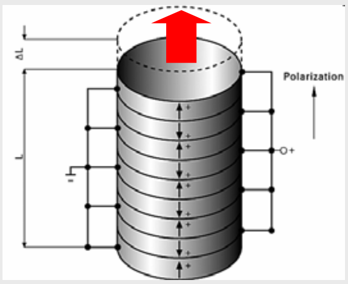
Piezo for Motion Control in Medical Design and Drug Research

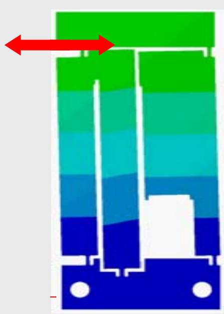
Piezo Pumps, Microdosing, Biohandling, Computer Aided Surgery, Microscopy

All Piezo Motors are Not Created Equal

Direct Actuators: Z-Stacks, Shear (X, XY)

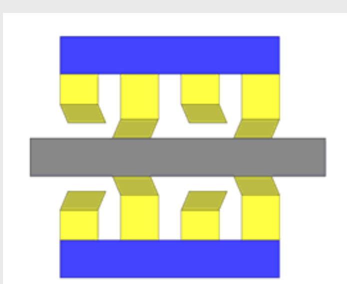


- Direct Motion = High Force & Very Fast Response (to Microseconds)
- Travel Range typically 10µm to 300µm
- Z, X, XYZ Motion
- No Wear & Tear



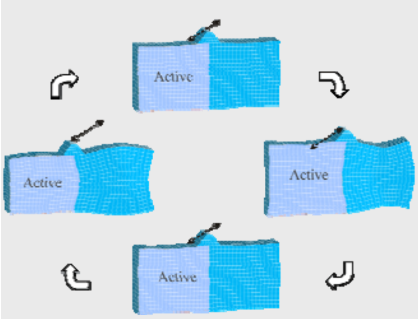
Flexure Lever Actuators

- Flexure Guiding System
- Response <1 msec
- Travel to 2 mm, Compact



PiezoWalk® Linear Motors

- Long Travel
- High Force
- Self Locking



Ultrasonic Linear Motors

- Long Travel
- Fast: 350 mm/sec
- Low Profile, Self Locking

All: Sterile, Low Power, No Lubricants, Non- Magnetic, Vacuum Compatible; High Resolution: Sub-Nanometer to Sub-Micron

SSUE 43

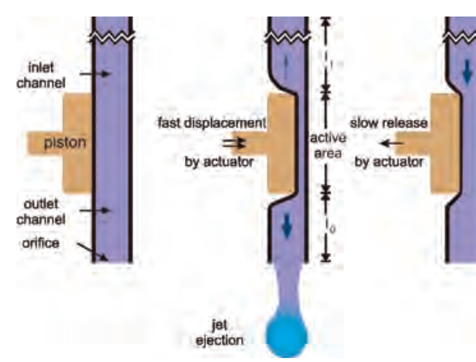
Piezo Actuators Are the Driving Force:

Nanoliter Dosing for Biotechnology, Diagnostics and Industry

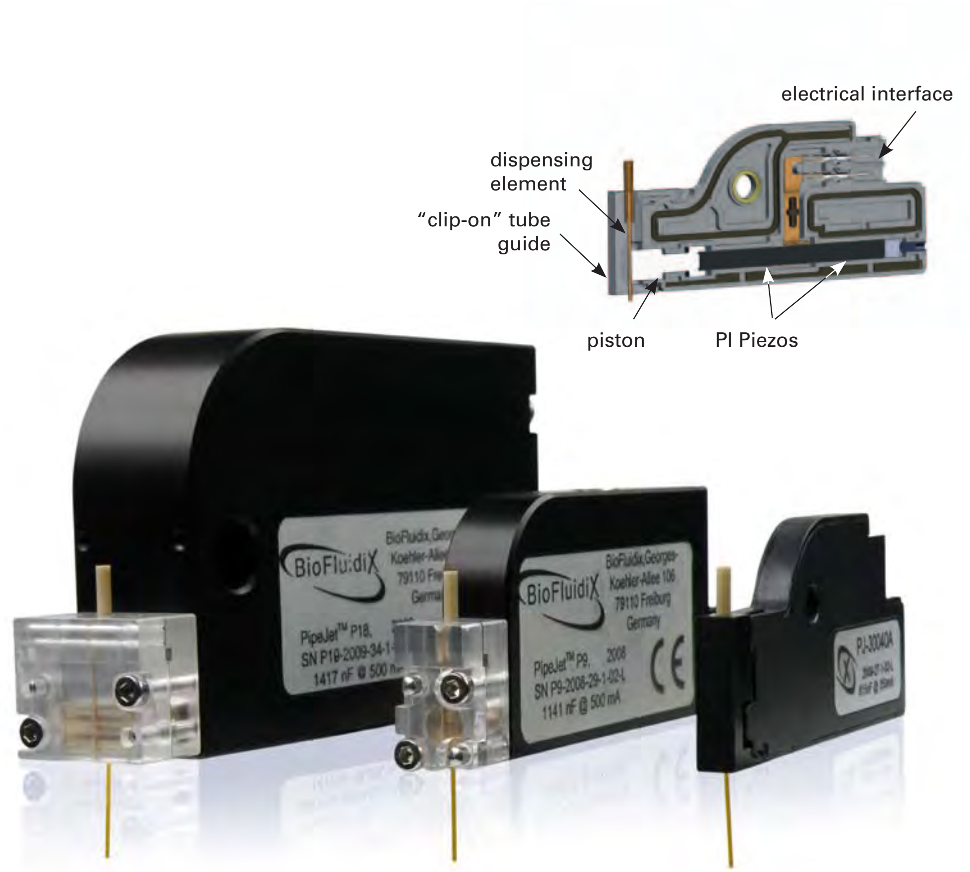
Microdispensers for nanoliter dosing are used in the manufacture of microarrays and lab-on-a-chip systems as well as in researching active agents. They must be able to generate perfect droplets, taking into account the viscosity and surface tension of the media and the dosing speed. Misting, satellite formation on impact or dripping must be reliably prevented.

Piezo-Driven Direct Displacement: PipeJet Technology

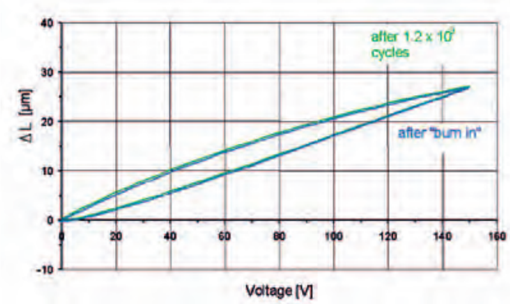
The best conditions for this are provided by the PipeJet™ technology developed by Biofluidix, which uses piezo-driven direct displacement for the dosing. The nanodispensers allow non-contact and flexible dosing of liquids in the volume range from a few nanoliters to several microliters per second.



The PipeJet dosing principle: The valveless method is based on the piezo-driven direct displacement of the liquid by an elastic polymer tube with a well-defined internal diameter (Photo: Biofluidix)



PICMA®: Patented, fully ceramic encapsulated multilayer piezo stack design provides maximum operating life: (Photo: PI)



PI piezo actuators have gone through several billion cycles in endurance tests without measurable changes in their behavior (Photo PI)

The piezo-driven direct displacement method of the PipeJet™ dispenser uses a fluid line made from an elastic polymer tube with a well-defined internal diameter which is not firmly attached to a piezo actuator. In order to provide sufficient force for force for the precise dosing of difficult media, Biofluidix employs a PI Ceramic multilayer PICMA® piezo stack compressing the polymer tube via a piston with 100 times the force of the conventional ring actuators. The particular volume is controlled via the amplitude of the piezo actuator. The dispenser is used in clinical diagnostics in Lateral Flow Assays, which are test strips requiring a specific dosage of fluids.

Fast, Precise and Durable: PICMA®

One of the key components in the dispenser is the P-885 PICMA® piezo stack, because of its high force, precise displacement controllability (to nanometers) and fast response. Its effect on the fluid-filled dosing tube causes the droplet to break away determining the properties of the drop. The actuators can also be used in multi-channel applications, where every channel can be controlled individually and the separation between the dispensing points is at least 9 mm. The modules are suitable for droplet volumes between 5 nL (nanoliters) and 60 nL with a dosing frequency of up to 100 hertz.

The high repetition rate puts extra high demands on the reliability of the actuators. PICMA® stack actuators were designed for consistent performance over billions of cycles. Long term results are shown in. They meet and exceed all the requirements of microdosing or pumping applications and operate with short response times down to the microsecond range and sub-nanometer resolution. Both the response and stroke can be controlled with extreme precision allowing for highly random motion profiles. The fast response makes it possible to implement short dosing cycles. The dosing processes can be precisely controlled by the variable stroke.

M-850 Hexapod Advances Research in Dental Biomechanics

From Christoph Bourauel and Ludger Keilig–Department for Orthodontics at the Rheinischen Friedrich-Wilhelms-Universität, Bonn.

Dental biomechanics deals with the interactions between dental materials, treatment instruments or dentures and the reaction of teeth, biological tissues, etc. to mechanical stresses. A wide spectrum of force systems occur here with masticatory forces exerting loads to 380 N and torques to several Nm.

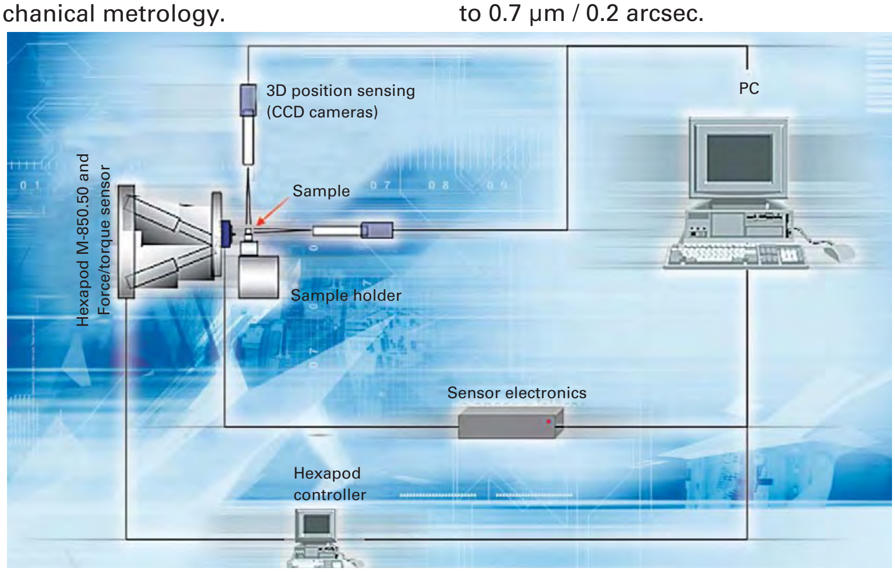
At the same time, movements of several orders of magnitude are involved: orthodontic equipment can change the position of teeth by up to several mm, whereas—during mastication—teeth are deflected by less than 100 µm and implants by as little as a few microns or less. These combinations of small forces with large deflections, on the one hand, and large forces and extremely small deflections on the other , represent a challenge with respect to the biomechanical metrology.

To deal with this challenge, the Dental Clinic of the University of Bonn designed the HexMeS (Hexapod Measuring System) based on the M-850.50 Hexapod. The ability to move in 6 degrees of freedom and the combination of small dimensions, very high stiffness and resolution of less than 1 µm (1 arcsec) were the key reasons for choosing the M-850 system.

HexMeS also features two 6-component force/torque sensors for the Hexapod with measuring ranges of 12 N (120 Nmm) and 130 N (10 Nm) respectively and an optical detection system equipped with 3 CCD cameras.

Because of its high stiffness (100 N/µm), sample deflections can usually be calculated directly from the Hexapod motion.

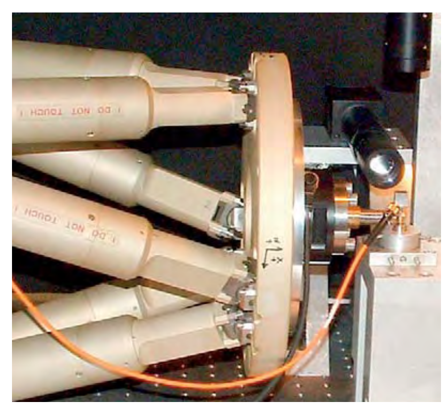
For high-load testing—simulations of mastication in the 100 N range—the optical portion of the HexMeS is used. It resolves sample deflections to 0.7 µm / 0.2 arcsec.



HexMeS block diagram.

The M-850-based HexMeS currently represents one of the most flexible measuring systems in the field of dental biomechanics. Its efficiency and the broad spectrum of its application have been demonstrated in a whole series of experimental investigations into dental implants, telescope crowns and orthodontic prostheses.

Load testing of a double crown.



Click here for Article on Hexapods in Spine Surgery

Piezo for Micro Pumps & Valves

Precision Dosing of Small Volumes

Variety of piezoactuators and lever-amplified systems

Miniaturized Technology

Displacement pumps are used worldwide in many diverse branches of industry. Increasing miniaturization means the market for their smaller "relatives" is also growing: Microdispensers take on distribution and dosing tasks where small volumes in the milliliter or microliter range have to be controlled

Wide Range of Applications for Promising Technology

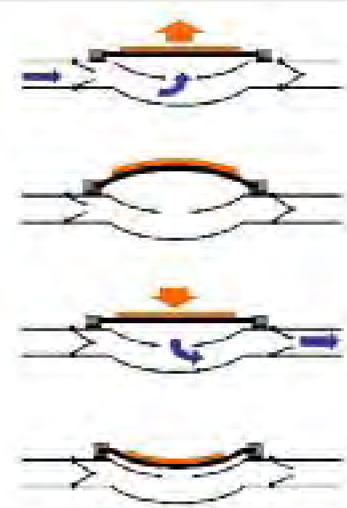
In laboratory and medical engineering, biotechnology or chemical analysis, tiny dispensers accurately dose active substances or medicines. Micropumps take care of the removal of reaction gases in closed processes. Industrial machines benefit from the possibility of using micro-valves to apply lubricants such as oils or grease in a decentralized way at the point where they are required – in an economical, precise and automated way.

Piezo is the Driving Force

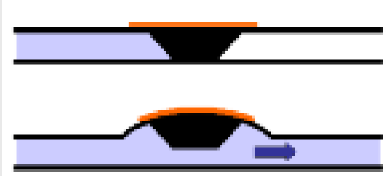
The design is based on the familiar principles of diaphragm pumps and valves and also makes use of the peristaltic principle. The miniaturized drives are based on piezoelectric actuators in various shapes and degrees of integration.

Adapted for Precision & Force

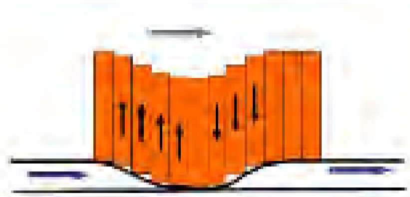
The properties of the pump media – viscosity and drop size, for example – determine the different forces which have to be applied and hence the size of the piezo actuator used. The piezo displacement is a variable parameter which controls the dosing volume. With micropumps, the frequency also determines the flow rate that can be achieved.



Micro-diaphragm pumps operate in a similar way to piston pumps, but the medium to be transported is separated from the drive by a diaphragm. Passive inlet and outlet valves control the pumping direction. Piezo elements in disk form which are mounted directly onto a metal disk make ideal drive systems for micro-diaphragm pumps: This drive solution occupies extremely little space, and the piezo displacement can be very finely adjusted, allowing the pumped volumes to be very precisely defined.



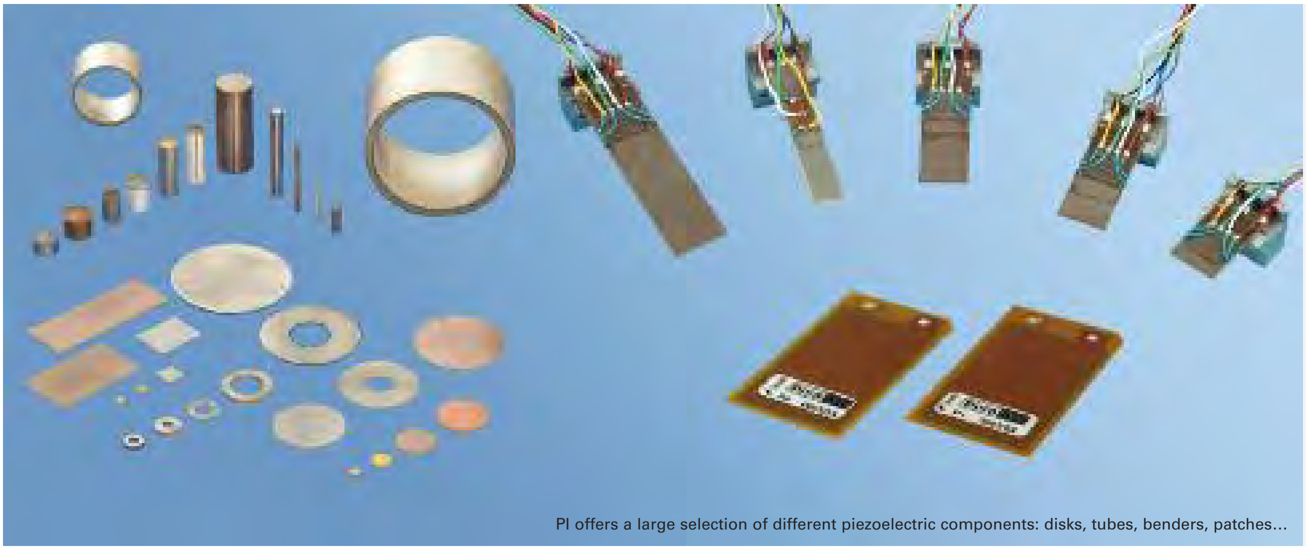
Working principle of a diaphragm valve. Usually, valve applications require higher forces than pumps.



The principle of peristaltic pumping makes directional valves obsolete; the pumping direction in this case is specified by the order in which the individual actuator elements are driven.

Piezo: Compact – Fast – High-Dynamics

Piezoceramic Elements Drive Micropumps



PI offers a large selection of different piezoelectric components: disks, tubes, benders, patches…

Reliable and Fast

The special properties of the piezo ceramics permit flexible flow rates of a few tenths of a microliter to several hundred milliliters per minute at pumping frequencies up to the kilohertz range accompanied by high dosing accuracy. The switching times of a few microseconds are significantly faster than those of magnetic designs. The piezo drives have the power and stiffness values required to also work against pressures of up to tens of bars and are thus also suitable for use with more viscous media.

Piezo ceramics are fundamentally very simple to use and integrate; their compact size even makes them suitable for integration into so-called labs-on-a-chip.

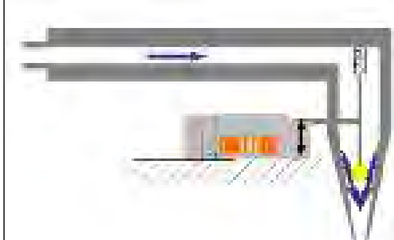
Variable Shapes, Different Forces

Simple piezo ceramic disks or rings are mounted onto a metal or silicon disk and, as the most compact bender element, thus control the opening or closing of diaphragm pumps or valves.

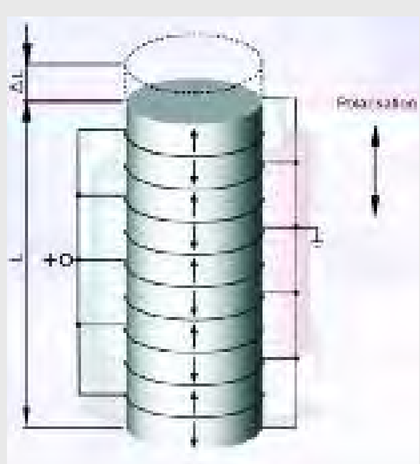
An alternative is to use piezo bender elements, which PI Ceramic can manufacture in almost all shapes and forms.

Small piezoelectric tubes have also been used for a long time for the drop-on-demand method as used in ink-jet-printing, for example. Piezo patches or, for greater forces, piezo stack actuators operate peristaltic pumps.

The corresponding drive electronics are compact and can even be used in portable instruments – for dosing medication, for example.



In micro-valves, particularly where viscous liquids are processed with higher pressures, translational actuators with and without prestress can be used. Where larger strokes of the valve tappet are required, the actuator stroke can be amplified by levers.



Piezo Actuators: Fast, Reliable and Easy to Integrate

Piezo actuators convert electrical energy directly into mechanical energy and vice versa. Travel ranges of up to one millimeter can typically be achieved with resolutions down to the nanometer range. High dynamics with frequencies of up to several kilohertz are also achievable. The movement is based on crystalline effects and so there are no rotating parts and no friction; piezo actuators are therefore maintenance-free and non-wearing and, because no lubrication is required, they are vacuum compatible. They can move large loads and have a very compact design.

Medical Engineering News: Driven by Piezo

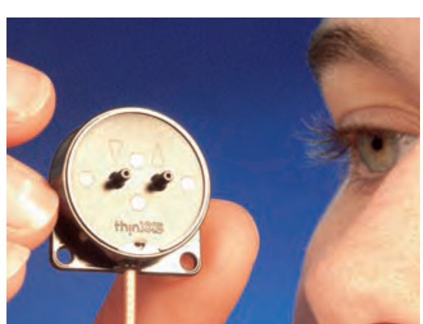
The continuing miniaturization in medical engineering places ever increasing demands on the components. Piezo drives are the solution for many motion control applications; the piezo effect efficiently generates fast and precise motion while requiring very little space.

Efficient Aerosol Generation with Piezo Elements

The treatment of respiratory diseases often involves medications being administered directly with atomizers. One method of atomization is to generate very fine droplets with the aid of ultrasonic piezo ceramics.

Specially shaped piezo disks excite a stainless steel diaphragm with several thousand holes to execute ultrasonic oscillations at more than 100 kilohertz: this produces particularly homogenous aerosols, allowing the medications to be dosed accurately and administered in a more targeted way.

An annular piezo disk serves as an ultrasonic transducer to produce the aerosol in the atomizer head of the eFlow® rapid Electronic Nebulizer series.
(source: Pari Pharma GmbH)



Custom piezo disks precisely dose liquids and gases in the ThinXXS micropump.
(source: thinXXS Microtechnology AG)

Piezo elements from PI Ceramic. The broad spectrum of standard products is supplemented by custom engineered products, with the shortest-possible time-to-market

Moreover, the piezo technology reduces the time required to atomize medications by up to 50 % compared to conventional systems increasing the quality of life for patients with chronic diseases.

Piezo ceramics meet the special hygiene requirements in medical engineering; the aerosol generators can be sterilized at high temperatures, even in autoclaves. The ultrasonic operation is soundless for humans, and the low power consumption of the piezo components allows battery operation.

Piezoelectric Drives in Microfluidics

Piezo-driven microdispensers, i.e. micropumps and microvalves, can dose minute volumes down to the microliter range with very high accuracy. Disk-shaped piezo elements mounted directly onto a metal microdiaphragm provide the highly dynamic drive for precision miniature liquid or gas pumps. Due to the separation of drive and medium through the diaphragm, interference with the pumped media is completely avoided.

Lab-on-a-chip applications are made possible by the minute dimensions.

Dispenser for Bio-Handling

PI is increasingly employing PILine® piezo ultrasonic drives in its positioning stages as an alternative to motor/leadscrew designs – particularly when the stages must be small and fast. They achieve positioning accuracies of up to 0.1 µm and speeds of up to several 100 mm/s.

Small and fast is not only a requirement in classical micropositioning technology, however. Piezo ultrasonic motors are also extremely well suited to applications where the accuracy requirements are not quite so demanding – in the range between 5 and 100 micrometers for example, which is usually suf ficient for industrial automation and handling tasks.

PI has developed the low cost M-664KCEP dispenser dri ve with PILine® piezo ultrasonic motors for this kind of application. Eight or more of these dri ves stac ked together can mo ve pipet tes ver tically and independently of each other in order to dispense liquids into well plates. A single actuator is only 9 millimeters wide to matc h the standardiz ed sample holder.

The M-664KCEP co vers the travel range of 50 millimeters in less than 250 milliseconds and generates forces of up to 4 N. The resolution of the positioning sensor is matched to the application and amounts to 5 micrometers.

Stack of 8 M-664KCEP linear actuators, shown with well plate. The integrated ceramic piezomotor provides high speeds of more than 200 mm/sec.

Movement in Micropositioning Technology

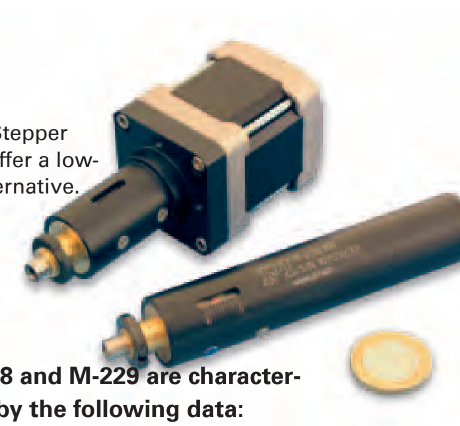
Low Cost PI Drives for Automation and Handling

Setting valves, adjusting components, pick and place ...

The specifications for these types of motion control applications dif fer from those PI is used to dealing with in only two respects: Not one nanometer but 10 micrometers and more are suf ficient for the positioning accuracy. The price plays a muc h more important role, however.

Good quality and good service are two things which customers do not want to forego, which is why PI has recently received many requests from the market segments mentioned.

These requests have led to the development of the M-228 and M-229 linear actuators. These have travel ranges of 10 or 25 mm and use classic stepper motors – with either a compact (motor + gearbox) or cubic (direct drive) configuration. Despite the low prices, the user need not forego useful features such as mechanical position display, a non-rotating spindle or safety limit switches.



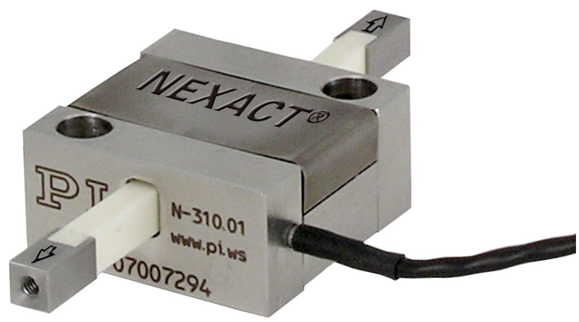
M-228 Stepper Mikes offer a low-cost alternative.

M-228 and M-229 are characterized by the following data:

- bi-directional repeatability: 5 µm
- unidirectional repeatability: 2 µm
- resolution 80 nm (with C-663 Mercury™ Step controller)
- backlash: 5 µm
- speed: 2 mm/sec
- positioning accuracy: 10 µm

Non Magnetic Piezo Motors

Compact, High-Speed PiezoWalk® Drive



N-310 Actuator with E-861 Servo-Controller (integrated drive electronics)

- **20 mm Standard Travel Range, Flexible Choice of the Runner Length**
- **Compact and Cost-Effective Design**
- **0.03 nm Resolution****
- **To 10 N Push/Pull Force**
- **Low Operating Voltage**
- **Self Locking at Rest, No Head Dissipation, Nanometer Stability**
- **Non-Magnetic and Vacuum-Compatible Working Principle**

N-310 NEXACT® PiezoWalk® linear drives feature travel ranges of 20 mm and push/pull force capacities to 10 N in a compact package of only 25 x 25 x 12 mm. With their high resolution, NEXACT® drives, are ideal for high-precision positioning over long travel ranges.

Application Examples

- Semiconductor technology
- Wafer inspection
- Nano lithography
- Surface Measurement Technique
- Profilometry
- Microscopy
- Motion in strong magnetic fields

The N-310 can be operated in open-loop and closed-loop mode (with the addition of an external position sensor). A variety of NEXACT® controllers facilitates the integration into micro- or nanopositioning applications.

Advantages of PiezoWalk® Piezo Stepping Drives

NEXLINE® and NEXACT® drives offer several advantages over traditional drive technologies:

- Resolution in the picometer range
- Compact dimensions
- High drive forces from ten newtons (NEXACT®) up to several hundred newtons (NEXLINE®)
- High-dynamics performance with sub-microsecond response
- Self-locking when powered down; no holding current
- Zero backlash, no wear or maintenance, no mechanical components like gears or leadscrews.
- Non-Magnetic and Vacuum Compatible Operating Principle

Working Principle for Application Flexibility

NEXACT® PiezoWalk® technology overcomes the limitations of conventional nanopositioning drives and combines virtually unlimited travel ranges with high stiffness in a very small package. Furthermore, NEXACT® actuators provide piezo-class resolution (far below one nanometer) and millisecond responsiveness. The special drive design reduces the operating voltage to 45 V and below.

In operation, piezoceramic bending elements act on the runner, which is connected to the moving part of the application. The length of the runner determines the travel range. Force capacity, resolution and velocity are determined by the piezo geometry and drive electronics and are scalable. To move the runner over longer distances the stepping mode is used, whereas for distances smaller than one step, the linear (analog) mode enables high-dynamics positioning with resolutions far below one nanometer.

Wear- and Maintenance-Free

In contrast to ordinary DC or stepper motor drives, the PiezoWalk® drives effect linear motion directly, without the need to transform rotation with mechanical elements such as gears, leadscrews and nuts. Therefore, mechanical limitations such as backlash and wear are eliminated and the drive is maintenance-free.

Self-Locking PiezoWalk® Piezo Stepping Drive

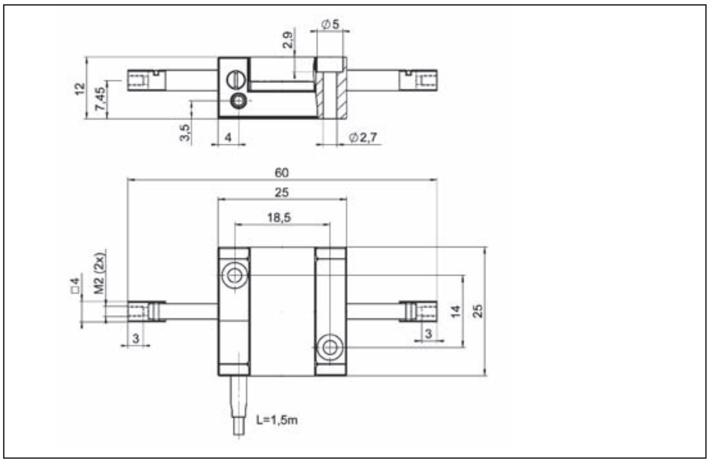
NEXLINE® and NEXACT® exhibit high stiffness and are self-locking even when powered down due to the clamping action of the piezo actuators in the mechanics. This entails nanometer position stability at rest, with no heat dissipation or servo-dither.

Controller and Drive Electronics Optimized for the Application

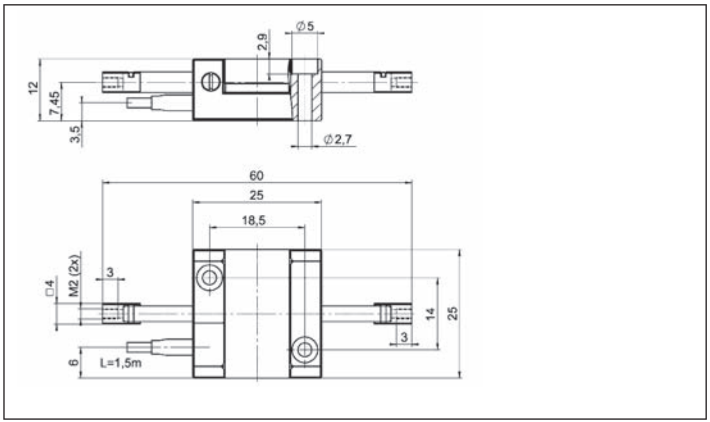
NEXACT® actuators require special drive electronics to control the complex stepping sequences. The E-860 series NEXACT® controllers are available in different open-and closed-loop versions. For example, the E-861 includes a complete NEXACT® servo-controller with low-noise, 24-bit drivers and a powerful DSP. It also comes with ample software for easy integration and highly effective computer control. For applications which do not require the highest resolution lower-priced drive electronics, ranging all the way to OEM boards, can be ordered.

The products described in this document are in part protected by the following patents:
German Patent No. P4408618.0

PI



N-381 piezo stepper linear actuator for sample positioning and manipulation provides long travel, high speed and very high resolution;



Technical Data

		Tolerance
Active axes	X	
Motion and positioning		
Travel range	20 mm	
Step size (in step mode)	5 nm to 5 µm	
Travel range in analog operation	7 µm	max.
Open-loop resolution	0.03 nm**	typ.
Step frequency	1.5 kHz*	max.
Max. speed	10 mm/s*	max.
Mechanical properties		
Push/Pull force (active)	10 N	max.
Drive properties		
Drive type	NEXACT® linear drive	
Operating voltage	-10 V to +45 V	
Miscellaneous		
Operating temperature range	0 to 50 °C	
Body material	Stainless steel, non-magnetic	
Mass	50 g	±5 %
Cable length	1.5 m	±10 mm
Connector	HD Sub-D connector 15 pin, single channel	
Recommended controller/driver	E-860-series (see p. 1-20)	

*Depending on the control electronics.
**Depending on the drive electronics. 1 nm with E-861.

Translation stage with N-310 NEXACT® drive. The positioner offers 20 mm travel range with an encoder resolution of 25 nm

PI

Piezo · Nano · Positioning
news
Issue 37

OCT: Piezo Motors in Medical Design

Ultrasonic piezo linear drives—new application in non-invasive medical technology

Piezo technology enables fast, compact, high-resolution OCT scanner

In addition to the classic, invasive, punch biopsy technique, there are a number of only partially satisfactory non-invasive procedures in clinical and cosmetic research for properly categorizing skin changes. Those based on ultrasound do not provide good resolution, and confocal microscopy cannot penetrate sufficiently below the epidermis. Now, however, there is a practical alternative: the new SkinDex scanner – developed by ISIS Optronics in Mannheim, Germany – combines the advantages of ultrasound and confocal microscopy.

In medical engineering, modern PILine® ultrasonic piezo motor drives are opening up applications which were impossible using classic electric motor leadscrew systems. Due to the piezoelectric effect and the direct creation of linear motion, PILine® drives are not only faster, lighter and more compact than conventional motorized drives, but they can also be made non-magnetic. They achieve resolutions of 20 nm (0.02 µm) and velocities of up to 1 m/s. Their travel range is basically unlimited, and they are available in a number of different integration levels to match the desired (OEM) application. Medical engineering provides an up-to-date example.

Continued from page 1

The SkinDex scanner is based on the technology of optical coherence tomography (OCT) and examines the tissue on and under the skin surface non-invasively. The results obtained are extraordinary. The information contained in the 2-D and 3-D sectional images is comparable to that of a histological examination.

OCT uses the basic transparency of skin together with the interference fringes obtainable with white light. The optical paths are made up of optical fibers.

Exact positioning for precise results

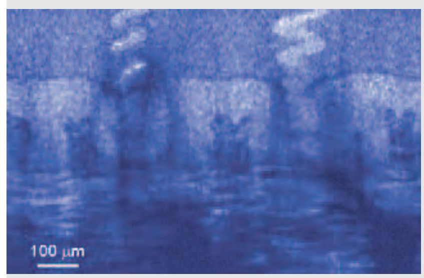
To enable creation of 2- and 3-dimensional images from interference patterns, the optical fibers must be moved both axially and laterally during the scan. This task requires positioners capable of the highest precision. Ultimately, it is the performance of the drives which determine the system resolution and hence the quality of the images.

A PILine® P-661 OEM motor is used to position the reference-arm mirror (depth parameter). This motor was chosen primarily because of its compact design and, considering its size, its high force capacity of 2 newtons (0.5 lbf). Total travel is 2 mm, the position resolution in this application 30 nm (0.03 µm, 1.18 micro-inch).

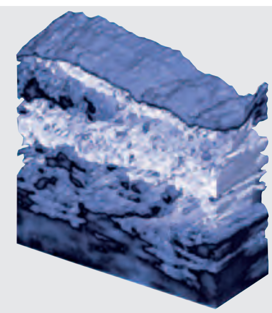
As the images are recorded sequentially, the high speed and excellent dynamic response of the drive is a great advantage. As a result, the SkinDex needs only a few seconds to generate its highly informati ve images. The lateral motions of the optical fiber s in the sensing arm executing the surface scan are also performed by a PI drive.

In this case it is a PIHera® P-622.2CD, a flexure-guided, 2-axis, piezo nanopositioning system, which provides a resolution of 1 nm (0.001 µm, 0.04 µ-inch) and covers an area of 250 x 250 µm. Piezo-motor drives have thus again contributed to an innovation from which many people will benefit in the future.

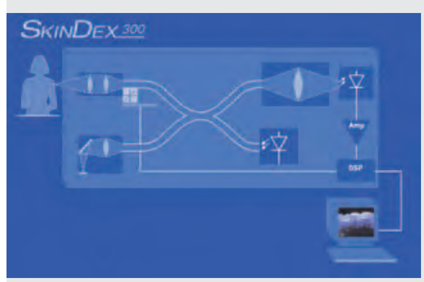
The SkinDex scanner based on OCT technology for non-invasive but reliable examination of the tissue on and under the skin surface (photo ISIS Optronics).



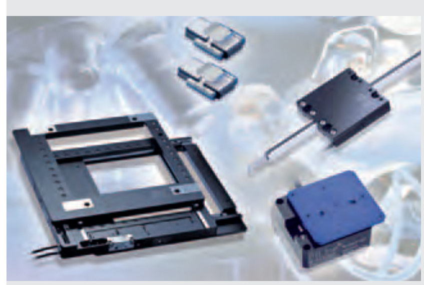
A look under the skin of the ball of the thumb. Even the untrained eye can recognize the spiral-shaped sweat-gland ducts.



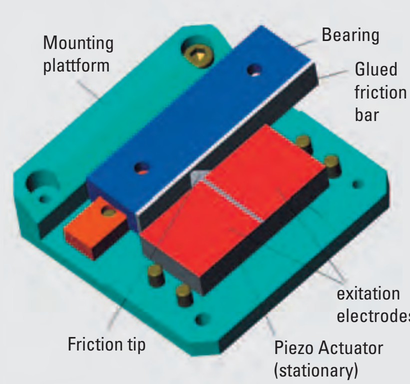
3-D OCT image: Individual laminar and cylindrical structures such as larger blood vessels are visible under the rough skin surface.



White-light interferometry is the basis of OCT. Using optical fibers, light is divided into a sensing and a reference beam. After being reflected by the target (i.e., a cutaneous structure) and the reference mirror respectively, the beams are recombined and enter the detector. An interference signal pattern results (photo: ISIS Optronics).



Integration levels in PILine® ultrasonic piezo motor technology: from 8-mm drives, through the successful Rod-Drive linear drive, to integrated multi-axis systems.



Working principle of an ultrasonic piezo motor drive.

PI nano™ Precision Positioning Systems for Microscopy

The new PI nano™ positioning system from PI was specifically designed for applications in optical microscopy.

The core component of the PI nano™ is an XY or XYZ piez o nano-positioning stage with a low profile of only 20 mm and a large central aperture for transmitted-light microscopy. The stage is equipped with long-life PILine® piezo actuators and provides travel ranges of 200 µm with nanometer positioning resolution. It comes with a matched piezo controller featuring a 24-bit interface (USB, Ethernet and RS-232) and a high-bandwidth analog interface. The contoller is suppor ted by all major image acquisition sof tware packages.

An optional, manual XY stage for coarse sample positioning can be equipped with stepper motor dri ves if required. The preloaded XY stage can be mounted directly onto the microscope and it pro vides the stiffness required to carry a highly dynamic piez o nanopositioning system.

Scanning microscopy methods such as single molecule fluorescence microscopy provide high lateral positioning resolution even below the limitations of the numerical aper ture. They require correspondingly precise sample positioning with resolutions in the range of a few nanometers. The PI nano™ system is designed so that its performance data and range of functions cor respond exactly to these requirements.

- Piezo-based XY/XYZ nanpositioning system with 200 µm travel for planar scanning and vertical focusing/z-stack acquisition
- Optional 25 x 25 mm coarse-positioning stage with manual or stepper motor drives, preloaded for high stability
- Nanopositioning system with large aperture and 20 mm low profile for easy integration into the microscope
- Mechanical compatibility with inverted microscopes from Zeiss, Nikon, Leica, Olympus
- Accessories and sample holders
- Powerful controller with USB and Ethernet Interface, and extensive software support

Due to their low profile, PI nano™ piezo stages can easily be integrated into existing microscope setups

The P-545 piezo stage provides 200 µm travel per axis with sub-nanometer resolution. PI nano™ features a larger aperture for 1x3 “ slides.

PI nano™ series comprising E-545 controller, P-545 piezo system and M-545 manual stage

Piezo · Nano · Positioning

news

Issue 39 · April 2009

Moving samples into the spotlight:

Nanopositioning systems in fluorescence microscopy

Single molecule analysis provides detailed information on chemical characteristics or biological functions, but the detection of individual molecules is by no means easy. The extremely sensitive method of laser-based fluorescence analysis is thus used to increase the signal-to-noise ratio.

(Photo: PicoQuant)

Confocal microscope with single molecule sensitivity

PicoQuant of Berlin, Germany supplies the MicroTime 200 confocal, time-resolved fluorescence microscope for this task. "This system uses the time-correlated single photon count for its data acquisition and can produce both 2D and 3D images" explains Dr. Felix Koberling, Head of System Development at PicoQuant. This makes it possible to realize a variety of the methods currently used in fluorescence microscopy such as FCS (Fluorescence Correlation Spectroscopy) and FRET (Fluorescence Resonance Energy Transfer) as well as so-called fluorescence lifetime imaging. Here not only the measured intensity but also the respective fluorescence lifetime is used for the visualization and quantification in order to analyze intracellular processes even in living cells. Its modular design means the fluorescence microscope is also very flexible in adjusting to different applications. (www.picoquant.de)

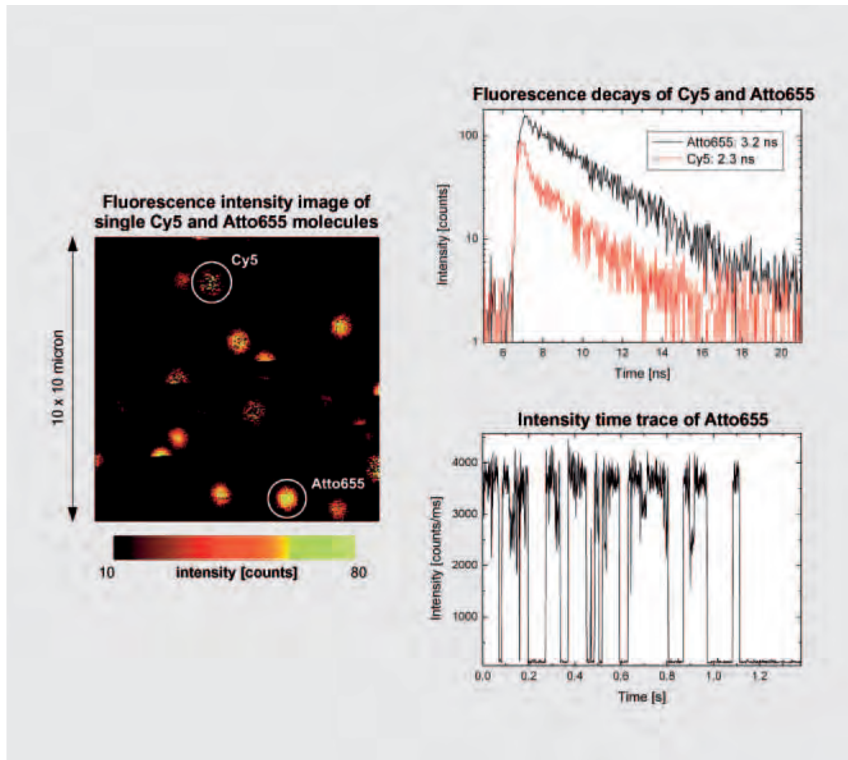
Maximum repeatability thanks to dynamic digital linearization

The P-733.2CD piezo stage was the scanner system of choice for the microscope. With a travel range of 100 x 100 µm and sub-nanometer resolution, this high-accuracy nanopositioning system matches the requirements of fluorescence microscopy perfectly.

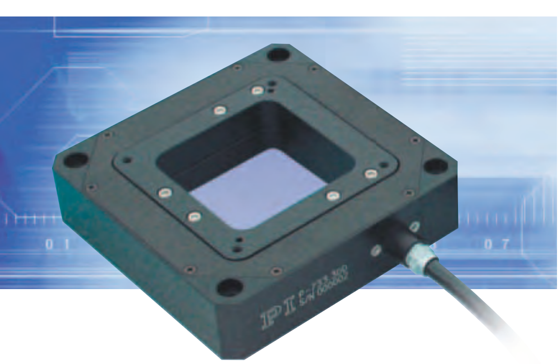
If the sample cannot be moved because it is enclosed in an environmental chamber, for example, the same positioning system can be used to the microscope objective instead. In all cases, however, the integrated direct-measuring capacitive sensors allow the scanner to produce an accurate determination of the actual position value. The first step is typically to record the image of a sample by scanning an area quickly before in a second step individual points of interest are analyzed in detail. In order to return to the exact location of these points within a few nanometers, an advanced digital control algorithm (DDL) was devised. The Dynamic Digital Linearization algorithm improves scanning linearity, i.e. repeatability by up to three orders of magnitude compared to conventional PID (proportional, integral, derivative control).

The third dimension: Additional focus adjustment

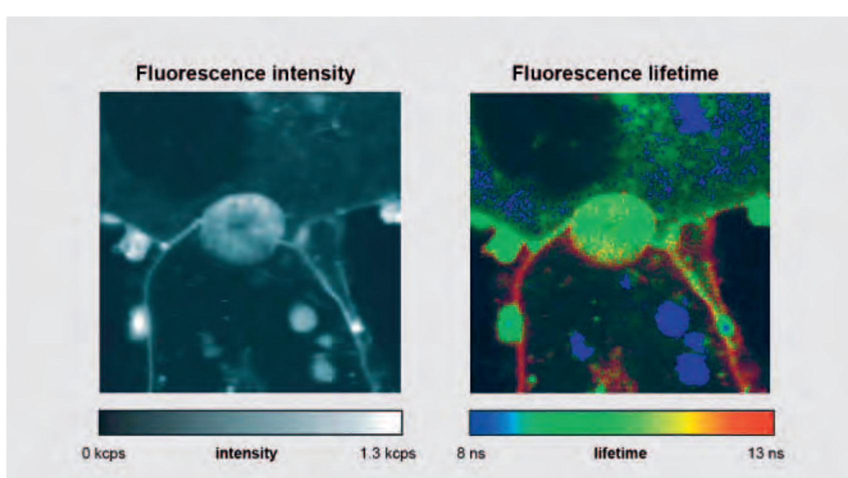
The P-721.CLQ PIFOC® Z-drives are used for three-dimensional images. They provide millisecond response times and their flexure guiding and capacitive sensors enable very accurate positioning, even when the travel ranges are relatively large. "PI's piezo-based nanopositioning systems make a decisive contribution to the fact that we can achieve very high-quality results with our MicroTime 200", says Koberling in conclusion.



Single molecule image of a mixture of immobilized Atto665- and Cy5-molecules. The single molecules can be distinguished by the fluorescence lifetime. (Photo: PicoQuant)



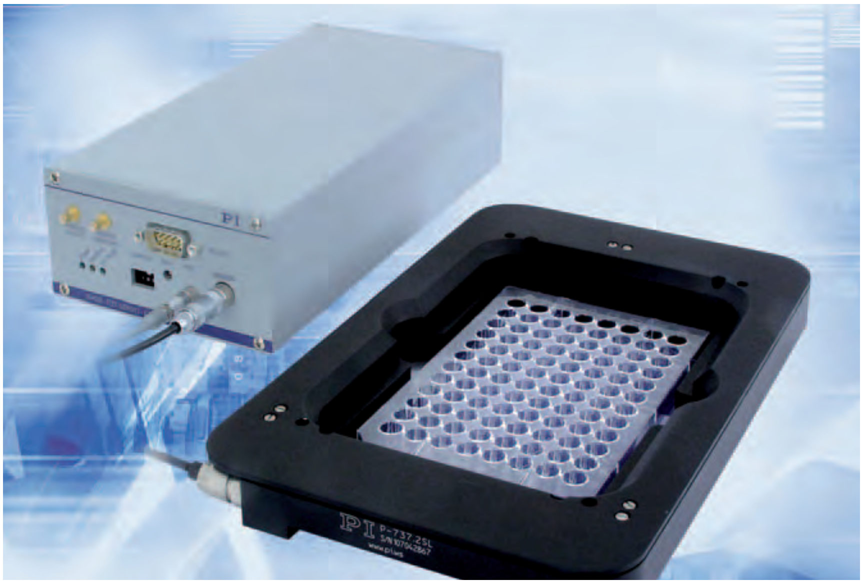
The P-733 piezo-based nanopositioning system provides a travel range of 100 x 100 µm. The optional Dynamic Digital Linearisation (DDL) features for digital motion controllers improves the scanning linearity by a factor of to 1000. Tracking error and phase lag are reduced to almost non noticeable values. (Photo: Physik Instrumente (PI))



Fluorescence intensity image (left) and fluorescence lifetime image of a liver cancer cell, stained with the NBD dye to analyze the organization of lipids. In the image on the right, the lifetime can be used to clearly identify different lipid structures. (Photo: PicoQuant)

PI

PIFOC® Revisited: P-737 Piezo-Z Microscopy Specimen Scanning Stage



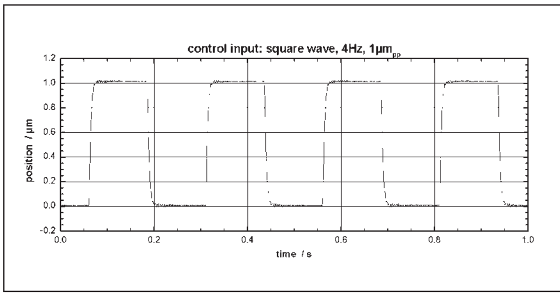
PI is the inventor of high-speed Piezo-Z objective steppers. Today the term PIFOC® is practically synonymous with all high-resolution vertical drives for microscope objectives. Depending on the application, it can be advantageous to adjust the sample instead of the objective. While no sample stage can beat the speed of the fastest PIFOC® objective positioners (due to the stiffer and more compact design), the P-737 stage allows for convenient Z-stack imaging with multiple objectives and very high throughput. Im both cases the effect remains the same: the focal plane moves through the sample. This is why the P-737 is also marketed under the PIFOC® trademark.

PIFOC® P-737 high-speed vertical positioning systems are designed for integration into motorized XY microscopy stages of leading manufacturers such as Märzhäuser. While the XY stage positions the sample, the piezo flexure-based P-737 moves the sample along the optical axis to adjust the focus quickly and precisely. Vertical stepping with nanometer precision takes only a few milliseconds. The large aperture is designed to accommodate a variety of specimen holders including slides or multiwell plates.

High-speed Z-steps for fast focus control and imaging

The immediate response of the solid-state piezo drives enables rapid Z-steps with typically 10-to-20-times-faster step-and-settle than classical stepper motor drives. This leads to significantly higher image acquisition speed and throughput. The P-737 is available with travel ranges of 100 or 250 µm and offers a choice of feedback sensors between strain gauge or non-contact, capacitive position sensors, depending on the accuracy requirements.

Settling time is in the 10 ms range – here, 1 µm steps



Analog or Digital Systems

The P-737 together with the E-625 piezo-controller, offers a cost-effective system for high-speed, high-resolution positioning of microscopy specimens. The controller features a choice of a 20-bit digital interface or a broadband analog interface for the target position.

The capacitive-sensor-equipped version can also be operated with the sophisticated E-753 digital servo-controller. The main advantage of this controller is its adaptability to changing load conditions on the piezo stage. No matter what load is applied, the system can always provide an optimum combination of speed, settling time and resolution.

PIFOC® objective positioners and scanners are available with travel ranges of up to 400 µm. QuickLock thread adapters enable fast mounting of the PIFOC® on the microscope and flexible replacement of objective

PI

PiezoMove: Moving, Positioning, Scanning

Microfluidics, Biotechnology, Medical Engineering, Adaptronics

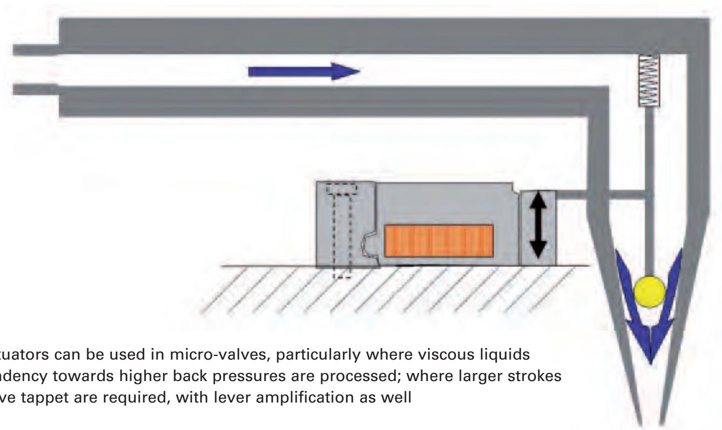
Piezo = nano = expensive?

Piezo actuators can do a lot more than "just" precision. Their excellent dynamics and high force play a crucial role in many areas, while the (nanometer) precision is of lesser importance: e.g. for fast switching, vibration cancellation, or to adjust tools in machines.

In these applications the piezo actuator is one – if not the only – solution and in the case of the new PiezoMove OEM actuators, at a very attractive price.

PiezoMove OEM actuators: Apply motion, how and where it is required

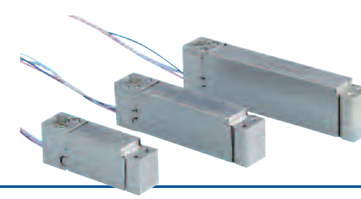
PiezoMove actuators combine guided motion and long travel ranges up to 1 mm and provide precision in the 10 nm range if ordered with the position sensor option. They are very compact, easy to integrate, require no maintenance and provide service life of Billions (10^9) of cyles.



Linear actuators can be used in micro-valves, particularly where viscous liquids with a tendency towards higher back pressures are processed; where larger strokes of the valve tappet are required, with lever amplification as well

PI supplies a variety of standard integration levels and also customized versions: From simple piezo stack components and preloaded linear actuators through to 6-axis positioning systems with sub-nanometer precision.

3 Actuator Families



P-601: Travel ranges to 400 µm, slight tilt

P-602: Travel ranges to 1000 µm, slight tip and tilt, high stiffness

P-603: Travel ranges to 500 µm, slight tilt, cost-optimized for high quantities

Application fields

Microfluidics:

Valves, pumps, microliter and nanoliter dosing

Biotechnology:

Cell manipulation, patch-clamp, microarrays, nanoliter dosing, dispensers, microstructuring with imprint processes

Medical engineering:

Diaphragm pumps, valves, dosing, injection, sample handling

Mechatronics, adaptronics:

Active structures, vibration isolation, active tools, structure deformation

Laser technology, metrology:

Cavity tuning, adjustment of optics or slit widths, sample positioning, beam control

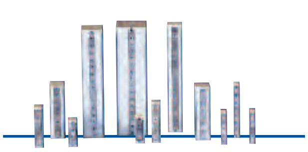
For more information visit http://www.pi.ws

Low-cost Piezo Systems with Various Levels of Integration

For more information visit http://www.pi.ws

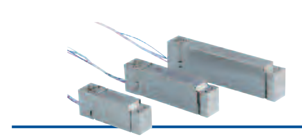
Piezo Actuator / Stage	Description	Travel Range up to	Guiding System	Mechanical Levels of Integrations	Positioning Sensor	Stiffness
P-882 - P-888	PICMA® Multilayer Piezo Stack Actuators	30 µm	-	-	optional SGS	up to 200 N/µm
P-871	PICMA® Piezo Bender Actuator	1600 µm	-	-	optional SGS	0.02 N/µm
P-842 - P-845	Preloaded Piezo Actuators	90 µm	-	case, mechanically preloaded	optional SGS	up to 200 N/µm
P-601	PiezoMove Linear Actuator	400 µm	flexure guiding system prevents tip and tilt	motion amplifier, mechanically preloaded	optional SGS	up to 0.8 N/µm
P-602	PiezoMove Flexure Actuator with High Stiffness	1000 µm	flexure guiding system provides straight motion with no tip and minimum tilt	motion amplifier, mechanically preloaded	optional SGS	up to 2.3 N/µm
P-603	PiezoMove Linear Actuator	500 µm	flexure guiding system prevents tip and tilt	motion amplifier, mechanically preloaded	optional SGS	up to 0.36 N/µm
P-712, P-713	Low-Profile Piezo Scanner	30 µm in X, XY	flexure guiding system provides straight motion with no tip and minimum tilt	motion amplifier, mechanically preloaded, P-713 parallel-kinematics	optional SGS	up to 0.8 N/µm
P-611	NanoCube® XYZ Piezo Stage	100 µm in up to 3 axes	flexure guiding system provides straight motion with no tip and minimum tilt	motion amplifier, mechanically preloaded, serial kinematics	optional SGS	up to 0.8 N/µm

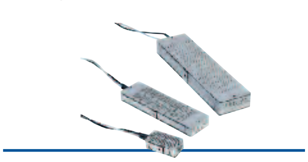
Controller	Function	Positioning Sensor	Number of Channels	Peak Output Current	Peak Output Power
E-831	Piezo Amplifier	-	1	100 mA (< 8 ms)	2 W without heat sink, 5 W with additional heat sink
E-610.00	Piezo Amplifier	-	1	180 mA (< 15 ms)	18 W (< 15 ms)
E-610.S0	Motion Controller	SGS	1	180 mA (< 15 ms)	18 W (< 15 ms)
E-621.SR	Networkable Motion Controller Module	SGS	1, networkable up to 16	120 mA (< 5 ms)	12 W (< 5 ms)


P-882 · P-888 PICMA® Multilayer Piezo Stack Actuators

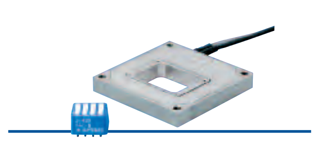

P-871 PICMA® Piezo Bender Actuator

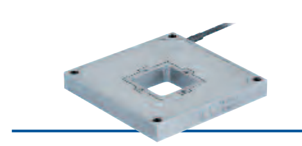

P-842 · P-845 Preloaded Piezo Actuators


P-601 PiezoMove Linear Actuator

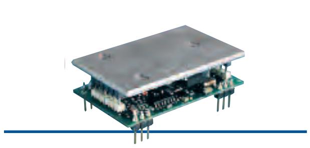

P-602 PiezoMove Flexure Actuator with High Stiffness


P-603 PiezoMove Linear Actuator


P-712 Low-Profile Piezo Scanner


P-713 Low-Profile Piezo Scanner


P-611 NanoCube® XYZ Piezo Stage


E-831 Piezo Amplifier


E-610 Piezo Amplifier/ Motion Controller


E-621.SR Motion Controller Module

PiezoMove: Travel Ranges to 1 mm

Easy Integration and Adaptation

Systems Thinking

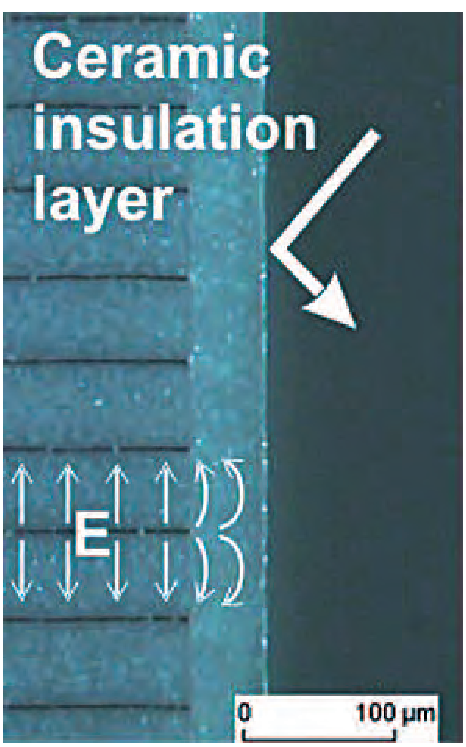
PI provides a range of different control electronics for PiezoMove actuators.
These range from solderable OEM piezo driver modules to advanced digital motion controllers.
PI's wide range of actuators and control electronics allows for an optimum match of performance and cost for any application.
In addition to standard products, modified or completely custom engineered solutions are available at competitive prices. The following parameters can be modified to suit an application:

- Travel range
- Dynamics
- Force
- Precision

Levels of Integration: From Stack Actuator to 6-Axis Stage

	Stack actuators	Lever-amplified actuators	Positioning systems
Travel ranges	up to approx. 150 µm	up to 1 mm	up to 2 mm
Axes moved	one	one	up to three linear axes and three tip/ tilt axes
Sensors	SGS optional	SGS optional	SGS or direct measuring capacitive sensors
Linearity	up to 99.8 %	up to 99.8 %	over 99.9 %
Guidance	none	flexures for rotations <10"	flexures for rotations <2"
Space required	low	low	depends on features
Price	low	low	depends on features
Integration effort	high	low	low

PI Actuators Offer Longer Service Life



The ceramic insulating layer prevents the penetration of water molecules and reliably protects the sensitive internal electrodes from mechanical damage and dirt

Different Piezo Solutions: Simple Piezo Components to Complex (Nano) Positioning Systems

Actuator: Piezo ceramic stack actuators are the driving force in many of PI's motion systems. Piezo actuators can move very rapidly due to their high stiffness; response times are as short as microseconds and scan frequencies up to several tens of kilohertz are feasible. The resolution is virtually unlimited, depending only on the electrical noise of the driver, making piezo actuators predestined for precision motion applications. The displacement of basic actuators is limited to a few tens of micrometers, however, and they need to be handled with care.

Preloading and Decoupling Against Lateral Forces: Encased piezo stacks can handle higher forces. The housing can decouple the piezo ceramics from lateral forces. Integrated mechanical preloading allows dynamic operation with higher loads.

Guiding System: Piezo ceramic stacks do not move in perfectly straight lines. For precise linear motion, a guiding system is required. Flexures guarantee the best performance because they provide frictionless, backlash-free motion and unlimited lifetime. If designed well, preloading and decoupling of unwanted forces can also be integrated without negative effects on the system stiffness.

Lever Amplification for Longer Travel Ranges: The guiding system can be designed in such a way that it acts like a mechanical lever and increases the displacement of the piezo ceramic stack. Lever amplifiers reduce the system stiffness and this is where experience pays off. PI uses CAD modeling, FEA analysis and laser vibrometry for design optimization and testing. Based on 3 decades of experience with piezo flexure design PI actuators provide the best combination of lifetime, stiffness, precision and size.

Sensor: Position feedback sensors are available when absolute position information is required. Strain gauge sensors (lower cost, accuracy to 0.5%) and capacitive sensors (higher precision to 0.01 %) are available.

Controller: The higher the demands placed on the system precision, the larger the role played by the motion controller. Open-loop actuators can be controlled directly via a voltage amplifier. To achieve maximum positional accuracy and scanning linearity, however, closed-loop control and digital control algorithms are indispensable.

Multi-Axis Positioners are constructed as parallel-kinematic systems for the highest possible precision, and controlled by advanced digital nanopositioning controllers.

PI

The compact M-810 is smaller in diameter than a CD, but offers long travel ranges in six axes with excellent position resolution

Six Degrees of Freedom in a Small Package

New Ultra-Compact Miniature Hexapod

The new M-810 miniature Hexapod combines all advantages of PI's other proven parallel-kinematic systems in the smallest of packages. With a diameter of only 10 cm and a height of 11.8 cm, the M-810 offers travel ranges of up to 40 mm in the XY plane and 13 mm in the Z-direction. Despite of its small size, the hexapod can reliably position loads of up to 5 kg at velocities of 10 mm/s.

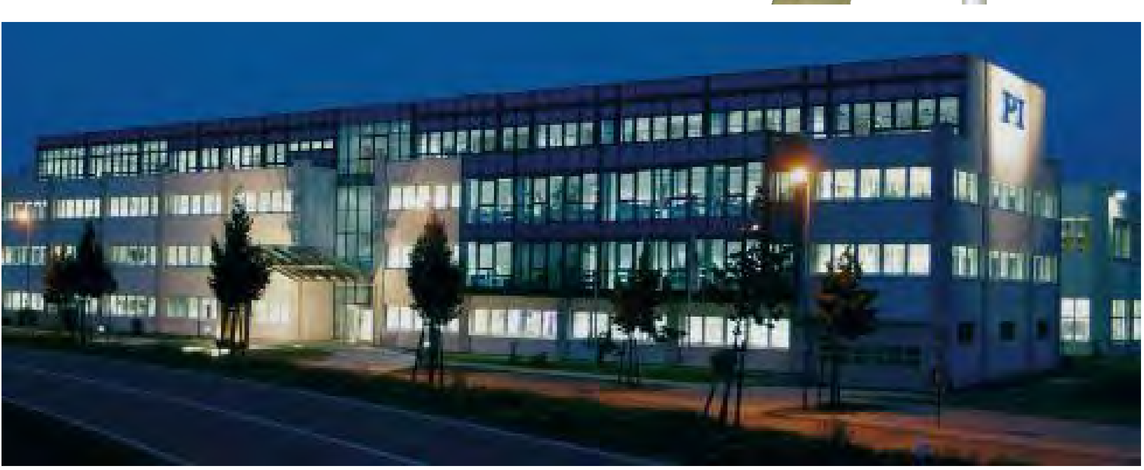
The limited space necessitated the usage of new tec hnologies for encoders, motors and limit switches. Nevertheless, control is 100 % compatible to previous standard PI Hexapods.

As with other parallel-kinematics positioners from PI, the six high-resolution actuators are connected directly to a single moving platform. The user is able to define the center of rotation (pivot point) independent of platform motion with a simple software command.

In contrast to conventional, stacked, multi-axis systems, there is no accumulation of guiding and lever-arm errors.

Click here for Article on

Hexapods in Spine Surgery



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