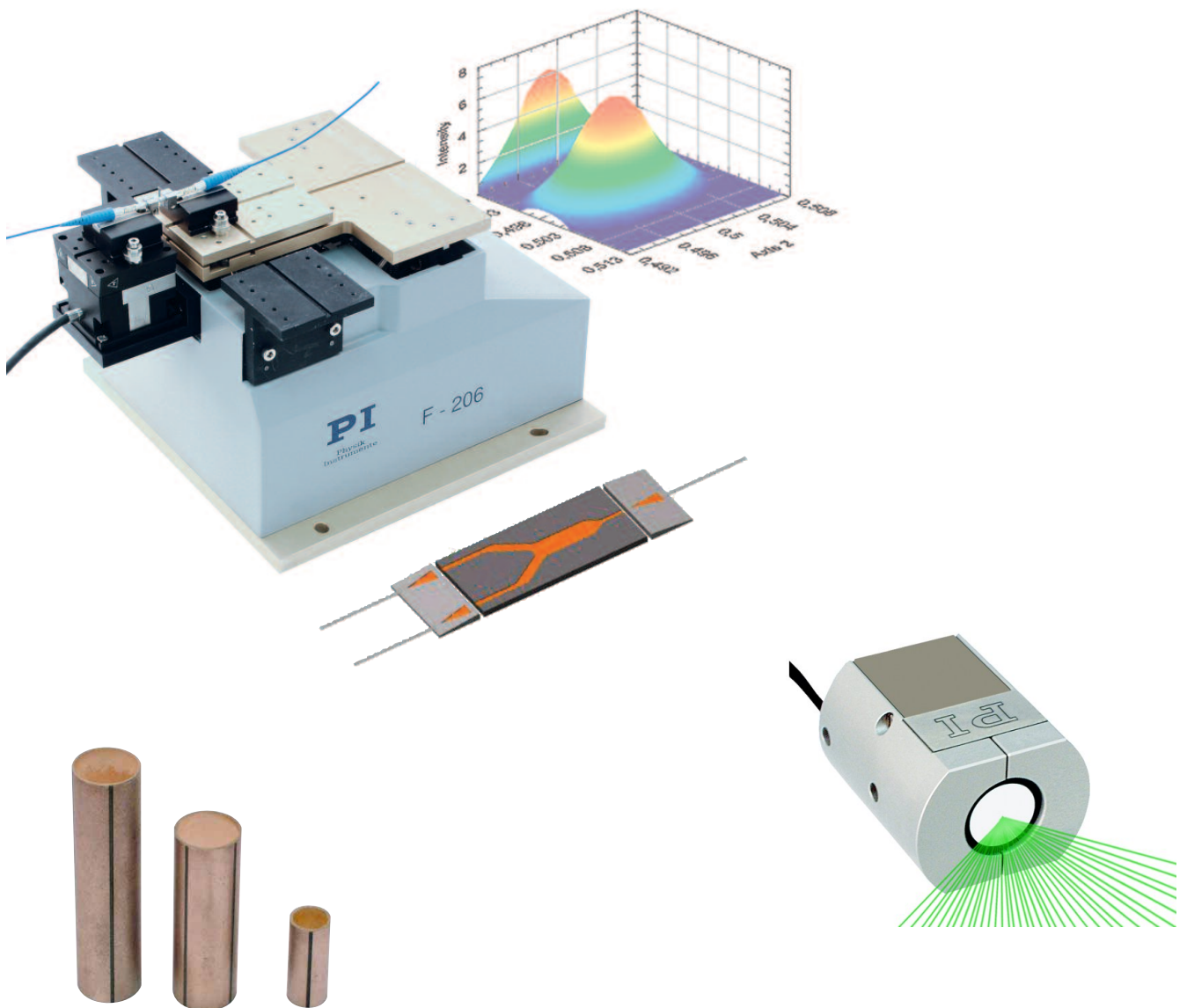
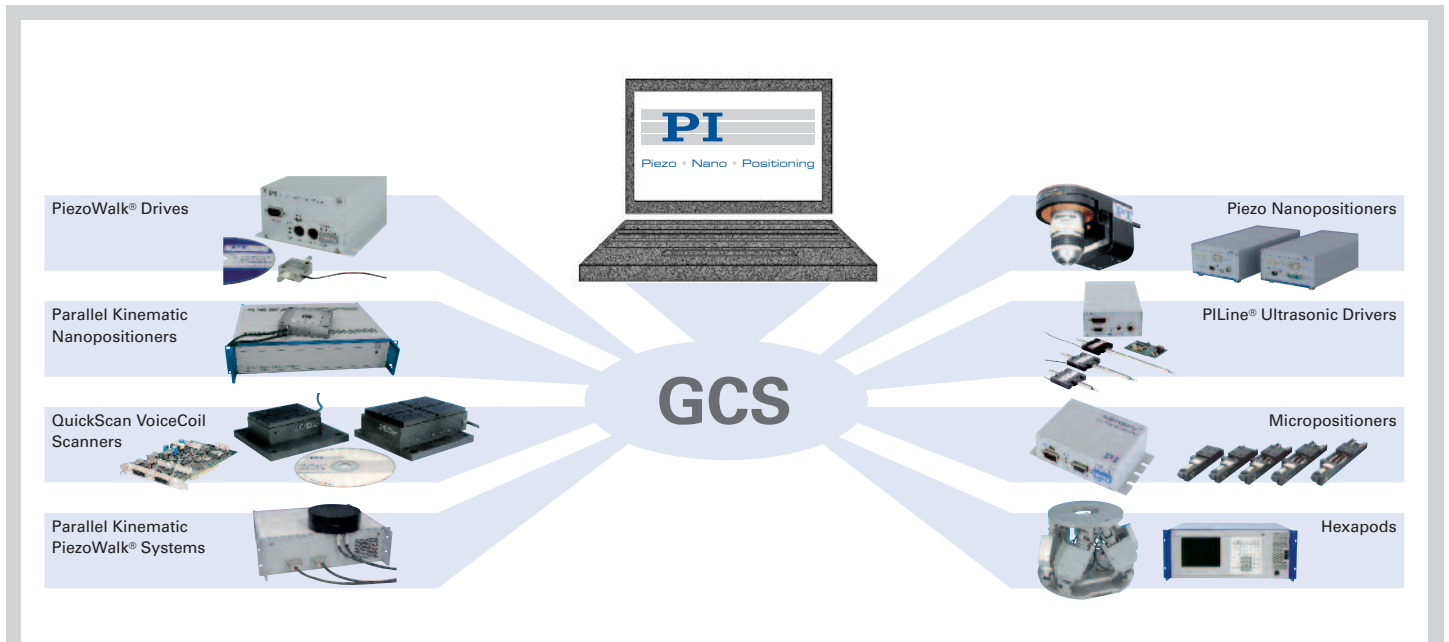


## Motion Control Systems for Fiber Optic Alignment & Optical Telecommunication



## PI Software Solutions

### Operating Positioning Systems Effectively & Conveniently



Communication between PI components is based upon a universal command set (GCS – General Command Set). It decouples hardware and software, and is used for all drive principles.

The high quality of positioning systems is made apparent in daily operation by PI software. Starting with simple commissioning, through convenient operation with a graphical interface, to quick and simple integration in customized programs with high performance, PI software covers all aspects important to an application.

#### Universal Command Set Simplifies Commissioning and Programming

For uniform operation of nano and micropositioning systems, the universal PI General Command Set (GCS) is used. GCS operation is independent of the controller or drive principle used, so that several positioning systems can be controlled together, or new systems can be introduced with a minimum of programming effort. With GCS the development of custom application programs is simplified and less prone to errors, because the commands for all supported devices are identical

in syntax and function. Through the use of the GCS command set with its convenient functions, the orientation phase and application development process is significantly accelerated.

The GCS commands are available at the controller terminal, in macros and in the form of a universal driver set for LabVIEW (VIs), Windows dynamic link libraries (DLL) and Linux

libraries for 32- and 64-bit platforms. This facilitates the development of custom macros, as well as integration with programming languages like LabVIEW, C++ or MATLAB.



All about software in the internet—a server offers download of manuals and software CD mirrors

#### Software Updates Online

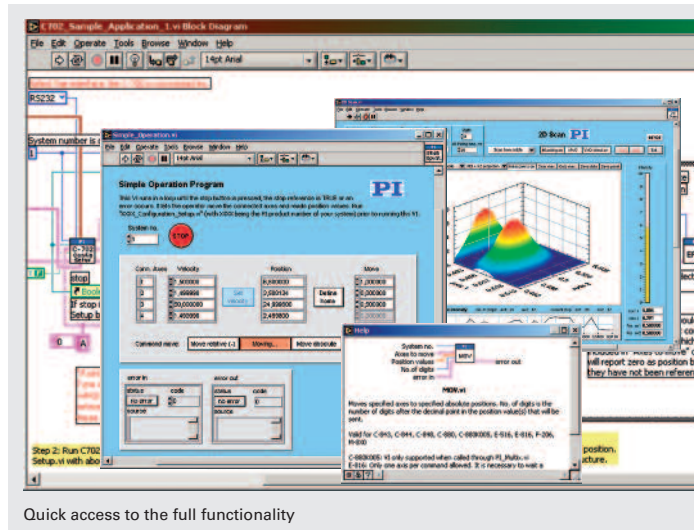
PI supports users with free updates, detailed online help and well structured manuals which ease initiation of the inexperienced but still answer the detailed questions of the professional.

#### Supported Operating Systems

- Microsoft Windows Vista
- Microsoft Windows XP
- Microsoft Windows 2000
- Linux

# Programming Support, Drivers, Examples

## Quick Integration in LabVIEW

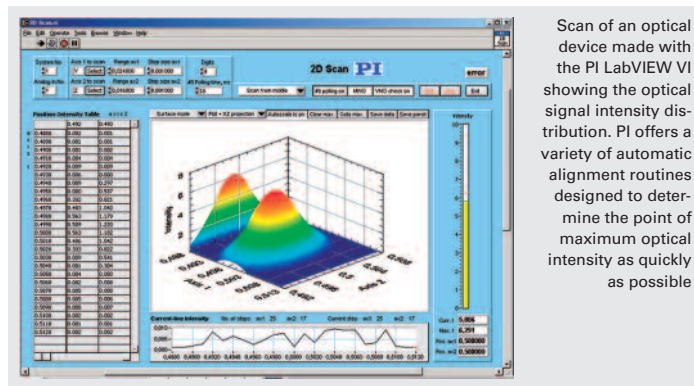


Quick access to the full functionality

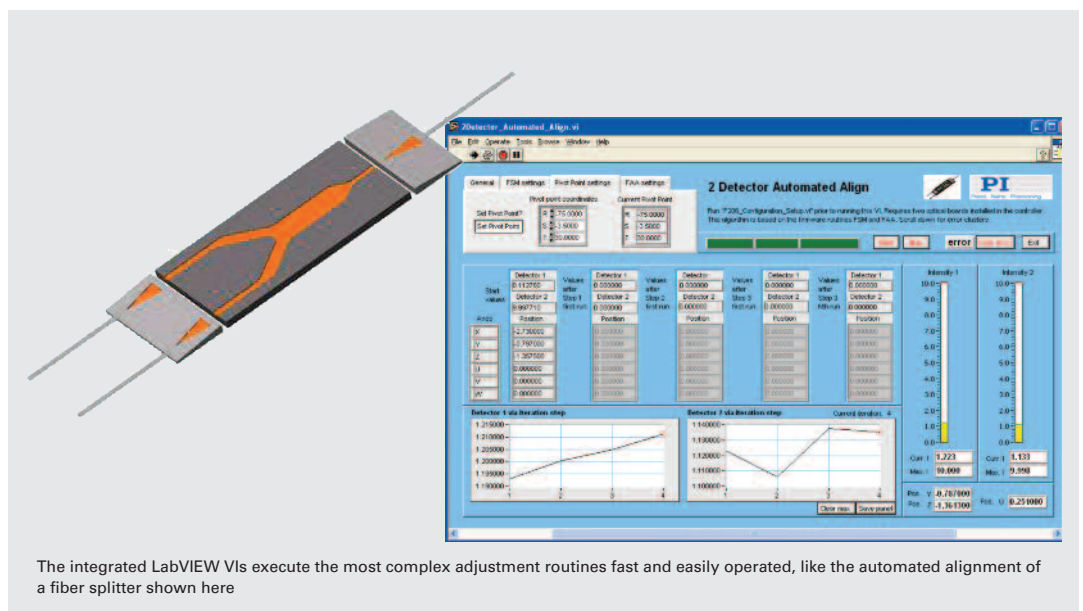
The integration and control of PI positioning systems under LabVIEW is greatly simplified by the provision of comprehensive LabVIEW libraries. The LabVIEW drivers support all controllers from PI, independent of the type of connected stage or controller interface. Thus it is possible to operate piezo, DC motor, piezomotor, hybrid and hexapod controllers with one driver together in one application.

### Full Support for NI DAQ Boards

The same LabVIEW programs (virtual instruments, VIs) that are available for PI digital controllers (e.g. set and read voltages and positions, velocity, etc.) can be used in conjunction with a National Instruments DAQ (data acquisition) board to operate positioning systems based on analog PI controllers. Furthermore, the patented HyperBit™ technology is available under LabVIEW for these systems. HyperBit™ allows attaining position resolution many times better than the resolution of the DAQ board used.



Scan of an optical device made with the PI LabVIEW VI showing the optical signal intensity distribution. PI offers a variety of automatic alignment routines designed to determine the point of maximum optical intensity as quickly as possible



The integrated LabVIEW VIs execute the most complex adjustment routines fast and easily operated, like the automated alignment of a fiber splitter shown here

## Quick and Easy System Setup

For commissioning a positioning system, the specific Configuration Setup VI is executed once. This VI gathers all necessary system information for LabVIEW, including:

- Communication parameters
- Connected controller(s)
- Types & configurations of the connected stages/axes and performs all necessary initialisation steps.

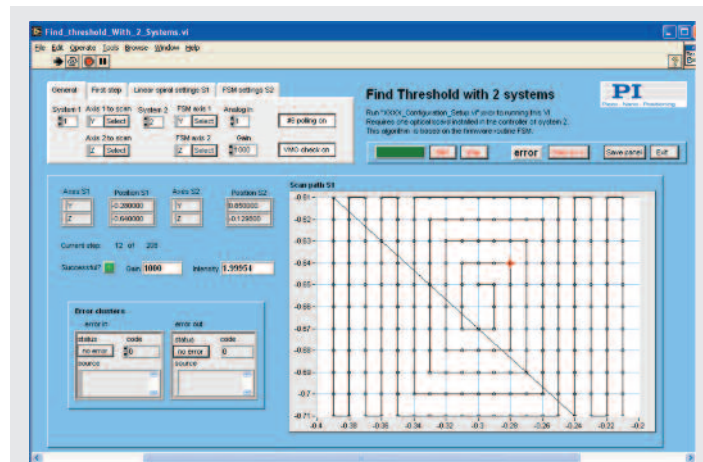
## Integrate & Customize Configuration Setup Vis

The Configuration Setup is implemented as a sub-VI in customer applications. With its connectors, it can be customized completely to meet the application requirements. After

it has been run, all command VIs and high-level routines of the system can be used. Controller upgrades or changes usually require the exchange of the Configuration Setup VI only. The open source code of many VIs offers additional flexibility in the case of modification needs.

## Using Powerful GUI Programs Directly

Beside the command VIs, high-level VIs can be included as sub-VI in customer applications. A comprehensive selection of GUI programs is provided, such as a terminal application, interface selection routine, wave generator samples, 1D and 2D scan and align functions, joystick control, etc.



Result of a 2D scan using two motion systems. The configuration setup VI makes setup of a system very comfortably: a special initialization VI is integrated to customize the software to the application's needs. After it has been run, all command VIs and high-level routines of the system can be used.

## Flexible Integration in Text-Based Programming Languages

The operation of PI positioning systems from customer applications running under Microsoft Windows or Linux is eased with function libraries and sample code included.

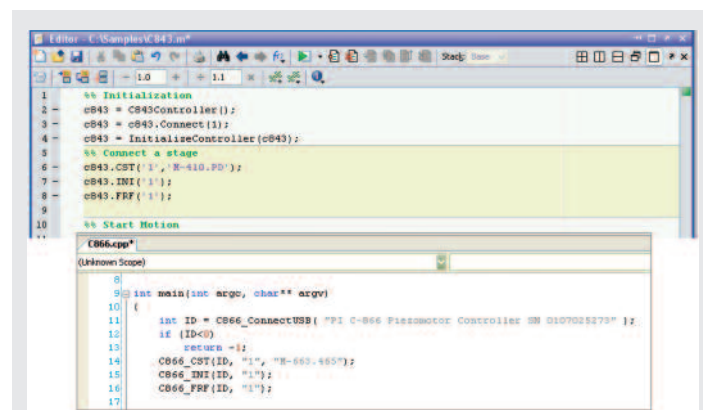
## Maximum Flexibility

The drivers which are provided support all current programming languages (see inset) and all positioning systems from PI. Since the drivers are based on the uniform PI GCS command set (see p. A-11), GCS functionality can be included directly in external programs. In addition to direct GCS commands, the driver sets also make more complex functionalities—

their own graphical interfaces—available to external programs. With just one function call by the customer applications, it is thus possible, for example to show a graphical user interface of the Wave Editor or Profile Generator that handles all user inputs.

### Languages Supported by PI

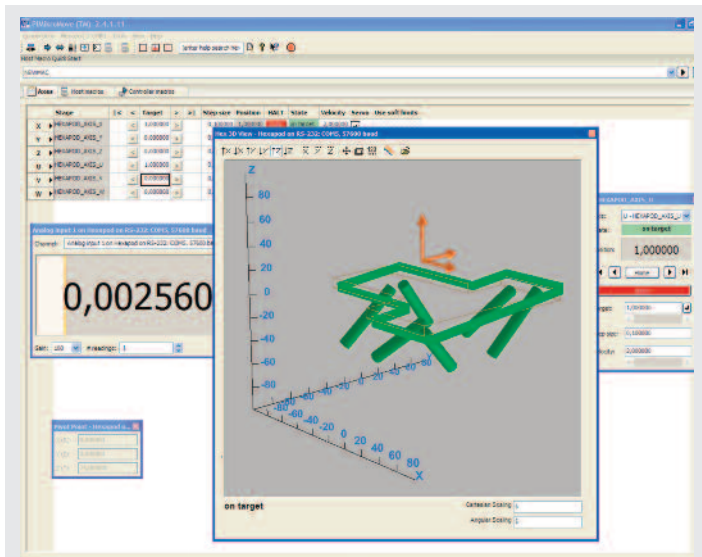
- MATLAB
- Visual Basic, Delphi
- C, C++, Python
- µManager
- Epics
- MetaMorph
- LabVIEW
- All programming languages that support loading of DLLs



A PI positioning system is initialized with C++ and with Matlab using DLL calls

# PIMikroMove™ Quick Start Software

## Simple Operation of Positioning Systems



The actual position of a multi-axis system can be visualized in addition to the display of single-axis motion. Shown here is a tilt motion of an F-206 Hexapod. Both the reference position and the actual position are indicated

- Operation of PI Motor, Piezo, Piezomotor, Hexapod & Hybrid Controllers
- 1D/2D Scan and AutoFind
- Profile Generator, Joystick Control etc.
- Macros for Recurring Tasks and Automation
- Optimizing all Servo Parameters

PI positioning systems can be controlled with PIMikroMove™ in a clear and simple manner; all connected controllers and axes are accessed via the same graphical interface.

PIMikroMove™ supports quick commissioning of controllers and positioners, comprehensive system optimization as well as the programming of macros.

### All Axes in One View

With PIMikroMove™ all axes connected can be controlled from one program instance. This, independent of which PI controller is connected to which axis and which interface (TCP/IP, USB, RS-232, GPIB, PCI). For ex-

ample, it is possible to have two axes in an XY application connected to two different controllers, but still command them with PIMikroMove™ from the same window.

### Optimal System Behavior

PIMikroMove™ also allows the user to optimize the system behavior through convenient servo tuning. This possibility is especially helpful if the mechanical properties of a system are changed, for example by applying a different load. The system response and stability can then be optimized with the convenient parameter tuning tool. For recurring tasks, different sets of optimized parameters

can be saved as stage profiles and then activated as needed in custom-programmed applications.

### Macros Ease Recurring Tasks

PIMikroMove™ considerably simplifies the creation of macros for recurring tasks. Execution of a macro, consisting of a previously stored list of GCS commands, can be commanded over the interface or, if supported by the controller, run automatically on power-up, with or without a host PC connected.

Controllers without their own macro facility, like the C-843, can be commanded by host macros which PIMikroMove™ edits and stores in the host PC. Host macro execution can be triggered with digital I/O lines or software commands and support multiple axes connected to different controllers.

With the position pad, two or more independent axes can be moved by a mouse or joystick as an XY stage, also in vector moves.

### 1D/2D Scan and AutoFind

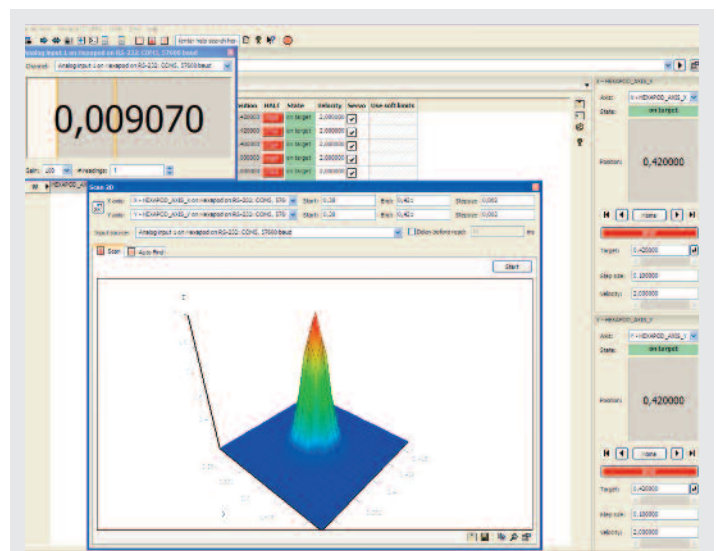
Scan 1D/2D can measure an input source while moving up to two axes. Moved axes and input source need not be assigned to the same controller. The input source to be measured can be an analog input, an axis position or a raw position sensor value. The measured data is visualized and can be saved to a file on the host PC. AutoFind tries to find the maximum of an intensity signal by modifying the position of two axes.

### FFT, Profile Generator, Data Recorder

PIMikroMove™ also supports controller-specific features.

Data recorder: record various motion and system parameters, run FFT (Fast Fourier Transformation) on the data as well as export it to programs like Microsoft Excel (CSV format).

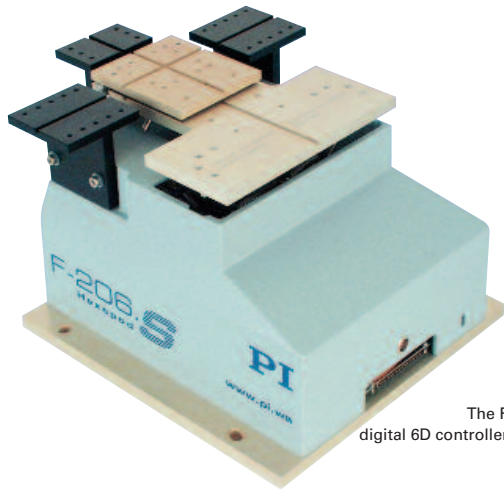
Profile Generator: synchronize motion of several axes along multi-order, mathematically defined curves or customized arbitrary functions.



Results of a 2D scan performed with an F-206 HexAlign™ micropositioning system

# F-206.S HexAlign™ 6 Axis Automatic 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  $\mu\text{m}$  Actuator Resolution**
- **Repeatability 0.3  $\mu\text{m}$  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 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, par-

allel 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.

### Application Examples

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

### 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 li-

### 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)

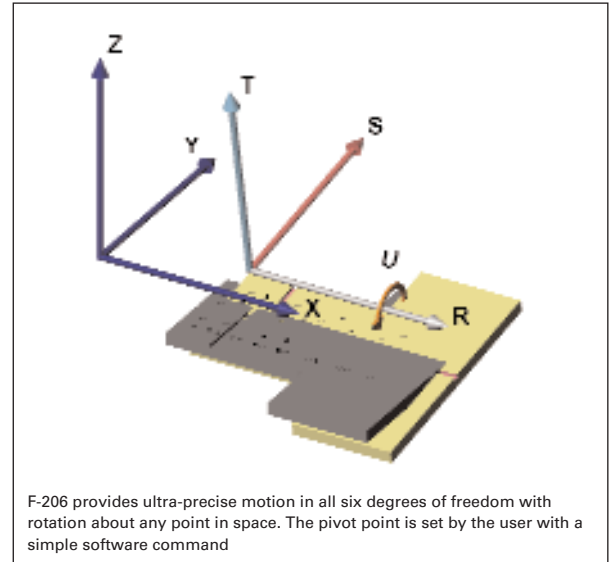
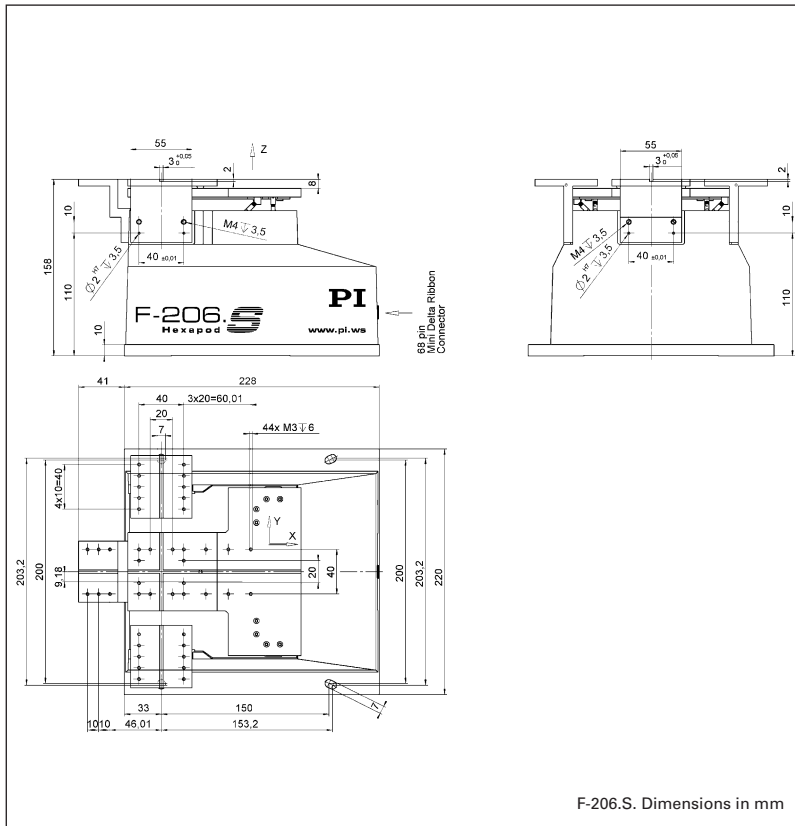
**F-361.10**  
Absolute-Measuring Optical Power Meter, 1000-1600 nm Wavelength

**Additional Accessories, see [www.pi.ws](http://www.pi.ws).**

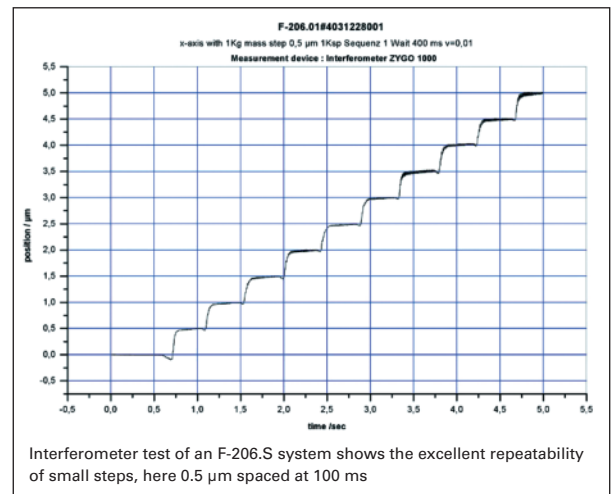
braries. The controller can be operated either through a host PC, or directly through a keyboard and monitor. It can also run programs stored in a user-friendly, fully documented macro language.

### 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](http://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

## Technical Data

<b>Model</b>	<b>F-206.S0 / F-206.SD</b>
Travel range X*	-8 to +5.7 mm
Travel range Y*	±5.7 mm
Travel range Z*	±6.7 mm
Travel range $\theta_x$ *	±5.7°
Travel range $\theta_y$ *	±6.6°
Travel range $\theta_z$ *	±5.5°
Actuator resolution	33 nm
Minimum incremental motion X, Y, Z**	0.1 μm (6-axis move!)
Minimum incremental motion $\theta_x, \theta_y, \theta_z$ **	2 μrad (0.4") (6-axis move!)
Bidirectional repeatability X, Y, Z	0.3 μm
Bidirectional repeatability $\theta_x, \theta_y, \theta_z$	3.6 μrad
Speed X, Y, Z	0.01 to 10 mm/s
Maximum load in Z	2 kg (centered on platform)
Mass	5.8 kg
Controller	Digital Hexapod controller with optional photometer card and integrated scan and align routines
Operating voltage	100–240 VAC, 50/60 Hz
Software	LabVIEW drivers, software for alignment of arrays, DLL libraries, scan and align software, terminal software

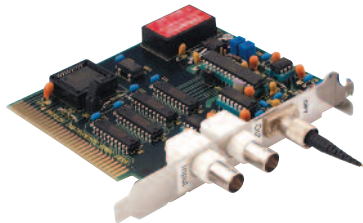


The Hexapod comes with a powerful 6D controller and sophisticated, user-friendly positioning and alignment software. Keypad and display are optional

\*Travel ranges in the coordinate directions (X, Y, Z  $\theta_x, \theta_y, \theta_z$ ) 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.

# Options & Accessories for Alignment and Positioning



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 0.1  $\mu\text{m}$  to 500  $\mu\text{m}$  (linear) and 0.001 to 0.5deg (angular) per step. Exter-

nal 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.

## Technical Data

	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)

## Options for F-206 systems

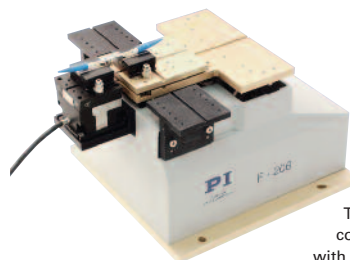
### Force-Limiting Platform

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

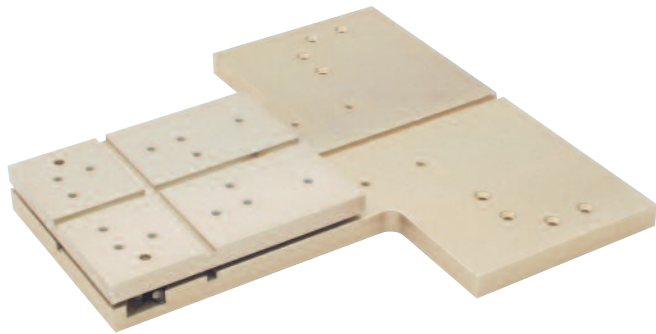
F-206.MHU is a magnetic kinematically clamped, add-on plat-

form 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.



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)



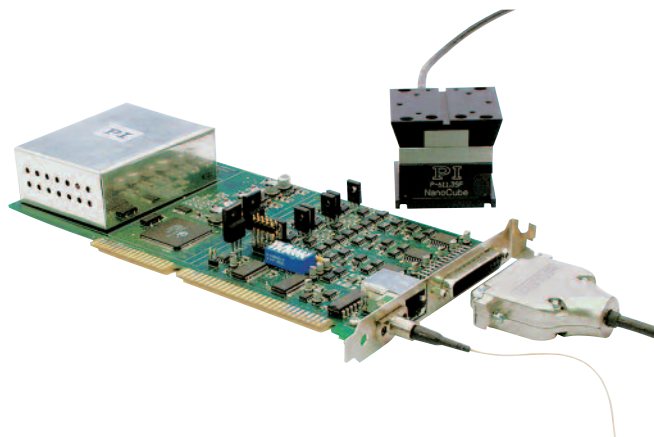


F-206.MHU Magnetic kinematically clamped force limiting platform

### 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

### Ordering Information

**F-206.MC6**  
6D Interactive Manual Control Pad

**C-815.MC6**  
3 m Extension Cable for Manual Control Pad

**F-206.iiU**  
2-Channel Photometer Card (IR Range)

**F-206.VVU**  
2-Channel Photometer Card (Visual Range)

**F-206.AC8**  
Upgrade for 2 Additional Servo-Motor Control Channels on Hexapod Controller

**F-311**  
PIMotion&Vision™ Imaging Processing for Intelligent Automation

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

### 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

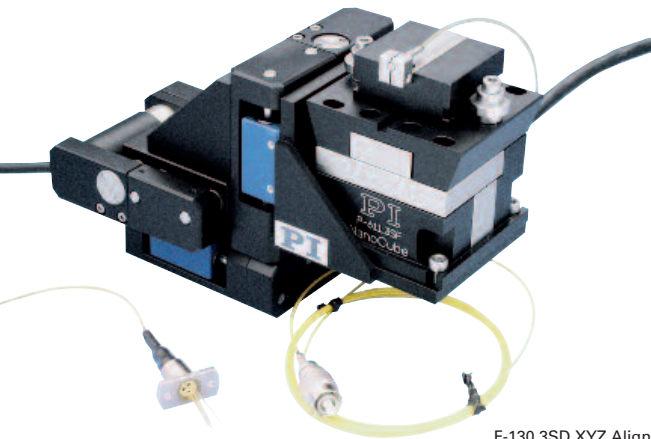
**F-206.NCU**  
Rapid Nanopositioning Upgrade for F-206. Consists of P-611.3SF NanoCube® and E-760 Controller Card

**M-500.206**  
Adapter Plate for Mounting F-206 on M-511, M-521 and M-531 Translation Stages

**Ask about custom designs!**

# F-131 Coarse/Fine XYZ Photonics Alignment System

## DC/Piezo Drive System for Nanometer Precision



F-130.3SD XYZ Alignment System, 1 nm resolution, with optional F-603.22 ferrule holder

- Up to 15 mm Travel
- 1 nm Resolution
- Closed-Loop Piezo Drives Available
- Stepper- & DC-Motor Drives

F-130 are compact computer-controllable XYZ alignment and positioning systems combining the advantages of ultra-high-resolution piezo drives with the long travel range of motorized stages.

They are based on the M-110/ M-111 micropositioning stages (see page 4-22) and the P-611

### Application Examples

- Photonics packaging
- Optical device testing
- MEMS positioning/alignment
- Fiber alignment
- Micromachining
- Micromanipulation (life sciences)
- Semiconductor test systems

rapid piezo NanoAlignment units (see page 2-20).

The F-130/F-131 is available in 8 different versions, with stepper- and DC-motor coarse drives, and open- and closed-loop piezoelectric fine drives. (see Ordering Information).

The motor drives provide better than 0.05  $\mu\text{m}$  resolution over a travel range of 5 and 15 mm. The piezo fine drives feature a 100  $\mu\text{m}$  travel range in X, Y and Z, with zero-stiction, zero-friction flexure guiding systems and 1 nm resolution.

Several fiber, waveguide and optics adapters are available from PI (e.g. model F-603.60, see "Fiber, Objective and Waveguide Holders").

The C-880 multi-axis automation platform (see page 4-124) is recommended as controller.

### Ordering Information

#### F-130.3SD

XYZ Alignment System, 5 mm / 100  $\mu\text{m}$ , DC Motor/Encoder, C/L Piezo

#### F-130.3SS

XYZ Alignment System, 5 mm / 100  $\mu\text{m}$ , Stepper Motor, C/L Piezo

#### F-130.3OD

XYZ Alignment System 5 mm / 100  $\mu\text{m}$ , DC Motor/Encoder, O/L Piezo

#### F-130.3OS

XYZ Alignment System, 5 mm / 100  $\mu\text{m}$ , Stepper Motor, O/L Piezo

#### F-131.3SD

XYZ Alignment System, 15 mm / 100  $\mu\text{m}$ , DC Motor/Encoder, C/L Piezo

#### F-131.3SS

XYZ Alignment System, 15 mm / 100  $\mu\text{m}$ , Stepper Motor, C/L Piezo

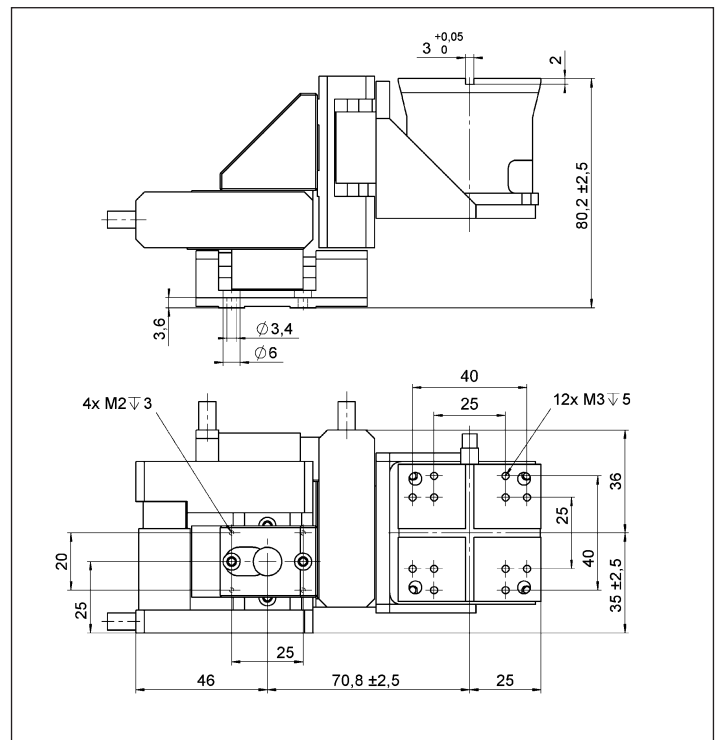
#### F-131.3OD

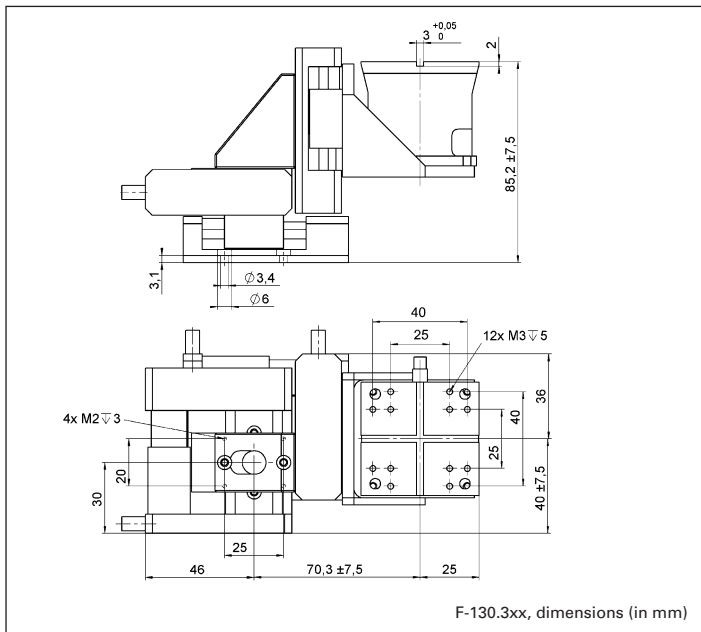
XYZ Alignment System, 15 mm / 100  $\mu\text{m}$ , DC Motor/Encoder, O/L Piezo

#### F-131.3OS

XYZ Alignment System, 15 mm / 100  $\mu\text{m}$ , Stepper Motor, O/L Piezo

Ask about custom designs!





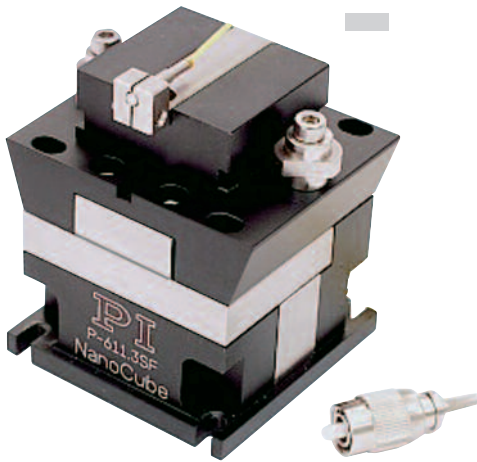
The C-880 Multi-axis automation platform is recommended as controller for the F-130/F-131

## Technical Data

Model	F-130.3SD	F-130.3SS	F-130.3OD	F-130.3OS	F-131.3SD	F-131.3SS	F-131.3OD	F-131.3OS	Units
Key features	Closed-loop DC motors, closed-loop PZT drives	Stepper motors, closed-loop PZT drives	Closed-loop DC motors, open-loop PZT drives	Stepper motors, open-loop PZT drives	Closed-loop DC motors, closed-loop PZT drives	Stepper motors, closed-loop PZT drives	Closed-loop DC motors, open-loop PZT drives	Stepper motors, open-loop PZT drives	
Active axes	X,Y,Z	X,Y,Z	X,Y,Z	X,Y,Z	X,Y,Z	X,Y,Z	X,Y,Z	X,Y,Z	
Motorized travel range (XYZ)	5	5	5	5	15	15	15	15	mm
Piezo travel range (XYZ)	100	100	100	100	100	100	100	100	µm
Design resolution (motor)	0.007	0.006	0.007	0.006	0.007	0.006	0.007	0.006	µm
Min. incremental motion (motor)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	µm
Closed-loop / open-loop resolution (PZT)	2/1	2/1	- / 1	- / 1	2/1	2/1	- / 1	- / 1	nm
Motorized stage	M-110.3DG	M-110.32S	M-110.3DG	M-110.32S	M-111.3DG	M-111.32S	M-111.3DG	M-111.32S	
Piezo drive	P-611.3SF	P-611.3SF	P-611.3OF	P-611.3OF	P-611.3SF	P-611.3SF	P-611.3OF	P-611.3OF	
Material	Al / S	Al / S	Al / S	Al / S	Al / S	Al / S	Al / S	Al / S	
Recommended controller	C-880	-	C-880	-	C-880	-	C-880	-	

# P-611. NanoCube® Piezo Flexure Positioner

## XYZ Rapid Photonics NanoAlignment Add-on System



P-611 NanoCube®, XYZ Compact NanoAlignment System, 100 x 100 x 100 µm travel range, 1 nm resolution, shown with optional F-603.22 ferrule holder.

- Ideal for Fiber Alignment and Photonics Packaging Applications
- 100 x 100 x 100 µm Travel Range, Ultra-Compact Package!
- 1 nm Resolution
- Closed- and Open-Loop Versions
- Precision Trajectory Control w/ Frictionless Flexures
- Fast Scanning and Settling
- Large Variety of Controllers

The P-611.30F and P-611.3SF NanoCube® NanoAlignment systems are based on PI's vast experience with ultra-high precision piezo scanning systems and photonics packaging appli-

cations. They combine a 100 x 100 x 100 µm XYZ positioning and scanning range with a zero stiction/friction wire-EDM-cut guiding system in an extremely compact package. NanoCube® systems provide motion with nanometer-scale resolution and settling times of only a few milliseconds.

### Application Examples

- Photonics packaging
- Optical device testing
- MEMS positioning/alignment
- Fiber alignment
- Micromachining
- Micromanipulation (life sciences)
- Semiconductor test systems

### Open- & Closed-Loop Models

Open- and closed-loop versions are offered to suit your application. Several fiber, waveguide and optics adapters are available for mounting on the NanoCube® (e.g. model F-603.60)

NanoCubes® are also available in a slightly different package without the fiber adapter interface, see page 2-52.

### Automatic Alignment

NanoCubes® can be operated with the E-664 bench-top controller. A variety of other rack-mount and bench-top controllers is also available.

NanoCubes® can be easily combined with a number of automated or manual PI micro-positioning systems, from single axis stages to 6-degree-of-freedom micromanipulators.

### Working Principle / Lifetime

P-611 nanopositioners are equipped with the award-winning PICMA® long-life piezoelectric drives integrated into a sophisticated flexure guiding system. The force exerted by the piezo drive pushes a multi-flexure parallelogram via an integrated motion amplifier. The wire-EDM-cut flexures are FEA modeled (finite element analysis) for zero stiction and friction,

### Ordering Information

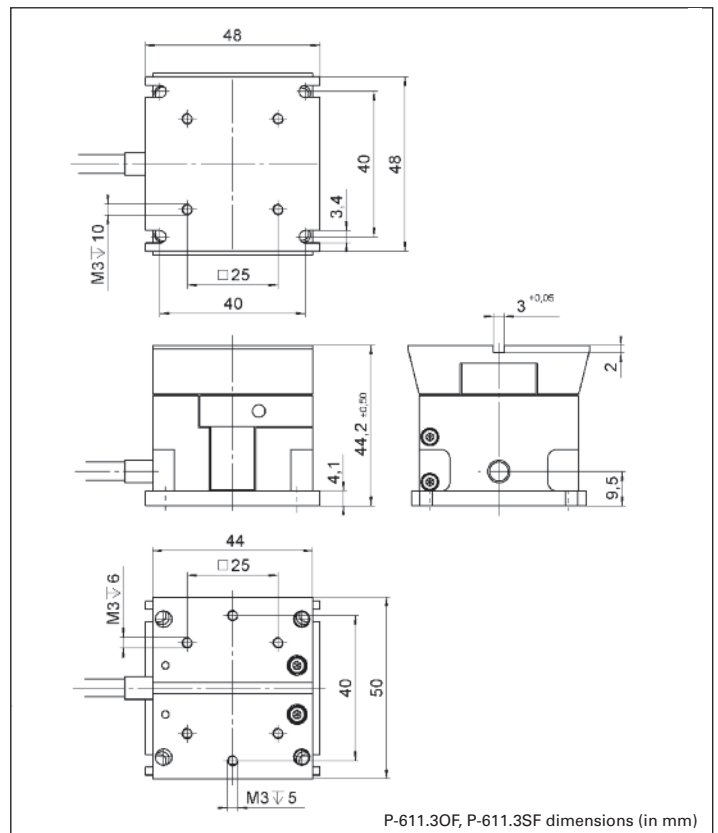
**P-611.3SF**  
NanoCube® XYZ NanoAlignment Stage, 100 x 100 x 100 µm, Closed-Loop, Fiber Adapter Interface

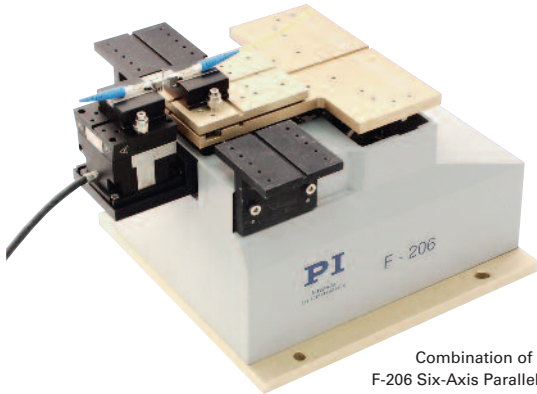
**P-611.30F**  
NanoCube® XYZ NanoAlignment Stage, 100 x 100 x 100 µm, Open-Loop, Fiber Adapter Interface

**F-206.NCU**  
Rapid Nanopositioning Upgrade for F-206. Consist of P-611.3SF NanoCube® and E-760 Controller Card

**Ask about custom designs!**

ultra-high resolution and exceptional guiding precision. All components are frictionless and maintenance-free.





Combination of NanoCube® and F-206 Six-Axis Parallel-Kinematics MicroMotion-Robot

## Technical Data

Model	P-611.3SF	P-611.3OF	Units	Tolerance
Active axes	X, Y, Z	X, Y, Z		
<b>Motion and positioning</b>				
Integrated sensor	SGS			
Open-loop travel, -20 to +120 V	120 / axis	120 / axis	µm	min. (+20%/0%)
Closed-loop travel	100 / axis	–	µm	
Open-loop resolution	0.2	0.2	nm	typ.
Closed-loop resolution	1	–	nm	typ.
Linearity	0.1	–	%	typ.
Repeatability	<10	–	nm	typ.
Pitch in X,Y	±5	±5	µrad	typ.
Runout $\theta_x$ (Z motion)	±10	±10	µrad	typ.
Yaw in X	±20	±20	µrad	typ.
Yaw in Y	±10	±10	µrad	typ.
Runout $\theta_y$ (Z motion)	±10	±10	µrad	typ.
<b>Mechanical properties</b>				
Stiffness	0.3	0.3	N/µm	±20%
Unloaded resonant frequency X / Y / Z	350 / 220 / 250	350 / 220 / 250	Hz	±20%
Resonant frequency @ 30 g X / Y / Z	270 / 185 / 230	270 / 185 / 230	Hz	±20%
Resonant frequency @ 100 g X / Y / Z	180 / 135 / 200	180 / 135 / 200	Hz	±20%
Push/pull force capacity in motion direction	+15 / -10	+15 / -10	N	Max.
Load capacity	15	15	N	Max.
<b>Drive properties</b>				
ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance	1.5	1.5	µF	±20%
Dynamic operating current coefficient	1.9	1.9	µA/(Hz • µm)	±20%
<b>Miscellaneous</b>				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum, steel	Aluminum, steel		
Dimensions	44 x 50 x 44.2	44 x 50 x 44.2	mm	
Mass	0.32	0.32	kg	±5%
Cable length	1.5	1.5	m	±10 mm
Sensor connector	Sub-D	–		
Voltage connection	Sub-D	Sub-D		
Recommended controller / amplifier	E-664 Nanocube® Controller (p. 2-137)	3 x E-610.00F OEM amplifier modules (p. 2-110); E-663 3-channel amplifier, bench-top (p. 2-136)		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 amplifier (p. 2-146)  
Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 50 µm at 10 Hz requires approximately 0.8 mA drive current.  
Adapter cable with LEMO connectors for sensor and operating voltage available.

# M-231 DC-Mike Precision Linear Actuator

## With Limit Switches, Suitable for Fiber Alignment



M-231.17 high-resolution DC-Mike actuator, 17 mm travel range

### Ordering Information

**M-231.17**  
High-Resolution DC-Mike Linear Actuator, 17 mm, Limit Switches

- Travel Range 17 mm
- Min. Incremental Motion to 0.1 μm
- Max. Velocity 2.5 mm/s
- Closed-Loop DC-Motors
- Non-Contact Limit and Reference Switches
- Fits M-105 Fiber Aligners
- MTBF >5.000 h

The M-231 is an ultra-high-resolution linear actuator providing linear motion up to 17 mm with sub-micron resolution in a compact package. It consists of a leadscrew which is driven by a closed-loop DC-motor/gear head combination with motor shaft-mounted, high-resolution encoder (2048 counts/rev.).

### Upgrade for Manual Aligners

The M-231 was especially designed to fit existing manual translation stages (e. g. M-105, see p. 4-50 ff) as a direct replacement for a manual micrometer.

### Limit and Reference Switches

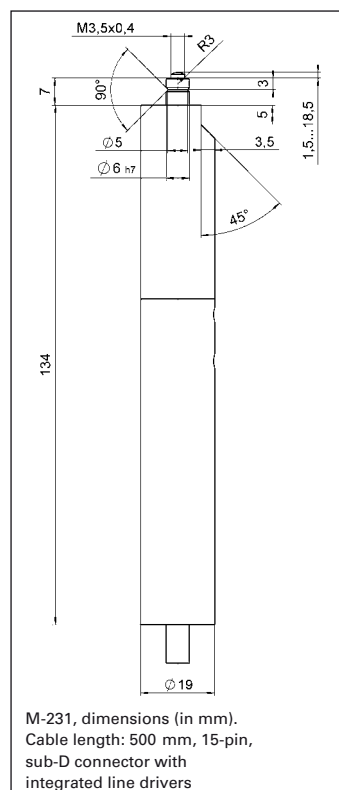
For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The reference switch supports advanced automation applications with high precision.

### Application Examples

- Fiber positioning
- Metrology
- Photonics packaging
- Quality assurance testing
- Testing equipment

### Integrated Line Drivers

All actuators include an integral 0.5 m cable with 15-pin sub-D connector and come with a 3 m extension cable. On the DC servo versions, the connector features integrated line drivers for cable lengths up to 10 meters between actuator and controller.



M-231 mounted on M-105 XYZ positioning systems



### Technical Data

Model	M-231.17	Units
Active axes	X	
<b>Motion and positioning</b>		
Travel range	17	mm
Integrated sensor	Rotary encoder	
Sensor resolution	2,048	Cts./rev.
Design resolution	0.007	μm
Min. incremental motion	0.1	μm
Backlash	2	μm
Unidirectional repeatability	0.2	μm
Max. velocity	1.5	mm/s
Reference switch repeatability	1	μm
<b>Mechanical properties</b>		
Spindle	Leadscrew	
Spindle pitch	0.4	mm
Gear ratio	28.44444:1	
Max. push/pull force	40	N
<b>Drive properties</b>		
Motor type	DC-motor, gearhead	
Operating voltage	0 to ±12	V
Electrical power	2	W
Limit and reference switches	Hall-effect	
<b>Miscellaneous</b>		
Operating temperature range	-20 to +65	°C
Material	Al (anodized), steel	
Mass	0.17	kg
Recommended controller/driver	C-863 single-axis (p. 4-114) C-843 PCI board, for up to 4 axes (p. 4-120)	

# M-232 DC-Mike Precision Linear Actuator

## Compact Package, Suitable for Fiber Alignment



M-232.17 high-resolution DC-Mike actuator mounted on M-105 translation stage

- Travel Range 17 mm
- Min. Incremental Motion to 0,1 µm
- Max. Velocity 2,5 mm/s
- Closed-Loop DC-Motors
- Non-Contact Limit and Reference Switches
- Fits M-105 Fiber Aligners
- MTBF >5.000 h

The M-232 is an ultra-high-resolution linear actuator providing linear motion up to 17 mm with sub-micron resolution in a compact package. It features a space-saving design with a leadscrew side-by-side to a closed-loop DC-motor/gearhead combination and a high-resolution encoder (2048 counts/rev.). They feature a low-stiction, low-friction construction allowing for minimum incremental motion of 100 nanometers at speeds of up to 2.5 mm/sec.

### Upgrade for Manual Aligners

The M-232 was especially designed to fit existing manual translation stages (e. g. M-105 see p. 4-50) as a direct replacement for a manual micrometer.

### Application Examples

- Fiber positioning
- Metrology
- Photonics packaging
- Quality assurance testing
- Testing equipment

### Limit and Reference Switches

For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The reference switch supports advanced automation applications with high precision.

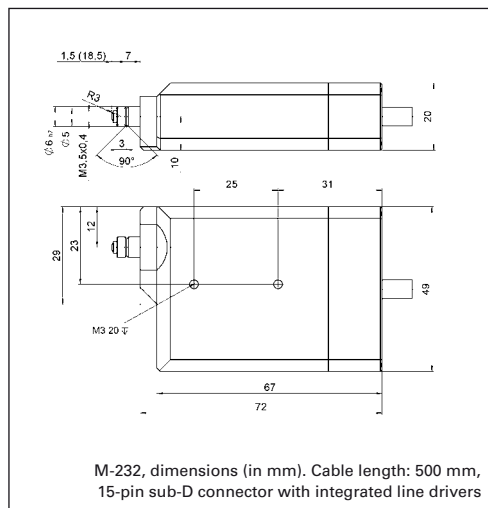
### Integrated Line Drivers

All actuators include an integral 0.5 m cable with 15-pin sub-D connector and come with a 3 m extension cable. On the DC servo versions, the connector features integrated line drivers for cable lengths up to 10 meters between actuator and controller.

For higher loads and travel ranges, refer to the M-230 (see p. 1-46), M-235 (see p. 1-50) and M-238 (see p. 1-52).

### Ordering Information

**M-232.17**  
Compact High-Resolution DC-Mike Linear Actuator, 17 mm, Limit Switches

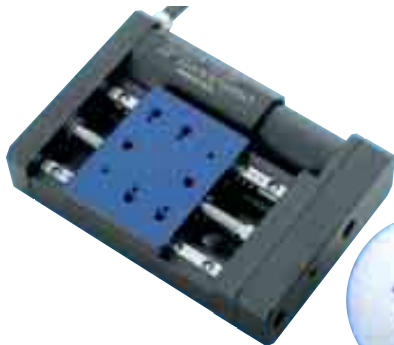


### Technical Data

Model	M-232.17	Units
Active axes	X	
<b>Motion and positioning</b>		
Travel range	17	mm
Integrated sensor	Rotary encoder	
Sensor resolution	2,048	Cts./rev.
Design resolution	0.007	µm
Min. incremental motion	0.1	µm
Backlash	2	µm
Unidirectional repeatability	0.2	µm
Max. velocity	1.5	mm/s
Reference switch repeatability	1	µm
<b>Mechanical properties</b>		
Spindle	Leadscrew	
Spindle pitch	0.4	mm
Gear ratio	28.44444:1	
Max. push/pull force	40	N
<b>Drive properties</b>		
Motor type	DC-motor, gearhead	
Operating voltage	0 to ±12	V
Electrical power	2	W
Limit and reference switches	Hall-effect	
<b>Miscellaneous</b>		
Operating temperature range	-20 to +65	°C
Material	Al (anodized), steel	
Mass	0.17	kg
Recommended controller/driver	C-863 single-axis (p. 4-114) C-843 PCI board, for up to 4 axes (p. 4-112)	

# M-122 Precision Micro-Translation Stage

## Fast & Compact with Direct Position Measurement



The M-122.2DD miniature translation stage features an optical linear encoder with 0.1  $\mu\text{m}$  position resolution and a highly efficient ballscrew

- Travel Range 25 mm
- 0.1  $\mu\text{m}$  Optical Linear Encoder for Highest Accuracy & Repeatability
- Min. Incremental Motion to 0.2  $\mu\text{m}$
- Max. Velocity 20 mm/s
- Cross-Roll Bearings
- Recirculating Ball Screw Drives Provide High Speeds & Long Lifetimes

The M-122 palm-top-sized translation stage combines small dimensions, high speeds and very high accuracy at a competitive price. It features a space-saving, folded drive train with the servo motor and drive screw side-by-side. Equipped with a non-contacting optical linear encoder and a preloaded, precision-ground, ball-screw, these stages can provide much higher accuracy and better repeatability than conventional stepper motor stages or rotary encoder-equipped servo motor stages.

### Low Friction, High Speed, Maintenance-Free

Due to its low-friction, the backlash-free ball screw yields significantly higher mechanical

efficiency than leadscrews, and allows maintenance-free, high duty-cycle operation at high velocities up to 20 mm/sec.

### XY and XYZ Combinations

M-122 stages can be combined to very compact XY and XYZ systems. The M-122.AP1 mounting bracket is available to mount the Z-axis.

### Limit and Reference Switches

For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

### Low Cost of Ownership

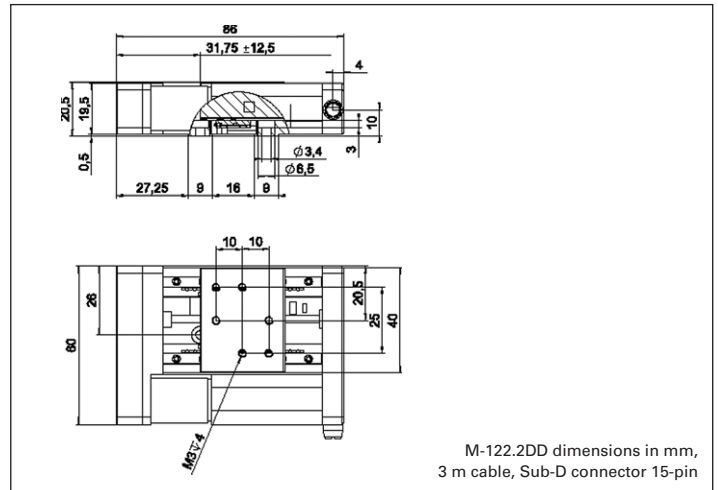
The combination of these positioners with the networkable, single-channel C-863 Mercury™ servo motor controller (s. p. 4-114) offers high performance for a very competitive price in both single- and multi-axis configurations. For multi-axis applications, the C-843 PC plug-in controller board with on-board servo amplifiers (s. p. 4-120) is another cost-effective alternative.

### Ordering Information

**M-122.2DD**  
High-Precision Translation Stage, 25 mm, Direct-Drive DC Motor, Ballscrew

### Accessories

**M-122.AP1**  
Angle bracket for vertical mounting of M-122 stages  
**Ask about custom designs**



M-122.2DD dimensions in mm, 3 m cable, Sub-D connector 15-pin

### Technical Data

Model	M-122.2DD
Active axes	X
<b>Motion and positioning</b>	
Travel range	25 mm
Integrated sensor	Linear encoder
Sensor resolution	0.1 $\mu\text{m}$
Design resolution	0.1 $\mu\text{m}$
Min. incremental motion	0.2 $\mu\text{m}$
Backlash	0.2 $\mu\text{m}$
Unidirectional repeatability	0.15 $\mu\text{m}$
Pitch	$\pm 150 \mu\text{rad}$
Yaw	$\pm 150 \mu\text{rad}$
Max. velocity	20 mm/s
Origin repeatability	1 $\mu\text{m}$
<b>Mechanical properties</b>	
Drive screw	Recirculating ballscrew
Thread pitch	0.5 mm
Stiffness in motion direction	0.25 N/ $\mu\text{m}$
Max. load	50 N
Max. push/pull force	20 N
Max. lateral force	25 N
<b>Drive properties</b>	
Motor type	DC motor
Operating voltage	0 to $\pm 12 \text{ V}$
Electrical power	2.25 W
Limit and reference switches	Hall-effect
<b>Miscellaneous</b>	
Operating temperature range	-20 to +65
Material	Aluminum, steel
Dimensions	86 x 60 x 20.5 mm
Mass	0.3 kg
Recommended controller/driver	C-863 (single-axis) C-843 PCI board (up to 4 axes)

### Application Examples

- Photonics packaging
- Fiber positioning
- Metrology
- Quality assurance testing
- Testing equipment
- Micromachining



# Piezo Tip/Tilt-Steering Mirror for Optical Communication

## Fast Steering Mirror with up to 120 mrad Deflection



S-334 Tip/Tilt Mirror System / Scanner Provides Optical Deflection Angle up to 120 mrad

- **Miniature Design**
- **Optical Beam Deflection to 120 mrad (~ 6.8°)**
- **Coplanar Axes & Fixed Pivot Point; Eliminate Polarization Rotation**
- **Factory Installed Mirror**
- **Millisecond Response, Resolution to 0.2 μrad**
- **Closed-loop Position Servo-Control for High Accuracy**
- **For Mirrors up to 12.5 mm (0.5") Diameter**
- **Frictionless, High-Precision Flexure Guiding System**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**

S-334 piezo tip/tilt mirrors / scanners provide extremely large deflection angles in a miniaturized package. These fast steering mirror systems are based on a sophisticated parallel-kinematics design with

two coplanar, orthogonal axes and a fixed pivot point.

### Large Tip/Tilt Ranges with Excellent Motion Characteristics

The novel flexure/lever design with minimized inertia allows

for the exceptionally large tip/tilt range of 60 mrad (50 mrad in closed-loop operation, which is equivalent to 100 mrad optical beam deflection) and very fast response in the millisecond range. These parameters make the system unique in the market of piezo driven tip/tilt mirror systems.

### Sub-Microradian Resolution

In addition to the large angles and the high dynamics the S-334 provides sub-microradian resolution. The integrated high-resolution, full-bridge strain gauge sensors (SGS) provide absolute position control, excellent repeatability and high linearity, typically better than 0.05 % over the entire travel range.

### Differential Drive for Improved Stability and Dynamics

The S-334 is based on a parallel-kinematics design with coplanar axes and a single moving platform. Two pairs of differentially-driven piezo actuators are employed to provide the highest dynamics and position stability over a wide temperature range.

Compared to stacked, (two-stage), piezo or galvo scanners, the single-platform design provides several advantages: smaller package size, identical

Ordering Information	
<b>S-334.1SD</b>	High-Dynamics Piezo Tip/Tilt Platform, 25 mrad, SGS, Sub-D Connector, incl. Mirror
<b>S-334.1SL</b>	High-Dynamics Piezo Tip/Tilt Platform, 25 mrad, SGS, LEMO Connector, incl. Mirror
<b>S-334.2SD</b>	High-Dynamics Piezo Tip/Tilt Platform, 50 mrad, SGS, Sub-D Connector, incl. Mirror
<b>S-334.2SL</b>	High-Dynamics Piezo Tip/Tilt Platform, 50 mrad, SGS, LEMO Connector, incl. Mirror

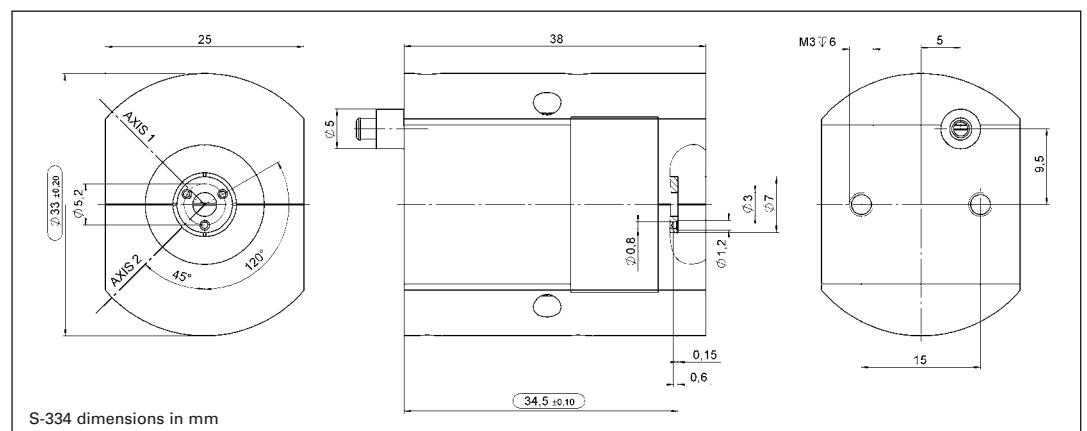
dynamic performance in both axes, faster response and better linearity. It also prevents polarization rotation.

### High Reliability and Long Lifetime

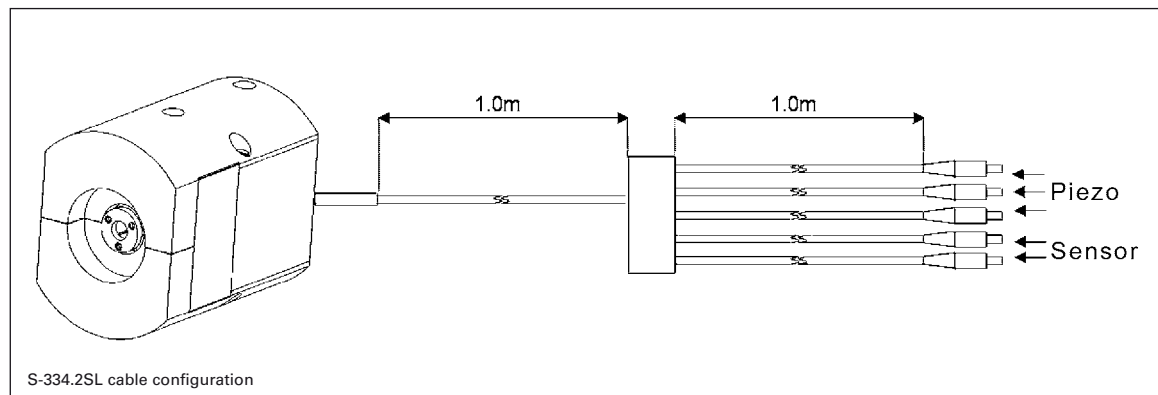
The compact S-334 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and provide better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free, not subject to wear and offer extraordinary reliability.

### Application Examples

- Image processing / stabilization
- Interlacing, dithering
- Laser scanning / beam steering
- Optics
- Optical filters / switches
- Scanning microscopy
- Beam stabilization



**Factory Installed Mirror** in diameter and 2 mm thick  
 The S-334 is equipped with a (flatness  $\lambda/5$ , reflectivity >98 %  
 factory-installed mirror 10 mm from 500 nm to 2  $\mu\text{m}$ ).



## Technical Data

Model	S-334.1SL S-334.1SD	S-334.2SL S-334.2SD	Units	Tolerance
Active Axes	$\theta_x, \theta_y$	$\theta_x, \theta_y$		
<b>Motion and positioning</b>				
Integrated sensor	SGS	SGS		
*Open-loop tilt angle at -20 to +120 V	30	60	mrad	min. (+20 %/-0 %)
*Closed-loop tilt angle	25	50	mrad	
Open-loop resolution	0.2	0.5	$\mu\text{rad}$	typ.
Closed-loop resolution	1	5	$\mu\text{rad}$	typ.
Linearity	0.05	0.05	%	typ.
Repeatability	2	5	$\mu\text{rad}$	typ.
<b>Mechanical properties</b>				
Resonant frequency underload (with standard mirrors)	3.0	1.0	kHz	$\pm 20\%$
Load capacity	0.2	0.2	N	Max.
Distance of pivot point to platform surface	6	6	mm	$\pm 1\text{ mm}$
Platform moment of inertia	1530	1530	$\text{g} \cdot \text{mm}^2$	$\pm 20\%$
Standard mirror (mounted)	diameter: 10 mm, thickness: 2 mm; BK7, $\lambda/5$ , R > 98 % ( $\lambda = 500\text{ nm}$ to 2 $\mu\text{m}$ )	diameter: 10 mm, thickness: 2 mm; BK7, $\lambda/5$ , R > 98 % ( $\lambda = 500\text{ nm}$ to 2 $\mu\text{m}$ )		
<b>Drive properties</b>				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance per axis	3	3	$\mu\text{F}$	$\pm 20\%$
<b>Miscellaneous</b>				
Operating temperature range	-20 to 80	-20 to 80	$^{\circ}\text{C}$	
Material casing	Titanium	Titanium		
Mass	0.065	0.065	kg	$\pm 5\%$
Cable length	2	2	m	$\pm 10\text{ mm}$
Sensor / voltage connection	LEMO connector / 25-pin sub-D connector	LEMO connector / 25-pin sub-D connector		

Recommended controller / amplifier

Closed-loop versions with D-sub connector: E-616 controller for tip/tilt mirror systems (p. 2-132);

Open-loop versions with LEMO connector: Modular piezo controller system E-500 (p. 2-142) with amplifier module E-503.00S (three channels) (p. 2-146) or 1 x E-505.00S and 2 x E-505 (high speed applications) (p. 2-147) and E-509 servo controller (p. 2-152 / 3-16)

Open-loop: E-663 three channel amplifier (p. 2-136)

Resolution of PI piezo tip/tilt platforms is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier, (p. 2-146).

\*Mechanical tilt, optical beam deflection is 120 mrad (open loop) and 100 mrad (closed-loop), respectively.

# Piezo Tip/Tilt-Steering Mirror for Optical Communication

## High-Dynamics, Large-Angle Piezo Tip/Tilt Platforms for Fast Steering Mirrors



S-330 tip/tilt platforms with optical beam deflection angles of 4, 10 and 20 mrad

- Resolution to 20 nrad, Excellent Position Stability
- Optical Beam Deflection to 20 mrad ( $>1^\circ$ )
- Higher Dynamics, Stability & Linearity Through Parallel-Kinematics Design
- Sub-Millisecond Response
- For Mirrors up to 50 mm Diameter
- Closed-Loop Versions for Better Linearity
- Excellent Temperature Stability

S-330 piezo tip/tilt platforms are fast and compact tip/tilt units, providing precise angular motion of the top platform around two orthogonal axes.

### Application Examples

- Image processing / stabilization
- Interlacing, dithering
- Laser scanning / beam steering
- Optics
- Optical filters / switches
- Beam stabilization

These flexure-guided, piezo-electric platforms can provide higher accelerations than other implementations, enabling step response times in the sub-millisecond range. Closed-loop and open-loop versions with 3 different tilt ranges up to 10 mrad (20 mrad optical deflection) are available.

### Parallel-kinematics design for improved stability, linearity and dynamics

PI piezo tip/tilt mirror systems are based on a parallel-kinematics design with coplanar axes and a single moving platform. Two pairs of differential-

ly-driven piezo actuators are employed to provide the highest possible angular stability over a wide temperature range. Compared to stacked, (two-stage) piezo or galvo scanners, the single-platform design provides several advantages: smaller package size, identical dynamic performance in both axes, faster response and better linearity. It also prevents polarization rotation.

### Fast Piezo Ceramic Drives

Frictionless, flexure-guided piezo ceramic drives provide higher accelerations than other actuators, such as voice-coils, and enable response in the millisecond range and below. Piezo actuators do not require energy to hold a position. The resulting low heat signature is a great advantage in infrared imaging systems like those used in astronomy.

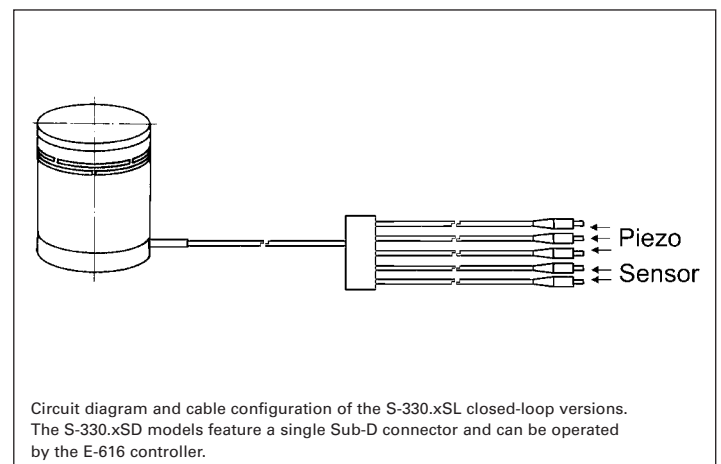
### Closed Loop Operation

For high stability and repeatability, absolute-measuring strain gauge sensors (SGS) are applied to appropriate locations on the drive train. They provide a high-bandwidth, position feedback signal to the controller. The sensors are connected in a bridge configuration to eliminate thermal drift,

### Ordering Information

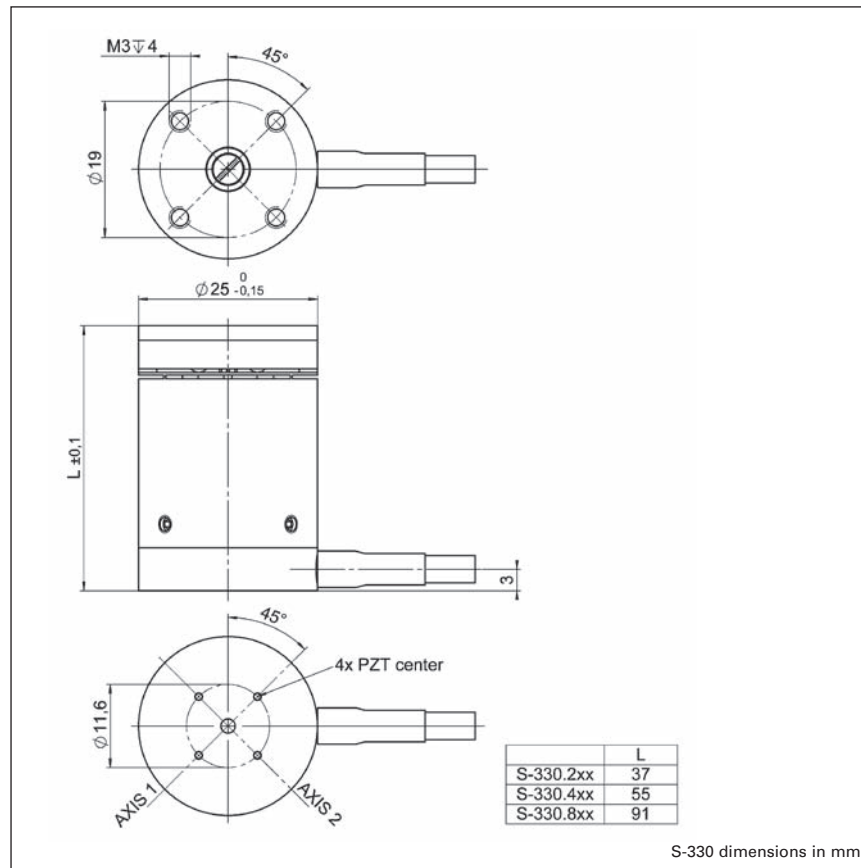
- S-330.2SL**  
High-Dynamics Piezo Tip/Tilt Platform, 2 mrad, SGS, LEMO Connector
- S-330.2SD**  
High-Dynamics Piezo Tip/Tilt Platform, 2 mrad, SGS, Sub-D Connector
- S-330.20L**  
High-Dynamics Piezo Tip/Tilt Platform, 2 mrad, Open-Loop, LEMO Connector
- S-330.4SL**  
High-Dynamics Piezo Tip/Tilt Platform, 5 mrad, SGS, LEMO Connector
- S-330.4SD**  
High-Dynamics Piezo Tip/Tilt Platform, 5 mrad, SGS, Sub-D Connector
- S-330.40L**  
High-Dynamics Piezo Tip/Tilt Platform, 5 mrad, Open-Loop, LEMO Connector
- S-330.8SL**  
High-Dynamics Piezo Tip/Tilt Platform, 10 mrad, SGS, LEMO Connector
- S-330.8SD**  
High-Dynamics Piezo Tip/Tilt Platform, 10 mrad, SGS, Sub-D Connector
- S-330.80L**  
High-Dynamics Piezo Tip/Tilt Platform, 10 mrad, Open-Loop, LEMO Connector

and assure optimal position stability. Open-loop systems are also available.



## Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.



### Technical Data

Model	S-330.2SL	S-330.4SL	S-330.8SL	S-330.2SD S-330.4SD S-330.8SD	S-330.20L S-330.40L S-330.80L	Units	Tolerance
Active axes	$\Theta_x, \Theta_y$	$\Theta_x, \Theta_y$	$\Theta_x, \Theta_y$	$\Theta_x, \Theta_y$	$\Theta_x, \Theta_y$		
<b>Motion and positioning</b>							
Integrated sensor	SGS	SGS	SGS	SGS	-		
Open-loop tip/tilt angle, -20 to +120 V	3.5	7	15	as SL version	as SL version	mrad	min.
Closed-loop tip/tilt angle	2	5	10	as SL version	-	mrad	
Open-loop tip/tilt angle resolution	0.02	0.1	0.2	as SL version	as SL version	$\mu$ rad	typ.
Closed-loop tip/tilt resolution	0.05	0.25	0.5	as SL version	-	$\mu$ rad	typ.
Linearity in $\Theta_x, \Theta_y$	0.1	0.2	0.25	as SL version	-	%	typ.
Repeatability $\Theta_x, \Theta_y$	0.15	0.5	1	as SL version	-	$\mu$ rad	typ.
<b>Mechanical properties</b>							
Unloaded resonant frequency ( $\Theta_x, \Theta_y$ )	3.7	3.3	3.1	as SL version	as SL version	kHz	$\pm 20\%$
Resonant frequency loaded in $\Theta_x, \Theta_y$ (with 25 x 8 mm glass mirror)	2.6	1.6	1.0	as SL version	as SL version	kHz	$\pm 20\%$
Distance of pivot point to platform surface	6	6	6	6	6	mm	$\pm 1$ mm
Platform moment of inertia	1530	1530	1530	1530	1530	g x mm <sup>2</sup>	$\pm 20\%$
<b>Drive properties</b>							
Ceramic type	PICMA®	PICMA®	PICMA®	PICMA®	PICMA®		
Electrical capacitance	3/axis	6/axis	12.5/axis	as SL	as SL	$\mu$ F	$\pm 20\%$
Dynamic operating current coefficient	0.22/axis	0.4/axis	0.8/axis	as SL	as SL	$\mu$ A/Hz • mrad	$\pm 20\%$
<b>Miscellaneous</b>							
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material case	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel		
Material platform	Invar	Invar	Invar	Invar	Invar		
Mass	0.2	0.38	0.7	as SL version	as SL version	kg	$\pm 5\%$
Cable length	1.5	1.5	1.5	1.5	1.5	m	$\pm 10$ mm
Sensor / voltage connection	LEMO	LEMO	LEMO	Sub-D connector	LEMO		

Recommended controller / amplifier

Versions with LEMO connector: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503.00S (three channels) (p. 2-146) or 1 x E-505.00S and 2 x E-505 (high speed applications) (p. 2-147) and E-509 controller (p. 2-152) (optional)

Open-loop: E-663 three channel amplifier (p. 2-136)

Versions with Sub-D connectors: E-616 servo controller for tip/tilt mirror systems (p. 2-132)

# Piezo Tube Actuators for Fiber Scanning / Stretching

## Piezoceramic Tube Actuators with Small Tolerances and Various Options



A selection of PT piezoceramic tubes

- **Standard & Custom Sizes**
- **Optional Quartered Electrodes for XYZ-Positioning & Scanning**
- **Sub-Nanometer Resolution**
- **Ideal for OEM-Applications**

PT-series piezoceramic tubes are used in a wide range of applications from microdispensing to scanning microscopy. These monolithic components contract laterally (radially) and longitudinally when a voltage is applied between their inner and outer electrodes. Multi-electrode tubes are available to provide XYZ motion for use in manipulation and scanning microscopy applications. PI also provides

ultra-high linearity, closed-loop scanning stages for SPM and nanomanipulation.

### Precision and Flexibility

PT piezo tubes are manufactured to the tightest tolerances. We can provide tubes with diameters as small as 0.8 mm and tolerances as tight as 0.05 mm. All manufacturing processes at PI Ceramic are set up for maximum flexibility. Should our standard actuators not fit your application, let us provide you with a custom design. Our engineers will work with you to find the optimum solution at a very attractive price, even for small quantities. Some of our custom capabilities are listed below:

- Custom Materials
- Custom Voltage Ranges / Displacement
- Custom Geometries
- Extra-Tight Tolerances
- Applied Sensors
- Special High / Low Temperature Versions

### Short Leadtime

Because all piezoelectric materials used in PT tube actuators are manufactured at PI Ceramic, leadtimes are short and quality is outstanding.

### Dimensions

max. L: 50 mm  
max. OD: 80 mm  
min. d: 0.30 mm

### Electrodes

Fired silver-plated inside and outside as standard; thin film electrodes (e. g. copper-nickel or gold) as outer electrodes optional.

### Options

Single or double wrapped, circumferential bands or quartered outer electrodes.

### Polarization

Inner electrode positive potential

Tube actuators are not designed to withstand large forces (see PICA™ Thru actuators p. 1-90), but their high resonant frequencies make them especially suitable for dynamic operation with light loads.

Application examples are micro pumps, scanning microscopy, ink-jet printing, ultrasonic and sonar applications.

### Piezo Drivers, Controllers & High-Voltage Amplifiers

High-resolution amplifiers and servo-control electronics, both digital and analog, are described in the "Piezo Drivers / Servo Controllers" section.

### Equations

The axial contraction and radial displacement of piezo tubes can be calculated as follows:

#### (Equation 1)

$$\Delta L \approx d_{31} \cdot L \cdot \frac{U}{d}$$

where:

$d_{31}$  = strain coefficient (displacement normal to polarization direction) [m/V]

$L$  = length of ceramic tube [m]

$U$  = operating voltage [V]

$d$  = wall thickness [m]

#### (Equation 2)

$$\Delta d \approx d_{33} \cdot U$$

where:

$d$  = change in wall thickness [m]

$d_{33}$  = strain coefficient (field and displacement in polarization direction) [m/V]

$U$  = operating voltage [V]

Typical values for  $d_{31}$  and  $d_{33}$  are -200 pm/V and 500 pm/V, respectively.



XY scanning tubes with quartered outer electrodes; see table for specifications

### Application Examples

- Micropositioning
- Scanning microscopy (AFM, STM, etc.)
- Fiber stretching / modulation
- Micropumps
- Micromanipulation
- Ultrasonic and sonar applications

The radial contraction is the superposition of the increase in wall thickness and the tangential contraction; it can be estimated by the following equation:

**(Equation 3)**

$$\frac{\Delta r}{r} \approx d_{31} \frac{U}{d}$$

where:

$r$  = radius of piezo tube

$d_{31}$  = strain coefficient (displacement normal to polarization direction) [m/V]

$U$  = operating voltage [V]

$d$  = wall thickness [m]

For a given division of the outer electrode of a piezo tube into four 90° sections the differential control ( $\pm U$ ) of opposing electrodes results in bending of one of the ends, due to super

position of radial and axial contraction. Such tubes are applied as XY scanner in scanning-probe microscopes such as atomic force microscopes. The scanning range can be evaluated as follows:

**(Equation 4)**

$$\Delta x \approx \frac{2\sqrt{2} \cdot d_{31} \cdot L^2 \cdot U}{\pi \cdot ID \cdot d}$$

where:

$\Delta x$  = scanning range in X and Y (for symmetrical electrodes) [m]

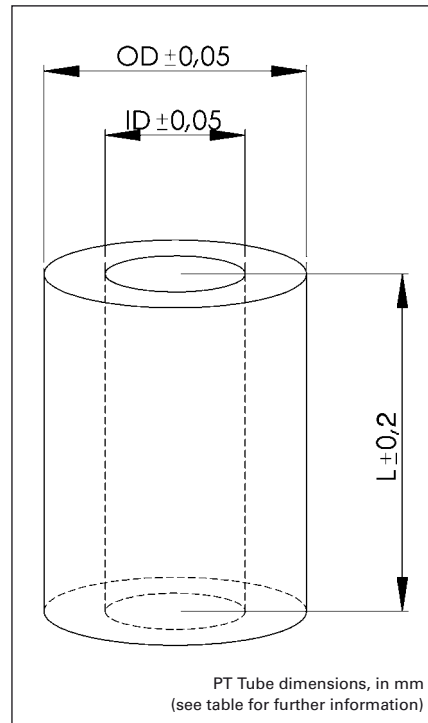
$d_{31}$  = strain coefficient (displacement normal to polarization direction) [m/V]

$U$  = operating voltage [V]

$L$  = length [m]

$ID$  = inner diameter [m]

$d$  = wall thickness [m]



PT Tube dimensions, in mm  
(see table for further information)

**Technical Data / Product Order Numbers**

Order number	Dimensions [mm] L x OD x ID**	Max. operating voltage [V]	Electrical capacitance [nF] $\pm 20\%$	Axial contraction [ $\mu\text{m}$ ] @ max. V	Radial contraction [ $\mu\text{m}$ ] @ max. voltage	XY deflection [ $\mu\text{m}$ ] @ $\pm 200$ V
PT120.00	20 x 2.2 x 1.0	500	3	5	0.7	-
PT130.00	30 x 3.2 x 2.2	500	10	9	0.9	-
PT130.90	30 x 3.2 x 2.2	500	12	9	0.9	-
PT130.94*	30 x 3.2 x 2.2	$\pm 200$	4 x 2.4	9	0.9	$\pm 35$
PT130.10	30 x 6.35 x 5.35	500	18	9	1.8	-
PT130.14*	30 x 6.35 x 5.35	$\pm 200$	4 x 3.8	9	1.8	$\pm 16$
PT130.20	30 x 10.0 x 9.0	500	36	9	3	-
PT130.24*	30 x 10.0 x 9.0	$\pm 200$	4 x 8.5	9	3	$\pm 10$
PT130.30	30 x 10.0 x 8.0	1000	18	9	3	-
PT130.40	30 x 20.0 x 18.0	1000	35	9	6	-
PT140.70	40 x 40.0 x 38.0	1000	70	15	12	-

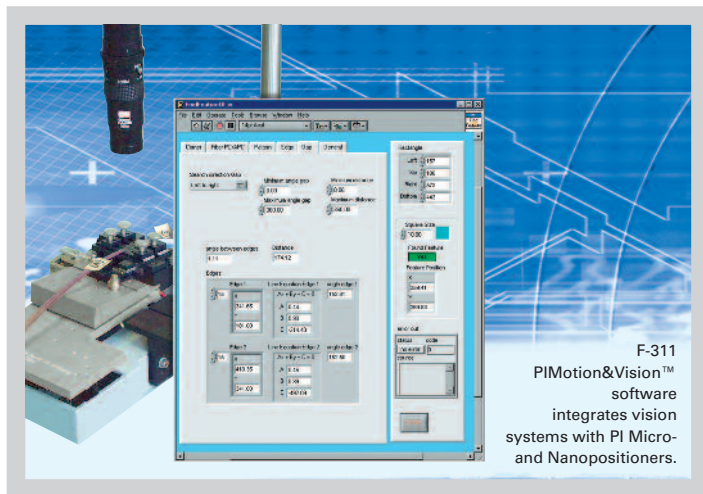
\*Quartered electrodes for XY deflection

\*\*OD (outer diameter), ID (inner diameter)  $\pm 0.05$  mm. PT120 / PT130.00: ID  $\pm 0.1$  mm

Other specifications on request.

# F-311 PIMotion&Vision™

## Integration of Vision System and Micro-/Nanopositioning



F-311  
PIMotion&Vision™  
software  
integrates vision  
systems with PI Micro-  
and Nanopositioners.

- Vision System for Integration with PI Micro- and Nanopositioning Systems
- Controls Motion Axes with Sub- $\mu\text{m}$  or Sub-nm (Sub- $\mu\text{rad}$ ) Resolution
- National Instruments Compatible Vision System
- Multi-Channel Vision for a Mix of Resolutions and/or 3D Observation
- Powerful LabVIEW VIs

PIMotion&Vision™ offers an integrated solution for difficult tasks such as automated positioning of optics, semi-conductor wafers, microsystems technology MEMS fabrication or alignment and scanning of samples under a microscope:

- Basic functions such as autofocus, edge and pattern

### Application Examples

- Optical 6D alignments
- Autofocussing
- Gap measurements
- Pattern recognition in
  - Semiconductor industry
  - Biotechnology
  - Life science
  - MEMS Manufacturing/MST
  - Photonics

recognition, and gap measurement.

- Intelligent automated procedures.

### NI Framegrabber

The hardware for the F-311 PIMotion&Vision™ system consists of a National Instruments PCI bus framegrabber card. This fact guarantees a high degree of compatibility for further system integration. The framegrabber card supports a number of camera systems and is available with one or four channels.

### Software Interface to Micro- and Nanopositioners

PIMotion&Vision™ offers a large number of LabVIEW drivers for continuous monitoring and processing of the image information, including standard procedures for gap measurement, autofocus, aligning edges

all the way to complex alignment routines in six degrees of freedom with an unlimited number of axes of motion, switching functions and read-in of analog signals (e.g. photometer signals for optical fiber alignment).

Motion is commanded using the PI General Command Set, which is supported by all PI multi-axis micropositioning and nanopositioning controllers.

The basic version contains all the drivers provided by PI; the Pro Version includes the full IMAQ development environment from National Instruments, making possible an even wider range of system integration and function development.

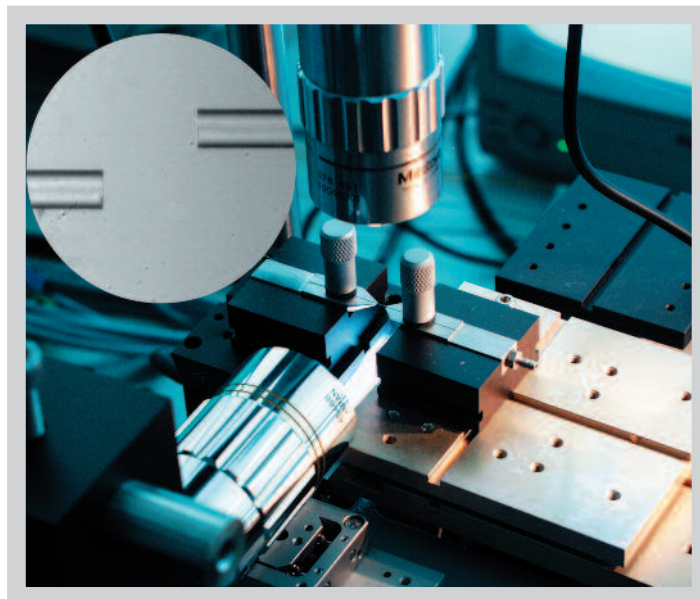
### Notes

Optimal performance in transmitted-light applications can be obtained with the F-311.L10 illumination system, developed by PI.

### Ordering Information

- F-311.V01**  
PIMotion&Vision™ Basic Module, 1CH
- F-311.V04**  
PIMotion&Vision™ Basic Module, 4CH
- F-311.V11**  
PIMotion&Vision™ Pro Module, 1CH
- F-311.V14**  
PIMotion&Vision™ Pro Module, 4CH
- F-311.V1U**  
PIMotion&Vision™ Upgrade to Pro Module
- F-311.L10**  
PIMotion&Vision™ Illumination System

The light intensity is adjustable and the use of LEDs assure long lifetime. The unit can be powered directly from the PI controller, a feature which helps reduce the number of components.

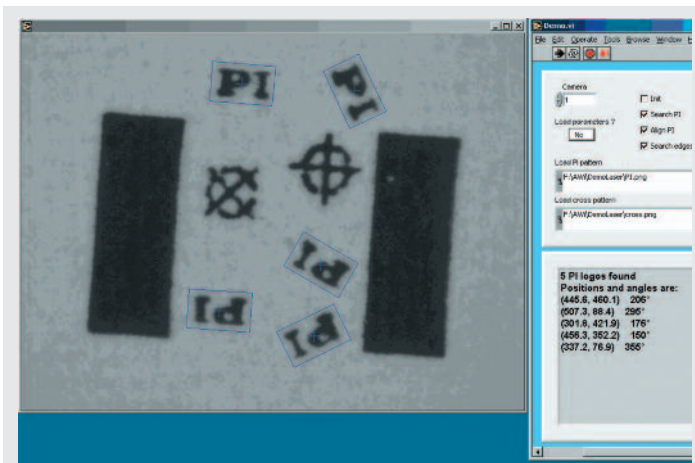


Optical fiber-alignment with F-206 6-axis-alignment system and P-611 NanoCube® 3D piezo nanopositioning / scanning system. Two cameras allow a 3-dimensional visual automated coarse alignment.

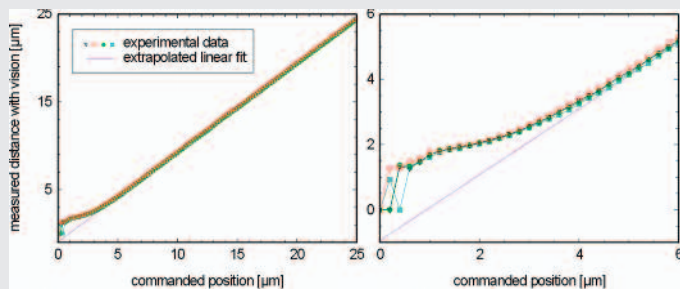


**NI**  
**Compatible**

Simple setup with a single camera, two M-111 stages in an XY configuration and an M-116 rotary platform (all controlled from a C-843 PCI card). This sample setup can be used for pattern recognition, as can be seen in the next graphics.



PIMotion&Vision™ sample pattern recognition task. The sample program searches for PI logos, counts and aligns them. The logos are 1 x 0.5 mm in size.

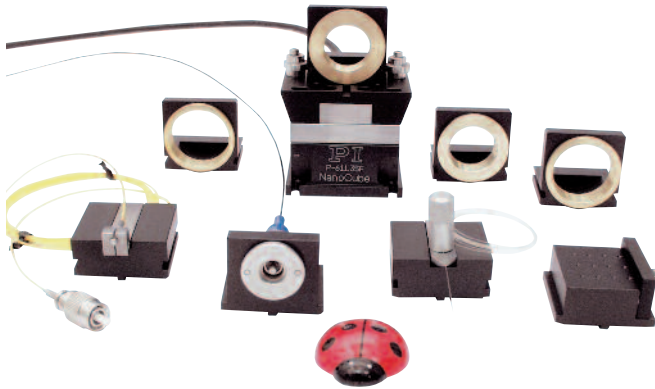


Example of a gap measurement with PIMotion&Vision™. The measurement is linear down to 5  $\mu\text{m}$ , depending on the used camera, and at separations down to 1  $\mu\text{m}$  the values provided can be used with correction. Optical gap measurement then begins to be limited by refraction and optical imperfections. The reference measurements were made with a P-611 NanoCube® Piezo-NanoPositioning system.



# F-603 Accessories

## Fiber, Objective and Waveguide Holders



Rear (left to right) Microscope Objective Holders: F-603.14, F-603.12 (mounted on P-611.3SF NanoCube® NanoAlignment System) F-603.11, F-603.13

- Mount on a Variety of PI Alignment Systems
- Precision Machined from High-Strength Aluminum/Brass

The F-603 series component holders for fiber optic applications can be combined with the following micro- and nanopositioning systems from PI:

- F-206 6D-Hexapod-Alignment System
- F-130 and F-131 Alignment Systems
- P-611.3OF and P-611.3SF NanoCube® NanoAligners
- A variety of combinations of NanoCubes® with other micropositioning systems

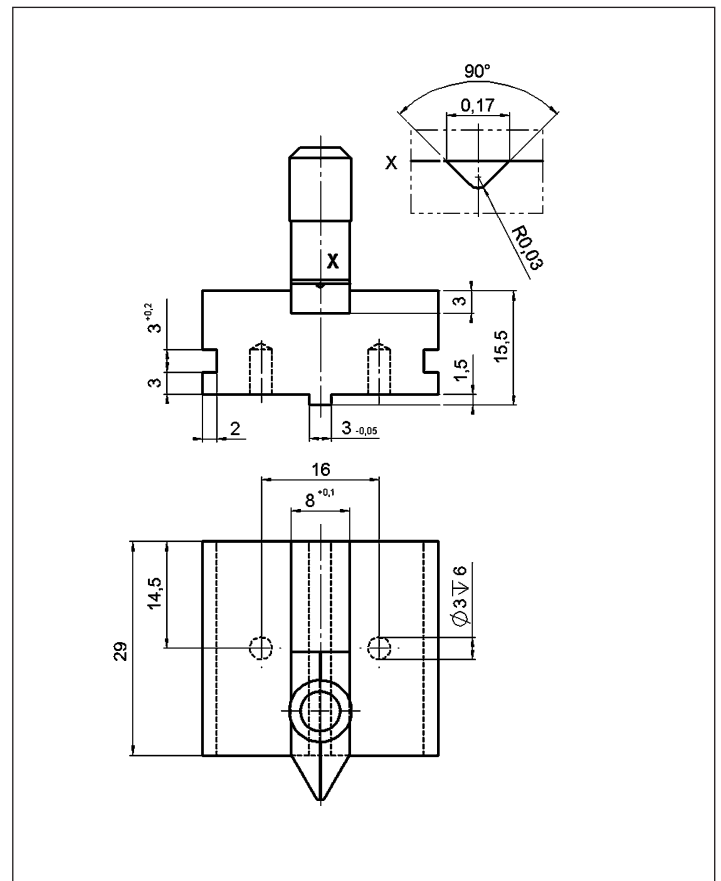
All adapters are equipped with a 3-mm-wide tongue that fits in a slot machined into the platform of the positioning system.

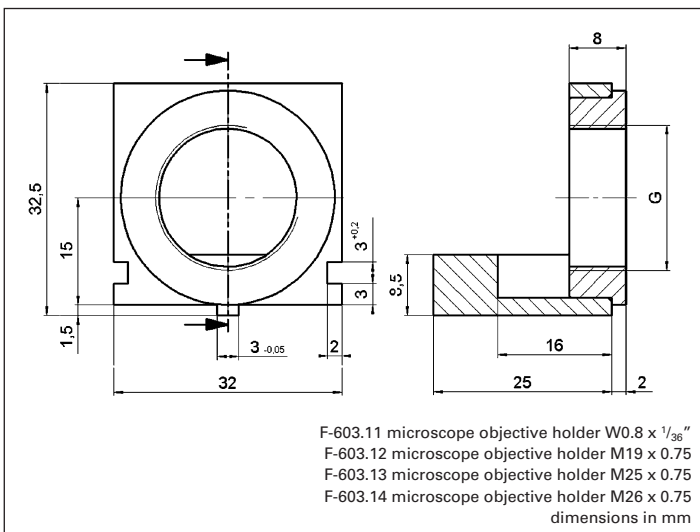
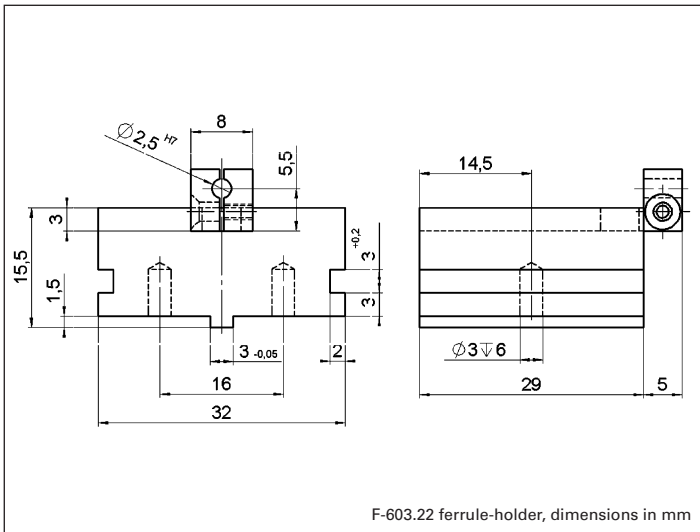
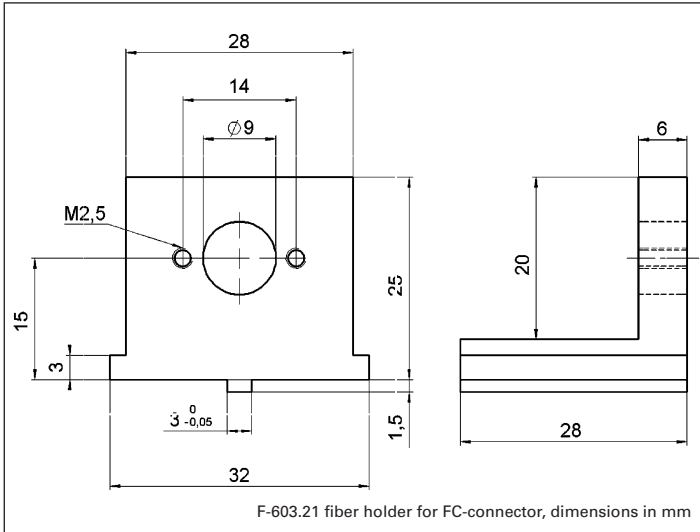
M3 capscrews and miniature cleats supplied with each F-603 adapter are used to fasten these accessories quickly.

### Ordering Information

- F-603.11**  
Microscope Objective Holder  
W0.8 x 1/36"
- F-603.12**  
Microscope Objective Holder  
M19 x 0.75
- F-603.13**  
Microscope Objective Holder  
M25 x 0.75
- F-603.14**  
Microscope Objective Holder  
M26 x 0.75
- F-603.20**  
Vacuum Waveguide Mount
- F-603.21**  
Fiber Holder for FC-Connector
- F-603.22**  
Ferrule Holder
- F-603.60**  
V-Groove Fiber Holder with Magnetic Clamp

Ask about custom designs!





## Moving the Nanoworld

### NanoAutomation®: Precision Positioning for Science and Industry

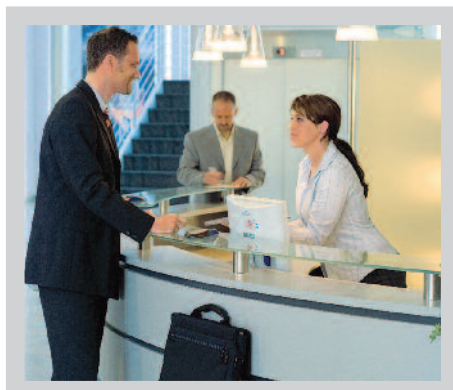


PI headquarters in Karlsruhe

#### Future Technology Solutions

Today PI delivers micro- and nanopositioning solutions for all important high-tech markets:

- Semiconductor Technology
- Optical Metrology, Microscopy
- Biotechnology and Medical Devices
- Precision Automation and Handling
- Precision Machining
- Data Storage
- Photonics, Fiber Optics, Telecom
- Nano Technology
- Microsystems Technology
- Aerospace Engineering
- Astronomy



PI reception desk:  
Our employees look forward to your visit

PI is market and technological leader for precision positioning systems with accuracies well under one nanometer. Nanometer-range motion control is the key to worlds where millions of transistors fit on one square millimeter, where molecules are manipulated, where thousands of “virtual slices” are made in the observation of living cells, or where optical fiber bundles no larger than a human hair are aligned in six degrees of freedom.

#### Worlds We Call NanoWorlds

Continuous innovation and reinvestment of profits over the decades has allowed PI to attain its present market status. This status is also based on long-term customer relationships and on the freedom to transform ideas into reality.

#### Over 30 Years Experience

When PI introduced piezoelectric nanopositioning technology more than 30 years ago, typical customers were research labs and universities working on laser cavity tuning, Fabry-Perot interferometers and filters. Few foresaw that whole industrial sectors like

semiconductor manufacturing or biotechnology would become dependent on progress in nanopositioning. Today, not even the precision machining industry can do without nanometer-level positioning systems.

#### Key Technologies In-House

PI follows a vertical integration strategy designed to develop and maintain all key technologies in-house. We supervise each and every step from design to delivery in the following areas: software, precision mechanics, digital and analog control electronics, sub-nanometer capacitive position sensors, piezo ceramics and piezo actuators. This assures the highest quality and reduces cost.

## Thinking in Systems All in One Hand—All from One Hand



Drive, sensors, mechanics and control electronics with software—components of PI's positioning systems

To assure that the subassemblies used satisfy PI's quality requirements, PI fabricates all components itself, develops the ultra-high-resolution sensors and controllers, and programs both control algorithms and operating software. In Lederhose (Thuringia) at PI Ceramic, piezoelectric drives are developed, optimized and manufactured. With PIC, PI is the only positioning system manufacturer worldwide which develops its own piezoelectric actuators to meet market requirements. The resulting flexibility is an important reason for the technological leadership enjoyed by PI and its customers.

### Capacitive Sensors for Nanometrology

Special sensors can fulfill the requirements of many applications for dynamics, linearity and stability better than that provided by standard strain gauges. Non-contact capacitive sensors measure position without drift and provide linearity to 0,01% of the measure-

ment range. The high resolution of up to 0.0005% allows detection and compensation of the smallest position errors. PI uses capacitive sensors developed in-house, making it possible to adapt the sensor geometries to the space available. Placing the sensors as close as possible to the moving platform, PI provides direct metrology systems—systems in which motion is detected where it is used. PI capacitive sensors are also offered as stand-alone products for nanometrology applications.

### Control of Positioning Systems

The characteristics of drives and sensors are made usable by the drive and control electronics. PI has designed all electronics to match the mechanics optimally. Electronic amplifiers for piezoelectric actuators must provide low noise and drift. Fast rise times make possible sub-millisecond response times and optimized control algorithms minimize settling times.

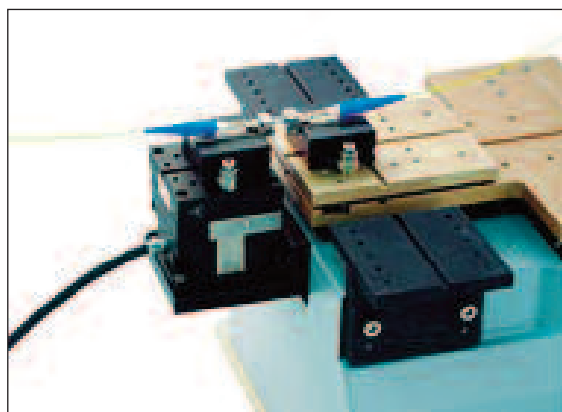
Digital controllers include advanced algorithms to improve the system performance: coordinate transformation matrices matched to the mechanical geometries allow for commanding complex systems in Cartesian coordinates; filters support servo-control by suppressing resonant vibrations; pre-shaping of control signals minimizes trajectory deviation during dynamic scans. All functions are easily accessible through fast and modern interfaces and comprehensive user software and software drivers.

### Flexibility Through Competent Partners

High quality requires qualified partners. Over the years PI has thus qualified a number of highly specialized suppliers with whom we now work as partners—partners whose conception of quality is every bit as high as our own.



An automation platform like the C-880 features built-in fiber alignment routines and can control up to 18 axes. The systems are easy to program and are supplied with a variety of comprehensive software drivers and tools



The F-206 HexAlign™ alignment system features 6 degrees of freedom and 0.1 μm minimal incremental motion. An optional high-speed, piezo-driven scanning module with 1 nm resolution is also available

Request or download the complete  
hardbound catalog  
"Piezo Nano Positioning"



Call or go to: <http://www.pi.ws>

## 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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