



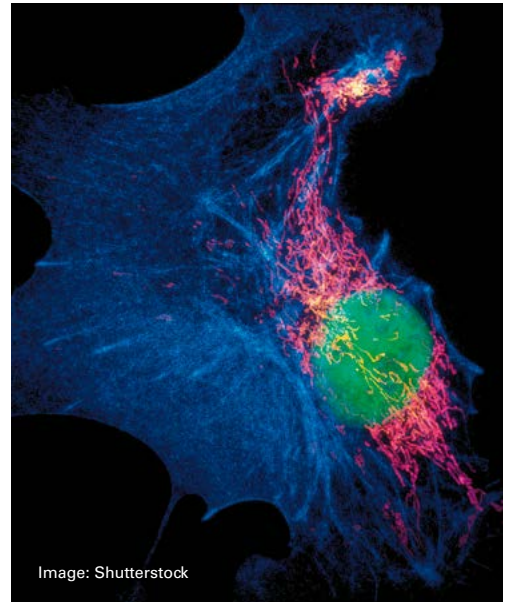
Nanopositioning for Microscopy

FAST, COMPACT, TO THE NANOMETER

Nanopositioning for Microscopy

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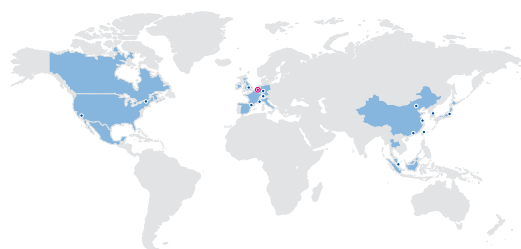
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Precision Positioning is the Key Element in all Types of Microscopy

High-resolution microscopy techniques must be capable of accurate and reproducible positioning of imaging elements or samples. Applications range from precise z-focus positioning of light microscope objectives in the depths of field, to exact positioning of tiny biological samples for 4Pi Resolft 2-Photon super-resolution fluorescence microscopy. Also in atomic force microscopy (AFM), electron microscopy (SEM and TEM) and correlative microscopy, PI's versatile nanopositioning solutions greatly support even the most demanding positioning tasks.

Depending on the lateral and axial resolution power of the microscopy technique, bidirectional positioning must be accurate in a range of a few hundred nanometers – as in routine widefield light microscopy – or only a few nanometers – as in super-resolution fluorescence microscopy. Here, PI's numerous nanopositioning solutions come into play. PI provides reliable precision positioning solutions based on piezo flexure, PiezoWalk®, piezo stick-slip, or parallel-kinematic drive technology.

This brochure provides an extensive overview of the nanopositioning technology and products recommended and offered by PI for any microscopy technique and application. Use cases are presented ranging from routine widefield microscopy for stained tissue slices to several super-resolution fluorescence microscopy techniques, to AFM, to SEM, and to industrial microscopy inspection.

PI's superior nanopositioners and controllers move your sample or microscope element to the right place – reliably and precise, always.



Have a look at PI solutions for microscopy on the PI YouTube channel www.youtube.com/user/phyinst

Routine Widefield Microscopy

Examination of Stained Tissue Slices on Slides



When analyzing tissue samples with a motorized microscope, an accurate autofocus in the depth of field is crucial for interpretable images. Reliable diagnostic results of histological slide, blood smears, and gynecological pap smears depend directly on the performance of the microscope system. PI offers ideally matched components for positioning the objective in Z direction as well as the sample in the X and Y directions.

To ensure depths of field between about 115 μm (4x) and about 800 nm (100x), the objective z-scanners need to be positioned over travel ranges between 100 and 400 μm with a bidirectional position repeatability of 200 nm and in settling times of the order of 20 ms.

Typically, the lateral microscope resolution is in a range of ≥ 250 nm. Therefore, positioning samples in XY requires a minimum incremental step size and a bidirectional position repeatability in a range of 100 to 200 nm.

Tasks	PI Solutions
Positioning Objectives in Z – for Autofocus	PIFOC® Objective Scanners for focusing and scanning in Z with nanometer precision >> page 15 et seq.
Positioning Samples in XY – for Sample Scanning	U-780 PILine® Piezo Ultrasound Stage System >> page 26 Customized solutions for sample positioning in upright microscopes available on request.

Life Cell Imaging in Research Microscopy

Fluorescence, Widefield, Laser Scanning, and Two-Photon Fluorescence Microscopy

The examination of living cells provides fundamental insights into intercellular processes, such as mitosis or the transport of protein molecules or membrane components, and enables investigation of metabolic processes. Different microscopy techniques such as fluorescence, widefield, or laser scanning are used for this purpose. They benefit from nanometer precision positioning of PI motion systems.

For Z stacking, settling times of <10 ms in a settling band of a few nanometers are required over a travel range of several hundred micrometers in Z. Typically, positioning samples in XY needs a bideractional accuracy of 100 nm or better in a range of 135 mm x 85 mm of travel.

In Total Internal Reflection Fluorescence Microscopy (TIRFM) the electromagnetic field of the laser beam penetrates the sample volume and forms an evanescent field with a penetration depth between 100 to 200 nm. As a result, a better Z resolution is achieved, which typically is in the range of 100 – 200 nm when compared to about 500 nm from other microscopic techniques.

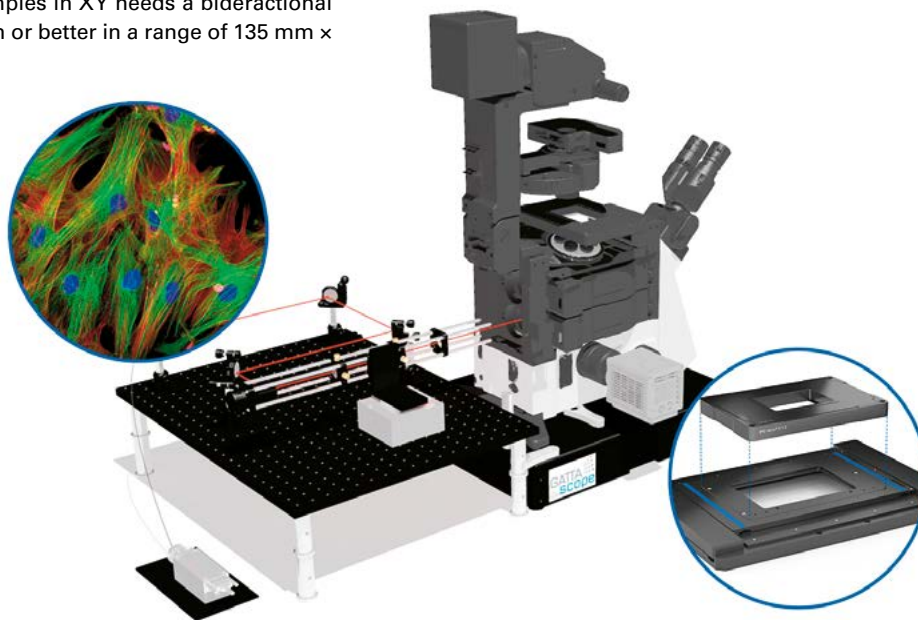


Image: GATTAquant / PI

Tasks	PI Solutions
Positioning Objectives in Z	PIFOC® Objective Scanners for focusing and scanning in Z with nanometer precision >> page 15 et seq.
Positioning Samples in XY	U-780 PiLine® Piezo Ultrasound Stage System >> page 26 Customized solutions for sample positioning in upright microscopes available on request.
Positioning Samples in Z	P-736 Plnano® Z Microscope Scanner >> page 24 P-737 PIFOC® Sample Z Positioner >> page 24
Coupling the Laser Beam for Total Internal Reflection Fluorescence (TIRF) Microscopy	Q-545 Q-Motion® Precision Linear Stage High Forces and Small Design Due to Piezo Motors <ul style="list-style-type: none"> ■ Only 45 mm in width ■ Incremental sensors with position resolution ■ Vacuum-compatible versions available ■ Push/pull force 8 N ■ XY combinations without adapter plate possible

Multiphoton Fluorescence Microscopy

For Deep Tissue Examinations

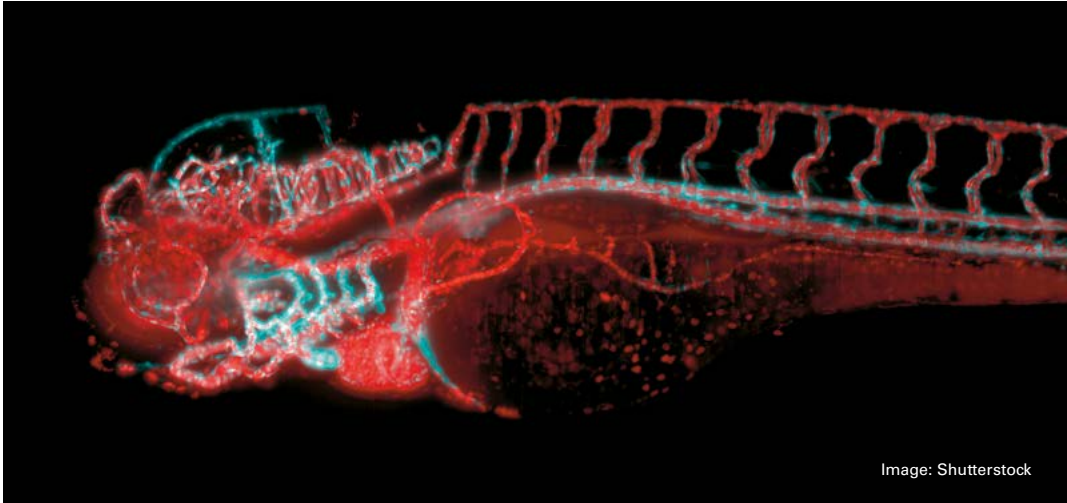
Two-photon (or multiphoton) excitation microscopy is preferably for experiments that require deep penetration of excitation light into living tissue or intact animal specimens. For this reason, laser excitation light is used at double the wavelength to increase the depth of penetration of infrared light into the strongly scattered tissue. Objective positioning systems with greater travel ranges are required for this purpose. Objectives or samples need to be positioned in Z with a settling time of <20 ms in a settling band of ± 200 nm and a travel range of some millimeters.



Tasks	PI Solutions
Positioning Objectives in Z	ND72Z2LAQ PIFOC® Objective Scanning System >> page 17 Customized long travel Voice Coil PIFOC® available on request.
Positioning Samples in XY	U-780 PLine® Piezo Ultrasound Stage System >> page 26 Customized solutions for sample positioning in upright microscopes available on request. P-545 Pinano® XY(Z) Piezo System >> page 29 M-545 Microscope XY Stage >> page 25
Positioning Samples in Z	P-736 Pinano® Z Microscope Scanner >> page 24 P-737 PIFOC® Sample Z Positioner >> page 24 P-545 Pinano® XYZ Piezo System >> page 29

Light-Sheet Fluorescence Microscopy

Planar Illumination for Live Imaging



Light sheet fluorescence microscopy (LSFM) is a technique used for 3-D and live imaging of large specimens over an extended period of time. It uses a unique planar illumination approach which is orthogonal to the observation direction that minimizes photobleaching and phototoxicity of the living specimen.

To examine small organisms such as a zebrafish in agarose gel, the samples are positioned to a few millimeters in XY with a bidirectional repeatability of 100 nm.

Tasks	PI Solutions
Positioning Objectives in Z	PIFOC® Objective Scanners for focusing and scanning in Z with nanometer precision >> page 15 et seq.
Positioning Samples in XY	P-620 – P-629 PIHera Piezo Linear Precision Positioner >> page 28

Super-Resolution Fluorescence Microscopy

Surpass the Diffraction Limit in Living Cell Imaging

A number of super-resolution techniques allow the capture of images with a higher resolution than the diffraction limit of light. Techniques such as Scanning Near-Field Optical Microscopy (SNOM), Stimulated Emission Depletion Microscopy (STED), 4PI Microscopy, Stochastic Optical Reconstruction Microscopy (STORM), and Structured Illumination Microscopy (SIM) have achieved improved lateral (XY) resolution down to tens of nanometers. These new approaches have created unprecedented opportunities for investigating the structure and function of living cells.

Positioning solutions in Z have typical travel ranges of 100 μm to 400 μm with a settling time <10 ms in a settling band of ± 1 nm. The sample is usually positioned 200 μm in three axes with a bidirectional repeatability of 1 nm.

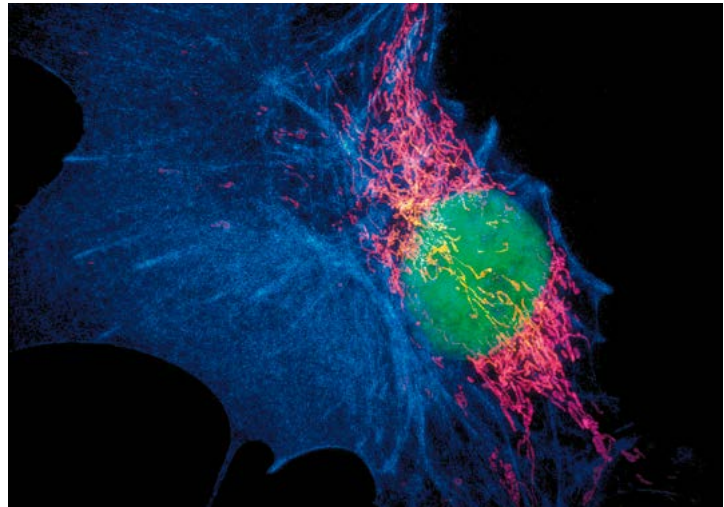


Image: Shutterstock

Tasks	PI Solutions
Positioning Objectives in Z	PIFOC® Objective Scanners for focussing and scanning in Z with nanometer precision >> page 15 et seq.
Positioning Objectives in XY	P-612.2 XY Piezo Nanopositioning System Compact, with Aperture <ul style="list-style-type: none"> ■ 100 μm \times 100 μm closed-loop travel range ■ Clear aperture 20 mm \times 20 mm ■ Compact: Footprint 60 mm \times 60 mm ■ Parallel kinematics for faster response times and higher multi-axis accuracy
Positioning Samples in XY	U-751 XY Stage with Piezomotors <ul style="list-style-type: none"> ■ Compact design: Only 32 mm in height, no lead screw ducts or flanged motors ■ Direct-measuring linear encoder with 100 nm resolution ■ Self-locking, no heat generation at rest, no servo jitter ■ Clear aperture 78 mm \times 78 mm (at maximum displacement 65 mm \times 65 mm) ■ Noncontact limit and reference point switches
Positioning Samples in Z	P-541.Z / P-541.T Piezo Z Stages / Z and Tip/Tilt Stages >> page 28 M-227 High-Resolution Linear Actuator with DC Motor <ul style="list-style-type: none"> ■ Min. incremental motion 0.05 μm ■ Nonrotating end piece ■ Subnanometer resolution with optional piezo drive P-736 Plano® Z Microscope Scanner >> page 24 P-737 PIFO C® Sample Z Positioner >> page 24

Stereo Microscopy

Examination of Whole Organs and Creatures

Some application fields require imaging of entire organs or even living beings. Objective and sample positioners that are designed for high loads and long travel ranges of several millimeters are perfect for this purpose.



Objective is not included in scope of delivery.

Tasks

Positioning Objectives in Z

Positioning Samples in XY

Positioning Samples in Six Axes

PI Solutions

Customized autofocus Z-scanner with ultrasound drive, more information on request.

U-780 PLine® Piezo Ultrasound Stage System >> page 26

H-811.I2 6-Axis Miniature Hexapod >> page 27

Digital Slide Scanning

Digitize Your Glass Slides



Image: gettyimages

Digital slide scanners digitize samples on glass slides at high speeds. For example, digital samples can be used for faster, more reliable, and more efficient work in healthcare, research, and education.

High-dynamics autofocus requires a maximum depth of field of 115 μm for 4x objectives, which means a travel range in Z is typically 100 – 400 μm . The settling time of objective positioners needs to be <10 ms in a settling band of ± 200 nm.

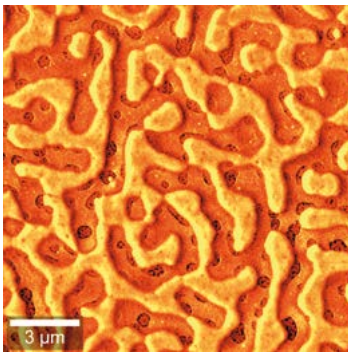
Fast positioning of samples in X, Y with a positioning accuracy of 100 nm and variable travel ranges is necessary, depending on the number and size of the inserted slides.

Tasks	PI Solutions
Positioning Objectives in Z	<p>P-725.xDD PIFOC® High-Dynamics Piezo Scanner >> page 18</p> <p>P-726 PIFOC® High-Load Objective Scanner >> page 18</p> <p>P-725KHDS PIFOC® Objective Scanner with High Dynamics >> page 18</p>
Positioning Samples in XY	<p>U-780 PILine® Piezo Ultrasound Stage System >> page 26</p> <p>V-738 PIMag® High-Precision XY Stage >> page 25</p>

Atomic Force Microscopy (AFM)

In Combination with Raman or Scanning Near-field Optical Microscopy (SNOM)

Atomic Force Microscopy (AFM) delivers topographical information of the sample, e. g., minerals, polymer mixtures, composite materials, or biological tissue. Confocal Raman Imaging identifies the chemical components. Scanning Near-field Optical Microscopy (SNOM) is used for optical imaging with resolution beyond the diffraction limit. All three methods can be combined in one system (correlative microscopy), thanks to the parallel-kinematic piezo stage with fast response time and high multi-axis accuracy. Positioning accuracy of down to 1 nm and below is demanded in all three axes.



Images: WITec



Tasks

Positioning Samples in XYZ

Positioning Samples in XY

PI Solutions

Customized solutions available on request.

P-517 / P-527 Multi-Axis Piezo Scanner >> page 29

Scanning Electron Microscopy (SEM)

Examination in UHV Environment

Electron microscopy allows investigation with extremely high lateral resolution down to a range of <1 nanometer. Demands on positioning systems subsequently comprise respective resolution, additionally stages have to be nonmagnetic and UHV compatible (10^{-7} hPa). Based on these features, positioning solutions from PI can also be deployed in Focused Ion Beam (FIB) systems and in combined FIB/SEM machines.

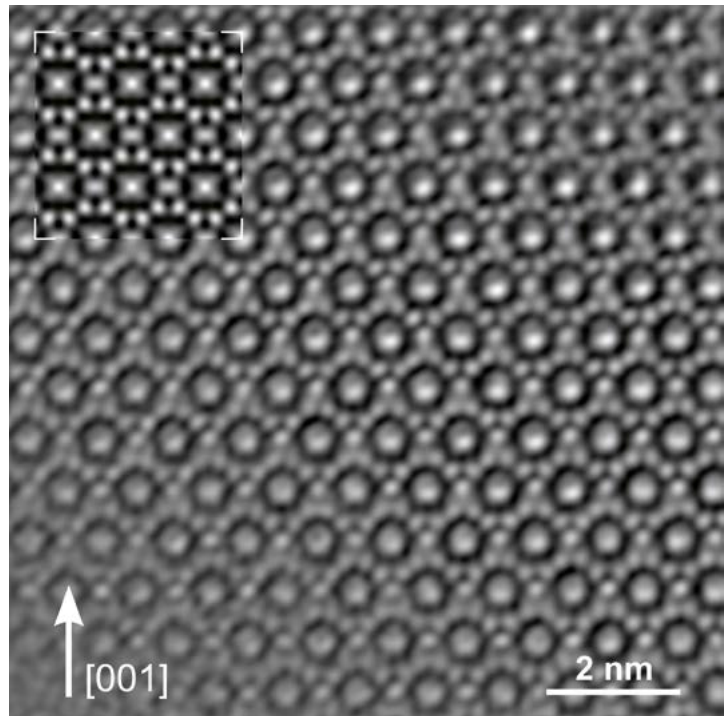


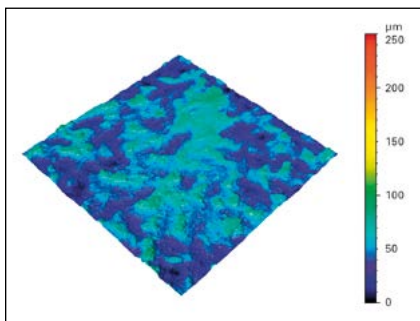
Image: Dr. Reiner Ramlau, MPI for chemical physics of solid materials

Tasks	PI Solutions
<p>Shifting Lenses or Apertures in XY</p>	<p>U-751 XY Stage with Piezomotors</p> <ul style="list-style-type: none"> ■ Compact design: Only 32 mm in height, no lead screw ducts or flanged motors ■ Direct-measuring linear encoder with 100 nm resolution ■ Self-locking, no heat generation at rest, no servo jitter ■ Clear aperture 78 mm × 78 mm (at maximum displacement 65 mm × 65 mm) ■ Noncontact limit and reference point switches
<p>Positioning Samples in XY</p>	<p>P-752 High-Precision Nanopositioning Stage</p> <ul style="list-style-type: none"> ■ Travel range to 35 μm ■ Resolution 0.1 nm ■ Rapid response ■ Highest linearity due to capacitive sensors

Industrial Inspection

Optical 3-D Surface Measuring Technology

The trend in surface inspection is moving towards smaller and smaller structures that must be reproduced or resolved accurately at nanometer level. Optical measuring processes are employed for many applications because they can be applied to almost all materials and are also suitable for sensitive samples. Highly precise, confocal reproduction principles can present the sample topography and roughness structures not only qualitatively, but also quantitatively using matching tactile measuring methods that are described in many industry standards. Piezo-based positioning systems are making considerable contributions in this field because they offer nanometer precision and high dynamics.



Images: NanoFocus

Tasks

Positioning Objectives in Z

Positioning Samples in XYZ

PI Solutions

PIFOC® Objective Scanners for focusing and scanning in Z with nanometer precision >> page 15 et seq.

P-620.1 – P-629.1 PIHera Piezo Linear Precision Positioner >> page 28

P-541 / P-517 / P-561 / P-562 Tracking and Scanning for Super-Resolution >> page 28 / 29 / 30

- Parallel kinematics for faster response times and higher multi-axis accuracy
- Travel ranges to 300 × 300 × 300 µm
- Subnanometer resolution

3-D Surface Inspection

White Light Interferometry



Image: Nikon

The contours and roughness of surfaces can be analyzed in real time at picometer resolution by employing noncontact, and nondestructive methods. For this purpose, high-resolution camera systems are combined with white light interferometry.

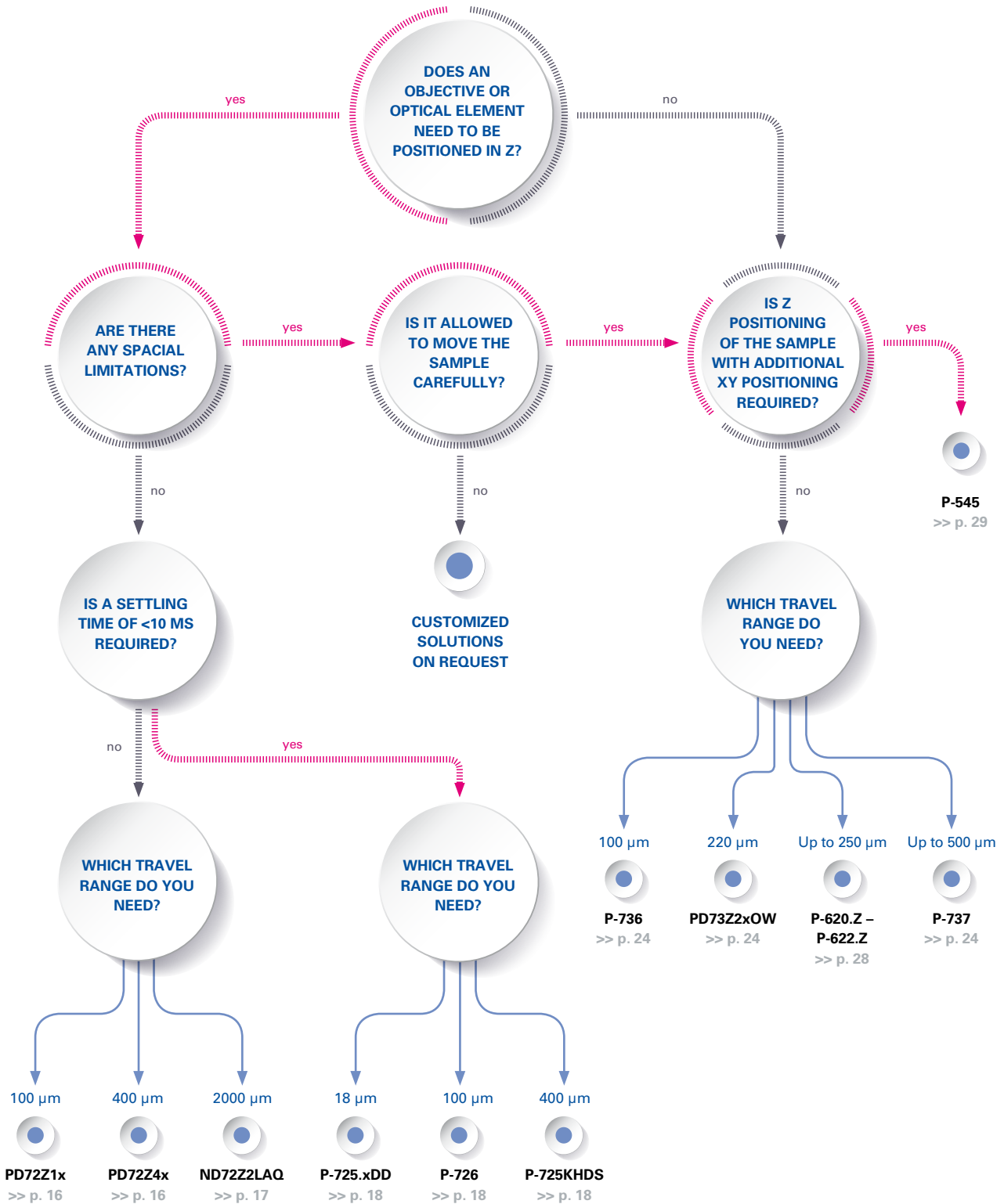
Fast and precise positioning of lenses is an important requirement for detailed analysis of the surface and for piecing individual measurement results together to produce meaningful images.

The position of the lens must be matched accurately to the individual image and only then is high-precision 3-D surface inspection possible.

Tasks	PI Solutions
Positioning Objectives in Z	PIFOC® Objective Scanners for focusing and scanning in Z with nanometer precision >> page 15 et seq.
Positioning Samples in XY	L-731 Precision XY Stage >> page 25
Positioning Samples in Six Axes	H-811.I2 6-Axis Miniature Hexapod >> page 27

Find Your Piezo Z-Nanopositioner

With Aperture



PIFOC® Objective Scanners

Focusing and Z-Stack Scanning with Nanometer Precision

Objective scanners of the PIFOC® series offer high dynamics in positioning and scanning tasks. Well adapted solutions for Z focusing of the objective are available as standard products, also as system packages with controller and software. Like all piezo systems, scanners are delivered precalibrated with measurement log.

- Significantly faster response and higher lifetime than stepper- or DC motor drives
- Nanometer precision and settling times in the range of milliseconds
- In combination with capacitive sensors highest linearity due to direct measuring technology
- High guiding accuracy due to zero-play flexure guides
- Clear aperture up to Ø 29 mm
- QuickLock thread adapters for easy installation >> page 19
- Spacers available to adapt additional objectives without PIFOC® in the same objective nosepiece, refer to >> page 19

P-725 PIFOC® Objective Scanners with Long Travel Ranges up to 400 µm

System packages also available incl. QuickLock thread adapter, controller and software >> page 16.

P-721 PIFOC® High-Precision Objective Scanners with Travel Ranges up to 100 µm

System packages also available incl. QuickLock thread adapter, controller and software >> page 16.

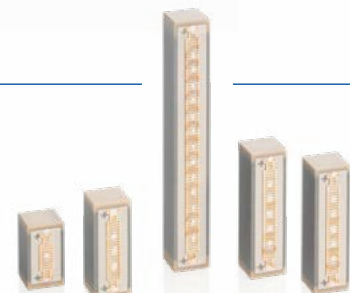


Objective is not included in scope of delivery.
QuickLock thread adapter to be ordered separately according to >> page 19 et seq.
Recommended electronics >> page 32



Technology: PICMA® Multilayer Piezo Actuators

PICMA® actuators take advantage of the indirect piezoelectric effect and achieve high forces. They only need a small amount of installation space. At the same time, the PICMA® actuators are very dynamic and can reach a position with an unprecedented precision. Due to their ceramic insulation, PICMA® actuators exhibit high reliability and climate resistance.



Fast PIFOC® Objective Scanning Systems

High Dynamics Piezo Drive for Subnanometer Resolution

- Fine positioning of objectives with sub-nm resolution
- Direct metrology with capacitive sensors (depending on model)
- Compatible with LabVIEW, µManager and MATLAB
- All servo-control parameters can be changed during operation
- Models with large aperture Ø 29 mm available
- USB, RS-232, analog interfaces



PD72Z1x PIFOC®

Objective Scanning System with 100 µm Travel Range

PD72Z2x * PD72Z4x PIFOC®

Objective Scanning System with 400 µm Travel Range



Systems include

- PIFOC® Objective Scanner
- E-709 Digital Controller
- QuickLock-Thread adapter M25 × 0.75 or M32 × 0.75 for PIFOC® with large aperture >> page 19 et seq.
- PIMikroMove® Software
- Drivers for LabVIEW, Matlab, C++ and more

Objective is not included in scope of delivery.
Further QuickLockThread adapters available, see >> page 19 et seq.
Recommended electronics >> page 32 et seq.

Long Travel PIFOC[®] Objective Scanning System

Nanometer Resolution and Fast Step-and-Settle

ND72Z2LAQ PIFOC[®] Objective Scanning System 2000 μm Nanometer Resolution and Fast Step-and-Settle

- Complete system with digital controller, software, and M32 QuickLock thread adapter
- USB, RS-232
- Sensor resolution 0.5 nm
- Highly dynamic step-and-settle for Z stacks
- Further thread adapters as optional accessory
- Compatible with $\mu\text{Manager}$, LabVIEW, and MATLAB
- Parameter changing during operation



Further QuickLockThread adapters available, see >> page 19
Further electronics and accessories available on request.



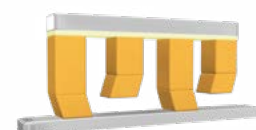
Systems include

- PIFOC[®] Objective Scanner
- E-861 Digital Servo Controller
- P-721.05Q QuickLock-Thread adapter M32 \times 0.75
- PIMikroMove[®] Software
- Drivers for LabVIEW, Matlab, C++ and more



Nanometer precision and high feed force with PiezoWalk[®] walking drives

Several piezo actuators perform a walking motion in the PiezoWalk[®] walking drive that leads to forward feed of a runner. Control of the actuators allows the smallest step and forward feed motion at a resolution of well under one nanometer.



High-Dynamics and High-Load PIFOC® Objective Scanners

Nanometer Resolution for Heavy Objectives

P-725.xDD PIFOC® High-Dynamics Piezo Scanner

- Travel range 18 μm , shortest settling time <5 ms with microscope objective
- Scans and positions objectives with sub nm resolution
- Parallel flexure guiding for minimized objective offset
- Direct metrology with capacitive sensors for highest linearity
- Cost-efficient version with SGS sensors
- Compatible with MATLAB, LabVIEW and $\mu\text{Manager}$
- Outstanding lifetime due to PICMA® piezo actuators
- QuickLock adapter for easy attachment



P-726 PIFOC® High-Load Objective Scanner

- Highly dynamic positioning and scanning for large objectives
- Resonant frequency 1120 Hz, 560 Hz with 210 g objective mass
- Typ. settling time of about 6 ms
- Travel range 100 μm
- Direct-metrology capacitive sensors for best linearity, stability and control dynamics
- Resolution 0.3 nm
- Zero-play, high-precision flexure guide system for better focus stability

P-725KHDS PIFOC®

Objective Scanner with High Dynamics

- Travel range 400 μm
- Step-and-settle 20 ms, with 400 g load
- Resonant frequency 120 Hz, with 400 g load
- QuickLock thread adapters up to M32

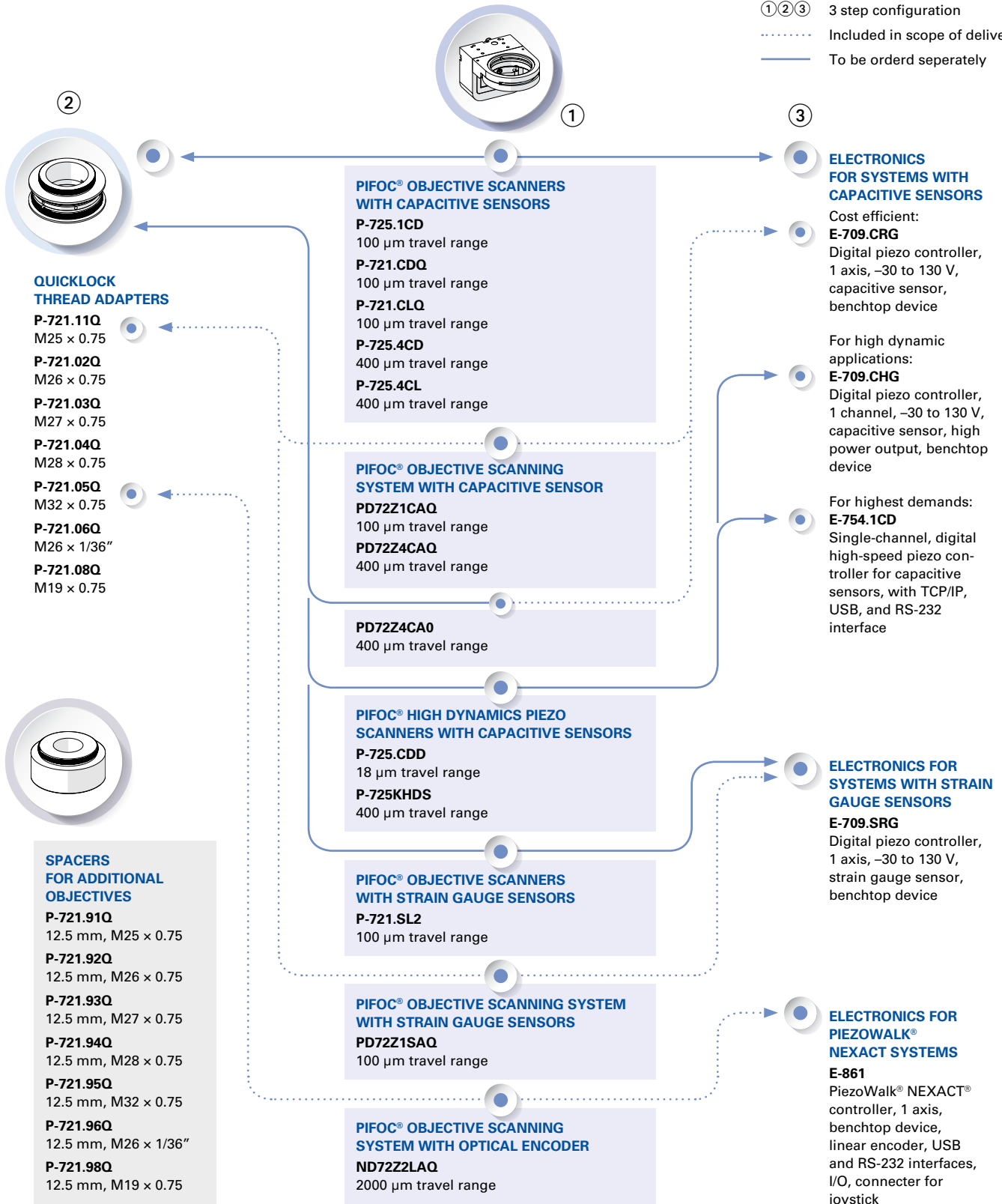


QuickLock thread adapter to be ordered separately according to >> page 19 et seq.
Recommended electronics >> page 32

Configuration Diagram for PIFOC[®] Objective Scanners with Standard Aperture

Aperture ≥ 21 mm, Depending on Thread Adapter

- ①②③ 3 step configuration
- Included in scope of delivery
- To be orderd separately



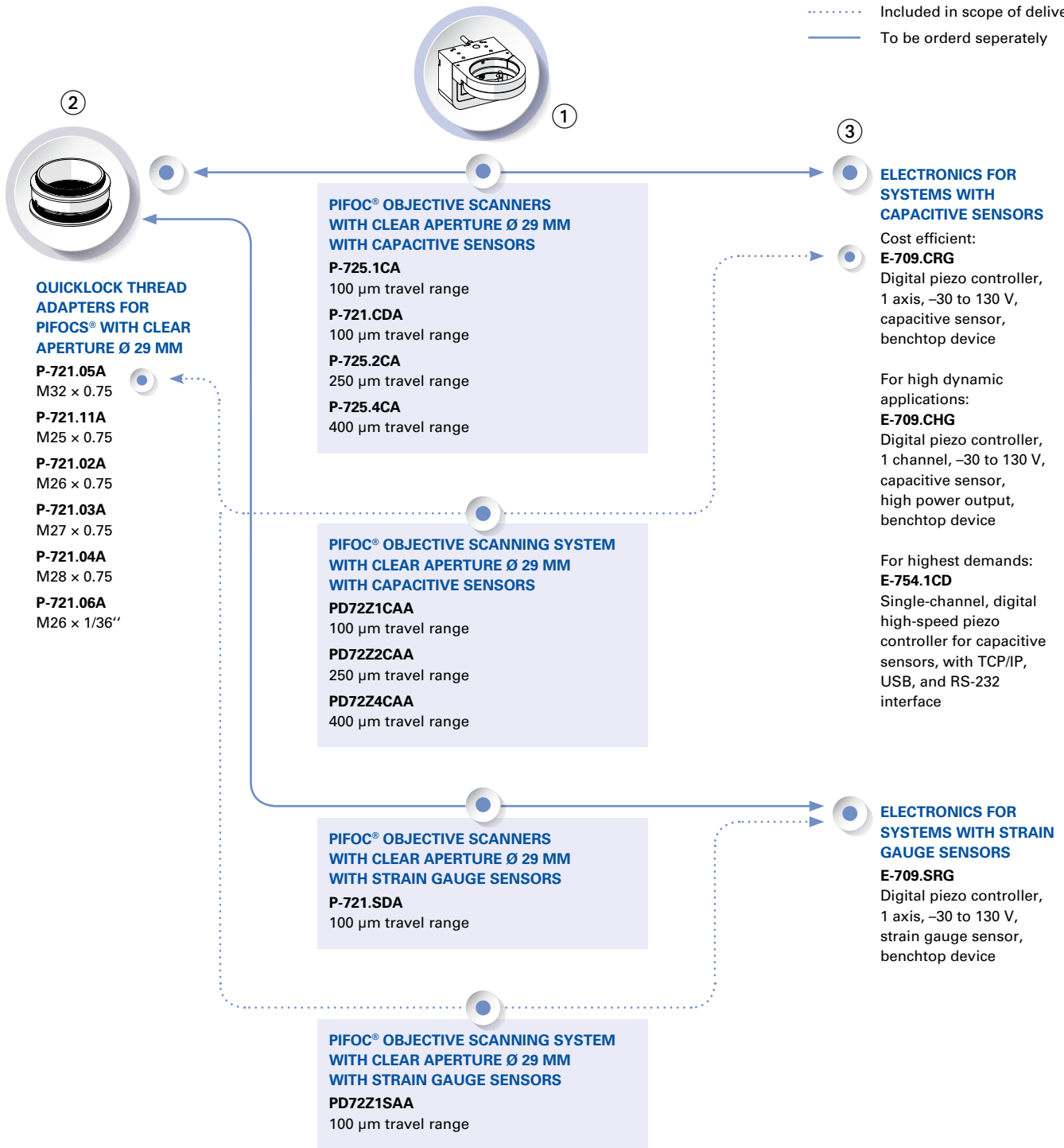
For all adapters and spacers see:

Links to detailed product webpages (PIFOC / Controllers) can be found on the respective product pages of this brochure.

Configuration Diagram for PIFOC® Objective Scanners with Large Aperture

Aperture up to 29 mm, Depending on Thread Adapter

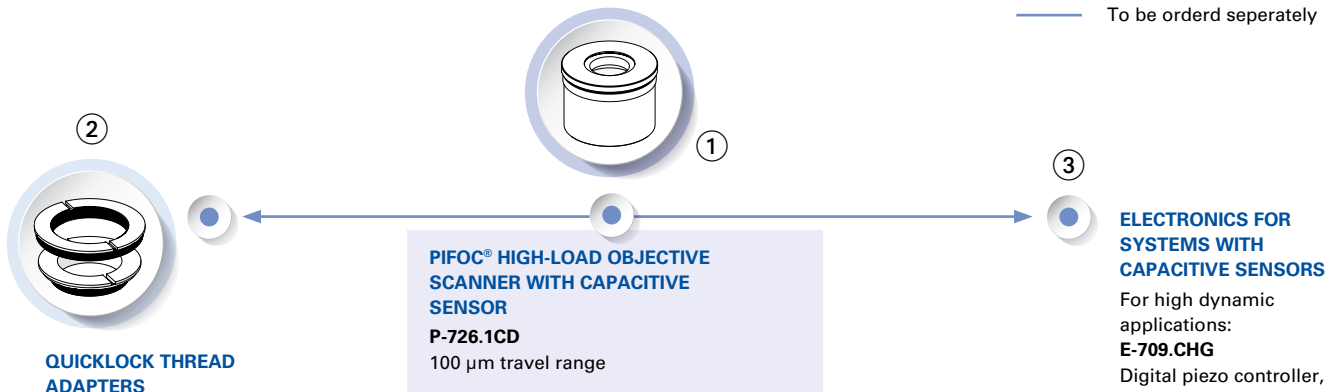
- ①②③ 3 step configuration
- Included in scope of delivery
- To be ordered separately



Configuration Diagram for P-726 PIFOC®

High-Load Objective Scanner

①②③ 3 step configuration
 — To be orderd seperately

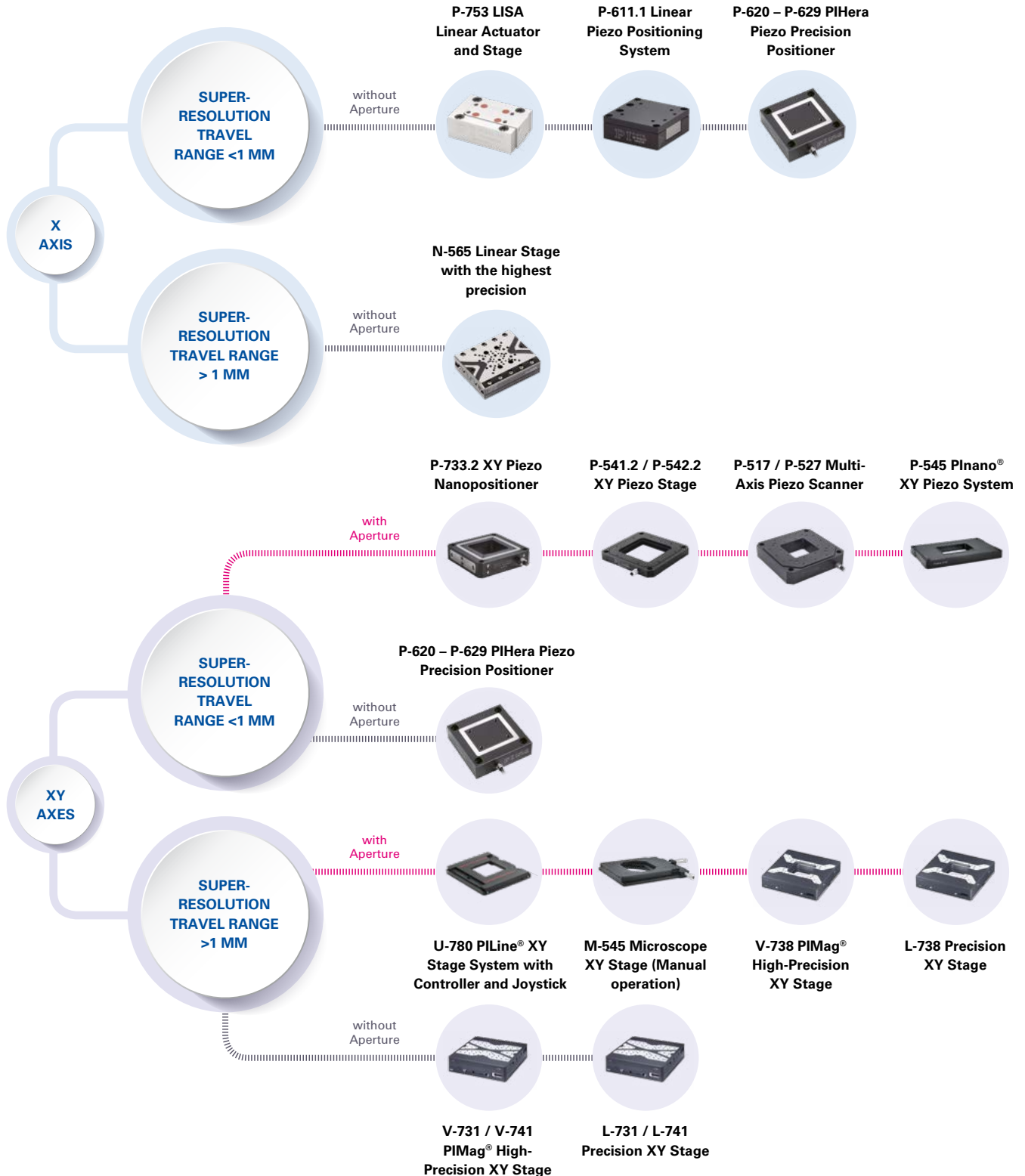


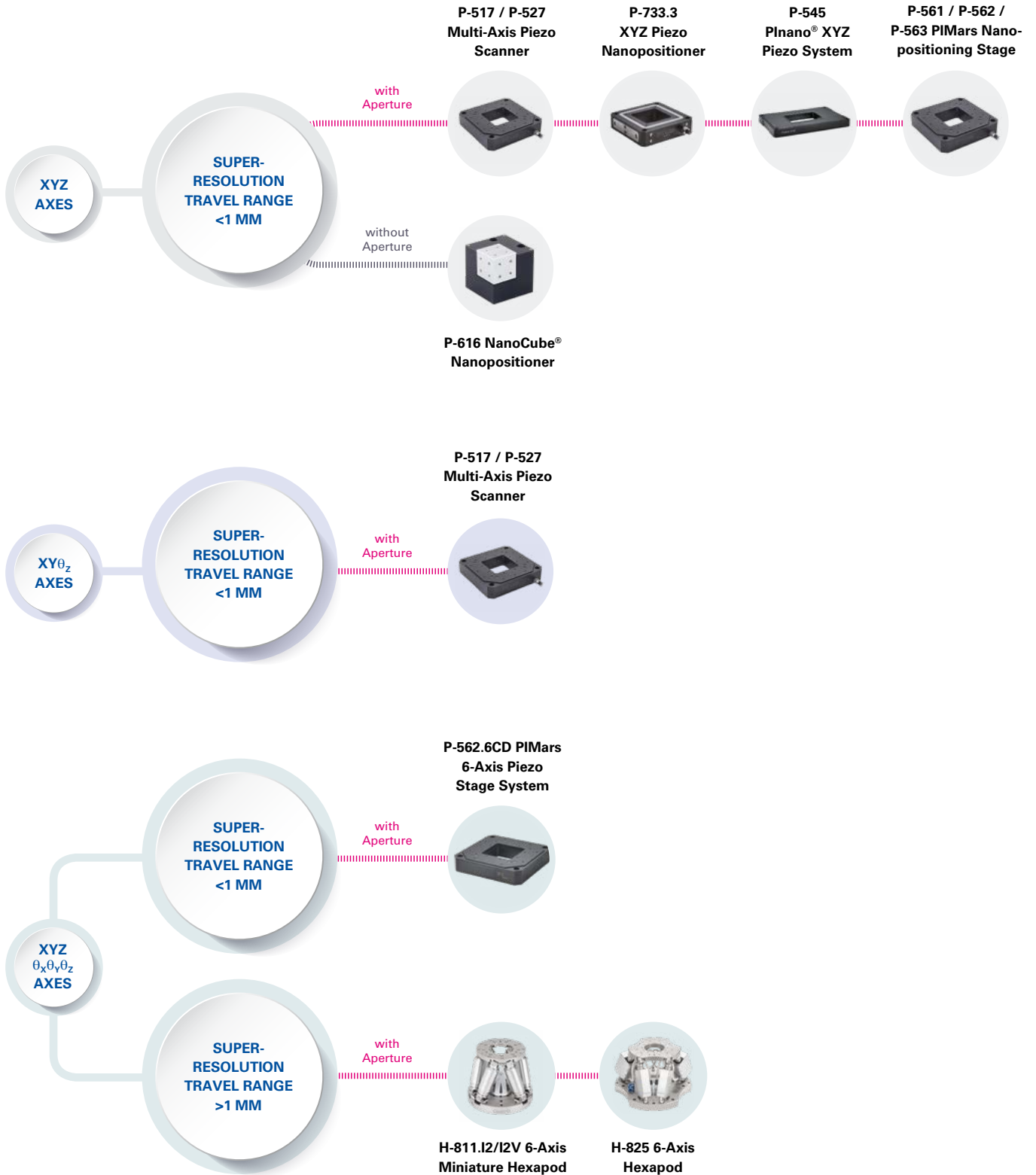
Exploded view of the P-726 QuickLock adapter with P-726 PIFOC (mounting tools included in the scope of delivery).

For all adapters and spacers see: [Links to detailed product webpages \(PIFOC / Controllers\) can be found on the respective product pages of this brochure.](#)

Sample Positioning in Several Axes

Product Selector





UHV-compatible version on request.

Sample Positioning in Z

Low Profile and Clear Aperture

PD73Z2xOW Plnano® Z Microscope Scanner System for Microtiter Plates

Large Clear Aperture, Low Profile, with Digital Controller

- For Inverted Olympus Microscopes
- Fast step & settle
- Clear aperture for well plates and low profile for easy integration
- Travel range 220 μm
- Outstanding lifetime due to PICMA® piezo actuators
- Piezoresistive sensors for lower cost
- Capacitive sensors for higher stability



P-736 Plnano® Z Microscope Scanner System

Inexpensive, with Low Profile

- Low overall height of 20 mm for easy integration
- Travel range 100 μm or 200 μm
- Clear aperture 93 mm \times 65 mm
- E-709 digital piezo servo controller in the scope of delivery
- USB, RS-232, analog interfaces
- Compatible with MATLAB, LabVIEW and $\mu\text{Manager}$



Systems include

- Plnano® Z piezo scanner
- E-709 digital servo piezo controller
- Extensive software package



P-737 PIFOC® Specimen Z Positioner

With Large Aperture and Low Profile

- Travel ranges to 500 μm
- Clear aperture 128.5 mm \times 86.5 mm to accommodate well plates
- Low profile 20 mm
- Compatible with MATLAB, LabVIEW and $\mu\text{Manager}$

Sample Positioning for Widefield Microscopy

Compact and Fast



N-565 Linear Stage with the Highest Precision

NEXACT® Piezo Walking Drive with Subnanometer Encoder Resolution

- Long travel ranges: 13 mm, 26 mm or 52 mm
- Ultraprecision: 2 nm minimum incremental motion and direct-measuring PIONe encoder with 0.5 nm resolution
- Compact design: 65 mm width, 20 mm height

U-521 PLine® Linear Stage

Compact Linear Stage with Ultrasonic Piezo Motor

- Travel ranges to 25 mm × 25 mm
- Positions small loads quickly and with precision: Velocity to 200 mm/s, minimum incremental motion to 0.3 μm
- Space-saving: Only 35 mm in width and 15 mm in height



M-545 Microscope XY Stage

Compact, Stable, Long Travel Range

- Travel range 25 mm × 25 mm
- Stable platform for P-545 PInano® piezo nanopositioning systems
- Low profile for easy integration: 30 mm
- Manual operation with micrometer screws, optional motorization with stepper motor actuators
- For inverted microscopes from Nikon, Zeiss, Leica, and Olympus

V-731 / V-741 PIMag® High-Precision XY Stage

High Travel Accuracy and Stability, Magnetic Direct Drive*

- Travel range 205 mm × 205 mm (8") or 305 mm × 305 mm (12")
- Bidirectional repeatability to ±0.25 μm
- Velocity to 200 mm/s
- Ironless 3-phase linear motor
- Incremental linear encoder with 1 nm resolution



V-738 PIMag® High-Precision XY Stage

Clear Aperture, High Travel Accuracy and Stability, Magnetic Direct Drive*

- Travel range 102 mm × 102 mm (4")
- 150 mm × 150 mm open frame (in reference position)
- Bidirectional repeatability to ±0.25 μm
- Velocity to 500 mm/s
- 3-phase linear motor
- Incremental linear encoder with 1 nm resolution

*Spindle-driven versions available (L-731, L-741, L-738)

Recommended electronics >> page 32 et seq.

Sample Positioning for Widefield Microscopy

Compact and Fast with Nanometer Resolution

Extensive Functions, Software Support

Powerful macro command language. Nonvolatile macro storage, e.g., for stand-alone operation with autostart macro. Data recorder. ID chip detection for fast startup. PID controller, parameter changing during operation. Extensive software support, e.g., for LabVIEW, C, C++, MATLAB, µManager. PIMikroMove user software.

U-780 PLine® XY Stage

System with Controller and Joystick

- High velocity constancy at 10 µm/s
- Velocity to 120 mm/s, bidirectional repeatability 0.3 µm
- Travel range to 135 mm × 85 mm (depending on model type)
- Compact, flat design: Unrestricted access to the sample
- Suitable for the following inverted microscopes:
 - Nikon Eclipse Ti-E/Ti-U/Ti-S
 - Olympus IX2
 - Leica DMI



Systems include

- PLine® XY Stage
- C-867.2U2 Piezomotor controller
- USB joystick
- Extensive software package



PLine® Ultrasonic Piezomotor

An integral part of a PLine® ultrasonic piezomotor is a piezo actuator that is preloaded against a movable, guided runner via a coupling element. The piezoceramic actuator is excited to ultrasonic oscillation by a high-frequency AC voltage between 100 and 200 kHz. Deformation of the actuator leads to periodic diagonal motion of the coupling element relative to the runner. The feed created is a few nanometers per cycle; the high frequencies lead to the high velocities. Preloading the piezoceramic actuator against the runner ensures self-locking of the drive when at rest and switched off.



Sample Positioning for Widefield Microscopy

Parallel-Kinematic Designs for Positioning in up to 6 Axes



H-811.I2/I2V 6-Axis Miniature Hexapod

Fast, Compact, and Highly Precise

- Travel ranges to ± 17 mm / $\pm 21^\circ$
- Load capacity to 5 kg
- Repeatability to ± 0.06 μm
- Velocity to 20 mm/s
- Superior lifetime
- Vacuum-compatible versions available

H-825 6-Axis Hexapod

- Load capacity to 30 kg, self-locking
- Travel ranges to ± 27.5 mm, rotation range to $\pm 11.5^\circ$
- Actuator resolution to 8 nm
- Minimum incremental motion to 0.25 μm in X, Y, and Z
- Repeatability to ± 0.1 μm / ± 2 μrad
- BLDC motors and absolute encoders

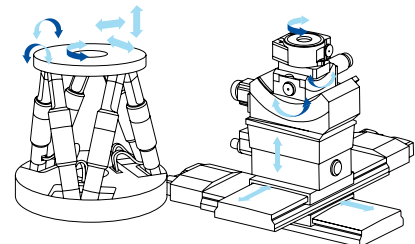


Recommended Hexapod Motion Controller C-887.52x >> [page 33](#)



Technology: Parallel Kinematic Hexapods

In a parallel-kinematic hexapod all drives act on a single moving platform, which results in a much more compact design than possible with stacked systems. Compared to a serial robot, hexapods show a much better ratio of payload to operating weight. As only one platform is moved, the overall moved mass is lower resulting in higher dynamics in all motion axes. Serial motion and positioning platforms have their advantages in the high modularity which allows for individual design of each moving axes. Motion control, especially the homing procedure, is simpler with no coordinate transformation required. On the other hand, the combined positioning errors of stacked systems affect the attainable overall system accuracy. Hexapods can have an improved path accuracy, higher repeatability and flatness of travel.



Sample Positioning for Super-Resolution Methods

Tracking and Scanning



P-753 LISA Linear Actuator and Stage

Dynamic and Stable in Position

- Travel range to 38 μm
- Resolution 0.05 nm
- Guided stage and actuator at the same time
- Particularly fast response behavior due to direct drive
- Highest linearity due to capacitive sensors

P-620 – P-629 PIHera Piezo Precision Positioner

Variable Travel Ranges and Axis Configuration

- Travel ranges 50 to 1800 μm
- Resolution to 0.1 nm
- Linearity error 0.02 %
- X, XY, Z versions; XYZ combination possible
- Vacuum-compatible versions to 10^{-9} hPa



P-541.Z / P-541.T Piezo Z Stages / Z and Tip/Tilt Stages

- Travel range to 150 μm
- Clear aperture 80 mm \times 80 mm
- Low profile for easy integration: 16.5 mm
- Tip/tilt angle to 1.2 mrad
- Parallel kinematics for faster response times and higher multi-axis accuracy
- Sensor technology: Inexpensive strain gauge sensors or capacitive sensors for higher performance
- Combination with microscope stages possible for long travel ranges

P-541.2 / P-542.2 XY Piezo Stage

- Travel range to 200 μm \times 200 μm
- Clear aperture 80 mm \times 80 mm
- Low profile for easy integration: 16.5 mm
- Parallel kinematics for faster response times and higher multi-axis accuracy
- High-dynamics direct-drive version



Sample Positioning for Super-Resolution Methods

Tracking and Scanning

P-733 XY(Z) Piezo Nanopositioner

- Travel ranges to 100 μm \times 100 μm and to 10 μm in Z
- Resolution to 0.1 nm due to capacitive sensors
- High-speed versions with direct drive
- Vacuum-compatible and non-magnetic versions available
- Parallel kinematics for higher accuracy and dynamics



P-517 / P-527 Multi-Axis Piezo Scanner

High Dynamics Nanopositioner / Scanner with Direct Position Measuring

- Travel ranges to 200 μm
- Subnanometer resolution
- 2- and 3-axis versions (XY and XY θ_z)

P-545 Plnano® Piezo XY(Z) Systems

- Subnanometer resolution and fast response in the ms range
- Low profile for easy integration: 20 mm
- E-727 USB controller and software included
- Extensive optional accessories >> [page 31](#)

P-545.3D8S Plnano® Trak Piezo Tracking System

- Travel ranges to 70 μm \times 70 μm \times 50 μm

P-545.xR8S Plnano® XY(Z) Piezo System

- Travel ranges to 200 μm \times 200 μm \times 200 μm
- Inexpensive cost-optimized design due to piezoresistive sensors

P-545.xC8S Plnano® Cap XY(Z) Piezo System

- Travel ranges to 200 μm \times 200 μm \times 200 μm
- Highest linearity due to capacitive sensors

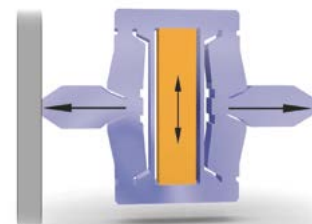


Recommended electronics >> [page 33](#)



Excellent Guiding Accuracy Through Flexure Joints

Flexure guides are free of maintenance, friction, and wear, and do not require lubrication. Their stiffness allows high load capacity and they are insensitive to shock and vibration. They are 100 % vacuum compatible and work in a wide temperature range.



Sample Positioning for Super-Resolution Methods

Tracking and Scanning

P-561 / P-562 / P-563 PIMars Nanopositioning Stage

High-Precision Nanopositioning System for up to 3 Axes

- Travel ranges to $300 \times 300 \times 300 \mu\text{m}$
- Parallel kinematics for faster response times and higher multi-axis accuracy

P-562.6CD PIMars 6-Axis Piezo Stage System

High-precision Nanopositioning System with 6 Degrees of Freedom

- Travel ranges to $200 \mu\text{m}$ linear and to 1 mrad tip/tilt angle
- Clear aperture $66 \text{ mm} \times 66 \text{ mm}$
- Excellent scanning flatness
- Parallel kinematics for faster response times and higher multi-axis accuracy



P-616 NanoCube® Nanopositioner

- Travel ranges to $110 \times 110 \times 110 \mu\text{m}$
- Ultra-compact: $40 \text{ mm} \times 40 \text{ mm} \times 40 \text{ mm}$
- Resolution to 0.3 nm
- Highly dynamic motion due to high resonant frequencies even with loads up to 100 g
- Only nanopositioner available on the market with ID chip functionality

Accessories for Sample Positioning Stages

Compatibility of Piezo Scanners with Manual, Motorized and PILine® XY Microscope Stages

	P-545.xR8S P-545.xC8S P-545.3D8S PInano® piezo system	P-736.ZCN2S P-736.ZRN2S PInano® Z piezo scanner system	PD73Z2COW PD73Z2ROW PInano® Z piezo scanner system	P-736.ZR1S P-736.ZR2S PInano® Z piezo slide scanner system	P-733.2xx P-733.3xx Piezo nanopositioning stage	P-541.2xx / P-541.Txx P-541.Zxx / P-542.2xx Piezo nanopositioning stage	P-737.xxx PIFOC® specimen-focusing Z stage
U-780.DNS PILine® XY stage system for Nikon microscopes	•	•				•	•
U-780.DOS PILine® XY stage system for Olympus microscopes	•		•			•	•
U-780.DLS PILine® XY stage system for Leica microscopes	•					•	•
M-545.2MN XY stage for Nikon microscopes TI series	•			•*	•**	•	
M-545.2MO XY stage for Olympus microscopes IX2, IX3	•			•*	•**	•	
M-545.2ML XY stage for Leica microscopes DMI series	•			•*	•**	•	
M-545.2MZ XY stage for Zeiss microscopes Axio Observer	•			•*	•**	•	

* With P-736.AP1 adapter plate / ** With P-733.AP1 adapter plate

Inserts for PI Sample Stages

	P-545.xR8S P-545.xC8S P-545.3D8S	P-736.ZCN2S P-736.ZRN2S	PD73Z2COW PD73Z2ROW	P-736.ZR1S P-736.ZR2S	P-541.2xx P-541.Txx P-541.Zxx P-542.2xx	P-737.xxx	U-780.DNS	U-780.DOS	U-780.DLS	M-545.2MN M-545.2MO M-545.2ML M-545.2MZ
Microscope slide holder	P-545.SH3*	P-736.SHN*	P-736.SHO*	P-545.SH3*		P-737.AP1*	P-736.SHN* P-736.SHO*	P-736.SHN* P-736.SHO*	P-736.SHN* P-736.SHO*	P-545.SH3* with M-545.SHP
Petri dish holder	P-545.PD3	P-736.PDN	P-736.PDO	P-545.PD3	P-542.PD1	P-737.AP2	P-736.PDN P-736.PDO	P-736.PDN P-736.PDO	P-736.PDN P-736.PDO	P-545.PD3 with M-545.SHP adapter plate
Microtiter plate holder		P-736.WPN	P-736.WPO		P-542.SH1*		P-736.WPN P-736.WPO	P-736.WPN P-736.WPO	P-736.WPN P-736.WPO	
Universal holder		P-736.UHN*	M-687.AP1*				P-736.UHN* M-687.AP1*	P-736.UHN* M-687.AP1*	P-736.UHN* M-687.AP1*	
Universal holding plate	P-545.PP3			P-545.PP3						P-545.PP3 with M-545.SHP

M-545.SHP adapter plate

* Also available: P-545.C18 Coverslip holder (for 18 mm x 18 mm coverslips), P-545.C22 (for 22 mm x 22 mm coverslips) and P-545.C25 (for 25 mm x 25 mm coverslips)

Single Channel Digital Controllers

Plug-and-Play via Extensive Software Package



E-709 Compact and Cost-Optimized Digital 1-Channel Piezo Controller

- Linearity error to 0.02 %
- Comprehensive I/O functions
- Fast 25 Mbit/s serial interface USB, digital RS-232, fast serial interface with up to 25 MBit/s

E-709.CHG Digital 1-Channel Piezo Controller for High Dynamic Applications

- Output power up to 50 W
- Linearity error to 0.02 %
- USB, RS-232
- SPI: Fast 25 Mbit/s serial interface
- Comprehensive I/O functions



E-754 Digital 1-Channel Piezo Controller for Highest Demands

- Next generation digital controller provides higher flexibility, accuracy, and speed
- Analog inputs and outputs
- Autoloading of calibration data from stage ID chip for interchangeability of controller and mechanics
- Digital I/O lines for task triggering

Further compatible electronics (e. g. analog controllers or OEM modules) available on request.



Extensive software for rapid start of productive operation

Thanks to support of MATLAB and LabVIEW as well as all common operating systems (Windows, Linux, and macOS), integration succeeds in virtually every environment – quickly and efficiently. Sophisticated programming examples and software tools such as PIMikroMove shorten the time to productive operation considerably.

Multi-Channel Digital Controllers

Plug-and-Play via Extensive Software Package



E-727 Digital Multi-Channel Piezo Controller

For Nanopositioning Systems with Capacitive, Piezoresistive or Strain Gauge Sensors

- 20 kHz control bandwidth
- Interfaces: Ethernet, USB, RS-232, SPI
- Digital inputs and outputs
- Optional analog inputs and outputs
- Autoloading of calibration data from stage
- ID chip for interchangeability of controller and mechanics
- 4th order polynomial linearization for mechanics and electronics

E-712 Digital Piezo Controller

Modular System for up to 6 Axes for Highest Precision

- Up to 50 kHz servo update rate
- Highly stable 20-bit D/A converter
- Real-time operating system for excellent trajectory control
- Autoloading of calibration data from stage ID chip for interchangeability of controller and mechanics
- Flexible interfaces: TCP/IP, USB, RS-232; optional broadband analog inputs and outputs
- Extensive software package



C-887.52x Hexapod Motion Controller

Compact Bench-Top Device for Controlling 6-Axis Systems

- Sophisticated controller using vector algorithms
- Commanding in Cartesian coordinates
- Easy customization of coordinate systems by command
- Analog interfaces and motion stop optional
- Extensive software package

Further compatible electronics (e. g. analog controllers or OEM modules) available on request.

Multi-Channel Digital Controllers

Plug-and-Play via Extensive Software Package



C-867.2U2 PLine® Motion Controller

For Two-Axis Positioning Stages with PLine® Ultrasonic Piezo Motors

- Integrated power amplifier with dynamic frequency control
- Multifunctional encoder input: A/B, sin/cos, BiSS
- Macro programmable for stand-alone functionality
- Integrated interfaces: USB, RS-232, TCP/IP, SPI, I/O, joystick
- Daisy chain networking
- Trajectory support for 1- or 2-D motion patterns

SMC Hydra Universal Motion Controller

For electromagnetic motors, DC servo and brushless DC motors (BLDC), linear and torque motors (2 / 3 phases), 2-phase stepper motors

- 2-D vector motion
- Digital inputs and outputs
- Optional: Encoder-based trigger output, Dynamic position correction
- Joystick operation via CAN bus



The PI Group

A Strong Partner for Industry and Research



PI (Physik Instrumente) has been one of the leading players in the global market for precision positioning technology for many years. The technological diversity of the PI Group is unique all over the world. PI develops, manufactures, and qualifies all its core technologies itself. PI is therefore not dependent on components available on the market to offer its customers the most advanced solutions.

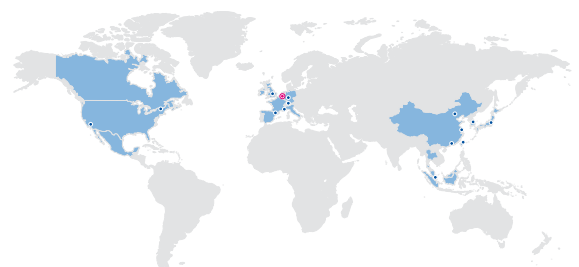
The complete control over vertically linked manufacturing processes allows flexible reaction to market developments and new requirements.

Modern organizational forms such as the fractal production model guarantee efficient production for batch sizes of 1, small series, and also OEM products in large quantities. By acquiring the majority shares in ACS Motion Control, a worldwide leading developer and manufacturer of modular motion controllers for multi-axis drive systems, PI can also offer solutions from one single source to meet the industry's increasing demands on precision and throughput.

The foremost priority for PI is to be a reliable and highly qualified partner for the customer.

Core Technologies

- In-house manufacturing of piezo components and piezo actuators
- Magnetic direct drives: linear motors and voice coils
- Air bearings, magnetic and flexure guides
- Comprehensive range of piezo motor technologies
- Nanometrology sensors
- Parallel-kinematic systems for positioning in six axes (Hexapods)
- Motion control technology
- Software

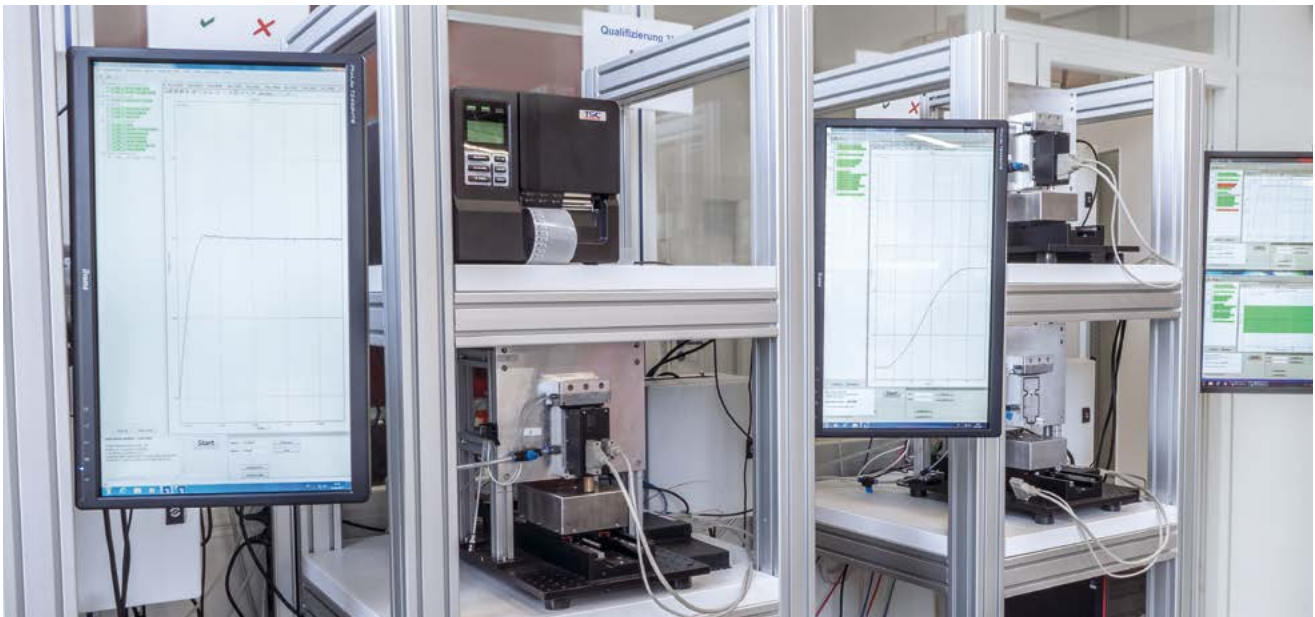


From 1-off to Series: OEM Customers Benefit From Maximum Flexibility

PI serves both the research and industrial markets. The complete control over the design and manufacturing process provides our customers with significant competitive advantages. Optimized processes allow PI to deliver customized products in quantities up to several 100,000 units per year at low cost and right on time. The range of OEM products offered by the PI Group varies widely, ranging from “bare” actuators and sensors to highly integrated parallel-kinematic positioning systems. Evaluation of pre-production run samples, test procedures, production processes and quality management are all included in the development process.

Services

- Global account management: Close proximity to the customer thanks to international presence
- Risk assessment from design to delivery
- Depending on the task: From the drive to the turnkey system
- Copy exactly policy
- Preparation of internal and external certification
- Production of series of several 10,000 units in the shortest time
- Sustainable spare parts service
- Manufacturing and testing capacities from functional samples to mass production



Standardized performance control with full documentation of individual measurement charts

Global Service and After-Sales



On-site training is key to optimize and maximize the potential of new PI systems

Start-Up, User Training and Life Long Support

PI is dedicated to supporting its customers right from the initial consultation through to when a customer has purchased a PI system. Beyond that, PI's services division is committed to ensuring that every aspect of owning a PI system is catered for.

Global Coverage

Supported by 4 Global Service Hubs in Asia, China, Europe and USA, with field product specialists working from these hubs, PI is able to support all technologies and customer applications via this global services team.

PI's Standard On-Site Services

- Set up and Commissioning – On-site support to un-box, set-up and commission the PI system
- Training Program – User training on software and programming, through to optimization of system performance
- Maintenance Systems Health Check – Preventative maintenance to prolong the life of the motion device
- Support – Ongoing remote and on-site support to maximize system uptime and provide maintenance for the whole life of any system

Contracted Services

Customers subscribing to Contractual Support Services will receive commitment from PI to achieving agreed Service Levels. These include responding to the customer's first contact and providing remote technical support, through to response times for a PI expert to be on site, either to repair or replace a defective unit.

Extended Warranty

Most customer applications require PI's systems to be operational beyond the standard warranty period. Extending the warranty for additional year(s), is simply extending the customers peace of mind and PI's commitment that the product will not fail due to poor workmanship or faulty materials. Should a customer's system then fail due to these conditions, PI will cover the costs to repair or replace it.

The PI Group Milestones

A Success Story

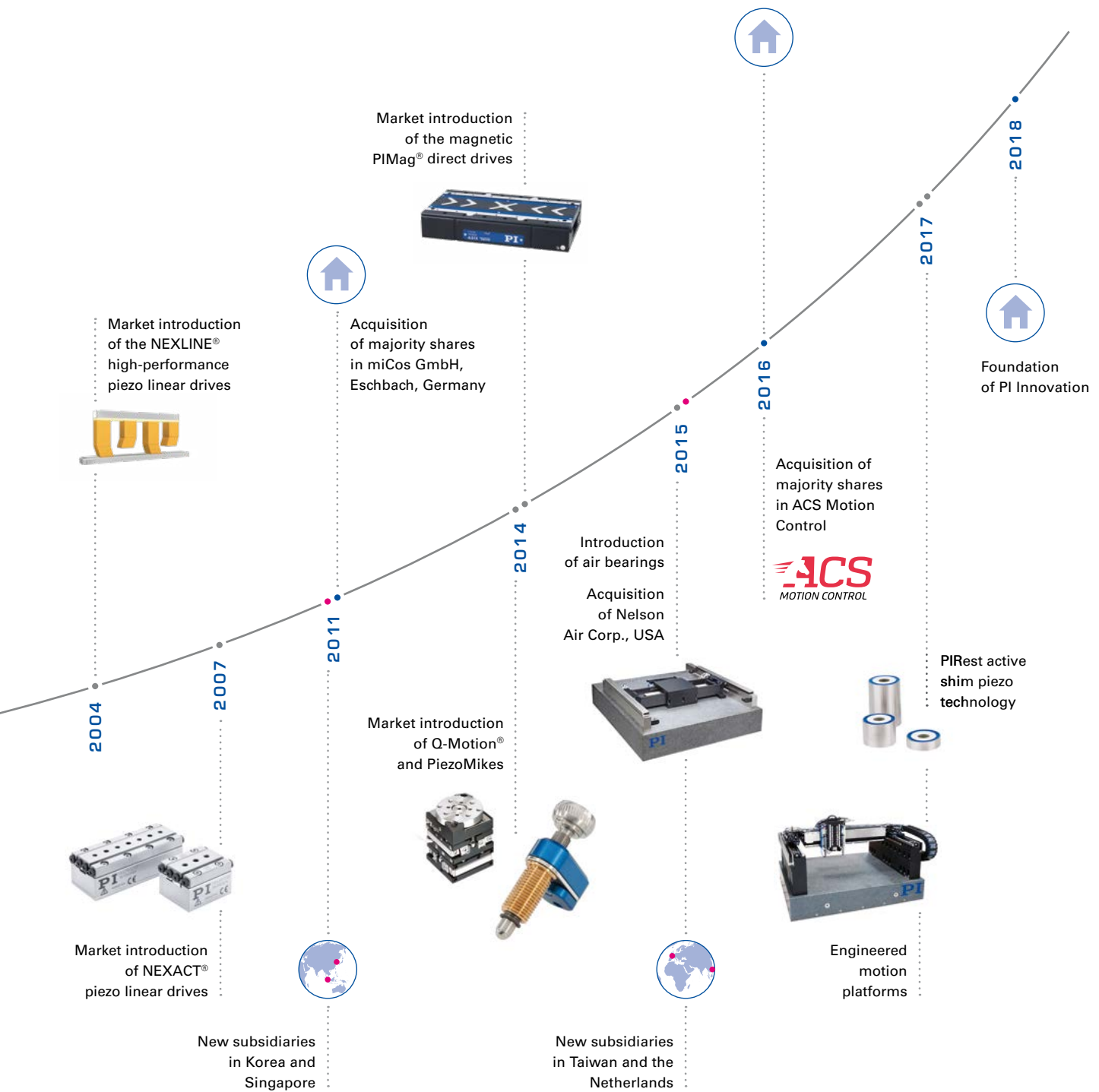
PI has been developing and manufacturing standard and OEM products with piezo or motor drives for more than 40 years. Continuous development of innovative drive concepts, products, and system solutions and more than 200 technology patents distin-

guish the company history today. In addition to four locations in Germany, the PI Group is represented internationally by fifteen sales and service subsidiaries. PI is a privately owned company with healthy growth and more than 1000 employees worldwide.



Market introduction of the PICMA® multilayer piezo actuators







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