6-Axis Hexapod

HIGH VELOCITY, MEDIUM LOAD, AFFORDABLE

H-840

- Load capacity to 30 kg
- Travel ranges to 100 mm / 60°
- Actuator resolution to 16 nm
- Repeatability to ±0.4 µm
- MTBF 20,000 h
- Velocity to 50 mm/s

EtherCAT® Option

EtherCAT® is a registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

Precision-class 6-axis system

Parallel-kinematic design for six degrees of freedom making it significantly more compact and stiff than serial-kinematic systems, higher dynamic range, no moved cables: Higher reliability, reduced friction

Drive variants

H-840.G1x with DC gear motors

H-840.D1x with powerful DC motors for higher velocity

Powerful digital controller, open software architecture

User-defined, stable pivot point, software-selectable. Positions commanded in Cartesian coordinates. Macro programming. Open source LabVIEW driver set. Work space simulation software. Virtual Hexapod machine software. Optional: Collision avoidance software (external obstacles).

H-840.xx1 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.iiU)
- F-206.NCU fast piezo nano-alignment system for alignment with nanometer precision

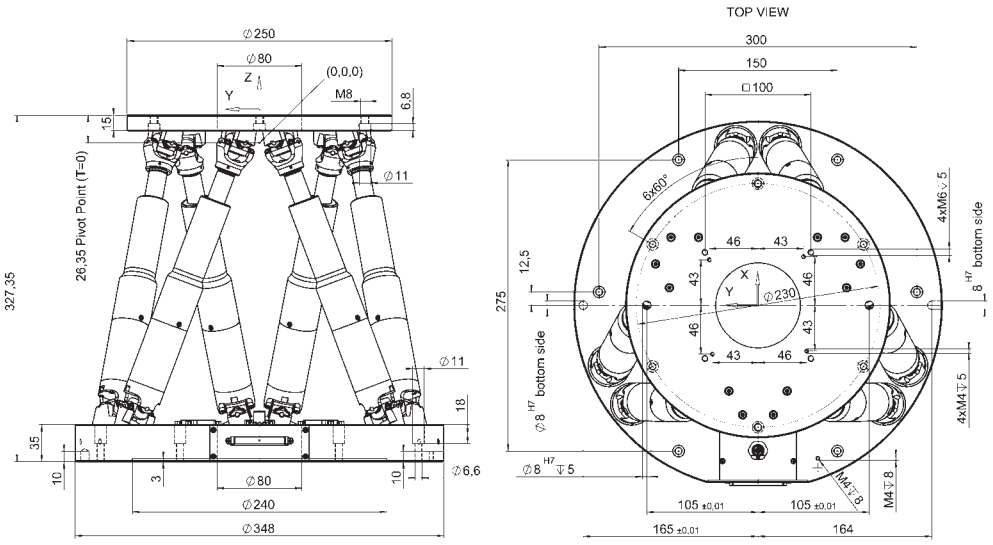
H-840.xx2 includes C-887.21 compact 6D vector motion controller

Fields of application

Research and industry. For micromanipulation, laser and optics alignment, biotechnology, tool control

	H-840.G1x	H-840.D1x	Unit	Tolerance
	for higher resolution and load	for higher velocity		
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z		
Motion and positioning				
Travel range* X, Y	±50	±50	mm	
Travel range* Z	±25	±25	mm	
Travel range* θ_X, θ_Y	±15	±15	°	
Travel range* θ_Z	±30	±30	°	
Single-actuator design resolution	0.017	0.5	µm	
Min. incremental motion X, Y	1	3	µm	typ.
Min. incremental motion Z	0.5	1	µm	typ.
Min. incremental motion θ_X, θ_Y, θ_Z	5	5	µrad	typ.
Backlash X, Y	3	3	µm	typ.
Backlash Z	0.2	0.2	µm	typ.
Backlash θ_X, θ_Y	20	20	µrad	typ.
Backlash θ_Z	30	30	µrad	typ.
Repeatability X, Y	±0.5	±0.5	µm	typ.
Repeatability Z	±0.4	±0.4	µm	typ.
Repeatability θ_X, θ_Y	±7	±7	µrad	typ.
Repeatability θ_Z	±12	±12	µrad	typ.
Max. velocity X, Y, Z	2.5	50	mm/s	
Max. velocity θ_X, θ_Y, θ_Z	30	600	mrad/s	
Typ. velocity X, Y, Z	2	30	mm/s	
Typ. velocity θ_X, θ_Y, θ_Z	20	300	mrad/s	
Mechanical properties				
Load (base plate horizontal / any orientation)	30 / 10	10 / 3	kg	max.
Holding force, de-energized (base plate horizontal / any orientation)	100 / 25	15 / 5	N	max.
Motor type	DC motor, gearhead	DC motor		
Miscellaneous				
Operating temperature range	-10 to 50	-10 to 50	°C	
Material	Aluminum	Aluminum		
Mass	12	12	kg	±5%
Cable length	3	3	m	±10 mm

Technical data specified at 20±3°C.
Ask about custom designs!
* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_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.



H-840, dimensions in mm

Controller for Hexapod Positioning Systems

6-D VECTOR MOTION CONTROL, COMPREHENSIVE FUNCTIONALITY

C-887

- Sophisticated controller using vector algorithms
- Freely programmable, virtual pivot point
- Data recorder
- Macro program functionality
- Stand-alone operation possible and control through TCP/IP and RS-232 interfaces
- Extensive software support

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

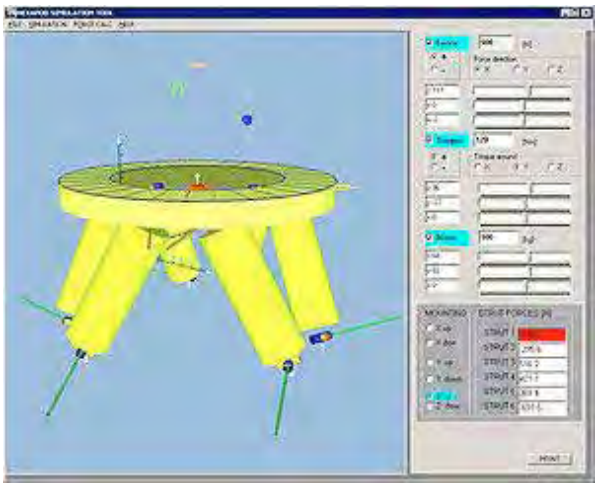
Interfaces

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.iiU)
- F-206.NCU fast piezo nano-alignment system for alignment with nanometer precision

	C-887.11	C-887.21
Function	6-D controller for Hexapods, 19“, incl. control of two additional single axes, can be enhanced with many options	6-D controller for Hexapods, compact bench-top for a lower system price
Drive type	Servo motors (Hexapod and additional axes) Optional: Piezo drives	Servo motors
Motion and control		
Servo characteristics	32-bit PID filter	
Trajectory profile modes	Trapezoid, linear interpolation	
Processor	CPU: 1.8 GHz, motion control chip with 2.5 kHz servo update rate	
Encoder input	AB (quadrature) differential TTL signal, 5 MHz	
Stall detection	Servo off, triggered by position error	
Reference point switch	TTL signal	
Electrical properties		
Max. output power per channel	10-bit output for PWM drivers, 24 kHz	
Max. output voltage per channel	TTL in PWM operation for SIGN and MAGN	
Interface and operation		
Communication interfaces	TCP/IP, RS-232 VGA (monitor), USB (keyboard, mouse, manual control unit)	
Hexapod connection	MDR, 68-pin for data transmission M12 4-pin. for power supply	
Connection for additional single axes	15-pin sub-D	–
I/O ports	Optional: Analog inputs (photometer cards)	–
Command set	PI General Command Set (GCS)	
User software	PIMikroMove	
Software drivers	LabVIEW driver, shared libraries for Windows and Linux	
Manual control	Optional: C-887.MC control unit for Hexapods	
Miscellaneous		
Operating voltage	100 to 240 VAC, 50 / 60 Hz	
Operating temperature range	5 to 40°C	
Mass	11 kg	5 kg
Dimensions	395 × 483 × 185 mm	255 × 226 × 185 mm



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

Hexapod-Specific Software

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 multiaxis 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

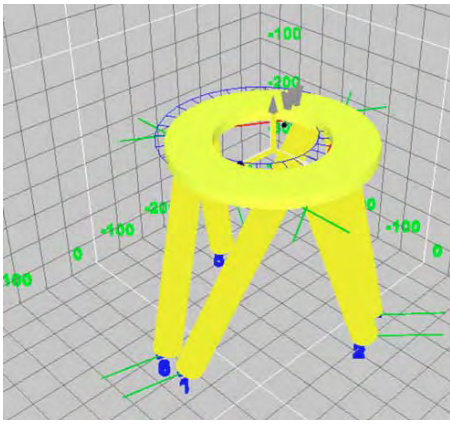
Another proprietary PI simulation software tool enables offline graphical configuration and simulation of the Hexapod motion in the application environment. CAD data of objects can be imported or approximated with simple shapes such as cylinders and cuboids. PIVeriMove then checks restrictions in the 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

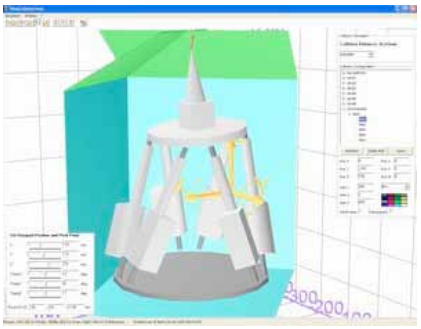
A virtual machine that can be installed on the customer's host PC is available to emulate a complete Hexapod systems (mechanics, controller and even peripherals). Application programs can then be developed and pre-tested, different load scenarios can be simulated and the work space can be determined 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 simulation software graphically displays the position and the available work space of the Hexapod model



The M-840 was replaced by the H-840 (see above)

M-840 HexaLight 6-Axis Positioning System

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

M-840 HexaLight 6D-Micropositioning System

- **Six Degrees of Freedom, Travel Ranges to 100 mm/ 60°**
- **Rapid Response**
- **No Moving Cables for Improved Reliability and Precision**
- **Self-Locking Version M-840.DG3: Load Capacity up to 30 kg**
- **Direct-Drive Version M-840.5PD: Velocity up to 50 mm/s**
- **Repeatability up to ±2 µm**
- **Encoder Resolution up 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 rely on high accuracy and speed in six independent axes. 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.

Application Examples

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

Fast Positioning in All Six Axes

Two models of the M-840 Hexapod are available. The M-840.5PD Hexapod, which features a higher speed and direct-drive actuators, positions loads of up to 10 kg in horizontal and up to 3 kg in random orientation at up to 50 mm/s and 600 mrad/s with micron accuracy. The DC-motor-version, M-840.DG3, is basically self-locking. It positions loads of up to 30 kg in horizontal and up to 10 kg in random orientation, and offers smallest sub-micron step sizes.

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

Ordering Information

M-840.5PD
Hexapod Microrobot with Controller, Direct Drive, 10 kg Load

M-840.DG3
Hexapod Microrobot with Controller, DC Motor Gearhead, 30 kg Load

Optional Photometer

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

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

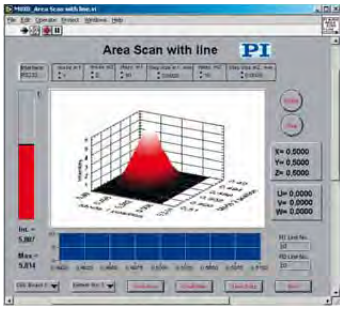
F-361.10
Absolute-Measuring Optical Power Meter, 1000 bis 1600 nm Wavelength

More Hexapod-Models:

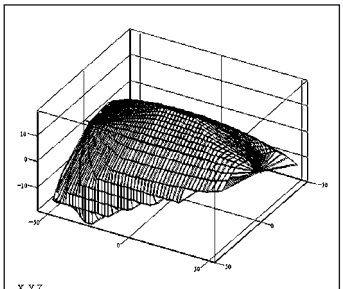
M-850 High-Load Hexapod s. p. 4-6

M-824 Vacuum Compatible Hexapod s. p. 4-10

F-206 Micropositioning System for Maximum Accuracy s. p. 4-12



HexControl software showing scan of a fiber optics component

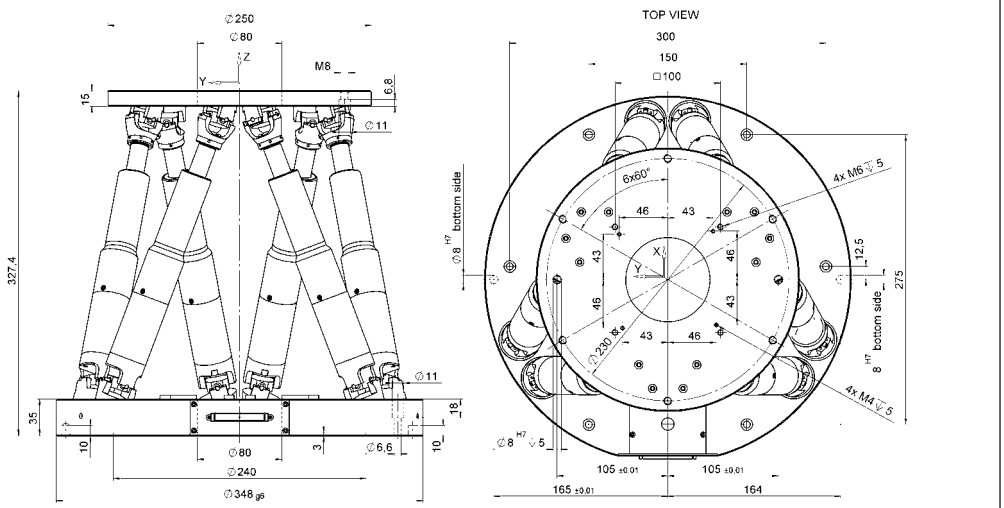


The X, Y, Z working space of the M-840 with θX = θY = θZ = 5°

macro language for programming and storing command sequences.

Automatic Optics 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 about the photometers see www.pi.ws.



M-840 dimensions in mm, 3 m cable included

High-speed F-361
Optical Power Meter

Technical Data

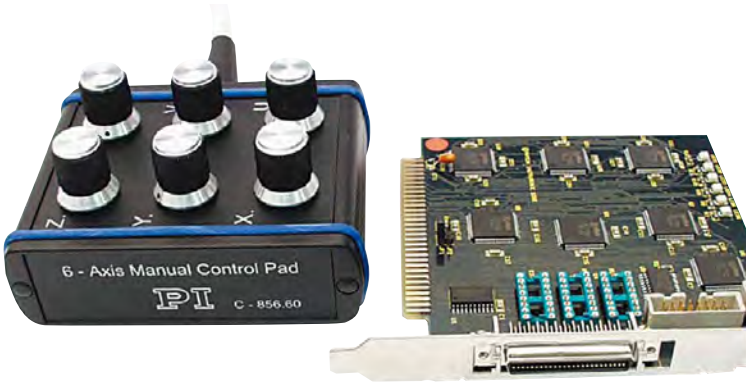
Model	M-840.5PD	M-840.DG3	Units
Active axes	X, Y, Z, θX, θY, θZ	X, Y, Z, θX, θY, θZ	
Motion and positioning			
*Travel range X, Y	±50	±50	mm
*Travel range Z	±25	±25	mm
*Travel range θX, θY	±15	±15	°
*Travel Range θZ	±30	±30	°
Actuator drive	DC-motor	DC-motor	
Actuator stroke	±25	±25	mm
Integrated sensor	Rotary encoder	Rotary encoder	
Sensor resolution	2048	2048	
Actuator design resolution	0.5	0.017	µm
**Min. incremental motion X, Y	3	1	µm
**Min. incremental motion Z	1	0.5	µm
**Min. incremental motion θX, θY, θZ	5	5	µrad
Repeatability X, Y	±2	±2	µm
Repeatability Z	±1	±1	µm
Repeatability θX, θY, θZ	±20	±20	µrad
Max. velocity X, Y, Z	50	2.5	mm/s
Max. velocity θX, θY, θZ	600	30	mrad/s
Typ. velocity X, Y, Z	30	2	mm/s
Typ. velocity θX, θY, θZ	300	20	mrad/s
Mechanical properties			
Max. load (baseplate horizontal / any orientation)	10 / 3	30 / 10	kg
Max. holding force (baseplate horizontal / any orientation)	15 / 5	100 / 25	N
Resonant frequency*** FX, FY	100	100	Hz
Resonant frequency*** FZ	300	300	Hz
Miscellaneous			
Operating temperature range	-10 to +50	-10 to +50	°C
Material	Aluminum	Aluminum	
Mass	12	12	kg
Controllers			
Delivered controller	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, 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.
** Six-axis move. No moving cables (unlike serial-kinematic stacked systems).
*** Horizontal mounted baseplate without load.

Hexapod Options & Accessories

Photometer card



The F-206.MC6 manual control pad facilitates system setup and testing procedures. It permits independent motion in all degrees of freedom with programmable step size

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.

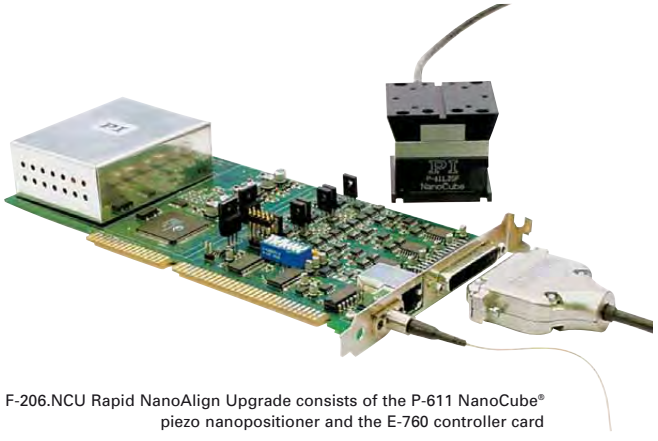
More Options see F-311 PIMotion&Vision™ System, F-361 Optical Power Meter and F-603 Fiber, Objective and Waveguide Holders. (www.pi.ws)

Technical Data

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

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.



F-206.NCU Rapid NanoAlign Upgrade consists of the P-611 NanoCube® piezo nanopositioner and the E-760 controller card