PI

MOTION | **Positioning**

THE PI CUSTOMER MAGAZINE

PIEZO-BASED SCANNING SYSTEMS FOR HIGH-PERFORMANCE MICROSCOPES

GOOD VIBRATIONS FOR DIE-SINKING

IMPRINT

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News from the PI Group

PICERAMIC.DE WITH A NEW OUTFIT

Sabine Fischer,
Online editor

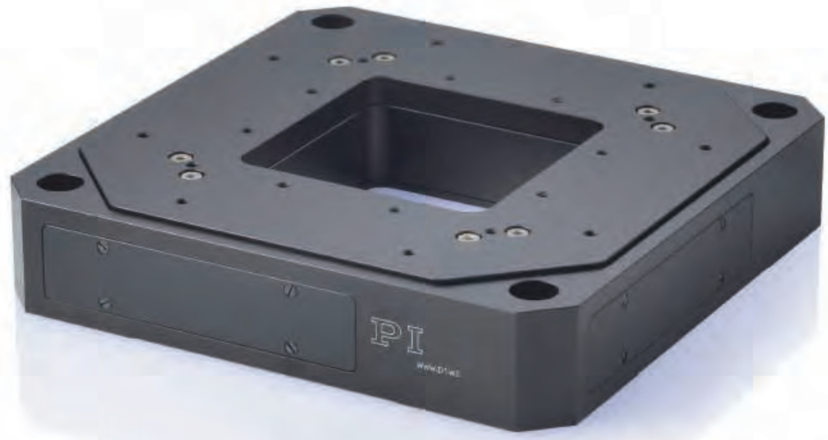
As of April, PI Ceramic GmbH presents itself with a new, fresh look on the Internet. The well-structured, tablet-optimized web design now allows surfing through the world of piezo technology without a desktop PC or mouse.

Next to a focus on product presentations you will find a number of interesting examples of applications and details of piezo technology know-how. The new Internet presence has been redesigned completely in terms of look, contents and structure so that you can access the entire range of products and services quickly and easily. The new PI Ceramic Infotheque offers a compact online service for downloads, news, events and more. In case of questions or if you need advice, take the online shortcut to our sales engineers: Simply browse through the piezo ceramic product ranges and send your query online. We will send you an individual quote.

Welcome to our online world, we will navigate you to your goal: **www.piceramic.com**

PIEZO-BASED SCANNING SYSTEMS FOR HIGH-PERFOR-MANCE MICROSCOPES

A Combination of Methods for High-Precision Optical, Topographic and Molecular Analyses



Piezo-based scanning stages are a good solution for high-precision and dynamic sample positioning since their compact design allows them to be integrated easily in microscopes

Very often classical microscopic methods are no longer sufficient in terms of optical resolution or information content. To obtain more extensive and more accurate measurement data of a sample, it is nowadays possible to combine different microscopic methods with one another.

Easy integration of the piezo scanner in a modular designed microscopy system

This combination of methods, however, not only makes high demands on the individual components of the microscopes, but also on the systems used for sample positioning. This was the reason why WITec GmbH (Ulm, Germany) decided in favor of piezo-based scanning stages from PI for the design of modular high-performance microscopes. Harald Fischer, Marketing Director at WITec GmbH, explains: "The broad range of scanning stages has made PI an ideal partner for us as a supplier of high-resolution modular microscopy solutions. Our systems require flexible components which offer maximum precision for a broad spectrum of applications."

Ultra-High Resolution Microscopy in a Modular System

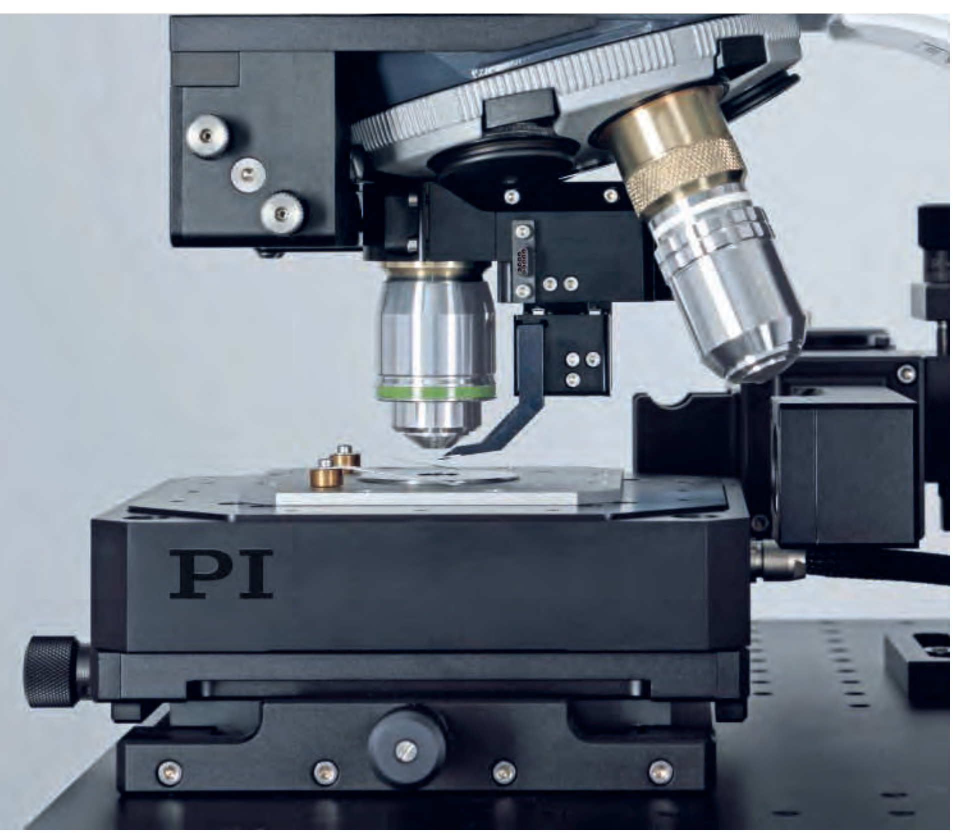
As a result of the modular structure of these microscopy systems, it is, for example, possible to combine a confocal Raman microscope with atomic force microscopy (AFM). The same device can then provide and link molecular Raman and structural AFM information from the same sample region. For high-resolution optical information, the microscope can also be equipped with scanning near-field optical microscopy (SNOM). "The scanning stage used for sample positioning is designed for working distances of 100 or 200 µm in the axes of the ▶

scanning plane and 20 µm in the direction of the Z axis. It allows a position resolution of better than 2 nm and thus provides the best conditions for all three methods," explains Fischer.

Molecular and High-Resolution Topographic Information Can Be Combined

Raman microscopy is based on a confocal, optical microscope and a Raman spectrometer. During measurement, a complete Raman spectrum is recorded for each pixel. These Raman spectra are like a specific fingerprint for each type of molecule, so that the chemical components of a sample can be identified for each pixel and their distribution in the sample can be displayed.

RAMAN MICROSCOPY IS BASED ON A CONFOCAL, OPTICAL MICROSCOPE AND A RAMAN SPECTROMETER.



Combining Raman imaging with AFM yields both molecular information and high-resolution topographic information. It measures the forces between a very thin measuring tip and the surface of the object. In doing so, it gives information on the topography of the surface at a lateral resolution capacity of 10 nm.

Since the distance between the measuring tip and the surface has to be kept constant, the position of the sample must be readjusted in the Z direction. This task is performed by the scanning stage.

"The AFM and Raman images are recorded in succession and then superimposed and related to one another. Precise positioning in all three axes and path accuracy during the scan are the prerequisites for achieving high-quality images which provide molecular, high-resolution topographic information on the sample surface," states Fischer.

Stability and Path Accuracy

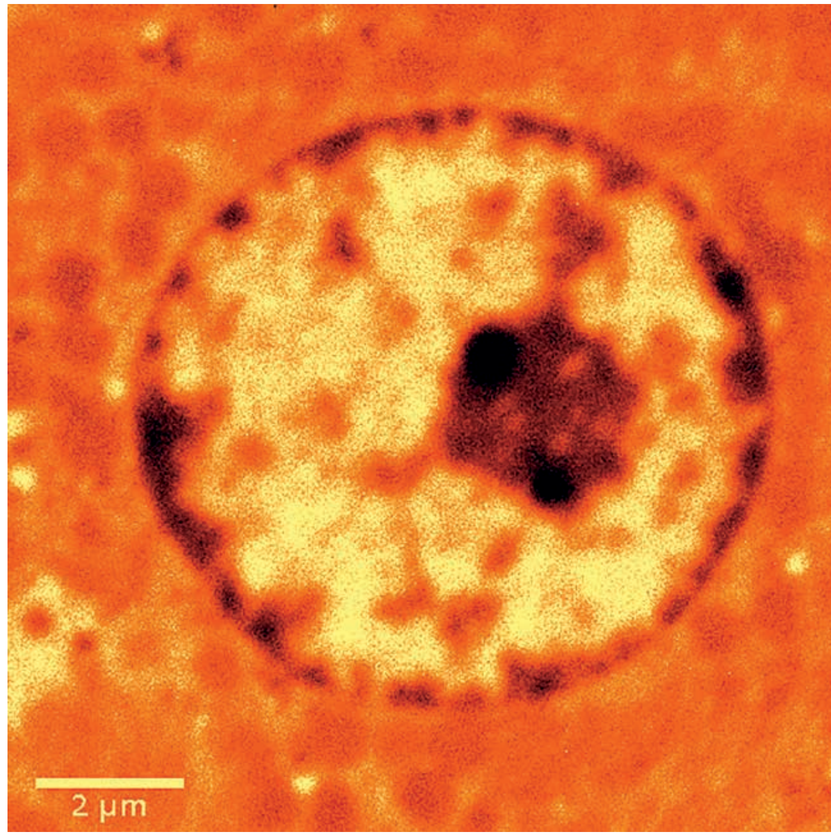
High stability and path accuracy during the scan are achieved by an active guiding. Capacitive sensors measure any deviations in the axis perpendicular to the direction of motion. Any undesired crosstalk of the motion can thus be detected and actively compensated in real time.

A digital controller, precisely adjusted to the piezo-based scanning stage, provides the necessary control. The digital electronics work with a high clock rate, since this is decisive for an accurate assignment of the position values of the scanner and the recording camera. If it were too slow or inaccurate, there would be a loss of resolution and distortions (jitter) during the assignment.

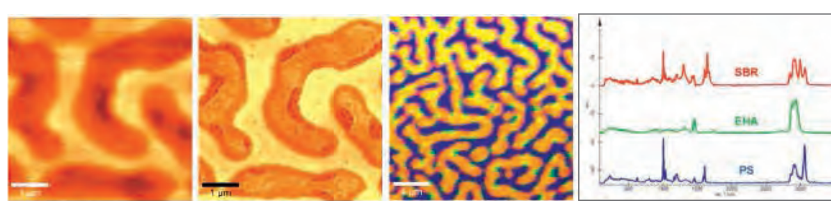
Scanning Near-Field Optical Microscopy for Optical Information below the Diffraction Limit

Scanning near-field optical microscopy (SNOM) allows the depiction of considerably smaller structures than is possible with conventional microscope technology. With SNOM, a glass fiber couples laser light into a measuring tip that is hollow inside. The light emerges through a tiny opening at the tip that has a diameter of less than 100 nm. If the opening of the measuring tip is brought to a short distance from the sample surface, a spot considerably below the diffraction limit of classic microscopy can be illuminated. A lateral position resolution of up to approx. 60 nm is achievable, while the value with confocal light microscopy is usually between around 200 to 300 nm.

The sample is scanned point by point and moved under the measuring tip of the high-resolution scanning stage for this purpose. At each position, the camera integrated in the microscope records the incoming light intensity and saves this value together with the position information. This is then used to create the image. The position resolution and accuracy of the image again depend on the positioning accuracy and stability of the scanning stage.



For high-resolution optical information, the microscope can be equipped with scanning near-field optical microscopy (SNOM): Shown here, the SNOM image of the nucleus of a rat liver cell (image: WITec GmbH)



AFM topography — AFM phase — Raman image — Raman spectra

Combining Raman imaging with AFM yields both molecular information and high-resolution topographic information on the sample surface. The figure shows a polymer mixture of three polymers (PS, EHA, SBR) on a glass substrate (image: WITec GmbH)

WITec in Brief

Since its foundation in 1997, WITec GmbH, based in Ulm, Germany, has become a market leader in high-resolution microscopy systems (Raman, AFM and SNOM) and generated average growth rates of annually 10%. With 52 employees worldwide, the company is represented today by subsidiaries in the USA and Asia, and has regional offices in Spain and Japan. The main application areas for modular high-performance microscopes, which allow the combination of different methods, are found in nanotechnology, materials sciences and life sciences. Europe, the USA and the Asia/Pacific region are the most important sales markets, with users coming from research and industry.

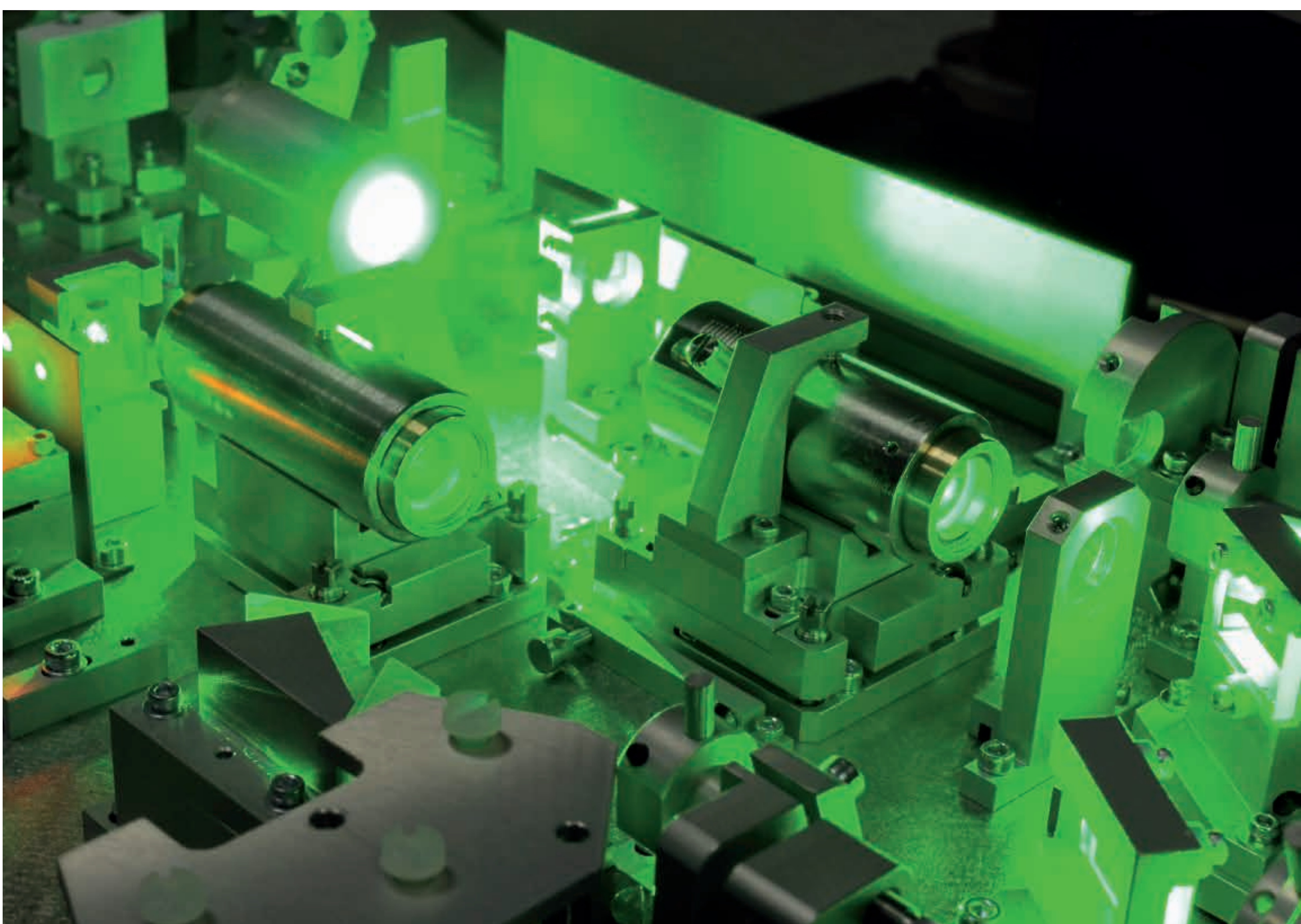
Harald Fischer,
Marketing Director
at WITec GmbH in Ulm, Germany

PIEZOMIKE
LINEAR ACTUATOR

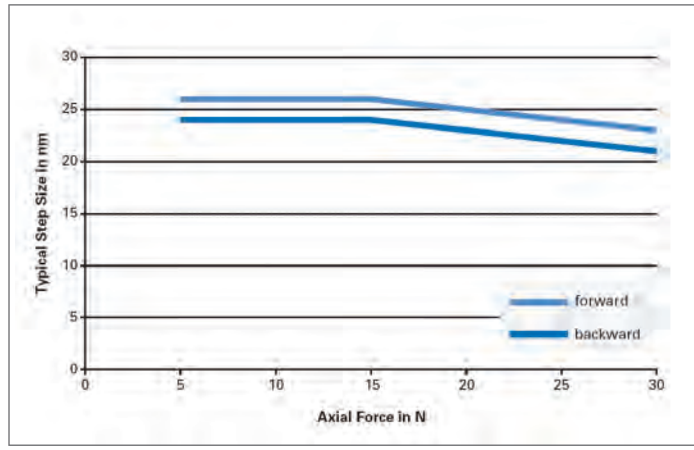
Set-and-Forget for Stable and Precise Positioning

The adjustment of the beam path of optomechanical assemblies not only requires stable and high-resolution drives, but also minimum-dimension drives that take up as little space as possible in the experiment.

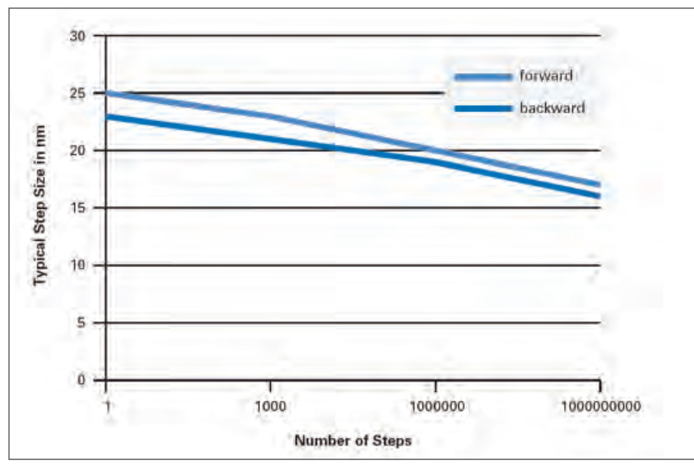
Compact N-470 PiezoMike linear actuator for high-resolution and stable positioning of opto-mechanical components



Vacuum compatible to 10^{-9} hPa



Typical step size depending on axial force



Reliable, even after a billion steps

With the new N-470 PiezoMike, PI has developed a linear actuator that can be easily integrated in conventional mirror mounts or stages, even when space is limited, and that automates the adjustment of mechanical and optomechanical components. It comes with a mounting thread or shank for installation into the existing application environment.

The linear actuator has a motion resolution of typically 20 nm and can align optical components with utmost precision. The piezo-based drive is very compact, with the N-470 currently being the smallest linear actuator of its performance range.

Simply Stable

The PiezoMike linear actuator keeps a position with long-term stability, is vibration-proof and shock-resistant. It provides a holding force of >100 N and a feed force of >20 N, making it the ideal choice for "set-and-forget" applications.

Powerful Drive

The N-470 achieves its high holding and feed force and high resolution by combining a piezomotor with mechanical thread translation. When at rest, the drive is self-locking and requires no current.

The piezomotor drive of the PIShift product line is based on the principle of inertia (stick-slip effect). Inertial drives utilize the cyclical alternation of static and sliding friction which is generated by the piezo element between a moving runner - in the case of the PiezoMike, a fine-thread screw - and the piezo actuator. This leads to a continuous feed of the runner with typically 20 nm per step cycle.

Simply Reliable

PiezoMike linear actuators run a billion steps, 20 meters or turn the screw 20,000 times. PI has specified the lifetime so that after this operating time, the initial step size will decrease

PiezoMike linear actuators replace manual micrometer screws in tip/tilt mirror mechanics

by maximum 30 %. Even after longer downtimes, the N-470 ensures a reliable start-up.

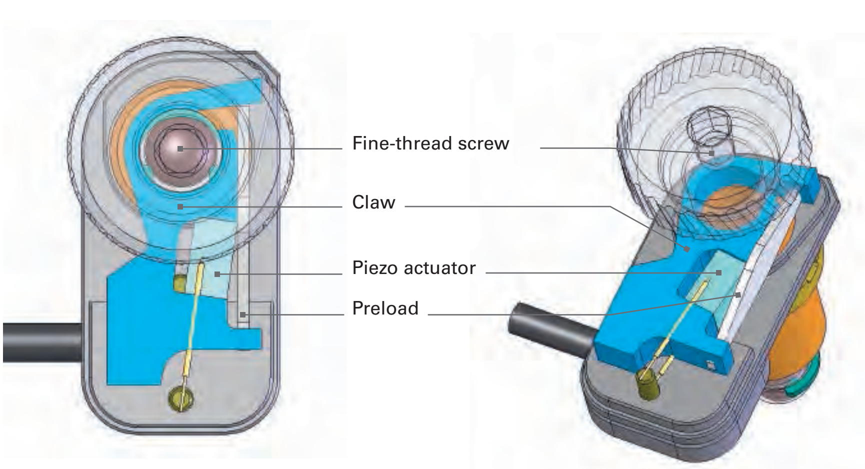
Simple to Operate

The E-870 drive electronics from PI are specifically tuned to the requirements of PiezoMike linear actuators. One amplifier can serially control a unit with up to four channels, this keeps investment costs low as a positive side-effect.

N-470 PiezoMike Linear Actuator

- Holding force >100 N
- Feed force 22 N
- Stiffness 15.5 N/µm
- Step size 20 nm
- Step frequency 2 kHz
- Travel ranges 7.5 to 26 mm
- Lifetime >1,000,000,000 steps
- Dimensions at 7.5 mm travel: 14 mm × 28 mm × 48 mm

Drive Principle of the N-470



The piezo actuators expands slowly when an electric voltage is applied. This expansion leads to a rotation of the claw. Since the claw grasps around the screw, the claw turns the screw when it rotates (stick effect).

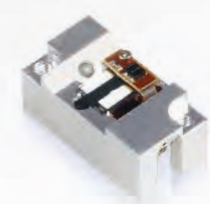
Once the piezo actuator has attained its maximum expansion, it quickly contracts and the claw returns to its initial position. With the fast contraction, the claw slips around the screw. The screw, however, stays in its initial position (slip effect) due to its inertial mass.

This stick-slip cycle can be repeated any time to achieve the desired feed forward of the screw's tip by turning the screw.

Of course, the motion also works in the other direction.

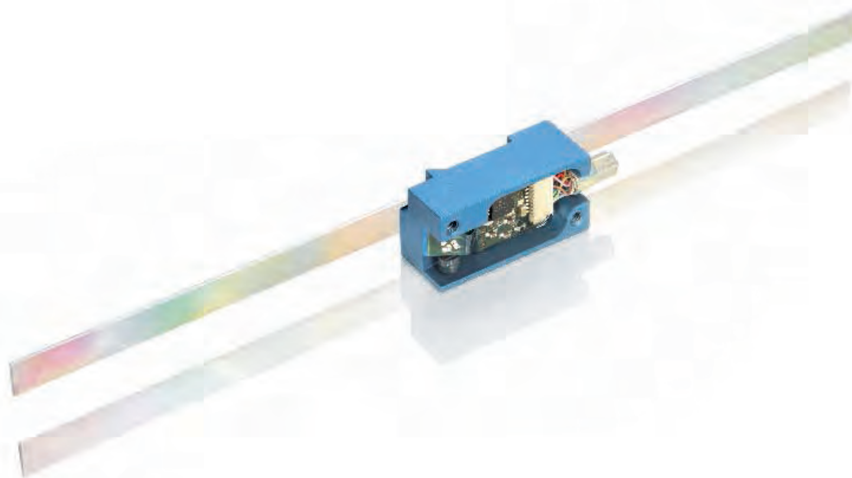
PIOne: HIGH PERFORMANCE FOR NANO-POSITIONING SYSTEMS

An In-house Development for Precision over Great Travel Ranges



"Developing the basics and the technical realization, both were quite challenging tasks. For me as a developer, the result is an exciting combination of optical, mechanical and electronic components which need to function as a single product."

Dr. Axel Grabowski
Team leader sensorics development at PI



Piezo stepping drives or magnetic drives enable high-precision positioning over large travel ranges. However, high resolution and linearity over large travel ranges can only be achieved with highest resolution measuring systems and methods.

Semiconductor industry demands maximum precision

For conventional nanopositioning with piezo actuators and travel ranges to 1 mm, capacitive sensors with sub-nanometer resolution achieve high stability and linearity. But for measuring ranges above 1 mm, capacitive measuring systems are no longer precise enough: Either resolution and linearity are reduced or the active sensor area needs to be enlarged and consequently also the required installation space. For this reason, incremental position sensors are used for longer travels. However, the linear encoders available on the market are often not sufficient to handle the requirements of nanopositioning mechanics.

"We developed the PIOne as there were no small sensors available for the resolution range of 1 nm or less", explains Axel Grabowski, team leader development sensorics at PI. "Some of the sensors available on the market meet the resolution requirement, but have larger dimensions than many of our stages and also have relatively high power requirements. Therefore, the objective of the in-house development was to realize a small sensor with maximum resolution and moderate energy consumption. We have succeeded with the incremental positioning sensor PIOne."

Resolution to 20 Picometers

The resolution of an incremental sensor, i.e. the smallest measurable displacement of the sensor head along the scale, is mainly influenced by the length of the signal period of the sensor, the noise of the processing electronics and the electronic interpolation factor of the signals.

The level of the interpolation factor, however, is limited by the noise of the signals and can only be selected within a certain range. For this reason, a signal period as small as possible is to be preferred, allowing for a high resolution even with a lower interpolation factor.

The PIOne sensor achieves a resolution of 20 picometers and better thanks to its small signal period of only 0.5 µm and the optimized signal processing. In this instance, interpolation with a factor of 4000 is possible without noise.

Linearity Error Below 1 %

Linearity not only depends on the quality of the grating and the quality of the signals, but also on mechanical influences.

Small signal periods of 0.5 µm, an accuracy class of the grating of better than 150 nm/30 cm and a high quality of the signals lead to a sensor linearity error of only < 1%.

The sensor head of a PIOne contains a Mach-Zehnder interferometer, where the optical paths are equalized and entirely symmetric. This allows compensation of ambient influences, such as temperature and humidity.

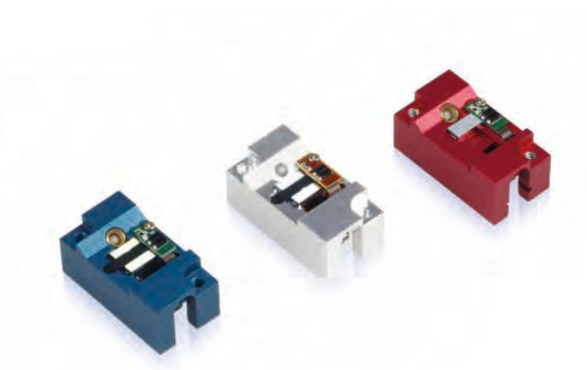
Minimum Heat Generation

The used laser diode operates at comparably low performance to minimize the heat generated in the sensor head. To largely avoid heat generation in a measuring system, the light can optionally be coupled via an optical fiber in the sensor head of the PIOne sensor.

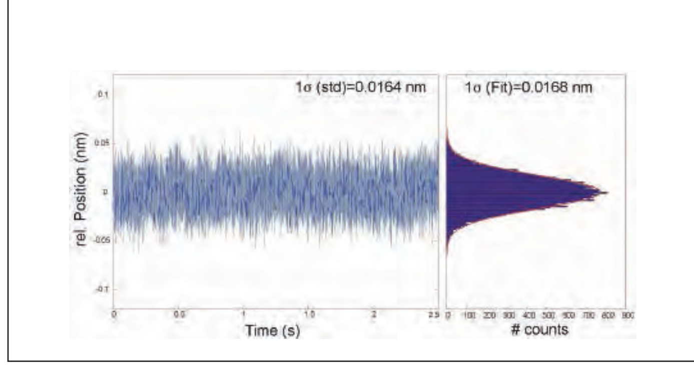
Since the signals of the PIOne sensor can be processed by different PI controllers, the sensor can be used in positioning systems with different drive technologies.

PIOne – a Class of its Own

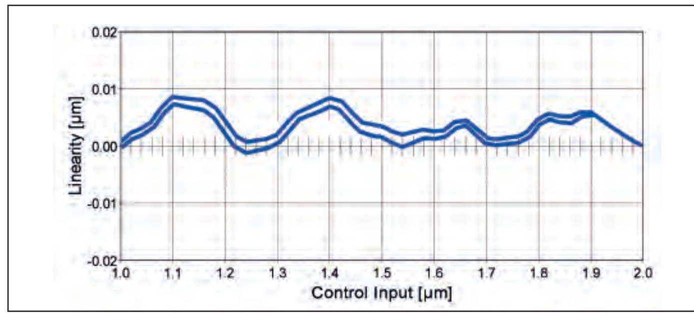
- Resolution to 20 picometers RMS and better
- Small dimensions
  23 mm × 12 mm × 9.5 mm
- Sine, cosine or quadrature output signals
- Low power consumption and low intrinsic heating
- Accuracy class of the grating 150 nm/30 cm
- Suitable for high vacuum up to 10^{-7} hPa, bakeout to 80 °C
- Preferably for travel ranges >1 mm
- For velocities up to 0.8 m/s at maximum resolution
- BiSS interface for secure data exchange



Blue: 0.5 µm signal period, for velocities >200 mm/s
White: 0.5 µm signal period, for vacuum conditions
Red: 2 µm signal period, for velocities >800 mm/s

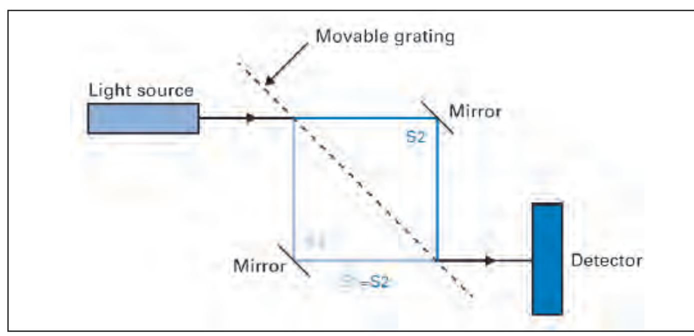


Noise measurement of a positioning system with the PIOne at approx. 400 kHz bandwidth and 18-bit resolution of the sensor input: 16 picometer RMS and 100 picometer peak-to-peak



Linearity measurement of an N-664 with integrated PIOne sensor and controlled via an E-861 motion controller. The linearity error is <10 mm

Mach-Zehnder Interferometer



Schematic diagram of a Mach-Zehnder interferometer with equalized beam paths. A beam coming from a laser diode is split into two optical beam paths when passing between two gratings and then united to a single beam again. The created interference pattern is detected by a photodiode and then processed further

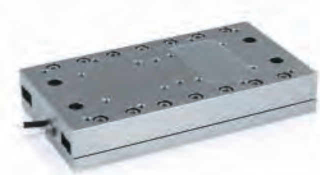
Product examples

MCS

With a 0.2 µm repeatability and a 3 µm positioning accuracy, the MCS provides a 5 nm resolution over the entire travel of 102 mm per axis

LPS-24

The LPS-24 miniature positioning stage with piezo stepping drive is only 24 mm wide. Equipped with the PIOne sensor, it achieves a minimum incremental motion of 1 nm over a 15 mm travel range



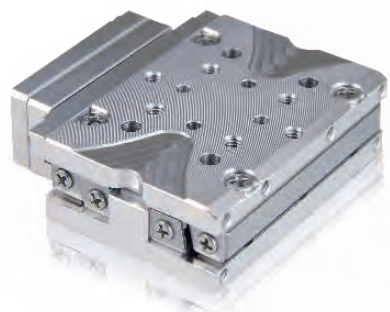
N-664

The N-664 high-resolution linear stage provides a minimum incremental motion of 2 nm over a travel range of 30 mm

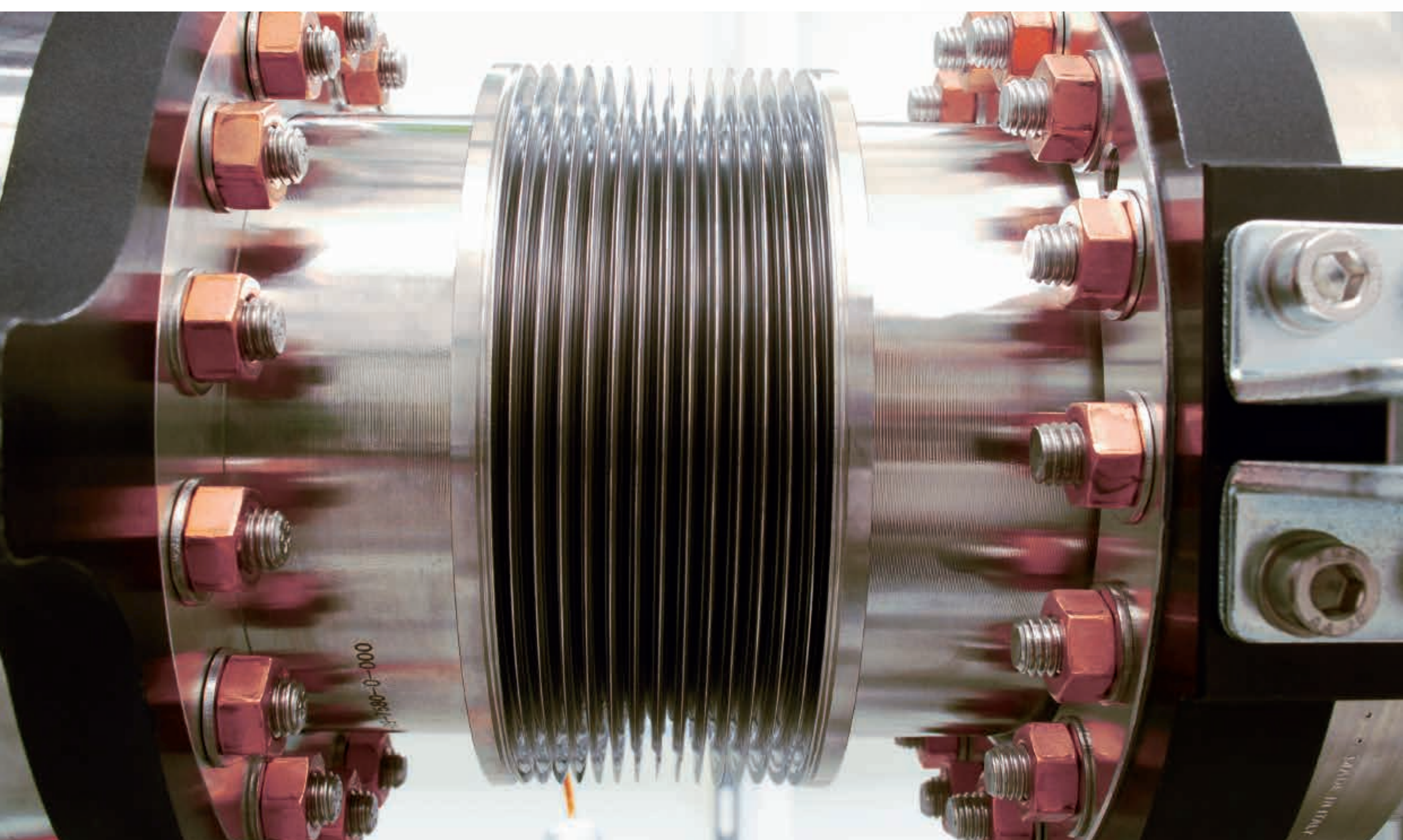
SMALL SMALLER SMALLEST

Miniaturized Linear and Rotary Stages

High positioning resolution and smallest dimensions are the key features of this new series of linear and rotary positioning systems from PI miCos.



Vacuum variant
of linear stage LPS-22



Design of a SpaceFab variant for positioning in up to six axes

With a width of only 22 mm, travel ranges of up to 26 mm and a resolution up to 1 nm in closed-loop operation, the LPS-22 is one of the smallest precision linear stages available on the market. The linear stage can attain velocities up to 10 mm/s.

The rotary stages of the RPS series, the smallest diameter of the rotating platform being at 14 mm, and can attain velocities of up to 45°/s.

Indispensable:
Piezo-Electric Drive Principle

These miniature linear and rotary stages are piezomotor-based drives. Thanks to this drive principle, small stage sizes with high resolution can be realized, making this series perfectly suited for precision positioning in applications where space is limited and for vacuum environments. The optional linear encoder for LPS-22 linear stages provides a resolution of up to 1 nm.

The linear and rotary stages can be stacked directly to XY linear and XYθZ configurations, no adapter is needed for this.

For closed-loop and open-loop operation, suitable drivers and motion controllers are available. These range from OEM boards without case and bench-top devices to multi-axis systems. User software and drivers for programming Windows or LabView applications are included in the scope of delivery.

Outlook – SpaceFAB and Goniometer

For positioning in up to six axes, PI miCos is currently developing a SpaceFab based on LPS-22 linear stages. In addition, goniometers will supplement the miniature stage series.

Left: Precision positioning, also under vacuum conditions

For XY or three-axial configurations with rotary stages the positioning stages of this series can be stacked directly without adapters

The Sonodrive 300 is a serial-production vibratory spindle, which, in high-precision microdrilling operations, can cut machining times by up to 60 %, compared with standard equipment, employing a patented process. As "Plug & Play" solution, it fits in with all commercially available die-sinking EDM machines (image: ICT-IMM)

Compact piezo actuator: Generating of vibrations is a classic piezo application

GOOD VIBRATIONS FOR DIE-SINKING EDM

Piezo Actuators Accelerate Microstructuring

The increasing complexity of products and processes requires the production processes to constantly increase throughput, precision, geometric diversity and precise repeatability.

At the same time, the trend in automation continues toward miniaturization. It is therefore hardly surprising that microstructured precision components are now being manufactured in the field of die-sinking EDM, often even in large quantities. Examples include the manufacture of filter elements or injection nozzles for the automotive industry. Cost-effective manufacturing processes are therefore also necessary in microstructuring.

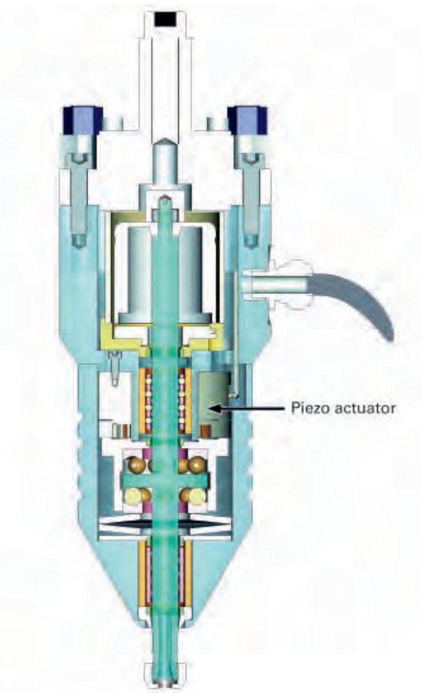
Faster Die-sinking EDM with a Vibratory Spindle

This topic has been taken up by the Institute for Microtechnology in Mainz (ICT-IMM), Germany, which has become part of the Fraunhofer Gesellschaft in 2014. The Sonodrive 300 is a serial-production vibratory spindle, which, in high-precision microdrilling operations, can cut machining times by up to 60 %, compared with standard equipment, employing a patented process. The spindle rotates and vibrates simultaneously, thus preventing the particles produced in EDM from being deposited in the hole, thereby eliminating the need to machine them again. In conventional methods, this is unavoidable, because the small electrode distances no longer allow any flushing in the micrometer range. Depending on the material to be machined and the task at hand, the vibration path can be set and adjusted at any time during the process.

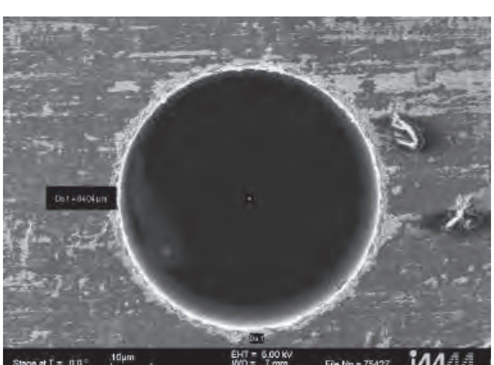
Compared with conventional methods, this delivers substantial benefits in velocity, therefore accelerating the entire production process. With a 0.2 mm diameter blind hole in 1.0 mm thick VA material, the machining time in a test on an EA12 sinker EDM machine by Mitsubishi Electric was reduced from 200 to slightly below 80 seconds. On an Agie Compact die-sinking EDM machine, the 0.2 mm diameter through-hole in 0.4 mm thick VA material was also obtained approx. 60 % faster through the use of a vibratory spindle. Hereby, the new spindle principle combines high concentricity tolerance of 1 to 2 µm absolute at a velocity of up to 3500 min^{-1} with a high-frequency vibration of max. 300 Hz and a stroke of up to 15 µm. The spindle fits all commercially available diesinking machines as "Plug & Play" solution. The matching miniaturized wire pay-off device which was also developed by ICT-IMM can also be easily integrated. This allows the concentricity tolerance to be improved to 1 µm absolute.

Piezo Actuator Ensures Vibration

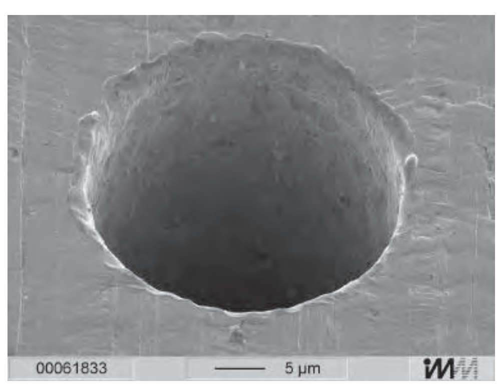
This technological leap in microstructuring was only possible by combining considerable know-how with components of high technical quality. Vibration is created using a PI piezo actuator. And there are a number of reasons for this choice. The creation of vibrations virtually is a classic piezo application, because the piezo element starts to oscillate when an AC voltage is applied. Here, travel ranges of a few hundred micrometers and high dynamics with frequencies up to several hundred hertz can typically be achieved. The short response times of the piezos also benefit the application as a vibration drive. With its height of 25 mm at a diameter of 50 mm and its inner aperture of 25 mm, the selected actuator was easy to integrate in the vibratory spindle. Since piezos are also suitable for large loads, the permanent motion of the spindle, whose weight varies between about 250 and 450 g, depending on the electrode, was not a problem for the small drive. If need be, it



The piezo actuator was integrated into the vibratory spindle in a space-saving manner (image: ICT-IMM)



A hole 64 µm in diameter produced with a die-sinking EDM machine equipped with a vibratory drilling spindle. The deviation between concentricity and cylindricity of the hole is only 1 µm in each case (image: ICT-IMM)



A hole only 20 µm in diameter produced with a die-sinking EDM machine equipped with a vibratory drilling spindle (image: ICT-IMM)

MORE INFORMATION ABOUT THE FRAUNHOFER ICT-IMM IN MAINZ, GERMANY

www.imm.fraunhofer.de

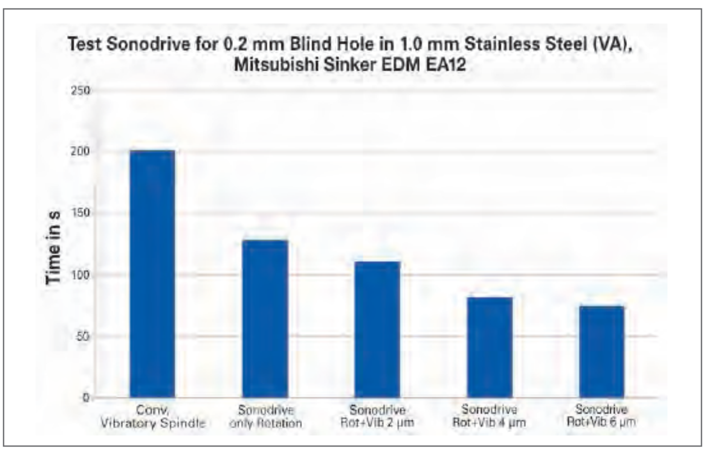
can lift more than one kilogram. In contrast, electromechanical components for vibration generation were not an option for this application. Due to their design and their larger dimensions, it would not have been possible to integrate them into a useful unit for practical use.

There are also a number of other arguments that speak in favor of using piezos: Since the motion is based on crystalline solid-state effects, there is no danger of abrasion with this technology and there are no cogwheels, bearings or other mechanical parts subject to wear. This makes the piezo actuator maintenance-free. This is an important feature worth considering, given that the piezo actuator operates throughout the entire machining operation. It has already proven its reliability, for example, in prototypes of the vibratory spindle, which has been operating at ICT-IMM for about four years now, and where it has by now completed approximately 100 million operating cycles.

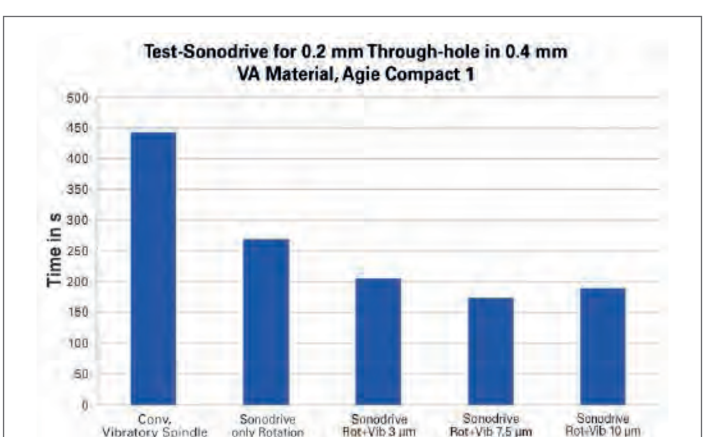
The piezo actuator is driven by an efficient, pulse-width-modulated high-power voltage amplifier, also from PI.

A Vibration-Supported Electrode Chuck Saves Time

Piezo actuators have also been tested and proven in a vibration-supported electrode chuck, which is also suitable as "Plug & Play" solution for all commercially available die-sinking EDM machines and clamping systems and offers a very compact design at 80 x 80 x 150 mm. Here, too, the 300-Hz vibrations at an adjustable stroke of up to 15 µm accelerate the production process considerably: Thus, a long-term experiment with a hard-metal electrode (0.2 x 5 mm) and a sinking depth of 7 mm resulted in a time saving of 70 %. Production time was reduced from 17 hours and 20 minutes to 5 hours and 15 minutes. This can benefit many areas of application. Typical examples are micro-machining, tool-making and mold-making and the manufacture of components for medical technology, metrology and machine technology. Piezo actuators used as vibration generators have thus made a substantial contribution to advancing the technology of dies-inking EDM to the lowest micrometer range.



With a 0.2 mm diameter blind hole in 1.0 mm thick VA material, the machining time in a test on a EA12 sinker EDM machine from Mitsubishi Electric was reduced from 200 to slightly below 80 seconds (image: ICT-IMM)



On an Agie Compact die-sinking EDM machine, the 0.2 mm diameter through-hole in 0.4 mm thick VA material was also obtained approx. 60 % faster through the use of a vibratory spindle (image: ICT-IMM)

This driver is especially designed for the demands of low-voltage piezo actuators. At a peak output power of up to 280 W and an average output power of up to 100 W, it can supply and consume a peak current of up to 2000 mA

Fast Hexapod

Further Development of the H-811 Mini-Hexapod for Oscillations with High Dynamics

The requirements for camera systems are continuously increasing. In particular, the wish to obtain sharp images without a tripod and to exclude the natural trembling of hands as well as vibrations due to a vehicle in motion.

Modern cameras are therefore fitted with image stabilization technology. For testing the cameras, it is necessary to generate vibrations with high dynamics.

PI has developed the H-811 specifically for this application. Like the H-811 Mini-Hexapod, the H-811.S11 offers linear travel ranges up to 34 mm and rotary travel ranges up to 42°. With 20 Hz over 0.1° travel range, the H-811.S11's dynamics are considerably higher.

Sharp images without a tripod: The H-811 tests modern image stabilization technologies

Pick-and-Place Robot

An Application Example for PIMag™ Linear Actuators

Parallel-kinematic Delta or Spider robots are often used for loading tasks. They possess the same dynamic properties over all motion axes and can be designed for high precision in the range of only a few micrometers. Tripods based on V-273 PIMag™ linear actuators are a typical example for an application.

The individual actuators have a position resolution of 0.1 µm, travel ranges up to 20 mm and a maximum velocity of 250 mm/s. In test designs, areas with up to 10 mm edge length could be covered dynamically.

Pick-and-place systems are, for example, employed for automated drug pill filling equipment

PI

TRADE FAIRS & EVENTS

The Graceful Eleganze of Precision

20. – 22.05.2014 | **Optatec Frankfurt**

02. – 06.06.2014 | **Euspen Dubrovnik, Croatia**

03. – 05.06.2014 | **MEDTEC Europe Stuttgart**

23. – 25.06.2014 | **ACTUATOR Bremen**

06. – 09.10.2014 | **Motek Stuttgart**

11. – 14.11.2014 | **Electronica Munich**

12. – 14.11.2014 | **COMPAMED Düsseldorf**

25. – 27.11.2014 | **sps ipc drives Nuremberg**