Fast Steering Mirrors with Piezoelectric Drives , / - - 3

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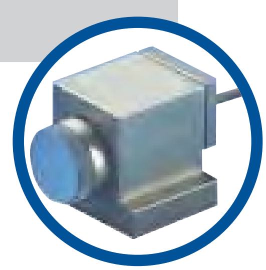


Contents

Active Optics / Steering Mirrors

Active Optics

Tip/Tilt Mirrors/Scanners, Beam Controllers, Mirror Translators

S-334 long-range steering mirror.

PI offers a wide range of ultra-fast piezo tip/tilt platforms and scanners.

These systems can perform optical beam steering over ranges of up to 100 mrad, have extremely low response times (milliseconds to microseconds) and resolutions in the nanoradian range. They are ideal for dynamic operation (e.g. tracking, scanning, drift and vibration cancellation) as well as static positioning of optics and samples.

Typical Applications in Active Optics

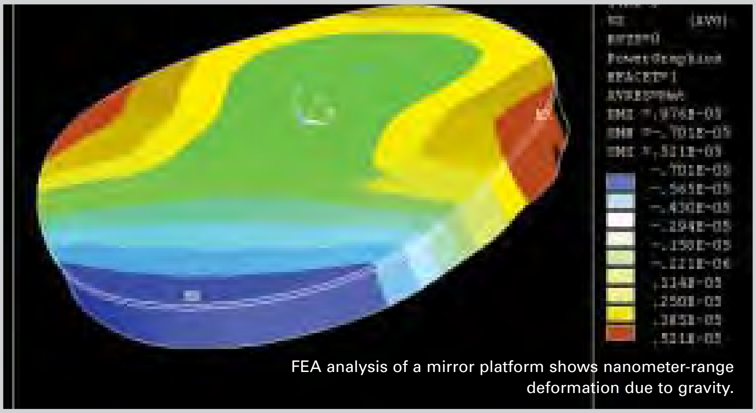
- Mass storage device testing and manufacture (CD, DVD mastering)
- Beam steering, alignment, switching
- Interferometry, Fabry-Perot filters
- Dynamic error correction (e.g. in polygon scanning mirrors)
- Optical path length stabilization
- Vibration cancellation (laser systems, imaging)
- Image stabilization (astronomical telescopes, imaging)
- Image resolution enhancement (pixel multiplication, dithering)
- Laser beam stabilization (resonators, optical setups)
- Laser beam scanning (lithography, optical setups)
- Laser beam steering and tracking (telecommunication satellites, etc.)
- Bore-sight systems

Basic design of an active optics platform featuring three actuators and four sensors

PI System Solutions

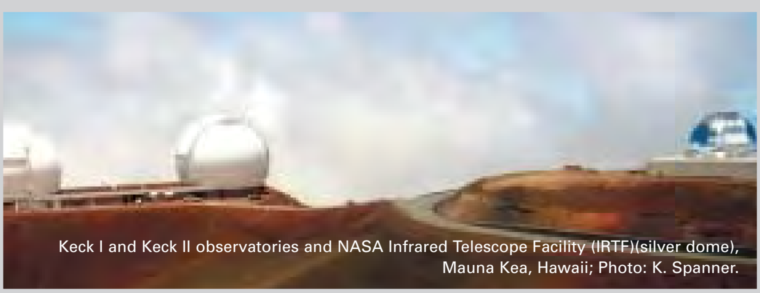
- Standard, OEM and custom designs
- One-, two- or three-axis systems with nanoradian/sub-nanometer resolution
- Microsecond response time
- Closed-loop operation for highest linearity and repeatability
- Optional integrated capacitive position sensors for extremely high accuracy, stability and resolution
- Optimized mechanical design, control algorithms and software for higher throughput
- High-performance controllers and amplifiers (digital, analog, modular, OEM)
- Patented feedforward techniques for rapid settling
- Dynamic Digital Linearization (DDL) to eliminate tracking error
- Finite Element Analysis (FEA) computer-designed flexures for ultra-precise trajectory control
- Invar, titanium, steel and aluminum versions for optimized thermal match
- Standard platforms accommodate optics to 100 mm in diameter
- Custom designs for optics up to 300 mm diameter (astronomical telescopes)

Reasons for Choosing PI


FEA analysis of a mirror platform shows nanometer-range deformation due to gravity.

- PI employs the most-experienced nanopositioning systems R&D and production teams
- Large variety of standard and custom systems available
- In-house PZT ceramics manufacture ensures high level of quality
- PICMA® ceramic-encapsulated piezo drives improve reliability
- Modern test, simulation and production equipment
- In-house controller development
- State-of-the-art metrology lab with 6-way isolaton (2 x thermal, 2 x seismic, acoustic and aerodynamic) for meaningful sub-nanometer measurements
- In-house design & manufacture of high-resolution capacitive sensors (sub-nanometer accuracy)
- Patented vibration-eliminating feedforward techniques for highest bandwidth
- ISO-9001 certified since 1994

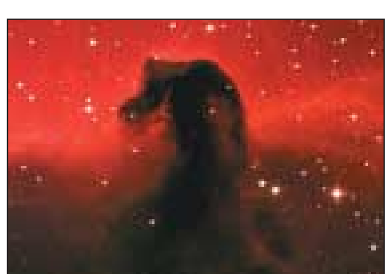
PI Active Optics in Astronomical Telescopes


Keck I and Keck II observatories and NASA Infrared Telescope Facility (IRTF)(silver dome), Mauna Kea, Hawaii; Photo: K. Spanner.

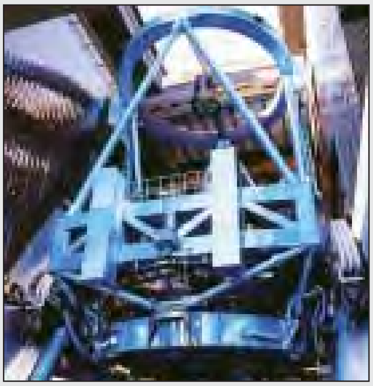
Resolution in large earthbound telescopes is limited by atmospheric turbulence and vibrations. During the last 15 years PI has designed several large-aperture tip/tilt systems for image stabilization. Piezoelectrically driven active secondary mirrors can improve the effective resolution up to 1000% by correcting for these image shifts in real time, especially during long integrations with weak light sources.

Momentum Compensation

Due to the inertia of the large mirrors and the high accelerations required to correct for image fluctuations, significant forces can be induced in the telescope structure, causing unwanted vibrations. PI has developed momentum compensation systems integrated into the tip/tilt platforms which cancel undesirable vibrations and thus offer significantly better stabilization than uncompensated systems.


The Horsehead Nebula; Photo: Brian Lula.

PI Active Optics in Astronomical Telescopes



View of the 8.2 m Subaru infrared telescope in Hawaii (from http://SubaruTelescope.org/Index.html), printed with permission of NAOJ.

Active tip/tilt mirror for the Subaru Telescope (Mauna Kea, Hawaii).
Mirror diameter: 150 mm
Tip/tilt range: ±600 µrad
Resonant frequency: 610 Hz

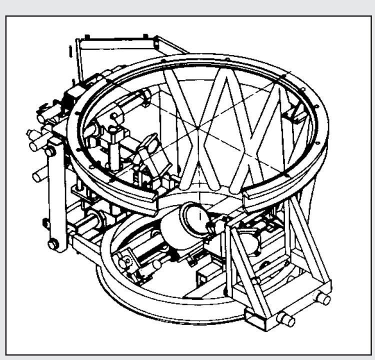
Active tip/tilt mirror for the Subaru telescope, rear view.

Active tip/tilt mirror for the United Kingdom infrared telescope (UKIRT) on Mauna Kea, Hawaii with Hexapod 6-D alignment system (for information on Hexapod systems, see the "Hexapods / Micropositioning" section).
Mirror diameter: 314 mm
Tip/tilt range: ±500 µrad
Resonant frequency: 280 Hz

Active secondary mirror for NASA Infrared Telescope Facility (IRTF) on Mauna Kea, Hawaii,with Hexapod 6-D alignment system (for information on Hexapod systems, see the "Hexapods / Micropositioning" section).
Mirror diameter: 244 mm
Tip/tilt range: ±250 µrad
Resonant frequency: 490 Hz

Active tip/tilt mirror system for the Keck Outrigger telescope in Hawaii. The units are controlled by a high-performance digital controller with a fiber optic interface (not shown).
Mirror diameter: 250 mm
Tip/tilt range: ±150 µrad
Resolution: nanoradian range
Position measurement: capacitive

Active secondary tip/tilt mirror for the 2.2 m ESO (European Southern Observatory) telescope in La Silla, Chile.
Mirror diameter: 100 mm
Tip/tilt range: ±400 µrad
Resonant frequency: 900 Hz



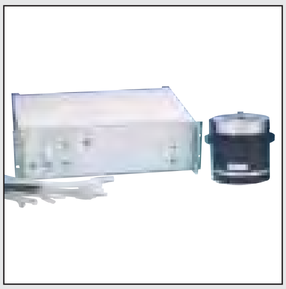
Telescope structure with active secondary mirror (from "Progress Report on DISCO: A Project for Image Stabilization at the 2.2 m Telescope," F. Maaswinkel, S. D'Odorico und G. Huster, ESO, F. Bortoletto, Istituto di Astronomia, University of Padova, Italy).

Active Optics / Steering Mirrors

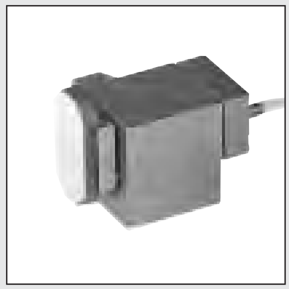
System Experience

PI offers the largest selection worldwide of high-resolution piezo actuators, nanopositioning systems and high-bandwidth tip/tilt systems for industrial and scientific applications.

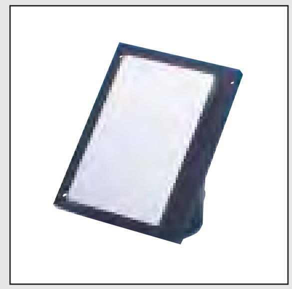
The following page shows but a few examples of the steering mirrors developed over the last few years. The systems shown were designed for special customer applications and are not available off the shelf; many other custom systems are subject to non-disclosure agreements and cannot be shown at all.



Custom tip/tilt mirror system with controllers for the Subaru telescope.

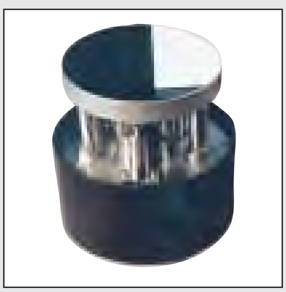


Custom high-speed tip/tilt mirror system.



Custom 2-axis tip/tilt mirror system.

Custom optics focusing and alignment system. Clear aperture: 75 mm, position measurement with 3 capacitive sensors.



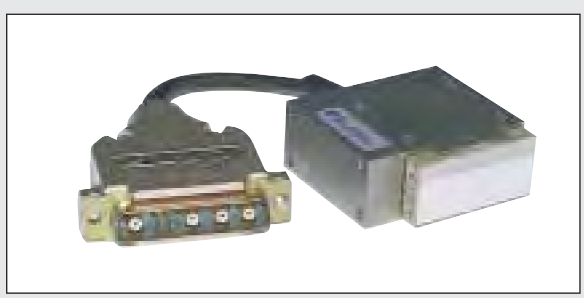
Custom 2-axis tip/tilt mirror system (100 mm Diameter).

Custom tip/tilt mirror sytem with controller for astronomical teleskopes.

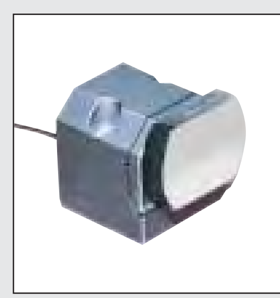
2-axis tip/tilt mirror system for astronomical telescopes, with digital servo-controller, fiberlink and digital transmission system for the capacitive sensor signals.

2-axis tip/tilt mirror with manual coarse adjustment.

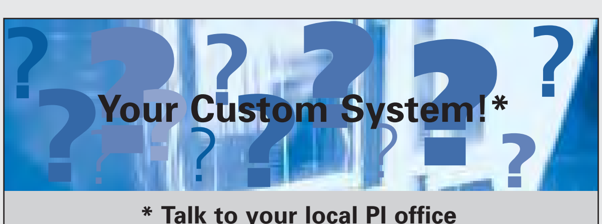
Custom tip/tilt mirror system with capacitive sensors for position control.



Custom tilt mirror system with capacitive sensors for closed-loop position control.



Custom high-speed tilt mirror.

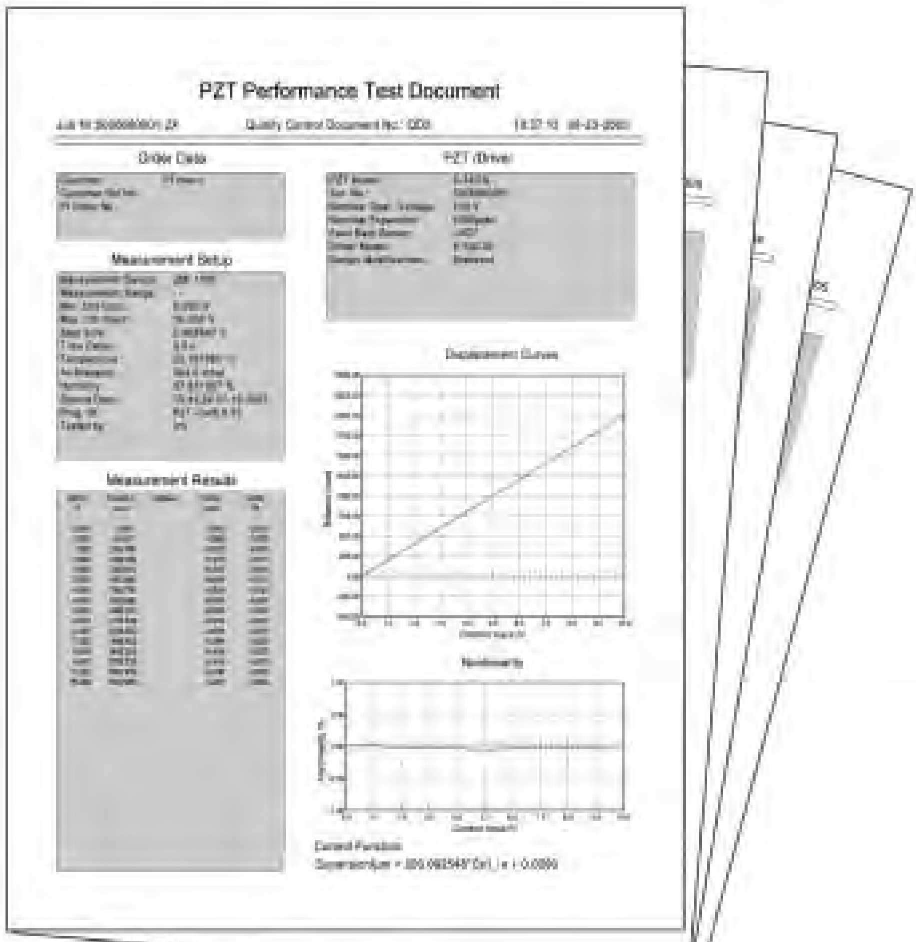


Test and Calibration—Why High-Quality Nanometrology Equipment Matters

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

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

Additionally, as part of our philosophy of continuous improvement, formal NIST traceability is scheduled to be established by the end of 2006.



Performance report for an S-340 tip/tilt system, measured with Zygo interferometer. All PI tip/tilt systems are shipped with performance reports.

An S-334 long-range tip/tilt mirror calibrated with a Moeller Wedel autocollimator.

An S-340 tip/tilt mirror calibrated with a Zygo interferometer.

Selection Guide

Active Optics / Steering Mirrors

Single-Axis Tip/Tilt Mirrors

*Models	Description	Number of Axes	Tilt Angle / opt. Deflection [mrad]	Mirror-Size	Linear Travel [µm]	Sensor	Page
S-224	with mirror, compact, very fast	1	2.2 / 4.4	Ø 15x4	–	–	3-14
S-226	with mirror, compact, very fast, with sensor.	1	2.0 / 4.0	Ø 15x4	–	SGS	3-14

1 – 3 Axis (Tripod) Piezo Phase Shifters / Tip/Tilt Systems with Clear Aperture

*Models	Description	Number of Axes	Tilt Angle / opt. Deflection [mrad]	Mirror-Size	Linear Travel [µm]	Sensor	Page
S-303	Extremely precise, 25 kHz resonant frequency	1	–	–	3	– / capacitive	3-12
S-310	Clear aperture, linear actuator	1	–	–	6	–	3-16
S-311	Clear aperture, tip/tilt and linear actuators	3	0.6 / 1.2	–	6	–	3-16
S-314	Clear aperture, linear actuator	1	–	–	12	–	3-16
S-315	Clear aperture, linear actuator	3	1.2 / 2.4	–	12	–	3-16
S-316	Clear aperture, closed-loop, tip/tilt and linear actuators	3	1.2 / 2.4	–	12	SGS	3-16
P-528	Z-axis and tip/tilt platform 66 x 66 mm clear aperture	3	2 / 4	–	200	capacitive	2-52
P-541	Z-axis and tip/tilt platform 80 x 80 mm clear aperture	3	2 / 4	–	100	capacitive / SGS	2-48 / 2-50

3-Axis (Tripod) Piezo Tip/Tilt Systems (Without Clear Aperture)

*Models	Description	Number of Axes	Tilt Angle / opt. Deflection [mrad]	Mirror-Size	Linear Travel [µm]	Sensor	Page
S-325	3-axis tip/tilt and Z-axis stages	3	5 / 10	–	30	SGS	3-18

2-Axis (Orthogonal) Piezo Tip/Tilt Systems

*Models	Description	Number of Axes	Tilt Angle / opt. Deflection [mrad]	Mirror-Size	Linear Travel [µm]	Sensor	Page
S-334	Largest deflection: 100 mrad, optical with mirror, ultra-compact.	2	50 / 100	Ø 10x2	–	SGS	3-20
S-330	Orthogonal 2-axis tip/tilt system for optics to 2” diameter.	2	2 / 4	–	–	SGS	3-22
S-340	Orthogonal 2-axis tip/tilt system for optics to 4” diameter.	2	2 / 4	–	–	LVDT	3-24

Microscope Objective Scanners / Nanofocussing Systems

*Models	Description	Number of Axes	Tilt Angle / opt. Deflection [mrad]	Mirror-Size	Linear Travel [µm]	Sensor	Page
P-725	PIFOC®, long travel range, compact, very accurate.	1	–	–	100 to 460	capacitive	2-22
P-721	PIFOC®, compact, very accurate.	1	–	–	100	capacitive	2-20

2-Axis XY Scanners for Interlacing

*Models	Description	Number of Axes	Tilt Angle / opt. Deflection [mrad]	Mirror-Size	Linear Travel [µm]	Sensor	Page
P-713/P-714	Compact, low-profile scanner.	2	–	–	15x15	SGS	2-56

Tip/Tilt Mirrors for Large Optics (e.g. Astronomical Telescopes) See p. 3-5

*Ask about custom sizes, sensors or special designs.
More custom systems: p. 3-5, p. 3-6

Recommended Amplifier/Controller Reference List

The list below is referred to by Technical Data Tables and should be used as a general guide only. For most PI piezo actuators and nanopositioning systems more than one amplifier/controller combination is available. The best choice depends on the requirements of the particular application. For low dynamics applications, a high-power controller is not necessary and in many OEM applications, compact PCB versions are preferable to the 19" modular units. Be sure to talk to a PI Sales Engineer. The Selection Guide covering all piezo electronics can be found on pp. 6-8 *ff.*

A – LVPZT Systems w/o sensors **

Low-dynamics applications:

E-660.00* (desktop) or
E-660.OE* (OEM module)

B – HVPZT Systems w/o sensors

a) low-dynamics applications:
E-463 3-channel desktop amp

b) Quasi-static applications:
E-461.00* (desktop) or
E-461.OE* (OEM module)

C – Systems without sensors

E-663 3-channel desktop amp or E-610.00* OEM amplifier module

D – Systems with SGS

E-665.SR* amplifier/controller (desktop) or E-610.S0* OEM amplifier/controller module or E-621.SR OEM amplifier/controller module, RS-232

E – Systems with LVDT

E-665.LR* amplifier/controller (desktop) or E-610.L0* OEM amplifier/controller module or E-621.LR OEM amplifier/controller module, RS-232

F – Systems with cap. sensors

E-665.CR amplifier/controllers (desktop) or E-610.C0* OEM amplifier/controller module or E-661.CP.

G – Systems without sensors**

a) Low- to medium-dynamics applications:
E-500 / E-501 chassis + E-503 (3-channel amplifier module), optional: E-515 / E-516 interface/display module.
Alternative: E-663 (3-channel desktop amplifier).

b) High-dynamics applications:
E-500 / E-501 chassis + E-505* (1-channel amplifier module), optional: E-515 / E-516 interface/display module

H – Systems with sensor

a) Low- to medium-dynamics applications:
E-500 / E-501 chassis + E-503 (3-channel amplifier module) +E-509.xy controller (x: sensor type; y: # of axes; see E-509 description p. 6-22), optional: E-515 / E-516 interface/display module, pp. 6-28 / 6-26.

b) High-dynamics applications:
E-500 chassis + E-505* (1-channel amplifier module) +E-509.xy controller (x: sensor type; y: # of axes; see E-509 description p. 6-22), optional: E-515 / E-516 interface/display module, pp. 6-28 / 6-26.

I – Systems without sensors**

a) Low- to medium-dynamics applications:
E-500 / E-501 chassis + E-507* (1-channel amplifier module), optional: E-515 / E-516 interface/display module, pp. 6-28 / 6-26.

b) High-dynamics applications:
E-420 (OEM amplifier module) or E-470 (1-channel amplifier, 19") or E-472 (2-channel amplifier, 19")

J – Systems with sensor

a) Low- to medium-dynamics applications:
E-500 / E-501 chassis + E-507* (1-channel amplifier module) +E-509.xy (x: sensor type; y: # of axes; see E-509 description p. 6-22), optional: E-515 / E-516 interface/display module, pp. 6-28 / 6-26.

b) High-dynamics applications:
E-471 +E-509.x1 (x: sensor type, see E-509 description p. 6-22), optional: E-515 / E-516 interface/display module, pp. 6-28 / 6-26.

K

E-710 digital controller, sub-D special connector for drive & sensors

L

E-710.4CL digital controller, LEMO connectors for drive & sensors.
Alternative:
E-501.10 / E-612.C0.

M

E-750 digital controller, sub-D special connector for drive & sensors.

N

E-664 NanoCube® controller.
Alternative: E-760 NanoCube® controller card.

Cited devices are described in detail on the pages listed below:	
E-420	6-48
E-461	6-44
E-463	6-40
E-470	6-48
E-471	6-48
E-472	6-48
E-480	6-50
E-500	6-18
E-501	6-18
E-501.10	6-38
E-503	6-24
E-505	6-25
E-507	6-23
E-509	6-22
E-515	6-28
E-516	6-26
E-610	6-34
E-612	6-38
E-621	6-36
E-660	6-45
E-661	6-38
E-663	6-41
E-664	6-32
E-665	6-30
E-710	6-14
E-750	6-12
E-760	6-33
E-831	6-42

* Depending on the number of axes (channels) to be driven, more than one module may be required.
** Open-loop

Designs

Piezo Tip/Tilt Mirrors & Scanners: Fundamentals

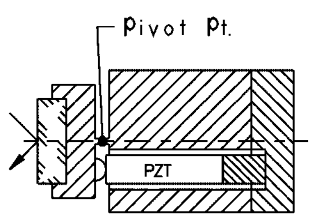


Fig. 1. Single-flexure, single-piezo actuator tilt platform design.

Single-Axis Systems / Scanners

Two designs of single-axis (θ_x) tilt platforms are available:

I. Single-Flexure, Single-Actuator Tilt Platform

Examples: S-224 and S-226, p. 3-14.

The platform is supported by one flexure and pushed by one linear piezo actuator (see Fig. 1). The flexure determines the pivot point and doubles as a preload for the piezo actuator. The advantages of the single-flexure, single-actuator design are the straightforward construction, low cost and small size. If angular stability over a wide temperature range is a critical issue, the differential piezo drive is recommended.

II. Differential-Piezo-Drive Tilt Platform

This design features two piezo actuators operating in push/pull mode supporting the platform (see Fig. 2). The actuators are wired in a bridge which is supplied with a constant and a variable drive voltage. The case features integrated zero-friction, zero-stiction flexures which assure excellent guiding accuracy.

The differential design exhibits excellent angular stability over a wide temperature range. With this arrangement, temperature changes only affect the vertical position of the platform (piston motion) and have no influence on the angular position. In the closed-loop models, availability of two sensor signals permits better linearity and resolution.

A variety of single- and multi-axis implementations is possible.

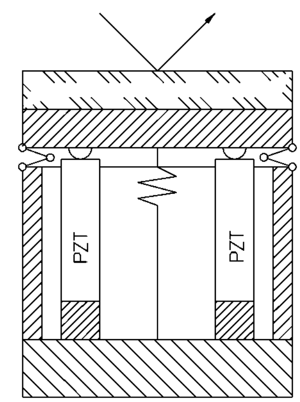


Fig. 2. Design of a differential-piezo-drive tilt platform.

Multi-Axis Tip/Tilt Systems / Scanners

PI offers two standard designs, both using parallel kinematics. Parallel kinematics systems have the following advantages over serial systems: only one moving platform, fixed pivot point, better dynamics, smaller form-factor. In addition, the design offers better linearity than attainable with two single-axis systems (e.g. two galvoscanners) in a stacked configuration.

I. Piezo Tripod Z/Tip/Tilt Platform

Examples: S-315 and S-316, p. 3-16, S-325 p. 3-18.

The platform is supported by three piezo actuators spaced at 120° intervals. Because expansion of an individual actuator affects both θ_x and θ_Y, more complex control algorithms are required.

With coordinate transformation, platform position commands can be resolved into targets for individual actuators (see the equations and Fig. 3 for details). The piezo tripod has one advantage over the differential drive: in addition to tilt motion, it allows active vertical control (piston motion) of the platform—an important feature for applications involving optical path-length adjustment (phase-shifting).

Also, the design allows for a central clear aperture, ideal for transmitted-light applications. As with the differential drives, temperature changes have no effect on the angular stability.

II. Differential-Piezo-Drive Tip/Tilt Platform

Examples: S-334, S-330, S-340, p. 3-20, 3-22 and 3-24.

The platform is driven by two pairs of piezo actuators arranged at 90° angles. Each pair is controlled as a unit in push-pull mode. The four actuators are connected in a bridge circuit and supplied with one fixed and two variable voltages. Because each actuator pair is parallel to one of the orthogonal tip/tilt axes θ_X and θ_Y, no coordinate transformation is required.

Like the piezo tripod design, the differential drive exhibits excellent angular stability over a wide temperature range. In the closed-loop models, availability of two sensor signals permits better linearity and resolution.

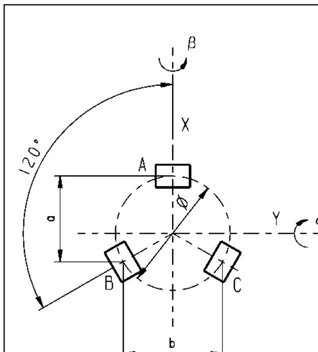


Fig. 3. Piezo tripod drive: A, B, C are the linear displacements of the respective actuators.

$$\alpha = \frac{2A - (B+C)}{2a}$$

$\beta = (B-C) / b$

$z = (A+B+C) / 3$

Example:
S-315 tip/tilt platform (see page 3-16).
Ø = 13.9 mm
a = 10.4 mm
b = 12.0 mm
A, B, C 0 to 12 µm

Dynamic Behavior

The maximum operating frequency of a tilt platform is heavily dependent on its mechanical resonant frequency. The performance characteristics of the amplifier, servo-controller and sensors are also very important. To estimate the effective resonant frequency of the tilt mirror system (platform + mirror), the moment of inertia of the mirror substrate must first be calculated.

Moment of inertia of a rotationally symmetric mirror:

$$I_M = m\left[\frac{3R^2 + H^2}{12} + \left(\frac{H}{2} + T\right)^2\right]$$

Moment of inertia of a rectangular mirror:

$$I_M = m\left[\frac{L^2 + H^2}{12} + \left(\frac{H}{2} + T\right)^2\right]$$

where:

m = mirror mass [g]

I_M = moment of inertia of the mirror [g · mm²]

L = mirror length perpendicular to the tilt axis [mm]

H = mirror thickness [mm]

T = distance, pivot point to platform surface (see technical data table for individual model) [mm]

R = mirror radius [mm]

Using the resonant frequency of the unloaded platform (see individual technical data table) and the moment of inertia of the mirror substrate, the system resonant frequency is calculated according to the following equation:
Resonant frequency of a tilt platform/mirror system

$$f' = \frac{f_0}{\sqrt{1 + I_M/I_0}}$$

where:

f' = resonant frequency of platform with mirror [Hz]

f_0 = resonant frequency of unloaded platform [Hz]

I_0 = moment of inertia of the platform (see technical data table for the individual model) [g · mm²]

I_M = moment of inertia of the mirror [g · mm²]

For more information on static and dynamic behavior of piezo actuators, see pp. 4-25 *ff.* in the "Tutorial" section.

S-303

High-Speed Piezo Phase Shifter (Mirror Translator) with Direct Metrology Option

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

- **25 kHz Resonant Frequency for Sub-Millisecond Dynamics**
- **<0.1 Nanometer Resolution**
- **Capacitive Sensor Option for Highest Linearity and Stability**
- **Invar Option for Highest Thermal Stability**
- **Aperture with Open-Loop Versions**
- **3 µm Travel Range**
- **Compact Size: 30 mm Diameter x 10 mm**

S-303 phase shifters are extremely fast and compact systems based on a piezo tripod drive. They offer angstrom level resolution, piston movement up to 3 µm with sub-msec response and settling dynamics. The S-303 is designed for mirrors and optics up to 25 mm diameter and can be mounted in any orientation. Open- and closed-loop versions are available.

S-303.0L: Open-Loop Z-Positioner

The S-303.0L open-loop model is ideal for applications where the position is controlled by an external loop and an external sensor. The platform position corresponds roughly to the drive voltage of the piezo actuators. The clear aperture was integrated for transmitted-light applications.

Application Examples

- Interferometry
- Optical path tuning
- Beam stabilization
- Laser physics
- Cavity tuning

S-303.CD: Superior Accuracy Through Direct-Motion-Metrology Capacitive Feedback Sensors

The S-303.CD closed-loop models are equipped with non-contact, zero-friction, direct-measuring two-plate capacitive position sensors and were designed for applications requiring nanometer positioning accuracy and stability. Capacitive sensors are absolute-measuring high-bandwidth devices and exhibit no periodic errors. Unlike conventional sensors, direct metrology measures the position of the platform directly rather than the strain in the actuator or guiding system. It improves phase fidelity and permits motion linearity of better than 0.03 % and effective resolution of better than 0.1 nanometers. This technique, combined with the inherent precision of the PI two-plate capacitive sensor and the temperature-compensated design, results in higher linearity scans, and provides superior responsiveness, resolution, repeatability and stability.

Working Principle / Lifetime

S-303 systems were developed for industrial applications where 10^9 motion cycles or more must be performed without failure or performance loss. The S-303 drive units incorporate PICMA® low-voltage multilayer piezo actuators. These highly optimized and ceramic-encapsulated drives are more robust than conventional piezo actuators, and feature superior lifetime in static and dynamic applications. Since drives and sensors in the S-303 are frictionless and not subject to wear and tear, these units offer an exceptionally high level of reliability.

Ordering Information

S-303.0L
Piezo Phase Shifter, 3 µm, Open-Loop

S-303.CD
Piezo Phase Shifter, 2 µm, Capacitive Sensor

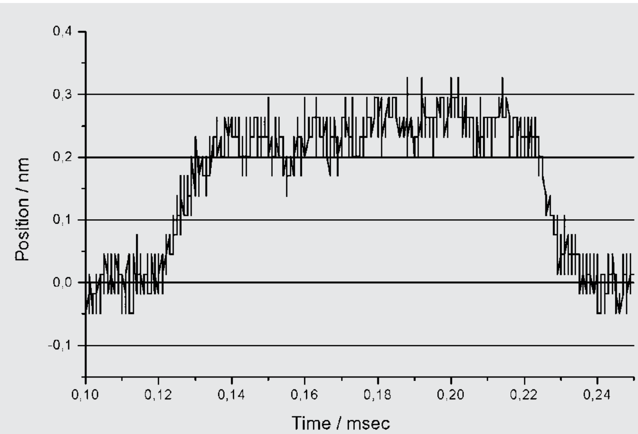
S-303.0Li
Piezo Phase Shifter, 3 µm, Open-Loop, Invar

S-303.CDi
Piezo Phase Shifter, 2 µm, Capacitive Sensor, Invar

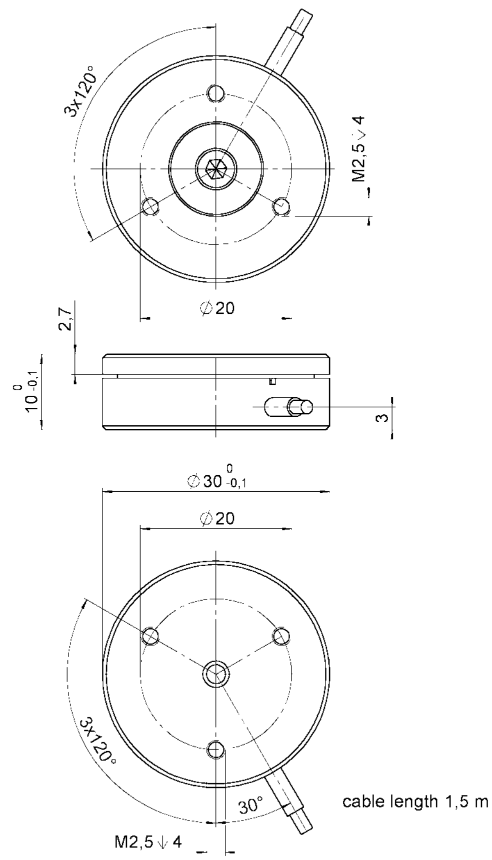
Ask about custom designs!

Notes

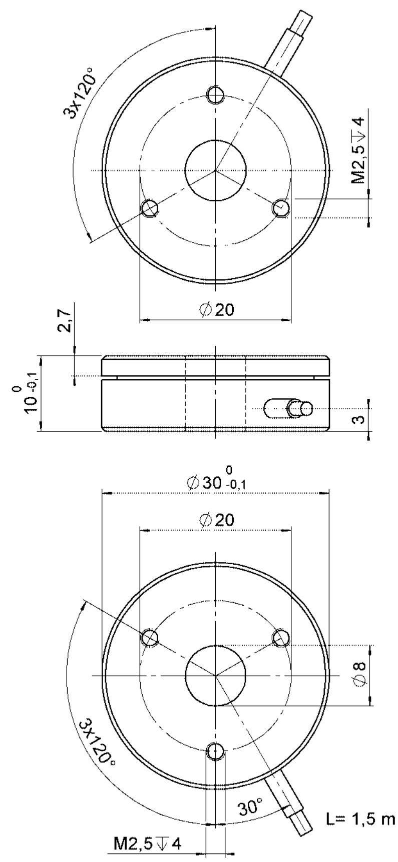
See the "Selection Guide" on p. 3-8 for comparison with other steering mirrors.



A 250 picometer step (0.25 nm) of the S-303 platform, controlled by an E-503 amplifier module and an E-509.C1A servocontroller module. Measured with special ultra-high-resolution capacitive gauge, ±0.02 nm resolution.



Dimensions of the S-303.CDx in mm



Dimensions of the S-303.0Lx in mm

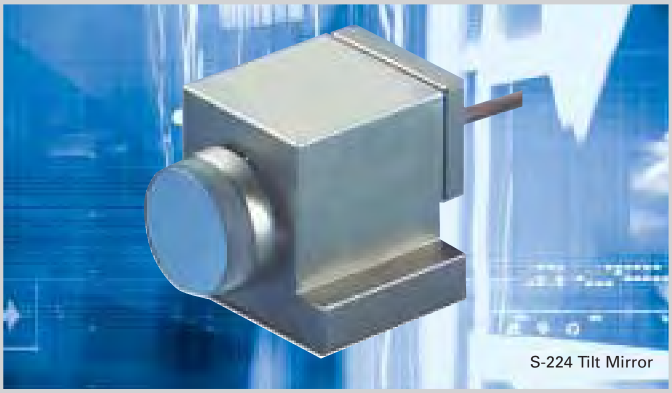
Technical Data

Models	S-303.CDx	S-303.0Lx	Units	Notes see page 3-26
Active axes	Z	Z		
Min. Open-loop travel @ -20 to +120 V	3	3	µm ±20%	A2
Closed-loop travel	2	-	µm	A5
Integrated feedback sensor	capacitive	-		B
* Closed-loop / open-loop resolution	0.03 / 0.03	- / 0.03	nm	C1
** Closed-loop linearity (typ.)	0.03	-	%	
Full-range repeatability (typ.)	0.7	-	nm	C3
Stiffness			N/µm ±20%	D1
Max. (±) normal load	0.5	0.5	N	D4
Electrical capacitance	0.9	0.9	µF ±20%	F1
*** Dynamic operating current coefficient (DOCC)	50	50	µA/(Hz x µm)	F2
Unloaded resonant frequency	25	25	kHz ±20%	G2
Operating temperature range	-20 to 80	-20 to 80	°C	H2
Voltage connection	D	VL		J1
Sensor connection	D	-		J2
Mass	100	30	g ±5%	
Body material	Al, Invar optional	Al, Invar optional		L
Recommended Amplifier / Controller (codes explained page 3-9)	F, M	G, C		

* For calibration information see p. 3-7. Resolution of PZT Nanopositioners is not limited by friction or stiction. Noise equivalent motion with E-503, E-710.
** With digital controller, analog controllers will provide a linearity of typ. 1 nm.
*** Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 1 µm at 10 Hz requires approximately 0.5 mA drive current.

S-224 · S-226

High-Speed Miniature Piezo Tilt Mirror (Beam Controller)


S-224 Tilt Mirror

- **Sub-µrad Resolution**
- **Sub-Millisecond Response**
- **Up to 4.4 mrad Optical Beam Deflection**
- **Closed-Loop Versions for Better Linearity**
- **Includes BK7 Mirror**
- **Zero Friction Flexure Guiding System**

S-224/S-226 miniature tilt platforms are extremely fast and compact tilt units, providing a tilt range of 2.2 mrad and sub-millisecond response. The S-224 and S-226 are delivered with a Ø 15 x 4 mm BK7 glass mirror.

Open- and Closed-Loop Operation

The S-224 is specifically designed for open-loop operation. The S-226 closed-loop version is available for highest accuracy and repeatability. In open-loop operation, the platform's angular position is roughly proportional to the drive voltage (see page 4-17 in the "Tutorial" section for behavior of open-loop piezos). Open-loop operation is ideal for applications where the position is controlled by data provided by an external optical sensor, a CCD camera, etc.

The closed-loop version (S-226) allows absolute position control, high linearity, and repeatability based on the internal ultra-high-resolution feedback sensor.

Working Principle / Lifetime

S-224/S-226 miniature tilt platforms are equipped with long-life, ceramic-encapsulated, high-performance PICMA® piezo drives pushing a frictionless, flexure-mounted platform. The flexure is FEA (finite element analysis) modeled for zero stiction, zero friction and exceptional guiding precision; it also serves as the pivot point and preload for the piezo actuator.

Since drives and guides are frictionless and not subject to wear and tear, these units offer an exceptionally high level of reliability.

Notes

See the "Selection Guide" on p. 3-8 for comparison with other steering mirrors.

See "Piezo Drivers & Nanopositioning Controllers" section for our comprehensive line of low-noise modular and OEM control electronics for computer and manual control.

Ordering Information

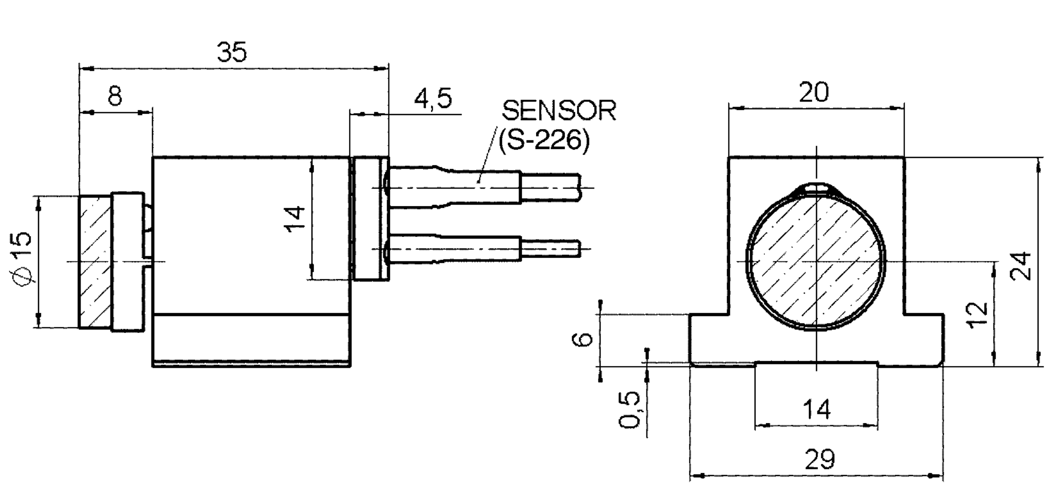
S-224.00
Piezo Tilt Platform 2.2 mrad (4.4 mrad optical) with Mirror, Open-Loop

S-226.00
Piezo Tilt Platform 2.0 mrad (4.4 mrad optical) with Mirror, Closed-Loop

Ask about custom designs!

Application Examples

- Laser beam steering & scanning
- Beam switching
- Correction of polygon scanner errors
- Laser beam stabilization



S-224, S-226 dimensions (in mm)

Technical Data

Models	S-224.00	S-226.00	Units	Notes see page 3-26
Active axes	θ_X	θ_X		
* Open-loop tilt angle @ 0 to 100 V	2.2	2.2	mrad ±20%	A2
* Closed-loop tilt angle	-	2.0	mrad	A3
Integrated feedback sensor	-	strain gauge		B
** Closed-loop / open-loop resolution	- / 0.05	0.1 / 0.05	µrad	C1
Closed-loop linearity (typ.)	-	0.2	%	
Full-range repeatability (typ.)	-	±3	µrad	C3
Electrical capacitance	1.5	1.5	µF ±20%	F1
*** Dynamic operating current coefficient (DOCC)	0.1	0.1	µA/(Hz x µrad)	F2
Unloaded resonant frequency (f_0)	9.0	9.0	kHz ±20%	G2
Resonant frequency w/ ø 15 x 4 mm glass mirror (included)	7.5	7.5	kHz ±20%	G3
Resonant frequency w/ ø 15 x 4 mm copper mirror	5.7	5.7	kHz ±20%	G3
Distance, pivot point to platform surface (T)	4	4	mm	
Platform moment of inertia	215	215	g · mm²	
Operating temperature range	- 20 to 80	- 20 to 80	°C	H2
Voltage connection	VL	VL		J1
Sensor connection	-	L		J2
Weight (w/o cables)	98	98	g ±5%	
Material (case / platform)	N-S / N-S	N-S / N-S		L
Recommended amplifier / controller (codes explained page 3-9)	G, C	H, D		

* Mechanical tilt, optical beam deflection is twice as large.

** For calibration information see p. 3-7.
Resolution of PZT tip/tilt platforms is not limited by friction or stiction.
Noise equivalent motion with E-503 amplifier.

*** Dynamic Operating Current Coefficient in µA per Hz and µrad. Example: Sinusoidal scan of 100 µrad at 10 Hz requires approximately 0.1 mA drive current.

S-310 – S-316

High-Speed Multi-Axis Tip/Tilt Platforms and Z Positioner (Mirror Translator)

S-310.10, S-316.10

- **10 mm Clear Aperture**
- **Piezo Tripod Design Allows Z Motion and Tilt**
- **Up to 2.4 mrad Optical Beam Deflection**
- **Piston Movement up to 12 µm**
- **Closed-Loop Versions for Better Linearity**
- **For Optics, Mirrors or Other Components**
- **Zero Friction Guiding Mechanism**
- **Single-Moving-Platform, Parallel-Kinematics Design: Equal Dynamics for all Axes, Better Linearity & Temperature Stability**

S-310 to S-316 multi-axis tip/tilt platforms and Z-positioners are fast and compact units based on a piezo tripod design (see page 3-10 for details and equations). They offer piston movement up to 12 µm and tilt movement up to 1.2 mrad (2.4 mrad optical) with sub-msec response and settling. The S-310 to S-316 systems are designed for mirrors and optics up to 25 mm diameter; the clear aperture is ideal for transmitted-light applications. The units can be mounted in any orientation.

Application Examples

- Image stabilization
- Beam switching
- Interferometry
- Optical filters
- Laser cavity tuning
- Laser beam stabilization
- Laser beam steering & scanning

Open / Closed-Loop Operation

In open-loop operation, the vertical position / platform angle roughly corresponds to the drive voltage (see the "Tutorial" section for behavior of open-loop piezos). The S-310 to S-315 open-loop models are ideal for applications where the position is controlled by an external loop based on data provided by a sensor (e.g. PSD, quad cell, CCD chip, ...). The S-316.10 closed-loop version allows absolute position control, high linearity and repeatability based on the internal ultra-high-resolution feedback sensor.

Working Principle

The S-310 to S-316 tilt platforms are equipped with three long-life, ceramic-encapsulated, high-performance PICMA® piezo drives (see page 3-7 for details and equations).

Available Versions

Five different versions are available:

- **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. The three piezo actuators are individually matched for equal displacement, providing straight motion with tilt errors of less than 70 µrad over the complete range.

- **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

Ordering Information

S-310.10
Vertical Piezo Positioner with Clear Aperture, 6 µm

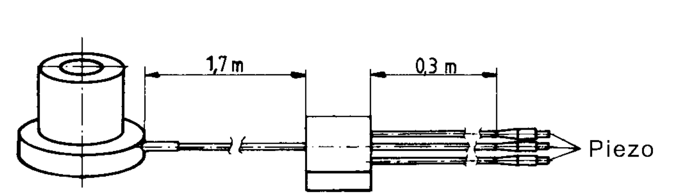
S-311.10
Multi-Axis Piezo Tip/Tilt Platform with Clear Aperture, 600 µrad, 6 µm

S-314.10
Vertical Piezo Positioner with Clear Aperture, 12 µm

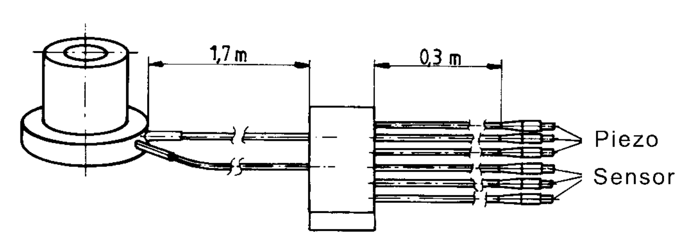
S-315.10
Multi-Axis Piezo Tip/Tilt Platform with Clear Aperture, 1200 µrad, 12 µm

S-316.10
Multi-Axis Piezo Tip/Tilt Platform with Clear Aperture, 1200 µrad, 12 µm, Closed-Loop

Ask about custom designs!



S-315 cable configuration

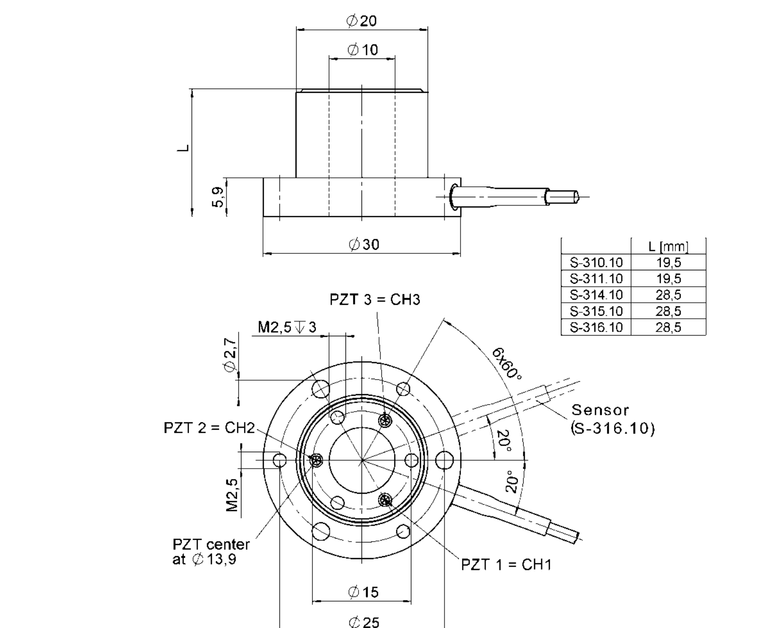


S-316 cable configuration

strain gauge position feedback sensors and can be driven individually (or in parallel) by a three-channel amplifier/position servo-controller. Vertical positioning (piston movement) and tip/tilt positioning are possible. The integrated position feedback sensors provide sub-µrad resolution and repeatability.

Higher Performance Through Parallel Kinematics

S-31x series tip/tilt systems feature a single moving platform, parallel-kinematics design. Compared to stacked, multi-axis systems, the parallel-kinematics design provides faster response and better linearity with equal dynamics for all axes in a smaller package.



S-310 - S-316 dimensions (in mm)

Technical Data

Models	S-310.10	S-314.10	S-311.10	S-315.10	S-316.10	Units	Notes see page 3-26
Active axes	Z	Z	Z, Θ_X, Θ_Y	Z, Θ_X, Θ_Y	Z, Θ_X, Θ_Y		
* Open-loop tilt angle @ 0 to 100 V	-	-	600	1200	1200	µrad ±20%	
* Closed-loop tilt angle	-	-	-	-	1200	µrad	A3
Open-loop linear travel @ 0 to 100 V	6	12	6	12	12	µm ±20%	A5
Closed-loop linear travel	-	-	-	-	12	µm	A6
Integrated feedback sensor	-	-	-	-	3 x strain gauge		B
** Closed-loop angular resolution	-	-	-	-	±0.05	µrad	C1
** Closed-loop / open-loop linear resolution	- / 0.1	- / 0.2	- / 0.1	- / 0.2	0.4 / 0.2	nm	C1
Stiffness (Z)	20	10	20	10	10	N/µm ±20%	D1
Electrical capacitance	0.7	1.4	3 x 0.23	3 x 0.45	3 x 0.45	µF ±20%	F1
*** Dynamic operating current coefficient (DOCC)	15	15	3 x 5	3 x 5	3 x 5	µA/(Hz x µm)	F2
Unloaded resonant frequency (f_0)	9.5	5.5	9.5	5.5	5.5	kHz ±20%	G2
Resonant frequency w/ ø 15 x 4 mm glass mirror	6.5	4.4	5.5	4.1	4.1	kHz ±20%	G3
Resonant frequency w/ ø 20 x 4 mm glass mirror	6.1	4.2	6.1	3.4	3.4	kHz ±20%	G3
Distance, pivot point to platform surface (T)	-	-	5	5	5	mm	
Platform moment of inertia	-	-	150	150	150	g · mm²	
Operating temperature range	- 20 to 80	- 20 to 80	- 20 to 80	- 20 to 80	- 20 to 80	°C	H2
Voltage connection	1 x VL, 2 m cable	1 x VL, 2 m cable	3 x VL, 2 m cable	3 x VL, 2 m cable	3 x VL, 2 m cable		J1
Sensor connection	-	-	-	-	3 x L, 2 m cable		J2
Weight (w/o cables)	45	55	45	55	55	g ±5%	
Material (case / platform)	N-S / N-S	N-S / N-S	N-S / N-S	N-S / N-S	N-S / N-S		L
Recommended amplifier/controller (codes explained p. 3-9)	G, C	G, C	G, C	G, C	H, D		

* Mechanical tilt, optical beam deflection is twice as large.
For maximum tilt range, all three piezo actuators must be biased at 50 V. Linear travel and tilt angle are interdependent. The values quoted here refer to pure linear / pure angular motion. See piezo tripod drive equation on page 3-10 for more information.

** For calibration information see p. 3-7.
Resolution of PZT tip/tilt platforms is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier.

*** Dynamic Operating Current Coefficient in µA per Hz and µm (per actuator). Example S-314.10: Sinusoidal scan of 10 µm at 10 Hz requires approximately 1.5 mA drive current.

S-325

High-Speed Piezo Tip/Tilt Platform and Z Positioner (Mirror Translator)

S-325

- Piezo Tripod Design Allows Z Motion and Tilt
- 10 mrad Optical Beam Deflection
- Piston Movement up to 30 µm
- Closed-Loop Versions for Better Linearity
- For Mirrors up to 25 mm (1”) Diameter
- Zero Friction Flexure Guides
- Single-Moving-Platform, Parallel-Kinematics Design: Equal Dynamics for all Axes, Better Linearity & Temperature Stability

The S-325 multi-axis tip/tilt platforms and Z-positioners are fast and compact units based on a piezo tripod design (see page 3-10 for details).

High Resolution, Rapid Motion and Stable Positioning

The S-325 offers piston movement up to 30 µm (ideal for path length adjustment) and tilt movement up to 5 mrad (mechanical tilt, which is equivalent to 10 mrad optical beam deflection) with sub-msec response and settling. The zero-friction PZT drives allow sub-nm linear resolution and sub-µrad angular resolution. The S-325 systems are designed for mirrors and optics up to 25 mm diameter and can be mounted in any orientation.

OEM-Proven

Developed for industrial applications, S-325s have performed 10^9 motion cycles without failure for OEM systems.

S-325.30L Open-Loop Z, Tip/Tilt Positioner

The S-325.30L open-loop model is ideal for applications where the position is controlled by an external loop based on data provided by a sensor (e. g. PSD, quad cell, CCD chip, etc.). 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-325.3SL Closed-Loop Z, Tip/Tilt Positioner

The S-325.3SL closed-loop version allows absolute position control, high linearity and repeatability based on internal position sensors. All three piezo linear actuators are equipped with high-resolution strain gauge sensors and can be driven individually (or in parallel). Vertical positioning (piston movement) and tip/tilt positioning are possible. The integrated position feedback sensors provide sub-µrad resolution (sub-nanometer for piston mode).

Ordering Information

S-325.3SL
Piezo Tip/Tilt Platform and Z-Positioner, 5 mrad, 30 µm, Closed-Loop

S-325.30L
Piezo Tip/Tilt Platform and Z-Positioner, 5 mrad, 30 µm, Open-Loop

Ask about custom designs!

Higher Performance Through Parallel Kinematics

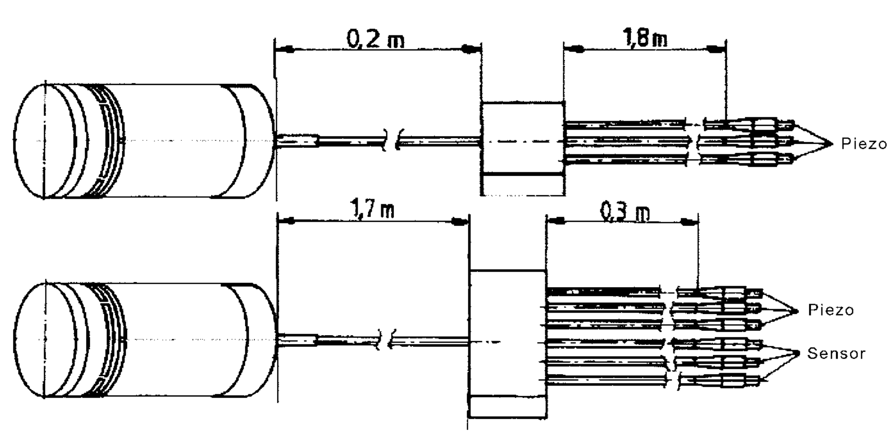
S-325 tip/tilt systems feature a single moving platform, parallel-kinematics design. Compared to stacked, multi-axis systems, the parallel-kinematics design provides faster response and better linearity with equal dynamics for all axes in a smaller package.

Working Principle / Lifetime

The S-325 tip/tilt platforms are equipped with three long-life, ceramic-encapsulated, high-performance PICMA® piezo drives. The closed-loop model features additional position feedback.
Since drives and guides are frictionless and not subject to wear and tear, these units offer an exceptionally high level of reliability.

Application Examples

- Image stabilisation
- Laser beam stabilization
- Beam switching
- Adaptive optics systems
- Laser beam steering and scanning
- Laser cavity tuning

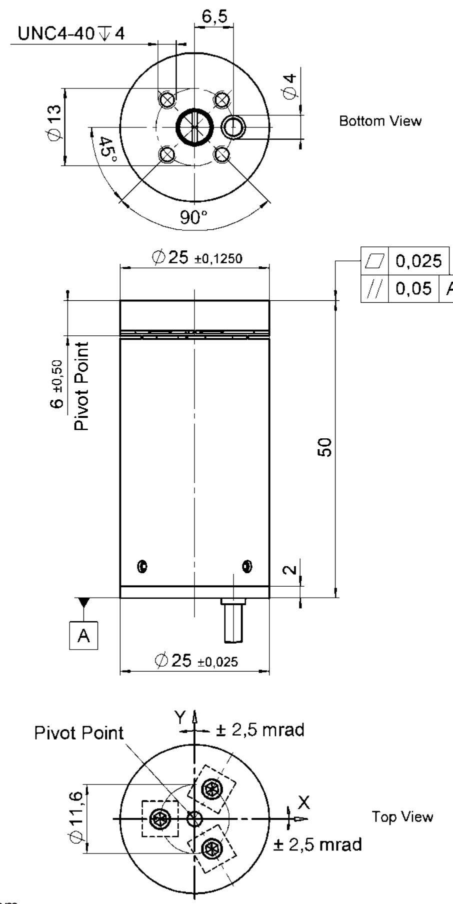


S-325 cable configuration (upper picture S-325.30L, lower picture S-325.3SL)

Notes

See the "Selection Guide" on p. 3-8 for comparison with other steering mirrors.

See "Piezo Drivers & Nanopositioning Controllers" section for our comprehensive line of low-noise modular and OEM control electronics for computer and manual control.



S-325 dimensions in mm

Technical Data

Models	S-325.30L	S-325.3SL	Units	Notes see page 3-26
Active Axes	Θ_X, Θ_Y, Z	Θ_X, Θ_Y, Z		
* Open-loop tilt angle @ 0 to 100 V	**5	**5	mrad ± 20%	
* Closed-loop tilt angle	-	**4	mrad	A3
* Open-loop linear travel @ 0 to 100 V	30	30	µm ± 20%	A5
* Closed-loop linear travel @ 0 to 100 V	-	30	µm	A6
Integrated feedback sensor	-	strain gauge sensor		B
*** Closed-loop/open-loop angular resolution	- / 0.05	0.1 / 0.05	µrad	C1
*** Closed-loop/open-loop linear resolution	- / 0.5	1.0 / 0.5	nm	C1
Electrical capacitance	3 x 3.0	3 x 3.0	µF ±20%	F1
Unloaded resonant frequency	2	2	kHz ±20%	G1
Resonant frequency with 25 x 8 mm glass mirror	1	1	kHz ±20%	G3
Distance of pivot point to platform surface	6 ±0.5	6 ±0.5	mm	
Platform moment of inertia	515	515	g · mm²	
Operating temperature range	-20 to 80	-20 to 80	°C	H2
Voltage connection	3 x VL, 2.0 m	3 x VL, 2.0 m		J1
Sensor connection	-	3 x L, 2.0 m		J2
Weight (without cables)	65	65	g ±5%	
Material casing	Al	Al		L
Recommended amplifier/controller (codes explain page 3-9)	G, C	H, D		

* For maximum tilt range, all three piezo actuators must be biased at 50 V. Linear travel and and tilt angle are interdependent. The values quoted here refer to pure linear / pure angular motion. See piezo tripod drive equation on page 3-10 for more information.

** Mechanical tilt, optical beam deflection is twice as large.

*** For calibration information see p. 3-7. Resolution of PZT tip/tilt platforms is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier.

S-334

Ultra-Long-Range Piezo Tip/Tilt Mirror (Beam Controller)


S-334.2SL

- **Optical Deflection to 100 mrad (~6°)**
- **1.0 kHz Resonant Frequency with Mirror**
- **Closed-Loop Version for Higher Linearity**
- **For Mirrors up to 12.5 mm (0.5") Diameter**
- **2 Fixed Orthogonal Axes with a Common Pivot Point**
- **Sensor Configuration for Excellent Temperature Stability**
- **Zero Friction Flexure Guides**

S-334 tip/tilt platforms are fast and compact units providing precise angular movements of a mirror around two orthogonal axes. The tip/tilt range is 50 mrad with sub-μrad resolution. Highest stability and accuracy is available in closed-loop operation.

Huge Tip/Tilt Ranges with Excellent Motion Characteristics

The novel lever design combines the exceptionally large tip/tilt range of 3° (50 mrad, which is equivalent to 100 mrad optical beam deflection) with the high resonant frequency of 1.0 kHz (including the mirror). These parameters make the system unique in the market of high-speed, long-range scanners.

Sub-Microradian Resolution and Stable Positioning

The S-334 provides sub-microradian resolution. When operated in closed-loop mode, it offers absolute position control and high linearity, typically under ±0.25 % over the entire travel range. This is achieved by high-resolution, full-bridge strain gauge sensors (SGS), calibrated specifically for each unit with the control electronics.

Higher Performance Through Parallel Kinematics

S-334 tip/tilt platforms feature a single moving platform, parallel-kinematics design with a common pivot point. Compared to stacked, multi-axis systems, the parallel-kinematics design provides faster response and better linearity with equal dynamics for all axes in a smaller package.

Working Principle / Lifetime

The S-334 is equipped with two pairs of long-life, ceramic-encapsulated, high-performance PICMA® piezo drives operating as a unit in push/pull mode. The linear-drive actuators are driven differentially in diagonal pairs. The casing is equipped with integrated, FEA-modeled flexures featuring zero stiction, zero friction and exceptional guiding precision.

Ordering Information

S-334.2SL
Piezo Tip/Tilt Platform, 50 mrad, Closed-Loop, 100 mrad Optical Deflection, BK7-Mirror, ø10 x 2 mm.

Ask about custom designs!

Since drives and guides are frictionless and not subject to wear and tear, these units offer an exceptionally high level of reliability.

Notes

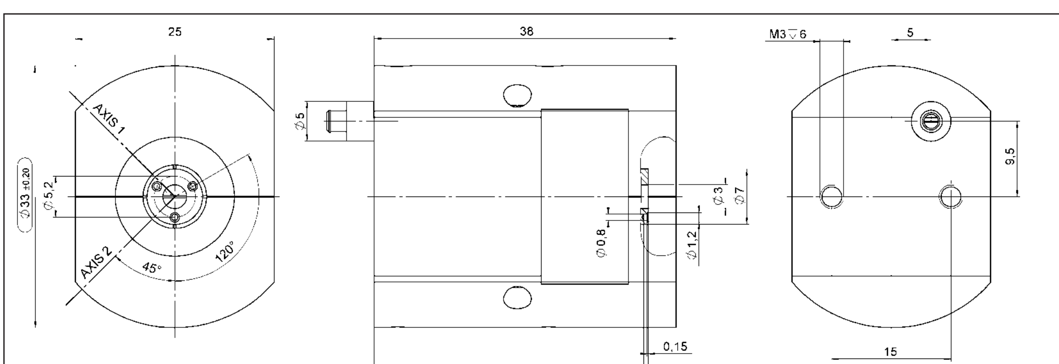
The S-334 is equipped with a factory-installed mirror 10 mm in diameter and 2 mm thick (flatness λ/5, reflectivity > 98 % from 500 nm to 2 μm).
Custom coatings, and mirrors up to 12.5 mm diameter, are available on request. Please contact your PI sales engineer.

See the "Selection Guide" on p. 3-8 for comparison with other steering mirrors.

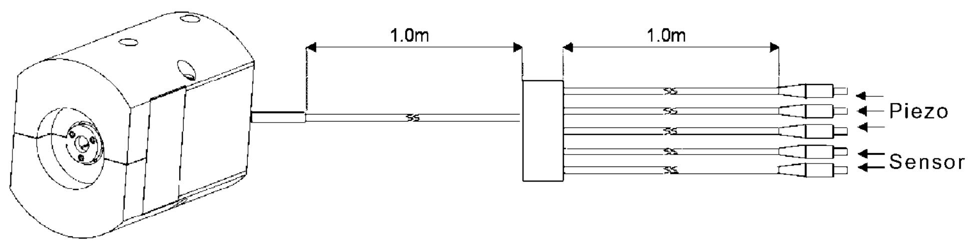
See "Piezo Drivers & Nanopositioning Controllers" section for our comprehensive line of low-noise modular and OEM control electronics for computer and manual control.

Application Examples

- Beam steering, scanning, stabilization
- Image stabilization
- Interlacing, dithering
- Beam switching
- Adaptive optics systems
- Imaging systems
- Scanning microscopy



S-334 dimensions in mm



S-334.2SL cable configuration

Technical Data

Models	S-334.2SL	Units	Notes see page 3-26
Active Axes	Θ_X, Θ_Y		
* Open-loop tilt angle @ 0 to 100 V	50	mrad ±20%	A2
* Closed-loop tilt angle	50	mrad	A3
Integrated feedback sensor	4 x full-bridge strain gauge sensors		B
** Closed-loop / open-loop angular resolution	<5 / 0.5	µrad	C1
Closed-loop linearity (typ.)	±0.25	%	
Electrical capacitance	3.0 / axis	µF ±20%	F1
Resonant frequency with 10 mm diam. x 2 mm glass mirror	1.0	kHz ±20%	G2
Resonant frequency with 12.5 mm diam. x 2.5 mm glass mirror	0.8	kHz ±20%	G3
Distance of pivot point to platform surface (lower mirror surface)	2 ±0.5	mm	
Operating temperature range	-20 to 80	°C	H2
Voltage connection	3 x LEMO FFA.00.250, 2 m		
Sensor connection	2 x LEMO FFA.0S.304, 2 m		
Weight (without cables)	65	g ±5%	
Standard mirror	diameter: 10 mm, thickness: 2 mm, BK7, λ / 5, R >98% (λ = 500 nm to 2 µm)		
Material casing	Titanium		L
Recommended amplifier/controller (codes explain page 3-9)	H[#], D		

* Mechanical tilt, optical beam deflection is 100 mrad.
** For calibration information see p. 3-7. Resolution of PI piezo tip/tilt platforms is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier.
[#] With (1 x E-505.00S + 2 x E-505.00) or 1 x E-503.00S

S-330

High-Speed Piezo Tip/Tilt Platform (Beam Controller)

S-330 Tip/Tilt Platform

- **Fixed Orthogonal Axes with a Common Pivot Point**
- **4 mrad Optical Beam Deflection**
- **Sub-μrad Resolution**
- **For Mirrors up to 50 mm Ø**
- **Closed-Loop Versions for Better Linearity**
- **Differential Design for Excellent Temperature Stability**
- **Zero Friction Flexure Guides**
- **Single-Moving-Platform, Parallel-Kinematics Design: Equal Dynamics for all Axes, Better Linearity & Temperature Stability**

S-330 piezo tip/tilt platforms are fast and compact tilt units, providing precise angular movements of the top platform in two orthogonal axes. The tip/tilt range is 2 mrad (equivalent to 4 mrad optical beam deflection) with sub-μrad resolution. Closed-loop versions are available for highest accuracy and repeatability. S-330 systems are designed for mirrors up to 50 mm diameter and have outstanding angular stability over a wide temperature range. To match the CTE (coefficient of thermal expansion) of Zerodur glass, the S-330 is equipped with an invar top platform.

Application Examples

- Image stabilization
- Laser beam stabilization
- Beam switching
- Adaptive optics systems
- Laser beam steering & scanning
- Correction of polygon scanner errors
- Interlacing, dithering

Open / Closed-Loop Operation

In open-loop operation, the platform angle roughly corresponds to the drive voltage (see page 4-17 in the "Tutorial" section for behavior of open-loop piezos).

The open-loop model is ideal for applications where the position is controlled by an external loop, based on data provided by a sensor (e.g. PSD, quad cell, CCD chip, etc.).

The closed-loop version is equipped with two pairs (one per axis) of strain gauge sensors operated in a bridge circuit for ultra-high resolution and angular stability. They provide sub-μrad resolution and repeatability.

Higher Performance Through Parallel Kinematics

S-330 tip/tilt platforms feature a single moving platform, parallel-kinematics design with a common pivot point. Compared to stacked, multi-axis systems, the parallel-kinematics design provides faster response and better linearity with equal dynamics for all axes in a smaller package.

Ordering Information

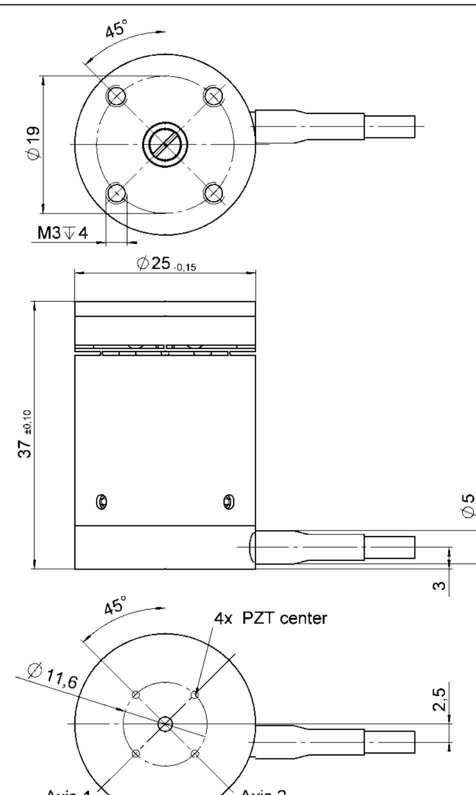
S-330.2SL
Θ_X, Θ_Y Piezo Tip/Tilt Platform
2 mrad (4 mrad optical), Closed-Loop

S-330.30
Piezo Tip/Tilt Platform 2 mrad
(4 mrad optical), Open Loop

Ask about custom designs!

Working Principle / Lifetime

S-330 platforms are equipped with two pairs of long-life, ceramic-encapsulated, high-performance PICMA® piezo drives operating as a unit in push/pull mode. The stainless steel case is equipped with an



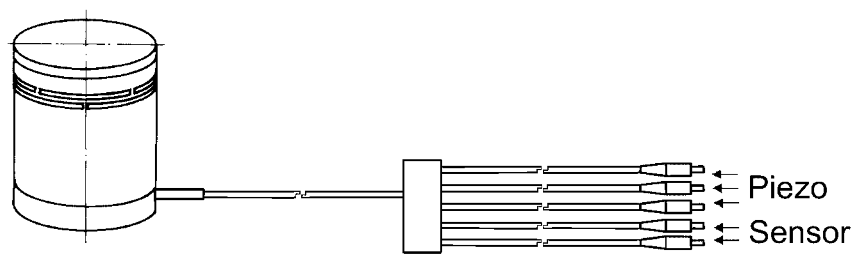
S-330 dimensions (in mm)

integrated, FEA-modeled (finite element analysis) circular flexure featuring zero stiction, zero friction and exceptional guiding precision.

Since drives and guides are frictionless and not subject to wear and tear, these units offer an exceptionally high level of reliability.

Notes

See the "Selection Guide" on p. 3-8 for comparison with other steering mirrors.
See the "Piezo Drivers & Nanopositioning Controllers" section for our comprehensive line of low-noise modular and OEM control electronics for computer and manual control.



S-330.2SL cable configuration

Technical Data

Models	S-330.30	S-330.2SL	Units	Notes see page 3-26
Active axes	Θ_X, Θ_Y	Θ_X, Θ_Y		
Open-loop tilt angle @ 0 to 100 V	2*	2*	mrad ±20%	A2
Closed-loop tilt angle	-	2*	mrad	A3
Integrated feedback sensor	-	4 x strain gauge		B
** Closed-loop / open-loop resolution	- / 0.05	0.1 / 0.05	µrad	C1
Closed-loop linearity (typ.)	-	±0.2	%	
Full-range repeatability (typ.)	-	±2	µrad	C3
Electrical capacitance	3.0 / axis	3.0 / axis	µF ±20%	F1
*** Dynamic operating current coefficient (DOCC)	0.2 / axis	0.2 / axis	µA/(Hz x µrad)	F2
Resonant frequency (f_0) without mirror	3.3	3.3	kHz ±20%	G2
Resonant frequency w/ ø 25 x 8 mm glass mirror	2.4	2.4	kHz ±20%	G3
Distance, pivot point to platform surface (T)	6	6	mm	
Platform moment of inertia	1530	1530	g · mm²	
Operating temperature range	- 20 to 80	- 20 to 80	°C	H2
Voltage connection	3 x VL	3 x VL		J1
Sensor connection	-	2 x L, 2 m cable		J2
Weight (w/o cables)	200	200	g ±5%	
Material (case / platform)	N-S / I	N-S / I		L
Recommended amplifier / controller (codes explained page 3-9)	G#, C	H#, D		

* Mechanical tilt, optical beam deflection is twice as large. Special version with 10 mrad available on request.
** For calibration information see p. 3-7. Resolution of PZT tip/tilt platforms is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier.
*** Dynamic Operating Current Coefficient in µA per Hz and µrad. Example: Sinusoidal scan of 100 µrad at 10 Hz requires approximately 0.2 mA drive current.
\# With (1 x E-505.00S + 2 x E-505.00) or 1 x E-503.00S

S-340

High-Speed Piezo Tip/Tilt Platform (Beam Controller)

S-340.AL Tip/Tilt Platform

- **Fixed Orthogonal Axes with a Common Pivot Point**
- **4 mrad Optical Beam Deflection**
- **For Mirrors to 100 mm Ø**
- **Sub-μrad Resolution**
- **Closed-Loop Versions for Better Linearity**
- **Differential Design for Excellent Temperature Stability**
- **Zero Friction Flexure Guides**
- **Single-Moving-Platform, Parallel-Kinematics Design: Equal Dynamics for all Axes, Better Linearity & Temperature Stability**

S-340 piezo tip/tilt platforms are fast and compact tilt units, providing precise angular movements of the top platform in two orthogonal axes. The tip/tilt range is 2 mrad (equivalent to 4 mrad optical beam deflection) with sub-μrad resolution. Closed-loop versions are available for highest accuracy and repeatability. S-340 systems are designed for mirrors up to 100 mm diameter and have outstanding angular stability over a wide temperature range.

Application Examples

- Image stabilization
- Laser beam stabilization
- Beam switching
- Adaptive optics systems
- Laser beam steering & scanning
- Correction of polygon scanner errors
- Interlacing, dithering

To match the CTEs (coefficients of thermal expansion) of various mirror materials, platforms made from different materials are available (see ordering information).

Open / Closed-Loop Operation

In open-loop operation, the platform angle roughly corresponds to the drive voltage (see page 4-17 in the "Tutorial" section for behavior of open-loop piezos). The open-loop models are ideal for applications where the position is controlled by an external loop, based on data provided by a sensor (e.g. PSD, quad cell, CCD chip, etc.).

The closed-loop versions are equipped with two pairs (one per axis) of LVDT (linear variable differential transformer) sensors operated in a bridge circuit for ultra-high resolution and angular stability. They provide sub-μrad resolution and repeatability.

Higher Performance Through Parallel Kinematics

S-340 tip/tilt platforms feature a single moving platform, parallel-kinematics design with a common pivot point. Compared to stacked, multi-axis systems, the parallel-kinematics design provides faster response and better linearity with equal dynamics for all axes in a smaller package.

Working Principle / Lifetime

S-340 tip/tilt platforms are equipped with two pairs of long-life, ceramic-encapsulated, high-performance PICMA® piezo drives operating as a unit in push/pull mode. The aluminum case is equipped with an integrated, FEA-modeled (finite element analysis) circular flexure featuring zero stiction, zero friction and exceptional guiding precision.
Since drives and guides are frictionless and not subject to wear and tear, these units offer an exceptionally high level of reliability.

Notes

See the "Selection Guide" on p. 3-8 for comparison with other steering mirrors.

See the "Piezo Drivers & Nanopositioning Controllers" section for our comprehensive line of low-noise modular and OEM control electronics for computer and manual control.

Ordering Information

S-340.A0
Θ_X, Θ_Y Piezo Tip/Tilt Platform, 2 mrad, Aluminum Top Plate

S-340.i0
Θ_X, Θ_Y Piezo Tip/TiltPlatform, 2 mrad, Invar Top Plate

S-340.S0
Θ_X, Θ_Y Piezo Tip/Tilt Platform, 2 mrad, Steel Top Plate

S-340.T0
Θ_X, Θ_Y Piezo Tip/Tilt Platform, 2 mrad, Titanium Top Plate

S-340.AL
Θ_X, Θ_Y Piezo Tip/Tilt Platform, 2 mrad, Aluminum Top Plate, Closed-Loop

S-340.iL
Θ_X, Θ_Y Piezo Tip/Tilt Platform, 2 mrad, Invar Top Plate, Closed-Loop

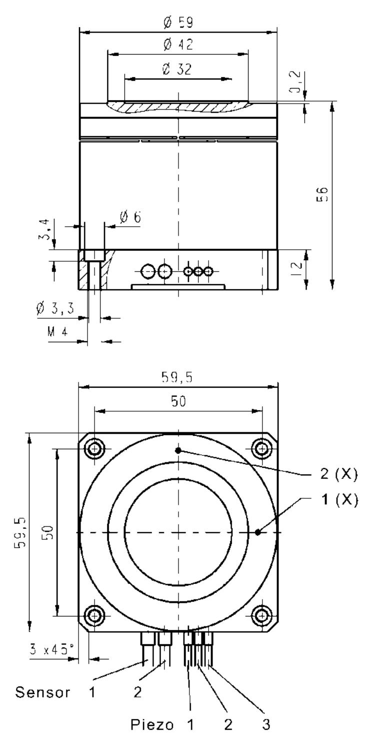
S-340.SL
Θ_X, Θ_Y Piezo Tip/Tilt Platform, 2 mrad, Steel Top Plate, Closed-Loop

S-340.TL
Θ_X, Θ_Y Piezo Tip/Tilt Platform, 2 mrad, Titanium Top Plate, Closed-Loop

Ask about custom designs!

Materials Match

Platform	Recommended Mirror	Models
Aluminum	Aluminum	S-340.Ax
Invar	Zerodur glass	S-340.ix
Titanium	BK7 glass	S-340.Tx
Steel		S-340.Sx



S-340 dimensions (in mm)

Technical Data

Models	S-340.x0	S-340.xL	Units	Notes see page 3-26
Active axes	Θ_X, Θ_Y	Θ_X, Θ_Y		
* Open-loop tilt angle 0 to 100 V	2 (4 optical)	2 (4 optical)	mrad ±20%	A2
* Closed-loop tilt angle	-	2 (4 optical)	mrad	A3
Integrated feedback sensor	-	4 x LVDT		B
** Closed-loop / open-loop resolution	- / 0.1	0.5 / 0.1	µrad	C1
Closed-loop linearity (typ.)	-	±0.1	%	
Full-range repeatability (typ.)	-	±1	µrad	C3
Electrical capacitance	6.0 / axis	6.0 / axis	µF ±20%	F1
*** Dynamic operating current coefficient (DOCC)	0.38 / axis	0.38 / axis	µA/(Hz x µrad)	F2
**** Unloaded resonant frequency (f_0)	1.4	1.4	kHz ±20%	G2
**** Resonant frequency w/ ø 50 x 15 mm glass mirror	0.9	0.9	kHz ±20%	G3
**** Resonant frequency w/ ø 75 x 22 mm glass mirror	0.4	0.4	kHz ±20%	G3
Distance, pivot point to platform surface (T)	7.5	7.5	mm	
**** Platform moment of inertia	18000	18000	g · mm²	
Operating temperature range	- 20 to 80	- 20 to 80	°C	H2
Voltage connection	3 x VL	3 x VL		J1
Sensor connection	-	2 x L		J2
Weight (w/o cables)	335	335	g ±5%	
Material (case / platform)	Al / depends on version	Al / depends on version		L
Recommended amplifier/controller (codes explained page 3-9)	G#, C	H#, E		

* Mechanical tilt, optical beam deflection is twice as large.

** For calibration information see p. 3-7. Resolution of PZT tip/tilt platforms is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier.

*** Dynamic Operating Current Coefficient in µA per hHz and µrad. Example: Sinusoidal scan of 100 µrad at 10 Hz requires approximately 0.38 mA drive current.

**** Value for aluminum top plate. Lower resonant frequency for other platforms due to higher moment of inertia: titanium: +60%; invar: +200%; steel: +190%.

\# With (1 x E-505.00S + 2 x E-505.00) or 1 x E-503.00S

Notes (Technical Data)

A2 Open-Loop Tilt Angle @ 0 to 100 V

Typical open-loop tilt angle at 0 to 100 V operating voltage. For differential-drive tilt platforms, 0° is reached at 50 V drive voltage, the maximum negative angle at 0 V and the maximum positive angle at 100 V. Max. operating voltage range is -20 to +120 V, (outside 0 to 100 V only for short durations).

A3 Closed-Loop Travel

Tilt provided in closed-loop operation at room temperature. PI LVPZT amplifiers have an output voltage range of -20 to +120 V to provide enough margin for the controller to compensate for load changes etc.

A5 Open-Loop Linear Travel @ 0 to 100 V

Typical open-loop travel at 0 to 100 V operating voltage. Max. operating voltage range is -20 to +120 V, (outside 0 – 100 V only for short durations).

A6 Closed-Loop Linear Travel

Travel provided in closed-loop operation. PI LVPZT amplifiers have an output voltage range of -20 to +120 V to provide enough margin for the controller to compensate for load changes etc.

B Integrated Feedback Sensor

Absolute-measuring SG (strain gauge), LVDT (inductive) or capacitive sensors are used to provide position information to the controller. For details see page 4-19 in the "Tutorial: Piezoelectrics in Positioning" section.

C1 Closed-Loop / Open-Loop Resolution

Resolution of piezo tilt platforms is basically infinitesimal because it is not limited by stiction/friction. Instead of resolution, the noise-equivalent motion is specified. Values are typical results (RMS, 1σ) measured with E-503 amplifier module in E-500/501 chassis.

C3 Full-Range Repeatability (typ.)

Typical values in closed-loop mode. Repeatability is a percentage of the total angle traveled. For small ranges, repeatability is significantly better.

D1 Stiffness

Static large-signal stiffness of the PZT ceramic at room temperature, 0 V. Small-signal stiffness and dynamic stiffness may differ because of effects caused by the active nature of the piezo material, compound effects, etc. For details see page 4-21 in the "Tutorial" section.

F1 Electrical Capacitance

The PZT capacitance values indicated in the technical data tables are small-signal values (measured at 1 V, 1000 Hz, 20 °C, no load; large-signal values at room temperature are 30 to 50% higher). The capacitance of PZT ceramics changes with amplitude, temperature, and load up to 200% of the unloaded, small-signal capacitance at room temperature. For detailed information on power requirements, refer to the amplifier frequency response curves in the "Piezo Drivers & Nanopositioning Controllers" section of this catalog.

F2 Dynamic Operating Current Coefficient (DOCC)

Average electrical current (supplied by the amplifier) required to drive a piezo actuator per unit frequency and unit displacement (sine wave operation). For example, to find out if a selected amplifier can drive a given piezo tilt platform at 50 Hz with 300 µrad amplitude, multiply the DOC coefficient by 50 and 300 and check if the result is less than or equal to the output current of the selected amplifier. For details see page 4-29 *ff.* in the "Tutorial: Piezoelectrics in Positioning" section.

G2 Unloaded Resonant Frequency (f_0)

Lowest tilt resonant frequency around active axis without mirror attached to platform (is above the maximum operating frequency). For further details see page 4-25 in the "Tutorial: Piezoelectrics in Positioning" section.

G3 Resonant Frequency with Mirror

Example of how a load (mirror) attached to the platform affects the resonant frequency (calculated data). See "Dynamic Behavior" page 3-11 for further details.

H2 Operating Temperature Range

Performance specifications are valid for room temperature (22 °C) and closed-loop systems are calibrated for optimum performance at this temperature (specifications for other operating temperatures on request). Recalibration is recommended for operation at a significantly higher or lower temperature. Custom designs for ultra-low or ultra-high temperatures on request.

J1 Voltage Connection

Typical operating voltage connectors are LEMO-type connectors.

VL (Voltage Low):
LEMO FFS.00.250, male.
Cable: coaxial, RG 178, Teflon coated, 1 m.

For extension cables and adapters, see "Accessories" on page 6-55 *ff.* in the "Piezo Drivers & Nanopositioning Controllers" section.

J2 Sensor Connection

Typical sensor connectors are LEMO-type connectors.

L: LEMO FFA.0S.304, female.
Cable: PUR, 1 m.

For extension cables and adapters, see "Accessories" see page 6-55 *ff.* in the "Piezo Drivers & Nanopositioning Controllers" section.

L Material (Case / Platform)

Al: aluminum
N-S: non-magnetic stainless steel
S: ferromagnetic stainless steel
I: invar

Small amounts of other materials may occur internally for spring preload, piezo coupling, mounting, etc.

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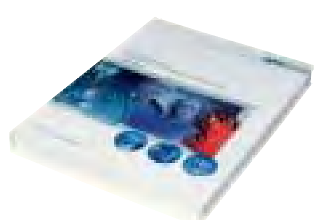

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- Piezo Nanopositioning Systems and Scanners
- Active Optics / Tip-Tilt Platforms
- Capacitive Sensors
- Piezo Electronics: Amplifiers and Controllers
- Hexapods
- Micropositioners
- Positioning Systems for Fiber Optics, Photonics and Telecommunications
- Motor Controllers
- Piezo Ceramic Linear Motors

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