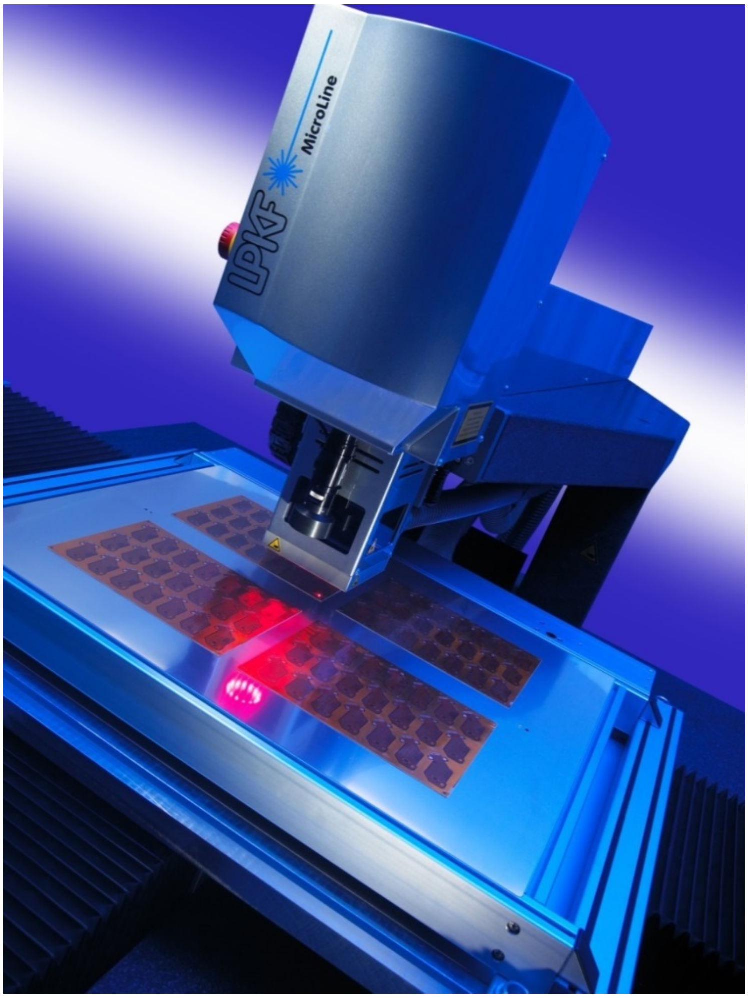
# Laser Beam Steering in Materials Processing, Laser Scanning Microscopy and Ophthalmology

**Piezoelectric Drive Components and their Possibilities**



Lasers are versatile tools. Nowadays, they are just as indispensable in materials processing as in eye surgery or super high resolution microscopy. The different areas of application have similarities, however, since a precise positioning of the laser beam is always crucial. At the same time, this laser beam steering and focusing also requires the drive systems used to be dynamic, reliable and compactly dimensioned, in order to allow simple integration in applications. It is therefore hardly surprising that piezoelectric drive components often have no serious alternative for laser beam steering.

Actuators exploiting this piezo effect move with resolutions in the sub-nanometer range and response times below one millisecond, which makes dynamic operation with scanning frequencies of up to one thousand hertz possible. The motion is based on crystalline solid state effects and so there are no rotating or friction-producing mechanical components. Piezo actuators are maintenance-free, because they have no moving parts in the conventional sense. This allows motions to be carried out in the subnanometer range at high velocity.


Fig. 1 Highly dynamic, piezo-drive tip/tilt platform with two orthogonal axes and optic deflection angles of up to 20 mrad. Up to four piezo actuators are directly coupled with the moving platform. The length of the actuators determines the tip/tilt angle range; the system is therefore scalable (Image: PI)

Moreover, piezo actuators dissipate no power in static operation, since electrically they act as capacitive loads. It is therefore no wonder that the compact, piezo-based positioning systems (Fig. 1) of PI (Physik Instrumente) are the means of choice today in many laser control applications. In addition, the analog or digital controllers adapted to the particular positioning system allow simple integration into the application.

A significant advantage of digital controllers is that all motion parameters can be specifically influenced using algorithms. This increases precision and dynamics with simultaneous high ease of use. Piezoelectric drive and positioning systems thus offer interesting possibilities for laser beam steering, especially since the sensors necessary for high-precision positioning are also included in the product range of PI.

## Precision Solutions for Materials Processing

Typical applications for materials processing via laser beam are found in electronics manufacturing, e.g. the production of templates that are used for coating PCB's with solder paste (Fig. 2).

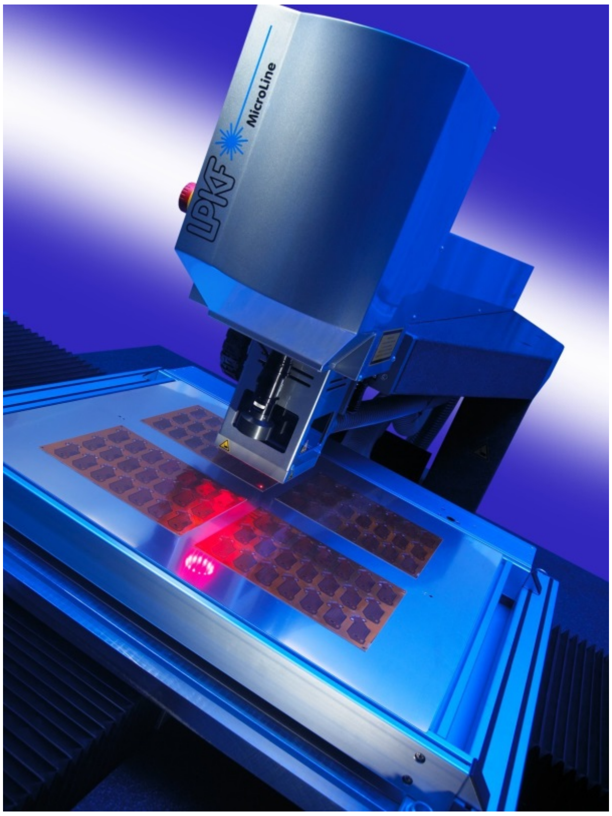



Fig. 2 PKF MicroLine series for professional laser processing of circuit carriers and printed circuit board. (Image: LPKF Laser & Electronics AG)

The requirements here are high; the material must be removed very precisely with exactly defined edges. High throughputs are also obligatory.

Common deflection techniques for the laser beam, such as the galvanometer scanners that are based on the induction principle, are suitable for such high-precision applications in principle, but also have disadvantages. In order to be able to position in two axes, two systems have to be switched in succession, in other words stacked. This results in different pivot points and the space requirement is relatively large. Piezo-driven tip/tilt platforms or tip/tilt mirror systems are the better alternative here since they not only offer the required accuracy but high accelerations and a great dynamic bandwidth at the same time as well.

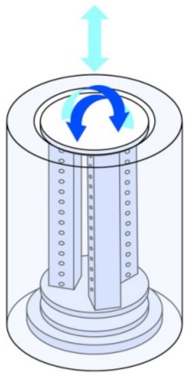


Fig. 3 In parallel kinematics systems all actuators act directly on the same platform; basic design with three actuators (Image: PI)

In the case of tip/tilt mirror systems and piezo-based scanning platforms with several motion axes, piezo drives are used in parallel kinematics positioning systems (Fig. 3). This structure has various advantages over serial systems: for example, there is only one moving platform with a common pivot point, the dynamics are higher and the size is smaller. In addition, the systems can achieve a higher accuracy than can be realized by switching two single-axis systems in succession – which is usually the case with galvanoscanners, for example.

Integrated high-resolution position sensors ensure high linearity values of better than 0.25 % over the full travel range and a repeatability of typically 5 µrad, which corresponds to roughly 0.3 millidegrees.

## Laser Scanning Applications in Super Resolution Microscopy

In laser scanning microscopy, the laser beam also has to be positioned and focused to excite fluorescence in the sample. While the precision of galvanoscanners certainly suffices for confocal methods in most cases, this solution may reach its limits in the field of super resolution microscopy (Fig. 4).

Here there are higher requirements for accuracy with resolutions of around 10 nm with simultaneous high dynamics. Piezo-driven tip/tilt mirrors and platforms (Fig. 1) demonstrate their advantages again here.

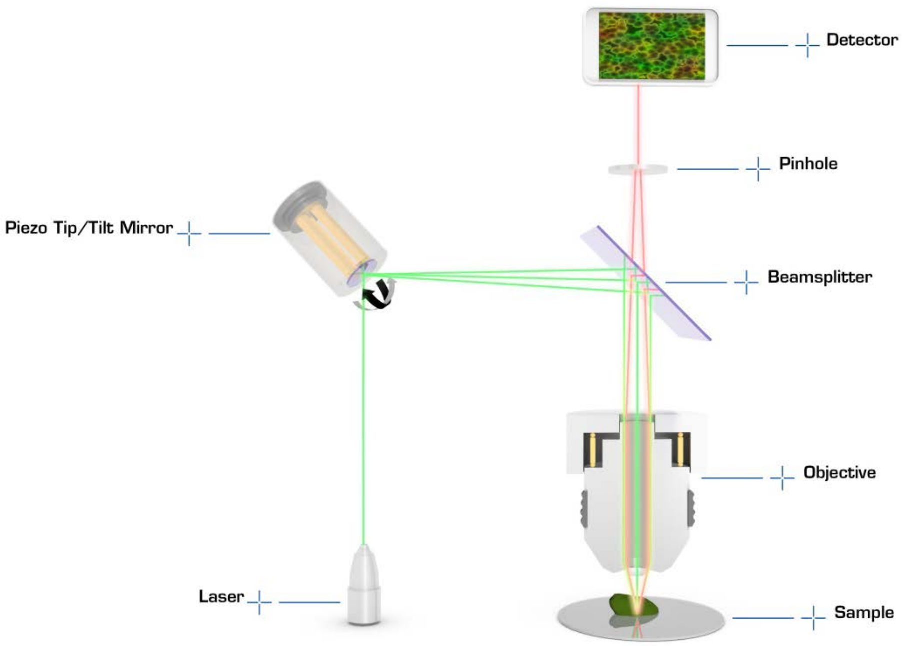



Fig. 4 Super-resolution laser scanning microscopy (Image: PI)

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The S-334 tip/tilt platforms and scanners (Fig. 5), for example, allow highly dynamic and precise tip/tilt motions of the top platform in two orthogonal axes with a common pivot point.


Fig. 5 The piezo-driven tip/tilt platforms are available with tilting angles of up to 3°, which are each offered with position sensors for closed-loop operation or without sensors as fast scanners (Image: PI)

The frictionless piezo drives and flexure guides allow higher accelerations than conventional drives and offer scanning frequencies of over 100 Hz over tip/tilt angle ranges of up to 3° in position control. The E-616 is a controller specially developed for piezo tip/tilt mirrors that combines the functions of a multi-channel controller and amplifier.

A coordinate transformation can be carried out via its internal hardware so that control is possible in direct proportion to the deflection angle.

## Piezo Ultrasonic Drives for Laser Beam Steering

Precise laser beam steering and focusing is also an important topic in medical technology. This makes it possible, for example, to correct ametropia in up to high diopter ranges thanks to refractive operation techniques.

For this purpose, the shape of the cornea is modeled in the optical axis by removing small cornea particles with laser beams so that the resulting refractive power of the cornea (epithelium) matches the length of the eyeball again (Fig. 6).The previously described tip/tilt mirror systems have a wide-ranging application area here as well.

The ceramic PILine® ultrasonic motors also open up interesting possibilities for laser beam steering. They are characterized by extremely high velocities and acceleration with simultaneous very compact dimensions. The patented drive principle (Fig. 7) makes them self-locking when at rest. Linear motors and drives are intended for integration in a customer system and are generally unguided. There are also complete solutions, however, that can be integrated ready for installation in many applications.


Fig. 6 In order to compensate for ametropia, the shape of the cornea is modeled in the optical axis by removing small cornea particles with laser beams so that the resulting refractive power of the cornea (epithelium) matches the length of the eyeball again (Image: PI)

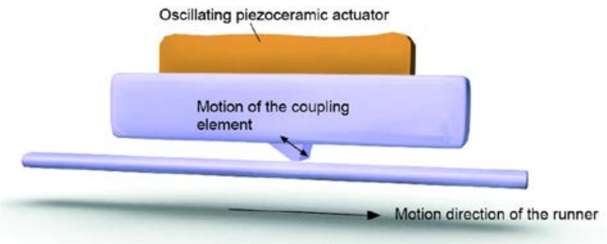


Fig. 7 Patented functional principle of the PILine® actuators: Oscillations with ultrasonic frequencies of a piezoceramic actuator are converted along a friction bar into a linear motion and thereby drive the movable part of a mechanical structure (Image: PI)

The M-663 precision micro linear stage (Fig. 8), which is also suitable for XY combinations if necessary, is a good example of this. It offers velocities of up to 400 mm/s and travel ranges up to 19 mm with resolutions up to 0.1 µm.

Fig. 8 PILine® micropositioning stage with linear encoder for direct position evaluation (Image: PI)

A contactlessly measuring optical linear encoder guarantees high linearity and repeatability. With a height of 15 mm, a width of 30 mm and a length of 35 mm, the micropositioning stage is very compact and can therefore be easily integrated in the respective application. This is also certainly due to the fact that PI also provides matching drive electronics and controllers, which are perfectly adapted to the micro linear stage. Such positioning solutions create interesting possibilities for laser beam steering and focusing which offer advantages in all areas in which laser processing can be used.

## About PI

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 fifteen sales and service offices abroad, the privately managed company operates globally.

Over 850 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 its 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.

## Author

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