

PI Goes Hybrid

Nanometer-class positioning systems with fast response and centimeter travel ranges demand new technical solutions

The basic idea of combining motorized positioners with high-resolution piezo actuators is not new. In the past, these systems consisted of two stacked stages with independent drives, feedback sensors and servo-controllers. The new PI hybrid systems combine integrated drive mechanisms with a single high-resolution encoder. A custom controller actuates both drives at the same time, giving a system with the advantages of both the piezo and the servo-motor.

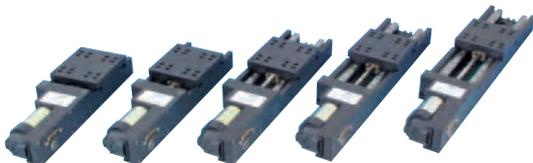
Continued on page 4

DC-servo motors and piezo actuators in perfect harmony:
The new hybrid stages and controllers from PI



Cost-Effective Micropositioners

48 versions, one for (almost) every application, provide travel from 25 to 300 mm and resolution to 0.1 µm



M-403 Micro-translation stages with 25 to 200 mm travel range

The new family of particularly cost-effective micropositioning stages includes a total of 48 versions, greatly extending the range of PI's micro-translation stages. In this extensive se-

lection you will find the optimal choice for a wide variety of applications.

The M-403 / M-413 and M-404 / M-414 series stages feature a modular design which allows combining a variety of bases, motors and screw drives. Available in a total of seven lengths, the translation stages provide travel ranges from 25 to 300 mm.

For easy differentiation, the 48 versions are divided into four series: M-403, M-413, M-404 and M-414. The M-403 contains the basic versions with up to 200 mm of travel; the M-413 series is more robust for higher loads and longer travel ranges, up to 300 mm.

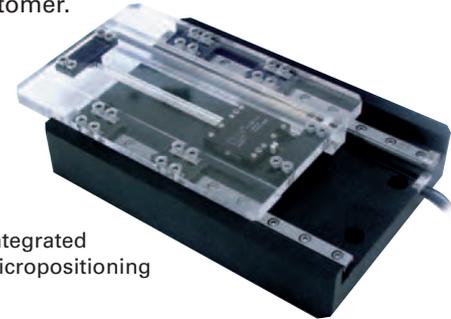
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RodDrive OEM Linear Actuators are Fast & Maintenance-Free



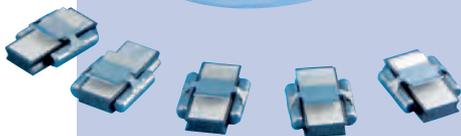
The compact M-674 OEM drives combine high accelerations of over 10 g with top speeds of up to 400 mm/s. Depending on the sensor chosen, loads can be positioned with a resolution of 0.05 µm. PILine® M-674 Rod Drives use ultrasonic piezomotors and are maintenance-free, non-magnetic and vacuum compatible. The travel range, power of the motor and the materials of the linear drives can be flexibly tailored to meet the needs of the customer.



New maintenance-free PILine® RodDrive linear drives offer extremely fast positioning over travel ranges of several centimeters

M-674 integrated into a micropositioning stage

Ultra-Compact Ultrasonic Drives



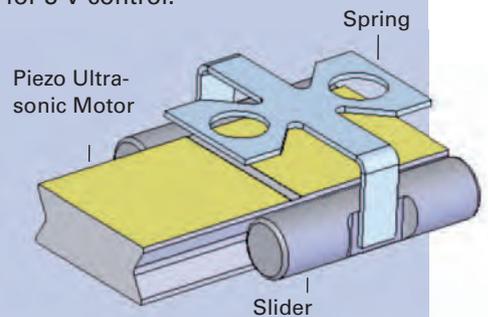
Ultra-compact P-652 OEM linear drives. Actual size shown

New, patented P-652 OEM linear drives: ultra-compact at 9 x 6.5 x 2.4 mm³, including sliders

Considering their minute size, P-652 linear drives provide an enormous travel range of 3.2 mm and speeds of up to 80 mm/s. The P-652 are also breaking new ground on the price front, as appropriate for the smallest OEM drives conceived for mass-production applications.

The P-652 have the simplest possible design, comprising an ultrasonic piezoelectric resonator and two lateral sliders pressed against it by a spring doubling as sled.

The load to be moved is mounted directly on the sled, and moved by a force of up to 110 mN. The P-652 requires only these 4 parts, unlike conventional electric motors. Highly integrated electronics are available for 3 V control.



Design of the P-652 OEM linear drive

PiezoMove® Z-Actuators Provide 480 μm of Flexure-Guided Motion

PiezoMove® P-601 lever-amplified actuators provide significantly straighter motion, larger travel ranges and higher lateral stiffness than stacked PZT translators. On the other hand, they are less costly and more compact than typical nanopositioning stages. Six open- and closed-loop models with travel ranges from 100 μm to 480 μm are available.

Their response times of a few milliseconds and resolution in the sub-nanometer range make them suitable for integration into static and dynamic applications. The high-precision, zero-friction flexure guidance gives very high lateral stiffness and thus excellent straightness of motion. These properties together with their compact dimensions and careful design, make the P-601 lever-amplified actuators particularly suitable for cost-sensitive OEM applications.



P-601 PiezoMove® lever-amplified actuators with unequalled straightness of motion

P-601 series PiezoMove® flexure-guided actuators are a cost-effective solution, not only for OEMs

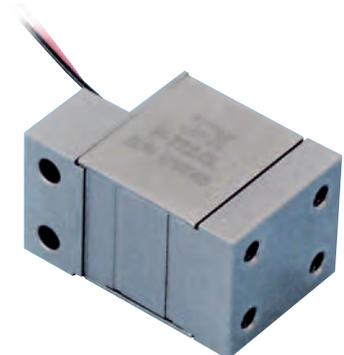
Miniature Piezo Stages Provide Picometer Resolution

Ultra-compact P-772 piezo-driven stages for cost-sensitive OEM applications

P-772 piezo nanopositioning stages with 10 μm travel range offer a very high resolution of 50 picometers (0.00005 μm). These nanopositioning stages were specially designed for ultra-high-precision positioning and high-dynamics applications like head & media testing in mass storage devices, laser tuning, scanning interferometry and biotechnology.

The direct-driven P-772 translation stages are very stiff and ultra-compact, with a length of just 24 mm (less than 1").

The resulting resonant frequency of 1.7 kHz is advantageous for both scanning and positioning tasks. The versions without position sensors can be easily integrated into open-loop applications, while those equipped with high-resolution capacitive position sensors support absolute positioning in closed-loop operation. These sensors determine the stage position by direct metrology and are immune to the typical measuring errors seen in lesser position sensors.



Small and extremely precise:
P-772 piezo translation stage
(DIP switch for size comparison)



Hybrid Systems: Long Travel Ranges, Fast Response, Nanometer Precision

continued from page 1

PI's new hybrid nan positioning systems feature standard travel ranges of up to 100 mm and nanometer-level position and velocity control. The direct integration of micropositioner technology and PICMA® PZT actuators makes it possible to achieve very fast response and resolutions of 2 nm and better – limited only by the incremental encoder. Currently a 100 mm translation stage and a 7 mm Z-stage are offered along with the C-702 2-axis hybrid controller



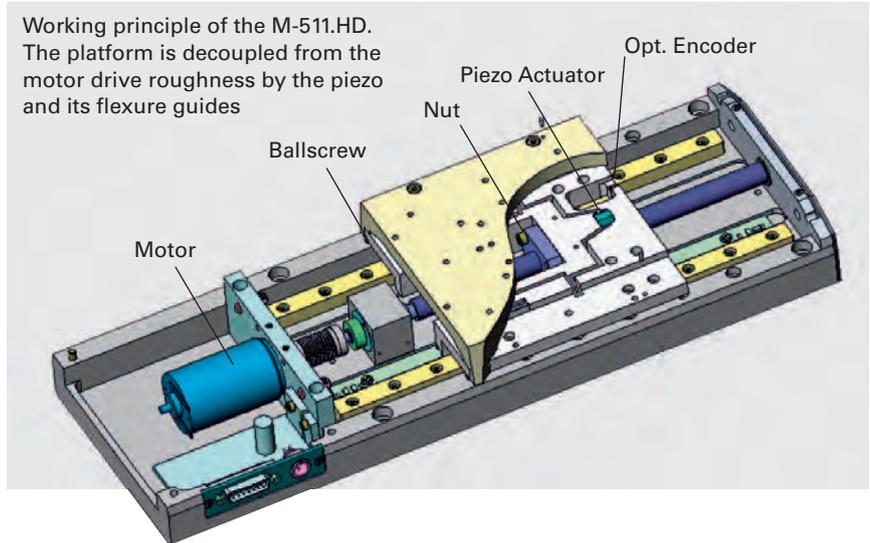
It is the direct integration of PZT actuators into the translation stages and the highly-advanced architecture of the new C-702 hybrid controller that makes it possible to combine piezo-class responsiveness with large travel ranges (up to hundreds of millimeters) and repeatability/resolution of a few nanometers. Compared to high-resolution magnetic linear drives, the hybrid principle also allows high

holding forces with minimum power consumption, without counterbalancing the load.

The advantages of the new hybrid technology stem from the fact that the motion control system uses a single internal sensor (parallel metrology) providing high accuracy and resolution over the full travel range. This means, for example, that the position of an event can be accurately recorded and

subsequently taken up again, or that an externally set position can be reached exactly, as required in applications like surface inspection.

PI's C-702 controller with integrated piezo amplifiers is the key to the high performance of the hybrid positioning systems. Its special control algorithms ensure that the DC motor and piezo actuator in the M-714 and M-511.HD hybrid-drive translation stages act in harmony at all times. Motion irregularities like stick-slip at startup and backlash can be fully compensated, allowing excellent speed control in dynamic operation. After a step, settling to the target position takes only a few milliseconds, and very small steps – in the nanometer range – are performed reliably. The controller algorithm required is complex and position information has to be transmitted and processed at very high speed. When, for example, the M-511.HD moves at a speed of 125 mm/s, the controller must count over 30 million pulses per second from the encoder.



Piezoelectric Z-Scanners Provide Fast Response

Thanks to its real-time operating system, the C-702 has coordinated servo-control loops for hybrid drives, new, extremely high-bandwidth sensor channels and very short response times. The intricacies of the hybrid drive are completely transparent to the user since the stage is controlled as a single axis. Interface to the host computer is via TCP/IP or RS-232. The TCP/IP interface makes it possible to operate and monitor the system over any TCP/IP-compatible network (intranet/Internet).

Two-channel C-702 controller for translation stages with hybrid drives



2 ms step-and-settle: ideal for high-dynamics applications like scanning microscopy

Fast piezo-driven P-732 vertical positioning stages are ideal for high-dynamics applications like scanning microscopy. Positioning tasks also profit from the resonant frequency of 1.5 kHz and resulting very short step-and-settle time of two milliseconds.

The very stiff stages with 15 μm vertical travel range are not only fast but also very precise, with 0.1 nm resolution, high linearity and low out-of-plane motion. P-732 piezo stages are equipped with high-resolution capacitive position sensors for closed-loop operation. These sensors determine the platform position by direct metrology and

thus avoid otherwise typical measurement errors. P-732 vertical positioners can easily be combined with matching P-733 XY piezo stages for scanning and positioning applications requiring three axes of motion.



Fast response: P-732 piezo Z-stage

Piezo Servo-Controller with 20 Bit Resolution

Cost-effective E-625 single-channel piezo servo-controller with fast analog and digital interfaces

The E-625 low-noise linear amplifier/controller is best suited for cost-sensitive automation applications. Up to four bench-top servo-controllers can be networked in parallel and controlled over a single RS-232 connection. E-625 versions are available to operate with strain gauge (SGS), inductive LVDT or capacitive position sensors, making the servo-controller suitable for a wide variety of PI piezo actuators and nanopositioning stages.

High-precision positioning in dynamic applications is handled by a high-speed RS-232 interface that enables up to 300 bidirectional read and write operations per second. For exceptional position stability and resolution, precision 20-bit A/D and D/A converters are incorporated. User-defined data points, calculated from any desired, arbitrary function, can be stored in a wave table in the E-625



E-625 servo controllers for piezo positioning systems

for later output under control of an external trigger, allowing for even faster and convenient commanding.

World's First Digital Piezo Nanopositioning Controller on PCI Board



The PCI bus allows for very rapid communication and easy integration with devices such as frame grabbers – a feature which is very advantageous in real-time data acquisition applications or when operating multiple axes or controllers simultaneously.

The internal coordinate transformation means it is no problem to operate complex, multi-axis stages, such as three-axis X-Y- Θ_z stages or Z-tip-tilt platforms. In systems with parallel metrology, the E-761 can also automatically compensate undesired off-axis motion (active trajectory control), making it possible to attain motion accuracies in the sub-nanometer range.

Of course, this digital controller has the technical refinements you have come to expect from PI, such as 32-bit digital filters, 24-bit DAC resolution, multi-stage sensor and electronics linearization, plug & play ID-chip support and an extensive software support package.

E-761 3-channel digital nanopositioning controller: very advanced control technology in cost-effective PCI format to control up to three logical axes

The E-761 digital nanopositioning controller offers very advanced control technology in the cost-effective PCI-board format. It is able to control nanopositioning systems with up to three logical axes and four piezo actuators.

Many of today's high-tech applications, such as imaging, metrology, scanning microscopy and surface analysis require a combination of high-speed motion control and high-resolution vision. They also require extremely fast data acquisition and precise synchronization between the imaging and motion control devices. Peripheral components with PCI bus interface are ideal for these tasks, because the PCI bus was designed to give high-bandwidth access to the microprocessor in the PC. With the E-761, PI intro-

duces the world's first fully digital piezoelectric nanopositioning controller on a PCI board.

P-541.2CD low-profile XY piezo stage with capacitive sensors: a perfect fit for the E-761



Miniature Translation/Rotation Stage Family Comes with Piezo Scanner Option

The M-110 series of micropositioning stages is one of the smallest motorized stage families in the world capable of delivering 50 nanometer incremental motion

Due to the folded drive train, these miniature motorized stages have a footprint as small as 62 x 60 mm. They provide linear motion of 5, 15 and 25 mm.

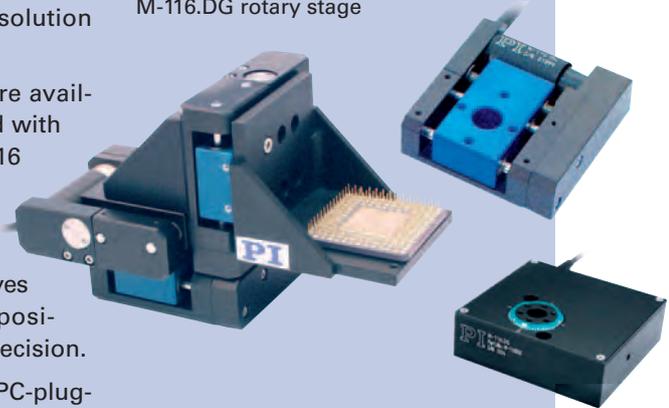
For maximum flexibility, leadscrews (higher resolution) and ballscrews (higher speed / longer lifetime) are offered, driven by stepper motors (lower cost) and closed-loop servo-

motors (higher precision). The encoder on the DC-servo-motor version features 0.007 μm resolution per count.

X, XY and XYZ systems are available and can be combined with the worm-gear-driven M-116 miniature rotary stage. The systems can also be equipped with the P-611-series high-speed piezo drives for fast scanning and positioning with nanometer precision.

A variety of cost-effective PC-plugin and stand-alone controllers are offered to suit all needs. Special software for alignment applications is also available.

M-110.1DG, 5 mm micropositioning stage, M-110 XYZ combination and M-116.DG rotary stage



These precision stages are ideally suited for applications in biotechnology, medical technology, optics and photonics alignment.

PISeCa™ Sensors Measure with Nanometer Accuracy

New single-electrode capacitive position sensors with excellent resolution

PISeCa™ capacitive sensors perform non-contact measurements of geometric quantities representing separation, position, length or other linear dimension against electrically conductive references such as metallic planes. These single-electrode sensors feature the highest resolution and linearity available. The models available have measuring ranges from 15 to 1000 μm . Single-electrode capacitive sensors such as PISeCa™ are fundamentally very temperature stable and easy to work with.



PISeCa™ high-accuracy capacitive position sensors

PI Wins Substantial Hexapod Contract for ALMA Millimeter Radio Telescope



General Dynamics subsidiary Vertex Antennentechnik has ordered 25 high-precision micropositioners for large array radio telescope

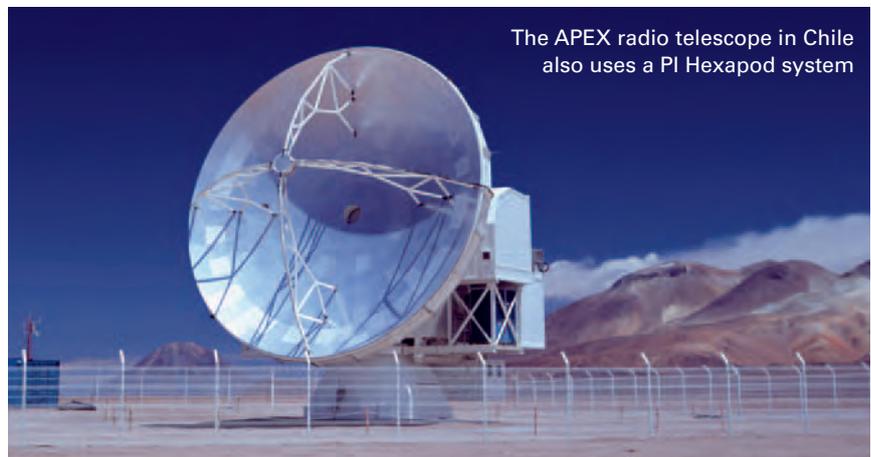
The ALMA (Atacama Large Millimeter Array) international partnership is constructing and will operate a radio telescope comprising an array of up to 64 antennas. The partnership is made up of North America (USA and Canada), Europe and Japan, in cooperation with Chile. PI will deliver a total of 25 Hexapod systems for the extremely precise alignment of the telescope's secondary reflectors to Vertex Antennentechnik in Duisburg, Germany by 2011. Hexapods are the first choice of positioning system for astronomical multi-axis alignment tasks. They can provide very high stiffness, a very large aperture, and are devoid of cable management issues.

The PI Hexapod combines a load capacity of 200 kg with sub-micron linear resolution and microrad-level angular resolution. A highly sophisticated digital controller provides advanced features such as a user-programmable virtual pivot point,

extremely important in complex alignment applications. Target positions in 6-space are entered in user-friendly coordinates and reached by smooth vectorized motion which saves valuable programming time when integrating the system. Similar six-axis micropositioning systems from PI have already proven reliable in operation at the ALMA VertexRSI test antenna and the Atacama Pathfinder Experiment (APEX) radio telescopes. Millimeter and sub-millimeter astronomy investigates the universe in the spectral range which traditionally stretches from radio waves to the infrared.

ALMA will be used in this spectral range to investigate the structure of the early universe as well as galaxies, stars and planets in their formative stages. ALMA is being built in the Chilean Atacama desert at an altitude of over 5000 m, one of the driest places on earth. These are favorable conditions for the best possible observations, since millimeter radiation is absorbed by water vapor in the atmosphere.

Each individual ALMA antenna has a primary reflector 12 m in diameter, higher than a four-story house. The mobile antennas will be used together in various arrangements as a single



The ALMA VertexRSI test antenna with PI Hexapod system



telescope. The spread of the antenna array will be between 150 m and a maximum of 12 km. On completion in 2011, ALMA will be the largest and most powerful radio telescope in the world, with a resolution ten times better than that of the Hubble space telescope.

In supplying the six-axis Hexapods and their high-performance controllers, Physik Instrumente is contributing its many years of experience in extremely high-precision positioning to the ALMA project. PI was able to demonstrate the reliability and accuracy of its systems in the ALMA VertexRSI test antenna in New Mexico, USA. ALMA's technological forerunner project, the APEX radio telescope in Chile, is already successfully using the same PI micropositioning system.

PI has been supplying hexapods, micropositioning actuators and active optics for astronomical telescopes, including several infrared telescopes on Mauna Kea in Hawaii as well as telescopes in Chile, South Africa and the Canary Islands, for over 15 years.

www.alma.nrao.edu

www.eso.org/projects/alma

www.apex-telescope.org



M-238 heavy-duty actuator (middle) shown together with M-235 actuator and CD for size comparison

Ultra-High-Load Precision Linear Actuators Combine Force, Accuracy & Speed

New M-238 heavy-duty actuators provide resolutions to 0.1 μm and velocities to 30 mm/sec despite the high force capacity of 400 N

M-238 precision linear actuators are self-contained packages consisting of a DC-servo motor/gearbox driving a preloaded ballscrew. Two models are available: a lower cost version with a rotary encoder (M-238.5PG) and a higher precision version with a linear encoder (M-238.5PL). Both can handle side loads to 100 N, provide a travel range of 50 mm and – despite the very high load capacity of 400 N (90 lbf) – a maximum velocity of 30 mm/sec.

The M-238.5PL model is equipped with a high-resolution, non-contact optical linear encoder (direct metrology) with an output resolution of 0.1 μm . Because the encoder measures the actual position of the non-

rotating actuator tip, drive train errors like backlash and elastic deformation are eliminated.

Like most other PI motorized precision actuators, the M-238 series features a non-rotating tip which ensures maximum stability and motion linearity. Integrated non-contacting limit switches and reference sensors increase the versatility and help to protect sensitive equipment in applications where excessive motion could cause damage.

M-238 actuators are ideally suited for applications in astronomy, precision machining and flexible automation.

Use of PI Parallel Kinematic Machines in Industrial Testing

Photothermics, a non-destructive testing method, uses PI Hexapods to orient test samples in University of Bremen study

Automatic testing methods in industrial production are an important component of quality assurance, non-destructive testing being the ideal objective. Photothermics is a method which has seen considerable development in recent years. In it, a laser source is used to heat up a spot on a test sample and the propagation of the heat wave is followed with appropriate sensors. By comparing the measured values from the sample with those from a calibration model, the sample can be characterized according to specific criteria. This makes it possible to ascertain layer thicknesses or hardness penetration depths and to detect cracks, pores and damage from local overheating while grinding.



Fig. 1: PI Hexapod with test piece in place

The University of Bremen and the Bremen Institute of Industrial Technology and Applied Work Science (BIBA) have developed a system with which photothermal measurements

on arbitrary surfaces can be performed. The kinematics of this system consists a six-axis PI M-840 Hexapod (Fig. 1) which can be coordinated with various common machines such as industrial robots or machine tools. Test samples used included medical implants.

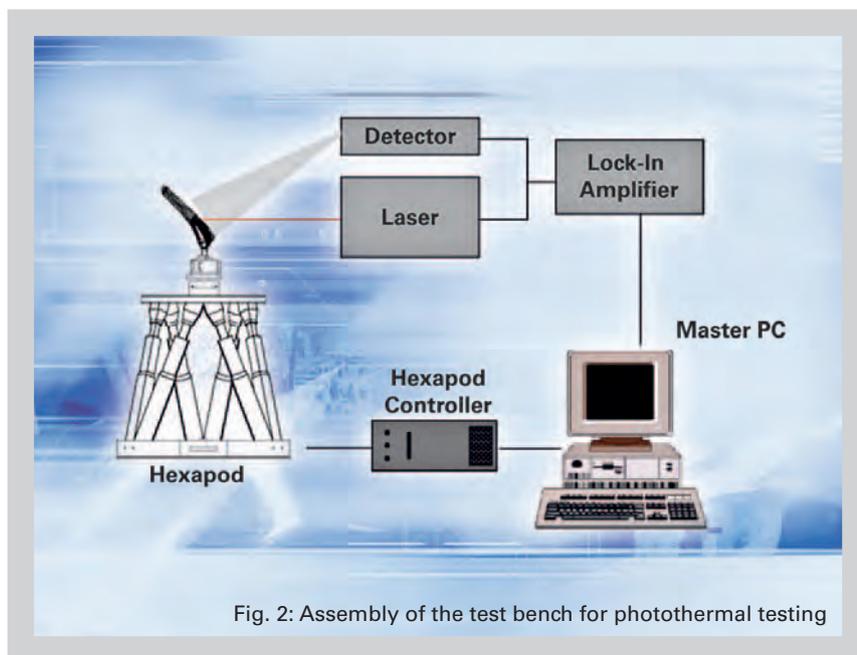


Fig. 2: Assembly of the test bench for photothermal testing

In the overall system concept (Fig. 2), a master PC assumes control of the whole testing unit, consisting of detector, laser and lock-in amplifier. The Hexapod controller and the Hexapod constitute the kinematic unit. The laser receives the command to switch on the laser source via the lock-in amplifier, through which the detector sends the heat wave propagation data to the master PC. The Hexapod controller receives its motion commands in Cartesian coordinates from the master PC. The controller performs the necessary coordinate transformation, chooses a trajectory, and sets the corresponding targets for the individual Hexapod struts.

Translation Stages in 48 Versions

Photothermics requires a defined angle of incidence of the laser beam. Using the technique on curved surfaces requires precise knowledge of the orientation and position of the areas to be tested. The system extracts this information from the geometric data describing the sample, and generates the appropriate control sequences. In addition, the test piece is scanned in the current mounting with fringe projection techniques before photo-thermal inspection. The fringe projection data is used to subdivide the scanned geometry into constituent, relatively-flat segments and establish their orientations. The normal vector of each segment is used to generate move instructions for the Hexapod which properly align the test sample with respect to the laser beam.

Using the industrial-class system presented here, it is possible to eliminate most of the actions which previously had to be carried out manually. The 6 degree-of-freedom Hexapod (6 DOF) can orient the test piece almost anywhere in space, opening new areas of application to photothermics in complex surface inspection.



M-403 with ActiveDrive™, motor-gearbox and stepper motor (left to right) and 100 mm travel range

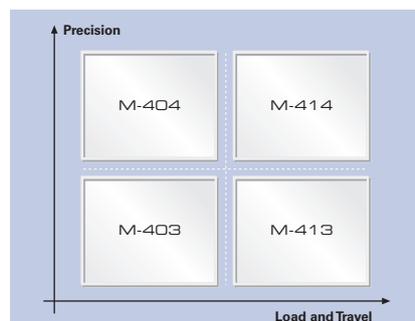
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M-403 and M-413 both provide a minimum incremental motion to 0.2 μm . The M-404 and M-414 series cover the same travel ranges and load capacities but offer even higher precision, thanks to their low-friction recirculating ballscrew drives and high-precision guides. As high-load series, the M-413 and M-414 have wider and higher bases than the M-403 and M-404 series and therefore provide more stability for higher loads. Depending on the requirements concerning precision and controller type, there is a choice

of three motors for all stages, from the inexpensive stepper motor to the tried-and-true ActiveDrive™.

Similarly cost-effective is the C-862 Mercury™ servo-controller, which can drive a single DC-motor stage. For applications with several axes, up to six Mercury's™ can be networked together. Alternatively, the C-843 servo-controller in PCI format can also easily control two or four axes simultaneously.

M-413 (right) with 50% more width and height than the M-403 (left) for higher loads and longer travel ranges



Tradeshows 2006

June			
27 – 29	Microscience	London, UK	
July			
11 – 13	Semicon West	San Francisco (CA), USA	Booth 6147 & D8
August			
15 – 17	Optics & Photonics	San Diego (CA), USA	Booth 925
September			
04 – 07	Photon06	Manchester, UK	
12 – 14	Elektronik 06	Odense, Denmark	
17 – 20	MNE	Barcelona, Spain	
19	Simtec	Lyon, France	
18 – 23	SIF or Bias	Turin, Italy	
25 – 27	ECOC	Cannes, France	Booth 157 / 159
26 – 29	Micronora	Besançon, France	
October			
03 – 04	Optics East	Boston (MA), USA	
03 – 06	Tekniska Mässan	Stockholm, Sweden	Booth A05/19
10 – 11	OSA Annual Meeting	Rochester (NY), USA	
10 – 13	Vienna-Tec	Vienna, Austria	
12	Simtec	Mandelieu, France	
18 – 19	Photonex	Coventry, UK	A01/A20/A30
17 – 19	ASPE Annual Meeting	Monterey (CA), USA	
17 – 19	OPTO	Versailles, France	N 25

Optical Bench Close-Out Sale

Product line being discontinued

Optical benches and opto-mechanical components have been important product lines for PI since the company was founded over 35 years ago and they were presented in their own catalog. In recent years, the focus of PI's activities has changed, so that this product line is not as important as it once was. The previously extensive range of

optical benches, mountings and vibration-isolation tables has not been actively promoted for some time, and now is being discontinued. We are therefore now offering the remaining stock from the optical benches product range at very attractive prices.

For more information on this one-time offer please get in touch with your PI representative (see list this page).

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