Piezo Linear Drives for Laser Technology

Automatic Mirror Positioning in Vacuum and in Inaccessible Places

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Lasers are versatile tools with a wide range of applications. For example, in material processing they are nowadays as indispensable as they are in medical technology or in material and environmental research. Everywhere the principle is the same: Tip/tilt mirrors ensure correct guidance of the laser beam.

This makes them important components, which, however, have to be positioned accurately, in order to achieve the desired result. Here manual setting is mostly still the state of the art. But manual adjustment is not always possible, for example, when tilt/tip mirrors are used in a vacuum or are mounted in inaccessible places where they have to be preset before start-up or readjusted. This is where piezo-based linear drives can provide a solution: These space-saving and low-cost microdrives work with a positioning accuracy down to the nanometer range and – when installed in a mirror mount – replace the manually actuated micrometer screws.

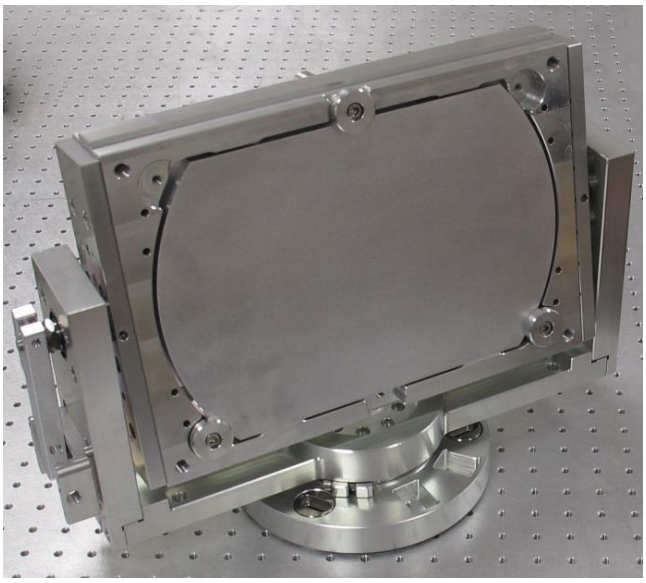

Fig. 1 Customized mirror mount for large optics. These mechanical systems can also be automated with PiezoMike drives (Image: Liop-Tec)

The Liop-Tec GmbH has shown by way of a good example how the positioning of tip/tilt mirrors, indispensable for laser technology, can be automated optimally adapted to the application.

Fig. 2 The mirror mounts are now also being offered with piezo drives instead of micrometer screws (Image: Liop-Tec)

The company offers standard and customized mirror mounts (Fig. 1), which can now optionally also be equipped with piezo drives instead of manual micrometer screws (Fig. 2).

"In collaboration with Physik Instrumente (PI), we have developed piezo-based linear actuators to series-production level and, in doing so, adjusted the screw and nut to the requirements of the drive principle.

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The PiezoMike drives from PI have been integrated successfully into the mirror mount concept of our Star series," explains Patrick Incorvaia, Sales Manager at Liop-Tec (Fig. 3).

Fig. 3 Patrick Incorvaia, Sales Manager at Liop-Tec (Image: Liop-Tec)

The piezomotors based on the inertia principle are operated at a frequency of up to 2 kHz. The PiezoMike linear actuator achieves forces of up to several 10 N, can be easily integrated into a wide range of applications and are also suitable for vacuum applications (Fig. 4) "We are particularly proud of being able to offer mirror mounts for high- and ultra-vacuum that are adjustable from outside with extremely high precision," continues Patrick Incorvaia. "The outstanding collaboration with PI has brought us a good step forward." The manual positioning screw is simply exchanged for a PiezoMike.

Fig. 4 PiezoMike linear actuator: Minimum dimensions, high force and stable positioning under vacuum conditions (Image: PI)

Operating Principle and Adjustment

Piezo-based inertia drives utilize the stick-slip effect for fine steps with step sizes of just a few micrometers. In the first part of the motion cycle, the actuator expands slowly taking along the moving rod (stick effect).

In the second part of the motion cycle, the actuator contracts so rapidly that it slides along the moved rod, which cannot follow this rapid motion due to its inertia, and thus remains in the same position (slip effect). The electric control is easy; its output signal is similar to a saw-tooth voltage. The drives are small, which makes them suitable for many application areas.

Typical fields of application for this drive principle can be found not only in laser technology, but also range from solder tip positioning to shutter and membrane adjustments in micromanipulation.

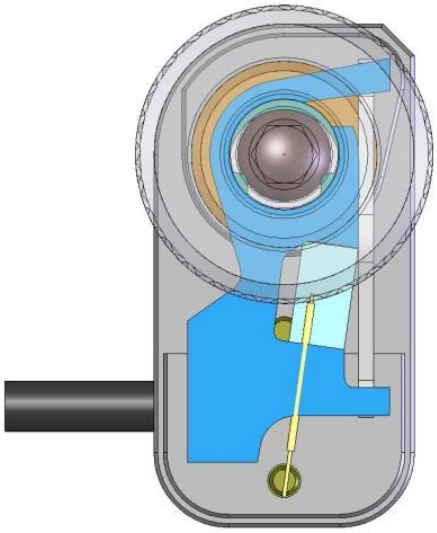

Fig. 5 Piezo-based inertia drives utilize the stick-slip effect for fine steps with step sizes of just a few micrometers (Image: PI)

The operating principle of the inertia drive has been adapted to the requirements of the application by the development partners PI and Liop-Tec (Fig. 5): In this case, the stick effect does not take along a moving rod but causes a screw to rotate.

The claw, which grasps around the screw, opens with the expansion of the actuator and causes the screw to slightly turn.

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Once the maximum expansion of the actuator has been reached, the actuator contracts quickly and the claw moves back to its initial position, but does not take along the screw, which due to its inertial mass, remains in its position (slip effect). This step cycle is repeated, causing the screw to continue its rotation until the desired position is reached. The motion sequence works, of course, also in the opposite direction. "Nevertheless, it has been a lengthy process to find out the optimum material parameters for the slip effect, which required a lot of know-how in the manufacture of the screw and nut. The implementation also required very stringent tolerance and surface quality requirements for the mechanical components," says Patrick Incorvaia.

Thanks to their compact dimensions, the inertia drives can be integrated in a space-saving manner.In addition, these drives also have other advantages.

Fig. 6 The E-870 driver (Figure 6), specifically tuned to the requirements of linear actuators, controls the actuator. One driver can serially control a unit with up to four channels, keeping investment costs low (Image: PI)

The piezo solution is not only much smaller than any motor-driven micrometer screw available on the market, but the PiezoMike linear actuator also works with a very high resolution. Step widths of approx. 20 mm can hardly be achieved using traditional stepper motor drives.

In doing so, the piezo-based linear drive develops a feed force of 22 N, works at a maximum speed of 3 mm/min and is designed for travel ranges from 7.5 mm to 26 mm.

Furthermore, their life expectancy of more than one billion steps is quite impressive. Converted, this would correspond to a working range of 20 m or to 100 hours of continuous operation. This is more than sufficient given the small travel ranges of a few micrometers, the short control times and the comparably rare motions.

Control and Fine Adjustment

The E-870 driver (Fig. 6), specifically tuned to the requirements of linear actuators, controls the actuatorOne driver can serially control a unit with up to four channels, keeping investment costs low. For fine adjustment, the piezo linear motors inserted into the mirror mounts can also be operated in analog mode: Here, the "stick phase" is more or less stopped in the last positioning phase and the piezo actuator is operated within the rising edge of the piezo actuator voltage and not in full-step mode. In this way, a positioning resolution of 5 nm can be achieved. The driver behaves then like a piezo voltage amplifier.

The development of high-precision PiezoMike drives will be pursued. Patrick Incorvaia is already looking forward to the continued collaboration with PI: "High-speed, noiseless direct drives (Fig. 7) and position-regulated variants currently in preparation should make our mirror mounts even more flexible in the future."

Fig. 7 Rod drive with piezoelectric stick-slip drive. The drive principle can be modified, depending on the application (Image: PI)

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About Liop-Tec

The LIOP-TEC GmbH with its headquarters in Radevormwald near Cologne, Germany, was established in 2012 by Dr. Jürgen Lindener-Roenneke and Privatdozent Dr. Michael Gutmann. Both can build on more than two decades of experience in laser technology. It should not come as a surprise, then, that the newly established company has an excellent reputation in the area of innovative laser technology and optomechanical components. Today the company's focus is on custom laser applications, especially in the area of molecular science, material and environmental science, general science and medical technology.

About PI (Physik Instrumente)

In the past four decades, PI (Physik Instrumente) with headquarters in Karlsruhe, Germany has become the leading manufacturer of nanopositioning systems with accuracies in the nanometer range.

With four company sites in Germany and ten sales and service offices abroad, the privately managed company operates globally. Over 700 highly qualified employees around the world enable the PI Group to meet almost any requirement in the field of innovative precision positioning technology. All key technologies are developed in-house. This allows the company to control every step of the process, from design right down to shipment: precision mechanics and electronics as well as position sensors.

The required piezoceramic elements are manufactured by our subsidiary PI Ceramic in Lederhose, Germany, one of the global leaders for piezo actuator and sensor products. PI miCos GmbH in Eschbach near Freiburg, Germany, is a specialist for positioning systems for ultrahigh vacuum applications as well as parallel-kinematic positioning systems with six degrees of freedom and custom-made designs.

PI headquarters in Karlsruhe, Germany: More than 350 employees work on high-resolution drive systems and positioning systems

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