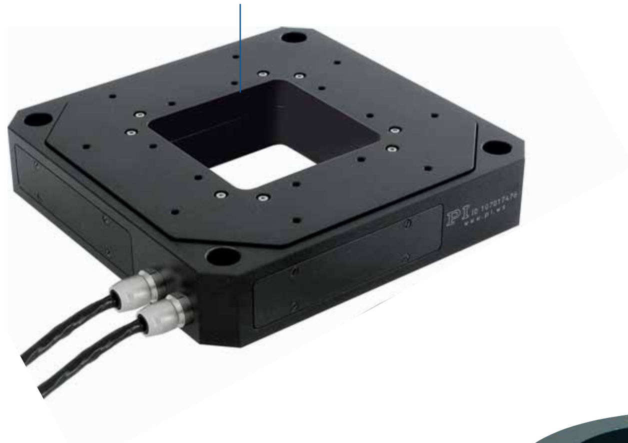
# 6-Axis Nanopositioning Systems

## Sophisticated Parallel-Kinematics Positioning Stages

SOPHISTICATED



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# 6-Axis Nanopositioning Stages / Systems

Non-magnetic 6-axis parallel kinematics Hexapod with PiezoWalk® high-load actuators, for High Energy Physics

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

P-587 6-axis long-travel piezo-flexure stage on top of E-710.6CD 6-axis digital piezo controller

M-810 miniature Hexapod. Available for standard and vacuum environments

# 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<br>$\theta_X$, $\theta_Y$, $\theta_Z$: 6° | 50 kg | Outer Ø baseplate, 380 mm<br>Ø moved platform (top) 300 mm<br>140 mm height |

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

## Nanometer Precision for Semiconductor Industry, Wafer Alignment

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

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

| Model | Travel | Load capacity | Linear velocity | Dimensions |
|---|---|---|---|---|
| N-510 NEXLINE® Z, tip, tilt platform | 1,3 mm vertical range<br>10 mrad tilt angle | 200 N | 0.2 mm/s | Ø 360 mm (14.2´´)<br>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<br>40 µm fine | 1 mm/sec | 50 nm (full travel) | 25 N | Ø 300 mm<br>68.5 mm height |

# P-562.6CD PIMars 6-Axis Piezo Stage System

## High-Precision Nanopositioning System with 6 Degrees of Freedom


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

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

**Ordering Information**

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

**Other travel ranges on request!**

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

**Application Examples**

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

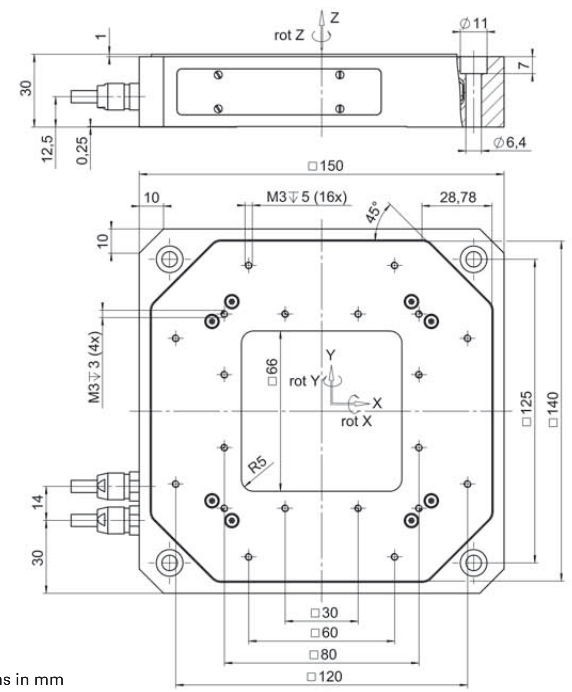
PIMars systems feature a large 66 x 66 mm clear aperture for transmitted-light applications such as near-field scanning or confocal microscopy and mask positioning. PIMars stages for ultra-high vacuum applications are also available. These versions contain vacuum-qualified components only. The integrated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

### Capacitive Sensors for Highest Accuracy and Stability

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

### Active and Passive Guidance for Nanometer Flatness and Straightness

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



P-562 dimensions in mm

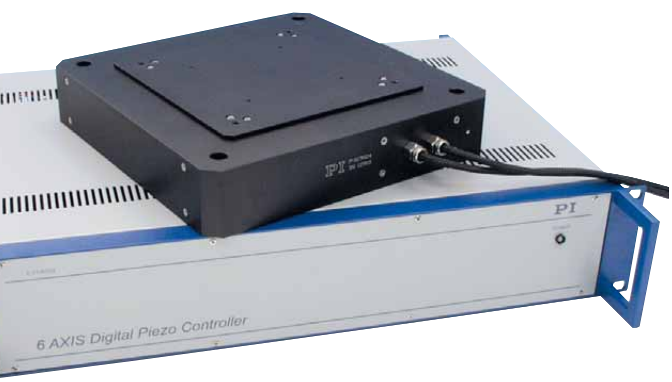
## Technical Data

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

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

# P-587 6-Axis Precision Piezo Stage

## Long Scanning Range, Direct Position Measurement




P-587 piezo-driven parallel-kinematics nanopositioning / scanning stage with E-710.6CD 6-axis digital controller

- **For Surface Metrology, Scanning and Positioning in all Six Degrees of Freedom**
- **800 x 800 x 200 µm Linear Range**
- **Up to 1 mrad Rotational Range**
- **Parallel-Kinematics / Metrology for Enhanced Responsiveness / Multi-Axis Precision**
- **Direct Metrology with Capacitive Sensors for Highest Linearity**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Frictionless, High-Precision Flexure Guiding System**
- **Active Trajectory Control in All 6 Degrees of Freedom**

The P-587.6CD is a unique, highly accurate, 6-axis scanning and positioning system based on piezo flexure drives. It provides a linear travel range of 800 x 800 x 200 µm and rotation ranges up to 1 mrad.

### Application Examples

- Interferometry
- Metrology
- Nano-imprinting
- Semiconductor testing
- Semiconductor fabrication

### Direct Position Measurement with Sub-Nanometer 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. A flatness and straightness in the low nanometer range is achieved, important for surface metrology applications.

### Parallel Kinematics and Metrology with Capacitive Sensors for High Trajectory Fidelity

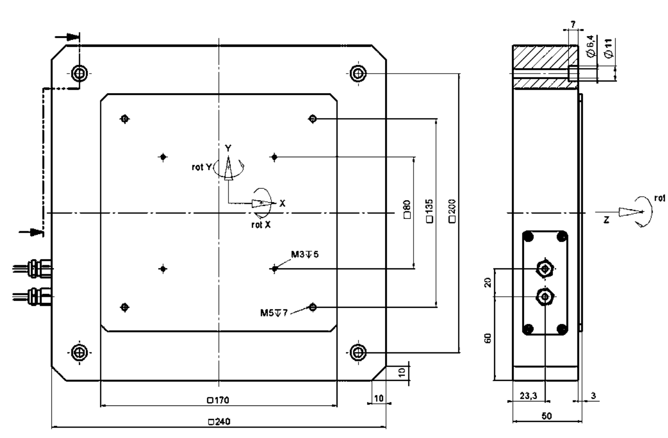
In a parallel kinematics multi-axis system, all actuators act directly on one moving platform. This means that all axes move the same minimized mass and can be designed with identical dynamic properties. Parallel kinematics systems have additional advantages over serially stacked systems, including more-compact construction and no cumulative errors from the individual axes. Multiaxis nanopositioning systems equipped with direct metrology are able to measure platform position in all degrees of freedom against one common reference. In such systems, undesirable motion from one actuator in the direction of another (cross-talk) is detected immediately and actively compensated by the servo-loops. This Active Trajectory Control Concept can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.

### Ordering Information

**P-587.6CD**
6-Axis Nanopositioning System with Long Travel Range, 800 x 800 x 200 µm, ±0.5 mrad, Parallel Metrology, Capacitive Sensors

### Automatic Configuration

PI digital piezo controllers and nanopositioning stages with ID-Chip can be operated in any combination, supported by the AutoCalibration function of the controller. Individual stage data and optimized servo-control parameters are stored in the ID-Chip and are read out automatically by the digital controllers.




P-587 dimensions in mm

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## Technical Data

| Model | P-587.6CD | Tolerance |
|---|---|---|
| Active axes | X, Y, Z, $\theta_X$, $\theta_Y$, $\theta_Z$ | |
| **Motion and positioning** | | |
| Integrated sensor | Capacitive | |
| Closed-loop travel X, Y | 800 µm | |
| Closed-loop travel Z | 200 µm | |
| Closed-loop tip/tilt angle | ±0.5 mrad | |
| Closed-loop θZ angle | ±0.5 mrad | |
| Open-loop / closed-loop resolution X, Y | 0.9 / 2.2 nm | typ. |
| Open-loop / closed-loop resolution Z | 0.4 / 0.7 nm | typ. |
| Open-loop / closed-loop resolution $\theta_X$, $\theta_Y$ | 0.05 / 0.1 µrad | typ. |
| Open-loop / closed-loop resolution $\theta_Z$ | 0.1 / 0.3 µrad | typ. |
| Linearity X, Y, Z | 0.01 % | typ. |
| Linearity $\theta_X$, $\theta_Y$, $\theta_Z$ | 0.1 % | typ. |
| Repeatability X, Y | ±3 nm | typ. |
| Repeatability | ±2 nm | typ. |
| Repeatability $\theta_X$, $\theta_Y$ | ±0.1 µrad | typ. |
| Repeatability $\theta_Z$ | ±0.15 µrad | typ. |
| Flatness | <15 nm | typ. |
| **Mechanical properties** | | |
| Stiffness X / Y / Z | 0.55 / 0.55 / 1.35 N/µm | |
| Unloaded resonant frequency in X / Y / Z | 103 / 103 / 235 Hz | ±20 % |
| Resonant frequency @ 500 g in X / Y / Z | 88 / 88 / 175 Hz | ±20 % |
| Resonant frequency @ 2000 g in X / Y / Z | 65 / 65 / 118 Hz | ±20 % |
| Push/pull force capacity in motion direction | 50 / 10 N | Max. |
| **Drive properties** | | |
| Ceramic type | PICMA® | |
| Electrical capacitance in X / Y / Z | 81 / 81 / 18.4 µF | ±20 % |
| Dynamic operating current coefficient (DOCC) in X, Y, $\theta_Z$ | 12.6 µA/(Hz • µm) | ±20 % |
| Dynamic operating current coefficient (DOCC) Z, $\theta_X$, $\theta_Y$ | 11.5 µA/(Hz • µm) | ±20 % |
| **Miscellaneous** | | |
| Operating temperature range | -20 to 80 °C | |
| Material | Aluminum | |
| Dimensions | 240 x 240 x 50 mm | |
| Mass | 7.2 kg | ±5 % |
| Cable length | 1.5 m | ±10 mm |
| Sensor / voltage connection | 2 x Sub-D Special | |
| Recommended controller / amplifier | E-710.6CD (p. 2-128) or E-712.6CD (p. 2-140) digital controller | |

The maximum rotational angle in $\theta_Z$ is 8 mrad, the tilt angles around X and Y rate 3 mrad.
Due to parallel kinematics linear motion is not possible when the stage is in extreme position.

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# M-850K Vacuum Hexapod 6-Axis Positioner

## Parallel-Kinematics System for Wide Temperature Ranges

This custom hexapod was designed to work in a thermo-vacuum chamber

- **6 Degrees of Freedom, Works in Any Orientation**
- **Vacuum Compatible up to $10^{-6}$ hPa**
- **200 kg Load Capacity (Vertical)**
- **Repeatability to ±1 µm**
- **Encoder Resolution to 5 nm**

| Model | Operating temperature range | Storage temperature | Travel ranges | Dimensions |
|---|---|---|---|---|
| M-850KTVH Vacuum Hexapod | -10 bis +25 °C | -20 bis +40 °C | ±50 mm (X,Y), ±25 mm (Z) ±15° ($\theta_X$, $\theta_Y$), ±30° ($\theta_Z$) | Ø 350 mm 330 mm height |

# M-850K Weatherproof Hexapod

## Ultra-High-Precision Hexapod for Outdoor Operation

This customer-specific M-850KWAH Hexapod can operate outdoors at altitudes up to 5000 m

- **Load Capacity to 750 N**
- **Unidirectional Repeatability to 5 µm**
- **Clear Aperture Ø 420 mm**
- **Long Lifetime: 2 Million Cycles**
- **Drive: Brushless Motors**
- **Correspond to protection class IP 64**
- **Corrosion Protection**

| Model | Travel Range X / Y / Z | Max. load capacity | Mass | Dimensions |
|---|---|---|---|---|
| M-850KWAH Weatherproof Hexapod | ±10 / ±11 / ±16 mm | 750 N | 46 kg | Outer Ø 580 mm height 357 mm |

# M-810 Miniature Hexapod

## High Precision in a Small Package

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

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

| Model | Load capacity | Travel range X / Y / Z | Travel range $\theta_x$ / $\theta_y$ / $\theta_z$ | Max. velocity | Dimensions |
|---|---|---|---|---|---|
| M-810.00 | 5 kg | ±20 mm ±20 mm ±6,5 mm | ±11° ±11° ±30° | 10 mm/s | Outer Ø 100 mm height 118 mm |

## 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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