Using piezo-based active shims to improve the precision of machines and optical assemblies

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Precision machine tools, laser processing equipment and optical apparatus are often complex assemblies of different components. The alignment of these components is critical for the overall precision and function of these systems. If a target dimension between two components changes, readjustment may be unavoidable. This can be the case when a machine is put into operation after delivery and tolerances are out of spec due to initial setting processes. However, long-term creep or temperature changes can also have the same effect.

Optical measuring facilities, astronomical devices, wafer processing machines, chip holders or positioning systems for precision-heavy industrial applications are frequently affected by these issues. Differences on the order of a few microns, or less, can exceed limitations. The classic solution to fix such differences is to use shims ground exactly to the required tolerances. However, the installation of such shims, often at hard-to-reach locations, can be a time-consuming and expensive disadvantage. Furthermore, this type of adjustment is not infinitely possible, and once the dimension has been fixed, it can be very difficult to change.

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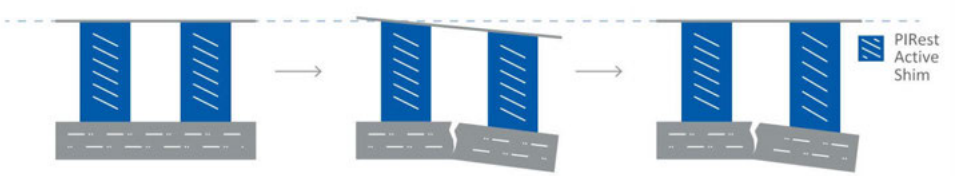
Piezo-based active shims, such as the PIRest from Physik Instrumente (PI), are a more practical solution to the adjustment process. Once installed in the machine, they can readjust the gap between two components at any time with nanometre precision.



▶ Aligning parts that have become misaligned due to stress, creep or settling processes is an application for piezo-based active shims when sub-micron or even nanometre precision and stability are required. ▶

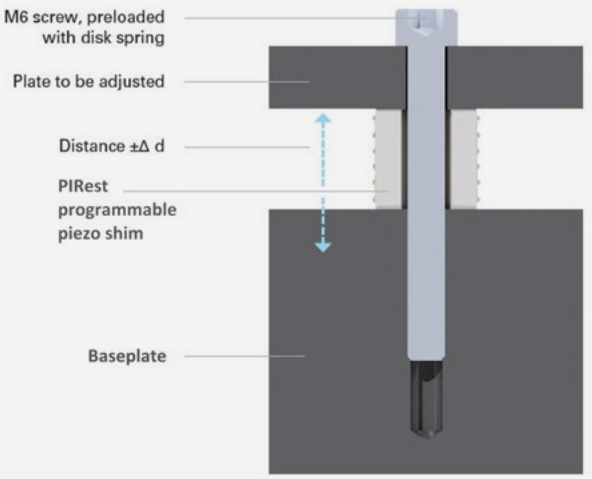
Piezo-based active shims simplify and speed up the adjustment process considerably. Due to the piezo element's high resolution, which is down to the nanometre range, it covers applications in classical mechanical precision engineering, as well as the alignment of optical components in astronomy, semiconductor manufacturing and in materials research employing beam-line instrumentation.

Piezo-based active shims to suit all products

Piezo-based active shims are installed in the product during its construction. They are available in virtually any shape, such as plates, rings and cylinders, and size, and they can be designed to hold loads of several tonnes.

▶ *Piezo-based active shims.* ▶

▶ *The programmable shims can be manufactured with any geometry and in any size and are built into the machine during its construction.* ▶



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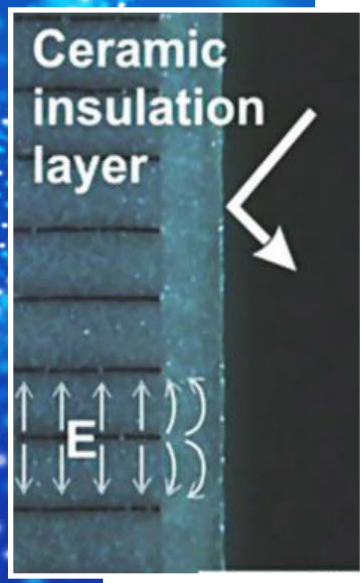
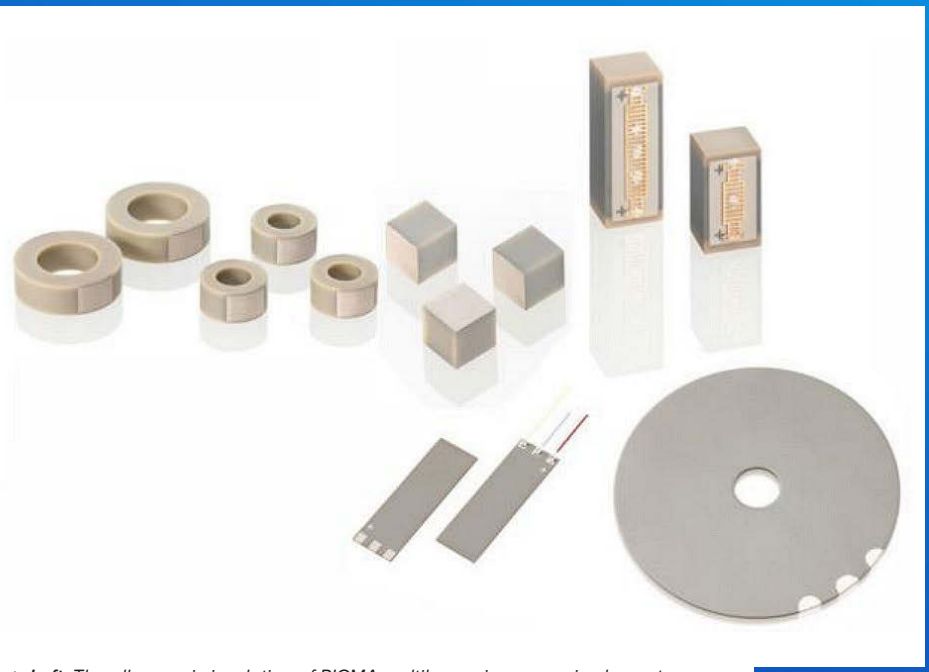
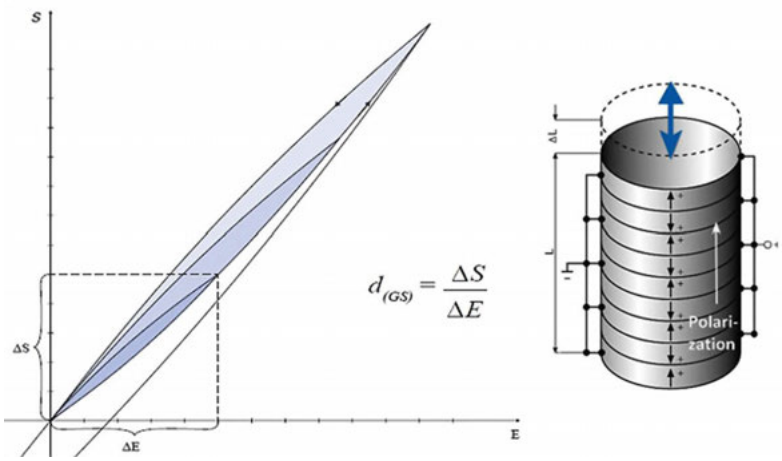




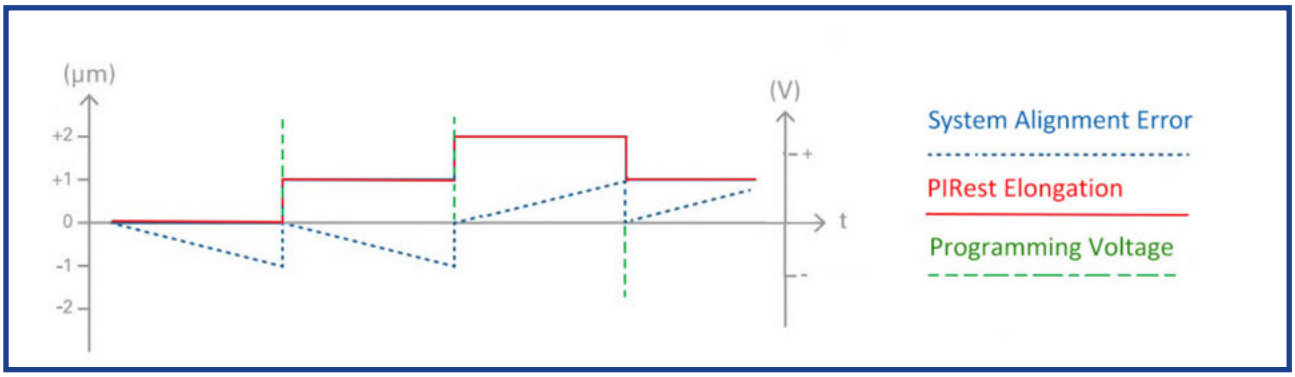
▶ ***Left**: The all-ceramic insulation of PICMA multilayer piezoceramic elements protects piezoceramic active elements from environmental influences. **Above**: A large variety of standard shapes and sizes of PICMA multilayer piezoceramic elements are available.* ▶

The electroceramic core of the PIRest shim is manufactured using the patented PICMA multilayer piezo actuator process. Here, the piezoceramic active element—a monolithic block, the active layers of which are made up of thin ceramic film—is protected by an all-ceramic insulating layer that fully protects it from environmental influences and humidity. The durability of this multilayer piezoceramic technology has been proven time and again in industry, life sciences, microscopy, medical technology and research. It has worked successfully in NASA's MARS Curiosity Rover for several years, having passed 100 billion cycles of a test programme without failures.

The concept of a piezoceramic actuator is well understood. Displacement is dependent on electric charge, and by changing the drive voltage, the actuator will expand or contract in real time. While drawing negligible power in steady state operation, the actuator will slowly recede to its zero position when the power source is removed.



▶ *Typical displacement curves of traditional open loop (no position feedback) piezo actuators (left), and basic design thereof (right). Displacement is roughly proportional to the electric field and when the drive voltage is removed, the displacement will recede to zero once the element is fully discharged.* ▶



▶ Misalignment caused by initial settling processes (during the installation of a machine), temperature changes or long-term creep effects may make it necessary to readjust machine components when they exceed a certain tolerance threshold. Piezo-based active shims can compensate alignment errors easily and remotely, without the need for a permanent power source and control voltage. Every time a misalignment occurs, the shim is reprogrammed by the required amount. ▶

Long-term displacement stability

Displacement of the PIRest shim is programmed using a specific control tool and remains after disconnection from the power source. The control tool is comparable to a self-locking screw type actuator but affords much higher precision and eliminates creep. A voltage connector for programming is provided with the shim. It only needs to be connected shortly for each respective adjustment. The necessary cables can be considered during design of the machine and become a permanent part of the system. After adjusting, the desired position remains stable without power and the power supply can then be disconnected.

The displacement stability only depends on the change of ambient temperature. Long-term tests in an environment within ±1 K temperature change using an actuator with 10 µm nominal adjustment range indicated a position drift of less than ±100 nm, irrespective of the displacement. As an option, piezo-based active shims can be equipped with a temperature sensor. A skilful combination of the shims makes it possible to adjust in up to six degrees of freedom (DoF).

If required, piezo-based active shims can also be combined with classical piezo actuators. Typical applications for these types of hybrid systems include dynamic vibration compensation, readjusting the focal plane during an optical measuring or scanning process, as well as controlling a laser beam in metrology systems or materials processing. ■

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▶ A hybrid combination of traditional piezo stack actuator for highly dynamic motion (bottom, orange) and programmable shim (top, blue). ▶