

Moving the NanoWorld

MicroPositioning, NanoPositioning, NanoAutomation®

Program Overview

- Photonic Subsystems
- Piezoelectric Translators (PZTs)
- Piezo Tip/Tilt Platforms for Mirrors and Optics
- Integrated Piezo Positioners and Piezo Controllers
- Parallel Kinematics—Hexapod Technology
- Micropositioning Technology
- Motor Controllers
- **PIline™** Positioners with Piezo Motors
- Piezoelectric Ceramics



PI Headquarters



PI's Piezo Ceramic Division

PI's Customers

PI products have long outgrown application exclusively in universities—PI customers now come from all sectors of manufacturing, quality assurance, research and development. And they are spread across many branches of industry: semiconductors, semiconductor test systems, medical engineering, biotechnology, telecommunications and precision engineering. PI's customers even include national standardization institutes.



Has been developing and manufacturing products in the field of nanotechnology for more than 30 years. During this time, we have achieved and continually consolidated our position as a global market leader. Prime examples of our core competencies and cutting-edge technology are to be found in the development of parallel kinematics—integrated 6-axis positioners based on the Hexapod—and in the field of nanopositioning with piezoceramic actuators.

PI is a vertically integrated company, with full control over the development and manufacture of all our products. The piezoceramic actuators are supplied by PI Ceramic, our piezo ceramic division.

PI employs more than 300 staff worldwide and has support, sales and engineering offices in USA, Japan, China Great Britain, France and Italy. In addition PI is represented

in many countries around the world.

PI Markets

PI products are characterized by their quality and innovation. Developed to give the highest degree of precision, we employ the most modern tools and software for product development like CAD and FEM calculations and simulations. To determine the performance level of our products, we use interferometers or capacitive sensors to push the measurement accuracies to the limit. The use of our products in laboratories and research establishments puts PI among the pioneers of modern sciences in areas like microstructure technology and nanotechnology. Over the years we have seen many technological advances make the transition

from the laboratory to daily life, advances requiring the utmost in positioning accuracy, advances inconceivable without PI. Finer and finer structures on semiconductor wafers for cost-effective mass production of high-performance electronics, or higher and higher information density in telecommunications streams with millisecond switching from network to network all in a minimum of a space: this is where PI is at home.

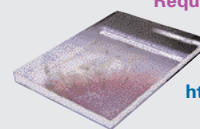
Choose PI

As our customer, you also profit from our more than 30 years' experience in micro- and nanopositioning technology. You will join an ever-increasing number of renowned companies and institutes whose products are at the cutting edge of innovation, research and technology. We move the nanoworld.



PI USA, East Coast Office Auburn, MA

The following pages give you an overview of our products and their applications. We will be pleased to answer any questions you may have.



Photonic Subsystems: F-206 HexAlign™ Robot and C-880 Automation Controller

	F-206	C-880
Function	Parallel-kinematic-robots for 6 degrees of freedom with controller	Flexible automation controller
Positioning	6-axis HexAlign™ robot plus – 2 additional motor axes (DC motor) – NanoCube™ high-resolution XYZ piezo system	up to 16 axes comprising – Individual actuator axes (DC motor, piezo motor, voice coil drive) – NanoCube™ high-resolution XYZ piezo system
Control	– 19" case with optional front-panel display and keyboard – 32-bit AMD K6-II 500 MHz processor – Controller cards and firmware for control of the 6-axis robot – Additional integrated options	– 19" case with optional front-panel display and keyboard – 32-bit AMD K6-II 500 MHz processor – Integration of actuator controls – Additional integrated options
Interface	RS-232, IEEE 488 optional	RS-232, IEEE 488 optional
Options	– Manual control pad for the 6-axis robot – Control card for the NanoCube™ XYZ piezo system – Optical photometer cards (IR, visible spectral range)	– Manual controls for 12 motorized axes – Control cards for motorized positioners (DC motor, piezo motor, voice coil drive) – Control card for NanoCube™ XYZ piezo system – Optical photometer cards (IR, visible spectral range) – 8-channel power switch relay card to trigger external events
Software	– Operating program – DLL, COM and LabVIEW™ drivers – Automatic scan and alignment routines	– Configuration program – Operating program – DLL, COM and LabVIEW™ drivers – Automatic scan and alignment routines

Application Examples

- Photonics packaging
- Fiber and fiber array alignment
- MEMS positioning and alignment
- Microsystems technology
- Microhandling
- Semiconductor handling

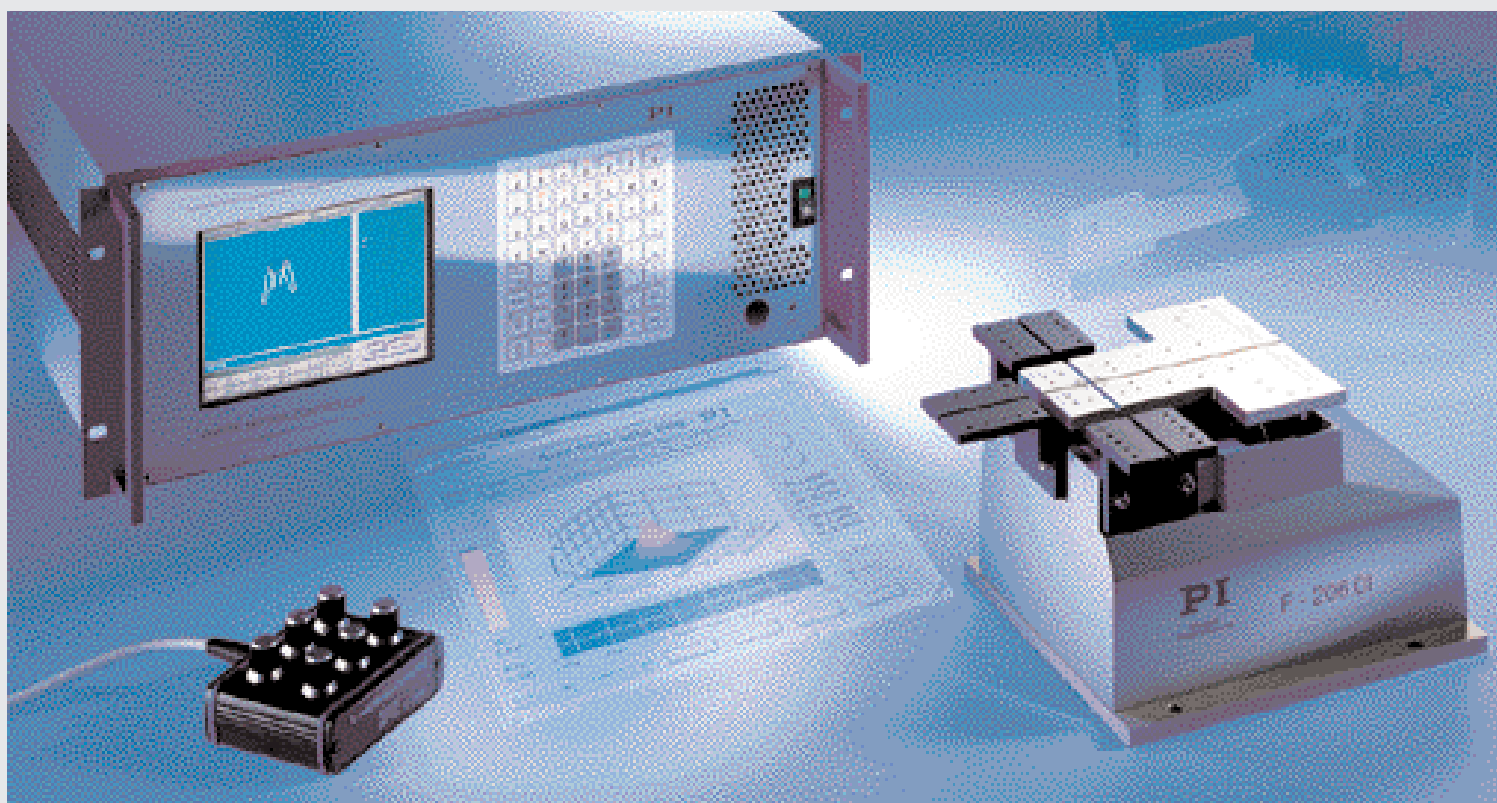
System Features

- Flexible customization
- Motorized positioning mechanics for submicrometer resolution
- XYZ piezo option with subnanometer resolution
- Comprehensive software with many automated functions
- DLL, COM and LabVIEW™ drivers

Features of F-206

HexAlign™ Robot with Controller

- Compact 6-axis positioner
- ± 6 mm travel in X, Y and Z
- ± 5° rotation about the X, Y and Z axes
- Min. incremental motion of 0.1 μm or 2 μrad resp.
- Parallel kinematics for constant, high repeatability in all axes and in space
- PivotAnywhere™ for fully virtualized center of rotation—pivot about any point in space
- Fiber coupling times of < 4 sec



Piezoelectric Translators (PZTs)

Piezoelectric translators are ceramic, solid-state actuators which convert electrical energy directly into mechanical motion.

Features

- Subnanometer resolution
- Zero friction, zero stiction
- Backlash-free
- High stiffness
- Extremely short settling times (< milliseconds)
- Optional integrated position sensors for closed-loop operation
- Vacuum compatible, operable at high or low temperatures
- Mechanical options to suit application: threads, ball tip, hardened end pieces
- Wide range of suitable control electronics
- OEM and custom designs

Application Examples

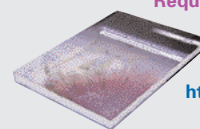
- Telecommunications: fine adjustment tasks in fiber splicing, cavity tuning
- Microscopy: sample positioning, setup and focus
- Metrology: interferometry, active vibration suppression
- Mechanical engineering: high-load PZTs for alignment of components and tools
- Microsystems technology: PZTs for alignment applications

Examples of Standard PZT Translators

Series	Travel [μm] ¹⁾	Resolution open-loop [nm]	Resolution closed-loop [nm]	Resonant frequency, unloaded [kHz]	Stiffness [N/μm]	Max. pushing force [N]	Dimensions (diameter x length) [mm]
P-830; P-831	15 – 60 (LV)	< 0.15 – 0.6	–	23 – 8.5	57 – 15	1000	10 x 22 – 70
P-840; P-841	15 – 90 (LV)	< 0.15 – 0.9	< 0.3 – 1.8	18 – 6	57 – 10	1000	12 x 32 – 122
P-239	5 – 180 (HV)	< 0.05 – 1.8	< 0.4 – 3.6	12 – 2	850 – 35	4500	25 x 36 – 184
P-247	20 – 120 (HV)	< 0.2 – 1.2	< 0.4 – 2.4	8 – 3	1280 – 240	30000	50 x 56 – 144
P-280 Block Translator (up to 3 axes)	30 – 100 (HV)	0.3 – 1	–	2.2 – 0.6	1.4 – 0.5	50	(15 – 25) ² x 30 – 50

¹⁾ LV: low voltage range 0 to +100 V
HV: high voltage range 0 to -1000 V





Piezo Tip/Tilt Platforms for Mirrors and Optics



Features

- Drive with low-voltage piezo translators
- Rapid multi-axis tilt with resolutions in the sub- μ rad range and settling times in the sub-millisecond range

- Tilt ranges up to ± 25 mrad
- Optional linear travel ranges up to 30 μ m
- Optional integrated position sensors for closed-loop operation
- Standard versions for mirrors up to 100 mm diameter
- Custom designs for optics up to 300 mm diameter
- Wide range of PI control electronics

Application Examples

- Laser beam steering and stabilization
- Adaptive optics
- Cavity tuning
- Imaging systems

Examples of Standard Tip/Tilt Platforms

Series	Active axes	Tilt range [mrad] / Z-travel [μ m]	Resolution (open-loop) [μ rad / nm]	Resolution (closed-loop) [μ rad / nm]	Resonant frequency [kHz] with mirror diam. x thickness [mm]	Repeatability over full travel range (closed-loop) [μ rad / nm]	Recommended optics diameter [mm]
S-224; S-226	θ_x	2.2 / -	< 0.05 / -	< 0.1 / -	7.5 with 15 x 4	± 3 / -	15
S-315; S-316	θ_x, θ_y, Z	± 0.6 / 12	< 0.03 / 0.2	< 0.05 / 0.4	4.1 with 15 x 4	± 3 / 45	25 (10 mm aperture)
S-325	θ_x, θ_y, Z	± 2 / 30	0.05 / 0.5	0.1 / 1	1.3 with 25 x 8	± 2 / 30	25
S-330	θ_x, θ_y	± 1 / -	0.05 / -	0.1 / -	2.4 with 25 x 8	± 2 / -	50
S-334	θ_x, θ_y	± 25 / -	0.5 / -	3 / -	1.3 with 12 x 3	± 8 / -	12
S-340	θ_x, θ_y	± 1 / -	0.1 / -	0.5 / -	0.9 with 50 x 15	± 1 / -	100

Piezoelectric Positioners and Stages

Features

- Resolutions in the nano-meter range with piezoelectric drives
- Travel ranges up to 800 μm with lever amplification
- Wire-EDM-cut flexure guidance for high straightness and flatness and backlash-free, friction-free motion
- Optional integrated position sensors with < 1nm resolution for closed-loop operation and linearisation
- Step or scan operations with settling times in the ms range
- Up to 6 degrees of freedom with crosstalk correction
- Large selection of PI amplifiers and controllers, modular systems and high-performance digital controllers
- Capacitive sensors with measurement ranges up to 450 μm
- OEM and custom designs

Applications

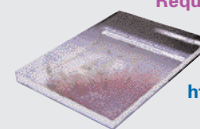
- All branches of microscopy: objective alignment, sample positioning and scanning
- Quality assurance: sample positioning and scanning, metrology systems
- Telecommunications: fiber alignment, alignment of MEMS, writing fiber Bragg gratings
- Semiconductors: wafer positioning and scanning, mask positioning
- Microsystems technology: alignment of components and tools
- Mechanical engineering: alignment of components and tools



Examples of Standard Piezo Positioners

Series	Axes	Travel [μm]	Travel [μrad]	Resolution (closed-loop) [nm]	Resonant frequency, unloaded [Hz]	Stiffness [N/ μm]	Position sensor	Dimensions [mm]
PIFOC®, P-721	Z	100	–	10; 1	620	0.3	LVDT; Capacitive	70 x 40 x 58
Nanocube™ P-611	X, Y, Z	100 x 100 x 100	–	2	Up to 350	0.3	SGS	44 x 44 x 44
P-733	X, Y	100 x 100	–	1	500	2	Capacitive	100 x 100 x 25 (aperture 50 x 50)
P-500 Family	X, Y, Z, $\theta_x, \theta_y, \theta_z$	Up to 200 x 200 x 20; 200 in Z	± 1300 ; ± 2000 in θ_z	1	Up to 1100	Up to 15	Capacitive	140 x 140 x 30 (aperture 66 x 66)
P-587	X, Y, Z, $\theta_x, \theta_y, \theta_z$	800 x 800 x 200	± 500	8	Up to 300		Capacitive	240 x 240 x 50 (aperture 170 x 170)
LISA P-753	X	12 – 38	–	Up to 0.05	Up to 5600	Up to 45	Capacitive	(44 – 80) x 30 x 15
P-772	X	10	–	0.05	1700	7	Capacitive	14 x 16 x 21
P-783.ZCL	Z	300	–	10	300	0.15	LVDT	90 x 17 x 29

*) The P-500 series offers a large number of stages with different combinations of scanning axes and scanning ranges with the same dimensions. The values given here are the respective maximum achievable values. They cannot be achieved simultaneously in any single P-500-series stage.



Parallel Kinematics—Hexapod Technology

Features

- 6 degrees of freedom
- Compact design
- Load capacities up to 200 kg
- PivotAnywhere™—fully virtualized center of rotation

- Simple control through use of logical axes
- With controller, software and drivers for system integration

A significant advantage of parallel kinematics over stacked multi-axis systems consisting of individual, single-axis positioners is the high accuracy in all active axes.

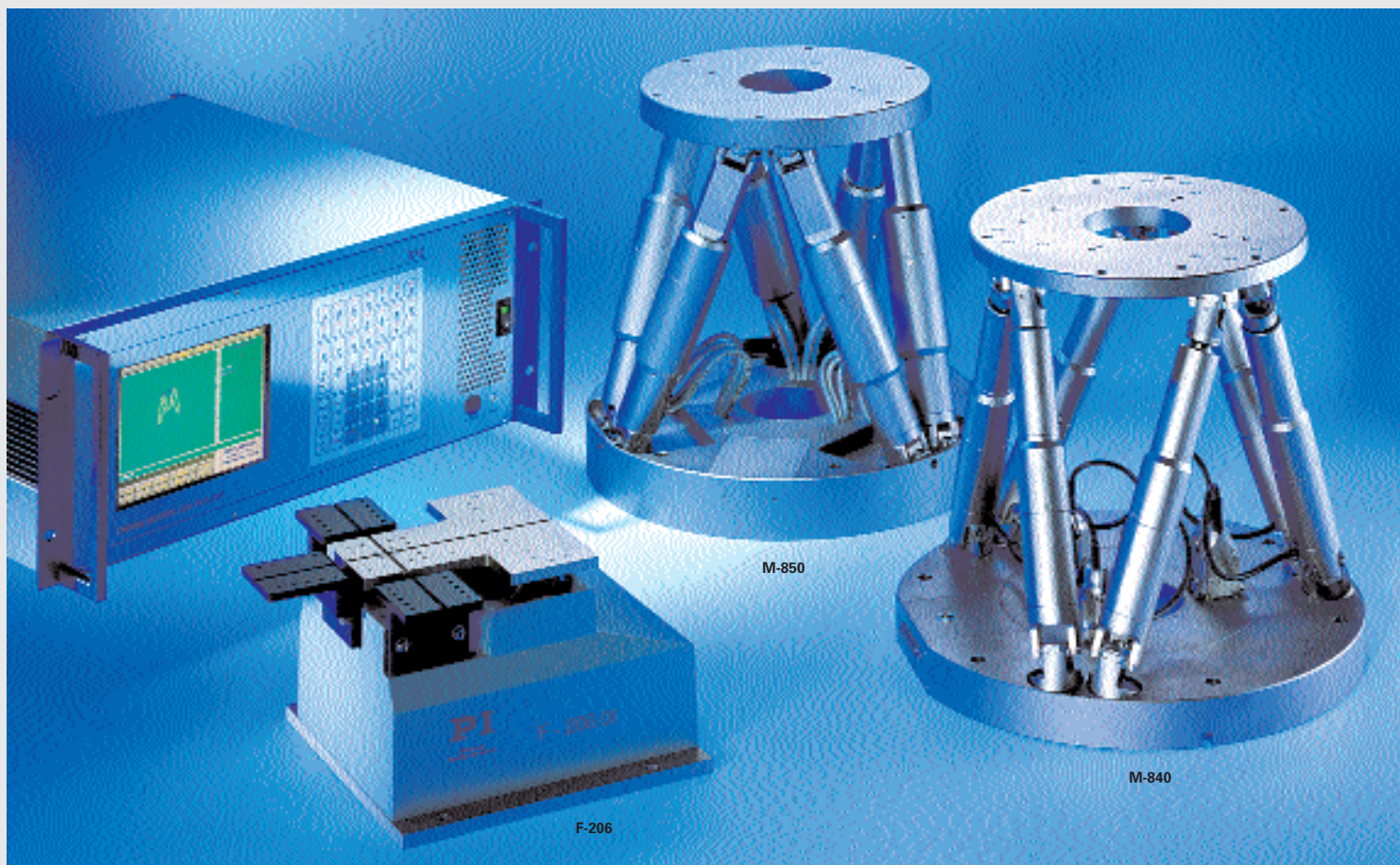
Applications

- Astronomy: pointing secondary mirrors
- Medical technology: surgical robots
- Mechanical engineering: assembly and alignment robots
- Microsystems technology: microhandling
- Photonics: alignment of fiber optic elements, MEMS and optics

Examples of Standard Hexapods

Model	Travel ¹⁾ X, Y, Z [mm]	Travel ¹⁾ $\theta_x, \theta_y, \theta_z$ [°]	Min. Incr. Motion X, Y, Z [μ m]	Min. Incr. Motion $\theta_x, \theta_y, \theta_z$ [μ rad]	Repeat- ability X, Y, Z [μ m]	Repeat- ability $\theta_x, \theta_y, \theta_z$ [μ rad]	Speed [mm/s] / [mrad/s]	Max. load [kg]
F-206	± 6	±5	0.1	2	± 1	± 10	10	2
M-840.5PD	± 50 (Z: ± 25)	± 15 (θ_z : ± 30)					20/250	20
M-850.11	± 50 (Z: ± 25)	± 15 (θ_z : ± 30)	1 (Z: 0,5)	5	± 2 (Z: ± 1)	± 10	0.5/6	200
M-850.50	± 50 (Z: ± 25)	± 15 (θ_z : ± 30)	1 (Z: 0,5)	5	± 2 (Z: ± 1)	± 10	8/100	200 (50 with self locking)

¹⁾ The travel ranges in the logical axes X, Y, Z and $\theta_x, \theta_y, \theta_z$ are interdependent. The table gives the maximum ranges, which cannot all be attained at once.



Micropositioning

Features

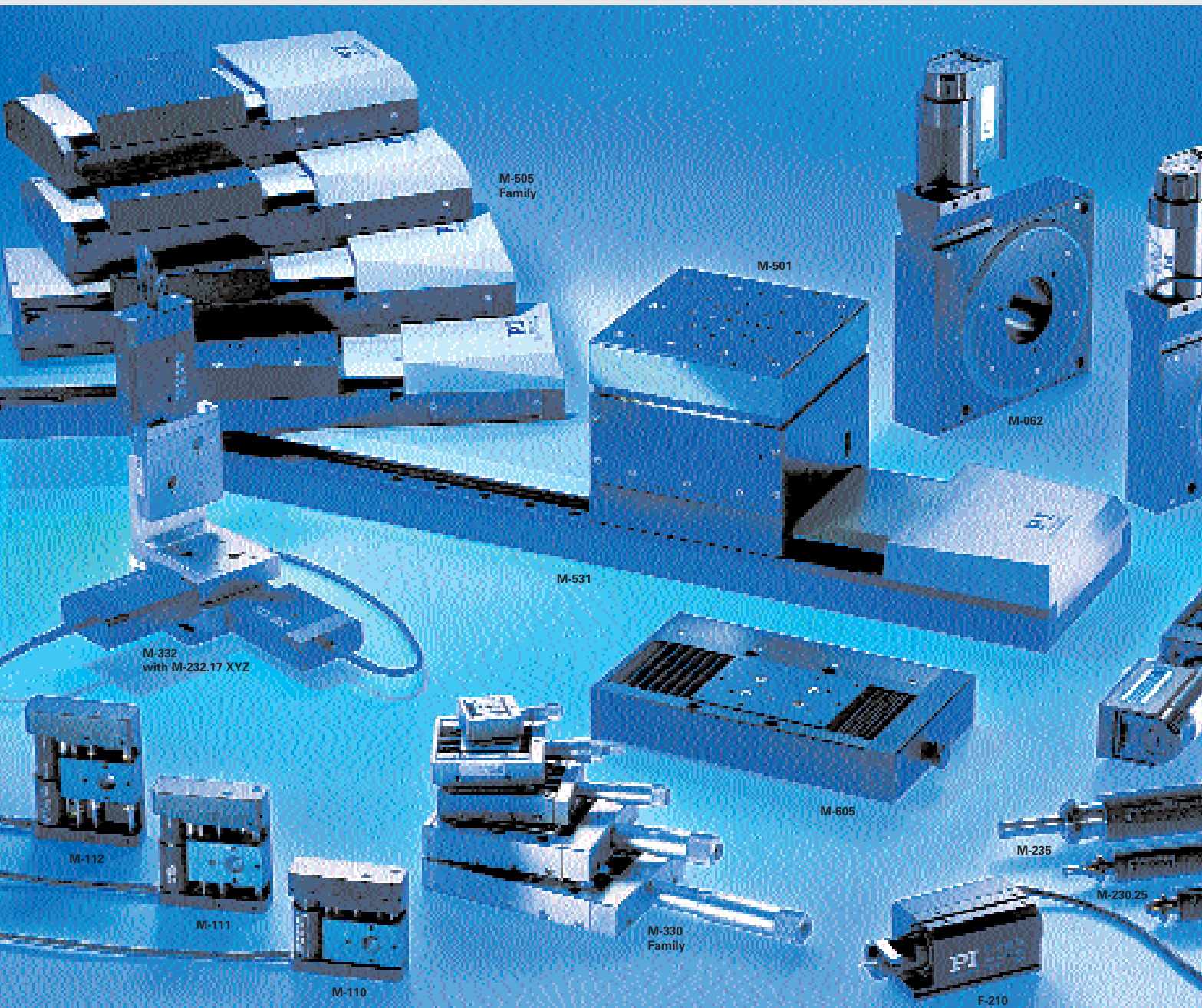
- Spindle/motor combinations or voice coil scanner
- Linear and rotary stages
- Resolutions to a few nanometers
- Repeatability to < 100 nm
- Min. incremental motion to < 100 nm

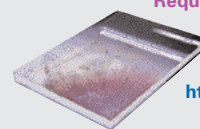
- Scanning ranges to 300 mm and > 360°
- Smooth, straight and flat motion
- Drive options: manual, DC, stepper or brushless motors, voice coil, piezo motor
- Position feedback: linear or rotation encoder

- Leadscrew or recirculating ballscrew drives
- Large range of motor controllers
- Add-on piezo translators for nanometer resolution
- Up to 20,000 hours MTBF

Owing to our wide range of translators, we can only give you a brief overview of the large number of applications here.

- Semiconductors: wafer positioning and scanning
- Mechanical engineering: assembly and positioning
- Quality assurance: positioning and scanning





- Photonics: alignment of fiber optic elements, MEMS and optics, component placing
- Biotechnology: positioning and scanning

Examples of Translation Stages

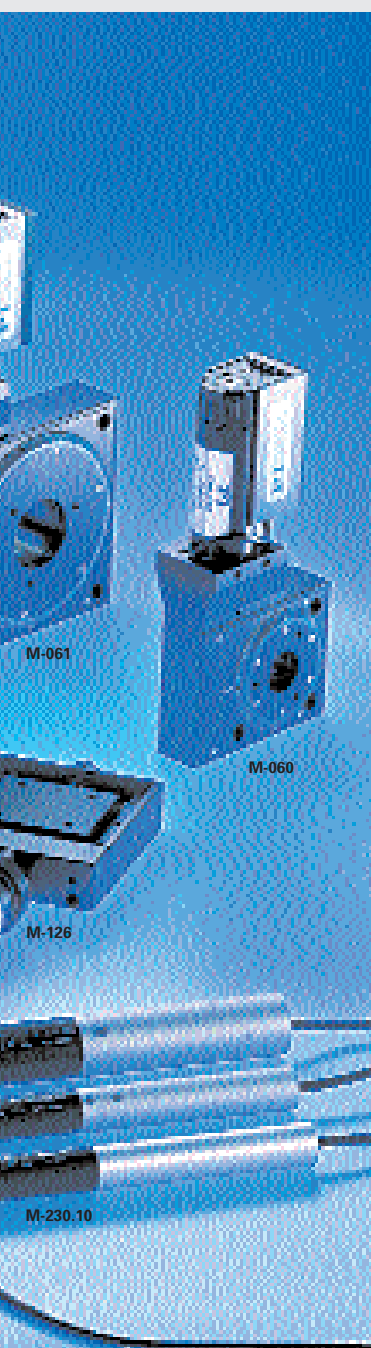
Series	Travel [mm]	Design resolution (version) [μm]	Min. incr. motion [μm]	Unidirectional repeatability [μm]	Backlash [μm]	Max. speed [mm/s]	Drive options	Max. load [kg]
M-331 – M-334	5 – 50	1 (Micrometer)	1	–	0	Manual Drive	Micrometer motorized linear actuator	4 – 20
M-110; M-111; M-112	5 – 25	0.007 (DC-motor/ drive)	0.05	0.1	2	1.5	DC-motor/ gearhead, stepper motor	1
M-126	25	0.0085 (DC-motor/ drive)	0.1	0.1	1	1.5	DC-motor/ gearhead, ActiveDrive™, stepper motor	20
M-505	25 – 150	0.25 (ActiveDrive™)	0.25	0.25	1	50	DC-motor/ gearhead, ActiveDrive™, stepper motor	100
M-605	50	0.1 (Linear encoder)	0.1	0.1	0.2	50	DC-motor/ gearhead, ActiveDrive™, stepper motor, brushless motors	30
M-501	12.5 vertical	0.008	< 0.1	0.1	< 0.5	1 – 15	DC-motor/ gearhead, ActiveDrive™	2 – 10
M-511; M-521; M-531	100 – 300	0.1 (Linear encoder, optional)	0.1	0.1	0.2	100	DC-motor/ gearhead, ActiveDrive™, stepper motor, brushless motors	100
V-102	5	0.1 (Linear encoder)	0.1	0.2	0.2	150	voice coil	0.1

Examples of Rotation Stages (DC-motor models)

Series	Travel [°]	Design resolution [μrad]	Min. incr. motion [μrad]	Unidirectional repeatability [μrad]	Backlash [μrad]	Max. speed [°/s]	Drive options	Max. load [kg]
M-038	> 360	0.59	5	20	200	6	Manual, piezo mike, DC-motor/ gearhead, ActiveDrive™, stepper motor	40
M-061	> 360	17.5	17.5	50	200	150	Manual, DC-motor/ gearhead, ActiveDrive™, stepper motor	55

Examples of Linear Actuators (DC-motor models)

Series	Travel [mm]	Design resolution [μm]	Min. incr. motion [μm]	Unidirectional repeatability [μm]	Backlash [μm]	Max. speed [mm/s]	Drive options	Pushing force [N]
M-227	10 – 50	0.0035	0.05	0.1	2	1	DC-motor/ gearhead, stepper motor	40
M-230	10; 25	0.0046	0.05	0.1	2	1.5	DC-motor/ gearhead, stepper motor	70
M-235	50	0.016 – 0.5	0.05 – 0.5	0.1 – 0.5	1	3 – 30	DC-motor/ gearhead, DC-motor/ direct drive, stepper motor	120 – 50



Motor Controllers

Applications

Micropositioning with DC servo-motors, brushless motors, piezo motors or stepper motors.

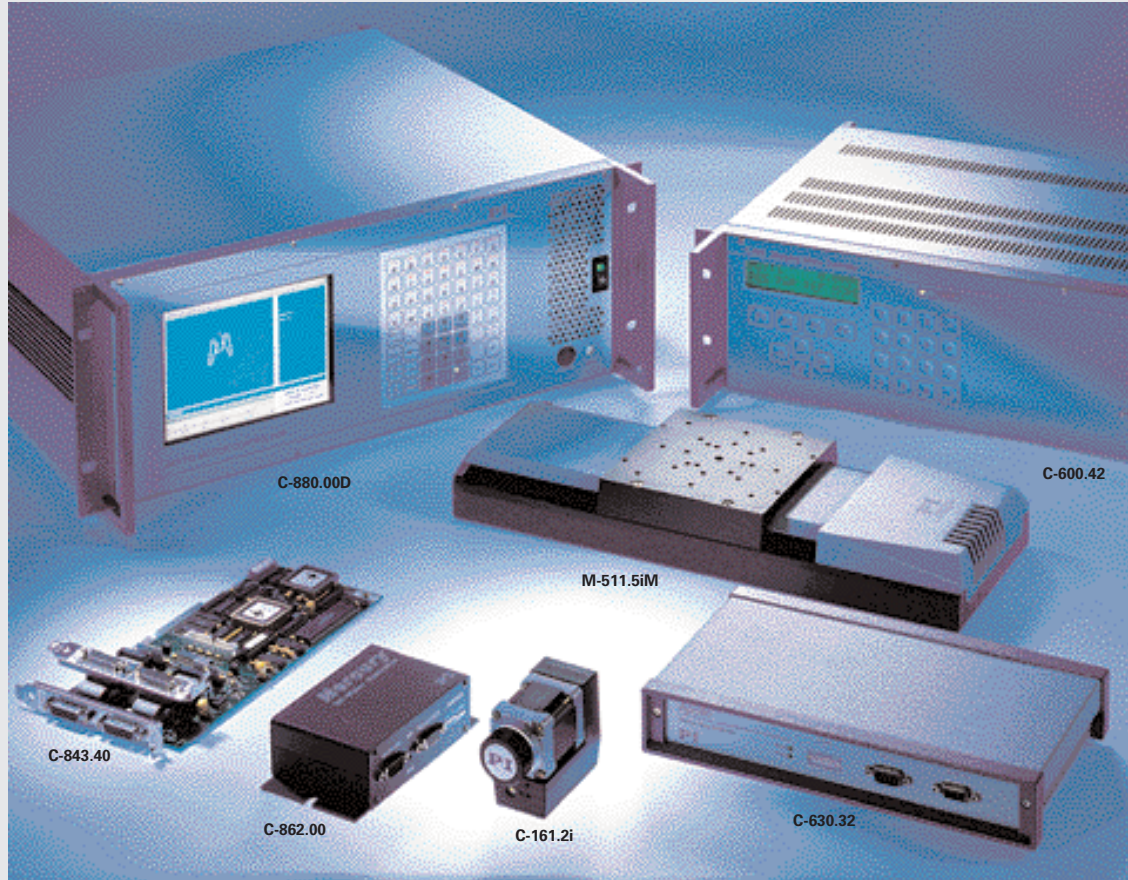
PI Drive Options— Well-Thought-Out Solutions for Practical Operation

ActiveDrive™ :

- Power amplifier integrated into the stage
- Operation of high-performance motors for high speeds and torques
- Controllable by all PI DC-motor controllers
- Fewer components—lower price

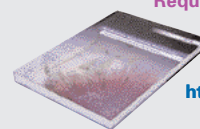
IntelliStage™:

- Stepper motor controller integrated into the stage
- Network-capable for multi-axis applications
- Plug & Play from all PCs, laptops via RS-232 interface
- Compatible with PI translators with stepper motors
- Fewer components—lower price
- Compatible with the Apollo stepper motor controller in the same network
- IntelliStep™ stepper motor with integrated controller, for mounting on PI's or other stages



Examples of Motor Controllers

Model	Axes	Type	Interface	Motor type	Notes
Mercury™ C-862.00	1	Compact desktop	RS-232	DC (analog and Active-Drive™), piezo motors	Network-capable for multi-axis apps.
IntelliStage™ M-511.5iM	1	Integrated in M-511 stage	RS-232	Stepper motor	Network-capable for multi-axis apps.
Apollo C-630.32	3	Desktop unit	RS-232	Stepper motor	Network-capable
C-843.20; C-843.40	2; 4	PC card	PCI bus	DC (analog and Active-Drive™), piezo motors	
C-873.20	2	PC card	PCI bus	Brushless motors	
C-844.40	4	Desktop unit	RS-232, IEEE 488	DC (analog and Active-Drive™)	
C-600.42	4	Desktop unit	RS-232	Stepper motors	Trajectory control
C-880.00	Up to 19	Desktop unit	RS-232, IEEE 488 optional	DC (analog and Active-Drive™); piezo motors, piezo systems	Modular



Piezoelectric Ceramics

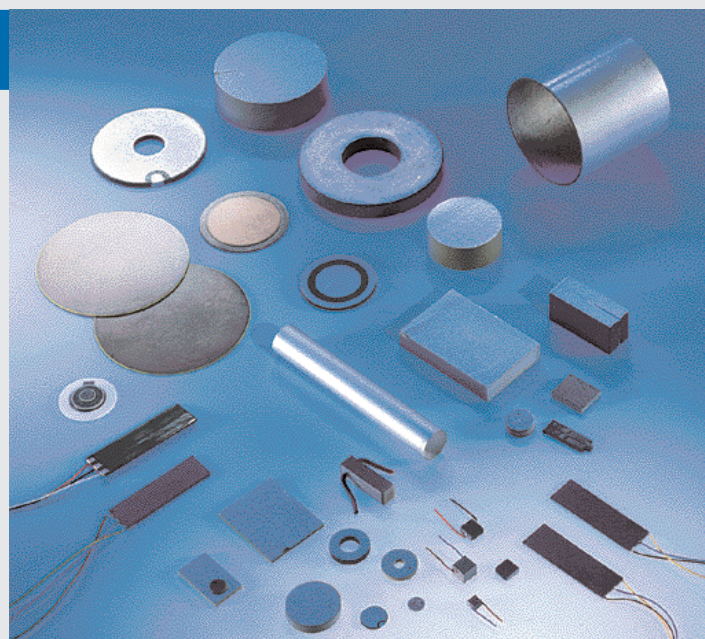
Application Examples

- NanoPositioning
- Ultrasonic transducers
- Sonar
- Medical diagnostics
- Buzzers
- Resonators
- Filters
- Piezo motors

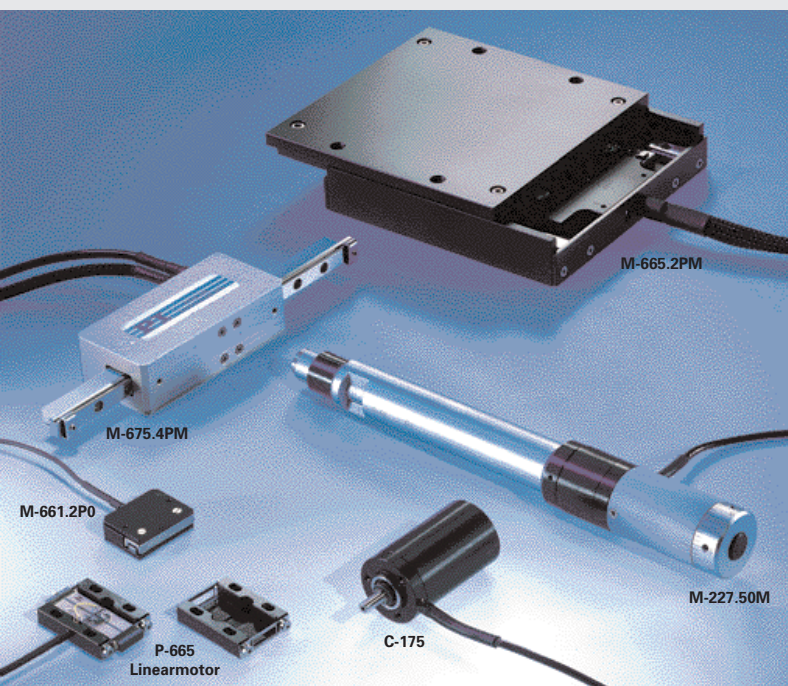
Overview

- Large range of piezo ceramics
- All manufacturing steps from PZT powder through to the end product are carried out and monitored for quality by PI

- Tube actuators: 2.2 to 20 mm outside diameter, 1 to 18 mm inside diameter
- Disk translators: 3 to 60 mm diameter, 0.25 to 10 mm thick
- Ring actuators: 10 to 25 mm outside diameter, 2.7 to 18 mm inside diameter, 0.5 to 2 mm disk thickness
- Multilayer low-voltage PZT stack actuators (to 100 V)
- Bimorph bender actuators
- OEM and custom designs



Ceramic disks, tubes, rings, benders



PIline™ Positioners with Piezo Motors

Features

of Piezo Motors

- Compact design
- High resolution
- Self braking
- Produce no magnetic fields / not affected by magnetic fields
- Direct position sensing with linear encoders
- Compatible with PI motor controllers

- Custom drives available
- Vacuum compatible and nonmagnetic drives available

Applications

- Photonics: alignment of fiber optic elements, MEMS and optics
- Microsystems technology: microhandling in limited-space environments
- Microscopy: high-resolution, low-profile alignment stage with long scanning ranges
- Alignment in electron- or ion-beam environments
- Alignment in NMR environments

The piezo motors of the **PIline™** translators are also available as OEM drive units.

Examples of PIline™ Translators

Model	Travel [mm]	Design resolution [μm]	Min. incr. motion [μm]	Unidirectional repeatability [μm]	Backlash [μm]	Max. speed [mm/s]	Max. load [kg]
M-661.2PM	20	0.1	0.2	0.5	0.5	20	1
M-665.2PM	50	0.1	0.2	0.2	0.2	50	5
M-675.4PM	100	0.1	0.2	0.2	0.2	50	–
M-227.10M – M-227.50M	10 – 50	0.01 (open-loop)	0.5	–	–	2	1.5

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