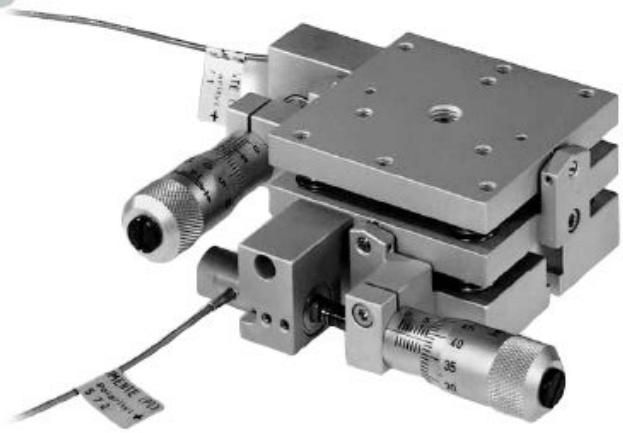
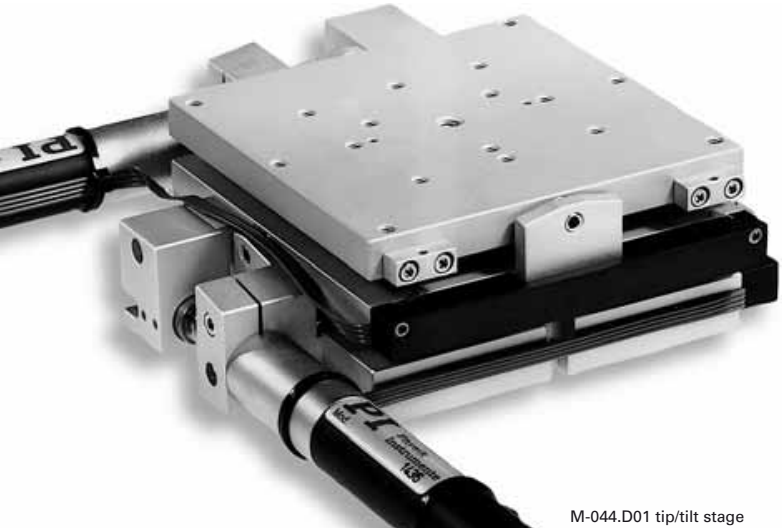
Tip-Tilt Stages, Steering Platforms, Piezo Stages



M-041 – M-044 Tip/Tilt Stage

Piezo Drive Option for Nanometer Precision



M-044.D01 tip/tilt stage

- **One- & Two-Axis Tilt Stages**
- **Zero Backlash**
- **Sub-µrad Resolution**
- **Manual and DC-Motor Drives**
- **Compatible with Leading Industrial Motion Controllers**
- **Optional Piezo Drives for Tracking and Scanning**

M-041 through M-044 are one- and two-axis (θ_X, θ_Y) tip/tilt stages for small loads. They are spring preloaded for elimination of backlash and feature resolution and repeatability superior to that of goniometric cradles. V ersions with piezo translators allow ultra-high-resolution dynamic scanning and tracking. See the "Fast Steering Mirrors / Active Optics" section for fast, ultra-high-resolution, tip/tilt platforms (p. 2-79 *ff*).

The two basic versions (with part number extension .00) are equipped with manual micro - meter drives providing 65 and 80 µrad minimum incremental motion, respectively . The versions with extension .D01 are equipped with closed-loop, DC-servo-motor drives (model M-227.10 (see p. 1-42) for further details and recommended motor controllers) providing 15 and 12 µrad minimum incremental motion, respectively . Sets of limit switches eliminate the possibility of overtravel.

High-Resolution Piezo Option

For sub-µrad resolution and dynamic tracking or scanning, optional open-loop/closed-loop piezo drive upgrade kits are available. See the P-840 and P-841 (see p. 1-74) in the "Piezo Actuators & Components" section for further details and recommended controllers. The piezo drives can also be ordered subsequently to upgrade manual or motorized systems.

Ordering Information

M-041.00
Small Tilt Stage, Manual Micrometer Drive

M-041.D01
Small Tilt Stage, DC-Motor Drive

M-042.00
Small Tip/Tilt Stage, Manual Micrometer Drive

M-042.D01
Small Tip/Tilt Stage, DC-Motor Drive

M-043.00
Tilt Stage, Manual Micrometer Drive

M-043.D01
Tilt Stage, DC-Motor Drive

M-044.00
Tip/Tilt Stage, Manual Micrometer Drive

M-044.D01
Tip/Tilt Stage, DC-Motor Drive

Upgrades

M-041.U0
Open-Loop Piezo Drive Upgrade Kit for M-041 Tilt Stages

M-041.US
Closed-Loop Piezo Drive Upgrade Kit for M-041 Tilt Stages

M-042.U0
Open-Loop Piezo Drive Upgrade Kit for M-042 Tip/Tilt Stages

M-042.US
Closed-Loop Piezo Drive Upgrade Kit for M-042 Tip/Tilt Stages

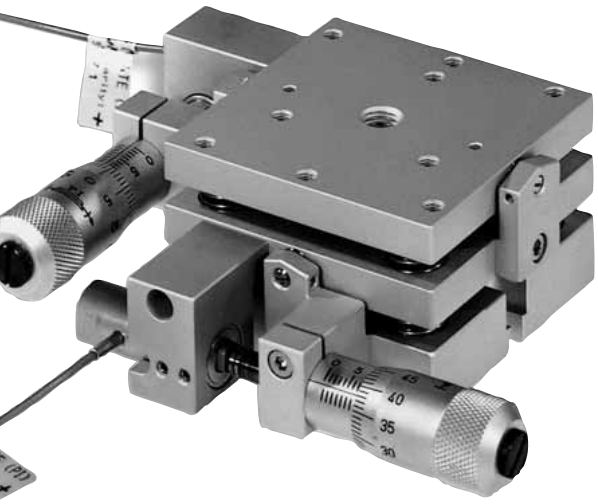
M-043.U0
Open-Loop Piezo Drive Upgrade Kit for M-043 Tilt Stages

M-043.US
Closed-Loop Piezo Drive Upgrade Kit for M-043 Tilt Stages

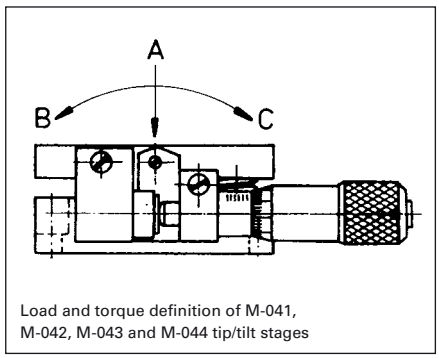
M-044.U0
Open-Loop Piezo Drive Upgrade Kit for M-044 Tip/Tilt Stages

M-044.US
Closed-Loop Piezo Drive Upgrade Kit for M-044 Tip/Tilt Stages

Ask about custom designs!



M-042.00 tip/tilt stage with optional PZT drives



Load and torque definition of M-041, M-042, M-043 and M-044 tip/tilt stages

Model	M-041.00	M-042.00	M-043.00	M-044.00	M-041.D01	M-042.D01	M-043.D01	M-044.D01	Units
Tilt axes	θ_x	$\theta_x\theta_y$	θ_x	$\theta_x\theta_y$	θ_x	$\theta_x\theta_y$	θ_x	$\theta_x\theta_y$	
Tilt range	±9	±9	±7	±7	±9	±9	±7	±7	° (axis)
Fine range (piezo option)	±1.2	±0.6	±1.4	±1.4	±1.2	±0.6	±1.4	±1.4	mrad (axis)
Design resolution	–	–	–	–	0.28	0.28	0.23	0.23	µrad
Min. incremental motion	80	80	65	65	5	5	5	5	µrad
Min. incremental motion (piezo option)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	µrad
Rotation / linear input	80	80	65	65	80	80	65	65	µrad/µm
Unidirectional repeatability	–	–	–	–	20	20	15	15	µrad
Backlash	–	–	–	–	200	200	175	175	µrad
Max. velocity (motor)	–	–	–	–	4.5	4.5	3.6	3.6	°/s
Max. load (A)	4	4	5	5	4	4	5	5	kg
Max torque (B, C)	450, 150	450, 150	750, 250	750, 250	450, 150	450, 150	750, 250	750, 250	mNm
Drive	M-622 Micrometer	M-622 Micrometer	M-624 Micrometer	M-624 Micrometer	M-227.10 DC-Mike	M-227.10 DC-Mike	M-227.10 DC-Mike	M-227.10 DC-Mike	
Piezo drive (optional) M-04x.U0 / M-04x.US	P-840.20 / P-841.20	P-840.10 / P-841.10	P-840.30 / P-841.30	P-840.30 / P-841.30	P-840.20 / P-841.20	P-840.10 / P-841.10	P-840.30 / P-841.30	P-840.30 / P-841.30	
Mass	0.4	0.6	0.8	1.2	0.5	0.7	0.9	1.5	kg
Body material	Al	Al	Al	Al	Al	Al	Al	Al	

M-833 XZ-Tip Stage: Parallel Kinematic Tripod / Goniometer

Precision Positioning in X, Z, θ_Y

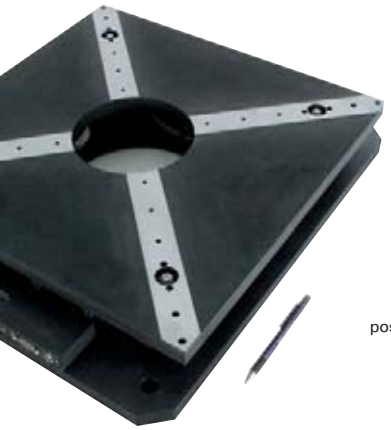
The M-833 parallel-kinematics tripod is designed for precision positioning, offering elevation, translation and tilt motion around the (horizontal) y-axis, with a user-defined pivot point

- **Goniometer Z Stage with Freely Selectable Pivot Point**
- **Travel Ranges ±25 mm / ±25 mm / ±30°**
- **Load Capacity to 4 kg**
- **Min. Incremental Motion to 0.1 µm**
- **ActiveDrive™ Servo Motors**
- **Compact Design with Parallel Kinematics**

Model	Travel ranges	Max. velocity	Stiffness	Dimensions
M-833.00 Tripod Goniometer-Stage	±25 mm (X, Z), ±30° (θ_Y) (linear)	10 mm/s	50 N/µm	223,2 x 110 x 192 mm

M-880 XY-Rot Stage Planar Precision Positioning System

XY-Rot-Z Parallel Kinematics System with Very High Holding Force



M-880.PD for planar load positioning up to 20 kg with sub-micron accuracy

- **Travel Ranges 20 x 20 mm / 8°**
- **Static Load Capacity to 150 kg**
- **ActiveDrive™ Servo Motors**
- **Low Profile through Parallel Kinematics**
- **Min. Incremental Motion to 0.75 µm**
- **Large Clear Aperture**
- **Sophisticated Controller Included**

Model	Active Axes	Travel range	Max. velocity	Stiffness (linear axes)	Dynamic load capacity	Static load capacity
M-880.PD	X, Y, θ_Z	±10 mm, ±4°	20 mm/s	5 N/µm	200 N	1500 N

M-810 Miniature 6-Axis Stage

High Precision in a Small Package

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

- **Most-Compact Hexapod in the PI Portfolio**
- **Travel Range 40 x 40 x 13 mm**
- **Resolution of a Single Strut <100 nm**
- **Integrated Driver Electronics**

Model	Load capacity	Travel range X / Y / Z	Travel range θ_x / θ_y / θ_z	Max. velocity	Dimensions
M-810.00	5 kg	±20 mm ±20 mm ±6,5 mm	±11° ±11° ±30°	10 mm/s	Outer Ø 100 mm height 118 mm

N-510 High-Force NEXLINE® Z/Tip/Tilt Stage

Nanometer Precision for Semiconductor Industry, Wafer Alignment

Z, tip, tilt nanopositioning platform with
3 integrated drives (tripod design)

- **Self Locking at Rest, No Heat Generation**
- **Vacuum Compatible and Non-Magnetic Designs Feasible**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**
- **NEXLINE® Piezo Walking Drive Free from Wear and Tear**
- **Load Capacity 200 N**
- **High Precision with Integrated 5 nm Incremental Sensors + Picometer Resolution Dithering Mode**

Model	Travel	Load capacity	Linear velocity	Dimensions
N-510 NEXLINE® Z, tip, tilt platform	1,3 mm vertical range 10 mrad tilt angle	200 N	0.2 mm/s	Ø 360 mm (14.2″) Clear aperture 250 mm

N-515K Non-Magnetic Tip/Tilt/Rot, XYZ Piezo Stage

6-Axis Precision Positioning System with NEXLINE® Linear Drives

- **Travel Ranges 10 mm Linear, 6° Rotation**
- **Large Clear Aperture Ø 202 mm**
- **Non-Magnetic**
- **Nanometer Resolution**
- **Low-Profile: 140 mm Height Only**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**
- **Up to 500 N Force Generation**
- **Self Locking at Rest, No Heat Generation**

Model	Travel range	Load capacity	Dimensions
N-515KNPH NEXLINE® Piezo Hexapod	X, Y, Z: 10 mm θ_X, θ_Y, θ_Z: 6°	50 kg	Outer Ø baseplate, 380 mm Ø moved platform (top) 300 mm 140 mm height

P-562.6CD Tip-Tilt-Rot, XYZ Stage with Piezo Flexure Drive

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

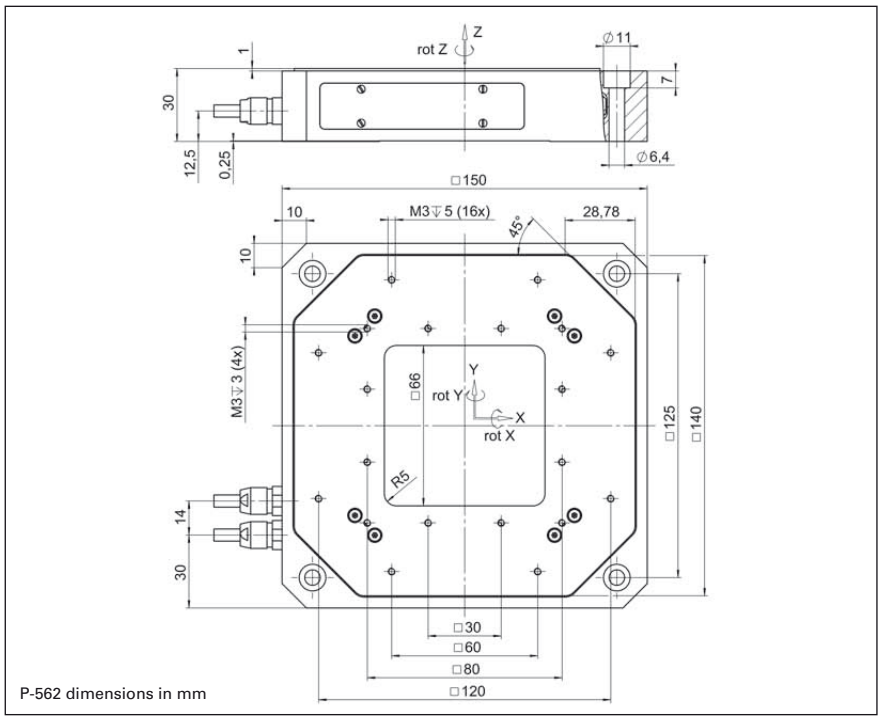
- Scanning microscopy (SPM)
- Mask/wafer positioning
- Interferometry
- Metrology
- Biotechnology
- Micromanipulation

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 run-out. 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 (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 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

S-340 Piezo Tip / Tilt-Stage Mirror Platform

High-Dynamics for Mirrors and Optics with a Diameter of up to 100 mm (4")

S-340 tip/tilt platform for mirrors with a diameter of up to 100 mm

- **Resolution up to 20 nrad, Excellent Position Stability**
- **Optical Beam Deflection to 4 mrad**
- **Higher Precision and Dynamics via Parallel Kinematics**
- **Only One Moving Platform with a Fixed Pivot Point Prevents the Change of the Polarization**
- **Sub-ms Response**
- **For Mirrors with a Diameter up to 100 mm**
- **Position-Controlled Versions for Better Linearity**
- **Excellent Temperature Stability**

S-340 tip/tilt platforms allow high-dynamic and precise angular movements of the top platform in two orthogonal axes with a common pivot point (parallel kinematics).
The systems are designed for mirrors with a diameter of up to 100 mm and their differential drive enables an outstanding angular stability in a wide temperature range. A variety of top platforms are available to achieve an optimum thermal adaptation to different mirror materials. For operation in closed-loop, the SD versions are equipped with high-resolution strain gauge sensors in a thermally stable circuit. All versions feature a sub-µrad resolution and a tip/tilt range of 2 mrad (equivalent to 4 mrad optical beam deflection).

Application Examples

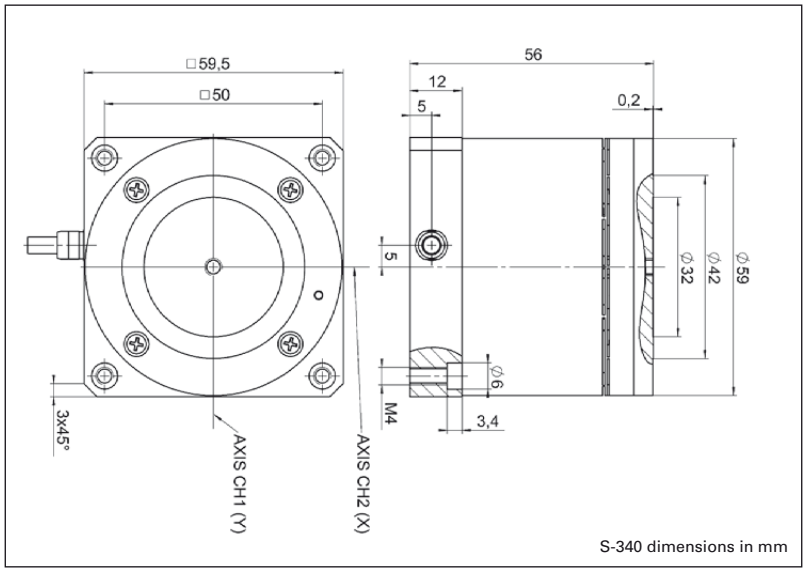
- Image processing / stablilization
- Laser scanning / beam steering
- Active and adaptive optics
- Optical filters
- Beam stabilization
- Correction of polygon mirror errors

Parallel-Kinematic Design for Improved Stability, Linearity and Dynamics

Piezo tip/tilt mirror systems of PI are based on parallel kinematics with a single movable platform for all directions of motion. The four actuators are controlled differentially in pairs depending on the tip/tilt movement of the platform. This results in an excellent stability in linear and angular positioning for a wide temperature range. Compared to systems with an independent positioner per tilt axis, parallel-kinematics offer the advantage of symmetrical dynamic properties of motion for all axes, faster response and better linearity with a compact design. For this kind of design no change of polarization of the reflected light occurs, different than for stacked single axis systems like e. g. galvo scanners.

Ceramic-Insulated Piezo Actuators Provide Superior Lifetime

The highest possible reliability is assured by employing the award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with a 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.



S-340 dimensions in mm

Technical Data

Model	S-340.ASD/.ASL	S-340.A0L	Units	Tolerance
Active axes	θ X, θY	θX, θY		
Motion and Positioning				
Integrated sensor	SGS	–		
Open-loop tip / tilt angle, -20 to +120 V	2	2	mrad	min.
Closed-loop tip / tilt angle	2	–	mrad	
Open-loop tip / tilt angle resolution	0.02	0.02	µrad	typ.
Closed-loop tip / tilt resolution	0.2	–	µrad	typ.
Linearity in θX, θY	0.1	–	%	typ.
Repeatability in θX, θY	0.15	–	µrad	typ.
Mechanical properties				
Unloaded resonant frequency (θX, θY)	1.4	1.4	kHz	±20 %
Resonant frequency loaded in θX, θY (with glass mirror diameter 50 mm, thickness 15 mm)	0.9	0.9	kHz	±20 %
Resonant frequency loaded in θX, θY (with glass mirror diameter 75 mm, thickness 22 mm)	0.4	0.4	kHz	±20 %
Distance of pivot point to platform surface	7.5	7.5	mm	±1 mm
Platform moment of inertia	18000	18000	g · mm²	±20 %
Drive properties				
Ceramic type	PICMA®	PICMA®		
Electrical capacitance	6 / axis	6 / axis	µF	±20 %
Dynamic operating current coefficient	0.45 / axis	0.45 / axis	µA / (Hz · mrad)	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material case	Aluminum	Aluminum		
Material platform	Aluminum; or optionally Steel, Titanium or Invar	Aluminum; or optionally Steel, Titanium or Invar		
Mass	0.355	0.35	kg	±5 %
Cable length	2	2	m	±10 mm
Sensor / voltage connection	Sub-D connector / LEMO	LEMO		

Recommended controller / amplifier
Closed-loop versions with Sub-D connectors: E-616 servo controller for tip / tilt mirror systems s. p. 2-132; with LEMO connector: E-500 System s. p. 2-142.
Open-loop: E-500 System s. p. 2-142.

S-323 Piezo Z/Tip/Tilt Stage Platform

High Dynamics & Stability Nanopositioning System with Direct Metrology

The S-323 Z/tip/tilt platform integrates capacitive sensors for highest resolution and stability

- **Optical Beam Deflection to 6 mrad**
- **Sub-µrad Resolution for High Positioning Stability**
- **Position Servo-Control with Capacitive Sensors**
- **Frictionless, High-Precision Flexure Guiding System**
- **System Combination with Digital Controllers for Highest Linearity**

Model	Active axes	Travel range	Resolution	Unloaded resonant frequency
S-323.3CD	Z, θ_X, θ_Y	30 µm, ±1.5 mrad	0.1 nm, ±0.05 µrad	1.7 kHz

S-303 Tip Tilt Piezo Phase Shifter

Highest Dynamics and Stability with Capacitive Feedback Sensor

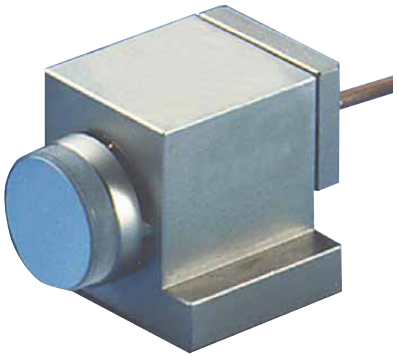
S-303 closed-loop model (left) and open-loop model (right). DIP switch for size comparison

- **25 kHz Resonant Frequency for Sub-Millisecond Dynamics**
- **Capacitive Sensor Option for Highest Linearity and Stability**
- **3 µm Travel Range**
- **Compact Size: 30 mm Diameter x 10 mm**
- **Aperture with Open-Loop Versions**
- **Invar Option for Highest Thermal Stability**

Model	Active axes	Closed-loop/ open-loop travel @ -20 to +120V	Closed-loop/ open-loop resolution	Unloaded resonant frequency
S-303.CD (closed-loop)/ S-302.0L (open-loop)	Z	2 / 3 µm	0.03 nm	25 kHz

S-224 – S-226 Piezo Tilt-Mirror

Fast Steering Mirror Combines Highest Dynamics and Compact Design



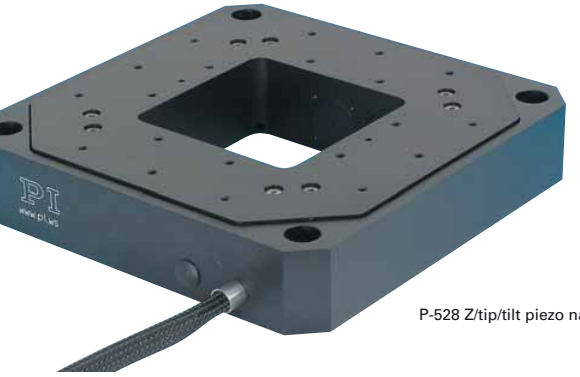
S-224 Piezo tip/tilt mirror for high-speed beam steering tasks and image stabilization applications

- **Optical Beam Deflection to 4.4 mrad**
- **Sub-µrad Resolution, Sub-Millisecond Response**
- **Frictionless, High-Precision Flexure Guiding System**
- **Includes BK7 Mirror**
- **Optional Position Feedback Sensor**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**

Model	Active axes	Open-loop tilt angle @ 0 to +100V	Closed-loop/ open-loop resolution	Unloaded resonant frequency
S-224.00 (open-loop)/ S-226.00 (closed-loop)	θ_X	2.0 / 2.2 mrad	0.05 / 0.1 µrad	9 kHz

Piezo Z/Tip/Tilt Stage

High-Dynamics with Large Clear Aperture



P-528 Z/tip/tilt piezo nanopositioning system

- **1- and 3-Axis Versions**
- **Closed-Loop Vertical / Tilt Range to 200 µm / 2 mrad (Open-Loop to 240 / 2.4)**
- **Parallel Kinematics / Metrology for Enhanced Responsiveness & Multi-Axis Precision**
- **Frictionless, High-Precision Flexure Guiding System**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Clear Aperture 66 x 66 mm**
- **Capacitive Sensors for Highest Linearity**

P-5x8 series, Z/tip/tilt nanopositioners / scanners are open-frame, high-resolution, piezo-driven stages providing motion to 240 µm and 2.4 mrad with resolutions of up to 0.5 nm and 50 nrad. The 66 x 66 mm clear aperture is ideal for transmitted-light applications.

XY and XYZ multi-axis versions in the same form factor are also offered as P-517, P-527 (see p. 2-70) models with six degrees of freedom are available upon request.

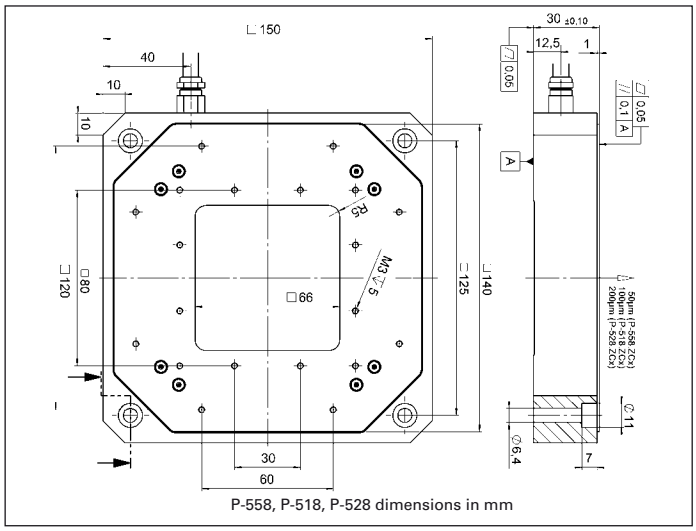
Capacitive Position Sensors for Higher Accuracy

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.

Excellent Guiding Accuracy

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

Flatness and Straightness is further enhanced by active trajectory control: 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. This Active Trajectory Control Concept can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.



P-558, P-518, P-528 dimensions in mm

Application Examples

- Metrology
- Interferometry
- Optics
- Lithography
- Scanning microscopy
- Mass storage device testing
- Laser technology
- Micromachining

Higher Precision in Periodic Motion

The highest dynamic accuracy in scanning applications is

made possible by the DDL algorithm, which is available in PI's modern digital controllers. DDL eliminates tracking errors, improving dynamic linearity and usable bandwidth by up to three orders of magnitude!

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.

Technical Data

Model	P-558.ZCD/ P-558.ZCL	P-558.TCD	P-518.ZCD/ P-518.ZCL	P-518.TCD	P-528.ZCD/ P-528.ZCL	P-528.TCD	Units	Tolerance
Active axes	Z	Z, θ_x, θ_y	Z	Z, θ_x, θ_y	Z	Z, θ_x, θ_y		
Motion and positioning								
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive		
Open-loop travel, -20 to +120 V	60	60	140	140	240	240	µm	min. (+20 %/-0 %)
Open-loop tip/tilt angle, -20 to +120 V	–	±0.3 mrad	–	±0.7 mrad	–	±1.2 mrad	mrad	min. (+20 %/-0 %)
Closed-loop travel	50	50	100	100	200	200	µm	
Closed-loop tip/tilt angle	–	±0.25 mrad	-	±0.5 mrad	–	±1 mrad	mrad	
Open-loop resolution	0.2	0.2	0.2	0.4	0.6	0.6	nm	typ.
Open-loop tip/tilt angle resolution	–	0.02	–	0.04	–	0.06	µrad	typ.
Closed-loop resolution	0.5	0.5	0.8	0.8	1	1	nm	typ.
Closed-loop tip/tilt resolution	–	0.05	–	0.05	–	0.1	µrad	typ.
Linearity θ_x, θ_y	–	0.03	–	0.03	–	0.03	%	typ.
Repeatability	±5	±5	±5	±5	±10	±10	nm	typ.
Repeatability θ_x, θ_y	–	±0.03	–	±0.05	–	±0.1	µrad	typ.
Runout θ_z (Z motion)	<10	<10	<10	<10	<20	<20	µrad	typ.
Runout θ_x, θ_y (Z motion)	<50	<50	<50	<50	<100	<100	µrad	typ.
Mechanical properties								
Stiffness	4	4	2.7	2.7	1.5	1.5	N/µm	±20 %
Unloaded resonant frequency (Z)	570	570	500	500	350	350	Hz	±20 %
Unloaded resonant frequency (θ_x, θ_y)	-	610	-	530	-	390	Hz	±20 %
Resonant frequency @ 30 g in Z	410	410	350	350	210	210	Hz	±20 %
Resonant frequency @ 500 g in X, Y	-	430	-	370	-	250	Hz	±20 %
Resonant frequency @2500 g in Z	245	245	200	200	130	130	Hz	±20 %
Resonant frequency @ 2500 g θ_x, θ_y	-	240	-	190 -		115	Hz	±20 %
Push/pull force capacity	100 / 50	100 / 50	100 / 50	100 / 50	100 / 50	100 / 50	N	Max.
Drive properties								
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	6	6	8.4	8.4	14.8	14.8	µF	±20 %
Dynamic operating current coefficient	15	15	10.5	10.5	9.2	9.2	µA/ (Hz•µm)	±20%
Miscellaneous								
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum		
Dimensions	150 x 150 x 30	150 x 150 x 30	150 x 150 x 30	150 x 150 x 30	150 x 150 x 30	150 x 150 x 30	mm	
Mass	1380	1380	1400	1400	1420	1420	g	±5 %
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	m	±10 mm
Sensor / voltage connection	CD-version: Sub-D special CL-version: LEMO	Sub-D Special CL-version:	CD-version: Sub-D special LEMO	Sub-D Special	CD-version: Sub-D special CL-version: LEMO	Sub-D Special		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. V alue given is noise equivalent motion with E-50 3 (p. 2-146) or E-710 controller (p. 2-128)
Recommended controller
CD-Versions:
Single-channel (1 per axis): E-610 servo controller / amplifier (p. 2-110), E-625 servo controller , bench-top (p. 2-114)
Single-channel digital controller: E-753 (bench-top) (p. 2-108)
CL-Versions:
Single-channel: E-500 modular piezo controller system (p. 2-142) with E-505 (p. 2-147) high-power amplifier module and E-509 serv o-controller (p. 2-152)
Multi-channel versions:
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-541.Z Piezo Z and Z/Tip/Tilt Stages

Low Profile, Large Aperture

P-541 series nanopositioning Z-stages and Z-tip/tilt stages offer travel ranges of 100 µm with sub-nanometer resolution. They feature a very low profile of 16.5 mm and a large 80 x 80 mm aperture. Versions with strain gauge and capacitive position feedback sensors are available

- **Low Profile for Easy Integration: 16.5 mm; 80 x 80 mm Clear Aperture**
- **Vertical and Z/Tip/Tilt Stages**
- **100 µm Travel Range, 1 mrad Tilt**
- **Parallel-Kinematics / Metrology for Enhanced Responsiveness / Multi-Axis Precision**
- **Choice of Sensors: Strain Gauge (Lower Cost) or Capacitive Sensors (Higher Performance)**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Combination with Long-Travel M-686 Microscopy Stages**

Low Profile, Optimized for Microscopy Applications

The P-541 Z stages and Z/tip/tilt stages are for ideal alignment, nano-focusing or metrology tasks in the nanometer range. They feature a very low profile of 16.5 mm, a large 80 x 80 mm aperture, and offer highly accurate motion with sub-nanometer resolution.

Application Examples

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

A variety of P-541 XY scanning stages with the same footprint are also available (see p. 2-60). Due to the low-profile design, the stages can easily be integrated in high-resolution microscopes.

Choice of Position Sensors

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

Alternatively, economical strain gauge sensors are available. PI uses a bridge configuration to eliminate thermal drift, and assure optimal position stability in the nanometer range.

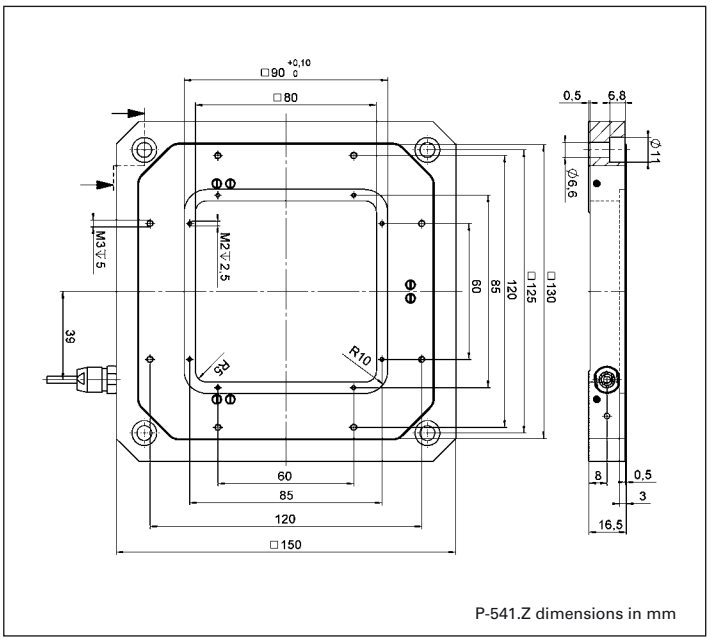
Active and Passive Guidance for Nanometer Flatness and Straightness

Flexures optimized with Finite Element Analysis (FEA) are completely free of play and friction to allow extremely high-precision motion. The FEA techniques also optimize straightness and flatness and provide for the highest possible stiffness in, and perpendicular to, the direction of motion.

Due to the parallel-kinematics design there is only one common moving platform for all axes, minimizing mass, enabling identical dynamic behaviour and eliminiating cumulative errors. Parallel kinematics also allows for a more compact construction and faster response compared to stacked or nested designs.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

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



P-541.Z dimensions in mm

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

Technical Data

Models	P-541.ZCD	P-541.TCD*	P-541.ZSL	P-541.TSL	P-541.T0L*	P-541.Z0L	Units	Tolerane
Active axes	Z	Z, θ_X, θ_Y	Z	Z, θ_X, θ_Y	Z	Z, θ_X, θ_Y		
Motion and positioning								
Integrated sensor	Capacitive	Capacitive	SGS	SGS	Open-loop	Open-loop		
Open-loop Z-travel, -20 to +120 V	150	150	150	150	150	150	µm	min. (+20 %/0 %)
Open-loop tip/tilt angle, -20 to +120 V	–	±0.6	–	±0.6	–	±0.6	mrad	min. (+20 %/0 %)
Closed-loop Z-travel	100	100	100	100	–	–	µm	
Closed-loop tip/tilt angle	–	±0.4	–	±0.4	–	–	mrad	
Open-loop Z-resolution	0.2	0.2	0.2	0.2	0.2	0.2	nm	typ.
Open-loop tip/tilt angle resolution	–	0.02	–	0.02	–	0.02	µrad	typ.
Closed-loop Z-resolution	0.5	0.5	2.5	2.5	–	–	nm	typ.
Closed-loop tip/tilt resolution	–	0.08	–	0.25	–	–	µrad	typ.
Linearity Z, θ_X, θ_Y	0.03	0.03	0.2	0.2	–	–	%	typ.
Repeatability Z	<2	<2	<10	<10	–	–	nm	typ.
Repeatability θ_X, θ_Y	–	0.01	–	0.05	–	–	µrad	typ.
Runout θ_X, θ_Y	±15	±15	±15	±15	±15	±15	µrad	typ.
Mechanical properties								
Stiffness Z	0.8	0.8	0.8	0.8	0.8	0.8	N/µm	±20 %
Unloaded resonant frequency (Z)	410	410	410	410	410	410	Hz	±20 %
Unloaded resonant frequency (θ_X, θ_Y)	–	330	–	330	–	330	Hz	±20 %
Resonant frequency @ 200 g (Z)	250	250	250	250	250	250	Hz	±20 %
Resonant frequency @ 200 g (θ_X, θ_Y)	–	270	–	270	–	270	Hz	±20 %
Push/pull force capacity	50 / 20	50 / 20	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	PICMA® P-885	PICMA® P-885		
Electrical capacitance	6.3	6.3	6.3	6.3	6.3	6.3	µF	±20 %
Dynamic operating current coefficient	7.9	7.9	7.9	7.9	7.9	7.9	µA / (Hz • µm)	±20 %
Miscellaneous								
Operating temperature range	20 to 80	20 to 80	20 to 80	20 to 80	20 to 80	20 to 80	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	750	750	730	730	700	700	g	±5 %
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	m	±10 mm
Sensoranschluss	Sub-D Special	Sub-D Special	LEMO	3 x LEMO	–	–		
Voltage connection	Sub-D Special	Sub-D Special	LEMO	3 x LEMO	LEMO	3 x LEMO		

*Parallel kinematics design; the maximum displacement for translation and tilt motion cannot be achieved at the same time

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 (p. 2-146) or E-710 controller (p. 2-128).

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)

Single-channel digital controller: E-753 (bench-top) (p. 2-108)

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)

S-310 – S-316 Piezo Z/Tip/Tilt Stage / Scanner

High-Speed System with Clear Aperture

S-310.10, S-316.10
piezo systems for scanning,
optics alignment and mirror shifter alignment

- **10 mm Clear Aperture**
- **Piezo Tripod Design**
- **Optical Beam Deflection to 2,4 mrad**
- **Piston Movement up to 12 µm (phase shifter)**
- **Sub-Millisecond Response, Sub-Microradian Resolution**
- **Closed-Loop Versions for Higher Precision**
- **For Optics, Mirrors or Other Components**
- **Frictionless, High-Precision Flexure Guiding System**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**

S-310 to S-316 multi-axis tip/tilt platforms and Z-positioners are fast, compact units based on a piezo tripod design. They offer piston movement up to 12 µm and tilt movement up to 1.2 mrad (2.4 mrad optical beam deflection) with sub-millisecond response and settling. The tripod design features optimum angular stability over a wide temperature range.

The systems are designed for mirrors and optics up to 25 mm in diameter and can be mounted in any orientation; the clear aperture is ideal for transmitted-light applications (e.g. for optical filters).

Application Examples

- Image processing / stablilization
- Interferometry
- Laser scanning / beam steering
- Laser tuning
- Optical filters / switches
- Beam stabilization

Open-Loop and Closed-Loop Operation

In open-loop mode, the tip/tilt angle is roughly proportional to the applied voltage. The S-310 to S-315 open-loop models are ideal for high-speed, high resolution applications where the absolute angular position is of secondary importance (e.g. for tracking) or where feedback is provided by an external sensor (e.g. CCD, PSD). The S-316.10 model is equipped with high-resolution strain gauge sensors and provides absolute position control, high linearity and high repeatability.

Available Versions

S-310.10, S-314.10

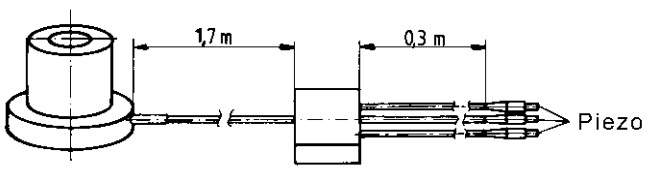
Open-loop Z-platforms; all three piezo linear actuators are electrically connected in parallel, providing vertical positioning (piston movement) of the top ring. Only one drive channel is required.

S-311.10, S-315.10

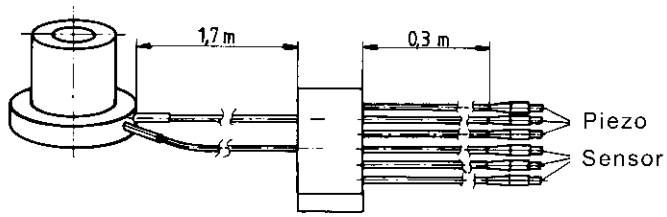
Open-loop Z/tip/tilt positioners; all three piezo linear actuators can be driven individually (or in parallel) by a three-channel amplifier. Vertical (piston movement) positioning and tip/tilt positioning are possible.

S-316.10

Closed-loop Z/tip/tilt positioner. All three piezo linear actuators are equipped with strain gauge position feedback sensors and can be driven individually (or in parallel) by a three-channel amplifier with a position servo-controller. Vertical positioning (piston movement) and tip/tilt positioning are possible. The integrated position feedback sensors provide sub-microradian resolution and high repeatability.



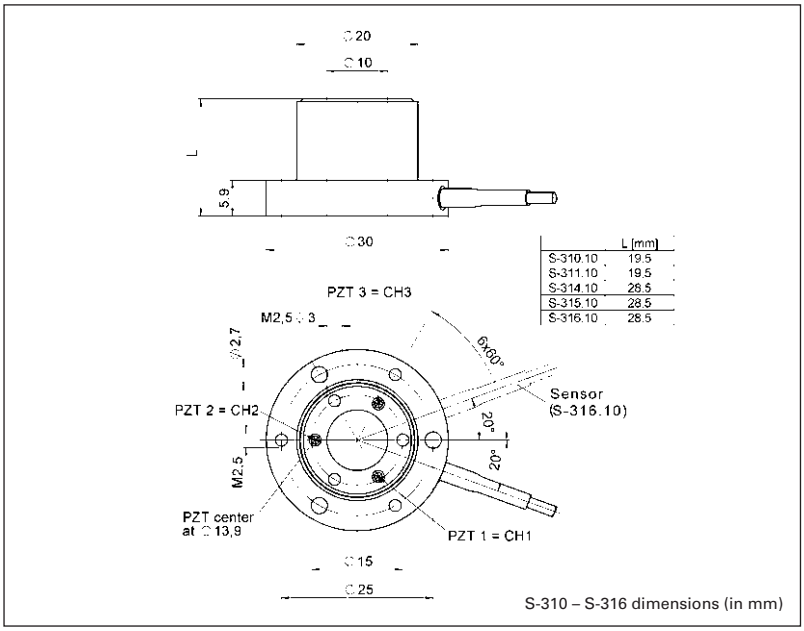
S-315 cable configuration



S-316 cable configuration

High Reliability and Long Lifetime

The compact S-310 - S-316 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and provide better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free, not subject to wear and offer extraordinary reliability.



S-310 – S-316 dimensions (in mm)

Technical Data

Model	S-310.10	S-314.10	S-311.10	S-315.10	S-316.10	Units	Tolerance
Active axes	Z	Z	Z, Θ_X, Θ_Y	Z, Θ_X, Θ_Y	Z, Θ_X, Θ_Y		
Motion and positioning							
Integrated sensor	–	–	–	–	SGS		
Open-loop travel, 0 to +100 V	6 / –	12 / –	6 / –	12 / –	12 / 12	µm	min. (+20 %/-0 %)
*Open-loop tilt angle @ 0 to 100 V	–	–	600	1200	1200	µrad	min. (+20 %/-0 %)
Closed-loop travel	–	–	–	–	12	µm	
*Closed-loop tilt angle	–	–	–	–	1200	µrad	
Open-loop resolution	0.1	0.2	0.1	0.2	0.2	nm	typ.
Open-loop tip/tilt angle resolution			0.02	0.05	0.05	µrad	typ.
Closed-loop resolution	–	–	–	–	0.4	nm	typ.
Closed-loop tip/tilt resolution	–	–	–	–	0.1	µrad	typ.
Linearity	–	–	–	–	0.2	%	typ.
Mechanical properties							
Stiffness	20	10	20	10	10	N/µm	±20 %
Unloaded resonant frequency (Z)	9.5	5.5	9.5	5.5	5.5	kHz	±20 %
Resonant frequency (with 15 x 4 mm glass mirror)	6.5	4.4	6.5	4.1	4.1	kHz	±20 %
Resonant frequency (with 20 x 4 mm glass mirror)	6.1	4.2	6.1	3.4	3.4	kHz	±20 %
Distance of pivot point to platform surface	–	–	5	5	5	mm	±1 mm
Platform moment of inertia	–	–	150	150	150	g • mm²	±20 %
Drive properties							
Ceramic type	PICMA® P-882	PICMA® P-882	PICMA® P-882	PICMA® P-882	PICMA® P-882		
Electrical capacitance	0.39	0.93	0.39	0.93	0.93	µF	±20 %
Dynamic operating current coefficient	8	10	8	10	10	µA / (Hz • mrad)	±20 %
Miscellaneous							
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel		
Mass	0.045	0.055	0.045	0.055	0.055	kg	±5%
Cable length	2	2	2	2	2	m	±10 mm
Sensor connection	–	–	–	–	LEMO		

Resolution of PI piezo tip/tilt platforms is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier (p. 2-146).

*Mechanical tilt, optical beam deflection is twice as large. For maximum tilt range, all three piezo actuators must be biased at 50 V. Due to the parallel-kinematics design linear travel and tilt angle are interdependent. The values quoted here refer to pure linear / pure angular motion (equations p. 2-84).

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)

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) (optional), E-517 interface module (p. 2-156) (optional)

S-334 Miniature Piezo Tip/Tilt-Stage Steering Mirror

Fast Steering Mirror with up to 120 mrad Deflection

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

- **Miniature Design**
- **Optical Beam Deflection to 120 mrad (~ 6.8°)**
- **Coplanar Axes & Fixed Pivot Point; Eliminate Polarization Rotation**
- **Factory Installed Mirror**
- **Millisecond Response, Resolution to 0.2 µrad**
- **Closed-loop Position Servo-Control for High Accuracy**
- **For Mirrors up to 12.5 mm (0.5") Diameter**
- **Frictionless, High-Precision Flexure Guiding System**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**

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

Large Tip/Tilt Ranges with Excellent Motion Characteristics

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

Sub-Microradian Resolution

In addition to the large angles and the high dynamics the S-334 provides sub-microradian resolution. The integrated high-resolution, full-bridge strain gauge sensors (SGS) provide absolute position control, excellent repeatability and high linearity, typically better than 0.05 % over the entire travel range.

Differential Drive for Improved Stability and Dynamics

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

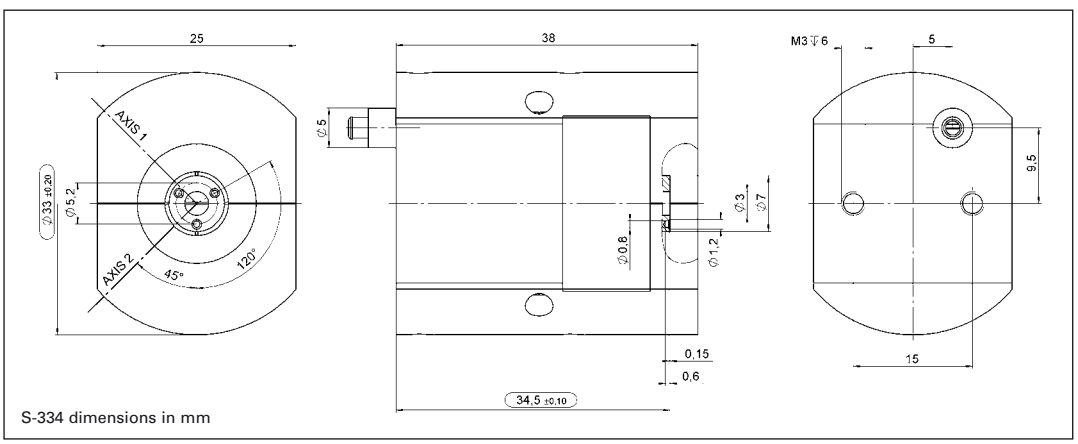
Compared to stacked, (two-stage), piezo or galvo scanners, the single-platform design provides several advantages: smaller package size, identical dynamic performance in both axes, faster response and better linearity. It also prevents polarization rotation.

High Reliability and Long Lifetime

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

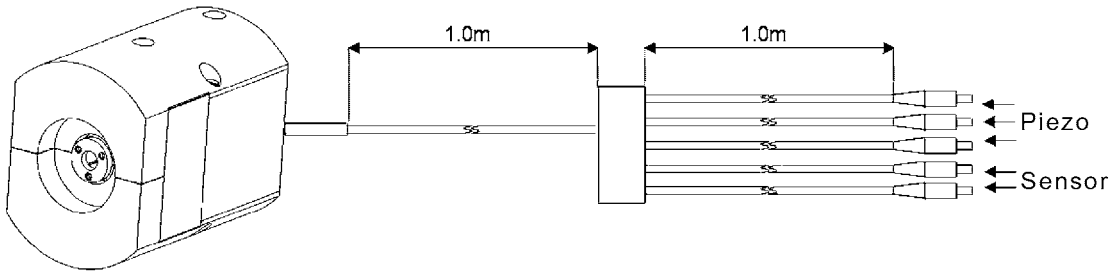
Application Examples

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



S-334 dimensions in mm

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



S-334.2SL cable configuration

Technical Data

Model	S-334.1SL S-334.1SD	S-334.2SL S-334.2SD	Units	Tolerance
Active Axes	θ_X, θ_Y	θ_X, θ_Y		
Motion and positioning				
Integrated sensor	SGS	SGS		
*Open-loop tilt angle at -20 to +120 V	30	60	mrad	min. (+20 %/-0 %)
*Closed-loop tilt angle	25	50	mrad	
Open-loop resolution	0.2	0.5	µrad	typ.
Closed-loop resolution	1	5	µrad	typ.
Linearity	0.05	0.05	%	typ.
Repeatability	2	5	µrad	typ.
Mechanical properties				
Resonant frequency underload (with standard mirrors)	3.0	1.0	kHz	±20 %
Load capacity	0.2	0.2	N	Max.
Distance of pivot point to platform surface	6	6	mm	±1 mm
Platform moment of inertia	1530	1530	g • mm²	±20 %
Standard mirror (mounted)	diameter: 10 mm, thickness: 2 mm; BK7, λ/5, R > 98 % (λ = 500 nm to 2 µm)	diameter: 10 mm, thickness: 2 mm; BK7, λ/5, R > 98 % (λ = 500 nm to 2 µm)		
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance per axis	3	3	µF	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material casing	Titanium	Titanium		
Mass	0.065	0.065	kg	±5 %
Cable length	2	2	m	±10 mm
Sensor / voltage connection	LEMO connector / 25-pin sub-D connector	LEMO connector / 25-pin sub-D connector		

Recommended controller / amplifier
Closed-loop versions with D-sub connector: E-616 controller for tip/tilt mirror systems (p. 2-132);
Open-loop versions with LEMO connector: Modular piezo controller system E-500 (p. 2-142) with amplifier module E-503.00S (three channels) (p. 2-146) or 1 x E-505.00S and 2 x E-505 (high speed applications) (p. 2-147) and E-509 servo controller (p. 2-152 / 3-16)
Open-loop: E-663 three channel amplifier (p. 2-136)

Resolution of PI piezo tip/tilt platforms is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier, (p. 2-146).

*Mechanical tilt, optical beam deflection is 120 mrad (open loop) and 100 mrad (closed-loop), respectively.

S-330 Piezo Tip/Tilt-Platform

High-Dynamics, Large-Angle Piezo Tip/Tilt Platforms for Fast Steering Mirrors

S-330 tip/tilt platforms with optical beam deflection angles of 4, 10 and 20 mrad

- **Resolution to 20 nrad, Excellent Position Stability**
- **Optical Beam Deflection to 20 mrad (>1°)**
- **Higher Dynamics, Stability & Linearity Through Parallel-Kinematics Design**
- **Sub-Millisecond Response**
- **For Mirrors up to 50 mm Diameter**
- **Closed-Loop Versions for Better Linearity**
- **Excellent Temperature Stability**

S-330 piezo tip/tilt platforms are fast and compact tip/tilt units, providing precise angular motion of the top platform around two orthogonal axes.

Application Examples

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

These flexure-guided, piezoelectric platforms can provide higher accelerations than other implementations, enabling step response times in the sub-millisecond range. Closed-loop and open-loop versions with 3 different tilt ranges up to 10 mrad (20 mrad optical deflection) are available.

Parallel-kinematics design for improved stability, linearity and dynamics

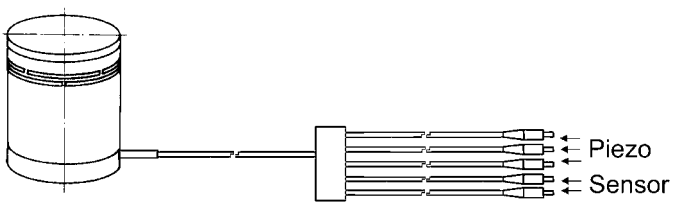
PI piezo tip/tilt mirror systems are based on a parallel-kinematics design with coplanar axes and a single moving platform. Two pairs of differentially-driven piezo actuators are employed to provide the highest possible angular stability over a wide temperature range. Compared to stacked, (two-stage) piezo or galvo scanners, the single-platform design provides several advantages: smaller package size, identical dynamic performance in both axes, faster response and better linearity. It also prevents polarization rotation.

Fast Piezo Ceramic Drives

Frictionless, flexure-guided piezo ceramic drives provide higher accelerations than other actuators, such as voice-coils, and enable response in the millisecond range and below. Piezo actuators do not require energy to hold a position. The resulting low heat signature is a great advantage in infrared imaging systems like those used in astronomy.

Closed Loop Operation

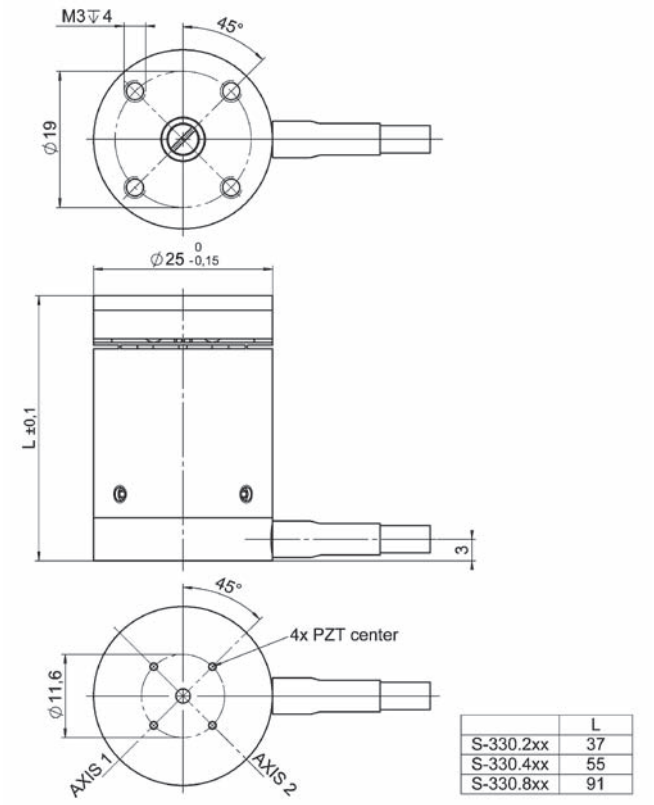
For high stability and repeatability, absolute-measuring strain gauge sensors (SGS) are applied to appropriate locations on the drive train. They provide a high-bandwidth, position feedback signal to the controller. The sensors are connected in a bridge configuration to eliminate thermal drift,



Circuit diagram and cable configuration of the S-330.xSL closed-loop versions. The S-330.xSD models feature a single Sub-D connector and can be operated by the E-616 controller.

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.



	L
S-330.2xx	37
S-330.4xx	55
S-330.8xx	91

S-330 dimensions in mm

Technical Data

Model	S-330.2SL	S-330.4SL	S-330.8SL	S-330.2SD S-330.4SD S-330.8SD	S-330.20L S-330.40L S-330.80L	Units	Tolerance
Active axes	Θ_X, Θ_Y	Θ_X, Θ_Y	Θ_X, Θ_Y	Θ_X, Θ_Y	Θ_X, Θ_Y		
Motion and positioning							
Integrated sensor	SGS	SGS	SGS	SGS	–		
Open-loop tip/tilt angle, -20 to +120 V	3.5	7	15	as SL version	as SL version	mrad	min.
Closed-loop tip/tilt angle	2	5	10	as SL version	–	mrad	
Open-loop tip/tilt angle resolution	0.02	0.1	0.2	as SL version	as SL version	µrad	typ.
Closed-loop tip/tilt resolution	0.05	0.25	0.5	as SL version	–	µrad	typ.
Linearity in Θ_X, Θ_Y	0.1	0.2	0.25	as SL version	–	%	typ.
Repeatability Θ_X, Θ_Y	0.15	0.5	1	as SL version	–	µrad	typ.
Mechanical properties							
Unloaded resonant frequency (Θ_X, Θ_Y)	3.7	3.3	3.1	as SL version	as SL version	kHz	±20%
Resonant frequency loaded in Θ_X, Θ_Y (with 25 x 8 mm glass mirror)	2.6	1.6	1.0	as SL version	as SL version	kHz	±20%
Distance of pivot point to platform surface	6	6	6	6	6	mm	±1 mm
Platform moment of inertia	1530	1530	1530	1530	1530	g x mm²	±20%
Drive properties							
Ceramic type	PICMA®	PICMA®	PICMA®	PICMA®	PICMA®		
Electrical capacitance	3/axis	6/axis	12.5/axis	as SL	as SL	µF	±20%
Dynamic operating current coefficient	0.22/axis	0.4/axis	0.8/axis	as SL	as SL	µA//Hz • mrad)	±20%
Miscellaneous							
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material case	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel		
Material platform	Invar	Invar	Invar	Invar	Invar		
Mass	0.2	0.38	0.7	as SL version	as SL version	kg	±5%
Cable length	1.5	1.5	1.5	1.5	1.5	m	±10 mm
Sensor / voltage connection	LEMO	LEMO	LEMO	Sub-D connector	LEMO		

Recommended controller / amplifier

Versions with LEMO connector: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503.00S (three channels) (p. 2-146) or 1 x E-505.00S and 2 x E-505 (high speed applications) (p. 2-147) and E-509 controller (p. 2-152) (optional)

Open-loop: E-663 three channel amplifier (p. 2-136)

Versions with Sub-D connectors: E-616 servo controller for tip/tilt mirror systems (p. 2-132)

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