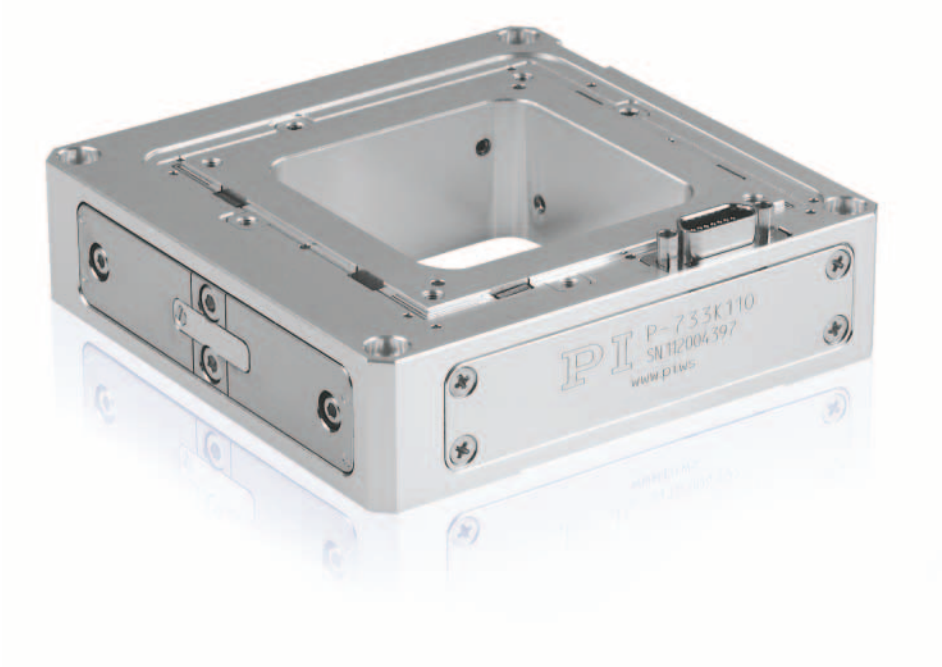
Actuators and Stages for Electron Microscopy

NONMAGNETIC VACUUM-COMPATIBLE ACTUATORS & POSITIONING SYSTEMS



Highest Precision and Reliability to Achieve the Decisive Competitive Edge

No other company in the world offers a broader and deeper portfolio of precision motion technologies than the PI Group. Four decades of continuous growth and steadily increasing market presence through the development of novel drive concepts, products and system solutions characterize the company.

With more than 700 employees worldwide and subsidiaries in 13 countries, the PI Group is in a position to fulfill almost any requirement with regard to micro- and nanopositioning technology.

Piezo actuator technology, different piezomotor drive principles, magnetic drives and guidings, nanometrology sensors and digital controllers – PI relies on a wide range of technological solutions that will always allow to find an approach that goes beyond common technologies.

Key Technologies from a Single Source

PI controls the design and manufacturing steps of all components from the piezo material to the mechanical construction, from the nanometrology sensors to the digital control circuits and software. All parameters can be modified directly, in order to push the technological possibilities to the limit, thus optimally fulfilling the customer's requirements.

From the original idea to the finished product, PI relies on close technical cooperation with the customer as its partner. This, of course, includes service and support, as well as after-sales support.

The range of products goes from the bare actuator or sensor to positioning systems for UHV applications and highly integrated parallel-kinematic six-axis systems.

Evaluation, test procedures, production processes and quality management are all included in the development process.

The drive and positioning solutions from the PI Group often go beyond the state-of-the-art, providing customers with the competitive edge necessary to be successful on the market and always one step ahead.

Contents

PI Products for Electron Microscopy

Electron microscopy allows examinations of extremely high precision down to the nanometer range. Such a high resolution makes high demands on the imaging elements, but also on the positioning systems of the individual beam guidance components, such as the apertures. The positioning of the sample must be just as precise.

The application of electron microscope methods is nowadays not limited to research, but also extends to the industrial sector whenever optical examination methods are no longer sufficient. Surface and structure tests are carried out using SEM and TEM methods, both in semiconductor technology and materials research and also in the life sciences sector. The increasingly automated test procedures require flexible, reliable drive solutions, in order to allow scans of high repeatability and stable positions to be carried out when taking micrographs.

Nonmagnetic and Vacuum-Compatible Actuators and Positioning Systems

PI offers drives, actuators and multi-axis positioning systems that are lubricant-free and vacuum-compatible. The piezo-based drive concepts developed in-house do not generate magnetic fields and are not influenced by them. This allows positioning systems to be assembled that are completely (including the guiding) or partly (except for the guiding) nonmagnetic.

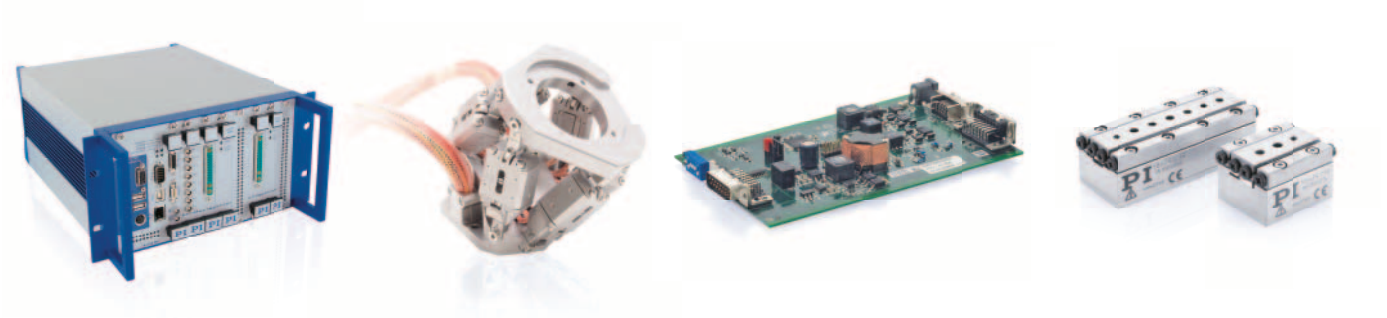
For positioning tasks, simple actuators or drives can be integrated directly at the electron beam, where they are used for correcting the beam guidance or for aligning apertures. For the positioning of the sample, either for preparation prior to examination, for rapid scans or for precise alignment in the beam path, linear and rotary stages are suitable. These stages can also easily be combined to multi-axis solutions. A particularly compact version are parallel-kinematic multi-axis stages with up to six degrees freedom in positioning.

Suitable control electronics and controllers are available for all systems; along with their analog and digital interfaces and extensive software support, they are integrated seamlessly into existing systems.

Customized Solutions

The products shown here represent only a small selection of all available positioning solutions. Special applications often require certain properties, for example travel ranges, mechanical coupling and dimensions, to be customized.

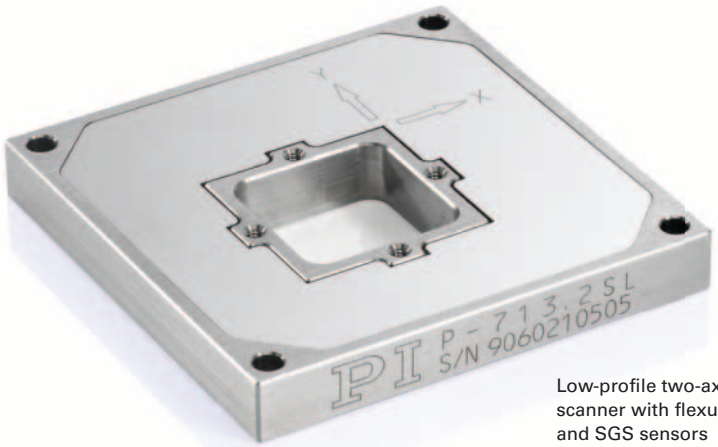
We will gladly develop a solution for your positioning task together with you. Take our word for it!



For every integration level of the mechanics, PI offers the matching electronics, ranging from compact open OEM boards to complex multi-axis control in the rack mount format. All PI controllers are commanded with the same common programming language

Piezo Actuators and Piezomotors

Technology of Piezo Drives



Low-profile two-axis piezo scanner with flexure joints and SGS sensors

Piezo Actuators - Ideal Drives for Nanometer-Precision, Reliably Repeatable Positioning

Piezo actuators are extremely compact. Their motion is based on friction-free solid-state effects, which makes their resolution in general unlimited. Their very high stiffness enables high force generation and dynamics with response times in the microsecond range.

In PI's piezo stages, a high-stiffness guiding system made of friction-free and zero-backlash flexure joints ensures optimum travel accuracy. An integrated lever mechanism increases the travel range from a few 10 micrometers down to millimeters.

The solid-state effects in the piezo ceramic produce a nonlinear motion subject to hysteresis. To achieve the excellent positioning stability, linearity and repeatability required for nanopositioning, a position control is used.

Piezomotors Offer Nanometer Precision Over Larger Travel Ranges

For travel ranges over 1 mm, PI uses piezomotors as drives, which also feature high stiffness and resolutions in the nanometer range. Piezomotors are optimally suited for using the specific properties of piezo actuators to achieve longer travel ranges.

Adapted for Nonmagnetic and UHV Environments

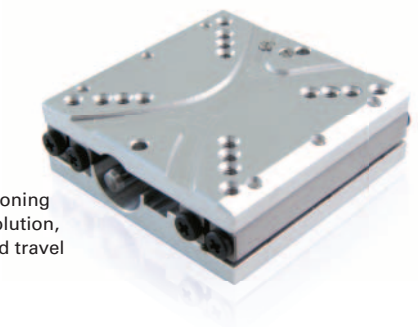
Piezo actuators and piezomotors themselves do not generate magnetic fields nor are they affected by them. In addition, they are vacuum-compatible to 10^{-11} hPa.

The integration components such as the case, position sensor or guiding systems are selected to fit the area of application of the individual drives and are, e.g. free of ferromagnetic materials.

Stable Position Holding, Even When De-Energized, High Reliability

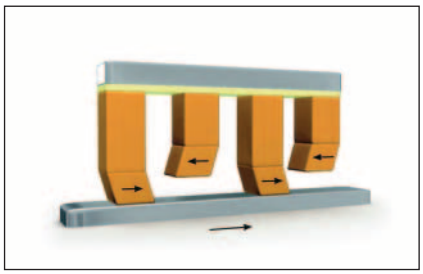
What all piezo motor technologies have in common, is stable, drift-free holding of the position at rest, without further power consumption. Consequently no heat is generated, which is advantageous especially in a vacuum environment. This makes piezomotors suitable for precise and stable positioning even during long downtimes.

Piezomotors are particularly reliable because they work as direct drives, without any additional mechanical transmission components, such as gearheads. This rules out mechanical restrictions such as backlash or wear, making the drive maintenance-free.

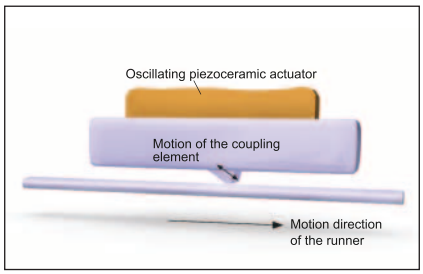


The vacuum-compatible LPS-45 linear positioning stage with piezomotors features a 2 nm-resolution, a compact footprint of only 45 mm width and travel ranges of up to 26 mm

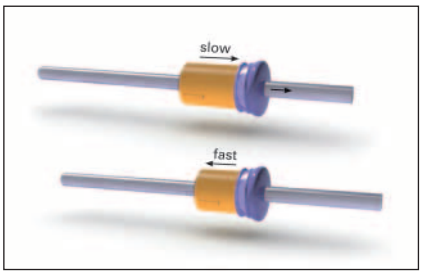
Piezomotor Technologies in Detail



In PiezoWalk® drives such as NEXACT® and NEXLINE®, piezo actuators work in pairs as clamping and feed elements on a moving runner. Cyclical control induces a stepping motion of the actuators on the runner, and the runner is moved forwards and backwards. NEXACT® offers nanometer resolution at velocities of up to 10 mm/s, whereas NEXLINE® drives are used for high force generation.



PILine® ultrasonic drives develop very high feed rates and position in the sub-micrometer range. The piezoceramic actuator is excited to ultrasonic vibrations with a high-frequency AC voltage between 100 and 200 kHz. Deformation of the actuator leads to a periodic diagonal motion of the coupling element, relative to the runner. The high frequencies result in high velocities of several 100 mm/s.

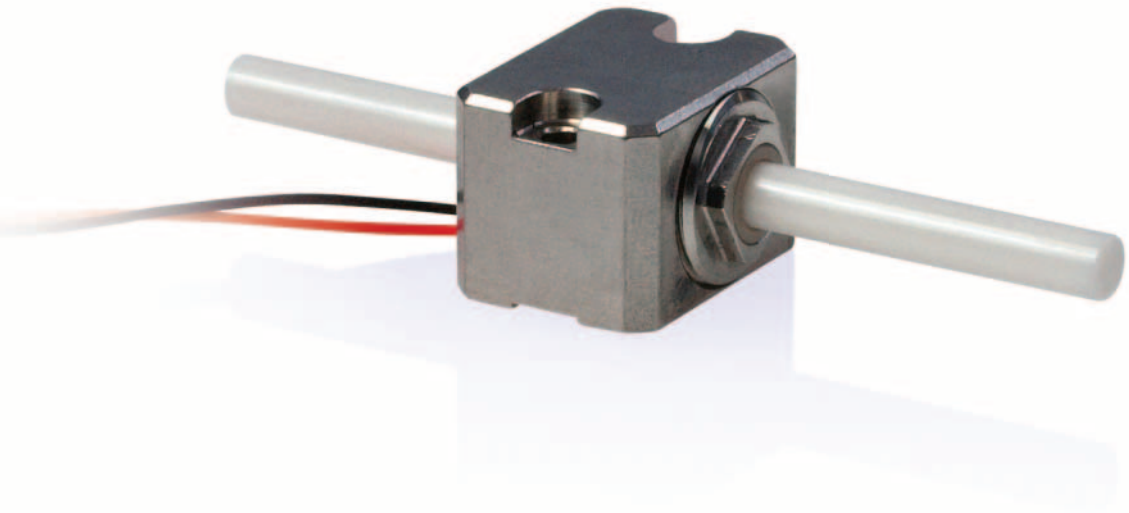


PIShift drives are based on a single piezo actuator and make use of a simple drive principle, which also allows nanometer-precision positioning. They make use of the stick-slip effect (inertia effect) – a cyclical alternation of static and sliding friction between a moving runner and the drive element generated by the piezo element. At an operating frequency above 20 kHz, PIShift drives reach a continuous feed at velocities of more than 10 mm/s.

Piezo Flexure Guides or Stack Actuators	**PiezoWalk® Piezo Stepping Drive**	**PILine® Ultrasonic Piezomotor**	**PIShift Piezo Inertia Drive**
Sub-nanometer resolution	Sub-nanometer resolution	Sub-micrometer resolution	Sub-nanometer resolution
Fast response times in the microsecond range	Velocity up to 10 mm/s High-dynamics scan mode	Very high operating frequency Noiseless drive High velocity of up to several 100 mm/s	Very high operating frequency Noiseless drive Velocity of more than 10 mm/s
Travel ranges of up to approx. 300 µm directly and 2 mm with lever amplification	Long travel ranges, only limited by the runner length	Long travel ranges, only limited by the runner length	Long travel ranges, only limited by the runner length
High stiffness Force generation of up to 100 kN	Very high forces of up to 800 N (NEXLINE®) Self-locking at rest	Forces up to 40 N Self-locking at rest	Forces up to 10 N Self-locking at rest
Ideal for:			
■ Nanometer-precision positioning with high dynamics ■ Lever-amplified and guided systems ■ Piezo scanners ■ Fine adjustment ■ Force generation ■ Active vibration insulation	■ Nanometer-precision positioning ■ Quasi-static applications with high holding force ■ Travel ranges of up to a few mm ■ Coarse and fine adjustment ■ Force generation ■ Active vibration insulation ■ Operation at constant, low velocity	■ Positioning with sub-µm accuracy ■ Fast step-and-settle ■ Scan mode with high velocities ■ Operation at constant, low velocity	■ Nanometer-precise positioning stable over a prolonged period ■ Quasi-static applications with low to medium holding force

Actuators and Drives

Compact Drive Solutions for Easy Integration



N-422

Highlights

- Vacuum compatible to 10^{-7} hPa
- Nonmagnetic versions
- Sub-millisecond response time and sub-nanometer resolution
- Versions with SGS sensors for positional stability and repeatabilities of only a few nanometers
- Travel range of up to several millimeters

Applications

Piezoelectric drives allow production of stages with minimum dimensions. The direct drive avoids mechanical components such as gears and spindles, making for reliable and high-resolution drives down to a few nanometers.

Piezo drives are in general vacuum-compatible and do not generate any magnetic interferences. In electron microscopy, this allows them to replace motorized drives in existing sample positioners and scanners.
Piezomotors and piezo actuators are also suitable as positioners during preparation of the samples. In addition, they are ideally suited, e.g. for positioning apertures when aligning the electron beam or for adjusting individual components.

P-843

P-602

N-603

	P-843	P-602	N-603	N-412 N-422
	Vacuum-compatible versions	Nonmagnetic and vacuum-compatible	Nonmagnetic and vacuum-compatible	Easy-to-control single-actuator principle with sub-nm resolution
Drive type	PICMA® multilayer actuator	PiezoMove® flexure actuator	NEXACT® piezo stepping drive with flexure guide	PIShift piezo inertia drive
Travel range	15 to 90 µm	100 to 1000 µm	2 mm	to 40 mm
Integrated sensor	SGS	SGS	SGS	combinable with linear encoder
Resolution	0.3 to 1.8 nm	2 nm	0.5 µm sensor-related Drive: sub-nm	sensor-dependent Drive: sub-nm
Repeatability	2 to 9 nm	10 to 60 nm	1 µm	sensor-dependent
Push force capacity in motion direction in N	800	100	4	10
Pull force capacity in motion direction in N	300	5	4	10
Unloaded resonant frequency in Hz	6000 to 18000	150 to 1000	750	20000
Velocity in mm/s	–	–	2 mm in 0.25 s	a few nm/s to 20 mm/s
Dimensions in mm	Ø14 × 37 to Ø14 × 127	28 × 17 × 9 to 126 × 34 × 14	42 × 42 × 7.4	21.5 × 18 × 13
Recommended controller	E-610, E-625, E-709	E-610, E-625, E-709	E-861.1S1	E-870 driver E-871 motion controller incl. driver
Interfaces / Communication	analog, USB, RS-232	analog, USB, RS-232	USB, RS-232	E-870: analog, USB E-871: USB, RS-232

Linear Stages

Miniature Stages with Direct Position Measurement

N-664

Highlights

- Compact multi-axis solutions
- High resolution and stability
- Nonmagnetic and vacuum-compatible versions to 10^{-7} hPa
- Drive without lubricants, guidings without or with vacuum-compatible lubricants
- Piezomotors are self-locking

Applications

Piezo drives are in general vacuum-compatible and do not generate any magnetic interference. This opens up application areas in which electric motors cannot be used, such as e.g. for sample scans in SEM. The stages are also ideally suited for sample positioning in surface analysis and processing using Focused Ion Beam (FIB) in SEM ultramicrotome applications or for sample preparation.

In combination with a directly measuring high-resolution encoder, these stages allow high-precision and repeatable positioning.

P-621

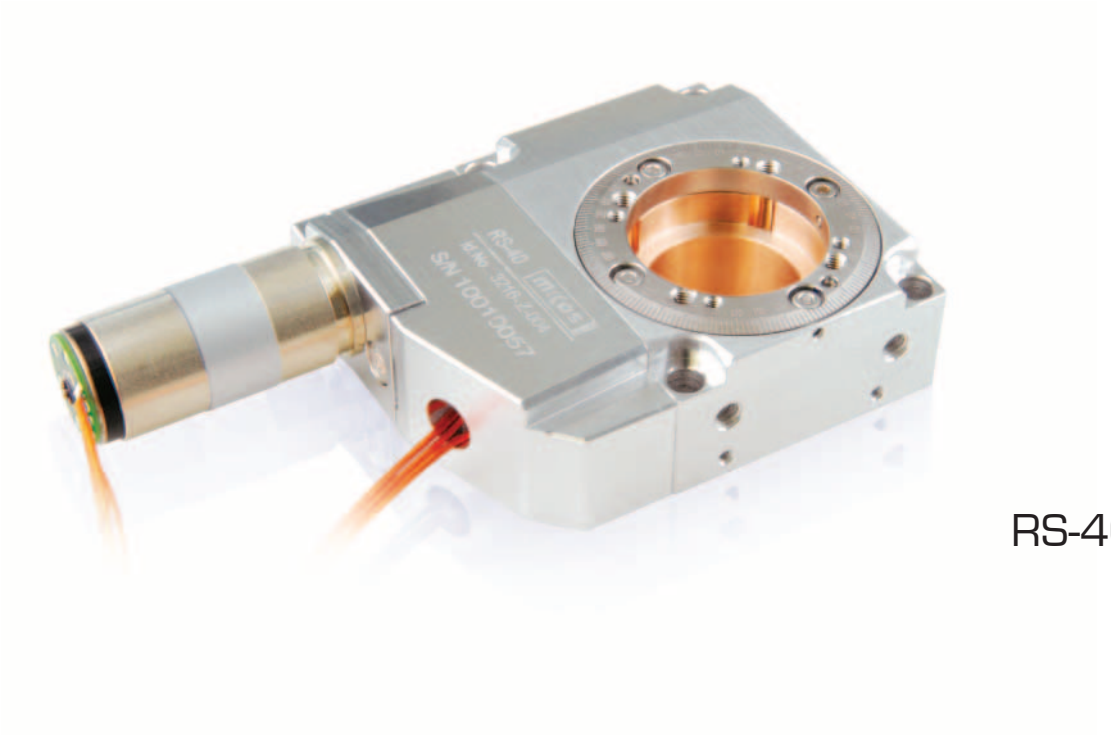
M-663

LPS-23

	P-621 P-622	M-663	LPS-23 (Preliminary data)	N-664
Drive type	PICMA® multilayer actuator with flexure guide	PILine® ultrasonic piezomotor	PIShift piezo inertia drive	NEXACT® piezo inertia drive
Travel range in mm	0.1; 0.25	19	13, 26	30
Resolution in nm	0.4; 0.7	100	1	0.5
Unidirectional repeatability in nm	1	200	20	0.5
Angular crosstalk (pitch / yaw) in µrad	±3	±200	±80 to ±110	20
Velocity in mm/s	–	250	10	10
Load capacity in N	10	5	2	20
Push / pull force in N	10	2	2	10
Dimensions in mm	40 × 40 × 15 50 × 50 × 15	35 × 35 × 15	23 to 35 × 23 × 10	120 × 65 × 20
Recommended controller (including driver electronics)	E-625.CR	C-867 single- or double-axis	E-871 single-axis	E-861 single-axis
Interfaces / Communication	USB, RS-232	USB, RS-232	USB, RS-232	USB, RS-232

Rotary Stages

Compact Rotary Stages with PILine® Ultrasonic Piezomotors



RS-40 HV

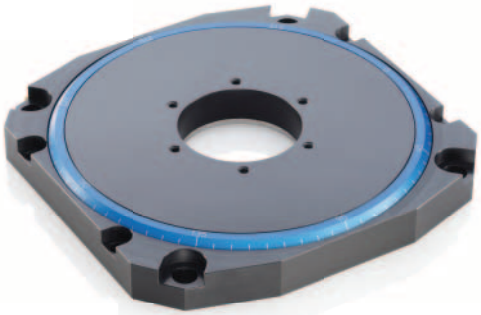
Highlights

- High resolution and stability
- Nonmagnetic and vacuum-compatible versions to 10^{-7} hPa
- Piezomotor: Drive without lubricants, guidings without or with vacuum-compatible lubricants
- Self-locking when at rest, no heat generation, no servo jitter

Applications

Rotary positioning of the sample is often required in sample preparation for SEM. These compact rotary stages allow the sample to be transported quickly, for example, in dual-beam installations from the electron beam path to FIB analysis and processing.

The rotary stages can also be used for generating multi-axis sample scans in SEM or for adjusting the angles in crystallographic examinations (Electron Backscatter Diffraction, EBSD).



M-660

U-624

U-624K

	RS-40	M-660	U-628	U-624K
	Versions up to UHV, clear aperture Ø 31 mm	Clear aperture Ø 36 mm	Preliminary data	Special models, preliminary data
Rotation range in °	360	>360	>360	>360
Drive type	DC or stepper motor	PILine® ultrasonic piezomotor	PILine® ultrasonic piezomotor	PILine® ultrasonic piezomotor
Design resolution in µrad	to 0.5	4 to 34	35	52 or open-loop
Min. incremental motion in µrad	to 35	12 to 34	105	150 or open-loop
Velocity in °/s	0.6	720	1 080	>360
Load capacity (axial force) in N	10	20	5	2
Torque cw / ccw in Nm	1	0.3	0.1	0.01
Dimensions in mm	56 × 64 × 20	116 × 116 × 14	50 × 50 × 19	40 × 40 × 20 (with sensor) to 20 × 20 × 12 (open-loop)
Recommended controller	SMC controller	C-867 PILine® motion controller	C-867 PILine® motion controller	C-867 PILine® motion controller
Interfaces / Communication	USB, RS-232, TCP/IP	USB, RS-232	USB, RS-232	USB, RS-232

Multi-Axis Stages

Precision Sample Positioning in up to Six Axes

P-733

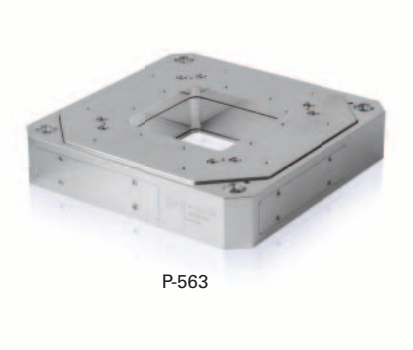
Highlights

- Parallel-kinematic design: All actuators act on the same moving platform
- Compact dimensions, low profile, light-weight
- High stiffness, high precision, optimum dynamics
- Nonmagnetic and vacuum-compatible versions to 10^{-7} hPa
- Drive without lubricants, guidings without or with vacuum-compatible lubricants
- One controller for all axes, many functionalities

Applications

These compact systems allow sample positioning in up to six axes of motion. With piezo nanopositioning systems, such as P-763 and P-563, highly dynamic scan processes over several hundred micrometers are possible.
The Mini-SpaceFAB SF-450 PS works precisely with nanometer resolution over longer travel ranges of up to several millimeters. Additional tilt and rotational axes serve for aligning the sample in the electron beam or during analysis and processing. High-resolution measurement systems allow highly precise and repeatable positioning.

P-733



P-563

SF-450 PS

(Preliminary data)

	Vacuum compatible to 10^{-9} hPa
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z
Drive type	PIShift piezo inertia drive
Travel range X, Y, Z in mm / θ_X, θ_Y, θ_Z in °	13 × 13 × 10 / 14
Resolution in nm	5
Unidirectional repeatability in nm	25
Max. velocity in mm/s	10
Load capacity in N	10
Dimensions in mm	200 × 200 × 77
Clear aperture in mm	Ø 35
Controller	included in the system
Interfaces / Communication	Ethernet (TCP/IP), RS-232, optional analog inputs

P-763

	Small footprint, highly dynamic
Active axes	X, Y
Drive type	PICMA® multilayer actuator with flexure guide
Travel range in µm	200 × 200
Resolution in nm	2
Unidirectional repeatability in nm	5
Resonant frequency in Hz	180 (load 260 g)
Load capacity in N	10
Dimensions in mm	70 × 70 × 25
Clear aperture in mm	30 × 30
Recommended controller	E-725 digital controller
Interfaces / Communication	Ethernet (TCP/IP), USB, RS-232 analog inputs

P-563

	Vacuum compatible to 10^{-9} hPa
Active axes	X, Y, Z
Drive type	PICMA® multilayer actuator with flexure guide
Travel range in µm	300 × 300 × 300
Resolution in nm	2
Unidirectional repeatability in nm	2
Resonant frequency in Hz	110 (load 330 g)
Load capacity in N	50
Dimensions in mm	150 × 150 × 30
Clear aperture in mm	66 × 66
Recommended controller	E-725 digital controller
Interfaces / Communication	Ethernet (TCP/IP), USB, RS-232, optional analog inputs

Product Portfolio

Nanopositioning Systems, Micropositioning Technology & Nanometrology

Nanopositioning

Resolution Down to Picometers

Nanopositioning systems achieve motion resolutions and positioning accuracy in the nanometer range and below. The target position is achieved within a few milliseconds and stably maintained. Piezo actuators or piezo stepping drives are used as drives. Digital motion controllers optimize the overall system performance. Such positioning systems are required, for example, in optical metrology, microscopy, or in microchip production. To achieve the necessary position resolution and stability, PI manufactures and develops the sensor systems and offers these as independent product line.

- From linear axes to motion in six degrees of freedom
- Parallel-kinematic principle for multi-axis systems
- Versions with direct position measurement
  - Capacitive sensors: Sub-nanometer resolution
  - Incremental sensors: Nanometer resolution, wide measuring ranges
- Available in a variety of designs, travel ranges, and precision classes

Hexapods – Parallel-Kinematic Positioning Systems

High-Precision Positioning in up to Six Axes of Motion

PI uses parallel-kinematic designs wherever multi-axis and high-precision motion is required. All drives act directly on the same moving platform. Precision and dynamics benefit from this, whereas with stacked axes systems, the errors of the individual axes add up and cause dynamic losses because the upper axes are also carried along. The parallel-kinematic principle is independent of the drive used. And so it is possible to produce micropositioning and nanopositioning systems with motion in up to six degrees of freedom.

- Low moving mass, low inertia
- Excellent dynamic behavior, fast step-and-settle
- Small installation space
- High stiffness
- Freely definable pivot point
- Minimized axis crosstalk
- Very good repeatability

PICMA® Piezo Ceramic Multilayer Actuators

Nanopositioning With High Resolution and Reliability

PI uses its own PICMA® piezo ceramic actuators in its high-precision positioning systems for nanopositioning. The actuators' all-ceramic insulation makes them insensitive to humidity and results in excellent reliability and durability. PI manufactures and develops piezo ceramics within the Group, thus allowing them to be flexibly customized.

- Long lifetime, high humidity resistance
- Flexible cross-sections and displacements
- Resolution to below one nanometer
- Response time to below one millisecond

Digital Control Technology

Achieve the Optimum in Performance

The performance characteristics of a precision positioning system depend equally on the stage mechanics and the control. Digital controllers use specially adapted algorithms to treat process values such as sensor signal or position target value. Motions on trajectories, settling times, or trajectory deviations can thus be optimized during fast scanning operations.

- For all drive systems
- High-resolution D/A and A/D converters
- State-of-the-art processors
- Digital real-time interfaces
- Extensive software and drivers
- Information on coordinates for parallel kinematics / Hexapods

Micropositioning

Precision Positioning over Long Travel Ranges

Micropositioning systems provide motion resolution and positioning accuracies in the range between a few tens of micrometers down to 0.1 µm. Brushless DC or stepper motors are available as drives, as are linear drives such as PILine® ultrasonic piezomotors or NEXACT® piezo stepping drives. The precision of the system depends on the components used for drive, position sensor, and guiding. In conventional motors, the quality of the gear, the spindle, or the worm drive also play an essential role. Digital controls with suitable control and linearization methods make it possible to improve the system characteristics.

- Linear positioners
  - –Travel ranges between 5 and 1000 mm
  - –Velocity of up to 150 mm/s
  - – Low-cost designs, variants as modular system
- Motorized micrometer drives
  - –Travel ranges to 50 mm and velocity to 30 mm/s
  - – Resolution to <100 nm
- Rotary stage with unlimited rotation range
  - – to 720 °/s
  - – Resolution to 1 µrad
  - – Optional encoders for direct position measurement

PI Catalog – Finding the Right Solution, Quickly and Reliably

Request Now!

The PI catalog 2013/2014 displays the PI Group's technical expertise in all precision positioning sectors on 270 pages. Here PI presents its wide range of high-performance precision positioning systems: Different drive technologies based on piezo elements as well as electrical and magnetic principles and their integration in positioning systems with up to six axes.

Get important background knowledge: Technical tutorials give you detailed information about the technologies used in the broad and deep product portfolio of PI (Physik Instrumente), PI miCos and PI Ceramic, expert in piezo technology.

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