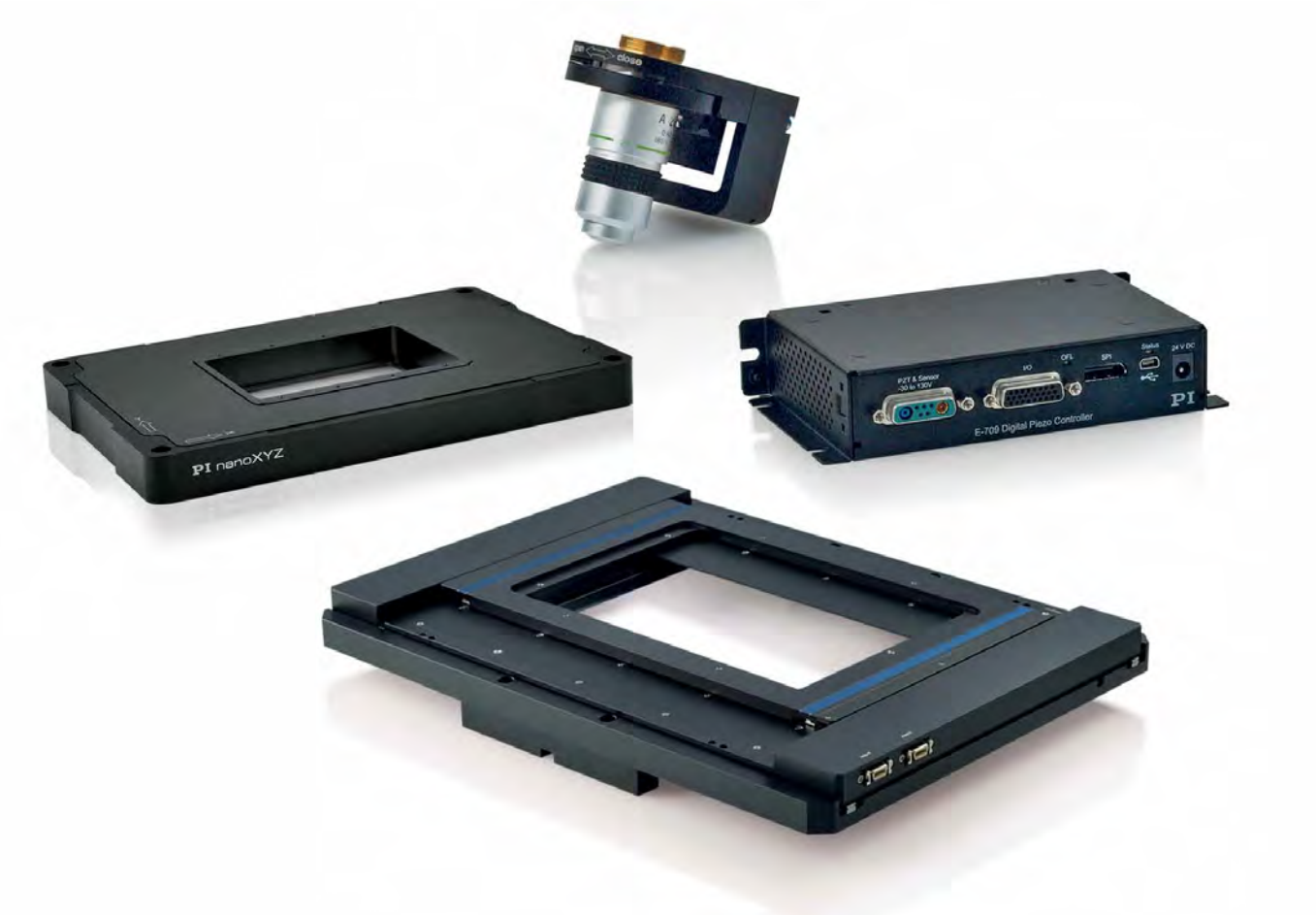
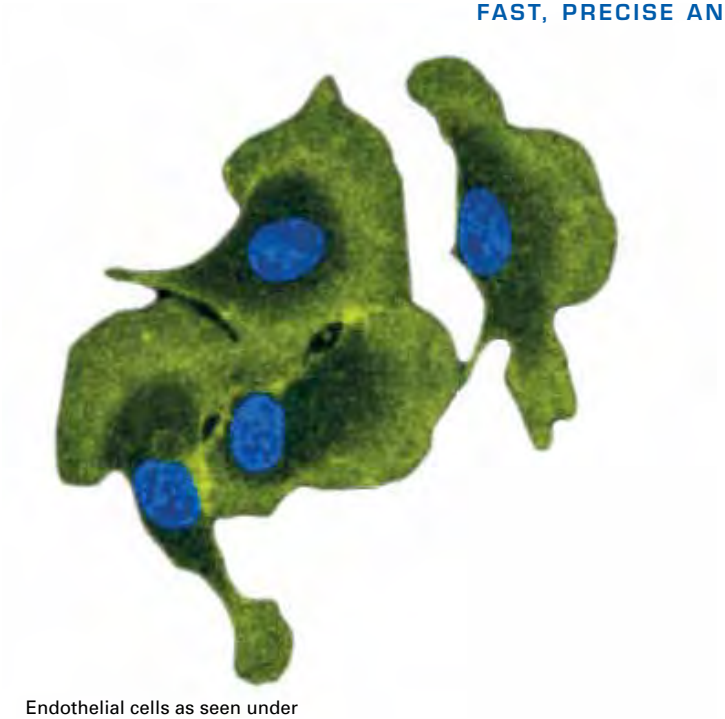


PI Products for Microscopy and Electron Microscopy

FAST, PRECISE AND COMPACT

PI Products for Microscopy

FAST, PRECISE AND COMPACT



Endothelial cells as seen under the microscope. Source: Lemke Group, EMBL Heidelberg

Positioning Tasks in Microscopy

Almost all microscopic techniques have similar basic requirements in regard to the positioning elements: compact design and very high accuracy. Often, many individual images are to be taken during the examination of a sample in as short a time as possible or dynamic processes are to be observed – both tasks place great demands on the dynamics of the stage.

However, if one considers the requirements of individual applications more closely, it becomes apparent that the details of the requirements are quite different.

Manual XY Motion - Vertical to the Optical Axis

Manual stages for high-resolution techniques are mainly used for the positioning of 3x1“ slides or individual Petri dishes. This

PInano® XY(Z) scanning system with additional M-545 manual stage

requires an adjustment range of approx. 25 mm in both axes. A good position stability of the stages as well as minimum play are important here. Naturally, the stages also have to fit on the corresponding microscopes. Here, PI offers the M-545.2M (p. 11), whose members are specifically designed for the most common inverted microscopes from Zeiss, Leica, Nikon and Olympus. Sample holders are available as accessories. The special design enables full rotation of the microscope turret without obstruction.

These stages are optionally available with stepper motors or, upon request, with integrated ultrasonic motors as well.

XY Scan with Additional High-Resolution Piezo Scanner

When the applications require an additional fine adjustment with step sizes in the nanometer range, the PInano® piezo systems are available (p. 6–9). They can be directly bolted onto the M-545 series – and with the available sample holders, the turret can also be turned here without changing the Z position.

PInano® stages are available in XY, XYZ and Z configurations, with a large clear aperture to accommodate 3x1" slides and Petri dishes.

A specially configured piezo controller is included and comes with three high resolution digital interfaces (USB, Ethernet, RS-232) and an analog interface, as well as solid software support for all major image acquisition packages.

XY Scan of Large Samples

If larger samples have to be examined (e. g. microtiter plates), stages with an XY travel range of approx. 130 x 80 mm and a large clear aperture of 160 x 110 mm are typically required.

For these applications PI offers highly compact systems with the innovative PILine piezo linear drives (p. 20).

These are characterized by a low profile, an extremely high dynamic range (10 µm/s to 100 mm/s) and very good velocity constancy, position stability and repeatability. The high position stability is due to the combination of the ceramic direct drive without flowing lubrication layers, a high-resolution linear encoder and a very low heat dissipation from the motor.

These stages are also very well suited for super resolution microscopy applications such as STORM, PALM, STED or SIM, which place very high demands on the stability of the positioning elements used, regardless of the sample size.

For applications where additional fine adjustment in the nanometer range is required, these stages can be combined with PInano® Cap systems (p. 6). Compared to the lower cost variants with piezoresistive sensors, their integrated capacitive feedback provides considerably better stability and repeatability.

Positioning Tasks in Microscopy

XY scan

- Object slides, Petri dishes
- Large samples

XY scan with piezo fine scanning

- in XY, XYZ, Z
- Object slides, Petri dishes
- Large samples

STORM

Stochastic Optical Reconstruction Microscopy

PALM

Photoactivated Localization Microscopy

STED

Stimulated Emission Depletion

SIM

Structured Illumination Microscope

XY microscope stage with integrated P-736K piezo Z scanner

XYZ tracking

Z scan

- Z stack acquisition
- Sample positioning
- Objective positioning

Autofocus

- Drift compensation

XY and XYZ Tracking with High Dynamics

If individual molecules are to be examined, a fast positioning system is required that can keep up with the small but very rapid and stochastically distributed molecule movements. In these applications, a small travel range (approx. 50 µm) is usually sufficient but in return much higher dynamics are required. The P-545.3D7 PInano® track system with its settling time of typically 5 ms (p. 9) is well suited to this purpose.

PInano® piezo tracking stage

Z Motion in the Direction of the Optical Axis

A coarse adjustment system in the Z direction is already integrated in light microscopes by the manufacturer. In addition to this, there are two different application areas for PI products in the area of Z fine adjustment:

- Autofocus or drift compensation
- Fast Z stacks for 3D techniques such as confocal or multi-photon microscopy

Z Stack Acquisition

In the case of Z stack acquisition, a large number of images typically have to be taken with a step size close to the resolution limit of the microscope. The configuration of the microscope and the sample to be moved determines whether the sample or the microscope objective should be moved. In the case of upright microscopes and large or very sensitive samples, the tendency is to adjust the objective and with inverted microscopes and small samples to adjust the sample.

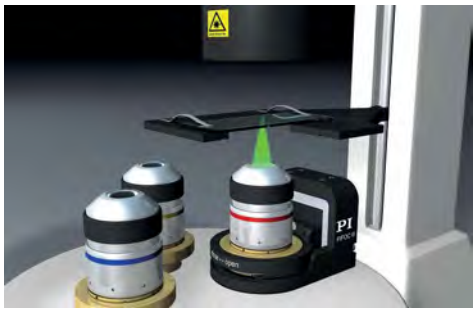
Sample Positioning

For sample positioning, PI offers PInano® Z piezo stages – either with a 100 or 200 µm stroke (p. 12). The free aperture accommodates 3x1'' slides, the profile is very low and thus easy to integrate. As a result of the settling times in the range of a few milliseconds, Z stacks can be quickly recorded, which considerably reduces the measurement times.

For larger samples, either P-737 Z stages for microtiter plates (p. 22) or PInano® systems with 160 x 110 mm clear aperture (see figure on p. 13) are suitable.

For XY positioning, there are suitable M-545 stages (p. 11) and the M26821LxJ systems for larger samples (p. 20).

Objective Positioning



PIFOC® in an inverted microscope

In the case of objective positioning, the application requirements are identical to those of sample positioning – precision and short settling time. In addition, however, coupling to the microscope must be possible with different thread types as well as at different angles. This is guaranteed by the PIFOC® systems with their easily exchangeable PI QuickLock thread inserts (p. 14–17).

Specially in the area of multi-photon microscopy, even greater travel ranges are desired due to the greater penetration depth of the IR pump light. For this purpose, systems with travel ranges of up to 500 µm (1 mm on request) are available. Even with large objectives, short settling times of approx. 10 ms and thus fast Z stack images are achieved. For macro objectives with a high NA value (numeric aperture), there are

PIFOC® system with QuickLock inserts and E-709 controller

PIFOC® objective positioners with a large clear aperture (up to 29 mm with a M32 thread).

The PIFOC® positioners are driven with a digital controller (p. 18), which can be operated via an analog input or digital interfaces (USB, RS-232). The system, consisting of a digital controller and a PIFOC® positioner with capacitive feedback, is characterized by maximum flexibility, easy operation and it is also more favorably priced than previous systems that use analog electronics (p. 23).

Autofocus or Drift Compensation

Typical autofocus applications arise when expanded samples are to be scanned in the XY direction, e. g. to compensate for a wedge error inside a fixed microtitre plate. For this purpose, PIFOC® positioners (p. 14) and the piezo Z stages (p. 12 – 17) have enough travel range and in addition they offer short settling times and high throughput rates.

In the case of long term measurements, the Z drift of the microscope and the mounting parts that influence the distance between the objective and the sample is a problem. The image either becomes blurred or drifts, i. e. the focus moves to another area of the sample.

To prevent this, the distance between the objective and the sample must be actively compensated by an objective or sample stage. If an autofocus signal is already present, PIFOC® systems (p. 14 – 17) or piezo Z stages (p. 12) can be used for this purpose. The controller can be switched to autofocus mode, if the autofocus signal is sent to the analog input of the digital controller. The distance between the sample and objective is kept constant.

With one software command the piezo stage can be referenced to the internal sensor again and then used e. g. for Z stack images.

The products listed here are only a small selection of the PI product range. If you cannot find the right solution for your applications – we will be happy to assist you! You can find your closest PI office on the back of this brochure.

PInano® Cap XY(Z) Piezo System

CAPACITIVE POSITIONING MEASUREMENT FOR SUPER-RESOLUTION MICROSCOPY

P-545.xC7

- Highest stability and repeatability
- Travel ranges up to 200 x 200 x 200 µm
- Sub-nanometer resolution
- ms-response times
- Low Profile for easy integration: 20 mm
- Recessed slide holder, free rotation of turret

Reference-class system: high-resolution piezo stage for 3x1" object slides
USB controller and software included

PICMA® high-performance piezo drive
Frictionless flexure guiding system, FEM-optimized flexure joints. Piezo actuators with ceramic insulation for outstanding lifetime. High-dynamics system with millisecond response times

Direct-metrology capacitive sensors
Significantly improved stability and repeatability compared to piezoresistive sensors

Easy implementation
Large clear aperture. For standard object slides (25 x 75 mm). Optional: object slide holder, further accessories and with M-545 microscope stage mountable on most microscopes of leading manufacturers

Fields of application
Super-resolution microscopy, screening, confocal microscopy, biotechnology. High reliability even under permanent high-humidity conditions

Accessories

M-545.2MO XY Microscope Stage, 25 x 25 mm, Micrometer Drive, High Stability, Compatible with PI Piezo Stages, for Olympus Microscopes

M-545.2MN XY Microscope Stage, 25 x 25 mm, Micrometer Drive, High Stability, Compatible with PI Piezo Stages, for Nikon Microscopes

M-545.2ML XY Microscope Stage, 25 x 25 mm, Micrometer Drive, High Stability, Compatible with PI Piezo Stages, for Leica Microscopes

M-545.2MZ XY Microscope Stage, 25 x 25 mm, Micrometer Drive, High Stability, Compatible with PI Piezo Stages, for Zeiss Microscopes

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

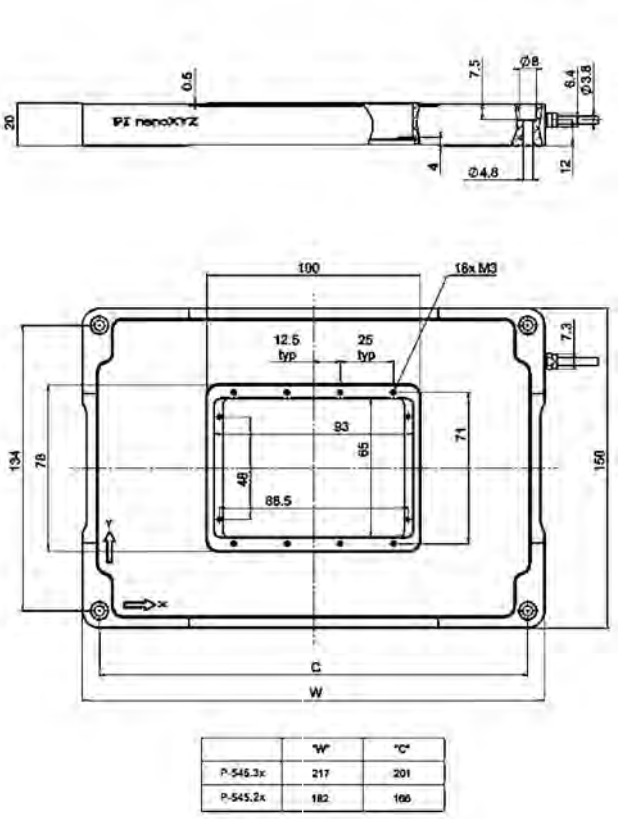
P-545.SH3 Microscope Slide Holder for PInano® Piezo Stages

P-545.PP3 Plain Plate for Accessories for PInano® Piezo Stages

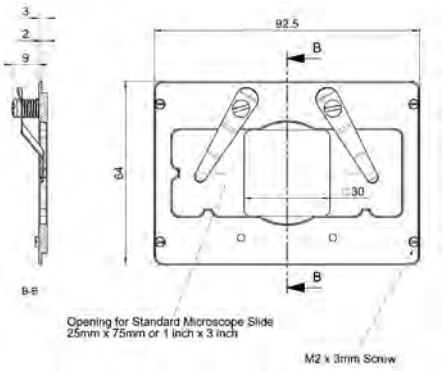
Additional accessories on request.

	P-545.2C7	P-545.3C7	Units	Tolerance
Active axes	X, Y	X, Y, Z		
Motion and positioning				
Integrated sensor	Capacitive	Capacitive		
Closed-loop travel	200 x 200	200 x 200 x 200	µm	
Closed-loop resolution*	< 1	< 1	nm	typ.
Mechanical properties				
Push / pull force capacity	50 / 30	50 / 30	N	max.
Recommended load**	0.5	0.5	kg	max.
Drive properties				
Piezo ceramics	PICMA® P-885	PICMA® P-885		
Electrical capacitance	6 (X, Y)	6 (X, Y), 12 (Z)	µF	±20%
Miscellaneous				
Material	Aluminum	Aluminum		
Mass	1	1.2	kg	±5%
Cable length	1.5	1.5	m	±10 mm
Piezo Controllers	E-545 (included in delivery)			
Communication interfaces	Ethernet (TCP/IP), USB, RS-232			
Control input socket	BNC			
Command set	PI General Command Set (GCS)			
User software	PIMikroMove			
Software drivers	LabVIEW drivers, shared libraries for Windows and Linux			
Supported functionality	Wave generator, data recorder, macro programming, auto zero, trigger I/O, MetaMorph, µManager, MATLAB			
Operating temperature range	5 to 50°C			
Controller dimensions	450 x 88 x 343 + mounting rails			

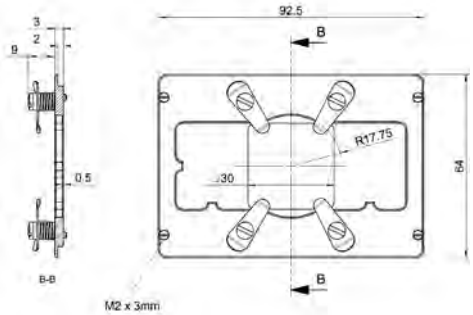
* With flexure guiding system resolution is not limited by friction or stiction. Value given is noise equivalent motion measured with interferometer.
** For dynamic operation. Higher dynamics is possible with a reduced load.
Ask about custom designs!



P-545, dimensions in mm



Accessories: sample holder, dimensions in mm



Accessories: Petri dish holder, dimensions in mm

PInano® XY(Z) Piezo System

LOW-COST NANOPOSITIONING SYSTEM FOR SUPER-RESOLUTION MICROSCOPY

P-545.xR7

- Cost-effective design due to piezoresistive sensors
- Travel ranges up to 200 x 200 x 200 µm
- Low profile for easy integration: 20 mm
- Large clear aperture for 3x1'' object slides, recessed sample holders
- Outstanding lifetime due to PICMA® piezo actuators
- Sub-nanometer resolution, ms-response times

Precision-class positioning system
USB controller and software included

PICMA® high-performance piezo drive
Frictionless flexure guiding system. FEM-optimized flexure joints. Piezo actuators with ceramic insulation for an outstanding lifetime. High-dynamics system with millisecond response times

High-resolution piezoresistive sensors
Closed-loop control for high repeatability and accuracy. Excellent positional stability. Cost-effective design

Easy implementation
Large clear aperture. For standard object slides (25 x 75 mm).
Optional: object slide holder, further accessories and with M-545 microscope stage mountable on most inverted microscopes of leading manufacturers

Fields of application
High-resolution microscopy, screening, confocal microscopy, biotechnology. High reliability under permanent high humidity conditions

	P-545.2R7	P-545.3R7	Units	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.
Mechanical properties				
Push / pull force capacity	50 / 30	50 / 30	N	max.
Recommended load**	0.5	0.5	kg	max.
Drive properties				
Piezo ceramics	PICMA® P-885	PICMA® P-885		
Electrical capacitance	6 (X, Y)	6 (X, Y), 12 (Z)	µF	±20 %
Miscellaneous				
Material	Aluminum	Aluminum		
Mass	1	1.2	kg	±5 %
Cable length	1.5	1.5	m	±10 mm
Piezo controller E-545 (included in delivery)				
Communication interfaces	Ethernet (TCP/IP), USB, RS-232			
Control in	BNC			
Command set	PI General Command Set (GCS)			
User software	PIMikroMove			
Software drivers	LabVIEW drivers, shared libraries for Windows and Linux			
Supported functionality	Wave generator, data recorder, macro programming, auto zero, trigger I/O, MATLAB, MetaMorph, µManager			
Operating temperature range	5 to 50°C			
Controller dimensions	450 x 88 x 343 mm + mounting rails			

* With flexure guide resolution is not limited by friction or stiction. Value given is noise equivalent motion measured with interferometer.
** For dynamic operation. Higher dynamics is possible with a reduced load.
Ask about custom designs!

Accessories
For suitable XY stages and sample holders see P-545.xC7 PInano® Cap XY(Z) piezo system, p. 6

PInano® Trak Piezo Tracking System

FAST XY(Z) STAGE FOR HIGH-DYNAMICS MICROSCOPY

P-545.xD7

- Fast response < 5 ms with sub-nanometer resolution: ideal for tracking
- Travel ranges up to 70 x 70 x 50 µm
- Low profile for easy integration: 20 mm
- Recessed slide holder, free rotation of turret

Precision-class system: fast positioning XY(Z) stage
USB controller and software included

PICMA® direct drive
High-performance piezo actuators without amplification for fastest response. Piezo actuators with ceramic insulation for an outstanding lifetime

High-resolution piezoresistive sensors
Closed-loop control for high repeatability and accuracy. Good positional stability. Cost-effective design

Easy implementation
Large clear aperture. For standard object slides (25 x 75 mm).
Optional: object slide holder, further accessories and with M-545 microscope stage mountable on most inverted microscopes of leading manufacturers

Fields of application
Tracking, high-resolution microscopy, inverted microscopy, screening, confocal microscopy, biotechnology. High reliability under permanent high humidity conditions

	P-545.2D7	P-545.3D7	Units	Tolerance
Active axes	X, Y	X, Y, Z		
Motion and positioning				
Integrated sensor	Piezoresistive	Piezoresistive		
Closed-loop travel	70 x 70	70 x 70 x 50	µm	
Closed-loop resolution*	< 1	< 1	nm	typ.
Mechanical properties				
Unloaded resonant frequency	1 (X,Y)	1 (X, Y), 0.8 (Z)	kHz	
Push / pull force capacity	100 / 30	100 / 30	N	max.
Recommended load**	0.5	0.5	kg	max.
Drive properties				
Piezo ceramics	PICMA® P-885	PICMA® P-885		
Electrical capacitance	6 (X, Y)	6 (X, Y), 12 (Z)	µF	±20 %
Miscellaneous				
Material	Aluminum	Aluminum		
Mass	1	1.2	kg	±5 %
Cable length	2	2	m	±10 mm
Piezo controller E-545 (included in delivery)				
Communication interfaces	Ethernet (TCP/IP), USB, RS-232			
Control in	BNC			
Command set	PI General Command Set (GCS)			
User software	PIMikroMove			
Software drivers	LabVIEW drivers, shared libraries for Windows and Linux			
Supported functionality	Wave generator, data recorder, macro programming, auto zero, trigger I/O, MetaMorph, µManager, MATLAB			
Operating temperature range	5 to 50°C			
Controller dimensions	450 x 88 x 343 mm + mounting rails			

* With flexure guide resolution is not limited by friction or stiction. Value given is noise equivalent motion measured with interferometer.
** For dynamic operation. Higher dynamics is possible with a reduced load.
Ask about custom designs!

Accessories
For suitable XY stages and sample holders see P-545.xC7 PInano® Cap XY(Z) piezo system, p. 6

PInano® Piezo Controller

THREE CHANNELS WITH USB INTERFACE

E-545

- Low-noise 24 bit D/A converter
- 25 kHz sampling rate
- Linearization for piezoresistive sensors
- Notch filter for higher bandwidth
- TCP/IP, USB, RS-232 and three analog interfaces

Controller for P-545 PInano® piezo nanopositioner
With fast digital and analog interfaces. For piezoresistive strain sensors (PRS) or capacitive sensors

Functions
General Command Set (GCS). Software drivers for LabVIEW, shared libraries for Windows and Linux
Wave Generator. Data recorder. Macro programming

Supported software
MetaMorph, µManager, MATLAB

	E-545.3RD	E-545.3CD
Function	Piezo Servo Controller for PInano® positioner	
Sensor type	Piezoresistive	Capacitive
Axes	3	3
Servo characteristics	P-I (analog), notch filter	P-I (analog), notch filter
Amplifier		
Min. output voltage	-20 to 120 V	-20 to 120 V
Peak output current, < 5 ms	140 mA	140 mA
Average current	60 mA	60 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Voltage gain	10 ±0.1	10 ±0.1
Interface and operation		
Communication interfaces	Ethernet (TCP/IP), USB, RS-232	
Piezo system connection	Sub-D 25	
Analog In	3x BNC	
Command set	PI General Command Set (GCS)	
User software	PIMikroMove	
Software drivers	LabVIEW drivers, shared libraries for Windows and Linux	
Supported functionality	Wave generator, data recorder, macro programming, auto zero, trigger I/O, MATLAB, MetaMorph, µManager	
Miscellaneous		
Operating temperature range	5 to 50°C	
Dimensions	450 x 88 x 343 mm + mounting rails	
Overheat protection	Deactivation at 85°C	
Operating voltage	90 – 120, 220 – 264 VAC	

Open-Frame Microscope Stage

LOW PROFILE, LOW DRIFT DESIGN, LONG TRAVEL RANGE

M-545

- Stable platform for P-545 PInano® piezo nanopositioning systems
- Low profile for easy integration: 30 mm
- Travel range 25 x 25 mm
- Micrometer screws, motor upgrade available
- For inverted microscopes made by Nikon, Zeiss, Leica, and Olympus

Standard-class, manual XY microscope stage
Coarse adjustment for P-545 piezo nanopositioning systems. Stiff design enables optimal scanning and settling behavior

Micrometer screw or optional stepper motor drive
The stage can be supplemented with motorized actuators, controller and joystick (see accessories)

Field of application
For inverted microscopes made by Nikon (TI), Zeiss (Axio Observer), Leica (DMI), and Olympus (IX2). Versions for other microscopes are available on request

	M-545.2M	Units	Tolerance
Active axes	X, Y		
Motion and positioning			
Travel range	25 x 25	mm	
Min. incremental motion	1	µm	typ.
Min. incremental motion with M-229 stepper linear actuators	1	µm	typ.
Velocity with M-229 stepper linear actuators	1.5	mm/s	max.
Mechanical properties			
Max. load	50	N	
Preloading	10	N	
Miscellaneous			
Material	Aluminum, stainless steel		
Mass	4	kg	±5%

Accessories
M-545.USG M-229 Stepper-Mike Upgrade for M-545 Stages: Includes Stepper-Mikes

M-545.SHP Adapter Plate for Microscope Sample Holder for M-545 XY Microscope Stage

M-545.USC Stepper-Mike Upgrade for M-545 Stages: Includes M-229 Stepper-Mikes, Controller and Joystick (not suitable for M-545.2MZ)

Compatible nanopositioning stages
P-517 • P-527 Multiaxis Piezo Scanner
P-518 • P-528 • P-558 Piezo Tip/Tilt Stage
P-541.2 • P-542.2 Piezo XY Stage
P-561 • P-562 • P-563 PIMars Nanopositioning Stage
P-545 PInano® Series

Compatible nanopositioning stages (with adapter plate)
P-733.2 • P-733.3 XY(Z) Piezo Nanopositioning Stage
P-736 PInano® Z Microscopy Scanner

Additional accessories and custom designs on request.

PInano® Z Microscopy Scanner

LOW-COST, LOW-PROFILE, WITH DIGITAL CONTROLLER

P-736

- Fastest settling time up to 5 ms
- Low profile for easy integration
- Travel ranges 100 or 200 µm
- Outstanding lifetime due to PICMA® piezo ceramic stacks
- Low-cost due to piezoresistive sensors

Precision-class nanopositioning system for high-resolution microscopy
Optimized for very fast step-and-settle at target position. Exceptionally low profile of 20 mm for easy integration. With large clear aperture

PICMA® piezo actuator drive
Ceramic insulation for outstanding life time. Significantly higher humidity resistance. Excellent guiding accuracy due to FEA-modeled flexure joints

High-resolution piezoresistive sensors
For stable position control

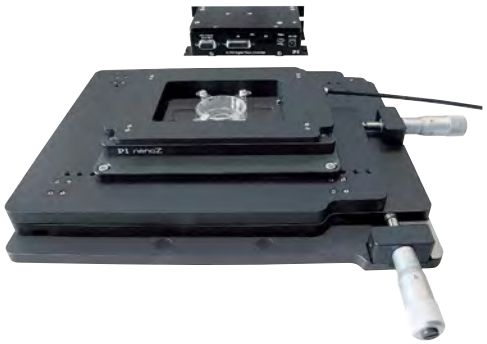
System with controller and software
The compact E-709 piezo controller is included in the delivery. Control is possible via USB, RS-232 and a broadband analog interface. Supports PIMikroMove, PI General Command Set (GCS). Drivers for LabVIEW, shared libraries for Windows and Linux. Compatible with µManager, MetaMorph, MATLAB

Fields of application
Scanning microscopy, 3D imaging, laser technology, interferometry, metrology, biotechnology, micromanipulation

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

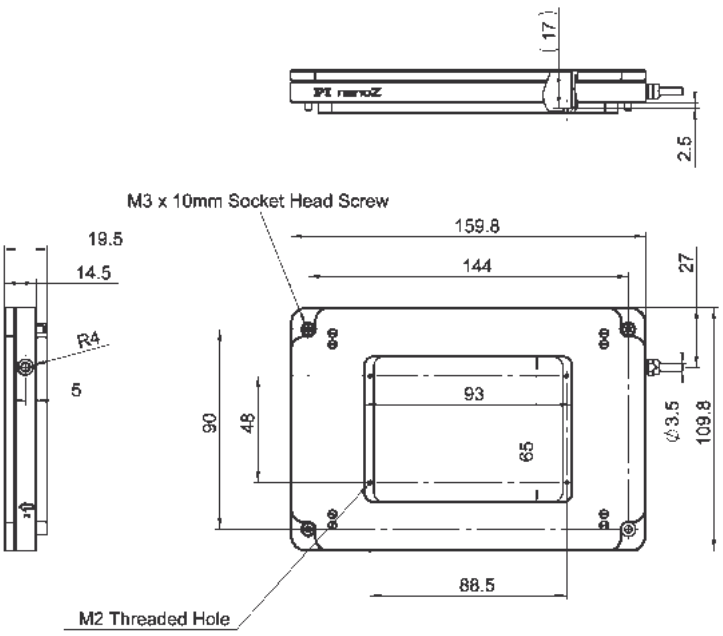
P-545.SH3 Microscope Slide Holder for PInano® Piezo Stages

P-736.AP1 Adapter Plate P-736 PInano® Z Piezo Slide Scanner to M-545 XY Microscope Stage



The PInano® Z stage can be combined with the M-545 XY 25 × 25 mm microscope stage

	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.
Mechanical properties				
Settling time (10 % step width)	5	7	ms	
Load capacity	500	500	g	max.
Drive properties				
Piezo ceramics	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
Piezo controller E-709 (included in delivery)				
Communication interfaces	USB, RS-232, SPI			
I/O Connector	HD-Sub-D 26-pin, 1 analog input 0 to 10 V, 1 sensor monitor 0 to 10 V, 1 digital input (LVTTL, programmable), 1 analog output, 5 digital outputs (LVTTL, 3x predefined, 2x programmable)			
Command set	PI General Command Set (GCS)			
User software	PIMikroMove			
Software drivers	LabVIEW drivers, shared libraries for Windows and Linux			
Supported functionality	Wave generator, data recorder, auto zero, trigger I/O, MATLAB, MetaMorph, µManager			
Controller dimensions	160 x 96 x 33 mm			



P-736, dimensions in mm

Custom versions are feasible. The example above shows a P-736 version with a particularly large aperture mounted on a motorized M-687 XY stage

PIFOC® Objective Scanning System 100 µm

HIGH-DYNAMICS PIEZO DRIVE FOR SUB-NANOMETER PRECISION

PD72Z1x

- Complete system with digital controller and software
- Travel range 100 µm
- Scans and positions objectives with sub-nanometer resolution
- Frictionless, high-precision flexure guiding system
- Direct metrology with capacitive sensors

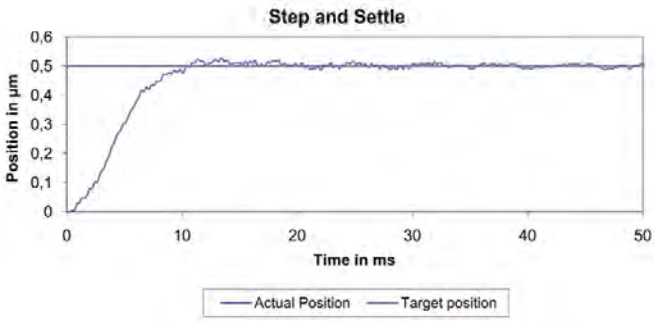
PIFOC® objective scanning system with digital controller and software
Clear aperture up to 29 mm Ø. QuickLock adapter for easy attachment

Position measurement
With lower-cost strain gauge sensors (SGS) or with highly accurate capacitive sensors for highest linearity and stability. All control parameters can be set and optimized by software

Interfaces
USB, RS-232 and analog

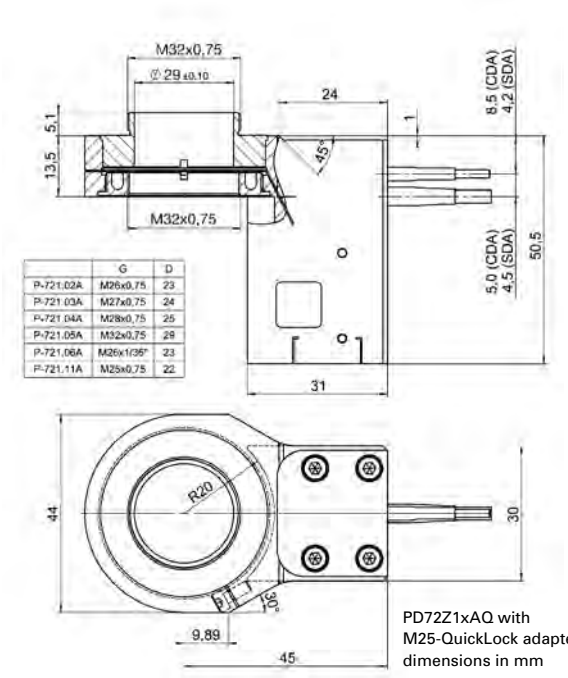
User software and functions
PIMikroMove, PI General Command Set (GCS). Drivers for LabVIEW, shared libraries for Windows and Linux. Compatible with µManager, MetaMorph, MATLAB

Fields of application
Microscopy, confocal microscopy, 3-D imaging, screening, autofocus systems, surface analysis, wafer inspection

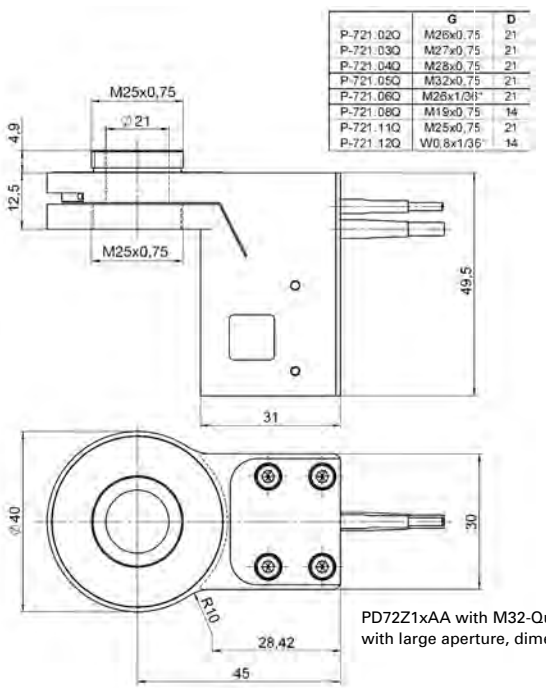


10 ms settling time with 150 g objective (PD72Z1CAQ system, measured with laser interferometer)

	PD72Z1SAA PD72Z1SAQ	PD72Z1CAA PD72Z1CAQ	Units	Tolerance
Active axes	Z	Z		
Motion and positioning				
Integrated sensor	SGS	Capacitive		
Closed-loop travel	100	100	µm	
Closed-loop resolution	5	1	nm	typ.
Linearity, closed-loop	0.2	0.06	%	typ.
Runout θ_X, θ_Y	13	13	µrad	typ.
Crosstalk in X, Y	100	100	nm	typ.
Settling time (0.5 µm step with 5 % accuracy, 150 g)	10	10	ms	typ.
Mechanical properties				
Stiffness in motion direction	0.3	0.3	N/µm	±20 %
Unloaded resonant frequency	580	580	z	±20 %
Resonant frequency @ 120 g	235	235	Hz	±20 %
Resonant frequency @ 200 g	180	180	Hz	±20 %
Push / pull force capacity in motion direction	100 / 20	100 / 20	N	max.
Drive properties				
Piezo ceramics	PICMA® P-885	PICMA® P-885		
Miscellaneous				
Operating temperature range	10 to 50	10 to 50	°C	
Material	Aluminum	Aluminum		
Mass	0.22	0.24	kg	±5 %
Cable length	1	1	m	
Piezo controller E-709 (included in delivery)				
Communication interfaces	USB, RS-232, SPI			
I/O Connector	HD-Sub-D 26-pin, 1 analog input 0 to 10 V, 1 sensor monitor 0 to 10 V, 1 digital input (LVTTL, programmable), 5 digital outputs (LVTTL, 3 predefined, 2 programmable)			
Command set	PI General Command Set (GCS)			
User software	PIMikroMove			
Software drivers	LabVIEW drivers, shared libraries for Windows and Linux			
Supported functionality	Wave generator, data recorder, auto zero, trigger I/O, MetaMorph, µManager, MATLAB			
Controller dimensions	160 x 96 x 33 mm			



PD72Z1xAQ with M25-QuickLock adapter, dimensions in mm



PD72Z1xAA with M32-QuickLock adapter with large aperture, dimensions in mm

PIFOC® Objective Scanning System 400 µm

HIGH-DYNAMICS PIEZO DRIVE FOR SUB-NANOMETER RESOLUTION

PD72Z2x/4x

- Complete system with digital controller and software
- Travel ranges to 400 µm
- Scans and positions objectives with sub-nanometer resolution
- Frictionless, high-precision flexure guiding system
- Direct metrology with capacitive sensors

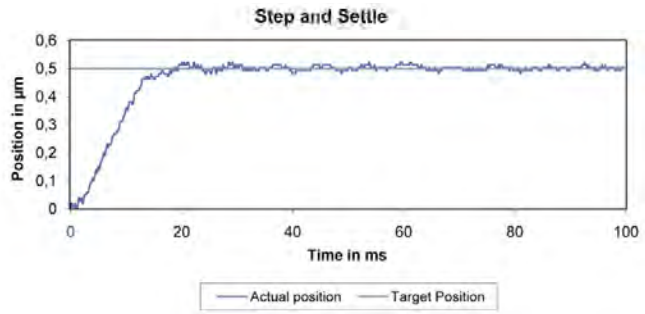
PIFOC® objective scanning system with digital controller and software
Clear aperture up to 29 mm Ø. QuickLock adapter for easy attachment

Direct metrology with capacitive sensors, digital controller
For highest linearity and stability. All control parameters can be set and optimized by software

Interfaces
USB, RS-232 and analog

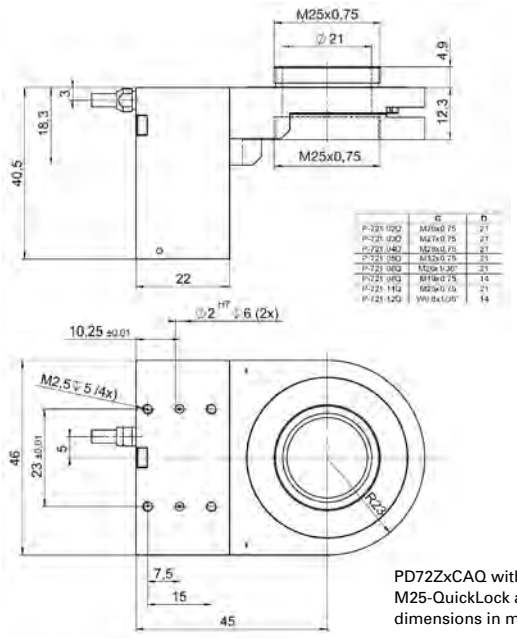
User software and functions
PIMikroMove, PI General Command Set (GCS). Drivers for LabVIEW, shared libraries for Windows and Linux. Compatible with µManager, MetaMorph, MATLAB

Fields of application
Microscopy, confocal microscopy, 3-D imaging, screening, autofocus systems, surface analysis, wafer inspection, multi-photon microscopy

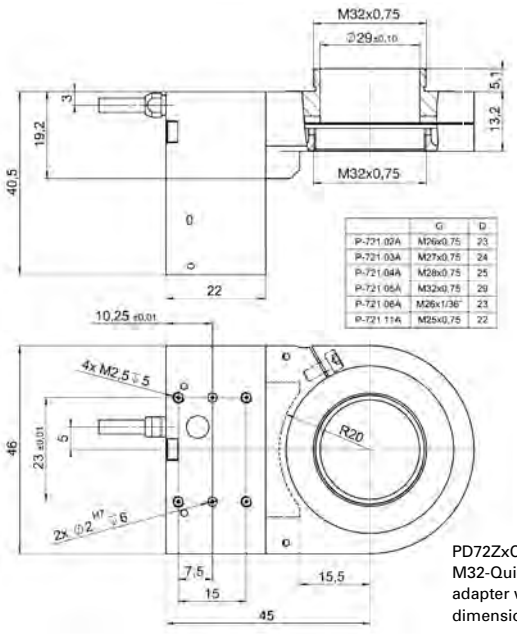


20 ms settling time with 150 g objective (PD72Z4CAQ system, measured with laser interferometer)

	PD72Z2CAA/PD72Z2CAQ	PD72Z4CAA/PD72Z4CAQ	Units	Tolerance
Active axes	Z	Z		
Motion and positioning				
Integrated sensor	Capacitive	Capacitive		
Closed-loop travel	250	400	µm	
Closed-loop resolution	1.5	2.5	nm	typ.
Linearity, closed-loop	0.06	0.06	%	typ.
Runout θ_X	6	10	µrad	typ.
Runout θ_Y	45	45	µrad	typ.
Crosstalk in X	20	60	nm	typ.
Crosstalk in Y	40	60	nm	typ.
Settling time (0.5 µm step with 5 % accuracy, 150 g)	15	20	ms	typ.
Mechanical properties				
Stiffness in motion direction	0.17	0.12	N/µm	±20 %
Unloaded resonant frequency	330	230	Hz	±20 %
Resonant frequency @ 150 g	140	120	Hz	±20 %
Push / pull force capacity in motion direction	100 / 20	100 / 20	N	max.
Drive properties				
Piezo ceramics	PICMA® P-885	PICMA® P-885		
Miscellaneous				
Operating temperature range	10 to 50	10 to 50	°C	
Material	Aluminum	Aluminum		
Mass	0.23	0.23	kg	±5 %
Cable length	1.5	1.5	m	
Piezo controller E-709 (included in delivery)				
Communication interfaces	USB, RS-232			
I/O Connector	HD-Sub-D 26-pin, 1 analog input 0 to 10 V, 1 sensor monitor 0 to 10 V, 1 digital input (LVTTL, programmable), 5 digital outputs (LVTTL, 3 predefined, 2 programmable)			
Command set	PI General Command Set (GCS)			
User software	PIMikroMove			
Software drivers	LabVIEW drivers, shared libraries for Windows and Linux			
Supported functionality	Wave generator, data recorder, auto zero, trigger I/O, MATLAB, MetaMorph, µManager			
Controller dimensions	160 x 96 x 33 mm			



PD72ZxCAQ with M25-QuickLock adapter, dimensions in mm



PD72ZxCAA with M32-QuickLock thread adapter with large aperture, dimensions in mm

Compact and Cost-Optimized Digital Piezo Controller

FOR SGS, PIEZORESISTIVE AND CAPACITIVE SENSORS

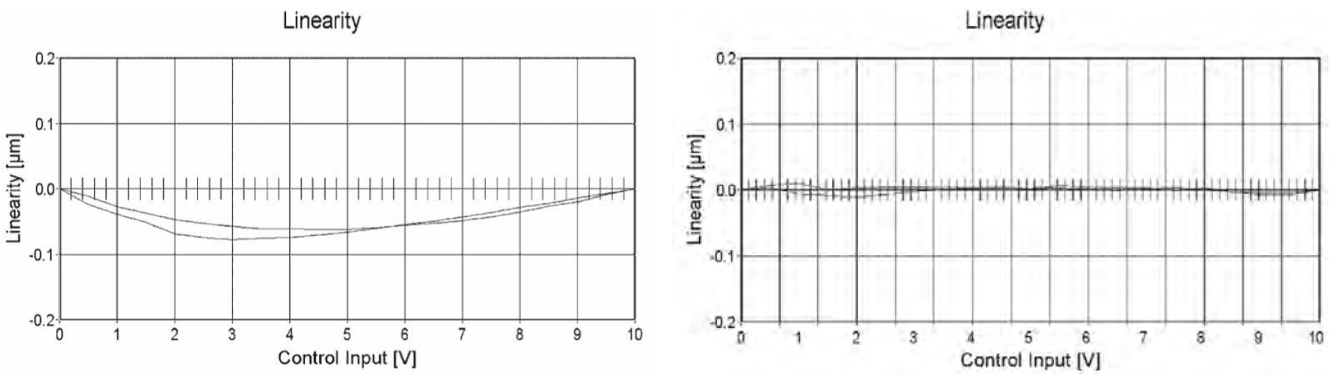
E-709

- Linearity to 0.02 %
- Fast 25 Mbit/s serial interface
- Comprehensive I/O functions
- Low-cost OEM versions available
- Extensive software support

Fast digital controller
As bench-top (.xRG) or as OEM board (.xR). Voltage range -30 to 130 V

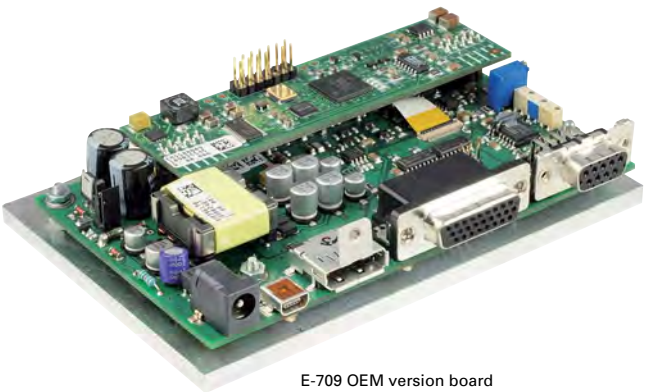
Interfaces
USB, digital RS-232, fast serial interface with up to 25 MBit/s. Additional high-bandwidth analog control input/sensor input. Analog output, e.g. for external amplifiers

User software and functions
PIMikroMove, PI General Command Set (GCS). Drivers for LabVIEW, shared libraries for Windows and Linux. Compatible with µManager, MetaMorph, MATLAB. Wave Generator. Linearization. Data recorder. Auto zero. Trigger I/O. Software configurable servo parameters

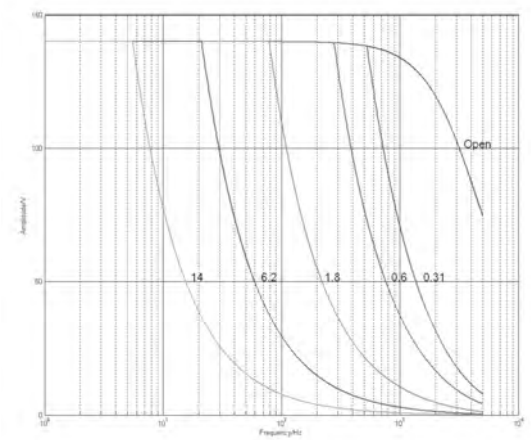


Comparison of the linearity of a strain gauge sensor with analog controller (top) and the E-709 digital controller (bottom), which improves the linearity by up to one order of magnitude

	E-709.SR/E-709.SRG	E-709.PR/E-709.PRG	E-709.CR/E-709.CRG
Sensor type	SGS	Piezoresistive	Capacitive
Function	Digital controller for single-axis piezo nanopositioning systems (.SR: OEM board)	Digital controller for single-axis piezo nanopositioning systems (.PR: OEM board)	Digital controller for single-axis piezo nanopositioning systems (.CR: OEM board)
Channels	1	1	1
Processor	DSP 32 bit floating point, 150 MHz	DSP 32 bit floating point, 150 MHz	DSP 32 bit floating point, 150 MHz
Servo characteristics	P-I, 2 notch filter, sensor linearization	P-I, 2 notch filter, sensor linearization	P-I, 2 notch filter, sensor linearization
Sampling rate, servo-control	10 kHz	10 kHz	10 kHz
Sampling rate, sensor	10 kHz	10 kHz	10 kHz
Sensor			
Linearization	5th order polynomials	5th order polynomials	5th order polynomials
Sensor bandwidth	5 kHz	5 kHz	5 kHz
Sensor resolution	16 bit	16 bit	16 bit
Ext. synchronization	No	No	No
Amplifier			
Output voltage	-30 V to +130 V	-30 V to +130 V	-30 V to +130 V
Peak output power	10 W (<5 ms)	10 W (<5 ms)	10 W (<5 ms)
Average output power	5 W (>5 ms)	5 W (>5 ms)	5 W (>5 ms)
Peak current	100 mA (<5 ms)	100 mA (<5 ms)	100 mA (<5 ms)
Average current	50 mA (>5 ms)	50 mA (>5 ms)	50 mA (>5 ms)
Current limitation	Short-circuit-proof	Short-circuit-proof	Short-circuit-proof
Resolution DAC	17 bit	17 bit	17 bit
Interface and operation			
Communication interfaces	USB, RS-232, SPI	USB, RS-232, SPI	USB, RS-232, SPI
Piezo / sensor connection	Sub-D, 9-pin	Sub-D, 9-pin	Sub-D-Special connector
I/O Connector	HD-Sub-D 26-pin, 1 analog input 0 to 10 V, 1 sensor monitor 0 to 10 V, 1 digital input (LVTTL, programmable), 1 analog output, 5 digital outputs (LVTTL, 3x predefined, 2x programmable)		
Command set	PI General Command Set (GCS)		
User software	PIMikroMove		
Software drivers	LabVIEW drivers, shared libraries for Windows and Linux		
Supported functionality	Wave generator, data recorder, auto zero, trigger I/O, MATLAB, MetaMorph, µManager		
Display	Status LED, overflow LED		
Miscellaneous			
Operating temperature range	8 to 50°C (above 40°C, power derated)	8 to 50°C (above 40°C, power derated)	12 to 50°C (above 40°C, power derated)
Dimensions	160 x 96 x 33 mm	160 x 96 x 33 mm	160 x 96 x 33 mm
Mass	260 g / 470 g	260 g / 470 g	260 g / 470 g
Operating voltage	24 VDC	24 VDC	24 VDC
Max. power consumptions	24 W	24 W	24 W



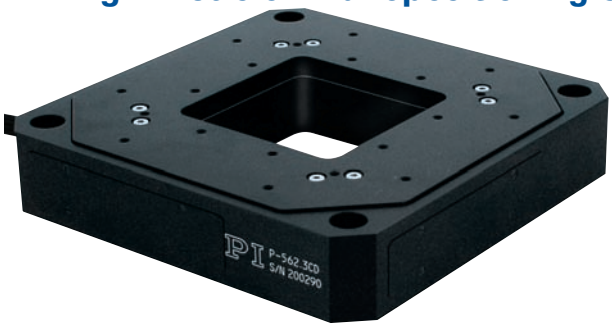
E-709 OEM version board



E-709: Operating limits with various PZT loads (open-loop), capacitance is measured in µF

P-561 · P-562 · P-563 PIMars™ XYZ Piezo System

High-Precision Nanopositioning Stage, 3 to 6 Axes



P-562 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 XYZ Version Available; Custom Versions to 6-DOF**
- **Clear Aperture 66 x 66 mm**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **UHV Versions to 10^{-9} hPa**

PIMars™ open-frame piezo stages are fast and highly accurate multi-axis scanning and nanopositioning systems with flatness and straightness in the nanometer range.

The 66 x 66 mm clear aperture is ideal for transmitted-light applications such as near-field scanning or confocal microscopy and mask positioning.

Large Variety of Models

PIMars™ multi-axis nanopositioners are offered in a large variety of configurations. Standard models include long-travel systems (to 300 x 300 x 300 µm), high-speed and vacuum versions. Custom six-axis designs with rotation to 6 mrad are available on request.

PI offers versions specially designed for applications in ultra-high vacuum with vacuum-qualified components only. The integrated ceramic-encapsulated PICMA® actuators allow high bakeout temperatures and assure minimal outgassing rates. A non-magnetizable version is available on request.

Application Examples

- Scanning microscopy
- Mask/wafer positioning
- Interferometry
- Metrology
- Biotechnology
- Micromanipulation

Direct Drive for Ultra-Fast Scanning and Positioning

The P-561.3DD versions have resonant frequencies to 1.0 kHz, enabling millisecond scanning rates with sub-nanometer resolution.

Capacitive Sensors for Highest Accuracy and Position Stability

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.

Active and Passive Guidance for Nanometer Flatness and Straightness

Wire-cut flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. The FEA techniques give the design the highest possible stiffness and minimize linear and angular runout. Further enhancement is achieved by active trajectory control: multi

Ordering Information

P-561.3CD
PIMars™ XYZ Piezo-Nanopositioning System, 100 x 100 x 100 µm, Parallel Metrology

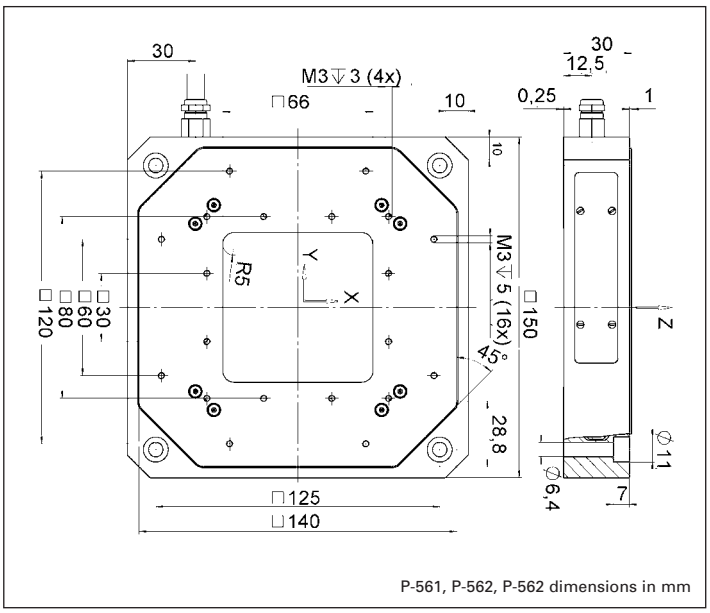
P-562.3CD
PIMars™ XYZ Piezo-Nanopositioning System, 200 x 200 x 200 µm, Parallel Metrology

P-563.3CD
PIMars™ XYZ Piezo-Nanopositioning System, 300 x 300 x 300 µm, Parallel Metrology

P-561.3DD
PIMars™ High-Dynamics XYZ Nanopositioning System, 45 x 45 x 15 µm, Parallel Metrology, Direct Drive

Vacuum-compatible versions to 10^{-6} hPa for the P-561.3CD, P-562.3CD and P-563.3CD models are available as P-561.3VD, P-562.3VD and P-563.3VD; versions to 10^{-9} hPa as P-561.3UD, P-562.3UD and P-563.3UD.

Super-invar & titanium versions are available, 6-DOF versions on request.

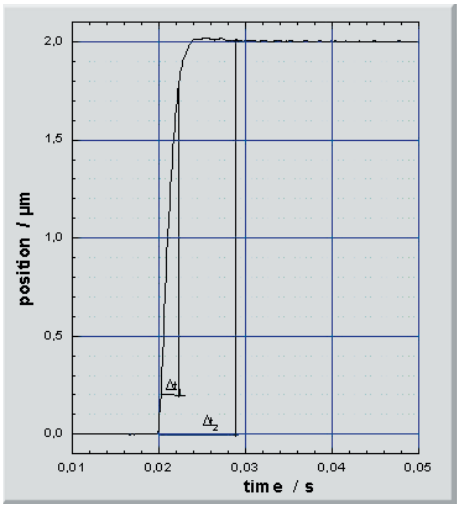


P-561, P-562, P-562 dimensions in mm

System properties

System Configuration	P-561.3CD with E-710 digital controller, 330 g load
Amplifier bandwidth, small signal	25 Hz in X, Y; 35 Hz in Z
Settling time (10 % step)	20 ms

axis nanopositioning systems equipped with parallel metrology are able to measure platform position in all degrees of freedom against a common, fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross-talk) is detected immediately and actively compensated by the servo-loops. This can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.



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

Technical Data

Model	P-561.3CD	P-562.3CD	P-563.3CD	P-561.3DD	Units	Tolerance
Active axes	X, Y, Z	X, Y, Z	X, Y, Z	X, Y, Z		
Motion and positioning						
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive		
Open-loop travel, -20 to +120 V	150 x 150 x 150	300 x 300 x 300	340 x 340 x 340	58 x 58 x 18	µm	min. (+20 %/0 %)
Closed-loop travel	100 x 100 x 100	200 x 200 x 200	300 x 300 x 300	45 x 45 x 15	µm	
Open-loop resolution	0.2	0.4	0.5	0.1	nm	typ.
Closed-loop resolution	0.8	1	2	0.2	nm	typ.
Linearity	0.03	0.03	0.03	0.01*	%	typ.
Repeatability in X, Y, Z	2 / 2 / 2	2 / 2 / 4	2 / 2 / 4	2 / 2 / 2	nm	typ.
Pitch in X,Y	±1	±2	±2	±3	µrad	typ.
Runout θ_x, θ_y (Z motion)	±15	±20	±25	±3	µrad	typ.
Yaw in X, Y	±6	±10	±10	±3	µrad	typ.
Flatness in X, Y	±15	±20	±25	±10	nm	typ.
Crosstalk X, Y (Z motion)	±30	±50	±50	±20	nm	typ.
Mechanical properties						
Unloaded resonant frequency in X / Y / Z	190 / 190 / 380	160 / 160 / 315	140 / 140 / 250	920 / 920 / 1050**	Hz	±20 %
Resonant frequency @ 100 g in X / Y / Z	–	145 / 145 / 275	120 / 120 / 215	860 / 860 / 950	Hz	±20 %
Resonant frequency @ 330 g in X / Y / Z	140 / 140 / 300	130 / 130 / 195	110 / 110 / 170	500 / 500 / 470	Hz	±20 %
Push force capacity in motion direction in X / Y / Z	200 / 200 / 50	120 / 120 / 50	100 / 100 / 50	200 / 200 / 50	N	Max.
Pull force capacity in motion direction in X / Y / Z	30 / 30 / 30	30 / 30 / 30	30 / 30 / 30	30 / 30 / 30		
Load capacity	50	50	50	50	N	Max.
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885 in Z, P-888 in XY		
Electrical capacitance in X / Y / Z	5.2 / 5.2 / 10.4	7.4 / 7.4 / 14.8	7.4 / 7.4 / 14.8	38 / 38 / 6	µF	±20 %
Dynamic operating current coefficient (DOCC) in X / Y / Z	6.5 / 6.5 / 13	4.6 / 4.6 / 9.25	3.1 / 3.1 / 6.1	106 / 106 / 50	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	1.45	1.45	1.45	1.55	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	m	±10 mm
Sensor / voltage connection	Sub-D Special	Sub-D Special	Sub-D Special	Sub-D Special		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-710 (p. 2-128) controller.
*With digital controller. Non-linearity of direct drive stages measured with analog controllers is typically up to 0.1 %.

Recommended controller
Multi-channel digital controllers: E-710 bench-top (p. 2-128), E-712 modular (p. 2-140), E-725 high-power (p. 2-126), E-761 PCI board (p. 2-130)

P-562.6CD PIMars 6-Axis Piezo Stage System

High-Precision Nanopositioning System with 6 Degrees of Freedom

P-562.6CD PIMars six-axis parallel-kinematics nanopositioning stage

- **6 Motion Axes: 3 x Linear, 3 x Rotation**
- **Travel Ranges to 200 µm Linear and 1 mrad Tilt Angle**
- **Enhanced Responsiveness & Multi-Axis Precision: Parallel Kinematics / Metrology**
- **Highest Linearity and Stability with Capacitive Sensors**
- **Frictionless, High-Precision Flexure Guiding System**
- **Excellent Scan-Flatness**
- **Clear Aperture 66 x 66 mm**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **UHV Versions to 10^{-9} hPa**

PIMars open-frame piezo stages are fast and highly accurate multi-axis scanning and nanopositioning systems with flatness and straightness in the nanometer range. Thanks to the parallel-kinematic design, where all piezo drives act on the same moving platform, and sophisticated digital control algorithms it is possible to achieve highly precise motion in all degrees of freedom: three linear axes and three rotary axes. The travel ranges amount to 200 µm in X, Y and Z, and the tilt angles are ±0.5 mrad about the respective axis. Systems with larger travel ranges or faster response are available on request. A six-axis system with 800 µm travel range in the X and Y axis is available as the P-587.6CD s. p. 2-76.

PIMars systems feature a large 66 x 66 mm clear aperture for transmitted-light applications such as near-field scanning or confocal microscopy and mask positioning. PIMars stages for ultra-high vacuum applications are also available. These versions contain vacuum-qualified components only. The integrated ceramic-encapsulated PICMA® actuators allow high bakeout temperatures and assure minimal outgassing rates. A non-magnetizable version is available on request.

Application Examples

- Scanning microscopy (SPM)
- Mask/wafer positioning
- Interferometry
- Metrology
- Biotechnology
- Micromanipulation

Ordering Information

P-562.6CD
PIMars 6-Axis Nanopositioning System, 200 µm, 1 mrad, Parallel Metrology

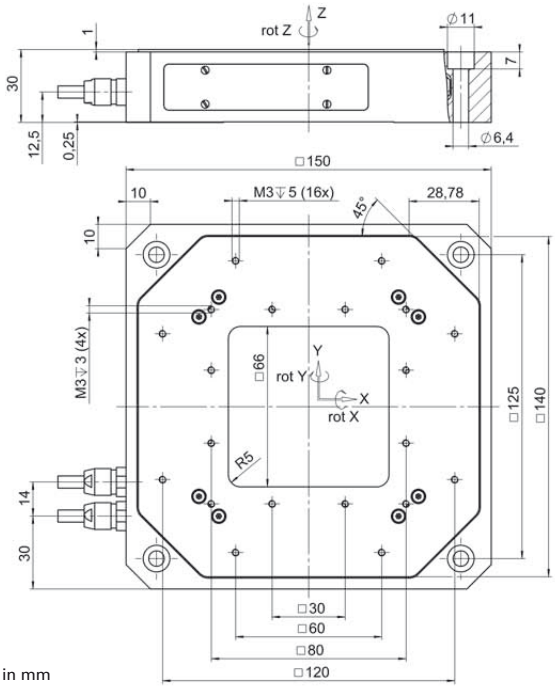
Other travel ranges on request!

Capacitive Sensors for Highest Accuracy and Stability

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. Further advantages of direct metrology with capacitive sensors are the excellent long-term stability, high phase fidelity and the high bandwidth of up to 10 kHz.

Active and Passive Guidance for Nanometer Flatness and Straightness

Wire-cut flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. The FEA techniques give the design the highest possible stiffness and minimize linear and angular runout. Further enhancement is achieved by active trajectory control: multiaxis nanopositioning systems equipped with parallel metrology are able to measure platform position in all degrees of freedom against a common, fixed reference. In such systems, undesirable motion from one actuator in the direction of another (crosstalk) is detected immediately and actively compensated by the servo-loops. This can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.



P-562 dimensions in mm

Technical Data

Model	P-562.6CD	Tolerance
Active axes	X, Y, Z, θX, θY, θZ	
Motion and Positioning		
Integrated sensor	Capacitive	
Closed-loop travel X, Y, Z	200 µm	
Closed-loop tip/tilt angle	±0.5 mrad	
Closed-loop resolution X, Y, Z	1 nm	typ.
Closed-loop tip/tilt resolution	0.1 µrad	typ.
Linearity X, Y, Z	0.01 %	typ.
Linearity θX, θY, θZ	0.1 %	typ.
Repeatability in X, Y, Z	±2 / ±2 / ±3 nm	typ.
Repeatability θX / θY / θZ	±0.1 / ±0.1 / ±0.15 µrad	typ.
Flatness	< 15 nm	typ.
Unloaded resonant frequency in X / Y / Z	110 / 110 / 190 Hz	±20%
Load capacity	50 N	max.
Push/pull force capacity in motion direction	120 / 30 N	max.
Drive properties		
Ceramic type	PICMA®	
Electrical capacitance in X / Y / Z	7.4 / 7.4 / 14.8 µF	±20%
Dynamic operating current coefficient in X, Y, Z	4.6 / 4.6 / 9.2 µA/(Hz • µm)	±20%
Miscellaneous		
Operating temperature range	-20 to 80 °C	
Material	Aluminium	
Mass	1.45 kg	±5%
Cable length	1.5 m	±10 mm
Sensor / voltage connection	2 x Sub-D Special	

Recommended controller / amplifier
E-710.6CD s. p. 2-128 or E-712.6CD digital controller s. p. 2-140

P-733.2 · P-733.3 XY(Z) Piezo-Nanopositioning Stage

High-Precision XY(Z) Scanner Family with Aperture

P -733.3 DD (left) and P -733.2 DD, high-speed, direct drive XY(Z) scanning stages are the fastest scanning stages with large aperture currently available (2.2 kHz resonant frequency!). Both units feature a footprint of only 100 x 100 mm. CD for size comparison.

- **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**

P-733 XY and XYZ piezo driven stages are fast and highly accurate nanopositioning and scanning systems. They provide a positioning and scanning range of 100 x 100 (x10) µm together with sub-nanometer resolution and are equipped with parallel-metrology capacitive position feedback for superior multi-axis linearity and repeatability. The guiding accuracy minimizes runout to under 10 nm over the whole travel range. In addition, the high-speed Z-axis of the P-733.3CD can actively compensate any out-of-plane Z-axis deviation during XY motion.

Application Examples

- Image processing / stablilization
- Scanning microscopy
- Surface inspection
- Metrology / interferometry
- Biotechnology
- Semiconductor testing
- Mask / wafer positioning
- Micromanipulation
- Nanopositioning with high flatness & straightness

Fastest Multi-Axis Systems / Direct Drive, Low Profile and Large Apertures

P-733.2DD / .3DD multi-axis piezo nanopositioning systems are the fastest ultra-high-precision, open-frame stages for scanning microscopy. They provide a positioning and scanning range of 30 x 30 (x10) µm. P-733 nanopositioning and scanning stages feature very low profiles, as low as 20 mm (0.8 inch). The novel, high-stiffness direct drive gives the systems resonant frequencies as high as 2.2 kHz (4 x that of other comparable systems), enabling millisecond scanning rates with sub-nanometer resolution.

Parallel-Kinematics / Metrology for Enhanced Responsiveness

In a parallel kinematics multi-axis system, all actuators act directly on one moving platform. This means that all axes move the same minimized mass and can be designed with identical dynamic properties. Multi-axis nanopositioning systems equipped with both parallel kinematics and parallel, direct metrology are able to measure platform position in all degrees of freedom against one common fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross talk) is detected immediately and actively compensated by the servo-loops.

Capacitive Sensors for Subnanometer Resolution

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. The closed-loop resolution is 0.3 nm for the X and Y axes and 0.2 nm for the optional Z-axis. The direct drive versions are rated to 0.1 nm resolution for every axis.

Large Variety of Models for a Broad Range of Applications

For Z-axis scanning applications, the P-733.ZCD (see p. 2-42) version is available with a travel range of 100 µm. For ultra-high-vacuum applications down to 10^{-9} hPa, nanopositioning systems as well as comprehensive accessories, such as suitable feedthroughs, are available.

Ordering Information

P-733.2DD
High-Dynamics High-Precision XY Nanopositioning System, 30 x 30 µm, Direct Drive, Capacitive Sensors, Parallel Metrology, Sub-D Connector

P-733.3DD
High-Dynamics Precision XYZ Nanopositioning System, 30 x 30 x 10 µm, Direct Drive, Capacitive Sensors, Parallel Metrology, Sub-D Connector

P-733.2CD* / P-733.2CL*
High-Precision XY Nanopositioning System, 100 x 100 µm, Capacitive Sensors, Parallel Metrology

P-733.3CD* / P-733.3CL*
Precision XYZ Nanopositioning System, 100 x 100 x 10 µm, Capacitive Sensors, Parallel Metrology

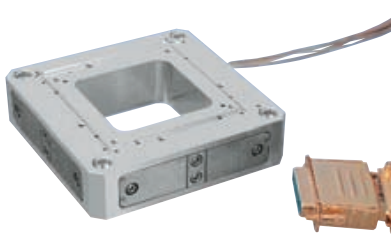
P-733.2VL* / P-733.2VD*
High-Precision XY Nanopositioning System, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, Vacuum Compatible to 10-6 hPa

P-733.2UD
High-Precision XY Nanopositioning System, 100 x 100 µm, Capacitive Sensors, parallel metrology, Sub-D Connector, Vacuum Compatible to 10-9 hPa

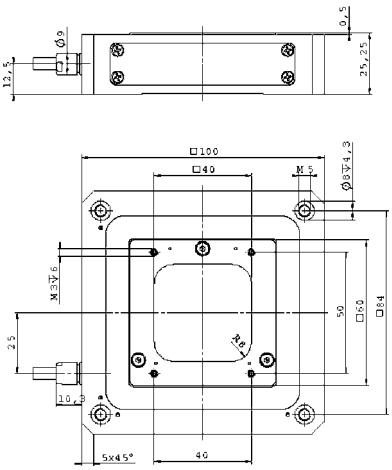
*.xxD with Sub-D Connector

*.xxL with LEMO Connector

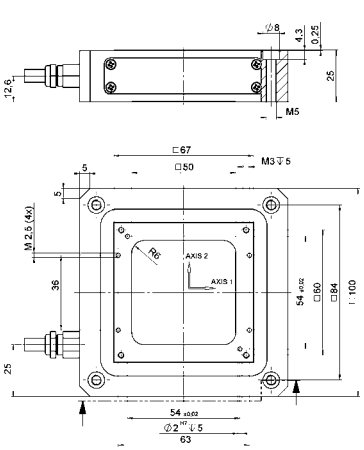
Ask about custom designs



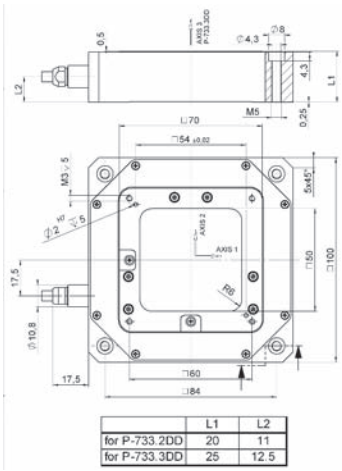
P-733.2UD non-magnetic XY scanning stage for UHV to 10^{-9} hPa



P-733.3 dimensions in mm



P-733.2 dimensions in mm



P-733.xDD dimensions in mm

Technical Data

Model	P-733.2CD P-733.2CL	P-733.3CD P-733.3CL	P-733.2DD	P-733.3DD	Units	Tolerance
Active axes	X, Y	X, Y, Z	X, Y	X, Y, Z		
Motion and positioning						
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive		
Open-loop travel, -20 to +120 V	115 x 115	115 x 115 x 12	33 x 33	33 x 33 x 14	µm	min. (+20 %/-0 %)
Closed-loop travel	100 x 100	100 x 100 x 10	30 x 30	30 x 30 x 10	µm	
Open-loop resolution	0.2	0.2 (0.1 in Z)	0.1	0.1	nm	typ.
Closed-loop resolution	0.3	0.3 (0.2 in Z)	0.1	0.1	nm	typ.
Linearity (X, Y)	0.03	0.03	0.03*	0.03*	%	typ.
Linearity (Z)	–	0.03	–	0.03*	%	typ.
Repeatability (X, Y)	<2	<2	<2	<2	nm	typ.
Repeatability (Z)	–	<1	–	<1	nm	typ.
Pitch (X,Y)	<±3	<±3	<±5	<±5	µrad	typ.
Yaw (X, Y)	<±10	<±10	<±10	<±10	µrad	typ.
Runout θZ (motion in Z)		<±5		<±5	µrad	typ.
Mechanical properties						
Stiffness	1.5	1.4 (9 in Z)	20	4 (10 in Z)	N/µm	±20 %
Unloaded resonant frequency	500	460 (1400 in Z)	2230	1200 (1100 in Z)	Hz	±20 %
Resonant frequency @ 120 g	370	340 (1060 in Z)	-	-	Hz	±20 %
Resonant frequency @ 200 g	340	295 (650 in Z)	1550	530 (635 in Z)	Hz	±20 %
Push/pull force capacity in motion direction	50/20	50/20	50/20	50/20	N	Max.
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	6	6 (2.4 in Z)	6.2	6.2 (3.3 in Z)	µF	±20 %
Dynamic operating current coefficient	7.5	7.5 (30 in Z)	25	25 (41 in Z)	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	0.58	0.675	0.58	0.675	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	m	±10 mm
Sensor/ voltage connection	Sub-D special (CD-version) LEMO (CL-version)	Sub-D special (CD-version) LEMO (CL-version)	Sub-D special	Sub-D special		

*With digital controller. Non-linearity of direct drive stages measured with analog controllers is up to 0.1 % typ.

Recommended controller:
Single-channel (1 per axis): E-610 servo controller / amplifier (p. 2-110), E -625 servo controller, bench-top (p. 2-114), E-621 controller module (p. 2-160)
Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152)
Multi-channel digital controllers: E-710 bench-top (p. 2-128), E-712 modular (p. 2-140), E-725 high-power (p. 2-126), E-761 PCI board (p. 2-130)

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

Direct Position Metrology and Clear Aperture

P-733.ZCD Piezo Z-Stage

- **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**

P-733.Z piezo vertical stages offer a positioning and scanning range of 100 µm with sub-nanometer resolution. The 50 x 50 mm clear aperture is ideal for applications such as scanning or confocal microscopy. Their fast settling time of less than 10 ms allows high throughput rates.

Application Examples

- Scanning microscopy
- Confocal microscopy
- Mask / wafer positioning
- Surface measurement technique
- Nano-imprinting
- Micromanipulation
- Image processing / stablilization
- Nanopositioning with high flatness & straightness

Capacitive Sensors for Highest Accuracy

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. The resolution of the P-733.Z is better than 0.3 nm.

Because of the direct measurement of the actual distance between the fixed frame and the moving part of the stage, errors in the drive train, actuator, lever arm or in guiding system do not influence the measuring accuracy. The result is exceptional motion linearity, higher long-term stability and a stiffer, more-responsive control loop, because external influences are immediately recognized by the sensor. The capacitive sensor non-linearity is typically less than 0.03 %, the repeatability of the P-733.Z is better than 2 nm.

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.

Large Variety of Models for a Broad Range of Applications

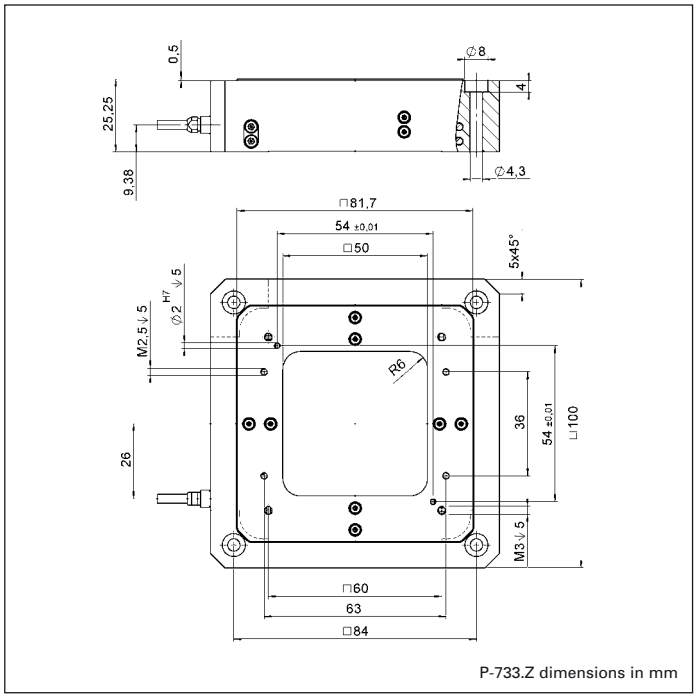
For scanning and positioning tasks in XY, the P-733.2CD and .3CD versions are available with a travel range of 100 x 100 µm. For high-dynamics applications, the P-733.2DD and P-733.3DD models can be offered with direct drive and reduced travel range (see p. 2-62).

For ultra-high-vacuum applications down to 10^{-9} hPa, nanopositioning systems as well as comprehensive accessories, such as suitable feedthroughs, are available.

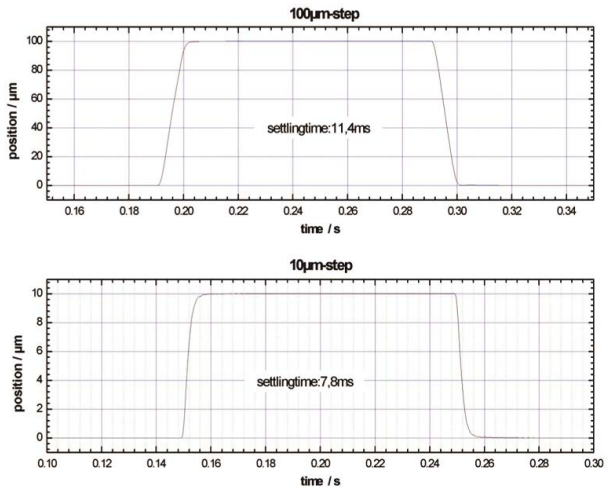
Ordering Information

P-733.ZCD
Compact Precision Nanopositioning Vertical Stage, 100 µm, Capacitive Sensor, Sub-D Connector

P-733.ZCL
Compact Precision Nanopositioning Vertical Stage, 100 µm, Capacitive Sensor, LEMO Connector



P-733.Z dimensions in mm



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

System properties	
System configuration	E-500 modular system with E-503 amplifier and E-509 sensor module; 20 g load
Amplifier bandwidth, small signal	96 Hz
Settling time (10 % step width)	8 ms

Technical Data

Model	P-733.ZCD P-733.ZCL	Tolerance
Active axes	Z	
Motion and positioning		
Integrated sensor	Capacitive	
Open-loop travel, -20 to +120 V	115 µm	min. (+20 %/-0 %)
Closed-loop travel	100 µm	
Open-loop resolution	0.2 nm	typ.
Closed-loop resolution	0.3 nm	typ.
Linearity	0.03 %	typ.
Repeatability	<2 nm	typ.
Rotation around Z	<10 µrad	typ.
Rotation around X	<5 µrad	typ.
Rotation around Y	<5 µrad	typ.
Mechanical properties		
Stiffness	2.5 N/µm	±20 %
Unloaded resonant frequency	700 Hz	±20 %
Resonant frequency @ 120 g	530 Hz	±20 %
Resonant frequency @ 200 g	415 Hz	±20 %
Push/pull force capacity	50 / 20 N	Max.
Drive properties		
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	
Dimensions	100 x 100 x 25 mm	
Mass	580 g	±5 %
Cable length	1,5 m	±10 mm
Sensor connection	Sub-D special (CD-version); 2x LEMO (CL-version)	
Voltage connection	Sub-D special (CD-version); 1 x LEMO (CL-version)	

Dynamic Operating Current Coefficient in µA per Hz and mrad. Example: Sinusoidal scan of 10 µm at 10 Hz requires approximately 3 mA drive current.
Recommended controller
One channel: E-610 controller / amplifier (p. 2-110), E-625 bench-top controller (p. 2-114), E-621 modular controller (p. 2-160)
Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152)
Single-channel digital controller: E-753 (bench-top) (p. 2-108)

P-611.3 NanoCube® 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 range, resolution 1 nm

- **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**

The P-611 NanoCube® piezo stage is a versatile, multi-axis piezo-nanopositioning system. Its 100 x 100 x 100 µm positioning and scanning range comes in an extremely compact package of only 44 x 44 x 44 mm. Equipped with a stiff, zero-stiction, zero-friction guiding system, this NanoCube® provides motion with ultra-high resolution and settling times of only a few milliseconds. The minimal moved masses and the stiff piezo drive make it ideal for high-throughput applications such as fiber alignment where it enables significantliy faster device characterization than achievable with conventional motorized drives.

Application Examples

- Photonics / integrated optics
- Micromanipulation
- Biotechnology
- Semiconductor testing
- Fiber positioning

Closed-Loop and Open-Loop Versions

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.

The open-loop models are ideal for applications where fast response and very high resolution are essential, but absolute positioning is not important, e.g. in tracking or fiber positioning. They can also be used when the position is controlled by an external linear position sensor such as an interferometer, a PSD (position sensitive diode), CCD chip / image processing system, or the eyes and hands of an operator.

Versatility & Combination with Motorized Stages

The P-611 family of piezo stages comprises a variety of single- and multi-axis versions (X, XY, Z, XZ and XYZ) that can be easily combined with a number of very compact manual or motorized micropositioning systems to form coarse/fine positioners with longer travel ranges (see p. 2-20, p. 2-36 and p. 2-50). For fiber positioning tasks, several fiber, waveguide and optics adapters are available for mounting on the NanoCube® P-611.3SF (e.g. for combination with the F-206.S nanoalignment system see p. 4-12).

High Reliability and Long Lifetime

The compact P-611 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.

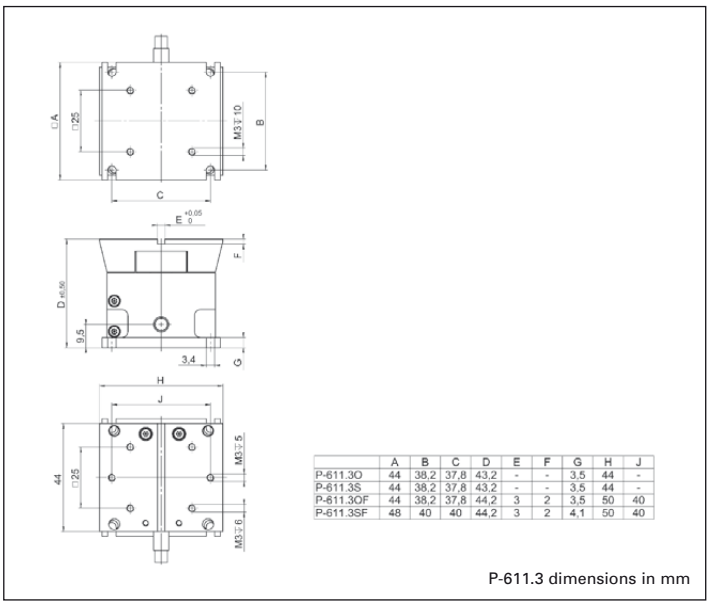
Ordering Information

P-611.3S
NanoCube® XYZ Nanopositioning System, 100 x 100 x 100 µm, Strain Gauge Sensors

P-611.30
NanoCube® XYZ Nanopositioning System, 100 x 100 x 100 µm, Open-Loop

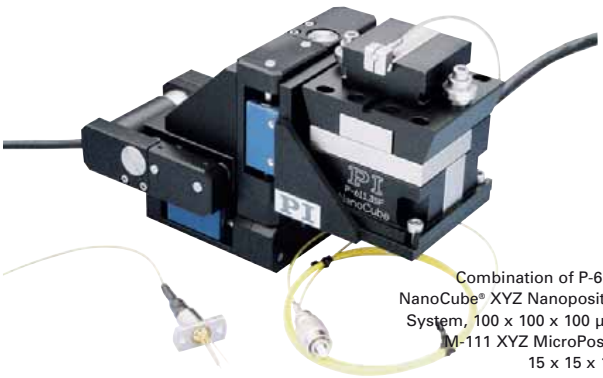
P-611.3SF
NanoCube® XYZ Nanopositioning System, 100 x 100 x 100 µm, Strain Gauge Sensors, Fiber Adapter Interface

P-611.30F
NanoCube® XYZ Nanopositioning System, 100 x 100 x 100 µm, Open-Loop, Fiber Adapter Interface



	A	B	C	D	E	F	G	H	J
P-611.3O	44	38,2	37,8	43,2	-	-	3,5	44	-
P-611.3S	44	38,2	37,8	43,2	-	-	3,5	44	-
P-611.3OF	44	38,2	37,8	44,2	3	2	3,5	50	40
P-611.3SF	48	40	40	44,2	3	2	4,1	50	40

P-611.3 dimensions in mm



Combination of P-611.3SF NanoCube® XYZ Nanopositioning System, 100 x 100 x 100 µm and M-111 XYZ MicroPositioner 15 x 15 x 15 mm

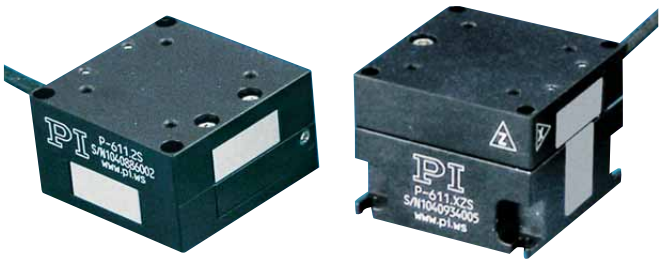
Technical Data

Model	P-611.3S P-611.3SF	P-611.3O P-611.3OF	Units	Tolerance
Active axes	X, Y, Z	X, Y, Z		
Motion and positioning				
Integrated sensor	SGS			
Open-loop travel, -20 to +120 V	120 / axis	120 / axis	µm	min. (+20 %/0 %)
Closed-loop travel	100 / axis	–	µm	
Open-loop resolution	0.2	0.2	nm	typ.
Closed-loop resolution	1	–	nm	typ.
Linearity	0.1	–	%	typ.
Repeatability	<10	–	nm	typ.
Pitch in X,Y	±5	±5	µrad	typ.
Runout θ_X (Z motion)	±10	±10	µrad	typ.
Yaw in X	±20	±20	µrad	typ.
Yaw in Y	±10	±10	µrad	typ.
Runout θ_Y (Z motion)	±10	±10	µrad	typ.
Mechanical properties				
Stiffness	0.3	0.3	N/µm	±20 %
Unloaded resonant frequency X / Y / Z	350 / 220 / 250	350 / 220 / 250	Hz	±20 %
Resonant frequency @ 30 g X / Y / Z	270 / 185 / 230	270 / 185 / 230	Hz	±20 %
Resonant frequency @ 100 g X / Y / Z	180 / 135 / 200	180 / 135 / 200	Hz	±20 %
Push/pull force capacity in motion direction	+15 / -10	+15 / -10	N	Max.
Load capacity	15	15	N	Max.
Drive properties				
ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance	1.5	1.5	µF	±20 %
Dynamic operating current coefficient	1.9	1.9	µA/(Hz • µm)	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum, steel	Aluminum, steel		
Dimensions	44 x 44 x 43.2 SF-version: 44 x 50 x 44.2	44 x 44 x 43.2 OF-version: 44 x 50 x 44.2	mm	
Mass	0.32	0.32	kg	±5 %
Cable length	1.5	1.5	m	±10 mm
Sensor connector	Sub-D	–		
Voltage connection	Sub-D	Sub-D		
Recommended controller / amplifier	E-664 Nanocube® Controller (p. 2-137)	3 x E-610.00F OEM amplifier modules (p. 2-110); E-663 3-channel amplifier, bench-top (p. 2-136)		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 amplifier (p. 2-146)
Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 50 µm at 10 Hz requires approximately 0.8 mA drive current.
Adapter cable with LEMO connectors for sensor and operating voltage available.

P-611.XZ · P-611.2 XZ & XY Nanopositioner

Compact 2-Axis Piezo System for Nanopositioning Tasks



P-611 XY- and XZ-nanopositioning systems (from left), 100 µm travel, resolution to 0.2 nm

- **Compact: Footprint 44 x 44 mm**
- **Travel Range to 120 x 120 µm**
- **Resolution to 0.2 nm**
- **Cost-Effective Mechanics/Electronics System Configurations**
- **Frictionless, High-Precision Flexure Guiding System**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **X, Z and XYZ Versions also Available**

P-611 piezo stages are flexure-guided nanopositioning systems featuring a compact footprint of only 44 x 44 mm. The XY- and XZ-versions described here are part of a family of positioners available in 1 to 3 axis configurations. Despite their small dimensions the systems provide up to 120 µm travel with sub-nanometer resolution. They are ideally suited for planar positioning tasks such as opticalpath length correction in interferometry, sample positioning in microscopy or scanning applications, for autofocus and photonics applications. Both versions are available with 100 µm travel per axis. Equipped with ceramic-encapsulated piezo drives and a stiff, zero-stiction, zero-friction flexure guiding system, all P-611 piezo stages combine millisecond responsiveness with nanometric precision and extreme reliability.

Application Examples

- Fiber positioning
- Semiconductor testing
- Micromachining
- Micromanipulation
- MEMS fabrication/testing
- Photonics / integrated optics

Closed-Loop and Open-Loop Versions

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.

The open-loop models are ideal for applications where fast response and very high resolution are essential, but absolute positioning is not important. They can also be used when the position is controlled by an external linear position sensor such as an interferometer, a PSD (position sensitive diode), CCD chip / image processing system, or the eyes and hands of an operator.

Versatility & Combination with Motorized Stages

The P-611 family of piezo stages comprises a variety of single- and multi-axis versions (X, XY, Z, XZ and XYZ) that can be easily combined with a number of very compact manual or motorized micropositioning systems to form coarse/fine positioners with longer travel ranges (see p. 2-20, p. 2-36 and p. 2-50).

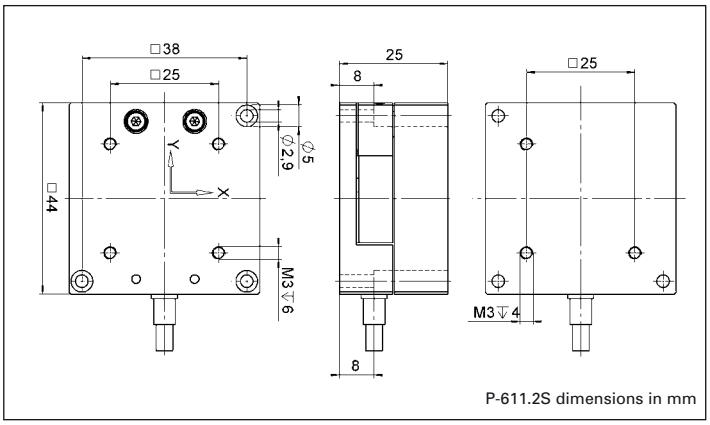
Ordering Information

P-611.2S
XY Nanopositioning System, 100 x 100 µm, SGS-Sensor

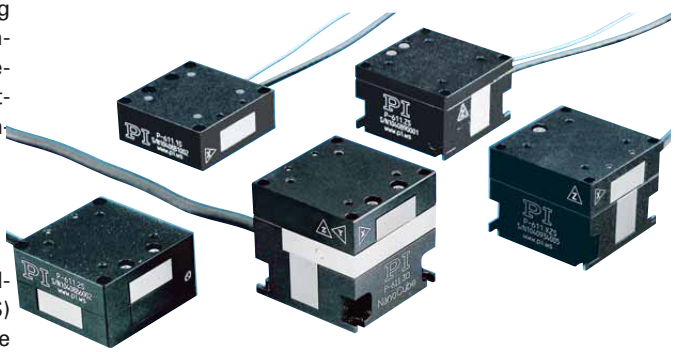
P-611.20
XY Nanopositioning System, 100 x 100 µm, No Sensor

P-611.XZS
XZ Nanopositioning System, 100 x 100 µm, SGS-Sensor

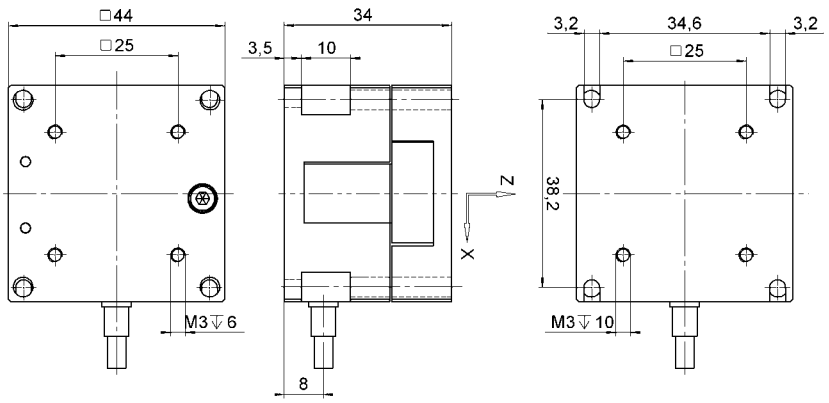
P-611.XZ0
XZ Nanopositioning System, 100 x 100 µm, No Sensor



P-611.2S dimensions in mm



The whole P-611 family: X, Z, XY, XZ and XYZ stages



P-611.XZS dimensions in mm

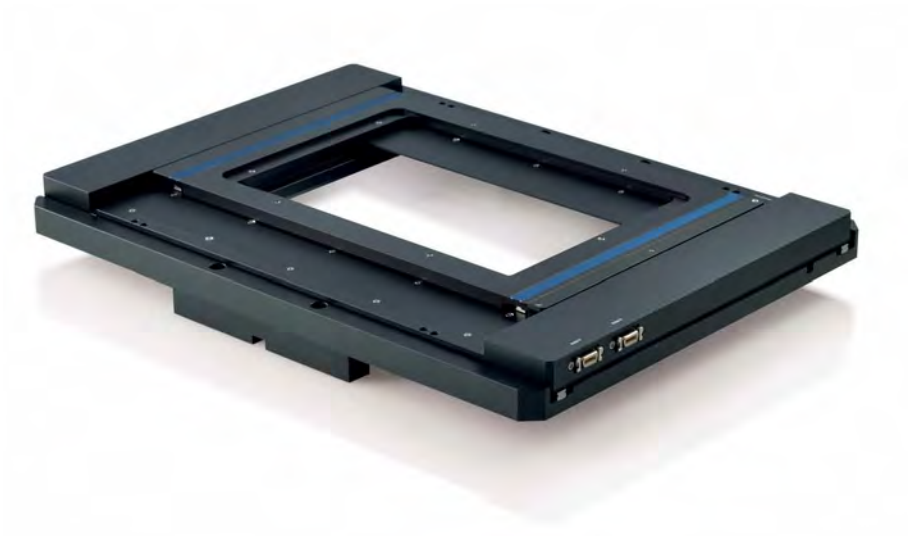
Technical Data

Model	P-611.2S	P-611.20	P-611.XZS	P-611.XZ0	Units	Tolerance
Active axes	X, Y	X, Y	X, Z	X, Z		
Motion and positioning						
Integrated sensor	SGS	–	SGS	–		
Open-loop travel, -20 to +120 V	120	120	120	120	µm	min. (+20 %/0 %)
Closed-loop travel	100	–	100	–	µm	
Open-loop resolution	0.2	0.2	0.2	0.2	nm	typ.
Closed-loop resolution	2	–	2	–	nm	typ.
Linearity	0.1	–	0.1	–	%	typ.
Repeatability	<10	–	<10	–	nm	typ.
Pitch in X,Y	±5	±5	±5	±5	µrad	typ.
Runout θ_X (Z motion)	–	–	±10	±10	µrad	typ.
Yaw in X	±20	±20	±20	±20	µrad	typ.
Yaw in Y	±10	±10	–	–	µrad	typ.
Runout θ_Y (Z motion)	–	–	±10	+/-10	µrad	typ.
Mechanical properties						
Stiffness	0.2	0.2	0.2 Z: 0.35	0.2 Z: 0.35	N/µm	±20 %
Unloaded resonant frequency	X: 345; Y: 270	X: 345; Y: 270	X: 365; Z: 340	X: 365; Z: 340	Hz	±20 %
Resonant frequency @ 30 g	X: 270; Y: 225	X: 270; Y: 225	X: 280; Z: 295	X: 280; Z: 295	Hz	±20 %
Resonant frequency @ 100 g	X: 180; Y: 165	X: 180; Y: 165	X: 185; Z: 230	X: 185; Z: 230	Hz	±20 %
Push/pull force capacity in motion direction	15 / 10	15 / 10	15 / 10	15 / 10	N	Max.
Load capacity	15	15	15	15	N	Max.
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	1.5	1.5	1.5	1.5	µF	±20 %
Dynamic operating current coefficient	1.9	1.9	1.9	1.9	µA/(Hz • µm)	±20 %
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Aluminum, steel	Aluminum, steel	Aluminum, steel	Aluminum, steel		
Dimensions	44 x 44 x 25	44 x 44 x 25	44 x 44 x 34	44 x 44 x 34	mm	
Mass	0.235	0.235	0.27	0.27	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	m	±10 mm
Sensor connection	LEMO	–	LEMO	–		
Voltage connection	LEMO	LEMO	LEMO	LEMO		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 amplifier (p. 2-146)
Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 50 µm at 10 Hz requires approximately 0.9 mA drive current.
Recommended controller / amplifier
Single-channel (1 per axis): E-610 servo controller / amplifier (p. 2-110), E -625 servo controller, bench-top (p. 2-114), E-621 controller module (p. 2-160)
Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152)

XY Microscope Stage with PILine® Motor, Controller and Joystick

STABLE, DYNAMIC, LOW PROFILE



M26821LNJ/OJ

- Highest stability
- 0.1 µm resolution
- Travel range up to 135 x 85 mm
- For inverted microscopes, free rotation of turret
- Suitable Z sample scanner available

Reference-class XY microscope stage
Controller and joystick included. 160 × 110 mm clear aperture. Versions for inverted microscopes:

- Nikon Eclipse Ti-E/Ti-U/Ti-S (NJ)
- Olympus IX2 (OJ)

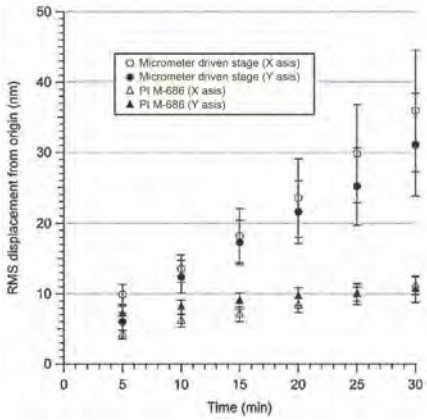
High-resolution piezo linear drive
Self-locking at rest. Low noise. Highest stability due to low thermal load and no need for lubricants. Large dynamics range of 10 µm/s to 100 mm/s, ideal for operation via joystick and automated high-content methods

Direct-metrology linear encoder
High resolution and repeatability

User software
PIMikroMove. PI General Command Set (GCS). Drivers for LabVIEW. compatible with µManager, MetaMorph, MATLAB

Accessories
M-687.AP1 plain plate for slide holder and petri dish holder

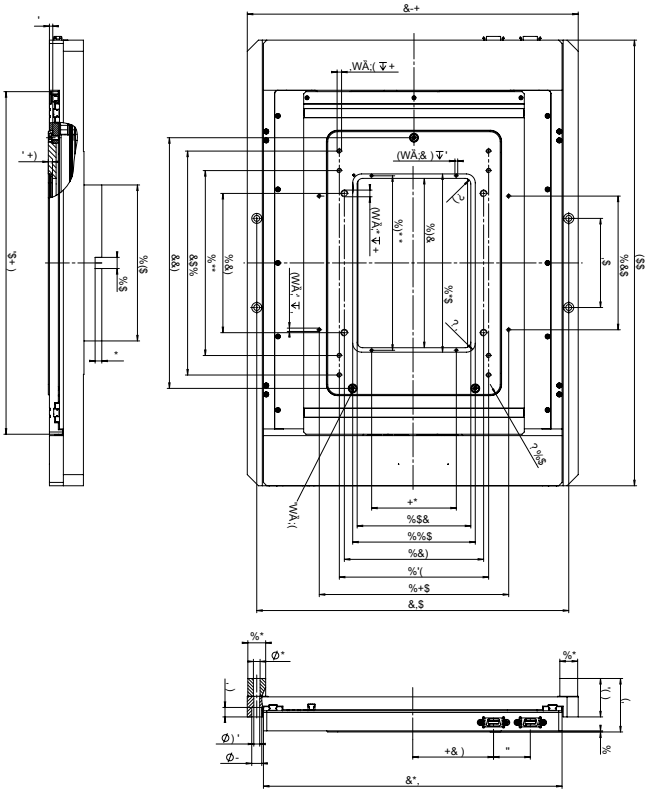
Fields of application
For inverted microscopes made by Nikon and Olympus, versions for other microscopes are available on request. For super-resolution microscopy, tiling, automated scanning microscopy



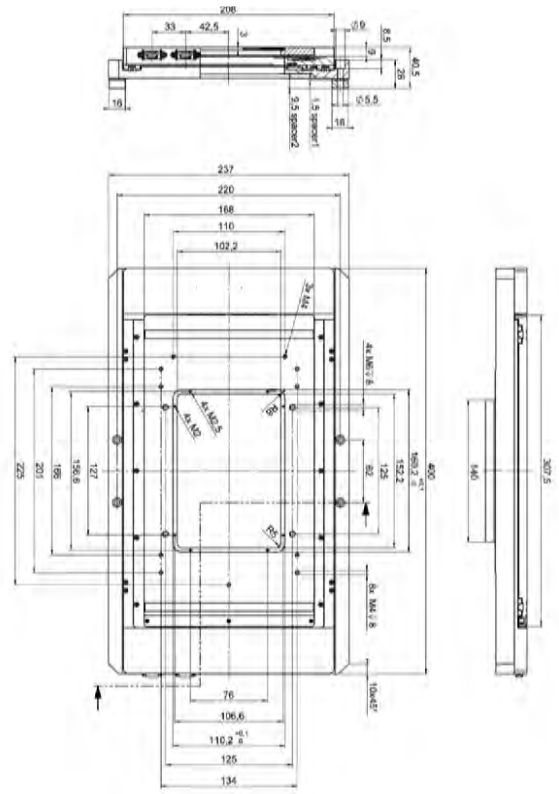
Stability of an M-686 XY stage in comparison to a stage with micrometer screw. Source: S.C. Jordan/P.C. Anthony: Design Considerations for Micro- and Nanopositioning: Leveraging the Latest for Biophysical Applications, Current Pharmaceutical Biotechnology, 2009, 10, 515-521

Suitable Z piezo stage with 200 µm stroke and 60 x 110 mm clear aperture available on request

	M26821LNJ	M26821LOJ	Units	Tolerance
	XY stage for Nikon microscopes	**XY stage for Olympus microscopes**		
Active axes	X, Y	X, Y		
Motion and positioning				
Travel range	135 x 85	100 x 75	mm	
Integrated sensor	Linear encoder	Linear encoder		
Sensor resolution	0.1	0.1	µm	
Bidirectional repeatability	0.4	0.4	µm	
Pitch / Yaw	±300	±300	µrad	typ.
Max. velocity	120	120	mm/s	
Reference point switches	Optical, 1 µm repeatability	Optical, 1 µm repeatability		
Limit Switches	Hall-effect	Hall-effect		
Mechanical properties				
Max. load	50	50	N	
Max. push / pull force	7	7	N	
Miscellaneous				
Operating temperature range	20 to 40	20 to 40	°C	
Material	Al (black anodized)	Al (black anodized)		
Mass	3.2	3.8	kg	±5 %
Piezomotor controller	C-867.262 with USB joystick (included in delivery)			
Communication interfaces	USB, RS-232, Ethernet			
I/O Connector	4 analog/digital in, 4 digital out (Mini-DIN, 9-pin) digital: TTL; analog: 0 to 5 V, USB joystick			
Command set	PI General Command Set (GCS)			
User software	PIMikroMove			
Software drivers	LabVIEW drivers, GCS-DLL, dynamic link libraries for Windows (DLL) and Linux			
Supported functionality	Start-up macro, macro, data recorder / trace memory, MetaMorph, µManager, MATLAB			
Controller dimensions	320 x 150 x 80.5 mm (including mounting rails)			



M-687.UN for Nikon Microscopes, dimensions in mm



M-687.UO for Olympus Microscopes, dimensions in mm

PIFOC® Sample Focus Positioner

LOW-PROFILE, LONG-TRAVEL Z NANOPOSITIONER FOR MICROSCOPY SAMPLE HOLDERS

P-737

- High-speed piezo Z motion with travel ranges up to 500 µm
- Nanometer-resolution
- Clear aperture 100 x 148 mm to accommodate sample holders and microtitre plates
- Perfect mechanical fit with XY OEM manual or motorized stages
- Millisecond response times

Miniature Tip/Tilt Steering Mirror

FAST TIP/TILT MIRROR FOR DEFLECTION ANGLE UP TO 100 MRAD

S-334

- Extremely compact design
- Optical beam deflection to 100 mrad (approx. 5.7°)
- One moving platform with fixed pivot point; prevents a polarization rotation
- Factory-installed mirror
- ms-response times, resolution to 0.2 µrad
- Closed-loop 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

Open-Frame Microscope Stage System

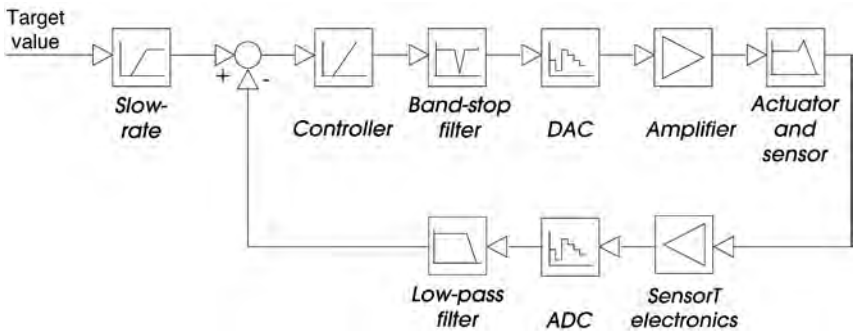
HIGH STABILITY CERAMIC LINEAR MOTOR DRIVES

MD5422L

- Motorized with PILine® linear drives
- Controller and software included
- Stable platform for P-545 Plnano® piezo nanopositioning systems
- Low profile for easy integration: 30 mm
- Travel range 25 x 25 mm
- For inverted microscopes made by Nikon, Zeiss, Leica, and Olympus

Digital Motion Controllers

IMPROVED PERFORMANCE THROUGH DIGITAL PROCESSES



Digital technology opens up possibilities for improving performance in control engineering which do not exist with conventional analog technology.

A significant advantage of digital controllers from PI is that all motion parameters can be optimized and modified by the user.

This serves to increase the precision and dynamic characteristics as well as the ease of use.

Suitable signal conversion

The most important prerequisite here is that the conversion of analog input signals such as sensor or piezo voltages to digital data takes place fast and with a high resolution. Information that is lost during conversion remains lost for further processing.

The same holds true for the generation of an analog signal for controlling the piezo drives.

For this reason, PI employs the lowest noise and highest stability precision A/D and D/A converters available on the market providing up to 24 bit resolution. As a result, analog signal amplitudes are resolved in over 1 million data points.

Fast data processing

The incoming pack of data has to be quickly processed in order match classic analog controllers in terms of "real time". For this purpose, fast processors are required. Depending on the task of the controller, PI uses state-of-the-art signal processors (DSP's), field-programmable gate arrays (FPGA's) or powerful PC solutions. A control cycle is thereby processed in 0.02 milliseconds, for example – this corresponds to a servo rate of 50 kHz. Updated sensor data and control signals also have to be provided correspondingly.

Parallel-kinematics 6-axis positioning system with digital multi-axis controller

Digital data processing for improving

- of the linearity
- of the path accuracy during the motion (dynamic linearity)
- of the control algorithms

Simplified operation

- Access to all parameters
- Recording of the system behavior
- Access to all functions
- ID chip, reading out of individual system data

Additional functions

- Data recorder
- Programmable function generators
- Macro programming and storage
- Coordinate transformation with parallel kinematics
- Autofocus algorithms

State-of-the-art interfaces

- USB, TCP/IP, PIO
- Serial real-time interfaces

With the single channel E-709 controller, PI introduces the advantages of digital controllers even for low-cost, single-axis system such as the PIFOC® objective stage.

Software for easy operation

The digitization of all process steps means the process parameters can be easily accessed using software. In addition, PI software offers diagnostic tools and assistance with the adjustment of settings, such as the graphic display of step responses for the optimization of parameter settings.

Mechanical stiffness, precisely engineered guiding systems, the resolution and bandwidth of the sensor and the noise level of the voltage source remain important prerequisites for high-precision and dynamic positioning and scanning.

With increasing requirements, however, the optimization of the performance of a positioning system is increasingly determined by the controller.

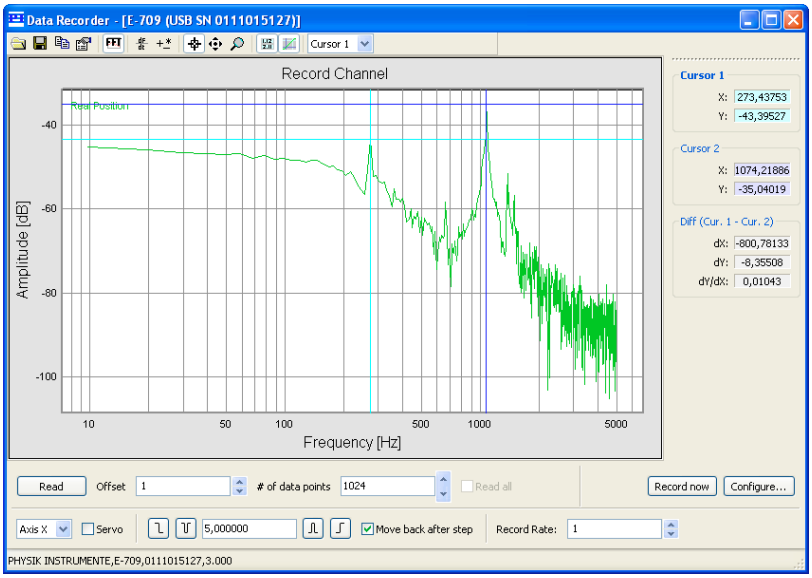
Semi-automated configuration

The adjustment to the system to be operated takes place in a few steps through a mainly automated configuration dialog. Predefined parameter sets for each PI stage allow for a fast and simple installation. The graphic display of the actual motion, such as step & settle (captured in the controller's trace memory) facilitates the optimal adaptation of the positioning system to the customer's application. All PI systems can be operated by the same user interface.

Dynamic control such as velocity, acceleration or PID parameters can be changed directly. Since nearly all PI controllers have a trace memory, which is supported by the PIMikroMove user software included in the delivery, the host PC transforms itself with just a few clicks into a virtual oscilloscope with which the settings can be optimized specifically for the customer application.

Third-party poftware package

Drivers for PI positioning systems are integrated in popular third party image acquisition packages such as MetaMorph, µManager, MATLAB or ScanImage, saving the user valuable time during system setup and programming.



Fast and simple system analysis with the PIMikroMove software. This tool is included in delivery

The Right Position Sensor Technology

NANOMETER-PRECISION MEASUREMENT TECHNOLOGY

Positioning systems that need to provide accuracies in the range of a few nanometers and below require a position measurement technique that can also detect motion in this range. The most important specifications for selecting a suitable method are linearity, resolution (sensitivity), stability, bandwidth and last but not least cost. Another important factor is the ability to detect the motion of the moving platform. The contact with the movable parts also affects the measuring result.

PI nanopositioners use three different types of sensors, capacitive, strain gauges and linear encoders.

Nanopositioning systems from PI use capacitive sensors of different sizes

Capacitive sensors from PI determine the distance between two plate electrodes without contact. These sensors are integrated in the nanopositioning system in such a way that no effects on the size and mass (inertia) are to be expected. With a corresponding arrangement, they directly detect the motion of the platform (direct metrology). Capacitive sensors achieve the best resolution, stability and bandwidth, as well as the best linearity and accuracy.

Strain gauge sensors consist of a thin metal (SGS) or semiconductor foil (piezo-resistive, PRS), which is attached to the piezoceramic or, for improved precision, on the guiding system of a flexure stage. This type of position and measurement is called inferred metrology because the position is inferred from strain measured on a component in the drive train. Strain gauge sensors derive the position information from their expansion. Full-bridge circuits with several strain gauge sensors per axis improve the thermal stability.

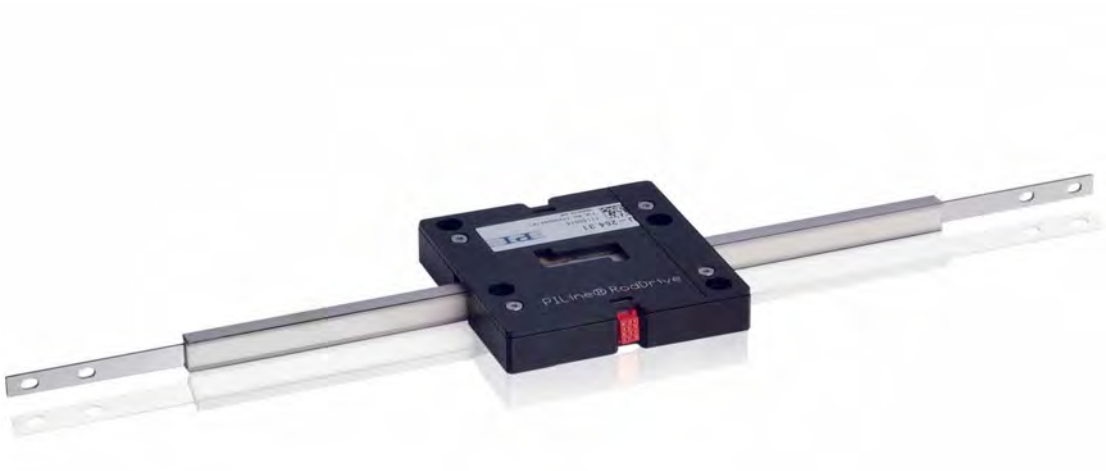
Linear encoders are incremental measuring systems that consist of a tape measure and measuring head. For longer travel ranges of approx. 1 millimeter or more, PI uses optic sensors that allow a position resolution down to the pictometer range when used with sophisticated signal processing and interpolation circuits.

Sensor type	Sensitivity / Resolution*	Linearity*	Stability / Repeatability	Bandwidth*	Measurement method	Measurement range
Capacitive	excellent	excellent	excellent	excellent	direct / non-contact	<2 mm
Strain gauge sensors made of metal foil (SGS)	very good	very good	good	very good	indirect / with contact	<2 mm
Piezo-resistive strain gauge sensors (PRS)	excellent	good	average	very good	indirect / with contact	<1 mm
Linear encoder	excellent	very good	excellent	very good	direct / non-contact	up to >100 mm

* The classifications refer to the characteristics of the nanopositioning system. The information on resolution, linearity and repeatability in the respective data sheet reflect the specifications of the overall system, including controller, mechanics and sensor. The checking is done with external measuring instruments (Zygo interferometer). This data must not be confused with the theoretical data of the sensor system!

PILine® Ultrasonic Piezomotors

COMPACT DRIVES, FAST AND SELF-LOCKING

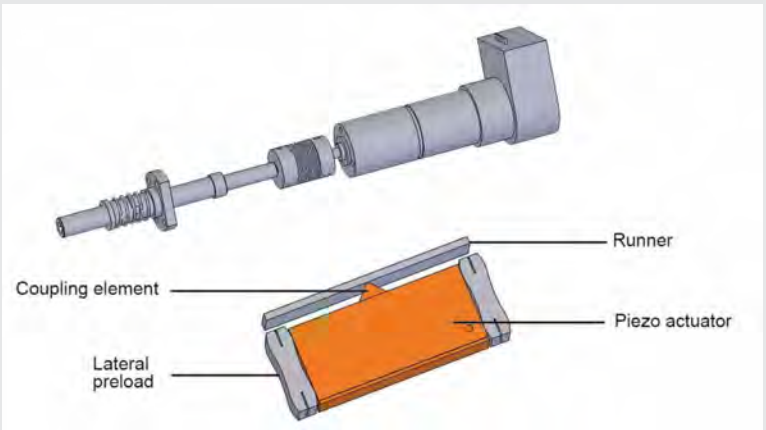


- Integration levels from economical OEM motors to multi-axis positioning systems
- Excellent dynamic properties, fast step & settle
- Basically unlimited travel ranges
- Easy mechanical integration
- Self-locking at rest
- Holding force up to 15 N
- Velocity up to 500 mm/s
- Resolution to 0.05 µm (50 nm)

Direct-driven PILine® linear motors

These linear drives dispense with the mechanical complexity of classical rotary motor/gear/leadscrew combinations. These components can be very susceptible to wear, especially in miniaturized systems.

The simplicity of the ultrasonic linear motor promotes its precision, reliability and cost efficiency. An integral part of the ultrasonic piezomotor is a piezo ceramic that is preloaded against a moving runner with a coupling element. The piezo element is electrically excited to produce high-frequency oscillations that cause the runner to move.



Motor-leadscrew combinations (above) transform the rotational motion of the motor into linear motion. Due to play in the mechanical components responsiveness is limited. Linear motors such as PILine® generate linear motion directly and provide much faster response and better stability

Piezomotors are self-locking

The preload of the piezoceramic actuator against the runner ensures that the drive self-locks at rest and when powered down. As a result, it does not consume any power, it does not heat up and keeps the position stable mechanically. Applications with a short duty cycle, that are battery-operated or heat-sensitive benefit from these characteristics.

Lifetime and reliability

The motion of the piezoceramic actuator is based on crystalline effects and is not subject to any wear. The coupling to the runner, on the other hand, is subject to friction effects. Depending on the operating mode, running distances over 2000 km or a MTBF of 20000 hours are achieved.

Dynamics in use

The stiff design, direct coupling and fast response of the piezo ceramics to electric inputs allows for very fast start / stop behavior and velocities to hundreds of mm/sec.

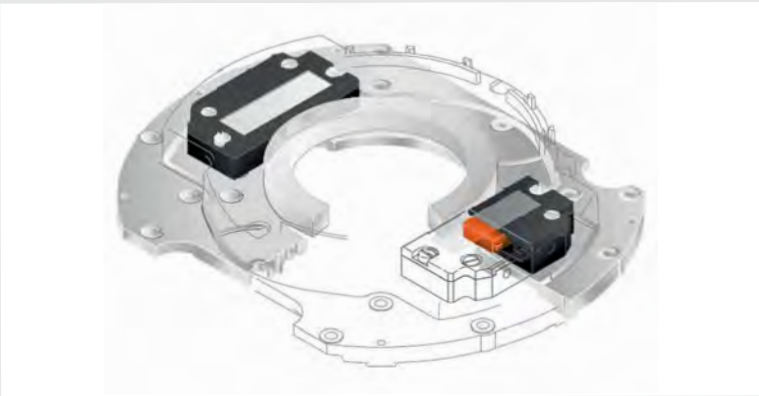
Patented technology

The products described in this document are in part protected by the following patents:

US Pat. No. 6,765,335B2

European Patent No. 1267425B1

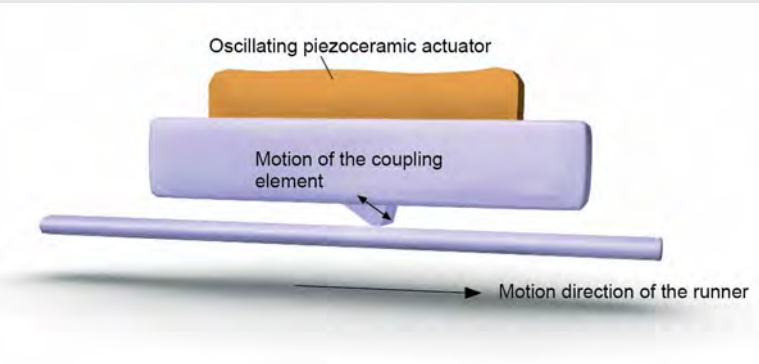
The benefit of the low profile PILine® drives becomes apparent with positioning systems such as the M-660 rotation stage (left, 14 mm high) or the M-687 microscopy XY stage (right, 25 mm high): a consistently flat design without lead screw ducts or flanged motors



Implementation of rotary motion: PILine® motors act on a ring-shaped runner

Piezomotors for all applications – e. g. in vacuum environments and strong magnetic fields

Piezomotors from PI are intrinsically vacuum-compatible and suitable for operation in strong magnetic fields. Special versions are offered for this purpose. Nanometer resolution or forces up to several 100 N can be achieved with PiezoWalk® linear motors.



The piezoceramic actuator is excited with a high frequency electric signal (100 to 200 kHz). The deformation of the actuator leads to a periodic diagonal motion of the coupling element to the runner. The created feed is roughly 10 nm per cycle; the high frequencies lead to the high velocities

PICMA® Piezo Actuators

HIGHLY RELIABLE MULTI-LAYER TECHNOLOGY

- Sub-nanometer resolution
- High reliability and superior lifetime through fully ceramic insulation
- Low operating voltage < 150 V
- High dynamics: response times in the range of a few microseconds
- High power generation
- Minimum power consumption when holding the position
- Ideal for OEM-Applications
- Neutral in magnetic fields
- UHV-compatible
- For cryogenic environments

Valid patents

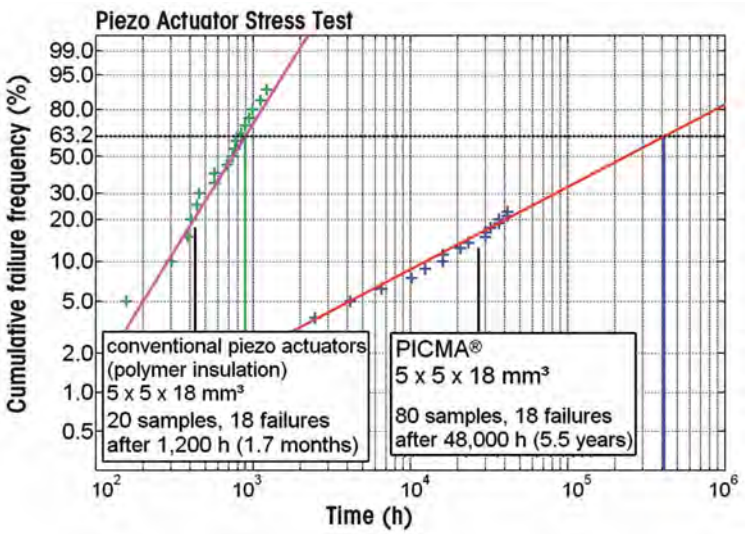
- German Patent No. 10021919C2
- German Patent No. 10234787C1
- German Patent No. 10348836B3
- German Patent No. 102005015405B3
- German Patent No. 102007011652B4
- US Patent No. 7,449,077

Piezoceramic nanopositioning drives: no friction, no wear

The displacement of piezoceramic actuators is based on crystalline effects and is thus frictionless. This allows positioning with a resolution in the sub-nanometer range. Unlike motor drives, there are no rotating parts, neither is there any friction; piezo actuators have zero play, are maintenance-free and non-wearing.

Long lifetime

PICMA® actuators are far superior to conventional polymer-insulated multi-layer piezo actuators. As a result of the ceramic insulation layer, the monolithic piezoceramic block is protected against humidity and failures due to increased leakage current. In this way, an especially high reliability is achieved even under extreme environmental conditions.



Comparison of PICMA® and conventional polymer-insulated piezo actuators. The extrapolated average lifetime (MTTF) for PICMA® actuators is more than 400,000 h, approx. 45 years. All comparison samples fail after 1,600 h at the latest, corresponding MTTF = 890 h, approx. 1 month. (Results of a life test with increased humidity for accelerated aging. Test conditions: 100 VDC, 22 °C, 90 % RH).

PICMA® multilayer piezo actuators are based on a special PZT (lead zirconate – lead titanate) ceramic, which ideally combines the desired characteristics of the components such as high stiffness, low electrical capacity, high specific displacement, low load and temperature dependence of the specifications and a long lifetime.

Large temperature range – optimum UHV compatibility – minimal outgassing – neutral in magnetic fields

The particularly high Curie temperature of 320°C gives PICMA® actuators a usable temperature range of up to 150°C, far beyond the 80°C limit of conventional multilayer actuators. This and the exclusive use of inorganic materials, e.g. for insulation and the electric contact, provide the optimum conditions for use in ultra-high vacuums: no outgassing and high bake-out temperatures. At a reduced travel range, piezo actuators even work at cryogenic temperatures. Every actuator is constructed exclusively of non-ferromagnetic materials, giving them extremely low residual magnetism of the order of a few nanotesla.

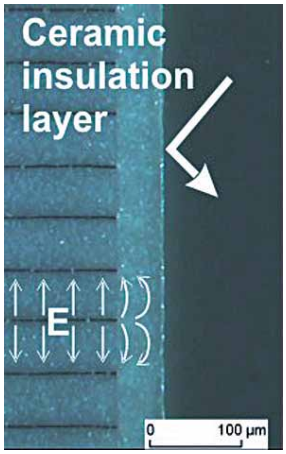
Extraordinarily robust: 10^{10} working cycles in dynamic operation

Due to the stability of the material behavior and the mechanical construction, PICMA® actuators exhibit no signs of wear even after many billions of load cycles. Dynamic test series show only an insignificant decrease in displacement.

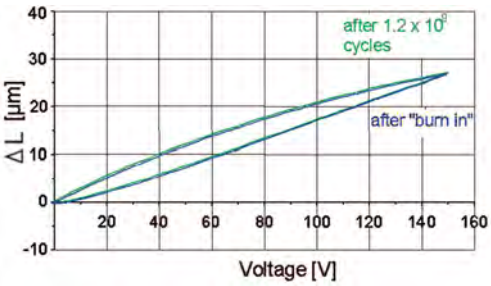
Protective ceramic layer

Measurements of the leakage current impressively demonstrate how effectively the monolithic structure of the PICMA® actuators suppresses the penetration of moisture.

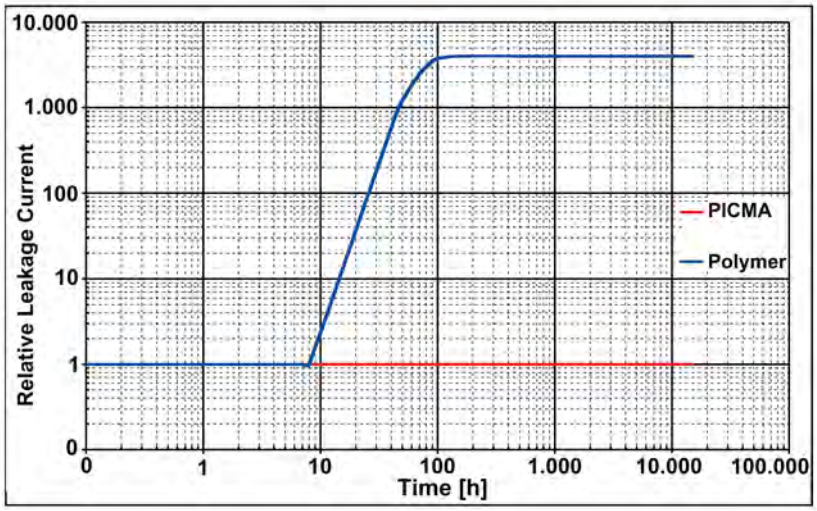
PICMA® actuators with patented external electrodes for up to 20 A charging current



The internal electrodes and the ceramic are sintered together (cofired technology), creating a monolithic piezoceramic block. The ceramic insulating layer prevents the penetration of water molecules and reliably protects the sensitive internal electrodes from mechanical damage and dirt



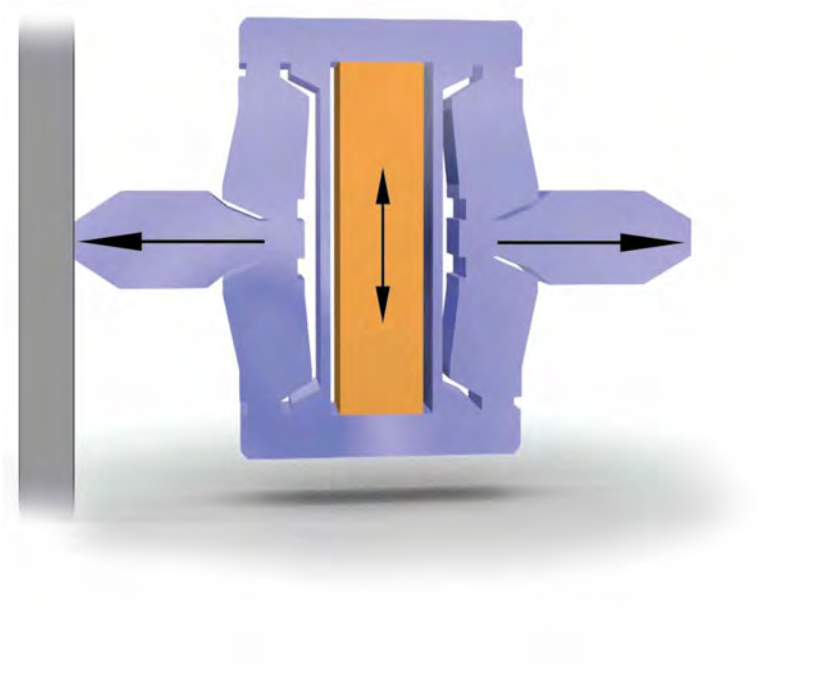
PICMA® actuators 5 x 5 x 18 mm: total number of cycles 4.0 x 10^9 cycles; 116 Hz sinusoidal actuation (1.0 x 10^7 cycles per day), 100 V unipolar operating voltage, 15 MPa preload. Check measurements after every 10^9 cycles



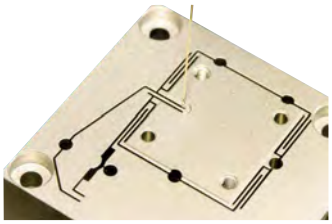
PICMA® piezo actuators (bottom curve, red) compared to polymer-coated multilayer piezo actuators. The high insulation resistance of the PICMA® actuators remains stable over several time decades, whereas conventional, polymer-coated actuators exhibit a significantly increased leakage current after only a few hours. (Test conditions: 100 VDC, 25 °C, 70 % RH)

Flexure Guides

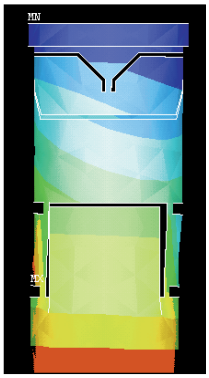
FRICTIONLESS AND PRECISE



This lever mechanism with flexure guides transforms the actuator travel range (vertical) into an even, straight motion (horizontal)



Flexure guiding systems of the highest accuracy class are manufactured with a wire cut discharge process



The deformation of the flexure guides is checked with FEM stress simulations

Flexure guides from PI have proven their worth in nanopositioning. They guide the piezo actuator and ensure a straight motion without tilting or lateral offset. A solid material is deformed by a frictionless, stictionless device (flexure) – completely without rolling or sliding parts. This deformation is sufficient to guide the actuator over travel ranges from several 10 to 100 µm.

No wear

Advantages are the high stiffness, load capacity and wear-resistance. Flexures are maintenance-free, can be manufactured from non-magnetic materials, require no lubricants or consumables and hence also function in a vacuum without any problem.

Flexures as levers

The travel range of a piezo actuator can also be multiplied by integrating lever mechanisms. The actuator is mechanically integrated in a flexure joint in such a way that the travel range is extended to up to 2 mm.

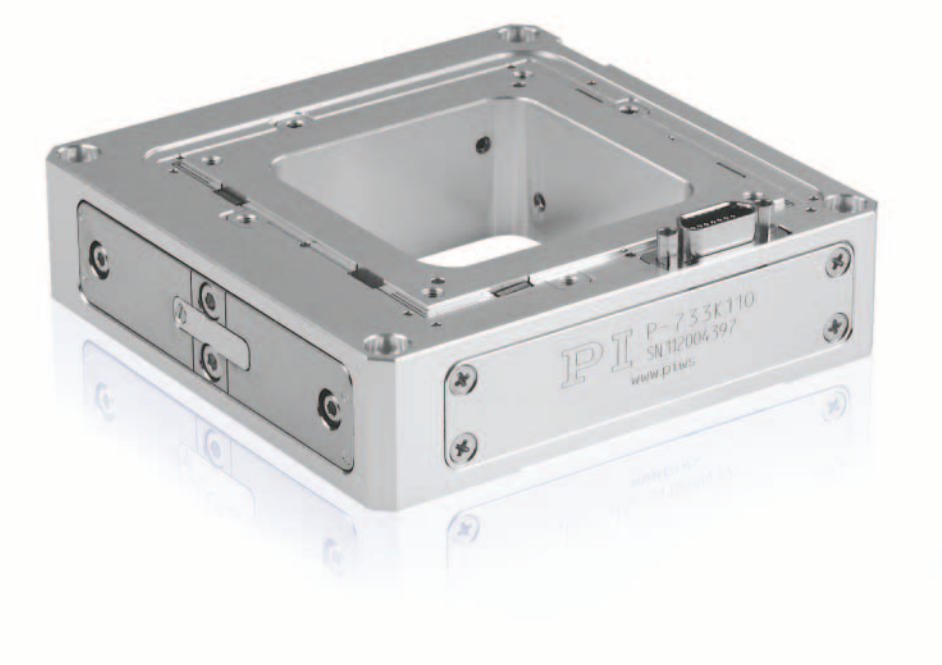
Since simple lever structures lose a considerable amount of guiding accuracy and stiffness, however, the design requires much more complex geometries. PI has continually optimized these mechanical systems as a result of 40 years of experience with micromechanics and nanopositioning.

Sub-nanometer accuracy

Flexures allow motions with an extremely high path accuracy. In order to compensate for height or transversal offset, PI has developed special multi-link flexure guides. These guiding systems, which are used in most nanopositioning systems from PI, allow a flatness and straightness in the sub-nanometer or microradian range.

Actuators and Stages for Electron Microscopy

NONMAGNETIC VACUUM-COMPATIBLE ACTUATORS & POSITIONING SYSTEMS



PI Products for Electron Microscopy

Electron microscopy allows examinations of extremely high precision down to the nanometer range. Such a high resolution makes high demands on the imaging elements, but also on the positioning systems of the individual beam guidance components, such as the apertures. The positioning of the sample must be just as precise.

The application of electron microscope methods is nowadays not limited to research, but also extends to the industrial sector whenever optical examination methods are no longer sufficient. Surface and structure tests are carried out using SEM and TEM methods, both in semiconductor technology and materials research and also in the life sciences sector. The increasingly automated test procedures require flexible, reliable drive solutions, in order to allow scans of high repeatability and stable positions to be carried out when taking micrographs.

Nonmagnetic and Vacuum-Compatible Actuators and Positioning Systems

PI offers drives, actuators and multi-axis positioning systems that are lubricant-free and vacuum-compatible. The piezo-based drive concepts developed in-house do not generate magnetic fields and are not influenced by them. This allows positioning systems to be assembled that are completely (including the guiding) or partly (except for the guiding) nonmagnetic.

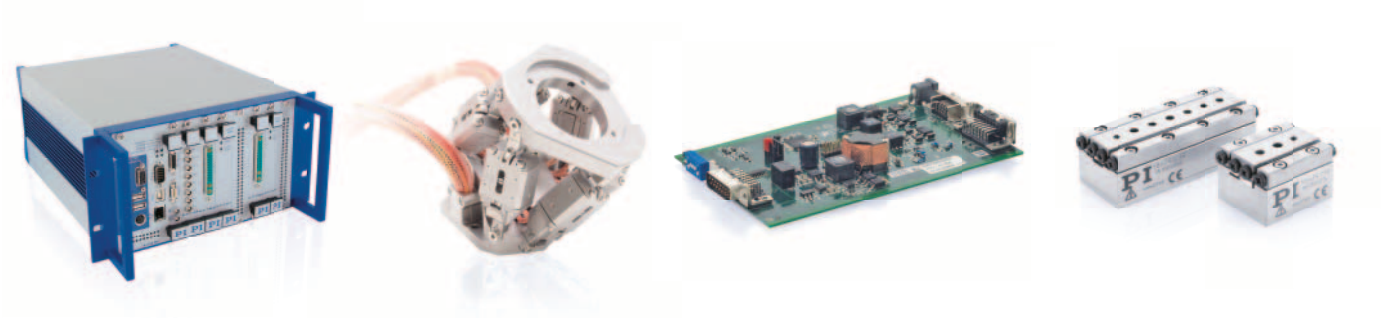
For positioning tasks, simple actuators or drives can be integrated directly at the electron beam, where they are used for correcting the beam guidance or for aligning apertures. For the positioning of the sample, either for preparation prior to examination, for rapid scans or for precise alignment in the beam path, linear and rotary stages are suitable. These stages can also easily be combined to multi-axis solutions. A particularly compact version are parallel-kinematic multi-axis stages with up to six degrees freedom in positioning.

Suitable control electronics and controllers are available for all systems; along with their analog and digital interfaces and extensive software support, they are integrated seamlessly into existing systems.

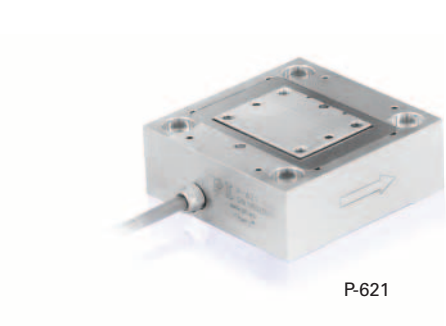
Customized Solutions

The products shown here represent only a small selection of all available positioning solutions. Special applications often require certain properties, for example travel ranges, mechanical coupling and dimensions, to be customized.

We will gladly develop a solution for your positioning task together with you. Take our word for it!



For every integration level of the mechanics, PI offers the matching electronics, ranging from compact open OEM boards to complex multi-axis control in the rack mount format. All PI controllers are commanded with the same common programming language



P-621

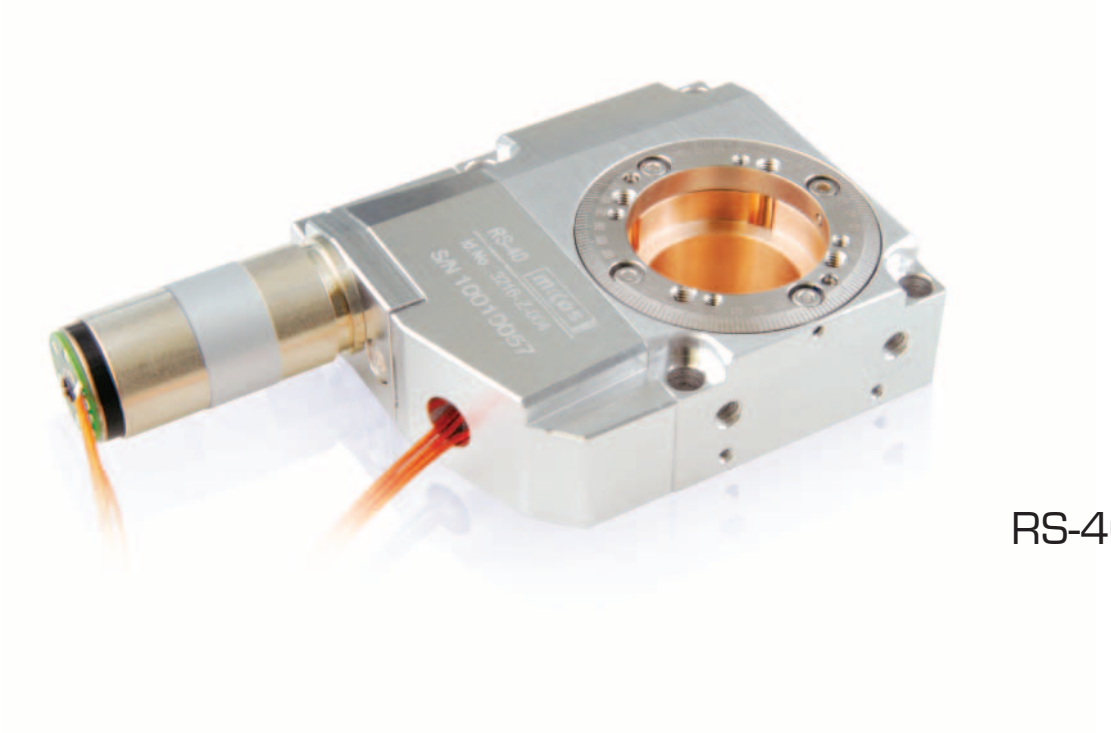
M-663

LPS-23

	P-621 P-622	M-663	LPS-23 (Preliminary data)	N-664
Drive type	PICMA® multilayer actuator with flexure guide	PILine® ultrasonic piezomotor	PIShift piezo inertia drive	NEXACT® piezo inertia drive
Travel range in mm	0.1; 0.25	19	13, 26	30
Resolution in nm	0.4; 0.7	100	1	0.5
Unidirectional repeatability in nm	1	200	20	0.5
Angular crosstalk (pitch / yaw) in µrad	±3	±200	±80 to ±110	20
Velocity in mm/s	–	250	10	10
Load capacity in N	10	5	2	20
Push / pull force in N	10	2	2	10
Dimensions in mm	40 × 40 × 15 50 × 50 × 15	35 × 35 × 15	23 to 35 × 23 × 10	120 × 65 × 20
Recommended controller (including driver electronics)	E-625.CR	C-867 single- or double-axis	E-871 single-axis	E-861 single-axis
Interfaces / Communication	USB, RS-232	USB, RS-232	USB, RS-232	USB, RS-232

Rotary Stages

Compact Rotary Stages with PILine® Ultrasonic Piezomotors



RS-40 HV

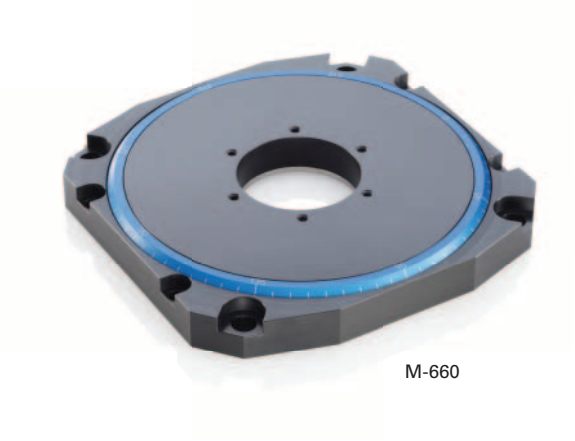
Highlights

- High resolution and stability
- Nonmagnetic and vacuum-compatible versions to 10^{-7} hPa
- Piezomotor: Drive without lubricants, guidings without or with vacuum-compatible lubricants
- Self-locking when at rest, no heat generation, no servo jitter

Applications

Rotary positioning of the sample is often required in sample preparation for SEM. These compact rotary stages allow the sample to be transported quickly, for example, in dual-beam installations from the electron beam path to FIB analysis and processing.

The rotary stages can also be used for generating multi-axis sample scans in SEM or for adjusting the angles in crystallographic examinations (Electron Backscatter Diffraction, EBSD).



M-660

U-624

U-624K

	RS-40	M-660	U-628	U-624K
	Versions up to UHV, clear aperture Ø 31 mm	Clear aperture Ø 36 mm	Preliminary data	Special models, preliminary data
Rotation range in °	360	>360	>360	>360
Drive type	DC or stepper motor	PILine® ultrasonic piezomotor	PILine® ultrasonic piezomotor	PILine® ultrasonic piezomotor
Design resolution in µrad	to 0.5	4 to 34	35	52 or open-loop
Min. incremental motion in µrad	to 35	12 to 34	105	150 or open-loop
Velocity in °/s	0.6	720	1 080	>360
Load capacity (axial force) in N	10	20	5	2
Torque cw / ccw in Nm	1	0.3	0.1	0.01
Dimensions in mm	56 × 64 × 20	116 × 116 × 14	50 × 50 × 19	40 × 40 × 20 (with sensor) to 20 × 20 × 12 (open-loop)
Recommended controller	SMC controller	C-867 PILine® motion controller	C-867 PILine® motion controller	C-867 PILine® motion controller
Interfaces / Communication	USB, RS-232, TCP/IP	USB, RS-232	USB, RS-232	USB, RS-232

Multi-Axis Stages

Precision Sample Positioning in up to Six Axes

Q-821

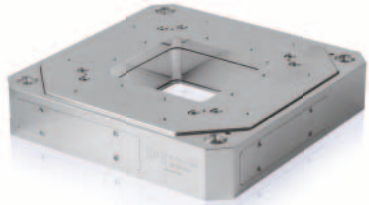
- Six-axis microrobotics system
- Dimensions in reference position 80 mm × 73 mm × 48 mm
- Linear travel ranges to 12 mm x 12 mm x 6 mm
- Rotary travel ranges to 14° x 15° x 40°
- 1 nm sensor resolution

Highlights

- Parallel-kinematic design: All actuators act on the same moving platform
- Compact dimensions, low profile, light-weight
- High stiffness, high precision, optimum dynamics
- Nonmagnetic and vacuum-compatible versions to 10^{-7} hPa
- Drive without lubricants, guidings without or with vacuum-compatible lubricants
- One controller for all axes, many functionalities

Applications

These compact systems allow sample positioning in up to six axes of motion. With piezo nanopositioning systems, such as P-763 and P-563, highly dynamic scan processes over several hundred micrometers are possible.
The Mini-SpaceFAB SF-450 PS works precisely with nanometer resolution over longer travel ranges of up to several millimeters. Additional tilt and rotational axes serve for aligning the sample in the electron beam or during analysis and processing. High-resolution measurement systems allow highly precise and repeatable positioning.



P-563

	P-763	P-563
	Small footprint, highly dynamic	Vacuum compatible to 10^{-9} hPa
Active axes	X, Y	X, Y, Z
Drive type	PICMA® multilayer actuator with flexure guide	PICMA® multilayer actuator with flexure guide
Travel range in µm	200 × 200	300 × 300 × 300
Resolution in nm	2	2
Unidirectional repeatability in nm	5	2
Resonant frequency in Hz	180 (load 260 g)	110 (load 330 g)
Load capacity in N	10	50
Dimensions in mm	70 × 70 × 25	150 × 150 × 30
Clear aperture in mm	30 × 30	66 × 66
Recommended controller	E-725 digital controller	E-725 digital controller
Interfaces / Communication	Ethernet (TCP/IP), USB, RS-232 analog inputs	Ethernet (TCP/IP), USB, RS-232, optional analog inputs

P-733

Motorized Stages / Systems

SERVO / STEPPER LINEAR, XY(Z) CONFIGURATIONS

Miniature Servo/Stepper Motor Linear Stage

XY(Z) COMBINATIONS

M-110, M-111, M-112

- Travel Ranges 5, 15 and 25 mm
- Very Cost Effective
- Min. Incremental Motion to 50 nm
- Max. Velocity 2 mm/s
- Closed-Loop DC Motors and Stepper Motors
- Non-Contact Limit and Reference Switches rotation axis
- Optional Recirculating Ball Screw Drives Provide High Speeds & Long Lifetimes
- Vacuum-Compatible Versions Available to 10-6hPa

M-110, M-111 and M-112 are ultra-high resolution motorized translation stages providing linear motion of 5 to 25 mm in an extremely compact package. They feature a precision lead-screw with sub-micron resolution and precision linear ball bearings guaranteeing <0.5 µm straightness of travel.

Compact Dimensions, High Performance
To meet industrial demands, the M-11x.2 linear translation stages are equipped with a re-circulating ball screw for precise motion with reduced friction. This allows 24/7 duty cycles. M-110, M-111 and M-112 can be combined to XY and XYZ systems for multi axis alignment applications.

Stepper and Servo Motors
A miniature DC or stepper motor actuates motion via a backlash-compensated screw/nut system and gearhead. Both drive options provide a cost-effective solution for industrial and OEM environments. To meet the most critical positioning demands, the DC motor is equipped with a high resolution encoder featuring resolution down to 0.007 µm per count.

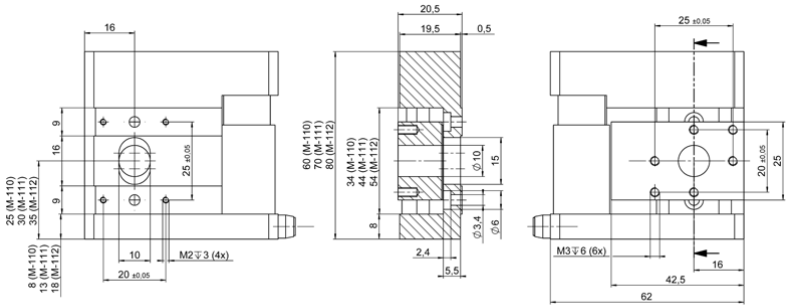
Limit and Reference Switches
For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

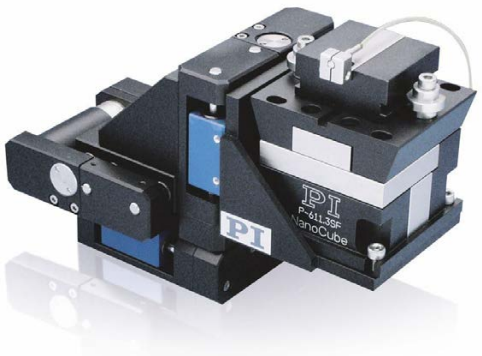
All stages include an integral 0.5 m cable with 15-pin sub-D connector and come with a 3 m extension cable. On the DC servo versions, the connector features integrated line drivers for cable lengths up to 10 meters between stage and controller (DC-motors only).

Low Cost of Ownership
The combination of these positioners with the networkable, single-channel C-863 Mercury™ or C-663 Mercury™ Step controller offers high performance for a very competitive price in both single- and multiaxis configurations. For 3 or 4 axes, the C-843 PC plug-in board for DC motors can also be recommended.

	M-110.1DG / M-111.1DG / M-112.1DG	M-110.12S / M-111.12S / M-112.12S	M-110.2DG / M-111.2DG / M-112.2DG	M-110.22S / M-111.22S / M-112.22S	Unit	Tolerance
Motion and positioning						
Travel range	5 / 15 / 25	5 / 15 / 25	5 / 15 / 25	5 / 15 / 25	mm	
Integrated sensor	Rotary encoder	–	Rotary encoder	–		
Sensor resolution	2048		2048		Cts./ rev.	
Design resolution	0.0069	0.038*	0.0086	0.046*	µm	
Incremental motion	0.05	0.05	0.2	0.2	µm	min.
Backlash	2	2	4	4	µm	
Unidirectional repeatability	0.1	0.1	0.5	0.5	µm	
Pitch / yaw	±50 / ±150 / ±150	±50 / ±150 / ±150	±50 / ±150 / ±150	±50 / ±150 / ±150	µrad	
Velocity	1 / 1.5 / 1.5	1 / 1 / 1	1.5 / 2 / 2	1 / 1 / 1	mm/ s	max.
Mechanical properties						
Drive screw	Leadscrew	Leadscrew	Recirculating ball screw	Recirculating ball screw		
Thread pitch	0.4	0.4	0.5	0.5	mm	
Gear ratio	28.44444:1	28.44444:1	28.44444:1	28.44444:1		
Motor resolution*	–	384*	–	384*		
Load capacity	30 / 30 / 20	30 / 30 / 20	30 / 30 / 20	30 / 30 / 20	N	max.
Push / pull force	10	10	10	10	N	max.
Holding force	10	10	10	10	N	max.
Lateral force	15 / 10 / 10	15 / 10 / 10	15 / 10 / 10	15 / 10 / 10	N	max.
Drive properties						
Motor type	DC gear motor	2- phase stepper motor	DC gear motor	2- phase stepper motor		
Operating voltage	0 to ±12	24	0 to ±12	24	V	
Motor power	0.52 / 1.75 / 1.75	1.5	0.52 / 1.75 / 1.75	1.5	W	
Current consumption	160 / 320 / 320**		160 / 320 / 320**		mA	
Reference point and limit switches	Hall effect	Hall effect	Hall effect	Hall effect		
Miscellaneous						
Operating temperature range	-20 to 65	-20 to 65	-20 to 65	-20 to 65	°C	
Material	Al (black anodized)	Al (black anodized)	Al (black anodized)	Al (black anodized)		
Mass	0.3 / 0.4 / 0.5	0.3 / 0.4 / 0.5	0.3 / 0.4 / 0.3	0.3 / 0.4 / 0.5	kg	
Recommended controller / driver	C-863 (single- axis) C-843 PCI board, for up to 4 axes	C-663 single- axis	C-863 single- axis C-843 PCI board, for up to 4 axes	C-663 (single- axis)		

* 2- phase stepper motor, 24 V chopper voltage, max. 0.25 A/ phase, 24 full steps/ rev., motor resolution with C-663 stepper motor controller.
** thermally limited.





This 3- axis fiber positioning system combines motorized stages for rough positioning over 15 mm with a step width of 50 nm with a fast piezo scanner for fine adjustment over a travel range of 100 µm with 1 nm resolution. The intensity of the light in the fiber determines the optimum position and is used as external control variable.

Translation Stage

VT-80

- Travel range up to 300 mm
- Uni- directional repeatability down to 0.4 µm
- Maximum speed 20 mm/ sec
- Load capacity up to 5 kg
- Integrated limit switches

The translation stage VT-80 is a popular laboratory stage with a wide range of travel lengths. A backlash- free re-circulating ball bearing along with a back- lash compensated lead screw guarantees quiet and smooth motion. The translation stages VT-80 are equipped with integrated limit switches and motorized with DC or 2- phase stepper motors. Additionally the VT-80 can be ordered with our smc pollux motor- controller module. Due to the compact dimensions, the VT-80 stages are especially suitable for applications in instrumentation, but suitable only for lower duty cycles. All translation stages of the series VT-80 can be directly assembled as XY. XY- assembly with travel of 25 mm must be set- up at our plant. Please indicate set- up configurations when ordering.

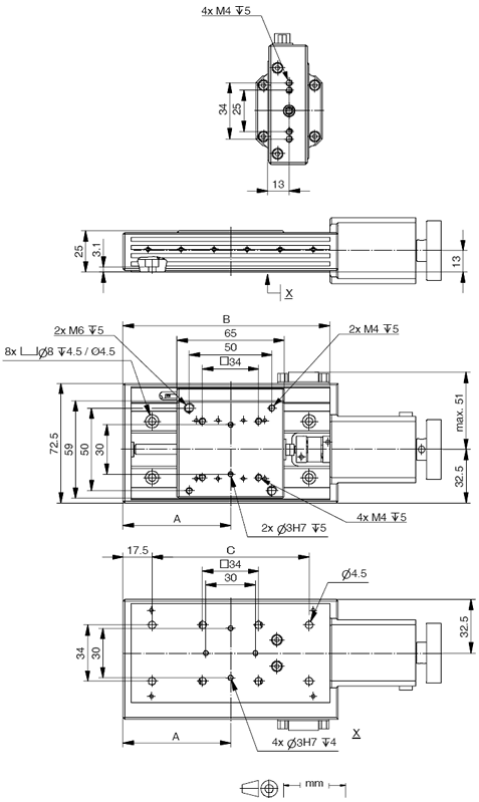
Specifications

VT-80								
Load Characteristics	**Fx (N)**	**Fy (N)**	**Fz (N)**	**Mx (Nm)**	**My (Nm)**	**Mz (Nm)**	**kax (µrad/ Nm)**	**kay (µrad/ Nm)**
DC- B-026	40	50	50	2.5	5	2.5	220	150
2Phase-041	40	50	50	2.5	5	2.5	220	150
2Phase-042	40	50	50	2.5	5	2.5	220	150
Travel Range (mm)	**25**	**50**	**75**	**100**	**150**	**200**	**250**	**300**
Straightness / Flatness (µm)	± 8	± 10	± 11	± 12	± 14	± 20	± 25	± 35
Pitch (µrad)	± 100	± 110	± 120	± 130	± 150	± 170	± 190	± 210
Yaw (µrad)	± 150	± 150	± 150	± 150	± 150	± 150	± 150	± 150
Weight (kg)	0.55	0.65	0.7	0.75	0.85	0.95	1.1	1.25

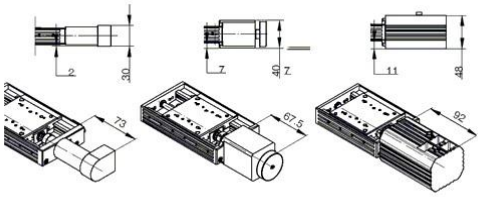
Specifications

Motor (Pitch 1 mm)	DC- B-026	2Phase-041	2Phase-042
Speed max. (mm/ sec)	20	20	13
Resolution calculated (µm)	0.5 (RE)	5 (FS)	5 (FS)
Resolution typical (µm)	0.5	0.2	0.2
Bi- directional Repeatability (µm)	± 10	± 10	± 10
Uni- directional Repeatability (µm)	0.8	0.4	0.4
Nominal Current (A)	0.98	1.7	0.5
Voltage Range (V)	24		
Accuracy	on request	on request	on request
Velocity Range (mm/ sec)	0.001 ... 20	0.001 ... 20	0.001 ... 20
Material	Aluminium, black anodized	Aluminium, black anodized	Aluminium, black anodized

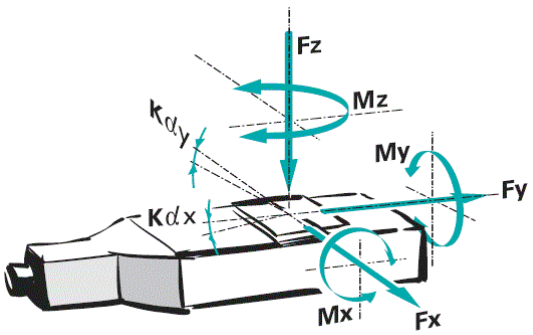
Drawings / Images



Travel range (mm):
25 / 50 / 75 / 100 /
150 / 200 / 250 / 300
A (mm): 52.5 / 65 /
77.5 / 90 / 115 / 140 /
165 / 190
B (mm): 100 / 125 /
150 / 175 / 225 / 275 /
325 / 375
C (mm): 70 / 95 / 120 /
145 / 195 / 245 / 295 /
345



DC- B-026,
2Phase-041, 2Phase-042



Linear Stage

LS-180

- Travel range up to 508 mm (20")
- Uni- directional repeatability down to 0.05 µm
- Maximum speed 200 mm/ sec
- Load capacity up to 100 kg
- Integrated limit switches
- Optionally: linear scale (center mounted)
- Vacuum Datasheet

The linear stage LS-180 was developed for industrial applications. Re- circulating ball guides mounted on rigid tempered aluminum- alloy guarantee a very high guiding stiffness and long life.
The ball screw with 5 mm pitch allows velocities up to 200 mm/ s. For demanding positioning tasks the linear stages LS-180 can be supplied with a linear scale which is centrally installed between the guides. Linear stages LS-180 can be equipped with a DC or a 2- phase stepper motor and are equipped with two mechanical limit switches.

Specifications

LS-180								
Load Characteristics	**Fx (N)**	**Fy (N)**	**Fz (N)**	**Mx (Nm)**	**My (Nm)**	**Mz (Nm)**	**kax (µrad/ Nm)**	**kay (µrad/ Nm)**
DC- B-040	500	200	1000	132	400	125	60	50
2Phase-052	500	200	1000	132	400	125	60	50

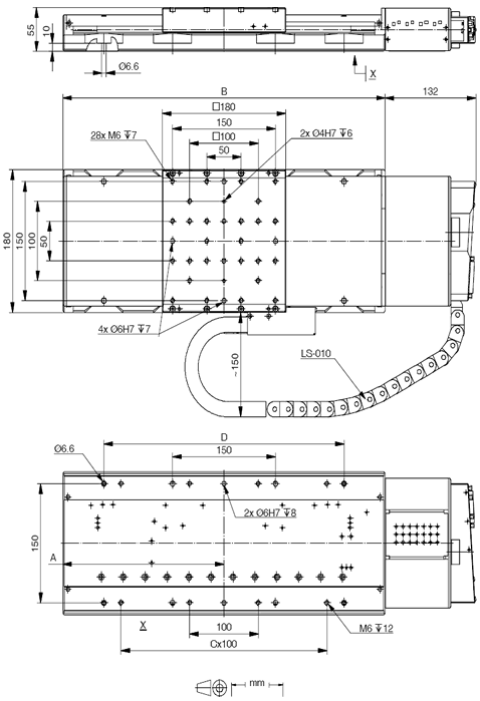
Specifications

Travel range (mm)	**155**	**205**	**305**	**408**	**508**
Straightness / Flatness (µm)	± 2	± 3	± 4	± 5	± 6
Pitch (µrad)	± 40	± 50	± 60	± 70	± 80
Yaw (µrad)	± 50	± 50	± 50	± 50	± 50
Weight (kg)	8.4	8.8	9.6	10.2	10.8

Specifications

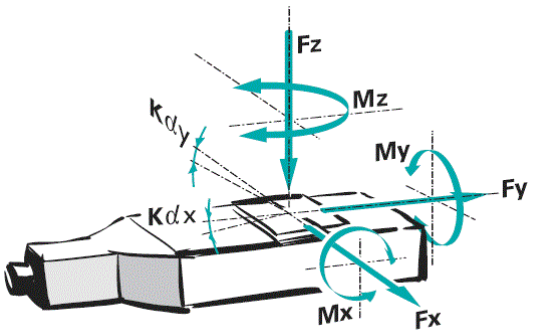
Motor (Pitch 5 mm)	**DC- B-040**	**2Phase-052**	
Linear scale			**LS-012**
Speed max. (mm/ sec)	200	75	
Resolution calculated (µm)	0. 25 (RE)	25 (FS)	0.05
Resolution typical (µm)	0.5	0.5	0.05
Bi- directional Repeatability (µm)	± 2.5	± 2.5	± 0.1
Uni- directional Repeatability (µm)	0.5	0.5	0.05
Nominal Current (A)	3.8	2	
Voltage Range (V)	24		
Accuracy	on request	on request	on request
Velocity Range (mm/ sec)	0.001 ... 200	0.001 ... 200	0.001 ... 200
Material	Aluminium, black anodized	Aluminium, black anodized	Aluminium, black anodized

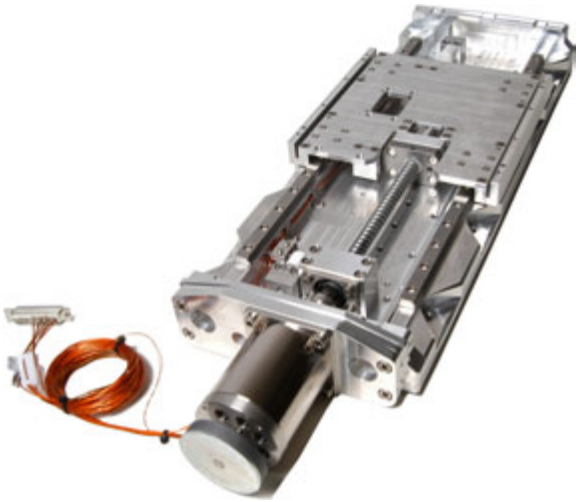
Drawings / Images



Travel range (mm)
155 / 205 / 305 / 408 / 508
A (mm) 235 / 260 / 310 / 360 / 410
B (mm) 470 / 520 / 620 / 720 / 820
C (mm) 3 / 3 / 5 / 5 / 5

D (mm) 350 / 350 / 450 / 550 / 650





PI: Drives that Set the World in Motion

PRECISION POSITIONING FOR SCIENCE AND INDUSTRY

PI (Physik Instrumente) is the leading supplier of piezo-based positioning systems with accuracies in the range of a few nanometers.

The extensive product portfolio is based on a wide range of technologies with electromotive or piezoelectric drives for up to six motion axes. Hexapods, nanometer sensors, control electronics as well as software and are supplemented by customized solutions.

All key technologies are developed in-house. This means that every phase from the design right down to the shipment can be controlled: The precision mechanics and the electronics as well as the position sensors and the piezo ceramics or actuators. The latter are produced by the subsidiary company PI Ceramic.

PI is, therefore, the only manufacturer of nanopositioning technology which employs the piezoelectric drives it produces. This ensures a high degree of flexibility for developing customized piezoceramic components.

More than 100 patents and patents applied for stand for more than 40 years of experience and pioneering work. PI products are employed wherever technology in industry and research is pushed forward – worldwide.

With four German factories and ten subsidiaries and sales offices abroad, the PI group is represented internationally.

PI stands for quality in products, processes and service. The ISO-9001 certification which focuses not only on product quality but also on customer expectations and satisfaction was achieved back in 1994.

PI is also certified according to the ISO 14001 (environmental management) and OHSAS 18001 (occupational safety) standards, which taken together form an Integrated Management System (IMS).

Future Technology Solutions

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

- Semiconductor technology
- Optical metrology, microscopy
- Biotechnology and medical devices
- Precision automation and handling
- Precision machining
- Data storage technology
- Photonics, telecommunications
- Nanotechnology
- Micropositioning
- Aerospace engineering
- Astronomy

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