Piezo · Nano · Positioning

news

Issue 41

Piezo actuators improve effectiveness, reliability and lifetime

Vibration isolation for industry, laboratory and research

Active piezoelectric vibration isolation system, isolators and controller: STACIS® from TMC

Ambient ground motion, power supply units, cooling systems – vibrations originate all around and are transmitted via the ground or the air. They become a problem when they affect high-precision manufacturing or measuring processes on a nanometer scale.

The tractability of these nanoscale processes worsens with a relentlessly diminishing scale and a high throughput is demanded in microscopy or in the semiconductor manufacturing industry: There is no time to wait for the disturbances to subside by themselves. Vibration isolation is necessary to speed up the settling process and dampen vibration effectively. Active vibration isolation is particularly suitable for applications in the nanoscale realm. It reduces the settling times significantly, the precision of measuring or production processes are improved and higher throughputs are possible. Conventional methods of vibration isolation do not suffice the requirements of existing high-precision technologies.

Figure 1 shows a typical example: A lithography device for semiconductor patterning does not have sufficient vibration isolation and so the 45 nm wide lines are practically not discernable (a). The picture next to it (b) shows the result when the vibration isolation uses active methods which not only dampen the vibration but actively attenuate it.

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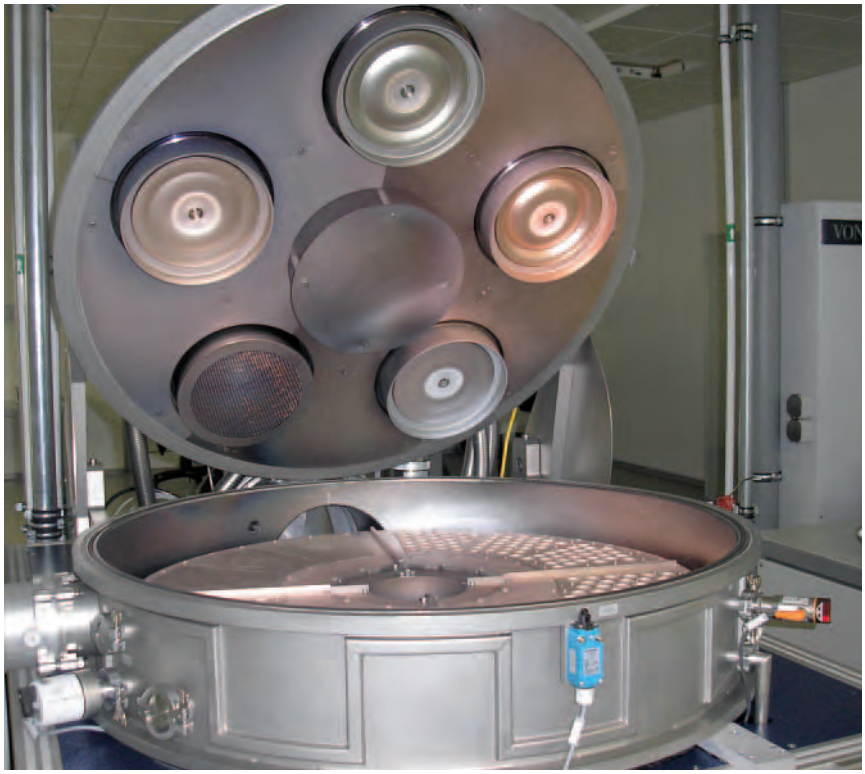
The problem solver here was an active vibration cancellation system of the STACIS® product family developed by TMC Technical Manufacturing Corporation. This system enables the isolation of very low oscillation frequencies starting at the sub-hertz range and thus prevents the vibrations having a detrimental effect on the machine. This not only improves the machining or testing quality but at the same time reduces the settling times (Figure 2). The cycle times are reduced and the throughput increases.

Detect and compensate vibrations in six degrees of freedom

The active vibration isolators use integrated acceleration sensors to detect vibrations occurring in six degrees of freedom. The counter movements necessary for compensating the vibrations are generated by piezo actuators which are controlled by a real time digital signal processor. The processor provides the computing power for the extremely fast calculations needed for active vibration compensation.

Their great stiffness, high load capacity and clean and low-cost operation without the need for compressed air make the piezo-based active isolators suitable for integration as OEM components in ultramodern tools and also for installation in isolation platforms for metrology devices or optical lithography systems.



Vacuum coating (Sputtering) of piezo ceramics by PI Ceramic

Piezos for active vibration isolation

The piezo actuators used by TMC are manufactured by PI Ceramic, the high-tech production plant and subsidiary of Physik Instrumente (PI). The actuators are part of the PICA series and can be supplied in a large range of diameters and overall lengths. They can be used for almost any actuator application and are optimally suited for vibration isolation: They are available for high loads up to several tons of payload and with resonant frequencies above 10 kHz, and come with displacement ranges of more than 100 µm and a blocking forces of over 75 kN.

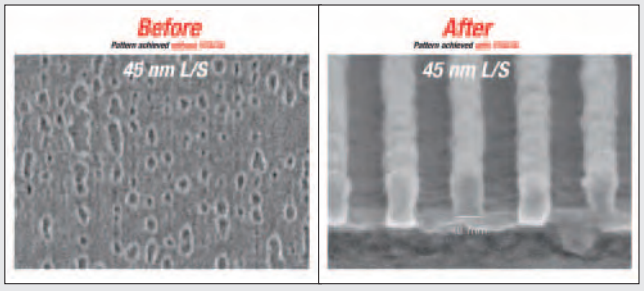


Figure 1: Test pattern with a line width of 45 nm, without (a) and with (b) STACIS® vibration isolation. (Photo: Sematech)

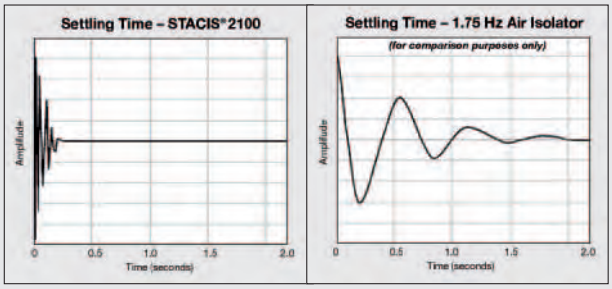


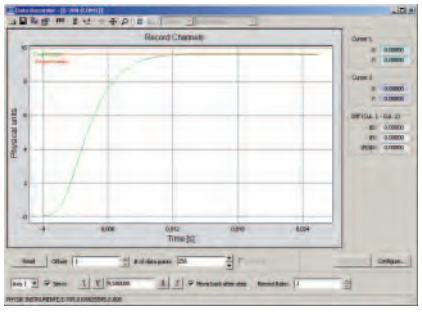
Figure 2: Settling time comparison of active piezo cancellation system and conventional air isolator as a reaction to the on-board perturbation when loading a microscopy table with the substrate. (Photo: TMC)

Positioning accuracy improved by up to one order of magnitude

Digital motion controller now also available for low-cost piezo systems

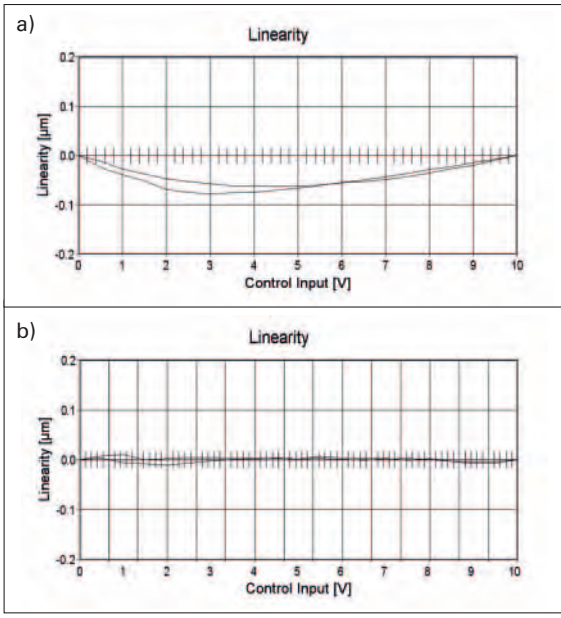
The E-709 digital piezo controller and the extremely low-profile P-712 piezo scanner form a low-cost nanopositioning system with a positioning accuracy of one nanometer.

The E-709 single channel piezo controller now opens up the digital technology and its advantages to lower-cost systems in the accuracy class from one to ten nanometers. It will initially support the strain gauge sensors (metal foil or piezo-resistive) which are used in low-cost piezo systems; a version for capacitive sensors will follow. The requirements placed on these systems mean that components with a well-balanced price-performance ratio are used in the E-709. The D/A conversion is 16 bit, the 32 bit processor with 150 MHz clock – pulse rate allows a servo rate of 10 kHz – i.e. position recalculations are carried out 10,000 times per second. The amplifier provides 5 W continuous power, for the dynamic operation of conventional nanopositioning systems such as the P-721 PIFOC® objective scanner, for example.



Settling of a Nanopositioning System. With the PIMikroMove software, system parameters can easily be observed and optimized.

The digital controller can be supplied with commands via USB and RS-232 interfaces and the advantages it has over analog systems are brought to bear in several ways. The digital control uses additional linearization algorithms to continuously recalculate the control voltage, thus improving the precision of the system both dynamically as well as for achieving the end position. Comparative measurements with a high-quality analog system for metal foil strain gauges, have shown that the nonlinearity has been improved from around 0.2 % to 0.02 % and therefore comes close to the values for capacitive sensors. The digital controller comes with an extensive software package. As is usual for PI, the system is supplied not only with the PIMikroMove operating program but also LabView drivers and DLLs for programming with Windows or LINUX. Its compatibility with software platforms such as µManager, MATLAB or Metamorph are important for microscopy applications.



Measurements with the P-712 piezo scanner (30 µm travel) with a) a conventional analog controller and b) the digital E-709. The nonlinearity for the analog controller amounts to 0.1 µm, corresponding to 0.3 %. The digital linearization means the deviation from linearity with the new E-709 is considerably lower.

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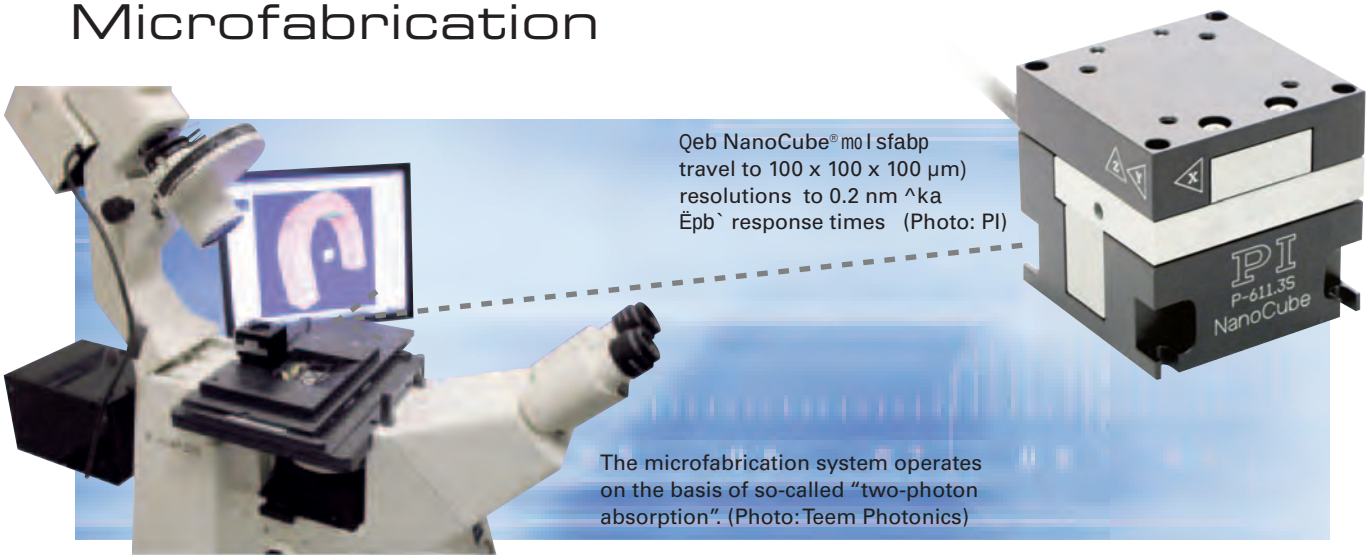
OEM controllers reduce system costs

In the E-609, PI uses a digital control with linearization algorithms in a device with analog control. The control parameters are set with software via a service interface.

The E-709 digital controller is also available as an OEM version with the same functionality but without a case. The E-609 controller serves the same performance class as the E-709. In contrast to the E-709, the E-609 has only analog interfaces for placing the position commands and fewer functions. It is therefore the ideal instrument for automation tasks without host PC. In contrast to conventional analog devices, the E-609 has a digital control which can be optimized using software and USB service interface. Additional linearization methods achieve significantly better linearity than completely analog devices.

Nano-mechatronics in precision positioning

Piezocube for 3D Structuring & Microfabrication



Qeb NanoCube® mo l sfabp travel to 100 x 100 x 100 µm) resolutions to 0.2 nm ^ka Ëpb` response times (Photo: PI)

The microfabrication system operates on the basis of so-called “two-photon absorption”. (Photo: Teem Photonics)

The NanoCube® P-611 XYZ nanopositioning systems – prove their ability time and again in new fields of application. The cube sides measure a mere 44 mm, making it suitable for travel ranges up to 100 x 100 x 100 µm and easy to integrate. The stages are driven by PICMA® piezo actuators and achieve resolutions of up to 0.2 nm at response times in the microsecond range. One example can be found in a product from the French company Teem Photonics, which uses the NanoCube® P-611 in the new µFab3D microfabrication system. The system builds three-dimensional microstructures and objects in light sensitive materials such as polymers, proteins or noble metals.

The microfabrication system operates on the basis of so-called “two-photon absorption”, where a pulsed beam of laser light is used to achieve a sufficiently high supply of energy at the focus. This changes the material structure by polymerization, cross linking of proteins or precipitations of metal ions. The typical fields of application include microfluidics, cell biology and the manufacture of photonic crystal structures in micro-optics.

The resolution of the system, i.e. the size of the machining points, which can be anywhere within the object, is 200 nm. The objects are fabricated “on the fly” at a speed of 100 µm/s. For a homogenous and high-quality result the laser must drive to the machining points precisely and with constant speed. The NanoCube® provides the optimum conditions here. Since the size of the object to be machined is currently limited solely by the travel range of the piezo system, a system with greater travel ranges may be used in the future.

Precise positioning solutions really can be low cost

Piezoelectric actuators for various levels of integration

Many fields of automation require a "fine touch". Examples are to be found wherever fine adjustment, i.e. high-resolution positioning is needed, often accompanied by high dynamics or force.

Lever-amplified actuators cover the levels of integration between preloaded stack actuators and complete, multi-axis stages.

Applications which require this are the setting of slit widths, cavity tuning in laser optics and microscanning for imaging methods, for example. Also included are dispensers, valves for microdosing, pumps in medical technology and biotechnology as well as force generation in adaptronics or for imprint systems. Those who prefer to use OEM products for technical or financial reasons can now keep the investment costs at a relatively low level even for demanding positioning tasks. The lever-amplified actuators of the PiezoMove Series cover the level of integration between preloaded stack actuators (displacement up to around 100 µm) and complete, multi-axis stages. The piezo actuators are mechanically integrated into flexures. This improves the guiding precision; there is no danger of rotation or lateral displacement. At the same time, the flexures translate the displacement of the piezo into larger travel ranges. Lever-amplified actuators are much smaller than nanopositioning systems and are thus easy to integrate. This compact size limits the choice of sensors and the realization of parallel-kinematics multi-axis solutions, however. The lever-amplified actuators in the PiezoMove series are available in three versions to cover different user requirements: P-601 lever-amplified actuators have travel ranges up to 400 µm, a high positioning accuracy and very compact dimensions. P-602 lever-amplified actuators operate with large travel ranges up to 1 mm. Thanks to their extremely flexible design, multilayer actuators with a footprint of 10 by 10 mm can be used here to increase the stiffness and thus produce greater force generation. And last but not least, P-603 lever-amplified actuators achieve travel ranges up to 500 µm and are designed for particularly cost-optimized large-scale production.

	Stack actuators	Lever-amplified actuators	Positioning systems
Travel ranges	up to approx. 150 µm	up to 1 mm	up to 2 mm
Axes moved	one	one	up to three linear axes and three tip/tilt axes
Sensors	SGS optional	SGS optional	SGS or direct measuring capacitive sensors
Linearity	up to 99,8 %	up to 99,8 %	over 99,9 %
Guidance	none	flexures for rotations < 10"	flexures for rotations < 2"
Space required	low	low	depends on features
Price	low	low	depends on features
Level of integration	high	low	low

The table provides an overview of the various levels of integration and their important characteristics.

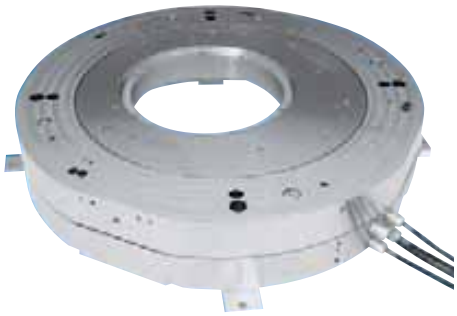
Piezo actuators, piezo stepping drives and nanopositioning systems

Fit for use in high vacuum

Positioning systems and linear actuators which operate on the basis of piezo ceramics are particularly suitable for use in high and ultra-high vacuum at pressures down to 10^{-10} hPa (mbar), because the motion is based on displacements in the crystal structure.

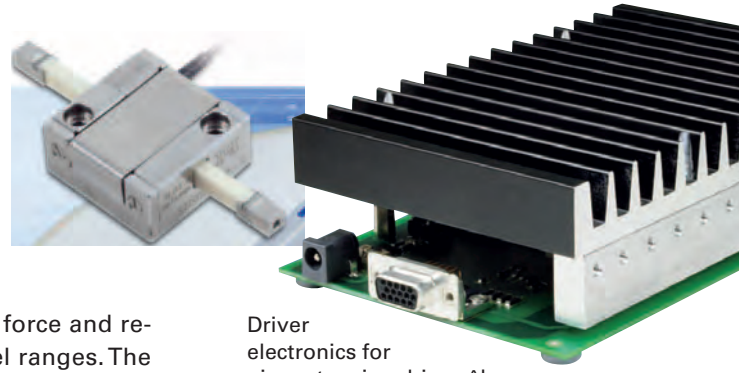
Therefore no conventional mechanical elements such as shafts or gears are necessary and thus no maintenance or lubrication either. Neither is there a danger of an outgassing of the materials used. The PICMA® actuators are completely encapsulated in ceramic and do not use a polymer insulation, for example. The German Aerospace Center (DLR) could not detect any measurable outgassing rates during appropriate testing. The ceramic insulation additionally increases the usable upper limit of the temperature range to 150 °C; an advantage for baking out in vacuum applications. Piezo stepping drives from the NEXACT® or NEXLINE® range – also manufactured completely in ceramic and vacuum compatible – lend themselves for larger travel ranges. Depending on the version, positioning systems equipped with piezo stepping drives are suitable for travel ranges to 125 mm and more. The positioning systems can cope with considerable loads. Heavy load versions achieve drive forces of up to 600 N, versions optimized for speed drive with up to 10 mm/s at a drive force of 10 N. Other characteristics of piezomotors can also be advantageous: They do not need electric power once the position is reached. There is therefore no undesirable heat generation in the vacuum. Additional brakes are not required because piezomotors are self-locking when at rest.

N-111 NEXLINE® Piezo stepping drives: high resolution, large travel and heavy loads. Piezo stepping drives combine piezo actuators with different motion characteristics. When driven in an appropriate way, both clamping and driving motions can be realized, the latter resembling the motion of a quadruped.



Vacuum-compatible hexapods with Piezo drives very efficiently realize multi-axis motion.

Low-Cost Drive Electronics for Piezo Linear Drives

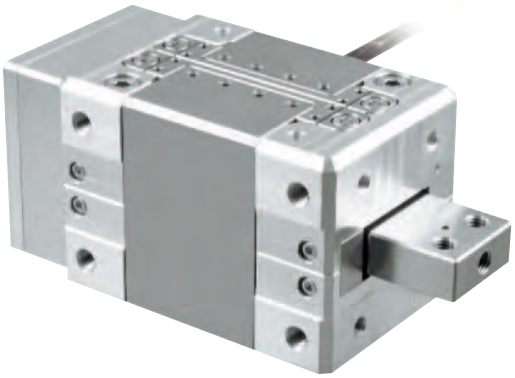


Driver electronics for piezo stepping drives ^ka KBU>@QÄ ifkb^o j lqlo%ibcq&

The compact NEXACT® piezo stepping drives push forward into a new performance class for linear drives: with high forces of 10 N, velocities of more than 10 mm/s, and at resolutions of a few nanometers they replace the typical stepper or DC servomotors in applications that depend on the combination of force and resolution on large travel ranges. The E-862 driver electronics is the ideal control for the NEXACT® drives when operated in open-loop or when used with an external positioning and velocity control. By using an analog input signal, the driver can be connected with external motion controllers or it can be operated directly by using a joystick.

Up to 600 N Driving Force at 20 mm Travel

High-load Linear Actuators for Nanopositioning



Up to 600 N drive force at 20 mm travel: N-216, high-load linear actuators for nanopositioning

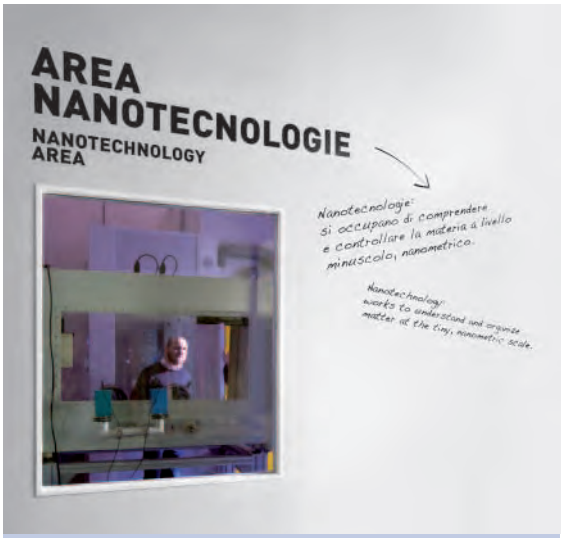
With the N-216 series NEXLINE® drives, PI has now available in its product range new high-load linear actuators which combine travel ranges of 20 mm, pull or push forces of up to 600 N and positioning accuracies in the nanometer range. They are suitable for open-loop and closed-loop operation: The integrated encoder of the versions which can be operated in closed-loop mode has a resolution of 5 nm over the total travel range. In open-loop mode, e.g. for highly dynamic applications, position resolutions of up to 30 picometers are achieved. In order to make the best possible adjustment of the drives to the relevant application, two different controllers are available: The E-755 offers all functions for a positioning with nanometer accuracy and covers thus most applications well. The E-712 controller system additionally has improved linearization algorithms for extremely steady motion and allows faster feed-forward motions with maximum force.

PI Ceramic Nominated for the Thuringian Innovation Award

New Piezo Stepping Actuators in the Top Three

The Thuringian Innovation Award took place for the 12th time in December 2009. The award, which has been established in 1994, has become both an impulse generator for the Free State of Thuringia and a mirror of its successful economic development. PI Ceramic from Lederhose was nominated out of more than 100 candidates in the categorie "Industry & Material" for their piezo stepping drive of the Nexact series. With this technology, the company came in the top three of all candidates. Even though a different company, who developed a drive technology concept for the automobile industry, won the award, the nomination itself is an outstanding achievement for such a small ceramic. A ceramic that can change the world of precision positioning.

N-310: High-resolution linear drive for travel ranges of up to 20 mm and holding forces of up to 10 N.



Spare time in Milan?

Visit a real nanotechnology lab!

The National Museum of Science and Technology Leonardo da Vinci opens a new nanotechnology area.

PI is a technical partner of the project and contributes making nanotechnologies visible by demonstrating "Nanopositioning" with piezoelectric actuators. The new area, in partnership with the University of Milan, stems from the Project NanoToTouch, funded by the European Union with the aim to effectively communicate research on nanotechnology: labs leave universities to find a space in science museums, where they are open to the general public.

PI in Motion

New Locations for PI UK and France

The new offices for PI UK at Trent House, which is part of Cranfield Technology Park, is 200 m squared. Over two months the unit was fitted out with a kitchen, laboratory, meeting room, store room, manager's office and open plan office area using a combination of glass panelling and solid walls. The glass panelling ensures the office is full of natural light and the location ensures that it is a quiet environment to work. The open-plan office area can currently accommodate 7 employees, but there is room to expand as the company grows. Situated in the countryside but close to Cranfield University makes access by car easy, but still ensures that there is access to local facilities such as shops, bank and cafes and restaurants.

In the new subsidiary of PI France, 170 square meters are available to offer optimal service to the French customers of PI and PI Ceramic.

PI France

PI UK

Tradeshows 2010

May, 18 – 20	**PhotonXpo (CLEO)**	San Jose, CA	**Booth #2329**
May, 24 – 26	**Brookhaven User Meeting**	New York, NY	
June, 1 – 3	**Euspen**	Delft, Netherlands	
June, 8 – 10	**ATX East**	New York, NY	**Booth #2748**
June, 15 – 18	**Optatec**	Frankfurt, Germany	**Hall 3, Booth F26**
June 29 – July 1	**Astronomical Instrumentation**	San Diego, CA	**Booth #200**
July, 13 – 15	**Semicon West**	San Francisco, CA	**Booth #6257**
Aug, 3 – 5	**Optics and Photonics**	San Diego, CA	
Sept, 13 – 16	**MOTEK**	Stuttgart, Germany	

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