PI

PRECISION
MOTION CONTROL
HIGH DYNAMICS
SPACEFAB
ETHERCAT®
HEXAPOD
6 DEGREES
OF FREEDOM
POSITIONING SYSTEMS
SCALABLE
DESIGN
PHOTONICS ALIGNMENT
REPEATABILITY
PARALLEL
KINEMATIC ROBOT
PAYLOAD FROM GRAMS
TO TONS

Hexapod Positioning Systems

Product Finder Online – What is the easiest way for you to find the best positioning solution?

The printed catalog is a major showcase for PI and, as well as presenting the entire product range, it also acts as a reference for all of our motion solutions. However, to take advantage of the latest products and developments, we recommend using the product finder on the PI website www.pi.ws.

How to use the product finder:

Select the product type specified by the axes of motion required. Selection of more criteria expands or shortens the list of results. Select more than one filter at a time, for example, to find positioning stages designed for higher load capacity, too.
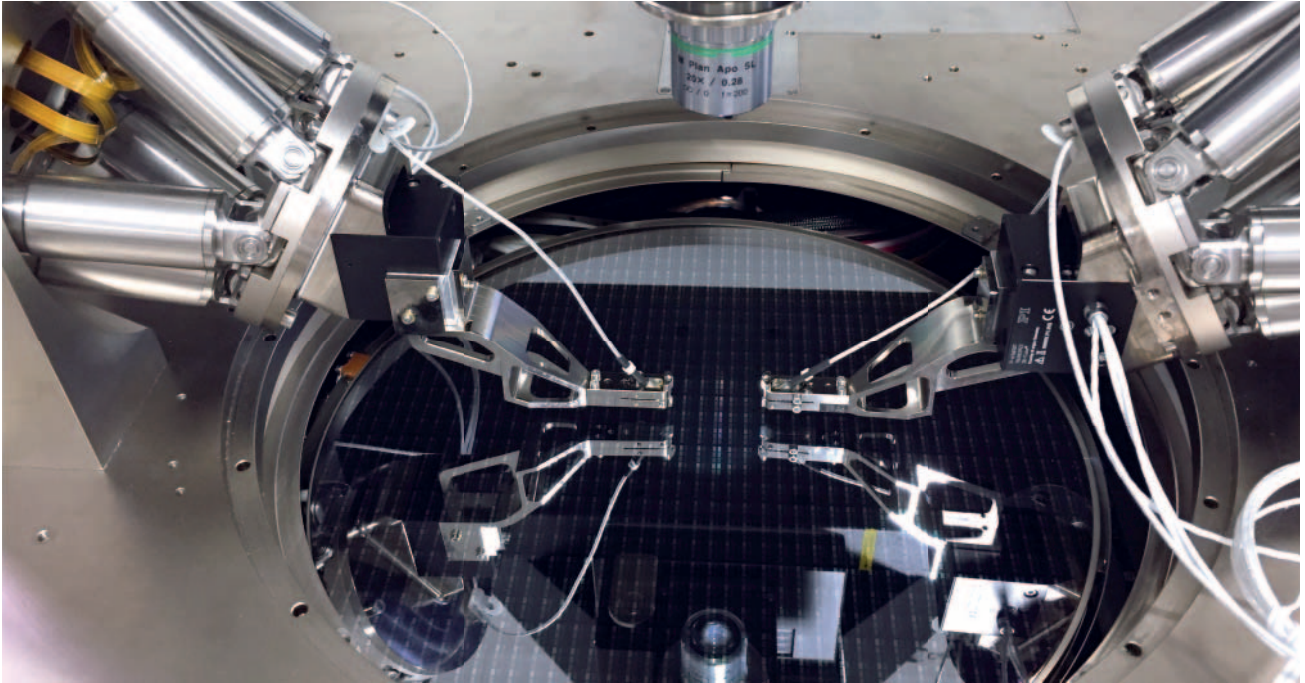
INTRODUCTION

PRODUCTS

More information, step-files and downloads are available from our website www.pi.ws.
All data subject to change without notice, ©PI 2018.

Compact Hexapods

Precision Positioning Hexapods

Dynamic Motion Hexapods

Fast Multi-Channel Photonics Alignment Systems

Motion Control

Specific Software for Hexapod Systems

Terms and Technology Glossary

MOTION | POSITIONING

Markets and Applications

18-Axis double alignment system provides fast NxM alignment of SiP devices in wafer probers. Cascade Microtech's pioneering CM300xi photonics-enabled engineering wafer probe station integrates PI's Fast Multichannel Photonics Alignment systems for high throughput, wafer-safe, nano-precision optical probing of on-wafer Silicon Photonics devices. (Image: Cascade Microtech, a FormFactor company)

SILICON PHOTONICS (SiP) PACKAGING AND TESTING

The convergence of photonics and semiconductors promises a leap in data throughput, parallelism and energy efficiency. Test and packaging of silicon photonics elements require nanoscale alignments that cannot be performed using visual or mechanical references. Instead, these optimizations must optimize the optical throughput itself.

In addition, silicon photonic designs often incorporate multiple parallel optical paths with multiple, interacting inputs and outputs, all needing optimization. PI automation subsystems allow this parallel optical alignment in several degrees of freedom all-at-once which is a decisive step forward in mass production

of silicon photonics components. Often, global optimization is achieved in less than a few hundred milliseconds, resulting in time savings that can exceed two orders of magnitude.

Because different devices and production applications present different requirements, PI's modular architecture offers solutions for virtually all production probing & packaging needs of SiP fabricators and their tool OEMs.

Fast Multi-Channel Photonics Alignment (FMPA) systems is based on a combination of a high-speed piezo scanner, a micro-positioning system (XYZ or 6-axis hexapod), and a high-performance controller with firmware-based routines for optical alignment.

OPTICAL ALIGNMENT

As miniaturization continues to advance, it becomes necessary to manufacture and assemble components with even more precision. PI hexapods are being used more frequently during the production and assembly process for optical components because they are capable of meeting the requirements on precision made by industry.

In the case of small cameras for example, the lenses or lens assemblies are positioned and sometimes the CCD chip itself. In most cases, not only the linear degrees of freedom need to be optimized but also the rotatory degrees of freedom and a hexapod simplifies this process considerably with its user-definable pivot point.
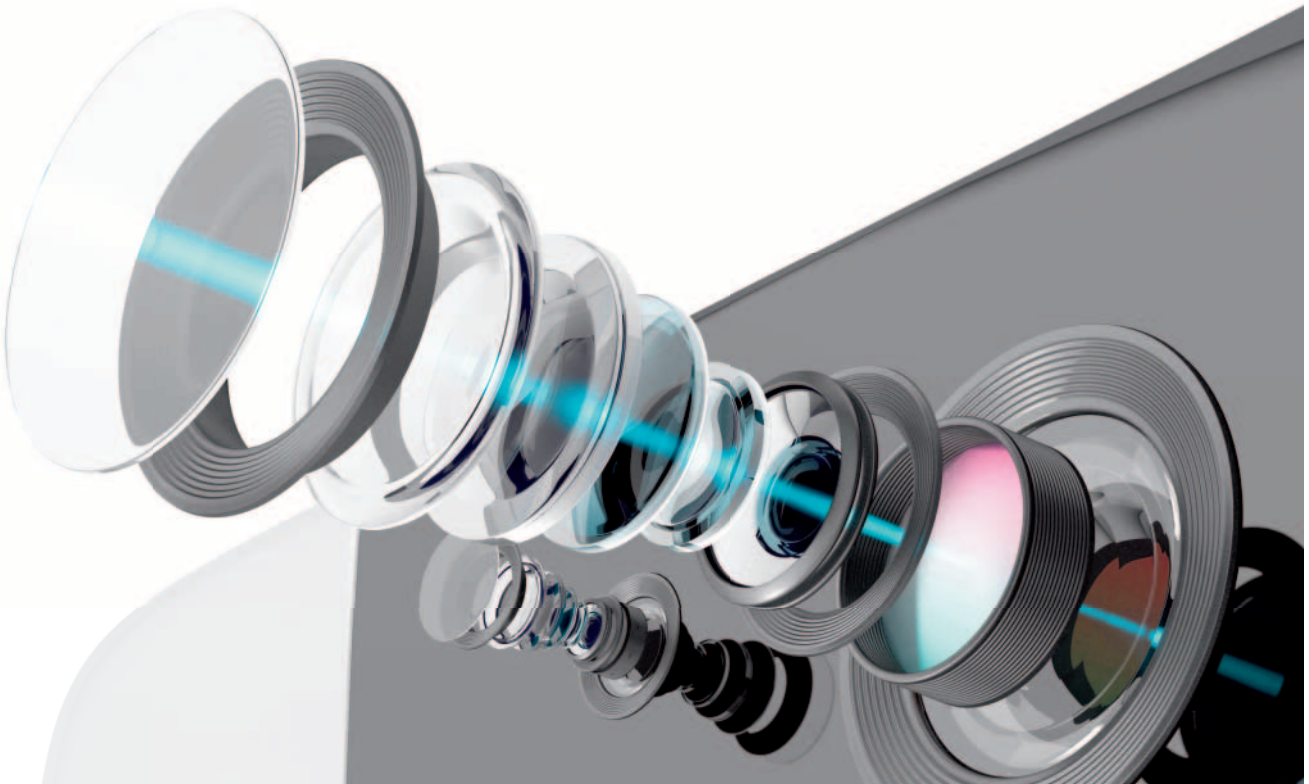
Markets and Applications

MICROPRODUCTION, ELECTRONICS MANUFACTURING, AUTOMATED PRODUCTION LINES

If multi-axis systems are required for positioning tasks in mechanical engineering parallel-kinematic hexapods are frequently used. Areas of application include, for example, handling systems in electronics production, tool control in precision machine tools, for drilling and milling, or for mounting tasks in vehicle, aircraft, or heavy equipment construction. The parent PLC or CNC can communicate with the hexapod system over a standardized real-time Ethernet interface. It then acts just like an intelligent drive. Of course, the hexapod controller can also act as master for position control. In this case, however, the motion cannot be synchronized with other drive axes, measuring systems, etc.
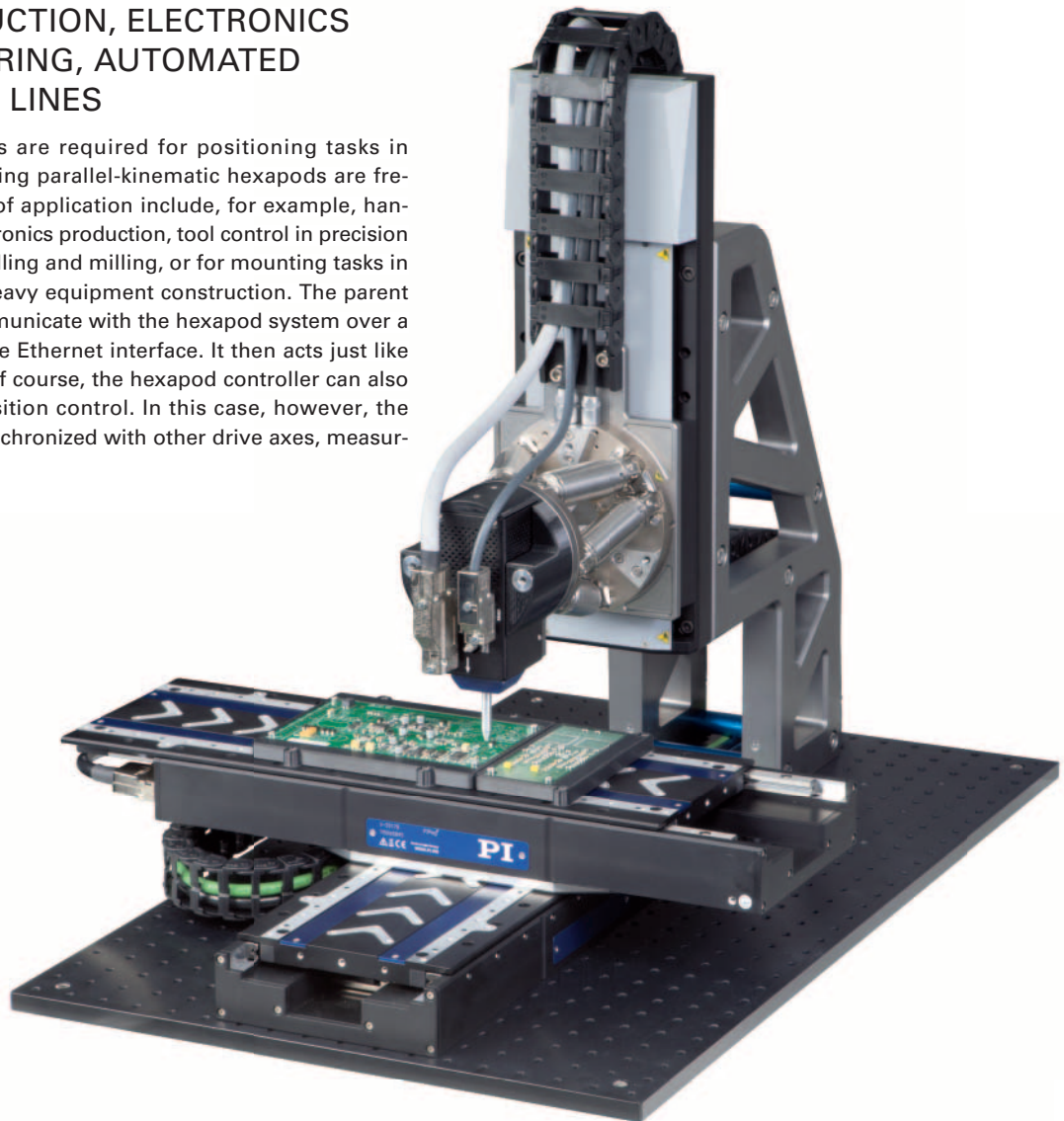
Automated testing procedures ensure quality, e.g., in the production process of printed circuit boards (PCBs). Thereby, the precise control of the forces acting on the sensitive boards as well as the fast capturing and interpretation of measurement data are extremely important.

INDUSTRIAL QUALITY ASSURANCE

Today, microproduction technology makes high-precision, mostly multi-axis positioning systems absolutely necessary for both assembly and quality assurance, and they also have to be as compact as possible to enable them to be properly integrated into the production units. In most cases, only small loads need to be positioned with high accuracy. Experience shows that parallel-kinematic hexapods are predestined for precision positioning with up to six degrees of freedom.
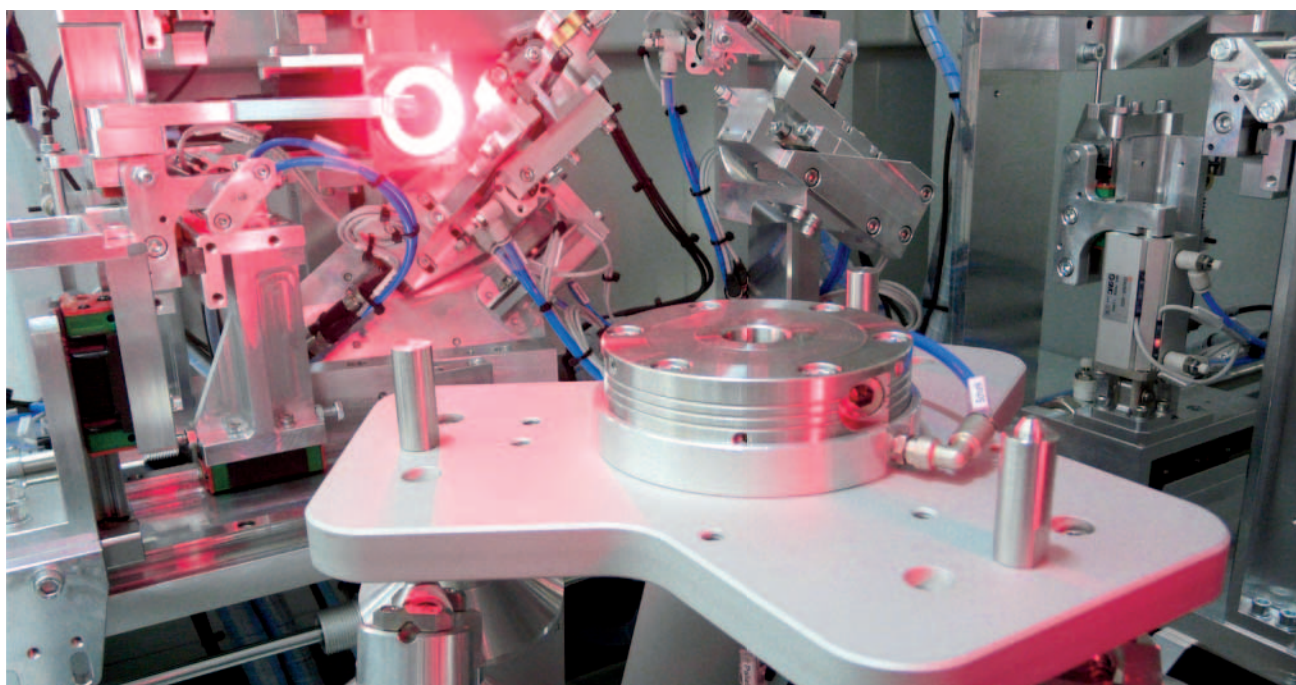
The Dimensional Measuring machine DM401 series of the DYMACO Group employs a H-820 Hexapod for positioning headlamps. The DM401 series is a very compact and flexible workstation for in-line automated dimensional measuring of headlamps in the automotive industry. The use of hexapod systems allow for an outstanding flexibility for a large variety of samples of in-line automation systems by minimizing the required space for motion robotics. (Image: DYMACO GROUP)

Markets and Applications

MOTION SIMULATION AND IMAGE STABILIZATION

Vibrating tables are used for testing resistance to vibration. Testing becomes even more complex if the behavior is to be examined with predefined motion such as vibrations of a vehicle or airplane at certain velocities. Further typical examples include devices in acceleration or gyroscopic sensors such as those used in smartphones, cell phones, and cameras that detect changes in position, e.g., in cameras for detecting any trembling motion of the photographer. The image stabilization system can then compensate automatically. Its algorithms and mechanical system also have to be checked.

To test image stabilization systems, technical standards are established by the CIPA (Camera and Imaging Product Association), an international alliance of camera manufacturers similar to an ISO committee. It has released DC-011-2015 as the new standard for motion simulation test conditions.

Of course, simulation for test purposes requires natural and artificial motion to be precise, repeatable, and simulated with the same dynamics and accuracy. This involves running high-precision trajectories with the corresponding dynamics. Therefore, multi-axis, precise, and dynamic positioning systems are necessary.

The H-811 Hexapod simulates camera shake for testing image stabilization systems according to the CIPA standard. Here in test equipment at Image Engineering. (Image: Image Engineering)

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Engineers installing a PI hexapod at a subreflector of an ALMA telescope. 50 antennas of the ALMA observatory use high-precision hexapods from PI. Under extreme ambient conditions of the Atacama Desert, the hexapods align the subreflectors to the large main reflectors of the radio telescopes. Technological demands here are high: Low air pressure, temperature differences of up to 50 °C, strong winds, dust and rain are additional challenges in 5000 meters above sea level that have to be faced.

ASTRONOMY

Ground-based observatories for the observation of radio waves or visible light use a complex design of many subsequent mirrors. To keep the optical path at its optimum, the subreflectors even out external impacts on the mechanical system. Deviations can occur, for example, with antenna tracking that compensates for global rotation, with bending of telescope components due to gravitation, or through thermal effects or wind load.

Typically, to optimally align primary and secondary mirror, the secondary mirror hast to be adjusted in five degrees of freedom. It is extremely important that the rotary correction is around the mirror vertex to avoid any alteration of the focal point.


The hexapod systems with six degrees of freedom in motion are installed behind the subreflectors and allow for 6-D positioning with resolution in the submicrometer and arcsecond range.

Markets and Applications

BASIC RESEARCH, SCIENTIFIC INSTRUMENTATION

In synchrotron radiation sources, X-ray diffraction and reflections of the radiation can be used to investigate all kinds of material properties or interactions. Common to all of these applications are the requirements of very high precision, a good time stability, and an excellent position repeatability. Hexapods are often the appropriate solution due to their compact size and the relatively long travel ranges in 6 degrees of freedom.
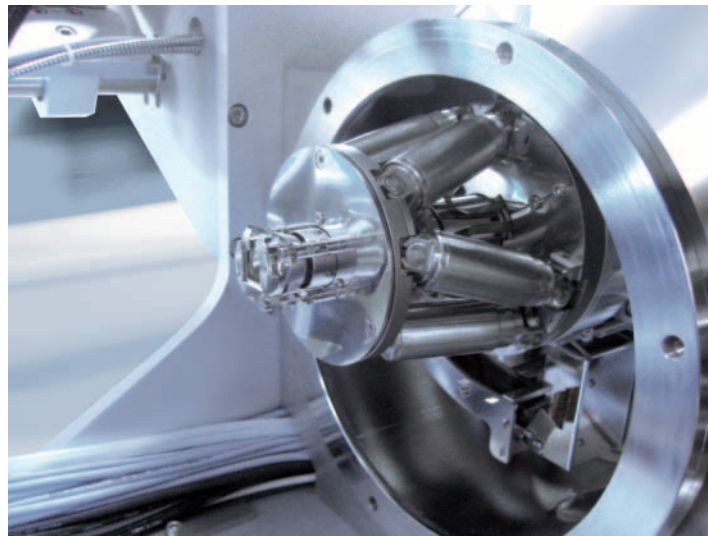
A hexapod, designed by PI for use in high vacuum, positions the sample, relative to the incident X-rays for an in-situ investigation of the growth of thin layers in high vacuum. (Image: SURFACE systems+technology GmbH & Co. KG)
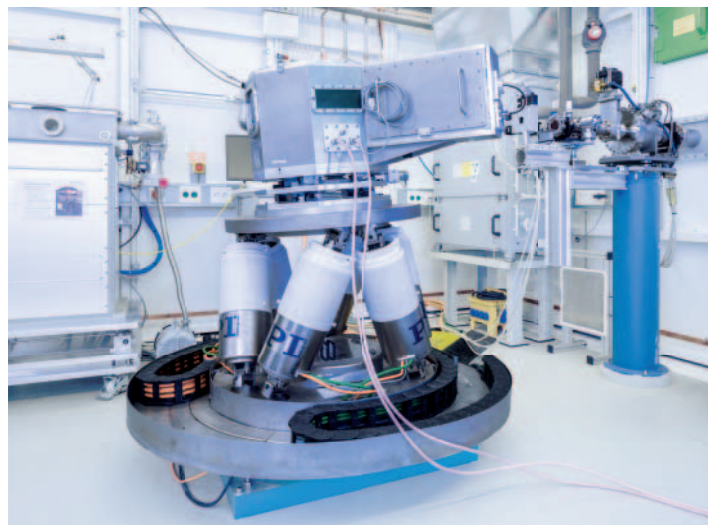

High-load hexapod positions a chamber for laser welding titanium aluminides in precisely the correct angle to the synchrotron beam, in EH3 experimental set-up of P07 beamline at PETRA III. (Image: PI / Helmholtz-Zentrum Geesthacht)

56 motors, 16 motion controllers, and 20 tons weight make the system for Microscopy and Quality Assurance (MiQA). The unique system integrates hexapods, rotation stages, goniometers, and a custom sample stage and will be used in a beamline for X-ray microscopy and the qualification of X-ray optics. Virtually all available PI technologies are combined here in a highly specialized solution providing the best possible accuracy for this application, resulting in 80 nm at the tool center point over multiple stacked axes.
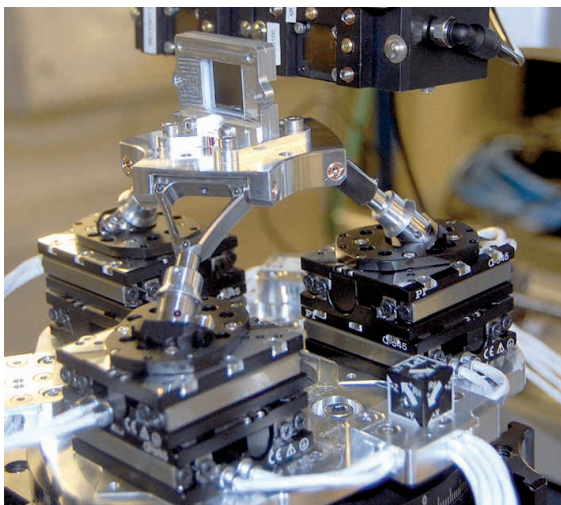
High stiffness is required to position the vacuum sample chamber (above) and attached detectors for 4-pi-measurement of X-ray diffraction results. The large base hexapod moves the entire structure in six degrees of freedom and so positions it in the synchrotron beam.


The miniature parallel-kinematic Q-845 aligns the probe extremely flexibly in all 6 degrees of freedom. The requirements are the lowest possible weight and an angular accuracy of up to 0.001° respectively, an error of less than 1 µm when positioning the probe during the rotation process. (Image: D. Hänschke, KIT Karlsruhe, Germany)

Custom Examples Picture Wall

Fast hexapod for loads to 60 kg
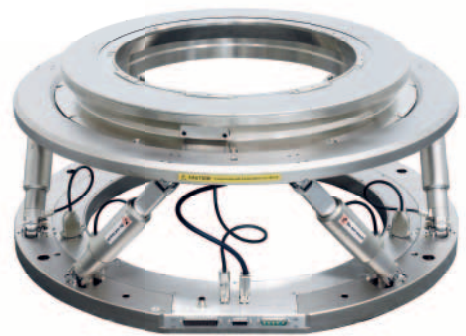
7 axes with large aperture: The hexapod inte-
grates a rotation stage in the motion platform
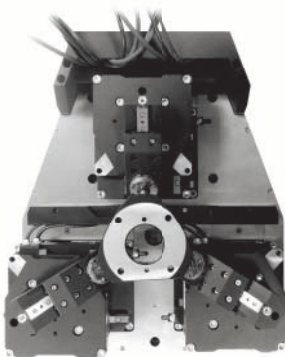
Customized parallel-kinematics stage with
six degrees of freedom. The PIMag® linear
motors ensure high dynamics and precision
as required in optical alignment or fiber align-
ment. The solution is based on 3 XY stages
which are driven by linear motors that allow
high dynamics for the precision alignment.
The SpaceFAB parallel kinematic allows a
very flat design with long strokes in x and y.
In comparison to a PI Hexapod, the footprint
of the SpaceFAB is relatively large, and the
hexapod is better suited for longer vertical
strokes.

Low-profile hexapod design for precision
orientation of laminar payloads to 200 kg, e.g.
of inspection and assembly systems in LCD
productions or the positioning of patients in
medical engineering. The design avoids all
moving cables, the controller is integrated.

PI

This customized tripod with PiezoMike inertia drives is used for adjusting a mirror. The mirror can be moved along an axis linearly and tilted in two further orthogonal axes. The constructive challenge was to realize a relatively long travel range of several millimeters in a compact installation space of 110 mm × Ø 50 mm.
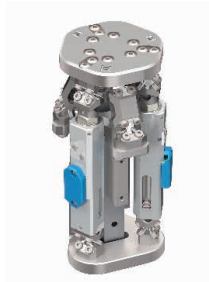
This miniature hexapod was developed on the basis of fast PILine® ultrasonic motors to enable fast motion in all six spatial directions (three linear, three rotational). The parallel-kinematic SpaceFAB design makes a particularly low overall height of only 80 mm possible. The individual axes can be commanded with up to 120 mm/s.
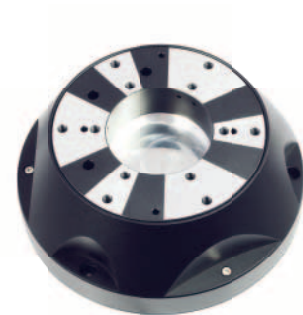
Piezo hexapod for fine adjustment and active, dynamic error correction

Hexapod for loads up to 500 kg, absolute encoders
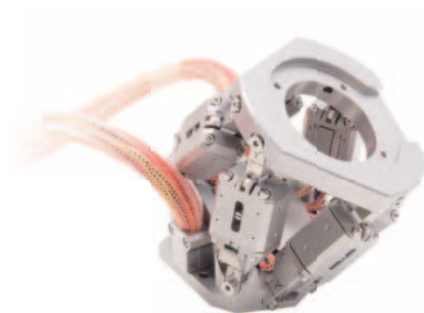
UHV-compatible miniature piezo hexapod. High-precision positioning even in strong magnetic fields

Weather-resistant hexapod for astronomy, precision 6-axis positioner for outdoor applications

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Custom Examples Picture Wall

Heavy-duty hexapod for a load
of 250 kg, clear aperture 800 mm Ø
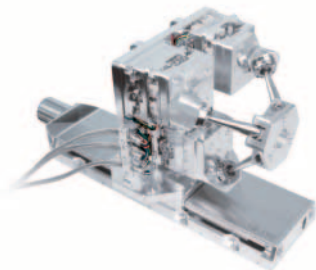
Long-range linear stage positions
a 6-axis low-profile parallel-kinematic
SpaceFAB on top, UHV to 10^{-7} hPa

Hexapod for loads up to 1.5 tons,
vacuum-compatible to 10^{-6} hPa

Hexapod with long travel ranges
up to 240 mm in X and Y

Impact of the Drive Technology

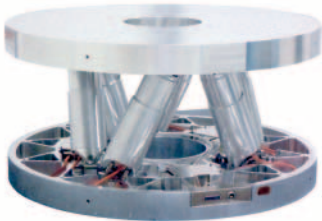| Drivetrain	Ideal for …	Why use parallel kinematics with this drive principle?
Brushless or brushed DC servo or stepper motor with and without gearhead	■ Positioning with sub-µm-accuracy ■ Miniaturization: Compact stages	6-axis positioning with high accuracy, e.g., sample positioning in laboratories and beamline experiments, fiber alignment, fiber-to-chip alignment, stable test systems, high-precision mounting fixtures Motion simulation, precision following of specified trajectories
Q-Motion® piezo inertia drive	■ Nanometer-precision and log-term stable positioning ■ Quasistatic applications with low to medium holding force ■ Miniaturization: very compact stages ■ Affordable positioning of small loads	Very compact designs Vacuum and nonmagnetic environments, sample positioning e.g., in x-ray tomography
PiezoWalk® piezo stepping drive	■ Nanometer-precision positioning ■ Quasistatic applications with high holding force ■ Travel ranges up to a few mm ■ Coarse and fine adjustment ■ Force generation ■ Active vibration insulation ■ Operation with constant low velocity	Compact designs Vacuum and nonmagnetic environments
PIMag® voice coil drive	■ Positioning with sub-µm-accuracy ■ Fast step-and-settle ■ Scan mode with high velocities ■ Miniaturization: Very compact stages	Automatic test cycles with high acceleration and high velocity Motion simulation with high frequencies, precision following of specified trajectories
PIMag® linear motor	■ Positioning with sub-µm-accuracy ■ Fast step-and-settle ■ Scan mode with high velocities	Virtually unlimited travel ranges. Automatic test cycles with high acceleration and high velocity Motion simulation with high frequencies, precision following of specified trajectories
PILine® ultrasonic piezo-motor	■ Positioning with sub-µm-accuracy ■ Fast step-and-settle ■ Scan mode with high velocities ■ Operation with constant low velocity	Compact designs Vacuum and nonmagnetic environments
Piezo stack actuator in multilayer or pressing technology	■ Nanometer-precision positioning with high dynamics ■ Lever-amplified and guided systems ■ Piezo scanners ■ Fine adjustment ■ Force generation ■ Active vibration insulation ■ Miniaturization: Very compact stages	Active vibration damping on 6 axes Vacuum and nonmagnetic environments

Reasons for Choosing a PI Hexapod System
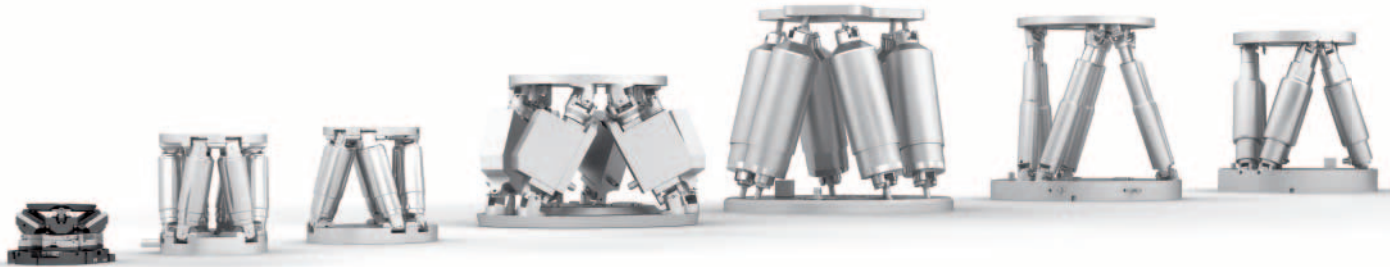
Hexapod Key Features

- Large central aperture
- Three linear axes, three rotational axes of motion
- Low moving mass, low inertia
- Excellent dynamic behavior, fast step-and-settle
- Minimized axis crosstalk motion
- Very good repeatability
- Small installation space
- High stiffness
- Stable, virtual pivot point that can be freely defined in space
- Reference system (Work, Tool) can be quickly and easily changed
- Position input via Cartesian coordinates, coordinate transformation handled by the controller
- Supports motor brakes and absolute-measuring sensors with BiSS interface

Precise Positioning of Loads from 2 kg to 2000 kg

PI hexapods area always used when highly precise motion in several degrees of freedom is required. They position the loads on six axes in space, three linear and three rotary. Depending on their design, Hexapods can position loads from several kg up to several tons in any spatial orientation, in other words independently of the mounting orientation and with submicrometer precision.

Compact Positioning System with 6 Degrees of Freedom

Hexapod platforms are used for precision positioning and alignment of loads in all six degrees of freedom, three linear axes, and three rotational axes Hexapods have a parallel-kinematics structure, i.e. , the work piece is actuated simultaneously by multiple actuators, rather than taking a stacked approach. The parallel arrangement of the actuators optimizes the overall system stiffness and allows for a large central aperture.
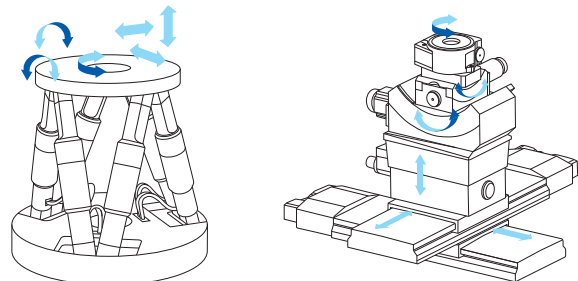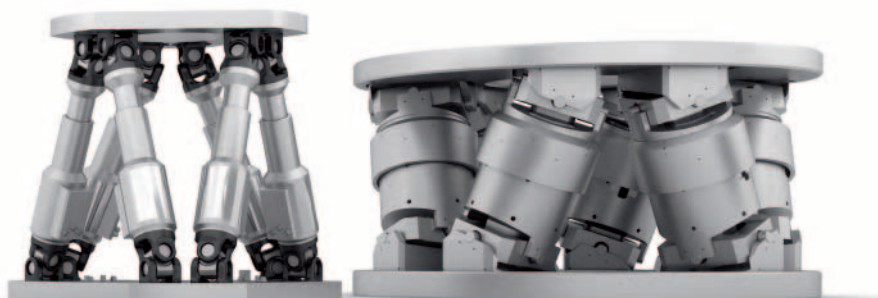
Virtual Pivot Point and User-Defined Coordinate Systems

The pivot point of the hexapod can be freely defined. To adapt the trajectory perfectly to the requirements of the application, it is possible to define various coordinate systems which refer, for example, to the position of workpiece or tool. This offers great advantages for applications in industrial automation, and for fiber alignment. Coordinate systems can be switched with one simple command.

Stacked or Parallel-Kinematic Motion Platforms?

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. Hexapods feature a high stiffness, therefore they can be mounted in any orientation and there is practically no settling time when the target position has been reached. As only one platform is moved, the overall moved mass is lower if compared with a stacked or nested positioning system, resulting in lower inertia and therefore higher dynamics, which is the same for all motion axes.

Compared to serial or stacked systems, hexapods have an improved path accuracy, higher repeatability and flatness of travel. Cable management is not an issue as PI hexapods only need two cables to connect to the controller.

Compared to a serial robot, hexapods show a much better relation of payload to operating weight.

Serial motion and positioning platforms have their advantages in the high modularity which allows for individual, if required asymmetric design of the moving axes. Motion control, especially the homing procedure, is simpler with no coordinate transformation required. On the other hand, positioning errors of stacked systems are adding up and may affect the attainable overall accuracy.

The parallel-kinematic SpaceFAB design allows for an asymmetric design of the motion axes with a very low profile. In this way, e.g. one linear axes may be longer to deliver a workpiece or to position a sample in the test area. The available workspace for the other axes remains the same.

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EtherCAT® Connectivity
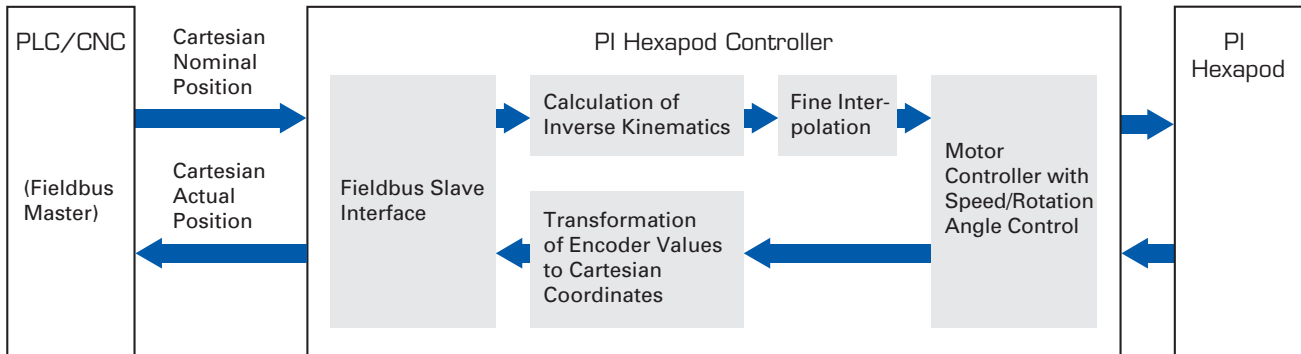
The controller transmits and receives Cartesian position data regularly. The typical cycle time is 1 ms.

Hexapod Motion Controllers provide EtherCAT® Connectivity

Real-time fieldbus interfaces are often used on automated production lines. Real time means that not only the transmission itself is secured but also the chronological sequence. That means that commands reach the individual devices in exactly the same sequential and chronological order that they were transmitted. Currently, the hexapod controllers support EtherCAT®. The required coordinate transformation for parallel kinematics are performed by the hexapod controller and do not affect the PLC.

Communication between the PLC and the Hexapod Controller

The high-level PLC operates in so-called CSP mode (Cyclic Synchronous Position Mode) and communicates with the hexapod controller via EtherCAT®. As master, it specifies the target positions or trajectories of the individual axes as Cartesian target coordinates in space and also reports the actual positions back to the fieldbus interface.

All other calculations required to command the parallel-kinematic six-axis system are done by the hexapod controller, i.e., transforming the target positions from Cartesian target coordinates into drive commands for the individual drives. On the bus, the hexapod system acts as an intelligent multi-axis drive.

PI Makes Hexapod Start Up Easy
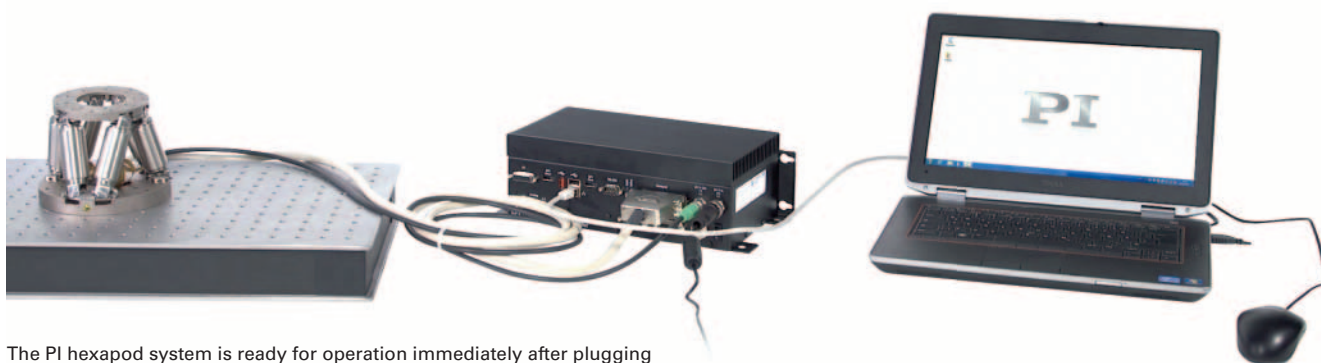
The PI hexapod system is ready for operation immediately after plugging

Every hexapod is delivered as a complete and factory-qualified system consisting of mechanics and controller ready for operation. The scope of delivery includes all communication cables and all connection cables as well as mounting material, software package and the full user documentation.

Extensive Software Package Included

PI provides PIMikroMove host software with graphical interface to make the start-up as easy and convenient as possibly. Even if several positioning systems are combined or different drive systems need to interact, all axes can be handled from one display window.

All connected controllers and axes are displayed and can be commanded in the same window, independently of the drive principle, and the number and configuration of the axes. You only need to enter your parameters into the application to avoid programming altogether.

PI software also supports a number of text-based languages, has its own NI LabVIEW, Python and MATLAB drivers, and the software is compatible with Windows, Linux, and OSX. The most recent software version is always available for download from the PI homepage.

In addition, PI Hexapods come with their own specific "Software Tools for Hexapods" such as the Hexapod Simulation Tool to calculate forces and workspace, and PIVeriMove to consider space restrictions. See the detailed description on p. ##

Individual System Measurement Log Provides Safety

Every Hexapod system is supplied with individual measurement and test protocols. The protocols include measurements covering both the entire travel range as well as individual sections. These measurements are performed with calibrated measurement devices such as interferometers and autocollimator based on a standardized procedure.

The following data can be found in the protocols:
- Positioning accuracy with motion in X, Y and Z,
- Unidirectional repeatability of a position with motion in X, Y and Z,
- Backlash with motion in X, Y and Z,
- Crosstalk in Z with motion in X and Y.

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Factory-Testing at PI
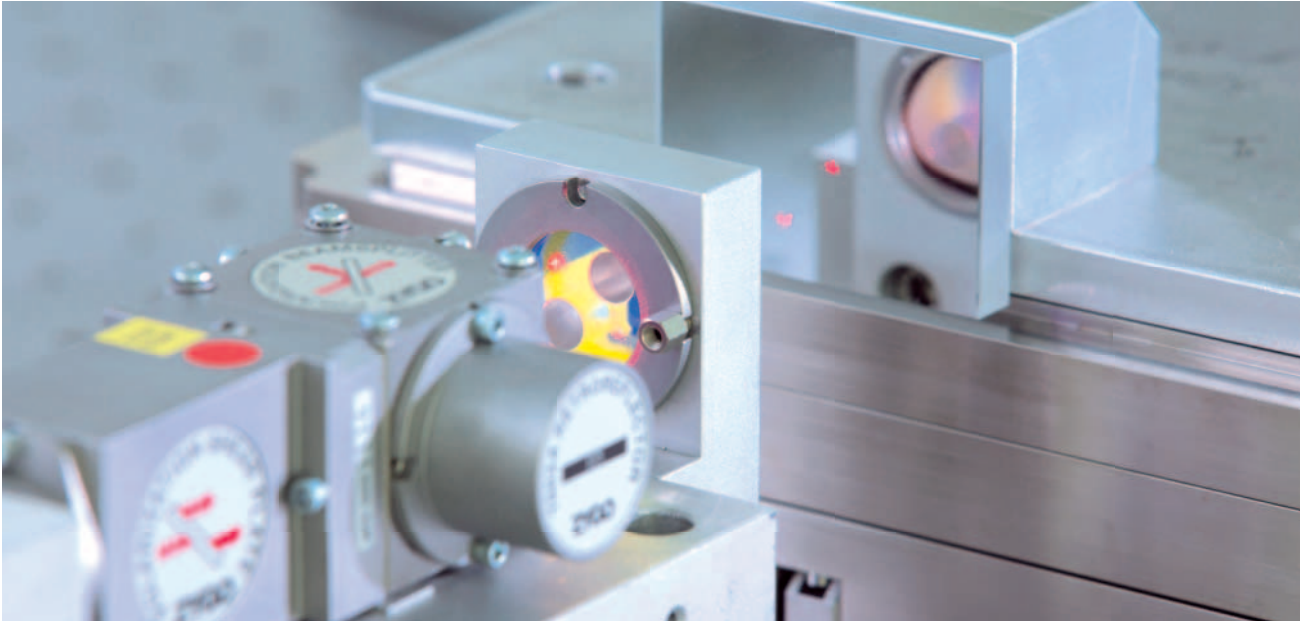
Laser interferometers measure the position exactly to the nanometer

The device is capable of lifting and rotating systems with a maximum weight of 7000 kg and up to 2 m diameter.

For PI, each individual measurement and qualification is an instrument for quality assurance. Automated qualification routines before dispatching ensure that the hexapod performance is well within the committed specifications.

Traceable, calibrated measuring equipment

PI uses high-resolution interferometers from leading manufacturers for precision path and length measuring that are accurate to within a few nanometers. Depending on the angular range, angle measurements are made with autocollimators, inclinometers, incremental rotary encoders or interferometers. For qualifying multi-axis systems such as hexapods special measuring equipment such as 3-D coordinate measuring machines and a 3-D laser tracker.

Installing and qualifying positioning systems weighing several tons

PI operates a heavy duty hall at its location in Karlsruhe for the assembly and measurement of masses up to five tons. A ground granite slab with a smoothness of 3.8 µm acts as assembly area. Air-cushioning elements also decouple the granite slab against external vibration. This allows precise alignment of the axes of a positioning system even during assembly.

To allow qualification of the behavior and specifications of heavy duty hexapods in a customer-relevant installation environment, a special lifting and rotating device is available. The lifting and rotating equipment allows infinite rotation of payloads up to seven tons around 360°. As both the product to be measured and the measuring device are mounted, PI ensures that only the actual motion of the products is measured.

PI

The PI Group – A Strong Partner for Industry and Research

The PI headquarters in Karlsruhe, Germany, manifests the continuous growth. In front, the 2017 Technology Center.

Over the last four decades, PI (Physik Instrumente) has developed into the leading manufacturer of nanopositioning technology. The key element and motivation of the entrepreneurial behavior have always remained the same: Finding the best possible solution for the customer.

PI is well known for the quality of its products and has been one of the leading players in the global market for precision positioning technology for many years. One of the most important building blocks for this is the team spirit within the international PI family, which is based on mutual understanding and support that goes beyond international borders and functional restrictions.

PI is a privately owned company with healthy growth, more than 1000 employees worldwide and a flexible, vertically integrated organization, which enables PI to fulfill almost any request in the field of innovative precision positioning technology. The foremost priority for PI is to be a reliable and highly qualified partner for the customer.

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 distinguish 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

Foundation of PI Ceramic in Thuringia, Germany, cornerstone for market leadership in nano-positioning technology

Market introduction of PILine® ultrasonic piezomotors

Founding year of PI

Market introduction of six-axis parallel-kinematic positioning systems (Hexapods)

Market introduction of capacitive position sensors, implementation in piezo-based nanopositioning systems

1970 **1987** **1991** **1992** **1993** **1994** **1998** **2001** **2002**

Market introduction of digital control electronics

New subsidiary in the USA

New subsidiary in Japan

New subsidiaries in Great Britain and France

New subsidiary in Italy

New subsidiary in China

Market introduction
of the magnetic
PIMag® direct drives

Acquisition
of majority shares
in miCos GmbH,
Eschbach, Germany

Market introduction
of the NEXLINE®
high-performance
piezo linear drives

Foundation
of PI Innovation

2018

2017

2016

2015

2014

2011

2007

2004

Acquisition of
majority shares
in ACS Motion
Control

ACS
MOTION CONTROL

Introduction
of air bearings

Acquisition
of Nelson
Air Corp., USA

PIRest active
shim piezo
technology

Market introduction
of Q-Motion®
and PiezoMikes

Market introduction
of NEXACT®
piezo linear drives

Engineered
motion
platforms

New subsidiaries
in Korea and
Singapore

New subsidiaries
in Taiwan and the
Netherlands

Expert Consulting

Time for qualified technical consultation is crucial for the success of high-tech projects

The PI Group can respond precisely to what customers want: Specific requirements can often only be satisfied by customized solutions – solutions that can be found by unconventional and creative thinking. Together with the customers, PI plans and realizes individual solutions for the most varied applications and integration levels. And that means that PI's customers can always be sure that they will get the best solution every time.

Customers directly benefit from:

Highly Qualified Consultancy Through Trained Specialists

Individual advice often is key to solve a complex problem. PI sales engineers are ready to come on site with all the time necessary for a solid understanding of the topic. Or they will gladly meet at the PI head office. All PI sales engineers have a background in natural sciences or engineering, and have up to 20 years of experience in optical, micro- or nanopositioning technology.

International Support

PI subsidiaries and distributors in many countries across the world guarantee global support – a decisive advantage, especially for globally operating customers. PI has its own sales and service offices in all important markets. Moreover, the company maintains testing devices for nanometrology on three continents. PI Shanghai and PI USA have additional development and manufacturing resources that allow rapid local reaction to custom-engineered specifications.

PI

Engineering Design Expertise and Customization
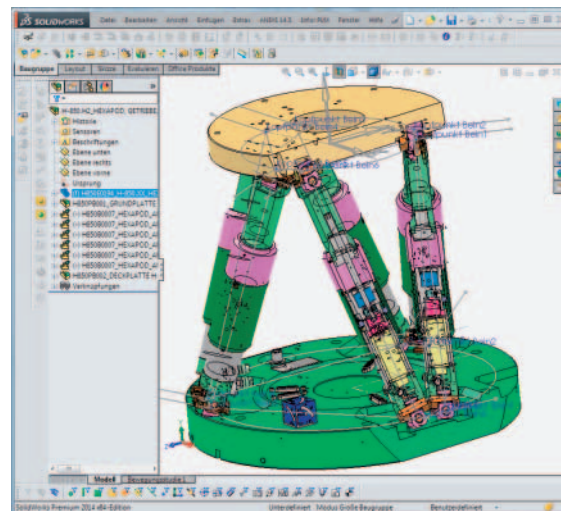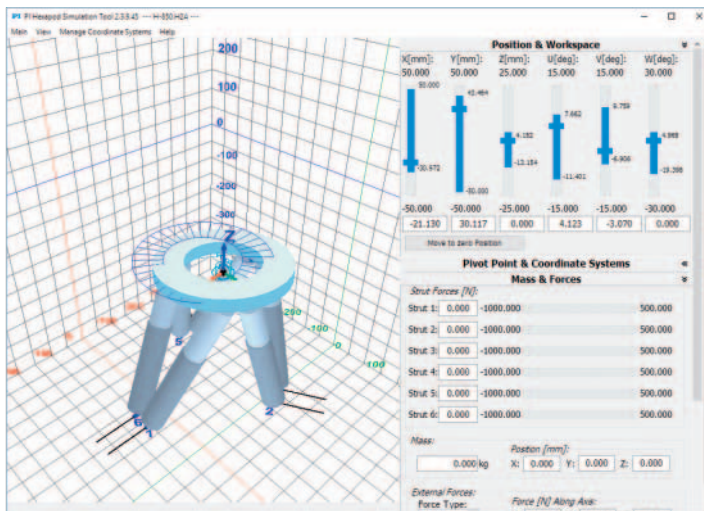
Unique Technological Breadth

The technological diversity of the PI Group is unrivalled 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. That puts PI in a position to offer its customers the most advanced products for motion and positioning tasks – without technological restriction.

Customized Solutions

With this background, PI develops positioning solutions with innovative drive technologies for high-tech applications worldwide. PI covers the whole motion range from finger-tip sized nanopositioners to large-scale stages with long travel ranges, through their plethora of different drive and guiding systems.

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

A software simulation helps to check and determine the exact requirements needed for a hexapod. The resulting forces, travel ranges, and installation space etc. then flow into the selection of components and the following construction. The geometrical date is also transferred to the corresponding controller. All in all, you get a perfectly matched six-axis positioning system.
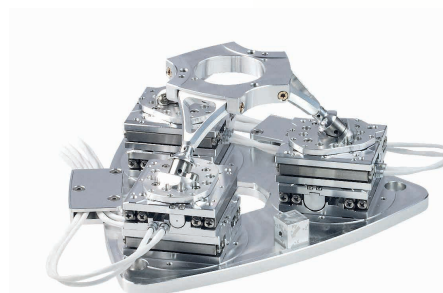
Production Capabilities

PI's flexibility in serial production allows for fast adaptation of both processes and quantities

A modern production management and an integrated management system allow PI to guarantee the high quality of its products, processes, and services. The continual improvement of organization and processes is an integral part of the corporate culture. KAIZEN workshops and an active innovation management are important elements for achieving this.

The production processes for the standard range are made flexible by the fractal production structure and it is therefore possible to manufacture even large series with full process control. Active, system-based requirements management makes it possible to dispense with comprehensive storage facilities.

Vertical Production Range and Production Capacity

The product spectrum ranging from the two-ton hexapod to the 10-gram nanopositioner requires PI to have the equipment and technologies at its disposal that allow the systems to be manufactured, assembled, and qualified.

- 13,000 m^2 of overall production space
- 5,000 m^2 for cleanrooms
- Air-conditioned and vibration-proof measuring conditions
- Vacuum chambers for startup and residual gas analysis
- Measuring technology with traceable, calibrated measuring equipment
- Monitoring of piezo actuator technology from material composition to final inspection
- In-house manufacturing of positioning sensors
- Production hall with measuring technology for heavy loads
- Fractal production organization
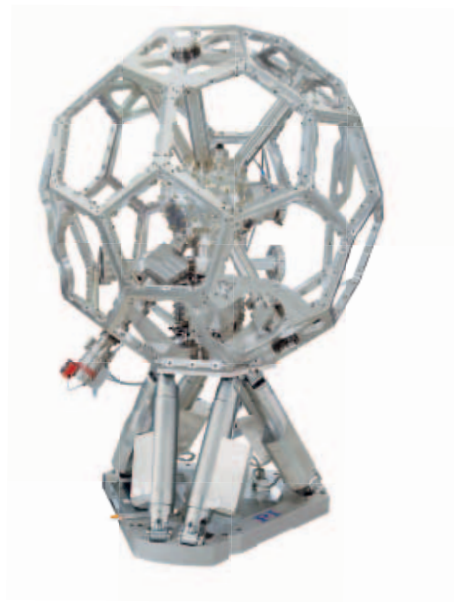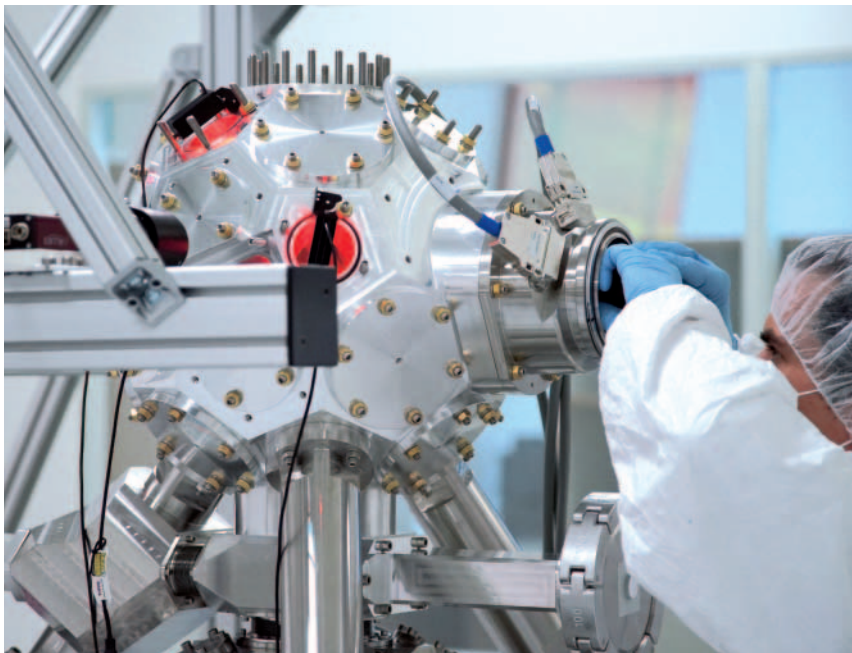
PI

Vacuum Know-How

High stiffness is required to position the vacuum sample chamber (above) and attached detectors for 4-pi-measurement of X-ray diffraction results. The large base hexapod moves the entire structure in six degrees of freedom and so positions it in the synchrotron beam.

PI offers high-precision solutions for positioning in vacuum conditions to 10^{-10} hPa. Positioning solutions in a vacuum follow clearly defined constraints. This applies to the limited installation space, as well as prevention of contamination and excessive heat input.

Selection of the optimum drive technology for the respective application and the mechanical design must be matched exactly to the required load capacity and velocity as well as the intended operating and planned duty cycles.

The handling regulations for vacuum positioning systems are just as important as the design principles. Cleanrooms are available for assembling larger parts. Suitable packaging and the corresponding instructions for the recipient are part of shipping.

Vacuum chambers are available in several sizes with vacuum levels down to 10^{-10} hPa, where start-up and measurement of outgassing, but also interferometric measuring of position accuracy under real operating conditions is possible.

At PI, several vacuum chambers are available in various sizes
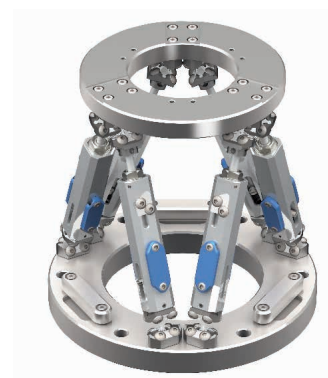
This customized, nonmagnetic, and HV-compatible hexapod is only 130 mm in height and has a diameter of 140 mm. Modified PiezoMike inertia drives serve as drives. With 5 mm/s, they are considerably faster than the classical PiezoMikes. A special joint construction ensures the necessary stiffness and at the same time, a long travel range of up to 10 mm.

From 1-off to Series:
OEM Users 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
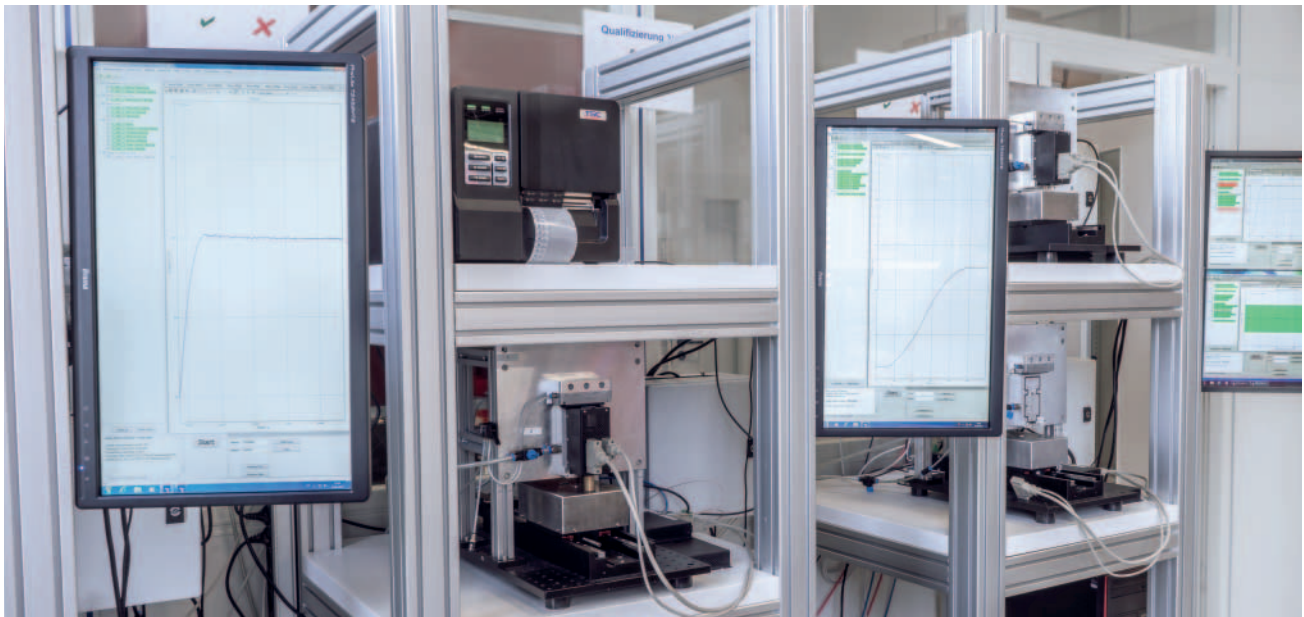
Standardized performance control with full documentation of individual measurement charts

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.

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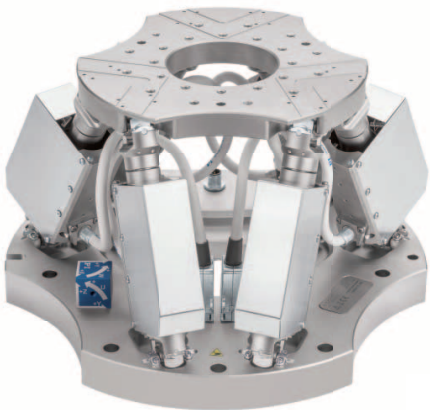
H-811.I2/I2V 6-Axis Miniature Hexapod

Fast, Compact, and Highly Precise

- Travel ranges to ±17 mm / ±21°
- Load capacity to 5 kg
- Repeatability to ±0.06 µm
- Velocity to 20 mm/s
- Superior lifetime
- Brushless DC motor (BLDC)
- Vacuum-compatible versions available

Parallel-kinematic design for six degrees of freedom making it significantly more compact and stiff than serial-kinematic systems, higher dynamic range, no moved cables: Higher reliability, reduced friction. Vacuum-compatible version to 10^{-6} hPa available.

Brushless DC motor (BLDC)

Brushless DC motors are particularly suitable for high rotational speeds. They can be controlled very accurately and ensure high precision. Because they dispense with sliding contacts, they run smoothly, are wear-free and therefore achieve a long lifetime.

Applications

- Optics alignment
- Fiber alignment
- Photonics testing
- Micro assembly
- Sample positioning

>> **Parallel Kinematics, Hexapods**
>> **Vacuum-Compatible Versions**

	H-811.I2 / .I2V**	Unit	Tolerance
	I2: High velocity I2V: Vacuum compatible to 10^{-6} hPa		
Motion and positioning			
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z		
Travel range* in X, Y	±17, ±16	mm	
Travel range* in Z	±6.5	mm	
Travel range* in θ_X, θ_Y	±10, ±10	°	
Travel range* in θ_Z	±21	°	
Actuator design resolution	5	nm	
Min. incremental motion X, Y	0.2	µm	typ.
Min. incremental motion Z	0.08	µm	typ.
Minimum incremental motion θ_X, θ_Y	2.5	µrad	typ.
Minimum incremental motion θ_Z	5	µrad	typ.
Backlash X, Y	0.2	µm	typ.
Backlash Z	0.06	µm	typ.
Backlash θ_X, θ_Y	2	µrad	typ.
Backlash θ_Z	4	µrad	typ.
Repeatability X, Y	±0.15	µm	typ.
Repeatability Z	±0.06	µm	typ.
Repeatability θ_X, θ_Y	±2	µrad	typ.
Repeatability θ_Z	±3	µrad	typ.
Max. velocity X, Y, Z	20 / 10	mm/s	
Max. velocity θ_X, θ_Y, θ_Z	500 / 250	mrad/s	
Typ. Velocity X, Y, Z	10 / 5	mm/s	
Typ. Velocity θ_X, θ_Y, θ_Z	240 / 120	mrad/s	
Mechanical properties			
Stiffness X / Y	0.7	N/µm	
Stiffness Z	8	N/µm	
Load capacity, horizontal base plate	5	kg	max.
Load capacity, base plate in any orientation	2.5	kg	max.
Holding force, power off, horizontal base plate	15	N	max.
Holding force, power off, base plate in any orientation	2.5	N	max.
Motor type	BLDC motor		
Miscellaneous			
Operating temperature range	0 to 50	°C	
Material	Stainless steel, aluminum		
Mass	2.2	kg	±5 %
Cable length	0.5 + 3 / 3 (air) + 2 (vacuum)	m	±10 mm
Recommended controller	C-887.5x		

Technical data specified at 20±3 °C.

* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent. The data for each axis
in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.

** For continuous operation in a vacuum, restrictions on operating parameters may be necessary due to heat generation.

Ask about customized versions.

H-811.I2, dimensions in mm

R44 ±0,15

3 F7

6

∅4,5 ±0,05 (3x120°)
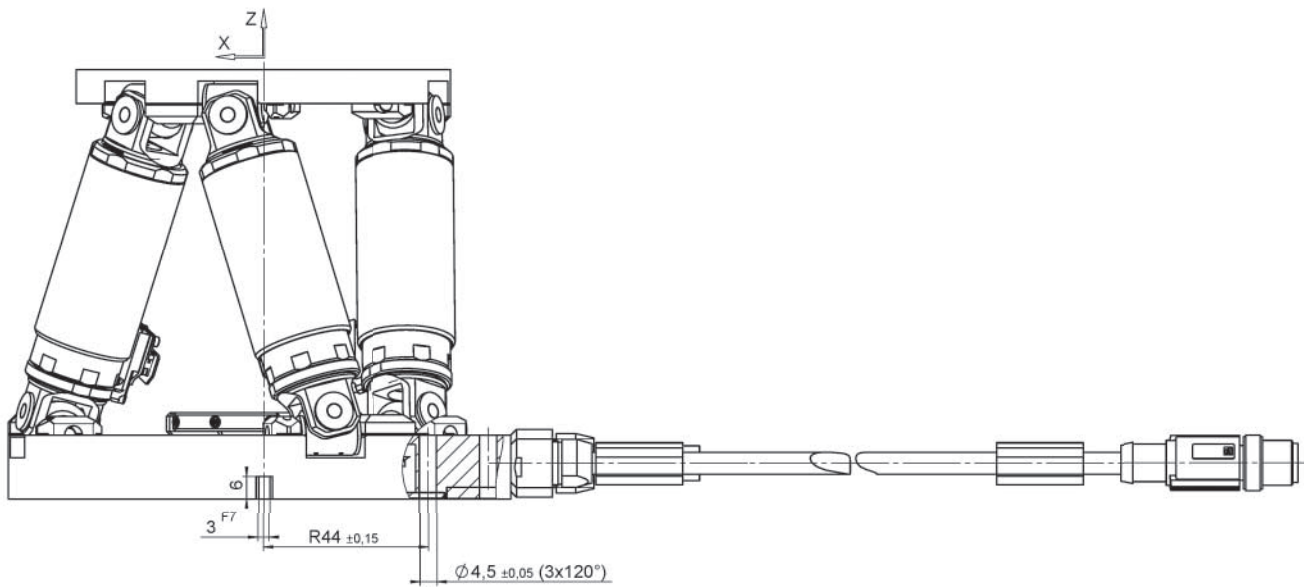
H-811.F2 6-Axis Miniature Hexapod

Ideal for Fiber Alignment

- Travel ranges to ±17 mm / ±21°
- Compact design
- Removable magnetic plate
- High dynamics and precision
- Freely programmable, virtual pivot point
- Superior lifetime
- Brushless DC motor (BLDC)

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

Brushless DC motor (BLDC)

Brushless DC motors are particularly suitable for high rotational speeds. They can be controlled very accurately and ensure high precision. Because they dispense with sliding contacts, they run smoothly, are wear-free and therefore achieve a long lifetime.

Removable magnetic plate

Accelerate your workflows. The next workpiece can be prepared parallel to our automated process step. The removable magnetic plate can be disassembled quickly without tools and subsequently reassembled accurately each time.

F-206.TMU Additional removable magnetic plate, for fast replacement of different assemblies, available as accessory

Applications

- Fiber alignment
- Photonics alignment

>> **Parallel Kinematics, Hexapods**

	H-811.F2	Unit	Tolerance
Motion and positioning			
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z		
Travel range* in X, Y	±17, ±16	mm	
Travel range* in Z	±6.5	mm	
Travel range* in θ_X, θ_Y,	±10, ±10	°	
Travel range* in θ_Z	±21	°	
Actuator design resolution	5	nm	
Min. incremental motion X, Y	0.2	µm	typ.
Min. incremental motion Z	0.08	µm	typ.
Minimum incremental motion θ_X, θ_Y,	2	µrad	typ.
Minimum incremental motion θ_Z	3	µrad	typ.
Backlash X, Y	0.2	µm	typ.
Backlash Z	0.06	µm	typ.
Backlash θ_X, θ_Y,	2	µrad	typ.
Backlash θ_Z	3	µrad	typ.
Repeatability X, Y	±0.15	µm	typ.
Repeatability Z	±0.06	µm	typ.
Repeatability θ_X, θ_Y,	±2	µrad	typ.
Repeatability θ_Z	±3	µrad	typ.
Max. velocity X, Y, Z	20	mm/s	
Max. velocity θ_X, θ_Y, θ_Z	500	mrad/s	
Typ. Velocity X, Y, Z	10	mm/s	
Typ. Velocity θ_X, θ_Y, θ_Z	240	mrad/s	
Alignment			
Scanning time of spiraled area scan 500 µm Ø**	<2	s	
Scanning time of spiraled area scan 100 µm Ø**	<0.5	s	
Scanning time of spiraled area scan 10 µm Ø**	<0.2	s	
Mechanical properties			
Stiffness X / Y	0.7	N/µm	
Stiffness Z	8	N/µm	
Load capacity (horizontal base plate / any orientation)	5 / 2.5	kg	max.
Holding force, power off (horizontal base plate / any orientation)	12 / 2	N	max.
Motor type	BLDC motor		
Miscellaneous			
Operating temperature range	0 to 50	°C	
Material	Stainless steel, aluminum		
Mass	2.2	kg	±5 %
Cable length	2	m	±10 mm
Recommended controller	C-887.5x		

Technical data specified at 20±3 °C.

* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent. The data for each axis
in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.

** Typical time period to scan the full area and move to the maximum intensity

Ask about customized versions.

H-811.F2, dimensions in mm

PI

Pivot Point (0,0,0)

A-A
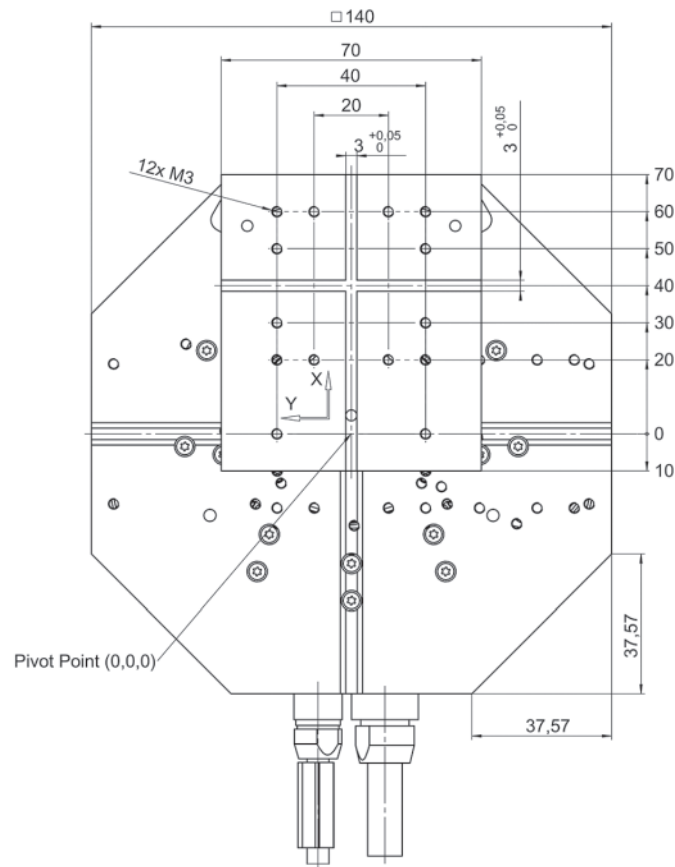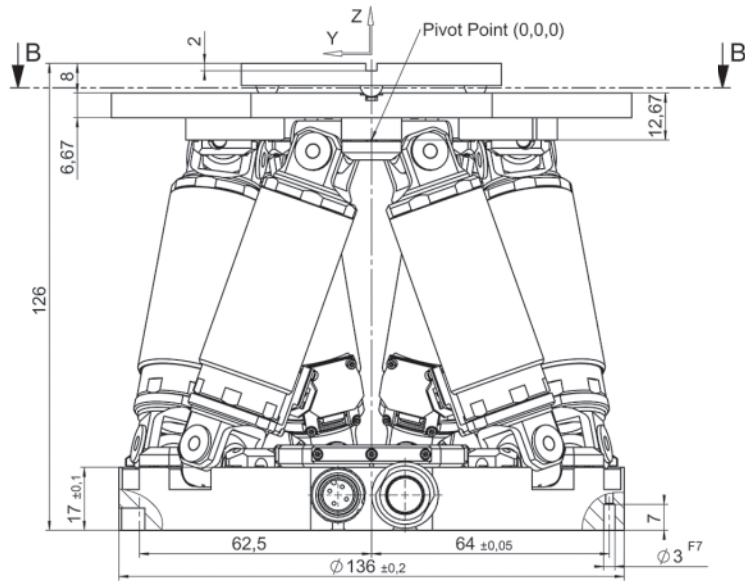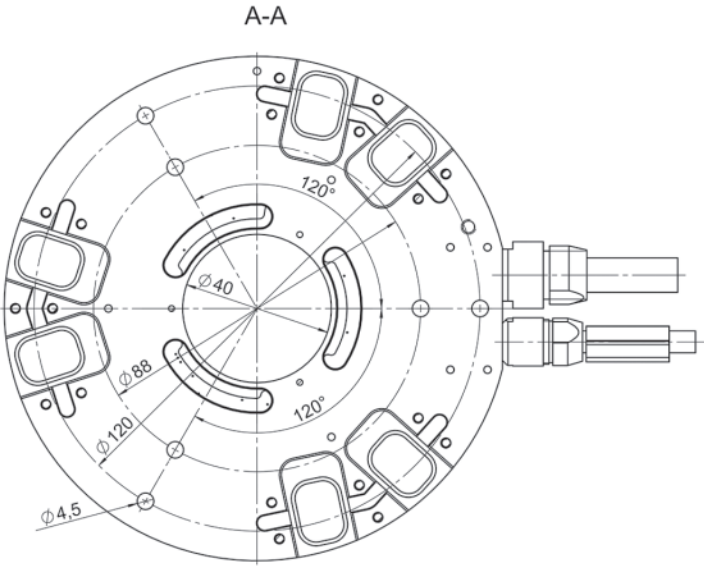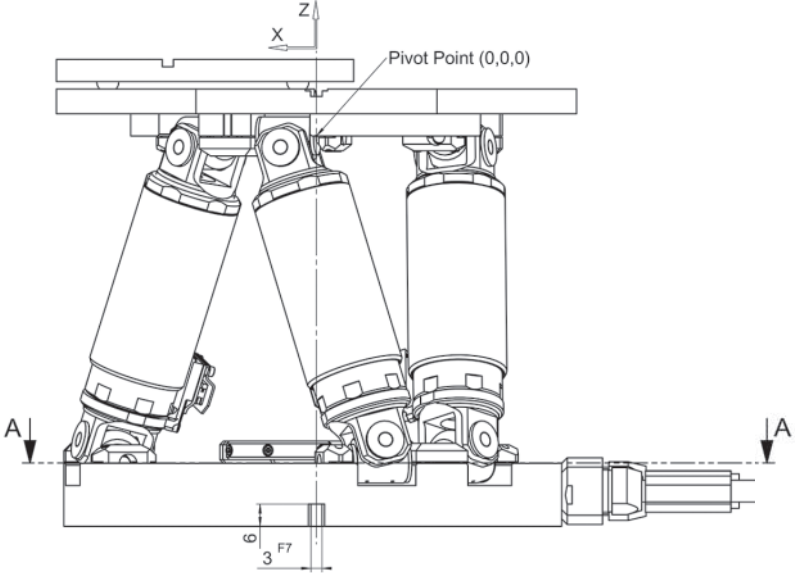
H-810 6-Axis Miniature Hexapod

High Precision in the Smallest Space

- Travel ranges to 40 mm / 60°
- Load capacity to 5 kg
- Repeatability to ±0.1 µm
- Velocity to 2.5 mm/s
- Brushless DC motor (BLDC)
- Works in any orientation
- Virtual pivot point

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

Brushless DC motor (BLDC)

Brushless DC motors are particularly suitable for high rotational speeds. They can be controlled very accurately and ensure high precision. Because they dispense with sliding contacts, they run smoothly, are wear-free and therefore achieve a long lifetime.

Applications

- Mirror positioning

	H-810.D2	Unit	Tolerance
Motion and positioning			
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z		
Travel range* X, Y	±20	mm	
Travel range* Z	±6.5	mm	
Travel range* θ_X, θ_Y	±10	°	
Travel range* θ_Z	±30	°	
Actuator design resolution	40	nm	
Min. incremental motion X, Y	1	µm	typ.
Min. incremental motion Z	0.5	µm	typ.
Minimum incremental motion θ_X, θ_Y	15	µrad	typ.
Minimum incremental motion θ_Z	30	µrad	typ.
Backlash X, Y	1	µm	typ.
Backlash Z	0.5	µm	typ.
Backlash θ_X, θ_Y	15	µrad	typ.
Backlash θ_Z	30	µrad	typ.
Repeatability X, Y	±0.5	µm	typ.
Repeatability Z	±0.1	µm	typ.
Repeatability θ_X, θ_Y	±3	µrad	typ.
Repeatability θ_Z	±15	µrad	typ.
Max. velocity X, Y, Z	2.5	mm/s	
Max. velocity θ_X, θ_Y, θ_Z	60	mrad/s	
Typ. Velocity X, Y, Z	2	mm/s	
Typ. Velocity θ_X, θ_Y, θ_Z	50	mrad/s	
Mechanical properties			
Load capacity (horizontal base plate / any orientation)	5 / 2.5	kg	max.
Holding force (horizontal base plate)	15	N	max.
Motor type	Brushless DC motor		
Miscellaneous			
Operating temperature range	0 to 50	°C	
Material	Stainless steel, aluminum		
Mass	1.7	kg	±5 %
Cable length	2	m	±10 mm
Recommended controller	C-887.5x		

Technical data specified at 20±3 °C.

* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent. The data for each axis
in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.

Ask about customized versions.

H-810, dimensions in mm

$\varnothing\,100 \pm 0{,}15$
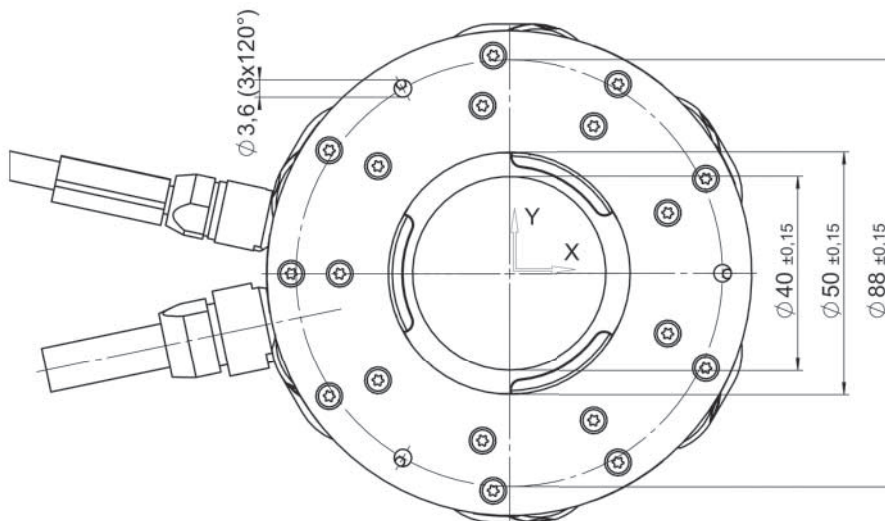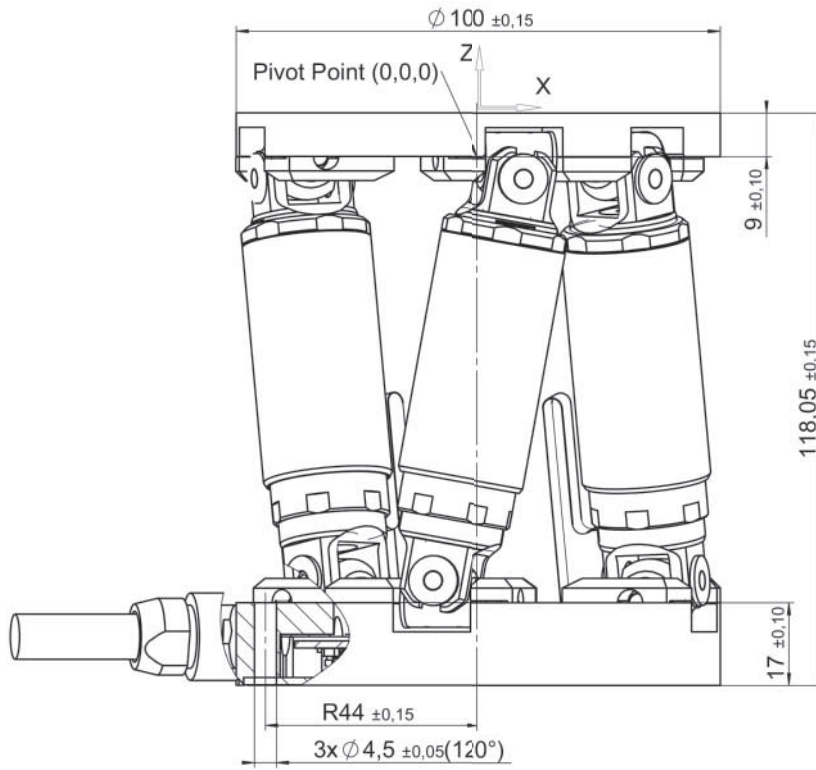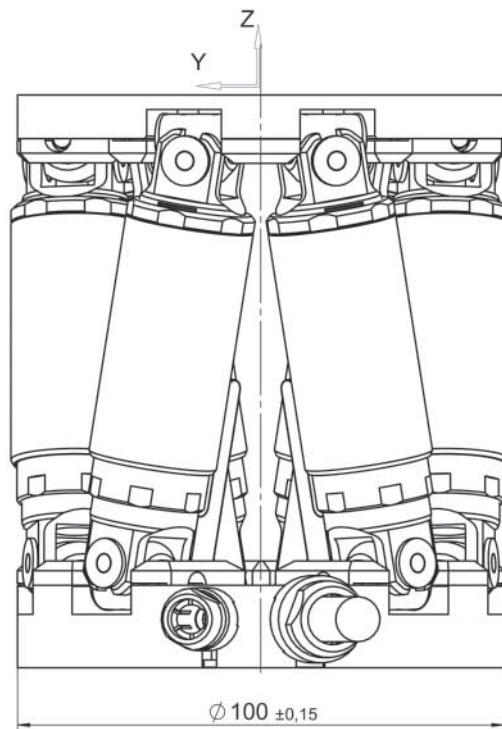
H-825 6-Axis Hexapod

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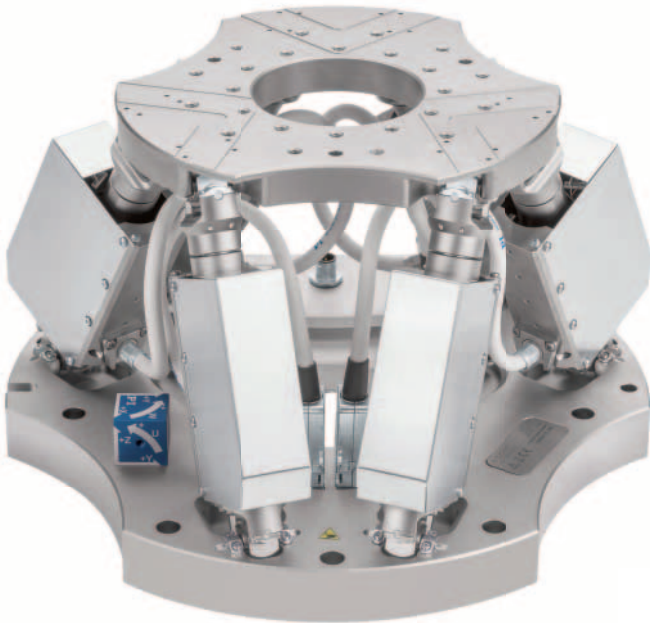
- Load capacity to 30 kg, self-locking
- Travel ranges to ±27.5 mm, rotation range to ±11.5°
- Actuator resolution to 8 nm
- Minimum incremental motion to 0.25 µm in X, Y, and Z
- Repeatability to ±0.1 µm / ±2 µrad
- BLDC motors and absolute encoders

H-825, dimensions in mm
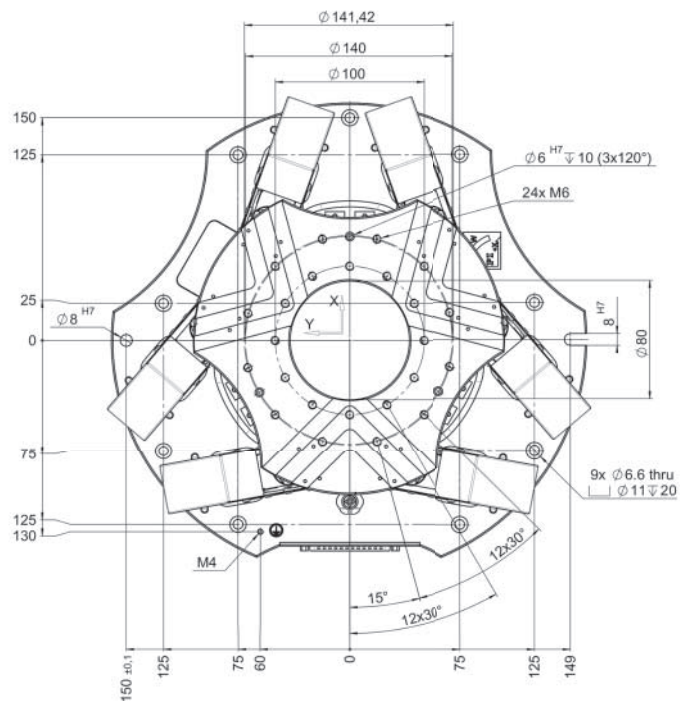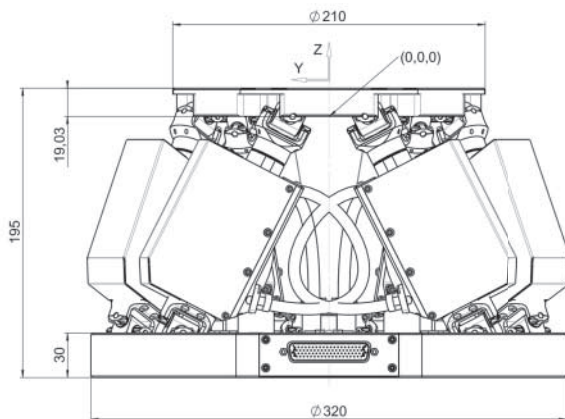
Applications

- Micro manipulation
- Micro assembly
- Optics alignment
- Sample positioning

>> **Absolute Encoder**

>> **Parallel Kinematics, Hexapods**

|	H-825.G2A	H-825.D2A	Unit	Tolerance
	High load capacity and holding force, no homing required	High velocity, no homing required		
Motion and positioning				
	BLDC gear motor with absolute encoder	BLDC motor with absolute encoder		
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z		
Travel range in X,Y *	±27.5; ±25	±27.5; ±25	mm	
Travel range in Z *	±14	±14	mm	
Travel range in θ_X, θ_Y *	±11.5; ±10.5	±11.5; ±10.5	°	
Travel range in θ_Z *	±19	±19	°	
Actuator design resolution	0.008	0.25	µm	
Minimum incremental motion in X,Y,Z	0.3; 0.3; 0.25	1; 1; 0.5	µm	typ.
Minimum incremental motion in θ_X, θ_Y, θ_Z	3.5; 3.5; 4	7; 7; 12	µm	
Backlash in X,Y	3	1.5	µm	typ.
Backlash in Z	1	1	µm	typ.
Backlash in θ_X, θ_Y	20	15	µrad	typ.
Backlash in θ_Z	25	25	µrad	typ.
Repeatability X,Y	±0.5; ±0.25	±0.5	µm	typ.
Repeatability in Z	±0.1	±0.15	µm	typ.
Repeatability in θ_X, θ_Y	±2	±2; ±1.5	µrad	typ.
Repeatability in θ_Z	±2.5	±3	µrad	typ.
Max. velocity in X,Y,Z	2.5	25	mm/s	
Max. velocity in θ_X, θ_Y, θ_Z	27	270	mrad/s	
Typ. velocity on X,Y,Z	2	20	mm/s	
Typ. velocity on θ_X, θ_Y, θ_Z	5.5	55	mrad/s	
Mechanical properties				
Stiffness in X,Y	1.7	1.7	N/µm	
Stiffness in Z	7	7	N/µm	
Load capacity (horizontal base plate / any orientation)	30 / 10	5 / 2.5	kg	max.
Holding force, power off (horizontal base plate / any orientation)	100 / 50	10 / 5	N	max.
Motor type	BLDC gear motor	BLDC motor		
Miscellaneous				
Operating temperature range	–10 to 50	–10 to 50	°C	
Material	Aluminum	Aluminum		
Mass	10	10	kg	±10 %
Recommended controller	C-887.5x	C-887.5x		

Technical data specified at 20±3 °C.
* The travel ranges of the individual coordinates (X,Y, Z, θ_X, θ_Y, θ_Z) are interdependent. The data for each axis
  in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.
Ask about customized versions.

H-824 6-Axis Hexapod

Compact and Precise

- Load capacity to 10 kg, self-locking version
- Travel ranges to 45 mm / 25°
- Min. incremental motion to 0.3 μm
- Repeatability to ±0.1 μm / ±2 μrad
- Velocity to 25 mm/s
- Vacuum-compatible versions available

H-824, dimensions in mm
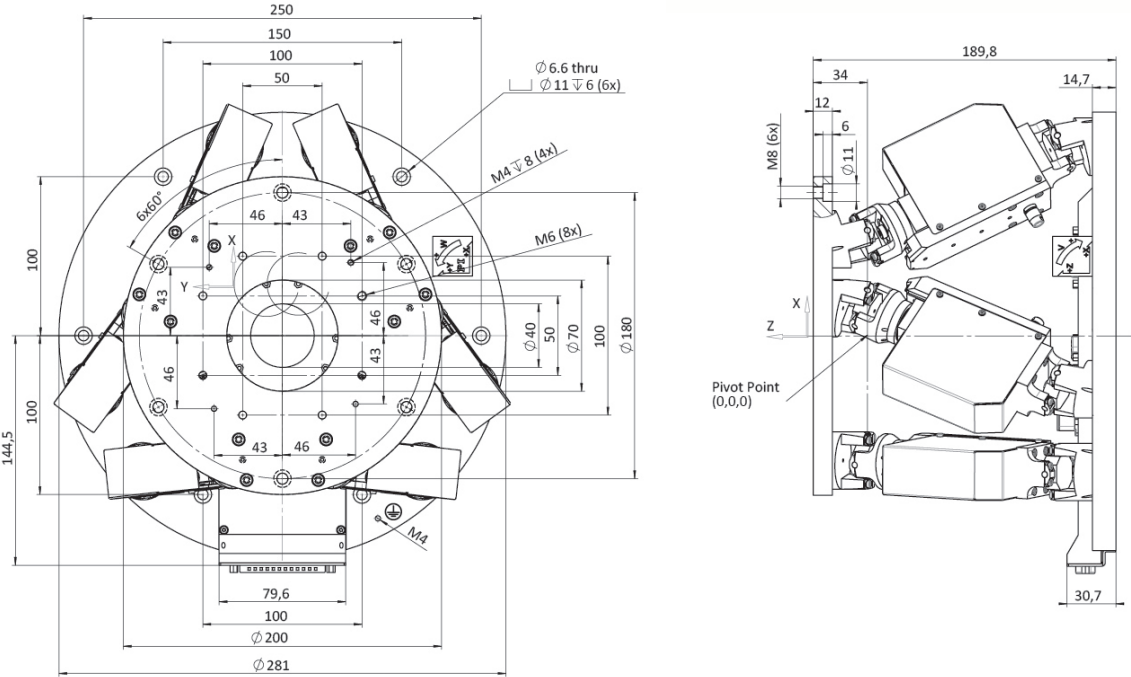
Applications

- Micro manipulation
- Micro assembly
- Optics alignment
- Sample positioning

>> **Parallel Kinematics, Hexapods**

>> **Vacuum-Compatible Versions**

Technology Glossary ………………… page **124**

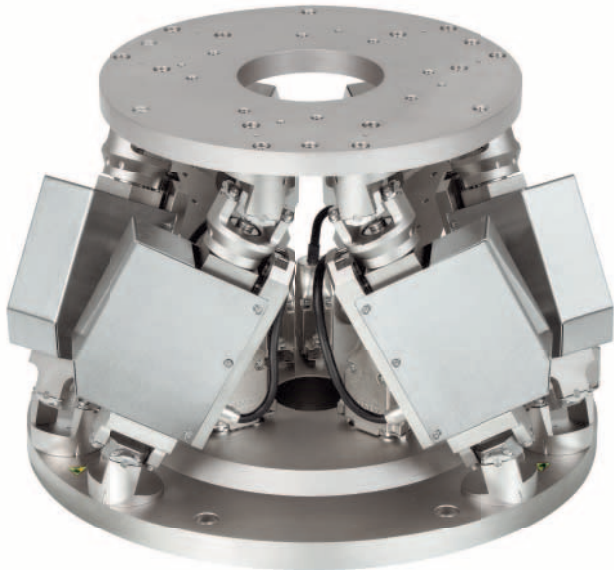|	H-824.G2 / G2V**	H-824.D2 / D2V**	Unit	Tolerance
Motion and positioning				
	for higher resolution and load G2V: Vacuum compatible to 10^{-6} hPa	for higher velocity D2V: Vacuum compatible to 10^{-6} hPa		
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z		
Travel range* in X, Y	±22.5	±22.5	mm	
Travel range* in Z	±12.5	±12.5	mm	
Travel range* in θ_X, θ_Y	±7.5	±7.5	°	
Travel range* in θ_Z	±12.5	±12.5	°	
Actuator design resolution	0.007	0.5	µm	
Minimum incremental motion X, Y, Z	0.3	2; 2; 1	µm	typ.
Minimum incremental motion θ_X, θ_Y, θ_Z	3.5	12; 12; 14	µrad	typ.
Backlash X, Y	2 / 5	1.5 / 3	µm	typ.
Backlash Z	0.7 / 1.5	1 / 1.5	µm	typ.
Backlash θ_X, θ_Y	14 / 30	15 / 20	µrad	typ.
Backlash θ_Z	17 / 45	30 / 60	µrad	typ.
Repeatability X, Y	±0.25 / ±0.4	±0.5	µm	typ.
Repeatability Z	±0.1	±0.15	µm	typ.
Repeatability θ_X, θ_Y	±2	±3	µrad	typ.
Repeatability θ_Z	±2 / ±3	±2.5	µrad	
Max. velocity X, Y, Z	1 / 0.5	25 / 12.5	mm/s	
Max. velocity θ_X, θ_Y, θ_Z	11 / 5.5	270 / 135	mrad/s	
Typ. Velocity X, Y, Z	0.5 / 0.2	10 / 5	mm/s	
Typ. Velocity θ_X, θ_Y, θ_Z	5.5 / 2.3	55 / 28	mrad/s	
Mechanical properties				
Stiffness X / Y	1.7	1.7	N/µm	
Stiffness Z	7	7	N/µm	
Load capacity, horizontal base plate	10 / 5	5 / 2.5	kg	max.
Load capacity, base plate in any orientation	5 / 2.5	2.5 / 1.25	kg	max.
Holding force, power off, horizontal base plate	100 / 50	15	N	max.
Holding force, power off, base plate in any orientation	50 / 25	5	N	max.
Motor type	DC gear motor	DC motor		
Miscellaneous				
Operating temperature range	−10 to 50	−10 to 50	°C	
Material	Aluminum	Aluminum		
Mass	8	8	kg	±5 %
Cable length	3	3	m	±10 mm
Recommended controller	C-887.5x	C-887.5x		

Technical data specified at 20±3 °C.

* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent. The data for each axis in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.

** For continuous operation in a vacuum, restrictions on operating parameters may be necessary due to heat generation. Ask about customized versions.

H-206 6-Axis Alignment System

Ideal for Fiber Alignment

- High-precision due to flexures
- Integrated scan routines for fiber optic alignment
- Repeatability 0.3 µm
- Velocity to 8 mm/s
- Freely programmable virtual pivot point
- Removable magnetic plate

H-206.F2, dimensions in mm
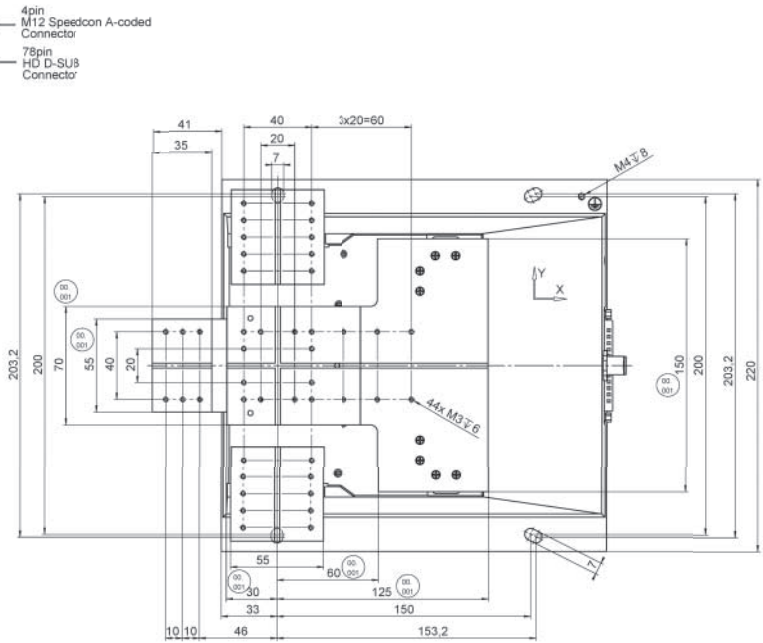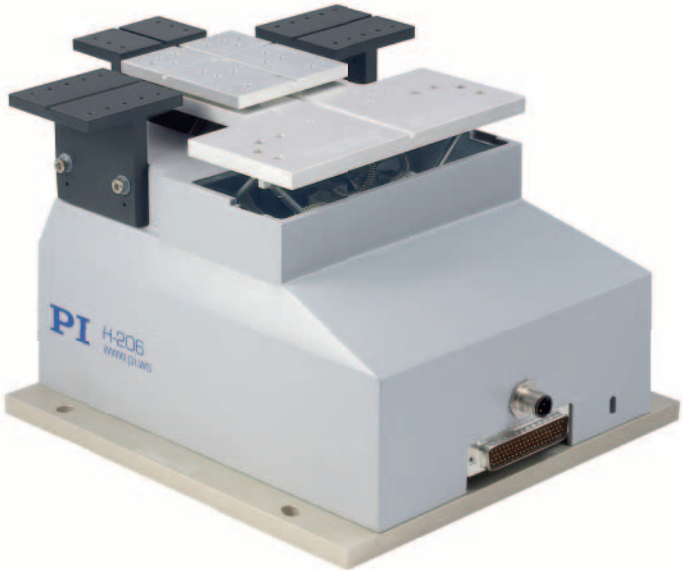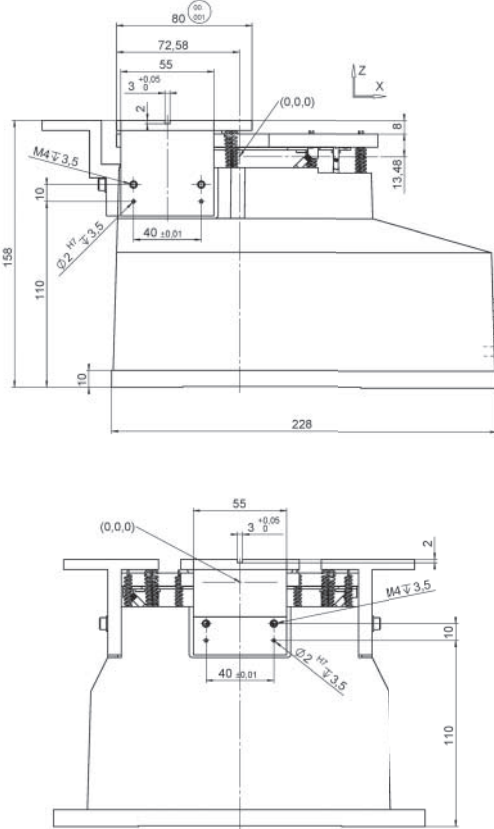
Applications

- Fiber alignment
- Photonics alignment

>> **Parallel Kinematics, Hexapods**

Technology Glossary .... page **124**

	H-206.F2	Unit	Tolerance
Motion and positioning			
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z		
Travel range* X	−8 to 5.7	mm	
Travel range* Y	±5.7	mm	
Travel range* Z	±6.7	mm	
Travel range* θ_X	±5.7	°	
Travel range* θ_Y	±6.6	°	
Travel range* θ_Z	±5.5	°	
Actuator design resolution	33	nm	
Minimum incremental motion X, Y, Z	0.5	µm	typ.
Minimum incremental motion θ_X, θ_Y, θ_Z	2 (0.4")	µrad	typ.
Repeatability X, Y, Z	0.3	µm	typ.
Repeatability θ_X, θ_Y, θ_Z	6	µrad	typ.
Velocity X, Y, Z	8	mm/s	max.
Velocity X, Y, Z	2	mm/s	typ.
Load capacity (horizontal base plate)	1.5	kg	max.
Miscellaneous			
Operating temperature range	5 to 35	°C	
Material	Aluminum		
Mass	5.8	kg	±5 %
Cable length	3	m	±10 mm
Recommended controller	C-887.5x		

Technical data specified at 20±3 °C.

* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent. The data for each axis in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.
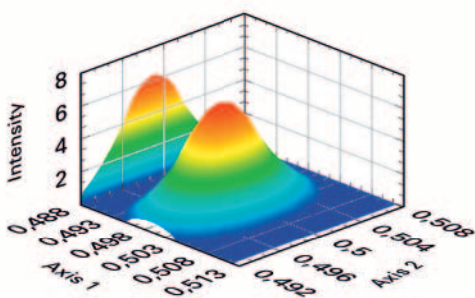
Ask about customized versions.

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

F-206.TMU Additional removable magnetic plate, for fast replacement of different assemblies, available as accessory

Q-821 Q-Motion® Miniature SpaceFAB Robot

Piezo-Motorized Inertia Drive, only 80 mm Side Length

Q-821.140, dimensions in mm

- Six-axis microrobotics system
- ±6 mm travel range in X and Y, and ±3 mm in Z
- ±6° rotation range in θ_X, θ_Y, and ±16.5° in θ_Z
- 1 nm sensor resolution
- Crossed roller guides, anti-creep

Applications

- Fine adjustment of the smallest components during assembly
- Photonics / Alignment Applications
- Microscopy
- Beamline systems
- Semiconductor technology
- Test laboratories

>> **Parallel Kinematics, Hexapods**

>> **Q-Motion® Piezoelectric Inertia Drive**

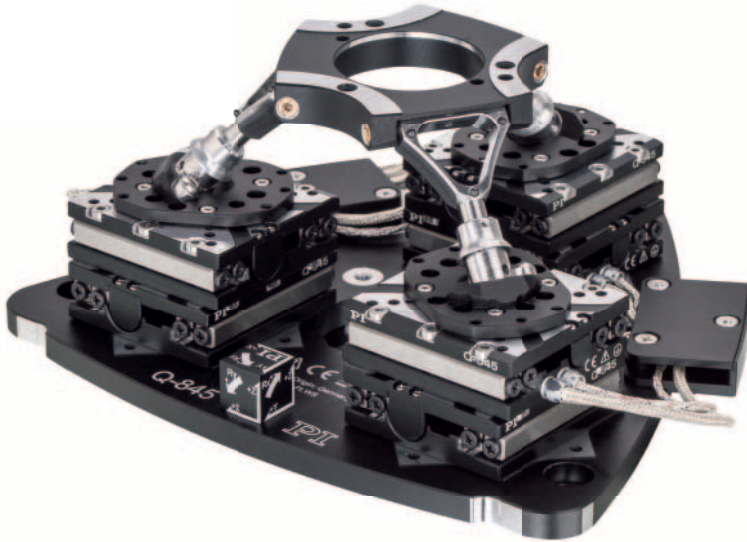|	Q-821.140	Unit	Tolerance
Motion and positioning			
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z		
Integrated sensor	Incremental, optical, direct measuring		
Travel range in X, Y	±6	mm	
Travel range in Z	±3	mm	
Rotation range in θ_X, θ_Y	±6	°	
Rotation range in θ_Z	±16.5	°	
Sensor resolution	1	nm	
Minimum incremental motion in X, Y	10	nm	typ.
Minimum incremental motion in Z	20	nm	typ.
Minimum incremental motion in θ_X, θ_Y, θ_Z	0.9	µrad	typ.
Unidirectional repeatability in X	±40	nm	typ.
Unidirectional repeatability in Y	±70	nm	typ.
Unidirectional repeatability in Z	±200	nm	typ.
Backlash in X, Y	40	nm	
Backlash in Z	80	nm	
Backlash in θ_X, θ_Y	45	µrad	
Backlash in θ_Z	25	µrad	
Max. speed in X, Y	5	mm/s	
Max. speed in Z	2	mm/s	
Mechanical properties			
Load capacity in X, Y	1	N	max.
Load capacity in Z (base plate horizontal)	2	N	max.
Holding force in X, Y, Z, passive	3	N	
Drive type	Piezoelectric inertia drive		
Guide type	Crossed roller bearings		
Miscellaneous			
Connection	6x Sub-D 15 (m)		
Material	Stainless steel, aluminum		
Mass without cable and connector	0.3	kg	±5 %
Cable length	2	m	±10 mm
Recommended electronics	C-886.31		

Q-845 Q-Motion® SpaceFAB

High Precision and High Stiffness
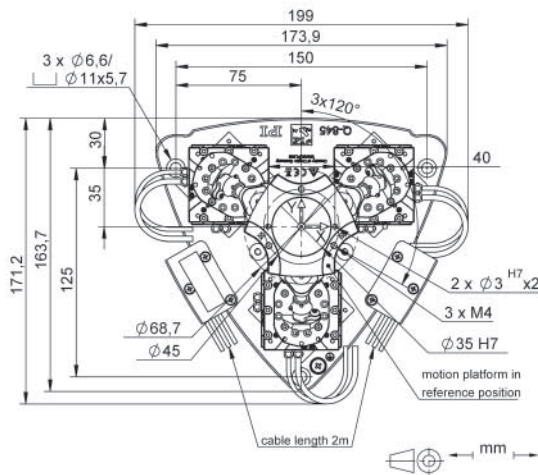
- Six degrees of freedom
- ±7 mm travel range in X and Y, and ±5 mm in Z
- ±7° rotation range in θ_X, θ_Y, and ±8° in θ_Z
- 10 N load capacity, center mounted
- Self-locking, no heat generation at rest
- Crossed roller guides, anti-creep
- Vacuum-compatible to 10^{-6} hPa

Top view of the Q-845.140, dimensions in mm.
The reference position corresponds to the center position of all axes.

Bottom and side view of the Q-845.140, dimensions in mm.
The reference position corresponds to the center position of all axes.
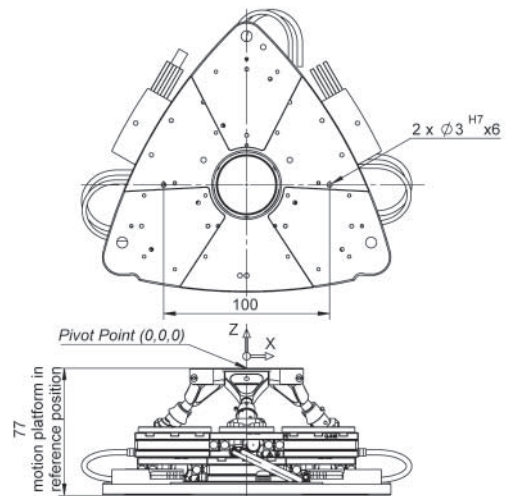
Applications

- Fine adjustment of the smallest components during assembly
- Photonics / Alignment Applications
- Microscopy
- Beamline systems
- Semiconductor technology
- Test laboratories

>> **Parallel Kinematics, Hexapods**
>> **Q-Motion® Piezoelectric Inertia Drive**
>> **Vacuum-Compatible Versions**

	Q-845.140	Unit	Tolerance
Motion and positioning			
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z		
Integrated sensor	Incremental linear encoder		
Travel range* in X, Y	±7	mm	
Travel range* in Z	±5	mm	
Rotation range* in θ_X, θ_Y	±7	°	
Rotation range* in θ_Z	±8	°	
Sensor resolution	1	nm	
Minimum incremental motion in X, Y	6	nm	typ.
Minimum incremental motion in Z	20	nm	typ.
Minimum incremental motion in θ_X, θ_Y, θ_Z	0.9	μrad	typ.
Unidirectional repeatability in X, Y	±30	nm	typ.
Unidirectional repeatability in Z	±35	nm	typ.
Unidirectional repeatability in θ_X	±20	μrad	typ.
Unidirectional repeatability in θ_Y	±10	μrad	typ.
Unidirectional repeatability in θ_Z	±6	μrad	typ.
Backlash in X, Y	40	nm	typ.
Backlash in Z	60	nm	typ.
Backlash in θ_X, θ_Y	35	μrad	typ.
Backlash in θ_Z	20	μrad	typ.
Max. velocity in X, Y, Z	5	mm/s	max.
Max. angular velocity in θ_X, θ_Y, θ_Z	50	mrad/s	max.
Mechanical properties			
Stiffness in X, Y	1	N/μm	
Stiffness in Z	2	N/μm	
Load capacity in X, Y	5	N	max.
Load capacity in Z (base plate horizontal)	10	N	max.
Holding force, power off (base plate horizontal / any orientation)	20 / 10	N	max.
Permissible torque in θ_X, θ_Y, θ_Z	0.5	N·m	max.
Drive type	Piezoelectric Inertia Drive		
Miscellaneous			
Operating temperature range	0 to 40	°C	
Connection	6x Sub-D 15 (m)		
Material	Stainless steel, aluminum		
Mass	1.9	kg	±5 %
Mass without cable and connector	1.2	kg	±5 %
Cable length	2	m	±10 mm

Technical data specified at 20±3 °C.

Ask about custom designs!

* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent.
  The data for each axis in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.

For operation in a vacuum, we recommend a reduced duty cycle of 20 % and a maximum motor push / pull force of 30 % compared to a standard environment.
The intrinsic mass of the slider plate must be considered accordingly.

N-865 NEXACT® SpaceFAB

6 Degrees of Freedom, Highest Precision, Low-Profile Hexapod Design

N-865.160, dimensions in mm
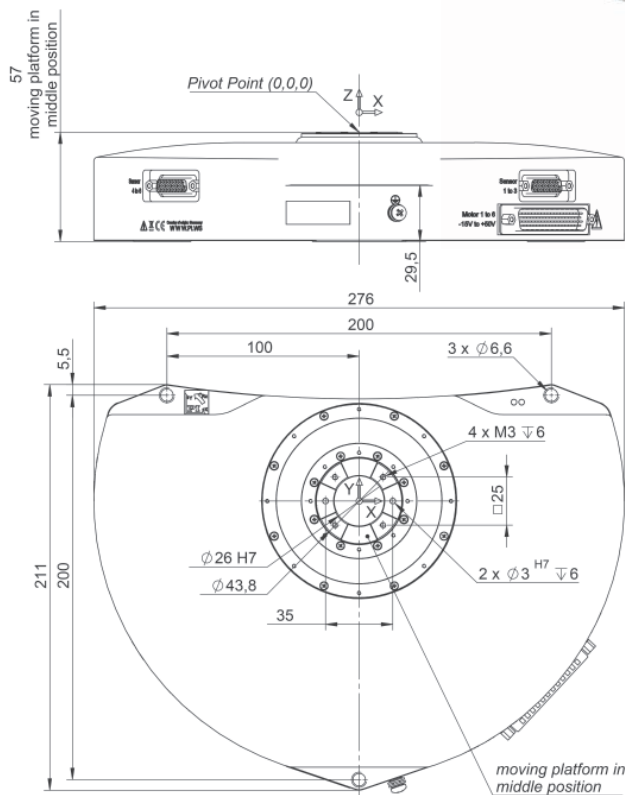
- Six degrees of freedom
- Clear aperture
- Sensor resolution 0.5 nm
- 15 N load capacity
- Self-locking when switched off: Saves energy and reduces generation of heat
- Crossed roller guides, anti-creep

Applications

- Fine adjustment of the smallest components during assembly
- Photonics / Alignment Applications
- Microscopy
- Beamline systems
- Semiconductor technology
- Test laboratories

>> **NEXACT® Piezo walking drive**
>> **Parallel Kinematics, Hexapods**
>> **PIOne Linear Encoder**
>> **Vacuum-Compatible Versions**

	N-865.160	Unit	Tolerance
Motion and positioning			
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z		
Integrated sensor	Incremental linear encoder PIOne		
Travel range* in X, Y	±6.5	mm	
Travel range* in Z	±5	mm	
Rotation range* in θ_X, θ_Y	±7	°	
Rotation range* in θ_Z	±8	°	
Sensor resolution	0.5	nm	
Minimum incremental motion in X, Y	2	nm	typ.
Minimum incremental motion in Z	2	nm	typ.
Minimum incremental motion in θ_X, θ_Y, θ_Z	0.2	µrad	typ.
Unidirectional repeatability in X	±40	nm	typ.
Unidirectional repeatability in Y	±30	nm	typ.
Unidirectional repeatability in Z	±20	nm	typ.
Unidirectional repeatability in θ_X	±5	µrad	typ.
Unidirectional repeatability in θ_Y	±7	µrad	typ.
Unidirectional repeatability in θ_Z	±7	µrad	typ.
Backlash in X	70	nm	typ.
Backlash in Y	30	nm	typ.
Backlash in Z	20	nm	typ.
Backlash in θ_X	12	µrad	typ.
Backlash in θ_Y	9	µrad	typ.
Backlash in θ_Z	4	µrad	typ.
Mechanical properties			
Load capacity in X, Y	7.5	N	max.
Load capacity in Z (base plate horizontal)	15	N	max.
Drive type	NEXACT® piezo walking drive		
Miscellaneous			
Connection	HD Sub-D 78 (m)		
Sensor connection	2x HD Sub-D 26 (f)		
Material	Stainless steel, aluminum		
Mass	3.9	kg	±5 %
Operating temperature range	10 to 50	°C	

Technical data specified at 20±3 °C.

Ask about custom designs!

* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent.
The data for each axis in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.
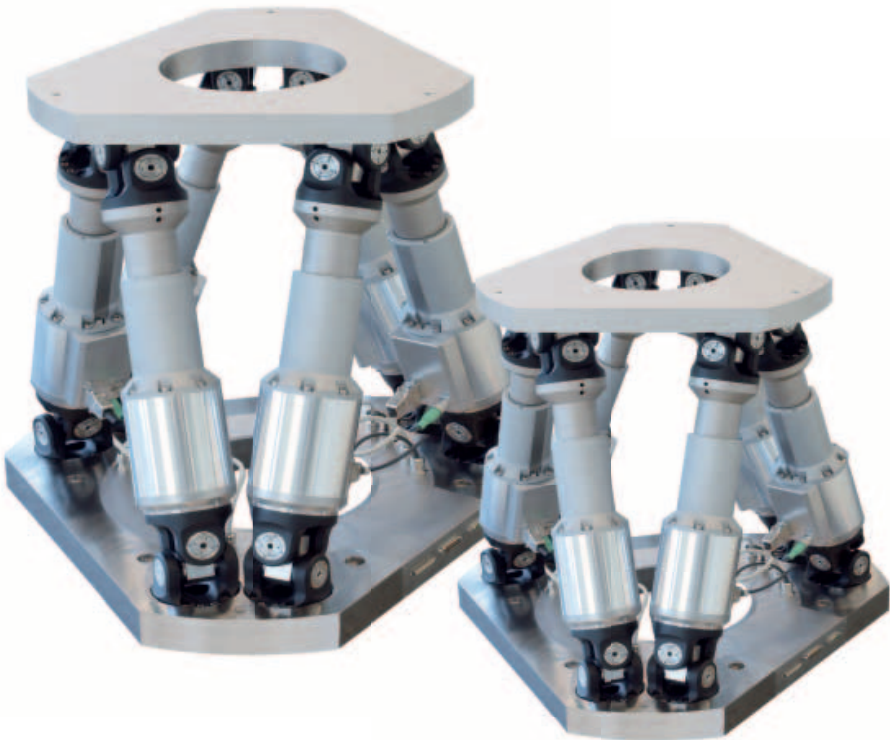
Parallel Kinematics / Hexapods

Medium and High Load Hexapods

Precision Positioning
Hexapods

55

H-850 6-Axis Hexapod

For Loads up to 250 kg

- Load capacity to 250 kg
- Repeatability to ±0.2 µm
- Travel ranges to ±50 mm / ±30°
- Actuator resolution to 2.5 nm
- Variants with BLDC motors and absolute encoders
- Works in any orientation

Parallel-kinematic design for six degrees of freedom making it significantly more compact and stiff than serial-kinematic systems, higher dynamic range, no moved cables: Higher reliability, reduced friction. Heavy-duty precision bearings for 24/7 applications.

Brushless DC motor (BLDC)

Brushless DC motors are particularly suitable for high rotational speeds. They can be controlled very accurately and ensure high precision. Because they dispense with sliding contacts, they run smoothly, are wear-free and therefore achieve a long lifetime.

Absolute encoder

Absolute encoders supply explicit position information that enables immediate determination of the position. This means that referencing is not required during switch-on, which increases efficiency and safety during operation.

Applications

- Part handling
- Precise robotics
- Astronomy
- Automated alignment
- Micromanipulation in vacuum

>> **Absolute Encoder**
>> **Parallel Kinematics, Hexapods**
>> **Vacuum-Compatible Versions**

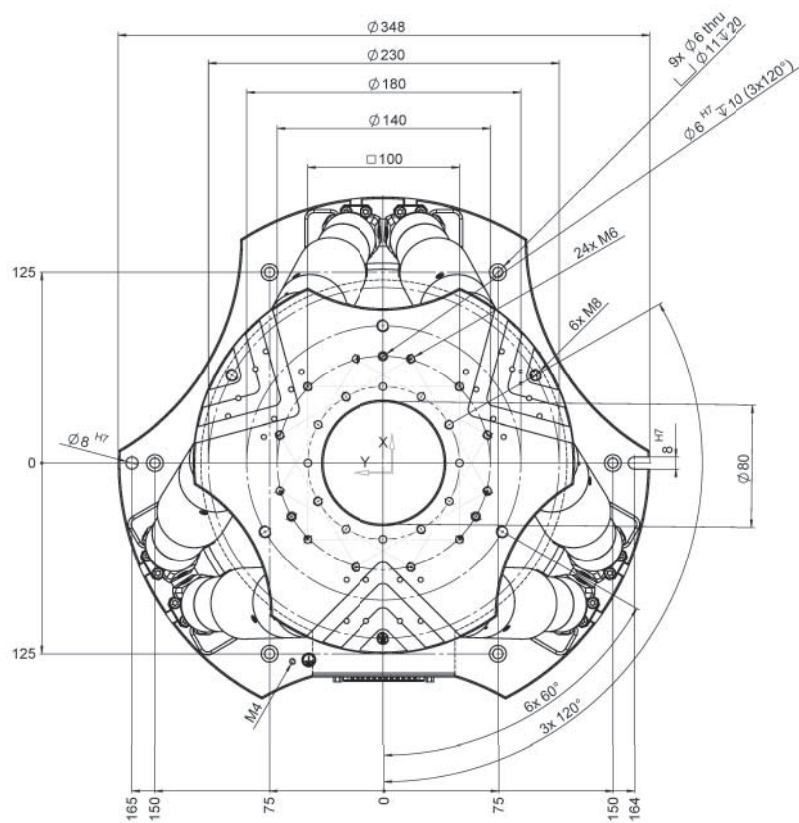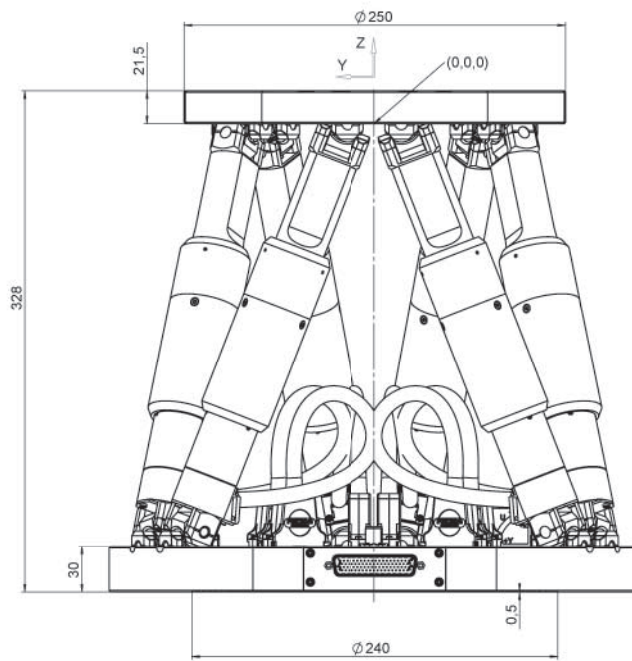|	H-850.H2A	H-850.G2A	H-850.H2 / H2V**	H-850.G2 / G2V**	Unit	Tolerance
	For high duty cycles, high precision, high load capacity and holding force, no homing required	For high duty cycles, faster motion, no homing required	For high precision, high load capacity and holding force H2V: Vacuum compatible to 10^{-6} hPa	For faster motion G2V: Vacuum compatible to 10^{-6} hPa		
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z		
Travel range* X, Y	±50	±50	±50	±50	mm	
Travel range* Z	±25	±25	±25	±25	mm	
Travel range* θ_X, θ_Y	±15	±15	±15	±15	°	
Travel range* θ_Z	±30	±30	±30	±30	°	
Sensor type	Absolute rotary encoder	Absolute rotary encoder	Incremental rotary encoder	Incremental rotary encoder		
Actuator design resolution	0.0025	0.025	0.005	0.05	µm	
Min. incremental motion X, Y	0.3	1	0.3	1	µm	typ.
Min. incremental motion Z	0.2	0.5	0.2	0.5	µm	typ.
Minimum incremental motion θ_X, θ_Y, θ_Z	3; 3; 5	7.5; 7.5; 15	3; 3; 5	7.5; 7.5; 15	µrad	typ.
Backlash in X, Y	4	6	4	6	µm	typ.
Backlash in Z	0.5	1.5	0.5	1.5	µm	typ.
Backlash in θ_X, θ_Y	7.5	25	7.5	25	µrad	typ.
Backlash in θ_Z	60	90	60	90	µrad	typ.
Repeatability X, Y	±0.6	±0.5	±0.5	±0.5	µm	typ.
Repeatability in Z	±0.2	±0.2	±0.2	±0.2	µm	typ.
Repeatability in θ_X, θ_Y	±3	±0.3	±3	±3	µrad	typ.
Repeatability in θ_Z	±9	±7.5	±9	±7.5	µrad	typ.
Max. velocity in X, Y, Z	0.5	8	0.5 / 0.15	8 / 2.5	mm/s	
Max. velocity in θ_X, θ_Y, θ_Z	6	120	6 / 1.8	120 / 30	mrad/s	
Typ. Velocity in X, Y, Z	0.3	5	0.3 / 0.1	5 / 2	mm/s	
Typ. Velocity in θ_X, θ_Y, θ_Z	3	75	3 / 1.2	75 / 25	mrad/s	
Mechanical properties						
Stiffness X, Y	7	7	7	7	N/µm	
Stiffness Z	100	100	100	100	N/µm	
Load capacity, horizontal base plate	250	50	250 / 80	50 / 25	kg	max.
Load capacity, base plate in any orientation	50	20	50 / 40	20 / 10	kg	max.
Holding force, power off, horizontal base plate	2000	250	2000	250	N	max.
Holding force, power off, base plate in any orientation	500	85	500	85	N	max.
Motor type	BLDC gear motor	BLDC gear motor	DC gear motor	DC gear motor		
Miscellaneous						
Operating temperature range	–10 to 50	–10 to 50	—10 to 50	—10 to 50	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	17	17	17	17	kg	±10 %
Cable length	3	3	3 / 3 (air) + 2 (vacuum)	3 / 3 (air) + 2 (vacuum)	m	±10 mm

Technical data specified at 20±3 °C.

* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent.
The data for each axis in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.
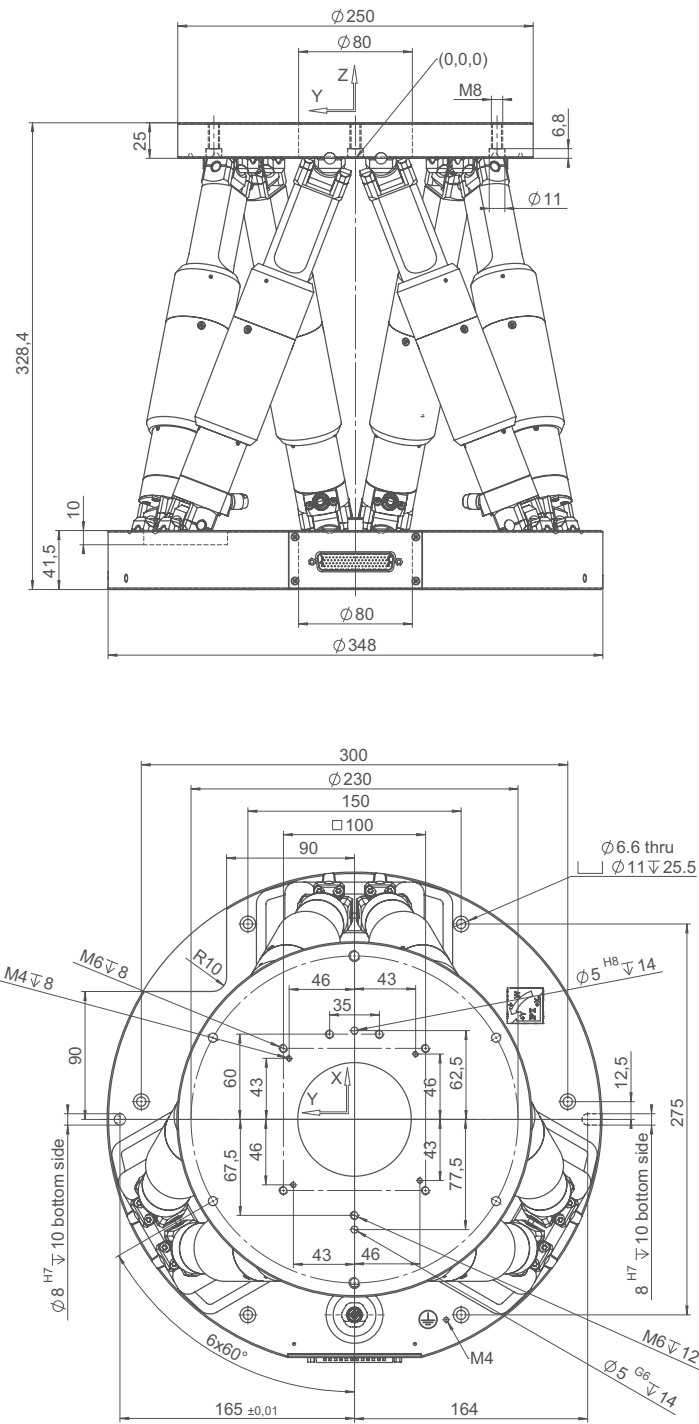
** For continuous operation in a vacuum, restrictions on operating parameters may be necessary due to heat generation.

Ask about customized versions.

H-850.x2A, dimensions in mm

H-850.x2 and H-850.x2V, dimensions in mm

H-840 6-Axis Hexapod

Inexpensive, Precise, and Fast

H-840.x2A / x2I, dimensions in mm

- Load capacity to 30 kg
- Travel ranges to ±50 mm / ±30°
- Repeatability to ±0.1 µm
- Velocity to 60 mm/s
- BLDC motors and variants with absolute encoders
- Works in any orientation

Applications

- Optics alignment
- Micro assembly
- Sample positioning
- Motion simulation for optical image stabilization (OIS)
- Precise robotics

>> **Absolute Encoder**
>> **Parallel Kinematics, Hexapods**

	H-840.G2A	H-840.D2A	H-840.G2I	H-840.D2I	Unit	Tolerance
	For high duty cycles, high load capacity and holding force, no homing required	For high duty cycles, faster motion, no homing required	For high duty cycles, high load capacity and holding force	For high duty cycles, faster motion		
Motion and positioning						
	BLDC gear motor with absolute encoder	BLDC motor with absolute encoder	BLDC gear motor with rotary encoder	BLDC motor with rotary encoder		
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z		
Travel range* X, Y	±50	±50	±50	±50	mm	
Travel range* Z	±25	±25	±25	±25	mm	
Travel range* θ_X, θ_Y	±15	±15	±15	±15	°	
Travel range* θ_Z	±30	±30	±30	±30	°	
Actuator design resolution	0.0085	0.25	0.005	0.037	µm	
Min. incremental motion X, Y	0.3	2.5	0.25	0.5	µm	typ.
Min. incremental motion Z	0.2	1	0.15	0.25	µm	typ.
Minimum incremental motion θ_X, θ_Y, θ_Z	3; 3; 5	15; 15; 40	4; 4; 6	4.5; 4.5; 8.5	µrad	typ.
Backlash in X, Y	1	0.5	1	0.5	µm	typ.
Backlash in Z	0.3	0.5	0.3	0.5	µm	typ.
Backlash in θ_X, θ_Y	5	8	5	8	µrad	typ.
Backlash in θ_Z	10	5	10	5	µrad	typ.
Repeatability X, Y	±0.3	±0.4	±0.3	±0.4	µm	typ.
Repeatability in Z	±0.15	±0.1	±0.15	±0.1	µm	typ.
Repeatability in θ_X, θ_Y	±2.5	±1.5	±2.5	±1.5	µrad	typ.
Repeatability in θ_Z	±3	±4	±3	±4	µrad	typ.
Max. velocity in X, Y, Z	2.5	60	2.5	60	mm/s	
Max. velocity in θ_X, θ_Y, θ_Z	30	700	30	700	mrad/s	
Typ. Velocity in X, Y, Z	2	40	2	40	mm/s	
Typ. Velocity in θ_X, θ_Y, θ_Z	25	480	25	480	mrad/s	
Mechanical properties						
Load capacity (horizontal base plate / any orientation)	30 / 10	10 / 3	30 / 10	10 / 3	kg	max.
Holding force, power off (horizontal base plate / any orientation)	100 / 25	15 / 5	100 / 25	15 / 5	N	max.
Miscellaneous						
Operating temperature range	–10 to 50	–10 to 50	–10 to 50	–w10 to 50	°C	
Material	Aluminum / steel	Aluminum / steel	Aluminum / steel	Aluminum / steel		
Mass	12	12	12	12	kg	±10 %
Cable length	3	3	3	3	m	±10 mm

Technical data specified at 20±3 °C.
Specifications for vacuum versions can differ.
* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent.
  The data for each axis in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.
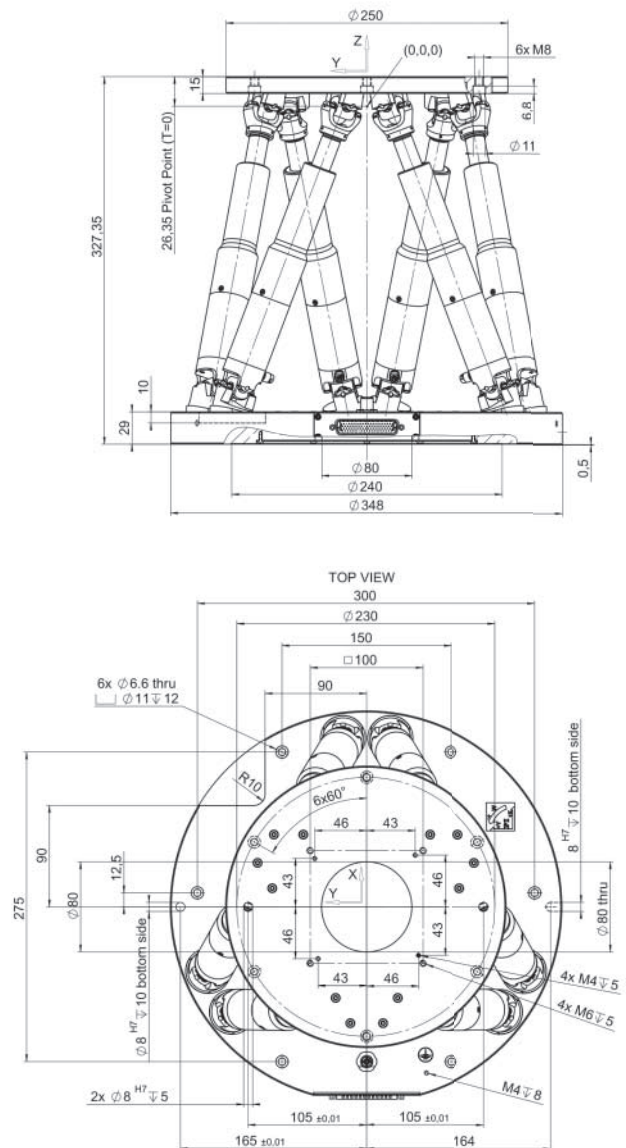Ask about customized versions.

H-840 6-Axis Hexapod

Inexpensive, Precise, and Fast

H-840.x2, dimensions in mm

- Load capacity to 30 kg
- Travel ranges to ±50 mm / ±30°
- Repeatability to ±0.1 µm
- Velocity to 50 mm/s
- Works in any orientation

Applications

- Optics alignment
- Micro assembly
- Sample positioning
- Motion simulation for optical image stabilization (OIS)
- Precise robotics

>> **Parallel Kinematics, Hexapods**

Technology Glossary .... page **124**

	H-840.G2	H-840.D2	Unit	Tolerance
	For high precision, high load and holding force	For faster motion		
Motion and positioning				
	DC gear motor	DC motor		
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z		
Travel range* X, Y	±50	±50	mm	
Travel range* Z	±25	±25	mm	
Travel range* θ_X, θ_Y	±15	±15	°	
Travel range* θ_Z	±30	±30	°	
Actuator design resolution	0.017	0.5	µm	
Min. incremental motion X, Y	0.3	5	µm	typ.
Min. incremental motion Z	0.2	3	µm	typ.
Minimum incremental motion θ_X, θ_Y, θ_Z	3; 3; 5	45; 45; 85	µrad	typ.
Backlash in X, Y	1	1	µm	typ.
Backlash in Z	0.3	0.4	µm	typ.
Backlash in θ_X, θ_Y	5	6	µrad	typ.
Backlash in θ_Z	10	10	µrad	typ.
Repeatability X, Y	±0.3	±1	µm	typ.
Repeatability in Z	±0.15	±0.1	µm	typ.
Repeatability in θ_X, θ_Y	±2.5	±1.5	µrad	typ.
Repeatability in θ_Z	±3	±10	µrad	typ.
Max. velocity in X, Y, Z	2.5	50	mm/s	
Max. velocity in θ_X, θ_Y, θ_Z	30	600	mrad/s	
Typ. velocity in X, Y, Z	2	30	mm/s	
Typ. velocity in θ_X, θ_Y, θ_Z	25	360	mrad/s	
Mechanical properties				
Load capacity (horizontal base plate / any orientation)	30 / 10	10 / 3	kg	max.
Holding force, power off (horizontal base plate / any orientation)	100 / 25	15 / 5	N	max.
Miscellaneous				
Operating temperature range	−10 to 50	−10 to 50	°C	
Material	Aluminum / steel	Aluminum / steel		
Mass	12	12	kg	±10 %
Cable length	3	3	m	±10 mm

Technical data specified at 20±3 °C.
Specifications for vacuum versions can differ.
* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent.
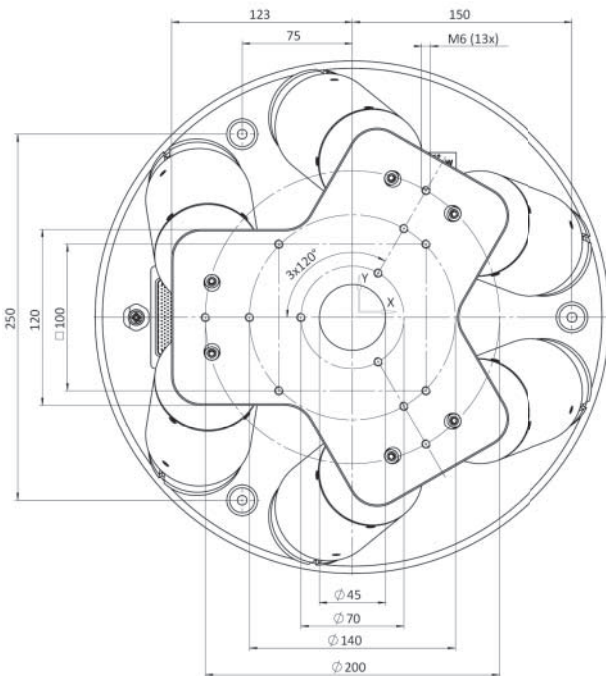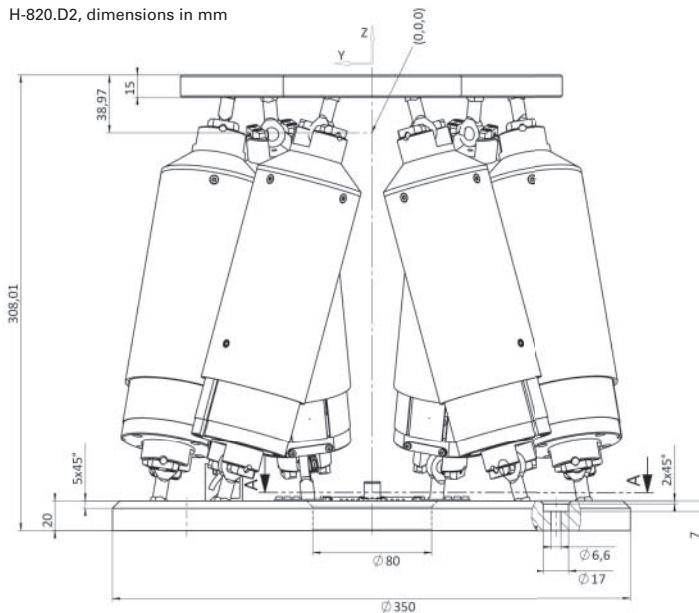 The data for each axis in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.
Ask about customized versions.

H-820 6-Axis Hexapod

Inexpensive Hexapod

H-820.D2, dimensions in mm

- Six degrees of freedom, travel ranges to 100 mm / 60°
- Load capacity to 20 kg
- Velocity under full load to 20 mm/s
- Repeatability up to ±0.5 µm
- Brushless DC motors (BLDC)
- Works in any orientation
- Fast response behavior

Applications

- Micro machining
- Automation

>> **Parallel Kinematics, Hexapods**

Technology Glossary .... page **124**

|	H-820.D2	Unit	Tolerance
Motion and positioning			
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z		
Travel range* X, Y	±50	mm	
Travel range* Z	±25	mm	
Travel range* θ_X, θ_Y	±15	°	
Travel range* θ_Z	±30	°	
Actuator drive	Torque motor, brushless (BLDC)		
Actuator design resolution	0.2	µm	typ.
Minimum incremental motion X, Y, Z	5	µm	typ.
Minimum incremental motion θ_X, θ_Y, θ_Z	12.5	µrad	typ.
Repeatability X, Y	±1.5	µm	typ.
Repeatability Z	±0.5	µm	typ.
Repeatability θ_X, θ_Y	±8	µrad	typ.
Repeatability θ_Z	±25	µrad	typ.
Backlash X, Y	30	µm	typ.
Backlash Z	3	µm	typ.
Backlash θ_X, θ_Y	30	µrad	typ.
Backlash θ_Z	300	µrad	typ.
Max. velocity X, Y, Z	20	mm/s	
Max. velocity θ_X, θ_Y, θ_Z	200	mrad/s	
Mechanical properties			
Load capacity (horizontal base plate)	20	kg	max.
Load capacity (base plate in any orientation)	10	kg	max.
Holding force (horizontal base plate)	200	N	max.
Holding force (base plate in any orientation)	100	N	max.
Miscellaneous			
Operating temperature range	0 to +50	°C	
Material	Aluminum		
Mass	15	kg	±5 %
Cable length	3	m	±10 mm
Recommended controller	C-887.5x		

Technical data specified at 20±3 °C.

* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent. The data for each axis
  in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.

Ask about customized versions.

H-845 Heavy-Duty Hexapod

Position up to 1 Ton with Micrometer Precision
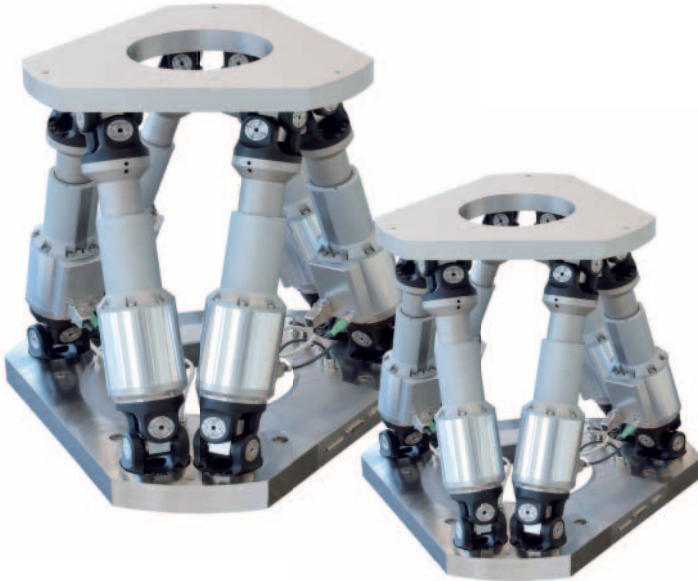
- Load capacity to 1000 kg
- Velocity to 50 mm/s
- Repeatability to ±0.5 µm
- Travel ranges to 340 mm / 60°
- Scalable design: Dimensions, travel ranges, and loads
- Drive: brushless motors with brake
- High-performance digital controller and software included

Product Overview

Parallel-kinematic design for six degrees of freedom making it significantly more compact and stiff than serial-kinematic systems, higher dynamic range, no moved cables: Higher reliability, reduced friction. Large aperture. Brushless DC motors with brake.

Rapid implementation of customer requests

The high-load hexapod has a modular structure and uses a set of different modules for drive units and joints. The platforms can be adapted to the customer's application. This allows for rapid implementation of special customer requirements.

High-performance digital controller, open software architecture

6-DOF controller for hexapods, including two additional servo axes. Freely programmable stable pivot point. Positions commanded in Cartesian coordinates. Macro programming. Open-source NI LabVIEW driver and libraries. Workspace simulation. Virtual machine for hexapod emulation. Optional: Software for avoiding collisions in restricted workspace.

Applications

- Robotic part handling
- Satellite testing
- Precision assembly

>> **Extensive Software Package**

>> **Parallel Kinematics, Hexapods**

	H-845.D11	H-845.D31	H-845.D51	H-845.D21	H-845.D41	H-845.D61	Unit	Tolerance
	For max load and holding force, high precision, small	Combines high dynamics and high load capacity, small	For best dynamics, small	For max. load and holding force, high precision, large	Combines high dynamics and high load capacity, large	For best dynamics, large		
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z		
Motion and positioning								
Travel range* X, Y	±110	±110	±110	±170	±170	±170	mm	
Travel range* Z	±50	±50	±50	±105	±105	±105	mm	
Travel range* θ_X, θ_Y	±15	±15	±15	±20	±20	±20	°	
Travel range* θ_Z	±30	±30	±30	±30	±30	±30	°	
Actuator design resolution	0.04	0.08	0.1	0.04	0.08	0.1	µm	
Min. incremental motion X, Y	1	2	2.5	1	2	2.5	µm	typ.
Min. incremental motion Z	0.5	1	1	0.5	1	1	µm	typ.
Minimum incremental motion θ_X, θ_Y, θ_Z	15	30	30	15	30	30	µrad	typ.
Backlash X, Y	5	10	10	5	10	10	µm	typ.
Backlash Z	1	2	2	1	2	2	µm	typ.
Backlash θ_X, θ_Y	15	30	30	15	30	30	µrad	typ.
Backlash θ_Z	30	60	60	30	60	60	µrad	typ.
Repeatability X, Y	±2	±4	±5	±2	±4	±5	µm	typ.
Repeatability Z	±0.5	±1	±2	±0.5	±1	±2	µm	typ.
Repeatability θ_X, θ_Y, θ_Z	±10	±20	±25	±10	±20	±25	µrad	typ.
Max. velocity X, Y, Z	20	40	50	20	40	50	mm/s	
Max. velocity θ_X, θ_Y, θ_Z	50	100	120	50	100	120	mrad/s	
Typ. velocity X, Y, Z	10	20	25	10	20	25	mm/s	
Typ. velocity θ_X, θ_Y, θ_Z	20	40	50	20	40	50	mrad/s	
Mechanical properties								
Load capacity (base plate horizontal / any orientation)	1000 / 300	500 / 150	400 / 120	1000 / 300	500 / 150	400 / 120	kg	max.
Motor type	BLDC motor	BLDC motor	BLDC motor	BLDC motor	BLDC motor	BLDC motor		
Miscellaneous								
Operating temperature range	−10 to 50	−10 to 50	−10 to 50	−10 to 50	−10 to 50	−10 to 50	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	120	120	120	150	150	150	kg	±5 %
Cable length	9	9	9	9	9	9	m	±10 mm
Controller								
Included in the scope of scope of delivery	C-887	C-887	C-887	C-887	C-887	C-887		

Technical data specified at 20±3 °C.

* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent. The data for each axis
   in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.
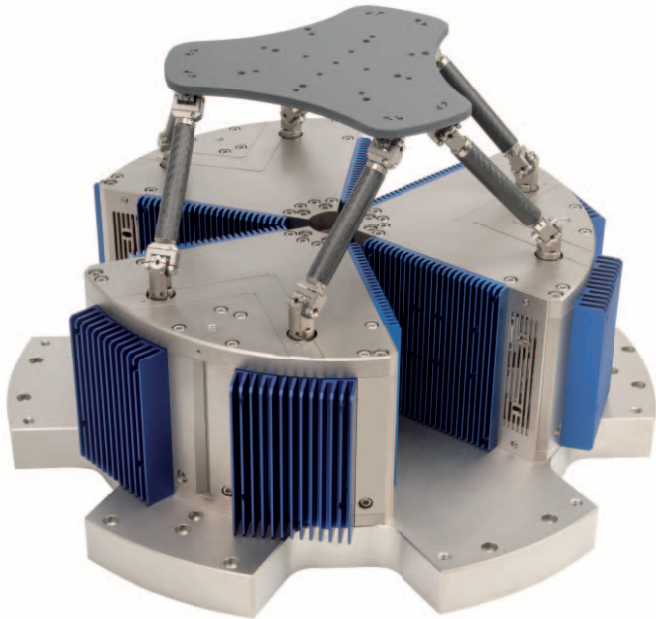Ask about customized versions.

H-845.D11, H-845.D31, and H-845 .D51, dimensions in mm
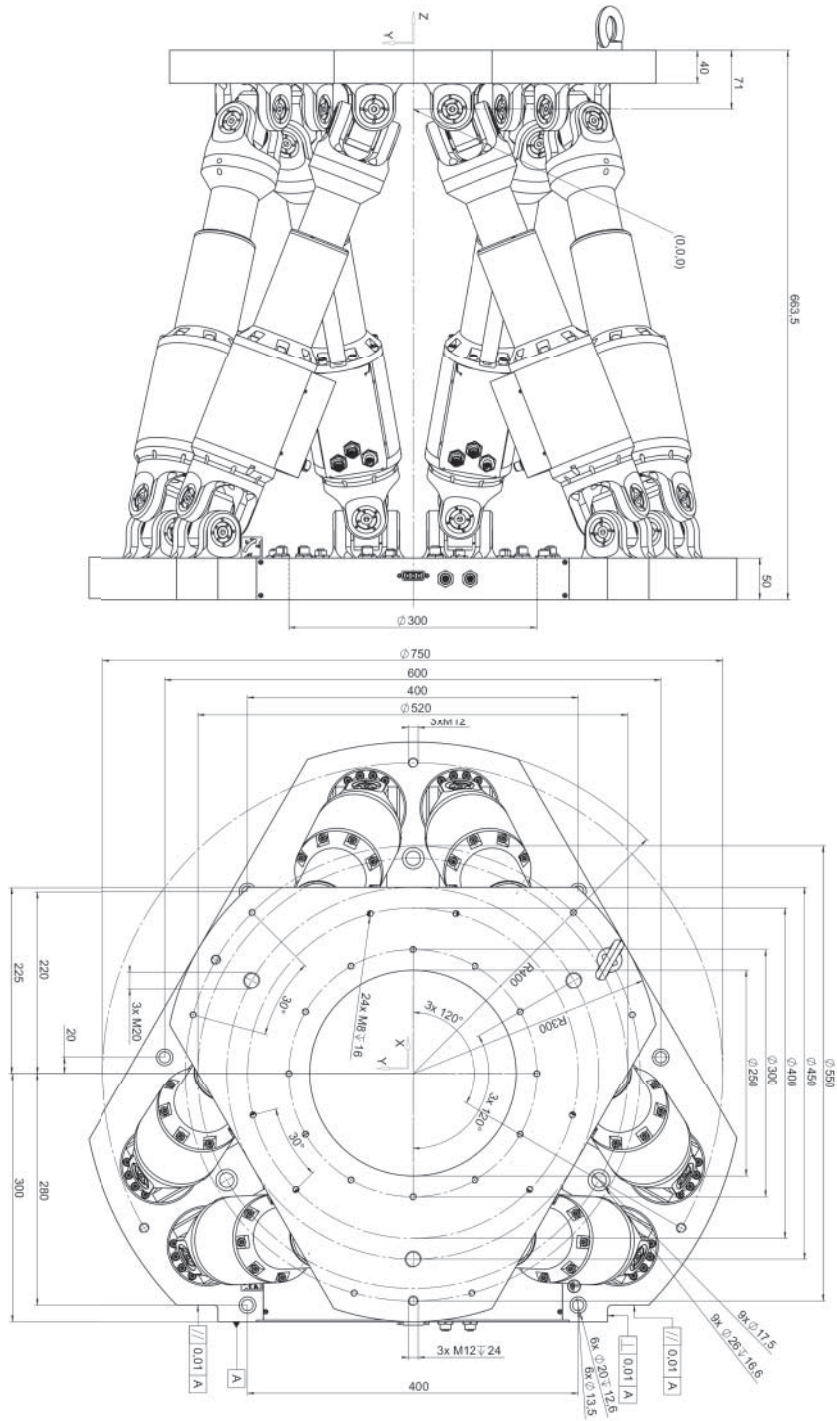
Dynamic Motion Hexapods

Dynamic Motion
Hexapods

H-811.S2 6-Axis Motion Hexapod

Fast and Compact for High Dynamics Applications

- CIPA certified
- Travel ranges to ±17 mm / ±21°
- Velocity to 25 mm/s
- Dynamics to 25 Hz over 0.1° travel range
- Brushless DC motors (BLDC)
- Developed for image stabilization inspection systems

Reference-class 6-axis positioning system

Parallel-kinematic design for six degrees of freedom making it significantly more compact and stiff than serial-kinematic systems, higher dynamic range, no moved cables: Higher reliability, reduced friction. Vacuum-compatible version to 10^{-6} hPa available.

Direct drive with brushless DC motors (BLDC) and long-life ball screws

High precision, velocity and lifetime.

The H-811 Hexapod simulates camera shake for testing image stabilization systems according to the CIPA standard. Here in test equipment at Image Engineering. (Image: Image Engineering)

Applications

- Motion simulation for optical image stabilization (OIS)

>> Parallel Kinematics, Hexapods

	H-811.S2	Unit	Tolerance
Motion and positioning			
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z		
Travel range* X, Y, Z	±17, ±16, ±6.5	mm	
Travel range* θ_X, θ_Y, θ_Z	±10, ±10, ±21	°	
Actuator design resolution	5	nm	
Min. incremental motion X, Y	1	µm	typ.
Min. incremental motion Z	0.5	µm	typ.
Minimum incremental motion θ_X, θ_Y, θ_Z	12	µrad	typ.
Minimum incremental motion θ_Z	25	µrad	typ.
Backlash X, Y	0.5	µm	typ.
Backlash Z	0.15	µm	typ.
Backlash θ_X, θ_Y	5	µrad	typ.
Backlash θ_Z	10	µrad	typ.
Repeatability X, Y	±0.5	µm	typ.
Repeatability Z	±0.2	µm	typ.
Repeatability θ_X, θ_Y	±6	µrad	typ.
Repeatability θ_Z	±10	µrad	typ.
Max. velocity X, Y, Z	25	mm/s	
Max. velocity θ_X, θ_Y, θ_Z	625	mrad/s	
Typ. Velocity X, Y, Z	10	mm/s	
Typ. Velocity θ_X, θ_Y, θ_Z	240	mrad/s	
Mechanical properties			
Stiffness X, Y	0.7	N/µm	
Stiffness Z	8	N/µm	
Load capacity (horizontal base plate / any orientation)	1.5 / 0.3	kg	max.
Holding force, power off (horizontal base plate / any orientation)	15 / 2.5	N	max.
Motor type	Brushless DC motor		
Miscellaneous			
Operating temperature range	0 to 50	°C	
Material	Stainless steel, aluminum		
Mass	2.2	kg	±5 %
Cable length	2	m	±10 mm
Recommended controller	C-887.5x		

Technical data specified at 20±3 °C.

* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent. The data for each axis in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.
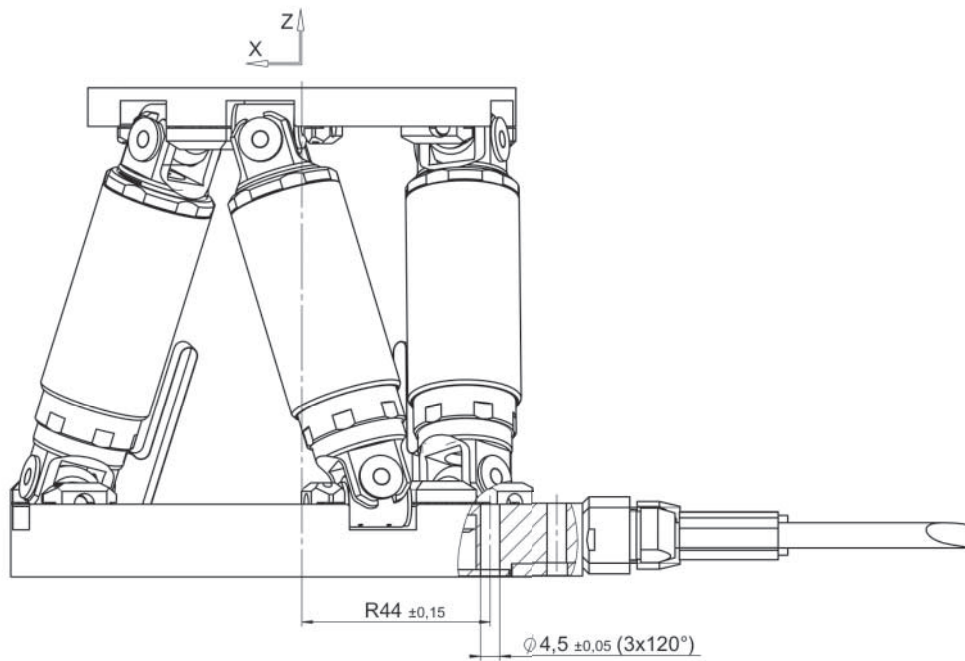
Ask about customized versions.

CiPa
Camera & Imaging Products Association

H-811 is certified by the CIPA for use in image stabilization systems

Dynamic Motion Hexapods
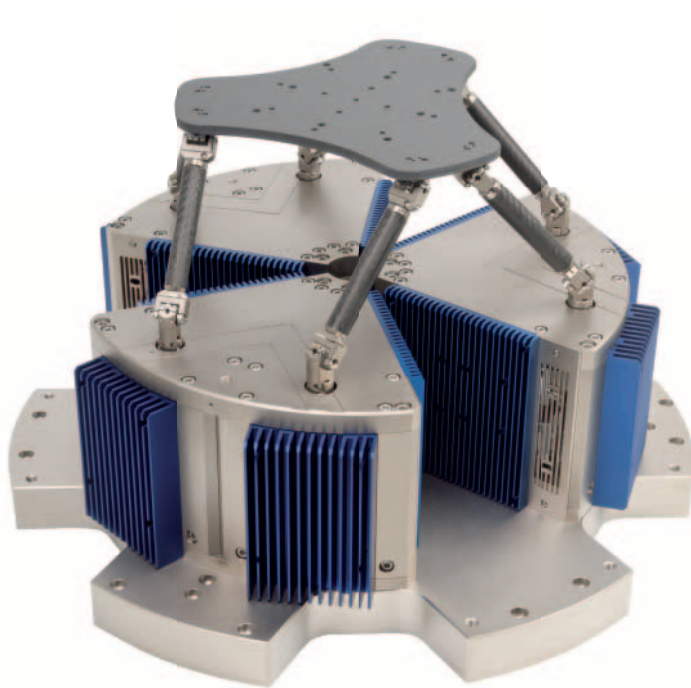
R44 ±0,15

⌀ 4,5 ±0,05 (3x120°)
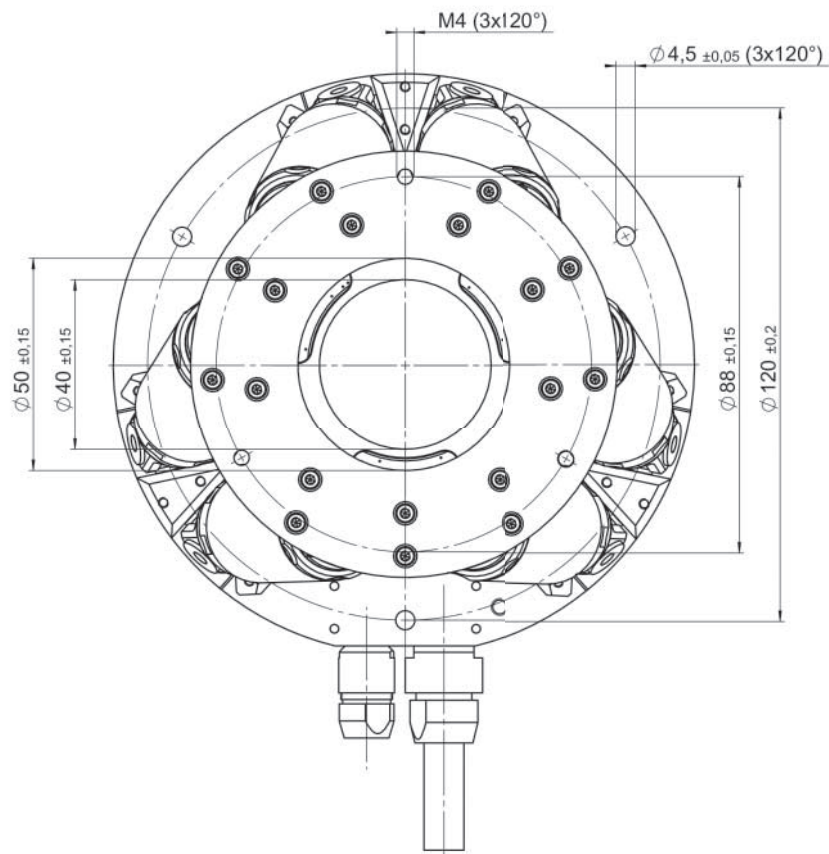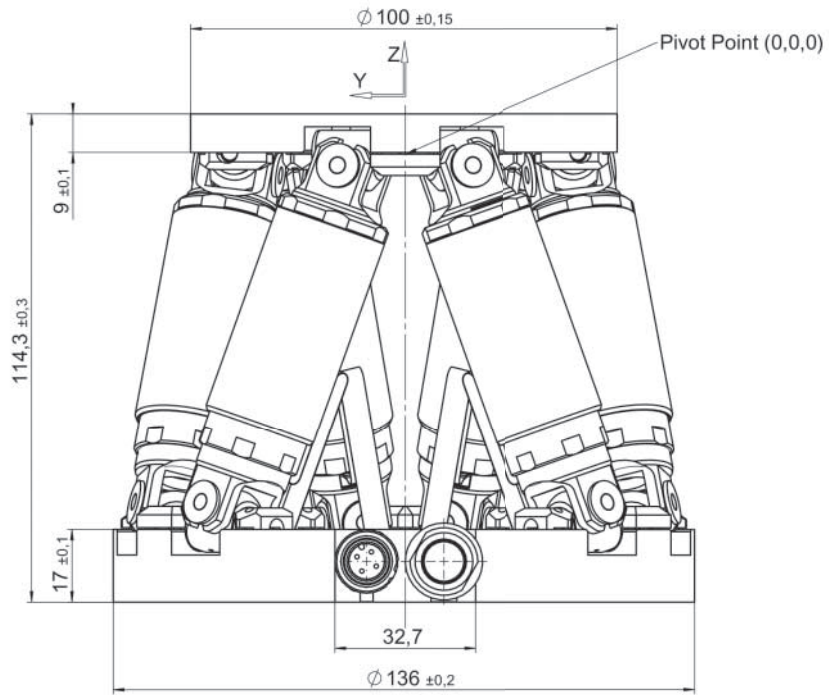
H-860 6-Axis Motion Hexapod

Magnetic Direct Drive for High Velocity

- High velocity and dynamics
- Low moving intrinsic mass
- Velocity up to 250 mm/s
- Precise path tracking
- Friction-free voice coil drive

Reference-class 6-axis positioning system

Parallel-kinematic design for six degrees of freedom making it significantly more compact and stiffer than serial-kinematic systems, no moved cables. Precise running of predefined motion profiles with high path accuracy: Sine curves and freely definable trajectories.

PIMag® Voice coil

Voice coil drives consist of 2 essential components: A permanent magnet and a coil, which are located in the air gap of the magnetic field. Thanks to their low weight and friction-free drive principle, voice coil drives are particularly suitable for applications that require high dynamics and high velocities at limited travel ranges. High scan frequencies and precision positioning are also possible with these drives, because they are free of the effects of hysteresis.

Applications

- Motion simulation for optical image stabilization (OIS)
- Testing of automotive LIDAR systems

>> **Flexures**
>> **Parallel Kinematics, Hexapods**
>> **PIMag® Voice Coil**

	H-860.S2H	Unit	Tolerance
Motion and positioning			
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z		
Travel range* in X, Y, Z	±7.5	mm	
Travel range* in θ_X, θ_Y, θ_Z	±4	°	
Actuator design resolution	5	nm	
Minimum incremental motion in X, Y	1	µm	typ.
Minimum incremental motion in Z	1	µm	typ.
Minimum incremental motion in θ_X, θ_Y, θ_Z	9	µrad	typ.
Backlash in X, Y	0.2	µm	typ.
Backlash in Z	0.06	µm	typ.
Backlash in θ_X, θ_Y	4	µrad	typ.
Backlash in θ_Z	4	µrad	typ.
Unidirectional repeatability in X, Y	±0.5	µm	typ.
Unidirectional repeatability in Z	±0.5	µm	typ.
Unidirectional repeatability in θ_X, θ_Y	±9	µrad	typ.
Unidirectional repeatability in θ_Z	±9	µrad	typ.
Velocity in X, Y, Z	250	mm/s	max.
Max. frequency	30	Hz	
Amplitude-frequency product in X, Y, Z	30	mm·Hz	
Amplitude-frequency product in θ_X, θ_Y, θ_Z	15	°·Hz	
Amplitude error	10	%	max.
Phase error	60	°	max.
Mechanical properties			
Stiffness in X, Y	0.7	N/µm	
Stiffness in Z	8	N/µm	
Load capacity (horizontal base plate / any orientation)	1	kg	max.
Motor type	Voice Coil		
Miscellaneous			
Operating temperature range	0 to 50	°C	
Material	Stainless steel, aluminum		
Mass	30	kg	±5 %
Recommended controller	C-887.5x		

Technical data specified at 20±3 °C.

 *The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent. The data for each axis in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.
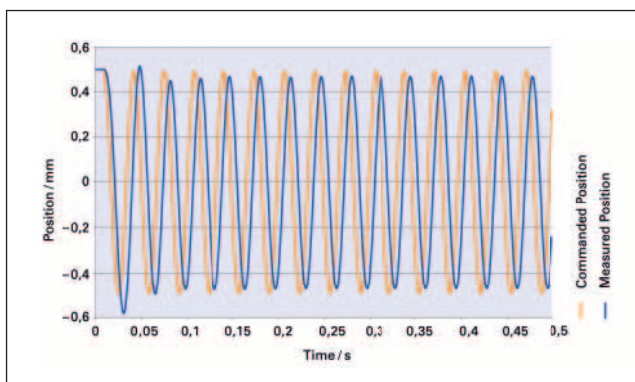
Ask about customized versions.
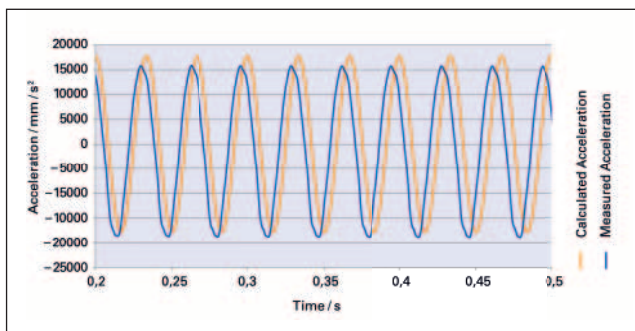
Dynamic Motion
Hexapods

H-860.S2H, dimensions in mm
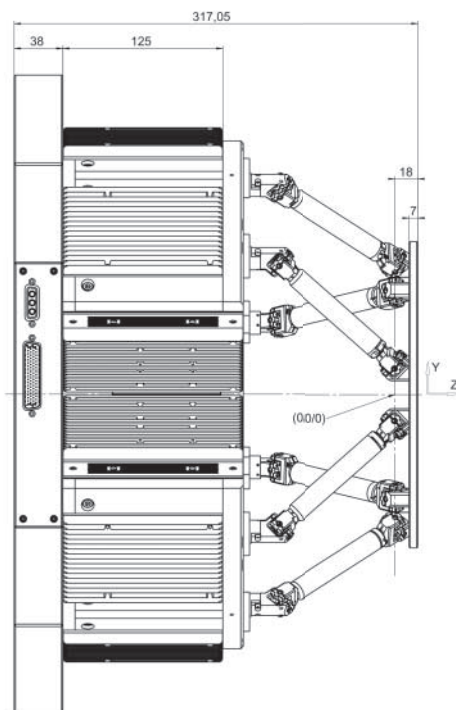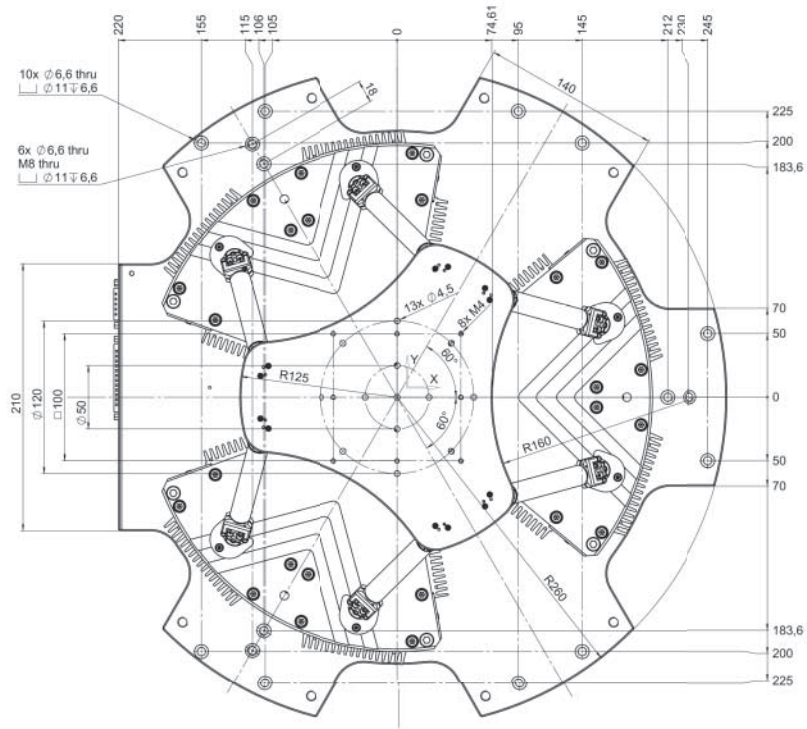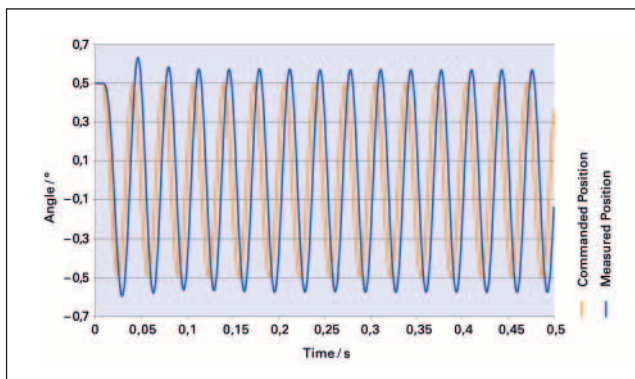
Sinusoidal oscillation with 30 Hz in θ_x.
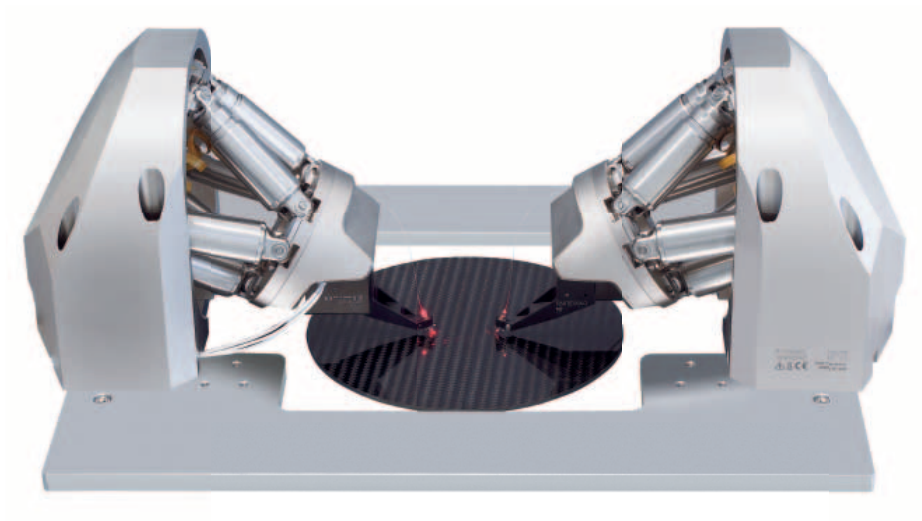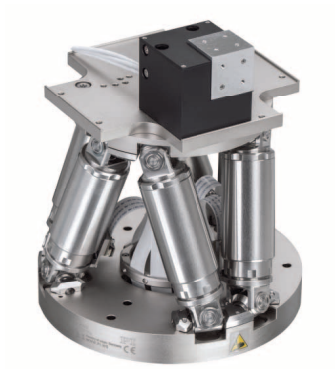The H-860 follows the specified trajectory
precisely.

Sinusoidal oscillation with 30 Hz in Z.
The H-860 follows the specified trajectory
precisely.

Sinusoidal oscillation with 30 Hz in Z, ampli-
tude 0.5 mm. Due to the high dynamics and
mass being moved, the H-860 can simulate
accelerations precisely. The acceleration was
measured in Z direction with an external
acceleration sensor directly at the motion
platform.

Dynamic Motion
Hexapods

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Fast Multi-Channel
Photonics Alignment Systems

PI

Fast Multi-Channel Photonics
Alignment Systems

Automated Alignment is the Key to High Throughput and Outstanding Quality

The key component of the alignment systems is PI's Nano-Cube®, a highly dynamic, closed-loop XYZ piezo scanner. It is so compact yet yields 100 x 100 x 100 μm travel with nanoscale repeatability and extreme speed. With a completely wear-free working principle, it makes even the most complicated coupling optimizations possible in typically a few hundred milliseconds. The integrated optical encoder offers the highest bandwidth and resolution for this high-dynamic application. Closed-loop operation helps ensure device safety and process repeatability.
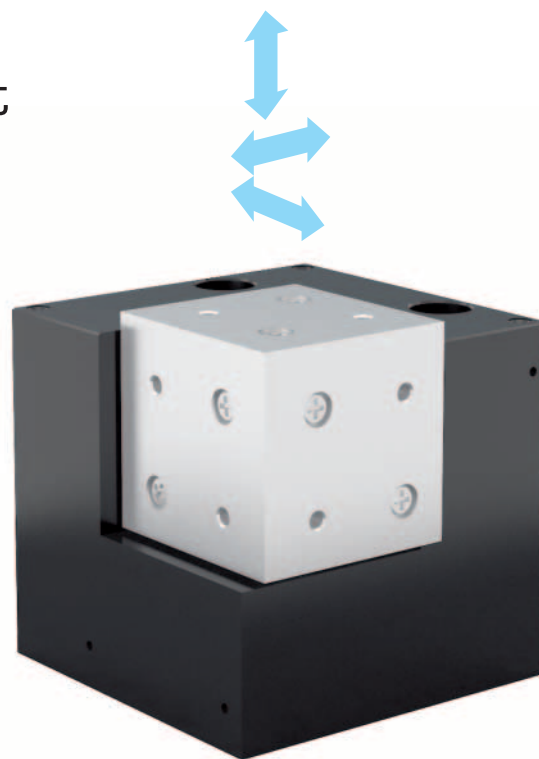
PI hexapods offer all 6 degrees of freedom, namely 3 linear and 3 rotational axes, combined into parallel kinematics. A further advantage of the hexapod is the user-definable pivot point that enables rotation directly around the fiber tip and if required, also allows any other point of rotation.

Either stacked linear axes or hexapods can be used for positioning or scanning larger areas. In the case of stacked systems, a lot of value was placed on robustness and stiffness. All linear axes are equipped with position sensors and are connected to each other by very stiff brackets. High-quality components and a solid design guarantee reliability and a long lifetime.

Basics of PI's Unique Fast Multi-Channel Photonic Alignment (FMPA)

Comprehensive Software Stack Enables Easy Integration and Use

PIMikroMove supports the user in setting up and parametrizing the overall system. For the execution of motion commands and additional optimizations, no additional programming effort is necessary. Intuitively operable user interfaces, comprehensive online help pages, graphic visualizations, and simple automation possibilities support a quick introduction and trouble-free usage.

Programming interfaces allow the user to integrate a PI controller into their own user programs. The control of the positioning system therefore becomes part of the user program. Interfaces are available for all common programming languages including NI LabVIEW and MATLAB.
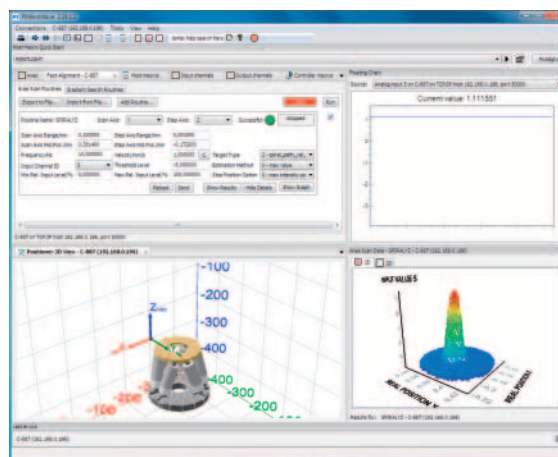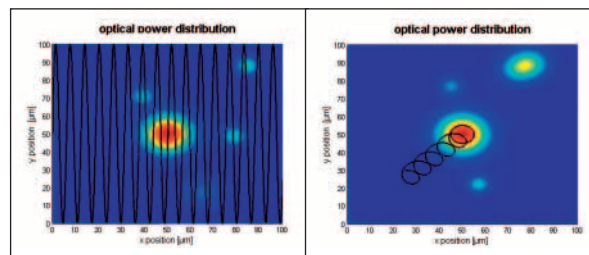

High-End Controllers for the Highest Demands

The F-712 FMPA systems include all necessary electronics to perform positioning and therefore automatic alignment. Because the demand on the computing power required for the complex algorithms with clock rates in the kilohertz range is very high, only high-performance controllers from PI are used. In addition, each controller has several high-resolution analog inputs with high bandwidth for supporting these dynamic applications.
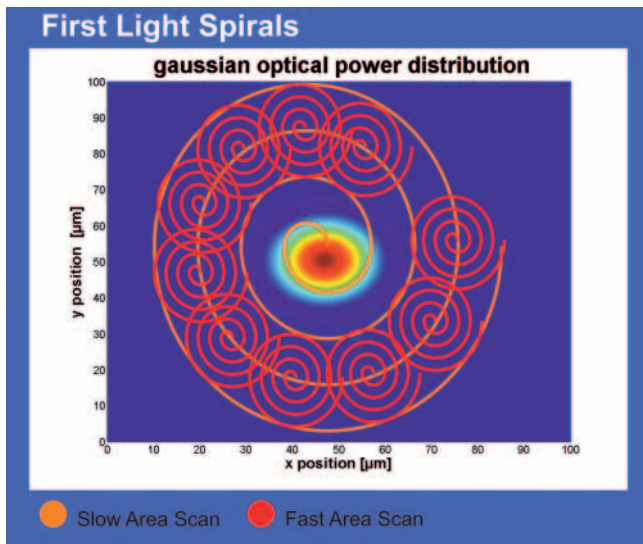
Typically, alignment systems with hexapod include the C-887.521 hexapod controller. For stacked systems, and to control the NanoCube®, a variant from the very flexible and modular E-712 controller series is used. This controller offers the highest computing performance and is therefore able to perform several scan algorithms for several axes simultaneously. That means that the controller not only calculates and commands the axes in real time but also records the corresponding position and analog values at the same time. Evaluation is even done within the servo cycle during a gradient search in order to control the motion of the axes according to the gradients found.

Groundbreaking Built-in-Routines for fastest Peak Finding

Built-in routines enable extremely high alignment speed. The algorithms for first light, area scan, and gradient search routines are extraordinarily fast and reliable for all kind of couplings. They offer process time of less than 1 second for aligning input and output simultaneously. PI algorithms even include automatic modeling of scan data to accurately localize the optimum even in fast, coarse scans. This includes the ability to rapidly localize the centroid of top-hat couplings – another PI world exclusive.


Fast Multi-Channel Photonics Alignment Systems

First Light Scan

First Light Spirals

gaussian optical power distribution
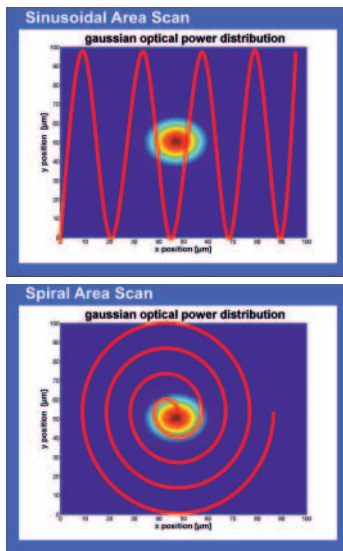
Slow Area Scan   Fast Area Scan

In order to determine the global maximum of a signal, it is necessary to make an intensity signal available to the controller that can be optimized. The built-in firmware algorithms provide all convenient and fast searching for 'first light'. To ensure extremely fast success for first light searching, it is possible to combine several area scan routines for this scan, which can be performed simultaneously.

This can be performed quickly and reliably even for double-sided tasks, where both sides need to be coupled at the same time; the firmware-based algorithms run fully automatically and simultaneously until the predefined threshold value has been reached or the entire area has been scanned.
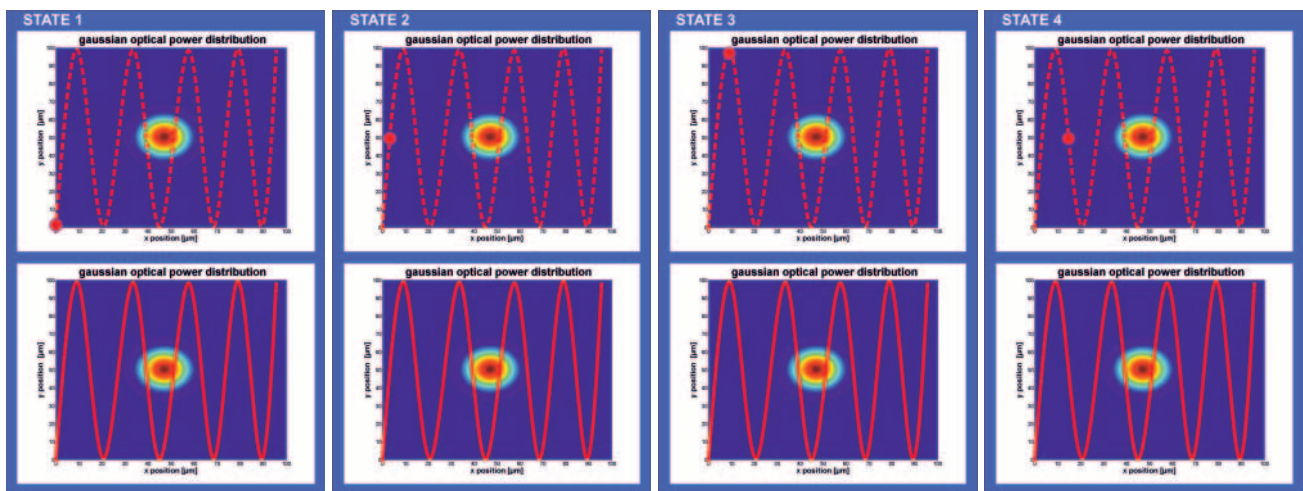
All axes, irrespective of whether they are coarse or fine axes, can be used and configured according to their dynamics. For example, the transmitter side can perform highly dynamic area scans, during which, the receiver side moves slowly but continuously. Therefore, the entire transmitter side is scanned for each and every position on the receiver side. It is also possible to set whether scanning stops as soon as the defined threshold value has been reached or whether the entire area of both sides should be examined.

Area Scan Routines

Sinusoidal Area Scan
gaussian optical power distribution

Spiral Area Scan
gaussian optical power distribution

The FMPA system offers 3 different routines for an area scan. The spiral scan with constant angular velocity, the spiral scan with constant path velocity, and the sinusoidal area scan. All routines can be configured individually and therefore optimized for the respective application case. Several scan routines can also be started simultaneously with a single command. It is possible to calculate the approximate maximum using a Gauss function or by determining the centroid.

In the case of the sinusoidal scan routine the defined surface is scanned continuously without strong acceleration or deceleration phases. Surface, starting point, line distance, and success criteria can be defined by the user.

In the case of the spiral scan routine, a defined area is scanned helically, whereby either a constant angle or a constant path velocity is maintained. The advantage of spiral scanning at a constant frequency is the ability to avoid system resonance. This ensures successful scanning. The advantage of spiral scanning at a constant path velocity is the ability to reduce the scanning duration in the case of lower system dynamics. Application-specific configuration of the routine is also possible here.

Gradient Search Routines

Ground-breaking results can be achieved with the unique implementation of this algorithm. If the light signal is present, this gradient search makes it possible to find the signal maximum in less than 1 second even in the case of double-sided tasks. It is also possible to run several searches at the same time and therefore optimize the signal simultaneously in several degrees of freedom. The routine allows excellent "tracking" and therefore it is possible to compensate any drift effects. Several parameters are also available here for optimizing the search for the respective application case.

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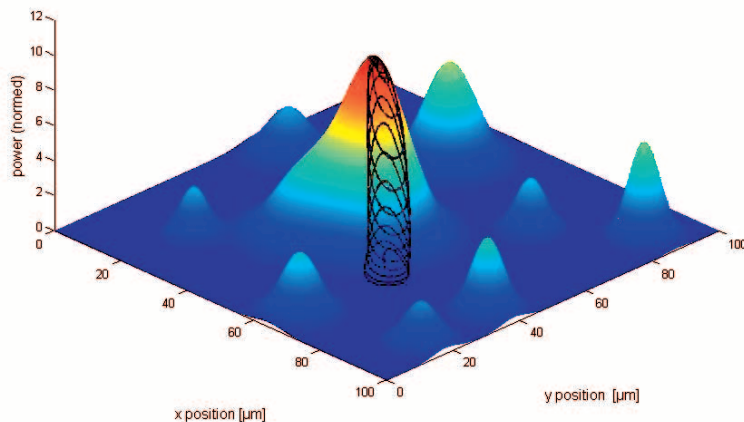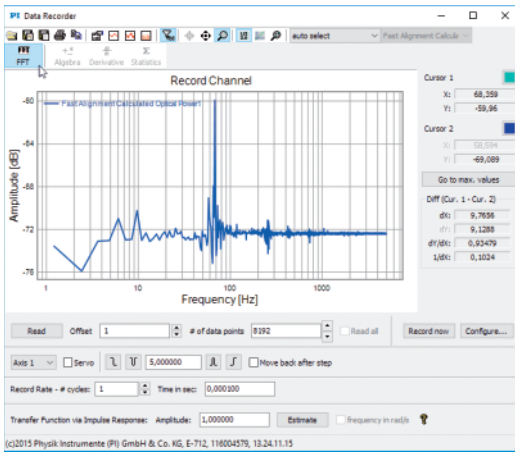
PIMikroMove

PIMikroMove gives you the option to control axes, perform (manual) tuning as well as record data from the controller in real time, display the data graphically and also analyze the data. Furthermore, it is also possible to access all controller algorithms and parametrize them conveniently; this also includes the fast alignment routines.

A live display of the analog inputs (incl. floating chart) as well as a 3-D view of optical distribution of the scanned area is particularly interesting for alignment tasks. Of course, it is also possible to export the data (.csv). Various tools are available for realtime data analysis, triggering, configuration, and much more.

PIMikroMove does not only offer the possibility of analyzing the dynamic properties of the PI axes, but can even perform an evaluation of the overall system with the help of an FFT analysis of the optical signal.
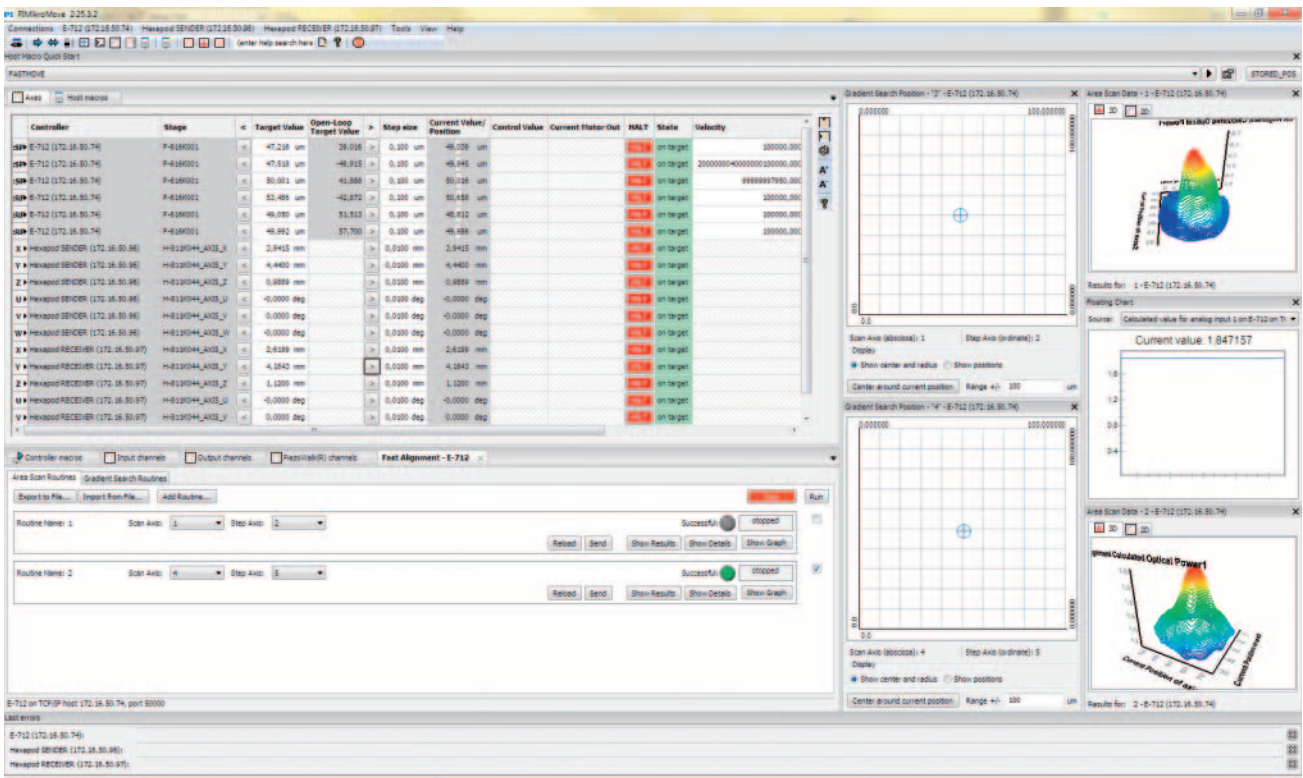
Available Programming Languages
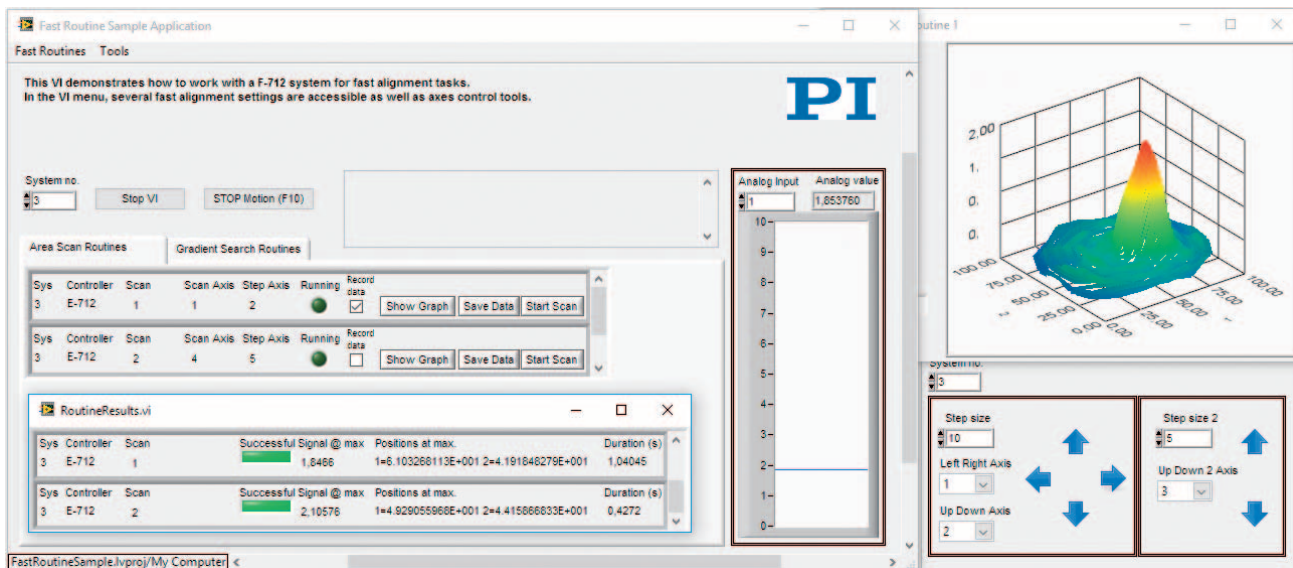
Ready-to-use NI LabVIEW sample application that provides fast access to controller-based alignment routines as well as visualization and system analysis.

User-friendly, platform-independent application development libraries and sample applications for easy, fast, and flexible implementation

- Libraries for C++, C#, VB.net, etc.
- Python
- NI LabVIEW
- MatLab

Available for Windows, Linux and OS X deployment. Universal Command Set (GCS) simplifies commissioning and programming. Supports PI controllers' built-in, ultrafast, and vibration-free scan/align algorithms. It is also possible to access the entire command set, including the fast alignment routines in the controller, in order to parameterize and execute them. This makes it possible for customers to integrate PI controllers into their own software solutions quickly and easily.

F-712.HU1 Fast Multi-Channel Photonics Alignment System

System with 6 Degrees of Freedom for Aligning Fibers and Optical Components

- Integrated scan routines for fiber optic alignment
- Ideal for applications in silicon photonics
- Extensive software package
- Position sensors for high accuracy and operational reliability
- Automatic alignment of several fibers in <0.2 s
- Freely selectable virtual pivot point
- High-resolution analog input

Fast and high-precision drives

The basis of the fiber alignment system is a very stiff setup with an H-811 hexapod and a P-616 NanoCube® nanopositioner. The parallel-kinematic design for motion in six degrees of freedom ensures high system stiffness. The motorized drives make long travel ranges possible and at the same time, the NanoCube® nanopositioner allows fast scanning motion and dynamic compensation of drift effects. Flexure guides and all-ceramic PICMA® actuators guarantee a long lifetime. Because all drives are equipped with position sensors, the system works precisely and reliably with high repeatability.

Applications

- Alignment of Optical Components
- Silicon Photonics Alignment
- Testing and packaging of Photonic Integrated Circuits
- Wafer Probing of Photonic Integrated Circuits

>> **Extensive software package**
>> **Flexures**
>> **Parallel Kinematics, Hexapods**
>> **PICMA® Multilayer piezo actuators**

	F-712.HU1	Unit
Motion and positioning		
Number of active axes	9	
Rough positioning		
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z	
Travel range in X, Y, Z	±17, ±16, ±6.5*	mm
Travel range in θ_X, θ_Y, θ_Z	±10, ±10, ±21*	°
Minimum incremental motion in X, Y	0.1	µm
Minimum incremental motion in Z	0.05	µm
Max. velocity	20	mm/s
Sensor type	Incremental rotary encoder	
Drive type	Brushless DC motor	
Fine positioning		
Active axes	X, Y, Z	
Travel range in X, Y, Z, closed loop	100	µm
Min. incremental motion, open-loop	0.3	nm
Min. incremental motion, closed-loop	2.5	nm
Linearity error, for the entire travel range**	2	%
Repeatability (bidirectional) 10 % travel range	2	nm
Sensor type	Incremental linear encoder	
Drive type	PICMA®	
Alignment		
Scanning time of spiraled area scan 500 µm Ø***	<2	s
Scanning time of spiraled area scan 100 µm Ø***	<0.3	s
Scanning time of spiraled area scan 10 µm Ø***	<0.2	s
Scanning time, gradient scan, randomized with ±5 µm (repeatability <0.01 dB)****	<0.3	s
Miscellaneous		
Operating temperature range, mechanics	0 to 50	°C
Operating temperature range, controller	5 to 40	°C
Cable length	2	m

Technical data specified at 20±3 °C.
* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent.
The data for each axis in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.
See the dimensional drawings for the default coordinate system and pivot point coordinates of the hexapod. Changing the pivot point will reduce the travel range in θ_X, θ_Y, θ_Z. Changing the orientation of the coordinate system (e.g., when the optical axis is to be the Z axis), will change the travel range in X, Y, and Z.
** without polynomial linearization
*** typical time span for scanning the entire area and moving to the highest intensity
**** reaching the global maximum after first light has been found
Ask about customized versions.

	Requirements for the optical power meter	Unit
Output signal	Analog output, ideally converted from linear to logarithmic	
Output voltage range, max.	–5 to 5	V
Bandwidth, min.	1	kHz
Noise level, max.	–60	dBm

F-712.HU1, dimensions in mm

Pivotpunkt (0;0;0)

Z+
Sender
Y+

64 ±0,05   62,5

7   6

∅3 F7

Fast Multi-Channel Photonics
Alignment Systems

F-712.HA1 High-Precision Single-Sided Fiber Alignment System

System with 6 Degrees of Freedom for Aligning Fibers and Optical Components

F-712.HA1, dimensions in mm

- Integrated scan routines for fiber optic alignment
- Ideal for applications in silicon photonics
- Extensive software package
- Direct detection of the optical signal, high-resolution analog input
- Position sensors for high accuracy and operational reliability
- Automatic alignment of several fibers in <0.2 s

Applications

- Alignment of Optical Components
- Silicon Photonics Alignment
- Testing and packaging of Photonic Integrated Circuits
- Wafer Probing of Photonic Integrated Circuits

>> Extensive software package
>> Flexures
>> Parallel Kinematics, Hexapods
>> PICMA® Multilayer piezo actuators

	F-712.HA1	Unit
Motion and positioning		
Number of active axes	9	
Rough positioning		
Active axes	X, Y, Z, θ$_X$, θ$_Y$, θ$_Z$	
Travel range in X, Y, Z	±6.5, ±16, ±8.5*	mm
Travel range in θ$_X$, θ$_Y$, θ$_Z$	±14.5, ±10, ±10*	°
Minimum incremental motion	0.1	µm
Max. velocity	10	mm/s
Sensor type	Rotary encoder	
Guide	–	
Drive type	Brushless DC motor	
Fine positioning		
Active axes	X, Y, Z	
Travel range in X, Y, Z, closed loop	100	µm
Min. incremental motion, open-loop	0.3	nm
Min. incremental motion, closed-loop	2.5	nm
Linearity error, for the entire travel range**	2	%
Repeatability (bidirectional) 10 % travel range	2	nm
Sensor type	Incremental	
Drive type	PICMA®	
Alignment		
Scanning time of spiraled area scan 500 µm Ø***	<2	s
Scanning time of spiraled area scan 100 µm Ø***	<0.3	s
Scanning time of spiraled area scan 10 µm Ø***	<0.2	s
Scanning time, gradient scan, randomized with ±5 µm (repeatability <0.01 dB)****	<0.3	s
Miscellaneous		
Operating temperature range, mechanics	0 to 50	°C
Operating temperature range, controller	5 to 40	°C
Cable length	2	m

Technical data specified at 20±3 °C.
* The travel ranges of the individual coordinates (X, Y, Z, θ$_X$, θ$_Y$, θ$_Z$) are interdependent.
The data for each axis in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.
See the dimensional drawings for the default coordinate system and pivot point coordinates of the hexapod. Changing the pivot point will reduce the travel range in θ$_X$, θ$_Y$, θ$_Z$. Changing the orientation of the coordinate system (e.g., when the optical axis is to be the Z axis), will change the travel range in X, Y, and Z.
** without polynomial linearization
*** typical time span for scanning the entire area and moving to the highest intensity
**** reaching the global maximum after first light has been found
Ask about customized versions.

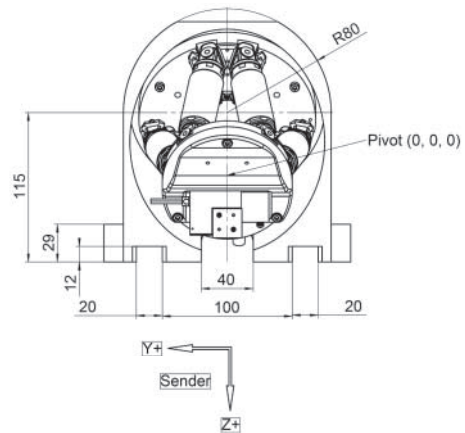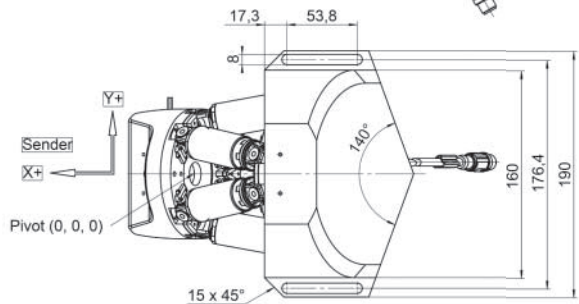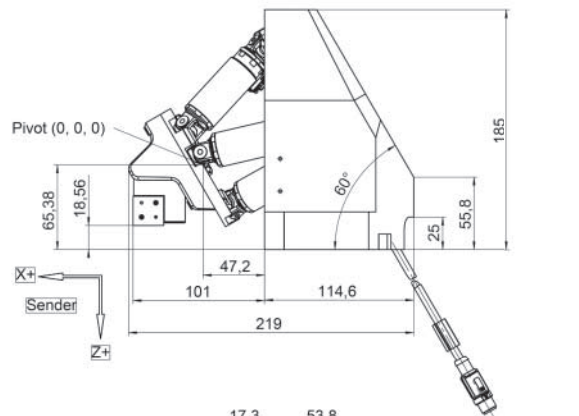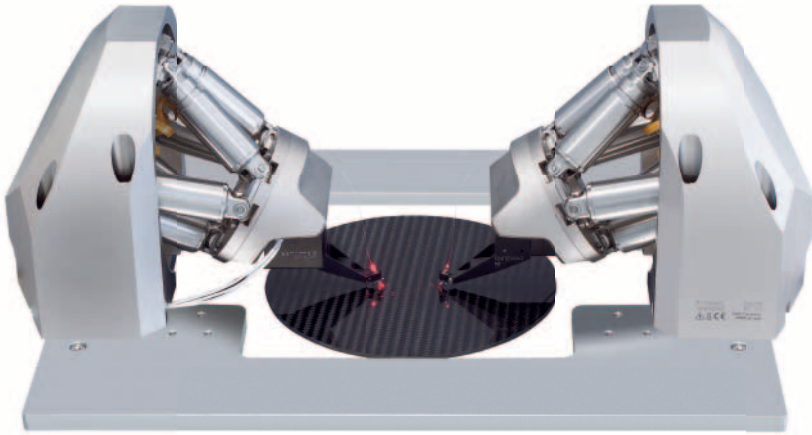|	Requirements for the optical power meter	Unit
Output signal	Analog output, ideally converted from linear to logarithmic	
Output voltage range, max.	–5 to 5	V
Bandwidth, min.	1	kHz
Noise level, max.	–60	dBm

F-712.HA2 High-Precision Double-Sided Fiber Alignment System

System with 6 Degrees of Freedom for Aligning Fibers and Optical Components

Double-sided fiber alignment system.
Actual model may differ.

- Integrated scan routines for fiber optic alignment
- Ideal for applications in silicon photonics
- Extensive software package
- Direct detection of the optical signal, high-resolution analog input
- Position sensors for high accuracy and operational reliability
- Automatic alignment of several fibers in <0.5 s
- Simultaneous alignment of the transmitter and receiver

Fast and high-precision drives

The basis of the fiber alignment system is a very stiff setup with an H-811 hexapod and a P-616 NanoCube® nanopositioner. The parallel-kinematic design for motion in degrees of freedom ensures high system stiffness. The motorized drives make longer travel ranges possible and at the same time, the NanoCube® nanopositioner ensures fast scanning motion and dynamic compensation of drift effects. Flexure guides and all-ceramic insulated PICMA® actuators guarantee a long lifetime. Because all drives are equipped with position sensors, it is possible for example, to reliably prevent collisions with expensive silicon wafers.

Applications

- Alignment of Optical Components
- Silicon Photonics Alignment
- Testing and packaging of Photonic Integrated Circuits
- Wafer Probing of Photonic Integrated Circuits

>> **Extensive software package**
>> **Flexures**
>> **Parallel Kinematics, Hexapods**
>> **PICMA® Multilayer piezo actuators**

Technology Glossary .... page **124**

	F-712.HA2	Unit
Motion and positioning		
Number of active axes	18	
Rough positioning		
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z	
Travel range in X, Y, Z	±6.5, ±16, ±8.5*	mm
Travel range in θ_X, θ_Y, θ_Z	±14.5, ±10, ±10*	°
Minimum incremental motion	0.1	µm
Max. velocity	10	mm/s
Sensor type	Rotary encoder	
Guide	–	
Drive type	Brushless DC motor	
Fine positioning		
Active axes	X, Y, Z	
Travel range in X, Y, Z, closed loop	100	µm
Min. incremental motion, open-loop	0.3	nm
Min. incremental motion, closed-loop	2.5	nm
Linearity error, for the entire travel range**	2	%
Repeatability (bidirectional) 10 % travel range	2	nm
Sensor type	Incremental	
Drive type	PICMA®	
Alignment		
Scanning time of spiraled area scan 500 µm Ø***	<5	s
Scanning time of spiraled area scan 100 µm Ø***	<1	s
Scanning time of spiraled area scan 10 µm Ø***	<0.5	s
Scanning time, gradient scan, randomized with ±5 µm (repeatability <0.01 dB)****	<0.3	s
Miscellaneous		
Operating temperature range, mechanics	0 to 50	°C
Operating temperature range, controller	5 to 40	°C
Cable length	2	m

Technical data specified at 20±3 °C.

* The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent.
The data for each axis in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.
See the dimensional drawings for the default coordinate system and pivot point coordinates of the hexapod. Changing the pivot point will reduce the travel range in θ_X, θ_Y, θ_Z. Changing the orientation of the coordinate system (e.g., when the optical axis is to be the Z axis), will change the travel range in X, Y, and Z.
** without polynomial linearization
*** typical time span for scanning the entire area and moving to the highest intensity
**** reaching the global maximum after first light has been found
Ask about customized versions.

	Requirements for the optical power meter	Unit
Output signal	Analog output, ideally converted from linear to logarithmic	
Output voltage range, max.	–5 to 5	V
Bandwidth, min.	1	kHz
Noise level, max.	–60	dBm

Fast Multi-Channel Photonics Alignment Systems

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F-712.HA2, dimensions in mm. The systems on both sides are identical and can be used as either sender or receiver.

Pivotpoint
(0, 0, 0)

18,56
65,38
60°
185
47,2
29
25
101
114,6
219

X- X+
Sender
Receiver
Z+
Z+

Pivotpoint
(0, 0, 0)
R80
115
12
40
20
100
20

Y- Y+
Sender
Receiver
Z+
Z+

17,3
53,8
8
Sender
Receiver
Y-
Y+
140°
160
176,4
190
X- X+
Pivotpoint
(0, 0, 0)

F-712.HA2 Double-sided fiber alignment system with two H-811 hexapods and two NanoCube® Nanopositioners, integrated mounting flanges. Image of actual model.
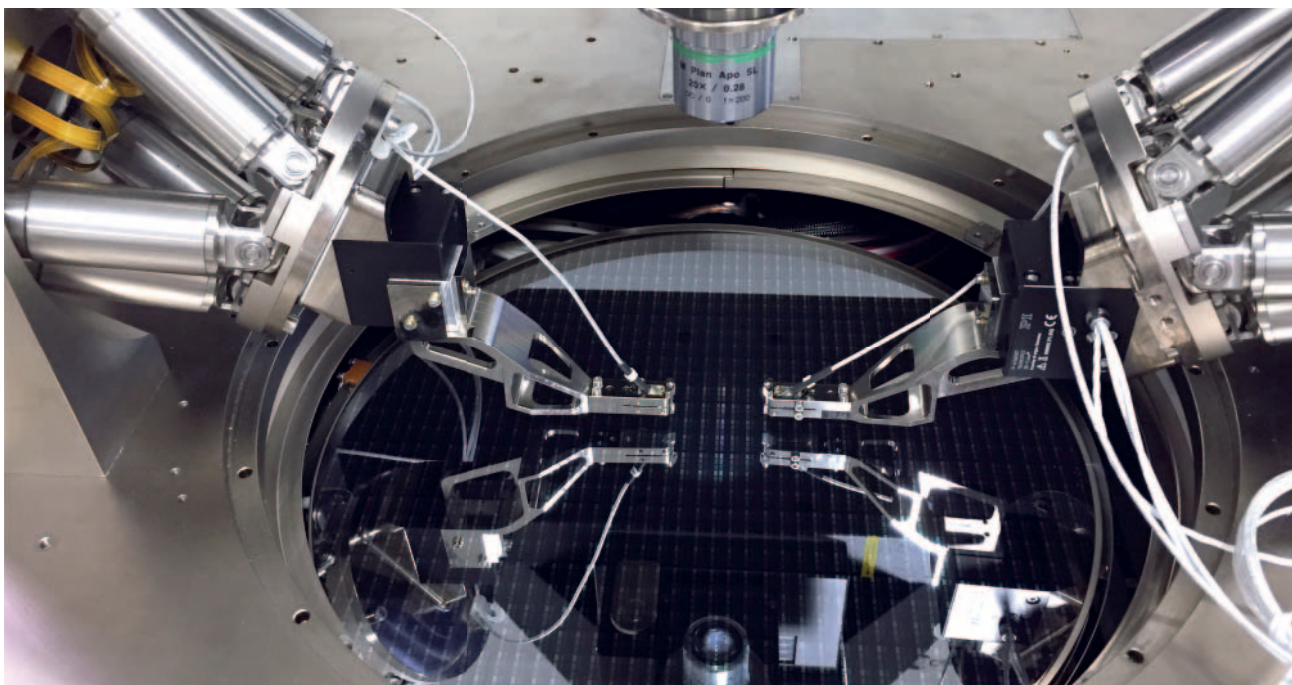
18-Axis double alignment system provides fast NxM alignment of SiP devices in wafer probers. Cascade Microtech's pioneering CM300xi photonics-enabled engineering wafer probe station integrates PI's Fast Multichannel Photonics Alignment systems for high throughput, wafer-safe, nano-precision optical probing of on-wafer Silicon Photonics devices. (Image: Cascade Microtech, a FormFactor company)

Before dispatching, the P-616 Nanocube® is tuned to follow a circular trajectory in order to achieve optimum results. The figure shows that the P-616 achieves almost perfect circular movement in any combination of the three axes. The circle diameter is 5 µm at a frequency of 100 Hz. Position units in micrometers.

Fast Multi-Channel Photonics Alignment Systems

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F-712.MA1 High-Precision Single-Sided Fiber Alignment System

Stacked Multi-Axis System for Aligning Fibers and Optical Components

- Integrated scan routines for fiber optic alignment
- Ideal for applications in silicon photonics
- Extensive software package
- Direct detection of the optical signal, high-resolution analog input
- Position sensors for high accuracy and operational reliability
- Automatic alignment of several fibers in <0.2 s

F-712.MA1, dimensions in mm
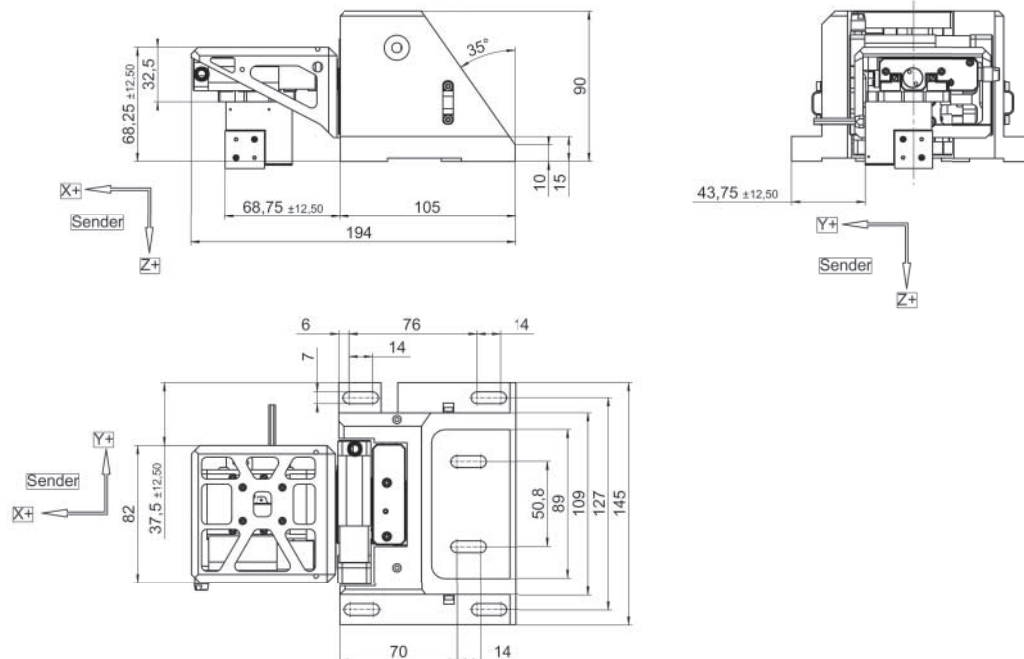
Applications

- Alignment of Optical Components
- Silicon Photonics Alignment
- Testing and packaging of Photonic Integrated Circuits
- Wafer Probing of Photonic Integrated Circuits

>> Extensive software package
>> Flexures
>> PICMA® Multilayer piezo actuators
>> Serial kinematics

Technology Glossary .... page **124**

	F-712.MA1	Unit
Motion and positioning		
Number of active axes	6	
Rough positioning		
Active axes	X, Y, Z	
Travel range in X, Y, Z	25, 25, 25	mm
Minimum incremental motion	3	µm
Max. velocity	20	mm/s
Sensor type	Rotary encoder	
Guide	Crossed roller guide	
Drive type	DC motor	
Fine positioning		
Active axes	X, Y, Z	
Travel range in X, Y, Z, closed loop	100	µm
Min. incremental motion, open-loop	0.3	nm
Min. incremental motion, closed-loop	2.5	nm
Linearity error, for the entire travel range*	2	%
Repeatability (bidirectional) 10 % travel range	2	nm
Sensor type	Incremental	
Drive type	PICMA®	
Alignment		
Scanning time of spiraled area scan 500 µm Ø**	<3	s
Scanning time of spiraled area scan 100 µm Ø**	<0.3	s
Scanning time of spiraled area scan 10 µm Ø**	<0.2	s
Scanning time, gradient scan, randomized with ±5 µm (repeatability <0.01 dB)***	<0.3	s
Miscellaneous		
Operating temperature range, mechanics	–20 to 65	°C
Operating temperature range, controller	5 to 40	°C
Cable length	3	m

Technical data specified at 20±3 °C.

*   without polynomial linearization

**   typical time span fod scanning the entire area and moving to the highest intensity

*** reaching the global maximum after first light has been found

Ask about customized versions.

	Requirements for the optical power meter	Unit
Output signal	Analog output, ideally converted from linear to logarithmic	
Output voltage range, max.	–5 to 5	V
Bandwidth, min.	1	kHz
Noise level, max.	–60	dBm

Fast Multi-Channel Photonics Alignment Systems

F-712.MA2 High-Precision Double-Sided Fiber Alignment System

Stacked Multi-Axis System for Aligning Fibers and Optical Components

- Integrated scan routines for fiber optic alignment
- Ideal for applications in silicon photonics
- Extensive software package
- Direct detection of the optical signal, high-resolution analog input
- Position sensors for high accuracy and operational reliability
- Automatic alignment of several fibers in <0.5 s
- Simultaneous alignment of the transmitter and receiver

Fast and high-precision drives

The basis of the fiber alignment system is a very stiff XYZ setup consisting of three motorized linear stages and a P-616 NanoCube® nanopositioner. The low overall height simplifies integration in limited installation space. The motorized drives make longer travel ranges possible and at the same time, the NanoCube® nanopositioner ensures fast scanning motion and dynamic compensation of drift effects. Flexure guides and all-ceramic insulated PICMA® actuators guarantee a long lifetime. Because all drives are equipped with position sensors, it is possible for example, to reliably prevent collisions with expensive silicon wafers.

Applications

- Alignment of Optical Components
- Silicon Photonics Alignment
- Testing and packaging of Photonic Integrated Circuits
- Wafer Probing of Photonic Integrated Circuits

>> Extensive software package
>> Flexures
>> Parallel Kinematics, Hexapods
>> PICMA® Multilayer piezo actuators
>> Serial kinematics

	F-712.MA2	Unit
Motion and positioning		
Number of active axes	12	
Rough positioning		
Active axes	X, Y, Z	
Travel range in X, Y, Z	25, 25, 25	mm
Minimum incremental motion	3	µm
Max. velocity	20	mm/s
Sensor type	Rotary encoder	
Guide	Crossed roller guide	
Drive type	DC motor	
Fine positioning		
Active axes	X, Y, Z	
Travel range in X, Y, Z, closed loop	100	µm
Min. incremental motion, open-loop	0.3	nm
Min. incremental motion, closed-loop	2.5	nm
Linearity error, for the entire travel range*	2	%
Repeatability (bidirectional) 10 % travel range	2	nm
Sensor type	Incremental	
Drive type	PICMA®	
Alignment		
Scanning time of spiraled area scan 500 µm Ø**	<6	s
Scanning time of spiraled area scan 100 µm Ø**	<1	s
Scanning time of spiraled area scan 10 µm Ø**	<0.5	s
Scanning time, gradient scan, randomized with ±5 µm (repeatability <0.01 dB)***	<0.3	s
Miscellaneous		
Operating temperature range, mechanics	–20 to 65	°C
Operating temperature range, controller	5 to 40	°C
Cable length	3	m

Technical data specified at 20±3 °C.
*   without polynomial linearization
**   typical time span fod scanning the entire area and moving to the highest intensity
*** reaching the global maximum after first light has been found
Ask about customized versions.

	Requirements for the optical power meter	Unit
Output signal	Analog output, ideally converted from linear to logarithmic	
Output voltage range, max.	–5 to 5	V
Bandwidth, min.	1	kHz
Noise level, max.	–60	dBm

F-712.MA2, dimensions in mm. The systems on both sides
are identical and can be used as either sender or receiver.
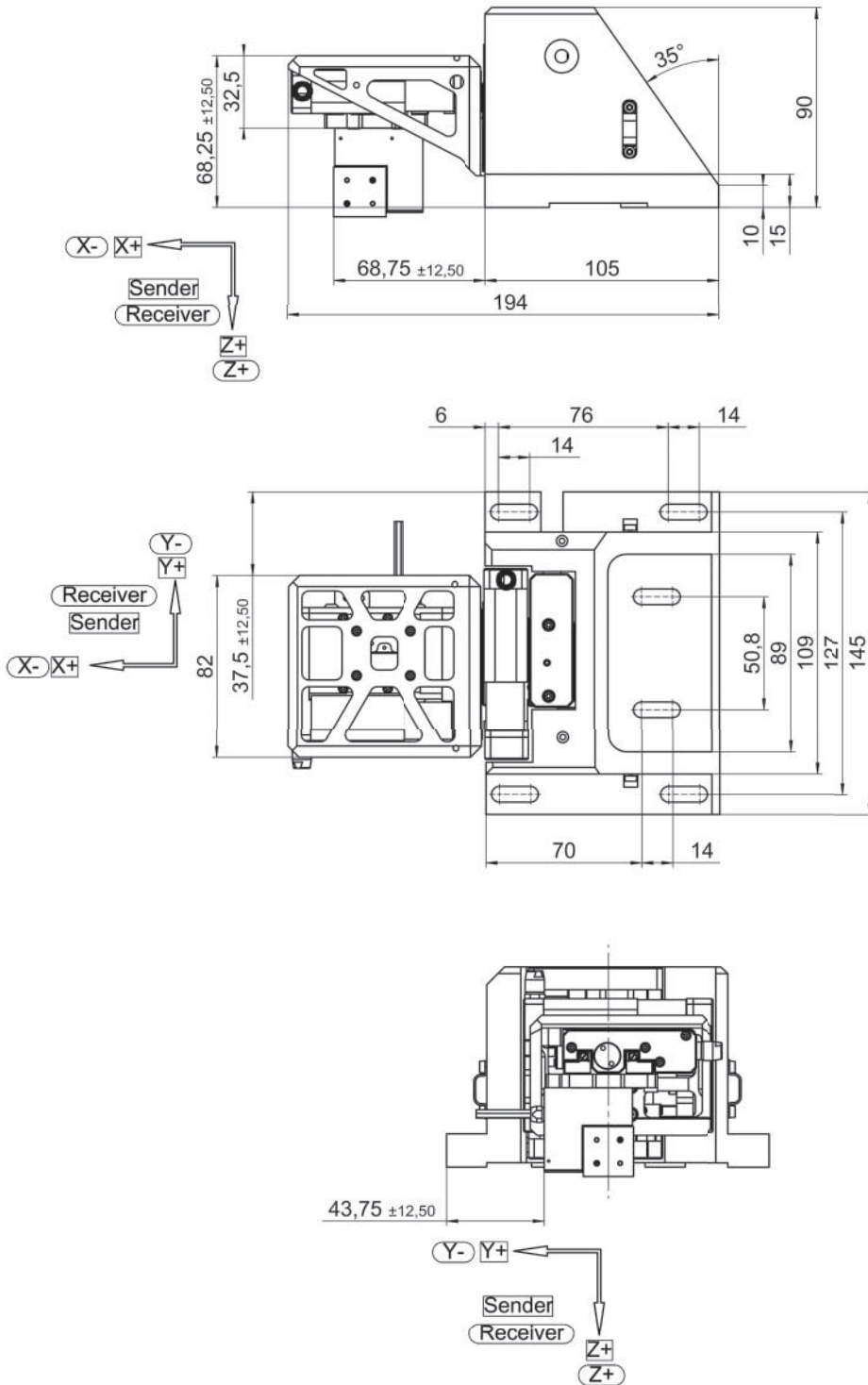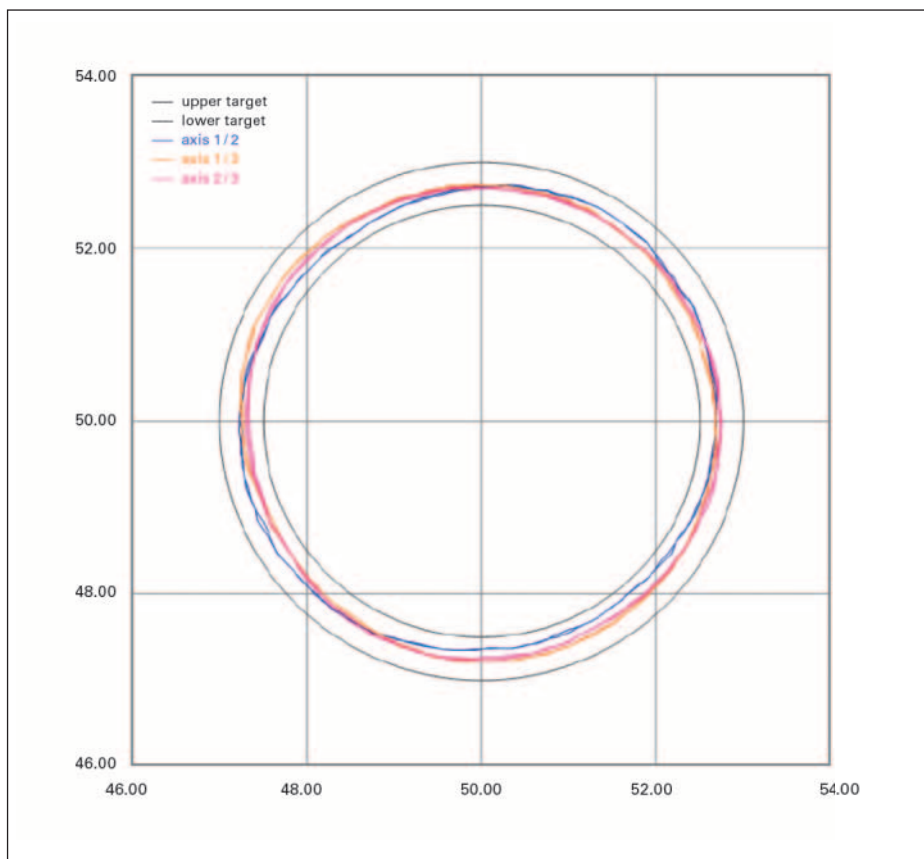
Before dispatching, the P-616 Nanocube® is tuned to follow a circular trajectory in order to achieve optimum results. The figure shows that the P-616 achieves almost perfect circular movement in any combination of the three axes. The circle diameter is 5 µm at a frequency of 100 Hz. Position units in micrometers.

F-712.PM1 Optical Power Meter

Ideal for Applications in Silicon Photonics

- Large signal bandwidth of 20 kHz
- High dynamic range
- Wavelength range 400 to 1550 nm
- Current input range to 1 mA
- Logarithmic output

F-712.PM1, dimensions in mm
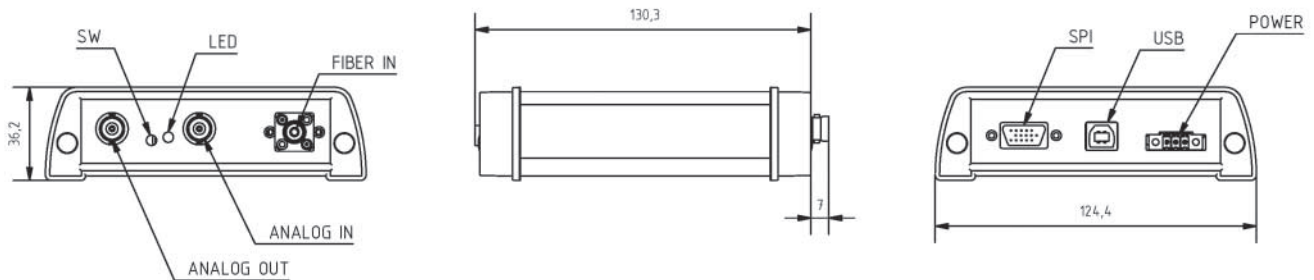
Applications

- Fiber Alignment
- Silicon Photonics Alignment

>> Extensive software package

>> Flexures

>> Parallel Kinematics, Hexapods

>> PICMA® Multilayer piezo actuators

	F-712.PM1	Unit	Tolerance
Optical input			
Wavelength range	400 to 1550*	nm	
Connectors	FC/PC, FC/APC		
Polarization dependence	None		
Minimum input power at 1550 nm	85	nW	
Maximum input power at 1550 nm	85	mW	
Average noise at 1550 nm	<10	nW	
Current input			
Connectors	BNC		
Minimum input current	0		
Maximum input current	1	mA	
Average noise	<120	pA	
Output			
Connectors	BNC		
Output signal	Analog, logarithmic		
Voltage range	−5 to 5	V	typ.
Bandwidth (3dB)	20	kHz	
Logarithmic increase	1	V/10 dB	
Output voltage at 85 mW, 1550 nm	≈ +5**	V	
Output voltage at 85 nW, 1550 nm	≈ −1.2**	V	
Output voltage at 1 mA input current	+5	V	
Miscellaneous			
Operating voltage	12 to 24	V	
Power consumption	2.4	W	
Overall mass	0.6	kg	
Relative humidity	20 to 70	%	Not condensing
Operating temperature range	5 to 40	°C	
Storage temperature range	−10 to 50	°C	

* See "Drawings and Images" for a typical course of sensitivity.
Individual measurement report on the exact distribution of sensitivity in scope of delivery.
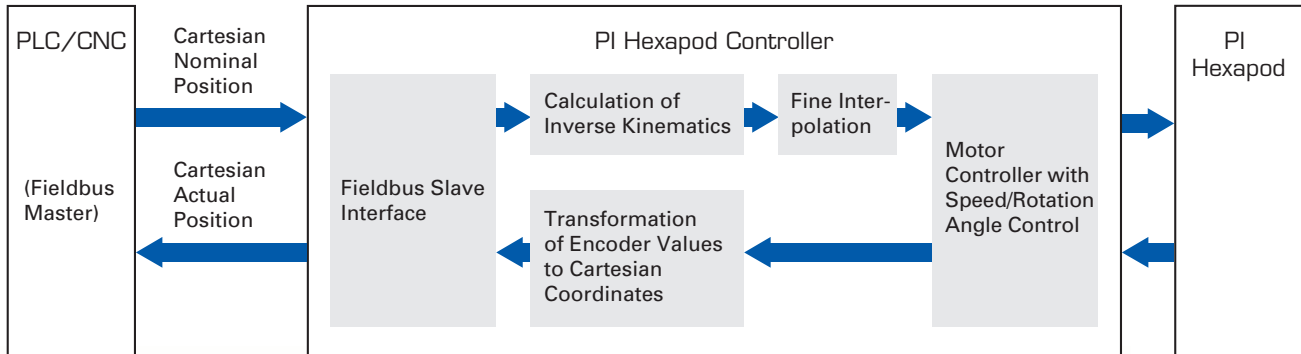** Measurement report in scope of delivery.
The exact calculation of the light output is described in the documentation supplied.
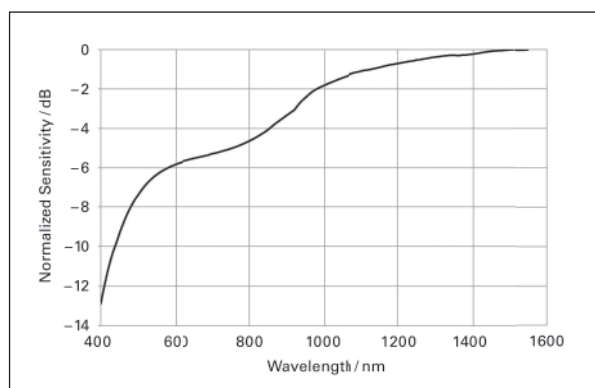
Typical sensitivity curve depending on the wavelength

Motion Control

MOTION | POSITIONING

Motion Control

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

C-887.5xx, dimensions in mm. Version-dependent interfaces
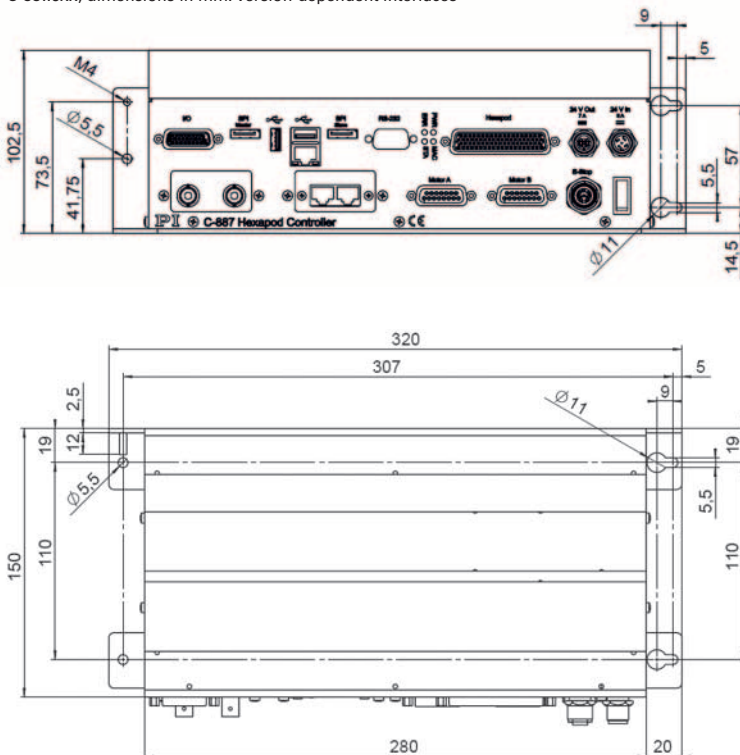
Functions

Position input via Cartesian coordinates, coordinate transformation handled by the controller. To simplify integration of the hexapod, the reference system (Work, Tool) can be quickly and easily changed. The real-time operating system prevents jitter and therefore guarantees constantly low response times. Stable, virtual pivot point can be freely defined in space. Data recorder for recording of operating data such as motor control, velocity, position or position errors. Macro programming. An autostart macro allows stand-alone operation. The controller supports motor brakes and absolute-measuring sensors with BiSS interface.

>> **Extensive Software Package**

	C-887.52 C-887.521 C-887.522 C-887.523
Function	6-axis controller for hexapods, incl. control of two additional single axes Compact benchtop device Extending the functionality of C-887.52: C-887.521: Additional analog inputs C-887.522: Additional motion stop C-887.523: Additional motion stop and analog inputs
Drive type	Servo motors (hexapod and single axes)
Motion and control	
Controller type	32-bit PID controller
Trajectory profiles	Jerk-controlled generation of dynamics profile with linear interpolation
Processor	Intel Atom dual core (1.8 GHz)
Servo cycle time	100 µs
Encoder input	AB (quadrature) differential TTL signal, 50 MHz BiSS
Stall detection	Servo off, triggered by position error
Reference point switch	TTL
Electrical properties	
Hexapod control	12-bit PWM signal, TTL, 24 kHz
Hexapod power supply	24 V
Maximum output current	7 A
Interfaces and operation	
Communication interfaces	TCP/IP, RS-232 USB (HID, manual control unit)
Hexapod connection	HD Sub-D 78 (f) for data transmission M12 4 (f) for power supply
Connectors for single axes	Sub-D 15 (f)
I/O lines	HD Sub-D 26 (f): 4 × analog input (-10 to 10 V, via 12-bit A/D converter) 4 × digital input (TTL) 4 × digital output (TTL)
Analog inputs	C-887.521 and C-887.523 only: 2 × BNC, –5 V to 5 V, via 16-bit A/D converter, 5 kHz bandwidth
Input for motion stop	C-887.522 and C-887.523 only: M12 8 (f)
Command set	PI General Command Set (GCS)
User software	PIMikroMove
Application programming interfaces	API for C / C++ / C# / VB.NET / MATLAB / Python, drivers for NI LabVIEW
Manual control	Optional: C-887.MC manual control unit for hexapods
Miscellaneous	
Operating voltage	24 V (external power adapter for 100 to 240 V AC, 50 / 60 Hz in the scope of delivery)
Maximum current consumption	8 A
Operating temperature range	5 to 40 °C
Mass	2.8 kg
Dimensions	280 (320) mm × 150 mm × 103 mm Power adapter: 170 mm × 85 mm × 42.5 mm

Motion Control

C-887.53x
Hexapod Motion Controller with EtherCAT®

Control a 6-Axis Positioning System via Fieldbus Interface

Digital controller with EtherCAT fieldbus interface

Digital controller for hexapods (6-axis parallel kinematics) with DC motors. Additional control for two further single axes is integrated. Can be integrated seamlessly into automation systems in industry and research. Performs coordinate transformation for parallel kinematics. Customer requires a higher-level PLC control for position commanding and feedback in Cartesian coordinates (EtherCAT master with CoE protocol).

Supported operating modes

Reference move of the hexapods to the middle position of all six axes. Absolute positioning in six Cartesian axes. Cyclic position commanding via PLC for synchronization with further automation components. Operation is possible via TCP/IP or RS-232 without PLC master. The controller functionality then corresponds to a C-887.52x. Commanding of the hexapods is then done directly via the PI GCS.

- Integration into an automation system
- Synchronous motion in 6 axes
- Cycle time 1 ms
- Commanding in Cartesian coordinates
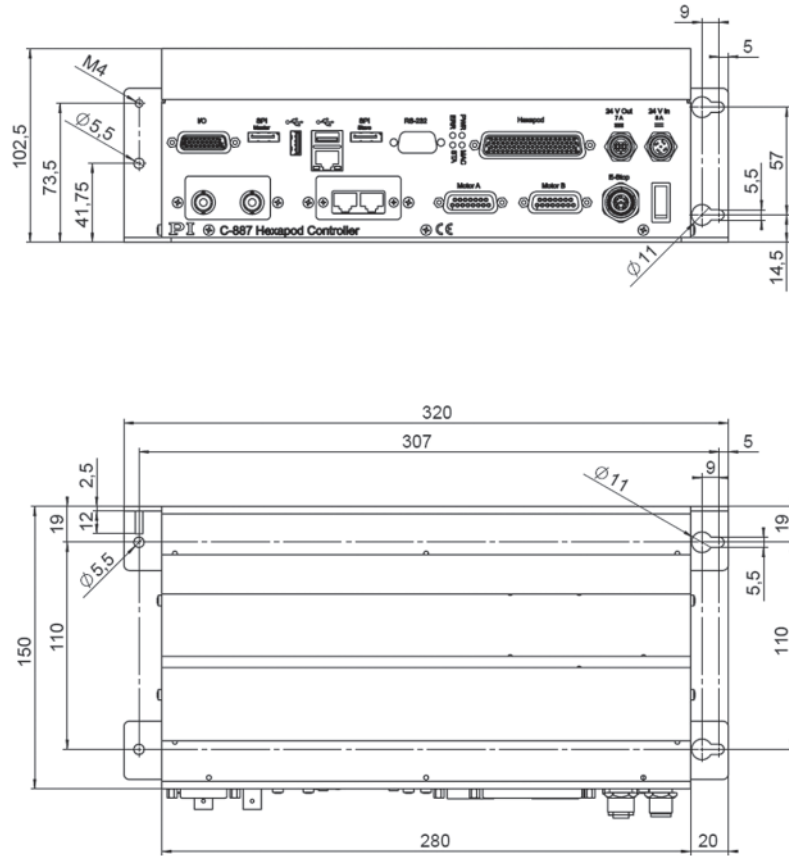- Analog interfaces and motion stop optional

>> EtherCAT® Fieldbus Interface
>> Extensive Software Package

C-887.53
C-887.531
**C-887.532**
C-887.533

Function	6-axis controller for hexapods, incl. control of two additional single axes Compact benchtop device with EtherCAT interface Extending the functionality of C-887.53: C-887.531: Additional analog inputs C-887.532: Additional motion stop C-887.533: Additional motion stop and analog inputs
Drive type	DC motors (hexapod and single axes)
EtherCAT Specifications	
Fieldbus protocol	EtherCAT (CoE = CANopen over EtherCAT)
Drive profile	CiA402 Drive Profile (IEC 61800-7-201)
Cycle time	1 ms
Supported modes of operation	Reference move (homing mode) Positioning mode with cyclical target position via the PLC (cyclic synchronous position mode) Configuration mode (initially for startup)
Supported modes of synchronization	Distributed Clock (DC) mode; SyncManager (SM) mode
Motion and control	
Controller type	32-bit PID controller
Trajectory profiles	Jerk-controlled generation of dynamics profile with linear interpolation
Processor	Intel Atom dual core (1.8 GHz)
Servo cycle time	100 µs
Encoder input	AB (quadrature) differential TTL signal, 50 MHz BiSS
Stall detection	Servo off, triggered by position error
Reference point switch	TTL
Electrical properties	
Hexapod control	12-bit PWM signal, TTL, 24 kHz
Hexapod power supply	24 V
Maximum output current	7 A
Interfaces and operation	
Communication interfaces	2 x RJ45 for EtherCAT (In/Out) TCP/IP, RS-232 USB (HID, manual control unit)
Hexapod connection	HD Sub-D 78 (f) for data transmission M12 4 (f) for power supply
Connectors for single axes	Sub-D 15 (f)
I/O lines	HD Sub-D 26 (f): 4 × analog input (-10 to 10 V, via 12-bit A/D converter) 4 × digital input (TTL) 4 × digital output (TTL)
Analog inputs	C.887.531 and C-887.533 only: 2 x BNC, –5 V to 5 V, via 16-bit A/D converter, 5 kHz bandwidth
Input for motion stop	C-887.532 and C-887.533 only: M12 8 (f)
Command set	PI General Command Set (GCS)
User software	PIMikroMove
Application programming interfaces	API for C / C++ / C# / VB.NET / MATLAB / Python, drivers for NI LabVIEW
Manual operation	Optional: C-887.MC control unit for hexapods
Miscellaneous	
Operating voltage	24 V (external power adapter for 100 to 240 V AC, 50 / 60 Hz in the scope of delivery)
Maximum current consumption	8 A
Operating temperature range	5 to 40 °C
Mass	2.8 kg
Dimensions	280 (320) mm × 150 mm × 103 mm Power adapter: 170 mm × 85 mm × 42.5 mm

Motion Control

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C-887.53x, dimensions in mm. Version-dependent interfaces

Example configuration: H811 miniature hexapod with C-887.532 motion controller
with EtherCAT interface and motion stop. The EtherCAT master, here a Beckhoff controller,
is provided and programmed by the customer.
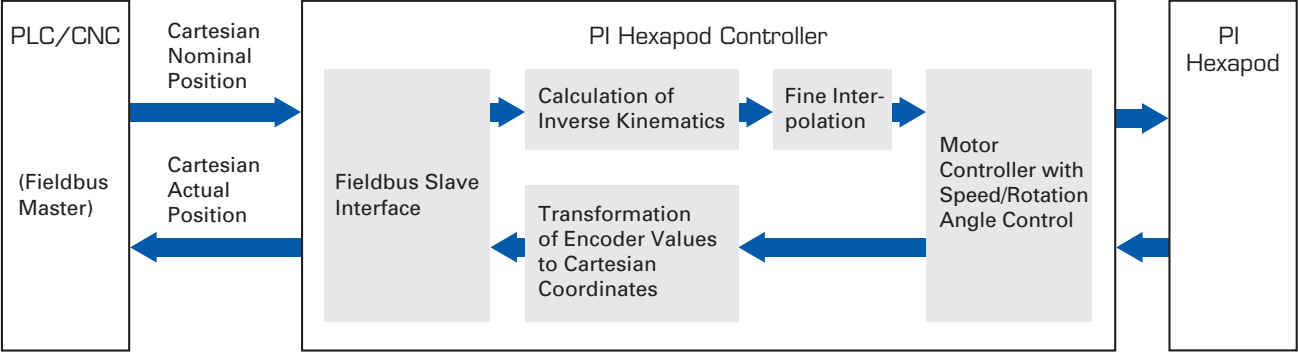
Integration of the hexapod motion controller into an automation system
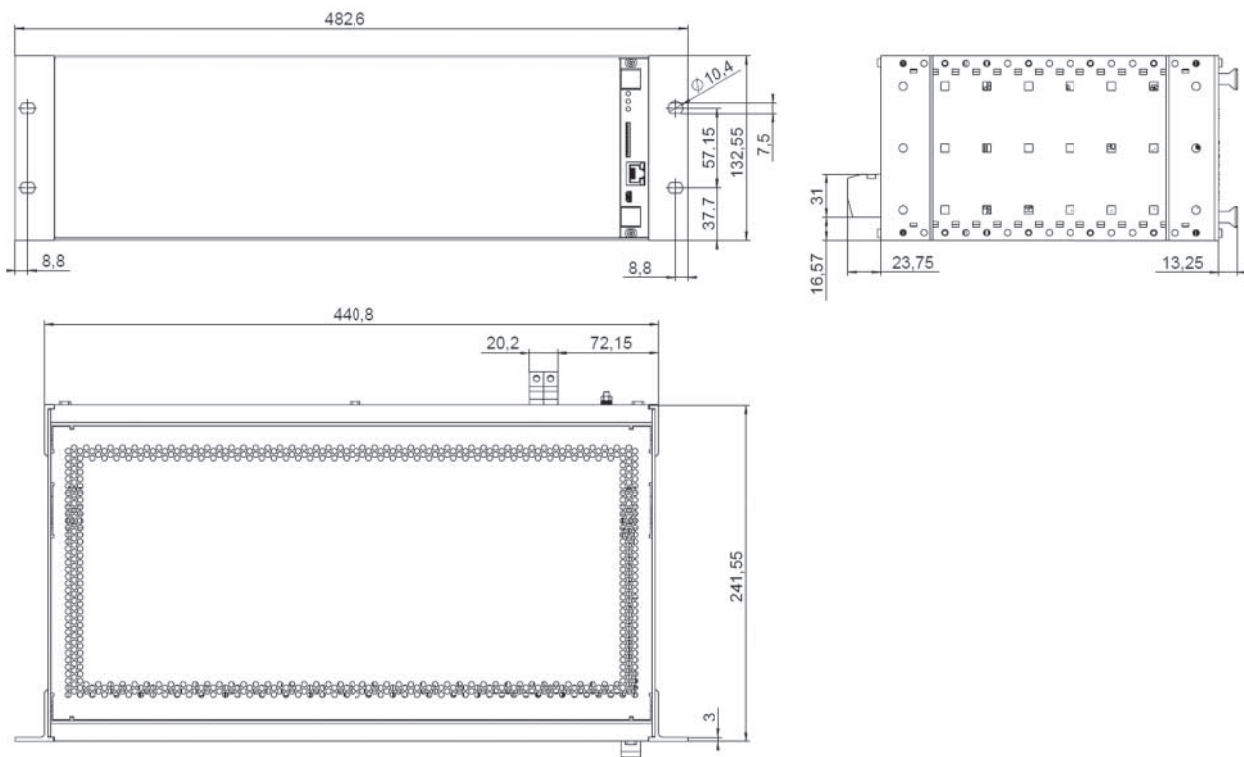
Motion Control

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C-886.31 Parallel Kinematics Controller

For Parallel-Kinematic Positioners with Q-Motion® Piezo Inertia Drive

- Sophisticated controller using vector algorithms
- Commanding in Cartesian coordinates
- Easy customization of coordinate systems by command
- Suitable for Q-Motion® SpaceFAB
- Can be optionally expanded by two single axes
- Extensive software package

C-886, dimensions in mm, here without drive modules

>> **Extensive Software Package**

>> **Q-Motion® Piezoelectric Inertia Drive**

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	C-886.31
Function	Controller for parallel-kinematic positioners
Axes	6 Optional: 2 additional single axes
Motion and control	
Drive type	Q-Motion® Piezo Inertia Drive Optional single-axis drive type
Motor connection	Sub-D 15 (f)
Controller type	PID controller
Servo cycle time of slave modules	50 µs
Cycle time of the C-886	10 ms
Encoder input	Sin / cos (differential), BiSS interface
Stall detection	Servo off, triggered by position error
Limit switches	2 × TTL per drive (polarity programmable)
Reference point switch	1 × TTL per drive
Characteristics of single axes	Depending on the drive type
Electrical properties	
Output voltage	0 to 48 V
Max. output power	30 W per drive
Characteristics of single axes	Depending on the drive type
Interfaces and operation	
Communication interfaces	TCP/IP: RJ45/Ethernet; USB: Mini-USB type B
Command set	PI General Command Set (GCS)
User software	PIMikroMove
Application programming interfaces	API for C / C++ / C# / VB.NET / MATLAB / Python, drivers for NI LabVIEW
Supported functions	User-defined coordinate system. Startup macro. Data recorder for recording operating data. Wave generator for periodic motion.
Miscellaneous	
Operating voltage	External power adapter 24 V / 10 A in the scope of delivery
Max. current consumption	32 A
Operating temperature range	10 to 40 °C
Mass	4.4 kg without drive modules for single axes
Dimensions	482.6 mm × 132.55 mm × 278.55 mm

Motion Control

C-887.MC
Manual Control Unit for Hexapods

Easy Manual Operation

C-887.MC in practical use

- 6 rotary knobs for independent positioning of all Cartesian axes; velocity and step size can be set
- Additional pushbuttons for motion stop and referencing
- Display of the position of all Cartesian axes
- Display of velocity, errors or pivot point possible
- USB port for direct connection to the controller
- Functionality integrated in the firmware of the C-887 controller

Ordering Information

C-887.MC   Manual control unit for hexapods, USB connector, 3 m cable

C-887.5xxx Hexapod Cable Sets

		Description	Length	Item number
C-887.5B03	Hexapod cable set 3 m, drag chain compatible*, consisting of:	Data transmission cable, HD Sub-D 78 f/m, 1:1 Power supply cable, M12 m/f, 1:1	3 m 3 m	K040B0270 K060B0262
C-887.5B05	Hexapod cable set 5 m, drag chain compatible*, consisting of:	Data transmission cable, HD Sub-D 78 f/m, 1:1 Power supply cable, M12 m/f, 1:1	5 m 5 m	K040B0271 K060B0222
C-887.5B07	Hexapod cable set 7.5 m, drag chain compatible*, consisting of:	Data transmission cable, HD Sub-D 78 f/m, 1:1 Power supply cable, M12 m/f, 1:1	7.5 m 7.5 m	K040B0295 K060B0223
C-887.5B10	Hexapod cable set 10 m, drag chain compatible*, consisting of:	Data transmission cable, HD Sub-D 78 f/m, 1:1 Power supply cable, M12 m/f, 1:1	10 m 10 m	K040B0296 K060B0224
C-887.5B20	Hexapod cable set 20 m, drag chain compatible*, consisting of:	Data transmission cable, HD Sub-D 78 f/m, 1:1 Power supply cable, M12 m/f, 1:1	20 m 20 m	K040B0297 K060B0225
C-887.5A50	Hexapod cable set 50 m, consisting of:	Line driver box for data transmission cable, controller-side	–	C887B0057
		Line driver box for data transmission cable, hexapod-side	–	C887B0058
		Short data transmission cable, HD Sub-D 78 f/m, 1:1	3 m	K040B0034
		Long data transmission cable, HD Sub-D 44 f/m, 1:1, three pieces	44 m	K040B0277
		Power supply cable for hexapod-side line driver box, with M12 connector (m)/M-12 connector (f)	47 m	K060B0228
		Power supply for hexapod, with M12 connector (f) and power cord	1.5 m**	C-887.5PS
		Würth snap-on ferrite, for hexapod power supply	–	000012097

*   For specifications, see "Drag Chain Compatible Cables"
** The length refers to the cable between the power supply and the hexapod

Drag Chain Compatible Cables

	C-887.5B03 C-887.5B05 C-887.5B07 C-887.5B10 C-887.5B20	Unit
Cable length	3 / 5 / 7.5 / 10 / 20	m
Maximum velocity	3	m/s
Maximum acceleration	7.5	m/s^2
Maximum number of bending cycles	1 million	
Power supply cable		
Operating temperature range	−10 to +70	°C
Minimum bending radius in a drag chain	94	mm
Minimum bending radius with the fixed installation	57	mm
Outer diameter	7.5	mm
Data transmission cable		
Operating temperature range	−20 to +80	°C
Minimum bending radius in a drag chain	67	mm
Minimum bending radius with the fixed installation	102	mm
Outer diameter	10.2	mm

C-887.MSB Motion Stop Box

Ordering Information

C-887.MSB   Motion stop box
for C-887 models with E-Stop socket

Motion-Stop-Box
C-887.MSB

Controller
C-887.5x2 or C-887.5x3

male
M12
8-pin

male
M12
4-pin

Power supply cable

female
M12
4-pin

male
HD D-Sub 78

Data transmission cable

female
HD D-Sub 78

female
M12
4-pin

Power Supply
C-887.5PS

E-Stop socket with C-887.MSB
motion stop box

PI

MOTION | POSITIONING

Motion Control

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Specific Software for Hexapod Systems
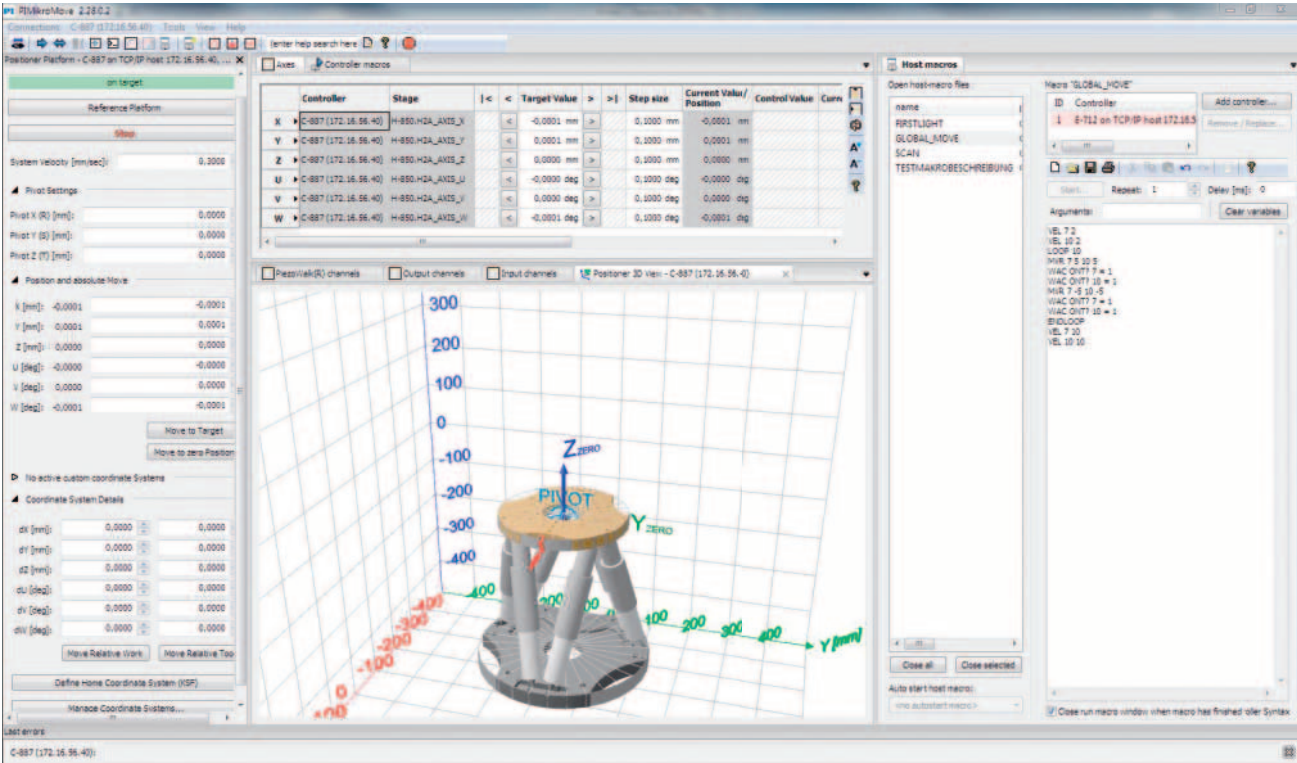
MOTION | POSITIONING

Specific Software
for Hexapod Systems

Specific Software for Hexapod Systems

PIVeriMove

Restricted space can cause problems for both motion and positioning systems and the setups on the motion platform as well as for the surroundings. Even when great care is taken during the design of an experimental setup or a production unit, it is not always possible to avoid the risk of collision. The PIVeriMove software calculates the permitted travel ranges for hexapods, if there are any obstacles in the motion range: Whether a sample setup, other moving parts or the wall of the vacuum chamber.

The newly created configurations can be stored as the basis for the geometric calculations in the hexapod controller. The safety gap to the objects is checked online for each motion or position command. This results in new limits for the positions that the hexapod is permitted to occupy.

The target positions and all points along the trajectory where a collision could take place, are checked before being executed. If a collision is impending, the motion is not carried out. For extra safety, a minimum gap can be specified, which is added to the distance irrespective of the direction in space.

The pivot point, which is the reference point for rotation of the platform can be changed at any time.
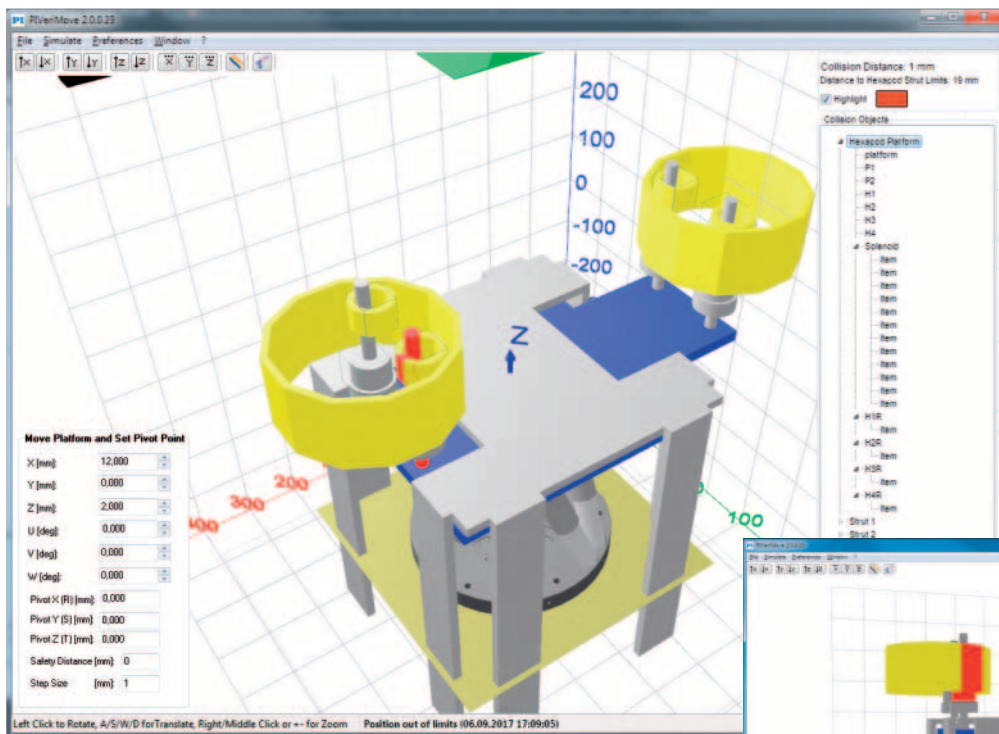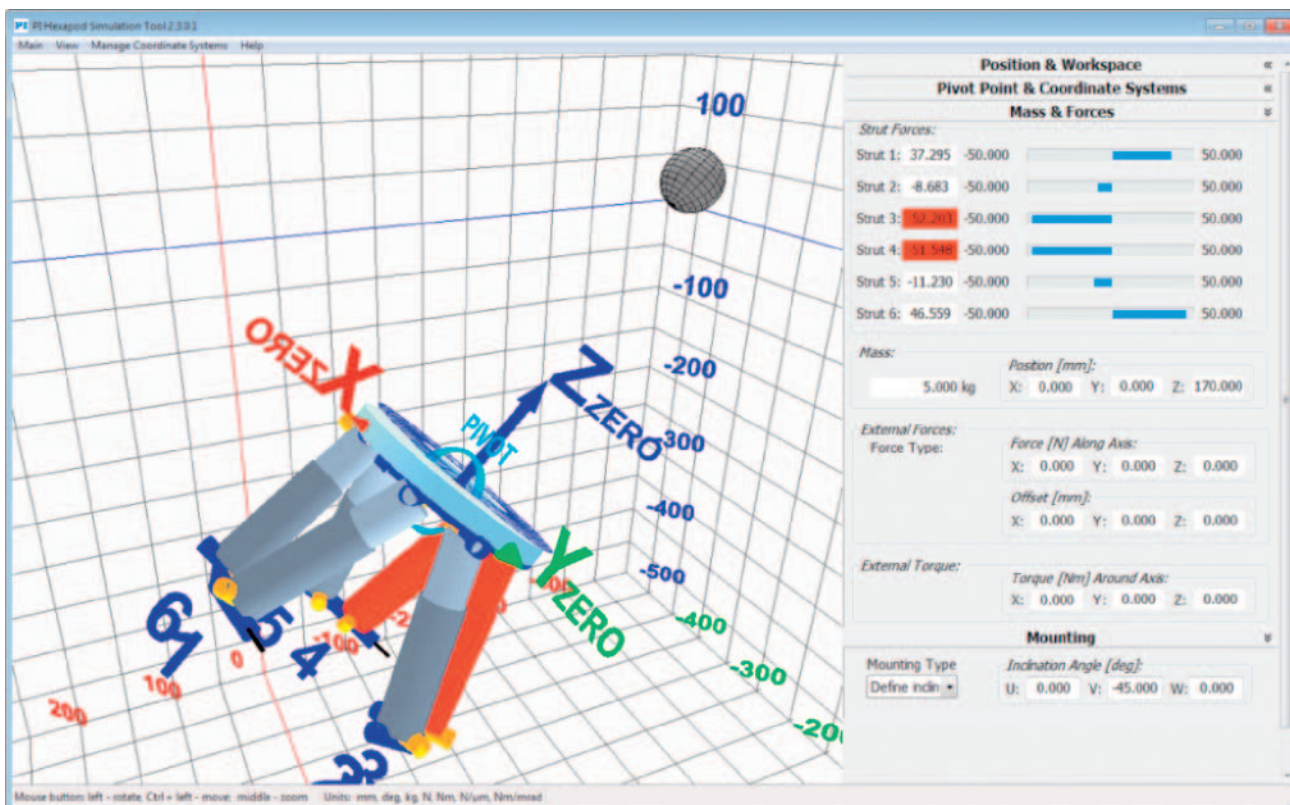

Representation of complex setups in PIVeriMove
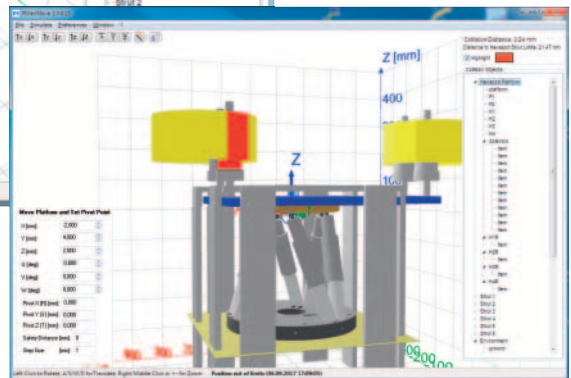
Representation of collisions (red area)

The acceptable load of the hexapod is exceeded: the SimuTool shows the respective values is red

Hexapod Simulation Tool

The limits of the workspace of parallel kinematics vary depending on the current position (translational and rotational coordinates), the current coordinates of the pivot point, and the chosen coordinate system. The scope of delivery of the PI hexapod software includes a program that can be used to comfortably calculate these limits and display them graphically. Mechanical problems can, therefore, be localized well before setting up the application.

The limit value for the load of the Hexapod varies as well depending on a number of factors:

- The orientation of the hexapod
- The load and the position of the center of mass,
- The position (translation and rotation coordinates) of the motion platform as well as
- The forces and torques which act on the motion platform of the hexapod.

These influencing factors can be simulated with the PI Hexapod Simulation Tool and possible issues can be solved early with the help of experienced PI sales engineers.

Software Emulators – the Hexapod System as a Virtual Machine

It is often desirable to implement the customer software early on without the system being available on site. PI supplies a suitable software that can be used to simulate a complete hexapod system (hexapod mechanics and controller) as a virtual machine on the host-PC. This allows the customers to develop, test, and optimize user programs even before the system is delivered.

For it to be used, the following third-party installation is required:

QEMU

QEMU is a free virtualization software which can emulate the entire hardware of the controller. Installation programs for Windows are available here: 32 bit / 64 bit.

Specific Software
for Hexapod Systems

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Terms and Technology Glossary

A

Absolute encoder

Sensor (encoder) for capturing changes of position or changes of angle. Signals from the absolute-measuring position sensor are used for axis position feedback. Absolute target positions can be commanded without the need of referencing.

ActiveDrive motor

The ActiveDrive Motor also integrates a servo amplifier into the motor housing, which is driven in PWM mode (Pulse Width Modulation). The operating voltage, which is mostly 24 V for ActiveDrive motors, is supplied by a separate power supply. Advantage: Lower costs, more compact design and higher reliability compared to an externally cabled amplifier; a higher degree of efficiency due to elimination of power loss between the amplifier and motor; avoidance of radiation interference because the amplifier and motor are built into the same shielded housing.

Area scan

Motion sequence that covers a predefined area. See "Scan routine".

B

Backlash

The position error that appears upon reversing direction. Backlash is caused by mechanical clearance in the drive train components, such as gearheads or bearings, or by friction in the guiding system. The backlash depends on temperature, acceleration, load, leadscrew position, direction, wear, etc. Backlash can be reduced by the preload on the drive train. A position measurement method, that can detect the position of the platform directly, eliminates all errors in the drive train (direct metrology).

Ball screw

In the case of ball screws, only rolling friction occurs, which allows higher speeds, drive performance, and longer lifetime than leadscrews. They are however, not self-locking.

Brushless DC motor (BLDC)

Compared to conventional DC motors, BLDC motors manage without wear-prone brushes meaning that a considerably longer lifetime is possible. Commutation is fully electronic and is generated completely by a rotating magnetic field in the stator that drags the rotor; the motor is based more on the concept of a synchronous machine. If sine commutation and a servo amplifier are used for position control instead of block commutation, the term synchronous servo motor (SSVM) is often encountered. Compared to DC motors, it is possible to realize a smaller and lighter design and provide the same performance, which results in a high ratio between the torque and the motor size. At the same time, the drivetrain can be shorter for the same travel range because the drive shaft is located inside the motor.

C

Center of rotation

See "Pivot point".

Closed-loop operation

Additional position feedback makes it possible to operate motors in a closed servo loop. Both the commanded and the achieved position are measured and compared. Closed-loop techniques are used to reach the target position optimally, to achieve a high position resolution, a uniform feed rate, and a large dynamic range for velocity and acceleration.

Coordinate systems

The position display, direction of motion, and center of rotation for the motion platform of the hexapod are determined by coordinate systems. The coordinate systems are always right-handed systems. To adapt the motion trajectory perfectly to the requirements of the application, it is possible to define various coordinate systems which refer, for example, to the position of workpiece or tool.

Crossed roller guide

Crossed roller guides are comparatively stiff and manage with low preload. This results in reduced friction with high load capacity, high guiding accuracy, and smooth running. An additional forced cage control helps to prevent the roller bearing from creeping.

Crosstalk

Deviation from the ideal motion in axes perpendicular to the direction of motion.
Linear errors are lateral runout such as xty = straightness, xtz = flatness.
Angular errors are xrx = roll, xry = pitch, xrz = yaw.

D

Data recoder

Tool for the analysis of data and measured values. It stores data from various data sources such as position feedback of analog inputs while displaying them as a function of time, and offers a fast visualization.

DC motor

A DC motor exploits the force effect of the electrical current via a pivoted conductor loop in a magnetic field. In conjunction with servo controllers (see "servo motor"), these types of motors allow high torques at low motor speeds, good dynamics over a large speed range, fast response, low heat generation as well as smooth and vibration-free operation.

Design resolution

The theoretical minimum increment of movement that can be commanded to move or to detect. Design resolution must not be confused with minimum incremental motion. In indirect position measurement methods, values for screw pitch, gear ratio, motor or sensor / encoder resolution, for example, are included in the calculation of the resolution. In general, it is considerably below the minimum incremental motion of a mechanical system.

Drag chain compatible cable

Drag chain compatible cables can be used in a cable carrier chain. They are able to maintain their function despite being subjected to a large number of bending cycles during their lifetime.

Drive type

Defines the types of drive supported by the controller / driver, such as DC motors, piezo stepping drives, piezo actuators, or linear motors.

E

Encoder

An encoder is used for determining the position. Basically, a difference is made between linear and rotary encoders. Depending on the configuration, encoders operate either incrementally or absolutely.

EtherCAT® fieldbus interface

PI hexapod controllers support EtherCAT®. EtherCAT (Ethernet for Control Automation Technology) is an Open Real Time Ethernet-based fieldbus system. The required coordinate trans-

formation for parallel kinematics are performed by the hexapod controller and do not affect the PLC. EtherCAT® is a registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

Extensive software package

Every PI controller is delivered with an extensive software package. The delivered user programs support the user in setting up and parametrizing the overall system. The PIMikroMove user software allows to display and command all connected controllers in the same graphical interface. Programming interfaces to integrate a PI controller into own user programs are available for all common programming languages including NI LabVIEW and MATLAB. Specific software tools for hexapods allow to simulate the motion range and determine the permissible forces.

F

Flexures

The motion of a flexure is based on elastic deformation of a solid, thus, avoiding any static, rolling or sliding friction. Flexure elements, such as joints and guiding systems, have high stiffness and high load capacity and they are very unsusceptible to shocks and vibrations. They do not wear, require no maintenance, are completely vacuum compatible, work in a wide temperature range, and do not require any lubricants.

Firmware

Software that is installed on the controller.

FMPA

Acronym for "Fast Multichannel Photonic Alignment".

G

Gearhead

Gearheads allow adjustment of the speed and the torque. The ratio between gear output and gear input is defined as transmission ratio.
In the case of transmission reduction, this ratio is greater than one, which results in a lower speed with a higher torque. The opposite applies in the case of higher speeds. Typical types of gears include for example, worm gears, spur gears, planetary gears, bevel gears, and belt gears.

Terms and Technology Glossary

Gradient search

Hill-climb algorithm for signal optimization. See "Scan routine".

H

Holding force

Force on the motion platform that can be applied to the system without moving even during a power-off state.

I

Incremental encoder

When incremental encoders are in motion, they generate impulses that are counted by the controller. However, in contrast to absolute encoders, it is a question of determining a relative position. To determine an absolute position, a limit switch or reference point switch signal must also be referenced.

L

Leadscrew

Leadscrews can achieve very high resolutions with smooth running and are often preloaded by springs to minimize backlash. This results in sliding friction and therefore a self-locking effect. However, this limits the speed, performance, and the lifetime.

Limit switch

The nominal travel range of a positioner is defined by parameters, but can be secured by limit switches that switch the motor current off when the limit switch has been reached.
Function: Optical, magnetic.

Linear encoder

Linear encoders measure the position of a linear actuator directly. Thus, a higher accuracy is achieved in comparison to rotary encoders, because nonlinearity, mechanical play, and elastic deformation have no influence.

Linear motor

A linear motor is an electromagnetic direct drive that generates straight linear motion. The range of a linear motor is practically unlimited. A linear measuring system is always required for motion and positioning; open loop operation of a linear motor is not possible. The linear motor does not require mechanical coupling elements to convert the rotation of the motor into linear motion as is the case with servo motors. Typically, 3-phase motors are used.

Linearity error

Deviation in motion direction, of measured position from commanded position. Measured with an external, traceable device. The target and measured actual values of the positions are plotted against each other, a line is drawn through the first and last data point, and the maximum absolute deviation is determined.

Load capacity

Maximum vertical load, when the stage is mounted horizontally. The punctual center of gravity of the load is considered.

M

Minimum incremental motion

The smallest motion that can be repeatedly executed is called minimum incremental motion, or typical resolution, and is determined by measurements. The data table shows typical measured values. The minimum incremental motion differs in most cases from the design resolution which can be considerably smaller in numerical values. See also "Design resolution".

N

NEXACT® piezo walking drive

Precision piezo motor that creates the walking motion by means of piezo bending elements in order to move a runner. The drives are very compact and achieve high velocities around 10 mm/s, and forces up to 10 N. A suitable selection of the piezo elements optimizes step size, clamping force, velocity, and stiffness for the respective applications.

NEXLINE® piezo walking drive

High-load piezo motor that combines piezo clamping and shear actuators in order to move a runner. The drives feature particularly high force of several 100 N, and high and stiffness. They are capable of dynamically compensating oscillations in the range of a few micrometers with nanometer resolution. Furthermore the drives are designed for positioning and holding forces of up to 800 N, and work at velocities of about 1 mm/s.

Nonlinearity

See "Linearity error".

O

Open-loop operation

The actuator is used without a position sensor. Creep, nonlinearity and hysteresis remain uncompensated. Open-loop operation is ideal for applications where fast response and very high resolution with maximum bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by external position sensors. Open-loop operation is not possible for electro-magnetic direct drives, such as linear motors and voice-coil drives. Stepper motors are frequently used in open-loop mode where counting the steps is used to determine the position. Missing steps occur when the stage is not designed according to the desired load and motion profile.

Operating temperature range

Maximum permissible temperature range in which the device can be operated safely.

Operating voltage

Allowed control input voltage range (also input frequency) for the supply of the device.

Optical power meter

An optical power meter converts optical power to an electric signal.

P

Patents

PI owns a large variety of patents on piezo and motor technology.

Parallel kinematics, hexapods

Hexapods are parallel-kinematic systems with six drives that are connected directly to a single platform. This makes it possible for users to position objects automatically in all degrees of freedom, X, Y, Z, and rotatory and, depending on the drive, with an accuracy in the micrometer range or lower. The parallel-kinematic system is very stiff, with only a low passive weight to move and, with the corresponding design, can carry loads of up to several tons.

PICMA® multilayer piezo actuators

PICMA® actuators take advantage of the indirect piezoelectric effect and achieve high forces with relatively low voltages. 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 a hitherto unattained precision. This is the reason why they are used as micropumps in metering technology. Due to their ceramic insulation, PICMA® actuators exhibit high reliability and climate resistance. PI (Physik Instrumente) also equips PICMA® actuators with individual connections for customer applications.

PICMAWalk

PICMAWalk drives achieve feed forces up to 50 N and holding forces to 60 N. The maximum velocity is 15 mm/s. PICMAWalk uses the proven PICMA® multilayer piezo actuators. That means lower piezo voltages to 120 V. PICMA® piezo actuators also ensure a long lifetime and the outstanding reliability of the PICMAWalk technology.

PiezoWalk® walking drive

PiezoWalk® drives take advantage of the piezo walking principle and combine a subnanometer resolution with high forces, a robust design, and a scalable travel range. Industry customers use walking drives for travel ranges greater than 1 mm and to hold a stable position with nanometer precision resolution. PI (Physik Instrumente) offers walking drives with high feed forces as well as positioning and holding forces, but also relatively high velocities, and they also have a long lifetime in a vacuum. See "NEXLINE®", "NEXACT®", and "PICMAWalk".

PILine® ultrasonic piezomotors

PILine® Ultrasonic piezomotors are precise, dynamic, small, and silent, and replace classical drive technologies, because the drives are also self-locking. As a result, they don't have to be supplied with current when at rest and that, in turn, reduces the energy requirements of the application. For this reason and due to their small size, the drives are very popular for mobile devices in the optical industry and measuring technology.

PIMag® magnetic linear motors

Magnetic direct drives from PI (Physik Instrumente) provide a direct and stiff connection between the load to be moved and the drive. The industry demand is particularly high when objects need to be positioned with high dynamics and precision. Thanks to the smooth-running precision linear guides with crossed roller bearings, these types of linear motor stages are particularly suitable for applications that require constant-velocity scanning. The drives operate without contact and therefore very reliable. Users can integrate the magnetic direct drives into existing machines and systems quickly and easily via standardized fieldbus systems. See "Linear motor", "Torque motor".

Terms and Technology Glossary

PIMag® voice coil

Thanks to their low weight and friction-free drive principle, voice coil drives are small and particularly suitable for applications that require high dynamics and high velocities over limited travel ranges – for example, in medical technology. Voice coil drives have a greater advantage for the customer when compared to traditional drive screw-based solutions, particularly with respect to wear and dynamics. High scan frequencies and precision positioning are possible with these drives, because they are free of hysteresis effects. See "Voice Coil Drive".

PIMikroMove

User software with graphic user interface (GUI) to control any PI positioning system, independently of the drive principle.

Pivot point

Freely definable reference or center point for rotation of the platform.

Power consumption

Maximum power consumption under full load.

Profile generator

Functionality of motor controllers that allows motion profiles such as linear interpolation, point-to-point, trapezoid, double bends. See "Trajectory generator".

Pulse width modulation (PWM)

PWM-controlled motors allow control of the (motor) performance with a high-frequency-signal. This means that the power signal can be separated from the digital control signal. PWM control is used, for example, with high-performance switching amplifiers for piezo actuators, or for controlling electric motors such as (BL)DC-motors, linear motors or voice coil drives. The "ActiveDrive Motor" is a special feature from PI, see there.

PZT

Acronym for plumbum (lead) zirconate titanate. Polycrystalline ceramic material with advanced piezoelectric properties. Often also used to refer to a piezo actuator or translator.

Q

Q-Motion® piezoelectric inertia drive

Piezo inertia drives are space-saving and affordable piezo-based drives with relatively high holding forces and a virtually unlimited travel range. With an operating frequency of up to 20 kHz, the drives reach velocities of more than 5 mm/s that directly on the runner. The Q-Motion® drive operates silently at the maximum operating frequency of 20 kHz. When at rest, the drive is self-locking, requires no current, and does not generate any heat. It holds the position with maximum force. It is therefore suitable for battery-powered, mobile applications with a low number of load cycles.

R

Reference point switch

In combination with incremental position encoders, it is necessary to use a reference point to determine the absolute position. Function: Optical, magnetic.

Repeatability

Typical values in closed-loop operation mode (RMS, 1). Repeatability is a percentage of the total distance or angle traveled. For small ranges, repeatability may be significantly better.

Rotary encoder

Rotary encoders that are mounted directly on the motor shaft measure the position indirectly. That means that they are attached to a rotating part of the drivetrain. Easy installation of the sensors is an advantage but backlash and mechanical play affect the precision of the position feedback.

S

Scan routine

Algorithm that executes a motion sequence and allows to evaluate corresponding data, e.g. search for an optimized analog input signal. Examples are "Area scan", "Gradient search".

Sensor resolution

The smallest calculable increment that can be detected by the measuring system used. Rotary encoder: Number of counts per rotation. Linear encoder: Smallest increment still detected by the sensor system used. Drivetrain design and interpolation is not considered in the sensor resolution, but in the "Design resolution", see there.

Serial kinematics

In a serial kinematics set-up each actuator acts on its own platform. There is a clear relationship between actuators and motion axes. The advantages are the relatively simple assembly and multi-axis control. The dynamic characteristics depend on the individual axis and the set-up of the serial kinematics, where the lower axes need to carry the upper axes resulting in high forces and lower dynamics. Guiding errors accumulate and the overall guiding accuracy is poorer if compared to "Parallel kinematics", see there.

Servo motor

A motor with position detection and control is called a servo motor. The motor itself is often a DC motor. Servo motors offer high torques at a low speed, good dynamics over a large speed range, fast response, low heat generation as well as smooth and vibration-free operation. Either incremental or absolute rotary encoders are used for detecting the position. A servo amplifier takes care of amplifying the signal and controlling the motor parameters. This is normally a PID controller (Proportional, Integral, Derivative) with additional filters in order to exploit the above-mentioned characteristics as best as possible.

SpaceFAB design

SpaceFABs are alternative parallel-kinematic set-ups with constant strut lengths that allow for an especially low profile. The six degrees of freedom are achieved by moving a passive strut in two or more axes: In a SpaceFAB, an XY arrangement of linear stages moves the individual struts. This mechanical layout allows for an asymmetric design, e.g., longer travel ranges in one selected direction of motion.

Specification

Performance specifications are tested before delivery for each system. Some specifications are not available in combinations, for example, moving maximum payload at maximum speed at maximum operating temperature may not be possible. Performance specifications are valid for room temperature (22 ±3 °C) and closed-loop systems are calibrated at this temperature (specifications for different operating temperatures on request). Recalibration is recommended for operation at significantly higher or lower temperature. Custom designs for ultralow or ultrahigh temperatures on request.

Stepper motor

Stepper motors only take discrete positions within one revolution. A position can be commanded with a constant step size without an additional encoder. The achievable step size is specified by the motor control. Intelligent wiring of the individual poles allows a so-called microstep mode, which, depending on the type, is able to realize several hundreds of thousands of microsteps between the full steps by electrical interpolation. However, step losses and the associated positioning errors can be the result in the case of excessively high loads and accelerations as well as resonance effects if an additional encoder is not used. High speeds are only possible with high numbers of steps, which however, prevents reaching the achievable torque. A mechanical damper on the motor shaft, which also works as handwheel, supports smooth running. To hold position without a self-locking gearhead, stepper motors must be supplied with current, which can then lead to jittering. Nevertheless, stepper motors offer a very long lifetime and, compared to DC motors, are especially suited to applications with reduced dynamics and in a vacuum.

Stiffness

Static stiffness in motion direction. The force acts in the direction of the motion axis.

Straightness

See "Crosstalk".

Synchronous servo motor (SSVM)

A servo motor that is designed as a synchronous machine. This type of motor for example, can be realized from a brushless DC servo motor with sine commutation (see brushless "DC motor" and "servo motor").

T

Threaded roller drive screw

In the case of threaded roller drive screws, the contact surface between the drive screw, roller, and nut is considerably larger than with ball screw drives. This results in a very high stiffness and higher loads are possible.

Torque motor

Torque motors are mainly brushless DC motors that are optimized for high torques or classical servo drives with a high number of poles. On the other side, it is possible to envisage torque motors as rolled-up linear motors. In contrast to conventional servo drives, torque motors achieve lower speeds but are able to achieve very high torques at medium to low speeds. The torque generated by a torque motor increases squared to the rotor diameter. As a rule, the rotor is a hollow shaft. When compared to the usual servo drives, the length of the installation space is not used and this allows low-profile dimensions. Torque motors represent a zero-play and stiff direct drive and can reach high positioning accuracy and repeatability with a high load. The high drive torque also allows higher accelerations and the associated high dynamics.

Trajectory control

Provisions to prevent deviation from the specified trajectory. Can be passive (e.g., flexure guidance) or active (e.g., using additional active axes and sensors).

Trajectory generator

A profile generator for multi-axis systems with known kinematics and interpolation. Hexapod controllers support linear interpolation, point-to-point, trapezoid, s-curve. See "Profile generator".

Terms and Technology Glossary

V

Vacuum-compatible versions

In a large number of industry sectors, production in a vacuum is becoming increasingly more important. Therefore, PI (Physik Instrumente) offers various different drive technologies to its customers that can be operated in a vacuum of 10^{-7} or even 10^{-10} hPa. This includes piezo actuators that work in strong magnetic fields and in a cryogenic environment, piezo systems with travel ranges lower than 1.5 mm and subnanometer precision, piezomotors in a variety of designs with respect to force, dynamics, and travel range, as well as classical motorization with specially designed DC or stepper motors that allow greater travel ranges.

Voice coil drives

These friction-free electromagnetic linear drives are characterized by their good dynamics, albeit with relatively low holding force.

Voice coil motors are direct drives. The drive principle is the technical implementation of the Lorentz force: The force that a live conductor exerts in a permanent magnetic field is proportional to the magnetic field strength and the current. The motion controller controls the force via PWM control. The drive is combined with a measuring system for precision positioning and operated in a closed loop. The travel ranges of voice coil drives are therefore limited by the technology and are between 0.5 mm and 25 mm.

Typical applications include short-range motion with fast settling times, applications with low noise generation, or sensitive programmable force controls.

W

Wave generator

Each axis can be controlled by a wave generator that outputs waveforms. The wave generator is particularly suitable for dynamic applications, in which the axis performs arbitrary, user-defined motion profiles.

Workspace

The entirety of all combinations of translations and rotations that the hexapod can approach from the current position is referred to as the workspace.

Product Index

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