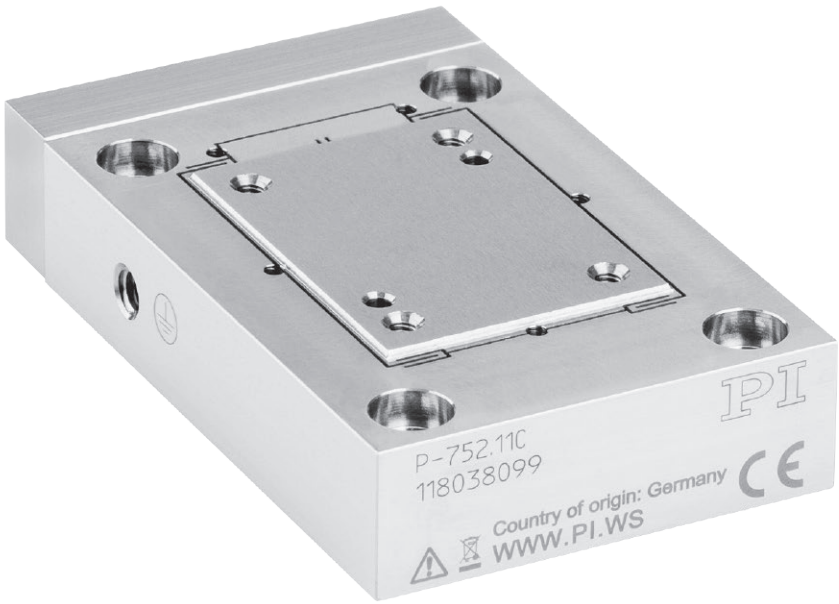
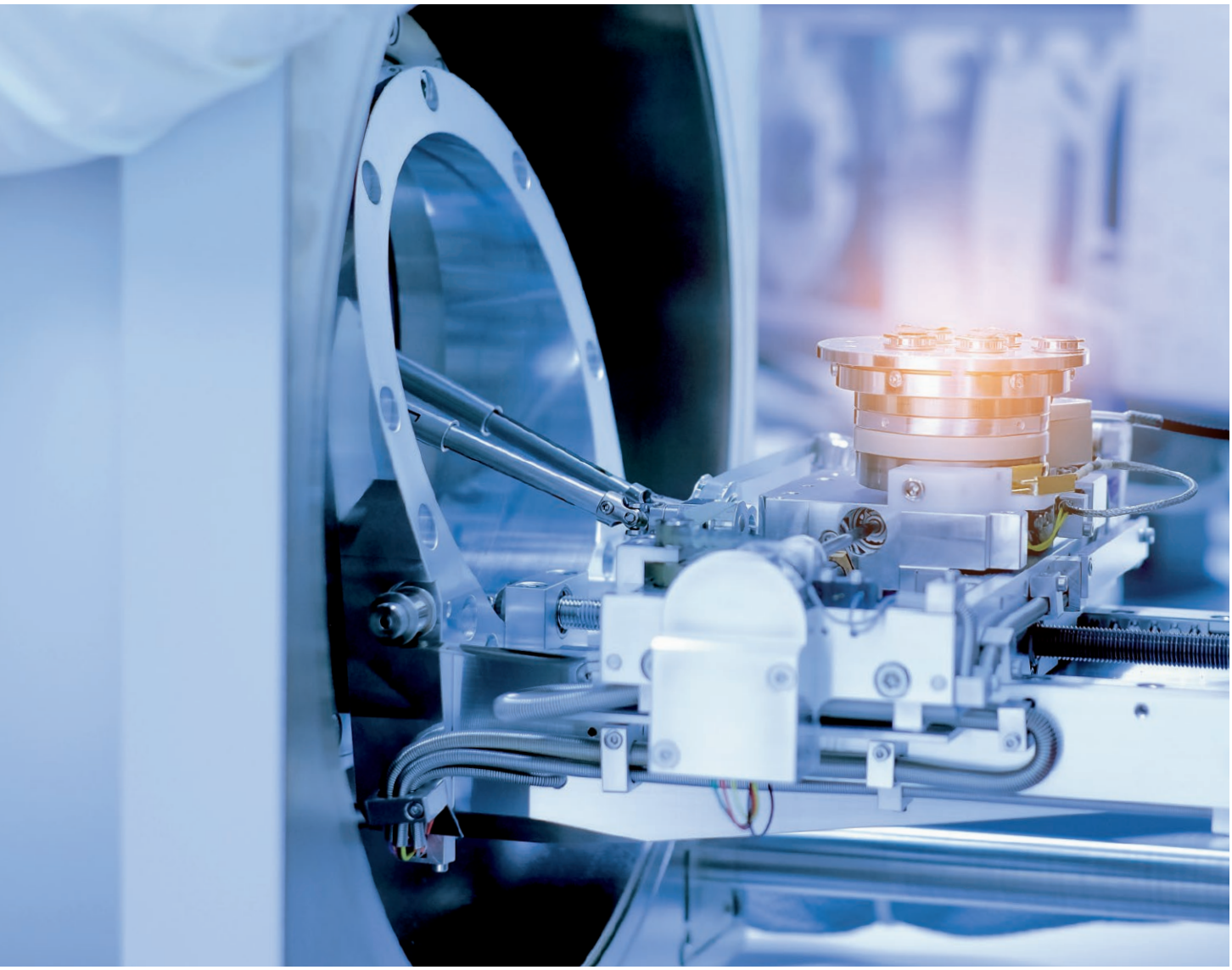


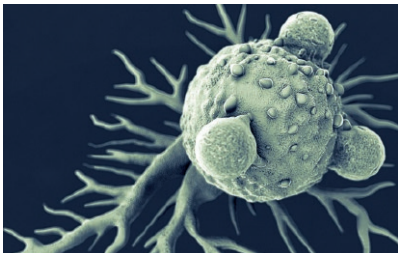
Electron- and Ion Microscopy

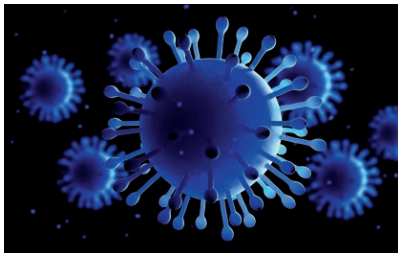
NONMAGNETIC AND VACUUM-COMPATIBLE ACTUATORS
AND POSITIONING SYSTEMS

Particle Beam Microscopy: Much More Than Just High Resolution

Particle beam microscopy, based on negatively charged particles, which means electrons or positively charged particles, ions from so different materials such as helium, neon or gallium, makes examination and manipulation possible into the subnanometer range with extremely high resolutions. Today, processes based on charged particles are used in applications that go far beyond the field of research and even in the industrial environment.







Raster scans for imaging surfaces, analyzing the material composition, crystallographic analyses, creating 3-D models – SEM, TEM and Cryo-TEM are versatile tools that are used in semiconductor technology, materials research and life sciences as well as for a myriad of quality assurance tasks. Systems with integrated ion beam columns are used for preparation processes, such as the creation of TEM lamellas or drilling holes with precisely defined dimensions, for the removal of sample material or for the deposition of materials at a nanoscale. These types of systems are often and quite rightly referred to as “Nanolab”.

All of these procedures and applications place the highest demands on the imaging modules and on the adjustment systems of the individual beam guidance components such as for example, apertures. Positioning the sample also needs to be just as precise. This task is made more difficult in particle beam microscopes, because there is a vacuum or even high vacuum, so the motion modules themselves, the lubricants used in them, and the feed cables must not be allowed to gas out. In addition, the modules must be nonmagnetic in order to avoid affecting the beam path.

The increasingly automated test procedures with SEM and TEM require flexible, reliable drive solutions in order to do scans with high repeatability and stable positioning.

Nonmagnetic and vacuum compatible:
Actuator technology and positioning systems from PI

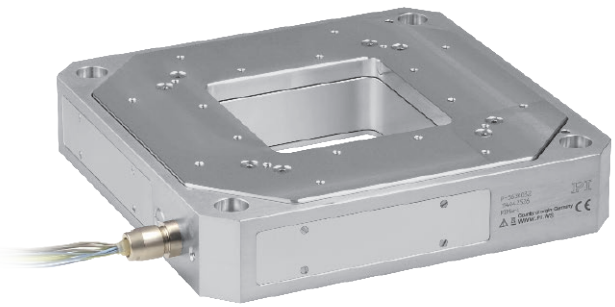
Based on many years of know-how, particularly in piezo technology, PI provides a broad range of drive systems for precisely these requirements. Simple actuators can be integrated for feeding the electron beam, where they are used to correct the beam guidance or to adjust apertures.

Linear and rotation stages are suitable for positioning the sample and can be combined easily to build multi-axis solutions. Parallel-kinematic multi-axis stages are particularly compact and offer positioning in up to six degrees of freedom. Suitable control electronics and controllers are available for all systems and can be integrated seamlessly into existing systems thanks to both their analog and digital interfaces and the extensive software support.

PI offers drives, actuators, and multi-axis positioning systems that require no lubricant and are also vacuum compatible. Drive concepts from PI based on in-house development of piezo technology do not generate any magnetic fields and are not influenced by them.

Customized solutions

The products shown here represent only a small selection of all positioning solutions available from PI. Specialized applications often require specific properties that need to be adapted and examples of these are travel ranges, mechanical coupling, and dimensions. We would be very happy to collaborate with you to develop a solution for your positioning task. Take our word for it!

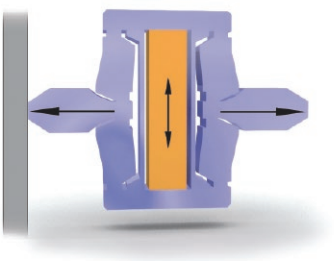


Piezo technology – the basis for several drive types

Piezo technology developed and manufactured exclusively by PI Ceramic, a PI subsidiary, forms the basis for several drive types that are ideally suited for use in particle beam microscopy. PICMA® piezoceramic multilayer actuators are the starting point for piezo drives. Basically, piezo actuators are vacuum compatible to 10^{-11} hPa and do not generate magnetic interference. The motion of these extremely compact piezo actuators is based on solid-state effects, and in principle, this makes their resolution unlimited. Their very high stiffness enables high force generation and dynamics with response times in the microsecond range. Flexible cross sections and displacements allow them to be adapted according to the application. Thanks to the all-ceramic insulation, actuators have a longer lifetime.

Excellent Guiding Accuracy Through Flexure Joints

The travel range of a piezo actuator can also be multiplied by integrating a lever mechanism. The actuator is mechanically integrated in a flexure joint in such a way that the travel range is extended to up to 2 mm. The motion of a flexure joint is based on the elastic deformation of a solid. This avoids any static, rolling or sliding friction. Their advantages are the high stiffness, load capacity, and wear resistance. Flexures are maintenance-free, can be manufactured from nonmagnetic materials, do not require lubricants or consumables and hence also function, without any problem, in a vacuum.



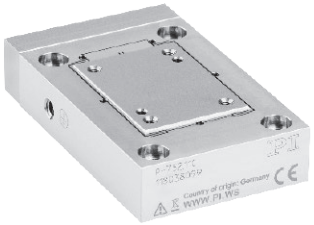
Positioners based on Piezo Actuators

PI offers a wide range of products that have been developed on the basis of piezo actuators. Piezo actuators do not require lubricants or cause abrasion. The PICMA® all-ceramic isolated actuators do not require polymer insulation and are therefore ideal for UHV applications. Their motion is based on crystalline solid state effects and is therefore wear-free. The piezo effect is based on electric fields, so piezo actuators neither generate nor are they affected by magnetic fields. The piezo effect exists even at lowest temperatures up to close to 0 Kelvin.

S-330 Piezo Tip/Tilt Platform

The S-330 PiezoTip/Tilt platform finds numerous applications in optical systems. The travel range of the piezo actuators in the S-330 tilting platform is multiplied by the integration of flexure guides.

- Resolution to 20 nrad
- Sub-ms response time
- Excellent position stability
- Parallel kinematics for higher accuracy and dynamics and full bridge strain gauge sensors

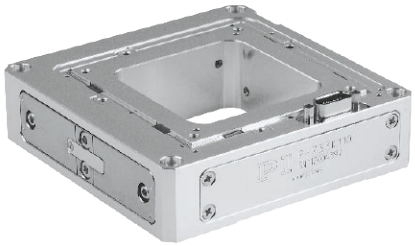


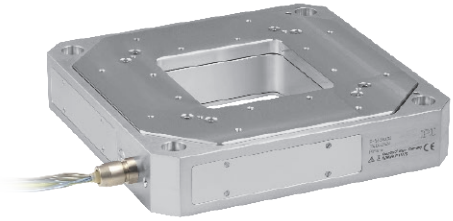
P-752 High-Precision Nanopositioning Stage

- Highest linearity due to capacitive sensors
- Resolution 0.1 nm
- Repeatability: ±1 nm
- Travel range to 35 µm
- Friction-free flexure guides for very high travel accuracy

P-733.3 XYZ Piezo Nanopositioner

- Travel ranges to 100 µm × 100 µm in X, Y and to 10 µm in Z
- Ultrahigh vacuum-compatible and nonmagnetic versions
- Zero-play, high-precision flexure guide system
- Parallel kinematics for higher accuracy and dynamics



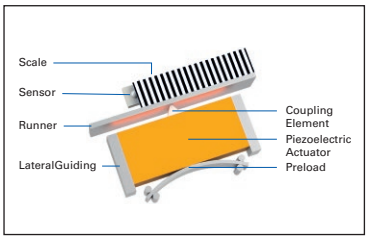


P- 563 PIMars Nanopositioning Stage

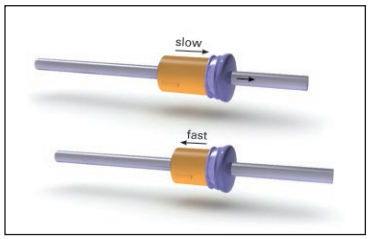
- Highest linearity due to capacitive sensors
- Repeatability in X/Y/Z: 2/2/2 nm
- Travel range to 300 × 300 × 300 µm
- UHV versions to 10^{-9} hPa
- Zero-play, high-precision flexure guide system

Piezomotor Technologies in Detail

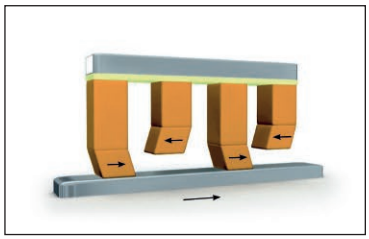
	PILine® Ultrasonic Piezomotor	**Piezo Inertia Drive**	**PiezoWalk® Piezo Stepping Drive**
	Sub-micrometer resolution	Sub-nanometer resolution	Sub-nanometer resolution
	Very high operating frequency Noiseless drive High velocity of up to several 100 mm/s	Very high operating frequency Noiseless drive Velocity of more than 10 mm/s	Velocity up to 10 mm/s High-dynamics scan mode
	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
	Forces up to 40 N Self-locking at rest	Forces up to 10 N Self-locking at rest	Very high forces of up to 800 N (NEXLINE®) Self-locking at rest
	Ideal for:		
	▪ 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	▪ 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



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.



Inertia 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, these drives reach a continuous feed at velocities of more than 10 mm/s.

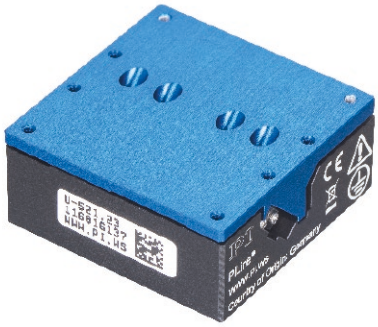


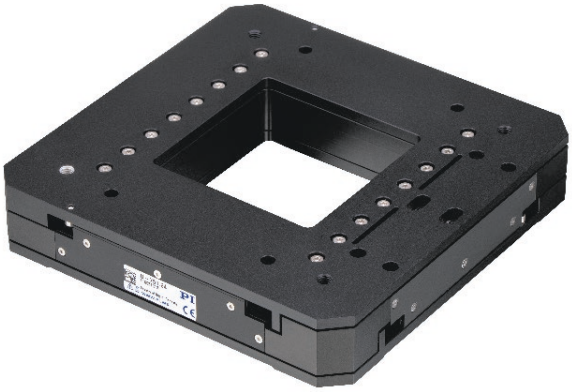
In PiezoWalk® drives such as NEXACT®, NEXLINE® and PICMAWalk, piezo actuators work in pairs as clamping and feed elements on a moving runner. Cyclical control induces a stepping motion of the actuators on the runner, and the runner is moved forwards and backwards. NEXACT® offers nanometer resolution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

PILine® Ultrasonic Piezomotors – Compact Drives, Fast and Self-Locking

U-521.24V PILine® Linear Stage

- Travel range to 18 mm
- Bidirectional repeatability ±0,2 µm
- Velocity: 200 mm/s
- Vacuumversion (to 10^{-6} hPa) available



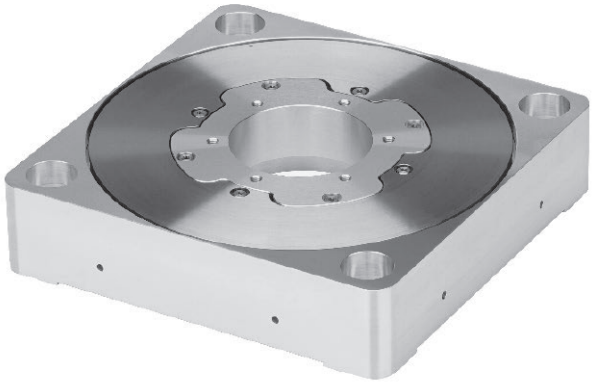


U-751.24V PILine® XY Stage

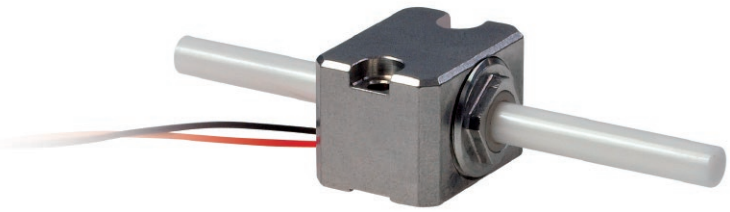
- Travel range: 25 x 25 mm
- Bidirectional repeatability: ±0,3 µm
- Velocity: 100 mm/s
- Non-magnetic vacuumversion (to 10^{-6} hPa) on request

U-653 PILine® Rotation Stage

- Rotation range: 360°
- Bidirectional repeatability: ±54 µrad
- Velocity: 360°/s
- Non-magnetic vacuumversion (to 10^{-6} hPa)



Space-saving and inexpensive drives based on the inertia effect



N-422 Linear Actuator with Piezo Motor

- Travel range: 35 mm
- Push/pull force (active): 7 N / Holding force (passive): to 10 N
- Resolution depends on the sensor / drive: sub nm
- Velocity: to 5 mm/s
- Vacuum-/cleanroom compatible (to 10^{-7} hPa) and non-magnetic

Q-545 Q-Motion® Precision Linear Stage

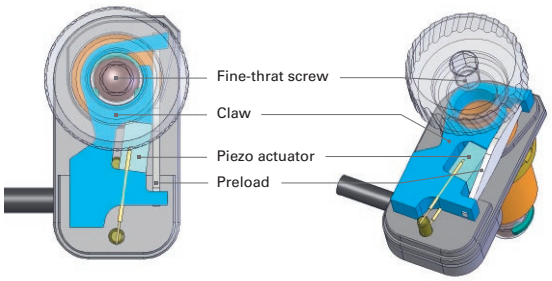
- Travel range 13 / 26 mm (depending on version)
- Drive force: 7 N
- Maximum load capacity: 0.5 kg (horizontal) / 0,1 kg (any axis)
- Bidirectional repeatability (depending on version): 100 / 200 nm
- Velocity to 8 mm/s
- Vacuum version (to 10^{-9} hPa): on request

N-470.V / N-470.U PiezoMike Linear Actuator

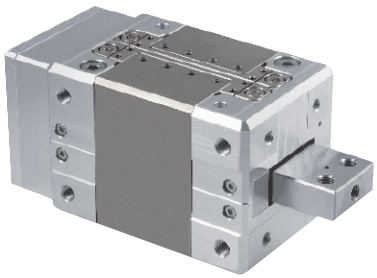
- Travel range 7.5 mm to 26 mm, step size 20 nm (typ.)
- Feed force (active) 22 N / Holding force (passive) >100 N
- self-locking at rest, requires no current, and does not generate any heat
- Lifetime >1.000.000.000 steps
- Non-magnetic, vacuum compatible to 10^{-6} hPa (version V) to 10^{-9} hPa (version U)

Drive Principle of the PiezoMike

The piezo actuators expands slowly when an electric voltage is applied. This expansion leads to a rotation of the claw. Since the claw grasps around the screw, the claw turns the screw when it rotates (stick effect). Once the piezo actuator has attained its maximum expansion, it quickly contracts and the claw returns to its initial position. With the fast contraction, the claw slips around the screw. The screw, however, stays in its initial position (slip effect) due to its inertial mass. This stick-slip cycle can be repeated any time to achieve the desired feed forward of the screw's tip by turning the screw. Of course, the motion also works in the other direction.



Nanometer Precision and a High Feed Force with PiezoWalk® Walking Drives

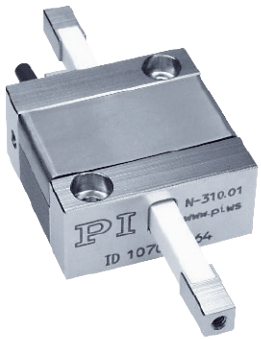


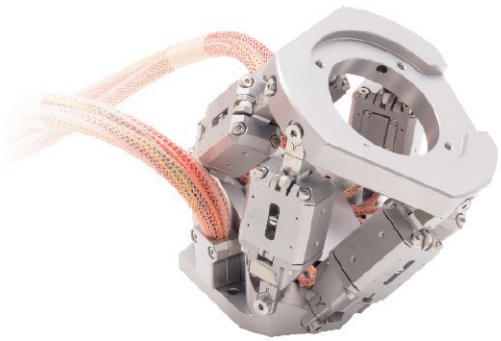
N-216 NEXLINE® Linear Actuator

- Travel range to 20 mm
- Force generation to 600 N / Holding Force to 800 N
- Resolution: 0.03 nm (open loop) / –5 nm (closed loop)
- Velocity to 1 mm/s
- Suitable for cleanrooms and under vacuum conditions / non-magnetic

N-310 NEXACT® OEM Miniature Linear Motor / Actuator

- Travel range 10 to 125 mm, variable runner lengths
- Feed force: to 10 N / Holding force: to 12 N
- Resolution: 0.03 nm (open loop) / –5 nm (closed loop)
- Velocity: to 10 mm/s
- Suitable for cleanrooms and under vacuum conditions / non-magnetic





P-911 UHV-Compatible Miniature Piezo Hexapod

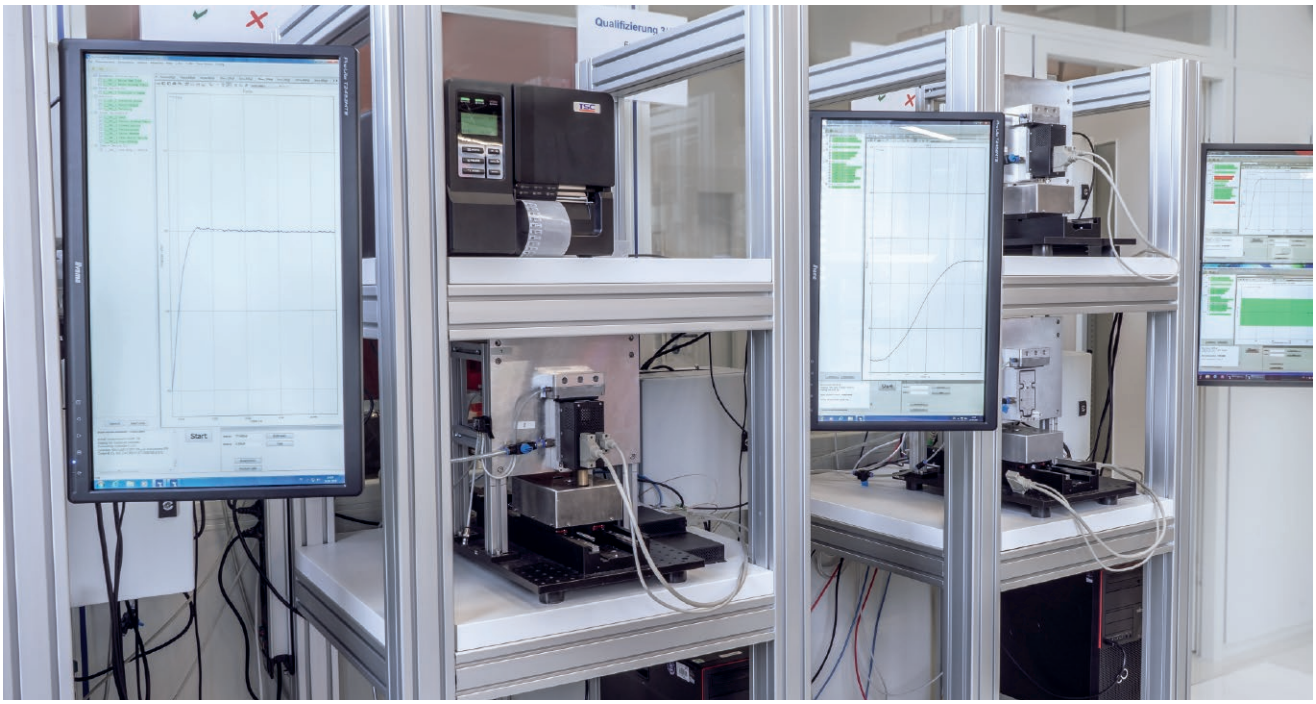
The space-saving parallel-kinematic design allows for the low overall height of less than 90 mm and a diameter of only 100 mm. NEXLINE® piezo stepping motor drives and integrated incremental sensors ensure a position resolution down to 0.1 µm in the linear axes.

- UHV-compatible to 10^{-9} hPa
- Non-magnetic
- With NEXLINE® piezo stepping drives
- Ultra-high precision flexure joints

N-331 PICMAWalk Walking Drive

- Travel range 10 to 100 mm, variable runner lengths
- Push/pull force (active) to 50 N / Holding force (passive) to 60 N
- Resolution: 0.02 nm (open loop) / <10 nm (closed loop)
- Velocity: to 15 mm/s
- Suitable for cleanrooms and under vacuum conditions / non-magnetic

From 1-off to Series:
OEM Customers Benefit From Maximum Flexibility



Standardized performance control with full documentation of individual measurement charts

PI serves both the research and industrial markets. The complete control over the design and manufacturing process provides our customers with significant competitive advantages. Optimized processes allow PI to deliver customized products in quantities up to several 100,000 units per year at low cost and right on time. The range of OEM products offered by the PI Group varies widely, ranging from “bare” actuators and sensors to highly integrated parallel-kinematic positioning systems. Evaluation of pre-production run samples, test procedures, production processes and quality management are all included in the development process.

Services

- Global account management: Close proximity to the customer thanks to international presence
- Risk assessment from design to delivery
- Depending on the task: From the drive to the turnkey system
- Copy exactly policy
- Preparation of internal and external certification
- Production of series of several 10,000 units in the shortest time
- Sustainable spare parts service
- Manufacturing and testing capacities from functional samples to mass production

Support Services – Extended Warranty – PI Express Service

PI is dedicated to supporting its customers right from the initial consultation through to when a customer has purchased a PI system. Beyond that, PI's services division is committed to ensuring that every aspect of owning a PI system is catered for. Supported by four Global Service Hubs in Asia, China, Europe and USA, with field product specialists working from these hubs, PI is able to support all technologies and customer applications via this global services team. PI has different service types in addition to the standard service offered today. The services are described below and can be tailored to each customer's specific needs.

	Standard Support	Extended Warranty	Extended Warranty PLUS	PI Express	PI Express PLUS
24 Months Warranty (Parts and Labour cover for manufacturing defects)	✓	✓	✓	✓	✓
Access to PI's Service Support Desk (TRT = Target Response Time) Standard Working Hours 8:00 –16:00	Regional Support For 2 Years TRT <12 working hours	Regional Support For up to 5 Years TRT <12 working hours	Regional Support For 3 Years TRT <12 working hours	Regional Support For up to 5 Years TRT <4 working hours	Regional Support For up to 5 Years TRT <4 working hours
Extended Warranty (Parts and Labour costs covered for manufacturing defects – 1, 2 or 3 additional years)		✓	✓	Optional	Optional
Extended Warranty PLUS (Extended warranty, plus cover for replacement parts that fail due to normal Wear and Tear.*)			✓	Optional	Optional
Extended Hours Support (Access to PI's Global Support team providing ad hoc planned out of hours support services)				✓	✓
Highest Priority Remote & On-Site Support**				✓	✓
Spares Holding (Dedicated holding of spare parts/ systems to minimise unscheduled downtime)					✓

Standard Support

This is the service level that all customers receive today. PI will respond to any customer's support request whether inside or outside of a valid warranty period. PI's remote support service is free of charge and while products are under warranty, customers benefit from a 12 working hour target response time, from the initial customer contact.

Extended Warranty

PI's Extended Warranty delivers wrap around protection for customers with the option to extend the product warranty cover period for up to 5 years. Extended Warranty can provide cost protection from any latent defects, service level response times for support enquiries and priority service for warranty repairs and fault analysis.

PI Express Service

PI's express subscription is the highest priority support service. If a customer experiences a product failure, PI will provide express remote support, express on-site response if required and can also ship out a dedicated spare system, to get the customer operational again as quickly as possible.

>> More information about PI services at www.pi.ws/service

* A normal wear and tear failure is defined as damaged that has been caused due to ordinary use. Wear and tear failures that are excluded for non-ordinary use might be where the system has been exposed to radiation; liquid or third party abrasive particles have entered the mechanics; the application or operation is beyond the stated capacity of the system (orientation, load, travel limits, environment); or where user error or an external force has been applied that caused the failure. Maximum 2 claims over the 3 year term.

** All on-site services are chargeable in advance at the on-site rate depending on customer location.

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