TOPICS

PIEZO NANO POSITIONING

PI

ISSUE 46

NEXLINE® Technology for the Large Binocular Telescope

Precision Gimbal Optical Mount for Astronomical Interferometry

Gimbal mirror mount with NEXLINE® drive and matching drive electronics (picture: PI)

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For the Large Binocular Telescope (LBT) in Arizona, the Max Planck Institute for Astronomy (MPIA) in Heidelberg has developed alternative tip/tilt platforms for dichroitic mirrors in a critical optical path.

Classic kinematic mirror mounts with standard actuators were not able to provide the necessary stability, resonant frequency and resolution in the limited space conditions. The innovative design uses piezoelectric NEXLINE® stepping drives from PI which directly act on the pivot points of the tilt axes. The result is a tip/tilt mirror system whose resonant frequency of 125 Hz is more than four times higher than that of conventional mirror mounts. The resolution is 0.3 arc seconds (closed-loop), and the position stability is better than 0.15 arc seconds.

The NEXLINE® piezo drives combine large travel ranges with high stiffness and better than 0.1 nm resolution.

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Piezoceramic longitudinal and shear elements act on a moving rod coupled to the payload. This allows an arbitrarily small position resolution that only depends on the stability of the control voltage signal. While the rod can be moved in full-step mode at maximum velocity over long distances, the nano-stepping mode allows uniform motion at a constant velocity. When de-energized, the drives provide maximum holding force with a nanometer stability, irrespective of their position.

The Max Planck Institute for Astronomy (MPIA) in Brief:

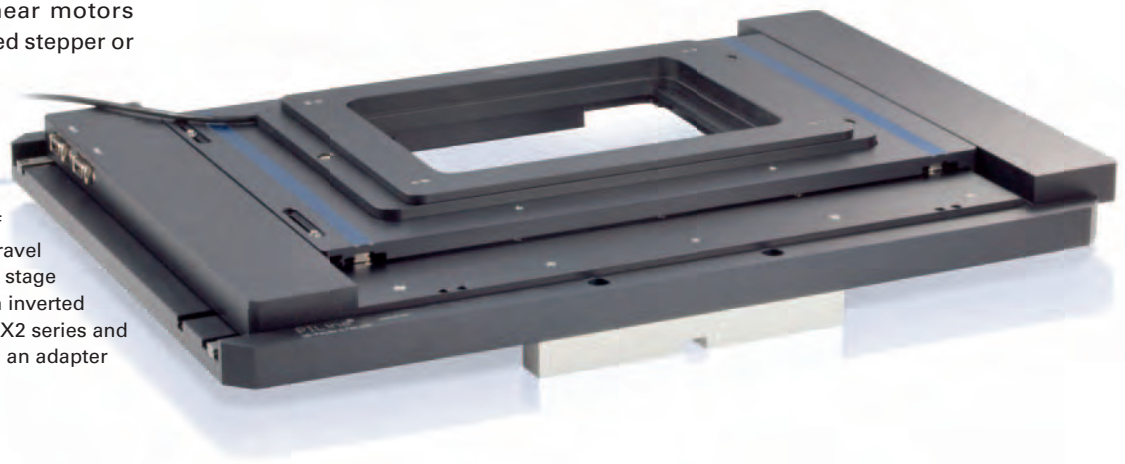
Astronomy is one of the oldest natural sciences and at the same time it is one of the most modern. This is proven by the Max Planck Institute for Astronomy in Heidelberg. Here, researchers solve the mysteries of the universe with high-tech instruments, manufacture clever accessories and detectors for telescopes and satellites which examine the light from strange sources by every trick in the book. New stars and the birth of planetary systems are the objects of scientific curiosity. "Is Earth the only populated place in space?" is one of the burning questions in research. But the Max Planck astronomers are also present in the depths of space and time, examining active galaxies and quasars to get a picture of the beginning and development of the now so richly structured universe.

Precise and Stable: M-687 Microscope Stages with Direct Drive

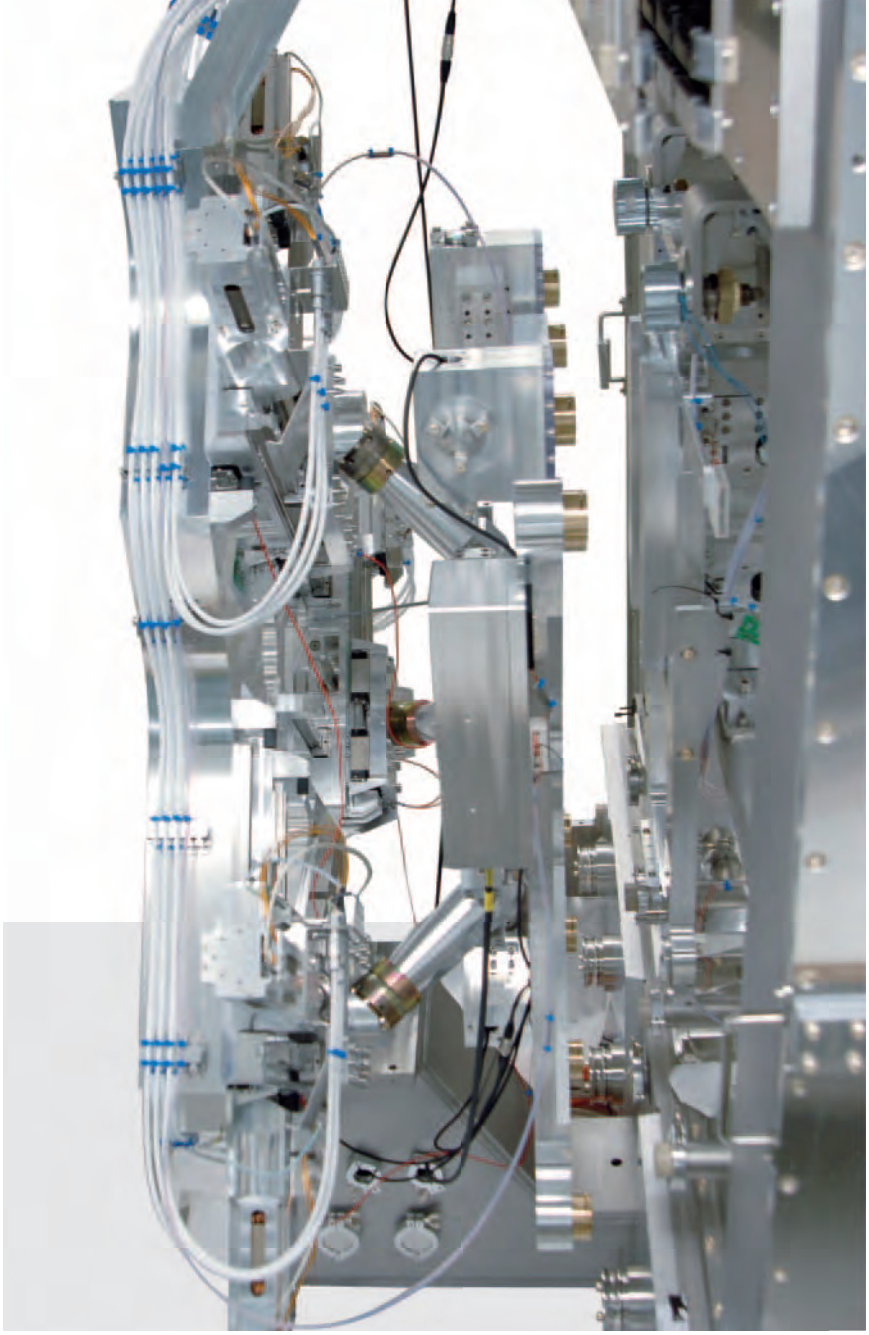
With the M-687 PI offers a new, fast, high-precision XY positioning system optimized for applications with inverted microscopes.

The M-687 XY stage provides travel ranges of up to 100 × 75 mm, and its large clear aperture of up to 160 × 100 mm can accomodate specimen holders as well as Z-specimen scanners. The currently available models can be used for Olympus IX2 series and for Nikon Eclipse TI inverted microscopes. The M-687 stage is driven by integrated PILine® piezoceramic linear motors which, in contrast to flanged stepper or DC motors with large lead screw, ducts do not increase the footprint. This facilitates the integration of the stage under the microscope and offers an unhindered access to the specimen. The PILine® motors transmit the force directly to the moving platform and thus keep the position stable, even when powered down with no heat generation. M-687 stages provide maximum closed-loop velocities of up to 250 mm/s. Their behavior is optimized, i.e. settling takes place within a few milliseconds. On the other hand, a slow movement is also of importance for users: Even with only a few micrometers per second the movement is constant and very smooth. It can still be observed under the microscope at 1000-fold magnification.

By combining a PILine® drive with a high-resolution position sensor, a stiff and high-precision stage has been designed which can reach positions repeatedly with sub-micron accuracy. This is particularly useful for imaging methods such as tiling and stitching which are required for large specimen.



Dynamic and precise: The combined stage, consisting of a motorized XY stage with a travel range of 100 × 75 mm and a Z stage for specimen scanning, fits on inverted microscopes of the Olympus IX2 series and Nikon Eclipse TI without using an adapter (picture: PI)



Parallel kinematics from PI miCos integrated in a fully automated vacuum production process (picture: PI miCos)

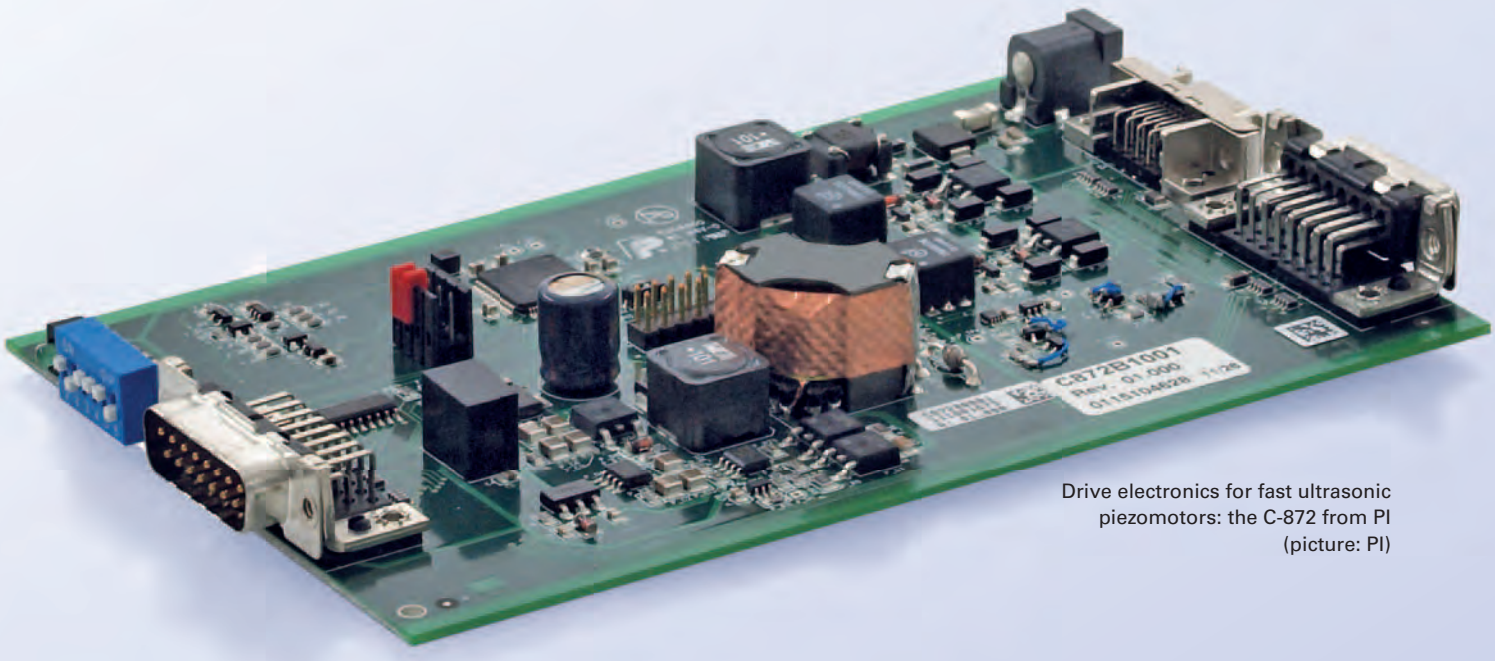
Assembly Line Production in Vacuum

A special challenge for the Eschbach engineers was a precision assembly line under vacuum conditions of 10^{-6} mbar. The fully automated assembly of a precision foil sandwiched between a carrier and a counter holder had to be integrated in the production process. The 1 m^2 foil has to be positioned with an accuracy of ±20 µm in relation to the carrier. Since the position of the carrier varies, the assembly process, which can take no longer than 10 seconds, could only be achieved with a 6-degree-of-freedom positioning system. For the desired travels of 50 mm in the direction of assembly and 20 mm perpendicular to this, a SpaceFAB was recommended due to its low height.

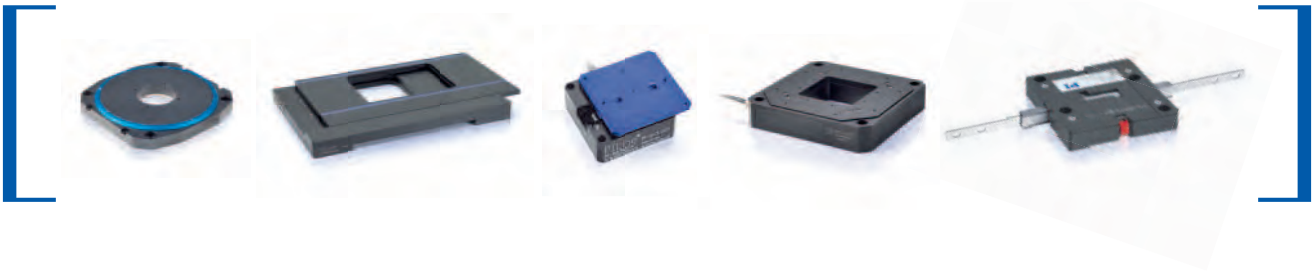
The system developed for this application can easily move loads of 100 kg, fast and very precisely with low vibration. In addition to several modifications of the standard SpaceFAB design, custom three-phase servo motors ensure the necessary dynamics. A vacuum-compatible holding brake was also redesigned since the solutions on the market did not meet the requirements of this application regarding material properties and heat dissipation. PI miCos also assumed responsibility for the control software of the sandwich assembly process, the integration of the sensor and camera measurements as well as for the monitoring of the gripper magnets. The vast experience and flexibility of the PI miCos team have turned this complex multidisciplinary high-tech project into another success story.

PI miCos

miCos GmbH was founded in 1990 in Eschbach, near Freiburg, and it is now known as PI miCos after joining the PI group in late 2011. With currently more than 50 employees, the company develops, produces and markets innovative motion systems and components for high-precision positioning applications throughout the world. A main focus is on optical measurement technology in research and industry. For this purpose, PI miCos offers customized system solutions with multiple axes in addition to a comprehensive standard program. Wide-ranging application know-how guarantees the implementation of technically demanding solutions. Flexible positioning systems for ultra-high vacuum applications with parallel-kinematics and six degrees of freedom, as well as systems with linear motors and air bearings are but a few examples of PI miCos's capabilities.



Drive electronics for fast ultrasonic piezomotors: the C-872 from PI (picture: PI)



Fast and Efficient Positioning Drives

Universal Driver for Ultrasonic Piezomotors

The PILine® series includes complete multi-axis positioning systems but also ultrasonic piezomotors for OEMs. The operation of ultrasonic piezomotors requires specific drive electronics that generate high-frequency AC voltage to excite the piezoelectric oscillations.

The C-872 universal drive electronics was especially designed for OEMs. It is optimized for low heat generation and power consumption and the active frequency tracking improves performance and efficiency. Velocity is controlled via an analog interface by input signals in the range between ±10 V.

Drive systems that are based on ultrasonic piezomotors offer advantages over classic rotary motor drive systems in respect to dynamics as well as velocity, start-stop behavior and installation space. They also outperform magnetic linear motors when the target position has to be kept stable without the drive being energized or in the presence of strong magnetic fields.

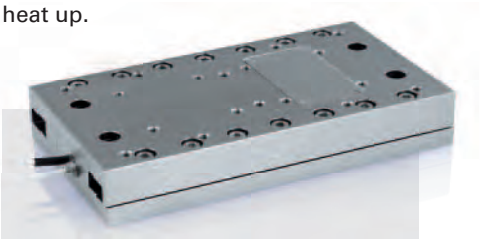
High-resolution positioning system for incremental motion in the nanometer range

Perfectly Aligned Precision

With the new N-664 linear positioning stage, PI has succeeded in developing a groundbreaking reference-class positioning system combining long travel with the advantages of piezo precision, speed and stiffness.

A NEXACT® piezo linear drive replaces the usual stepper or DC servo motor in the N-664, making sub-nanometer resolution feasible. Closed-loop position feedback is provided by the novel PIOne optical linear encoder featuring 0.5 nm incremental resolution. The N-664 is equipped with precision-aligned high-load crossed-roller bearings made of stainless steel. The PIOne linear encoder is based on an interferometric measurement principle capable of providing very precise measurement results in the subnanometer range even at high positioning speeds.

The self-clamping NEXACT® piezo-walk motor direct drive keeps the position stable even when powered down, reducing energy consumption, heat dissipation and eliminating the need for external brakes. The drive does not have to be supplied with current and does not heat up.



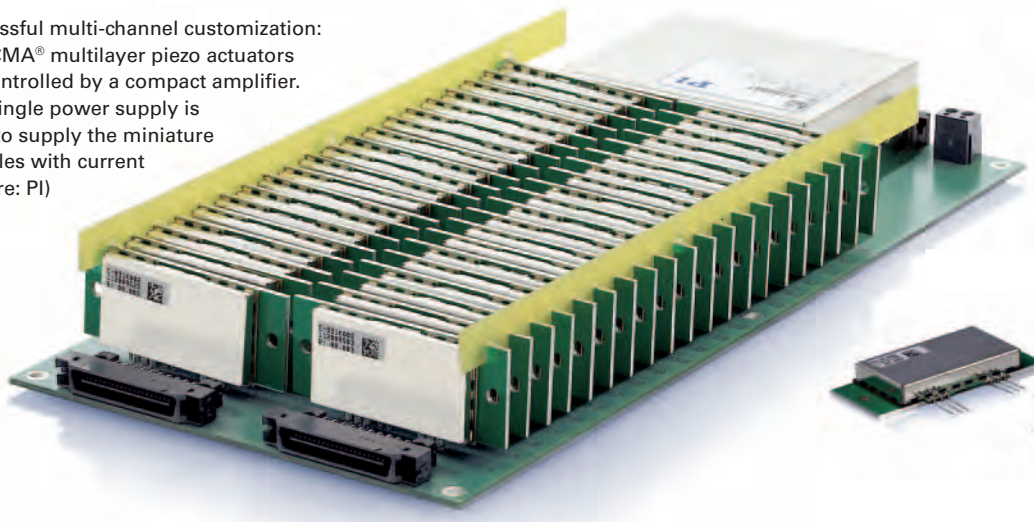
The N-664 micropositioning stage combines long travel, speed to 10 mm/s and laser-interferometer documented incremental motion of 2 nm (picture: PI)

Cost-Effective and Compact:

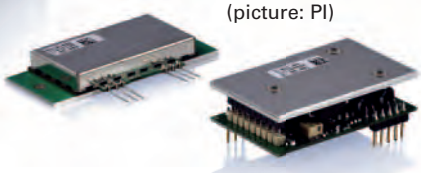
Miniature Piezo Amplifier Module for Modular Multi-Axis Control

Smaller, more powerful, and more dynamic: The E-831.05 piezo amplifier module for piezo voltages from –30 to 130 V, with a peak current of 250 mA, and a bandwidth of up to 15 kHz offers more than previous miniature modules. This benefits OEM customers operating a large number of PICMA® multilayer piezo actuators. With dimensions of only 60 x 28 x 6 mm, the mini-driver is well-suited to be mounted close by the actuator, easing the use in active vibration damping or other adaptive systems applications. In addition to the miniature modules, PI also offers compact DC/DC converters to provide the supply voltage for up to three amplifier modules. The DC/DC converters can be customized to facilitate integration into the customer's system.

Successful multi-channel customization: 40 PICMA® multilayer piezo actuators are controlled by a compact amplifier. One single power supply is used to supply the miniature modules with current (picture: PI)



Small and even smaller: The new E-831.05 piezo amplifier module (picture: PI)



E-712: The Smart Way to a Millionth of a Millimeter

Digital Controllers for Piezo-Based Nanopositioning Systems

Modern piezo-nanopositioning systems achieve the highest performance and flexibility through a combination of precision mechanical and electrical engineering. Since the control requirements of piezo ceramic positioning systems are significantly more demanding than those of traditional stepper or serve motors magnetic motors, purpose-built digital controllers are the premium choice. Together with direct-measuring position sensors, modern digital servo piezo controllers can provide higher linearity, and faster response than is possible with traditional analog servo controllers. In addition, controllers such as the E-712 can handle a variety of piezo-based positioning systems, from flexure based drives to NEXACT® and NEXLINE® piezo-walk type linear motors. The E-712 modular digital controller system is probably the most efficient device for the nanopositioning with piezo ceramic actuators or PiezoWalk® motors.

Piezo-based multiaxis systems for precise positioning (picture: PI)

Nanometer Positioning Accuracy

Digital piezo controllers from PI influence all motion parameters through adaptive algorithms and enable the use of a variety of correction models, e.g for the linearity deviations of the sensors. Thus linearity values below 0.001 % with positioning applications can be achieved, corresponding to a precision of below a nanometer for travel ranges of 100 µm.

Dynamic Linearization

Digital technology minimizes phase shift and trajectory errors in dynamic-periodic applications. This is especially important for scanning applications and for dynamic synchronization with other processes. Pls proprietary DDL (Digital Dynamic Linearization) algorithm reduces rolloff, phase error and hysteresis improving dynamic linearity and effective bandwidth by up to 3 orders of magnitude for repetitive (periodic) signals.

Advanced Piezo Control

The Advanced Piezo Control algorithm actively counteracts resonances up to approx. 1 kHz as opposed to classic PID and achieves much higher suppression rations than classical PID algorithms with passive notch filters can do. The result is faster settling, considerably better disturbance suppresion and better phase accuracy. The algorithm requires a mechanical design with clearly separated resonant frequencies.

Piezo Actuators

High Accuracy and Dynamics

Piezo actuators convert electrical energy directly into mechanical energy and vice versa. Typically, travel ranges of up to around 1 mm can be covered with nanometer resolution and high dynamics, with frequencies of several kilohertz. Since the motion is based on crystalline effects, there are no rotating parts or friction; piezo actuators are therefore practically maintenance-free and nonwearing, and since no lubrication is necessary, they are also vacuum compatible. They can move large loads, cannot be disturbed by even strong magnetic fields and have very compact dimensions.

PICMA® bender actuators with various contours and dimensions (picture: PIC)

High reliability and compact dimensions make them ideal for use in medical technology

PICMA® Bending Actuators from PI Ceramic Can Be Easily Customized

Thanks to a new type of production technology, multilayer bender actuators can now be manufactured in large quantities with almost any desired contour and dimension. Even unusual shapes such as trapezoid and internal holes with a full ceramic insulation are feasible. The piezo actuator is protected against humidity and has a high insulation resistance significantly improving its lifetime compared to common polymer-insulated actuators. The thickness of the active layers is variable starting from 15 µm, making even applications where drive voltages are limited to only 10 V feasible. PICMA® benders can be produced in very small dimensions of only a few millimeters, e.g. with a 4 x 10 mm edge length.

As a result of their flexible size and operating voltage, PICMA® bender actuators are ideal for integration into mobile devices such as hearing aids. Here the piezo element functions as an acousto-mechanical transducer, and the sound transmission takes place e.g. via bone conduction. In addition to reasonable prices for customized versions, PIC offers optimum support from prototype-phase to the integration into the customer's OEM product.

PIC in Brief:

PI Ceramic (PIC) has been developing and manufacturing piezo ceramic materials and components for standard and OEM solutions for 2 decades: piezo components, ultrasonic transducers, actuators, and system solutions. The PICMA® multilayer actuator technology, which received an award for its reliability, is one of many innovations of PIC. PI Ceramic, a subsidiary of Physik Instrumente (PI), is located in the city of Lederhose, Thuringia, Germany.

Linear Actuators with Piezomotor

Ceramic Drivers for Higher Precision

Piezo stepping drives replace the usual electromagnetic motors in the linear actuators of the N-381 series. The linear piezo-stepping motor is free of precision losses due to the conversion of rotary motion to linear motion. The N-381 is 10 mm/s fast, provides resolution of 20 nanometers based on an integrated linear encoder. The position is locked when not in operation, without drift or oscillations. The position holding force is 15 N. The drive does not have to be supplied with current in its target position and does not heat up. Furthermore, the drive principle of the piezo stepping motor enables very high resolution within one step cycle. In open-loop operation, the motion can be resolved to about one nanometer and lower. PI also offers controllers suitable for the linear actuator.

The N-381 linear actuator with NEXACT® piezo stepping drive combines dynamic motion and high position resolution in a compact design (picture: PI)

From left to right: Dr. Peter Schittenhelm, Dr. Karl Spanner, Markus Spanner, Norbert Ludwig (picture: PI)

Expansion of PIs Management

Continuity Spread Across Several Shoulders

On April 01, 2012, PI appointed three new managing directors. Norbert Ludwig, Dr. Peter Schittenhelm and Markus Spanner together with Dr. Karl Spanner, who also acts as chairman, now constitute a committee of four which will lead the company in the future.

The commercial management of the entire PI group is in good hands with Mr. Markus Spanner who graduated in economics and spent some time in Asia. Mr. Ludwig takes on the responsibility for Sales and Marketing and Dr. Schittenhelm is responsible for Operations. Both hold masters degrees in physics and with that the background knowledge to understand market demands and to realize technical solutions.

Headquarters

GERMANY

Physik Instrumente (PI) GmbH & Co. KG
Auf der Roemerstr. 1
76228 Karlsruhe/Palmbach
Tel. +49 (721) 4846-0
Fax +49 (721) 4846-1019
info@pi.ws
www.pi.ws

PI miCos GmbH
Eschbach
info@pimicos.de
www.pimicos.de

PI Ceramic GmbH
Lederhose
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) & MEXIKO

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.
Tachikawa
Business Center Bldg. 5F
2-38-5 Akebono-cho
Tachikawa-shi, Tokyo 190-0012
Tel. +81 (42) 526 7300
Fax +81 (42) 526 7301
info@pi-japan.jp
www.pi-japan.jp

PI Japan Co., Ltd.
Hanahara Daini Bldg. #703
4-11-27 Nishinakajima
Yodogawa-ku, Osaka-shi
Osaka 532-0011
Tel. +81 (6) 6304 5605
Fax +81 (6) 6304 5606
info@pi-japan.jp
www.pi-japan.jp

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

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

FRANCE

PI France S.A.S.
244 bis, avenue Marx Dormoy
92120 Montrouge
Tel. +33 (1) 55 22 60 00
Fax +33 (1) 41 48 56 62
info.france@pi.ws
www.pifrance.fr

CHINA

Physik Instrumente (PI Shanghai) Co., Ltd.
Building No. 7-106
Longdong Avenue 3000
201203 Shanghai, China
Tel. +86 (21) 518 792 98
Fax +86 (21) 687 900 98
info@pi-china.cn
www.pi-china.cn

SOUTH EAST ASIA

PI (Physik Instrumente) Singapore LLP
20 Sin Ming Lane
#05-60 Midview City
Singapore 573968
Tel. +65 665 98400
Fax +65 665 98404
info-sg@pi.ws
www.pi-singapore.sg
For ID / MY / PH / SG / TH

KOREA

PI Korea Ltd.
6F Jeongu Bldg.
Cheonho-Daero 1111
Gangdong-gu
138-814 Seoul
Tel. +82 2475 0060
Fax +82 2475 3663
info-kr@pi.ws
www.pi-korea.ws