

# 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  $\mu\text{m}$  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  $\mu\text{m}$  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  $\mu\text{m}$ , Direct Metrology, Capacitive Sensors

#### P-541.TCD

Vertical Tip / Tilt Nanopositioning Stage with Large Aperture, 100  $\mu\text{m}$  / 1 mrad, Parallel Metrology, Capacitive Sensors

#### P-541.ZSL

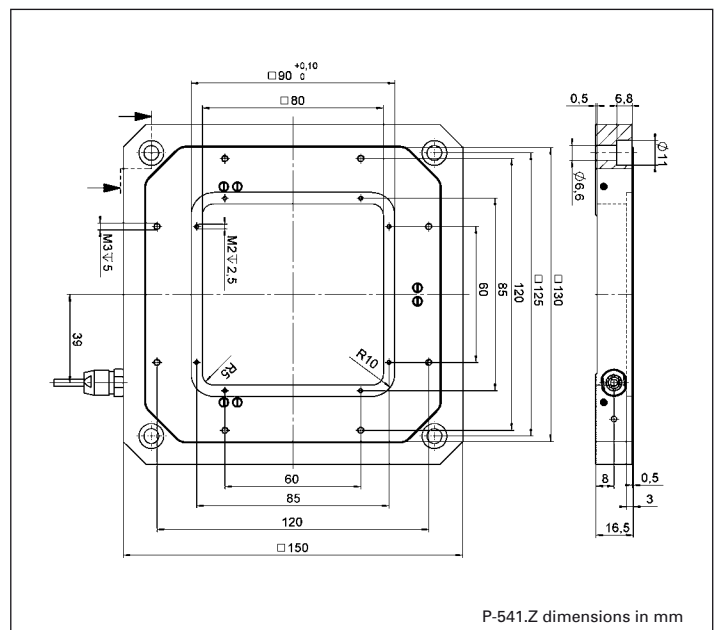
Vertical Nanopositioning Stage with Large Aperture, 100  $\mu\text{m}$ , Strain Gauge Sensors

#### P-541.TSL

Vertical Tip / Tilt Nanopositioning Stage with large Aperture, 100  $\mu\text{m}$ , 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.T0L*	P-541.Z0L	Units	Tolerance
Active axes	Z	Z, $\theta_x$ , $\theta_y$	Z	Z, $\theta_x$ , $\theta_y$	Z	Z, $\theta_x$ , $\theta_y$		
<b>Motion and positioning</b>								
Integrated sensor	Capacitive	Capacitive	SGS	SGS	Open-loop	Open-loop		
Open-loop Z-travel, -20 to +120 V	150	150	150	150	150	150	$\mu\text{m}$	min. (+20%/0%)
Open-loop tip/tilt angle, -20 to +120 V	–	$\pm 0.6$	–	$\pm 0.6$	–	$\pm 0.6$	mrad	min. (+20%/0%)
Closed-loop Z-travel	100	100	100	100	–	–	$\mu\text{m}$	
Closed-loop tip/tilt angle	–	$\pm 0.4$	–	$\pm 0.4$	–	–	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	$\mu\text{rad}$	typ.
Closed-loop Z-resolution	0.5	0.5	2.5	2.5	–	–	nm	typ.
Closed-loop tip/tilt resolution	–	0.08	–	0.25	–	–	$\mu\text{rad}$	typ.
Linearity Z, $\theta_x$ , $\theta_y$	0.03	0.03	0.2	0.2	–	–	%	typ.
Repeatability Z	<2	<2	<10	<10	–	–	nm	typ.
Repeatability $\theta_x$ , $\theta_y$	–	0.01	–	0.05	–	–	$\mu\text{rad}$	typ.
Runout $\theta_x$ , $\theta_y$	$\pm 15$	$\pm 15$	$\pm 15$	$\pm 15$	$\pm 15$	$\pm 15$	$\mu\text{rad}$	typ.
<b>Mechanical properties</b>								
Stiffness Z	0.8	0.8	0.8	0.8	0.8	0.8	N/ $\mu\text{m}$	$\pm 20\%$
Unloaded resonant frequency (Z)	410	410	410	410	410	410	Hz	$\pm 20\%$
Unloaded resonant frequency ( $\theta_x$ , $\theta_y$ )	–	330	–	330	–	330	Hz	$\pm 20\%$
Resonant frequency @ 200 g (Z)	250	250	250	250	250	250	Hz	$\pm 20\%$
Resonant frequency @ 200 g ( $\theta_x$ , $\theta_y$ )	–	270	–	270	–	270	Hz	$\pm 20\%$
Push/pull force capacity	50 / 20	50 / 20	50 / 20	50 / 20	50 / 20	50 / 20	N	Max.
<b>Drive properties</b>								
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	$\mu\text{F}$	$\pm 20\%$
Dynamic operating current coefficient	7.9	7.9	7.9	7.9	7.9	7.9	$\mu\text{A} / (\text{Hz} \cdot \mu\text{m})$	$\pm 20\%$
<b>Miscellaneous</b>								
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 Special	Sub-D Special	LEMO	3 x LEMO	–	–		
Voltage connection	Sub-D Special	Sub-D Special	LEMO	3 x LEMO	LEMO	3 x LEMO		

\*Parallel kinematics design; the maximum displacement for translation and tilt motion cannot be achieved at the same time  
Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 (p. 2-146) or E-710 controller (p. 2-128).  
Recommended controller / amplifier

Single-channel (1 per axis): E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-621 controller module (p. 2-160)

Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152)

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

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

## Linear Actuators & Motors

## Nanopositioning/Piezoelectrics

### Piezo Flexure Stages / High-Speed Scanning Systems

Linear

### Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

### Fast Steering Mirrors / Active Optics

### Piezo Drivers / Servo Controllers

Single-Channel

Multi-Channel

Modular

Accessories

### Piezoelectrics in Positioning

## Nanometrology

## Micropositioning

## Index

# P-541.2 – P-542.2 Piezo XY-Stage

## Low-Profile XY Nanopositioning System with Large Aperture



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

- **Low Profile for Easy Integration: 16.5 mm; 80 x 80 mm Clear Aperture**
- **Up to 200 x 200  $\mu\text{m}$  Travel Range**
- **Parallel-Kinematics / Metrology for Enhanced Responsiveness & Multi-Axis Precision**
- **High-Dynamics Direct-Drive Version**
- **Choice of Sensors: Strain Gauge (Lower Cost) or Capacitive Sensors (Higher Performance)**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Combination with Long Travel Microscopy Stages or Longer Stroke**

### Low Profile, Optimized for Microscopy Applications

P-541/P-542 nanopositioning and scanning stages are designed for easy integration into high-resolution microscopes. 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. A variety of Z stages and Z-tip/tilt stages with the same footprint are also offered to suit a wide range of applications

### Application Examples

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

(p. 2-44). They are ideal for alignment, nano-focusing or metrology tasks.

### Choice of Drives: Long Range or High-Speed Direct Drive

Lever-amplified XY systems with 100 and 200  $\mu\text{m}$  travel and direct-driven XY scanners with 45  $\mu\text{m}$  travel are available. Their high resonant frequencies of 1.5 kHz in both axes allow for faster step response and higher scanning rates, needed for example in single-molecule microscopy, or in other time-critical applications.

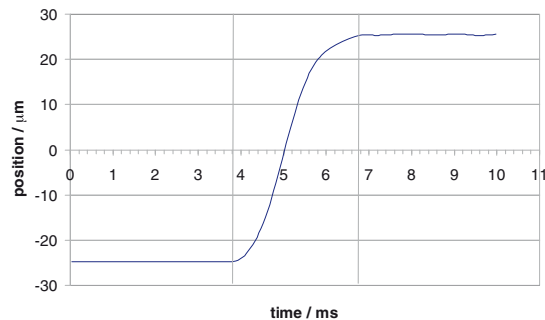
### Parallel Kinematics for Fast Response

In a parallel kinematics multi-axis system, all actuators act directly on one moving platform. This means that all axes move the same minimized mass and can be designed with identical dynamic properties. Systems with

parallel kinematics and metrology have additional advantages over serially stacked or nested systems, including more-compact construction and no cumulative error from the different axes. Parallel kinematics systems can be operated with up to six degrees of freedom with low inertia and excellent dynamic performance. Multi-axis nanopositioning systems equipped with both parallel kinematics and parallel, direct metrology are able to measure platform position in all degrees of freedom against one common fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross talk) is detected immediately and actively compensated by the servo-loops.

### Tailored Position Measurement

Integrated high-resolution position sensors provide fast response and positional stability in the nanometer range. Top-of-the-line models use capacitive sensors. They measure displacement directly and without physical contact (direct metrology) enabling superior linearity. Alternatively, versions with cost-effective strain gauge sensors (SGS) are also available.



The settling time of a P-541.2DD stage is only 3 ms for a 50  $\mu\text{m}$  step

### System properties

System configuration	P-541.2CD and E-500 modular system with E-503 amplifier and E-509 sensor module, 200 g load
Amplifier bandwidth, large signal	35 Hz
Settling time (full travel)	28 ms

### Ordering Information

#### P-541.2DD

XY Nanopositioning System with Large Aperture, High-Speed Direct Drive, 45 x 45  $\mu\text{m}$ , Parallel Kinematics, Capacitive Sensors

#### P-541.2CD

XY Nanopositioning System with Large Aperture, 100 x 100  $\mu\text{m}$ , Parallel Kinematics, Capacitive Sensors

#### P-542.2CD / P-542.2CL

XY Nanopositioning System with Large Aperture, 200 x 200  $\mu\text{m}$ , Parallel Kinematics, Capacitive Sensors

#### P-541.2SL

XY Nanopositioning System with Large Aperture, 100 x 100  $\mu\text{m}$ , Strain Gauge Sensors

#### P-542.2SL

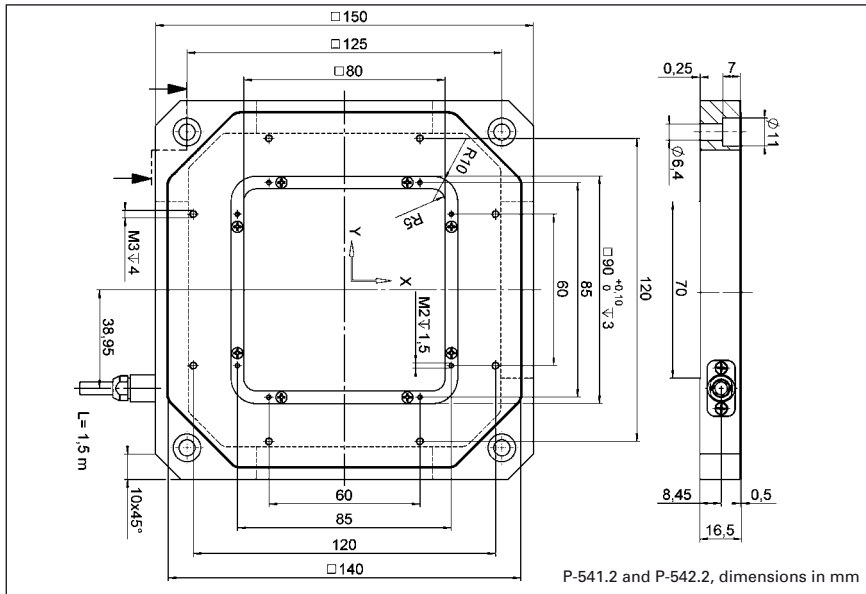
XY Nanopositioning System with Large Aperture, 200 x 200  $\mu\text{m}$ , Strain Gauge Sensors

#### P-541.20L

XY Nanopositioning System with Large Aperture, 100 x 100  $\mu\text{m}$ , Open Loop

#### P-542.20L

XY Nanopositioning System with Large Aperture, 200 x 200  $\mu\text{m}$ , Open Loop



#### Technical Data

Model	P-541.2CD	P-542.2CD P-542.2CL	P-541.2DD	P-541.2SL	P-542.2SL	P-541.20L	P-542.20L	Units	Tolerance
Active axes	X, Y	X, Y	X, Y	X, Y	X, Y	X, Y	X, Y		
<b>Motion and positioning</b>									
Integrated sensor	Capacitive	Capacitive	Capacitive	SGS	SGS	–	–		
Open-loop travel, -20 to +120 V	175 x 175	290 x 290	60 x 60	175 x 175	290 x 290	175 x 175	290 x 290	µm	min. (+20%/0%)
Closed-loop travel	100 x 100	200 x 200	45 x 45	100 x 100	200 x 200	–	–	µm	
Open-loop / closed-loop resolution	0.2 / 0.3	0.4 / 0.7	0.1 / 0.3	0.2 / 2.5	0.4 / 4	0.2 / –	0.4 / –	nm	typ.
Linearity	0.03	0.03	0.03*	0.2	0.2	–	–	%	typ.
Repeatability	<5	<5	<5	<10	<10	–	–	nm	typ.
Pitch	<±5	<±5	<±3	<±5	<±5	<±5	<±5	µrad	typ.
Yaw	<±10	<±10	<±3	<±10	<±10	<±10	<±10	µrad	typ.
<b>Mechanical properties</b>									
Stiffness in motion direction	0.47	0.4	10	0.47	0.4	0.47	0.4	N/µm	±20%
Unloaded resonant frequency	255	230	1550	255	230	255	230	Hz	±20%
Resonant frequency @ 100 g	200	190	–	200	190	200	190	Hz	±20%
Resonant frequency @ 200 g	180	–	1230	180	–	180	–	Hz	±20%
Resonant frequency @ 300 g	150	145	–	150	145	150	145	Hz	±20%
Push/pull force capacity in motion direction	100 / 30	100 / 30	100 / 30	100 / 30	100 / 30	100 / 30	100 / 30	N	Max.
Load capacity	20	20	20	20	20	20	20	N	Max.
<b>Drive properties</b>									
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance per axis	4.2	7.5	9	4.2	7.5	4.2	7.5	µF	±20%
Dynamic operating current coefficient per axis	5.2	4.8	25	5.2	4.8	5.2	4.8	µA/(Hz·µm)	±20%
<b>Miscellaneous</b>									
Operating temperature range	20 to 80	20 to 80	20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	1100	1150	1210	1050	1100	1050	1100	g	±5%
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m	±10 mm
Sensor connection	Sub-D Special	Sub-D Special / LEMO	Sub-D Special	LEMO	LEMO	–	–		
Voltage connection	Sub-D Special	Sub-D Special / LEMO	Sub-D Special	LEMO	LEMO	LEMO	LEMO		

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

Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 10 µm at 10 Hz requires approximately 0.48 mA drive current for the P-542.2CD.

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

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) (for systems with sensors)

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)