

Tip/Tilt & Z-Piezo Nanopositioning Stages

Optics Alignment, Beam Steering, Wavefront Sensing

FAST



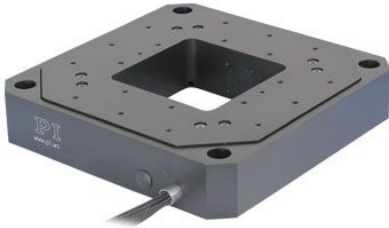
PRECISE



INDIVIDUAL

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Piezo Nanopositioning Tip/Tilt Stages



P-528 Tip/tilt & Z piezo platform with aperture



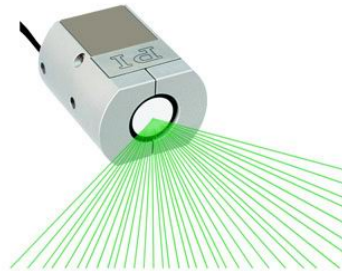
P-541 Low profile tip/tilt & Z piezo platform with large 80x80mm aperture



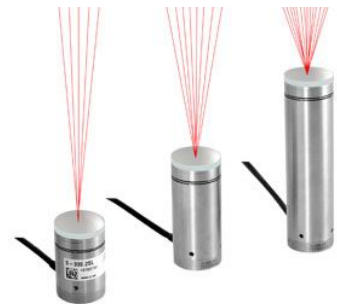
S-340 tip/tilt platform for mirrors & optics up to 4" diameter



S-325.3 piezoelectric fast steering mirror platform / scanner



The S-334 Tip/Tilt Mirror System/Scanner provides optical deflection angles to 120mrad



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



Long-travel, large aperture piezo Z/tip/tilt platform. Tripod design with PiezoWalk® linear motor drives

P-915K XY-Theta-Z Piezo Stage

3 Degrees of Freedom in the XY Plane



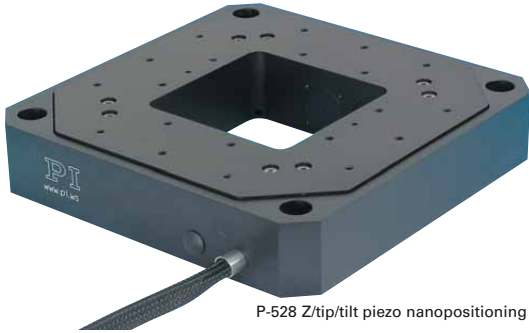
The P-915KPPS is equipped with FEA-modeled flexures for higher stiffness in all three directions of motion

- Travel Ranges 250 x 250 μm , 16 mrad
- Frictionless, High-Precision Flexure Guiding System
- High Stiffness $>1 \text{ N}/\mu\text{m}$
- Outstanding Lifetime Due to PICMA® Piezo Actuators

Model	Travel	Resolution	Load capacity	Settling (system combination with E-621)	Dimensions
P-915KPPS	250 x 250 μm	3 nm	2 kg	45 ms (250 μm)	60 x 60 x 100 mm
XY-Rot-Z- Piezo Stage	± 8 mrad	15 μrad		28 ms (16 mrad)	

P-518, P-528, P-558 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

Application Examples

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

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

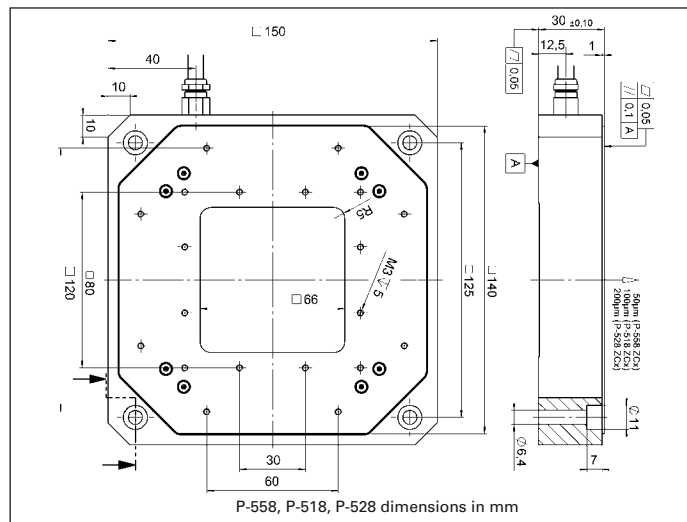
PI's proprietary capacitive sensors measure position directly and without physical contact.

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



Ordering Information

- P-558.ZCD**
Precision Nanopositioning Z-Stage, 50 μm , Direct Metrology, Capacitive Sensors, Sub-D Connector
- P-558.ZCL**
Precision Nanopositioning Z-Stage, 50 μm , Direct Metrology, Capacitive Sensors, LEMO Connector
- P-518.ZCD**
Precision Nanopositioning Z-Stage, 100 μm , Direct Metrology, Capacitive Sensors, Sub-D Connector
- P-518.ZCL**
Precision Nanopositioning Z-Stage, 100 μm , Direct Metrology, Capacitive Sensors, LEMO Connector
- P-528.ZCD**
Precision Nanopositioning Z-Stage, 200 μm , Direct Metrology, Capacitive Sensors, Sub-D Connector
- P-528.ZCL**
Precision Nanopositioning Z-Stage, 200 μm , Direct Metrology, Capacitive Sensors, LEMO Connector
- P-558.TCD**
Precision Nanopositioning Z/Tip/Tilt Stage, 50 μm , 0.6 mrad, Parallel Metrology, Capacitive Sensors, Sub-D Connector
- P-518.TCD**
Precision Nanopositioning Z/Tip/Tilt Stage, 100 μm , 1.4 mrad, Parallel Metrology, Capacitive Sensors, Sub-D Connector
- P-528.TCD**
Precision Nanopositioning Z/Tip/Tilt Stage, 200 μm , 2.4 mrad, Parallel Metrology, Capacitive Sensors, Sub-D Connector

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.

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	$\mu\text{A}/(\text{Hz}\cdot\mu\text{m})$	± 20 %
Miscellaneous								
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	$^{\circ}\text{C}$	
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	CD-version: Sub-D special CL-version: 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-503 (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 servo-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)

S-340 Piezo Tip/ Tilt-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- μ rad resolution and a tip/tilt range of 2 mrad (equivalent to 4 mrad optical beam deflection).

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

Ordering Information	
S-340.A0L	Piezo Tip/Tilt Platform, 2 mrad, Open-Loop, LEMO Connector, Aluminum Top Plate
S-340.ASL	Piezo Tip/Tilt Platform, 2 mrad, SGS, LEMO, Aluminum Top Plate
S-340.ASD	Piezo Tip/Tilt Platform, 2 mrad, SGS, Sub-D Connectors, Aluminum Top Plate
Various material for the top platforms are available on demand:	
S-340.S0L / .SSL / .SSD:	High-Grade Steel
S-340.T0L / .TSL / .TSD:	Titanium
S-340.i0L / .iSL / .iSD:	Invar

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.

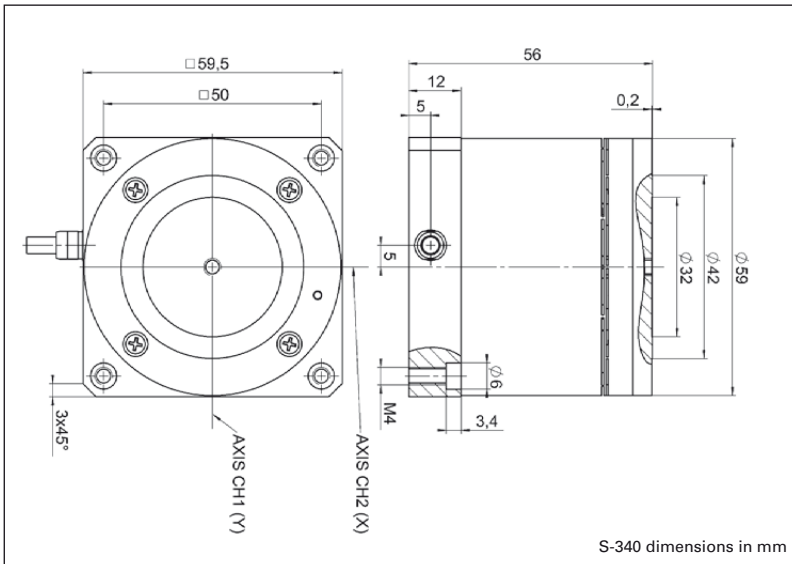
Ceramic-Insulated Piezo Actuators Provide Superior Lifetime

The highest possible reliability is assured by employing the award-winning PICMA® multi-layer 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.

Application Examples

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

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Technical Data

Model	S-340.ASD/.ASL	S-340.A0L	Units	Tolerance
Active axes	$\theta X, \theta Y$	$\theta X, \theta Y$		
Motion and Positioning				
Integrated sensor	SGS	-		
Open-loop tip / tilt angle, -20 to +120 V	2	2	mrاد	min.
Closed-loop tip / tilt angle	2	-	mrاد	
Open-loop tip / tilt angle resolution	0.02	0.02	μ rad	typ.
Closed-loop tip / tilt resolution	0.2	-	μ rad	typ.
Linearity in $\theta X, \theta Y$	0.1	-	%	typ.
Repeatability in $\theta X, \theta Y$	0.15	-	μ rad	typ.
Mechanical properties				
Unloaded resonant frequency ($\theta X, \theta Y$)	1.4	1.4	kHz	± 20 %
Resonant frequency loaded in $\theta X, \theta Y$ (with glass mirror diameter 50 mm, thickness 15 mm)	0.9	0.9	kHz	± 20 %
Resonant frequency loaded in $\theta X, \theta Y$ (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	$g \cdot mm^2$	± 20 %
Drive properties				
Ceramic type	PICMA®	PICMA®		
Electrical capacitance	6/axis	6/axis	μ F	± 20 %
Dynamic operating current coefficient	0.45/axis	0.45/axis	μ A / (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.

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.

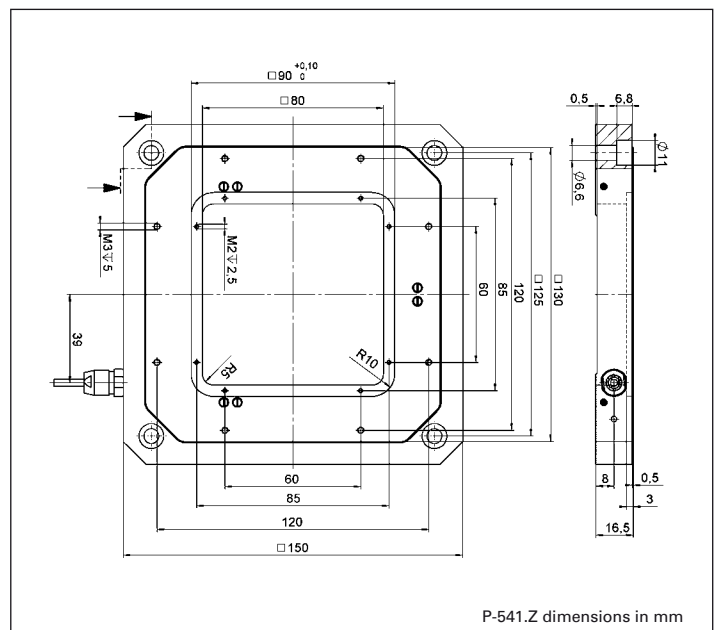
Due to the parallel-kinematics design there is only one common moving platform for all axes, minimizing mass, enabling identical dynamic behaviour and eliminating cumulative errors. Parallel kinematics also allows for a more compact construction and faster response compared to stacked or nested designs.

Ordering Information

- P-541.ZCD**
Vertical Nanopositioning Stage with Large Aperture, 100 µm, Direct Metrology, Capacitive Sensors
- P-541.TCD**
Vertical Tip / Tilt Nanopositioning Stage with Large Aperture, 100 µm / 1 mrad, Parallel Metrology, Capacitive Sensors
- P-541.ZSL**
Vertical Nanopositioning Stage with Large Aperture, 100 µm, Strain Gauge Sensors
- P-541.TSL**
Vertical Tip / Tilt Nanopositioning Stage with large Aperture, 100 µm, Strain Gauge Sensors

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

System properties

System configuration	P-541.ZCD and E-500 modular system with E-503 amplifier and E-509 sensor module, 20 g load
Amplifier bandwidth, small signal	60 Hz
Settling time (10 % step width)	9 ms

Technical Data

Models	P-541.ZCD	P-541.TCD*	P-541.ZSL	P-541.TSL	P-541.TOL*	P-541.ZOL	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	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	$\pm 20\%$
Unloaded resonant frequency (Z)	410	410	410	410	410	410	Hz	$\pm 20\%$
Unloaded resonant frequency (θ_x , θ_y)	–	330	–	330	–	330	Hz	$\pm 20\%$
Resonant frequency @ 200 g (Z)	250	250	250	250	250	250	Hz	$\pm 20\%$
Resonant frequency @ 200 g (θ_x , θ_y)	–	270	–	270	–	270	Hz	$\pm 20\%$
Push/pull force capacity	50 / 20	50 / 20	50 / 20	50 / 20	50 / 20	50 / 20	N	Max.
Drive properties								
Ceramic type	PICMA®	PICMA®	PICMA®	PICMA®	PICMA®	PICMA®		
	P-885	P-885	P-885	P-885	P-885	P-885		
Electrical capacitance	6.3	6.3	6.3	6.3	6.3	6.3	μF	$\pm 20\%$
Dynamic operating current coefficient	7.9	7.9	7.9	7.9	7.9	7.9	$\mu\text{A} / (\text{Hz} \cdot \mu\text{m})$	$\pm 20\%$
Miscellaneous								
Operating temperature range	20 to 80	20 to 80	20 to 80	20 to 80	20 to 80	20 to 80	$^{\circ}\text{C}$	
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	750	750	730	730	700	700	g	$\pm 5\%$
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	m	$\pm 10\text{ mm}$
Sensoranschluss	Sub-D	Sub-D	LEMO	3 x LEMO	–	–		
	Special	Special						
Voltage connection	Sub-D	Sub-D	LEMO	3 x LEMO	LEMO	3 x LEMO		
	Special	Special						

*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)

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

Nanometer Precision for Semiconductor Industry, Wafer Alignment



Z, tip, tilt nan positioning 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 300 mm (12") Clear aperture 250 mm

N-510K High-Stiffness NEXLINE® Z Stage

High-Precision Positioning, with Capacitive Sensors



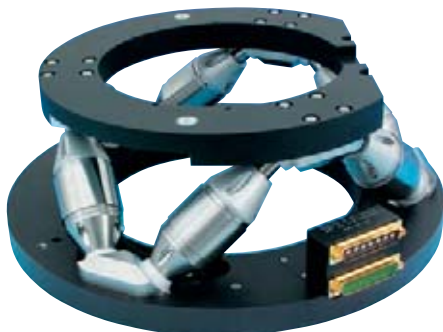
The N-510KHFS hybrid-drive nanopositioner offers maximum accuracy for semiconductor inspection applications

- Self Locking at Rest, No Heat Generation
- Hybrid Drive: PiezoWalk® plus PICMA®
- Travel Range: 400 µm Coarse + 40 µm Fine
- 2 µm Closed-Loop Resolution
- Direct Metrology:
One Single Control Loop with Capacitive Sensors
- High Push and Holding Force to 25 N
- Piezo Walking Drive w/o Wear and Tear & Outstanding Lifetime due to PICMA® Piezo Actuators

Model	Vertical travel	Velocity	Bidirectional repeatability	Load capacity	Dimensions
N-510KHFS Hybrid-Focus System	400 µm coarse 40 µm fine	1 mm/sec	50 nm (full travel)	25 N	Ø 300 mm 68.5 mm height

N-515K Non-Magnetic Piezo Hexapod

6-Axis Precision Positioning System with NEXLINE® Linear Drives



6-axis parallel kinematics (Hexapod) with integrated N-215 NEXLINE® high-load actuators, suitable for applications in strong magnetic fields

- 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 $\theta_x, \theta_y, \theta_z: 6^\circ$	50 kg	Outer Ø baseplate, 380 mm Ø moved platform (top) 300 mm 140 mm height

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, piezo-electric 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 differential-

ly-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.

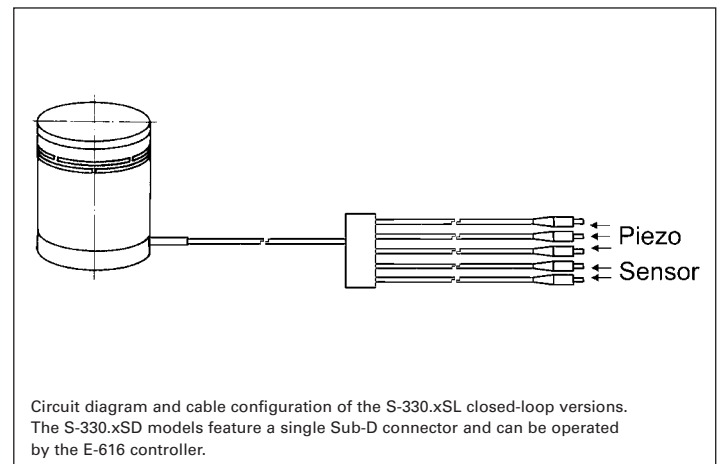
Closed Loop Operation

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,

Ordering Information

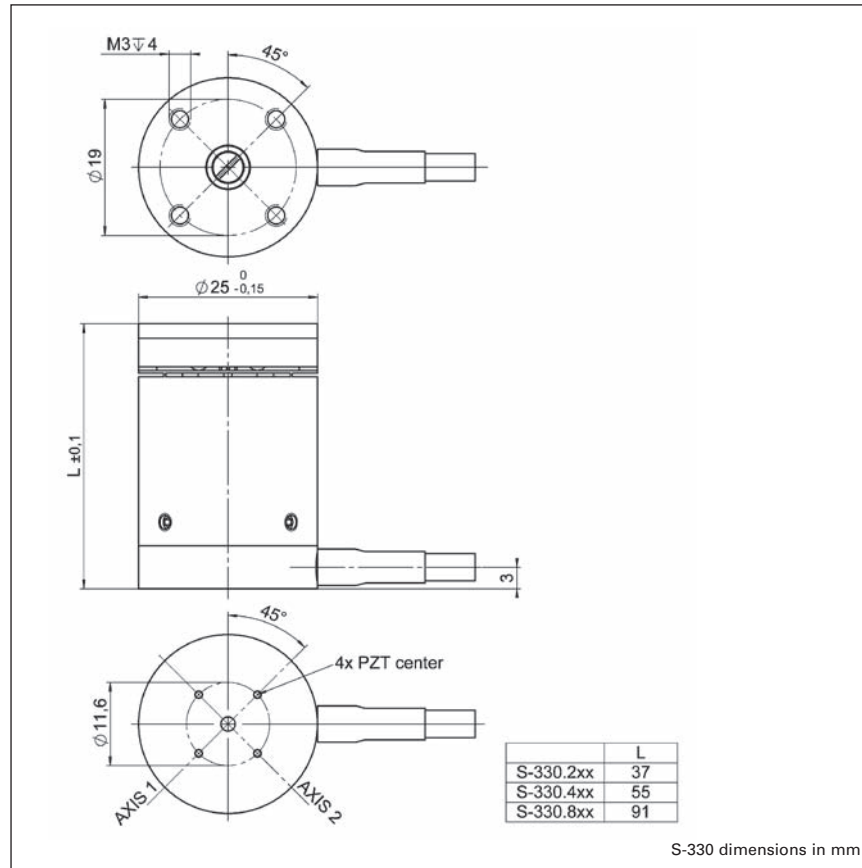
- S-330.2SL**
High-Dynamics Piezo Tip/Tilt Platform, 2 mrad, SGS, LEMO Connector
- S-330.2SD**
High-Dynamics Piezo Tip/Tilt Platform, 2 mrad, SGS, Sub-D Connector
- S-330.20L**
High-Dynamics Piezo Tip/Tilt Platform, 2 mrad, Open-Loop, LEMO Connector
- S-330.4SL**
High-Dynamics Piezo Tip/Tilt Platform, 5 mrad, SGS, LEMO Connector
- S-330.4SD**
High-Dynamics Piezo Tip/Tilt Platform, 5 mrad, SGS, Sub-D Connector
- S-330.40L**
High-Dynamics Piezo Tip/Tilt Platform, 5 mrad, Open-Loop, LEMO Connector
- S-330.8SL**
High-Dynamics Piezo Tip/Tilt Platform, 10 mrad, SGS, LEMO Connector
- S-330.8SD**
High-Dynamics Piezo Tip/Tilt Platform, 10 mrad, SGS, Sub-D Connector
- S-330.80L**
High-Dynamics Piezo Tip/Tilt Platform, 10 mrad, Open-Loop, LEMO Connector

and assure optimal position stability. Open-loop systems are also available.



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	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	μ rad	typ.
Closed-loop tip/tilt resolution	0.05	0.25	0.5	as SL version	-	μ rad	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	-	μ rad	typ.
Mechanical properties							
Unloaded resonant frequency (Θ_x, Θ_y)	3.7	3.3	3.1	as SL version	as SL version	kHz	$\pm 20\%$
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	$\pm 20\%$
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 mm ²	$\pm 20\%$
Drive properties							
Ceramic type	PICMA®	PICMA®	PICMA®	PICMA®	PICMA®		
Electrical capacitance	3/axis	6/axis	12.5/axis	as SL	as SL	μ F	$\pm 20\%$
Dynamic operating current coefficient	0.22/axis	0.4/axis	0.8/axis	as SL	as SL	μ A/Hz • mrad)	$\pm 20\%$
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	$\pm 5\%$
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)

S-325 Piezo Z/Tip/Tilt Platform

High-Speed Tripod System for Mirrors and Optics



S-325.30L piezoelectric fast steering mirror platform / scanner

- Optical Beam Deflection to 10 mrad, Resolution to 50 nrad
- Piston Movement up to 30 μm (for Path Length Adjustment)
- Compact Tripod Design with Coplanar Axes Eliminates Polarization Rotation
- Sub-Millisecond Responsiveness
- Closed-Loop Versions for Higher Precision
- For Mirrors up to 25 mm (1") Diameter
- Frictionless, High-Precision Flexure Guiding System
- Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy

The S-325 Z/tip/tilt platforms and actuators provide high speed and precise movement of the platform in two tilt axes as well as sub-nanometer linear resolution with sub-millisecond response. The design is based

on a parallel-kinematics direct-drive piezo tripod (see p. 2-83), and they are especially optimized for industrial applications where 1,000,000.000 motion cycles have to be performed without failure or per-

formance degradation. The systems are designed for mirrors and optics up to 25 mm in diameter and can be mounted in any orientation.

The tripod drive offers optimum 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 size, identical dynamic performance in all axes, faster response and better linearity. It also prevents polarization rotation.

All three piezo linear actuators can be driven individually (for tip/tilt movement) or in parallel (for vertical movement) by a three-channel amplifier.

High Resolution, Stability and Dynamics

The S-325 offers piston movement of up to 30 μm (ideal for path length adjustment) and mechanical tilt up to 5 mrad (equivalent to 10 mrad optical beam deflection). The zero-friction piezo drives and flexure guidance allow sub-nanometer linear resolution and sub-microradian angular resolution.

Ordering Information

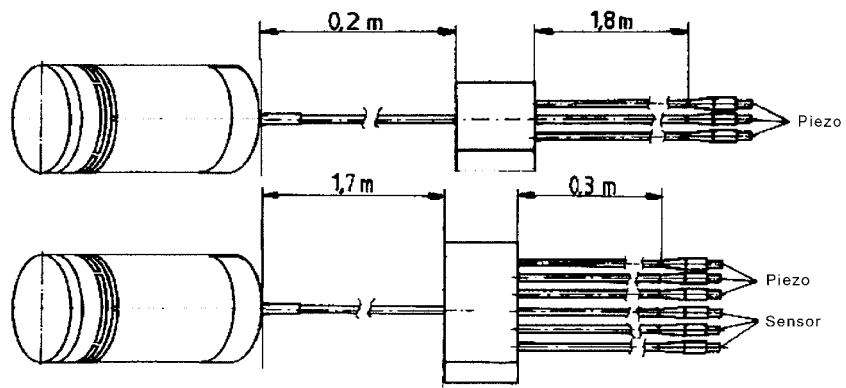
- S-325.3SD**
High-Dynamics Piezo Z/Tip/Tilt Platform, 5 mrad, 30 μm , SGS, Sub-D Connector
- S-325.3SL**
High-Dynamics Piezo Z/Tip/Tilt Platform, 5 mrad, 30 μm , SGS, LEMO Connector
- S-325.30L**
High-Dynamics Piezo Z/Tip/Tilt Platform, 5 mrad, 30 μm , Open-Loop, LEMO Connector

Open-Loop and Closed-Loop Operation

In open-loop mode, the platform linear motion is roughly proportional to the applied voltage. The S-325.30L open-loop model is ideal for high-bandwidth, 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-325.3SL model is equipped with high-resolution strain gauge sensors and provides absolute position control, high linearity and high repeatability. The new E-616 controller/driver module (see p. 2-132) is ideally suited for tip/tilt OEM applications.

Application Examples

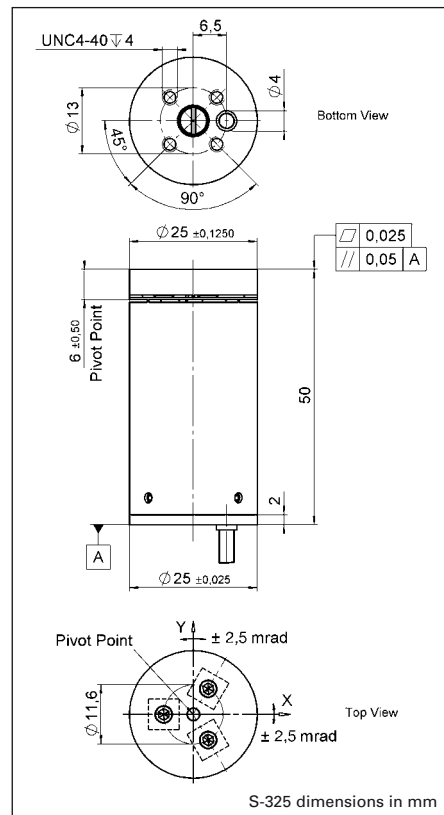
- Image processing / stabilization
- Optical trapping
- Laser scanning / beam steering
- Laser tuning
- Optical filters / switches
- Optics
- Beam stabilization



S-325 cable configuration (top: S-325.30L, bottom: S-325.3SL)

High Reliability and Long Lifetime

The compact S-325 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.



Technical Data

Model	S-325.30L	S-325.3SL	S-325.3SD	Units	Tolerance
Active axes	Z, θ_X , θ_Y	Z, θ_X , θ_Y	Z, θ_X , θ_Y		
Motion and positioning					
Integrated sensor	–	SGS	SGS		
Open-loop travel, 0 to +100 V	30	30	30	μm	min. (+20 %/-0 %)
Open-loop tip/tilt angle, 0 to +100 V	5	5	5	mrad	min. (+20 %/-0 %)
Closed-loop travel	–	30	30	μm	
Closed-loop tip/tilt angle	–	4	4	mrad	
Open-loop resolution	0.5	0.5	0.5	nm	typ.
Open-loop tip/tilt angle resolution	0.05	0.05	0.05	μrad	typ.
Closed-loop linear resolution	–	0,6	0,6	nm	typ.
Closed-loop tip/tilt resolution	–	0.1	0.1	μrad	typ.
Mechanical properties					
Unloaded resonant frequency	2	2	2	kHz	±20 %
Resonant frequency (with 25 x 8 mm glass mirror)	1	1	1	kHz	±20 %
Distance of pivot point to platform surface	6	6	6	mm	±0.5 mm
Platform moment of inertia	515	515	515	g • mm ²	±20 %
Drive properties					
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	9.3	9.3	9.3	μF	±20 %
Dynamic operating current coefficient	39	39	39	μA / (Hz • mrad)	±20 %
Miscellaneous					
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	°C	
Material casing	Aluminum	Aluminum	Aluminum		
Mass	0.065	0.065	0.065	kg	±5 %
Cable length	2	2	1.5	m	±10 mm
Sensor / voltage connection	LEMO	LEMO	Sub-D		

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 inter-dependent. The values quoted here refer to pure linear / pure angular motion. See equations (p. 2-84).
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)
Single-channel (1 per axis): E-610 OEM servo controller / amplifier (p. 2-110), E-625 servo controller bench-top (p. 2-114)
Versions with Sub-D connectors: E-616 servo controller for tip/tilt mirror systems (p. 2-132)

S-334 Miniature Piezo Tip/Tilt-Mirror

Fast Steering Mirror with up to 120 mrad Deflection



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

- **Miniature Design**
- **Optical Beam Deflection to 120 mrad (~ 6.8°)**
- **Coplanar Axes & Fixed Pivot Point; Eliminate Polarization Rotation**
- **Factory Installed Mirror**
- **Millisecond Response, Resolution to 0.2 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

Ordering Information	
S-334.1SD	High-Dynamics Piezo Tip/Tilt Platform, 25 mrad, SGS, Sub-D Connector, incl. Mirror
S-334.1SL	High-Dynamics Piezo Tip/Tilt Platform, 25 mrad, SGS, LEMO Connector, incl. Mirror
S-334.2SD	High-Dynamics Piezo Tip/Tilt Platform, 50 mrad, SGS, Sub-D Connector, incl. Mirror
S-334.2SL	High-Dynamics Piezo Tip/Tilt Platform, 50 mrad, SGS, LEMO Connector, incl. Mirror

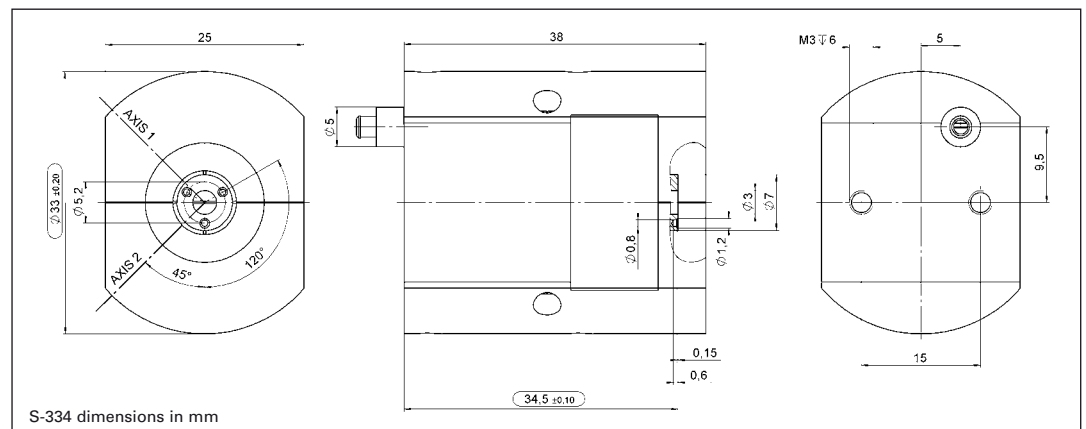
dynamic performance in both axes, faster response and better linearity. It also prevents polarization rotation.

High Reliability and Long Lifetime

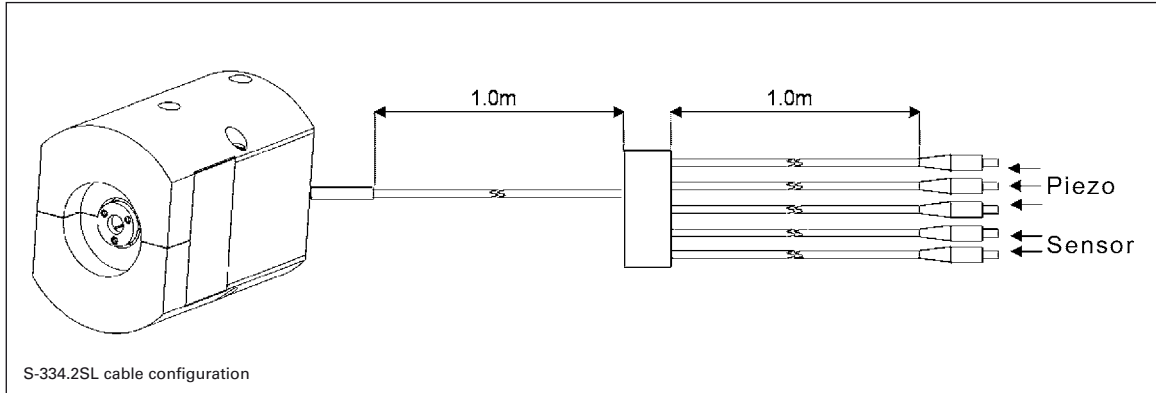
The compact S-334 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and provide better performance and reliability than conventional piezo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

Application Examples

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



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



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	$\pm 20\%$
Load capacity	0.2	0.2	N	Max.
Distance of pivot point to platform surface	6	6	mm	$\pm 1\text{ mm}$
Platform moment of inertia	1530	1530	$\text{g} \cdot \text{mm}^2$	$\pm 20\%$
Standard mirror (mounted)	diameter: 10 mm, thickness: 2 mm; BK7, $\lambda/5$, R > 98 % ($\lambda = 500\text{ nm}$ to $2\ \mu\text{m}$)	diameter: 10 mm, thickness: 2 mm; BK7, $\lambda/5$, R > 98 % ($\lambda = 500\text{ nm}$ to $2\ \mu\text{m}$)		
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance per axis	3	3	μF	$\pm 20\%$
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	$^{\circ}\text{C}$	
Material casing	Titanium	Titanium		
Mass	0.065	0.065	kg	$\pm 5\%$
Cable length	2	2	m	$\pm 10\text{ mm}$
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.

Program Overview

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

Request or download the complete PI Nanopositioning & Piezo Actuator Catalog



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