

## New Coordinate Measuring Machine for Quality Assurance Applications

To meet the increasing quality assurance needs of our customers, we have again extended our comprehensive line of measuring devices. Now, in addition to six laser interferometers from market leaders Zygo and Zeiss, surface interferometers, auto-collimators and laser vibrometers, our growing quality assurance line includes a new 3D coordinate measuring machine.

Fig. 11 Checking a high-precision part with the 3D coordinate measuring device

## NanoCube: New XYZ Nanopositioning Stage<sup>3/4</sup> Ideal for Fiber Alignment

Another new development in the PI nanodevices program is the P-611 NanoCube. This compact, piezo-driven system with zero-backlash mechanism combines high accuracy for the smallest measurements with low system cost.

NanoCube enables rapid positioning operations of  $100 \times 100 \times 100 \mu\text{m}^3$  with nanometer-range resolution. It is ideal for fiber optics scanning tasks or positioning operations in photonics packaging applications.

At present two models are available: a closed-loop version with integrated position sensors for servo operation, and an open-loop version. Which version is most suitable depends on the individual application.

In simple combination with different PI positioning systems (from the M-105 manual stage to the 6-axis Hexapod), a virtually unlimited range of applications can be covered.

NanoCube can be operated with all low-voltage piezo amplifiers and controllers available from PI.

### Highlights:

- Ideal for glass fiber positioning and photonics packaging applications
- $100 \times 100 \times 100 \mu\text{m}^3$  travel range
- Resolution of 1 nm
- Open- and closed-loop versions
- Compact size:  $44 \times 44 \times 44 \text{ mm}^3$  (closed-loop version!)
- Rapid scanning and stabilization
- Wide choice of electronic controls

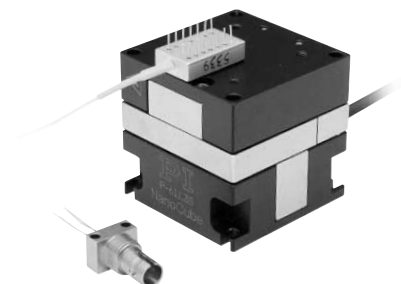


Fig. : NanoCube XYZ nanopositioner and scanning system,  $100 \times 100 \times 100 \mu\text{m}^3$  travel range  
Fig.: NanoCube on M-105.30 XYZ translation stage (for "coarse" adjustment)

## PIIntelliStages: High-Precision Positioning Stages with Integrated Controller

Perform high-precision positioning tasks with the simplest of means? This wish is now reality! The M-500.SMC line of linear positioners has high-resolution stepper motors with the controller incorporated in the stage itself. Just connect the RS-232 cable to the PC, and the intelligent translation stage is ready to operate.

Up to three translation stages can be networked and operated on a single serial port. Power supply and software are included. With a step size of 0.1  $\mu\text{m}$  these translation stages offer maximum precision at minimum system cost.

### Technical Data:

Travel Range:	102, 204 or 306 mm
Motor:	5-phase stepper motor; resolution 20,000 steps/rev.
Linear resolution:	0.1 $\mu\text{m}$
Max. speed:	20 mm/s
Command set:	ASCII or binary
Software:	Windows 95/98 and NT

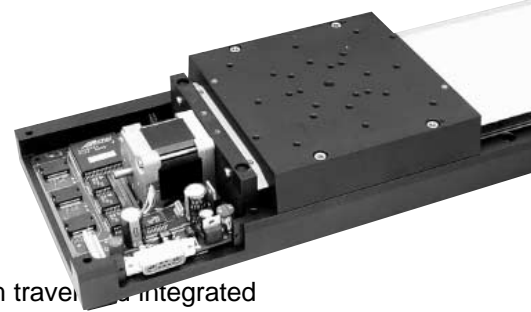


Fig. 3: IntelliStage M-531.5SC: Linear positioner with 0.1  $\mu\text{m}$  resolution, 304 mm travel and integrated controller

## Fast and Accurate Active Optics

PI is the market and know-how pioneer in fast active optics (piezo tilt mirror systems). In addition to equipping the largest astronomical telescopes (Fig. 4), we supply compact units for small mirrors to OEM customers (Fig. 5), laser beam guiding systems or dynamical error compensation in exposure systems, image processing and setting systems.

Active optics at PI feature a number of vital attributes that are decisive in research and industry:

- A) PI employs first-grade piezo ceramics that are specifically manufactured for us by our subsidiary *PI Ceramic*. These materials excel in exemplifying high stiffness, large deflection and an exceptionally long life. Using these ceramics, systems with resonant frequencies in the kHz region at lifetimes of several billion cycles can be produced.
- B) PI draws on the experience of our subsidiary *GSG Elektronik* by using state-of-the-art electronics that capitalized on the theoretically unlimited resolution open to piezo translators and capacitive sensors by successfully implementing these features practically. Fast digital or analog controllers simplify connection to a diverse assortment of systems.
- C) PI can draw on a formidable assortment of the latest hi-tech equipment for model design, simulation and evaluation. Our team of scientists and engineers incorporate Finite Element Analysis (FEA) simulation, stress and vibration analysis by scanning laser vibrometers, testing and control with laser interferometers and autocollimators and other tools (long established at PI) to design cutting-edge technologically innovative products.
- D) PI is supported by a unique systems integration know-how the world over in such fields as actuators, sensors, mechanical design and digital electronics.

Fig. 4: 250 mm tip/tilt steering mirror unit (mirror not shown), digital controller and an ultra-fast capacitive sensor controller (fiber link interface) for the Keck Outrigger telescope in Hawaii. A total of 4 telescopes will be set up. Tilt range:  $\pm 150 \mu\text{rad}$ , resolution: nanorad region.

Fig. 5: Fast and compact tilt mirror with capacitive sensors. Tilt range: 2 mrad, resolution: nanorad region. Applications: beam deflection, correcting lens errors and semiconductor technology.

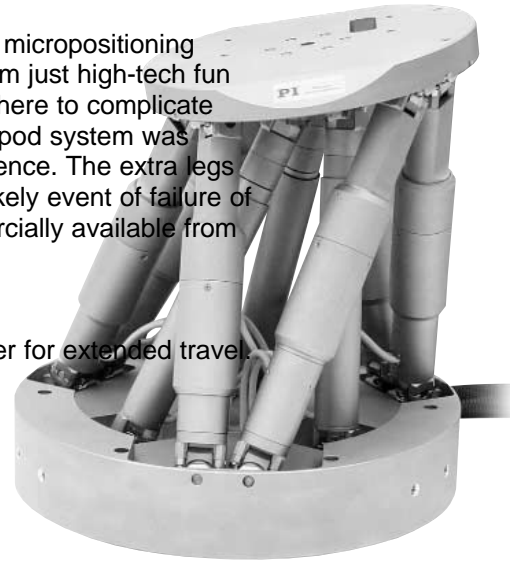


## Hexapod +3 Medical Robot with Highest Levels of Reliability

Our years-long experience with the development and production of 6-axis Hexapod micropositioning systems served as the basis for the next step: the Nonapod. What at first might seem just high-tech fun and games has, in fact, far greater significance. The three "extra" legs are not just there to complicate controller programming with overdetermination, but to increase reliability. The Hexapod system was developed for use as a medical robot—an application where reliability is of the essence. The extra legs contain redundant sensors which enable immediate corrective measures in the unlikely event of failure of the standard measuring systems. The complete system (fig. 2) will soon be commercially available from Universal Robot Systems, GmbH & Co. KG (<http://www.medicalrobots.com/>).

Fig. 9. Hexapod for medical applications

Fig. 10: Operations cockpit and Hexapod with supplementary M-521-linear positioner for extended travel.



## More Bits to Byte into Your Positioning Applications Digital Controller Line Expanded

PI has again extended its selection of digital piezo controllers (Fig. 6). 1-4 channel models (up to 7 channels for special designs) in a variety of forms furnished with versatile interfaces are now available. Some key interfaces available include:

- High-speed fiber link (1 Mbit/s)
- Parallel port (PIO)
- DSP link
- RS-232
- IEEE 488
- High-speed analog

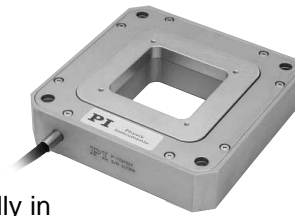
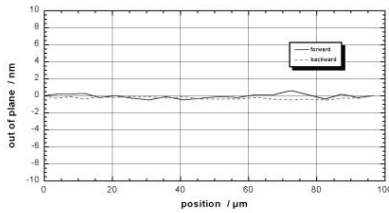
All devices feature 32-bit digital servo-loop technology, extremely low-noise piezo power amplifiers and capacitive position sensor inputs. A linearity of up to 0.001% in positioning motion is possible depending on the positioning mechanism.

To operate and optimize configuration, a comprehensive assortment of software (DLLs, LabView driver etc.) is supplied with these devices (Figs. 7 & 8). The mechanical parts include ID chips containing all calibration data that is transferred to the controller when powered up. This feature ensures reliable, optimal operation with the added bonus of allowing the controller and the nanopositioning system to be interchanged at will.

Fig. 6: A selection of high-resolution digital piezo controllers, 1-4 channels with various interfaces

Fig. 7: A Bode plot can be produced, among other things, by using the NanoCapture software for piezo digital controllers to obtain precise analysis of the attached nanopositioning mechanism

Fig. 8: The software can even analyze analog control signals to high-precision



### New Nanostaging Stage for Super-Planar Motion.

High-resolution motion that is confined to a plane is essential for applications in metrology—especially in wafer inspection where high-resolution motion along the XY-plane is required—and motion perpendicular to this plane (Z) is unsatisfactory because this leads to undesirable results.

Here, the order of magnitude of the dimensions involved is at the one nanometer scale. Flatness to this precision is entirely inaccessible to roller or ball bearings. EDM wire cut frictionless flexures are the only feasible options. However the demands on these flexure systems are enormous. The commonly deployed 'simple parallelogram flexures' are subject to cosine errors and so cannot be exploited. Designing complex guiding systems eliminate this error. However, even the most perfectly constructed flexures only function in practice when mechanical errors in the manufacturing process are reduced to a minimum.

Of particular interest is the introduction of the driving force. Forces with a single degree of freedom that are absolutely parallel to the plane of motion are crucial as just tiny errors in angle lead to trajectory tilting.

PI's phenomenal experience in constructing nanomechanical parts was mobilized to meet this difficult challenge. We have developed over a hundred different nanostaging systems down the past 20 years. Our performance-proven expertise and resources were pooled together to design and develop the device depicted in Fig. 12, i.e., the P-731K022 nanostaging stage. By using capacitive sensors, the unit provides sub-nanometric resolved travel, stability through a  $100 \times 100 \mu\text{m}^2$  travel range and flatness in the nanometric region (Fig. 13).

Fig. 12: The  $100 \times 100 \mu\text{m}^2$  P-731K022 nanostaging stage with capacitive sensors and an ultra-planar flexure guiding system

Fig. 13: Flatness of the P-731K022

### New Fiber Alignment Software for the F-206 Mini-Hexapod

New Hex-Control host software is now available for the F-206 six-axis micropositioning and handling systems. These windows (95/98 & NT) applications feature manual operation as well as fully automatic scanning and auto alignment. Further, Hex-Control evaluates the F-206 controller analog-input data—for example, optical power meter signals—and optimizes the position until maximum intensity is reached. The results are presented as a 3D graphical plot (Fig. 14).

The F-206 platform position is depicted in 3D-space in manual mode with respect to the coordinate origin and the freely adjustable pivot point (Fig. 15). Increment, scanning region, intensity threshold and all other crucial parameters can be called-up and configured via intuitive, user-friendly menus in all modes of operation.

Some F-206 specifications:

- Fully automated 6D system for photonics packaging and micro-handling applications
- $\pm 6 \text{ mm}$  travel range along X, Y & Z
- $\pm 5^\circ$  rotation about X, Y & Z
- Point of rotation can be freely selected
- $0.1 \mu\text{m}$  resolution
- $0.4 \mu\text{m}$  repeatability
- Optional NanoCube scan and alignment module providing 1 nm resolution

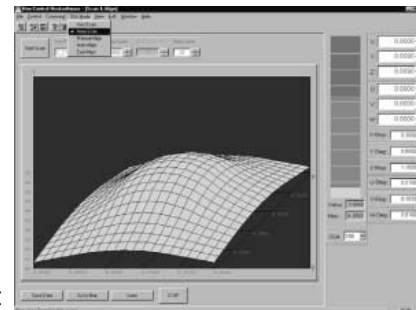


Fig. 14: Hex-control software: flat-scan intensity distribution plot of a fiber optic component

Fig. 15: Hex-control software: spatial representation of the F-206 platform with respect to the origin and the pivot point

Fig. 16: Optional NanoCube scan and alignment module providing 1 nm resolution

## New Linear Actuators for a Variety of Applications PI's DC-Mike Range Extensively Expanded

PI has extensively added to its range of DC-Mike linear actuators. The latest models to reinforce PI's range include the M-230, M-231 and M-235. They are all fitted with high-precision integrated limit switches and differ from one another via design and load capacity. Rotating or non-rotating lead screws, or recirculating ball screws are used depending on the particular model.

These devices can achieve a resolution of 50 nm and below at speeds to 3 mm/s with push/pull loads up to 150 N. A special drive guiding system can withstand lateral forces up to 100 N, crucial for fixed-clamp applications and where lateral loads cannot be ruled out.

Backlash was reduced to an incredible 0.5  $\mu\text{m}$  in the M-235.5DG model, an unprecedented, unrivaled value, by exploiting the characteristics of exceptionally high-grade components having practically no friction.

### Key Features:

- 50 mm travel range
- Resolution < 50 nm
- Up to 3 mm/s max. speed
- Up to 150 N load capacity
- Integrated non-contacting limit switches
- Backlash only 0.5  $\mu\text{m}$
- Clamp or screw fastened mounts
- Closed-loop operation
- Low-cost motor controllers
- Optional stepper motors



The time-proven M-22x.20 and M-22x.50 models continue to be available from PI.

Fig. 21: M-235.5DG (50 mm, recirculating ball screw); M-230.25, M-230.10 (25, 10 mm, non-rotating lead screws) and M-231.17 (17 mm) linear actuators





### New Control Unit for Piezoelectric Bender Actuators

Two new piezo bender actuator controllers are now available. These devices have been specifically designed to meet the needs of the PI multi-layer bender (see Fig. 20 for basic principle). The bench top version, i.e., E-650.00, features a display, manual offset adjustment, and sockets for the control signal, monitor and the piezo output (Fig. 18).

The E-650.OE compact model was specifically developed for OEM use. This model's inputs and outputs are via 8 soldering pins (Fig. 19). The peak output power is 18 W for the E-6500.00 and 8 W for the E-650.0E and the output voltage for both devices is between 0 and 60 V.

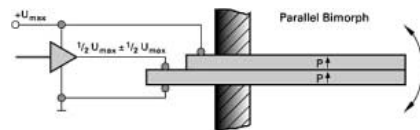


Fig. 18: The E-650.00 control unit for piezoelectric bender actuators

Fig. 19: The E-650.OE OEM control unit for Piezoelectric Bender Actuators

Fig. 20: Basic principle behind the piezoelectric bender actuator. The PL-140.251 provides a  $\pm 1$  mm travel range.

### M-105.1DC Translation Stage with Closed-Loop Control

The compact M-105 translation stage has always been supplied with a variety of manual and piezoelectrical drives. A new feature has been added allowing closed-loop DC operation with model number M-105.1DC. This system is capable of resolving to 0.1  $\mu\text{m}$  at speeds up to 2 mm/s. Up-grading your existing M-105 stage for motor operation is straightforward. Simply remove the micrometer screw and replace with the M-231.17 linear drive (see "New Linear Actuators for A Variety of Applications.") M-105 linear translation stages are ideally suited to adjustment applications, measuring, optics, fiber optics (photonics packaging) and life science applications (patch clamp etc.)

#### M-105 Series Key Features:

- Resolution with DC motor: 0.1  $\mu\text{m}$
- Highly accurate guiding system and long lifetime by employing crossed roller bearings
- Travel range to 18 mm
- Stainless steel construction
- XY and XYZ combinations
- Optional piezo mike having a 10 nm resolution

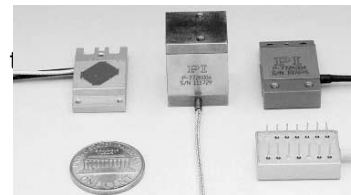
Fig. 17: XYZ positioning stage from a combination of three M-105.1DCs, e.g., for fiber alignment applications



### New: Ultra-Small Nanopositioning Stages

Among PI's products include the world's smallest piezo nanopositioning systems with integrated capacitive sensors and flexure guiding systems. They provide **sub-nanometric resolution** and **settling times in the millisecond region**, though they are hardly larger than a cent. Stages of this caliber are predominantly found in the computer disk-drive and fiber optic industries. A digital controller is used to drive the ID chip equipped stages enabling optimum compensation and straightforward interchangeability without the necessity for re-calibration.

Fig. 22: A selection of capacitive sensor equipped miniature nanopositioning stages compared to a cent coin and a telecommunications laser



## Several Million Invested at *PI Ceramic*

*PI Ceramic*, a subsidiary of PI, has invested several million German marks over the past two years on the latest technology. The financial infusion has been used among other things to procure another micrometer exact ceramic saw to slice ceramics into disks, and a new sputtering system. Thin film electrodes of Cu, CuNi, Ag and other materials on ceramic substrates for actuators and sensors can now be manufactured in fully automated and exact reproducible processes. This hi-tech equipment further enhances the range of cutting edge products manufactured by *PI Ceramic*, and increases the company's flexibility, reliability and competence.

Fig. 23: Sputtering System

## PI at ACTUATOR 2000

**ACTUATOR** is an international conference on new actuators which is held in Bremen every second year. The newest trends in the actuator field were presented between the 19-21 of June, this year. PI and *PI Ceramic* held nine presentations and poster sessions on the latest research in various actuator fields.

### Topics included were:

- Breakthrough in Piezoactuator Applications (review)
- Low Temperature Properties of Piezoelectric Actuators
- Actuators with Piezoelectric Impact Drives
- Hexapod Parallel Kinematics with Sub-Micrometer Accuracy
- Different Methods of Signal Preshaping for Highly Dynamic Piezo Positioning Systems
- Investigations of the Loss Power of Stacked Actuators
- A New Piezo Spindle Drive Combines Microstep Movement and Continuous Motion
- Novel Digital Control Algorithm Improves Dynamic Performance of Piezo-NanoScanners by Several 100 Times
- Reactionless, Momentum Compensated Resonant Linear Drives

Visit [www.actuator.de](http://www.actuator.de) for more information on ACTUATOR.



## Micropositioning Platform with Piezo Tube Drives from *PI Ceramic*

Juhász László, who is an assistant at the Faculty of Technology in Novi Sad, Yugoslavia, has developed a platform capable of unlimited movement in the x and y directions and providing less than 0.1  $\mu\text{m}$  incremental step resolution. The manipulation of samples in electron microscopes (SEM) or other types of online inspection have been reported as possible fields of application. The device can be battery powered and operated by remote control.

Three PT130.90 piezoelectric tubes from *PI Ceramic* were used. The fundamental platform setup is illustrated in Fig. 24. The legs with ball ends are attached to the piezo tubes and are clearly visible in the picture.

The tube actuators can bend in all directions if differentially controlled due to the use of quadrature electrodes. High resolution, coordinated motion is possible via suitable interplay between the motion of the individual legs. An integrated control platform prototype is depicted in Fig. 25, while a schematic representation of the entire system is given in Fig. 26.

Fig. 24: Structure of the platform with PZT legs  
Fig. 25: Prototype with on-board controller

Fig. 26: Micropositioning platform setup



## Nanotechnology for Any Microscope Or how can I find my atom again?

The answer to this question is best answered by realizing that the P-500 Nanopositioning stages from PI offer the broadest spectrum of piezo scanning and positioning units in the "NANOWORLD" (Fig. 27).

Two different designs rendering 11 different positioning range variations cover nearly all possibilities to suit microscopy and metrology applications. Scanning or positioning along the Z and tip/tilt axes are catered for, in addition to the typical X and Y axes with a resolution in the sub-nanometric region.

Scanning up to 200  $\mu\text{m}$  and 2 mrad per axis are supported. For the P-500 family, PI is dedicated towards an internal design mechanism in which all actuators and measuring instruments act on the same platform. This PI commitment ensures an **active prevention** of a cross-talk between axes. Adopting and applying these methods can achieve a true trajectory better than 1 nm; and this in several dimensions (Fig. 28).

The high resonant frequency is a prerequisite for fast settling times in incremental positioning and for good scanning stage dynamical behavior. The integrated capacitive sensors resolve to better than 0.1 nm and are capable of a scanning linearity to 0.02%: ideal attributes for near-field and confocal microscopy. The compact chassis design, with a height of only 30 mm (XYZ stage!) and an aperture of 66 mm, means that it can be adopted for use with practically any microscope irrespective of whether measuring a reflecting or transmitting source.

The P-500 range are excellently poised for the step into the atomic domain: scanning probe microscopy (SPM). This tube actuator scanning stage dominated field has been revitalized by PI's piezo stages. Tube actuator scanner side effects, e.g., cross-talk, position drift and angle error, that occur while scanning are eliminated by resorting to the PI-500 family.

A design specially developed for the German institute of standards (PTB) features monitoring on all 6 degrees of freedom and any axis cross-talk is reduced to an order of magnitude in the sub-nanometer or sub- $\mu\text{rad}$  region.

Fig. 27: The P-517.3C XYZ nanopositioning stage  
Fig. 28: XY scan flatness using a P-500 stage

