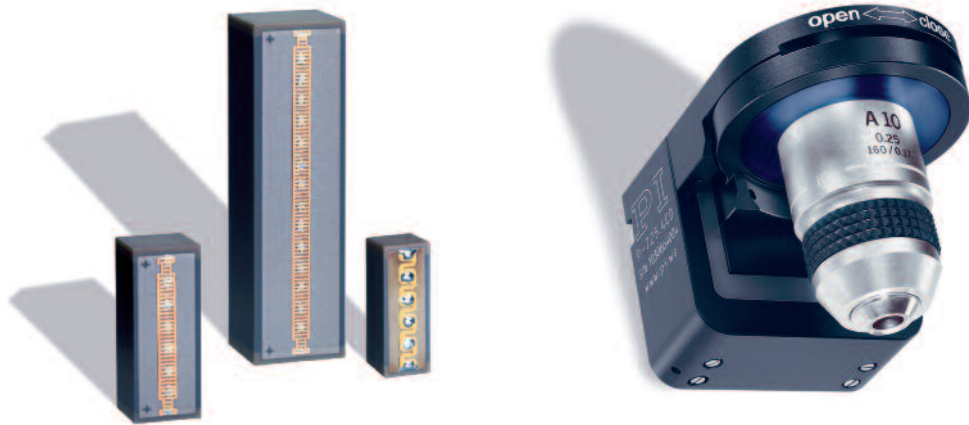


Piezo Nano Positioning

Product Overview



Moving the Nanoworld

NanoAutomation®: Precision Positioning for Science and Industry

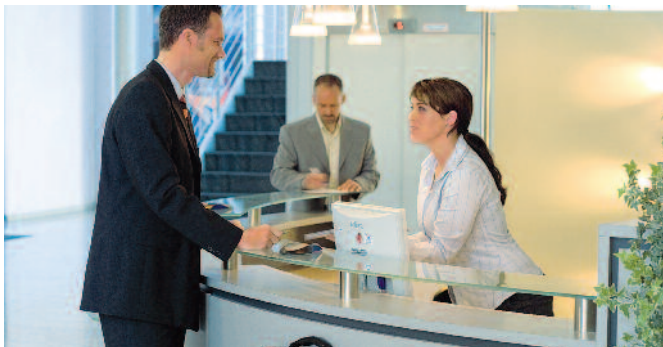


PI headquarters in Karlsruhe

Future Technology Solutions

Today PI delivers micro- and nanopositioning solutions for all important high-tech markets:

- Semiconductor Technology
- Optical Metrology, Microscopy
- Biotechnology and Medical Devices
- Precision Automation and Handling
- Precision Machining
- Data Storage
- Photonics, Fiber Optics, Telecom
- Nano Technology
- Microsystems Technology
- Aerospace Engineering
- Astronomy



PI reception desk:

Our employees look forward to your visit

PI is the market and technology leader for precision positioning systems with accuracies well under one nanometer. Nanometer-range motion control is the key to worlds where millions of transistors fit on one square millimeter, where molecules are manipulated, where thousands of “virtual slices” are made in the observation of living cells, or where optical fiber bundles no larger than a human hair are aligned in six degrees of freedom.

Worlds We Call NanoWorlds

Continuous innovation and reinvestment of profits over the decades has allowed PI to attain its present market status. This status is also based on long-term customer relationships and on the freedom to transform ideas into reality.

Over 30 Years Experience

When PI introduced piezoelectric nanopositioning technology more than 30 years ago, typical customers were research labs and universities working on laser cavity tuning, Fabry-Perot interferometers and filters. Few foresaw that whole industrial sectors like semiconductor manufacturing or biotechnology would become dependent on progress in nanopositioning. Today, not even the precision machining industry can do without nanometer-level positioning systems.

Key Technologies In-House

PI follows a vertical integration strategy designed to develop and maintain all key technologies in-house. We supervise each and every step from design to delivery in the following areas: software, precision mechanics, digital and analog control electronics, sub-nanometer capacitive position sensors, piezo ceramics and piezo actuators. This assures the highest quality and reduces cost.

The PI Group

High Quality and Strong Brands on a Global Scale

PI—World Market Player

As a privately run company with a healthy growth rate, over 500 employees and a flexible, vertically integrated organization, PI can meet the most diverse requirements in the area of innovative precision positioning and supply customers anywhere in the world with outstanding products.

International Service and Sales Network

PI has established subsidiaries for sales and service in the most important local markets all over the world and maintains nanometrology test labs on three continents. In addition to PI's main R&D and manufacturing centers in Europe, PI Shanghai and PI USA provide development and manufacturing capabilities to meet the specific demands of local markets faster. In addition to the branch offices, PI has distributors in many other industrial countries. A network of highly qualified personnel around the world assures successful, long-term relationships with customers.

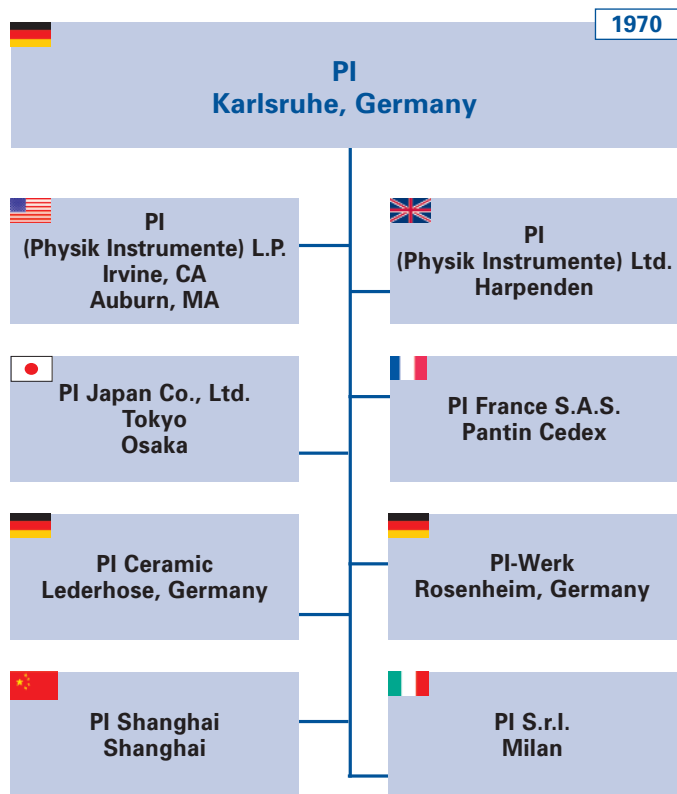
Quality and Brand Policy

We measure the quality and reliability of our products against the strictest of standards. ISO 9001 certification, which also emphasizes points like customer expectations and satisfaction, has been accorded in 1994, making PI the first manufacturer of nanopositioning technology following this standard. PI's Integrated Management System (IMS) includes also Environmental Protection and Job Safety (according to ISO 14001:2004 and OHSAS 18001:1999). This system assures legal conformity of all procedures as well as continuous optimization of the processes at all PI locations.

PI brands and colors are well known throughout the high-tech world. PIFOC® is almost used as a synonym for objective positioners in general and PICMA® stands for the highest reliability in piezo actuator products. PI stands for quality and precision – worldwide.



PI Ceramic—a PI Subsidiary—is a world-class supplier of high-performance piezoelectric actuator and transducer components and subassemblies.



PI USA

Nanopositioning, Piezo Systems, Beam Steering

Controlling Motion to better than 1 Nanometer in up to 6 axes

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; capacitive position sensors provide optimum positioning resolution. Digital motion controllers optimize the performance of the system. Positioning systems in this precision class are used commercially in microscopy and optical metrology, and also in the manufacture of microchips. PI offers the broadest spectrum of drives and systems for nanopositioning worldwide.



Nanopositioning Systems

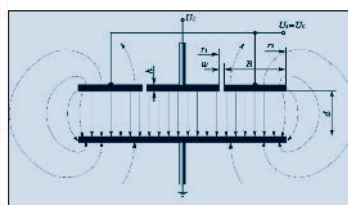
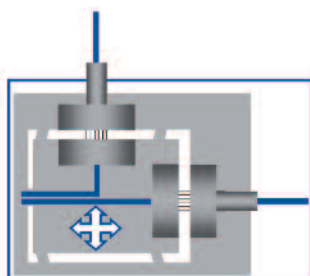
Precision for up to 6 axes

- From linear axes to motion with 6 degrees of freedom
- Parallel kinematics principle for multi-axis systems
- Versions with direct position measurement and capacitive sensors
- Travel ranges between 5 and 1800 μm
- Available in a variety of designs, travel ranges and precision classes

Precision Tip / Tilt Mirrors and Beam Steering Systems

High-Dynamic Beam Deflection / Stabilization

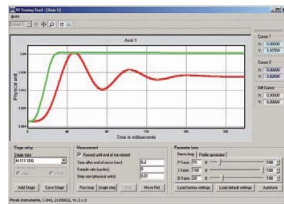
- Optical deviation angle to $>6^\circ$
- Resonant frequency to $>2\text{ kHz}$
- Parallel kinematics for improved dynamics
- PICMA[®] actuators for long lifetime
- Motion resolution $<1\ \mu\text{rad}$



Integrated Direct Metrology

Measure the Position Where it Counts

- Capacitive sensors: Sub-nanometer resolution
- Incremental sensors: Nanometer resolution, wide measurement ranges
- No position errors caused by indirect measurement in the drivetrain
- No position errors caused by hysteresis and play



Digital Piezo Nanopositioning Controllers Gain the Optimum in Performance

- For all drive systems
- High resolution D/A and A/D converters, state of the art processor technology
- Data processing in real time
- Comprehensive software and drivers

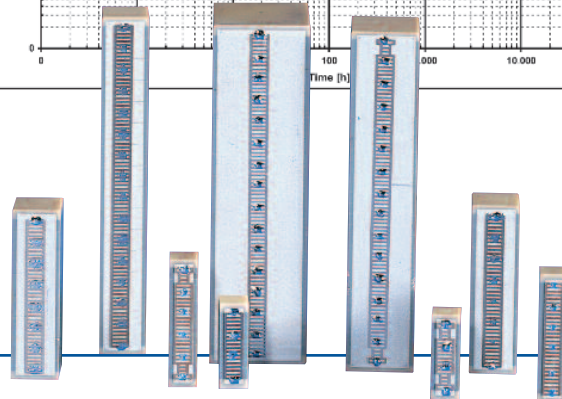
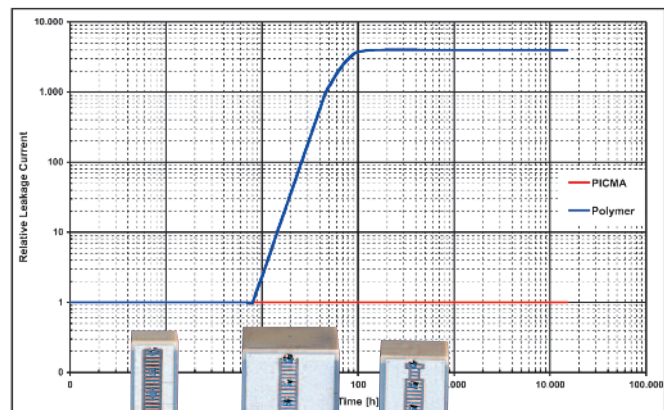
The performance characteristics of a precision positioning system depend equally on the stage mechanics and the control. Digital controllers use specially adapted algorithms to process process values such as sensor signal or position target value. Motions on trajectories, settling times or trajectory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

Nanopositioning Engines: PICMA® Piezoceramic Multilayer Actuators

Higher Reliability and Performance

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

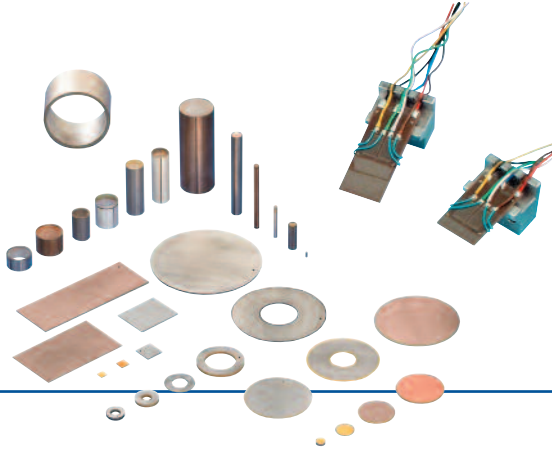
PI uses its own PICMA® piezoceramic actuators in its classical positioning systems for nanopositioning. This in-house development incorporates a special insulation which increases the lifetime especially at static displacements. PI piezo actuators can be flexibly matched to customer specifications because they are produced in-house.



Piezoelectric Ceramics

In-House Development and Production: Flexibility for Specific Adaptations

For nanopositioning, ultrasonic motors or stepping drives: The centerpiece of the motion is the piezoceramic actuator. PI Ceramic, a subsidiary of PI, has specialized in the development and production of piezoceramics and can manufacture individual prototypes and also high-volume series.



Piezoceramic Components and Stack Actuators

- Versatile geometries and lengths or travel ranges
- Linear and shear actuators
- Tubes, discs or benders
- Stack actuators: Diameters to 35 mm (standard; more on request)
- Stack actuators: Travel ranges to 180 μm (standard; more on request)
- High resonant frequencies for fast response times
- For high loads up to 4 tons

Cased Actuators / Guided Actuators

For Improved Protection and Longer Lifetime

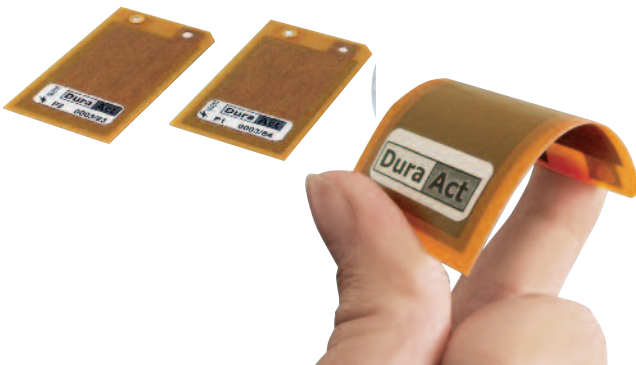
- Easy to integrate into all motion systems
- Versatile geometries and lengths or travel ranges
- With position sensors as an optional extra
- Hermetically sealed versions
- Versions with protective air connection
- Guided actuators with leverage for travel ranges to 400 μm
- High resonant frequencies for fast response times
- For high loads up to 4 tons



DuraAct™ Patch Transducer

Versatile Piezo Elements for Adaptronics

- Laminated piezoceramics for mechanical flexibility
- Can be produced flexibly in different shapes and dimensions
- Can be used as composite or applied onto the structure
- Can be used as an actuator for active vibration compensation
- Can be used as a sensor for structural health monitoring
- Can be used for energy harvesting; to transform oscillation and deformation into electrical energy



PiezoWalk® Stepping Drives

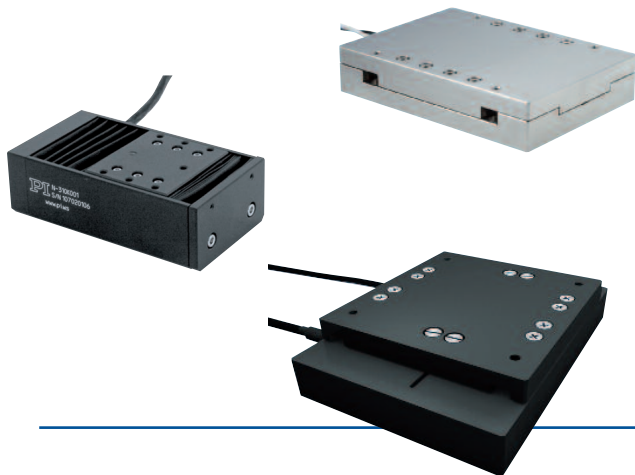
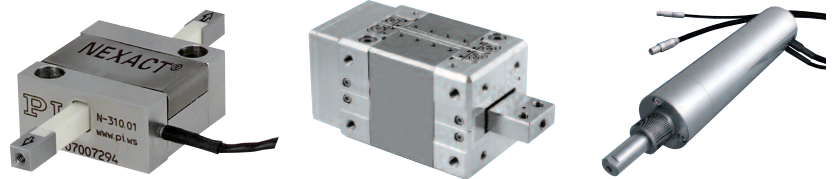
Precise Positioning over Several Millimeters

Piezo stepping drives transfer the advantages of conventional piezo actuators to applications with larger travel ranges. The interplay of the motion of individual actuators brings about a walk motion with high resolution and dynamics within a single step and thus, in principle, allows unlimited travel ranges. The actuators are prestressed against the moving slider. The drive is therefore self-locking by at least the drive force when switched off without holding currents or additional mechanical components. There is therefore no heat dissipation by holding currents and no control dither, the drive maintains a stable position.

PiezoWalk® Linear Drive

High Resolution over Long Travel

- NEXLINE®: Up to 600 N drive force
- NEXACT®: 10 N force and 10 mm/s speed
- Versions with linear encoder to 5 nm resolution
- Self-locking when switched off
- Travel ranges between 10 and 125 mm



Precision Stages with Long Travel Ranges

With NEXACT® Stepping Drives

- Travel ranges to 30 mm
- Resolution <1 nm open loop
- Linear encoder with 20 nm resolution (closed loop)
- 10 N drive force
- 10 mm/s speed
- Highly dynamic operation: >100 Hz over 5 µm

High load Nanopositioning Systems With NEXLINE® Stepping Drives

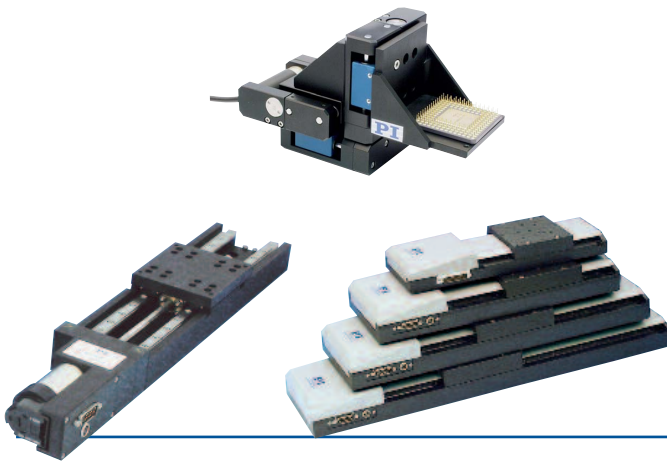
- For high loads and nanometer precision
- Linear encoders with up to 5 nm resolution
- Parallel kinematics
- For chip manufacturing and inspection systems



Micropositioning Stages and Actuators

Precision Positioning over Long Travel

Micropositioning systems provide motion resolution and positioning accuracies in the range between a few tens of micrometers and $0.1 \mu\text{m}$. Conventional DC or stepper motors are available as drives, as well as linear drives such as PLine® piezo ultrasonic motors or NEXACT® piezo stepping drives. The precision of the system depends both on the drive and also on components such as the position sensor, the guides and, for conventional motors, also on the quality of the spindle or the worm drive and possibly also the gear. Digital controls with suitable regulation and linearization methods make it possible to improve the system characteristics.



Linear Positioners

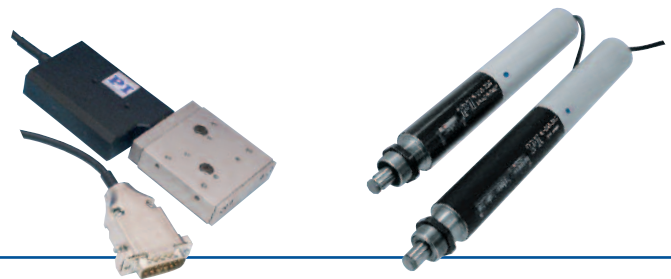
Solutions for All Fields of Application

- Travel ranges between 5 and 300 mm
- Compact stages to high load positioners
- Speed to 150 mm/s
- Incremental encoders for direct position measurement as an optional extra
- Conventional drive versions with DC and stepper motors
- Systems with piezo linear motors for high speed and compact size
- Low-cost designs, variants as modular system

DC and Stepper Micrometer Drives

Low-Cost Precision

- Flexible designs with non-rotating drive tip
- High-load versions to 400 N
- Travel ranges to 50 mm and speed to 30 mm/s
- Resolution to $<100 \text{ nm}$



Rotation Stages

Large Selection for a Broad Spectrum of Applications

- Unlimited rotation range
- Reference and optional limit switches
- Velocity to $720^\circ/\text{s}$
- Resolution to $1 \mu\text{rad}$
- Incremental encoders for direct position measurement as an optional extra
- Conventional drive versions with DC and stepper motors
- Systems with piezo motors for high speed and compact size

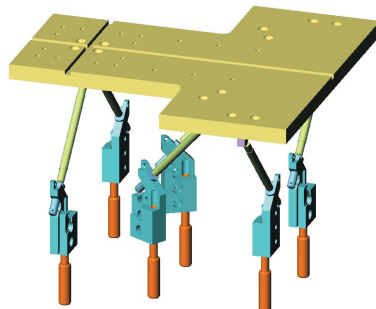
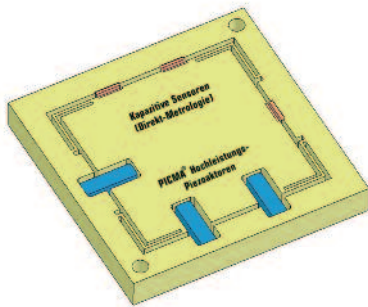
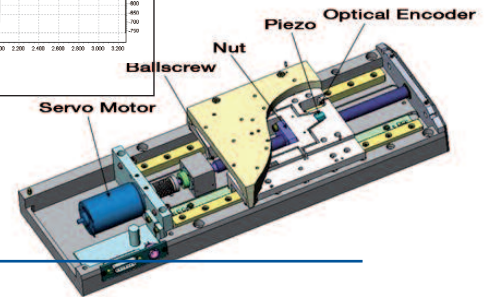
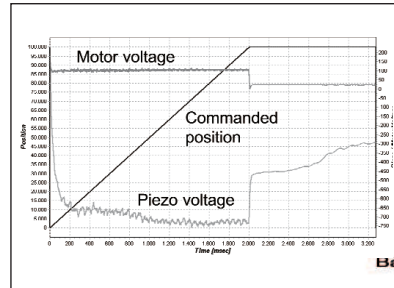
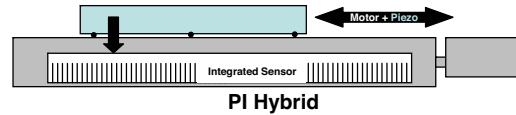
Advanced Drive Concepts

Hybrid Drive Systems

Piezo & Servo Motors Team Up

- Long travel ranges and speeds to 50 mm/s
- Resolution to 2 nm closed loop
- Shortest incremental motion below 10 nm
- Digital controller with sophisticated regulation

The hybrid PI systems have conventional motorized drive solutions coupled to piezoceramic actuators. A control to regulate both drives with high-resolution sensor provides high trajectory fidelity, immediate startup and fast, precise settling.



Parallel Kinematics

Precision and Dynamics for Several Axes

- Higher dynamics in all axes
- Compact designs
- No cumulation of errors

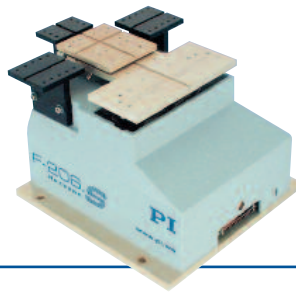
Independent of the drive: Piezo actuators, piezo stepping drives, conventional motors...

PI uses parallel kinematics designs wherever multi-axis and high-precision motion is required. All drives here act directly on the same platform to be moved. This creates advantages in the precision and dynamics compared to stacked axes, where the errors of the individual axes are cumulative and dynamic losses are caused because the upper axes are also dragged along.

Hexapods, Tripods – Parallel Kinematics

Efficient Implementation of Multi-Axis Motion

PI uses parallel kinematics designs wherever multi-axis and high-precision motion is required. All drives here act directly on the same platform to be moved. This creates advantages in the precision and dynamics compared to stacked axes, where the errors of the individual axes are cumulative and dynamic losses are caused because the upper axes are also dragged along. The parallel kinematics principle is independent of the drive used. It is thus possible to produce micropositioning and nanopositioning systems with motion with up to six degrees of freedom.

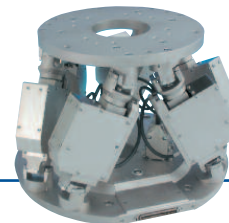


Compact Hexapods

- Linear travel ranges to 20 mm
- Rotation ranges to 60°
- Actuator resolution to 33 nm
- Loads up to 50 N
- DC motors and brushless DC motors

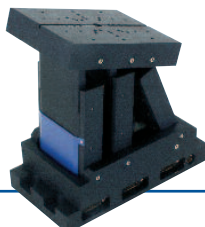
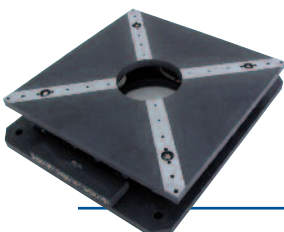
Hexapods for High Precision and High Loads

- Linear travel ranges to 100 mm
- Rotation ranges to 60°
- Actuator resolution to 5 nm
- Speeds to 50 mm/s
- DC motors, brushless DC motors and piezo linear drives
- Loads to 10,000 N



Parallel Kinematics with Different Motion Axes

- Tripod with X, Z and θ_y : Travel ranges to 50 mm and 60°
- Tripods with X, Y and θ_z : Travel ranges to 20 mm and 8°
- Loads to 2,000 N
- Actuator resolution to 5 nm
- DC motors and piezo linear drives



PILine® Piezo Ultrasonic Motors

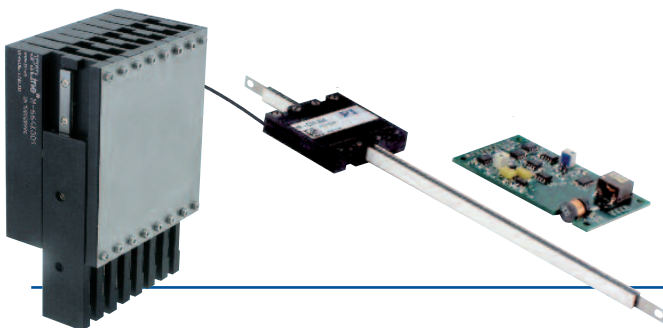
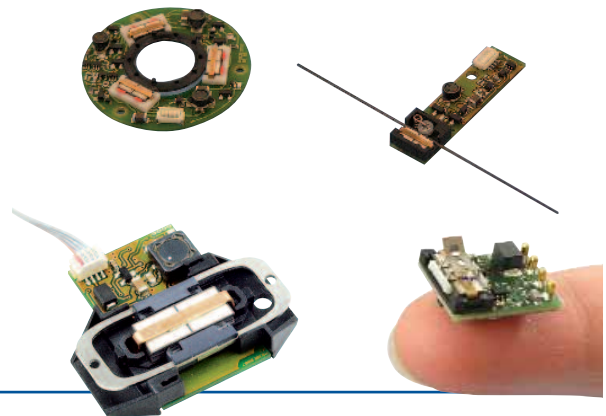
Small and Fast over Long Distances

Piezo ultrasonic motors can replace conventional motor/spindle combinations or magnetic linear drives. PILine® drives have a very small form factor, generate high forces and are self-locking when switched off. PI uses ultrasonic motors in micropositioning for minute stages and systems where the space occupied is a limiting factor. PILine® ultrasonic motors can achieve speeds up to 0.5 m/s and forces up to several tens of newtons. PI supplies miniaturized versions, OEM motors and drives, and also complete positioning systems with controller.

PILine® Miniature Stages and Motors

OEM Drives for High-Volume Application

- Dimensions incl. driver electronics: 15 x 11 x 8 mm
- Travel ranges to 2 mm, rotational motion or rod drives
- Speed to 100 mm/s
- Low-cost design for mass production



PILine® Manipulator and Linear Actuator

For Bio-Handling and Automation

- Low profile height of 9 mm
- Low-cost design
- Travel ranges to 150 mm
- PILine® ultrasonic motors

Linear Stage Drives with PILine®

Fast and Compact

- Speed to 400 mm/s
- Direct position measurement with linear encoder
- Dimensions from 35 x 35 x 15 mm
- Self-locking when powered down



Motion Controllers

From OEM Amplifiers to Digital Multi-Axis Control

Precision positioning in the nanometer range or complex drive technologies require a control technology which is matched to the characteristics of the system. PI uses its own in-house developments, low-noise amplifiers or stable sensor evaluation, for example. In addition, PI exploits the digital technology to optimize the system performance even further.



Piezo Controller for Nanopositioning High Resolution and Fast Response

- For 1-6 axes
- Analog or digital systems
- Analog, USB, TCP/IP and digital real-time interface (some optional)
- Sophisticated algorithms for linearization and regulation
- Comprehensive software support, software drivers for D/A boards
- Low-cost OEM versions

Hexapod-Controllers

Convenient Control of Parallel Kinematics

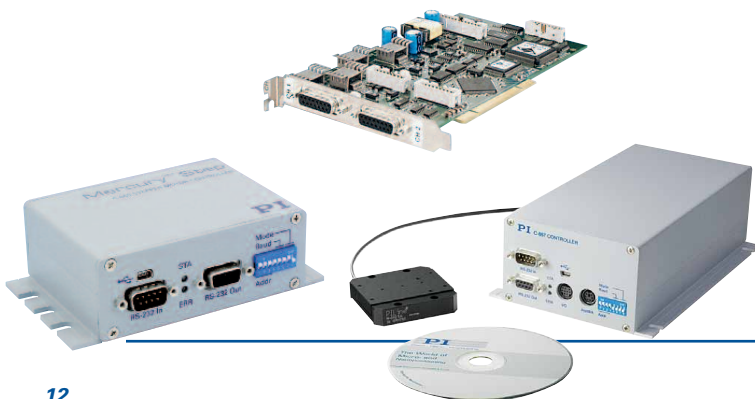
- Independent of the drive
- Places commands in Cartesian coordinates
- Real-time operating system
- Analog, USB, TCP/IP and RS-232 interface
- Comprehensive software support and simulation programs

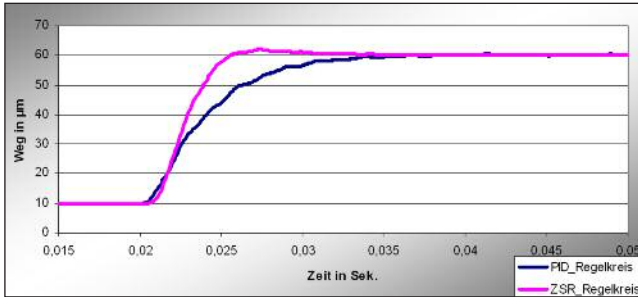


Motor Controllers

For Conventional Drives and Piezo Motors

- 1 to 20 axes
- Analog, USB and RS-232 interfaces (some optional)
- Sophisticated algorithms for linearization and regulation
- Comprehensive software support, software drivers for D/A boards
- Low-cost OEM versions and PC boards



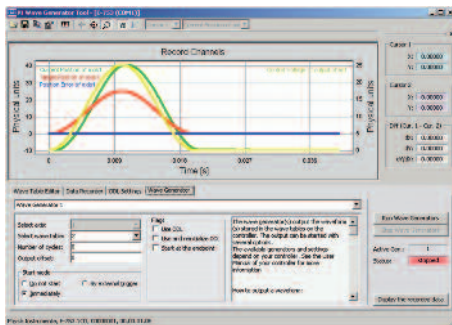
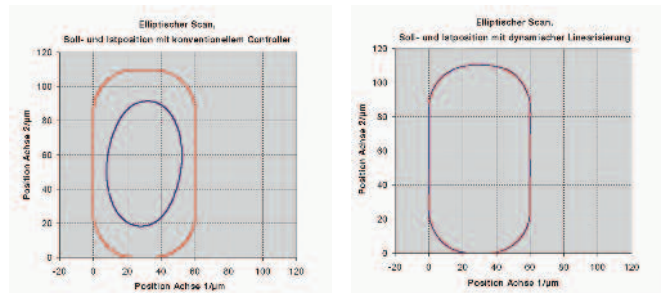


Control Concepts Advanced Piezo Control

- An alternative to conventional PID control
- Improved settling
- Increased trajectory fidelity during motion
- Decreased phase shift with respect to driving voltage
- Insensitive to interferences from the outside
- For digital piezo controllers

Linearization Concepts Dynamic Digital Linearization

- Improves the trajectory fidelity during fast scan motions by up to three orders of magnitude compared to conventional PID control
- For digital piezo controllers

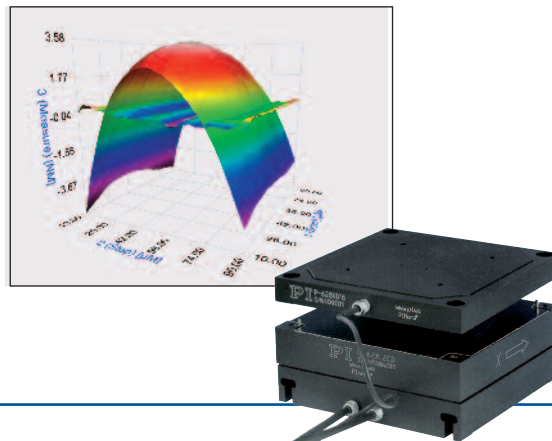


Software Concepts PI General Command Set – One for All

- Places commands independently of drive and device
- PIMikroMove™ application program for operation, fast start-up and system optimization
- Drivers for Windows, LabVIEW, LINUX and real-time LINUX, Matlab, C++
- Drivers for analog D/A boards

Picoplane™ For Piezo Systems Realize Motions with Nanometer Flatness

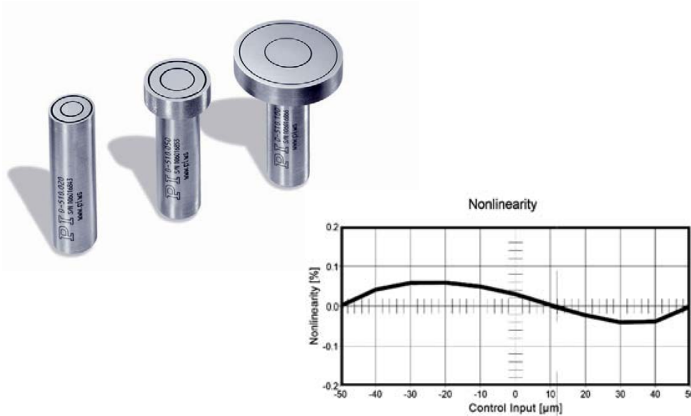
- Improved flatness of 1 nm
- Additional PICOPlane™ axis required



Capacitive Sensors

Metrology for Nanopositioning

Increasing demands on the resolution and positioning stability of the sensor in high-precision positioning technology motivated PI at a very early stage to develop in-house metrology. We therefore use our own capacitive sensors for nanopositioning systems. The advantages lie in the non-contact measurement principle which does not affect the measurement and is maintenance-free. The resolution is up to 0.0005% of the measurement range, linearity up to 0.01%. Capacitive single electrode sensors are meanwhile supplied as an independent PISeca™ product line. They are flexible in their application and easy to adjust.



PISeca™ Capacitive Single Electrode Sensors

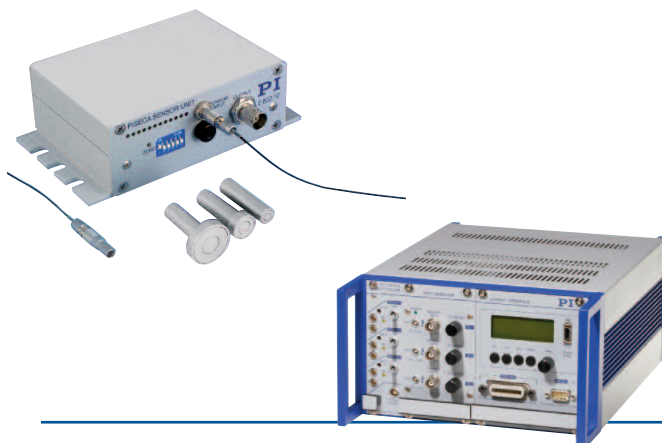
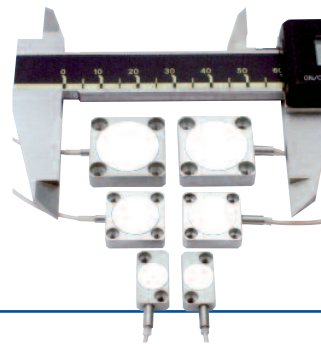
Nanometer Accuracy for External Installation

- Measuring range to 1 mm
- Flexible designs and sizes
- Simple integration by clamp installation and plug
- Resolution 0.001%
- Linearity 0.1%
- Lateral shift of reference plane possible
- Measures with reference to electrically conducting surfaces

Capacitive Two-Electrode Sensors

Maximum Precision

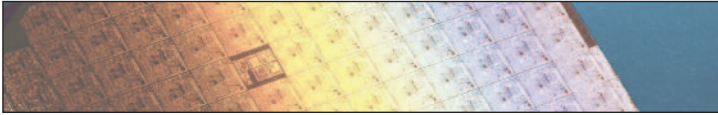
- Measuring range to 0.1 mm
- Flexible designs and sizes
- Resolution 0.0005%
- Linearity 0.01%
- Bandwidth 10 kHz
- For all surfaces



Signal Conditioners and Controllers Makes Nanometer Metrology Accessible

- 1-6 channels
- Fast adjustment display
- Measuring range adjustment from nominal to 10-fold
- Bandwidth adjustment
- Controller option for output of a position target value
- Optional digital signal transmission for large separations between sensor and electronics

Applications



Semiconductor Technology



Microscopy / Imaging



Biotechnology
Life Science



Medical Design
Medical Technology



Metrology / Laser-Systems
Optical Inspection / Tribology



Nanotechnology
Nanofabrication
Nanoautomation®



Photonics
Telecommunications
Integrated Optics



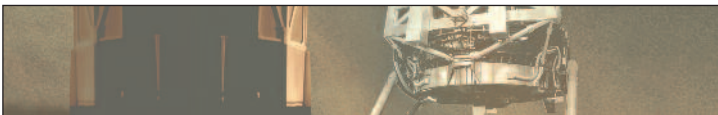
Precision Machining
(Metal, Optics, Laser Cutting,
Diamond Turning)



Data Storage Technology



Aeronautics
Image Processing
Cryogenic & Vacuum Environment



Astronomy
Adaptive Optics



The new hardbound "Piezo Nano Positioning Inspirations 2009" catalog from PI is available now. The 530 page publication is the most comprehensive reference book on the fundamentals of nanopositioning, piezo systems and micropositioning technology yet. The new catalog contains 200 product families, 30% of them new, with more than 1000 drawings, graphs, images and technical diagrams.

The 530 page publication presents PI's state-of-the-art products and technologies-such as:

- Nanopositioning / Scanning Stages
- Scanning Microscopy Stages
- Steering Mirrors, Mirror Shifters
- Piezo Actuators
- Piezo Motors
- Piezo Controllers
- Motorized Stages & Actuators
- Motor Controllers
- Hexapod 6-Axis Alignment Systems

The catalog also contains a tutorial on piezo technology and application examples of nanopositioning products in the following industries:

- Biotechnology / Life Sciences
- Semiconductor Technology
- Data Storage Technology
- Nanotechnology
- Aeronautics
- Astronomy
- Adaptive Optics
- Metrology / Laser-Systems
- Precision Machining

Headquarters

GERMANY

Physik Instrumente (PI) GmbH & Co. KG
 Auf der Römerstr. 1
 76228 Karlsruhe/Palmbach
 Tel: +49 (721) 4846-0
 Fax: +49 (721) 4846-100
 info@pi.ws · www.pi.ws

PI Ceramic GmbH
 Lindenstr.
 07589 Lederhose
 Tel: +49 (36604) 882-0
 Fax: +49 (36604) 882-25
 info@piceramic.de
 www.piceramic.de

Subsidiaries

USA (East) & CANADA

PI (Physik Instrumente) L.P.
 16 Albert St.
 Auburn, MA 01501
 Tel: +1 (508) 832 3456
 Fax: +1 (508) 832 0506
 info@pi-usa.us
 www.pi-usa.us

USA (West) & MEXICO

PI (Physik Instrumente) L.P.
 5420 Trabuco Rd., Suite 100
 Irvine, CA 92620
 Tel: +1 (949) 679 9191
 Fax: +1 (949) 679 9292
 info@pi-usa.us
 www.pi-usa.us

JAPAN

PI Japan Co., Ltd.
 Akebono-cho 2-38-5
 Tachikawa-shi
 Tokyo 190
 Tel: +81 (42) 526 7300
 Fax: +81 (42) 526 7301
 info@pi-japan.jp
 www.pi-japan.jp

PI Japan Co., Ltd.
 Hanahara Dai-ni Building, #703
 4-11-27 Nishinakajima,
 Yodogawa-ku, Osaka-shi
 Osaka 532
 Tel: +81 (6) 6304 5605
 Fax: +81 (6) 6304 5606
 info@pi-japan.jp
 www.pi-japan.jp

CHINA

Physik Instrumente (PI Shanghai) Co., Ltd.
 Building No. 7-301
 Longdong Avenue 3000
 201203 Shanghai, China
 Tel: +86 (21) 687 900 08
 Fax: +86 (21) 687 900 98
 info@pi-china.cn
 www.pi-china.cn

UK & IRELAND

PI (Physik Instrumente) Ltd.
 Trent House
 University Way,
 Cranfield Technology Park,
 Cranfield,
 Bedford MK43 0AN
 Tel: +44 (1234) 756 360
 Fax: +44 (1234) 756 369
 uk@pi.ws
 www.physikinstrumente.co.uk

FRANCE

PI France S.A.S.
 32 rue Delizy
 93694 Pantin Cedex
 Tel: +33 (1) 57 14 07 10
 Fax: +33 (1) 41 71 18 98
 info@pifrance.fr
 www.pifrance.fr

ITALY

Physik Instrumente (PI) S.r.l.
 Via G. Marconi, 28
 20091 Bresso (MI)
 Tel: +39 (02) 665 011 01
 Fax: +39 (02) 610 396 56
 info@pionline.it
 www.pionline.it