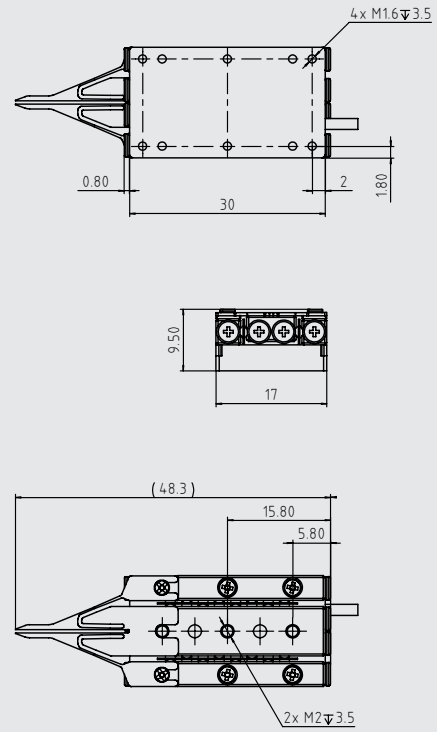


The SG-06 micro-gripper is ideal for space constrained setups and applications where miniaturization is the top priority. Gripper jaws for this product line are exchangeable or permanently fixed to the positioner and can be customized to match your specific requirements. The optionally integrated click-in place system supports easy exchange of the gripper jaws and continues SmarAct's stringent idea of modular and adaptable products.
As the SG-06 gripper is available in a vacuum compatible version it is also the ideal solution for in-vacuo sample handling and transferring tasks.
In combination with linear stages of the SL-06 and SLC-17 product series it can also be seen as one the most compact pick and place robots available.

		SG-06
Mechanical	Opening [mm]	~ 1
	Gripping Force [N]	0.3
	Dimension [mm], L x W x H	11 x 19 x 5
	Weight [g]	2
	Jaws	Exchangeable (-EX)
Closed-loop	Sensor Types	--
	Gripping Time [ms]	100
	Gripping Resolution [nm]	< 100
Material Options		Aluminum as standard; Black anodized (-BK)
Vacuum Options		HV (10^{-6} mbar), UHV / UHVT (10^{-11} mbar)

Micro-Grippers
SG-1730

SG-1730 Micro-Gripper with standard gripper jaw

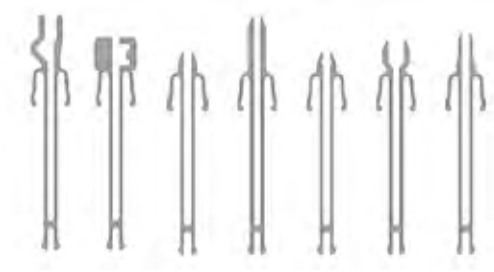


The SG-1730 micro-gripper utilizes the SLC-1730 as its core component. Based on one of SmarAct's most compact linear stages this gripper system became a very compact and versatile tool for pick and place applications for optics and electronics. It can be equipped with different position sensors allowing to control and monitor the gripping process. Moreover, available vacuum compatible variants extend the field of application to pressure ranges down to ultra-high vacuum.
A wide variety of dedicated jaw geometries is available. As the jaws can be easily exchanged the SG-1730 gripping system can be reconfigured on-site to be adapted to different gripping tasks.
Most recently, a quick exchange system for gripper jaws – comparable to the click-in place system of the SG-06 Series – was developed and is available upon request. Customization of the jaw geometry to address specific applications is possible. Please do not hesitate to discuss your requirements with our application scientists to create your very own gripper jaw design.

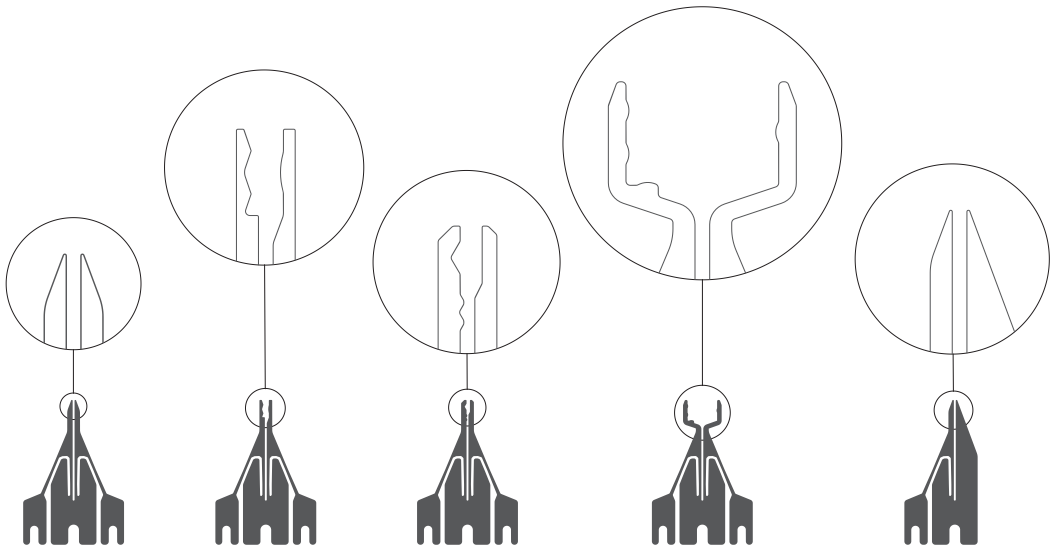
		SG-1730
Mechanical	Opening [mm]	> 1
	Gripping Force [N]	1
	Dimension [mm], L x W x H	17 x 32 x 10
	Weight [g]	25
	Jaws	Exchangeable (-EX)
Closed-loop	Sensor Types	S, L
	Gripping Time [ms]	< 10
	Gripping Resolution [nm]	< 10
Material Options		Aluminum as standard; Black anodized (-BK)
Vacuum Options		HV (10^{-6} mbar), UHV / UHVT (10^{-11} mbar)

Standard Gripper Jaws

For various applications standard gripper jaw geometries are available. Typically, the jaws are made from electrically conductive materials like stainless steel or copper beryllium. Jaw designs have already been produced for all kind of different object shapes like cylindrical, spherical and rectangular as well as dedicated designs to handle optical fibers and lenses and optoelectronic components and devices.



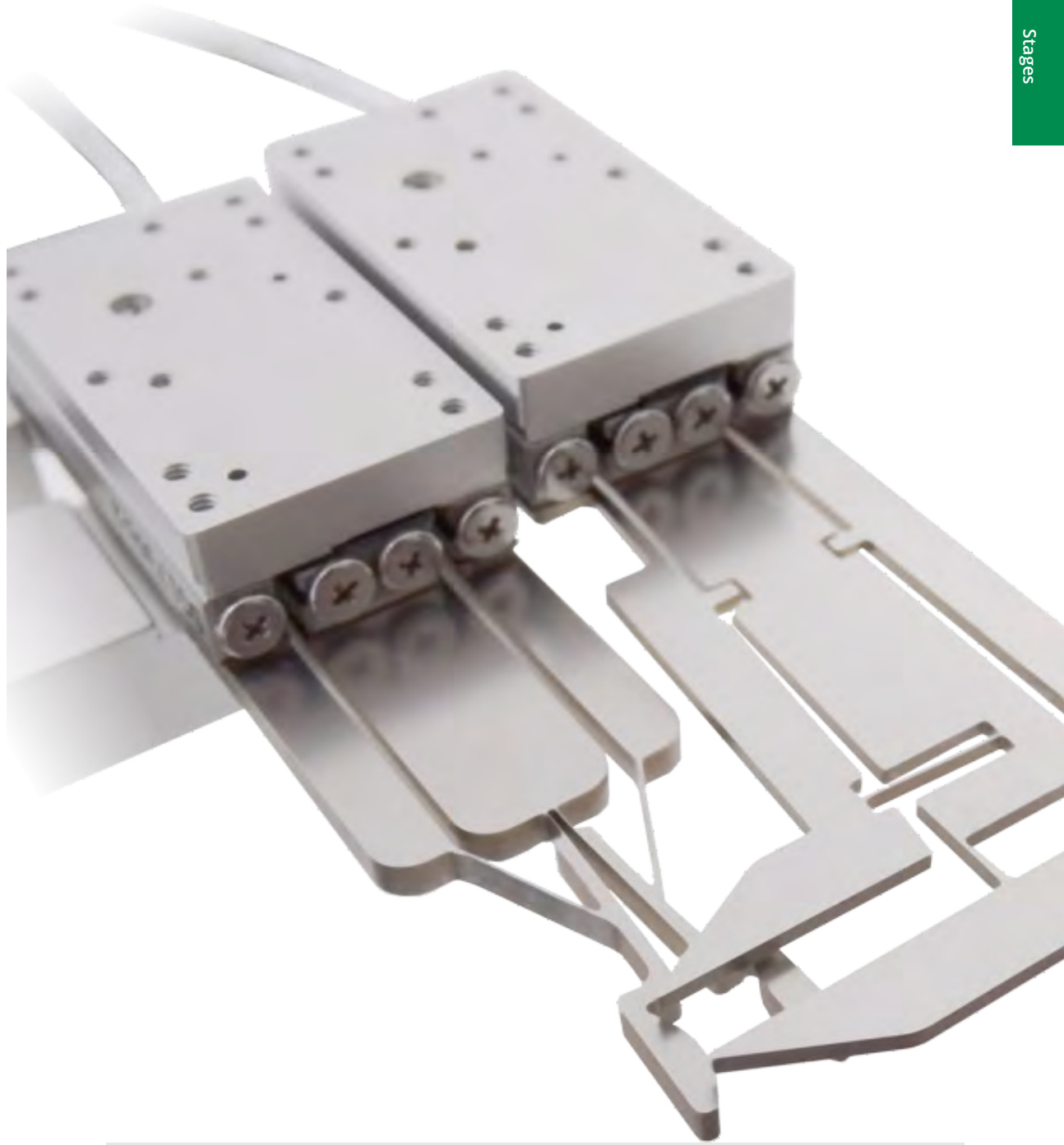
Standard gripper jaws for SG-06-EX (SGH-06-STD)



Standard gripper jaws for SG-1730-EX (SGH-17-STD)

Customized and Bespoken Gripper Jaws

Over the years various jaw shapes have been designed on a bespoken basis like parallel grippers, slit apertures as well as cranked jaws. All designs can be adapted and fully customized to exactly match your specific requirements. Like the standard gripper jaws the customized ones are made of conductive material like stainless steel or copper-beryllium. Other materials, even non-conductive are available upon request.
We are continuously developing and testing new approaches and designs for highly sophisticated handling tasks, for example in the field of micro-manipulation and microassembly. Please feel free to contact us to discuss your application and possible customized designs for your specific requirements.



Customized micro-grippers SG-1730-S-EX used for the aligning of micro-optic components.

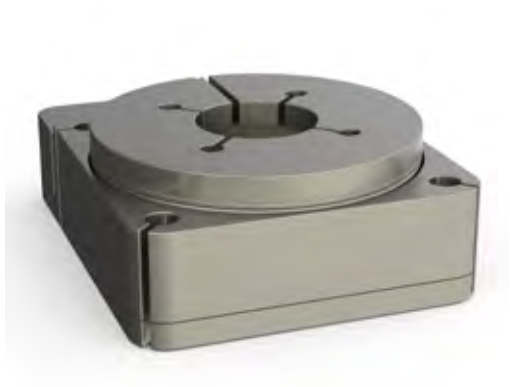
Rotation Stages
SR Series

Based on the SmarAct piezo drive technology rotation stages and platforms are available. They can be easily combined with each other or with our linear piezo stages to form more complex setups like gimbals, rotable Eulerian cradles, multi-axes or multi-rotation positioning systems. SmarAct rotation stages allow for continous and mechanically unlimited rotation. They differ by blocking force, velocity and outer dimensions as well as by the available options when it comes to integrated position sensors and vacuum compatibility.

		SR-1908	SR-2013	SR-2812	SR-3211	SR-4011	SR-4513
Mechanical	Travel [°]	∞					
	Blocking Torque [Ncm]	≥ 0.5	≥ 0.5	≥ 3	≥ 2	≥ 3	≥ 5
	Max. Normal Force [N]	5	3	3	3	10	20
	Dimensions [mm], L x W x H	24.7 x 20 x 8.5	22.5 x 20 x 10.2	37.5 x 30 x 12	32 x 32 x 11	40 x 40 x 11	45 x 45 x 12.5
	Weight [g]	13	11	35	35	60	89
	Aperture [mm]	7	--	9	--	9	8
Open-Loop	Angular Velocity [°/s]	~ 45	~ 45	~ 15	--	~ 15	≥ 15
	Resolution [µ°]	< 3	< 4	< 2	< 4	< 2	
Closed-loop	Sensor Types	--	S		L, S	--	L, S
	Resolution [µm]	--	25			15	
Material Options		--	Aluminum as standard; steel base (-ST); titanium base (-TI);				
Performance Options		--	--	Higher blocking torque			
Vacuum Option		HV (10^{-6} mbar)	HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)			HV (10^{-6} mbar)	
Non-Magnetic Option		--	Yes (-NM)			--	--

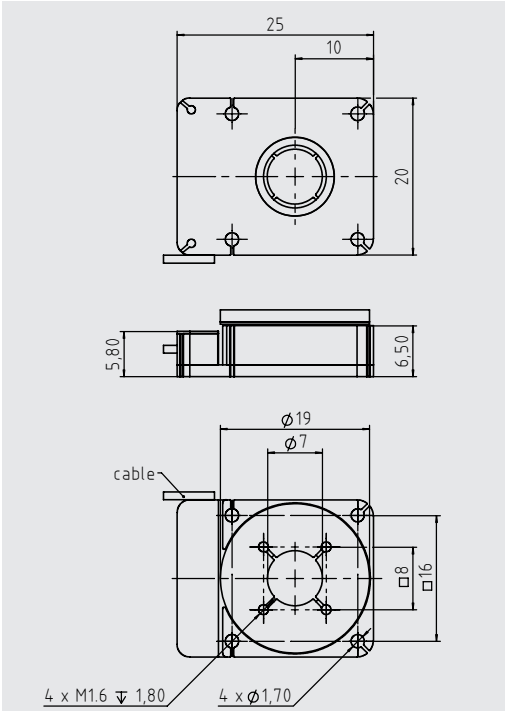
		SR-5014	SR-5714	SR-5714C	SR-7012	SR-9219	SR-9219C	SR-12012
Mechanical	Travel [°]	∞						
	Blocking Torque [Ncm]	≥ 5	≥ 7	≥ 7	≥ 10	≥ 10	≥ 10	≥ 15
	Max. Normal Force [N]	20	25	25	25	25	25	20
	Dimensions [mm], L x W x H	50 x 50 x 14	57 x 57 x 14	57 x 57 x 13.75	70 x 70 x 12	92 x 92 x 19	92 x 92 x 19	120 x 120 x 12
	Weight [g]	100	110	105	100	450	250	320
	Aperture [mm]	8	25	25	30	25	25	82
Open-Loop	Angular Velocity [°/s]	≥15	≥ 9	≥ 9	≥ 9	≥ 9	≥ 9	≥ 5
	Resolution [µ°]	< 2	< 1.5	< 1.5	< 1	< 1	< 1	< 0.5
Closed-loop	Sensor Types	L, S		S	L, S		S	L, S
	Resolution [µm]	15						5
Material Options		Aluminum as standard; steel base (-ST); titanium base (-TI);						
Performance Options		Higher blocking torque						
Vacuum Option		HV (10^{-6} mbar)	HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)	HV (10^{-6} mbar)		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)		HV (10^{-6} mbar)
Non-Magnetic Option		--	Yes (-NM)	--		Yes (-NM)		--

Rotation Stages
SR-1908



SR-1908 Rotation Stage

The SR-1908 is our most compact and cost efficient rotation stage. With its small outer dimensions the stage is a perfect solution for setups with space constraints. The robust stainless steel bearing together with an aperture opening of 7 mm enables a broad range of possible applications.

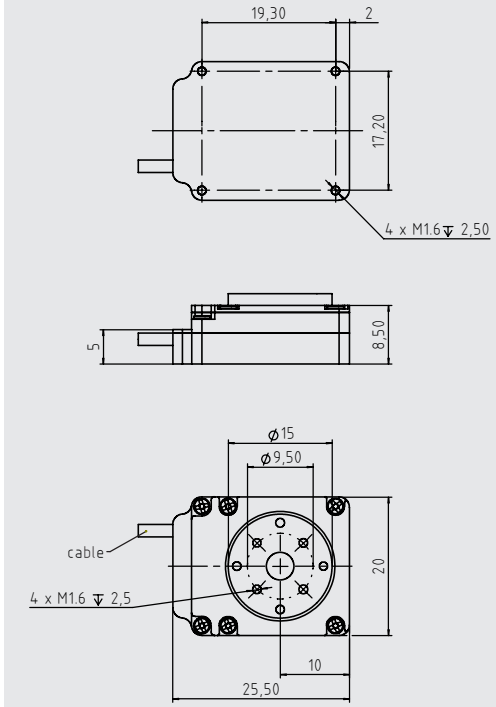


		SR-1908
Mechanical	Travel [°]	∞
	Blocking Torque [Ncm]	≥ 0.5
	Max. Normal Force [N]	5
	Dimensions [mm], L x W x H	24.7 x 20 x 8.5
	Weight [g]	13
	Aperture [mm]	7
Open-Loop	Angular Velocity [°/s]	~ 45
	Resolution [µ°]	< 3
Closed-loop	Sensor Types	--
	Resolution [µm]	--
Material Options		Steel as standard
Performance Options		--
Vacuum Option		HV (10^{-6} mbar)
Non-Magnetic Option		--

Rotation Stages
SR-2013

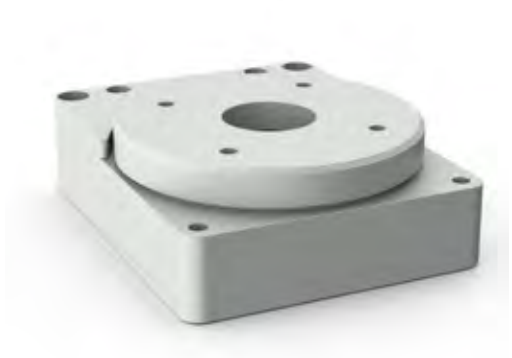
SR-2013 Rotation Stage

The SR-2013 is our lightest and smallest closed-loop rotation stage. A tailored, backlash-free ceramic bearing leads to a very high accuracy and an extremely low radial runout.
It is also available with different options like ultra-high vacuum compatibility or as a fully non-magnetic version



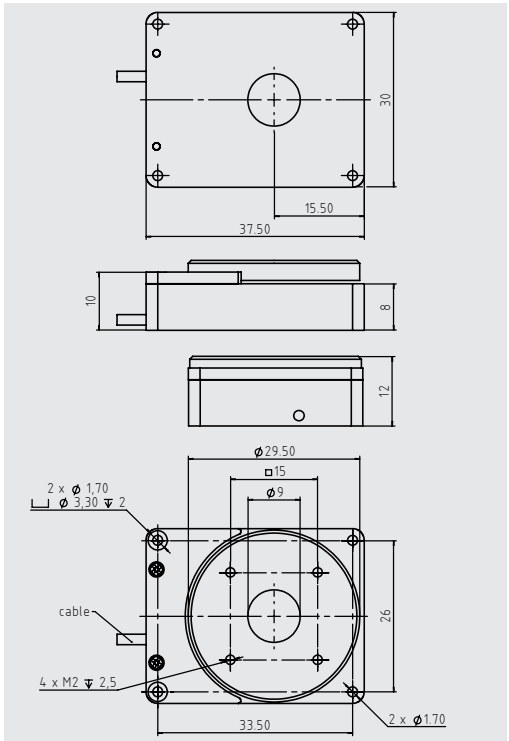
		SR-2013
Mechanical	Travel [°]	∞
	Blocking Torque [Ncm]	≥ 0.5
	Max. Normal Force [N]	3
	Dimensions [mm], L x W x H	22.5 x 20 x 10.2
	Weight [g]	11
	Aperture [mm]	--
Open-Loop	Angular Velocity [°/s]	~ 45
	Resolution [µ°]	< 4
Closed-loop	Sensor Types	S
	Resolution [µm]	25
Material Options		Aluminim as standard; steel-base (ST); titanium base (-TI)
Performance Options		--
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)
Non-Magnetic Option		Yes (-NM)

Rotation Stages
SR-2812



SR-2812 Rotation Stage

The SR-2812 is the smallest closed-loop rotation stage with an aperture opening of 9 mm. A tailored, backlash-free ceramic bearing leads to a very high accuracy and an extremely low radial runout. This stage is available with different options like ultra-high vacuum compatibility or as a fully non-magnetic version.

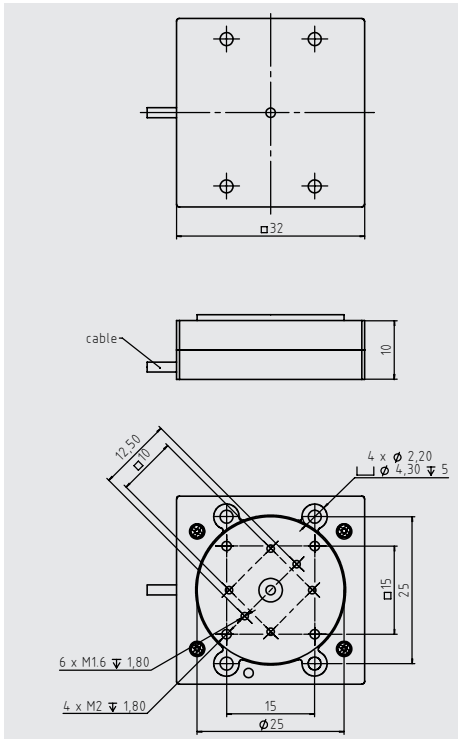


		SR-2812
Mechanical	Travel [°]	∞
	Blocking Torque [Ncm]	≥ 3
	Max. Normal Force [N]	3
	Dimensions [mm], L x W x H	37.5 x 30 x 12
	Weight [g]	35
	Aperture [mm]	9
Open-Loop	Angular Velocity [°/s]	~ 15
	Resolution [µ°]	< 2
Closed-loop	Sensor Types	S
	Resolution [µm]	25
Material Options		Aluminum as standard: Steel-base (-ST); titanium base (-TI)
Performance Options		Higher blocking torque
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)
Non-Magnetic Option		Yes (-NM)

Rotation Stages
SR-3211

SR-3211 Rotation Stage

The SR-3211 rotation stage is designed to be easily mounted onto linear piezo stages of the SLS Series. It is also available with different options like ultra-high vacuum compatibility or as a fully non-magnetic version.

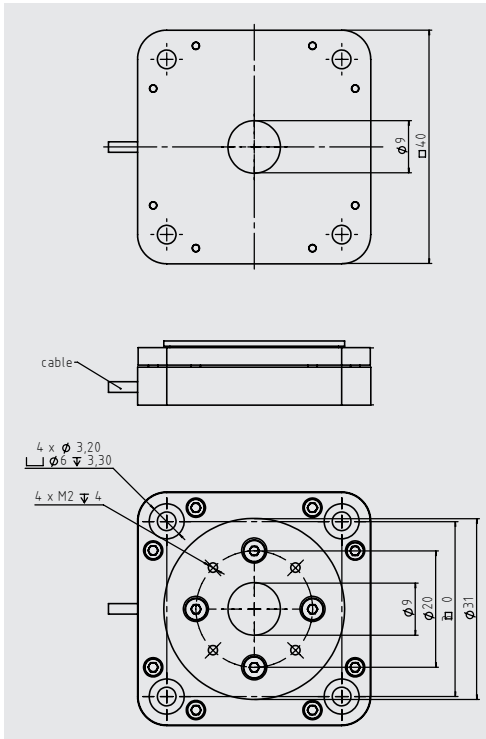


		SR-3211
Mechanical	Travel [°]	∞
	Blocking Torque [Ncm]	≥ 2
	Max. Normal Force [N]	3
	Dimensions [mm], L x W x H	32 x 32 x 11
	Weight [g]	35
	Aperture [mm]	--
Open-Loop	Angular Velocity [°/s]	--
	Resolution [µ°]	< 4
Closed-loop	Sensor Types	L, S
	Resolution [µm]	25
Material Options		Aluminum as standard: Steel-base (-ST); titanium base (-TI)
Performance Options		Higher blocking torque
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)
Non-Magnetic Option		Yes (-NM)

Rotation Stages
SR-4011

SR-4011 Rotation Stage

The SR-4011 rotation stage has a square base and exhibits a free aperture opening of 9 mm in diameter. It is also available in a high vacuum compatible version.

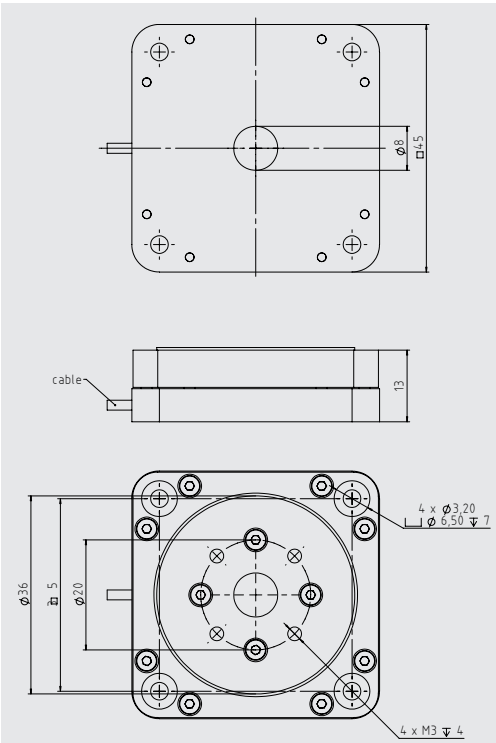


		SR-4011
Mechanical	Travel [°]	∞
	Blocking Torque [Ncm]	≥ 3
	Max. Normal Force [N]	10
	Dimensions [mm], L x W x H	40 x 40 x 11
	Weight [g]	60
	Aperture [mm]	9
Open-Loop	Angular Velocity [°/s]	~ 15
	Resolution [µ°]	< 2
Closed-loop	Sensor Types	--
	Resolution [µm]	15
Material Options		Aluminum as standard: Steel-base (-ST); titanium base (-TI)
Performance Options		Higher blocking torque
Vacuum Option		HV (10^{-6} mbar)
Non-Magnetic Option		--

Rotation Stages
SR-4513

SR-4513 Rotation Stage

The SR-4513 rotation stage has a square base and exhibits a free aperture opening of 8 mm in diameter. Compared to its footprint its height is relatively low, making this stage an excellent choice for integration into flat positioning systems. It is also available in a high vacuum compatible version.

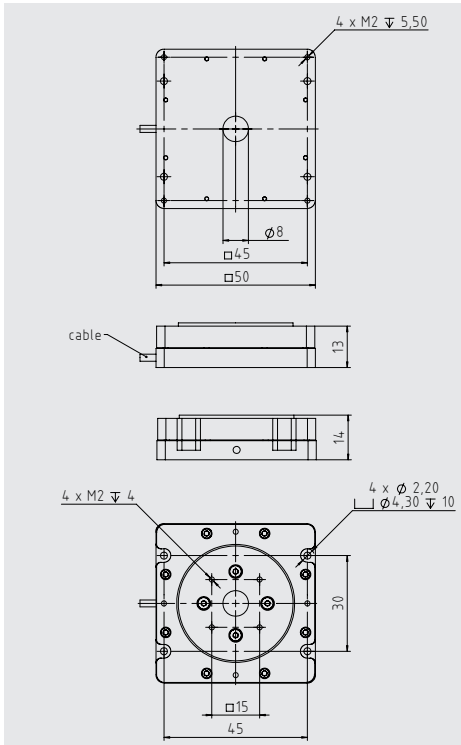


		SR-4513
Mechanical	Travel [°]	∞
	Blocking Torque [Ncm]	≥ 5
	Max. Normal Force [N]	20
	Dimensions [mm], L x W x H	45 x 45 x 13.5
	Weight [g]	89
	Aperture [mm]	8
Open-Loop	Angular Velocity [°/s]	≥ 15
	Resolution [µ°]	< 2
Closed-loop	Sensor Types	L, S
	Resolution [µm]	15
Material Options		Aluminum as standard: Steel-base (-ST); titanium base (-TI)
Performance Options		Higher blocking torque
Vacuum Option		HV (10^{-6} mbar)
Non-Magnetic Option		--

Rotation Stages
SR-5014

SR-5014 Rotation Stage

The SR-5014 rotation stage was designed with the compatibility to SmarAct's SLS Series in mind allowing them to be easily mounted to linear stages of this Series and to goniometer stages of the SGO Series.

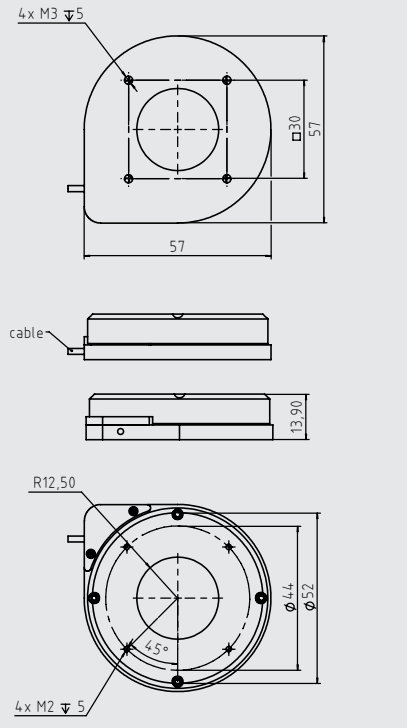


		SR-5014
Mechanical	Travel [°]	∞
	Blocking Torque [Ncm]	≥ 5
	Max. Normal Force [N]	20
	Dimensions [mm], L x W x H	50 x 50 x 14
	Weight [g]	100
	Aperture [mm]	8
Open-Loop	Angular Velocity [°/s]	≥15
	Resolution [µ°]	< 2
Closed-loop	Sensor Types	L, S
	Resolution [µm]	15
Material Options		Aluminum as standard: Steel-base (-ST); titanium base (-TI)
Performance Options		Higher blocking torque
Vacuum Option		HV (10^{-6} mbar)
Non-Magnetic Option		--

Rotation Stages
SR-5714

SR-5714 Rotation Stage

Despite its compactness the SR-5714 was designed to offer a large aperture of 25 mm in diameter. Its robustness makes it the perfect solution for a broad range of applications.

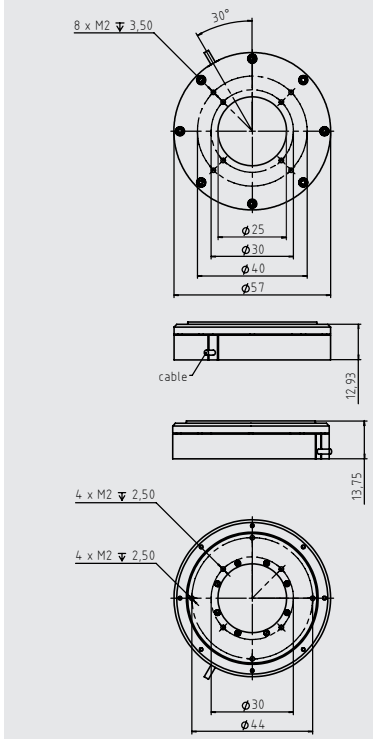


		SR-5714
Mechanical	Travel [°]	∞
	Blocking Torque [Ncm]	≥ 7
	Max. Normal Force [N]	25
	Dimensions [mm], L x W x H	57 x 57 x 14
	Weight [g]	110
	Aperture [mm]	25
Open-Loop	Angular Velocity [°/s]	≥ 9
	Resolution [µ°]	< 1.5
Closed-loop	Sensor Types	L, S
	Resolution [µm]	15
Material Options		Aluminum as standard: Steel-base (-ST); titanium base (-TI)
Performance Options		Higher blocking torque
Vacuum Option		HV (10^{-6} mbar)
Non-Magnetic Option		--

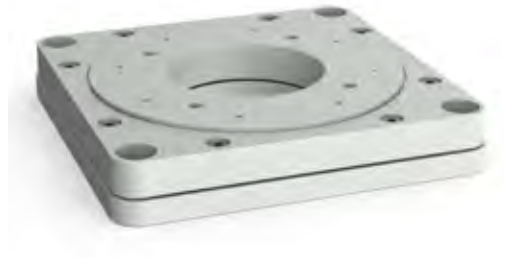
Rotation Stages
SR-5714C

SR-5712C Rotation Stage

The SR-5714C is equipped with a ceramic bearing while exhibiting the same aperture opening of the SR-5714 of 25 mm. It is available in an ultra-high vacuum compatible and non-magnetic version and is the right solution if robustness and the applicability in harsh environments is top priority.

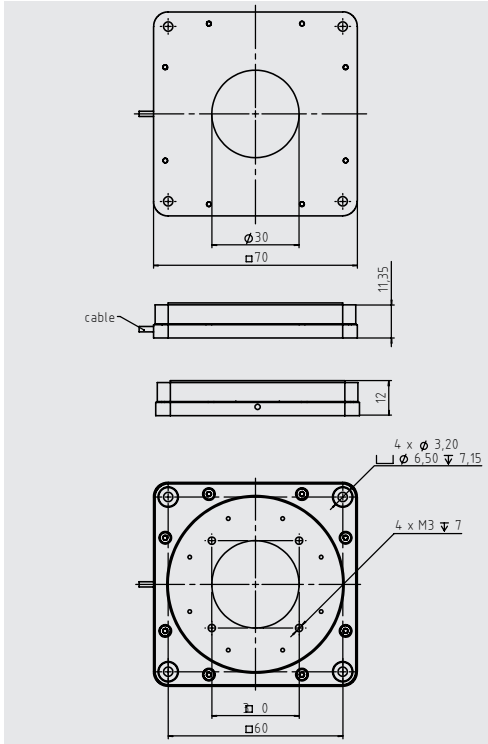


		SR-5714C
Mechanical	Travel [°]	∞
	Blocking Torque [Ncm]	≥ 7
	Max. Normal Force [N]	25
	Dimensions [mm], L x W x H	57 x 57 x 13.75
	Weight [g]	105
	Aperture [mm]	25
Open-Loop	Angular Velocity [°/s]	≥ 9
	Resolution [µ°]	< 1.5
Closed-loop	Sensor Types	S
	Resolution [µm]	15
Material Options		Aluminum as standard: Steel-base (-ST); titanium base (-TI)
Performance Options		Higher blocking torque
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)
Non-Magnetic Option		Yes (-NM)



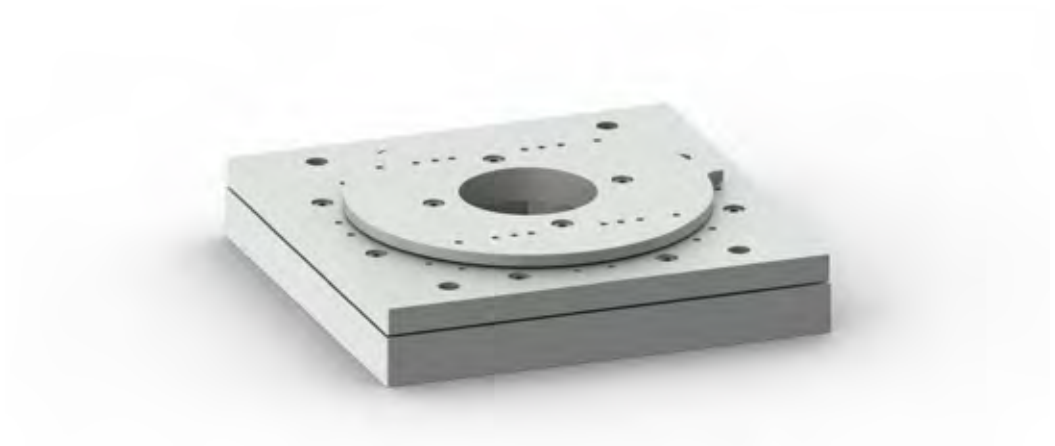
SR-7012 Rotation Stage

With its square base, its rotation platform diameter of 60 mm and a free aperture opening of 30 mm the rotation stage SR-7012 is very versatile. Because of its low height of only 12 mm and its overall ruggedness it can be used to carry bigger and heavier positioning setups



		SR-7012
Mechanical	Travel [°]	∞
	Blocking Torque [Ncm]	≥ 10
	Max. Normal Force [N]	25
	Dimensions [mm], L x W x H	70 x 70 x 12
	Weight [g]	100
	Aperture [mm]	30
Open-Loop	Angular Velocity [°/s]	≥ 9
	Resolution [µ°]	< 1
Closed-loop	Sensor Types	L, S
	Resolution [µm]	15
Material Options		Aluminum as standard: Steel-base (-ST); titanium base (-TI)
Performance Options		Higher blocking torque
Vacuum Option		HV (10^{-6} mbar)
Non-Magnetic Option		--

Rotation Stages
SR-9219

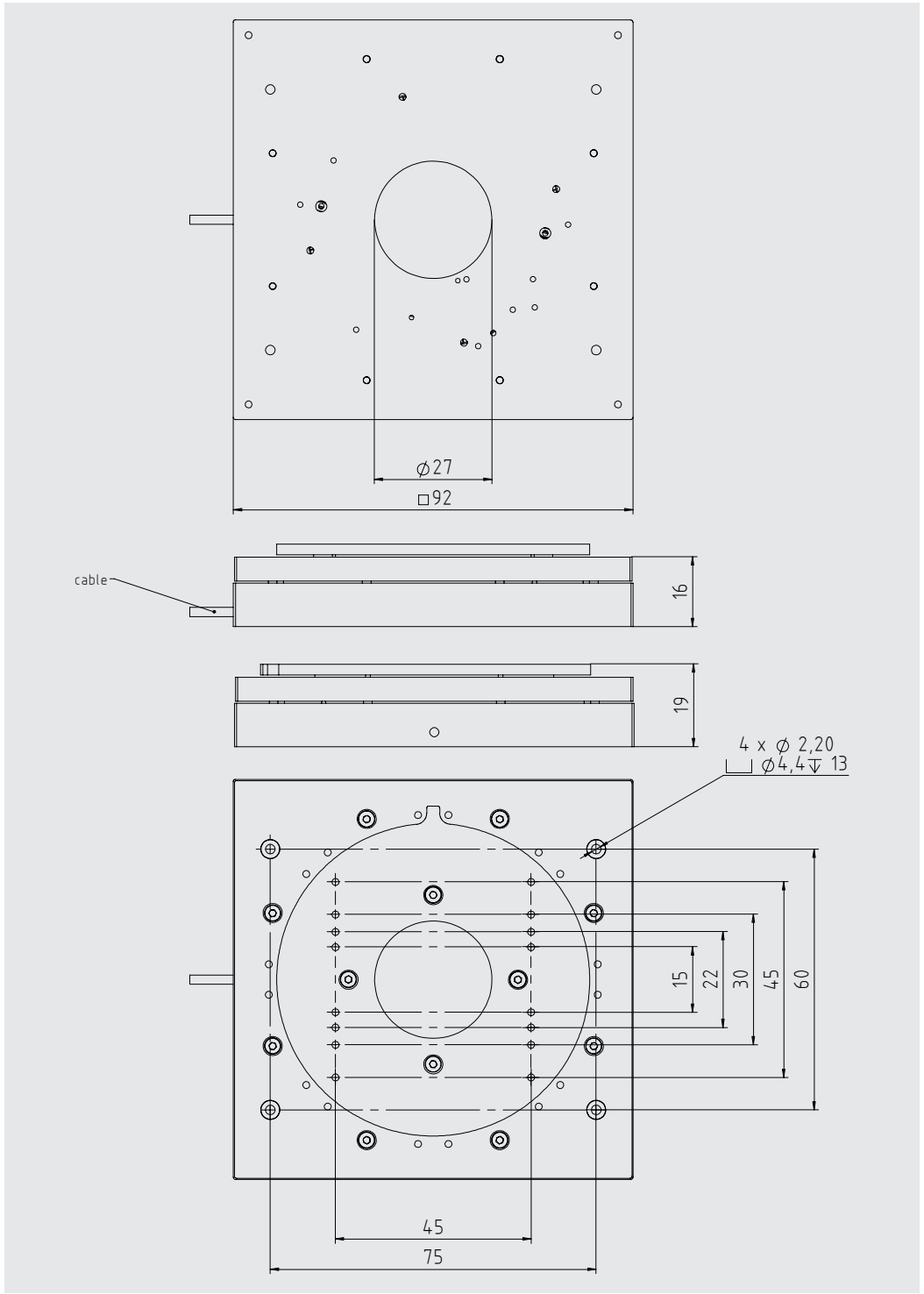


Rotation Stage SR-9219 (C)

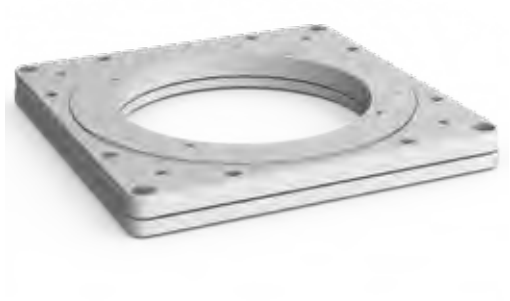
The SR-9219 rotation stage was designed with the compatibility to SmarAct's SLS Series in mind allowing it to be easily mounted to linear piezo stages of this series.

The SR-9219C stage is equipped with a ceramic bearing offering full ultra-high vacuum compatibility. Beside the vacuum compatibility versions made of non-magnetic materials are also possible.
Its outer dimensions and its mounting hole pattern allows this rotation stage to be directly mounted onto SLS-92 Series linear stages.

		SR-9219	SR-9219C
Mechanical	Travel [°]	∞	∞
	Blocking Torque [Ncm]	≥ 10	≥ 10
	Max. Normal Force [N]	25	25
	Dimensions [mm], L x W x H	92 x 92 x 19	92 x 92 x 19
	Weight [g]	450	250
	Aperture [mm]	25	25
Open-Loop	Angular Velocity [°/s]	≥ 9	≥ 9
	Resolution [µ°]	< 1	< 1
Closed-loop	Sensor Types	L,S	S
	Resolution [µm]	15	15
Material Options		Aluminum as standard: Steel-base (-ST); titanium base (-TI)	Aluminum as standard: Steel-base (-ST); titanium base (-TI)
Performance Options		Higher blocking torque	Higher blocking torque
Vacuum Option		HV (10^{-6} mbar)	HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)
Non-Magnetic Option			Yes (-NM)

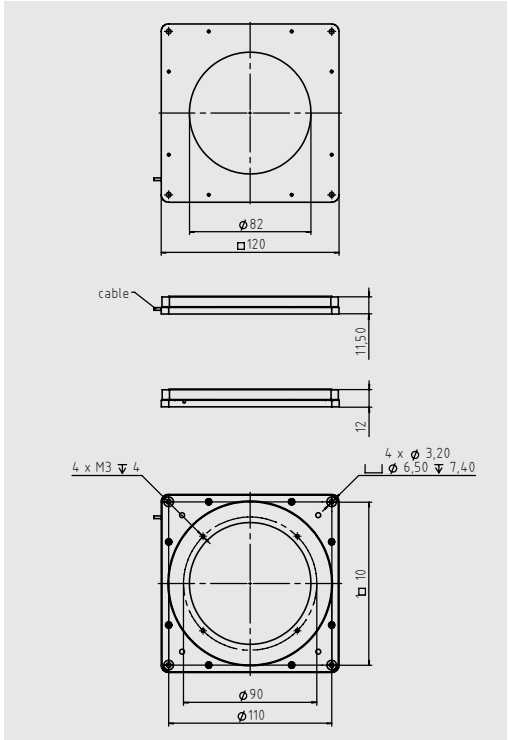


Rotation Stages
SR-12012



SR-12012 Rotation Stage

With its 120 x 120 mm footprint the SR-12012 rotation stage offers an aperture opening of 82 mm while maintaining a low profile with a height of only 12 mm. This stage is mostly chosen for applications where a big aperture and highest precision is absolutely essential.

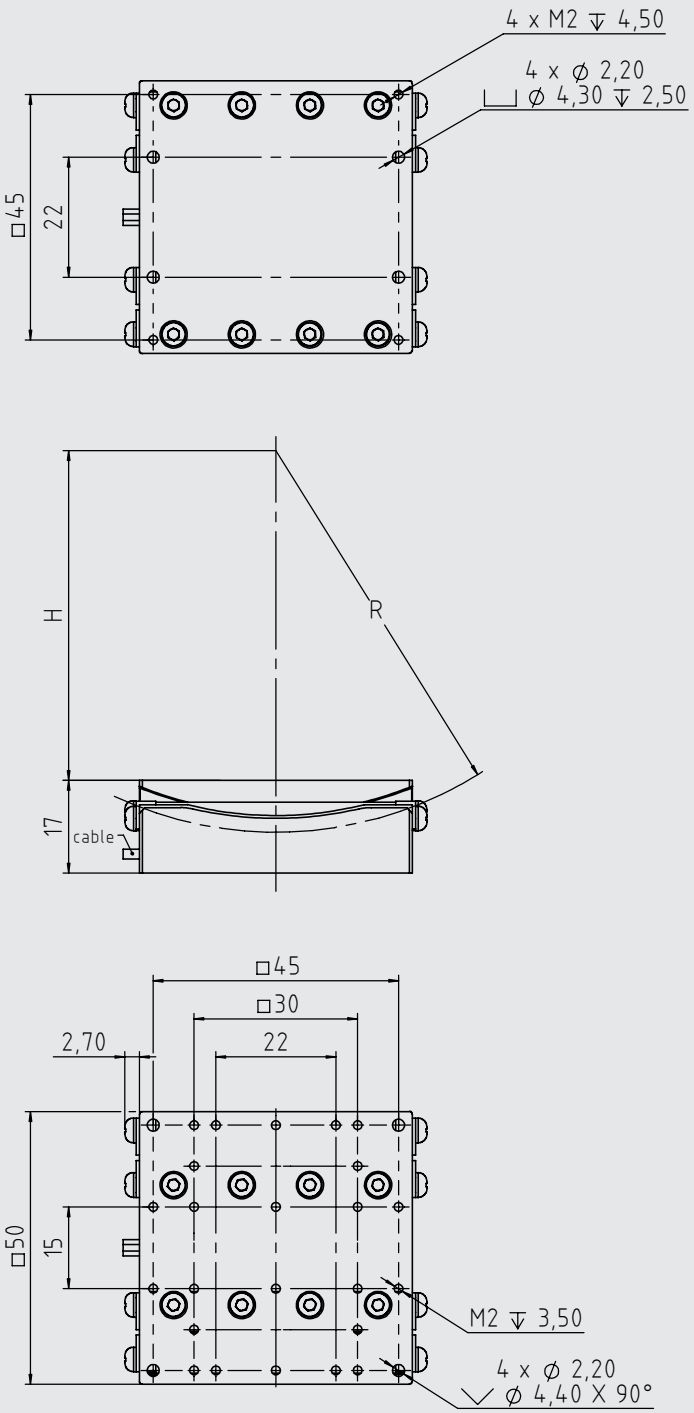


		SR-12012
Mechanical	Travel [°]	∞
	Blocking Torque [Ncm]	≥ 15
	Max. Normal Force [N]	20
	Dimensions [mm], L x W x H	120 x 120 x 12
	Weight [g]	320
	Aperture [mm]	82
Open-Loop	Angular Velocity [°/s]	≥ 5
	Resolution [µ°]	< 0.5
Closed-loop	Sensor Types	L, S
	Resolution [µm]	5
Material Options		Aluminum as standard: Steel-base (-ST); titanium base (-TI)
Performance Options		Higher blocking torque
Vacuum Option		HV (10^{-6} mbar)
Non-Magnetic Option		--

SGO Goniometer Stage

All piezoelectric goniometer stages are based on SmarAct piezo drive technology. Goniometer stages are available with different radii. In addition to their compactness, these stages are very rigid and therefore ideally suited for micro- or nanopositioning tasks.
Due to the usage of high precision crossed roller bearings their angular accuracy is very high.
The goniometer stages offer highest resolution of motion and are directly stackable. By combining two stages with appropriate radii it is possible to build a compact Euler goniometer with a common center of rotation.
Their mechanical interface perfectly fits to the SLS-52 Series stages. Thus, allowing the creation of multi-axis systems by direct combination of linear, rotation and goniometer stages.
The SmarAct goniometer stages can be operated by any of our control units and are also available with integrated positioning sensors. Furthermore, the SGO Series goniometer stages are available for different environmental conditions, such as high vacuum and ultra-high vacuum environments.

		SGO-60.5	SGO-77.5	SGO-93.5
Mechanical	Travel [°]	± 5		
	Blocking Torque [Ncm]	20		
	Lateral Torque [Nm]	1.2		
	Max. Normal Force [N]	5		
	Dimensions [mm], L x W x H	50 x 50 x 17		
	Weight [g]	~ 140		
	Center of Rotation [mm]	60.5	77.5	93.5
Open-Loop	Velocity [°/s]	4		
	Resolution [µrad]	0.01		
Closed-loop	Sensor Types	S, L (with mechanical end stop)		
	Resolution [µrad]	0.03 (S) 0.12 (L)		
	Repeatability, Full Stroke **MCS**2 [µrad]	0.12 (S)		
Material Options		Aluminum as standard; steel base (-ST); titanium base (-TI)		
Performance Option		Higher blocking force (D): +1.5 N		
Vacuum Compatibility		HV (10^{-6} mbar), UHV / UHVT (10^{-11} mbar)		



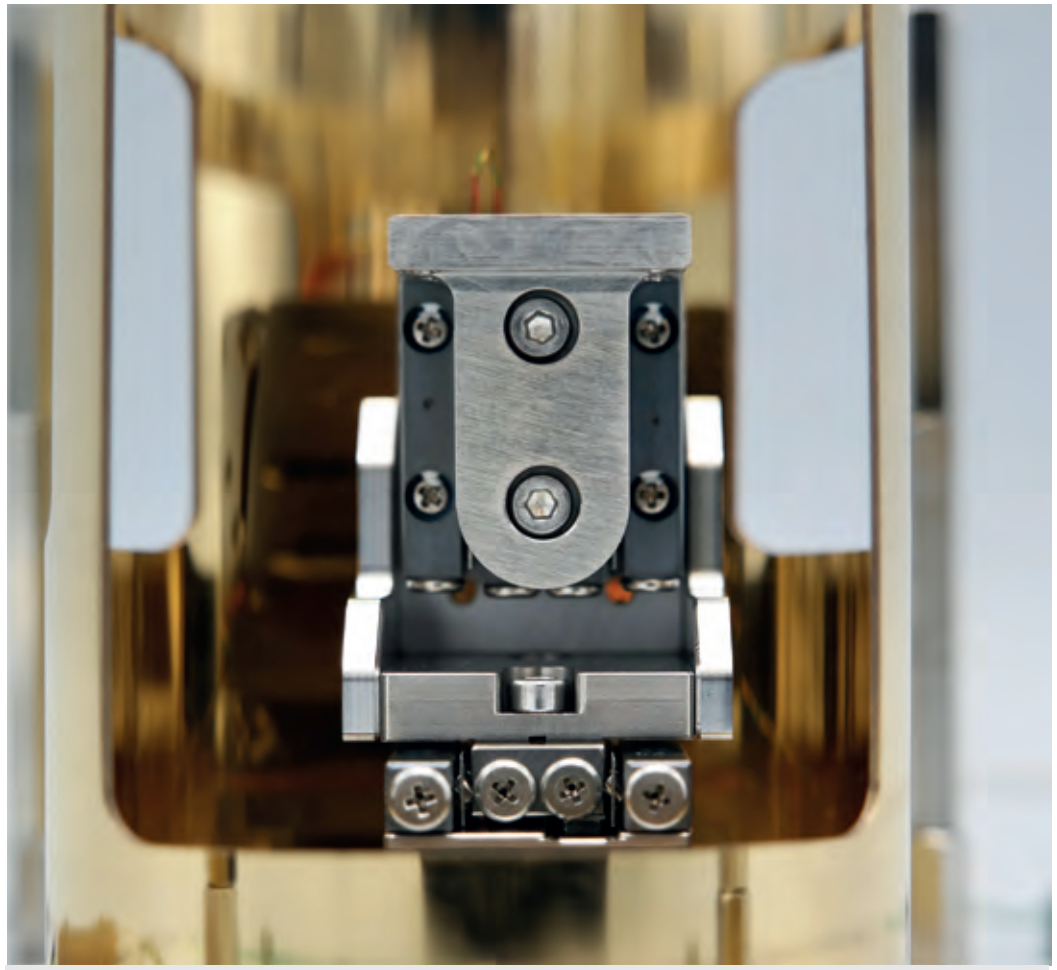
Environment-Specific Stages
Introduction

SmarAct stages are designed for a wide variety of applications in industry and science.
The standard version of our stages are suitable to operate under normal conditions, at room temperature and at atmospheric pressure.
For applications that require rather extreme operating conditions like cryogenic temperatures, vacuum conditions or high magnetic fields, we have developed and optimized specialized versions of our stages. The specialization includes for example the use of specific materials, different cabling and different production processes but normally do not change the outer dimensions of the stage itself.

If you are unsure whether or not your application requires specialized versions of SmarAct stages, please do not hesitate to contact our applications specialist to discuss the specific environmental constrains of your setup.

Two miniaturized XY stages mounted to a ConFlat flange (DN100CF, 6.00 inch OD) with UHV compatible cabling and connectors.

Environment-Specific Stages
Cryogenic Stages



Optimized for confined spaces. A three axes cryo positioning system inside of cryostat's heat shield.

SmarAct stages are designed for different, sometimes extreme, conditions ranging from atmospheric to ultra-high vacuum conditions.
Many applications in industrial and medical research as well as in fundamental research require cryogenic temperatures often well below ten Kelvin. Additionally, in many cases it is not only necessary to cool the samples but also to mechanically manipulate them precisely within the cryostat.
We have developed stick-slip piezo actuators with low-heat profiles and ultra-high vacuum compatibility which allow sample manipulation in temperatures down to the mK regime. Resistive cabling (based on phosphor bronze) is optionally available to reduce the heat load on the positioning stages.
Additionally, they can be used at temperatures of up to 330 K like our standard UHV positioners. Furthermore, they are bakeable at temperatures of up to +150 °C.
For the use in high magnetic fields at cryogenic temperatures non-magnetic versions are available.
SmarAct's cryogenic stages can be easily assembled into complete positioning systems including thermalization management and customization to your specific application.

Linear Cryogenic Stages

The linear cryogenic stages are specialized versions of SLC Series stages. They completely retain the compact design of the room temperature versions and are therefore ideally suited for limited spaces typically found in heat shields of cryostats. We use titanium for the base of the stages and solid-state coating as dry lubricants for our high precision bearings. Titatnium was selected as the perfect material for the base of the stage as it matches the thermal properties of the bearing material, thus preventing mechanical stress during cooling and heating cycles. Accordingly, it ensures long lifetime in cryogenic and ultra-high vacuum conditions.

In comparison to standard SLC Series stages the bases of linear cryo stages are made of Titanium.

		SLC-1720	SLC-1730	SLC-1740	SLC-1750	SLC-1760	SLC-2430	SLC-2445	SLC-2460
Mechanical	Travel [mm]	6	21	26	31	41	16	29	35
	Blocking Force [N]	≥ 2							
	max. Normal Force [N]	20	30						
	max. Lift Force [N]	< 1							
	Dimensions [mm]. L x W x H	22 x 17 x 8.5	30 x 17 x 8.5	40 x 17 x 8.5	50 x 17 x 8.5	60 x 17 x 8.5	30 x 24 x 10.5	45 x 24 x 10.5	60 x 24 x 10.5
	Weight [g]	13	20	26	32	38	36	54	72
Open-Loop	Velocity [mm/s]	up to 20							
	Resolution [nm]	< 1							
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)							
Non-Magnetic Option		Yes (-NM)							

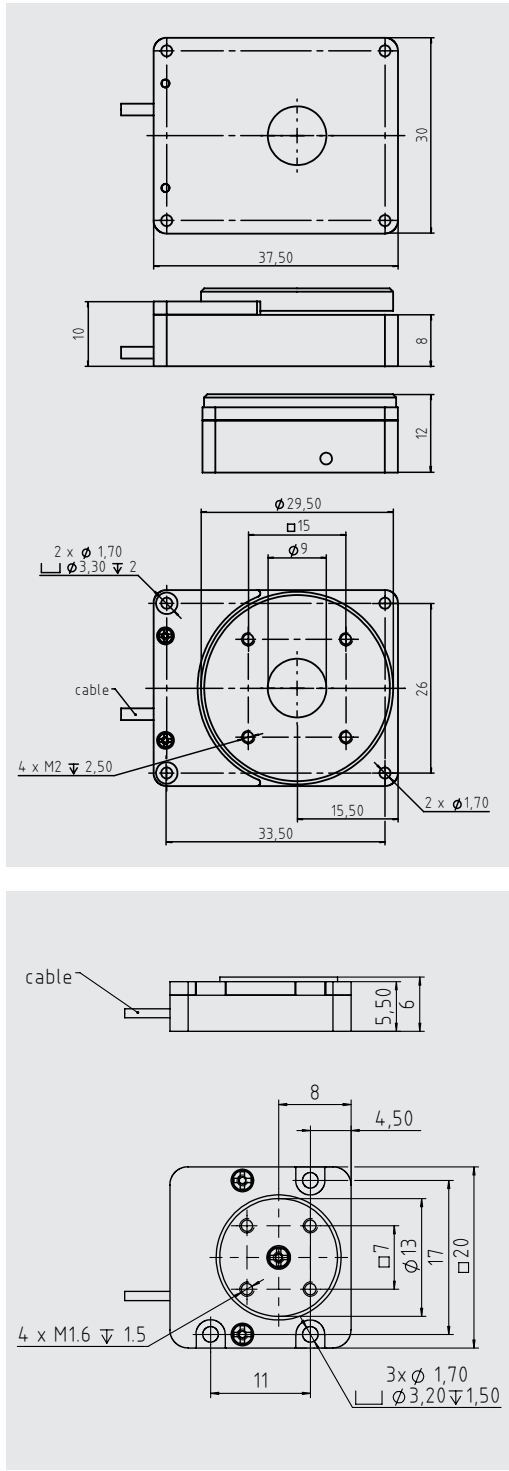
For technical drawing please refer to page 18 and following.

A rotation cryo stage mounted on top of a three axes cryo positioning system.

Rotation Cryogenic Stages

Recently, we have extended our cryogenic product portfolio with rotation stages. With this addition more complex setups that combine linear and rotational sample manipulation in cryogenic temperatures are possible. Their size perfectly matches multi-axis setups consisting of cryogenic versions of SLC-17 and SLC-24 stages.

		SRT-2006	SR-2812
Mechanical	Blocking Torque [Ncm]	≥ 0.5	≥ 1
	Max. Normal Force [N]	0.5	2
	Dimensions [mm]	24.7 x 20 x 6	37.5 x 30 x 12
	Travel [°]	∞	
Open-loop	Resolution [µ°]	< 4	
	Angular Velocity [°/s]	≥ 10	≥ 5
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)	
Non-Magnetic Option		Yes (-NM)	



Vacuum Environment

SmarAct stages are not only the perfect match for applications in ambient conditions but also for more extreme environments like high vacuum (HV, 10^{-6} mbar) and ultra-high vacuum (UHV, (10^{-11} mbar). Most of the stages presented in this catalog are available in versions especially prepared to be able to operate in vacuum conditions. UHV versions are bakeable at up to 130 °C (recommended, 150 °C maximum) and are available with two different cable types:

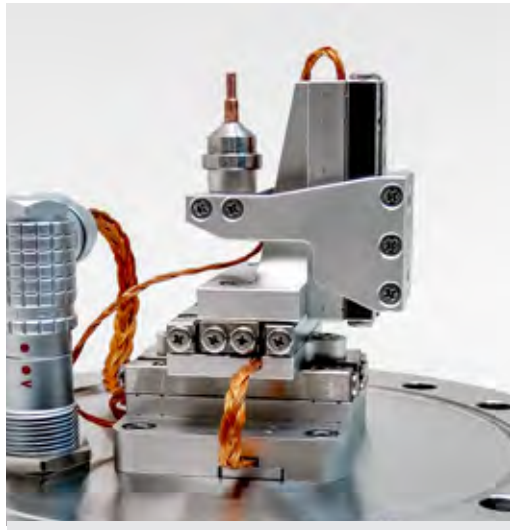
- The cost efficient version utilizes Teflon® insulated wires.
- The Kapton® insulated version is a fluorine free solution.

As SmarAct is a full solution provider HV and UHV positioning systems come with suitable electrical feedthroughs. As a standard we use:

- HV as bulkhead LEMO® feedthroughs which are O-ring sealed.
- UHV tight welded versions for the usage in ultra-high vacuum.

To discuss your specific requirements please do not hesitate to contact our application scientists.

For vacuum compatible stages of the SLC-17 and SLC-24 Series that will have to be baked after installation we strongly recommend to also opt for the U-shaped base to increase the overall stiffness of the stage.



UHV compatible positioning system with Kapton insulated cabling and LEMO multipin feedthrough on DN100CF flange.

Please note that the U-shaped base resembles the same mounting hole pattern but adds 6 mm to the width of the stage itself. As a result the width of a SLC-17 stage enlarges to 23 mm and the width of a SLC-24 stage to 30 mm, respectively (see page 20 and 24 for details). Thus, waiving the U-shaped base option is only advisable if compactness is the top most requirement.

	Atmospheric Conditions	High Vacuum (HV)	Ultra-High Vacuum (UHV)	Ultra-High Vacuum (UHVT)
Pressure		Down to 10^{-6} mbar	Down to 10^{-11} mbar	
Wiring	Teflon® - insulated stranded wires with braided shield and Teflon® coating	Teflon® - insulated stranded wires with braided shield	Kapton® - insulated stranded wires	Teflon® - insulated stranded wires with braided shield
Grease	Standard grease	HV compatible grease	Grease-free, ceramic-coated guideways	
Sensor Options	S, L, I	S, I	S	
$T_{Bake-Out}$	--	Up to 130°C upon request	Recommended 130°C (max. 150° C)	
Vacuum Feedthrough	--	LEMO® feedthroughs • O-ring tightened by a screw nut • Flanges available upon request • Electronics outside the vacuum chamber	LEMO® compatible steel multipin or D-SUB15 PEEK feedthroughs welded into vacuum flange • DN40CF or DN63CF flange, other sizes upon request • Electronics outside the vacuum chamber	

Magnetic Fields

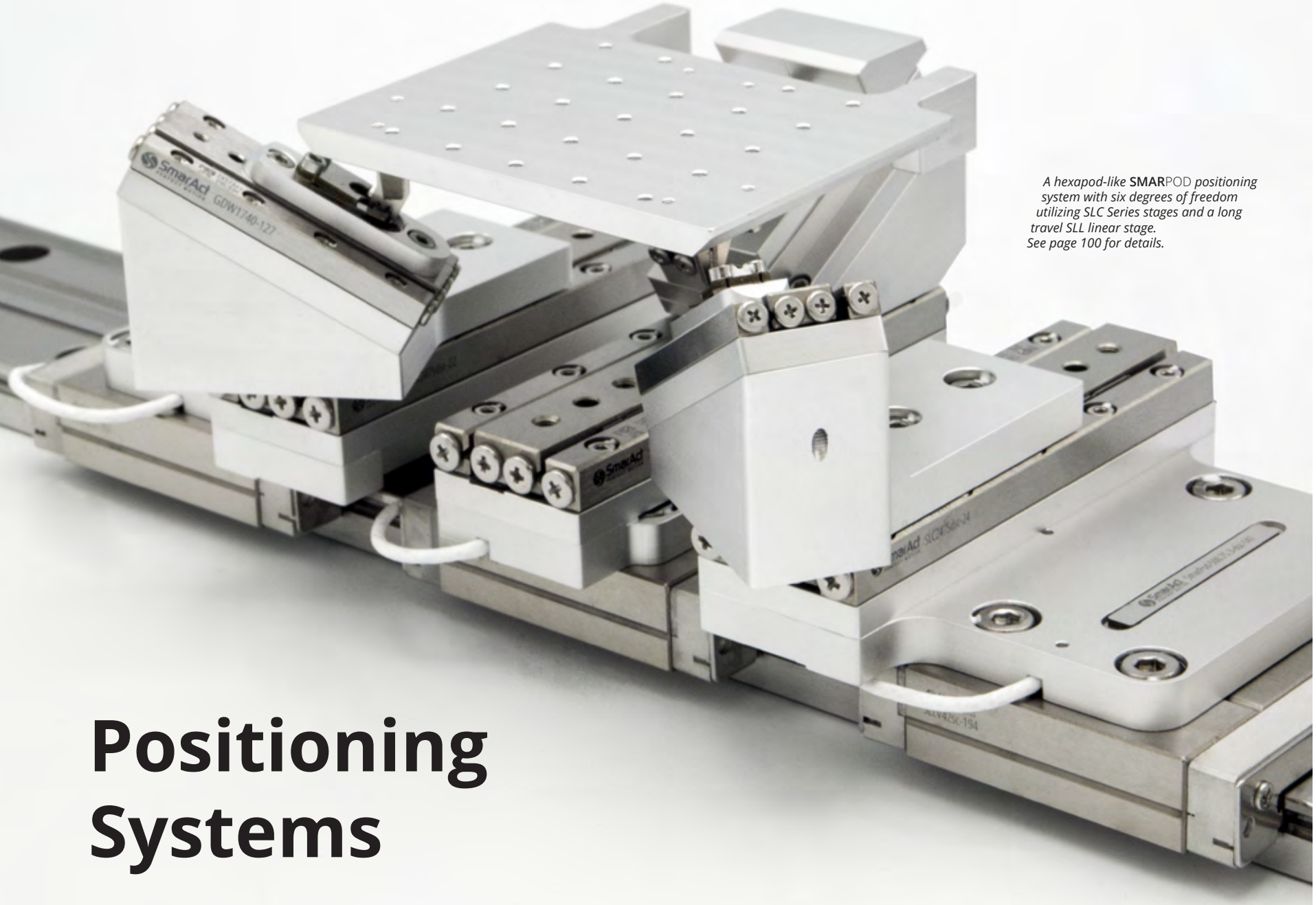
For applications in magnetic fields or where else stages made of non-magnetic materials are needed, specialized versions of linear and rotation stages are available. Typical materials used in these types of stages are copper beryllium, titanium, ceramics and copper wires with Teflon® or Kapton® insulation.

Non-magnetic stages of the SLC-17 and SLC-24 Series include ceramic guideways. Therefore we strongly recommend to also opt for the U-shaped base to increase the overall stiffness of the stage.

Please note that the U-shaped base resembles the same mounting hole pattern but adds 6 mm to the width of the stage itself. As a result the width of a SLC-17 stage enlarges to 23 mm and the width of a SLC-24 stage to 30 mm, respectively. Thus, waiving the U-shaped base option is only advisable if compactness is the top most requirement.

Ultra-compact non magnetic positioning system with ceramic guideways. Please note: This photograph shows a customized setup without the recommended U-shaped base option.

*Also **SMAR**PODs are optionally available in non-magnetic versions for use in high magnetic fields or for the use in ion- or electron spectroscopy experiments.*



A hexapod-like **SMAR**POD *positioning system with six degrees of freedom utilizing SLC Series stages and a long travel SLL linear stage.*
See page 100 for details.

Positioning Systems

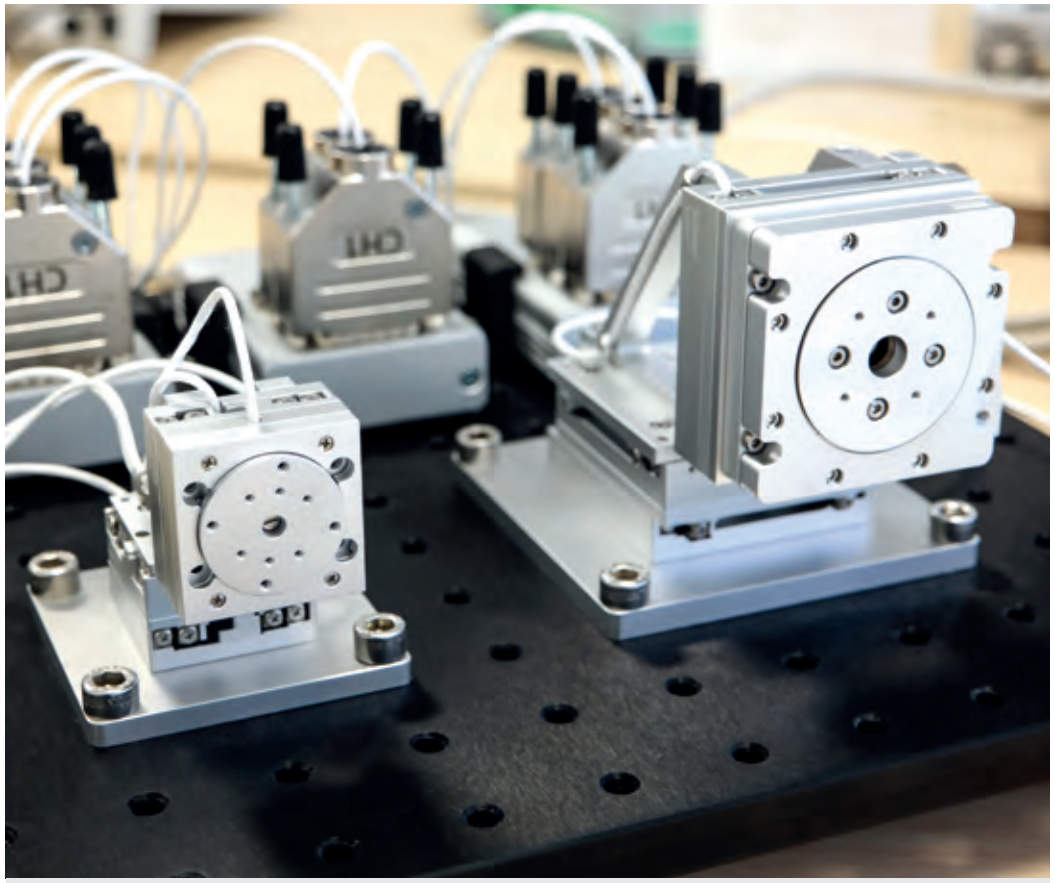
Most applications in academia and industry require more than one degree of freedom when it comes to the precise positioning of samples, tools or equipment.
SmarAct´s mission is to provide our customers with innovative solutions to successfully complete their specific positioning tasks. From straightforward positioning of components and samples on a plane surface in a rectangular axis configuration to highly complex positioning tasks that require the combination of several lateral and rotational axes SmarAct positioning systems are the perfect choice.
The intention of this catalog section is to provide an overview over our solutions for multi-dimensional positioning projects. We will begin with the SmarAct Modular System Concept and Pre-Defined Positioning Systems before changing over to the more complex positioning systems inheriting our **SMAR**POD hexapod-like system arrangements and our newest product line the SmarAct **TRI**POD before presenting the **SMAR**GON a versatile multi-axes positioning system combining serial and parallel kinematic approaches.
The application scientists of the SmarAct sales team are eager to help you with selecting the right component or discuss customization and development of solutions to create a perfect match to your requirements.

Change is a constant in academic and industrial research. Equipment needs to be adaptable to address new requirements and to reduce pressure on the projects budget.

The SmarAct Modular System is a product concept which allows customers to adapt, modify and reconfigure even complex multi-axis positioning systems in the field, based on stringent modularity and intercompatibility between linear, rotation and goniometer stages.

It allows the combination of compatible stages of the SLS, SLC, SGO and SR Product Series to form complex and reconfigurable positioning setups.
Standardized brackets, mounts, adapters and accessories provide the flexibility required to combine SmarAct single axis stages into convertible instruments while guaranteeing highest precision and highest quality of the so created positioning solution.
Due to the high modularity and large number of components and accessories the SmarAct Modular System offers almost endless possibilities to build your very own setup. The application scientists of the SmarAct sales team are eager to help you with selecting the optimal combination of components to create a perfect match to your requirements.

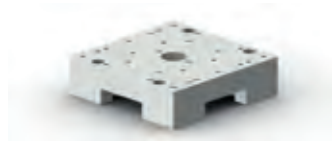
The positioning systems we are presenting on the following serve as examples, to show the possibilities and on-site reconfigurability of the SmarAct Modular System.



With standardized connection elements the SmarAct Modular System allows to build multi-dimensional positioning systems.

Breadboard Adapters and Base Plates

Several breadboard adapters are available to fix the positioning system onto your existing optical table or breadboard based experimental setup. The product portfolio includes adapters of different sizes and shapes perfectly matching the corresponding linear stages of the SLC and SLS Series. The hole pattern of the adapters allows for mounting of linear stages of different length while also providing anchoring points for cable management clamps.

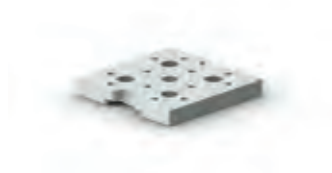


Spacer

Spacers have the same outer dimensions like the corresponding linear stages. They can be mounted directly onto breadboard adapters, on top of stages and also on top of each other.

Brackets

Brackets allow the vertical mounting of linear or rotation stages on top of horizontal stages or directly on the breadboard adapters. Several different dimensions are available to allow mounting of SLC, SLS linear stages and rotation stages of different sizes.



Adapter Plates and Clamps

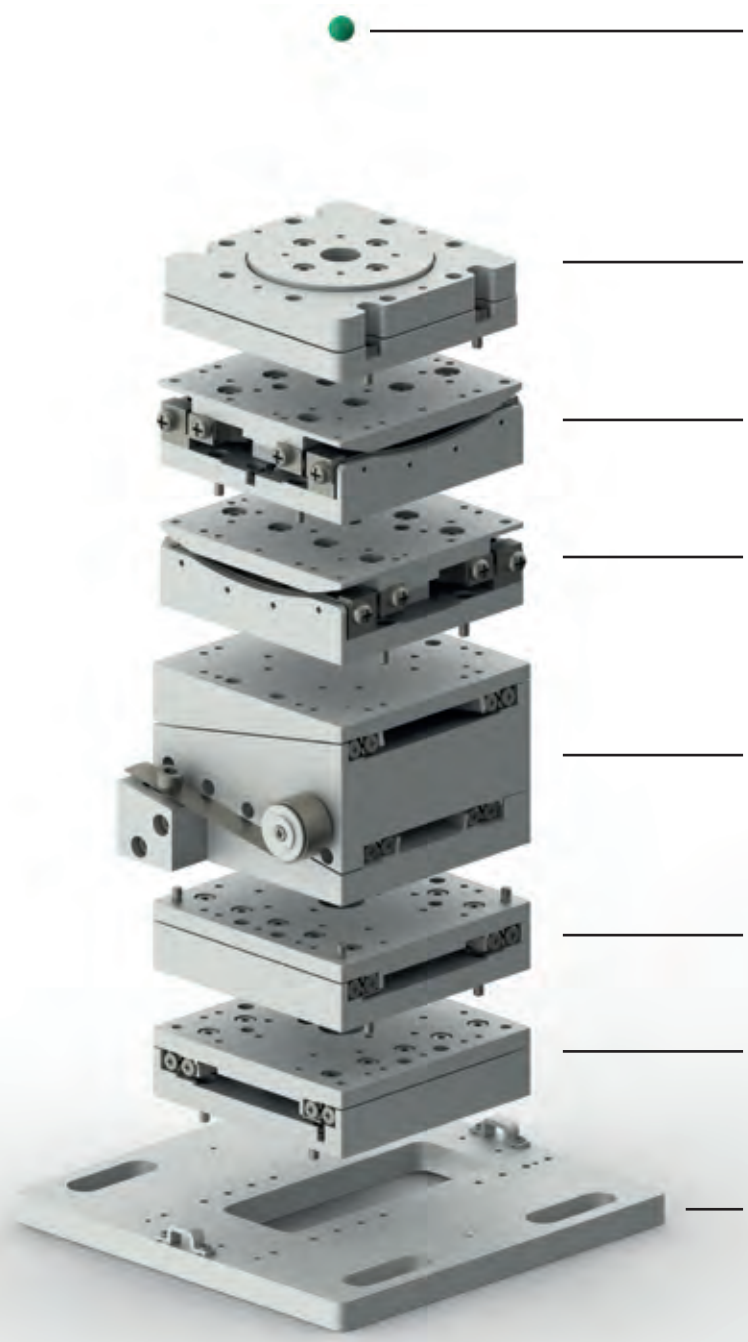
When stacking linear stages or mounting right angle brackets or rotation stages adapter plates and clamps are required. The shape of the clamp strongly depends on the length and the hole pattern of the linear stages that are being used. Clamps are available to mount right angle brackets onto linear stages, or to mount two linear stages perpendicular to each other.

Constant Force Springs

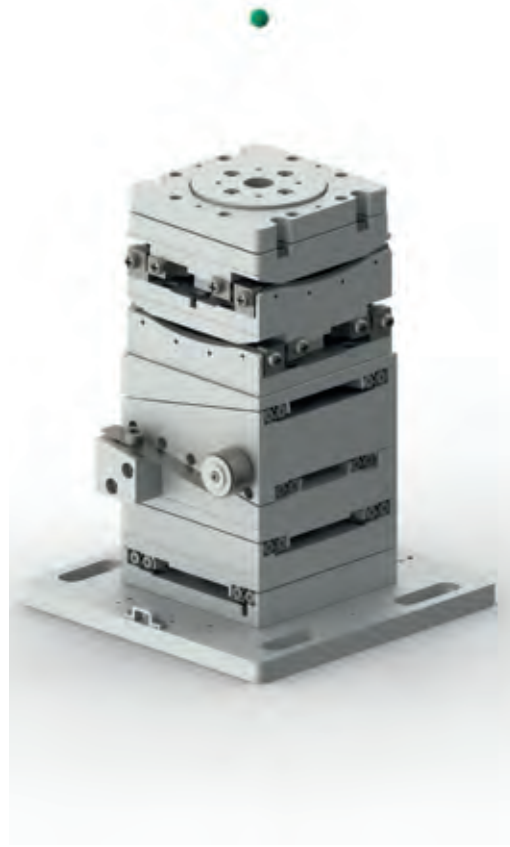
Constant force spring assemblies are available ready to be mounted to stages and brackets to compensate for statically loads on stages when used in vertical orientations. Each assembly includes an adapter which will be attached to the bracket as the anchoring point of the spring and an adapter plate to be mounted to the front of the vertical stage.

Cable Management

The SmarAct Modular System Concept also includes clamps for cable management purposes. Different clamps sizes are available optimized to securely and safely hold a defined number of cables of different diameters.



SmarAct Modular System
Example 1: A 6D Positioning System



Based on SmarAct's SLS-Series multi-axis positioning systems with a high number of degrees of freedom are possible even in confined spaces. The direct mounting capabilities of the components guarantee the high stiffness and robustness of these setups.

To present the possibilities of SmarAct's Modular System we will take the following positioning system as an example. Due to the stringent intercompatibility of the used stages it is also possible to remove any of the shown axis or add them to the setup at a later point. Therefore, a high number of permutations and a high number of possible system designs with one, two, three and up to six degrees of freedom can be created.

This exemplary positioning system with six degrees of freedom is especially useful for applications in the field of X-ray deflection where a small footprint is required while maintaining large travel ranges. The two goniometer stages form an Eulerian cradle with a common center of rotation represented by the green sphere in the rendering. The rotation axis on top of the goniometer stage allows for a continuous rotation. The XYZ stage underneath creates the possibility to freely define the common center of rotation within the addressable volume. If larger travel ranges in X and Y are required by the application the SLS-5252 stages can be easily exchanged for SLS-5282 which offer 20 mm more travel range. Thanks to the intercompatibility within the SmarAct Modular System the height of the system will remain the same.

Alternative Setups

The modular system ensures the intercompatibility of all used components. Based on the parts list of this example different setups can be realized. Depending on the requirements of the applications these setups can be very simple with only a few axes or more complex. Parts can be easily exchanged and setups reconfigured and adapted to new requirements or tasks. With the SmarAct Modular System Concept these on site reconfigurations are an easy to perform task and offers full flexibility for current and upcoming applications.

A XY stage represents a most versatile platform for mircoassembly setups, as a microscopy stages or simply whenever components or substages need to be precisely and reproducibly positioned in two dimensions.

Rotation stages in combination with linear stages increase the versatility even further. When the XY table is mounted on top of the rotation stage the positioning system offers the possibility to precisely position the rotation center on the top plate or to align the XY coordinate system with the surrounding setup. Of course the rotation stage can also be mounted on top of the XY platform depending on the system requirements.

A XY stage represent a most versatile platform for mircoassembly setups, as microscopy stages or simply whenever components or substages need to be precisely and reproducibly positioned in two dimensions.

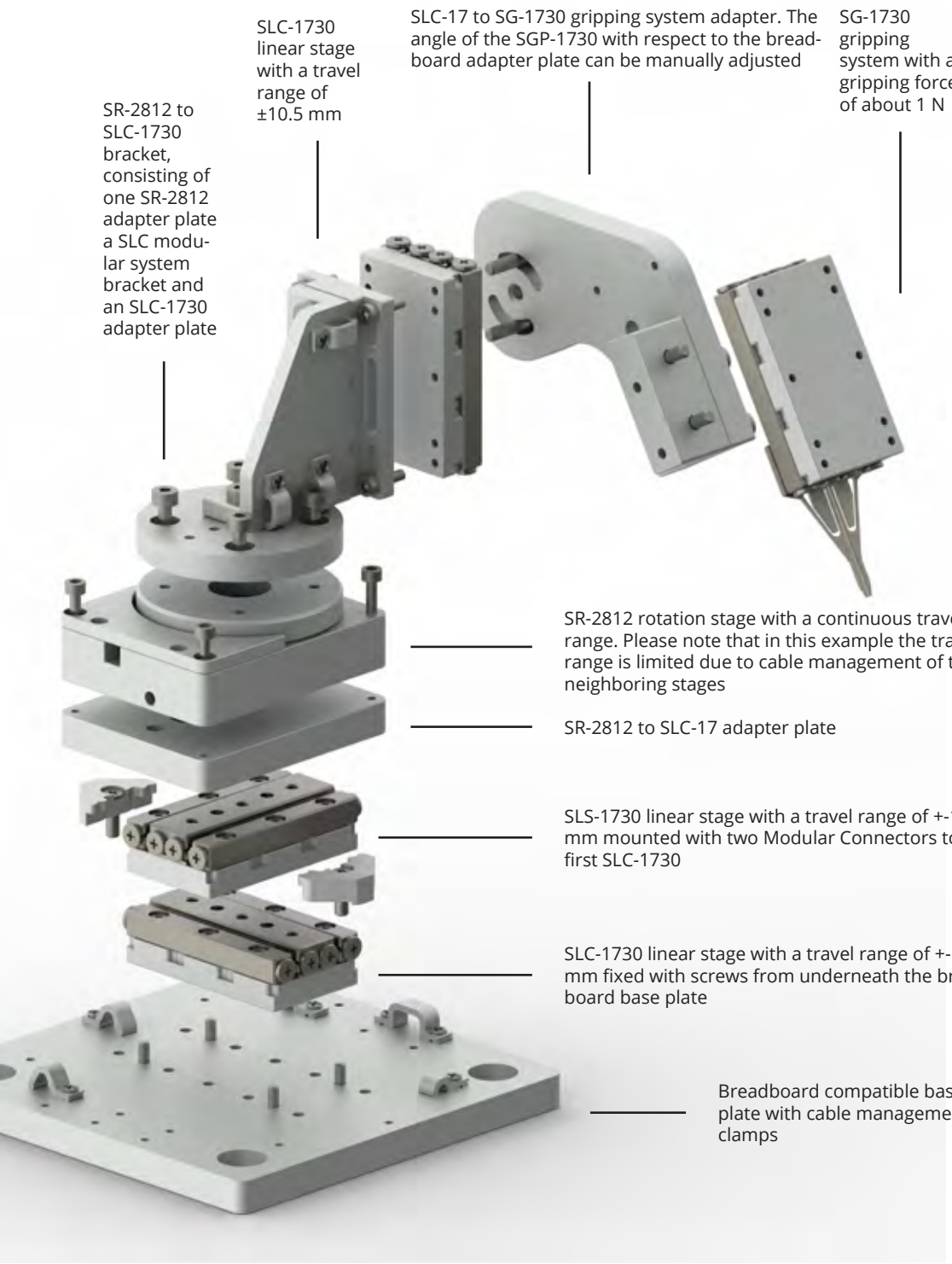
SmarAct Modular System
Example 1: A 6D Positioning System

Systems

A rotation stage can be mounted directly onto the XYZ platform adding a rotational degree of freedom to the setup

The combination of a SGO-60.5 and a SGO-77.5 goniometer stage yields an Eulerian cradle. When both are placed to top the rotation stage the cradle can also be rotated around the central axis of the system.

Adding the SHL-5237 lifting stage to the XY table transforms the 2D system into a XYZ platform. A three axis XYZ stage is more or less a standard device in sample positioning tasks or as a versatile platform for rotation and goniometer stages. For example, as a reflected light microscopy stage it would allow the sample to be precisely positioned underneath the objective lens while the Z axis can be used as a focusing stage.



SmarAct Modular System
Example 2: A 5D Micromanipulation Device

Very compact and versatile positioning systems and micromanipulation devices can be realized on the basis of SmarAct's SLC-Series. The example presented on these pages utilize the SmarAct Modular System to create a micromanipulation device that can be used for example for pick and place tasks or for in-situ manipulation of samples under an optical microscope.

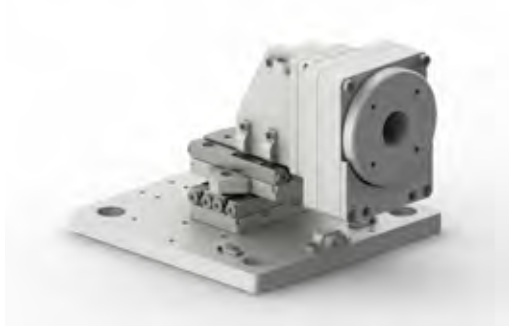
In this example an SG-1730 gripping system is mounted as an end effector but it can easily be replaced with a SLC-1730 linear stage for handling of pipettes, micro-knives, microinjectors or other mechanical or electrical probes.

Alternative Setups

The modular system ensures the intercompatibility of all used components. Based on the parts list of this example different setups can be realized. Depending on the requirements of the applications these setups can be very simple with only a few axes or more complex. Parts can be easily exchanged and setups reconfigured and adapted to new requirements or tasks. With the SmarAct Modular System Concept these on site reconfigurations are an easy to perform task and offers full flexibility for current and upcoming applications.

A XY stage represents a versatile platform for mircoassembly setups, can be used as microscopy stages or simply whenever components or substages need to be precisely and reproducibly positioned in two dimensions. SLC linear stages can be easily and securely mounted on top of each other with the help of modular connectors.

With the help of a bracket and an SLC-1730 adapter plate a third SLC-1730 linear stage can be mounted to the XY table transforming the 2D system into a XYZ platform. A three axis XYZ stage is more or less a standard device in sample positioning task. In optical setups for example this three axis positioning system can be used for the alignment of optical detectors or segmented photo diodes.



Utilizing the SR-2812 to SLC-17 adapter plate a rotational degree of freedom can be added to the former XYZ positioning system. The so created setup allows the rotation center on the rotatable platform to be precisely positioned within a cube with an edge length of 21 mm.

SmarAct Modular System
Example 2: A 5D Micromanipulation Device

Systems

For applications where a motion in the X direction is not necessary the bracket can also be mounted directly onto the slide of the lower SLC-1730 stage..

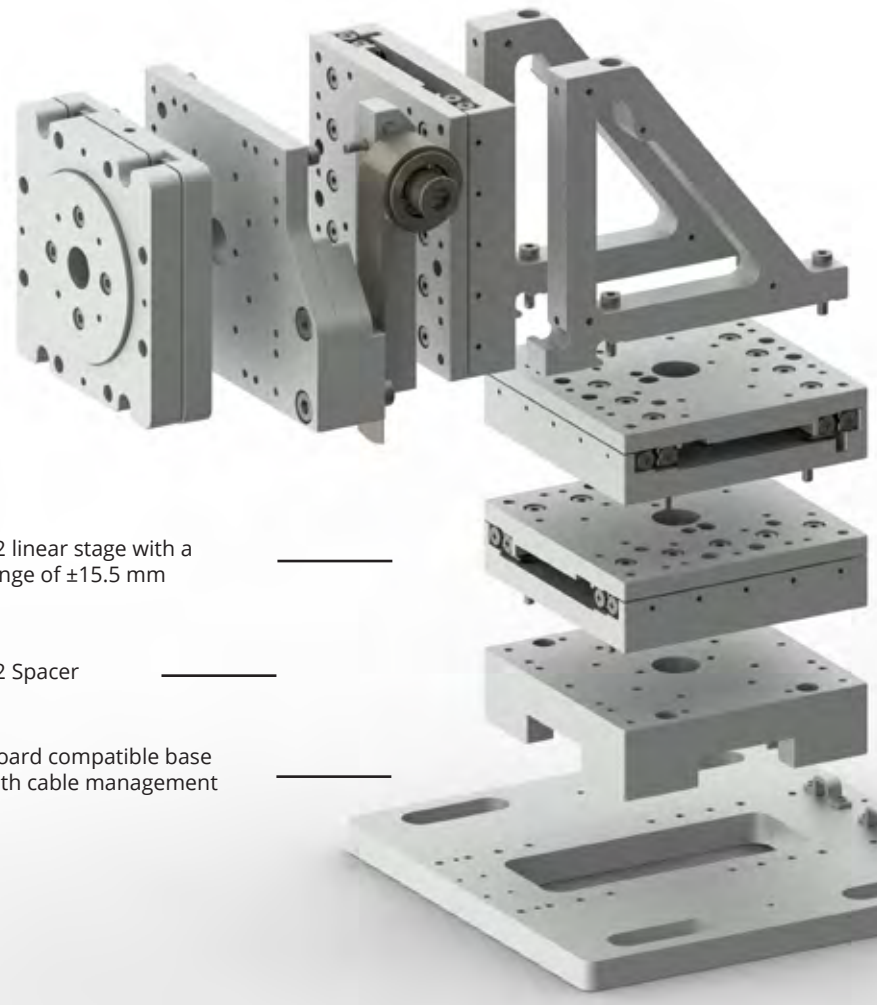
The SG-1730 gripping system of the initial example can also be exchanged for a fourth SLC linear stage creating a tool platform with a travel range of 21mm, when using an SLC-1730 stage. Pipettes, micro-knives, microinjectors or other mechanical or electrical probes can then be mounted to the platform.

SR-5014 rotation stage with a continuous travel range.

Constant force spring for the use with SLS-5252 stages

SLS-5252 linear stage with a travel range of ±15.5 mm

SLS-52 rectangular brackets with cable management clamps



SLS-5252 linear stage with a travel range of ±15.5 mm

SLS-5252 Spacer

Breadboard compatible base plate with cable management clamps

SmarAct Modular System
Example 3: A Versatile 4D Positioning System

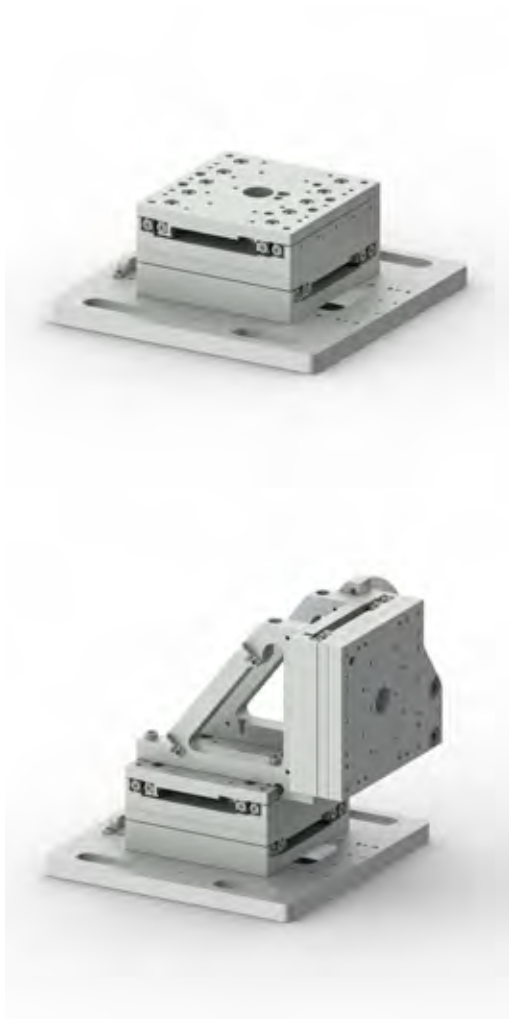
Systems

SmarAct's Modular System let customers create complex multi axis positioning systems with a high flexibility and the possibility to update, extend or reconfigure the setups even on site.
In this example the Modular System Concept is utilized to create a versatile positioning system with four degrees of freedom.

The idea behind this exemplary positioning system is to present the some of the connection elements that are available within the SLS Modular System. From Spacers to compensate height differences over Breadboard Adapters to Cable Management Clamps and Constant Force Spring Setups to allow the system to handle heavy payloads.
In this example the XY platform and the load compensated Z axis allows the center of the rotation stage to be positioned in space within a volume of 31 x 31 x 31 mm^3. The attached rotation stage allows a continuous rotation of the payload.

Alternative Setups

The modular system ensures the intercompatibility of all used components. Based on the parts list of this example different setups can be realized. Depending on the requirements of the applications these set-ups can be very simple with only a few axes or more complex. Parts can be easily exchanged and setups reconfigured and adapted to new requirements or tasks. With the SmarAct Modular System Concept these on site reconfigurations are an easy to perform task and offers full flexibility for current and upcoming projects.



A XY stage represents a most versatile platform for mircoassembly setups, can be used as micros-copy stages or simply whenever components or substages need to be precisely and reproducibly positioned in two dimensions. Due to matched bore hole pattern SLS Series stages can be easily stacked.

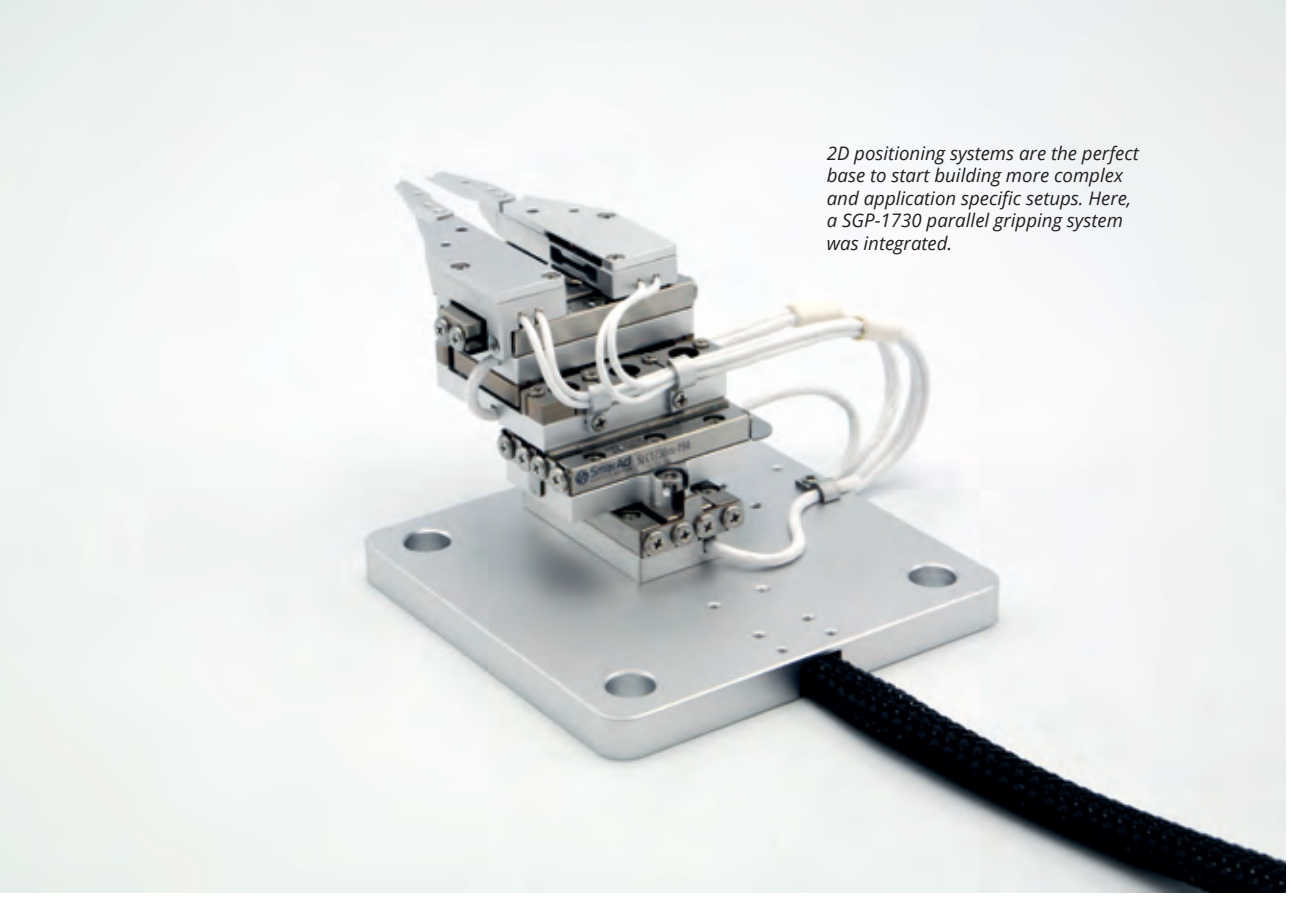
With the help of brackets and another SLS-5252 linear stage mounted the XY table transforms into a XYZ platform. A three axis XYZ stage is more or less a standard device in sample positioning task. To compensate for the weight of the payload that is going to be mounted to the positioning system a constant force spring setup can be used (left).
If the application does not require an XY table but only one linear axis stages can be exchanged for simple mechanical spacers (right).

SmarAct Modular System
Example 3: A Versatile 4D Positioning System

Systems

A SR-3211 rotation stage can be added to the former XYZ positioning system as in the initial example or directly to the brackets. The so created setup allows the rotation center on the rotatable platform to be precisely positioned in two dimensions.

The combination of rotation and linear stages serve a wide field of application.
With the two displayed setups the rotation center of the rotation platform can be precisely positioned in square with an edge length of 31 mm in relation to the breadboard adapter (left) and to top platform (right).

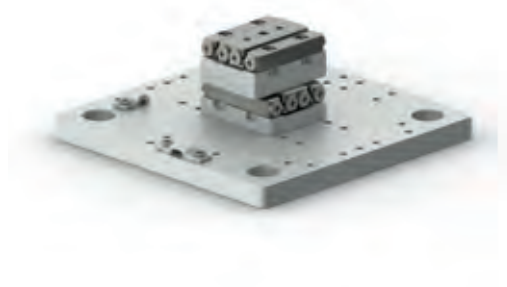


2D positioning systems are the perfect base to start building more complex and application specific setups. Here, a SGP-1730 parallel gripping system was integrated.

2D Positioning Systems
SmarAct Pre-Defined Positioning Systems

Within the scope of the SmarAct Modular System also fully pre-built and pre-configured positioning systems are available. These pre-defined Positioning Systems are customer inspired and present the systems and platforms most commonly requested by our customers.
The systems are very versatile and applicable to a wide field of positioning tasks. In the following the systems are displayed including a breadboard adapter. All systems are also available without the bread-board adapter if a direct mounting method is preferred.
On the basis of this pre-defined systems and in combination with customized connection elements and customized stages very complex serial positioning systems can be realized. Some of them will be also presented on the following pages.
If your application requires a special configuration that is not shown in the following, please do not hesitate to contact our application specialists to discuss your applications requirements.

2D Systems consist of two linear stages of the SLC or SLS Series in a XY configuration. Such setups represent most versatile platforms whenever components or substages, like gripping systems, need to be precisely and reproducibly positioned in two dimensions.



XY-SLC17:22: A 2D positioning system based on SLC-1720 stages

XY-SLC17:30: A 2D positioning system based on SLC-1730 stages

		XY-SLC-17:22	XY-SLC-17:30
	Degrees of Freedom	2	2
	Linear Stage X	SLC-1720	SLC-1730
	Travel X [mm]	12	21
	Linear Stage Y	SLC-1720	SLC-1730
	Travel Y [mm]	12	21
	Payload [N]	20	
	Resolution **MCS**2 [nm]	1 (S)	
Breadboard Mount	Dimensions [mm]. L x W x H	65 x 65 x 24	65 x 65 x 22
Breadboard Mount	Height of Working Platform above Ground [mm]	24	22
Direct Mount	Dimensions [mm] L x W x H	22 x 22x 19	22 x 22x 17
Direct Mount	Height of Working Platform above Ground [mm]	19	17

XY-SLC17:80: A 2D positioning system based on SLC-1780 stages

XY-SLC24:60: A 2D positioning system based on SLC-2460 stages

		XY-SLC-17:80	XY-SLC24:60
	Degrees of Freedom	2	2
	Linear Stage X	SLC-1780	SLC-2460
	Travel X [mm]	51	35
	Linear Stage Y	SLC-1780	SLC-2460
	Travel Y [mm]	51	35
	Payload [N]	30	
	Resolution **MCS**2 [nm]	1 (S)	
Breadboard Mount	Dimensions [mm]. L x W x H	80 x 80 x 22	65 x 65 x 26
Breadboard Mount	Height of Working Platform above Ground [mm]	22	26
Direct Mount	Dimensions [mm] L x W x H	80 x 80 x 17	60 x 60 x 21
Direct Mount	Height of Working Platform above Ground [mm]	17	21

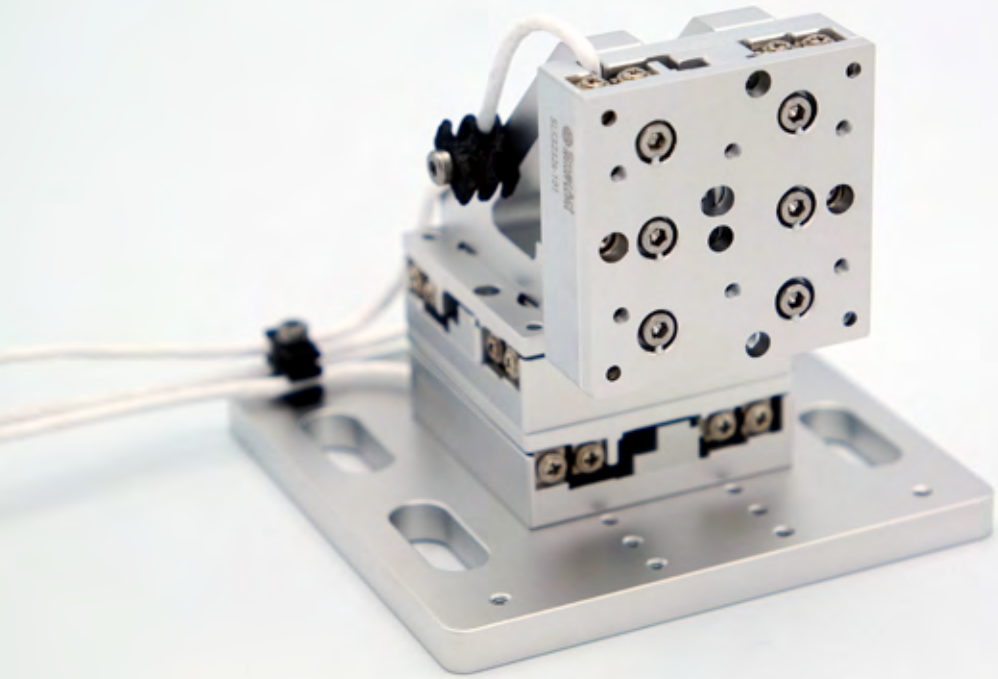
SmarAct Pre-Defined Positioning Systems
2D Positioning Systems

Systems

XY-SLS32:32: A 2D positioning system based on SLS-3232 stages

XY-SLS52:52: A 2D positioning system based on SLS-5252 stages

		XY-SLS32:32	XY-SLS52:52
	Degrees of Freedom	2	2
	Linear Stage X	SLS-3232	SLS-5252
	Travel X [mm]	21	31
	Linear Stage Y	SLC-3232	SLS-5252
	Travel Y [mm]	21	31
	Payload [N]	20	
	Resolution **MCS**2 [nm]	1 (S)	
Breadboard Mount	Dimensions [mm]. L x W x H	65 x 65 x 27	90 x 90 x 34
Breadboard Mount	Height of Working Platform above Ground [mm]	27	34
Direct Mount	Dimensions [mm] L x W x H	32 x 32 x 22	52 x 52 x 28
Direct Mount	Height of Working Platform above Ground [mm]	22	28

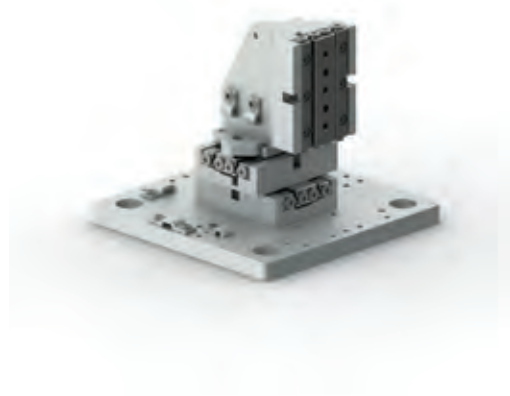


A versatile 3D positioning system (XYZ) based on three SLS-3232 stages.

3D Positioning Systems
SmarAct Pre-Defined Positioning Systems

Within the scope of the SmarAct Modular System also fully pre-built and pre-configured positioning systems are available. These Pre-Defined Positioning Systems are customer inspired and present the systems and platforms most commonly requested by our customers.
They are very versatile and applicable to a wide field of positioning tasks. In the following the systems are displayed including a breadboard adapter. All systems are also available without the breadboard adapter if a direct mounting method is preferred.
On the basis of this pre-defined systems and in combination with customized connection elements and customized stages very complex serial positioning systems can be realized. Some of them will be also presented on the following pages.
If your application requires a special configuration that is not shown in the following, please do not hesitate to contact our application specialists to discuss your applications requirements.
3D Systems consist of three linear stages of the SLC or SLS Series in a XYZ configuration. Such setups represent standard devices for sample positioning tasks. In optical setups for example this three axis positioning system can be used for the alignment of optical detectors or segmented photo diodes or whenever components or substages, need to be precisely and reproducibly positioned in three dimensions.

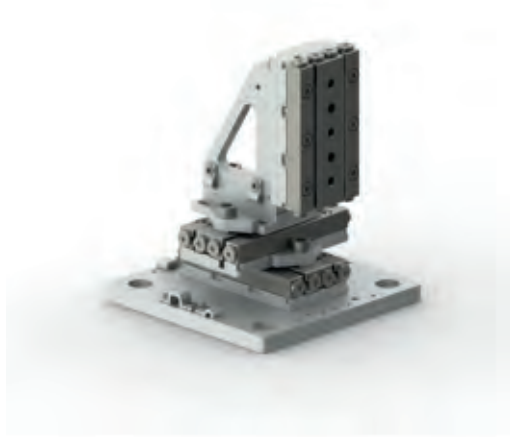
XYZ-SLC17:30: A 3D positioning system based on SLC-1730 stages.



XYZ-SLC23:30: A 3D positioning system based on SLC-1730-W stages with a U-shaped base for higher mechanical strength.

		XYZ-SLC17:30	XYZ-SLC23:30
	Degrees of Freedom	3	3
	Linear Stage X	SLC-1730	SLC-1730-W
	Travel X [mm]	21	21
	Linear Stage Y	SLC-1730	SLC-1730-W
	Travel Y [mm]	21	21
	Linear Stage Z	SLC-1730	SLC-1730-W
	Travel Z [mm]	21	21
	Payload [N]	1.5	
	Resolution MCS2 [nm]	1 (S)	
Breadboard Mount	Dimensions [mm]. L x W x H	65 x 65 x 41	65 x 65 x 57
	Center of Stage Z above Ground [mm]	30 (24 .. 36)	42 (31.5 .. 52.5)
Direct Mount	Dimensions [mm] L x W x H	33.5 x 22 x 36	38 x 32 x 52
	Center of Stage Z above Ground [mm]	25 (19..21)	37 (26.5..47.5)

XYZ-XY SLC17:40 Z SLC17:30: A 3D positioning system based on SLC stages with different travel ranges.



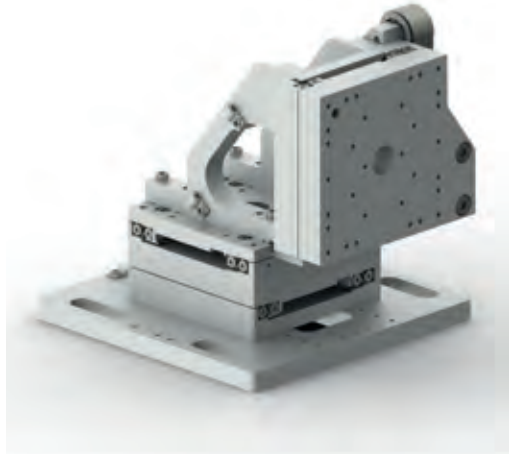
XYZ-SLC24:45: A 3D positioning system based on SLC-2445 stages.

		XYZ-XY SLC17:40 Z SLC17:30	XYZ-SLC24:45
	Degrees of Freedom	3	3
	Linear Stage X	SLC-1740	SLC-2445
	Travel X [mm]	26	29
	Linear Stage Y	SLC-1740	SLC-2445
	Travel Y [mm]	26	29
	Linear Stage Z	SLC-1740	SLC-2445
	Travel Z [mm]	21	29
	Payload [N]	1.5	
	Resolution **MCS**2 [nm]	1 (S)	
Breadboard Mount	Dimensions [mm]. L x W x H	65 x 65 x 62	65 x 65 x 81
Breadboard Mount	Center of Stage Z above Ground [mm]	47 (36.5 .. 57.5)	58.5 (44 .. 73)
Direct Mount	Dimensions [mm] L x W x H	42 x 40 x 57	52 x 45 x 76
Direct Mount	Center of Stage Z above Ground [mm]	42 (31.5 ..52.5)	53.5 (49 .. 78)

SmarAct Pre-Defined Positioning Systems
3D Positioning Systems

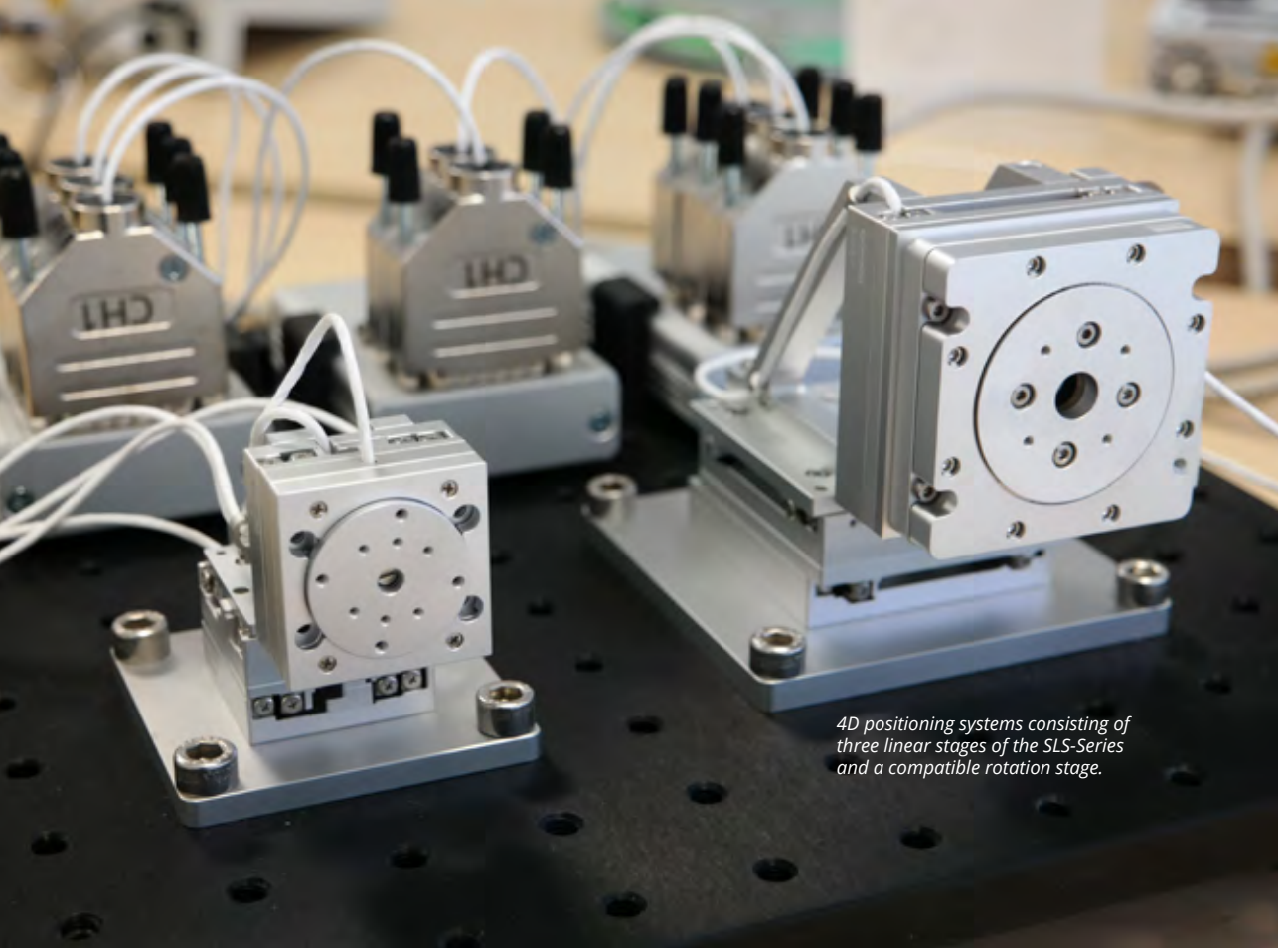
Systems

XYZ-SLS32:32: A 3D positioning system based on SLS-3232 stages.



XYZ-SLS52:52: A 3D positioning system based on SLS-5252 stages.

		XYZ-SLS32:32	XYZ-SLS52:52
	Degrees of Freedom	3	3
	Linear Stage X	SLS-3232	SLS-5252
	Travel X [mm]	21	31
	Linear Stage Y	SLS-3232	SLS-5252
	Travel Y [mm]	21	31
	Linear Stage Z	SLS-3232	SLS-5252
	Travel Z [mm]	21	31
	Payload [N]	1.5	
	Resolution **MCS**2 [nm]	1 (S)	
Breadboard Mount	Dimensions [mm]. L x W x H	65 x 65 x 59	65 x 65 x 59
Breadboard Mount	Center of Stage Z above Ground [mm]	43 (32.5...53.5)	62 (46.5...77.5)
Direct Mount	Dimensions [mm] L x W x H	48.5 x 32 x 54	79 x 63.5 x 89.5
Direct Mount	Center of Stage Z above Ground [mm]	38 (27.5...48.5)	56 (40.5...71.5)



4D positioning systems consisting of three linear stages of the SLS-Series and a compatible rotation stage.

4D Positioning Systems
SmarAct Pre-Defined Positioning Systems

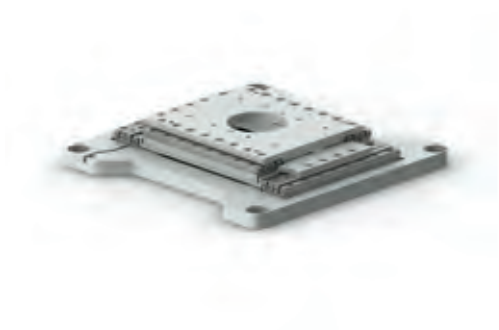
Within the scope of the SmarAct Modular System also fully pre-built and pre-configured positioning systems are available. These Pre-Defined Positioning Systems are customer inspired and present the systems and platforms most commonly requested by our customers.
They are very versatile and applicable to a wide field of positioning tasks. In the following the systems are displayed including a breadboard adapter. All systems are also available without the breadboard adapter if a direct mounting method is preferred.
On the basis of this pre-defined systems and in combination with customized connection elements and customized stages very complex serial positioning systems can be realized. Some of them will be also presented on the following pages.
If your application requires a special configuration that is not shown in the following, please do not hesitate to contact our application specialists to discuss your applications requirements.
4D Systems consist of three linear stages of the SLC or SLS Series and a rotation stage of the SR Series in a XYZR configuration. These setups allow the rotation center on the rotatable platform to be precisely positioned within the working range of the three linear stages.

XYZR-XYZ SLC17:30 Z SRP20:11: A 4D positioning system consisting of three SLC-1730 linear stages and one SR-2011 rotation stage

XYZR-XYZ SLS32:32 Z SRP32:11: A 4D positioning system consisting of three SLS-3232 linear stages and one SR-3211 rotation stage

		XYZR-XYZ SLC17:30 Z SRP20:11	XYZR-XYZ SLS32:32 Z SRP32:11
	Degrees of Freedom	4	4
	Linear Stage X	SLC-1730	SLS-3232
	Travel X [mm]	21	21
	Linear Stage Y	SLC-1730	SLS-3232
	Travel Y [mm]	21	21
	Linear Stage Z	SLC-1730	SLS-3232
	Travel Z [mm]	21	21
	Rotation Stage	SR-2011	SR-3211
	Travel Θ	unlimited	unlimited
	Payload [N]	1.3	3.3
	Resolution **MCS**2 [nm]	1 (S)	
Breadboard Mount	Dimensions [mm]. L x W x H	68 x 65 x 57	79 x 65 x 70
	Center of Rotation Stage above Ground [mm]	41.5 (31...52)	43 (32.5...53.5) (32.5...53.5)
Direct Mount	Dimensions [mm] L x W x H	50 x 30 x 52	62.5 x 45.5 x 65
	Center of Rotation Stage above Ground [mm]	36.5 (26...47)	38 (27.5...48.5)

2D Positioning System with Aperture
Pre-Defined Positioning Systems

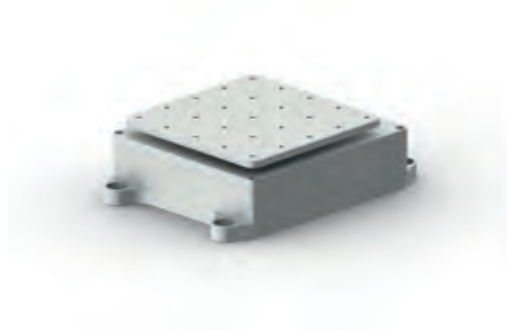


The XY-SLC17:80 Aperture positioning system consist of four linear stages in an XY configuration with an opening in the base plate and top platform. The so created aperture can be moved in X and Y direction without changing its size. Such positioning systems can be easily integrated into microscopes for handling of slide, well plate or petri dishes.

XY-SLC17:80 Aperture: A 2D positioning system made of SLC-1780 stages.

		XY-SLC17:80 Aperture
	Degrees of Freedom	2
	Linear Stage X	SLC-1780
	Travel X [mm]	51
	Linear Stage Y	SLC-1780
	Travel Y [mm]	51
	Aperture [mm]	60
	Payload [N]	30
	Resolution **MCS**2 [nm]	1 (S)
Direct Mount	Dimensions [mm]. L x W x H	138 x 138 x 22
Direct Mount	Height of Working Platform above Ground [mm]	22

3D Positioning System for High Payloads
Pre-Defined Positioning Systems

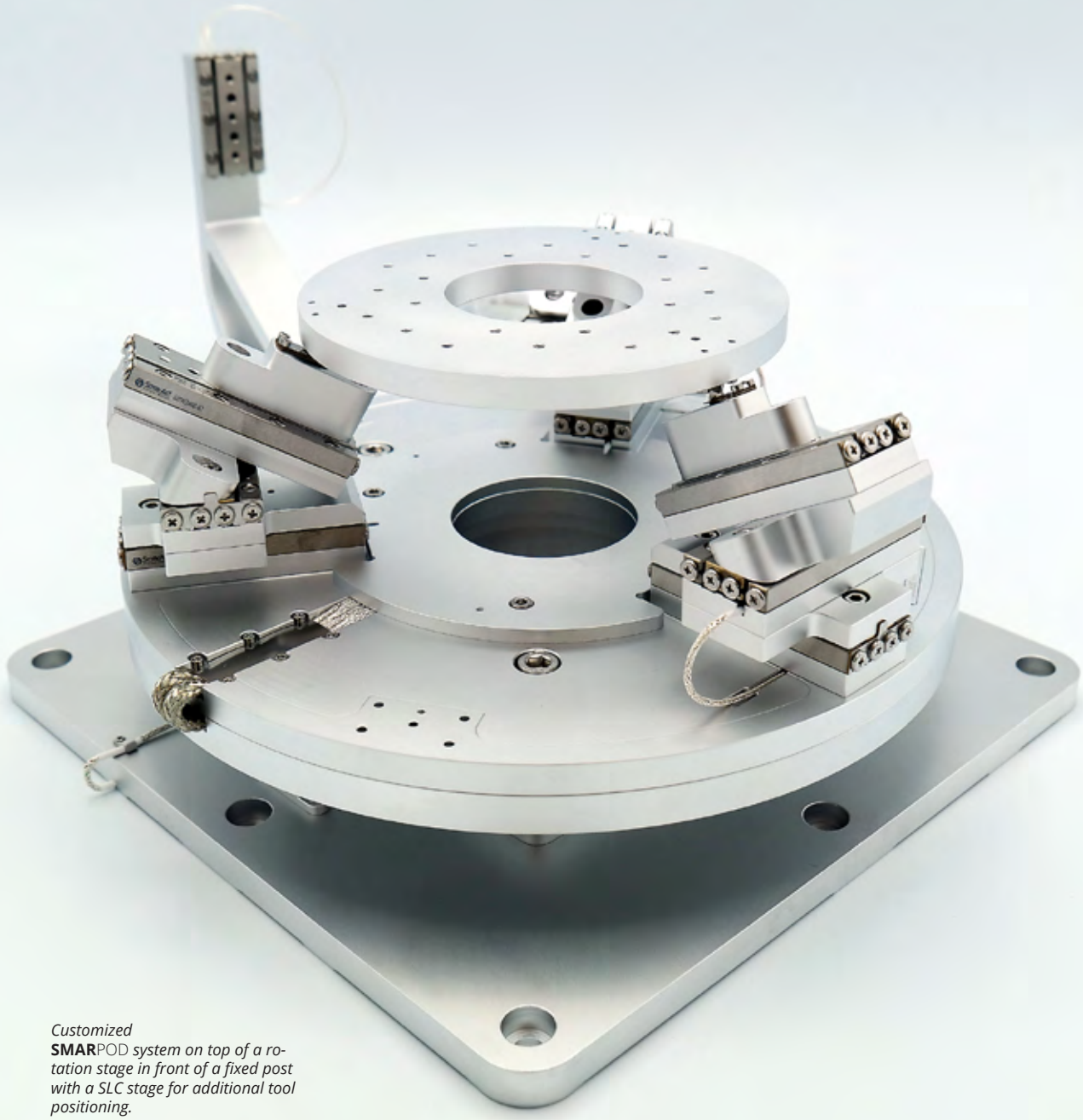


The XYZ-SHL-3D5N-5 is a 3D positioning system based on a parallel kinematic design that can handle high payloads of up to 500g. Its platform like design separates it from the other 3D positioning systems of this section. The working platform is horizontal and allows for direct mounting of heavier substages and components. Because of its low profile it is very versatile and can be used in optical setups as well as in micro-assembly applications or as a general positioning device.

XYZ-SHL-3D5N-5: A 3D positioning system for heavy loads.

		XYZ-SHL-3D5N-10
	Degrees of Freedom	3
	Linear Stage X	SHL-3D5N-5
	Travel X, Y, Z [mm]	10
	Payload [N]	5
	Resolution **MCS**2 [nm]	1 (S)
Direct Mount	Dimensions [mm]. L x W x H	100 x 140 x 40
Direct Mount	Heght of Working Platform above Ground [mm]	47 (36.5 .. 57.5)

SMARPOD
Hexapod-like Parallel Kinematics



Customized **SMAR**POD *system on top of a rotation stage in front of a fixed post with a SLC stage for additional tool positioning.*

The multidimensional positioning systems presented in the previous section are based on the serial combination of translational and rotational stages to create setups with a high number of degrees of freedom. Although the modularity and reconfigurability of these setups is tremendous, their space requirements can become quite large, especially as a positioning system with six degrees of freedom. To circumvent this drawback SmarAct has designed an alternative positioning system based on a parallel kinematic approach. In classical hexapod position systems six motorized legs are being used to generate three translational degrees of freedom and three rotational degrees of freedom. While transferring this approach into the world of SmarAct piezo stages, we came up with a highly versatile hexapod-like solution.
The **SMAR**POD offers the same degrees of freedom as classical hexapod systems while guaranteeing high resolution and repeatability. Compared to serial kinematic systems with six degrees of freedom **SMAR**PODs exhibit a higher stiffness and a higher rigidity. A user friendly software package allows easy integration into your own control environment assuring a very short setup time.

The **SMAR**POD, like all other SmarAct products, is highly customizable and can be integrated into completely customized setups. Regardless if your application requires only a modified base or top plate or a completely different configuration do not hesitate to contact us to discuss your requirements and the best-suited solution. Let us assist you in bringing your idea to life.

Working Principle

The **SMAR**POD is a parallel kinematics positioning system. The top plate is actuated by the simultaneous movement of multiple linear stages in contrast to a serial kinematic approach where each translation is the result of the movement of a specific linear or rotation stage.

The parallel arrangement of the **SMAR**POD's stages contributes to the overall stiffness of the system and allows to the top plate to be translated and rotated in six degrees of freedom.

Control in Cartesian Coordinates

Calculation of the kinematics model and device control is encapsulated in a software package. Programming interfaces and graphical user interfaces allow to move the **SMAR**POD in Cartesian coordinates (X, Y, Z, roll, pitch and yaw) and to adjust the systems pivot point and coordinate system.

User-Definable Pivot Point and Axis Alignment

The great advantage of the **SMAR**POD is the possibility to freely set the rotations' pivot point. Thus, defining the center of rotation for all axis which allows you to precisely rotate around any point in space. This is a great advantage in many applications, e.g. for the alignment of optical components. For example. when mounting a fiber optic holder with a free standing fiber onto the **SMAR**POD you can easily define the end face of the fiber as the pivot point. Such a setup allows you to precisely change the orientation of the emitted beam while keeping the fiber end point pinned to a fixed point in space. The coordinate system can be adjusted as well. Shifting and rotating the base coordinate system allows the **SMAR**POD axes to be aligned with objects in its environment.

Apertures

All **SMAR**PODs with circular base plates include an aperture in the base and in the top plate, respectively. These apertures allow to gain access from beneath the positioning system to electrically connect the payload or to gain optical access to mounted components.

Environmental Specific

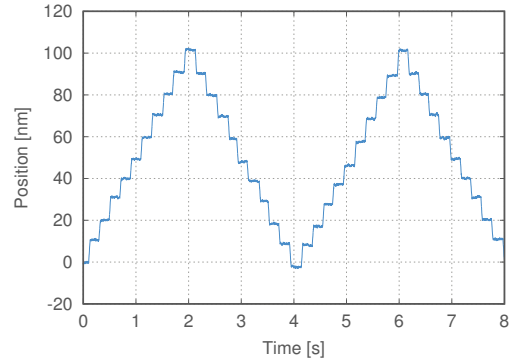
For in-vacuo applications SmarAct **SMAR**PODs are available in high and ultra-high vacuum compatible versions. Furthermore, they can also be made out of fully non-magnetic materials to be used in applications utilizing charged particle beams or high magnetic fields.
A minor restriction applies to the P-SLL **SMAR**POD as its X stage is based on a SLL stage which is only HV compatible and is not available in a non-magnetic version.

SMARPOD
Key Features

Systems

High Resolution

A backlash-free mechanical design makes it possible to achieve a movement performance of the positioning system which is in the same order of magnitude as for our single stages. The smallest movement increment is 1 nm for linear and 1 µrad for rotary motions.

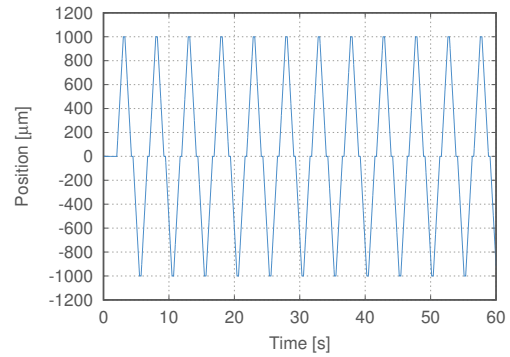


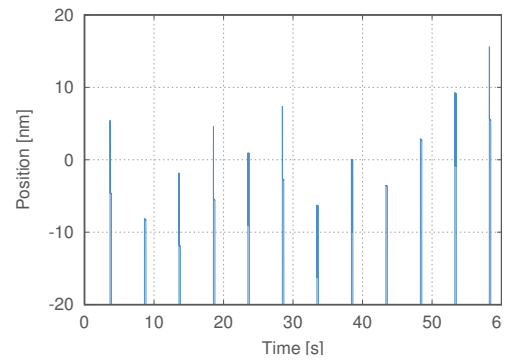
Linear Repeatability

When using the whole travel range the linear bidirectional repeatability in X, Y and Z is 200 nm. For smaller movements the repeatability is in the order of several nanometers which has been verified in a test bench setup utilizing SmarAct's **PICO**SCALE interferometer.

For this test, a plane mirror was mounted to the top plate of a **SMAR**POD facing a **PICO**SCALE sensor head. The **SMAR**POD was then commanded to move 10 steps back and forth with a step height of 10 nm and hold time between each step of 200 ms. The position data recorded with the **PICO**SCALE Interferometer verifies the excellent linear repeatability of the **SMAR**POD.

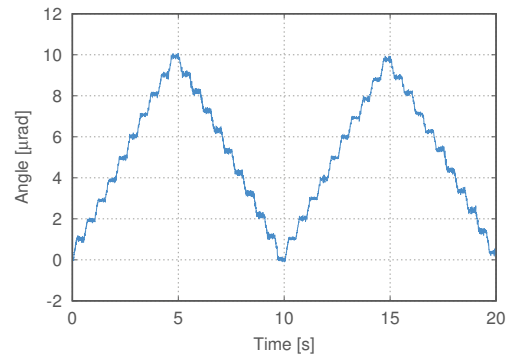
When repeating the test for longer travel ranges of 1 mm the linear bidirectional repeatability shows that the reference position can be repeatedly reached with an accuracy of 7 nm.





Angular Repeatability

The bidirectional repeatability of the top plates' rotation was also measured in a test setup utilizing three **PICO**SCALE sensor heads. A plane mirror was mounted to the top plate of the **SMAR**POD facing the two sensor heads. When performing a rotation the two sensor heads measure a change in the optical path length from which the rotation angle can be calculated. In this test the top plate was tilted in 10 steps of 1 µrad each back and forth. The hold time between each step was 500 ms. The angular data recorded with the **PICO**SCALE Interferometers verifies the excellent angular repeatability of the **SMAR**POD.



SMARPOD *Hexapod -like positioning systems with circular bases.* **SMAR**POD *225.75 (left), 110.45 (center), 70.42 (right).*

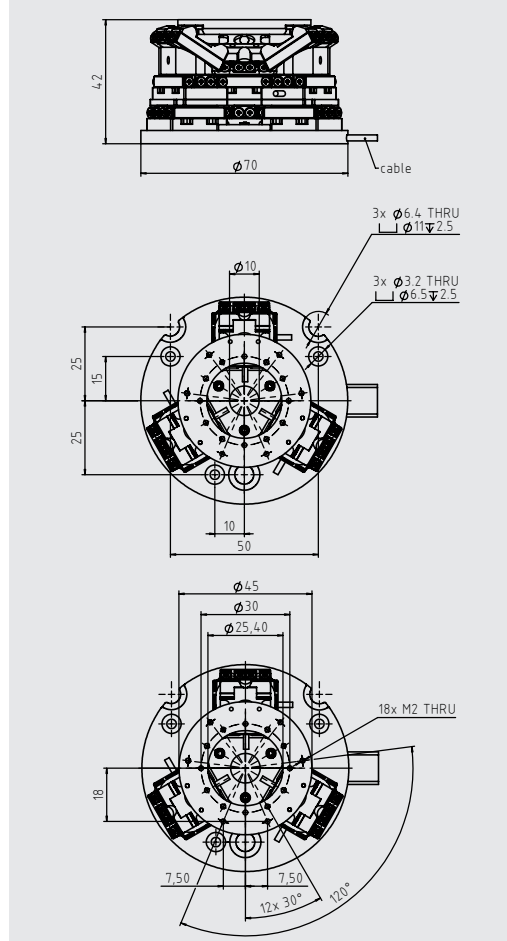
		70.42	110.45	225.75	P-SLC-17	P-SLC-24	P-SLL
Mechanical	Travel x [mm]	10	20	41	48	79 .. 119	20 .. 1200
	Travel y [mm]	10	20	71	28 ..48	45 .. 119	45 .. 119
	Travel z [mm]	5	10	21	≤ 9	≤ 12	≤ 16
	Rotation Θ_x [°]	14	21	20	≤ 28	≤ 31	≤ 42
	Rotation Θ_y [°]	16	24	23	≤ 26	≤ 27	≤ 33
	Rotation Θ_z [°]	28	38	41	≤ 20	≤ 42	≤ 42
	max. Vertical Load [N]	5	5	10	5	10	10
	max. Horizontal Load [N]	2.5	2.5	5	2.5	5	5
	Dimensions [mm]	Ø 70	Ø 110	Ø 225	> 110 x 80	> 150 x 100	> 250 x 93
	Height [mm]	42	45	75	> 67.5	> 87	> 67.5
	Weight [g]	300	400	1000	300 .. 2000		
Cloded-loop	Sensor Types	S, SC					
	Smallest Increment [nm]	1					
	Smallest Increment [µrad]	1					
	Repeatability for Full Travel Range [nm]	< ± 200					
	Repeatability for Full Travel Range [µrad]	< ± 10					
	Repeatability for 1 mm Linear Travel [nm]	< ± 15					
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)					HV (10^{-6} mbar)
Non-Magnetic Option		Yes (-NM)					--

SMARPOD *70.42: The most compact 6D positioning system. Shown in zero position.*

SMARPOD *70.42 in deflected pose.*

The **SMAR**POD *70.42* is SmarAct's smallest hexapod-like positioning System with a base plate diameter of only 70 mm. Despite its overall compactness it is a robust and precise system that can handle payloads of up to 5 N to be positioned with a centimeter travel range in X and Y.
It is also available in a high vacuum and ultra-high vacuum compatible version and can be built from fully non-magnetic materials.

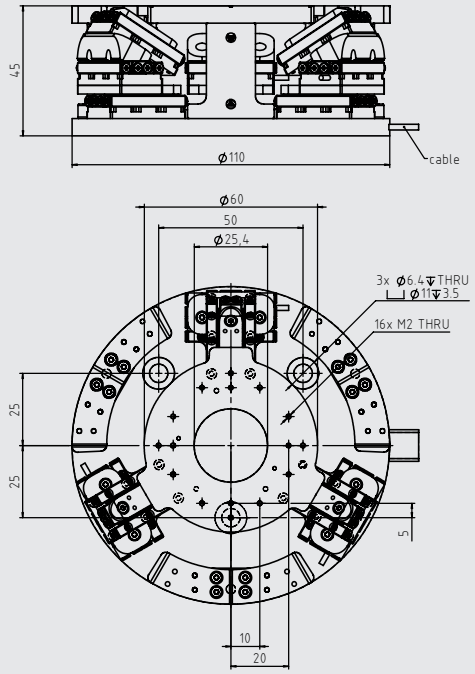
		70.42
Mechanical	Travel x [mm]	10
	Travel y [mm]	10
	Travel z [mm]	5
	Rotation Θ_x [°]	14
	Rotation Θ_y [°]	16
	Rotation Θ_z [°]	28
	max. Vertical Load [N]	5
	max. Horizontal Load [N]	2.5
	Dimensions [mm]	Ø 70
	Height [mm]	42
	Weight [g]	300
Cloded-loop	Sensor Types	S, SC
	Smallest Increment [nm]	1
	Smallest Increment [µrad]	1
	Repeatability for Full Travel Range [nm]	< ± 200
	Repeatability for Full Travel Range [µrad]	< ± 10
	Repeatability for 1 mm Linear Travel [nm]	< ± 15
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)
Non.Magnetic		Yes (-NM)



SMARPOD *110:45: A mid size hexapod-like 6D positioning system. Shown in zero position.*

SMARPOD *110.45 in a deflected pose.*

The **SMAR**POD *110.45* is a mid-size hexapod-like positioning system. Because of its larger travel ranges it is extremely versatile. Optionally, the base plate can be equipped with mounting posts for tools, components or sensors, converting the positioning system to a core device for micro assembly and any other application involving precise alignment. Like other SmarAct **SMAR**POD's, the 110.45 is also available in a high vacuum and ultra-high vacuum version or made out of fully non-magnetic materials.

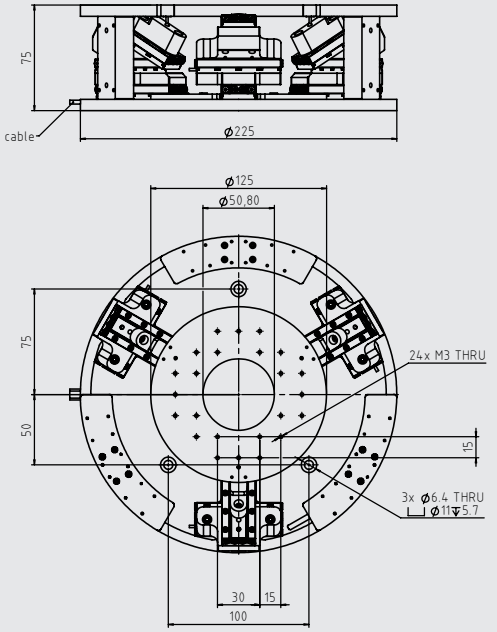


		110.45
Mechanical	Travel x [mm]	20
	Travel y [mm]	20
	Travel z [mm]	11
	Rotation Θ_x [°]	21
	Rotation Θ_y [°]	24
	Rotation Θ_z [°]	38
	max. Vertical Load [N]	5
	max. Horizontal Load [N]	2.5
	Dimensions [mm]	Ø 110
	Height [mm]	45
	Weight [g]	400
Cloded-loop	Sensor Types	S, SC
	Smallest Increment [nm]	1
	Smallest Increment [µrad]	1
	Repeatability for Full Travel Range [nm]	< ± 200
	Repeatability for Full Travel Range [µrad]	< ± 10
	Repeatability for 1 mm Linear Travel [nm]	< ± 15
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)
Non-Magnetic Option		Yes (-NM)

SMARPOD *225.75: A large size hexapod-like 6D positioning system. Shown in zero position.*

SMARPOD *225.75 in a deflected pose.*

The **SMAR**POD *225.75* is one of the larger SmarAct **SMAR**POD's offering a large travel range of over 40 mm in X and Y. As an option, the base plate can be equipped with mounting posts for placing tools, sensors or other components close to the moving platform of the **SMAR**POD. Like other SmarAct **SMAR**POD's the 225.75 is also available in a high vacuum and ultra-high vacuum version or made out of fully non-magnetic materials.

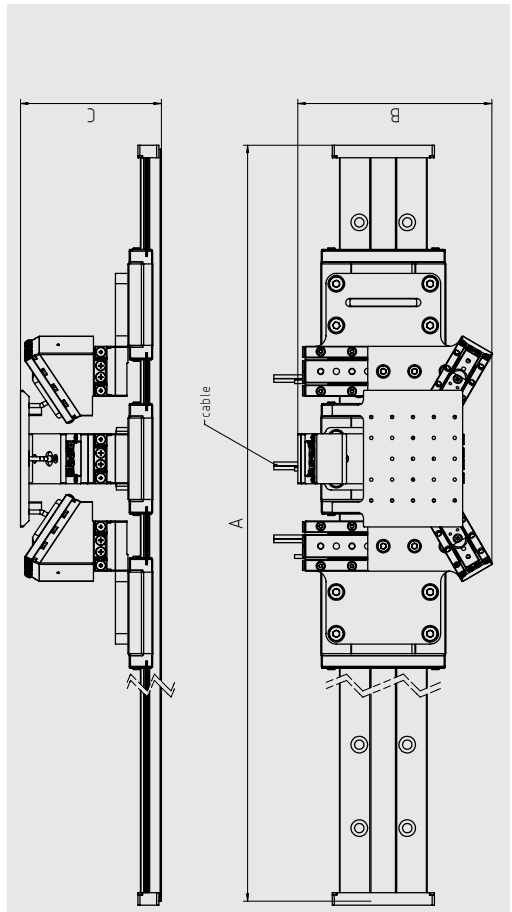


		225.75
Mechanical	Travel x [mm]	41
	Travel y [mm]	71
	Travel z [mm]	21
	Rotation Θ_x [°]	20
	Rotation Θ_y [°]	23
	Rotation Θ_z [°]	41
	max. Vertical Load [N]	10
	max. Horizontal Load [N]	5
	Dimensions [mm]	Ø 225
	Height [mm]	75
	Weight [g]	1,000
Cloded-loop	Sensor Types	S, SC
	Smallest Increment [nm]	1
	Smallest Increment [µrad]	1
	Repeatability for Full Travel Range [nm]	< ± 200
	Repeatability for Full Travel Range [µrad]	< ± 10
	Repeatability for 1 mm Linear Travel [nm]	< ± 15
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)
Non-Magnetic Option		Yes (-NM)

SMARPOD *P-SLL: A* **SMAR**POD *based on three carriages of the SLL-Series.*

SMARPOD *P-SLL in a deflected pose.*

The **SMAR**POD *P-SLL* is based on SLC stages for the movement in the Y direction and a SLL stage in the X direction. Due to this specific combination of different linear stages, the P-SLL offers an extremely large travel range in the X direction of up to 1200 mm while maintaining a small footprint in the Y direction. It is also available as high vacuum compatible version.

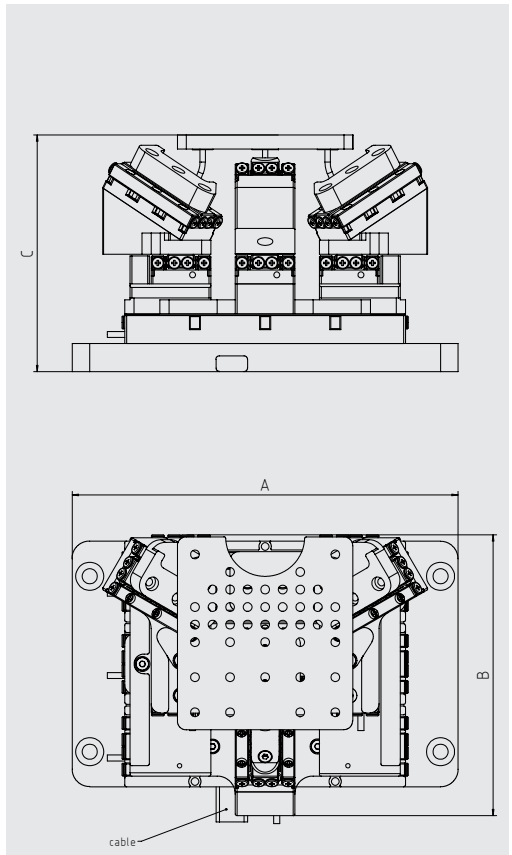


		P-SLL
Mechanical	Travel x [mm]	20 .. 1200
	Travel y [mm]	45 .. 119
	Travel z [mm]	≤ 16
	Rotation Θ_x [°]	≤ 42
	Rotation Θ_y [°]	≤ 33
	Rotation Θ_z [°]	≤ 42
	max. Vertical Load [N]	10
	max. Horizontal Load [N]	5
	Dimensions [mm]	> 250 x 93
	Height [mm]	> 67.5
	Weight [g]	300 .. 2000
Cloded-loop	Sensor Types	S, SC
	Smallest Increment [nm]	1
	Smallest Increment [µrad]	1
	Repeatability for Full Travel Range [nm]	< ± 200
	Repeatability for Full Travel Range [µrad]	< ± 10
	Repeatability for 1 mm Linear Travel [nm]	< ± 15
Vacuum Option		HV (10^{-6} mbar)

SMARPOD *P-SLC-17 : A mid-size* **SMAR**POD *based on SLC-17 stages in a parallel orientation.*

SMARPOD *P-SLC-17 in a deflected pose.*

The **SMAR**POD *P-SLC-17* is based on a different mechanical design w in relation to the orientation of the horizontally mounted stages. In comparison with a circular **SMAR**POD of nearly the same size, the P-SLC-17 offers a much larger travel range in dispense of the aperture that is available in the circular designs. Based on SLC-17 Series stages, the **SMAR**POD *P-SLC-17* is also available in a high and ultra-high vacuum version as well as a version that is made out of fully non-magnetic materials.



		P-SLC-17
Mechanical	Travel x [mm]	48
	Travel y [mm]	28 ..48
	Travel z [mm]	≤ 9
	Rotation Θ_x [°]	≤ 28
	Rotation Θ_y [°]	≤ 26
	Rotation Θ_z [°]	≤ 20
	max. Vertical Load [N]	5
	max. Horizontal Load [N]	2.5
	Dimensions [mm]	> 110 x 80
	Height [mm]	> 67.5
	Weight [g]	300 .. 2000
Cloded-loop	Sensor Types	S, SC
	Smallest Increment [nm]	1
	Smallest Increment [µrad]	1
	Repeatability for Full Travel Range [nm]	< ± 200
	Repeatability for Full Travel Range [µrad]	< ± 10
	Repeatability for 1 mm Linear Travel [nm]	< ± 15
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)
Non-Magnetic Option		Yes (-NM)

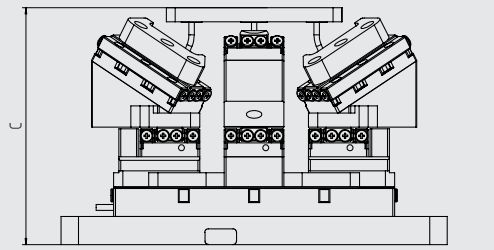
SMARPOD
SMARPOD *P-SLC-24*

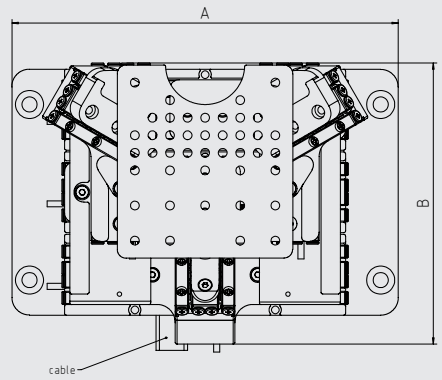
SMARPOD *P-SLC-24: A mid-size* **SMAR**POD *based on SLC-24 stages in a parallel orientation.*

SMARPOD *P-SLC-24 in a deflected pose.*

SmarAct's **SMAR**POD *P-SLC-24* utilizes the SLC-24 linear stages in an orthogonal orientation allowing large travel ranges while maintaining a comparably small footprint. Due to its ability to handle high payloads and its long travel ranges, the P-SLC-24 is one of the most versatile multi-axis positioning system available. As it is based in SLC-24 Series stages it is also available as a high and ultra-high vacuum compatible version. If required by the application it can be made out of fully non-magnetic materials.

		P-SLC-24
Mechanical	Travel x [mm]	79 .. 119
	Travel y [mm]	45 .. 119
	Travel z [mm]	≤ 12
	Rotation Θ_x [°]	≤ 31
	Rotation Θ_y [°]	≤ 27
	Rotation Θ_z [°]	≤ 42
	max. Vertical Load [N]	10
	max. Horizontal Load [N]	5
	Dimensions [mm]	> 150 x 100
	Height [mm]	> 87
	Weight [g]	300 .. 2000
Cloded-loop	Sensor Types	S, SC
	Smallest Increment [nm]	1
	Smallest Increment [µrad]	1
	Repeatability for Full Travel Range [nm]	< ± 200
	Repeatability for Full Travel Range [µrad]	< ± 10
	Repeatability for 1 mm Linear Travel [nm]	< ± 15
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)
Non-Magnetic Option		Yes (-NM)

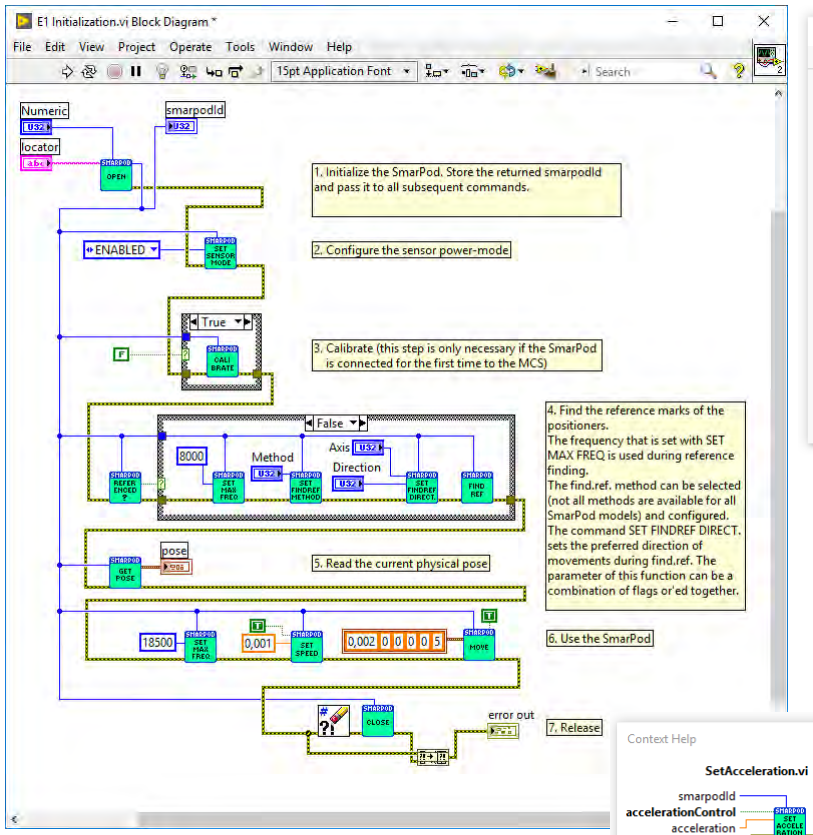


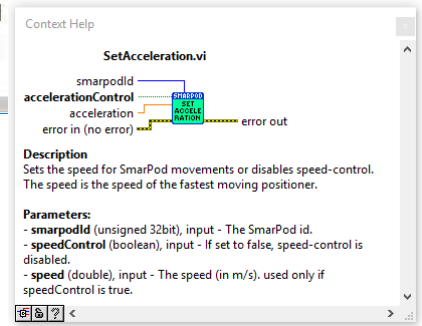


A customized **SMAR**POD *110.45 for overhead installation with cut-outs in base and top plate.*

SmarAct **SMAR**POD's can be controlled in different ways. Apart fom the **SMAR**POD hardware a control software with graphical user interfaces, a Software Development Kit, programming examples in C/C++ and LabVIEW® is part of the delivery. Please refer to page 100 for details about the **SMAR**POD Control Software and the Precision Tool Commander.
The LabVIEW® SDK included offers a tool palette with all necessary VI´s to integrate the **SMAR**POD into your own control application. The programming examples are well commented and the SubVI's include an in depth documentation about their functionality and parameters.

All kinematic calculations are performed within a software layer that is being called by the SubVIs allowing you to move every **SMAR**POD in Cartesian coordinates - with no need to perform inverse kinematic calculations for the positioning system. Therefore the integration of a SmarAct **SMAR**POD into your own application is an easy-to-perform task guaranteeing very short implementation times.





SMARPOD **Hand Controller**

Software is only one way to control SmarAct's **SMAR**POD's. If you prefer a more tactile feedback a hand held controller with knobs and buttons might be a more convenient option for you. The **SMAR**POD *Hand Controller* is connected via USB to the PC running the **SMAR**POD *Control Software* offering six turning knobs to control each translational and rotational degree of freedom. It also lets you store and recall poses or position sets from your fingertips.

Embedded Control Module (ECM)

An Embedded Control Module (ECM) allows controlling **SMAR**POD's (as well as single SmarAct stages) without the need to install special software. The ECM provides a text-based command interface for easy integration into existing control environments.
The ECM is available as a rack module, designed to be installed together with a **MCS**2 controllers in a modular rack enclosure, as well as a tabletop device. Both variants can be easily configured to add more **SMAR**POD units (or single SmarAct Stages) at any time.

A customized **SMAR**POD *225.75 mounted on top of a rotation stage. The base is equipped with a bracket and an additional SLC-17 linar stage that is being used for tool handling.*

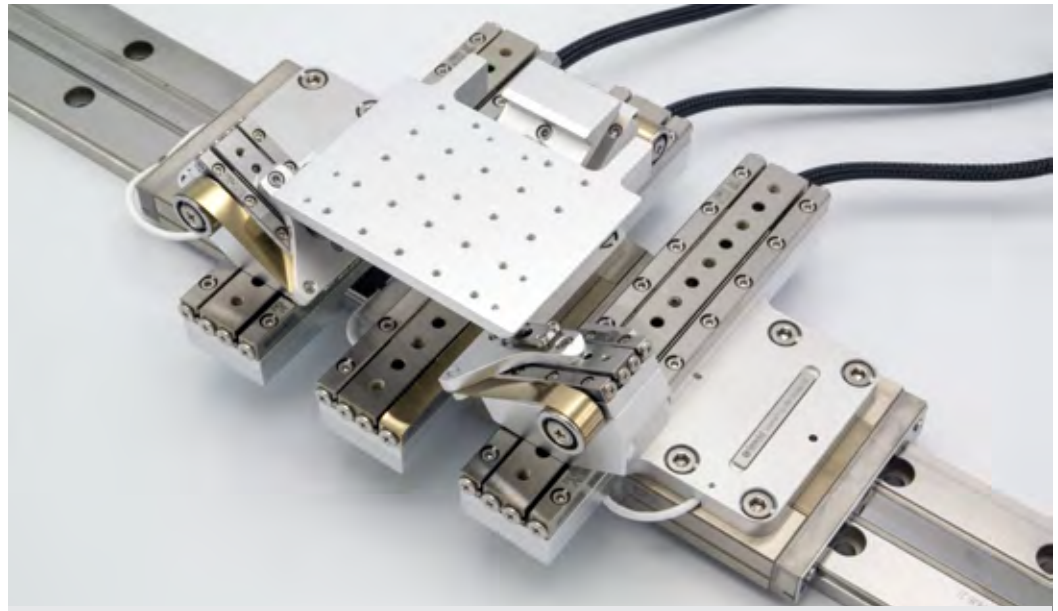
A modified **SMAR**POD *110.45 in a non-magnetic version for use in ultra-high vacuum environments.*

A customized non-magnetic **SMAR**POD *110.45 mounted to a lifting stage for larger travel ranges in the vertical direction.*

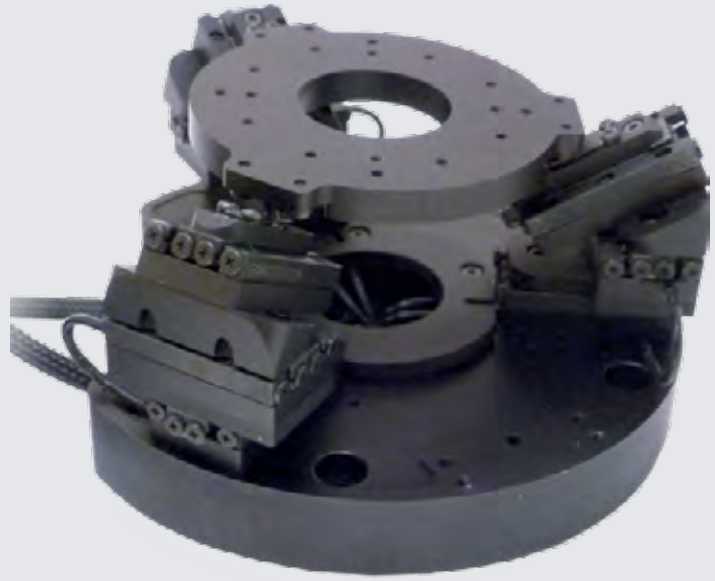
A customized **SMAR**POD *110.45 equipped with a bracket holding an SR rotation stage and a SGP-1730 parallel gripping system.*

A modified P-SLC-24 **SMAR**POD

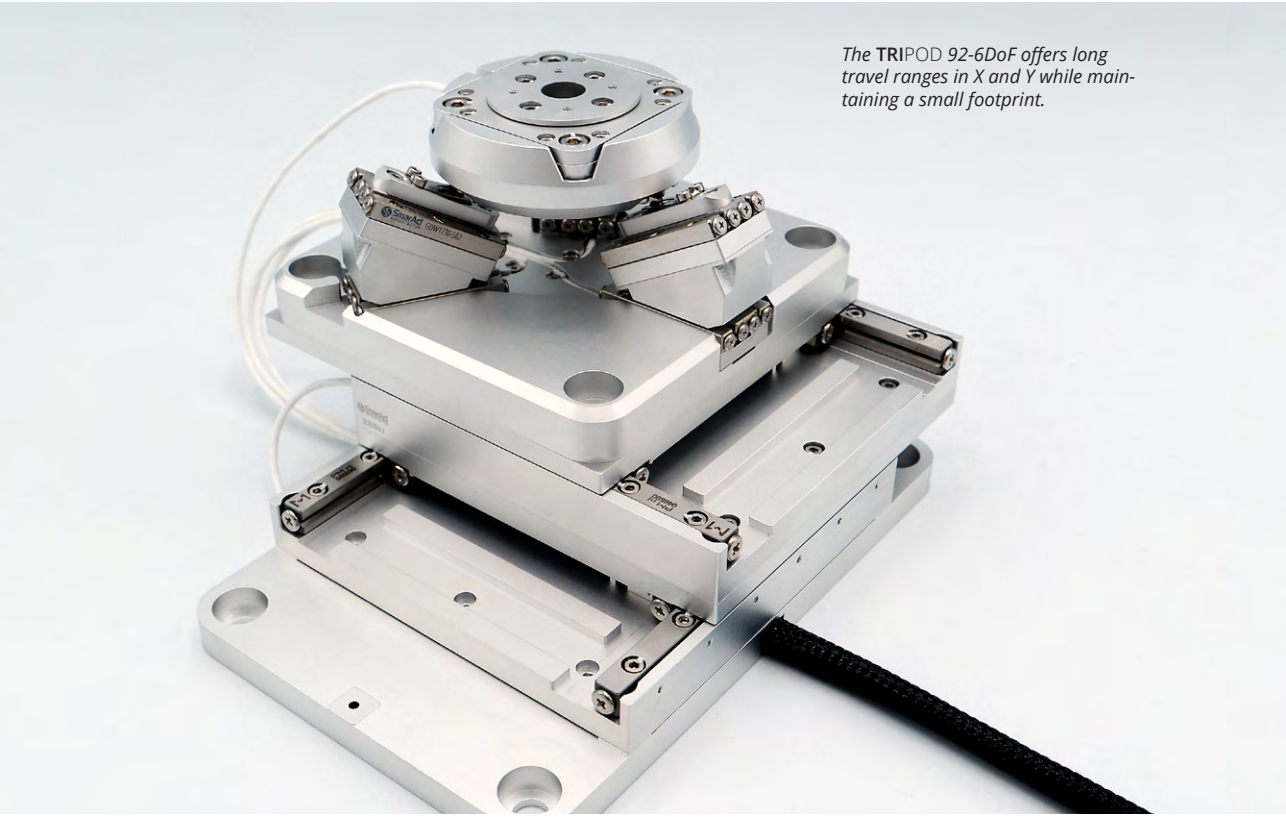
A customized **SMAR**POD *110.45 equipped with a gripping system for micro-assembly applications.*



A customized **SMAR**POD *P-SLL modified for longer X and Y travel ranges and equipped with constant force springs to handle heavier payloads.*



Black anodized **SMAR**POD to be used in the field of optical assembly and optical alignment.



*The **TRI**POD 92-6DoF offers long travel ranges in X and Y while maintaining a small footprint.*

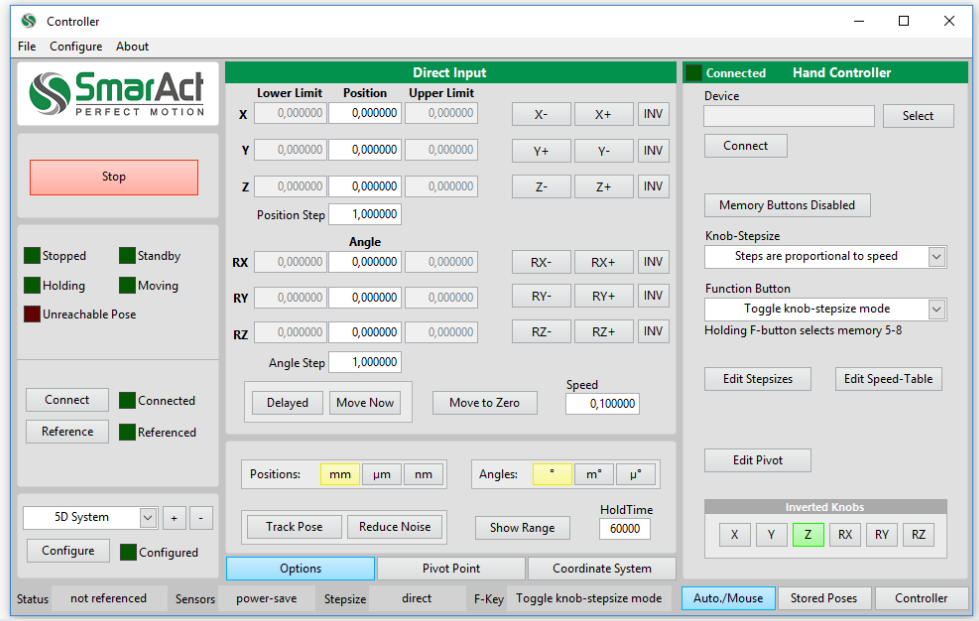
The SmarAct **TRI**POD Product Series is the newest addition to our portfolio of compact and modular multi-dimensional positioning systems, combining serial and parallel kineamtics in a hybrid design comparison to classical hexapods, which are in some way limited in regard to the rotation around their Z-axis. **TRI**PODs offer continous rotation capability.
A **SMAR**POD that should be able to rotate continuously around its Z-axis would have to be equipped with a rotation stage on its top plate which would influence system complexity and the overall cost of such a system. The **TRI**POD on the other hand includes such rotation capabilities without these mechanical and economical drawbacks.

Unique Features

The central component of a **TRI**POD positioning system is the 3D **TRI**POD, a tip-tilt stage offering two rotational and one translational degree of freedom in a very compact design. Because the **TRI**POD is fully compatible to the SmarAct Modular System (see page 74 for details). it can be mounted on top of a high precision XY platform made of SLS linear piezo stages. The resulting 5D system allows the positioning of the pivot point, as the common center of rotation, in all three dimensions. The top plate offers a mounting space for an additional rotation stage yielding to a modular positioning system with six degrees of freedom whereas the rotation around the Z-axis is continuous by design.

The **TRI**POD is currently available in two different sizes, the smaller one is compatible with the SLS-52 Modular System, the larger one with the SLS-92 Modular System, respectively.

A user friendly software package allows easy integration into your own control environment assuring a very short setup time. The **TRI**POD, like all other SmarAct products, is highly customizable



*The **TRI**POD control software offers to save poses, customize the pivot point and coordinate system and to command the **TRI**POD in cartesian coordinates.*

and can be integrated into completely customized setups. Regardless if your application requires only a modified base or top plate or a completely different configuration do not hesitate to contact us to discuss your requirements and to work together on the best solution. Let us assist you in bringing your idea to life.

Working Principle

The **TRI**POD in its maximum configuration as a 6D stage is a hybrid of a parallel and a serial kinematic positioning system. The top plate is actuated by the simultaneous movement of multiple linear stages in contrast to pure serial kinematic approaches where each translation is the result of the movement of a specific linear or rotation stage.
The arrangement of all the **TRI**POD's linear stages contributes to the overall stiffness of the system and allows the top plate to be translated and rotated with five degrees of freedom, when the additional rotation stage is mounted on the top plate the number of degrees of freedom increases to six.

Control in Cartesian Coordinates

Calculation of the kinematics model and device control is encapsulated in a software package. Programming interfaces and graphical user interfaces allow to move the **SMAR**POD in Cartesian coordinates (X, Y, Z, roll, pitch and yaw) and to adjust the systems pivot point and coordinate system.

User-Definable Pivot Point

The great advantage of the **TRI**POD, as well as the **SMAR**POD, is the possibility to freely set the rotations pivot point. Thereby defining the center of rotation for all axis which allows you to precisely rotate around any adressable point in space.
Environmental Specific
For applications that require vacuum conditions the SmarAct **TRI**PODs are available in high and ultra-high vacuum compatible versions. Furthermore, they can also be made out of fully non-magnetic materials to be used in higher magnetic fields.

High Resolution

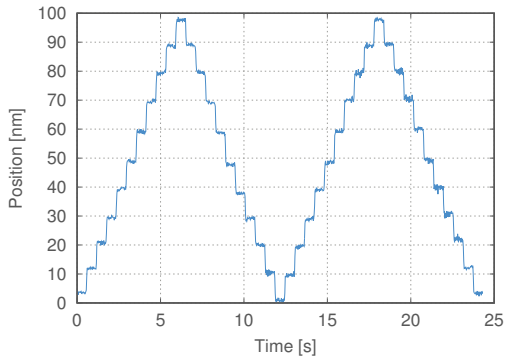
A backlash-free mechanical design makes it possible to achieve a movement performance of the positioning system which is in the same order of magnitude as for our single positioners. The smallest movement increment is 1 nm for linear and 1 µrad for rotary motions.

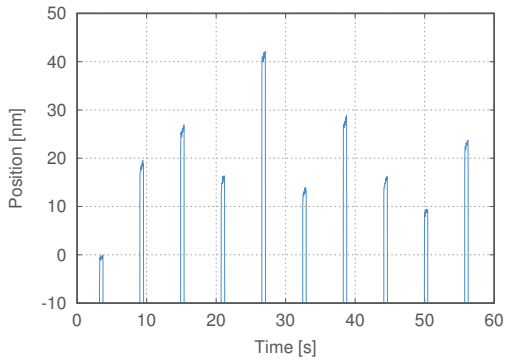
TRIPOD
Repeatability

Linear Repeatability

The linear bidirectional repeatability when using the whole travel range in X, Y and Z is 200 nm. For smaller movements the repeatability is in the order of several nanometers which has been verified in a test bench setup utilizing SmarAct's **PICO**SCALE *Interferometer*.
For this test a mirror was mounted to the top plate of a mid-size **TRI**POD facing a **PICO**SCALE sensor head. The **TRI**POD was then commanded to move 10 steps back and forth in the Z direction with a step height of 10 nm and hold time between each step of 600 ms. The position data recorded with the **PICO**SCALE *Interferometer* verifies the excellent linear repeatability of the **TRI**POD.

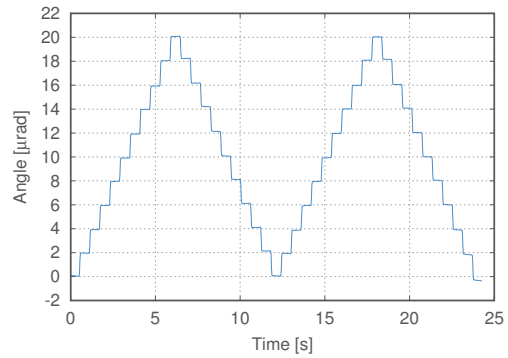
When repeating the test for longer travel ranges of 1 mm the linear bidirectional repeatability shows that the reference position can be repeatedly reached with an accuracy of 12 nm.

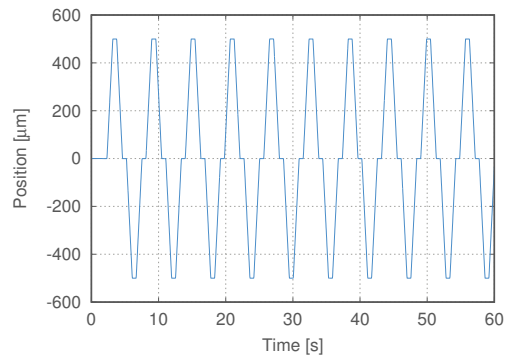




Angular Repeatability

The bidirectional angular repeatability when tilting the top plate back and forth was also measured with a test setup utilizing three **PICO**SCALE *Interferometers*. A mirror was mounted to the top plate of a mid-size **TRI**POD facing the three sensor heads. When performing a rotation, the three sensor heads measure a change in the optical path length from which the rotation angle can be calculated. In this test the top plate was tilted in 10 steps of 1 µrad each back and forth. The hold time between each step was 300 ms. The angular data recorded with the **PICO**SCALE *Interferometers* verifies the excellent angular repeatability of the **TRI**POD.
When repeating the test for longer travel ranges of 1 mm the linear bidirectional repeatability shows that the reference position can be repeatedly reached with an accuracy of 12 nm.





*The **TRI**POD 52-6DoF is equipped with two SLS-52 linear stages and a continous rotation stage on its top plate.*

SR-3211 rotation stage with continuous rotation around the Z-axis Θ_z

3D **TRI**POD Core 52

SLS-5252 linear stage with a travel range of ±15.5 mm

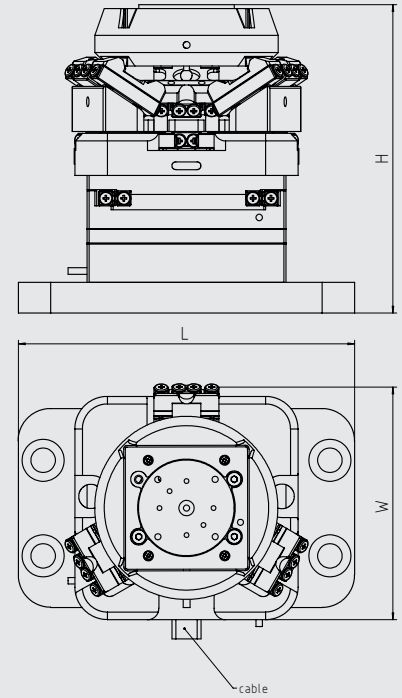
SLS-5252 linear stage with a travel range of ±15.5 mm

Breadboard compatible base plate

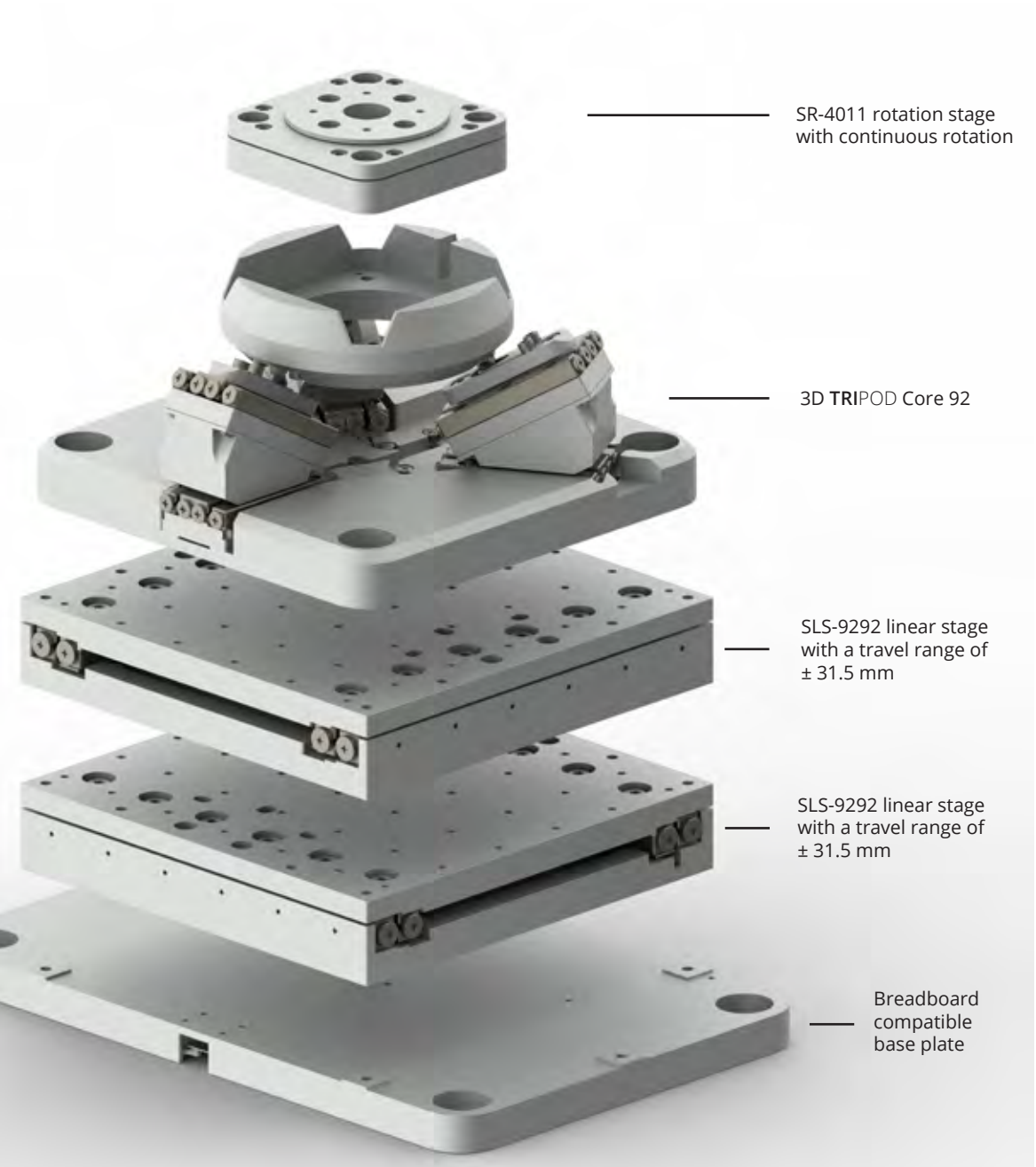
TRIPOD
TRIPOD *52-6DoF*

TRIPOD 52-6DoF

The **TRI**POD 52-6DoF is compatible with the SLS-52 Modular System and consists like its larger equivalent of a tip-tilt stage. Here the arrangement of the three turrets allows a roll and pitch motion of the top plate in the range of ±8.5° for Θ_x, ±9.5° for Θ_y and a linear translation in the Z direction of 11 mm. The top plate includes a mounting slot for a SR-3211 rotation stage to add a fourth degree of freedom to the setup. The bottom plate on the contrary allows a direct mounting to a breadboard or a XY platform consiting of two SLS-52 linear translation stages. The later possibility yields to a 5D or together with the SR-3211 to a 6D positioning system.



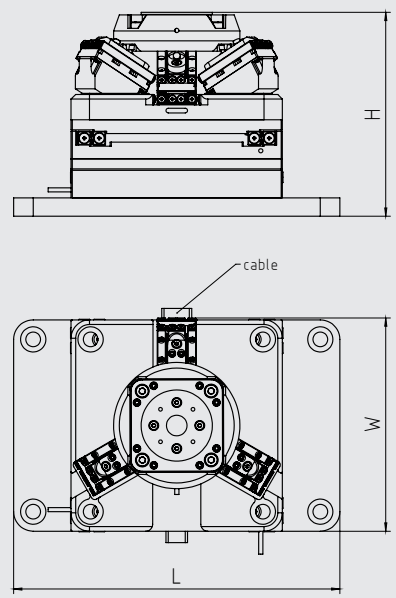
		52-6DoF
Mechanical	Travel x [mm]	31
	Travel y [mm]	31
	Travel z [mm]	11
	Rotation Θ_z [°]	17
	Rotation Θ_y [°]	19
	Rotation Θ_z [°]	unlimited
	max. Vertical Load [N]	5
	max. Horizontal Load [N]	2.5
	Dimensions L x W [mm]	88 x 61 (64 x 61 without base plate)
	Height [mm]	81
	Weight [g]	~ 550
Cloded-loop	Sensor Types	S
	Smallest Increment [nm]	1
	Smallest Increment [µrad]	1
	Repeatability for Full Travel Range [nm]	< ± 200
	Repeatability for Full Travel Range [µrad]	< ± 10
	Repeatability for 1 mm Linear Travel [nm]	< ± 15
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)
Non-Magnetic Option		Yes (-NM)



TRIPOD
TRIPOD *92-6DoF*

TRIPOD 92-6DoF

The larger of the two **TRI**POD is compatible with the SLS-92 Modular System. A tip-tilt stage is the core component of this positioning system. The arrangement of the three turrets allows a roll and pitch motion of the top plate in the range of ±13° for Θ_x, ±15° for Θ_y and a linear translation in the Z direction of 10 mm. The top plate also includes a slot to mount a SR-4011 rotation stage to add a fourth degree of freedom to the setup. The bottom plate on the contrary allows a direct mounting to a breadboard or a XY platform consisting of two SLS-92 linear translation stages. The later possibility yields to a 5D or together with the SR-4011 to a 6D positioning system.



		92-6DoF
Mechanical	Travel x [mm]	63
	Travel y [mm]	63
	Travel z [mm]	10
	Rotation Θ_x [°]	26
	Rotation Θ_y [°]	30
	Rotation Θ_z [°]	unlimited
	max. Vertical Load [N]	5
	max. Horizontal Load [N]	2.5
	Dimensions L x W [mm]	142 x 101
	Height [mm]	89
	Weight [g]	~ 1850
Cloded-loop	Sensor Types	S
	Smallest Increment [nm]	1
	Smallest Increment [µrad]	1
	Repeatability for Full Travel Range [nm]	< ± 200
	Repeatability for Full Travel Range [µrad]	< ± 10
	Repeatability for 1 mm Linear Travel [nm]	< ± 15
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)
Non-Magnetic Option		Yes (-NM)

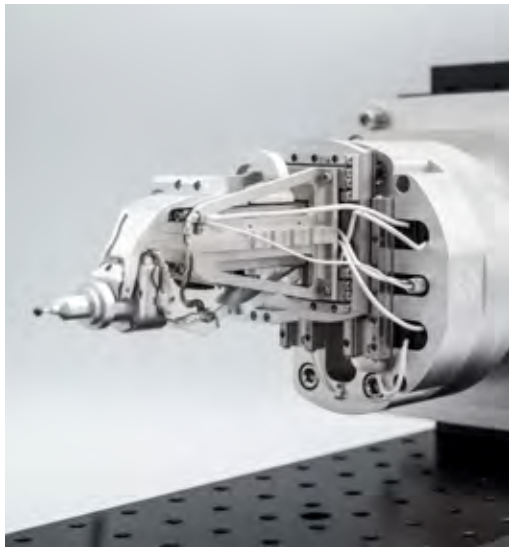
The overall compactness and the narrow outline of SmarAct's goniometer **SMARG**ON *makes it the perfect sample manipulator for every XRD setup.*

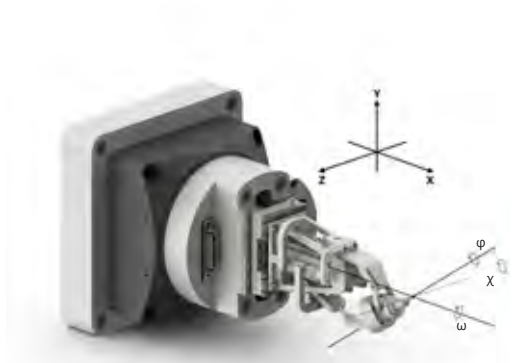
Highest precision, robustness and reliability are the top priority properties when selecting equipment for the use in synchrotron endstations.
In collaboration with the Swiss Light Source (SLS) Group for Macromolecular Crystallography at the Paul Scherrer Institut (PSI) SmarAct has designed a goniometer with six degrees of freedom to be used at synchrotron beamlines and in laboratories with standard X-ray sources.
The **SMAR**GON is an innovative multi-axis goniometer for crystal positioning and reorientation in macromolecular crystallography. Its compact design reduces self-shadowing effects and allows large rotary angles even in confined experimental setups. With a smart automated calibration routine it achieves a sphere of confusion in the single-digit micrometer range for all rotary axes.
As with all standard SmarAct products, customization options for specialization of **SMAR**GON systems are also available. Please feel free to contact our application scientists to discuss your specific requirements or customization.

The **SMAR**GON consists of a combination of a positioning system with five degrees of freedom mounted on top a heavy duty rotation stage. A piezo driven rotation stage or a high precision air bearing can be used for the ω-rotation of the positioning system. The five axis positioning stage allows the sample under investigation to be positioned in X, Y and Z direction and to be rotated in the χ- and φ-direction. The **SMAR**GON control system calculates the partially parallel kinematic ttransformation which allows for direct positioning and alignment in the beam.

In its standard configuration a magnetic sample holder is mounted at the frontend which offers a fast and convenient way to load and unload different samples.

This high precision goniometer was especially designed for the use in X-ray diffraction experiments. Therefore, SmarAct devoted particular attention to





The six degrees of freedom of the **SMAR**GON *positioning system.*

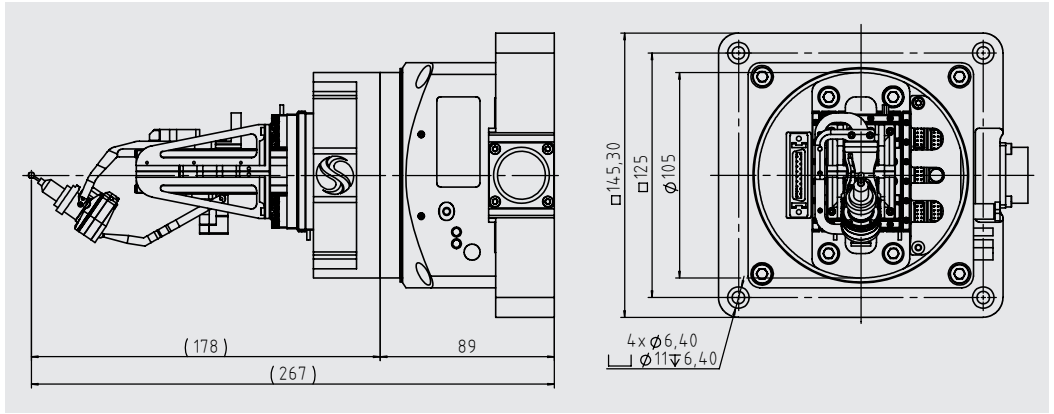
the goniometers overall compactness and its small footprint to minimize self-shadowing effects. This also allows the X-ray detector to be placed much closer to the sample, yielding a larger portion of the diffraction cone to be detected.

SmarAct is also able to offer the **SMAR**GON in a vacuum compatible versions or fully made out of non-magnetic materials.
The sphere of confusion of the entire setup represents the overall performance and strongly depends on the precision of each individual positioning stage. Therefore, each stage is accurately aligned to ensure synergy in the combined multi-axial system. Furthermore, a sophisticated calibration via the available Calibration Kit provides the basis of an active compensation routine which is implemented in the systems motion controller. The following table provides an overview of the system specifications determined during on site operation after successful calibration.

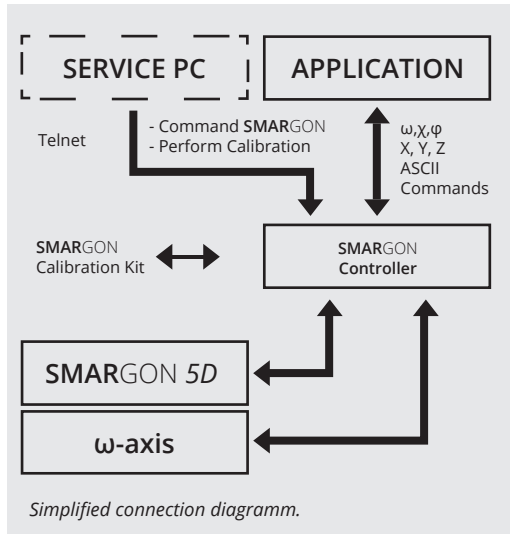
	ω	χ	φ	X	Y	Z
Travel Range	Infinite	0°.. 90°	Infinite	± 2 mm		
Sphere Of Confusion [µm]	< 1	< 7	< 7	--		
Resolution of Motion	< 100 µ°	< 20 µ°		< 5 nm		
Velocity	180 °/s	10 °/s	80 °/s	~10 mm/s		
Max. Sample Weight [g]	50					

The **SMAR**GON *can be calibrated with the help of a calibration kit and a special calibration sample.*

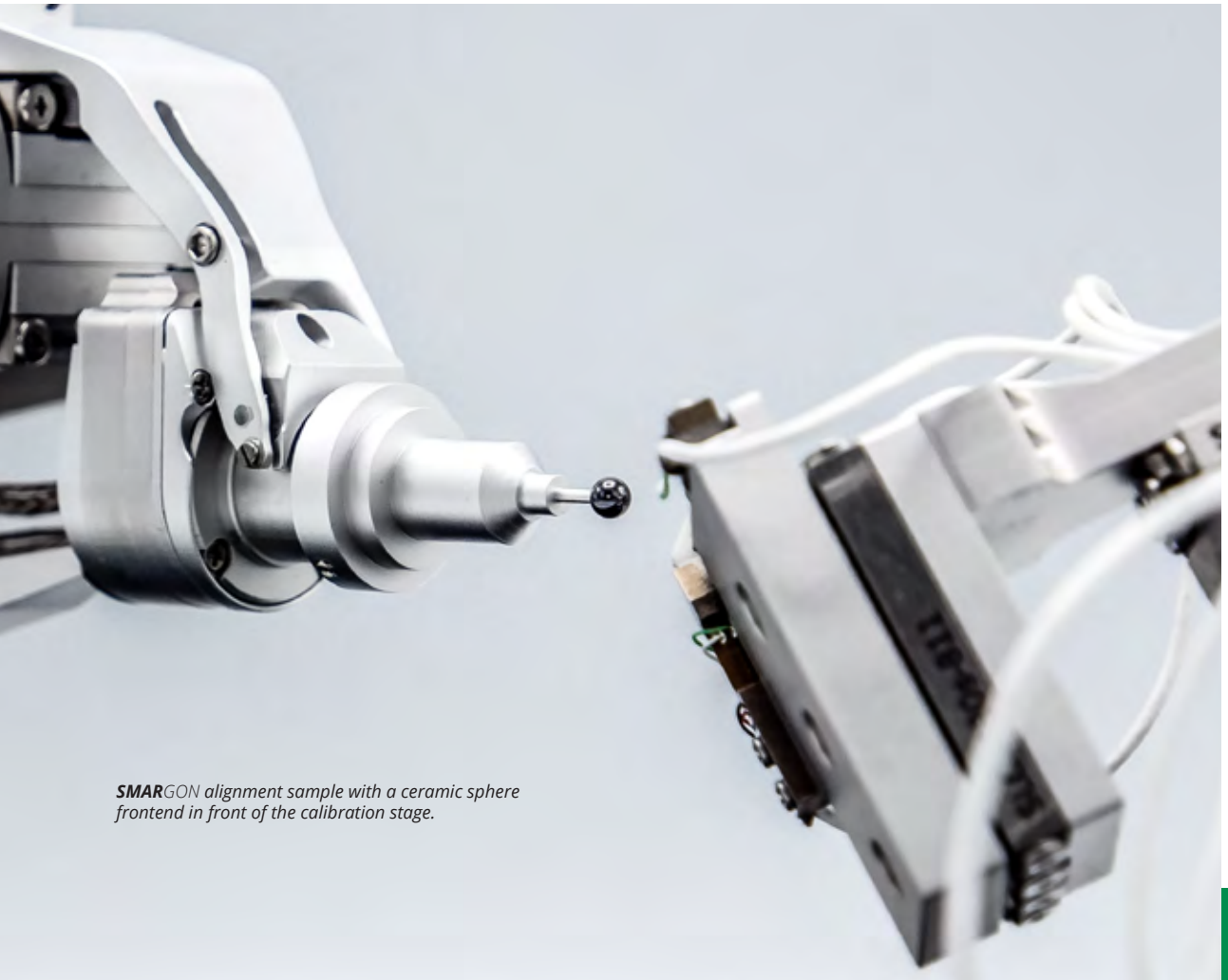
Aside from the detector, the goniometer is one of the core parts of every diffraction setup. The **SMAR**GON is delivered as a complete system ready for integration. Its scope of delivery consists of the **SMAR**GON positioning system and a rack-mountable control system.
The control system utilizes on a programmable multi-axis controller (PMAC), which is connected to SmarAct's **SDC**2 piezo stage controllers. The necessary kinematic calculation is performed on the PMAC in combination with an active correction of positioning inaccuracies. This ensures the highest positioning precision and repeatability. The PMAC and the **SDC**2 together with the necessary power supplies and communication hardware is mounted in 19-inch rack-mountable chassis. The Ethernet communication interface of the PMAC is a human readable string based ASCII protocol defined by Delta-Tau. This simplifies the integration into existing customer specific control environments.



The calibration kit consists of a hardware and a software part, both designed to automatically measure deviations from an ideal rotation and to calculate compensation parameters which will be stored in the PMAC. The hardware part includes a calibration sample equipped with a ceramic sphere as test object. A three dimensional positioning system with force sensors is used to measure the lateral displacement of the ceramic sphere while the calibration sample is rotated by the **SMAR**GON. A sophisticated routine ensures the calibration of the goniometer within minutes.
The **SMAR**GON positioning system includes in its standard configuration an air bearing round table as the ω-axis. Nontheless, it can also be delivered without the air bearing to be mounted on an existing customer owned omega-axis on request.



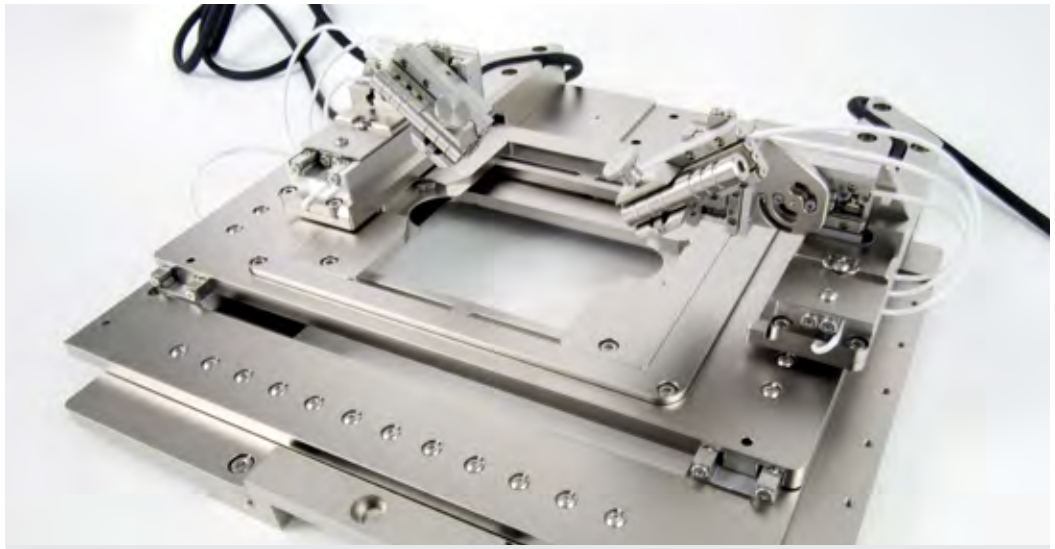
Simplified connection diagramm.



***SMAR**GON alignment sample with a ceramic sphere frontend in front of the calibration stage.*

The roots of the **SMAR**GON can be found in Synchrotron XRD applications. But looking at the basis of the design one finds a universal device that can be described as a hybrid of a parallel and a serial kinematic positioning system. With a kinematic that allows the **SMAR**GON to translate in three dimensions and to rotate compucentric around a definable point in its working space it is not only a scientific tool but can be seen as a very versatile robotic handling system for other fields of application.
For example, when exchanging the heavy duty air bearing of the XRD version of the **SMAR**GON for a high precision piezo driven SmarAct rotation stage the **SMAR**GON becomes even more compact. If additionally, the magnetic XRD sample receptacle would be removed and exchanged for a receptacle that accepts SEM stubs we would have created a high precision SEM sample stage with six degrees of freedom and very thin silhouette. Due to the availability of HV and UHV compatible versions of the device it would be also possible to use it as a sample manipulator for Auger- or Photo-Electron Spectroscopy or other analytical techniques that require vacuum conditions.
One could also think of exchanging the **φ** axis and the sample receptacle with a SmarAct Gripping System. With this modification we could create a versatile robotic handling system. When the so created robot would be placed on a long linear stage rail system of the SLL Series it would be the perfect solution for precise material and sample handling tasks. An additional synergy effect would arise by the fact that it could not only be used for sample transportation from sample storages to analysis systems or microscopes but could also double as the primary sample stage for laboratories requiring high sample throughput.
Combining high precision positioning with large travel ranges open up new fields of applications. Get inspired and start a discussion about high precision robotics with our application specialists.

Systems



Microscopy stage with large free aperture and two micromanipualtors.

In life sciences precise specimen handling and manipulation is the most crucial part of the daily business at a microscopy workplace, therefore equipment being used has to be extremely precise and reliable.

Microscopy Stages and Manipulators

To address this requirements, SmarAct has developed microscopy stages that not only allow the specimen to be positioned in two dimensions, but also allow mounting of micromanipulation systems for *in situ* sample manipulation. The microscopy stage itself is based on compact linear stages and allows long travel ranges with nanometer precision and highest repeatability in closed-loop control mode.

In addition to the standard universal object slide holder, a unified well-plate holder and petri dish holders are available. For high throughput experiments also a magnetic holder is available which allows an easy and fast exchange of slides and coverslips.
Micromanipulation systems are very versatile devices when it comes to handle pipettes, micro-knives, micro-grippers, microinjectors or other mechanical or electrical probes.
Our portfolio includes several different manipulators with three and four degree-of-freedom for the most common tasks.

Larger stages support not only one but two or more micromanipulators which gives you even more degrees-of-freedom to manipulate your specimens. Both manipulators can be moved totally independent of each other and of course can be equipped with different tools and axes configurations.

Compatibility and Adaptability

SmarAct microscopy stages are compatible with Leica DMI3000 and DM2700M and also with Olympus BX microscopes. The stages can be highly customized and adapted to other models and brands. Please do not hesitate to contact us to discuss customized adaptation of our stages to your specific microscope model or your self-developed setup.

A four axis micromanipulator allows positioning of tools with nanometer precision in front of the objective lens.

Control Systems and Software

The XY stage and the micromanipulators are being controlled by our **MCS**2 control system, allowing up to 18 positioning stages addressed from one controller. This make even highly versatile setups consisting of one XY stage and four micromanipulators with four degrees-of-freedom each possible. A special driving mode of the driving sound of the piezo stage called “quiet mode” reduce the piezo noise significantly by shifting the driving frequency out of the human hearing range. The stage and manipulators can be commanded by different hand control devices with tactile buttons and joysticks or with SmarAct’s Precision Tool Commander software (please refer to page 166). Integration of the XY stage and the manipulators into your own control software can be realized with the help of the supplied Software Development Kits which include documentation, libraries and programming examples for C/C++ and LabVIEW®. Based on the control interface, the microscopy stage can easily be integrated into existing software frameworks. Even an integration into Micro-Manager an open source software package for microscope image acquisition and device control by Open Imaging, Inc. is available.

The SOM-MS-CST-SLC-1780 stage was designed to fit in all Olympus© BX series microscopes.

All microscopy stages and components incl. micromanipulators are also available with a black anodized surface finish.

		SOM-MS-CST-SLC-1750	SOM-MS-CST-SLC-1780	SOM-MS-1.0
Mechanical	Travel X [mm]	31	51	103
	Travel Y [mm]	31	51	83
	Blocking Force [N]	≥ 3.5		
	max. Normal Force [N]	30		
	Dimensions [mm], L x W x H	90 x 80 x 18	120 x 110 x 18	238 x 218 x 27
Open-loop	Velocity [mm/s]	> 20		
	Resolution [nm]	< 1		
Closed-Loop	Resolution **MCS**2 [nm]	1 (S) 4 (L)		
	Repeatability, Full Stroke **MCS**2 [nm]	± 50 (S) ± 100 (L)	± 80 (S) ± 160 (L)	± 150 (S) ± 300 (L)
	Resolution (H)CU [nm]	50 (L)		
	Repeatability, Full Stroke (H)CU [nm]	± 1000 (L)		
Material Options		Steel base (-ST); titanium base (-TI); black anodized (-BK)		
Vacuum Options		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)		

Motorized Opto-Mechanics

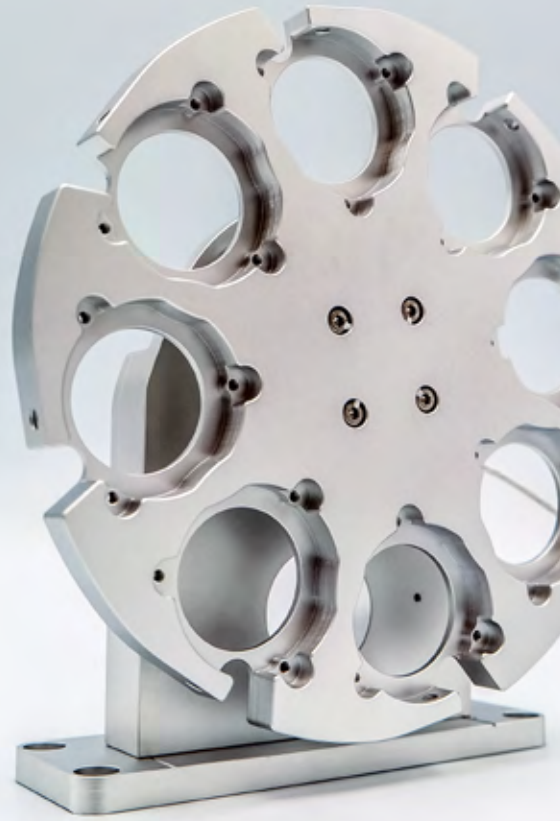
Large customized iris diaphragm with an opening range of 20 mm to 160 mm

Because of their miniaturization and overall compactness as well as their modularity SmarAct positioning systems are the optimal solution for optical setups and experiments in the field of optics.

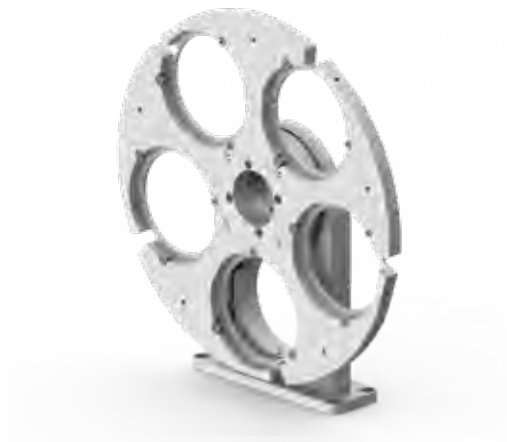
In addition to multi-axes positioning systems we have also developed a large number of dedicated opto-mechanical components like motorized tip-tilt mirror mounts, iris diaphragms, filter wheels, rectangular apertures and beam shutters. Combined with positioning sensors, they enable closed-loop position control and are perfectly suited for automated or remotely controlled experimental setups.

To address the high demand of in-vacuum optical setups nearly all components are available as high vacuum variants. For setups where reflections have to be omitted black anodized versions of the components are available.

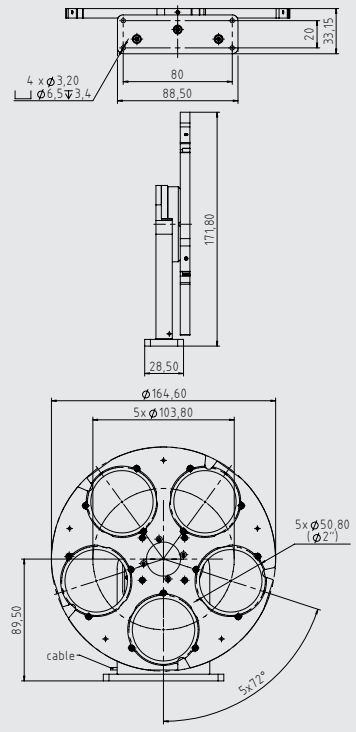
All presented opto-mechanical components and devices in this catalog section can be highly customized. Our applications scientists are eager to discuss customized solutions to exactly match your requirements.



Filter wheels can be also customized for special applications.



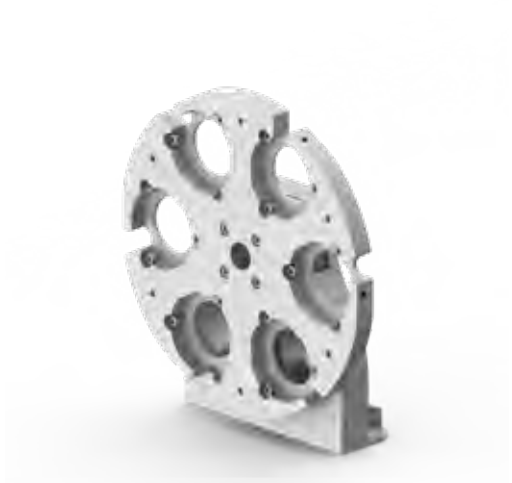
SFW-5-50.8: A filter wheel for five filters with a diameter of two inches each.



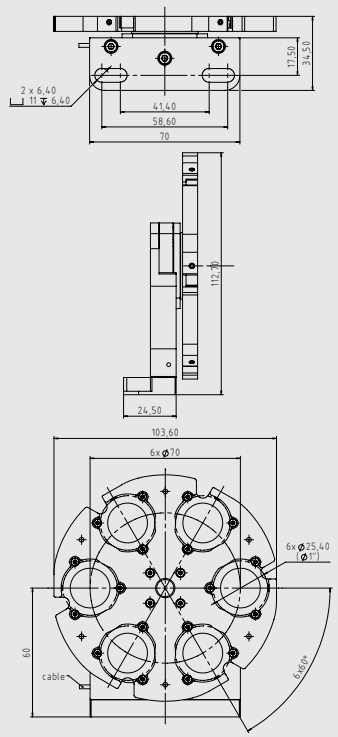
Filter Wheels
Motorized Opto-Mechanics

SmarAct motorized filter wheels are the ideal solution for optical setups that require frequent and automated change of optical filters. The filter wheels are available in different designs for different number of filters and different filter sizes of 0.5, 1, 1.5 and 2 inches.
Closed-loop controlled and high vacuum or ultra-high vacuum versions are available as well as filter wheels made of different materials like aluminum, steel, titanium or fully non-magnetic materials.
Our application scientist are eager to help you in selecting the perfect configuration or to discuss possible customizations.

		SFW-5-50.8
Mechanical	Filter Size [inch]	2
	Filter Number	5
	Dimensions [mm]	105 x 35 x 113
	Weight [g]	450
Closed-loop	Resolution **MCS**2 [µ°]	15 (S) 60 (L)
	Resolution (H)CU [m°]	1 (L)
Material Options		Black anodized (-BK), Titanium base (-TI), Steel base (-ST)
Vacuum Option		HV (10^{-6} mbar), UHV / UHVT (10^{-11} mbar)
Non-Magnetic Options		Yes (-NM)

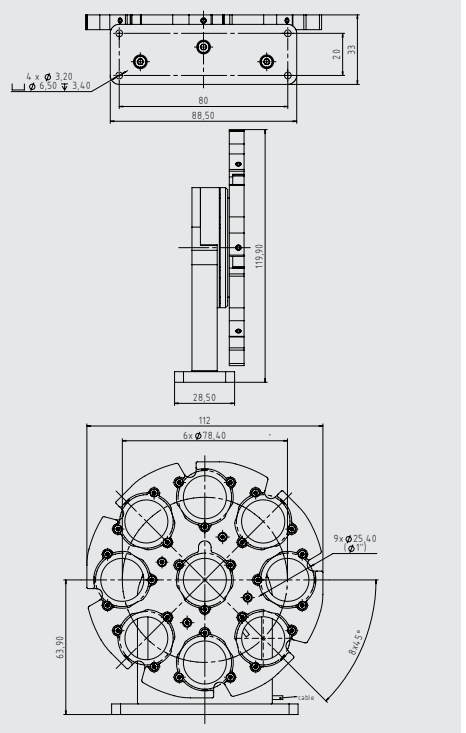


SFW-6-12.7: A filter wheel for up to 6 filters with a diameter of 0.5 inches.



		SFW-6-12.7
Mechanical	Filter Size [inch]	0.5
	Filter Number	6
	Dimensions [mm]	105 x 35 x 113
	Weight [g]	260
Closed-loop	Resolution **MCS**2 [µ°]	15 (S) 60 (L)
	Resolution (H)CU [m°]	1 (L)
Material Options		Black anodized (-BK); Titanium base (-TI); Steel base (-ST)
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)
Non-Magnetic Options		Yes (-NM)

SFW-8-25.4: This filter wheel allows to mount up to eight filters with one inch diameter.



		SFW-8-25.4
Mechanical	Filter Size [inch]	1
	Filter Number	8
	Dimensions [mm]	114 x 31 x 121
	Weight [g]	300
Closed-loop	Resolution **MCS**2 [µ°]	15 (S) 60 (L)
	Resolution (H)CU [m°]	1 (L)
Material Options		Black anodized (-BK); Titanium base (-TI); Steel base (-ST)
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)
Non-Magnetic Options		Yes (-NM)

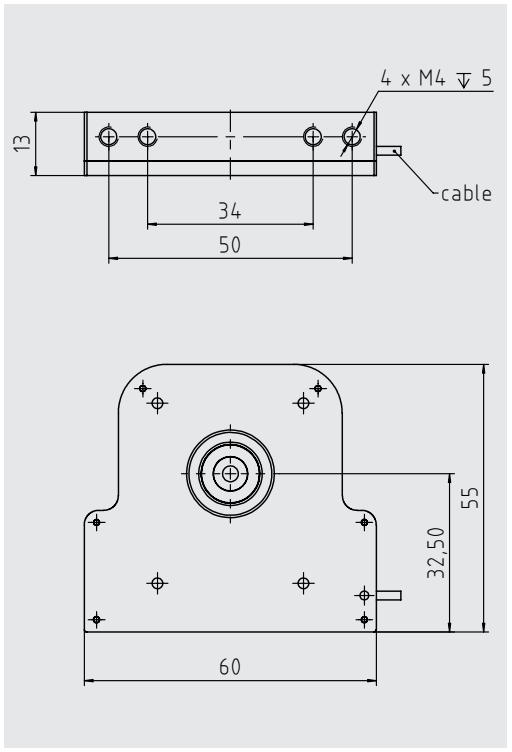
Iris diaphragms can be customized as well. The photo shows a SID-7 motorized iris diaphragm compatible with an optical tube system.

Iris Diaphragms
Motorized Opto-Mechanics

Motorized iris diaphragms are used for example in the fields of opto-electronics, lasers and medical technology and create the possibility to fully remote control optical setups. This comes in handy especially in confined spaces like chambers, cabinets, enclosures or simply when automation is required.

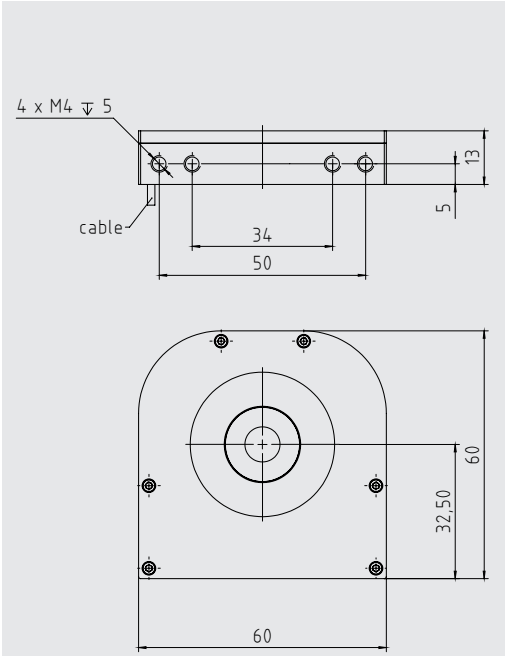
These precision opto-mechanical devices allow perfect dosing of the amount of light and the exact control of the projection and the size of the illuminated surface. Due to the used high quality materials the iris diaphragms keep their reliable functionality over many thousand open-close cycles, even in extreme conditions.
The iris diaphragms can be optionally equipped with positioning sensors allowing for a closed-loop control of the aperture diameter. Furthermore high vacuum and ultra-high vacuum compatible versions are also available as well as customized assemblies regarding aperture size, base materials and overall dimensions.

SID-7: A motorized iris diaphragm with a maximum opening of 7 mm.

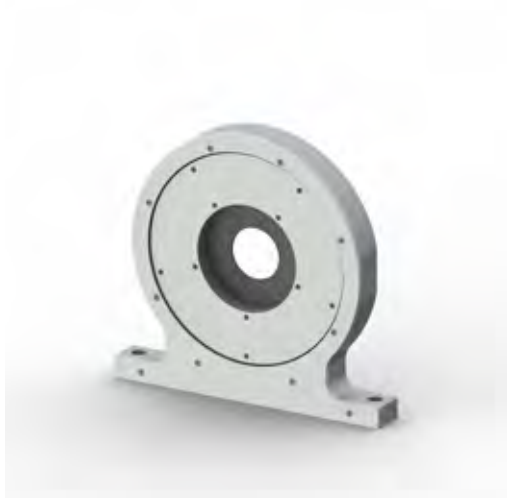


		SID-7
Mechanical	Smallest Aperture [mm]	0.5
	Largest Aperture [mm]	7
	Dimensions [mm], L x W x H	60 x 13 x 55
	Weight [g]	135
Closed-loop	Opening Resolution [µm]	< 1
	Opening Velocity [mm/s]	4
	Repeatability (unidirectional) [µm]	20
Material Options		Steel base (-ST); Titanium base (-TI); Black anodized (-BK)
Vacuum Option		--

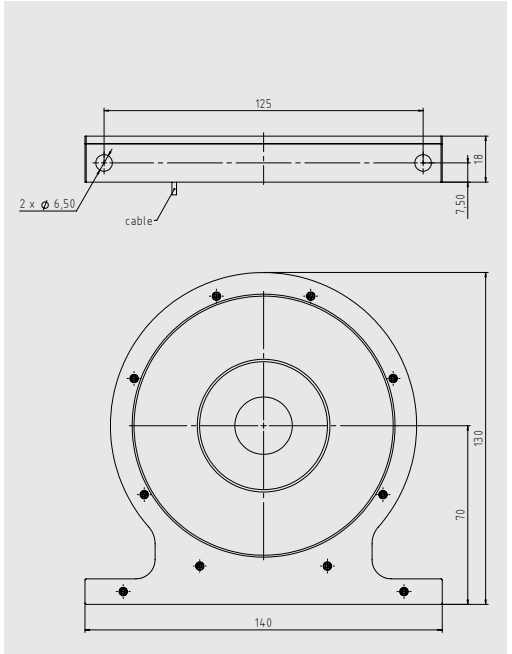
SID-18: A motorized iris diaphragm with a maximum opening of 18 mm.



		SID-18
Mechanical	Smallest Aperture [mm]	1
	Largest Aperture [mm]	18
	Dimensions [mm], L x W x H	60 x 13 x 60
	Weight [g]	135
Closed-loop	Opening Resolution [µm]	< 1
	Opening Velocity [mm/s]	6
	Repeatability (unidirectional) [µm]	20
Material Options		Steel base (-ST); Titanium base (-TI); Black anodized (-BK)
Vacuum Option		HV (10^{-6} mbar)



SID-50: A motorized iris diaphragm with a maximum opening of 50 mm.

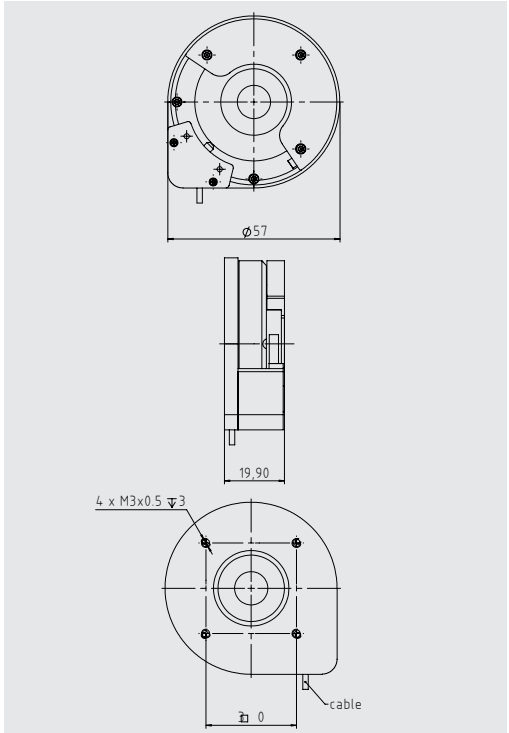


		SID-50
Mechanical	Smallest Aperture [mm]	5
	Largest Aperture [mm]	50
	Dimensions [mm], L x W x H	140 x 18 x 130
	Weight [g]	135
Closed-loop	Opening Resolution [µm]	< 1
	Opening Velocity [mm/s]	6
	Repeatability (unidirectional) [µm]	20
Material Options		Steel base (-ST); Titanium base (-TI); Black anodized (-BK)
Vacuum Option		--

Opto-Mechanics

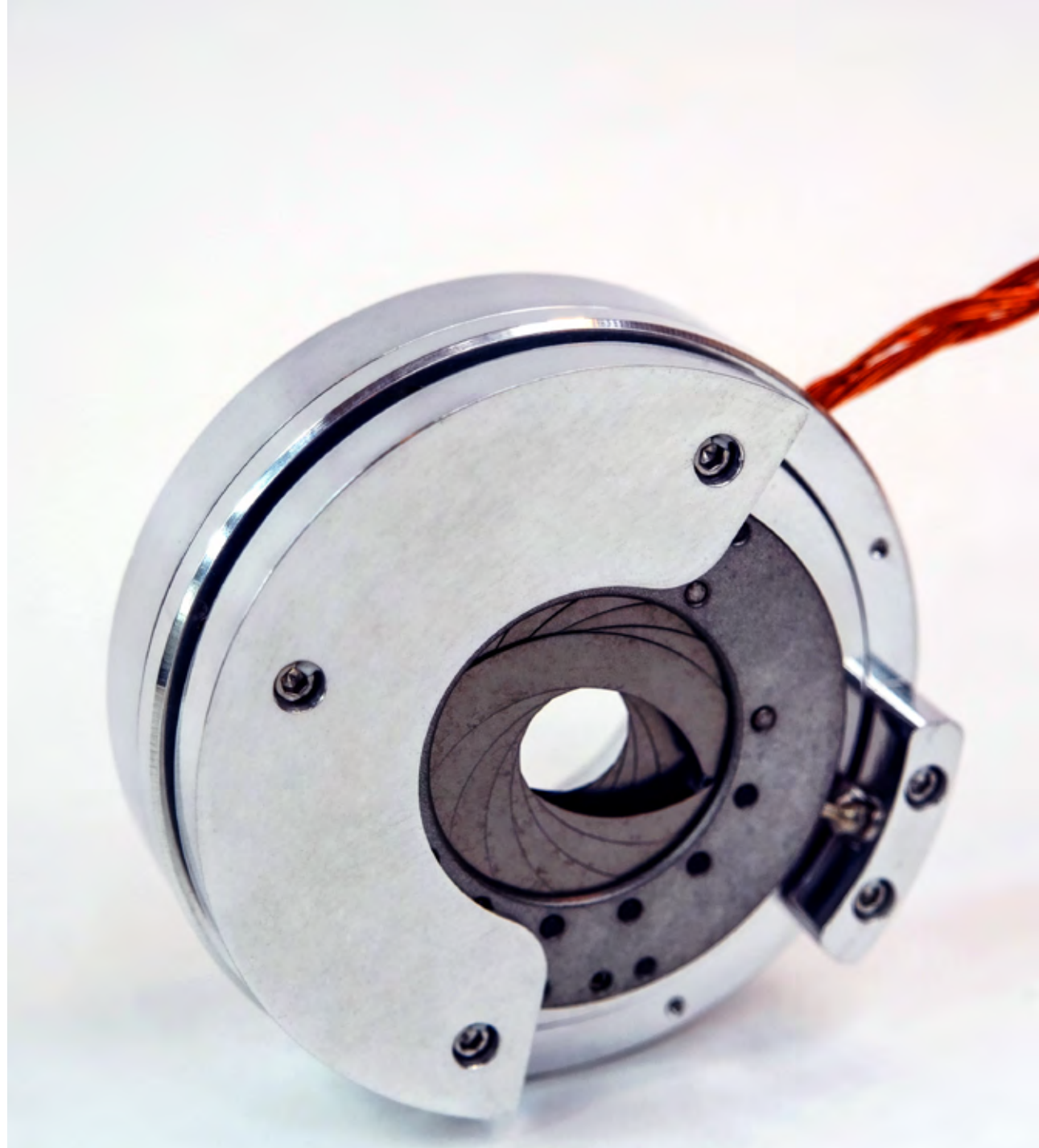
Motorized Opto-Mechanics
Iris Diaphragm SID-5714

SID-5714: A modular iris diaphragm system with exchangable iris diaphragm inserts.



The SID-5714 iris diaphragm was especially designed as a modular component which consists of a motorized stage and an iris diaphragm insert.

		SID-5714		
		ID-18	ID-22	ID-25
Mechanical	Smallest aperture [mm]	1.2	fully closing	4
	Largest aperture [mm]	18	22	25
	Dimensions [mm], L x W x H	57 x 19.9 x 57		
	Weight [g]	135		
Closed-loop	Opening Resolution [µm]	< 1		
	Opening Velocity [mm/s]	6		
	Repeatability (unidirectional) [µm]	20		
Material Options		Steel base (-ST); Titanium base (-TI); Black anodized (-BK)		
Vacuum Option		HV (10^{-6} mbar); UHV / UHVT (10^{-11} mbar)		
Non-Magnetic Option		Yes (-NM)		



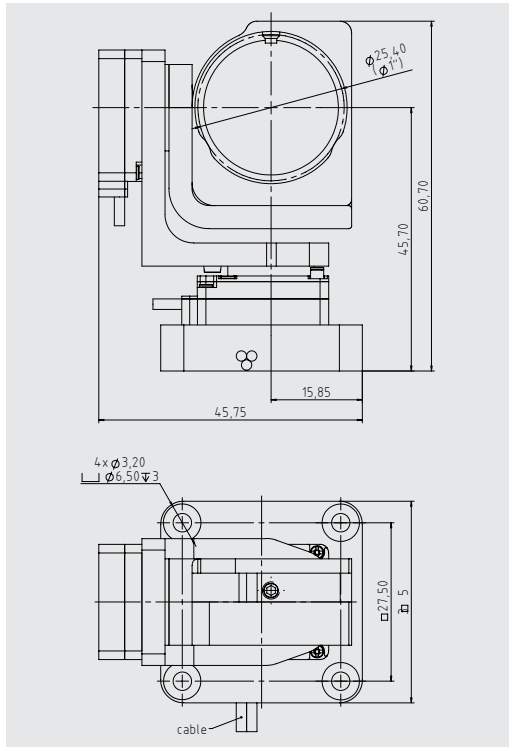
SID-5714 with a fully closing ID-22 insert as a vacuum compatible version.

Tip-Tilt Mirror Mounts can be combined with linear stages to be precisely positioned in the optical beam path.

Tip-Tilt Mirror Mounts
Motorized Opto-Mechanics

Motorized tip-tilt mirror mounts are a key components in optical systems. They are ideally suited for automation tasks and for actuation in encapsulated environments. Our tip-tilt mirror mounts accommodate the most popular mirror sizes on the market from 0.5 up to 2 inches in diameter.
Furthermore, thanks to our rich experience in manufacturing UHV systems we can offer mirror mounts which are highly qualified for low-contamination applications for example in high-power laser cavities.
We offer tip-tilt mirror mounts with active position control. Closed-loop, they are especially powerful tools when external feedback is unavailable and active drift needs to be corrected. Our clear edge motorized optical mounts can add even more compactness to your setup.
If your application requires the use of non-circular mirrors or optical components please discuss your requirements with our application scientist.

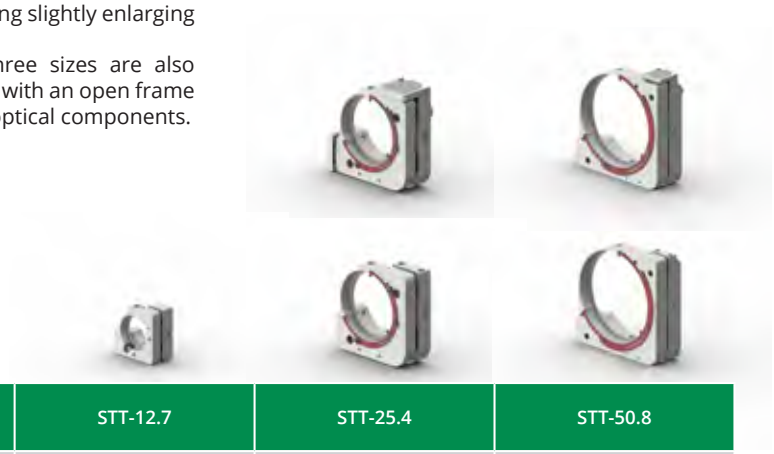
A gimbal type mirror mount utilizing to rotation stages for the positioning of half-inch or one inch mirrors or other optical components.



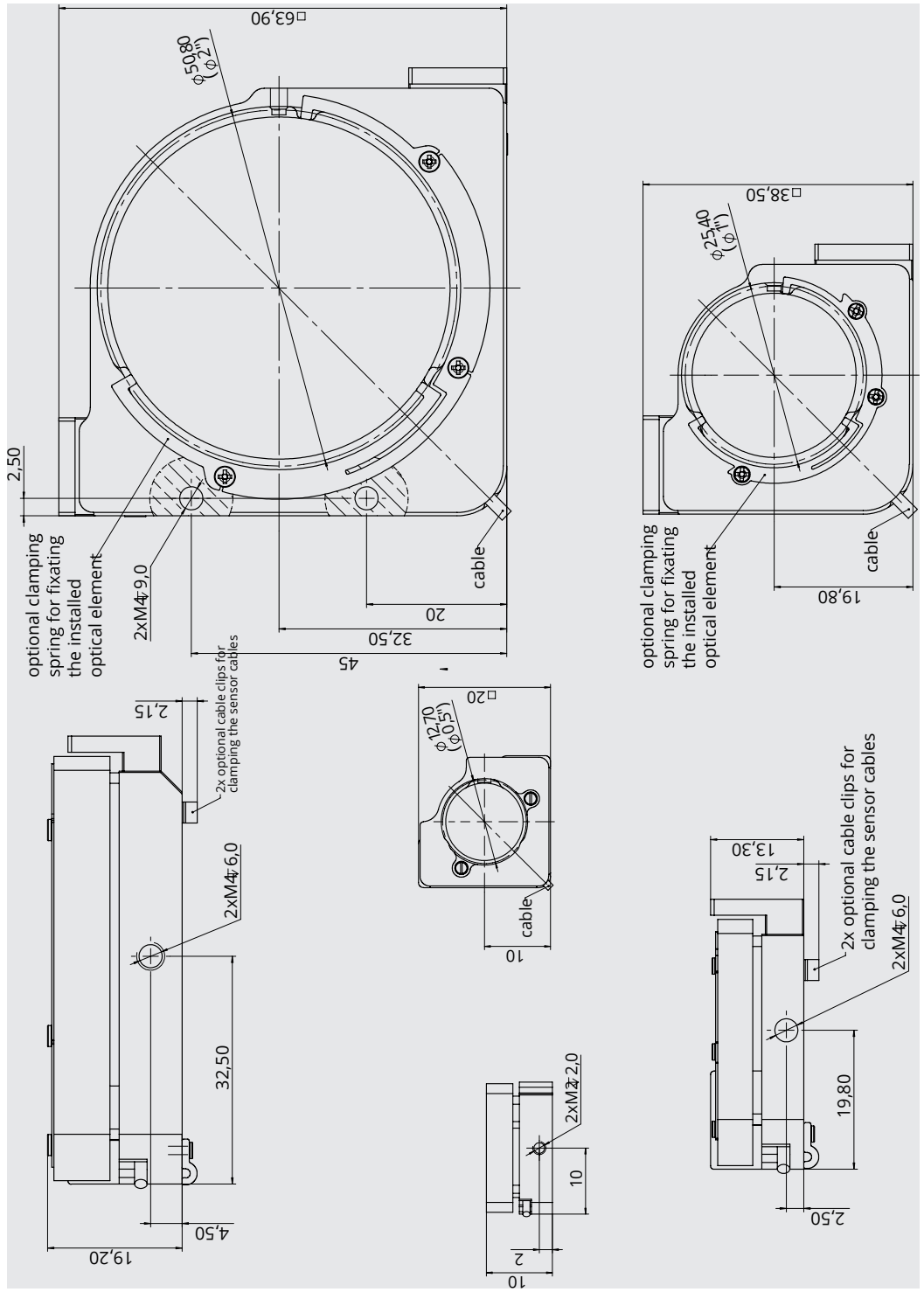
In difference to the kinematic mirror mounts presented on the following page, the STT-2013 mirror mount has a gimbal design which allows for full 360° rotations in two degrees of freedom. With the use of an adapting mirror mount optical mirrors of 0.5 and 1 inch diameter can be used. It is available as an open-loop or a closed-loop version as well as a specialized version to be used in high and ultra-high vacuum environments

		STT-2013
Mechanical	Mirror Diameter [inch]	0.5; 1
	Tip Angles [°]	± 90
	Tilt Angles [°]	± 90
	Dimensions [mm]	35 x 46 x 61
	Weight [g]	30
Closed-loop	Velocity [°/s]	45
	Resolution **MCS**2 [µ°]	25 (S)
Material Options		Steel base (-ST); Titanium base (-TI); Black anodized (-BK)
Vacuum Options		HV (10^{-6} mbar); UHV (10^{-11} mbar)
Non-Magnetic Option		Yes (-NM)

The motorized mirror mounts STT-12.7, 25.4 and 50.8 can be seen as the motorized counterparts of classical kinematic mounts for mirrors, lenses or other optical components. The two larger mounts can be equipped with position sensors allowing to monitor and control the alignment process of the optical component in closed-loop. Due to their overall compactness the position sensors are mounted outside the housing slightly enlarging their outer dimensions.
For special applications all three sizes are also available in a clear edge design with an open frame structure for mounting of the optical components.

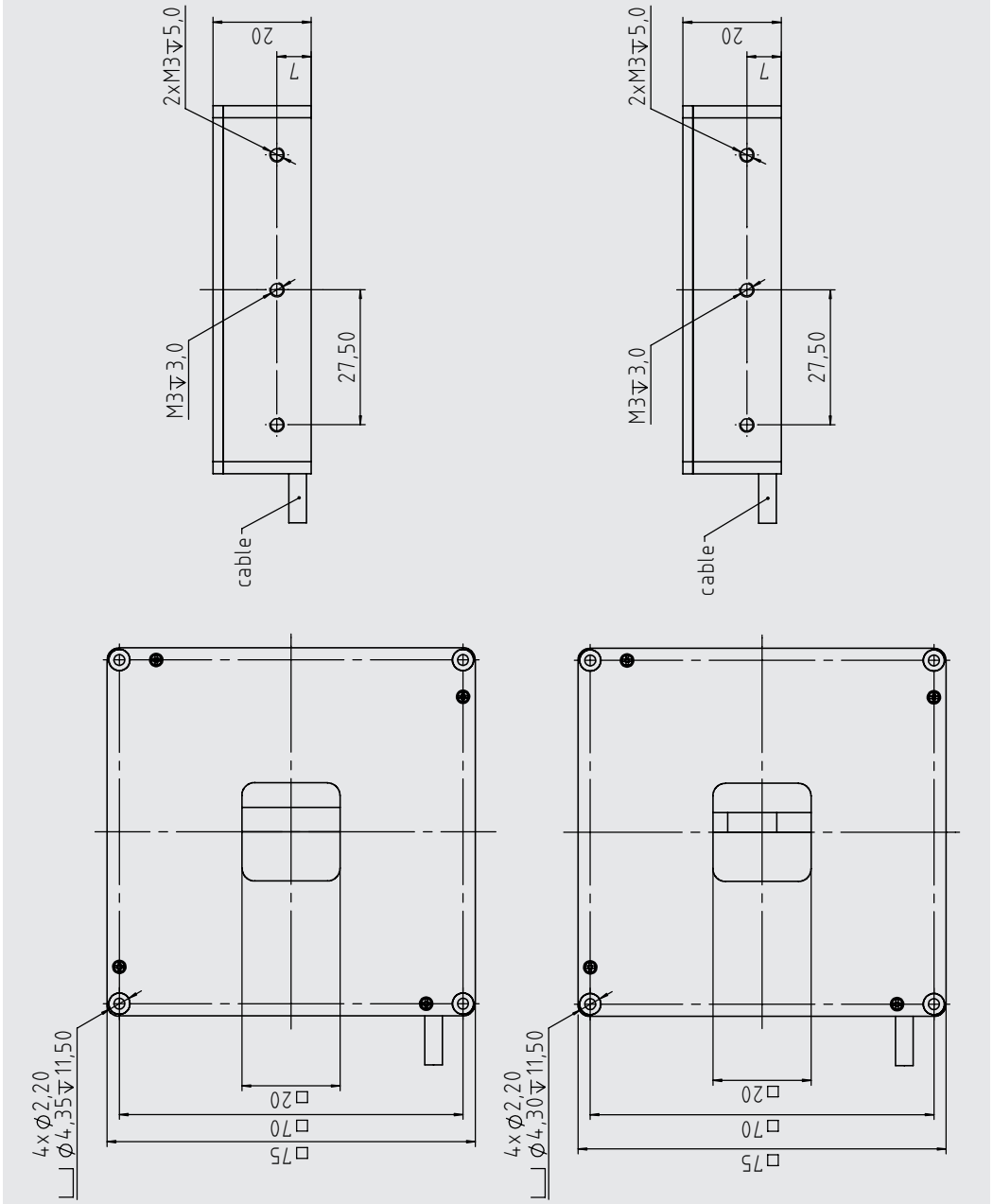


		STT-12.7	STT-25.4	STT-50.8
Mechanical	Mirror Diameter [inch]	0.5	1	2
	Tip Angles [°]	± 2	±2.5 ± 2.15 (I)	± 1 ± 1 (I)
	Tilt Angles [°]	± 2	± 2.5 ± 2.15 (I)	± 1
	Dimensions [mm]	20 x 20 x 10	36 x 36 x 12	61 x 61 x 18
	Weight [g]	20	25	30
Closed-loop	Velocity [°/s]	15		
	Sensor Resolution [m°]	--	0.7 (I)	0.4 (I)
	Repeatability [°]	--	± 0.01	
Material Options		Steel base (-ST); Titanium base (-TI); Black anodized (-BK)		
Mechanical Option		--	Clear Edge (-CE)	
Vacuum Option		HV (10^{-6} mbar); UHV (10^{-11} mbar)		
Non-Magnetic Option		Yes (-NM)		



SmarAct's precision motorized rectangular apertures can be used to define the optical path in optical experiments or to mask out individual parts of your optical setup for example in front of a detector.
Two different versions are available. The first includes two individually movable blades with their edges aligned parallel to each other allowing to set the slits width in the horizontal direction between 0 and 20 mm while allowing to define the slits position within the 20 mm by 20 mm window of the enclosure.
The second design includes four independently movable blades aligned in two parallel pairs oriented rectangular to each other. The setup allows to define the size of the aperture opening independently in width and height with a side length from 0 to 20mm.
In both versions position sensors allow for closed-loop positioning of each blade to precisely define the size and the position of the aperture within the 20 by 20 mm window of the enclosure.
Specialized versions are available for the use in high and ultra-high vacuum environments. Customized versions are also available. Please do not hesitate to contact us to discuss your specific requirements.

		SMS-20-0	SMS-20-20
Mechanical	Dimensions [mm]	75 x 75 x 20	
	Number of Blades	2	4
Open-loop	Velocity [mm/s]	> 20	
	Resolution [nm]	< 1	
Closed-loop	Resolution **MCS**2 [nm]	1 (S) 4 (L)	
	Repeatability, Full Stroke **MCS**2 [nm]	± 30 (S) ± 60 (L)	
	Resolution H(CU) [nm]	50 (L)	
	Repeatability, Full Stroke H(CU) [nm]	± 1000 (L)	
Material Options		Steel base (-ST); Titanium base (-TI); Black anodized (-BK)	
Vacuum Options		HV (10^{-6} mbar); UHV (10^{-11} mbar)	
Non-Magnetic Option		Yes (-NM)	



MCS2 *integrated handheld controller with three channels, two joysticks and touchscreen interface.*

Every successful positioning solution rest at least on two pillars. The first is defined by the mechanical part of the solution, the second by the electronics and software to control it. Our sophisticated and easy to use control systems together with our intuitive software solutions and software development kits (SDKs) are the basis for a fast and easy integration of our positioning technology into your application. SmarAct's control system portfolio consists of a wide variety of components optimized for different applications and integration scenarios. From single channel hand held controllers up to rack mountable modules with up to 18 channels, we are able to equip you with the right tools.

MCS2

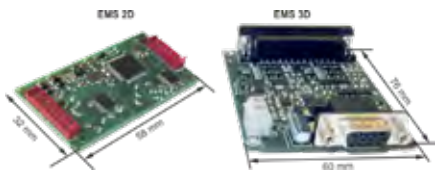
The **MCS**2 is SmarAct's most versatile and modular control system. Ethernet and USB interfaces together with included control software and software development kits guarantee easy and fast integration into your setup.
The modular concept of the **MCS**2 control system does not only include different enclosures, number of channels and additional input and output modules but also firmware modules that increases the functionality of this powerful device even further.

CU and HCU

The CU product line of control systems include one and three channel drivers with optional support of closed-loop positioners. All control systems of this product line are equipped with a USB connection. In addition, the three channel systems allow also for external control also via an RS232 interface. Beside the availability as fully integrated handheld controllers (HCU) for desktop usage, the three channel version is also available as an OEM single board controller to be exclusively computer controlled.

AVC

The AVC OEM single board control system was exclusively designed to be integrated into existing electronics to drive a single piezo stage with external analog signals. Analogue inputs (±10 V) determine driving direction and speed.



EMS - Embedded Microsensor System (2D/ 3D)

The EMS product line is defined by two OEM single board controllers exclusively for integration into existing electronics. The board dimensions and connectors differ whether the two channel or three channel version is required. External communication is realized via an TWI interface.

SDC2

The Step-Direction Control System **SDC**2 is a low-level control system which allows to drive our piezo stages in a stepper motor like fashion with very high resolution. Controllers of this product line are available as rack mountable modules, mounted into tabletop enclosures or as OEM single board controllers for integration into existing electronics.

	Controller Type	MCS2	CU	AVC	EMS	SDC2
Overview	Number of Controller Channels	n x 3	1 3	1 n x 1	2 3	1 n x 2
	Positions Sensor Compatibility	S,L, **PICO**SCALE	L, I	--	L, I	S, L
	Available Interfaces	USB, Ethernet	USB, RS232	Analog Voltage	TWI	Step/ Directions signals
	Scalabilty	stackable 3-channel boards	--	--	Up to 8 per TWI (depending on connected PC)	Single channel OEM, adapter for two SDC boards
	Enclosure Options	Tabletop, modular 19" rack or OEM board	Tabletop or OEM board	OEM board		Tabletop, modular 19" rack or OEM board

MCS2 *integrated hand control module to control up to three positioning stages*

Tabletop enclosures can be equipped with driver modules for up to 12 positioning stages and can be controlled via an external hand control module.

The **MCS**2 is SmarAct's most versatile and powerful control system. Its stringent modular design approach makes it the perfect choice for a all field of applications. From single positioning stages up to the most complex multi-axes systems with up to 18 positioning stages the **MCS**2 can be configured to match every setups specific requirements.

Key Features

User Friendly

- Pre-configured modular system
- Intuitive hand control module with joysticks and touchscreen
- Demo applications for a quick start
- Programming examples for LabVIEW® and C++

Intuitive

- Remote Control Module with intuitive user interface
- Touchscreen
- Two configurable analog 2D joysticks
- Tactile buttons and knobs

Powerful

- Compatible with all SmarAct tages
- Support S, L and **PICO**SCALE position sensors
- Fast control loop with up to 50 kHz

Smart

- Synchronous motion of multiple axes
- Complex customizable trajectories
- Up to 1 kHz trajectory point frequency
- Power save mode for vacuum applications
- Scan mode for sub-nm slip-free piezo motion
- Quiet mode for life science applications.

Upgradeable

- Sophisticated firmware modules
- Low-vibration mode to reduce vibrations caused by stick-slip motion
- Advanced sensor calibration for increased accuracy

Versatile

- Optional I/O Modules
- Trigger inputs for external synchronization
- Configurable trigger outputs for each channel
- 16-bit analog inputs e.g. as control-loop input
- 16-bit analog outputs e.g. to control external components
- High speed data reader (HSDR) module for synchronous detection of position and external signals
- High speed position data streaming

Control Systems

The **MCS**2 Series is based on a highly modular system concept which allows SmarAct to provide you with a perfectly adapted and pre-configured control system. The following modules of the **MCS**2 modular system are available.

Main Controller Module with communication interface:

This module is the core component of every **MCS**2 configuration. It reads the sensor data from the sensor module and performs closed-loop position control and drives the stages. It also includes the communication interface module which can offer either an USB or an Ethernet interface.

Sensor Module

This module converts the analog sensor data into digitized data which is processed by the main controller module.

Hand Control Module

The hand control module offers a touchscreen, physical buttons and two analog joysticks to manually interact with the positioning system. Physical axis of the positioning system can be easily mapped to joystick axis for easy manual positioning. If the stages are equipped with position sensors the actual stage position can be read of the module's touchscreen.

I/O Modules:

SmarAct offers a wide variety of I/O modules. From simple modules with digital outputs up to multi-purpose modules with both digital and analog input and output functionality. Fast digital outputs can be used to trigger external devices on specific internal events of the main controller (e.g. Position Reached Events). Digital device inputs allow to trigger the **MCS**2 by an external device for example to perform, an emergency stop or to synchronize data streaming. General purpose digital inputs and outputs provide control signals to control light sources, relays, dispensers, etc. or to read the state of safety switches, light barriers, etc. Analog inputs can be used to read analog voltage signals from external devices. The controller supports to feed these signals into the control loop allowing closed loop operation depending on external sensor signals. I/O modules double also as multifunctional data aqcuisition cards as the value of the connected signals is available via the SDK.
Whenever it is required to stream data from a **MCS**2 controller equipped with specific I/O module it is possible to equip it also with a High Speed Data Reader (HSDR) extension board. The HSDR allows to stream position and other channel data with a maximum possible frame rates of up to 50kHz via a dedicated USB port using the SmarAct API.

Module	I/O Type	Number of Channels	Resolution	Max. Sample Update Rate	Purpose
Type 1	Digital-Output	3		50 kHz	Output Trigger: Position Compare, Position Reached, Actively Moving
Type 2	Digital Input	1		1 kHz	Input Trigger: Emergency Stop, Trajectory Streaming, Synchronization, Command Group Trigger
		4			General Purpose Digital Input
	Digital Output	3		50 kHz	Output Trigger: Position Compare, Position Reached, Actively Moving
		4			General Purpose Digital Output, Open Collector
	Analog Input	6	16 bits	15 kHz	General Purpose Analog Input, Control Loop Feedback
	Analog Output	2	16 bits		General Purpose +/- 10V Analog Voltage Output
Type 3	Digital Input	1		1 kHz	Input Trigger: Emergency Stop, Trajectory Streaming, Synchronization, Command Group Trigger
	Digital Output	3		50 kHz	Output Trigger: Position Compare, Position Reached, Actively Moving
Type 4	Digital Input	1		1 kHz	Input Trigger: Emergency Stop, Trajectory Streaming, Synchronization, Command Group Trigger
		4			General Purpose Digital Input
	Digital Output	3		50 kHz	Output Trigger: Position Compare, Position Reached, Actively Moving
		4			General Purpose Digital Output, Open Collector
	Analog Input	6	16 bits	15 kHz	General Purpose Analog Input, Control Loop Feedback
	Analog Output	2	16 bits		Output Trigger: Position Compare, Position Reached, Actively Moving
Type 6	Digital Input	1		1 kHz	Input Trigger: Emergency Stop, Trajectory Streaming, Synchronization, Command Group Trigger
		4			General Purpose Digital Input
	Digital Output	3		50 kHz	Output Trigger: Position Compare, Position Reached, Actively Moving
		4			General Purpose Digital Output, Open Collector
	Analog Input	6	16 bits	15 kHz	General Purpose Analog Input, Control Loop Feedback
	Analog Output	2	16 bits		Output Trigger: Position Compare, Position Reached, Actively Moving
	HSDR	1			High Speed Data Reader with dedicated USB Interface

Depending on the specific configuration of the **MCS**2 the modules are integrated in one of the following enclosures.

Integrated Handheld

The integrated handheld is equipped with a main controller module including a communication interface and a human machine interface module. All together combined in a small and light enclosure.

Rack Enclosure

The modular rack enclosure with 6 slots is equipped with a main controller module including a communication interface and a backplane. It is compatible with 3-channel main control modules encapsulated into module carriers which will use up one slot. Consequently, up to six main controller modules can be mounted into the three height unit rack enclosure making it possible to control up to 18 popsitioning stages.

Tabletop Enclosures

Tabletop enclosures are equipped with a main controller module including a communication interface in the most basic configuration. They can also be equipped with three other main controller or I/O modules which means up to 12 positioning stages can be controlled with one compact desktop device. Manual control is optional available and realized via an external hand control module.

Firmware Modules and Features

To increase the functionality of **MCS**2 control system even further and to adapt driving parameters of the connected piezo stages to the application SmarAct has developed several firmware modules and features. Some of them are enabled by default in every **MCS**2 Controller others are available as options.

Power Save Mode

This firmware feature is especially interesting for stages that are going to be used in vacuum experiments. The mode changes the duty cycle of the position sensors LED when the stage in an idle state and not moving. This significantly reduces the heat dissipation of the position sensor and the overall heat load on the stage and the positioning system.

Scan Mode

Enabling this firmware feature affects the control loop in a way that it exclusively uses the scan feature of the piezo drive omitting large distance steps occurring during a stick-slip motion. This feature is useful whenever the controlled stage is being used for scanning probe applications where a stick-slip motion could harm or damage samples and tools.

Quiet Mode

The Quiet Mode firmware feature was especially developed for life science applications. This mode shifts the driving frequency of the piezo motor out of the human hearing range, significantly reducing the inevitable audible noise caused by the stick-slip motion of the piezo motor.

Zero-Voltage Mode

This firmware feature also affects the control loop in a way that it guarantees that the supply voltage after each stick-slip motion is controlled to zero Volts. This feature is especially interesting for stages that are being used in scanning electron microscopy systems, or experiments utilizing low energy electrons or ions.

Low-vibration Mode (Optional)

The Low-Vibration Mode firmware module was especially developed for ultra-high precision applications like Scanning Probe Microscopy and life science experiments. This algorithm reduces the vibrations which inevitably occur by the stick-slip driving principle. The result is a smooth motion which enables the usage of our stick-slip piezo stages even for most demanding applications.

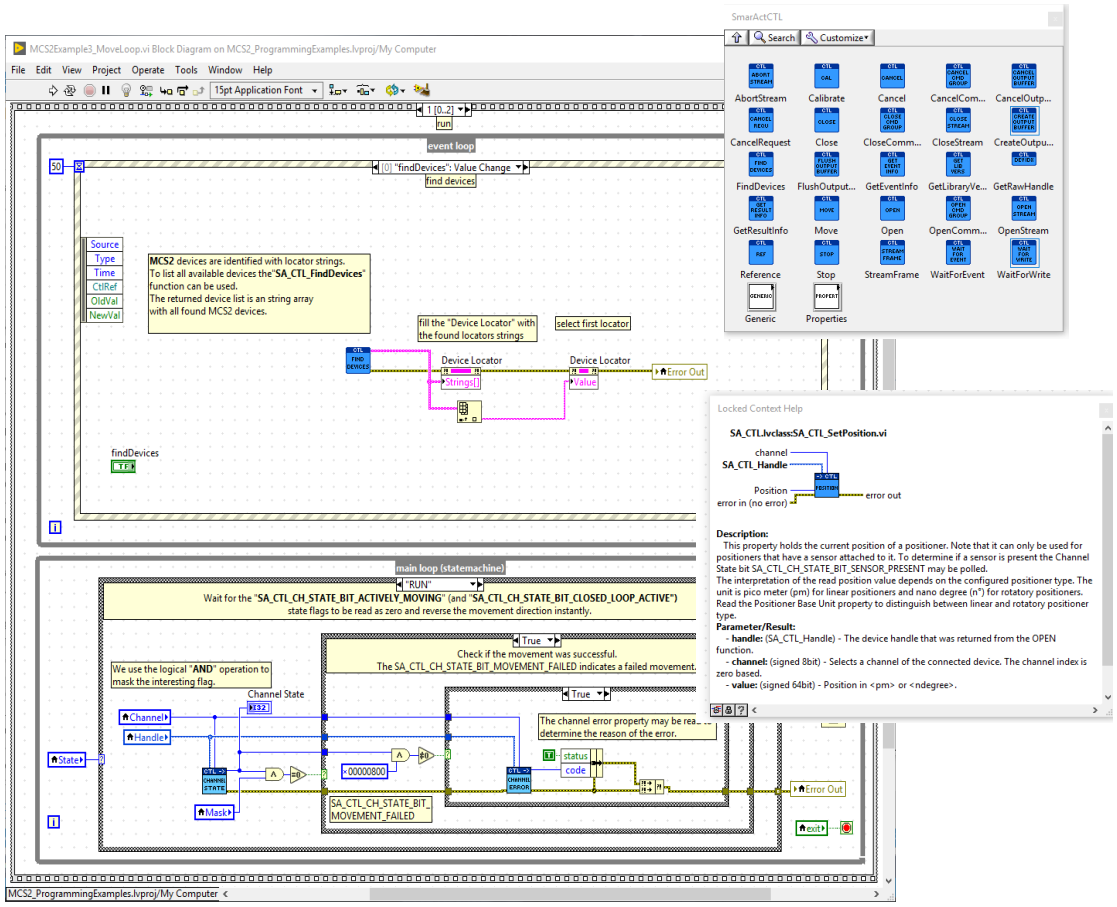
Advanced Sensor Calibration (Optional)

SmarAct stages and systems can be equipped with integrated nanosensors (S). These are based on optical incremental encoders, which interpolate between stripes on a sensor scale. This leads to a small periodic interpolation error, with a periodicity matching the grating pattern of sensor scale, i.e. the spacing between the stripes. This error affects the absolute accuracy of the stages but not the repeatability. The Advanced Sensor Calibration firmware module reduces these periodic errors significantly. This patented feature is especially interesting for applications where absolute accuracy is crucial. These include for example high-precision scanning and stitching of microscopy images.

Embedded Control Module (ECM)

The Embedded Control Module is equipped with serial and Ethernet interfaces and uses an ASCII based command language which allows an easy integration into existing control environments like TANGO or EPICS. It can control SmarAct positioning stages connected to **MCS**2 controllers and does not require any driver software on the client side. Due to its powerful embedded software it is also possible to adapt the system to your requirements. The ECM is available as a rack mountable module compatible to the rack enclosure or as tabletop device.

MCS2 control systems can be integrated into your own software environment in different ways. A control software program with a graphical user interface as well as a Software Development Kit with programming examples in C/C++ and LabVIEW® are included.
The LabVIEW® SDK offers a tool palette with all necessary VIs to integrate the **MCS**2 into your own control application. The programming examples are well commented and the SubVIs include an in-depth documentation about their functionality and parameters. Therefore, the integration of a **MCS**2 into your own application is an easy to perform task guaranteeing very short implementation times.



CU - Control Unit

The CU product line of control systems include one and three channel drivers with optional support of closed-loop stages. All control systems of this product line are equipped with a USB connection. In addition, the three channel systems allow can be externally controlled via USB or RS232 interfaces. Despite the availability as fully integrated Hand Control Module (HCU) for desktop usage, the three channel version is also available as an OEM single board controller to be exclusively computer controlled.

	HCU-1CX	CU-1CX	HCU-3CX	CU-3CX
Number of Channels	1	1	3	3
Feedback Loop	open-loop, closed-loop			
Sensor Options	L, I			
Enclosure Type	Hand Control Module	OEM single board controller, tabletop enclosure	Hand Control Module	OEM single board controller, tabletop enclosure
Manual Control Features	Control knob and LED array	--	Control knobs, joy-stick and LCD	--
Stage Interface	1X DSUB 15	1x DSUB 15	1x DSUB 26 HD	1x DSUB 26 HD
PC Interface	USB	USB, RS232		
Software and Drivers	Drivers for Windows® and Linux®, LabVIEW® SDK			

AVC - Analog Voltage Control

The AVC is an OEM single board control system, designed to be integrated into your own electronics. Thus, allowing you to design your own closed-loop control system for SmarAct stages by using external analog feedback signal. The AVC does not require to be connected to a computer which allows an easy integration into your products for different applications, such as beam stabilization and others.

	AVC
Compatible positioners	All SmarAct positioners with stick-slip drives
Power Supply	12 .. 48 V, 24W
Input Signals for Frequency and Direction	Backware - 18.5 k Hz @ -10 V ..1 m Hz @ -1 V, no movement between -1 V ..1 V forward - 1 m Hz @ 1 V .. 18.5 k, Hz @ 10 V
Input Signal for Step Size	0 V @ -10 V .. 100 V @ 10 V
Dimensions	100 x 60 mm² OEM board

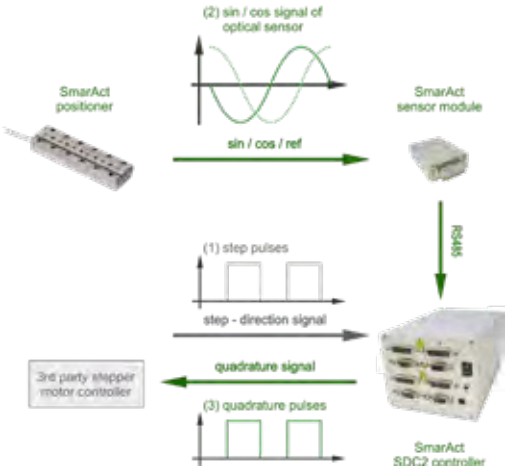
EMS - Embedded Microsensor System

The EMS product line constists of two OEM single board controllers (EMS; 2D for two channels and 3D for three channels) exclusively for integration into existing electronics. Because of their small size, they are perfectly suited to be integrated into your OEM product. Their small footprint and the available TWI interface make them the best choice for your control electronics design.

	EMS-2D	EMS-3D
Compatible Stages	All SmarAct stages with Stick-Slip drives (60 V), I and L sensors supported	
Channels	2	3
Power Supply	5 .. 7 V , 4 W / 12 .. 24 V, 12 W	12 .. 24 V, 18 W
Stage Interface	Micromatch	DSUB 25, female
PC Interface	Two wire interface (TWI)	
Scalability	Maximum 8 via TWI (depending on connected PC)	
Voltage Range, max. Current	0 .. 60 V, 250 mA	
Dimensions [mm]	58 x 32	76 x 60

SDC2 - Step-Direction Control System

The Step-Direction Control System **SDC**2 is a low-level control system which allows to drive our piezo stages in a stepper motor like fashion but with very high resolution.
The standard inputs of the **SDC**2 controller are step and direction signals. Thus, allowing you to profit from the performance of SmarAct stages with only minor changes to your own established control environment. For every step a closed-loop controlled position increment is performed in the specified direction. In order to deliver position to your stepper motor controller the **SDC**2 supports quadrature signal feedback.
Controllers of this product line are available as rack mountable modules, tabletop enclosures or as OEM single board controllers for integration into existing electronics.



*The **SDC**2 receives step-direction signals (1) from a stepper motor controller and generates the necessary signals to drive the stage. The position change of the stage then leads to a sinus / cosinus signal of the integrated optical sensor (2). This signal is then digitized in a sensor module and transmitted to the **SDC**2 controller. Based on this position feedback the **SDC**2 controller performs closed-loop position control and outputs quadrature signals to the stepper motor controller (3).*

	SDC2
Channels	2 channels per controller module
Feedback Loop	Open-loop, closed-loop
Sensor Support	L, S
Position Feedback	Quadrature feedback (A, B, Index), limit (+/-), home
Stage Interface	1x DSUB 15 per channel
PC Interface	STEP / DIR 5 V TTL or open collector RS232 for configuration via ASCII
Power Supply	12-24 V, 60 W (table-top), up to 600 W (19“ rack)
Housing	Single control board (-OEM), table-top (-TAB), 19“ rack module (2-12 channels, -MOD)
software / drivers	**SDC**2 configuration program for Windows®

Control Systems

SmarAct's control systems come bundled with different software tools that supports you during setup, configuration and controlling your positioning systems. Depending on the specific control system the bundle includes one or more of the following tools and software development kits.

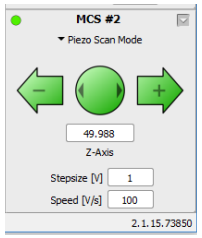
Precision Tool Commander (PTC)

The Precision Tool Commander offers a graphical user interface to interact with **MCS**2 and **SMAR**POD controllers. Connected stages can be controlled in open-loop, closed-loop and piezo-scan mode. It also allows quick switching between configurations of the positioning systems used in your setup. The PTC´s user interface gives the user access to different software modules.

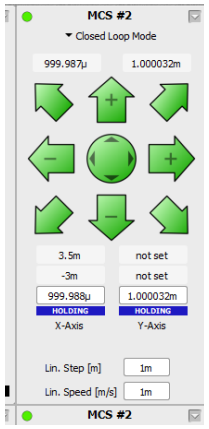
Crop of Precision Tool Commander main window

Dashboard

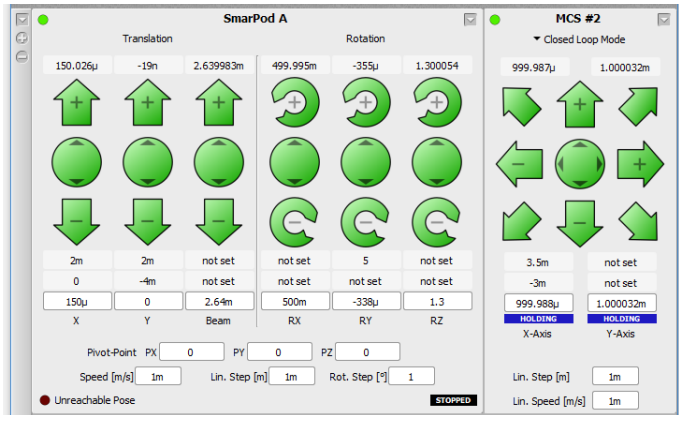
The dashboard represents an easy and intuitive way to control SmarAct stages independent of their complexity from single stages to our hexapod-like **SMAR**PODs and **TRI**PODs. Stages can be moved by direct input of the destination position, or by using your computers mouse.



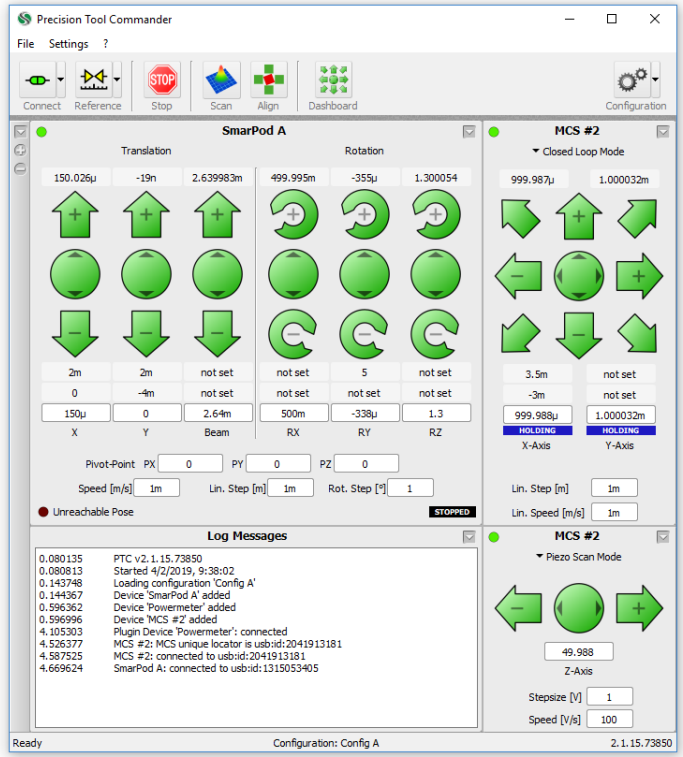
Dashboard view on a single SmarAct stage connected to a **MCS**2 control system



Dashboard view on two stages configured as an XY table



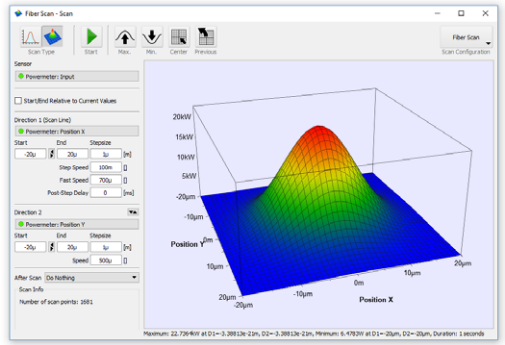
Dashboard view on a **SMAR**POD. The PTC also performs the kinematic calculation for the axes allowing to drive a **SMAR**POD in Cartesian coordinates.



Full view on a Dashboard of a 9 axes system controlled by a **SMAR**POD Controller and a **MCS**2.
Also multiple positioning systems can be simultaneously controlled with the PTC, giving you access to a high number of stages from a single software.

Scan

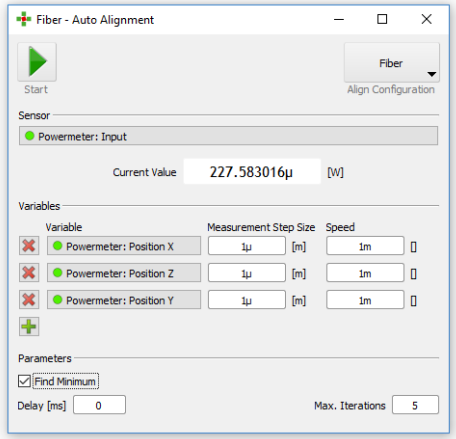
The Precision Tool Commander uses driver plug-ins to communicate with third party devices. Data measured by these external sensors can be correlated by the PTC to the position data of the stages. Thus, allowing to perform 1D and 2D position scans while logging additional sensor data. The PTC is able to display these 3D data sets as well as export them as an image or a CSV file.
Please feel free to contact our application scientists to receive a list of supported third party measurement equipment or discuss the possibility to integrate your own measurement devices.



Scan module displaying measurement result

Align

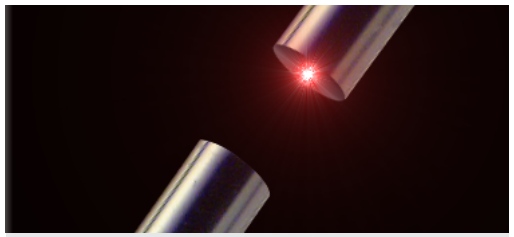
The Align software module makes also use of the Precision Tool Commanders ability to communicate with third party measurement equipment. It uses an iterative algorithm to find the optimum position for defined axes of a positioning system to minimize or maximize an input value measured by the selected sensor.
Typical Applications for the Align Module of the PTC are fiber coupling, beam-profiling, quality assurance and assistance for micro assemblies.



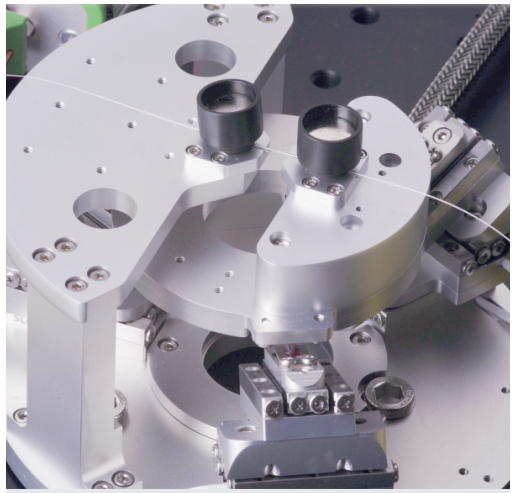
Align module parameter dialog

Example Application: Automated fiber alignment setup

The fibers were aligned concentric and orthogonal with the Scan and Align features of the PTC. Any virtual axis can be used for the auto alignment. This includes all three translational and three rotational degrees of freedom of a **SMAR**POD.



View on the optical fibers end faces during alignment



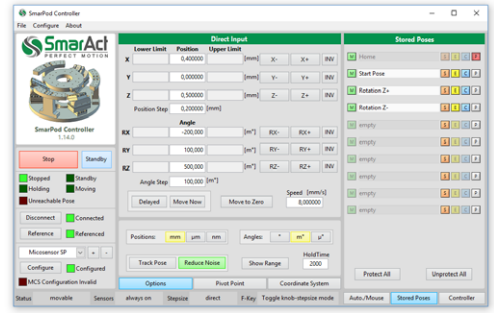
SMARPOD *with alignment holders for fiber optics*

SMARPOD **Control Software**

The **SMAR**POD Control Software is a graphical user interface, which can control all current **SMAR**POD models.

Main Features:

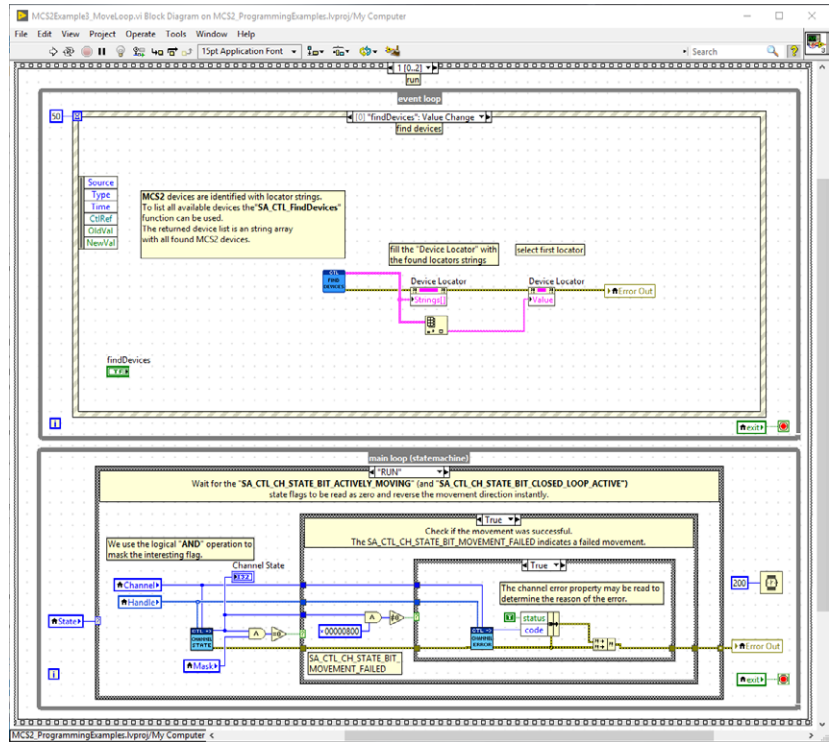
- Can handle different **SMAR**POD configurations, incl. position of the Pivot point.
- Allows to store up to 10 **SMAR**POD poses (absolute axis positions) which can easily be recalled with the klick of a button.
- Several possibilities to move the **SMAR**POD including your computer mouse, **SMAR**POD hand controller or a 6D mouse.



SMARPOD *Control Software main window*

Software Development Kits

With every control system SmarAct supplies Software Development Kits for easy and fast integration of the positioning system into your control environment. The development kits come with detailed documentation of all functions and procedures.
They include not only C/C++ but also LabVIEW programming examples, tool palettes and demo software programs.



Optical Metrology

SmarAct's mission is to provide high precision positioning solutions and accurate metrology tools. The **PICO**SCALE product line is based on a compact Michelson interferometer and features non-invasive displacement measurements at atomic length scales. The combination with SmarAct's positioning portfolio recently gave rise to the **PICO**SCALE *Vibrometer* for high frequency modal analysis of small structures like micro-electro-mechanical systems (MEMS).
Explore the possibilities of SmarAct Metrology products and services!

SmarAct's Metrology Solutions

Today's standards in manufacturing, quality control and research require methods to measure distances and displacements at the highest possible accuracy. SmarAct offers a range of metrology solutions to help you characterizing and improving your processes.

SmarAct's **PICO**SCALE products are based on optical methods for the contactless measurement of displacements and vibrations. Because no physical contact is required, the objects will not be affected by the measurement. This is especially relevant for smaller objects, whose dynamics are easily influenced by the attachment of conventional measurement probes.

The **PICO**SCALE *Interferometers* are widely used in positioning technology and allow tracking of displacements at pm resolution. A variety of sensor heads have been developed to adapt the measurement to your exact requirements. This includes the operation at different distances, on different samples but also the measurement of angles. Special sensor heads are available for extreme conditions such as cryogenics, high radiation and vacuum.

Beyond measuring displacements, **PICO**SCALE *Interferometers* are used for the characterization of the dynamic performance during motion. Because the positional data is measured at a very high bandwidth, vibrations can be accurately identified in real time. The **PICO**SCALE *Interferometer* can simultaneously measure vibrations at up to 3 points on an object. To address the need to measure more points for modal analysis, the **PICO**SCALE *Vibrometer* measures up to 1 million points on an object.

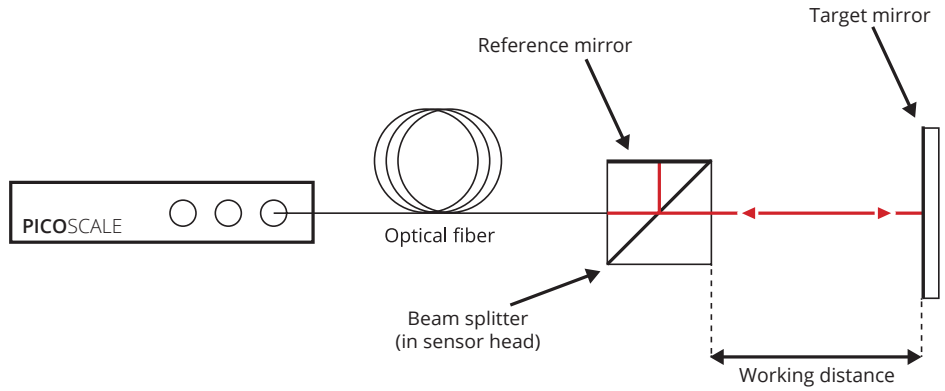
The **PICO**SCALE *Vibrometer* is a turnkey solution to measure vibrations of micromechanical structures with sizes that range from just a few µm up to 20 mm. Applications include the testing of MEMS, miniature loudspeakers and microphones but also bearings and actuators. Because the instrument is equipped with an integrated microscope and can measure up 1 million points, it is excellently suited to visualize vibrational modes at high spatial and temporal resolution.

The nature of some projects does not justify the investment in specialized instrumentation and

Optical Metrology
Interferometric Solutions

knowledge. To meet this situation, we offer laboratory services, that enable you to add state-of-the-art metrology approaches to your project. Equipment includes a raster scanning electron microscope, **PICO**SCALE *Interferometers* and a **PICO**SCALE *Vibrometer*. Measurements can be either performed on site or at our laboratories. In both cases you will maximally benefit from our latest equipment and expertise.

Please contact us to discuss the possibilities.



The Core Technology: Interferometry

All **PICO**SCALE products are based on a Michelson interferometer, a precise method to measure displacements and vibrations. The Michelson interferometer consists of a wavelength-stabilized laser, a beam splitter, a target and a reference mirror.
At the beam splitter, the light from the laser is divided into two arms. One arm is directed to the target surface while the other is directed to the reference mirror. After the light of both arms is reflected by the target surface and reference mirror, respectively, it travels back to the beam splitter. Here, both arms recombine and interference takes place.
The interference signal contains information on the displacement of the target surface with respect to the reference mirror.

Metrology

PICOSCALE *Interferometer*

For high precision displacement measurements, SmarAct offers the **PICO**SCALE *Interferometer,* a powerful sensor with picometer resolution. Based on an extremely compact Michelson interferometer, non-invasive measurement with low restrictions on the target reflectivity can be realized very efficiently.

Sensor heads are available for general purpose or optimized for specific tasks like angular or differential measurements. Furthermore, we provide sensor heads for use in vacuum, cryogenic or other harsh environments. Due to their compactness, they fit into almost every setup.
Powerful firmware modules and versatile accessories complement the **PICO**SCALE portfolio to emphasize its use as a laboratory device for synchronization with other devices, signal generation, real-time calculation and many more applications.

Key Features	
Resolution [pm]	1
Number of Channels	3
Working Distance [mm]	0 .. 1000
Maximum Target Velocity [m/s]	1
Data Rate [MHz]	Up to 10
Measurement Laser Wavelength [nm]	1550, laser class 1
Pilot Laser Wavelength [nm]	650, laser class 1
Measurement Conditions	Ambient, high vacuum, ultra-high vacuum, cryogenics, hard radiation
GPIO Interface	3x ADC, 5x DAC, Serial data, AquadB
Controller Chassis	33 x 27 x 7.2 cm, weight 3.5 kg (tabletop) 48.2 x 31 x 4.5 cm, weight 3.8 kg (19″ rack)

About PICOSCALE Sensor Heads

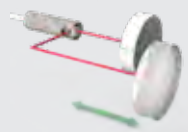
The **PICO**SCALE sensor heads are mandatory equipment to perform high resolution displacement measurements. Within the heads, the probe and the reference beam interfere, and the interference pattern contains the information on the target mirror's position. Currently, SmarAct offers three classes of sensor heads with different beam geometries that were designed for a great variety of applications.

Customization

Since SmarAct designs and manufactures all products in-house, we can efficiently design and produce customized sensor heads. This includes integration of **PICO**SCALE sensor heads into SmarAct's motion systems and customized solutions with specific properties according to your needs. Please contact SmarAct's direct and flexible customer support.

	C01	C02	C03	F01	F02	L01
Beam Geometry	Collimated			Focused		Line-focused
Focal Length [mm]	-			10*	6	30*
Spot Size [µm]	400	1560	1600	28	7	50 x 1600
Divergence [mrad]	2.5	0.6		35	140	20
Angular Working Range [deg]	± 0.05	± 0.001	± 0.001	± 2	± 6	± 1.3 (focused axis) ± 0.01 (collimated axis)
Typical Targets	Mirror	Mirror / Retro-reflector		Mirror/ Small samples	Small and microscopic samples	Mirror Cylindrical samples
Compatibility	HV, UHV, CRYO	HV, UHV				
Dimensions [mm]	4 x 13	9 x 22.7	6 x 20.6	6 x 21	11 x 12 x 34	9 x 25.5
Working Distance [mm]	13 .. 650	0 .. 1000	0 .. 500	10 ± 0.5	5 ± 0.1	30 ± 10

**customizable*

Sensor Head Options	
	Several sensor heads are available for different environments such as ambient air, ultra-high vacuum, cryogenic or hard radiation.
	For C01 sensor heads different beam splitter cubes are available: • Standard: The reference mirror is directly coated to the side surface. • Front reference: The reference mirror is coated to the front surface so that the measurement beam exits perpendicularly. • External reference: Without coating, differential displacement measurements become possible (see picture).
	The sensor heads are connected to the controller by optical glass fibers. In addition to our standard polyamide fibers we offer a robust metal shielding (see picture), PTFE for UHV and radiation resistant PEEK tubing.

Mounting Accessories	
	We offer adapter plates for all sensor heads to fix them in conventional ½" or 1" mounts. The sensor head is automatically secured in the adapter when it is fastened in a mount.
	Remote alignment of sensor heads with SmarAct's STT mirror mount. A small aluminum spacer with 1/2" diameter can be attached for easy assembly in setups with strict space constraints.
	Manual alignment mount by using flexures and fine adjustment screws.
	Angular measurement assembly with three C01 sensor heads in a L-shaped configuration. Furthermore a variant for C03 heads is available, which can be used together with a corresponding retro-reflector target assembly.

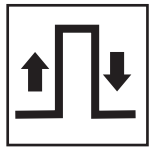
Software and Graphical User Interface

Included with every **PICO**SCALE is an extensive software bundle with drivers, libraries, LabVIEW® VI's as well as a variety of supplementary documents. All functions of the device are explained in the **PICO**SCALE User Manual and the most common applications are explained in short User Guides. If you still need support, please do not hesitate to contact our well-trained technical sales team.

Every **PICO**SCALE is delivered with a graphical user interface to configure the device. All firmware modules can conveniently be addressed with a few clicks.
Furthermore, all data sources can be monitored in customizable panels. The data can be directly displayed in a time series or pre-processed to show spectra or spectral densities, for example.

Firmware Modules

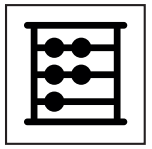
The **PICO**SCALE provides a number of unique firmware modules that can be linked almost arbitrarily. Ultra-fast response times are realized as all modules directly run on the controller itself to easily set up complex experiments without programming software code.



Advanced Trigger

Fast Trigger Pulse Processing for:

- Synchronization with master clock of external devices
- Triggered data acquisition
- Alert system in case of unforeseen events, e.g. loss of optical signal, to be used as an emergency stop of external motion systems



Calculation System

Real-time Data Processing for:

- Calculation of angles
- Scaling of results
- Output of position data via the GPIO interface within control loops
- Output of functions based on user defined look-up tables

Signal Generator

Arbitrary Function Generator for:

- Basic signal generator functionality (sine, square, sawtooth, custom)
- Excitation of targets and analysis of their frequency response with 1 mHz to 2.5 MHz

Clock Generator

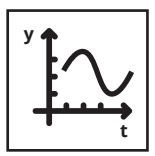
Generate Your Own System Clock for:

- Timing of internal or external processes
- Generation of periodic trigger events with 1 mHz to 10 MHz

Counter

Counter Module Used for:

- Counting of user defined trigger events
- Counting the clock pulses between trigger events
- Counting of system clock pulses for absolute timing of data



Stream Generator

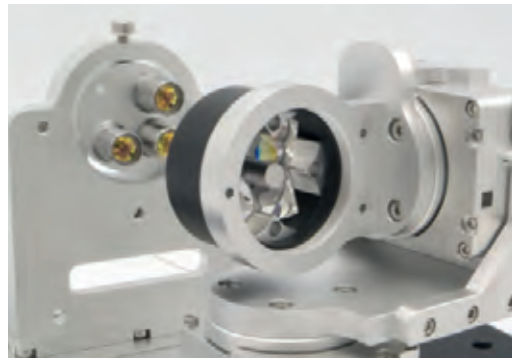
Configuration of Data Stream to User PC:

- Up to 10 MHz data rate
- Many options to filter data
- Connected to trigger module for synchronized data acquisition

Application Examples

Closed-loop Angle Control

Three position channels are used in the **PICO**SCALE *Calculation System* to infer angular motions of a target. The output can be directly used as sensor data in a **MCS**2 *Controller* so that closed-loop angular positioning is possible without the need of a permanent user PC interface.
You achieve alignment and stabilitzation of components such as Laue lenses with interferometric accuracy.



Device Synchronization

Using the **PICO**SCALE advanced trigger module, internal and external events can be used to synchronize processes.
Accurate timing of the Interferometer's data with a master clock is obtained with a few clicks.

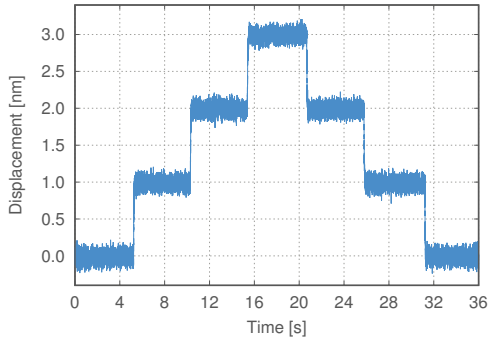
The **PICO**SCALE *Interferometer* offers various multi-user access to extract data. Connections to a user PC can be established via USB and/or Ethernet (multi-user ready).

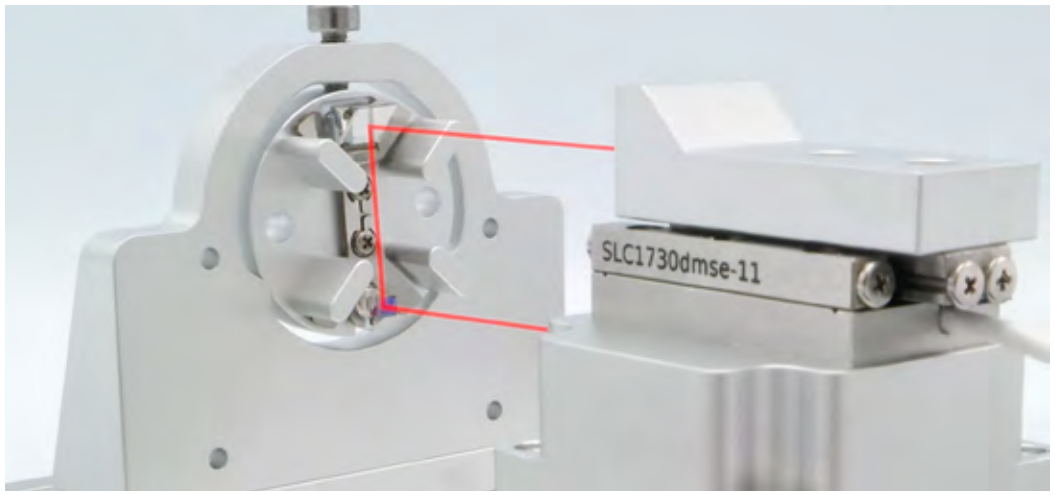
Key Features	
USB and Ethernet	Data transfer to a user PC with up to 10 MHz data rate of all available data sources. Up to two connections at the same time.
Serial Data	Serial data transmission of displacement or *Calculation System* data.
AQuadB	Incremental transmission of displacement or *Calculation System* data.
Analog Inputs	3 analog-to-digital converters with up to 16 bit resolution accessible via the **PICO**SCALE *Breakout Box.*
Analog Output	5 digital-to-analog converters with up to 16 bit resolution accessible via the **PICO**SCALE *Breakout Box.*
Trigger Inputs/ Outputs	1 input at the controller front plate, 9 inputs/ outputs accessible via the **PICO**SCALE *Breakout Box.*

PICOSCALE as Closed-loop Sensor

The **MCS**2 is SmarAct's most powerful modular control system. The **PICO**SCALE can be easily linked to the **MCS**2 as a displacement sensor. By using the interferometer's position data, the performance of closed-loop positioning can significantly be improved compared to standard sensor types. Furthermore, the results of the **PICO**SCALE *Calculation System* are available as data sources allowing for angular control, for example.

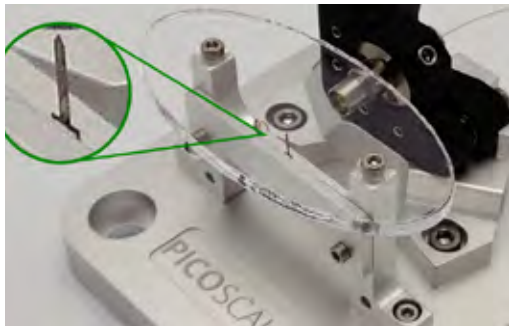
A **PICO**SCALE differential sensor head is used to track the position of a target mirror mounted on a SmarAct SLC1730 stage relative to another mirror mounted on the base. Due to the differential measurement, air fluctuations are intrinsically reduced. Using the **PICO**SCALE in combination with the **MCS**2 consequently allows for sub-nanometer closed-loop movements.

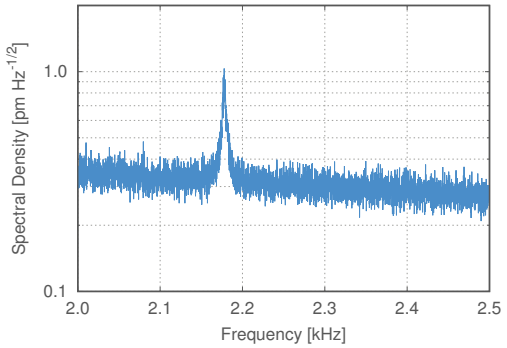




Vibration Measurement

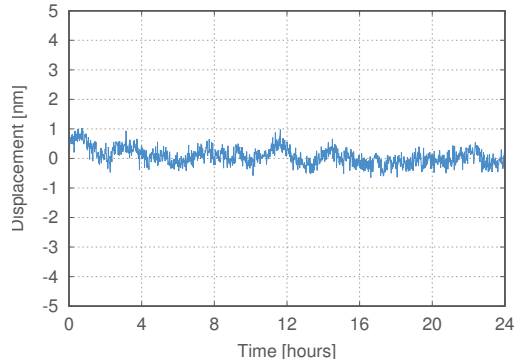
A **PICO**SCALE sensor head is used to measure the thermally exited motion of a small cantilever. The spectral analysis of the displacement data reveal single picometer oscillation amplitudes on a 300 fm / √Hz noise floor.





Stability Measurement in Ambient Air

A sensor head and a target mirror are mounted on a metal block. The displacement of the target mirror as well as the environmental parameters are recorded for a full day. After real-time correction for changes of the refractive index of air using the **PICO**SCALE *Environmental Module* and compensation for thermal drifts, the stability of the sytem is within 1 nm (2σ = 563 pm) in ambient air.



PICOSCALE *Breakout Box*

The optional **PICO**SCALE *Breakout Box* provides a simple and convenient access to the many different interfaces of the **PICO**SCALE controller. Analog and digital GPIOs can be accessed via BNC connectors while the DDI (AquadB or Serial Data) signals are mapped to D-Sub 15 connectors.

Key Features	
Digital 1-4	0 .. 5 V, rising/falling edge time < 50 ns
Digital 5-9	0 .. 3.3 V, rising/falling edge time < 50 ns
ADC 1	16 bit resolution, 10 MSa/s, bandwidth 2 MHz, ± 10 V input voltage
ADC 2, ADC 3	16 bit resolution, 100 kSa/s, bandwidth 40 kHz, ± 10 V input voltage
DAC 1	12 bit resolution, 10 MSa/s, bandwidth 2 MHz, ± 10 V output voltage
DAC 2-5	16 bit resolution, 200 kSa/s, bandwidth 150 kHz, ± 10 V output voltage
DDI Ch 1 - Ch 3	0 .. 5 V differential output
Power	12 V / 250 mA source to supply external circuitry

	Accuracy	Resolution
Temperature [°C]	0.5	0.01
Pressure [mbar]	1.5	0.02
Humidity [% RH]	1.8	0.04

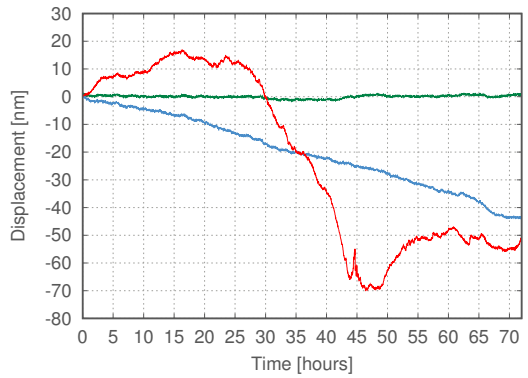
PICOSCALE *Environmental Module*

The Environmental Module is an accessory product for the **PICO**SCALE. It monitors the environmental parameters such as temperature, relative humidity, and air pressure. With these data the **PICO**SCALE controller is able to correct the recorded displacement data online for changes in the refractive index of air and thus virtual drifts of the target mirror.

Key Features	
Number of Channels	10
Sensor Connection	M8 sockets
Measurement Mode	4-wire
Sensor Type	PT1000, Class A
Sensor Tolerance [°C]	0.15

PICOSCALE *Temperature Box*

The **PICO**SCALE *Temperature Box* is a powerful accessory for the **PICO**SCALE *Interferometer*. The *Temperature Box* provides ten channels to connect platinum temperature sensors, which can be extremely compact. The sensors can be mounted to very confined setups to perform local temperature measurements. Furthermore, the sensors can be directly used to measure the temperature of a material. Compensation for thermal expansion becomes more accurate because the data can be directly processed in the **PICO**SCALE *Calculation System*.



Application Example

The **PICO**SCALE *Environmental Module* is used to record pressure, relative humidity and temperature of the ambient air of a setup, and consequently changes in the air's refractive index are corrected. The very compact sensors of the **PICO**SCALE *Temperature Box* were attached to the experimental setup so that the thermal expansion coefficient was inferred. As the sensor data is available in the **PICO**SCALE *Calculation System*, the thermal expansion can also be subtracted immediately. The graph on the left shows the uncorrected position measured by the **PICO**SCALE *Interferometer* (red), the displacement with activated deadpath correction (blue), and the position corrected for thermal drift (green).

Metrology

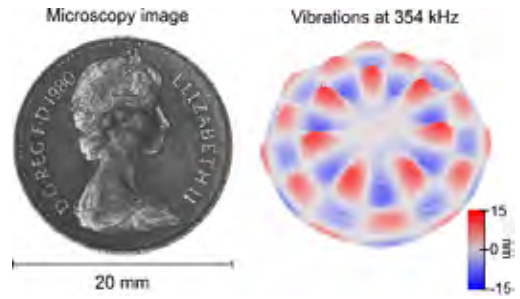
The **PICO**SCALE *Vibrometer* combines pm resolution interferometry with a 3D positioning system to provide a complete vibrational analysis of complex micromechanical devices.

Imaging Vibrations

The **PICO**SCALE *Vibrometer* is designed for megapixel imaging of vibrational modes of small structures like actuators, sensors and MEMS. This is achieved by raster-scanning a tightly focused laser beam of a Michelson interferometer over the sample to measure the vibrations for each pixel of the microscopic image. Vibrations in the sample can be induced by the advanced piezo-based shaker stage but also directly with an electrical signal that is generated by the **PICO**SCALE *Vibrometer*.

The use of SmarAct's closed-loop piezo positioners makes it possible to image structures with sizes from just a few µm up to 20 mm. A unique feature of the **PICO**SCALE *Vibrometer* is that the interferometer laser beam is used simultaneously to record a microscopy image of the sample. This microscopy image is thus intrinsically aligned with the vibration measurements and a separate microscope imaging system is not required.

The **PICO**SCALE *Vibrometer* is delivered as a turnkey system and includes an extensive software package for data acquisition and analysis.



Megapixel microscopy image of a coin (left image). The coin was excited with the shaker stage at 354 kHz and the resulting vibrations were recorded simultaneously at each pixel of the image, from which a vibration image can be reconstructed (right image).

System Controller

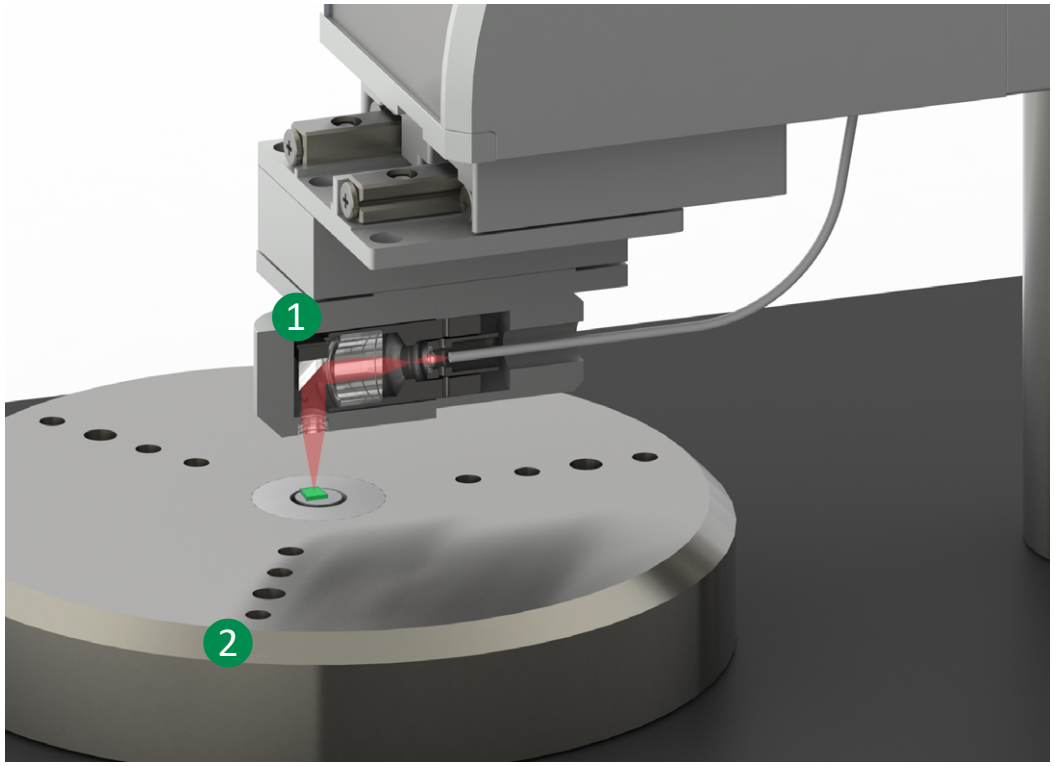
The vibrometer controller hosts all the necessary optical components and electronics to generate an infrared laser beam and to detect the interference signal that is received from the sensor head. Furthermore, it contains the circuitry to convert the measured interferometric data into a position signal in order to extract frequency, amplitude and phase of the vibrations. The stage controller contains the electronics for operating the 3D positioning stage in closed-loop and to provide access to internal system signals through the different GPIO connectors. Additionally, it includes a high-bandwidth power amplifier to drive the shaker stage to enable modal analysis.

1 3D Positioner with Sensor Head

The 3D positioner is used to scan the interferometer over the region of interest. It is built around three SmarAct closed-loop positioners enclosed in a compact protective housing. Each positioner has a maximum scan range of 20 mm and a repeatability of 30 nm. The sensor head is mounted on the lowest positioner and contains a miniature Michelson interferometer with focusing optics and is connected via a single-mode optical fiber to the vibrometer controller.
The 3D positioner with sensor head is mounted on a 25 mm diameter post so that its height is easily adjusted to accommodate samples of different dimensions. It is possible to remove the assembly from its mounting post in order to install it in a custom setup.

2 Shaker Stage

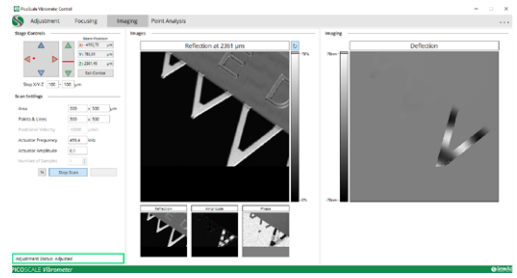
The shaker stage can be used to mechanically actuate a sample over a wide frequency range. It is based on a fast piezo based actuator mounted in a solid stainless steel housing and driven by the stage controller. To allow a reliable analysis of the dynamic characteristics of the sample, the shaker stage was optimized to deliver a smooth response by minimizing pronounced peaks in its amplitude spectrum.

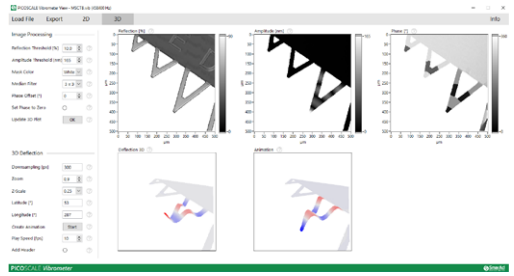


Extensive Software Package

The **PICO**SCALE *Vibrometer* is delivered with two programs that can be operated in parallel:

1. The vibrometer control software is required to operate the instrument with a regular PC. An intuitive user interface allows to perform complicated measurements with a few mouseclicks.





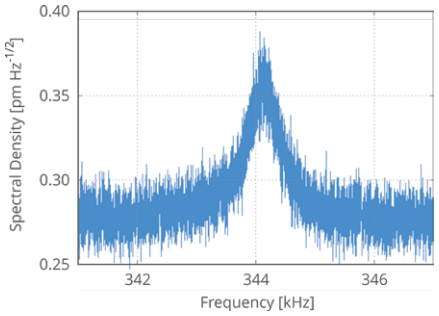
2. The vibrometer view software is offered to analyze the recorded vibrometry data. It contains a variety of options to process the data for visualization optimization in 2D and 3D but also to export the recorded binary data file into formats that can be easily imported by third party software.

Key Features		
Vibration Measurements	Vibration Resolution in Single Point Mode [pm]	< 1
	Vibration Resolution in Imaging Mode [nm]	0.1
	Frequency Range [MHz]	Up to 2.5[1]
Optical Microscope	Optical Lateral Resolution [µm]	2 .. 7[2]
	Working Distance [mm]	1.5 .. 10[2]
	Maximum Image Size [mm]	20 x 20
	Minimum Pixel Size [µm]	1
	Maximum Number of Pixels	1000 x 1000
Dimensions	Controller	2 units of each 33 x 27 x 7.2 cm (W x L x H), combined weight 7.6 kg
	Scanning Stage	5.5 x 11.0 x 7.5 cm (W x L x H), weight 0.25 kg
	Scanning Mount	Granite stone 15 x 20 x 4 cm (W x L x H) with stainless steel post 2.5 x 15 cm (Ø x H), combined weight 4.3 kg
	Shaker Stage	Stainless steel 8 x 1.5 cm (Ø x H), weight 0.5 kg

[1] lowest frequency in imaging mode is 250 Hz
[2] depending on sensor head

Characterizing Vibrations by FFT Analysis

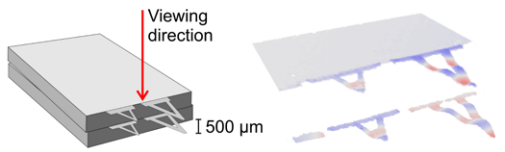
At each position of the imaged structure, the out-of-plane vibrations can be measured by interferometry. When a single or a few positions are measured on the sample, the data can be simply transformed into the frequency domain by a fast Fourier transform (FFT), which will reveal the frequency response at the measured positions. FFT plots consisting of up to 2.5 million data points can be recorded with the **PICO**SCALE *Vibrometer*, which allows a high-resolution analysis of the recorded spectra.



FFT plot showing the amplitude spectrum of a micro cantilever measured at a single position. Although the cantilever was not actively excited, the high resolution of the interferometric measurements still allows to detect the thermal fluctuations, in this case 0.36 pm at 344 kHz.

Optical Sectioning with Confocal Microscopy

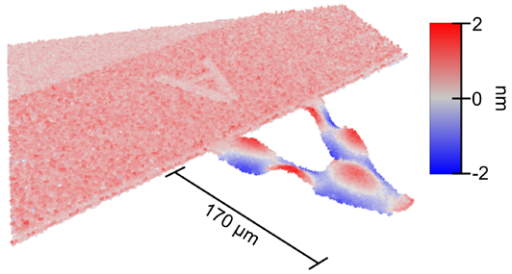
The sensor head employs a confocal measurement principle: only light reflected from the focal plane will be detected while all out-of-focus light is suppressed. This results in a higher signal-to-noise ratio of both the microscopy and vibration data. Furthermore, it becomes possible to image through semi-transparent materials and to image samples that are partly hidden by other objects, a feature that is especially useful when investigating structures that consist of multiple layers.



Measuring vibrations of multi-layered samples. Two AFM cantilever chips were positioned on top of each other such that the view on the lower cantilevers was blocked by the upper ones. By confocal imaging of each of the layers, the vibrations can still be clearly resolved.

Recording Megapixel Vibration Images with a Lock-in Amplifier

When a high number of positions on a structure need to be measured, the recording of individual

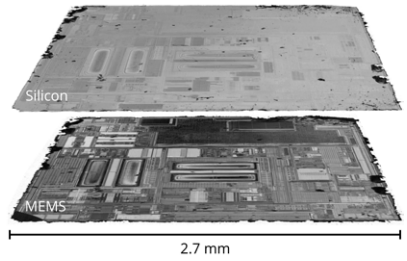


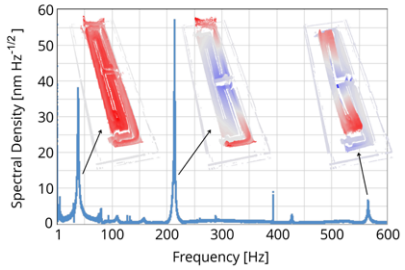
3D deflection plot of a micro cantilever that was excited at 2.1 MHz. The plot was reconstructed from the amplitude and phase information that was obtained by the lock-in amplifier.

FFT spectra becomes impractical due to the very high amounts of data that need to be processed. To overcome this, the **PICO**SCALE *Vibrometer* is equipped with a dual-phase lock-in amplifier. Basically, the lock-in amplifier extracts the amplitude and phase at one specific frequency from the measured data and thereby reduces the amount of data to just two values. Finally, the use of a lock-in amplifier allows on-the-fly analysis of the vibrations. It is thus possible to record vibration images while quickly raster-scanning the measurement laser over the region of interest. This reduces the recording time of images with a high number of pixels enormously.

Measuring MEMS through Silicon with an Infrared Measurement Laser

All **PICO**SCALE products are based on an infrared 1550 nm laser source. A unique advantage of using such wavelength is that it allows to 'look' through materials that are non-transparent for visible light such as silicon. Nevertheless, when the measurement laser is focused on a silicon structure, the reflection is still high enough to record a microscopic image and to measure the vibration of the structure.

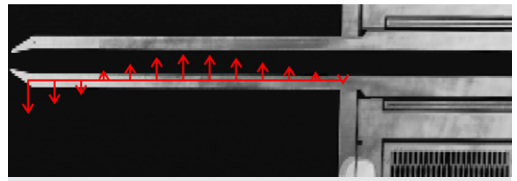




Measuring vibrations of MEMS through a packaging of silicon is made possible by confocal imaging with an IR light source. We thank InvenSense, a TDK Group Company, for their support with this application example.

Measuring Lateral Vibrations

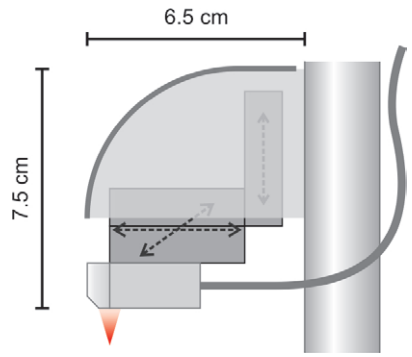
With the interferometric measurement principle only out-of-plane vibrations (parallel to the optical axis) can be measured. To enable the measurement of in-plane vibrations (perpendicular to the optical axis) a module has been developed that records a sequence of microscopic images that span a single vibration cycle (conceptionally similar to stroboscopic imaging). Through optical flow algorithms, in-plane vibrations as small as 10 nm can be extracted from laterally moving parts of the sample.



Measuring lateral vibrations. With a tracking routine the in-plane motion of selected parts of the imaged microgrippers can be measured.

Compact Design with Closed-loop Positioners

The sensor head is combined with the 3D positioner in a compact assembly. This makes it possible to integrate the vibrometer in custom setups and even in vacuum chambers (upon request). The use of SmarAct's motor technology makes it possible to position the laser beam with very high accuracy at any part of the sample. This can be used to measure vibrations at specific points on the sample at very high resolution, for example to reveal sub-pm vibrations.



Applications and Customized Solutions

This SEM sample stage with eight degrees of freedom consists of several SLC 17 linear stages combined with two rotation stages allowing an eucentric rotation of the specimen.

SmarAct's mission is to develop and manufacture devices in the sector of high-precision technology and to supply our customers with innovative solutions also for the most demanding applications. Regardless of whether a customer's project requires only a minor adaption of a single stage or if a complex multi-axis positioning system has to explicitly matched to the customers' requirements, SmarAct is the perfect partner for projects of all scales.

With our experts in diverse fields such as physics, material science, mechanical engineering, optics, electrical engineering and computer science we are able to develop all parts of our products in-house, ranging from motor technology, controller, measurement technology to firmware and application software. The members of our sales team with have strong scientific backgrounds across all fields of application and are able to discuss your specific requirements with you at eye level.

We dedicate this chapter of the catalog to a few of the many projects and solutions we have been working on for and together with our customers.

The Art of SEM Imaging

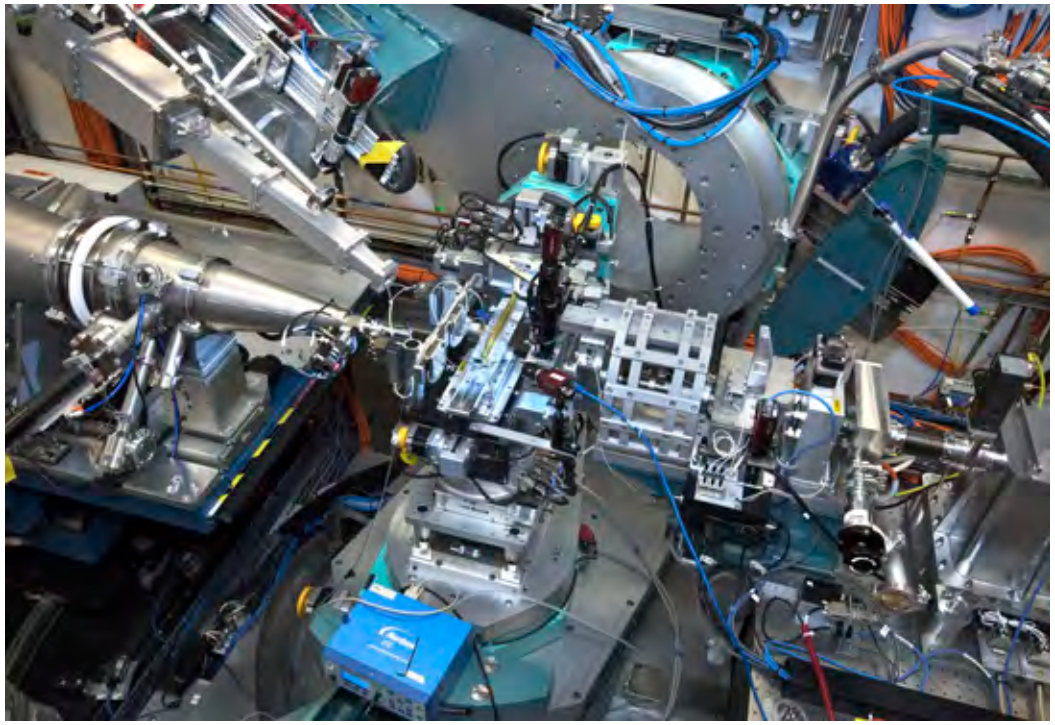
for Stefan Diller, Scientific Photograph, Würzburg, Germany

The Leipzig Panometer displays changing visual panoramas inside a former gasometer and was created by the Austrian-born artist Yadegar Asisi, who also named the building as a portmanteau of “panorama” and “gasometer”. Each panorama is accompanied by a thematic exhibition. From January 26th 2019 the exhibition “Carolas Garden” is shown. The exhibition takes visitors on a journey to the foreign world of the microcosm. From the perspective of a grain of pollen, visitors can observe a giant bee as it pollinates the flower and discover the universe behind a flower calyx. A familiar world unfolds as if under a gigantic microscope. The depicted world around is one hundred times its real size.

The scientific photographer Stefan Diller took part in this by generating scanning electron microscopy (SEM) images of the bee and the chamomile blossom: “A technically very complex project, which in the end was perfectly presented in the Rotunda of the Panometer. The honey bee sitting on the chamomile blossom is probably the largest printed image derived from scanning electron microscopy data”, says Diller.

It is one of the world’s largest 360° cycloramas with a dimension of 110 x 32 m sublimation printed on thirty-seven polyester sheets. The image data used for these gigantic prints needed to be extremely detailed. Therefore, conventional macro photography cannot be used because the image resolution is simply not high enough. Instead, Stefan Diller used a scanning electron microscope (TESCAN MIRA3 FE-SEM) equipped with a multi detector setup and a SmarAct SEM stage.

SmarAct’s eight-axis SEM piezo stage was used to position the motifs precisely under the SEM’s objective lens while recording the many tiles necessary to create the stitched image. The stage offers three axis of rotation and five translational degrees of freedom to position the SEM sample with nanometer precision under the electron lens.



3D Printer Stage for Fundamental Research in Additive Manufacturing

At the CHX Beamline, National Synchrotron Light Source II (NSLS-II), Brookhaven National Laboratory, Uton, New York, USA

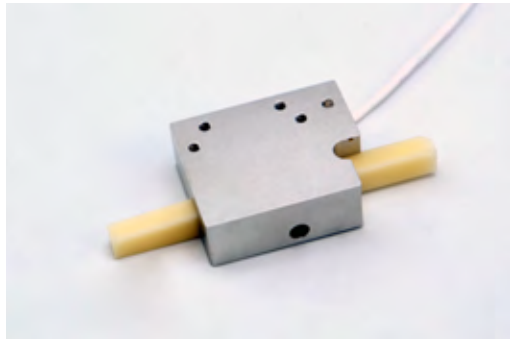
With new opportunities and challenges from additive manufacturing, novel characterization approaches are needed to realize reliable and industry-transferrable material systems and processes. [1]
Different additive manufacturing capabilities have been co-developed and implemented on three beamlines at NSLS-II.
A printing platform was developed and implemented at the CHX beamline for operando studies of structure and dynamics during Continuous-flow Direct Writing (CDW) processing. To avoid artifacts in XPCS measurements and preserve spatial resolution in microbeam experiments, eliminating vibrations during the printing process was an important design goal. [1]
SmarAct has developed the XYZ stage for positioning of the printbed. It is based on a serial combination of linear stages of the SLC and SLL Series. The gantry that is being used to position the printheads makes use of one of the key feature of the SLL Product Series, which is its unique ability to use several piezo driven carriages on a single rail. Here this feature is being used to simultaneously hold two different printheads, one of which can be also equipped with a Y-translation. This is realized by an SLS-3232 linear stage that can be mounted on top of one of the carriages. See the latest article of the group for more details about the experimental setup and first results [1].

[1] L. Wiegart, G. S. Doerk, M. Fukuto, S. Lee, R. Li, G. Marom, M. M. Noack, C. O. Osuji, M. H. Rafailovich, J. A. Sethian, Y. Shmueli, M. Torres Arango, K. Toth, K. G. Yager & R. Pindak (2019) Instrumentation for In situ/Operando X-ray Scattering Studies of Polymer Additive Manufacturing Processes, Synchrotron Radiation News, 32:2, 20-27, DOI: 10.1080/08940886.2019.1582285

Cryo Compatible Positioners to Align the Optics Combining the Images of the Individual Telescopes

For European Southern Observetory (ESO), Mt. Cerro Paranal, Chile

The Very Large Telescope array (VLT) is the flagship facility for European ground-based astronomy. It consists of four Unit Telescopes which can be combined to form a giant astronomical interferometer, allowing astronomers to see details much finer than with the individual telescopes.
The light beams are combined using a complex system of mirrors which is designed with only a few moving parts for readjustment. In cooperation with ASTRON Nova, SmarAct developed a compact precision positioner for the use in cryo environments after a previous solution became unavailable.
SmarAct's compact positioning stages were combined with a guiding mechanism to perfectly fit Nova's mirror design and to enable the successful commissioning of the equipment.



Multi-Axis Positioning and Probing System for a Synchrotron Endstation

At the FORMOSA Beamline, Taiwan Photon Source (TPS@NSRRC), Hsinchu, Taiwan

Understanding the micro- and nanostructure of materials requires many different analytical techniques. The most sophisticated techniques involve the use of focused x-ray beams generated by a synchrotron light source.

For better understanding of the crystal phases, orientations and strain/stress distribution together with their optical, electrical, mechanical and surface properties, SmarAct developed a unique sample positioning and probing system for the endstation of the “FOcus x-Ray for MicrO-Structure Analysis” (FORMOSA) beamline at the Taiwan Light Source.

Combining four micro-manipulators with three degrees of freedom each, a sample stage and a full hexapod-like **SMAR**POD (see page 100) with six degrees of freedom in a compact setup that fits in a tightly confined space of a vacuum chamber.

The multi-axis positioning system allows to move the sample with nanometer resolution in the X-ray beam or orientate it towards the electron column of a SEM which is also connected to the system. The customized **SMAR**POD offers up to 110 mm by 80 mm travel in the horizontal and 70 mm in the vertical plane, allowing for tilt angles of up to 20° in order to align the sample platform to the different detectors mounted to the chamber.

Highly Compact XYR-Stage for an automated Laser Ablation System

For 3D-MICROMAC AG, Chemnitz, Germany

3D-Micromac's microPREP™ PRO is a laser ablation system complementing existing approaches to sample preparation such as focused ion beam micromachining. It offers up to 10,000 times higher ablation rates and therefore lower cost of ownership compared to focused ion beam methods. microPREP™ PRO is used for fast high-volume sample preparation of metals, semiconductors, ceramics and compound materials for microstructure diagnostics and failure analysis. The sample preparation stage of the microPREP™ PRO was developed by SmarAct in a cooperation 3D-Micromac AG and ensures for the correct alignment of the material under the laser beam.

The highly compact stage with two translational and one rotational degree of freedom is based on SLC-1780 (see page 18) linear stages and a SR-4011 rotation stage (see page 48). The integrated position encoders guarantee a closed-loop resolution of 100nm of the linear and 500µ° of the rotation axis.

High Precision Lens Alignment for Macromolecular Crystallography

At the X10SA Beamline, Swiss Light Source (SLS) at the Paul Scherrer Institut (PSI), Switzerland

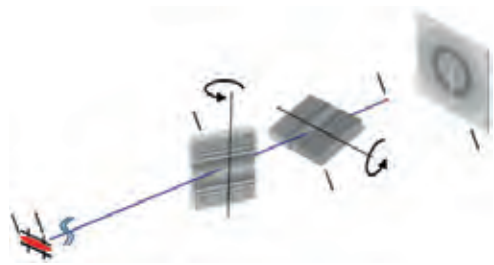
Researchers of the PSI have developed an innovative solution based on a two-stage demagnification microfocus module for hard X-rays based on a hybrid reflective-diffractive approach [1].

A prefocusing of the undulator source of the X10SA beamline at the Swiss Light Source (SLS) is achieved with a pair of reflective and diffractive optics which creates a secondary source. A second demagnification stage refocuses the beam to the sample position utilizing a pair of high-efficiency kinoform diffractive lenses.

Two **SMAR**PODs (see page 100) are used to precisely align the kinoform lenses within the X-ray beam. Per dimension, three chips containing four lenses each are mounted on top of two of the hexapod-like **SMAR**PODs. Due to the long travel ranges of these customized positioning systems an array of lenses can be mounted at once, whereas each lens combination can be positioned and precisely aligned in the X-ray beam. All mechanical units including the lenses are placed in a high-vacuum chamber. Thus, a single lens can be selected and aligned in all six degrees of freedom with nanometer precision in high-vacuum. Both **SMAR**PODs glide on a 1 Meter SLLV42 rail for coarse positioning along the X-ray axis.

Macromolecular crystallography often requires focused high-intensity X-ray beams for solving challenging protein structures from micrometer-sized crystals using synchrotron light sources. The design of optical focusing schemes for hard X-rays showing high efficiency and flexibility in beam size is therefore continuously pursued.

[1] High-intensity x-ray microbeam for molecular crystallography using silicon kinoform diffractive lenses, Maxime Lebugle et al., Applied Optics, Vol. 57, No. 30, 20 October 2018, doi: 10.1364/AO.57.009032

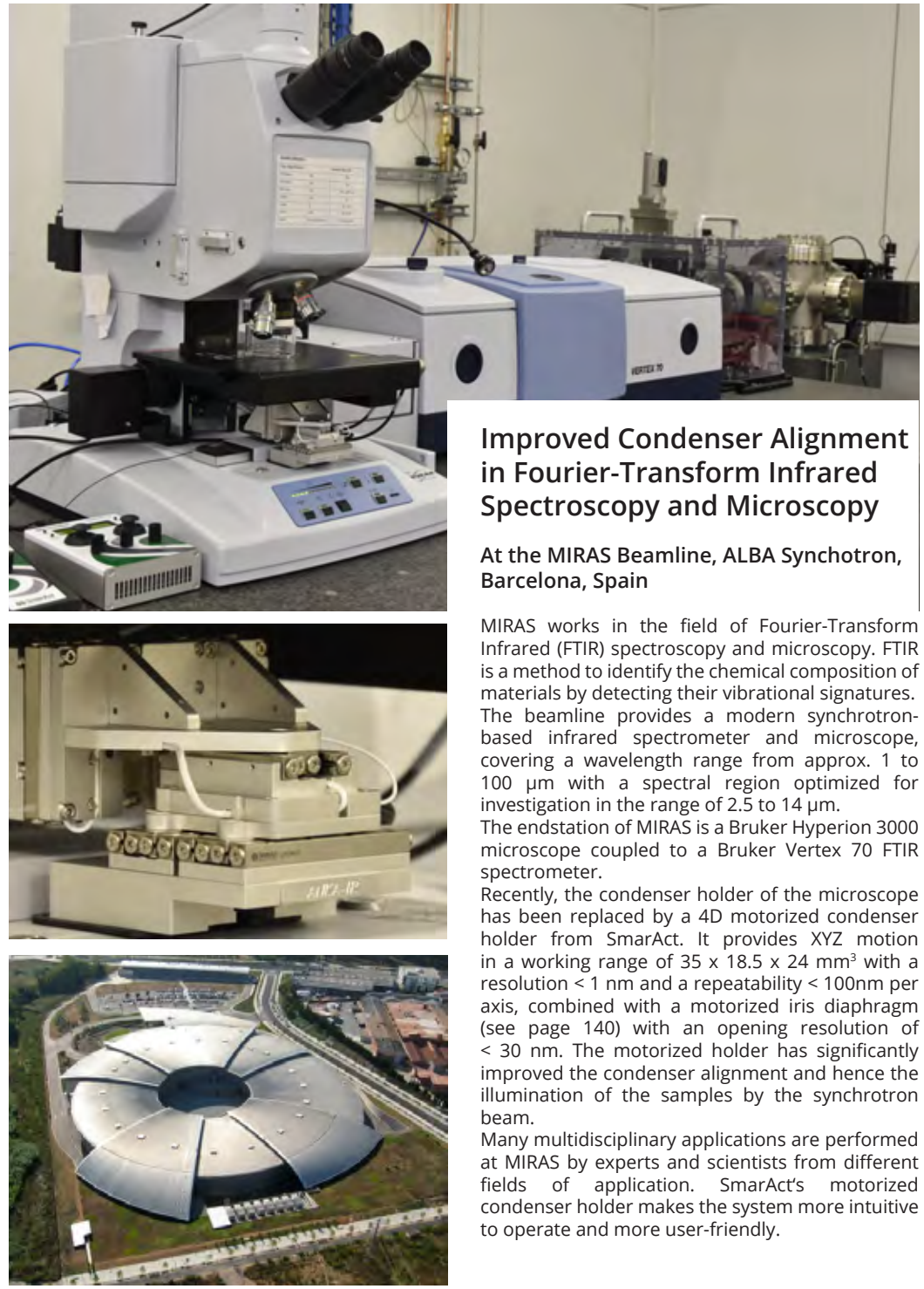


Solutions

Plasma Acceleration Experiments with SMARPODs

At the REGAE Beamline, DESY, Hamburg, Germany

Laser-Plasma Accelerators have the potential to become the next-generation technique for the acceleration of electrons. This technique allows these charged particles to be accelerated in a smaller space, thus making the systems more compact. Synchrotron facilities around the world are participating in the progress of this technology. Two non-magnetic **SMAR**PODS (see page 100) are in use in the interaction chamber of the REGAE Beamline at DESY in order to investigate Laser-Plasma Acceleration. Working at ultra-high vacuum conditions (10^{-9} mbar) and in high-magnetic fields, those **SMAR**PODS have been specially designed in cooperation with the scientists working on this project. Both **SMAR**PODS are capable to carry a load of 1.7 kg and offer a travel range of 149 mm, 49 mm and 2.8 mm in X, Y, and Z, respectively, in order to align a Solenoid and a gas supply stage in six degrees of freedom accurately with a resolution of a single nanometer.



Improved Condenser Alignment in Fourier-Transform Infrared Spectroscopy and Microscopy

At the MIRAS Beamline, ALBA Synchotron, Barcelona, Spain

MIRAS works in the field of Fourier-Transform Infrared (FTIR) spectroscopy and microscopy. FTIR is a method to identify the chemical composition of materials by detecting their vibrational signatures.
The beamline provides a modern synchrotron-based infrared spectrometer and microscope, covering a wavelength range from approx. 1 to 100 µm with a spectral region optimized for investigation in the range of 2.5 to 14 µm.
The endstation of MIRAS is a Bruker Hyperion 3000 microscope coupled to a Bruker Vertex 70 FTIR spectrometer.
Recently, the condenser holder of the microscope has been replaced by a 4D motorized condenser holder from SmarAct. It provides XYZ motion in a working range of 35 x 18.5 x 24 mm^3 with a resolution < 1 nm and a repeatability < 100nm per axis, combined with a motorized iris diaphragm (see page 140) with an opening resolution of < 30 nm. The motorized holder has significantly improved the condenser alignment and hence the illumination of the samples by the synchrotron beam.
Many multidisciplinary applications are performed at MIRAS by experts and scientists from different fields of application. SmarAct's motorized condenser holder makes the system more intuitive to operate and more user-friendly.

Ophthalmic Drug Delivery Platform

For the Ophthalmology department of klinikum rechts der Isar, Technical University of Munich, Germany

High precision in the treatment of age-related macular degeneration. For a research project of the TU Munich (Augenklinik und Poliklinik, Dr.-Ing. M. Ali Nasseri) we provide a set of piezo driven SLC-1750 stages (see pages 19) with integrated position encoders. With a travel range of 31 mm and an outer dimension of only 17 x 50 mm² the stages is a perfect compromise between travel range and compactness. These piezo driven linear stages are the main part of a hybrid parallel-serial kinematic used as a pre-generation medical device that enables ophthalmologists to improve administration of substances such as drugs and stem-cells to desired targets located below the retina.
The design of the kinematic system allows an end-effector precision of 14 µm (x), 10 µm (y) and 4 µm (z). A detailed explanation about the applications of such a drug delivery platform can be found in recent publications of the group [1].

[1] A targeted drug delivery platform for assisting retinal surgeons for treating Age-related Macular Degeneration (AMD), M. A. Nasseri et al., 2017 39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), doi: 10.1109/EMBC.2017.8037815

Precise Control of Rotating Objects in Beamlines

For National Synchrotron Radiation Research Center (NSRRC), Hsinchu, Taiwan

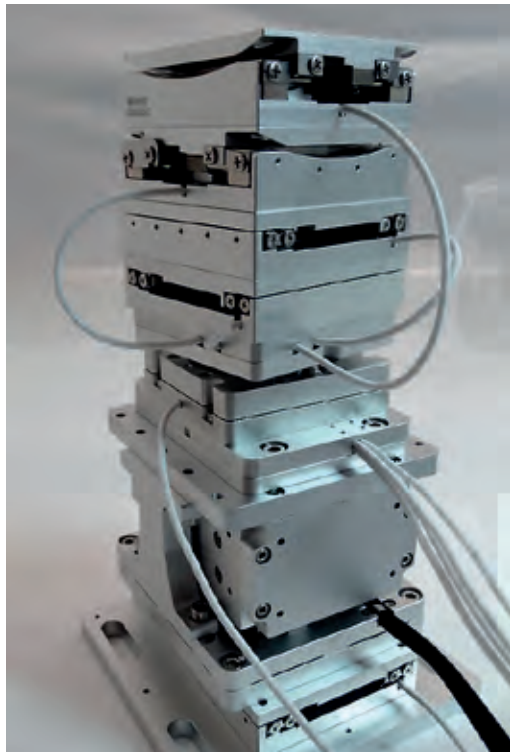
A **PICO**SCALE line focusing sensor head is used to track the motion of a polished cylinder for the use in a synchrotron beamline. Our positioners mounted on a rotary stage allow to place the cylinder without eccentricity. Alternatively, the cylinder is used with a stub offset to keep the sample stationary.

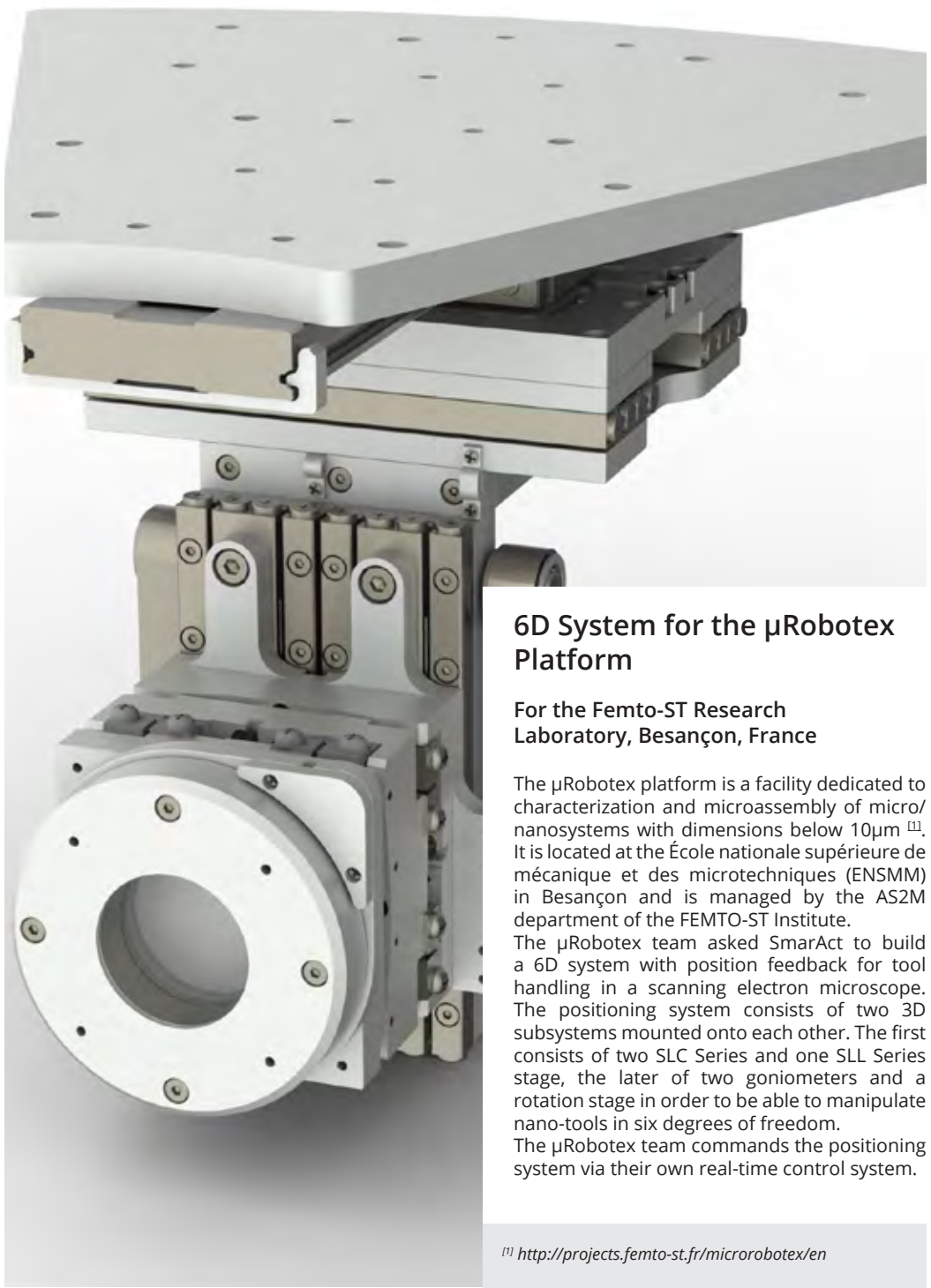
© Huang-Yeh Chen, NSRRC

7D System for X-Ray Imaging

At the NANOSCOPIUM Beamline, Synchrotron Soleil, Gif-sur-Yvette, France

The NANOSCOPIUM hard X-ray (5-20 keV) nanoprobe beamline at the Synchrotron SOLEIL is dedicated to multi-technique X-ray imaging using fast scanning and high spatial resolution. The beamline team develops and offers state-of-the-art X-ray nano-imaging and tomography techniques.
The team asked SmarAct to build a 7D sample stage, consisting of SLS modular system components. The positioning system consists of two substages mounted on top eachother. The bottom part includes a SLS Series linear stage (see page 26) with an SHL lifting stage (see page 36) on top and a rotation platform (see page 48). The top substage, which is mounted onto the rotation platform consists of an XY table made of two SLS linear stages and two Goniomter stages (see page 64) as the topmost part, forming an Eulerian cradle with a common center of rotation. The XY stage allows to precisely position the center of the Eulerian cradle in the axis of the rotation stage. Which with the help of the linear and lifting stage in the bottom part can be precisely positioned in the beam axis.





6D System for the µRobotex Platform

For the Femto-ST Research Laboratory, Besançon, France

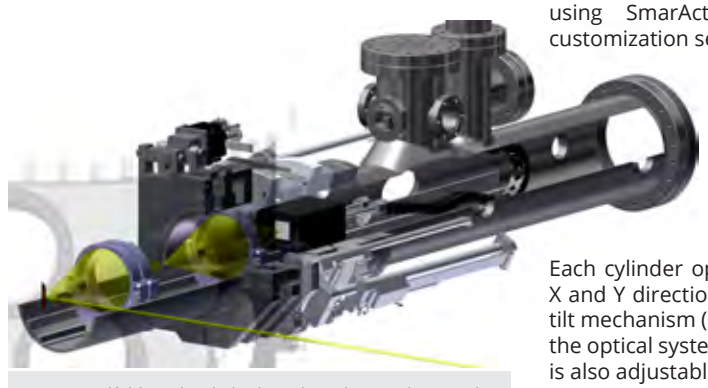
The µRobotex platform is a facility dedicated to characterization and microassembly of micro/nanosystems with dimensions below 10µm [1]. It is located at the École nationale supérieure de mécanique et des microtechniques (ENSMM) in Besançon and is managed by the AS2M department of the FEMTO-ST Institute.
The µRobotex team asked SmarAct to build a 6D system with position feedback for tool handling in a scanning electron microscope. The positioning system consists of two 3D subsystems mounted onto each other. The first consists of two SLC Series and one SLL Series stage, the later of two goniometers and a rotation stage in order to be able to manipulate nano-tools in six degrees of freedom.
The µRobotex team commands the positioning system via their own real-time control system.

[1] *http://projects.femto-st.fr/microrobotex/en*

Motion System for Compact von Hamos X-Ray Spectrometer

For National Metrology Institute (PTB), BESSY II Photon Source, Berlin, Germany

Research on new advanced materials requires improved calibratable X-ray spectrometers aiming for high detection efficiency and high spectral resolution. The National Metrology Institute (PTB) developed a compact von Hamos Spectrometer using SmarAct's positioning technology and customization services.

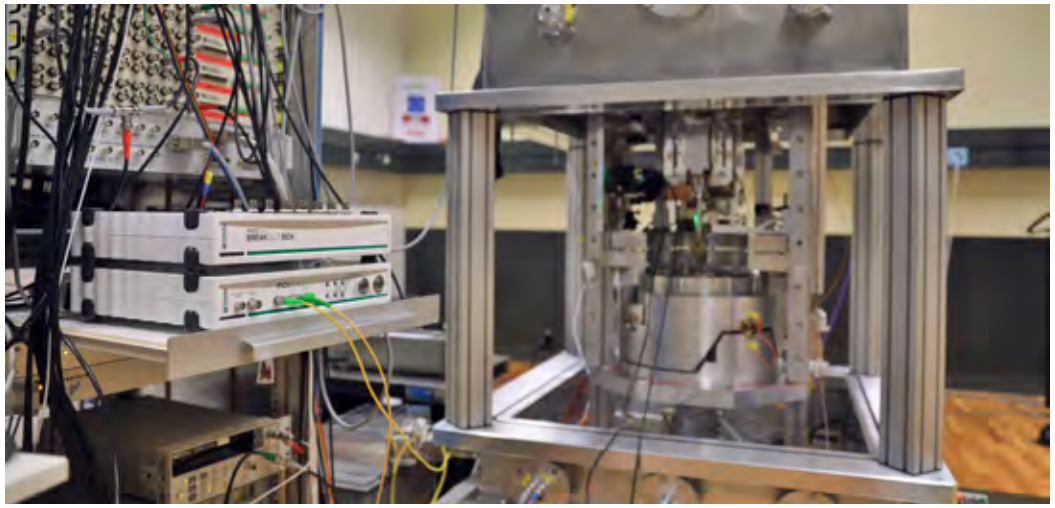


Up to three full-cylinder optics and a water cooled CCD camera can be adjusted on a 1.2 m long SLL42 linear positioning system with three individually moveable carriages along the optical Z axis.

Each cylinder optics can be individually moved in X and Y direction (±2 mm) and also includes a tip-tilt mechanism (up to 2°) for a precise alignment of the optical system. The position of the CCD camera is also adjustable in three degrees of freedom. The entire system is ultra-high vacuum compatible and has an outer diameter of less than 150 mm.

© Ina Holfelder, Physikalisch-Technische Bundesanstalt (PTB)

Solutions

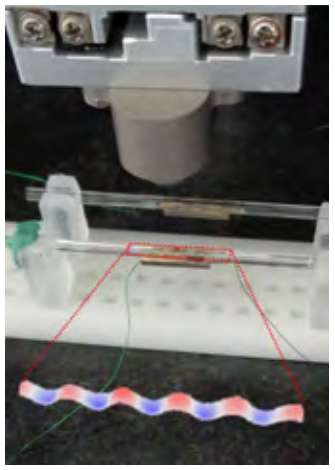


The Watt Balance: An Experiment to Realize the New Definition of the Kilogram

For METAS, Federal Institute of Metrology, Berne, Switzerland

The Watt balance is comparing mechanical and electrical powers. In a first step, the mechanical force on a test mass in the earth's gravitational field is balanced with an electro-magnetic force using a current-carrying coil. In a second step, the coil is moved through the magnetic field, which induces a voltage. The precise knowledge of the electrical, gravitational and dynamical properties allows to infer the mass by using natural constants only, which allows to redefine the kilogram - instead of using the prototype mass in Paris. One requirement during the two phases of the experiment is the accurate determination of the position and angular orientation of the coil. This measurement is performed using the **PICO**SCALE *Interferometer*.

For details please refer to https://www.metas.ch/metas/en/home/fue/forschungsprojekte/wattwaage.html



Modal Analysis of Acoustofluidic Devices

For ETH Zurich, Switzerland

Particle manipulation in microfluidics with acoustic fields is a promising technique with applications that range from 3D metal printing to life science. The research group of Professor Jürg Dual at the Institute of Mechanical Systems at the ETH in Zurich operates at the forefront of the fundamental research on such acoustofluidic devices. Of key interest is the understanding of how induced mechanical vibrations of the device can lead to well-defined pressure fields in the liquid.

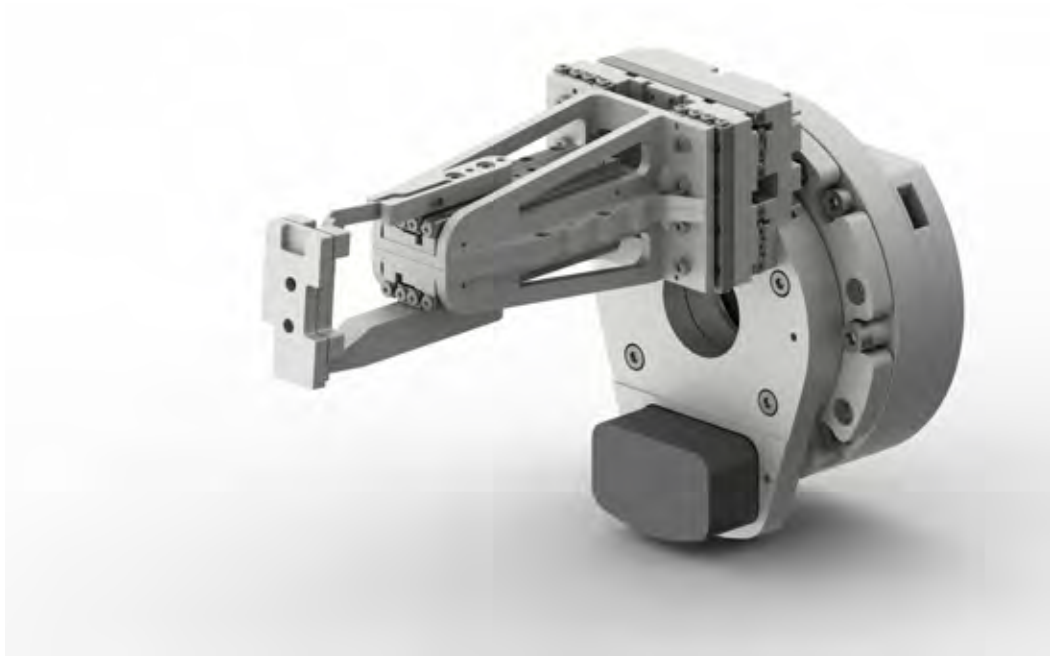
The confocal optical design of the **PICO**SCALE *Vibrometer* makes it possible to image the nanometer vibrations of the multi-layered transparent devices which helps to understand and to improve their performance.

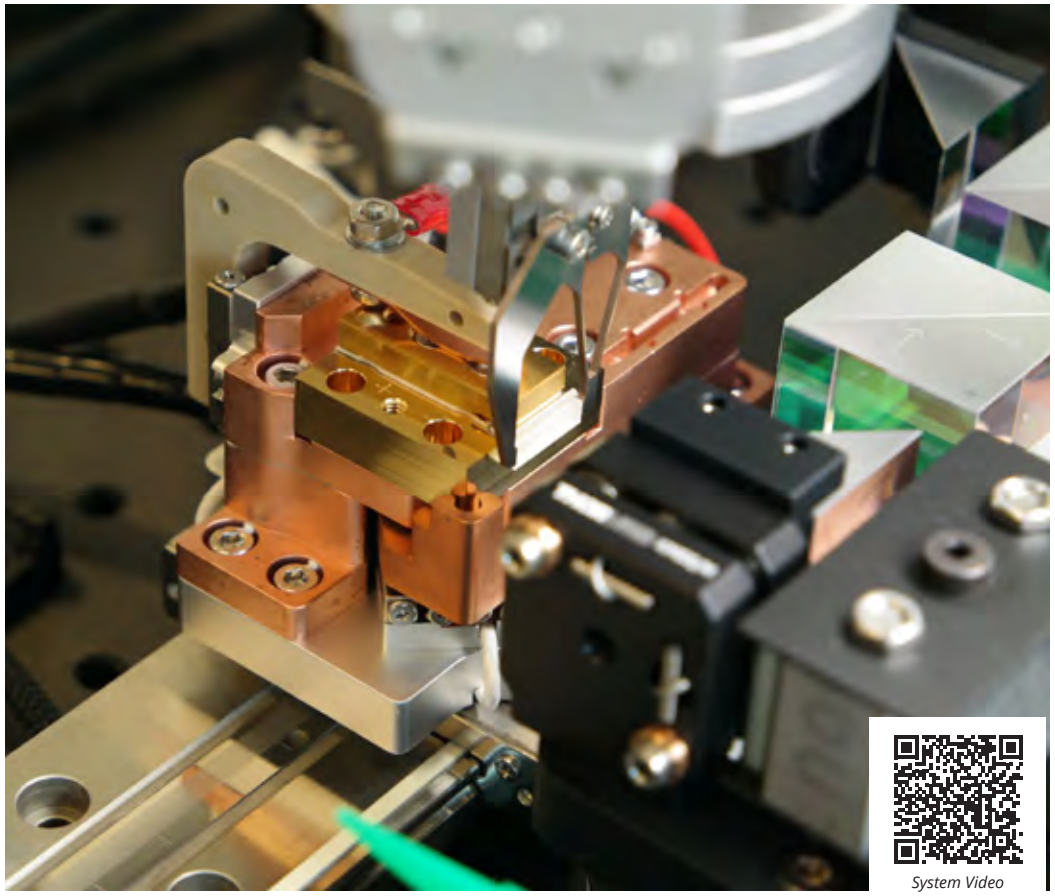
Automated Sample Delivery in Serial Femtosecond Crystallography (SFX)

For Center for Free-Electron Laser Science (CFEL), University of Hamburg, Germany

Serial femtosecond crystallography (SFX) uses X-ray pulses from free-electron laser (FEL) sources. SFX may open the way to determine the structure of biological molecules that fail to crystallize readily into large well-diffracting crystals. Taking advantage of FELs with high pulse repetition rates could lead to short measurement times of just minutes. Automated delivery of sample suspensions for SFX experiments could potentially give rise to a much higher rate of obtaining complete measurements than at today's third generation synchrotron radiation facilities, as no crystal alignment or complex robotic motions are required. New challenges arise from the resulting high rate of data collection, and in providing reliable sample delivery.[1]
To deliver the samples, a emulsion jet is dispensed in a vacuum chamber via a nozzle that is oriented and positioned by a SmarAct **SMAR**GON goniometer (see page 126). The goniometer consists of four linear stages that are attached to a larger rotation stage, forming a partially parallel kinematic structure. Each of the stages is equipped with SmarAct's piezo drive technology that provides nanometer-resolved and repeatable movements. The 5D goniometer system allows tilting the liquid jet by ± 30° and moving it by ± 15 mm. A special feature is a magnetic exchange system that allows picking a nozzle from a nozzle magazine.
SmarAct's 5D goniometer is part of this automated sample delivery system that leads to shorter measurement times and therefore higher sample throughput.

[1] Possibilities for serial femtosecond crystallography sample delivery at future light sources, L. M. G. Chavas, L. Gumprecht and H. N. Chapman, Structural Dynamics 2, 041709 (2015), doi: 10.1063/1.4921220





System Video

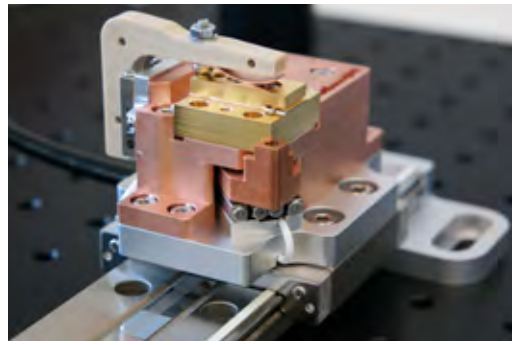
Automated FAC Alignment Station

The FAC Alignment Station automates the assembly of Fast Axis Collimation (FAC) lenses to laser diodes. The complete process, starting with contacting laser modules up to the final measurements of beam collimation after adhesive curing.
In less than 25 seconds, the alignment of the lens in front of a multi-emitter laser diode bar is achieved.

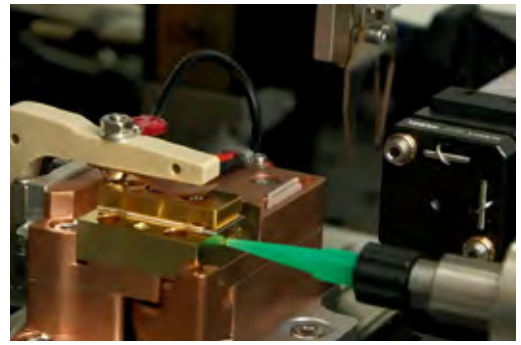
FAC Station Features	
Laser diode bars Visible and near infrared wavelengths Operation at up to 50 W pulsed	Alignment resolution using **SMAR**POD Down to 1 nm translational steps Down to 1 µrad rotational steps
Active alignment Single and multiple emitters Alignment in less than 25 seconds	Grippers Customized gripper jaws for deterministic gripping Gripper jaws for objects from 50 µm to several cm Force-feedback gripping for delicate objects
Alignment station features Automatic laser module clamping and referencing Needle valve, volumetric or jet dispensers Integrated UV-curing source	Control software User interface for monitoring and manual control Scripting interface for process development Customized GUI for small series production

Applications and Customized Solutions
Automation

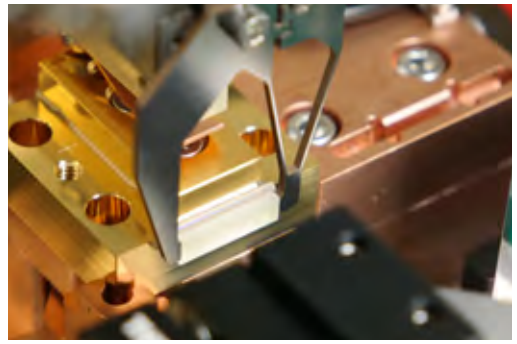
Process Steps



Loading:
Upon loading, the laser modules are centered and connected automatically. The laser mount serves as heat sink.

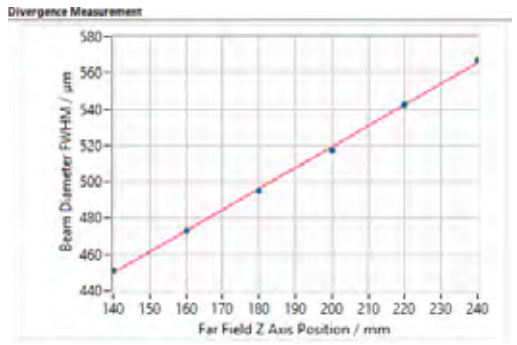


Dispensing:
Adhesive is dispensed in just the right amount. Here we employ a needle valve dispenser.

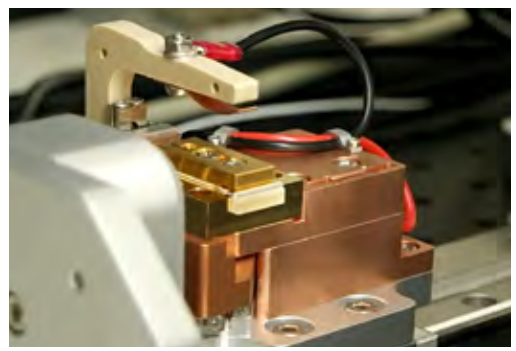


Gripping:
A SmarAct micro gripper is used to manipulate the lens.

Active alignment:
Sensor feedback from the beam analysis optics is used to precisely align the lens in front of the laser using a **SMAR**POD.



Post-cure measurement:
After curing the final optical characteristics are measured.



Unloading:
The assembled module is released to be unloaded.

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SmarAct develops high-performance solutions for handling and positioning in the micro- and nanometer range. The broad product portfolio - from single stages to complex parallel kinematics, miniaturized robots and easy-to-use control systems - is completed by sophisticated measuring equipment based on powerful laser interferometers.

We serve high accuracy positioning and metrology applications in research and industry within such fields as optics, life sciences, micro-assembly, semiconductors and microscopy. Maintaining the complete production in house allows a high level of customization.

Thus, we always provide you with the optimal individual or OEM solution.

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