6-Axis Precision Alignment System

IDEAL FOR FIBER ALIGNMENT

H-206

- Flexure based for highest precision
- Includes integrated scan algorithms for fiber optic alignment
- Actuator resolution 33 nm
- Repeatability 0.3 µm / 6 µrad
- Min. incremental motion 0.1 µm / 2 µrad
- Velocity from 10 µm/s to 10 mm/s

Reference-class 6-axis positioning system
Parallel-kinematic design for six degrees of freedom making it significantly more compact and stiff than serial-kinematic systems, guidance errors of individual axes do not add up. Higher dynamics, higher reliability. Driven by DC motors

Powerful digital controller, open software architecture

H-206.F11 includes C-887.11, 6D vector motion controller plus 2 additional servo axes. Options:
- Analog interfaces/photometer cards for visible light (F-206.VVU) or the infrared light range (F-206.IIIU)
- F-206.NCU fast piezo nano-alignment system for alignment with nanometer precision

H-206.F12 includes C-887.21 compact 6D vector motion controller

Fields of application
Research and industry. For fiber alignment, micromanipulation systems, optical testing set-ups

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The H-206 includes rapid automatic scan routines for fast multi-axis alignment. The graphic shows 2D optical signal intensity of a fiber optic component. Complete device scan ensures detection of the global peak and prevents locking on to a local maximum.
### H-206.F1x

<table>
<thead>
<tr>
<th>Active axes</th>
<th>Unit</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>X, Y, Z, θ₁, θ₂, θ₃</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Motion and positioning

<table>
<thead>
<tr>
<th>Travel range* X</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel range* Y</td>
<td>mm</td>
</tr>
<tr>
<td>Travel range* Z</td>
<td>mm</td>
</tr>
<tr>
<td>Travel range* θ₁</td>
<td>°</td>
</tr>
<tr>
<td>Travel range* θ₂</td>
<td>°</td>
</tr>
<tr>
<td>Travel range* θ₃</td>
<td>°</td>
</tr>
</tbody>
</table>

**Single-actuator design resolution:** 33 nm

- **Min. incremental motion X, Y, Z**: 0.1 μm typ.
- **Min. incremental motion θ₁, θ₂, θ₃**: 2 μrad (0.4°) typ.
- **Repeatability X, Y, Z**: 0.3 μm typ.
- **Repeatability θ₁, θ₂, θ₃**: 6 μrad typ.
- **Max. velocity X, Y, Z**: 10 mm/s
- **Load (baseplate horizontal)**: 1.5 kg max.

### Miscellaneous

- **Operating temperature range**: 5 to 35 °C
- **Material**: Aluminum
- **Mass**: 5.8 kg ± 5%
- **Cable length**: 3 m ± 10 mm

Technical data specified at 20±3°C.

* The travel ranges of the individual coordinates (X, Y, Z, θ₁, θ₂, θ₃) 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.

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The H-206 Hexapod shows extremely good repeatability of minute steps, in the above graph: 0.5 μm steps with a load of 1 kg in X direction.

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H-206.F1x, dimensions in mm
Controller for Hexapod Positioning Systems

6-D VECTOR MOTION CONTROL, COMPREHENSIVE FUNCTIONALITY

Digital controller for 6-axis-parallel kinematics
Included in the delivery of all PI standard Hexapod systems
- C-887.11, 19" controller, comprises the control for two additional single axes with servo motors, the functionality can be enhanced with many additional options
- C-887.21 compact bench-top controller for a lower system price
Extensive software support

Functions
Real-time system. Position control using Cartesian coordinates, vectorized motion. Stable, virtual pivot point can be defined freely in the working space. Data recorder for recording operating parameters such as motor control, velocity, position or position error. Macro command language. Stand-alone operation possible with Autostart macro or connection of keyboard and monitor. Optional: Manual control unit

Custom designs
Custom designs are available for use at high altitudes, e.g. for astronomical telescope applications. Processing of absolute sensors. Control of motor brakes. Processing of additional (redundant) position sensors for increased safety requirements, e.g. in medical technology

Software
PIMikroMove user software. Common command set for all PI positioning systems. Shared libraries for Windows and Linux. Complete set of LabVIEW VI's. Graphical user interfaces, configuration software and graphically displayed scan routine. Optional: PIVeriMove software for checking a restricted operating space

Interfaces
TCP/IP Ethernet can also be used for remote control and service, RS-232. Monitor, mouse and keyboard interface. On request: RS-422 for up to 1.4 km cable length

Possible enhancements for C-887.11
- Analog interfaces/photometer cards for visible light (F-206.VVU) or the infrared light range (F-206.iu)
- F-206.NCU fast piezo nano-alignment system for alignment with nanometer precision
<table>
<thead>
<tr>
<th>Feature</th>
<th>C-887.11</th>
<th>C-887.21</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function</strong></td>
<td>6-D controller for Hexapods, 19&quot;, incl. control of two additional single axes, can be enhanced with many options</td>
<td>6-D controller for Hexapods, compact bench-top for a lower system price</td>
</tr>
<tr>
<td><strong>Drive type</strong></td>
<td>Servo motors (Hexapod and additional axes)</td>
<td>Servo motors</td>
</tr>
<tr>
<td><strong>Motion and control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Servo characteristics</td>
<td>32-bit PID filter</td>
<td></td>
</tr>
<tr>
<td>Trajectory profile modes</td>
<td>Trapezoid, linear interpolation</td>
<td></td>
</tr>
<tr>
<td>Processor</td>
<td>CPU: 1.8 GHz, motion control chip with 2.5 kHz servo update rate</td>
<td></td>
</tr>
<tr>
<td>Encoder input</td>
<td>AB (quadrature) differential TTL signal, 5 MHz</td>
<td></td>
</tr>
<tr>
<td>Stall detection</td>
<td>Servo off, triggered by position error</td>
<td></td>
</tr>
<tr>
<td>Reference point switch</td>
<td>TTL signal</td>
<td></td>
</tr>
<tr>
<td><strong>Electrical properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. output power per channel</td>
<td>10-bit output for PWM drivers, 24 kHz</td>
<td></td>
</tr>
<tr>
<td>Max. output voltage per channel</td>
<td>TTL in PWM operation for SIGN and MAGN</td>
<td></td>
</tr>
<tr>
<td><strong>Interface and operation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication interfaces</td>
<td>TCP/IP, RS-232, VGA (monitor), USB (keyboard, mouse, manual control unit)</td>
<td></td>
</tr>
<tr>
<td>Hexapod connection</td>
<td>MDR, 68-pin for data transmission</td>
<td></td>
</tr>
<tr>
<td>Connection for additional single axes</td>
<td>15-pin sub-D</td>
<td></td>
</tr>
<tr>
<td>I/O ports</td>
<td>Optional: Analog inputs (photometer cards)</td>
<td></td>
</tr>
<tr>
<td>Command set</td>
<td>PI General Command Set (GCS)</td>
<td></td>
</tr>
<tr>
<td>User software</td>
<td>PIMikroMove</td>
<td></td>
</tr>
<tr>
<td>Software drivers</td>
<td>LabVIEW driver, shared libraries for Windows and Linux</td>
<td></td>
</tr>
<tr>
<td>Manual control</td>
<td>Optional: C-887.MC control unit for Hexapods</td>
<td></td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating voltage</td>
<td>100 to 240 VAC, 50 / 60 Hz</td>
<td></td>
</tr>
<tr>
<td>Operating temperature range</td>
<td>5 to 40°C</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>11 kg</td>
<td>5 kg</td>
</tr>
<tr>
<td>Dimensions</td>
<td>395 × 483 × 185 mm</td>
<td>255 × 226 × 185 mm</td>
</tr>
</tbody>
</table>

All PI Hexapod systems are delivered with an extensive software package. Included are simulation programs that calculate the working space of the Hexapod and the individual loads on each actuator depending on the Hexapod orientation in space.

Highly advanced digital controllers are also available for Hexapods with piezo stepping drives which are suitable for operation in strong magnetic fields or UHV environments.
Due to their parallel kinematic structure, Hexapods necessitate a particularly complex control system. The position coordinates, for example, are given in virtual Cartesian axes which are then converted into positioning commands for the individual actuators by the controller. PI supplies special software that allow the 6-axes positioners to be more convenient in operation and easier to integrate.

**Determining the work space**

The limits of the work space vary depending on the current position of the Hexapod (translation and rotation coordinates) and the current coordinates of the pivot point. A special software tool included with each PI Hexapod calculates these limits and displays them graphically.

**Checking the permissible load**

As with any multi-axis positioning system, the load limit of the Hexapod varies as a function of a number of factors such as orientation of the Hexapod, size and position of the payload, current position (translation and rotation coordinates) of the Hexapod platform, and forces and moments acting on the platform.

The Hexapod software package includes a PI simulation tool that calculates all forces and moments and compares them individually against the specified load limits of the corresponding Hexapod mechanics.

**Preventing collisions with PIVeriMove**

Another proprietary PI simulation software tool enables offline graphical configuration and simulation of the Hexapod motion in the application environment. CAD data of objects can be imported or approximated with simple shapes such as cylinders and cuboids. PIVeriMove then checks restrictions in the work space. Implemented in the controller firmware or the application software, this prevents the Hexapod from approaching positions where the platform, struts, or the mounted load would collide with the surroundings.

**Emulation: The Hexapod system as a virtual machine**

A virtual machine that can be installed on the customer’s host PC is available to emulate a complete Hexapod systems (mechanics, controller and even peripherals). Application programs can then be developed and pre-tested, different load scenarios can be simulated and the work space can be determined before the system arrives, saving significant cost and development time.

**HexaApp: PI Hexapod control via iPhone, iPad or iPod**

The Hexapod system can also be controlled wirelessly from mobile Apple iOS devices. A corresponding app enables command control of touchscreen, motion sensors or via a command input window.
The F-206.S HexAlign™ 6 Axis-Hexapod Parallel-Kinematics Precision Alignment System / Manipulator, with Controller

F-206.S HexAlign™ 6 Axis-Hexapod Parallel-Kinematics Precision Alignment System / Manipulator, with Controller

Application Examples
- Micromanipulation
- Photonics packaging
- Fiber alignment
- Semiconductor handling / test systems
- Micromanipulation (life science)
- Optical device testing
- Collimator and fiber bundle alignment
- MEMS positioning/alignment

The F-206.S HexAlign™ 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.

Ordering Information
F-206.S0 Hexapod 6-Axis Precision Alignment System / Manipulator with 6 DOF Hexapod Controller
F-206.SD Hexapod 6-Axis Precision Alignment System / Manipulator with 6 DOF Hexapod Controller, Built-in Display and Keypad

Options and Accessories
F-206.AC8 Upgrade for 2 Additional Servo-Motor Control Channels on F-206 Controller
F-206.MHU Force-Limiting Mounting Platform, (included with F-206.SD)
F-206.NCU Upgrades: Rapid Nanopositioning Upgrade for F-206.S. Consists of P-611.3SF NanoCube and E-760 Controller Card
F-206.MC6 6D Interactive Manual Control Pad
F-206.VVU 2-Channel Photometer Card, (Visual Range)
F-206.iIU 2-Channel Photometer Card (IR Range)
F-361.10 Absolute-Measuring Optical Power Meter, 1000-1600 nm Wavelength

Additional Accessories, see www.pi.ws.
F-206 provides ultra-precise motion in all six degrees of freedom with rotation about any point in space. The pivot point is set by the user with a simple software command.

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

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**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 (0.4°) (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, 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.

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The F-206 was replaced by the H-206, see above.
The F-206 was replaced by the H-206, see above

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**F-206.NCU Rapid NanoAlign Upgrade**

For applications where alignment with nanometer-range resolution is required, or where rapid mapping of the entire cross-section of a component in as short a time as possible is desired, the F-206.NCU Rapid NanoAlign upgrade is recommended. It consists of the P-611.3SF XYZ piezo-drive NanoCube® (see p. 2-52) and the E-760 controller board (see p. 2-138), which is installed in the F-206 controller.

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**Ordering Information**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-206.MC6</td>
<td>6D Interactive Manual Control Pad</td>
</tr>
<tr>
<td>C-815.MC6</td>
<td>3 m Extension Cable for Manual Control Pad</td>
</tr>
<tr>
<td>F-206.iIU</td>
<td>2-Channel Photometer Card (IR Range)</td>
</tr>
<tr>
<td>F-206.VVU</td>
<td>2-Channel Photometer Card (Visual Range)</td>
</tr>
<tr>
<td>F-206.AC8</td>
<td>Upgrade for 2 Additional Servo-Motor Control Channels on Hexapod Controller</td>
</tr>
<tr>
<td>F-311</td>
<td>PiMotion&amp;Vision™ Imaging Processing for Intelligent Automation</td>
</tr>
<tr>
<td>F-361.10</td>
<td>Absolute-Measuring Optical Power Meter, 1000-1600 nm Wavelength</td>
</tr>
</tbody>
</table>

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**Upgrades / Options for F-206 Systems**

- F-206.MHU: Force-Limiting Mounting Platform (included with F-206.Sx)
- F-206.TMU: Additional Mounting Platform, for rapid exchange of different setups
- F-206.NCU: Rapid Nanopositioning Upgrade for F-206. Consists of P-611.3SF NanoCube® and E-760 Controller Card
- M-500.206: Adapter Plate for Mounting F-206 on M-511, M-521 and M-531 Translation Stages

Ask about custom designs!
Hexapod Options & Accessories

Optical Metrology Boards
The controllers for the F-206, M-840 and M-850 Hexapod systems can be equipped/retrofitted with the following photometer cards: F-206.VVU (2-channel, visual) and F-206.iiU (2-channel, IR).

F-206.MC6 6D Interactive Control Pad Upgrade
The F-206.MC6 manual control pad facilitates system setup and testing procedures. It consists of a board that plugs into the Hexapod controller and a control pad with six digital “potentiometer” knobs (one for each degree of freedom).

The manual pad works seamlessly with the Hexapod software, and allows programmable step sizes of 1 μm to 500 μm (linear) and 0.001 to 0.5deg (angular) per step.

External positioning commands (via the computer interface) can be intermixed with manual positioning input without loss of the true position, because both inputs operate on the same position registers of the Hexapod controller. The control pad comes with a 3 m cable. A 3 m extension cable is available as part number C-815.MC6.

More Options see F-311 PIMotion&Vision™ System, F-361 Optical Power Meter and F-603 Fiber, Objective and Waveguide Holders. (www.pi.ws)

Options for F-206 systems

Force-Limiting Platform
In some applications it may be useful to limit the forces on or from the F-206 platform to protect the mechanics or components mounted on the F-206 from damage:

F-206.MHU
F-206.MHU is a magnetic kinematically clamped, add-on platform which consists of two parts. The upper part, also available separately under order number F-206.TMU, releases itself automatically when a certain force or torque is exceeded. With multiple F-206.TMUs, complete setups mounted on different top plates can be interchanged quickly and easily. F-206.MHU is included as standard with F-206.Sx.

Technical Data

<table>
<thead>
<tr>
<th>Model</th>
<th>F-206.iiU, F-206.VVU Optical Metrology Boards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical power range</td>
<td>5 nW – 10 mW</td>
</tr>
<tr>
<td>Analog input voltage range</td>
<td>0 – 10 V</td>
</tr>
<tr>
<td>A/D resolution</td>
<td>16-bit</td>
</tr>
<tr>
<td>Sample rate</td>
<td>10 kHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>300 Hz (optical input), 10 kHz (electrical input)</td>
</tr>
<tr>
<td>Max. sensitivity at:</td>
<td>880 nm (visible, F-206.VVU); 1550 nm (IR range, F-206.iiU)</td>
</tr>
<tr>
<td>40% sensitivity at:</td>
<td>480 / 1040 nm (visible, F-206.VVU); 850 / 1680 nm (IR range, F-206.iiU)</td>
</tr>
</tbody>
</table>

The F-206 HexAlign™ 6D alignment system combines high resolution and high accuracy with rapid response, and allows fully automatic alignment of fiber optic components. The optional NanoCube® module (front left) achieves nanometer resolution and, with its rapid-response piezo drive, can scan and characterize the entire cross-section of an optical component in a few seconds (see P-611, p. 2-52).