Tools for Microscopy & Biomedical Design

Piezo Stages, Lens Positioners & Scanners, Steering Mirrors, Actuators

Overview

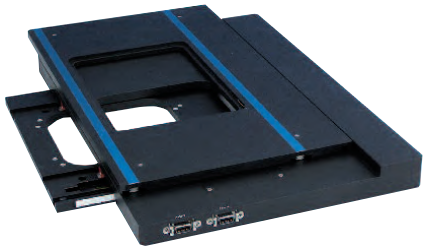
Piezo Stages, Objective Scanners

PInano™ Cost Effective Piezo Stages for SR Microscopy

- Z, XY, XYZ, Low Profile, Travel to 200x200x200µm
- Fast Response, High Speed Version for Particle Tracking
- Cost-Effective and Very Reliable with PICMA® Technology
- Compatible w/ Leading Image Acquisition Software Package

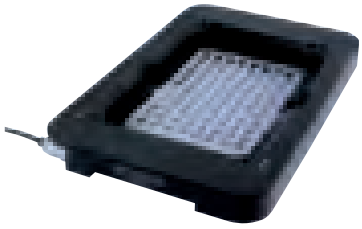
PIFOC® Drives: Fastest Z-Steps, for high NA Objectives

- Fastest Z-Scanners. Fres to 1100 Hz, Step & Settle <5 msec
- Long Travel Versions to 1000 µm
- Capacitive Non-Contact Sensors; Superior Linearity & Stability
- Quick Lock Adapter for Easy Attachment



PILine® Long Travel XY Piezo Linear-Motor Stages

- Closed-Loop; Linear Motors & Encoders: High Speed to 100 mm/s
- Self-Locking Piezomotor Principle:
  Extreme Stability at Rest, No Heat Generation
- Low Profile Design, Motors Completely Integrated
- Compatible with PI Piezo Scanning Stages



Piezo Stage for Well Plate Scanning

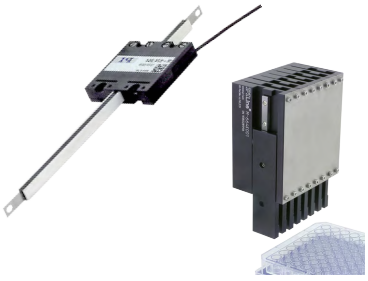
- High-Speed Piezo Motion with Travel Ranges to 500 µm
- Nanometer Resolution + much Faster than Motorized Stages
- Large Clear Aperture to Accommodate Specimen Holders
- Perfect Mechanical Fit to OEM Manual or Motorized Stages

Overview

Actuators, Linear Motors, PZT Tubes

NEXACT® Piezo Micromanipulator / Nanopositioning Motors

- Fast Step & Scan Mode, Replaces Piezo Worm Actuators
- 30 mm Standard Travel Range, Picometer Resolution
- Self Locking, with no Heat Dissipation, Nanometer Stability
- Non-Magnetic and Vacuum-Compatible Working Principle

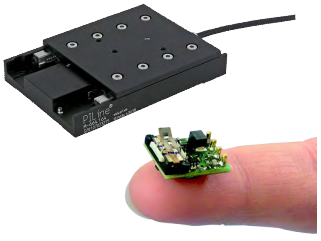


Ultrasonic Ceramic High Linear Motors for Bio-Automation

- Fast: Velocity to 450 mm/sec
- Travel Ranges to 150 mm
- Self-Locking at Rest, Non Magnetic
- Resolution to 0.05 µm

Piezo Tubes and Shear Piezo Actuators

- Standard & Custom Sizes, for OEM Applications
- XYZ-Positioning
- Sub-Nanometer Resolution
- For Scanning Microscopy



Miniature Motorized Linear Stages & Linear Slides

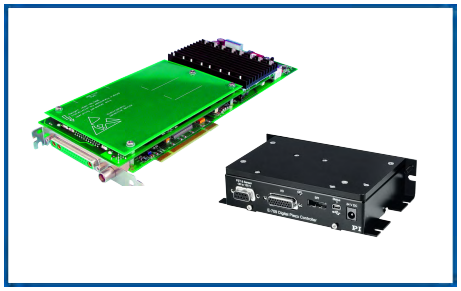
- Travel Ranges 2 mm to 50 mm
- Sub-µm Resolution, 2 to 400 mm/sec Velocity
- DC-Servo, Stepper and Piezo Motor Drives
- Optional Linear Encoders & Vacuum Versions

Overview

Piezo Controllers and Drivers

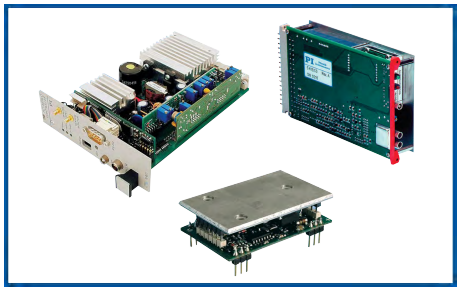
Advanced Digital Piezo Controllers

- Change Parameters on the Fly
- Digital Linearization Provides up to 3 Orders Improved Scanning Accuracy
- ID Chip Support for Automatic Calibration
- Real Time Interfaces: PIO, SPI; additional USB, Ethernet, RS-232



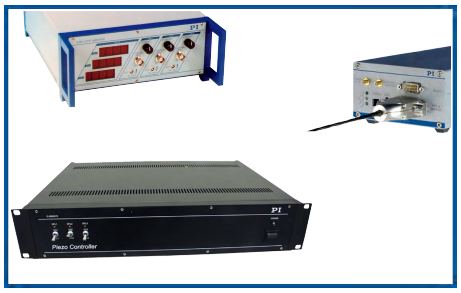
Affordable Digital Controllers

- Digital Performance for the Cost of Analog
- Bench-Top and Plug-In Cards
- I/O, Trigger Functions, Wave Table for User-Defined Curves
- Extensive Software Support



OEM Controllers and Amplifiers

- Low Cost
- Analog & Optional 24-Bit USB Interfaces
- For Capacitive and Piezoresistive Strain Gauge Sensors
- Open-Loop and Closed-Loop Versions



Bench Top Closed-Loop Controllers

- Analog & Optional 24-Bit USB Interfaces
- For Capacitive and Piezoresistive Strain Gauge Sensors
- Optional Display and Manual Operation
- 1 to 3 Channels

Piezo · Nano · Positioning

news

Issue 39

Moving samples into the spotlight:

Nanopositioning systems in fluorescence microscopy

(Photo: PicoQuant)

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 t o increase the signal-to-noise ratio.

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)

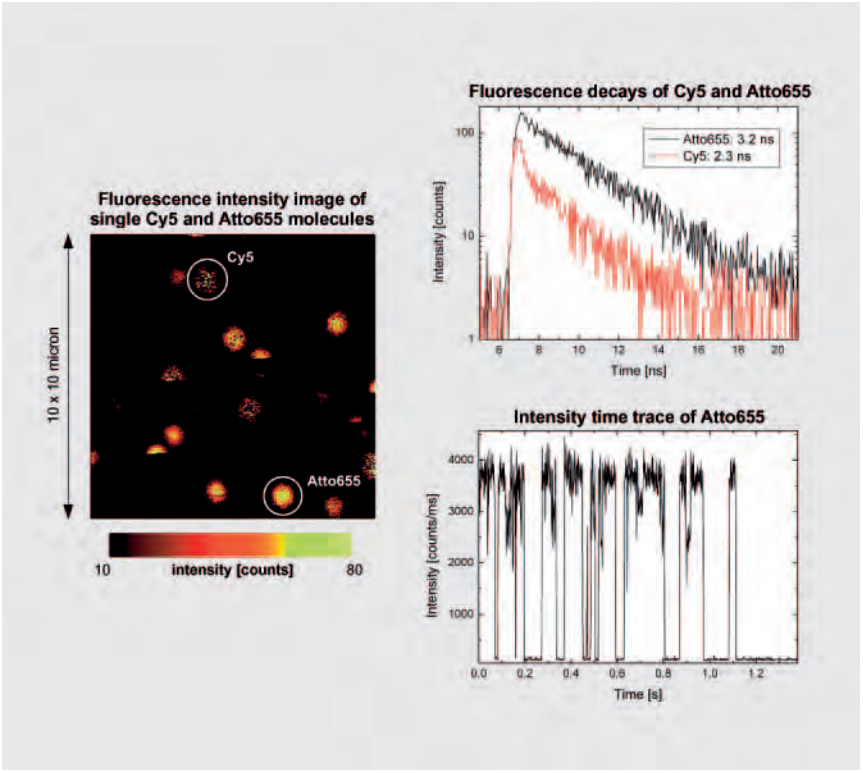
Maximum r epeatability thanks t o dynamic digital linearization

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.

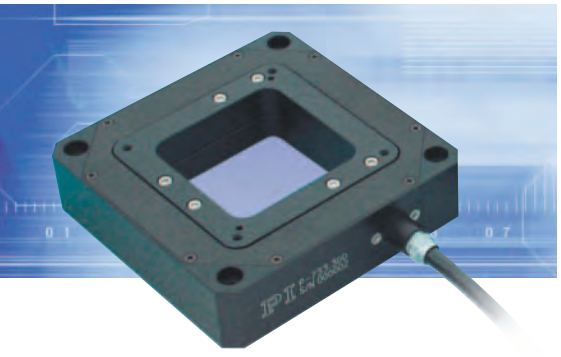
If the sample cannot be moved because it is enclosed in an environmental chamber, for example, the same positioning system can be used to the microscope objective instead. In all cases, however, the integrated direct-measuring capacitive sensors allow the scanner to produce an accurate determination 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

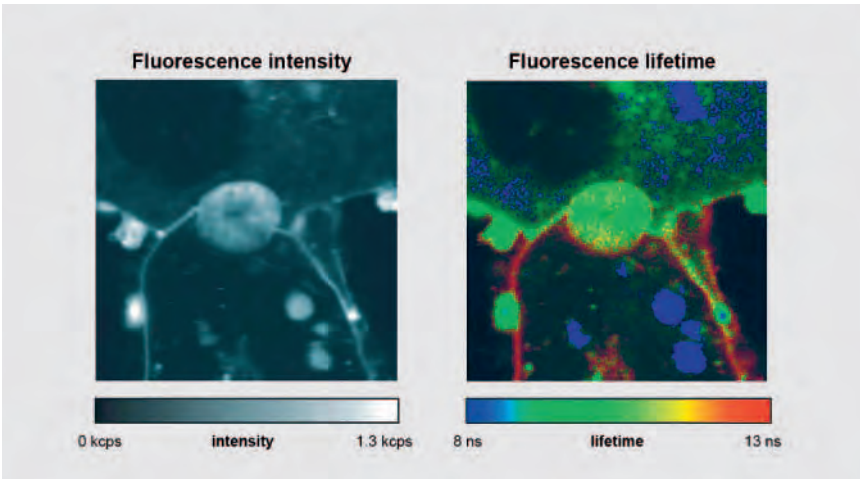
The P-721.CLQ PIFOC® Z-drives are used for three-dimensional images. They provide millisecond response times and their flexure guiding and capacitive sensors enable very accurate positioning, even when the travel ranges are relatively large. "PI's piezo-based nanopositioning systems make a decisive contribution 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))

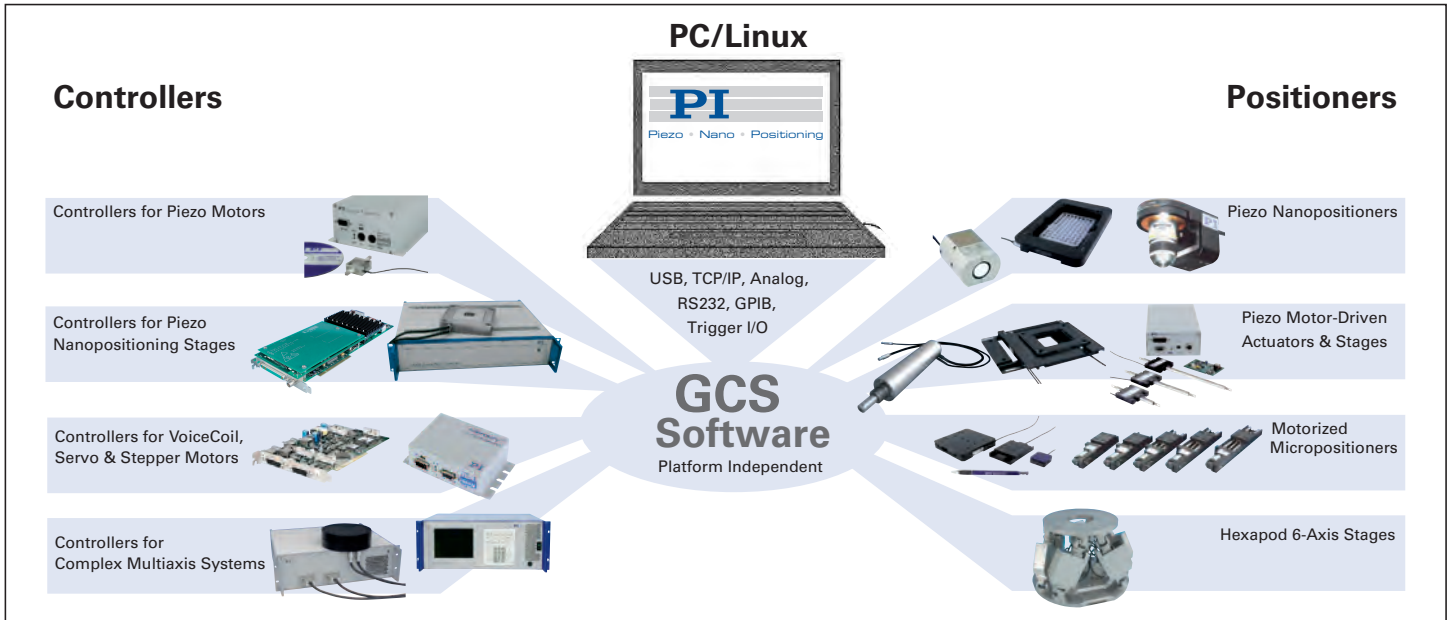


Fluorescence intensity image (left) and fluorescence lifetime image of a liver cancer cell, stained with the NBD dye to analyze the organization of lipids. In the image on the right, the lifetime can be used to clearly identify different lipid structures. (Photo: PicoQuant)

Software Tools

For LabView, C++, VB, Matlab, Image Acquisitiong Packages, NI DAC Cards, ...

PI provides high-level, robust, easy-to-use software tools for fast, seamless integration of motion systems into application control software

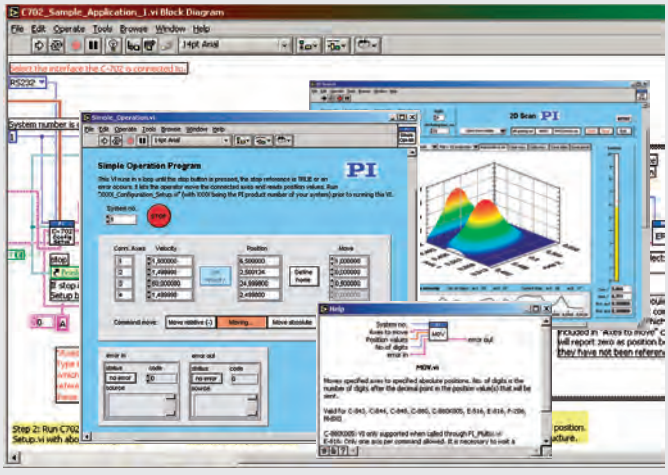


Communication between PI components is based upon a universal command set (GCS – General Command Set). It decouples hardware and software, and is used for all drive systems

The high quality of positioning systems is made apparent in daily operation by PI software. Starting with simple commissioning, through convenient operation with a graphical interface, to quick and simple integration in customized programs with high performance, PI software covers all aspects important to an application.

Universal Command Set Simplifies Commissioning and Programming

For uniform operation of nano and micropositioning systems, the universal PI General Command Set (GCS) is used. GCS operation is independent of the controller or drive principle used, so that several positioning systems can be controlled together, or new systems can be introduced with a minimum of programming effort. With GCS the development of custom application programs is simplified and less prone to errors, because the commands for all supported devices are identical in syntax and function. Through the use of the GCS command set with its convenient functions, the orientation phase and application development process is significantly accelerated. The GCS commands are available at the controller terminal, in macros and in the form of a universal driver set for LabVIEW (VIs), Windows dynamic link libraries (DLL) and Linux libraries. This facilitates the development of custom macros, as well as integration with programming languages like LabVIEW, C++ or MATLAB.



Easy integration in LabView. Quick access to the full functionality
Contact PI for our extensive library of software examples!

PI piezo stages & controllers are compatible with all major image acquisition software packages such as Andor iQ™, Metamorph™, µManager™, Slidebook™,Simple PCI™, NIS Elements™, ImagePro™.

For more information on PI software support, go online or request the PI software brochure

Software and manuals can be downloaded, from the PI Support server

Software Updates Online

PI supports users with free updates, detailed online help and well structured manuals which ease initiation of the inexperienced but still answer the detailed questions of the professional.

Supported Operating Systems
Microsoft Windows Vista
Microsoft Windows XP
Microsoft Windows 2000
Linux

M-545 Microscope Stage

Long-Range Motion for Sample Positioning

M-545 manual XY microscopy stage with 25 x 25 mm travel shown with optional PI nano™ piezo nanopositioner (200 µm motion in X, Y und Z) on top. The M-545 stage was designed to provide a stable basis for piezo stages, especially when the highest step-and-settle performance is required

- **Stable Platform for P-545 PI nano™ Piezo-Nanopositioniersysteme**
- **Low Profile for Easy Integration: 30 mm**
- **25 mm x 25 mm Travel Range**
- **Micrometer Screws, Motor Upgrade Available**
- **For Nikon, Zeiss, Leica and Olympus Mikroscopes**

The M-545, 25 x 25 mm microscope stage, is designed to provide a stable platform for piezo scanning stages of the P-545 PI nano™ series. These high-speed, high-resolution XY / XYZ piezo stages allow nanometer-precision adjustment of the specimen holder in up to three dimensions over 200 µm. The M-545 is also compatible with the following capacitive-feedback type piezo stages: P-733, P-5x7, P-5x8, P-54x and P-56x (s. p. 2-72).
The basic M-545 model is equipped with manual micrometers.

Motorizing for Automated Tasks

The M-545 XY-stage can be supplemented with motorized actuators M-229 (s. p. 1-44). The product number M-545.USC comprises the complete package of two stepper linear actuators with controller and joystick. M-545.USG includes two stepper linear actuators with mounting hardware.

Ordering Information

M-545.2MO
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Olympus Microscopes

M-545.2MN
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Nikon Microscopes

M-545.2ML
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Leica Microscopes

M-545.2MZ
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Zeiss Microscopes

Versions for other microscopes on request.

Accessories

M-545.USC
Upgrade Kit with Stepper-Mikes, Controller and Joystick for M-545 PI nano™ Manual XY Open-Frame Stage

M-545.USG
Upgrade Kit with Stepper-Mikes, for M-545 PI nano™ Manual XY Open-Frame Stage

M-545.SHP
Adapter Plate for Sample Holders for M-545 PI nano™ Manual XY Open-Frame Stage

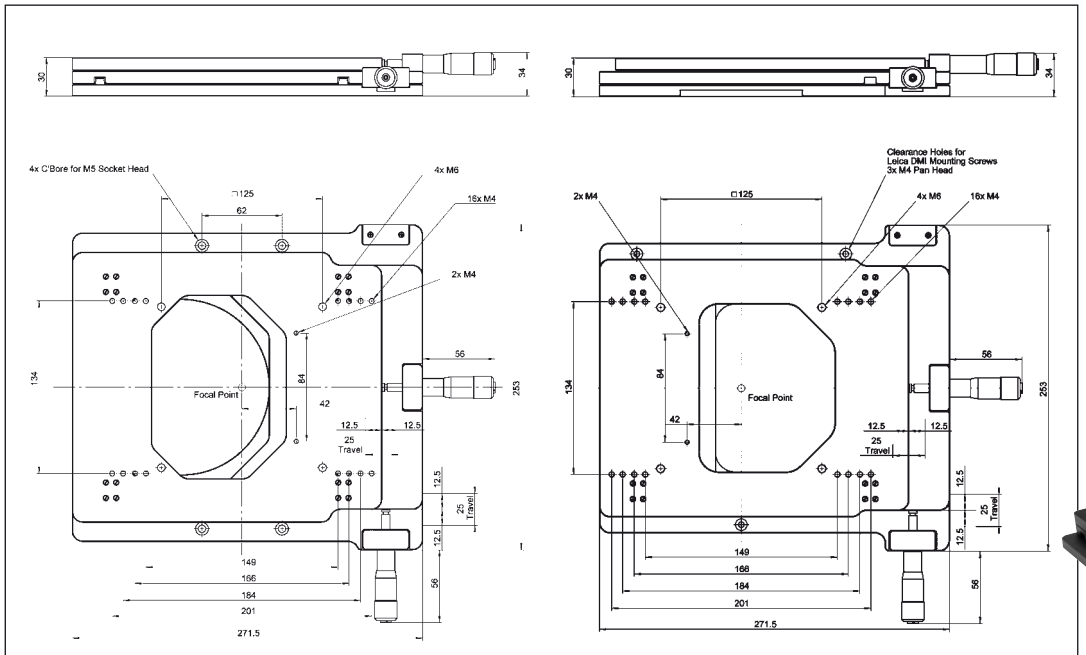
Accommodates the following PI nanopositioning stage series:
P-517/518/527/528, P-541/542, P-560 PIMars™ and P-545 PI nano™

Adapter available for P-733 nanopositioners:

P-733.AP1
Adapter Plate for Mounting of P-733 Stages on M-545 PI nano™ Manual XY Open-Frame Stage

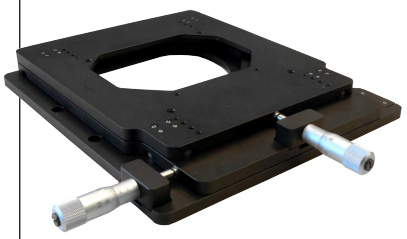
Additional accessories on request.

Ask about custom designs!



M-545.2MO, M-545.2MN dimensions in mm.
Mounting adapters for Olympus and Nikon microscopes respectively included in delivery

M-545.2ML dimensions in mm



M-545 manual XY microscopy stage

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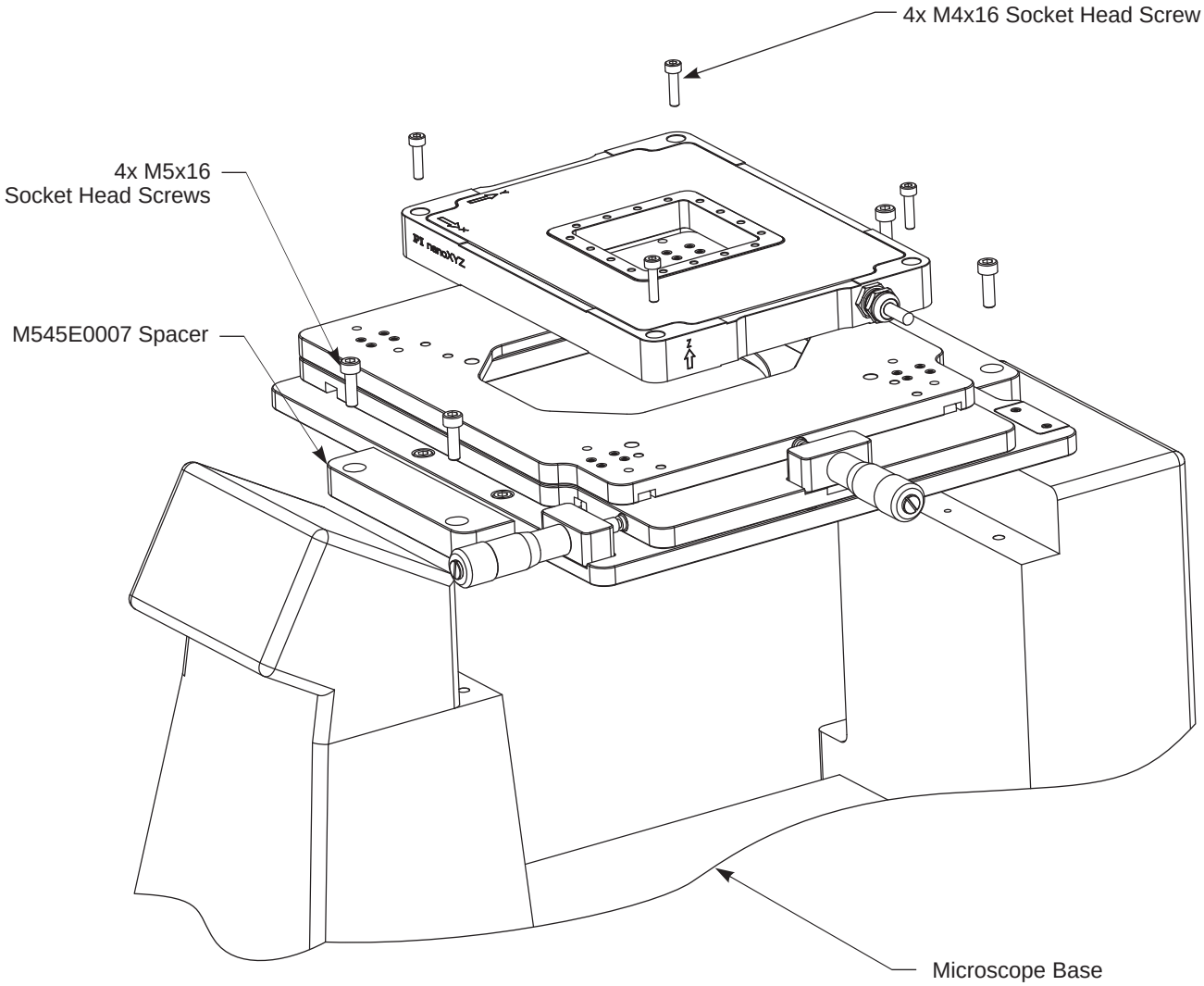
The newest release for data sheets is available for download at www.pi.ws. R1 10/01/14.0

5.2. M-545.2MN Mounting (for Nikon Microscopes)

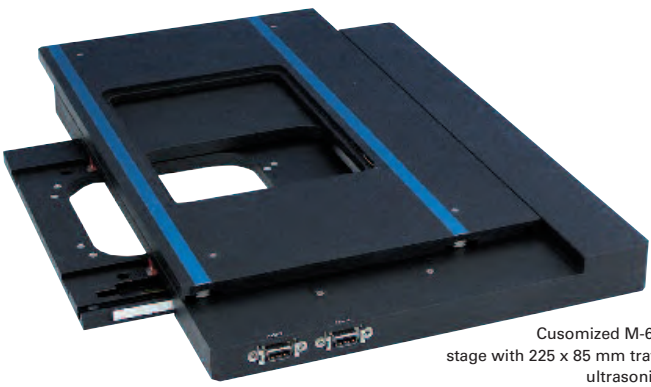
Spacer plates are used to adapt the M-545 stage to the Nikon microscope base.

The proper hardware sizes are shown below.



M-686K Custom Piezo Motor Microscope Stage

Low Profile and High Velocity with PILine® Ultrasonic Piezo Motors



Cusomized M-686 microscopy stage with 225 x 85 mm travel and PILine® ultrasonic piezo motors

- **Low 27-mm-profile**
- **Velocity 100 mm/s**
- **Large Clear Aperture to Accomodate Specimen Holders or P-737 PIFOC® Specimen-Focusing Z-Stage**
- **Travel Range 25 x 25 mm, 130 x 85 mm or 225 x 85 mm**
- **Up to 7 N Force Generation**
- **Direct Metrology Linear Encoder with 0.2 µm Resolution**
- **PILine® Ceramic Motors: Non-Magnetic and Vacuum-Compatible Working Principle**
- **Self Locking at Rest**

P-545 PI nano™ XY / XYZ Piezo Microscope Stages

Low-Profile, Low-Cost Nanopositioning Systems for Super-Resolution Microscopy

PI nano™ series nanopositioning stages feature a very low profile of 20 mm (0.8), a large aperture for 3 x 1'' slides and deliver highly accurate motion with sub-nanometer resolution in up to 3 axes. Slide / petri dish holders optional

- **Low Profile for Easy Integration: 20 mm (0.8'')**
- **Up to 200 x 200 x 200 µm Travel Ranges**
- **Large Clear Aperture for 3 x 1'' Slides**
- **Recessed Sample Holders for Maximized Utility Available**
- **Outstanding Lifetime Due to PICMA®Piezo Actuators**
- **Cost-Effective Design due to Piezoresistive Sensors**
- **Compatible w/ Leading Image Acquisition Software Package**
- **Closed-Loop Control for High Repeatability and Accuracy**
- **Millisecond Step Time, Ideal for Super-Resolution Microscopy**
- **24-Bit Controller w/ USB, Ethernet, RS-232 Interface and Analog Control**
- **Available Manual Long-Travel Stage with Motor Upgrade Option**

Long Travel, Low Profile, Optimized for Microscopy

PI nano™ XY and XYZ low-profile piezo scanning stages are optimized for easy integration into high-resolution microscopes. They feature a very low profile of 20 mm (0.8") and a large aperture designed to hold Petri dishes and standard slide holders. The long travel ranges of up to 200 x 200 x 200 µm with nanometer closed-loop resolution are ideal for leading-edge microscopy and imaging applications.

Application Examples

- Super-resolution microscopy
- 3D Imaging
- Laser technology
- Interferometry
- Metrology
- Biotechnology
- Screening
- Micromanipulation

Cost Effective Design, High Performance

PI nano™ series piezo positioning stages are designed to provide high performance at minimum cost. For highly-stable, closed loop operation, piezoresistive sensors are applied directly to the moving structure and precisely measure the displacement of the stage platform. The very high sensitivity of these sensors provides optimum position stability and responsiveness as well as nanometer resolution. A proprietary servo controller significantly improves the motion linearity compared to conventional piezoresistive sensor controllers.

High Reliability and Long Lifetime

The compact P-545 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and provide better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free, not subject to wear and offer extraordinary reliability.

Background: the piezo controller is included and comes with a 24-bit resolution USB port as well as ethernet, RS-232 and analog interface. Foreground: The optional M-545 manual XY stage provides a stable platform for the PI nano™ piezo stages. Custom stage version shown

Ordering Information

P-545.2R7
PI nano™ XY Nanopositioning System, Aperture for 3 x 1" Microscope Slides, 200 x 200 µm, Piezoresistive Sensors, with USB Controller

P-545.3R7
PI nano™ XYZ Nanopositioning System, Aperture for 3x1" Microscope Slides, 200 x 200 x 200 µm, Piezoresistive Sensors, with USB Controller

Accessories

M-545.2MO
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Olympus Microscopes

M-545.2MN
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Nikon Microscopes

M-545.2ML
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Leica Microscopes

M-545.2MZ
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Zeiss Microscopes

P-545.PD3
35mm Petri Dish Holder for P-545 PI nano™ XY Nanopositioning Systems

P-545.SH3
25 x 75mm Slide Holder for P-545 PI nano™ XY Nanopositioning Systeme

P-545.PP3
Plain Plate for Accessories for P-545 PI nano™ XY Nanopositioning Systems

POWERED BY LabVIEW

MetaMorph®

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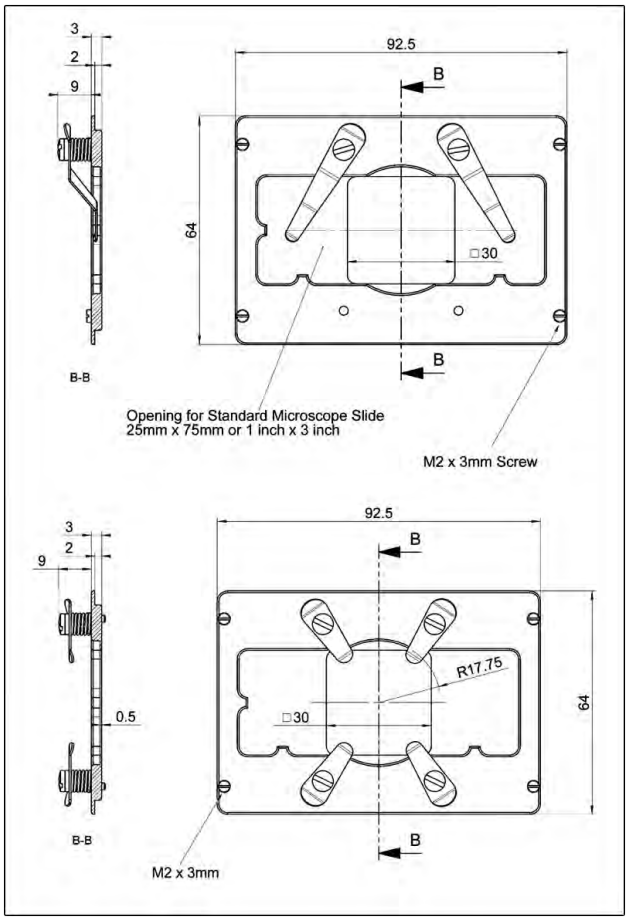
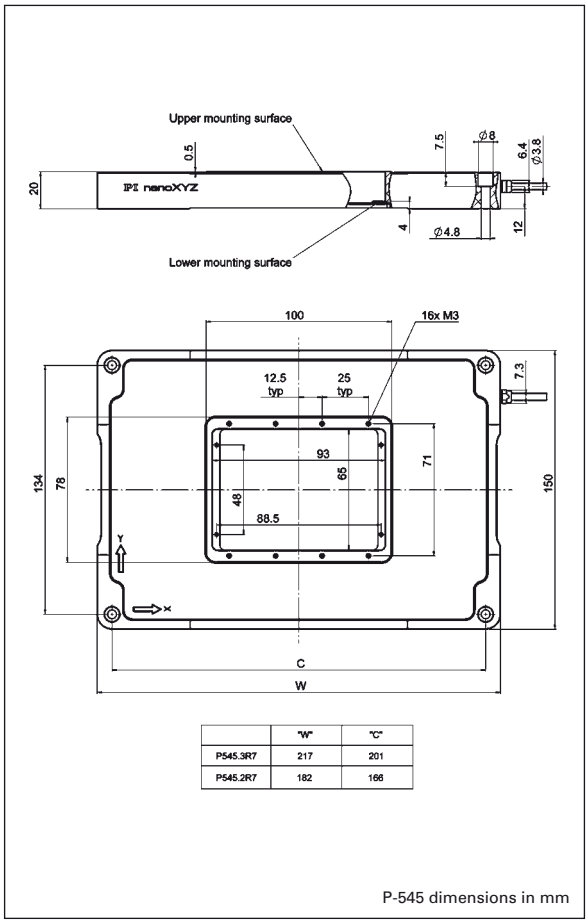
The newest release for data sheets is available for download at www.pi.ws. R1 10/01/14.0

High Speed Version for Particle Tracking Available





	"W"	"C"
P545.3R7	217	201
P545.2R7	182	166

P-545 dimensions in mm

Accessories: Slide holder (above) and Petri dish holder (below), dimensions in mm

Technical Data

Model	P-545.2R7	P-545.3R7	Unit	Tolerance
Active axes	X, Y	X, Y, Z		
Motion and positioning				
Integrated sensor	piezoresistive	piezoresistive		
Closed-loop travel	200 x 200	200 x 200 x 200	µm	
Closed-loop resolution*	1	1	nm	typ.
Linearity	±0.1	±0.1	%	typ.
Repeatability	< 5	< 5	nm	typ.
Mechanical properties				
Push/pull force capacity	100 / 30	100 / 30	N	max.
Load	50	50	N	max.
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance	6	6 (X, Y), 12 (Z)	µF	±20%
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum		
Mass	1	1.2	kg	±5%
Cable length	1.5	1.5	m	±10 mm
Sensor / voltage connection	Sub-D, 25 pin	Sub-D, 25 pin		
Piezo controller (included in delivery)	E-545	E-545		

* Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion measured with interferometer.

PInano™ Z, High-Speed Piezo-Z Slide Scanner

Low-Profile, Low-Cost, Nanopositioning System for Super Resolution Microscopy

PInano™ Z nanopositioning stages (shown with optional slide and Petri dish holder) feature a very low profile of 20 mm (0.8"), a large aperture and deliver highly accurate motion with sub-nanometer resolution

- **Extremely Fast Step & Settle, From 5 msec**
- **Low Profile for Easy Integration: 20 mm (0.8")**
- **100 and 200 µm Travel Ranges**
- **Proprietary Technology: Outstanding Lifetime Due to PICMA® Piezo Ceramic Stacks**
- **Cost-Effective Design due to Piezoresistive Sensors**
- **Compatible w/ Leading Image Acquisition Software Package**
- **Closed-Loop Control for High Repeatability and Accuracy**
- **USB Controller & Software Included**

High-Speed, Low Profile, Optimized for Microscopy

The new PInano™ Z low-profile piezo Z stages are optimized for very fast step and settle and easy integration into high-resolution microscope applications. They feature a very low profile of 0.8" (20 mm), a large aperture, and travel ranges of up to 200 µm with sub-nanometer closed-loop resolution–ideal for leading-edge microscopy and imaging applications.

Application Examples

- 3D Imaging
- Scanning microscopy
- Laser technology
- Interferometry
- Metrology
- Biotechnology
- Micromanipulation

Longest lifetime is guaranteed by the integrated ceramic-encapsulated PICMA® piezo actuators. Due to the significantly higher humidity resistance, the patented PICMA® design provides up to 10 times longer life than conventional piezo actuators (see latest test results at www.pi.ws/picma).

Cost Effective Design, High Performance

PInano™ series piezo positioning stages are designed to provide high performance at minimum cost. For highly-stable, closed loop operation, piezoresistive sensors are applied directly to the moving structure and precisely measure the displacement of the stage platform. The very high sensitivity of these sensors provides optimum position stability and responsiveness as well as nanometer resolution. A proprietary servo controller significantly improves the motion linearity compared to conventional piezoresistive sensor controllers.

Excellent Guiding Accuracy

Flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. FEA techniques are used to give the design the highest possible stiffness in, and perpendicular to, the direction of motion, and to minimize linear and angular runout. Flexures allow extremely high-precision motion, no matter how minute, as they are completely free of play and friction.

Controller & Software Included

The PInano™ Z stage comes complete with a powerful digital closed-loop controller. The controller features two digital interfaces (USB & RS-232) as well as a high-speed analog interface and is compatible with leading image acquisition software packages such as MetaMorph etc.
The controllers are delivered including software for Windows operating systems. DLLs and LabVIEW drivers are available for automated control.
The extensive command set is based on the hardware-independent General Command Set (GCS), which is common to all current PI controllers for both nano- and micropositioning systems. GCS reduces the programming effort in the face of complex multi-axis positioning tasks or when upgrading a system with a different PI controller.

Ordering Information

P-736.ZR1S
PInano™ Z Piezo Slide Scanner System, 100 µm, Slide-Size Aperture, Piezoresistive Sensors, with USB Fully Digital Controller

P-736.ZR2S
PInano™ Z Piezo Slide Scanner System, 200 µm, Slide-Size Aperture, Piezoresistive Sensors, with USB Fully Digital Controller

Accessories

P-545.PD3
35mm Petri Dish Holder for P-545 PInano™ Piezo Stages

P-545.SH3
Microscope Slide Holder for PInano™ Piezo Stages

P-736.AP1
Adapter Plate P-736 PInano™ Piezo Z to M-545 XY Microscope Stages

The PInano™ Z stage can be combined with the M-545 high-stability, long-travel manual/motorized microscope stage (25 x 25 mm)

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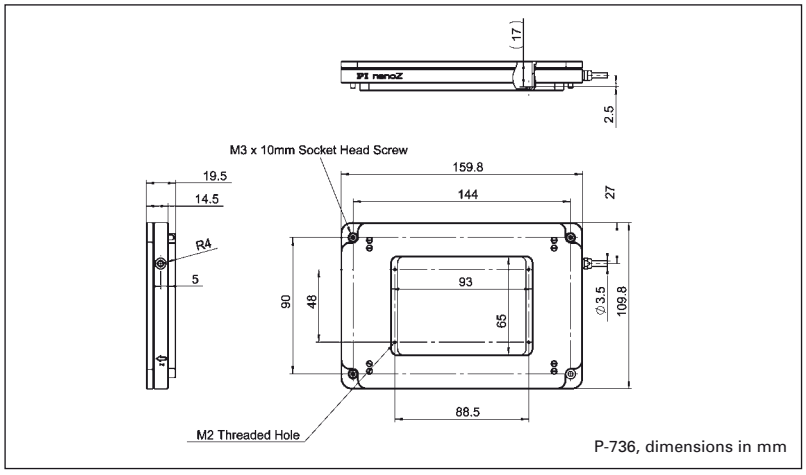
A compact piezo controller with a digital servo, USB, RS-232 and a high–speed analog interface is included



P-736, dimensions in mm

Technical Data

Model	P-736.ZR1S	P-736.ZR2S	Units	Tolerance
Active axes	Z	Z		
Motion and positioning				
Integrated sensor	piezoresistive	piezoresistive		
Closed-loop travel	100	200	µm	
Open-loop resolution	0.2	0.4	nm	typ.
Closed-loop resolution	0.4	0.7	nm	typ.
Linearity	±0.1	±0.1	%	typ.
Repeatability	<4	<5	nm	typ.
Mechanical properties				
Settling time (10% step width)	5	7	ms	
Load	500	500	g	max.
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Miscellaneous				
Operating temperature range	15 to 40	15 to 40	°C	
Material	Aluminum	Aluminum		
Mass	550	550	g	±5%
Cable length	1.5	1.5	m	±10 mm

P-737 PIFOC® Specimen-Focusing Z Stage

Low-Profile, Long-Range Piezo Z Nanopositioner for Microscopy Samples

P-737 piezo Z-stage for high-resolution microscopy

- **High-Speed Piezo Z Motion with Travel Ranges to 250 µm (Up to 500 µm on Request)**
- **Nanometer Resolution**
- **Large Clear Aperture to Accommodate Specimen Holders**
- **Perfect Mechanical Fit with XY OEM Manual or Motorized Stages**
- **Response Times in the Millisecond Range**

PIFOC® P-737 high-speed vertical positioning systems are designed for use with XY microscopy stages–OEM manual stages as well as aftermarket motorized stages.

While the XY stage positions the sample, the piezo-actuator-based P-737 moves the sample along the optical axis to quickly and precisely adjust the focus. Vertical stepping with an accuracy in the nanometer range takes only a few milliseconds.

The large aperture is designed to accommodate a variety of specimen holders including slides or multiwell plates.

Application Examples

- Fluorescence microscopy
- Confocal microscopy
- Biotechnology
- Autofocus systems
- 3D Imaging
- Medical technology

High-Speed Z Steps for Fast Focus Control and Z Stack Acquisition

The immediate response of the solid-state piezo drives enables rapid Z-steps with typically 10 to 20 times faster step & settle times than classical stepper motor drives. This leads to higher image acquisition speed and throughput.

Closed-Loop Position Control for High-Precision and Stability

For high stability and repeatability, P-737 stages are equipped with position feedback. High-resolution, fast-responding, strain gauge sensors (SGS) are applied to appropriate locations on the drive train and provide a high-bandwidth, nanometer-precision position feedback signal to the controller. The sensors are connected in a full-bridge configuration to eliminate thermal drift, and assure optimal position stability in the nanometer range.

Excellent Guiding Accuracy

Flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. FEA techniques are used to give the design the highest possible stiffness in, and perpendicular to, the direction of motion, and to minimize linear and angular runout. Flexures allow extremely high-precision motion, no matter how minute, as they are completely free of play and friction.

Ordering Information

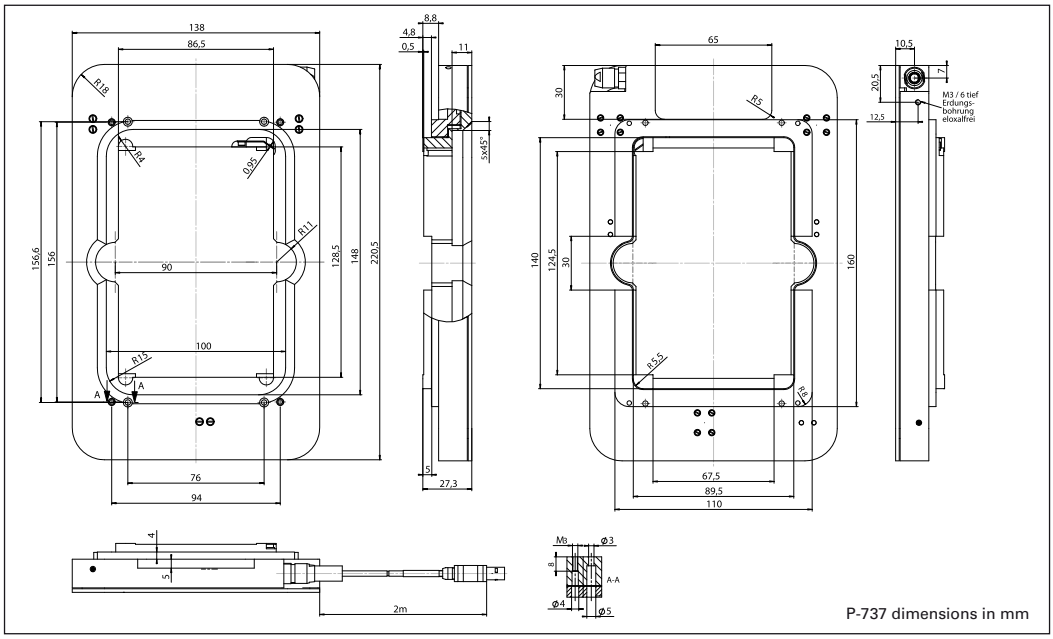
P-737.1SL
PIFOC® Nanofocusing Z-Stage for Microscope Sample Holder, 100 µm, SGS, LEMO Connector, for Märzhäuser Microscope Stages

P-737.2SL
PIFOC® Nanofocusing Z-Stage for Microscope Sample Holder, 250 µm, SGS, LEMO Connector, for Märzhäuser Microscope Stages

Versions with up to 500 µm travel or with direct-measuring, high-resolution capacitive sensors on request.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.



P-737 dimensions in mm

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The P-737 piezo Z-stage (shown with multiwell plate) is compatible with motorized microscope XY stages like the one shown from Mᵃrzhᵃ user

Technical Data

Model	P-737.1SL	P-737.2SL	Units	Tolerance
Active axes	Z	Z		
Motion and positioning				
Integrated sensor	SGS	SGS		
Open-loop travel, -20 to +120 V	150	280	µm	min. (+20 %/-0 %)
Closed-loop travel	100	250	µm	
Open-loop resolution	0.8	1	nm	typ.
Closed-loop resolution	2.5	4	nm	typ.
Linearity, closed-loop	0.2	0.2	%	typ.
Repeatability	6	12	nm	typ.
Runout X	±36	±36	µrad	typ.
Runout Y	±36	±140	µrad	typ.
Mechanical properties				
Unloaded resonant frequency	270	210	Hz	±20 %
Resonant frequency @ 100 g	230	180	Hz	±20 %
Resonant frequency @ 200 g	210	155	Hz	±20 %
Push/pull force capacity in motion direction	50 / 20	50 / 20	N	Max.
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical Capacitance	6.3	9.3	µF	±20 %
Dynamic operating current coefficient	7.9	4.6	µA/(Hz • µm)	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum		
Dimensions	220.5 x 138 x 27.3	220.5 x 138 x 27.3	mm	
Mass	0.7	0.7	kg	±5 %
Cable length	2	2	m	±10 mm
Sensor / voltage connection	LEMO	LEMO		
System properties				
System configuration	E-500 System with E-503 amplifier (6 W) E-509 servo module	E-500 System with E-503 amplifier (6 W) E-509 servo module		
Closed-loop amplifier bandwidth, small signal	60	30	Hz	typ.
Settling time (10 % step width)	24	30	ms	typ.

Recommended controller / amplifier
Single-channel: E-610 servo controller / amplifier (p. 2-110), E-625 servo controller , bench-top (p. 2-114), E-665 powerful servo controller, bench-top (p. 2-116)

M-686 PILine® XY Ultra-High Stability Piezo Linear-Motor Stage

Fast, Low Profile and Large Aperture with Direct Position Measurement

The M-686.D64 open-frame stage with closed-loop piezo motors provides 25 x 25 mm travel range

- **Integrated Closed-Loop Piezomotor Drives Provide High Speed to 100 mm/s**
- **Travel Ranges 25 x 25 mm**
- **Integrated Linear Encoders with 0.1 µm Resolution**
- **Compact Design: 32 mm Profile Height, 170 x 170 mm Footprint**
- **Clear Aperture 78 x 78 mm, 66 x 66 mm in Extreme Position**
- **Self-Locking at Rest**
- **Compatible with PI Piezo Nanopositioning / Scanning Stages**

M-686 open-frame piezomotor stages are mainly designed for automated positioning applications in microscopy. The optimized form factor with a low profile height of only 32 mm and the standardized mounting pattern allows the combination with many PI standard nanopositioning systems.

Application Examples

- Biotechnology
- Microscopy
- Scanning microscopy
- Confocal microscopy
- Semiconductor testing
- Handling

Space Saving Piezomotors

Compared to conventional motorized translation stages, the M-686 provides a lower profile and smaller footprint. The compact PILine® piezoelectric linear motors and high-resolution linear encoders make both, the lead screw duct and the flanged, bulky stepper motor employed in traditional stages obsolete. In addition, the piezomotors are self-locking at rest and hold the stage in a stable position without heating up.

Compatibility to PI Nanopositioning and Scanning Stages

A number of standard PI piezo flexure stages (150 x 150 mm footprint) can be mounted directly on the M-686 open-frame stage. Depending on the application, these highly specialized, ultra-precise nanopositioning systems are available as fast XY scanners (for fluorescence microscopy), as vertical Z positioners (3D imaging), or with up to 6 degrees of freedom.

Limit and Reference Switches

For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

Advantages of PILine® Micropositioning Systems

The ultrasonic piezoceramic drives used in PIline® micropositioners have a number of advantages over classical drives:

- Higher Accelerations, up to 5 g
- Speeds up to 500 mm/s
- Small Form Factor
- Self-Locking When Powered Down
- No Shafts, Gears or Other Rotating Parts
- Non-Magnetic and Vacuum-Compatible Drive Principle

Ordering Information

M-686.D64
XY Open-Frame Stage with Closed-Loop PILine® Piezomotor Drives, 25 x 25 mm, 7 N, 0.1 µm Linear Encoder

Ask about custom designs!

POWERED BY NATIONAL INSTRUMENTS LabVIEW

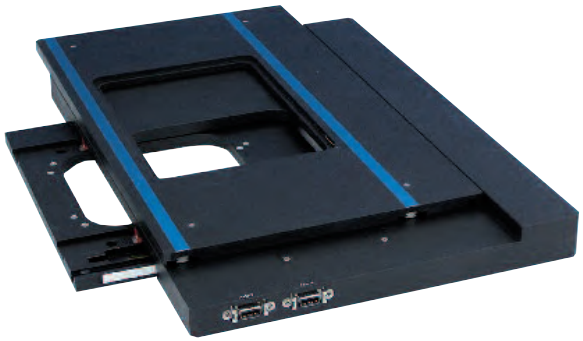
Notes

Nanopositioning stages that fit directly on the M-686:

P-561 to P-563
PIMars™ XYZ Nanopositioning systems with up to 300 µm travel

P-541.2 to P-542.2
Low-profile microscopy XY scanners

P-541.Z
Low-profile Z/tip/tilt piezo nanopositioning stages for microscopy



Cusomized M-686 microscopy stage with 225 x 85 mm travel and PILine® ultrasonic piezo motors

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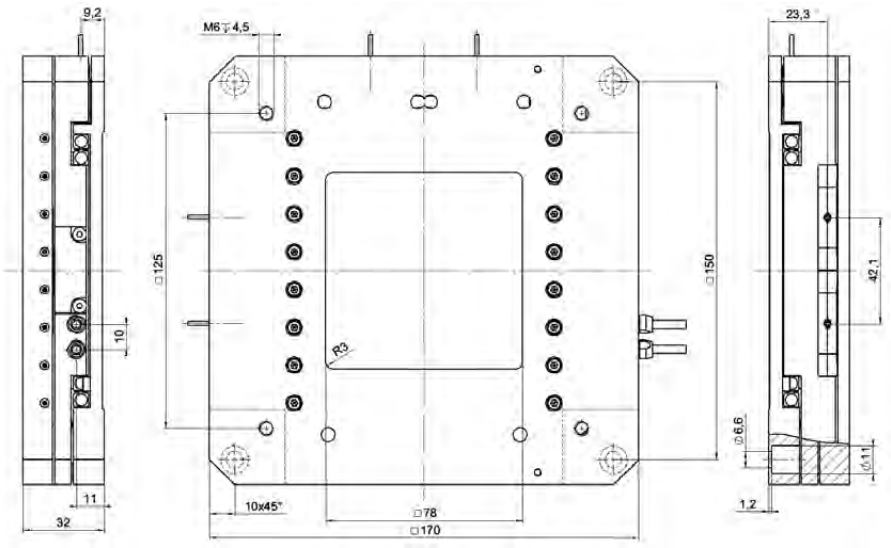
The newest release for data sheets is available for download at www.pi.ws. Cat120E Inspirations2009 08/10.18

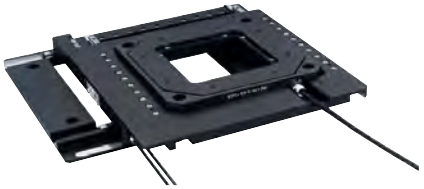
Download Paper on Stability Test Results!



M-686.D64, dimensions in mm. The minimum aperture is 66 x 66 mm with both axes at the maximum position

M-686 open-frame stage with P-541.2DD piezo scanner on top, providing a resolution of 0.1 nm and a scanning range of 30 x 30 µm. The system height of the combination with the P-541 XY (or Z) piezo scanner is only 48 mm

M-660 ultra low profile (.6", 15mm) rotation stage

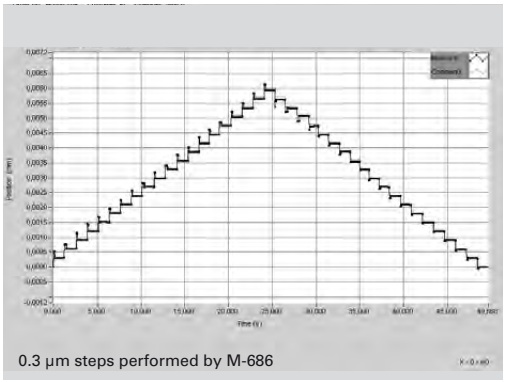


Customized M-686 stage with a bigger footprint, to sink the piezo Z scanner. The system height together with the P-541 piezo scanner is reduced to only 33 mm

Technical Data

Model	M-686.D64
Active axes	XY
Motion and positioning	
Travel range	25 x 25 mm
Integrated sensor	Linear encoder
Sensor resolution	0.1 µm
Design resolution	0.1 µm
Min. incremental motion	0.3 µm
Bidirectional repeatability	0.3 µm
Pitch / yaw	±50 µrad
Max. velocity	100 mm/s
Mechanical properties	
Load Capacity*	50 N
Max. push/pull force	7 N
Max. lateral force	4 N
Drive properties	
Motor type	2 x PILine® P-664 per axis
Operating voltage	190 V (Peak-Peak)** 67 V (RMS)**
Electrical power	10 W / axis***
Miscellaneous	
Operating temperature range	-20 to +50 °C
Material	Aluminium (black anodized)
Mass	1.2 kg
Cable length	1.5 m
Connector	2 x MDR connector, 14-pin
Recommended controller/driver	2 x C-867.D64 single-axis controller / driver 2 x C-185.D64 single-axis drive electronics for external servo-controllers (p. 4-116, p. 1-36)

*10 N for max. velocity
**The operating voltage or the piezomotor is supplied by the drive electronics which requires 12 VDC
***For drive electronics



0.3 µm steps performed by M-686

M-660 PILine® Ultra Low Profile Rotation Stage

Fast Positioning, Ultra-Low Profile

The M-660 PILine® rotation stage allows high positioning speeds of up to 2 full turns/sec. The 35 mm Ø clear aperture offers flexible usage

- **Unlimited Travel Range**
- **Max. Velocity 720 °/s**
- **Low Profile: Only 15 mm in Height**
- **Self-Locking Ceramic Direct Drive: Energy Saving & High Position Stability**
- **Direct Metrology Linear Encoder, 40 µrad Resolution**
- **PILine® Direct Drive: Non-Magnetic and Vacuum-Compatible Working Principle**
- **Compact Combinations with Linear Stages**

M-660 precision rotation stages use PILine® ultrasonic piezo motors that act on a ceramic friction ring to drive the platform. This direct drive principle allows for the compact design and low profile of the stage. An integrated incremental encoder offers precision position control with up to 40 µm resolution. The integrated U-164 PILine® linear motors provide a maximum torque of 0.3 Nm, independent from the direction of motion, and a maximum velocity of up to 720 °/sec. The maximum load is 1 kg.

M-660s can be built in different sizes or with other specifications, and they are available upon request as vacuum-compatible versions.

Applicatotion Examples

- Biotechnology
- Micromanipulation
- Microscopy
- Quality assurance testing
- Metrology
- Mass storage device testing
- R&D
- Photonics packaging

Advantages of PILine® Micropositioning Systems

Positioning systems equipped with ceramic ultrasonic drives of the PILine® series provide several advantages over positioners that apply classic drive technology:

- Smaller dimensions
- Higher holding force when powered down; no holding current
- Increased acceleration of up to 5 g
- Increased velocity of up to 500 mm/s or 720 °/s, resp.
- No leadscrews, gears or other mechanical components, no wear or maintenance
- No lubricants
- Non-magnetic and vacuum-compatible operating principle

Optimized Controller and Drive Electronics

For optimum performance, the highly specialized C-867 motion controller (s. p. 4-116) is recommended. This dedicated piezo motor controller also integrates the drive electronics which PILine® motors require to generate the ultrasonic oscillations on the piezoceramic element.

Furthermore, the controller has a number of special characteristics to address the requirements of ultrasonic motors, such as continuous automatic drive frequency adjustment, dynamic parameter switching for optimized high-speed motion and settling behavior. The broad-band encoder input (50 MHz) supports the outstanding high accelerations and velocities of PILine® drives at high resolutions.

Optionally, the C-185 analog drive electronics (stand-alone unit) (s. p. 1-36) is available for use with third party servo controllers. It accepts an analog ±10 V signal to control the motor velocity. For optimum performance, the driver must be tuned together with the mechanics and should be ordered at the same time as the motor / stage.

Ordering Information

M-660.55
PILine® Rotation Stage, Ø 102 mm, 360°, 40 µrad Resolution

Ask about custom designs!

Patented Technology

The products described in this document are in part protected by the following patents:
US Pat. No. 6,765,335
German Patent No. 10154526

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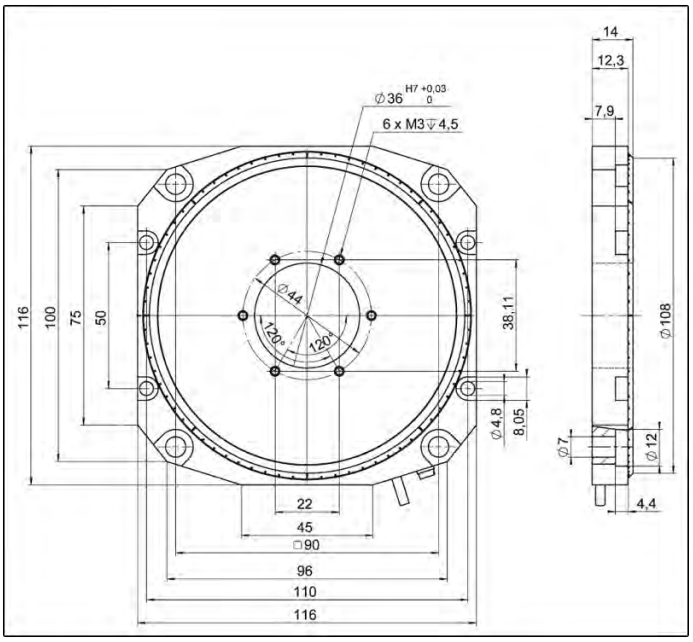

M-660.55, dimensions in mm (preliminary)

Technical Data (preliminary)

Model	M-660.55	Units	Tolerance
Active axes	Theta Z		
Motion and positioning			
Rotation range	No limit	°	
Integrated sensor	Incremental encoder		
Design resolution	40	µrad	typ.
Min. incremental motion	120	µrad	typ.
Backlash	40	µrad	typ.
Unidirectional repeatability	120	µrad	typ.
Bidirectional repeatability	180	µrad	
Max. velocity	720	°/s	
Mechanical properties			
Load capacity / axial force	10	N	max.
Holding force	0.3	Nm	max.
Max. torque cw/ccw (θ Z)	0.3	Nm	max.
Drive properties			
Motor type	2 x U-164 PILine® ultrasonic piezo drive		
Operating voltage	60 (RMS)*	V	
Electrical power	1.4	W	nominal
Current consumption**	1.5	A	
Reference switch	optical		
Miscellaneous			
Operating temperature range	-20 to +50	°C	
Material	Al (black anodized)		
Mass	0.4	kg	±5%
Cable length	1	m	±10 mm
Connector	MDR, 14-pin		
Recommended controller / driver	C-867.160 single-axis controller / driver		

* The operating voltage is supplied by the drive electronics
** For drive electronics

M-810 Miniature Hexapod 6 Axis Stage

6 Degrees of Freedom & High Precision in a Small Package

The miniature Hexapod M-810 provides long travel ranges despite its compact design

- **Most-Compact Hexapod in the PI Portfolio**
- **Travel Ranges 40 x 40 x 13 mm, Rotation to 60 Degrees**
- **Load Capacity to 5 kg**
- **Resolution of a Single Strut 40 nm**
- **Min. Incremental Motion to 200 nm**
- **Repeatability up to ±0.5 µm**
- **Velocity to 10 mm/s**

With a platform diameter of only 10 cm the M-810 Hexapod is the most compact parallel-kinematics micropositioning system to date. In addition to positioning all six axes with high speed and accuracy, it allows the user to define the center of rotation (pivot point) anywhere inside or outside the system envelope by one simple software command. This makes it ideal for all complex positioning tasks with restricted space.

Application Examples

- Biotechnology
- Semiconductor technology
- Micromachining
- Micromanipulation
- X-ray diffraction measurements
- Tool control

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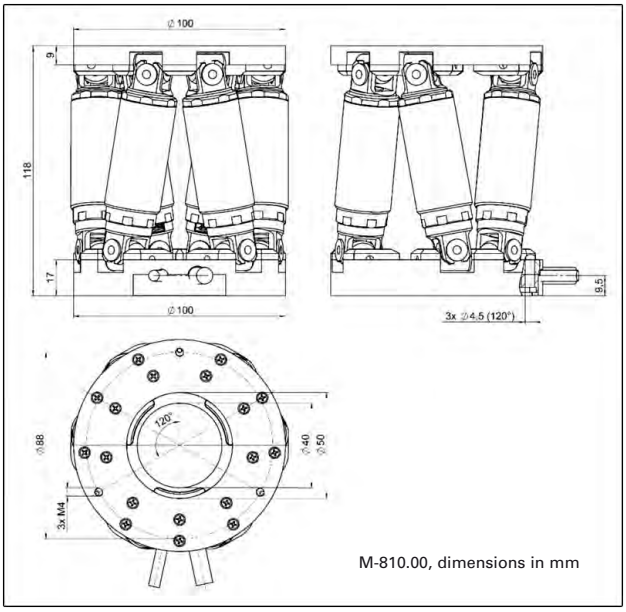
Extremely Compact, Great Freedom of Motion

The M-810.00 with its direct-drive torque motors and ActiveDrive™ system with integrated servo amplifiers provides an increased velocity of up to 10 mm/s for loads up to 5 kg. Small and compact, the Hexapod allows a large stroke of up to 40 mm (linear) and 60° (angular).

Hexapod vs. Serial Kinematics Systems

The Hexapod is driven by six high-resolution actuators all connected directly to the same moving platform. This design provides a high system stiffness and a large clear aperture.

Because of the low mass of the moving platform, positioning operations can be performed with far lower settling times than with conventional, stacked multi-axis systems. In such systems, runout, guiding errors, and the friction and inertia of moving cables all accumulate to limit accuracy and repeatability-problems which do not affect parallel kinematic systems like the Hexapod.



M-810.00, dimensions in mm

Ordering Information

M-810.00
Miniature-Hexapod Microrobot with Controller, Direct Drive

Ask about custom designs

User-Defined Pivot Point

For optics and other alignment tasks, it is important to be able to define a fixed pivot point. The sophisticated Hexapod-controller allows choosing any point in space as the pivot point for the rotation axes with a simple software command. The pivot point remains fixed relative to the platform.

Target positions in 6-space are entered in user-friendly coordinates and reached by smooth vectorized motion.

Open Architecture

Control of the hexapod is facilitated by the controller's open interface architecture, which provides a variety of high-level commands and includes a macro language for programming and storing command sequences.

M-810 with modified cable exit.

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The newest release for data sheets is available for download at www.pi.ws. 09/08/25.0

Technical Data

	M-810.00	Unit
Active axes	X, Y, Z, θX, θY, θZ	
Motion and positioning		
*Travel range X, Y	±20	mm
*Travel range Z	±6.5	mm
*Travel range θX, θY	±11	°
*Travel range θZ	±30	°
Actor drive	Brushless DC Motor, ActiveDrive™	
Actuator stroke	±7.5	mm
Single-actuator design resolution	0.04	µm
Integrated sensor	Rotary encoder	
Sensor resolution	12800	Cts./rev.
**Min. incremental motion X, Y	1	µm
**Min. incremental motion Z	0.2	µm
**Min. incremental motion θX, θY, θZ	3.5	µrad
Repeatability X, Y	±2	µm
Repeatability Z	±0.5	µm
Repeatability θX, θY, θZ	±5	µrad
Backlash X, Y	2	µm
Backlash Z	0.5	µm
Max. velocity X, Y, Z	10	mm/s
Max. velocity θX, θY, θZ	250	mrad/s
Typ. velocity X, Y, Z	5	mm/s
Typ. velocity θX, θY, θZ	120	mrad/s
Mechanical properties		
Stiffness X, Y	0.1	N/µm
Stiffness Z	4	N/µm
Max. load (baseplate horizontal / optional)	5 / 2.5	kg
Miscellaneous		
Operating temperature range	0 to +50	°C
Material	Stainless steel, aluminum	
Mass	1.7	kg

* The travel ranges of the individual coordinates (X, Y, Z, θX, θY, θZ) are interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or rotational coordinates are not zero, the available travel may be less.

** Six-axis move. No moving cables (unlike serial-kinematic stacked systems). Eliminates bending, inertia and friction, improving accuracy.

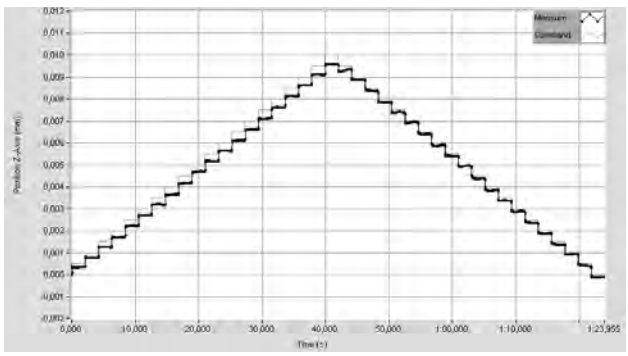
Technical data are specified at 20 ±3°C. Data for vacuum versions may differ.

PI Hexapods come with a powerful 6D controller and sophisticated, user-friendly positioning and alignment sofware. Keypad and display are optional.

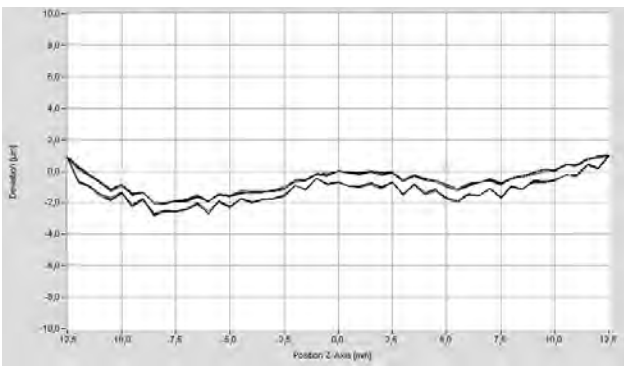
M-824 Compact 6-Axis-Stage

Precision Micropositioner with Controller, Vacuum Versions

M-824.3DG compact 6-axis Hexapod



Interferometer tests show the high repeatability, here with 500 nm steps



The interferometer test shows the Z axis accuracy over the entire travel range of 25 mm and the extremely high repeatability of ±0.046 µm

P-721 PIFOC® Piezo Flexure Objective Scanner

Fast Nanopositioner and Scanner for Microscope Objectives

P-721.CLQ piezo objective nanopositioning system with P-721.12Q QuickLock option and objective (adapter and objective not included)

- **Scans and Positions Objectives with Sub-nm Resolution**
- **Travel Ranges to 140 µm, Millisecond Settling Time**
- **Significantly Faster Response and Higher Lifetime than Motorized Z-Stages**
- **Parallel Precision Flexure Guiding for Better Focus Stability**
- **Choice of Position Sensors: Capacitive Direct Metrology (Higher Performance) or Strain Gauge (Lower Cost)**
- **Compatible with Metamorph™ Imaging Software**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **QuickLock Adapter for Easy Attachment**

P-721 PIFOCs® are high-speed, piezo-driven microscope objective nanofocusing/scanning devices, providing a positioning and scanning range of 100 µm with sub-nanometer resolution and very high motion of linearity up to 0.03 %.

Application Examples

- 3D-Imaging
- Z Stack Acquisition
- Screening
- Interferometry
- Metrology
- Disc-drive-testing
- Autofocus systems
- Confocal microscopy
- Biotechnology
- Semiconductor testing

PIFOCs® are also available with up to 460 µm travel (P-725 p. 2-28), and for exceptional dynamic and step performance (models P-726 p. 2-32 and P-725.SDD p. 2-30).

Superior Accuracy With Direct-Metrology Capacitive Sensors

Capacitive position feedback is used in the top-of-the-line models. PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

Alternatively, strain gauge sensor (SGS) models are available. The sensors are connected in a bridge configuration to eliminate thermal drift, and assure optimal position stability in the nanometer range.

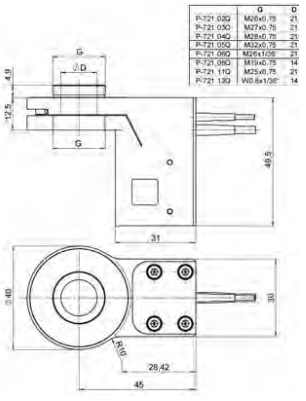
Open-loop models are available for applications where fast response and very high resolution are essential. Here, specifying or reporting absolute position values is either not required or is handled by external sensors, such as interferometers, a vision system or photodiode PSD (position sensitive detector). These models retain the inherent piezo advantages such as high resolution and speed.

Simple Installation with QuickLock Thread Options

The PIFOC® is mounted between the turret and the objective with the QuickLock thread adapter. After threading the adapter into the turret, the Quick Lock is affixed in the desired position. Because the PIFOC® body need not to be rotated, cable wind-up is not an issue.

QuickLock Adapter

	G	D
P-721.02Q	M26x0.75	21
P-721.03Q	M27x0.75	21
P-721.04Q	M28x0.75	21
P-721.05Q	M32x0.75	21
P-721.06Q	M26x1/36"	21
P-721.08Q	M19x0.75	14
P-721.11Q	M25x0.75	21
P-721.12Q	W0.8x1/36"	14



P-721.CLQ, .CDQ, .SL2 dimensions in mm (adapter to be ordered separately)

Ordering Information

P-721.CDQ
Fast PIFOC® Piezo Nanofocusing Z-Drive, 100 µm, Direct Metrology, Capacitive Sensor, Sub-D Connector, for Quick Lock Thread Adapters

P-721.CLQ
Fast PIFOC® Piezo Nanofocusing Z-Drive, 100 µm, Direct Metrology, Capacitive Sensor, LEMO Connector, for Quick Lock Thread Adapters

P-721.SL2
Fast PIFOC® Piezo Nanofocusing Z-Drive, 100 µm, SGS-Sensor, LEMO Connector, for Quick Lock Thread Adapters

P-721.0LQ
Fast PIFOC® Piezo Nanofocusing Z-Drive, 100 µm, No Sensor, LEMO Connector, for Quick Lock Thread Adapters

Extension Tubes for Objectives

P-721.90Q
Extens. Tube, 12.5 mm, Thread W0.8 x 1/36"

P-721.91Q
Extens. Tube, 12.5 mm, Thread M25 x 0.75

P-721.92Q
Extens. Tube, 12.5 mm, Thread M26 x 0.75

P-721.93Q
Extens. Tube, 12.5 mm, Thread M27 x 0.75

P-721.94Q
Extens. Tube, 12.5 mm, Thread M28 x 0.75

P-721.95Q
Extens. Tube, 12.5 mm, Thread M32 x 0.75

P-721.96Q
Extens. Tube, 12.5 mm, Thread M26 x 1/36"

P-721.98Q
Extens. Tube, 12.5 mm, Thread M19 x 0.75

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High Reliability and Long Lifetime

The compact PIFOC® systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and thus offer better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free and not subject to wear, and thus offer an extraordinary reliability.

Choice of Controllers

A large choice of analog and digital piezo controllers as OEM, bench-top and 19-inch-rack-mount versions is available.

QuickLock P-721.12Q thread adapter exploded view with microscope objective and PIFOC® P-721.CLQ (mounting tools are included, QuickLock adapter and objective not included)

Technical Data

Model	P-721.CLQ	P-721.CDQ	P-721.SL2	P-721.0LQ	Units	Tolerance
Active axes	Z	Z	Z	Z		
Motion and positioning						
Integrated sensor	Capacitive	Capacitive	SGS	–		
Open-loop travel, -20 to +120 V	140	140	140	140	µm	min. (+20 %/-0%)
Closed-loop travel	100	100	100	–	µm	calibrated
Open-loop resolution	0.5	0.5	0.5	0.5	nm	typ.
Closed-loop resolution	0.7	0.7	5	–	nm	typ.
Linearity, closed-loop	0.03	0.03	0.2	–	%	typ.
Repeatability	±5	±5	±10	–	nm	typ.
Runout θX, θY	13	13	13	13	µrad	typ.
Crosstalk X, Y	100	100	100	100	nm	typ.
Mechanical properties						
Stiffness in motion direction	0.3	0.3	0.3	0.3	N/µm	±20 %
Unloaded resonant frequency	580	580	580	550	Hz	±20 %
Resonant frequency @ 120 g	235	235	235	235	Hz	±20 %
Resonant frequency @ 200 g	180	180	180	180	Hz	±20 %
Push/pull force capacity in motion direction	100 / 20	100 / 20	100 / 20	100 / 20	N	Max.
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	3.1	3.1	3.1	3.1	µF	±20 %
Dynamic operating current coefficient	3.9	3.9	3.9	3.9	µA/(Hz•µm)	±20 %
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	0.24	0.24	0.22	0.22	kg	±5 %
Max. objective diameter	39	39	39	39	mm	
Cable length	1	1	1	1	m	±10 mm
Sensor / voltage connection	LEMO	Sub-D Special	LEMO	LEMO (no sensor)		
Recommended controller / amplifier	E-610 servo controller/amplifier (p. 2-110), modular piezo controller system E-500 (p. 2-142) with amplifier module E-505 (high performance) (p. 2-147) and E-509 servo controller (p. 2-152)	E-625 servo controller, bench top (p. 2-114), E-665 powerful servo controller, bench-top (p. 2-116), Single-channel digital controller: E-753 (bench-top) (p. 2-108)	E-610 servo controller/amplifier, E-625 servo controller, bench-top, E-665 powerful servo controller, bench-top	E-610 servo controller/amplifier		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 amplifier (p. 2-144)

P-726 PIFOC® High-Load Objective Scanner

High-Dynamic Piezo Z Scanner for Heavy Objectives

High-dynamics P-726 PIFOC® for large microscope objectives over 60 mm in length

- **High-Dynamics Positioning and Scanning for Large Objectives**
- **1120 Hz Resonant Frequency, 560 Hz with 210 g Load**
- **Typical Settling Time about 6 ms**
- **Travel Range 100 µm**
- **Direct-Metrology Capacitive Sensors for Best Linearity, Stability and Control Dynamics**
- **Resolution to 0.3 nm**
- **Frictionless, High-Precision Flexure Guiding System for Better Focus Stability**

The P-726 PIFOC® Nanofocusing system was developed to achieve the fastest possible stepping time with the heavy, high-numerical-aperture objectives used in many of today's high-resolution microscopy applications. Its extremely stiff design offers excellent settling time and scanning frequency values even when objectives of several hundred grams are moved. High stiffness is achieved with the rotationally symmetric arrangement of multiple piezo drives and the optimized design of the flexure and lever elements, which assure the excellent guiding accuracy and dynamics.

Furthermore, like other members of the PIFOC® family, the P-726 is equipped with direct metrology capacitive position sensors that allow resolutions far below one nanometer.

Application Examples

- 3-D Imaging
- Screening
- Autofocus systems
- Microscopy
- Confocal microscopy
- Surface analysis
- Wafer inspection

Direct Metrology with Capacitive Sensors for Highest Stability and Accuracy

PI's proprietary capacitive position sensors measure the actual motion of the moving part relative to the stationary base (direct metrology). Errors in the drive train, actuator, lever arm or in guiding system do not influence the measurements. The result is exceptional motion linearity, higher long-term stability and a stiffer, more-responsive servo loop, because external influences are immediately recognized by the sensor. Due to this sensor principle, the P-726 features a resolution of under 0.4 nm in closed-loop and a linearity of 0.02 %.

Simple Installation with QuickLock Thread Options

The PIFOC® is mounted between the turret and the objective with the QuickLock thread adapter. After threading the adapter into the turret, the QuickLock is affixed in the desired position. Because the PIFOC® body need not to be rotated, cable wind-up is not an issue.

Ordering Information

P-726.1CD
High-Dynamics PIFOC® Piezo Nanofocusing Z-Drive, 100 µm, Capacitive Sensor

QuickLock Thread Adapter as Accessories:

P-726.04
P-726 PIFOC® Thread Adapter M28 x 0.75

P-726.05
P-726 PIFOC® Thread Adapter M32 x 0.75

P-726.06
P-726 PIFOC® Thread Adapter M26 x 1/36"

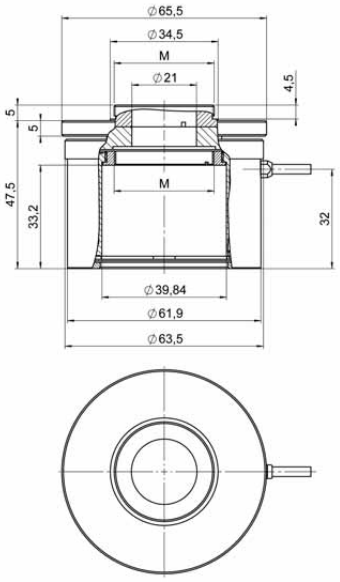
P-726.11
P-726 PIFOC® Thread Adapter M25 x 0.75

P-726.12
P-726 PIFOC® Thread Adapter W0.8 x 1/36"

Ask about custom designs!

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.



P-726 dimensions in mm with P-726.05 M32 QuickLock adapter

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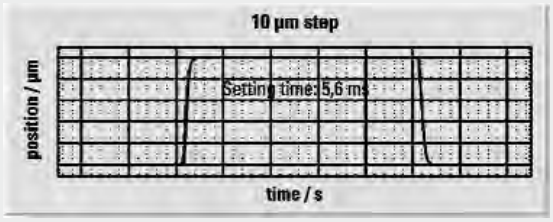

P-726 settling time under load

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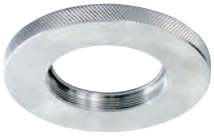
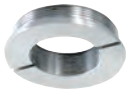
Technical Data

	P-726.1CD	Tolerance
Active axes	Z	
Motion and positioning		
Integrated sensor	Capacitive, direct metrology	
Closed-loop travel	100 µm	calibrated
Closed-loop resolution	0.4 nm	typ.
Open-loop resolution	0.3 nm	typ.
Linearity, closed-loop	0.02 %	typ.
Repeatability	±3 nm	typ.
Runout Θ_X, Θ_Y	±5 µrad	typ.
Crosstalk X, Y	50 nm	typ.
Mechanical properties		
Stiffness in motion direction	3.4 N/µm	±20 %
Unloaded resonant frequency	1120 Hz	±20 %
Resonant frequency under load	560 Hz @ 210 g	±20 %
Resonant frequency under load	480 Hz @ 310 g	±20 %
Push/pull force capacity in motion direction	100 / 50 N	Max.
Drive properties		
Piezo ceramic type	PICMA® P-885	
Electrical capacitance	6 µF	±20 %
Dynamic operating current coefficient	7.5 µA/(Hz • µm)	±20 %
Miscellaneous		
Operating temperature range	-20 to 80 °C	
Material	Aluminum, steel	
Dimensions	Diameter: 65 mm, Height: 50.7 mm	
Max. objective diameter	M32	
Mass	575 g	±5 %
Cable length	1.5 m	±10 mm
Sensor / voltage connection	Sub-D Special	
Recommended controller / amplifier	Single-channel digital controller: E-753 (bench-top) (p. 2-108) E-625 bench-top controller (p. 2-114), E-665 high-power bench-top controller (p. 2-116) E-500 modular piezo controller system (p. 2-142) with E-505 high-power amplifier module (p. 2-147) and E-509 servo-controller (p. 2-152)	
System properties		
System configuration	E-500 modular piezo controller system with E-505 high-power amplifier module and E-509 servo-controller 310 g load (objective mass)	
Closed-loop amplifier bandwidth, small signal, 10 µm	130 Hz	
Closed-loop amplifier bandwidth, large signal	70 Hz	

Microscope Turret


Knurled Ring


Turret Ring


PIFOC®


Objective Ring


Objective

P-726 QuickLock thread adapter exploded view with P-726 PIFOC® (mounting tools included)

P-725 PIFOC® Long-Travel Microscope Objective Scanner

High-Precision Positioner / Scanner for Microscope Objectives

P-725.2CD
(QuickLock adapter
and objective not included)

- **Travel Ranges to 460 µm**
- **Significantly Faster Response and Higher Lifetime than Motorized Z-Stages**
- **Scans and Positions Objectives with Sub-nm Resolution**
- **Direct Metrology with Capacitive Sensors for Highest Linearity**
- **Parallel Precision Flexure Guiding for Better Focus Stability**
- **Compatible with Metamorph™ Imaging Software**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **QuickLock Adapter for Easy Attachment**

P-725 PIFOC® nanofocus systems are long-travel, high-speed, piezo-driven microscope objective nanofocusing/scanning devices. Despite the increased travel ranges (up to 460 µm), they are 20 % shorter than P-721 units (p. 2-25) while providing sub-nanometer resolution. The innovative, frictionless, flexure guiding system provides enhanced precision for superior focus stability with fast response for rapid settling and scanning.

Application Examples

- 3D-Imaging
- Screening
- Interferometry
- Metrology
- Disc-drive-testing
- Autofocus systems
- Confocal microscopy
- Biotechnology
- Semiconductor testing

Fastest Step-and-Settle: 25 Milliseconds for 250 Microns

The P-725.2CL can perform a 250 µm step to 1 % accuracy in only 25 ms (E-665.CR controller, no load) and in 50 ms with a load of 150 g.

Superior Accuracy With Direct-Metrology Capacitive Sensors

Cpacitive position feedback is used in the top-of-the-line models. PI's proprietary capacitive position sensors measure the actual motion of the moving part relative to the stationary base (direct metrology). Errors in the drive train, actuator, lever arm or in guiding system do not influence the measurements. The result is exceptional motion linearity, higher long-term stability and a stiffer, more-responsive servo loop, because external influences are immediately recognized by the sensor.

Open-loop models are available for applications where fast response and very high resolution are essential. Here, specifying or reporting absolute position values is either not required or is handled by external sensors, such as interferometers, vision system or photodiode PSD (position sensitive detector). These models retain the inherent piezo advantages as high resolution and speed.

Simple Installation with QuickLock Thread Options

The PIFOC® is mounted between the turret and the objective with the QuickLock thread adapter. After threading the adapter into the turret, the Quick Lock is affixed in the desired position. Because the PIFOC® body need not to be rotated, cable wind-up is not an issue.

High Reliability and Long Lifetime

The compact PIFOC® systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and thus offer better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free and not subject to wear, and thus offer an extraordinary reliability.

Ordering Information

P-725.1CD
PIFOC® Piezo Nanofocusing Z-Drive for Long Scanning Ranges, 100 µm, Capacitive Sensors, Sub-D Connector, for Quick Lock Thread Adapters

P-725.1CL*
PIFOC® Piezo Nanofocusing Z-Drive for Long Scanning Ranges, 100 µm, Capacitive Sensors, LEMO Connector, for Quick Lock Thread Adapters

P-725.2CD
PIFOC® Piezo Nanofocusing Z-Drive for Long Scanning Ranges, 250 µm, Capacitive Sensors, Sub-D Connector, for Quick Lock Thread Adapters

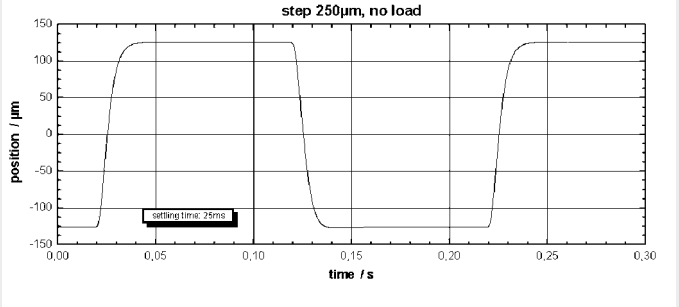
P-725.2CL*
PIFOC® Piezo Nanofocusing Z-Drive for Long Scanning Ranges, 250 µm, Capacitive Sensors, LEMO Connector, for Quick Lock Thread Adapters

P-725.4CD
PIFOC® Piezo Nanofocusing Z-Drive for Long Scanning Ranges, 400 µm, Capacitive Sensors, Sub-D Connector, for Quick Lock Thread Adapters

P-725.4CL*
PIFOC® Piezo Nanofocusing Z-Drive for Long Scanning Ranges, 400 µm, Capacitive Sensors, LEMO Connector, for Quick Lock Thread Adapters

*Also available w/o sensor (open-loop): P-725.10L, P-725.20L and P-725.40L

Accessories
QuickLock thread adapters and extension tubes for objectives (see p. 2-26)



Top dynamic performance of the P-725.2CL PIFOC®: only 25 ms for a 250 µm step

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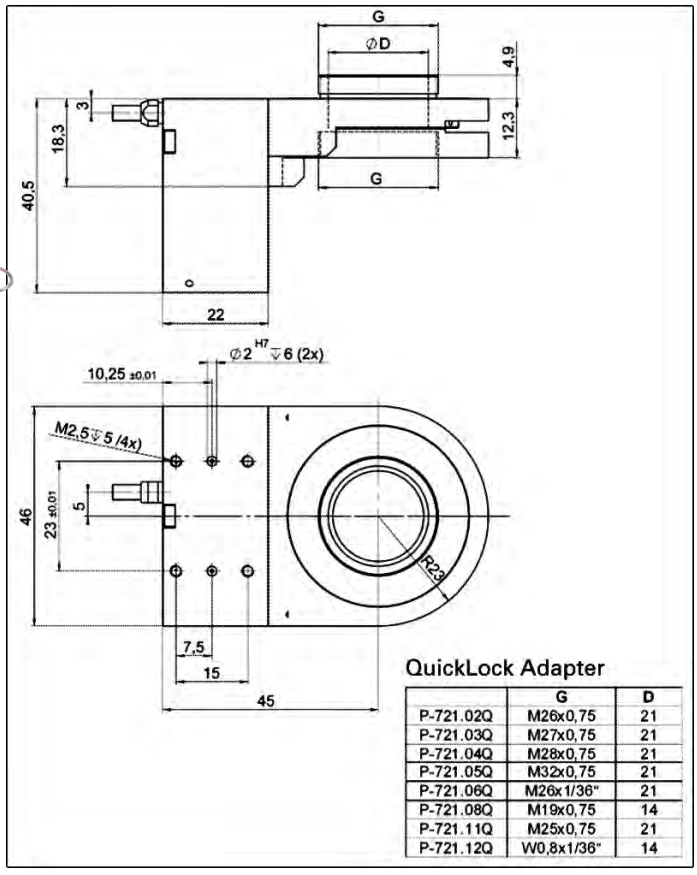
The newest release for data sheets is available for download at www.pi.ws. R1 09/09/09.0

P-721.12Q QuickLock thread adapter, exploded view with microscope objective and PIFOC® (mounting tools are included, QuickLock adapter and objective not included)



QuickLock Adapter

	G	D
P-721.02Q	M26x0.75	21
P-721.03Q	M27x0.75	21
P-721.04Q	M28x0.75	21
P-721.05Q	M32x0.75	21
P-721.06Q	M26x1/36"	21
P-721.08Q	M19x0.75	14
P-721.11Q	M25x0.75	21
P-721.12Q	W0.8x1/36"	14

P-725 dimensions in mm (thread adapter ordered separately)

Technical Data

Model	P-725.1CL, P-725.1CD	P-725.2CL, P-725.2CD	P-725.4CL, P-725.4CD	Units	Tolerance
Active axes	Z	Z	Z		
Motion and positioning					
Integrated sensor	Capacitive	Capacitive	Capacitive		
Open-loop travel, -20 to +120 V	150	330	460	µm	min. (+20 %/0 %)
Closed-loop travel	100	250	400	µm	calibrated
Open-loop resolution	0.3	0.4	0.5	nm	typ.
Closed-loop resolution	0.65	0.75	1.25	nm	typ.
Linearity, closed-loop	0.03	0.03	0.03	%	typ.
Repeatability	±5	±5	±5	nm	typ.
Runout Θ_X	1	6	10	µrad	typ.
Runout Θ_Y	20	45	45	µrad	typ.
Crosstalk in X	20	20	60	nm	typ.
Crosstalk in Y	20	40	60	nm	typ.
Mechanical properties					
Stiffness in motion direction	0.23	0.17	0.12	N/µm	±20 %
Unloaded resonant frequency	470	330	230	Hz	±20 %
Resonant frequency @ 150 g	185	140	120	Hz	±20 %
Push/pull force capacity in motion direction	100 / 20	100 / 20	100 / 20	N	Max.
Drive properties					
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	4.2	6.2	6.2	µF	±20 %
Dynamic operating current coefficient	5.2	3.1	1.9	µA/(Hz • µm)	±20 %
Miscellaneous					
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum	Aluminum		
Max. objective diameter	39	39	39	mm	
Mass	0.215	0.23	0.23	kg	±5 %
Sensor / voltage connection	CL-version: LEMO CD-version: Sub-D special	CL-version: LEMO CD-version: Sub-D special	CL-version: LEMO CD-version: Sub-D special		

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Recommended controller / amplifier
"CL"-versions:
E-610 servo controller / amplifier (p. 2-110); E-500 modular piezo controller system (p. 2-142) with E-505 high-performance amplifier module (p. 2-147) and E-509 controller (p. 2-152)
"CD"-versions:
E-621 controller module (p. 2-160), E-625 servo controller, bench-top (p. 2-114), E-665 display servo controller, with digital interface, bench-top (p. 2-116)
Single-channel digital controller: E-753 (bench-top) (p. 2-108)

NEXACT® Long-Range Focusing System for Microscopy

NEXACT® technology enables 1 mm travel and maximum dynamics

Special PIFOC® design with PiezoWalk Linear Motor drive: 5 nm resolution over 1 mm µm travel

The new PIFOC® drives with NEXACT® piezo stepping motors are unique objective nanopositioners. They combine travel ranges of one millimeter or more with 5-nanometer resolution and high dynamics. For fast step-and-settle, the drives have a resonant frequency of 560 Hz carrying an objective weighing 200 g.

P-721K PIFOC® Nosepiece / Turret Nanopositioners

For High-Resolution Microscopy. High-Load Capacity, Capacitive Feedback

- Positioning and Scanning of Microscope Turrets
- Direct-Metrology Capacitive Sensors for Highest Linearity, Stability and Control Dynamics
- Frictionless, High-Precision Flexure Guiding System for Better Focus Stability
- Outstanding Lifetime Due to PICMA® Piezo Actuators

P-720 PIFOC® Piezo Scanner for Small Objectives

Compact High-Dynamics Scanner

- Travel Range 100 µm
- Rapid Response & Settling Behavior
- Scans and Positions Objectives with Sub-nm Resolution
- Frictionless, High-Precision Flexure Guiding System
- Outstanding Lifetime Due to PICMA® Piezo Actuators

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MetaMorph®

News & Applications

The fastest microscope objective Z-piezo stage

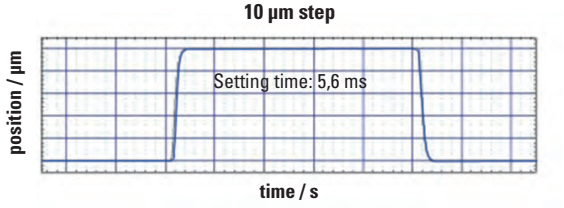
P-726 High-Performance PIFOC®

PI has extended its successful PIFOC® line of objective nanopositioners with a new, high-power unit. The P-726 PIFOC® can move heavy, high-NA immersion lenses (>200 g) faster than any other system currently available, with accuracies of 1 nm over a travel range of 100 µm.

Here, the convincing performance specifications – achieved with a load of 300 g (11 oz). The E-726 can be operated with a variety of controllers ranging from the economical E-621 card, the E-625 controller to a number of digital controllers for the highest possible performance.

- Resonant frequency: 430 Hz (with 300 g), 1100 Hz without objective
- Closed-loop position noise: <0.4 nm
- Position stability over 100 s: 4 nm
- Maximum operating frequency (amplitude <10 µm): 150 Hz*
- Maximum operating frequency with full travel (100 µm): 60 Hz*
- Settling time (10 µm steps): 6 ms**
- Settling time (full travel): 15 ms**

* Amplifier power limited. Higher performance with E-505, 200 W power module
** Faster settling with smaller load



Settling behavior of the P-726 for a 10 µm step.

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 sufficient for industrial automation and handling tasks.

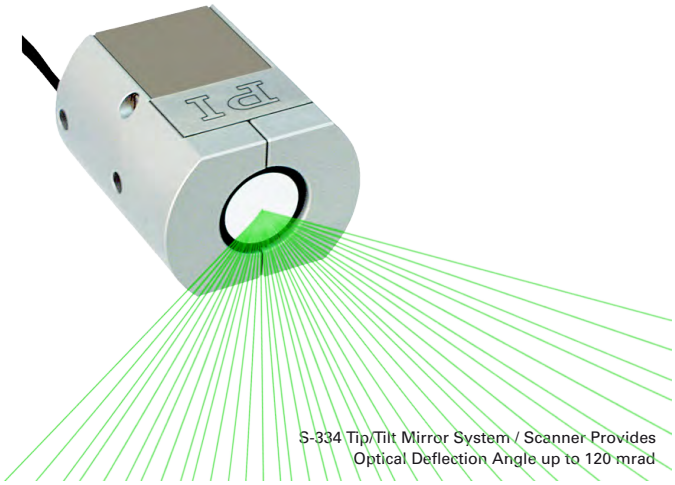
PI has developed the low cost M-664KCEP dispenser drive with PILine® piezo ultrasonic motors for this kind of application. Eight or more of these drives stacked together can move pipettes vertically and independently of each other in order to dispense liquids into well plates. A single actuator is only 9 millimeters wide to match the standardized sample holder.

The M-664KCEP covers 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.

S-334 Miniature Piezo Tip/Tilt-Mirror

Fast Steering Mirror with up to 120 mrad Deflection



S-334 Tip/Tilt Mirror System / Scanner Provides Optical Deflection Angle up to 120 mrad

- **Miniature Design**
- **Optical Beam Deflection to 120 mrad (~ 6.8°)**
- **Coplanar Axes & Fixed Pivot Point Eliminate Polarization Rotation**
- **Factory Installed Mirror**
- **Millisecond Response, Resolution to 0.5 µrad**
- **Closed-loop Position Servo-Control for High Accuracy**
- **For Mirrors up to 12.5 mm (0.5") Diameter**
- **Frictionless, High-Precision Flexure Guiding System**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**

S-334 piezo tip/tilt mirrors / scanners provide extremely large deflection angles in a miniaturized package. These fast steering mirror systems are based on a sophisticated parallel-kinematics design with two coplanar, orthogonal axes and a fixed pivot point.

Large Tip/Tilt Ranges with Excellent Motion Characteristics

The novel flexure/lever design with minimized inertia allows for the exceptionally large tip/tilt range of 60 mrad (50 mrad in closed-loop operation, which is equivalent to 100 mrad optical beam deflection) and very fast response in the millisecond range. These parameters make the system unique in the market of piezo driven tip/tilt mirror systems.

Sub-Microradian Resolution

In addition to the large angles and the high dynamics the S-334 provides sub-micro-radian resolution. The integrated high-resolution, full-bridge strain gauge sensors (SGS) provide absolute position control, excellent repeatability and high linearity, typically better than 0.25 % over the entire travel range.

Differential Drive for Improved Stability and Dynamics

The S-334 is based on a parallel-kinematics design with coplanar axes and a single moving platform. Two pairs of differentially-driven piezo actuators are employed to provide the highest dynamics and position stability over a wide temperature range.

Compared to stacked, (two-stage), piezo or galvo scanners, the single-platform design provides several advantages: smaller package size, identical dynamic performance in both axes, faster response and better linearity. It also prevents polarization rotation.

High Reliability and Long Lifetime

The compact S-334 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and provide better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free, not subject to wear and offer extraordinary reliability.

Factory Installed Mirror

The S-334 is equipped with a factory-installed mirror 10 mm in diameter and 2 mm thick (flatness λ/5, reflectivity >98 % from 500 nm to 2 µm).

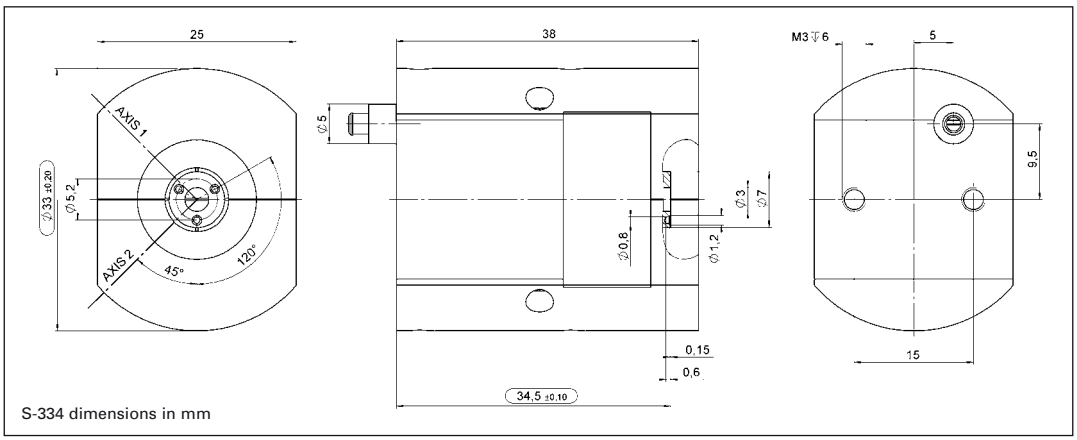
Ordering Information

S-334.2SD
High-Dynamics Piezo Tip/Tilt Platform, 50 mrad, SGS, Sub-D Connector, incl. Mirror

S-334.2SL
High-Dynamics Piezo Tip/Tilt Platform, 50 mrad, SGS, LEMO Connector, incl. Mirror

Application Examples

- Image processing / stablilization
- Interlacing, dithering
- Laser scanning / beam steering
- Optics
- Optical filters / switches
- Scanning microscopy
- Beam stabilization



S-334 dimensions in mm

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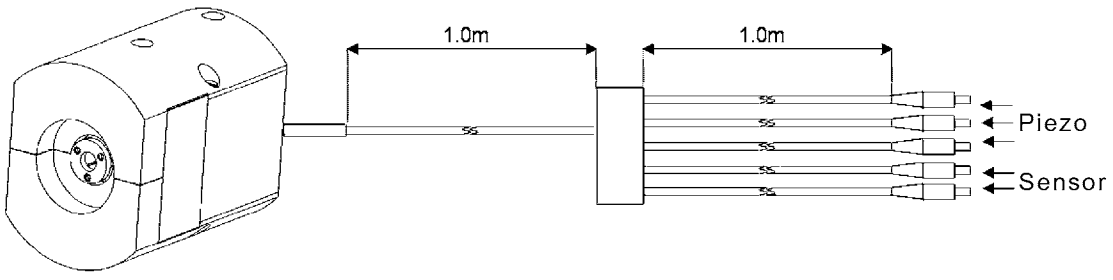


S-334.2SL cable configuration

Technical Data

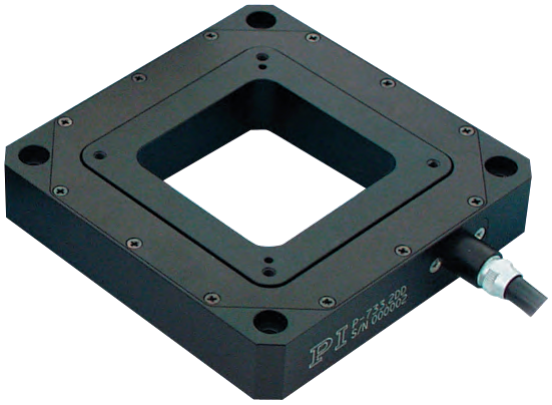
Model	S-334.2SL	S-334.2SD	Units	Tolerance
Active Axes	θ_X, θ_Y	θ_X, θ_Y		
Motion and positioning				
Integrated sensor	SGS	SGS		
*Open-loop tilt angle at -20 to +120 V	60	60	mrad	min. (+20 %/-0 %)
*Closed-loop tilt angle	50	50	mrad	
Open-loop resolution	0.5	0.5	µrad	typ.
Closed-loop resolution	5	5	µrad	typ.
Linearity	0.05	0.05	%	typ.
Repeatability	5	5	µrad	typ.
Mechanical properties				
Resonant frequency under load (with standard mirrors)	1.0	1.0	kHz	±20 %
Resonant frequency with 12.5 mm diam. x 2 mm glass mirror	0.8	0.8	kHz	±20 %
Load capacity	0.2	0.2	N	Max.
Distance of pivot point to platform surface	6	6	mm	±1 mm
Platform moment of inertia	1530	1530	g x mm²	±20 %
Standard mirror (mounted)	diameter: 10 mm, thickness: 2 mm, BK7, λ/5, R > 98 % (λ = 500 nm to 2 µm)	diameter: 10 mm, thickness: 2 mm, BK7, λ/5, R > 98 % (λ = 500 nm to 2 µm)		
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance	6	6	µF	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material casing	Titanium	Titanium		
Mass	0.065	0.065	kg	±5 %
Cable length	2	2	m	±10 mm
Sensor / voltage connection	LEMO connector	25-pin sub-D connector		
Recommended controller / amplifier	Modular piezo controller system E-500 (p. 2-144) with amplifier module E-503.00S (three channels) (p. 2-146) or 1 x E-505.00S and 2 x E-505 (high speed applications) (p. 2-147) and E-509 servo controller (p. 2-152) Open-loop: E-663 three channel amplifier (p. 2-136)	E-616 controller for tip/tilt mirror systems (p. 2-132)		

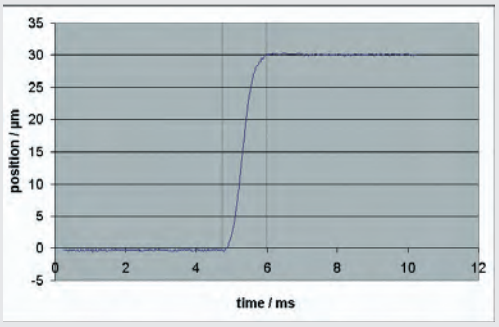
The E-616 OEM controller and the S-334 fast steering mirror system providing a tip/tilt range of up to 60 mrad

Resolution of PI piezo tip/tilt platforms is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier. (p. 2-146)
*Mechanical tilt, optical beam deflection is 120 mrad (open loop) and 100 mrad (closed-loop), respectively.

P-733.2 · P-733.3 XY(Z) Piezo-Stage: High Speed for Tracking

High-Precision XY(Z) Scanner Family





0 to 100 % travel in 1.36 msec, without overshoot. The P-733.2DD is the fastest, highest precision closed-loop XY scanning stage with large aperture currently available.

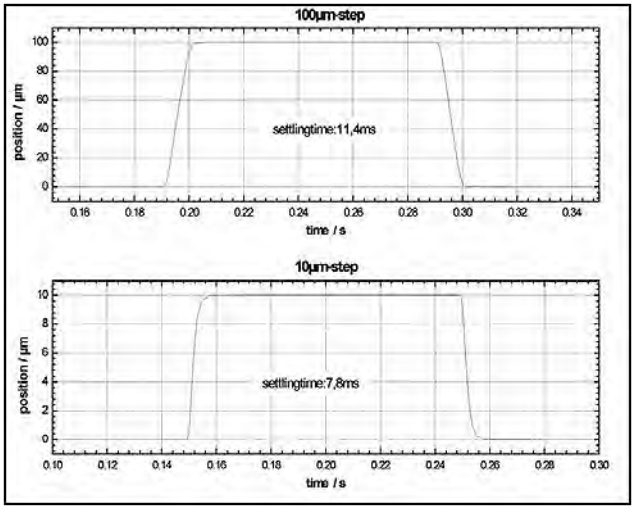
- Travel Ranges to 100 x 100 µm in X,Y & to 10 µm in Z
- Resolution to 0.1 nm with Capacitive Sensors
- High-Speed Versions with Direct Drive
- Vacuum and Non-Magnetic Versions
- Parallel Kinematics for Better Multi-Axis Accuracy and Dynamics
- Parallel Metrology for Active Trajectory Control
- Frictionless, High-Precision Flexure Guiding System
- Clear Aperture 50 x 50 mm for Transmitted-Light Applications

POWERED BY LabVIEW

MetaMorph®

P-733.Z High-Dynamics Z-Nanopositioner / Scanner

Direct Position Metrology and Clear Aperture

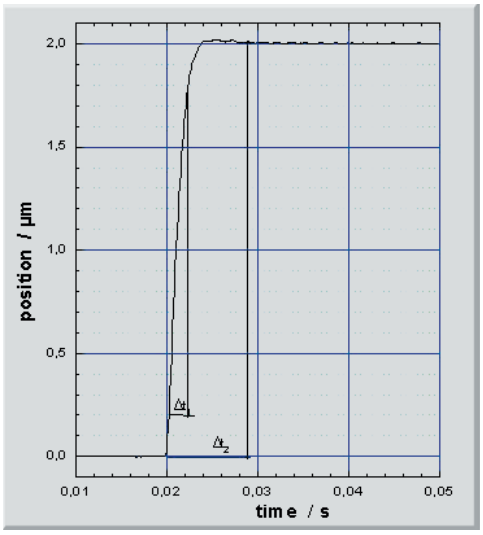


Step response of the P-733.ZCD. Settling time is in the 10 ms range

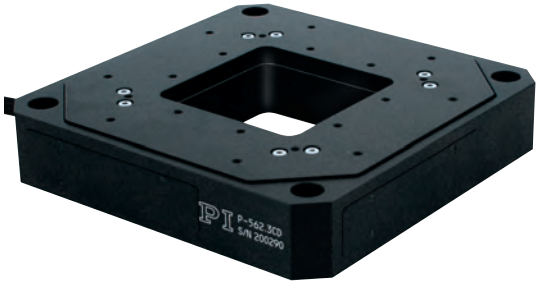
- Travel Range 100 µm
- Direct Metrology with Capacitive Sensors
- Resolution to 0.3 nm, Closed-Loop
- Clear Aperture 50 x 50 mm
- Versions with Additional Degrees of Freedom Available
- XY and XYZ Versions Also Available
- Vacuum-Compatible Versions Available

PIMars™ XYZ Piezo Microscope Stage with Direct Metrology

Long Travel, Ultra Stability & Linearity Capacitive Sensors



P-562.3CD (unloaded) step and settle is aster than 10 ms in X, Y and Z



PIMars™ multi-axis, parallel-kinematics nanopositioning stages are available with up to 340 µm travel per axis. Custom versions to 6 DOF are available

- **Parallel-Kinematics / Metrology for Enhanced Responsiveness / Multi-Axis Precision**
- **Travel Ranges to 340 x 340 x 340 µm**
- **Capacitive Sensors for Highest Linearity**
- **Frictionless, High-Precision Flexure Guiding System**
- **Excellent Scanning Flatness**
- **High-Dynamics Direct Drive Version Available; Custom Versions to 6-DOF**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **UHV Versions to 10^{-9} hPa**

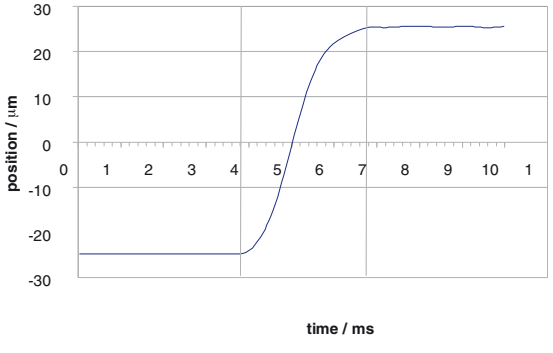
P-541 Low Profile XY, Z/Tip/Tilt-Stages: High Speed Tracking

High Speed Tracking Version & Choice of Sensors Available

The P-541/P-542-series nanopositioning stages feature a very low profile of 16.5 mm, a large 80 x 80 mm aperture and deliver highly accurate motion with sub-nanometer resolution. Dimensions and hole pattern are the same for all P-541/P-542 stages

M-686 open-frame stage with P-541 piezo scanner on top makes an ideal combination for microscopy tasks. The system height is only 48 mm

- **Low Profile 16.5mm; 80x 80mm Aperture**
- **Up to 200x 200µm XY, 100µm Z-Travel ,1 mrad Tilt**
- **Parallel-Kinematics / Metrology for Enhanced Responsiveness & Multi-Axis Precision**
- **High-Dynamics Direct-Drive Version**
- **Choice of Sensors: Strain Gauge (Lower Cost) or Capacitive Sensors (Higher Performance)**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Combination with Long Travel Microscopy Stages**

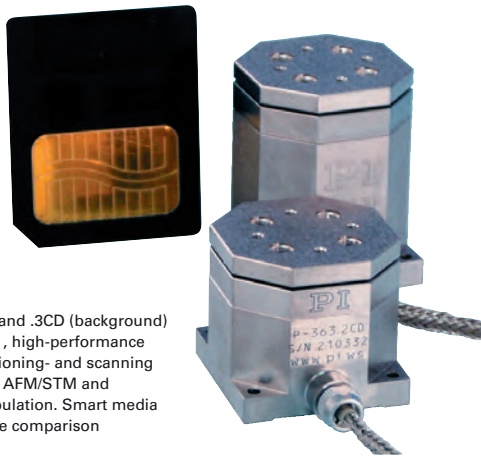


The settling time of a P-541.2DD stage is only 3 ms for a 50 µm step

P-363 PicoCube™ XY(Z) Piezo Scanner for AFM Microscopes

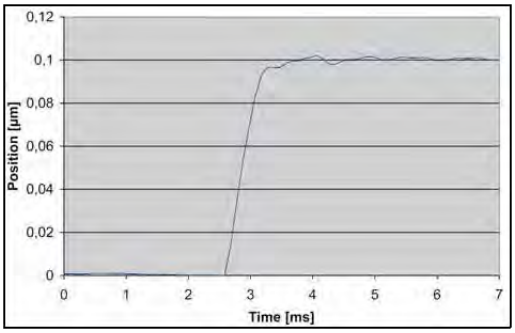
High-Dynamics Nanoscanner for Scanning Probe Microscopy

- **Ultra-High-Performance Closed-Loop Scanner for AFM/SPM**
- **Compact Manipulation Tool for Bio/Nanotechnology**
- **Resonant Frequency 9.8 kHz**
- **Capacitive Sensors for Highest Accuracy**
- **Parallel-Motion Metrology, Automated Guiding Error Compensation**
- **50 Picometer Resolution, 5 x 5 x 5 µm Travel Range**
- **Vacuum-Compatible Versions**

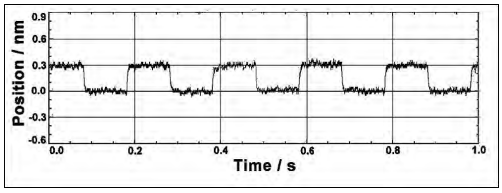


P-363.2CD and .3CD (background) PicoCube™, high-performance piezo positioning- and scanning systems or AFM/STM and nanomanipulation. Smart media card for size comparison

The P-363 settles to within 1 nm in 1 ms (100 nm step, X and Y motion; faster response in Z)

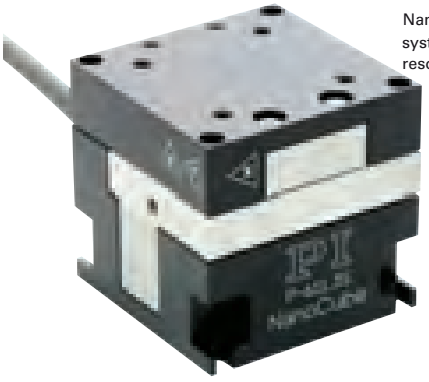


300 picometer steps (0.3 nm) performed with the P-363, measured with an external high-resolution, capacitive measurement system

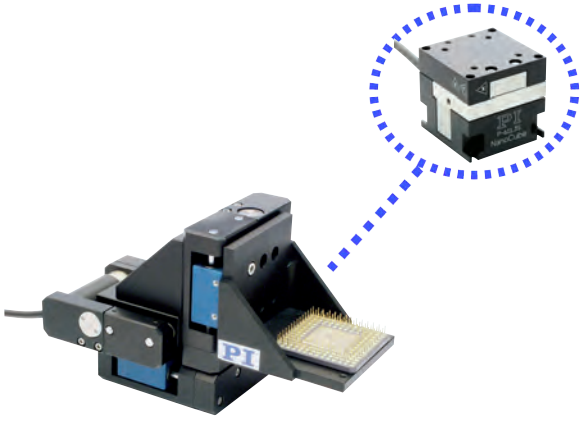


P-611.3 NanoCube® Miniature XYZ Piezo Stage

Compact Multi-Axis Piezo System for Nanopositioning and Fiber Alignment



NanoCube® XYZ-nanopositioning system, 100 x 100 x 100 µm closed-loop travel, resolution 1 nm

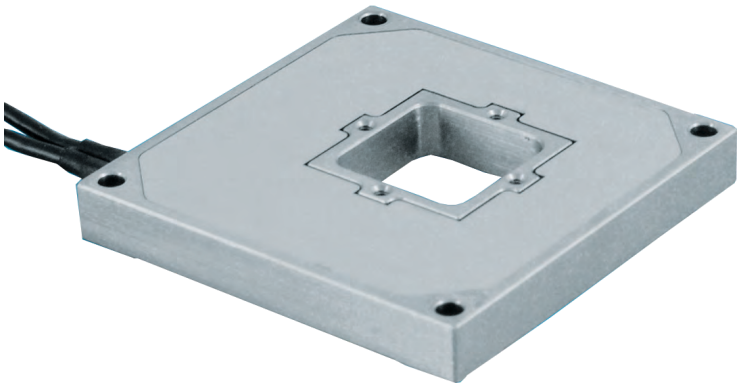


NanoCube® can be integrated with motorized M-111 XYZ stages

- **Up to 120 x 120 x 120 µm Travel Range**
- **Very Compact: 44 x 44 x 44 mm**
- **Resolution to 0.2 nm, Rapid Response**
- **Frictionless, High-Precision Flexure Guiding System**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Fast Multi-Axis Scanning**
- **Version with Integrated Fiber Adapter Interface**
- **Cost-Effective Mechanics/Electronics System Configurations**

P-713 · P-714 XY Piezo Imaging Scanner

Cost-Effective OEM System with Low Profile



P-714 Piezo Scanner: Cost-effective design with very small footprint:45x45x6mm

- **Ideal for Pixel Sub-Stepping in Image Enhancement**
- **Small Footprint and Low Profile: 45 x 45 x 6 mm with Clear Aperture**
- **Very Cost-Effective Design**
- **Travel Ranges to 20 x 20 µm**
- **Parallel Kinematics for Better Multi-Axis Accuracy and Dynamics**

P-713 / P-714 family piezo scanners and positioners with travel ranges of 15 x 15 µm feature especially compact designs. Ideal applications for the P-713 and P-714 are high-dynamics scanning or tracking tasks such as sub-stepping methods for enhancing image resolution. Such tasks involve moving to specific positions in a small area (e. g. marked cells or CCD photosites) and from there following or performing motion with an amplitude of a few microns. The resonant frequency of up to over 2 kHz makes for settling times of a few milliseconds, even after a full-range move, all with closed-loop repeatability of under 5 nm.

A single-axis version with similar footprint is available as P-712 (see p. 2-14) and XY versions with longer travel ranges are available on request.

Application Examples

- Pixel dithering / sub-stepping image resolution enhancement
- Quality assurance testing
- Optical Metrology
- Microscopy
- Imaging
- CCD / CMOS camera technology

Flexibility

P-713 and P-714 nanopositioners are offered in different versions for different applications. The lowest-cost, basic version of the P-713 offers guiding accuracy in the motion plane of 50 µrad, a value generally good enough for dithering and interlacing tasks in scanning patterns of a few microns. For more demanding applications, the P-714 offers greater accuracy, typically 5 µrad or <10 nm absolute.

Nanometer Position Servo-Control

If servo-control is required and no external position sensor is available, the P-714.2SL version, equipped with high-resolution strain gauge sensors (SGS) can provide nanometer-range resolution.

High-resolution, broadband, strain gauge sensors (SGS) are applied to appropriate locations on the drive train and measure the displacement of the moving part of the stage relative to the base indirectly. The SGS sensors assure optimum position stability in the nanometer range and fast response.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

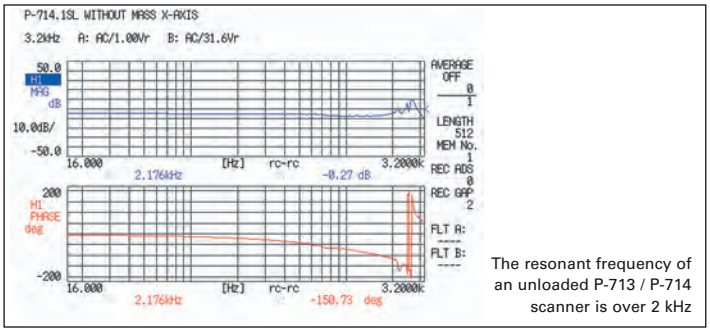
Ordering Information

P-713.20L
Low-Profile OEM XY Nanoscanner, 20 x 20 µm, No Sensor, LEMO Connector

P-714.20L
Low-Profile OEM XY Nanoscanner, 20 x 20 µm, Improved Guiding Accuracy, No Sensor, LEMO Connector

P-713.2SL
Low-Profile OEM XY Nanoscanner, 15 x 15 µm, SGS-Sensor, LEMO Connector

P-714.2SL
Low-Profile OEM XY Nanoscanner, 15 x 15 µm, Improved Guiding Accuracy, SGS-Sensor, LEMO Connector



The resonant frequency of an unloaded P-713 / P-714 scanner is over 2 kHz

Settling time for the P-713/P-714 at 15 µm is in the 2 ms range

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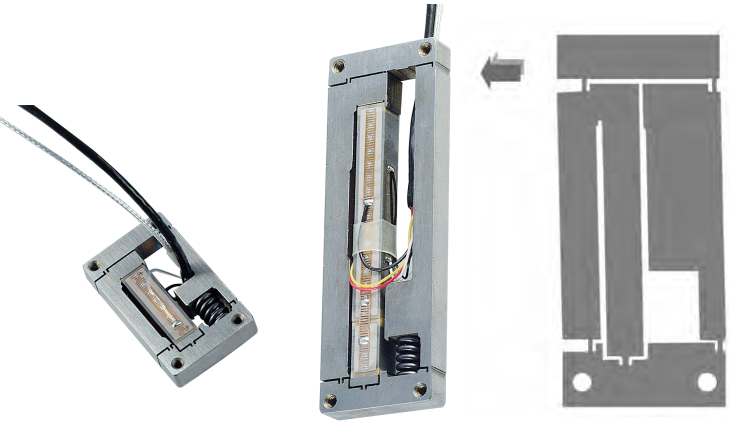
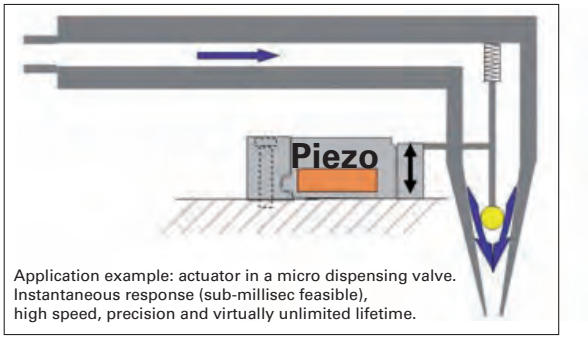
P-603 PiezoMove® Low Cost Flexure Linear Actuator

Long Travel, Compact, for High-Volume Applications



P-603 Flexure design prevents tilt at motion output.
Slight offset only.



Application example: actuator in a micro dispensing valve.
Instantaneous response (sub-millisec feasible),
high speed, precision and virtually unlimited lifetime.

- **Low Cost, Ideal for High Volumes**
- **Up to 500 µm Travel with Integrated Frictionless Motion Amplifier**
- **High Dynamics, Stiffness, Backlash-free**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Available with Integrated Position Sensor**
- **Custom Designs: Larger Travel, Faster Response, Non Magnetic**
- **Ideal for Applications in Adaptronics, Biotech, Microfluidics**

P-602 PiezoMove® Flexure Actuator: High Stiffness, to 1000 µm

Integrated Guiding System, High Force and Large Travel Ranges

P-602 linear actuator
family featuring travel ranges
of 100, 500, and 1000 µm (from left to right).
Flexure guides provide straight motion without tip and minimum tilt

- **Frictionless Flexure Guiding System for Straight Motion**
- **Up to 1000 µm Travel with Integrated Motion Amplifier**
- **High Dynamics, Stiffness, Forces to 400 N, Backlash-free**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Available with Integrated Position Sensor**
- **Custom Designs: Larger Travel, Faster Response, Non Magnetic**
- **Ideal for Applications in Adaptronics, Biotech, Microfluidics**

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The newest release for data sheets is available for download at www.pi.ws. 10/05/03.0

P-601 PiezoMove™ Z-Actuator

Flexure-Guided OEM Piezo Actuator with Long Stroke to 400 µm

P-601 PiezoMove® Lever Amplified Z-Actuators.

- **Flexure Guidance for Frictionless, Ultra-Straight Motion**
- **Travel Ranges to 400 µm**
- **Resolution to 0.2 nm**
- **High Dynamics and Stiffness**
- **Custom Designs with Longer Travel or Faster Response and Non-Magnetic Versions Feasible**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Choice of Closed-Loop and Open-Loop Models**
- **Ideal OEM Actuator for Precision Motion Control in Optics, Medical, Biotech and Microfluidics Applications**

The flexure-guided, lever-amplified PiezoMove™ P-601 actuators provide large vertical travel ranges up to 400 µm, fast response and high positioning accuracy in a very small package. With settling times of only a few milliseconds and a resolution in the sub-nanometer range they are well suited for both static and dynamic applications.

P-601 PiezoMove™ lever-amplified actuators cover the range between direct-driven preloaded piezo translators, such as the P-840 series (see p. 1-74) and single-axis nanopositioning stages, like the P-611 series (see p. 2-20). Compared to direct-driven piezo translators, lever-amplified actuators offer larger travel ranges and much higher lateral stiffness and guiding precision. Compared to single-axis nanopositioning stages, they offer significantly smaller sizes. PiezoMove™ lever-amplified actuators feature a resolution to 0.2 nm and a repeatability to 8 nm.

Application Example

- Nanopositioning
- Imaging
- High-speed switching
- Patch clamp
- Micro-dispensing
- Semiconductor testing
- Adaptronics / Automation
- Photonics / integrated optics
- Biotechnology

OEM Actuator with Integrated Guidance

With their highly precise, frictionless flexure guidance, a very high stiffness and excellent straightness of motion are achieved. Together with their small dimensions and the cost-effective design, the P-601 lever amplified actuators are especially suited for OEM applications. Versions with strain-gauge sensors (SGS) are equipped with a full bridge circuit that is insensitive to thermal drift. Versions without sensors are also available for open-loop applications such as in high-speed switches and pumps. In addition to the standard steel models, special invar and non-magnetic versions are available on request.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Ordering Information

P-601.1S
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 100 µm, SGS-Sensor

P-601.3S
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 250 µm, SGS-Sensor

P-601.4S
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 400 µm, SGS-Sensor

P-601.1SL
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 100 µm, SGS-Sensor, LEMO Connector

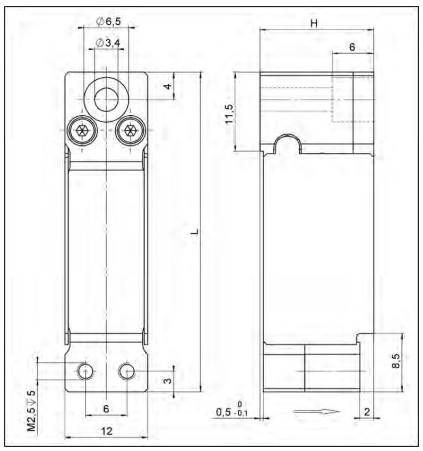
P-601.3SL
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 250 µm, SGS-Sensor, LEMO Connector

P-601.4SL
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 400 µm, SGS-Sensor, LEMO Connector

P-601.10
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 100 µm, Open-Loop

P-601.30
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 250 µm, Open-Loop

P-601.40
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 400 µm, Open-Loop



	H	L
P-601.1S	16,5	46,5
P-601.3S	18,0	64,5
P-601.4S	20,5	82,5

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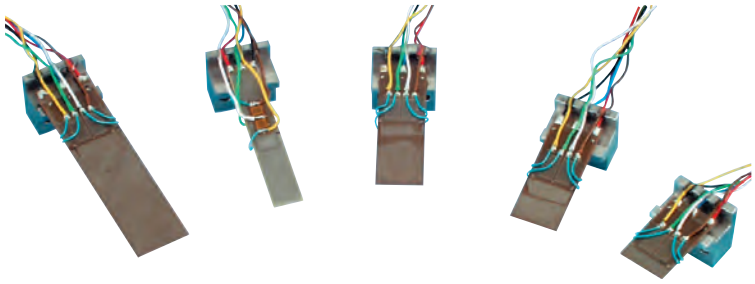
P-871 PICMA® Piezo Bender Actuators

Low-Voltage Multilayer Piezo Bender Actuators with Position Sensor



P-871.140, P-871.128, P-871.122 and P-871.112
closed-loop bender actuators (from left to right)

- **Closed-Loop Operation for Superior Accuracy**
- **Nanometer-Resolution**
- **Displacement to 1.6 mm**
- **Ceramic Encapsulation for Extended Lifetime**
- **Ideal for Scanning Applications**
- **Vacuum-Compatible Versions**
- **Low Operating Voltage**
- **Mounting Hardware Included**
- **Special OEM- and Bench-Top Amplifiers Available**

P-871 transducers are unique closed-loop piezo benders based on the open-loop PL 122 to PL 140 PICMA® -series multilayer actuators p. 1-94. Equipped with high-resolution position feedback sensors they provide better linearity, accuracy and repeatability than other piezo benders on the market. P-871 bender actuators achieve longer positioning ranges than typical piezo stack actuators, up to 1.6 mm, while still providing fast response times in the millisecond range.

Application Examples

- Wire bonders
- Pneumatic valves
- Fiber optic positioning & switches
- (Laser)- Beam steering
- Micropositioning
- Acceleration sensors
- Nanotechnology

Design

These multilayer piezoelectric components are manufactured from ceramic layers of only about 50 µm thickness. They feature internal silver-palladium electrodes and ceramic insulation applied in a cofiring process. Due to the thin layers the operating voltage is significantly lower than for classical parallel bimorph bender elements. For ease of installation, the units come complete with the mounting hardware, cables and connectors.

Closed-Loop Position Control for Higher Accuracy

P-871s are ideal devices for scanning, positioning and beam deflection applications and provide much better accuracy, stability and repeatability than conventional open-loop actuators. The special bender design allows the direct application of a strain gauge sensor to the surface without the need for a polymer insulation layer in between. The advantages are faster response, reduced phase lag and precise position control with non-linearity of <0.5 %. The settling time for a small-signal step (up to 1 % nominal travel) to an accuracy of better than 1 % is between 10 ms (P-871.112) and 30 ms (P-871.140).

Ceramic Insulated Piezo Actuators Provide Long Lifetime

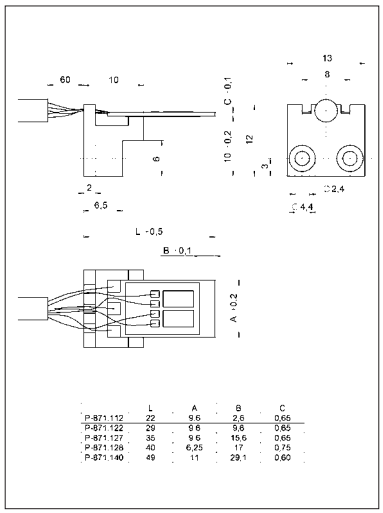
Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Optimum UHV Compatibility - Minimum Outgassing

The lack of polymer insulation and the high Curie temperature make for optimal ultra-high-vacuum compatibility (no outgassing / high bakeout temperatures, up to 150 °C).

Amplifiers, Drivers & Controllers

PI offers a wide range of standard amplifiers and controllers for piezo actuators. The E-651.1S and E-651.2S desktop controllers and the OEM board E-614.2BS (see p. 2-123) are specifically designed to operate P-871 bender actuators.



	L	A	B	C
P-871.112	22	9.6	2.6	0.65
P-871.122	29	9.6	9.6	0.65
P-871.127	35	9.6	15.6	0.65
P-871.128	40	6.25	17	0.75
P-871.140	49	11	29.1	0.60

Ordering Information

P-871.112
PICMA® Multilayer Piezo Bender Actuator, 160 µm, 9.6 mm Width, SGS-Sensor

P-871.122
PICMA® Multilayer Piezo Bender Actuator, 400 µm, 9.6 mm Width, SGS-Sensor

P-871.127
PICMA® Multilayer Piezo Bender Actuator, 720 µm, 9.6 mm Width, SGS-Sensor

P-871.128
PICMA® Multilayer Piezo Bender Actuator, 720 µm, 6.3 mm Width, SGS-Sensor

P-871.140
PICMA® Multilayer Piezo Bender Actuator, 1600 µm, 11 mm Width, SGS-Sensor

Ask about custom designs

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M-228 · M-229 Stepper Linear Actuator Series

High-Load, Compact and Highly Cost-Efficient, with Limit Switches

M-228 and M-229 series linear actuators are driven by powerful direct-drive stepper motors, or are equipped with more compact, gearhead stepper motors: M-229.26S, M-228.11S, M-229.25S, M-228.10S (from left)

- **Highly Cost-Efficient, Compact Design**
- **10 and 25 mm Travel Range**
- **High Load Capacity to 80 N**
- **Gearhead Version: 46 nm Resolution (with C-663 Controller)**
- **Direct Drive: Max. Velocity 5 mm/s**
- **Non-Rotating Tip**
- **Non-Contact Limit and Reference Switches**

M-228 and M-229 series linear actuators provide a travel range of 10, resp. 25 mm, and are equipped with high-resolution stepper motors. The stepper mikes can push or pull loads up to 80 N, and provide speeds up to 5 mm/s. Models featuring gearhead/stepper motor combinations offer the same stroke in a more compact package.

Application Examples

- Quality assurance testing
- Testing equipment
- Alignment of secondary mirrors
- Automation
- Metrology
- Precision machining

Cost-Effective Design, Valuable Features

The cost-effective design offers many useful features such as a non-rotating tip, limit and reference switches and a mechanical position display.

A spherical tip and a 3 m extension cable are included in the delivery. The more compact gearhead versions include an additional flat tip.

Non-Rotating Tip

Compared to conventional rotating-tip micrometer drives, the non-rotating tip design offers several advantages:

- Elimination of torque-induced positioning errors
- Elimination of sinusoidal motion errors
- Elimination of wear at the contact point
- Elimination of tip-angle-dependent wobble

Limit and Reference Switches

For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

Low Cost of Ownership

The combination of these actuators with the networkable C-663 Mercury Step controller (s. p. 4-112) offers high performance for a very competitive price in both single and multi-axis configurations.

Ordering Information

M-228.10S
Stepper-Mike Linear Actuator, 10 mm, Stepper Motor, Gearhead, Limit Switches

M-228.11S
Stepper-Mike Linear Actuator, 10 mm, Stepper Motor, Direct Drive, Limit Switches

M-229.25S
Stepper-Mike Linear Actuator, 25 mm, Stepper Motor, Gearhead, Limit Switches

M-229.26S
Stepper-Mike Linear Actuator, 25 mm, Stepper Motor, Direct Drive, Limit Switches

Ask about custom designs!

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

N-310 OEM Piezo Stepper Actuator

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Medical Engineering News: Driven by Piezo

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

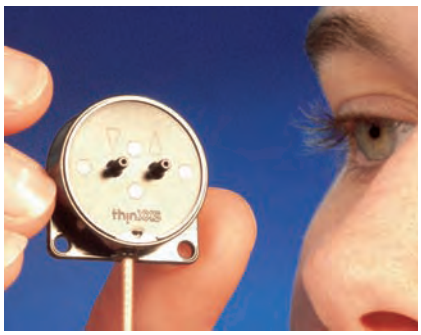
The continuing miniaturization in medical engineering places ever increasing demands on the components. Piezo drives are the solution for many motion control applications; the piezo effect efficiently generates fast and precise motion while requiring very little space.

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)

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.

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.

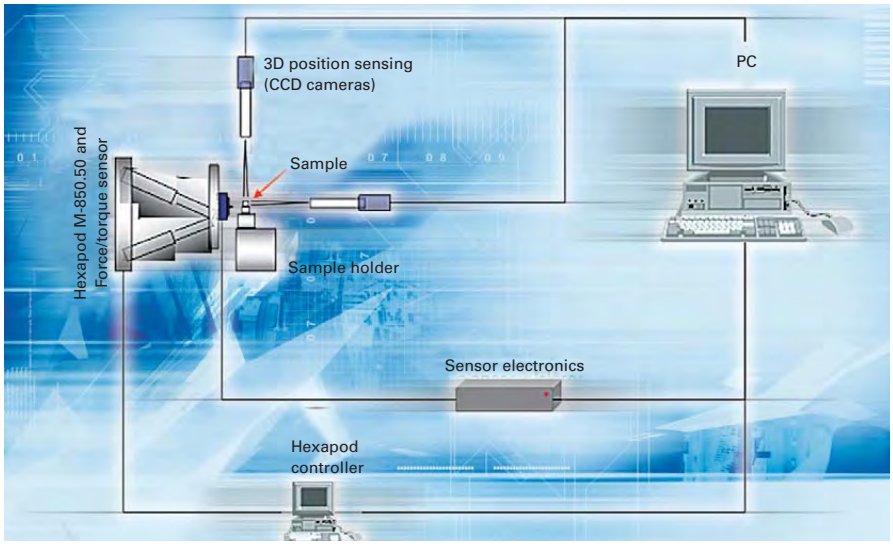
At the same time, movements of several orders of magnitude are involved: orthodontic equipment can change the position of teeth by up to several mm, whereas—during mastication—teeth are deflected by less than 100 µm and implants by as little as a few microns or less. These combinations of small forces 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.

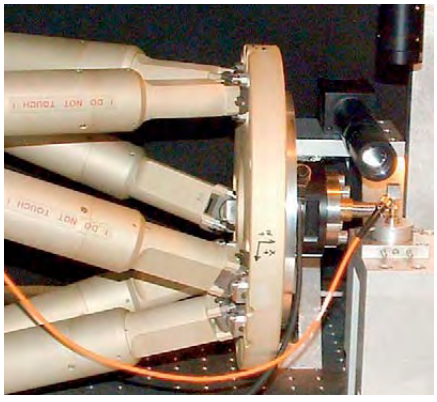
For high-load testing—simulations of mastication in the 100 N range—the optical portion of the HexMeS is used. It resolves sample deflections to 0.7 µm / 0.2 arcsec.



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.



Request Information on Hexapods in Spine Surgery

Piezo · Nano · Positioning

news

Issue 37

OCT: Piezo Motors in Medical Design

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

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.

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.

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

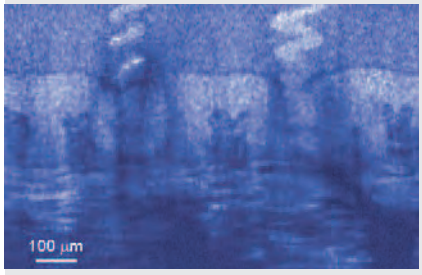
To enable creation of 2- and 3-dimensional images from interference patterns, the optical fibers must be moved both axially and laterally during the scan. This task requires positioners capable of the highest precision. Ultimately, it is the performance of the drives which determine the system resolution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

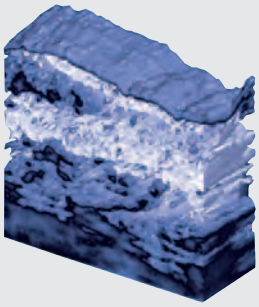
As the images are recorded sequentially, the high speed and excellent dynamic response of the drive is a great advantage. As a result, the SkinDex needs only a few seconds to generate its highly informative images. The lateral motions of the optical fibers in the sensing arm executing the surface scan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

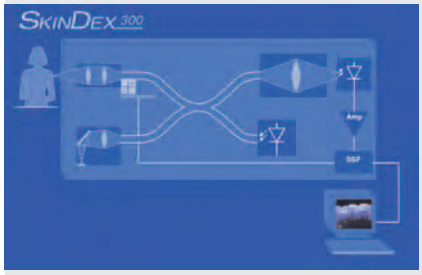
The SkinDex scanner based on OCT technology for non-invasive but reliable examination of the tissue on and under the skin surface (photo ISIS Optronics).



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

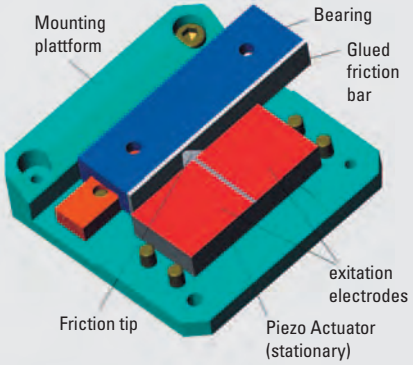


3-D OCT image: Individual laminar and cylindrical structures such as larger blood vessels are visible under the rough skin surface.



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 piezo nanopositioning 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 supported by all major image acquisition software packages.

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

Scanning microscopy methods such as single molecule fluorescence microscopy provide high lateral positioning resolution even below the limitations of the numerical aperture. 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 correspond 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.

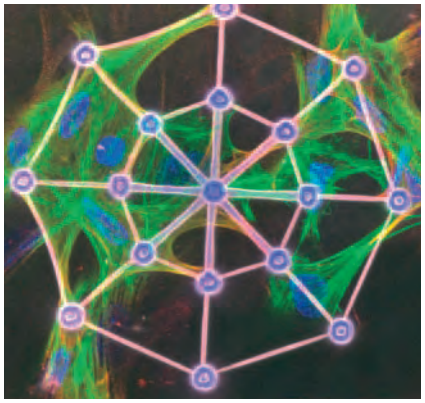
PI nano™ series comprising E-545 controller, P-545 piezo system and M-545 manual stage

Piezo · Nano · Positioning

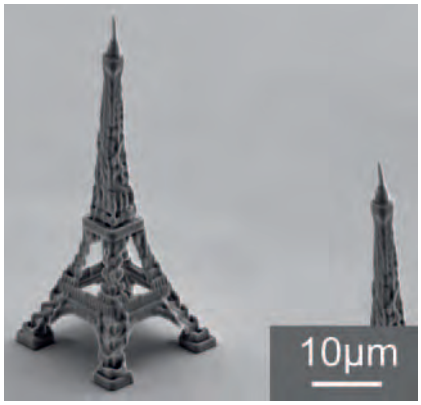
news

Issue 38

3D Structuring in Nanotechnology



Cell embedded in artificial three-dimensional extra-cellular matrix. (Photo: Nanoscribe)



Complex three-dimensional structure: An Eiffel tower 50 micrometer in height was produced using the Nanoscribe 3D lithography process (Photo: Nanoscribe)

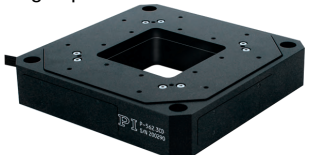
A novel 3D laser lithography system based on PI nanopositioning technology is now available from Nanoscribe GmbH (www.nanoscribe.de). The new system allows for the first time the fully automated production of complex three-dimensional microstructures and nanostructures using photosensitive materials.

Typical fields of application for the new technology are, for example, the production of three-dimensional matrices for cellular biology, the manufacture of micro-optical components or photonic crystals and also as a rapid-prototyping instrument for microfluidic and nanofluidic systems and their production in small batches. The desired structures can be designed and then imported using any CAD software which supports the DXF format.

Track Widths to 150 nm and Below

The operating principle of the new lithography process, which is suitable for all commercially available photoresists, is easily understood: Ultrashort laser pulses are strongly focused into the material, which is then exposed by means of a nonlinear optical process in the focal point. Like a pen that is moved in three dimensions, the laser beam writes on the material following arbitrary paths. It is thus possible to achieve track widths from several micrometers down to 150 nm. Two-dimensional 2D structuring or $2^1/_2$D structuring with surface profiles are, of course, also possible and have a resolution which is significantly higher than that allowed by conventional instruments up to now.

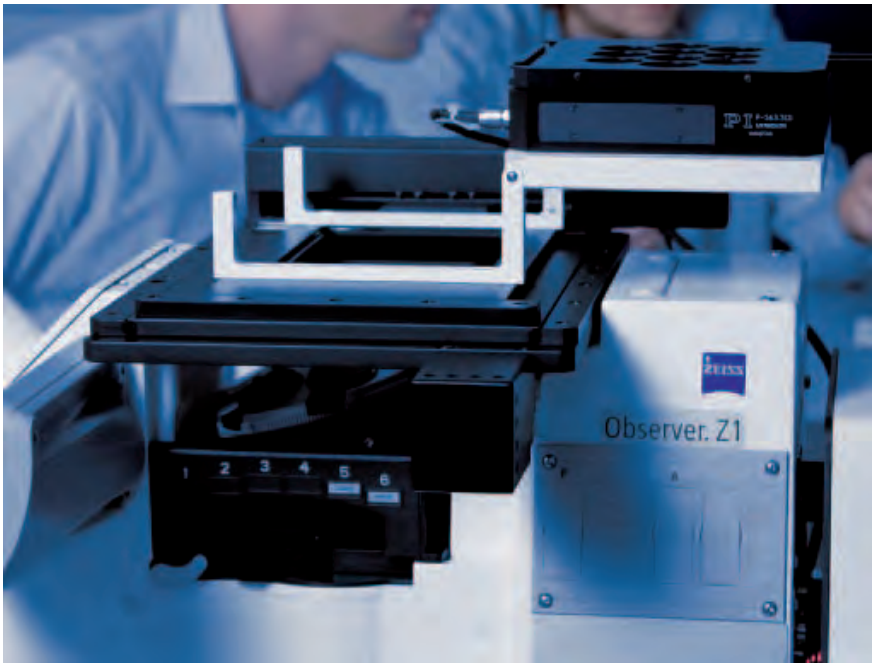
The P-563 PIMars™ Piezo Stage is a fast & accurate 3D positioning system based on piezo drives, friction-less flexure guides and non-contacting capacitance sensors.



Nanopositioning in 3D Structuring

The PI nanopositioning system used by Nanoscribe for its lithographs consists of a 3-axis P-563 stage and an E-761 digital controller. The P-563.3CD PIMars™ multi-axis nanopositioning stage provides travel ranges of up to 300 x 300 x 300 µm 4 nanometer repeatability. Its construction as a parallel-kinematics multi-axis system contributes to the high positioning accuracy. All piezo actuators act on a central platform so all axes behave with identical dynamics. One "slower" axis, mostly unproblematic for linear scans, would have detrimental effects here. Moreover, the high-resolution capacitive sensors can register any deviation from the commanded path in 3D space in real time. This type of position measurement directly at the moving platform against a fixed reference (parallel metrology) allows the immediate determination and active compensation for axis crosstalk and lateral runout. The PCI-board-based E-761.3CD digital piezo controller is matched to the multi-axis parallel-kinematics piezo nanopositioning system and provides the exact trajectory control necessary for this task.

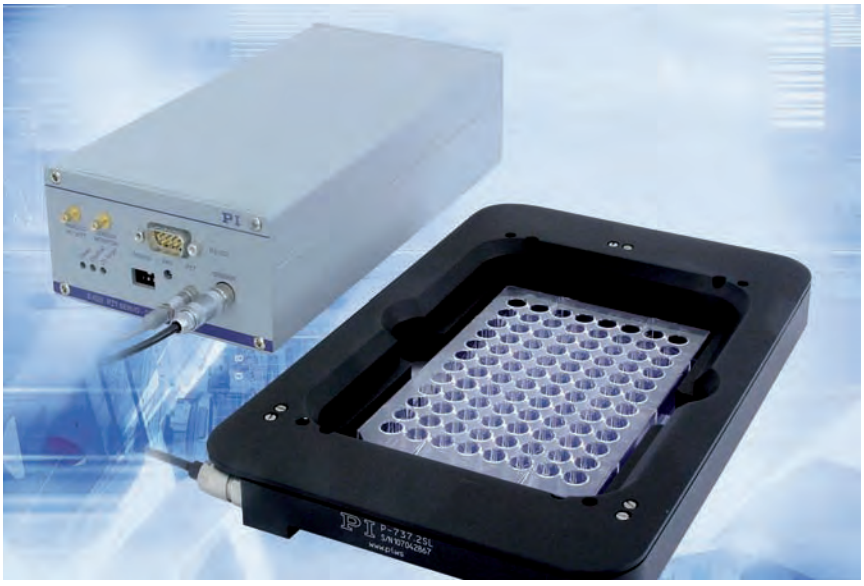
The P-563.3CD nanopositioning system with its E-761, PC plug-in digital controller (foreground) is ideally suited to the application because of its high positioning accuracy and travel range of 300 µm in three axes.



Novel laser lithography system which – for the first time – allows the production of complex three-dimensional microstructures and nanostructures using photosensitive materials. The precise adjustment of object or sample is achieved by using a P-563 PIMars™, a parallel-kinematics multi-axis piezo nanopositioning system (Photo: Nanoscribe)

News & Applications

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



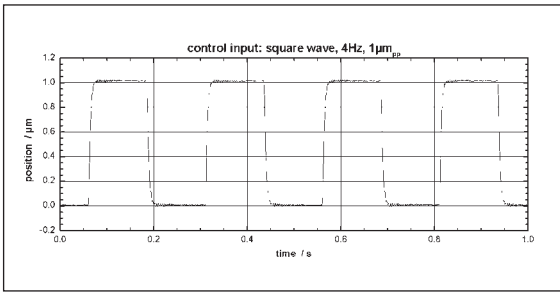
PI is the inventor of high-speed Piezo-Z objective steppers. Today the term PIFOC® is practically synonymous with all high-resolution vertical drives for microscope objectives. Depending on the application, it can be advantageous to adjust the sample instead of the objective. While no sample stage can 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.

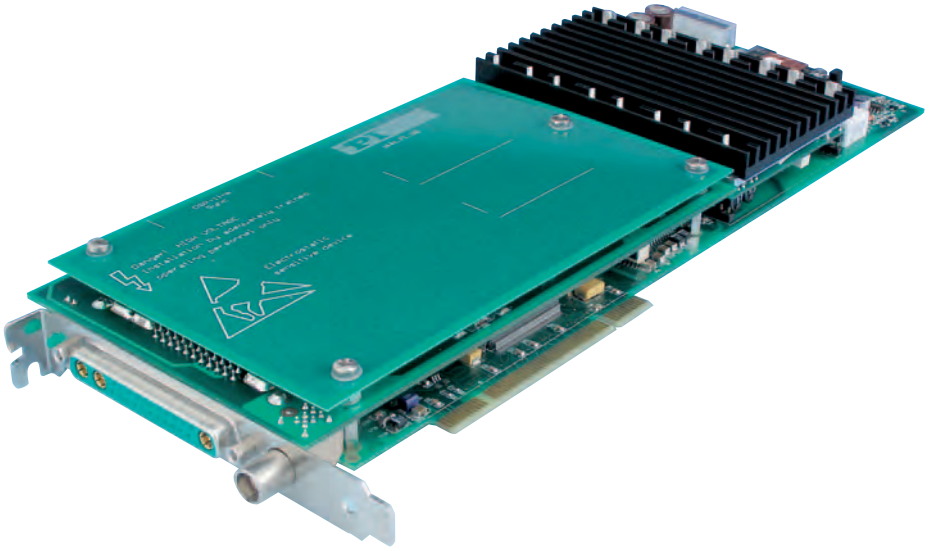
The capacitive-sensor-equipped version can also be operated with the sophisticated E-753 digital servo-controller. The main advantage of this controller is its adaptability to changing load conditions on the piezo stage. No matter what load is applied, the system can always provide an optimum combination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

News & Applications

World's First Digital Piezo Nanopositioning Controller on PCI Board

New E-761 digital piezo controller in the PCI-board format



E-761 3-channel digital nanopositioning controller: very advanced control technology in cost-effective PCI format to control up to three logical axes

The E-761 digital nanopositioning controller offers very advanced control technology in the cost-effective PCI-board format. It is able to control nanopositioning systems with up to three logical axes and four piezo actuators.

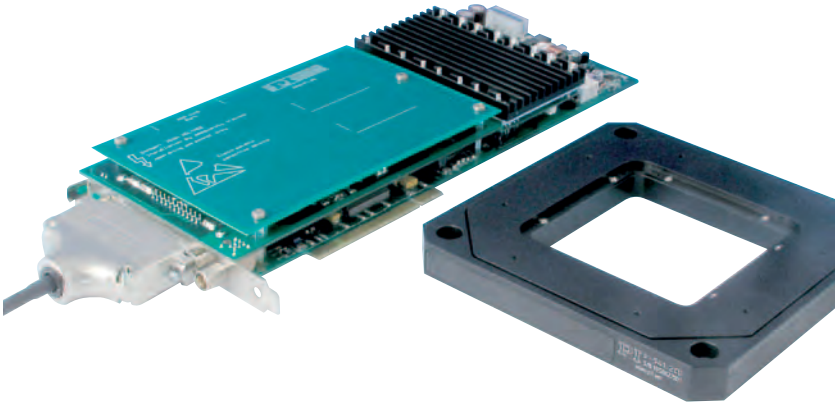
Many of today's high-tech applications, such as imaging, metrology, scanning microscopy and surface analysis require a combination of high-speed motion control and high-resolution vision. They also require extremely fast data acquisition and precise synchronization between the imaging and motion control devices. Peripheral components with PCI bus interface are ideal for these tasks, because the PCI bus was designed to give high-bandwidth access to the microprocessor in the PC. With the E-761, PI introduces the world's first fully digital piezoelectric nanopositioning controller on a PCI board.

The PCI bus allows for very rapid communication and easy integration with devices such as frame grabbers – a feature which is very advantageous in real-time data acquisition applications or when operating multiple axes or controllers simultaneously.

The internal coordinate transformation means it is no problem to operate complex, multi-axis stages, such as three-axis X-Y-Θ_Z stages or Z-tip-tilt platforms. In systems with parallel metrology, the E-761 can also automatically compensate undesired off-axis motion (active trajectory control), making it possible to attain motion accuracies in the sub-nanometer range.

Of course, this digital controller has the technical refinements you have come to expect from PI, such as 32-bit digital filters, 24-bit DAC resolution, multi-stage sensor and electronics linearization, plug & play ID-chip support and an extensive software support package.

P-541.2CD low-profile XY piezo stage with capacitive sensors: a perfect fit for the E-761



News & Applications

New Multi-Axis Piezo Controller Provides Higher Precision, Flexibility

Digitally Controlling the Nano-World – in up to 6 Axes

The E-712 controller is available in 3- and 6-channel configurations.

The new, E-712 multi-axis piezo-controller picks up where the successful E-710 left off. It features a faster processor, a real-time operating system and significantly higher servo update and sensor sampling rates to provide extremely precise coordinated motion in up to 6 degrees of freedom with nanometer precision.

Additional advantages:

- Versatile interfaces: TCP/IP for remote control through the internet; additional USB 2.0 and the classic RS-232. Available high-resolution analog inputs for direct control with high-bandwidth analog signals.
- 20-bit D/A converters make possible sub-nanometer position resolution, even over long travel ranges of >1000 µm, like those of the new P-629 PIHera® piezo nanopositioning stages.
- Available high-power amplifier modules, to supplement the integrated amplifiers for high-frequency scanning / tracking applications.
- Software – tunable, proportional-integral, digital servo-control with 2 notch filters allows operation of the piezomechanics closer to its resonant frequency.
- 600 MHz processor and sensor and servo update rates of up to 50 kHz assure faster updating of the position and control data – especially important for high-dynamics periodic motion. In addition, optional Digital Dynamic Linearization, ensures that tracking errors are reduced to the nanometer level even in high-dynamics scanning applications.
- Internal coordinate transformation for parallel-kinematics systems with user-friendly position commands in Cartesian coordinates.

Mature operating software with intuitive interfaces make operating the system almost child's play. No programming knowledge is needed, whether commissioning, optimizing system parameters, creating new user-defined motion profiles for the integrated wave generator, or recording data generated during the motion. The comprehensive package of supporting software, including LabVIEW drivers and DLLs, ensures easy integration in a variety of system environments.

News & Applications

Ultra-Low-Noise PicoCube® Controller

Reference-Class System for AFM Nanotechnology

New E-536 controllers enable even higher resolution and bandwidth with the minute P-363 PicoCube® piezo stages.

The minute P-363 PicoCube®, together with its reference-class, ultra-low-noise E-536 driver/controller, are ideally suited for nanotechnology applications. They provide significantly higher dynamics, resolution and positional stability than previous multi-axis scanning stages. Nano-imprint lithography, scanning microscopy and biotechnology benefit from the extremely high resolution of up to 25 picometers over travel ranges of 5 µm per axis.

Controllers: Optimized for Highest Resolution / Bandwidth

Two controller versions are available. For high-speed scanning applications the E-536.3C high-power models featuring 100 watts per channel are recommended. The E-536.3CH ultra-low noise versions are optimized for highest positioning accuracy and resolution in the picometer range.

Compact 2-Axis and 3-Axis Stages

The compact PicoCube® is available as XY and XYZ system. It is based on exceptionally robust, high-stiffness shear piezo drives and employs non-contact, direct-measuring, parallel-metrology capacitive sensors for position feedback.

The low-inertia drives allow for a resonant frequency of 10 kHz, important for high speed scanning applications. Measuring only 30 x 30 x 26 mm (XY version), it is easy to integrate in any scanning apparatus.

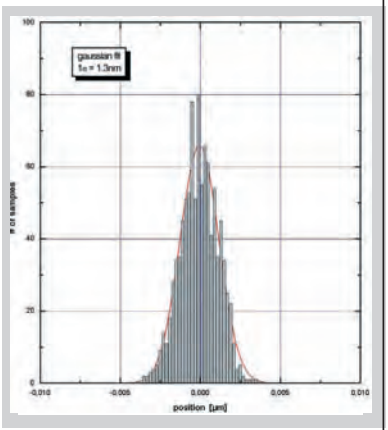
Test and Calibration—Why High-Quality Nanometrology Equipment Matters

Piezo nanopositioning systems are significant investments and PI believes in optimizing the performance of every customer's system. PI individually calibrates every stage and optimizes the dynamic performance for the customer's application. Furthermore, PI makes significant continuing investments in improved-quality, higher-performance nanometrology equipment so that we can deliver better value to our customers.

Because a nanomechanism can only be as accurate as the equipment it was tuned and tested with, PI closed-loop stages are calibrated exclusively with the prestigious Zygo ZMI-2000 and ZMI-1000 interferometers. PI's nanometrology calibration laboratories are seismically, electromagnetically and thermally isolated, with temperatures controlled to better than 0.25 C° / 24hr. We are confident that our calibration capabilities and procedures are the benchmark for the industry.

Prestigious Zygo ZMI-2000 and ZMI-1000 interferometers are used in PI´s nanometrology calibration labs. Each stage is individually calibrated and optimized for dynamic response.

State-of-the-art, room-in-room metrology lab with multiple thermal, acoustic and seismic isolation for meaningful sub-nanometer measurements.



Fully randomized position repeatablity measurement of a direct metrology-equipped 100 µm PIHera™ stage, made with Zygo interferometer. The data show the exceptional precision of these mid-level nanopositioning devices.

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Nanometrology, Nanopositioning, NanoAutomation®

Ultra-Precision Motion Control Solutions for Optics, Imaging, Photonics


PI Headquarters

Motion Control Technology - 30 Years Ahead of its Time

PI has been a world market leader in nanopositioning technology and ultra-high-precision motion-control systems for many years.

Key Technologies Under One Roof: A Plus for Our Customers

PI has a strategy of vertical integration with all key technologies developed and maintained in one company.

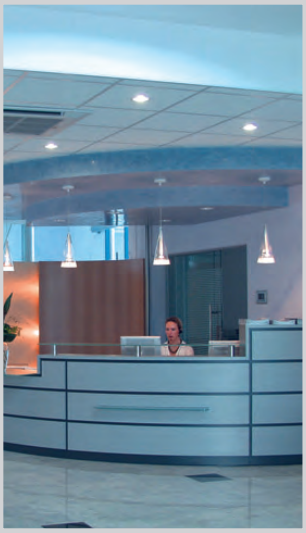
Why Vertical Integration Matters

- **To provide higher performance and better value to customers**
- **To advance the state-of-the-art with leading edge technologies that are just not commercially available**
- **To maintain leadership in proprietary design & manufacture capabilities of control electronics, sensor/metrology technology and actuators acquired over the years**
- **To provide systems with longer lifetime, higher performance, and more robustness to OEM and scientific customers**

Applications

Today PI delivers Nanopositioning & measuring solutions for all high-tech markets:

- Microscopy & Optics
- Bio & Nanotechnology
- Semiconductors, Photonics, Telecom
- Life Sciences
- Lasers, Metrology
- Aerospace Engineering
- Medical Technology
- Astronomy




PI USA Headquarters - Auburn, MA

Piezo • Nano • Positioning

Program Overview

- Piezo Ceramic Actuators & Motors
- Piezo Nanopositioning Systems and Scanners
- Active Optics / Tip-Tilt Platforms
- Capacitive Nanometrology Sensors
- Piezo Electronics: Amplifiers and Controllers
- Hexapod 6-Axis Positioners / Robots
- Micropositioning Stages & Actuators
- Photonics Alignment Systems, Solutions for Telecommunications
- Motor Controllers
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