6-Axis Robots
6 DOF Motion Platforms
Hexapod Positioning Systems
PI is the leading manufacturer of Hexapod high-performance micro- and nanopositioning systems. These parallel-kinematic devices, in a number of different forms, are suitable for diverse applications, ranging from handling systems in electronics fabrication and tool control in precision machining, through medical technology, to optical systems like those found in space telescopes and satellite receiving antennas. Various models of the powerful parallel kinematic machines (PKM) can move masses of 50, 200 or even 1000 kilograms with micron accuracy as required in their respective applications.

These Hexapod systems are all built with six, high-resolution electro-mechanical or piezo-electric actuators all acting on a common platform. It is the familiar flight simulator design, but considerably more precise: in place of hydraulic cylinders, the Hexapods are driven by highly accurate, precision-controlled rotary or linear motors. Different drive principles are employed, depending on the application: Hexapods with NEXLINE® drives make for a positioning system which is not only vacuum compatible but also completely non-magnetic, p. 15.

All PI Hexapod systems include a sophisticated, yet easy to use controller. The Hexapod controller allows the user to set a pivot point anywhere inside or outside the Hexapod working space, by a simple software command. This freely definable pivot point stays with the platform, no matter how it moves—an invaluable feature for example in optics applications. Moves are specified in Cartesian coordinates and the PC-based controller transforms them into the required motion-vectors for the individual actuator drives. The latest controller generation features flexible interfaces: high-speed RS-232, or TCP/IP interface for remote / network / Internet addressing.

**Advantages of PKM:**

- Low moved mass, lower inertia
- Better dynamic behaviour, shorter settling times
- Smaller package size
- Higher stiffness
- No accumulation of position errors, increased accuracy
- Freely definable pivot point
- Reduced runout errors
- No moving cables: better repeatability

This automated interferometric inspection system allows optical mold inserts to be checked directly while still on the production line. The hexapod is mounted “upside down” on a 20-millimeter-thick aluminum plate with the interferometer positioned in the central core of the hexapod, where it does interfere with the motion. Control is integrated into a MatLab program, which also handles the metrological image processing (photo: Physik Instrumente (PI) / Fraunhofer Institute for Production Technology IPT).
**M-810.0A Miniature Hexapod 6-Axis Robot**

- Most-Compact Hexapod in the PI Portfolio
- Travel Ranges 40 x 40 x 13 mm, Rotation to 60 Degrees
- Clear Aperture Ø 59 mm
- Load Capacity to 5 kg
- Resolution of a Single Strut 40 Nm
- Min. Incremental Motion to 200 Nm
- Repeatability up to ±0.5 µm
- Velocity to 10 mm/s

<table>
<thead>
<tr>
<th>Model</th>
<th>Load capacity</th>
<th>Travel range X / Y / Z</th>
<th>Travel range θx / θy / θz</th>
<th>Max. velocity</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-810.00</td>
<td>5 kg</td>
<td>±20 mm</td>
<td>±11°</td>
<td>10 mm/s</td>
<td>Outer Ø 100 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>±20 mm</td>
<td>±11°</td>
<td></td>
<td>height 118 mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>±6.5 mm</td>
<td>±30°</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The M-810 miniature Hexapod is now available with a modified cable exit. This makes for even more compact integration.

**M-850K Vacuum Hexapod 6-Axis Robot**

Parallel-Kinematics System for Wide Temperature Ranges

- 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

<table>
<thead>
<tr>
<th>Model</th>
<th>Operating temperature range</th>
<th>Storage temperature</th>
<th>Travel ranges</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-850KTVH</td>
<td>-10 bis ±25 °C</td>
<td>-20 bis ±40 °C</td>
<td>±50 mm (X,Y), ±25 mm (Z), ±15° (θx/θy), ±30° (θz)</td>
<td>Ø 350 mm 330 mm height</td>
</tr>
</tbody>
</table>

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

**M-850K Weatherproof Hexapod 6-Axis Robot**

Ultra-High-Precision Hexapod for Outdoor Operation

- 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

<table>
<thead>
<tr>
<th>Model</th>
<th>Travel Range X / Y / Z</th>
<th>Max. load capacity</th>
<th>Mass</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-850KWAH</td>
<td>±10 / ±11 / ±16 mm</td>
<td>750 N</td>
<td>46 kg</td>
<td>Outer Ø 580 mm height 357 mm</td>
</tr>
</tbody>
</table>

This customer-specific M-850KWAH Hexapod can operate outdoors at altitudes up to 5000 m.
M-850K Ultra-High-Load Hexapod 6-Axis Robot

Precise Hexapod for Ultra-High Loads up to 1 Ton

- Six Degrees of Freedom
- Max. Load Capacity to 1000 kg
- Repeatability to 2 µm
- Drive: Brushless Motors with Brake
- Vacuum Compatible up to 10⁻⁶ hPa

The vacuum compatible Hexapod M-850KHLH provides six degrees of freedom for loads up to 1 t, here with a standard M-840 hexapod for size comparison.

<table>
<thead>
<tr>
<th>Model</th>
<th>Travel range X / Y / Z</th>
<th>Rotation range θx / θy / θz</th>
<th>Max. velocity X/Y/Z</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-850KHLH</td>
<td>±12 mm</td>
<td>±3° / ±3° / ±4°</td>
<td>0.5 mm/s</td>
<td>Ø outside 1 m height 0.5 m</td>
</tr>
</tbody>
</table>

M-850K Large-Aperture High-Load Hexapod 6-Axis Robot

6-Axis Precision Positioning & Alignment System for Inspection Systems

- 200 kg Load Capacity (Vertical)
- Very Large Aperture (640 x 820 mm)
- Six Degrees of Freedom
- No Moving Cables for Improved Reliability and Precision
- Parallel-Kinematics Design—Significantly Smaller and Stiffer than Serial-Kinematics Systems, Better Dynamics
- Virtual Pivot Point
- Sophisticated Controller Using Vector Algorithms Included

Dimensions of 100 x 84 x 40 cm and a load capacity of up to 200 kg makes this custom Hexapod system suitable for all kinds of fine-positioning tasks, as in TV-screen inspection.

<table>
<thead>
<tr>
<th>Model</th>
<th>Max. load base-plate horizontal optional</th>
<th>Travel range X / Z / Z</th>
<th>Travel range θx / θy / θz</th>
<th>Typ. velocity</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-850KLAH</td>
<td>200 / 50 kg</td>
<td>±25 mm</td>
<td>±5°</td>
<td>2 mm/s lin. 25 mrad/s rot.</td>
<td>100 x 84 x 40 cm</td>
</tr>
</tbody>
</table>

M-850K Ultra-High Load Hexapod 6-Axis Robot

6-Axes, Long Travel, Micron Precision, 1 Ton in Any Orientation

- Load Capacity to 1000 kg in Any Orientation
- Six Degrees of Freedom
- Travel Ranges to ±200 mm, to ±20°
- Resolution to 0.8 µm, to 0.5 µrad
- Drive: Brushless Motors with Brake
- Sophisticated Controller Using Vector Algorithms

This custom parallel-kinematics system positions loads up to one ton in any orientation with micron accuracy.

<table>
<thead>
<tr>
<th>Model</th>
<th>Travel ranges X (X, Y, Z), Push pull force 10,000 N</th>
<th>Max. velocity 1 mm/s</th>
<th>Unidirectional Repeatability ±1 µm ±3 µrad</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-850KHTH</td>
<td>±200 mm (X, Y), ±100 mm (Z), ±20° (θx, θy, θz)</td>
<td>5° (θz)</td>
<td>Baseplate: 900 mm Ø Upper platform: 800 mm Ø height 714 mm aperture: Ø 500 mm</td>
<td></td>
</tr>
</tbody>
</table>
M-810 Miniature Hexapod 6-Axis Robot
6 Degrees of Freedom & High Precision in a Small Package

The newest release for data sheets is available for download at www.pi.ws.09/08/25.

With a platform diameter of only 10 cm the M-810 Hexapod is the most compact parallel-kinematics micropositioning system to date. In addition to positioning all six axes with high speed and accuracy, it allows the user to define the center of rotation (pivot point) anywhere inside or outside the system envelope by one simple software command. This makes it ideal for all complex positioning tasks with restricted space.

Extremely Compact, Great Freedom of Motion
The M-810.00 with its direct-drive torque motors and ActiveDrive™ system with integrated servo amplifiers provides an increased velocity of up to 10 mm/s for loads up to 5 kg. Small and compact, the Hexapod allows a large stroke of up to 40 mm (linear) and 60° (angular).

Hexapod vs. Serial Kinematics Systems
The Hexapod is driven by six high-resolution actuators all connected directly to the same moving platform. This design provides a high system stiffness and a large clear aperture.

Because of the low mass of the moving platform, positioning operations can be performed with far lower settling times than with conventional,
stacked multi-axis systems. In such systems, runout, guiding errors, and the friction and inertia of moving cables all accumulate to limit accuracy and repeatability-problems which do not affect parallel kinematic systems like the Hexapod.

**User-Defined Pivot Point**
For optics and other alignment tasks, it is important to be able to define a fixed pivot point. The sophisticated Hexapod controller allows choosing any point in space as the pivot point for the rotation axes with a simple software command. The pivot point remains fixed relative to the platform.

Target positions in 6-space are entered in user-friendly coordinates and reached by smooth vectorized motion.

### Technical Data

<table>
<thead>
<tr>
<th></th>
<th>M-810.00</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active axes</strong></td>
<td>X, Y, Z, (\theta)X, (\theta)Y, (\theta)Z</td>
<td></td>
</tr>
<tr>
<td><strong>Motion and positioning</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Travel range X, Y</td>
<td>±20</td>
<td>mm</td>
</tr>
<tr>
<td>*Travel range Z</td>
<td>±6.5</td>
<td>mm</td>
</tr>
<tr>
<td>*Travel range (\theta)X, (\theta)Y</td>
<td>±11</td>
<td>°</td>
</tr>
<tr>
<td>*Travel range (\theta)Z</td>
<td>±30</td>
<td>°</td>
</tr>
<tr>
<td><strong>Actor drive</strong></td>
<td>Brushless DC Motor, ActiveDrive™</td>
<td></td>
</tr>
<tr>
<td><strong>Actuator stroke</strong></td>
<td>±7.5</td>
<td>mm</td>
</tr>
<tr>
<td><strong>Single-actuator design resolution</strong></td>
<td>0.04</td>
<td>µm</td>
</tr>
<tr>
<td><strong>Integrated sensor</strong></td>
<td>Rotary encoder</td>
<td></td>
</tr>
<tr>
<td><strong>Sensor resolution</strong></td>
<td>12800 Cts./rev.</td>
<td></td>
</tr>
<tr>
<td><strong>Min. incremental motion X, Y</strong></td>
<td>1</td>
<td>µm</td>
</tr>
<tr>
<td><strong>Min. incremental motion Z</strong></td>
<td>0.2</td>
<td>µm</td>
</tr>
<tr>
<td><strong>Min. incremental motion (\theta)X, (\theta)Y, (\theta)Z</strong></td>
<td>3.5</td>
<td>µrad</td>
</tr>
<tr>
<td><strong>Repeatability X, Y</strong></td>
<td>±2</td>
<td>µm</td>
</tr>
<tr>
<td><strong>Repeatability Z</strong></td>
<td>±0.5</td>
<td>µm</td>
</tr>
<tr>
<td><strong>Repeatability (\theta)X, (\theta)Y, (\theta)Z</strong></td>
<td>±5</td>
<td>µrad</td>
</tr>
<tr>
<td><strong>Backlash X, Y</strong></td>
<td>2</td>
<td>µm</td>
</tr>
<tr>
<td><strong>Backlash Z</strong></td>
<td>0.5</td>
<td>µm</td>
</tr>
<tr>
<td><strong>Max. velocity X, Y, Z</strong></td>
<td>10</td>
<td>mm/s</td>
</tr>
<tr>
<td><strong>Max. velocity (\theta)X, (\theta)Y, (\theta)Z</strong></td>
<td>250</td>
<td>mrad/s</td>
</tr>
<tr>
<td><strong>Typ. velocity X, Y, Z</strong></td>
<td>5</td>
<td>mm/s</td>
</tr>
<tr>
<td><strong>Typ. velocity (\theta)X, (\theta)Y, (\theta)Z</strong></td>
<td>120</td>
<td>mrad/s</td>
</tr>
<tr>
<td><strong>Mechanical properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stiffness X, Y</strong></td>
<td>0.1 N/µm</td>
<td></td>
</tr>
<tr>
<td><strong>Stiffness Z</strong></td>
<td>4 N/µm</td>
<td></td>
</tr>
<tr>
<td><strong>Max. load (baseplate horizontal / optional)</strong></td>
<td>5 / 2.5 kg</td>
<td></td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Operating temperature range</strong></td>
<td>0 to +50 °C</td>
<td></td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td>Stainless steel, aluminum</td>
<td></td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>1.7 kg</td>
<td></td>
</tr>
<tr>
<td><strong>Controller</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Operating Voltage</strong></td>
<td>100–240 VAC, 50/60 Hz</td>
<td></td>
</tr>
</tbody>
</table>

* The travel ranges of the individual coordinates \(X, Y, Z, \theta X, \theta Y, \theta Z\) are interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or rotational coordinates are not zero, the available travel may be less.

** Six-axis move. No moving cables (unlike serial-kinematic stacked systems). Eliminates bending, inertia and friction, improving accuracy.

Technical data are specified at 20 ±3°C. Data for vacuum versions may differ.

---

**Open Architecture**
Control of the hexapod is facilitated by the controller's open interface architecture, which provides a variety of high-level commands and includes a macro language for programming and storing command sequences.
M-850 Hexapod 6-Axis Robot
High-Load Parallel-Kinematics Micropositioner with Controller, to 2000 N

-The M-850 is the ideal micro-positioning system for all complex positioning tasks which depend upon high load capacity and accuracy in six independent axes. The use of extremely stiff and accurate components for the M-850 Hexapod results in an unusually high natural frequency of 500 Hz with a 10 kg load. It can withstand loads of 200 kg vertically, and at least 50 kg in any direction. In addition to positioning all axes with resolutions in the submicron and arc-second ranges, it allows the user to define the center of rotation (pivot point) anywhere inside or outside the system envelope by one simple software command.

Two models are available: The M-850.50 featuring higher speed and direct-drive actuators, and the M-850.11 with a gear ratio that makes it self-locking even with large loads.

Hexapod vs. Serial Kinematics Systems
The Hexapod is driven by six high-resolution actuators all connected directly to the same moving platform. This design provides a high system stiffness and a large clear aperture. Because of the low mass of the moving platform, positioning operations can be performed with far lower settling times than with conventional, stacked multi-axis systems. In such systems, runout, guiding errors, and the friction and inertia of moving cables all accumulate to limit accuracy and repeatability—problems which do not affect parallel kinematic systems like the Hexapod.

Fixed Virtual Pivot Point
For optics and other alignment tasks, it is important to be able to define a fixed pivot point. The sophisticated Hexapod controller allows choosing any point in space as the pivot point for the rotation axes by software command. The pivot point remains fixed relative to the platform.

Target positions in 6-space are entered in user-friendly coordinates and reached by smooth vectorized motion.

Open Architecture
Control of the hexapod is facilitated by the controller’s open interface architecture, which provides a variety of high-level commands and includes a macro language for programming and storing command sequences.

Automatic Optical Alignment
With the internal or external photometer option and the integrated scanning routines, just a few commands are needed to perform an automated alignment of optical components. For more information on photometers / optical power meters, see www.pi.ws.

A smaller, even-more-precise hexapod, specially developed for alignment of collimators, fiber bundles and I/O chips, is available as the F-206 (see p. 10).
### Technical Data

#### Model | M-850.11 | M-850.50 | Units
---|---|---|---
**Active axes** | X, Y, Z, θ<sub>XY</sub>, θ<sub>YZ</sub>, θ<sub>ZX</sub> | X, Y, Z, θ<sub>XY</sub>, θ<sub>YZ</sub>, θ<sub>ZX</sub> | 
**Motion and positioning** | | | 
*Travel range X, Y* | ±50 | ±50 | mm
*Travel range Z* | ±25 | ±25 | mm
*Travel range θ<sub>X</sub>* | ±15 | ±15 | °
*Travel range θ<sub>Y</sub>* | ±30 | ±30 | °
**Actuator drive** | DC-motor | DC-motor | 
**Actuator stroke** | ±25 | ±25 | mm
**Integrated sensor** | Rotary encoder | Rotary encoder | 
**Sensor resolution** | 2048 | 2048 | 
**Actuator design resolution** | 0.005 | 0.05 | µm
**Min. incremental motion X, Y, Z** | 1 (XY), 0.5 (Z) | 1 (XY), 0.5 (Z) | µm
**Min. incremental motion θ<sub>XY</sub>, θ<sub>YZ</sub>, θ<sub>ZX</sub>** | 5 | 5 | µrad
**Repeatability X, Y** | ±2 | ±2 | µm
**Repeatability Z** | ±1 | ±1 | µm
**Repeatability θ<sub>XY</sub>, θ<sub>YZ</sub>, θ<sub>ZX</sub>** | ±10 | ±10 | µrad
**Max. velocity X, Y, Z** | 0.5 | 8 | mm/s
**Max. velocity θ<sub>XY</sub>, θ<sub>YZ</sub>, θ<sub>ZX</sub>** | 6 | 100 | mrad/s
**Typ. velocity X, Y, Z** | 0.3 | 5 | mrad/s
**Typ. velocity θ<sub>XY</sub>, θ<sub>YZ</sub>, θ<sub>ZX</sub>** | 3 | 50 | mrad/s
**Mechanical properties** | | | 
Stiffness (k<sub>x</sub>, k<sub>y</sub>) | 3 | 3 | N/µm
Stiffness (k<sub>z</sub>) | 100 | 100 | N/µm
Max. load (baseplate horizontal/any orientation) | 200 / 50 | 200 / 50 | kg
Max. holding force (baseplate horizontal/any orientation) | 2000 / 500 | 250 / 85 | N
Resonant frequency** | 90 | 90 | Hz
Resonant frequency** | 500 | 500 | Hz
**Miscellaneous** | | | 
Operating temperature range | -10 to +50 | -10 to +50 | °C
Material | Aluminum | Aluminum | 
Mass | 17 | 17 | kg
**Controller** | | | 
Controller included | M-850.502 | M-850.502 | 
Operating voltage | 100–240 VAC, 50/60 Hz | 100–240 VAC, 50/60 Hz | 

*Technical data are specified at 20 ±3 °C. Data for vacuum versions may differ.*

---

**The max. travel of the several coordinates (X, Y, Z, θ<sub>XY</sub>, θ<sub>YZ</sub>, θ<sub>ZX</sub>) are interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or rotational coordinates are not zero, the available travel may be less.**

**Six-axis move. No moving cables (unlike serial-kinematic stacked systems) to introduce bending forces, torque and friction which degrade positioning accuracy.**

Example: The following position is in the workspace:

- X: +20 mm
- Y: +20 mm
- Z: +5 mm
- θ<sub>X</sub>: +10°
- θ<sub>Y</sub>: +10°
- θ<sub>Z</sub>: -2°

***Baseplate mounted horizontally with 10 kg load***
M-840 HexaLight™ 6-Axis Robot

High-Speed Parallel-Kinematics Micropositioner with Controller, to 50 mm/s

*Six Degrees of Freedom, Travel Ranges to 100 mm/
60° Rapid Response*

*No Moving Cables for Improved Reliability and Precision*

*Load Capacity 10 kg, Self-Locking Version M-840.DG*

*Velocity up to 50 mm/s*

*Repeatability up to ±2 µm*

*Encoder Resolution to 0.016 µm*

*Significantly Smaller and Stiffer than Serial-Kinematics Systems, Better Dynamics*

*Vacuum-Compatible Versions Available*

*Virtual Pivot Point*

*Sophisticated Controller Using Vector Algorithms*

*MTBF 20,000 h*

The M-840 is the ideal Micropositioning System for all complex positioning tasks which depend upon high speed and accuracy in six independent axes.

**Faster Positioning in All Six Axes**

In comparison with the M-850 Hexapod (see p. 4 ff) the M-840 is designed for higher speeds and lighter loads. Loads of up to 10 kg can be positioned at up to 50 mm/s and 600 mrad/s with micron accuracy. In addition to positioning all axes, it allows the user to define the center of rotation (pivot point) anywhere inside or outside the system envelope by one simple software command.

Two models are available: The M-840.5PD featuring higher speed and direct-drive actuators, and the M-840.5DG with a gear ratio that makes it self-locking.

**Hexapod vs. Serial Kinematics Systems**

The Hexapod is driven by six high-resolution actuators all connected directly to the same moving platform. This design provides a high system stiffness and a large clear aperture.

Because of the low mass of the moving platform, positioning operations can be performed with far lower settling times than with conventional, stacked multi-axis systems. In such systems, runout, guiding errors, and the friction and inertia of moving cables all accumulate to limit accuracy and repeatability—problems which do not affect parallel kinematic systems like the Hexapod.

**Fixed Virtual Pivot Point**

For optics and other alignment tasks, it is important to be able to define a fixed pivot point. The sophisticated Hexapod controller allows choosing any point in space as the pivot point for the rotation axes by software command. The pivot point remains fixed relative to the platform.

**Target positions in 6-space are entered in user-friendly coordinates and reached by smooth vectorized motion.**

**Open Architecture**

Control of the hexapod is facilitated by the controller’s open architecture.

**Application Examples**

- Biotechnology
- Semiconductor technology
- Micromachining
- Micromanipulation
- X-ray diffraction measurements
- Tool control

**Ordering Information**

M-840.5PD
Hexapod 6-Axis Parallel Kinematics Microrobot with Controller, Direct Drive

M-840.5DG
Hexapod 6-Axis Parallel Kinematics Microrobot with Controller, Gearhead Drive

**Optional Photometer**

F-206.iiU
Photometer Card, IR Range, 2 Channels

F-206.VVU
Photometer Card, Visible Range, 2 Channels

F-361.10
NIST Traceable Optical Power Meter, 1000 to 1600 nm

*Ask about custom designs!*
interface architecture, which provides a variety of high-level commands and includes a macro language for programming and storing command sequences.

Automatic Optical Alignment
With the internal or external photometer option and the integrated scanning routines, just a few commands are needed to perform an automated alignment of optical components. For more information on photometers / optical power meters, see www.pi.ws.

A smaller, even-more-precise hexapod, specially developed for alignment of collimators, fiber bundles and I/O chips, is available as the F-206 see p. 10 ff.

For a compact, vacuum-compatible Hexapod see M-824 see p. 8 ff.
The M-824 is the ideal micro-positioning system for all complex positioning tasks which depend on high speed and accuracy in six independent axes. In addition to positioning all axes, it allows the user to define a center of rotation (pivot point) anywhere inside or outside the system envelope by one simple software command.

**Extremely Compact, Two Motor Versions**

The M-824 uses a very compact drive with motor and spindle mounted side-by-side and, with a height of 188 mm, has a considerably lower profile than either the M-850, page 4-6, or M-840, page 4-8 Hexapods. Two versions featuring different drives are offered: the self-locking M-824.3DG with DC motor and gearhead can position loads of up to 5 kg in any orientation (10 kg with baseplate horizontal) with sub-micron precision. The M-824.3PD with integrated ActiveDrive™ system provides a significantly higher velocity of up to 25 mm/sec with loads up to 5 kg.

**Hexapod vs. Serial Kinematics Systems**

The Hexapod is driven by six high-resolution actuators all connected directly to the same moving platform. This design provides a high system stiffness and a large clear aperture.

Because of the low mass of the moving platform, positioning operations can be performed with far lower settling times than with conventional, stacked multi-axis systems. In such systems, runout, guiding errors, and the friction and inertia of moving cables all accumulate to limit accuracy and repeatability—problems which do not affect parallel kinematic systems like the Hexapod.

**Fixed Virtual Pivot Point**

For optics and other alignment tasks, it is important to be able to define a fixed pivot point. The sophisticated Hexapod controller allows choosing any point in space as the pivot point for the rotation axes by software command. The pivot point remains fixed relative to the platform. Target positions in 6-space are entered in user-friendly coordinates and reached by smooth vectorized motion.

**Open Architecture**

Control of the hexapod is facilitated by the controller’s open
interface architecture, which provides a variety of high-level commands and includes a macro language for programming and storing command sequences.

**Vacuum Versions**
Both models are available as vacuum versions that enable use in applications such as X-ray diffraction microscopy with ambient pressures down to $10^{-6}$ hPa.

### Technical Data

<table>
<thead>
<tr>
<th>Model</th>
<th>M-824.3DG</th>
<th>M-824.3PD</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active axes</td>
<td>X, Y, Z, θx, θy, θz</td>
<td>X, Y, Z, θx, θy, θz</td>
<td></td>
</tr>
<tr>
<td>Motion and positioning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Travel range X, Y</td>
<td>±22.5</td>
<td>±22.5</td>
<td>mm</td>
</tr>
<tr>
<td>*Travel range Z</td>
<td>±12.5</td>
<td>±12.5</td>
<td>mm</td>
</tr>
<tr>
<td>*Travel range θx, θy</td>
<td>±7.5</td>
<td>±7.5</td>
<td>°</td>
</tr>
<tr>
<td>*Travel range θz</td>
<td>±12.5</td>
<td>±12.5</td>
<td>°</td>
</tr>
<tr>
<td>Single-actuator drive</td>
<td>DC-motor, gearhead</td>
<td>ActiveDrive™ DC Motor</td>
<td></td>
</tr>
<tr>
<td>Actuator stroke</td>
<td>±12.5</td>
<td>±12.5</td>
<td>mm</td>
</tr>
<tr>
<td>Single-actuator design resolution</td>
<td>0.007</td>
<td>0.5</td>
<td>μm</td>
</tr>
<tr>
<td>Integrated sensor</td>
<td>Rotary encoder</td>
<td>Rotary encoder</td>
<td></td>
</tr>
<tr>
<td>Sensor resolution</td>
<td>2048</td>
<td>2048</td>
<td>cts./rev.</td>
</tr>
<tr>
<td>**Min. incremental motion X, Y, Z</td>
<td>0.3</td>
<td>1</td>
<td>μm</td>
</tr>
<tr>
<td>**Min. incremental motion θx, θy, θz</td>
<td>3.5</td>
<td>12</td>
<td>μrad</td>
</tr>
<tr>
<td>Repeatability X, Y, Z</td>
<td>±0.5</td>
<td>±0.5</td>
<td>μm</td>
</tr>
<tr>
<td>Repeatability θx, θy, θz</td>
<td>±6</td>
<td>±6</td>
<td>μrad</td>
</tr>
<tr>
<td>Max. velocity X, Y, Z</td>
<td>1</td>
<td>25</td>
<td>mm/s</td>
</tr>
<tr>
<td>Max. velocity θx, θy, θz</td>
<td>11</td>
<td>270</td>
<td>mrad/s</td>
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<tr>
<td>Typ. velocity X, Y, Z</td>
<td>0.5</td>
<td>10</td>
<td>mm/s</td>
</tr>
<tr>
<td>Typ. velocity θx, θy, θz</td>
<td>5.5</td>
<td>55</td>
<td>mrad/s</td>
</tr>
<tr>
<td>Mechanical properties</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>*Stiffness X, Y</td>
<td>1.7</td>
<td>1.7</td>
<td>N/μm</td>
</tr>
<tr>
<td>Stiffness Z</td>
<td>7</td>
<td>7</td>
<td>N/μm</td>
</tr>
<tr>
<td>Load capacity (baseplate horizontal/any orientation)</td>
<td>10/5***</td>
<td>5/2.5</td>
<td>kg</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating temperature range</td>
<td>-10 to +50</td>
<td>-10 to +50</td>
<td>°C</td>
</tr>
<tr>
<td>Material</td>
<td>Aluminum</td>
<td>Aluminum</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>8</td>
<td>8</td>
<td>kg</td>
</tr>
<tr>
<td>Controller</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controller included</td>
<td>M-850.502</td>
<td>M-850.502</td>
<td></td>
</tr>
<tr>
<td>Operating voltage</td>
<td>100–240 VAC, 50/60 Hz</td>
<td>100–240 VAC, 50/60 Hz</td>
<td></td>
</tr>
</tbody>
</table>

*The travel ranges of the individual coordinates (X, Y, Z, θx, θy, θz) are interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or rotational coordinates are not zero, the available travel may be less.

**Simultaneous motion of all 6 actuators!**
No moving cables (as in serial-kinematics stacked systems) to introduce bending sources, torque and friction, which degrade positioning accuracy.

***Self Locking
Technical data are specified at 20 ±3 °C. Data for vacuum versions may differ.
F-206.S HexAlign™ 6 Axis-Robotics Alignment System
Parallel-Kinematics Precision Alignment System / Manipulator, with Controller

The F-206.S Hexapod comes with a digital 6D controller and comprehensive software.

- Parallel Kinematics with 6 Degrees of Freedom
- 0.033 µm Actuator Resolution
- Repeatability 0.3 µm in Space
- No Moving Cables for Improved Reliability, Reduced Friction
- Better Dynamics, More Compact than Serial Kinematics Systems
- For Scanning and Alignment
- Cartesian Coordinate Control with Virtualized Pivot Point
- Powerful Digital Controller with Open Source LabVIEW Drivers, DLL Libraries...
- Integrated Fiber Alignment Routines

The F-206.S Hexapod is a highly accurate micro-positioning system for complex multi-axis alignment tasks. It is based on PI’s long experience with ultra-high-resolution, parallel kinematics stages. Unlike hexapods with variable-length struts ("legs") the F-206 features constant-length struts and friction-free flexure guides. This gives the F-206 even higher precision than other hexapod designs.

Compact, Plug & Play
The F-206.S Hexapod is considerably smaller and more accurate than comparable serial kinematics six-axis systems (stacks of single-axis units).

The parallel kinematics of the F-206 is immune to the cumulative bending and guiding errors of the various axes which, together with the inertia and friction of the moving cables, can limit accuracy in stacked systems. In addition, rotations are not set in hardware, but about a pivot point freely definable in software. A high-performance controller does all necessary coordinate transformation for coordinating the six drives. Because all the actuators are attached directly to the same moving platform, there are none of the servo-tuning problems associated with the loading and inertia differences of the different axes, as are inherent in stacked systems.

Virtualized Pivot Point
It is important to have a fixed pivot point for alignment tasks, especially in photonics packaging. Because the parallel kinematics motion of the F-206 is calculated with complex algorithms in the digital controller, it was easy to allow programming any point in space as center of rotation. Furthermore, the cartesian coordinates of any position and any orientation can be entered directly and the specified target will be reached after travel along a smooth path.

Six Degrees of Freedom, No Moving Cables
In the F-206 parallel kinematics design, all cable terminations are on the stationary base, eliminating unpredictable friction and inertia, improving resolution and repeatability. Further advantages of the system are:

- No cable guides required
- Reduced Size and Inertia
- Improved Dynamic and Settling Behavior
- Identical Modular Actuators for Simplified Servicing

Open Command Set, Simplified Programming
Integration of the F-206 in complex applications is facilitated by the system’s open command set and comprehensive tool libraries. The controller can be operated either through a host PC, or directly through a keyboard and monitor. It can also run programs stored in a user-friendly, fully documented macro language.

Automatic Optical Alignment
Optional internal and external photometers are available.
Both types are fully integrated with the controller hardware and with routines designed for automatic alignment of collimators, optical fibers and arrays. For more information on the photometers see www.pi.ws.

HexControl™ Software displaying scan of photonics component

Interferometer test of an F-206.S system shows the excellent repeatability of small steps, here 0.5 µm spaced at 100 ms

---

Technical Data

<table>
<thead>
<tr>
<th>Model</th>
<th>F-206.S0 / F-206.SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel range X*</td>
<td>-8 to +5.7 mm</td>
</tr>
<tr>
<td>Travel range Y*</td>
<td>±5.7 mm</td>
</tr>
<tr>
<td>Travel range Z*</td>
<td>±6.7 mm</td>
</tr>
<tr>
<td>Travel range θx*</td>
<td>±5.7°</td>
</tr>
<tr>
<td>Travel range θy*</td>
<td>±6.6°</td>
</tr>
<tr>
<td>Travel range θz*</td>
<td>±5.5°</td>
</tr>
<tr>
<td>Actuator resolution</td>
<td>33 nm</td>
</tr>
<tr>
<td>Minimum incremental motion X, Y, Z**</td>
<td>0.1 µm (6-axis move!)</td>
</tr>
<tr>
<td>Minimum incremental motion θx, θy, θz**</td>
<td>2 µrad (0.400115°) (6-axis move!)</td>
</tr>
<tr>
<td>Bidirectional repeatability X, Y, Z</td>
<td>0.3 µm</td>
</tr>
<tr>
<td>Bidirectional repeatability θx, θy, θz</td>
<td>3.6 µrad</td>
</tr>
<tr>
<td>Speed X, Y, Z</td>
<td>0.01 to 10 mm/s</td>
</tr>
<tr>
<td>Maximum load in Z</td>
<td>2 kg (centered on platform)</td>
</tr>
<tr>
<td>Mass</td>
<td>5.8 kg</td>
</tr>
<tr>
<td>Controller</td>
<td>Digital Hexapod controller with optional photometer card and integrated scan and align routines</td>
</tr>
<tr>
<td>Operating voltage</td>
<td>100–240 VAC, 50/60 Hz</td>
</tr>
<tr>
<td>Software</td>
<td>LabVIEW drivers, software for alignment of arrays, DLL libraries, HexControl™, scan and align software, terminal software</td>
</tr>
</tbody>
</table>

*Travel ranges in the coordinate directions (X, Y, Z θx, θy, θz) are interdependent. The data given shows maximum travel range of the axis in question (i.e. its travel when all other axes are at their zero positions). If this is not the case, the available travel may be less.

**Six-axis move. No moving cables (unlike serial-kinematic stacked systems) to introduce bending forces, torque and friction which degrade positioning accuracy.
Non-Magnetic Piezo Hexapod 6-Axis Robot

6-Axis Precision Positioning System with NEXLINE® Linear Drives

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

<table>
<thead>
<tr>
<th>Model</th>
<th>Travel Range</th>
<th>Load capacity</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-515KNPH</td>
<td>X, Y, Z: 10 mm</td>
<td>50 kg</td>
<td>Outer Ø baseplate, 380 mm</td>
</tr>
<tr>
<td>NEXLINE®</td>
<td>θx, θy, θz: 6°</td>
<td></td>
<td>Ø moved platform (top) 300 mm</td>
</tr>
<tr>
<td>Piezo Hexapod</td>
<td></td>
<td></td>
<td>140 mm height</td>
</tr>
</tbody>
</table>

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

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Products and Technologies
- Nanopositioning / Scanning Stages
- Scanning Microscopy Stages
- Steering Mirrors, Mirror Shifters
- Piezo Actuators
- Piezo Motors
- Piezo Controllers
- Motorized Stages & Actuators
- Motor Controllers
- Hexapod 6-Axis Alignment Systems

Fields of Applications
- Biotechnology / Life Sciences
- Semiconductor Technology
- Data Storage Technology
- Nanotechnology
- Aeronautics
- Astronomy
- Adaptive Optics
- Metrology / Laser-Systems
- Precision Machining

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