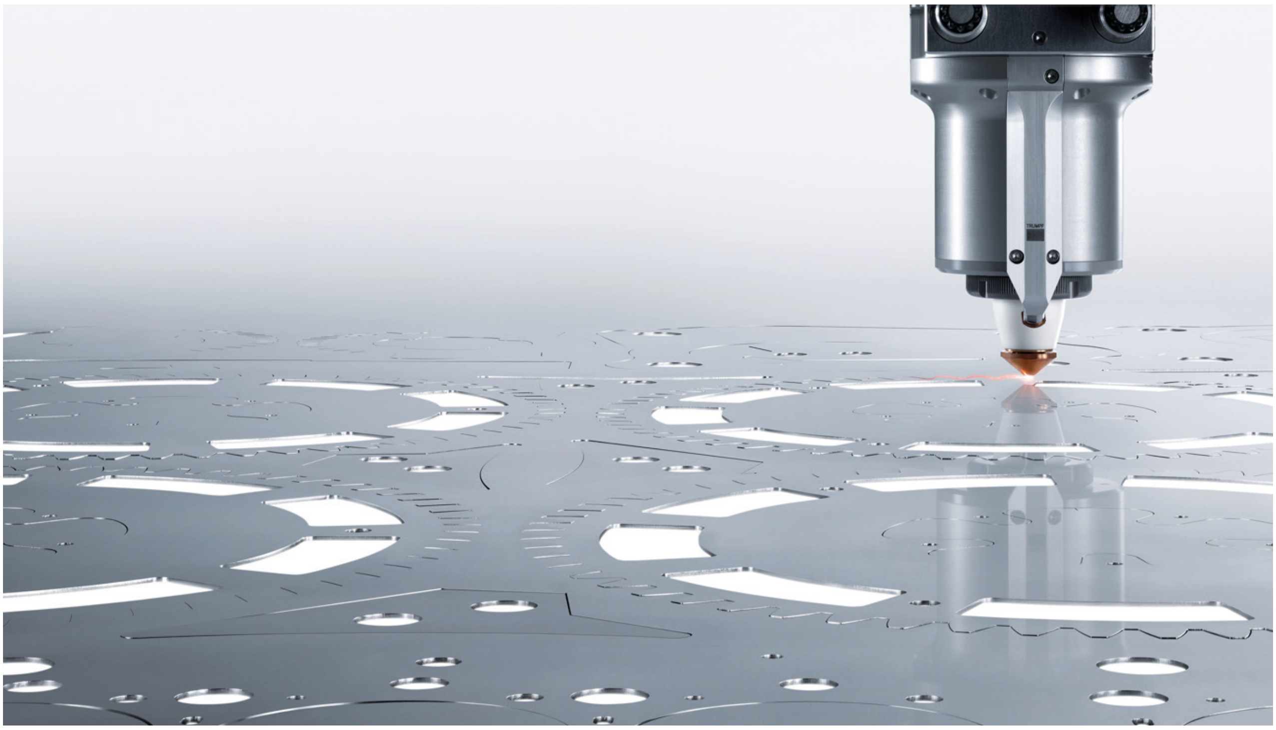
Increasing Throughput in Many Applications

Combining advanced motion controllers and highly accurate and dynamic positioning stages gives an edge to systems integrators and equipment manufacturers

Markus Simon and Stefan Vorndran



Cutting, drilling, welding, marking or structuring – lasers are used in a wide variety of applications in many industrial sectors to optimize manufacturing processes and satisfy the need for an ever increasing quality of components. This is especially true for the electronics and semiconductor industry, where requirements for accuracy and speed are higher than in most other applications.

As far as throughput and precision are concerned, laser power is usually not the limiting factor. Gains in productivity and quality come from high-performance positioning systems, motion controllers, and software along with higher speed communication and synchronization between motion platforms, laser controllers, and beam steering units.

Engraving Diamonds

Diamonds are often laser engraved with a code or serial number (**Figs. 2a and b**) to certify their authenticity. A multi-axis, high-dynamics positioning system moves the workpiece in the X and Y directions while the laser fires away. Positioning of the laser objective in the vertical direction is achieved with another high-dynamics linear stage. Three-phase linear motors and voice-coil drives (for shorter travel ranges up to 1”) are well established for high-speed positioning and scanning. They combine high acceleration and velocity with virtually unlimited service life due to their non-contact delivery of force. Scanning frequencies in the 10-Hz range are feasible for short travel ranges.

Guiding precision in the sub-micron range is ensured by crossed roller bearings, and direct measuring. Integrated

▲ **Fig.1** Workpieces and structural density are particularly large during the production and processing of templates. Longer travel ranges and micrometer precision are required from positioning systems. (Source: Trumpf)

linear encoders provide the required position resolution and repeatability (the best linear encoders currently available can resolve motion to below one nanometer). An advanced motion controller triggers the laser, dependent on both position and speed, matching positioning system and laser exactly to each other when running complex patterns, circles

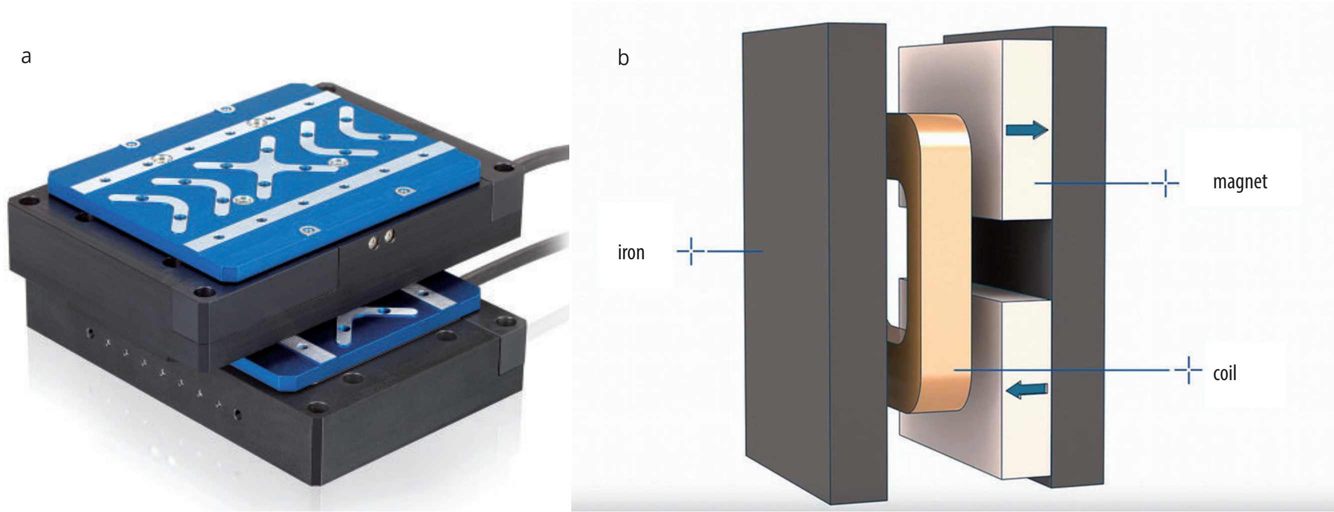


Fig. 2 Linear stages with highly dynamic electromagnetic direct drives are used to scan and position diamonds in the XY plane to laser-engrave a code certifying their authenticity (a). Operating principle of a voice-coil motor (b). (Source: PI)

or sharp edges. An optimized algorithm in the controller synchronizes the motion of the workpiece with the laser pulses so that the shape, size and gap between adjacent points remain constant.

Wafer dicing

Dicing semiconductor wafers also demands a highly precise motion system. The cutting width must remain constant, and deviations along the programmed path must be limited to a few micrometers per meter to avoid damage of individual dies during the cutting process. An air bearing planar stage, such as the Physik Instrumente Model A-322, is a suitable positioning system for such applications (**Figs. 3a / b**).

Air bearings replace mechanical contact with an air film, eliminating friction, particle generation and wear. The A-322 stage is driven by sine-commutated, 3-phase linear motors providing acceleration of 20 m/s². The lack of friction provides better geometric performance and motion with very high-speed constancy. Ironless linear motors are non-cogging, providing smoother motion and higher resolution to one nanometer and below. The combination of air bearings, linear encoders and ironless linear motors maximizes the throughput while ensuring the highest precision.

Producing stencils and printed circuit boards

The requirements for the production and processing of stencils and printed circuit boards are similar (**Fig. 1**). Workpieces and structural density are particularly large here, demanding motion and positioning systems with longer travel ranges while still maintaining micrometer precision.

Gantry motion systems, with their high stiffness but relatively low-inertia motion platforms, are the best approach – here the part to be processed is stationary while the laser head and the optics are moving. Cable management and operation are optimized so that vertical motion axes, autofocus sensors, and the laser feed can be integrated. The absolute-position measuring system renders the typical initialization/homing process unnecessary – another step towards higher efficiency.

Laser marking of dials

Galvanometer scanner heads can be combined with multi-axis positioning systems. A galvanometer is a high-dynamics moving-coil motor. In modern galvo scanners, a low-inertia mirror is driven in closed loop to position a laser beam with high speed, precision and repeatability. The combination of two galvo scanners inside one system allows the laser beam to be steered in two dimensions. Typical scan angles are in the range of ±20°. This leads to good results with respect to dynamics and precision when, for example, dials are to be written onto functional components. Motion in the XY plane can be extended by a linear motor-driven, cross-roller XY positioning stage.

Equipped with optical linear encoders, the stage achieves minimum incremental motion: as low as 0.02 μm and

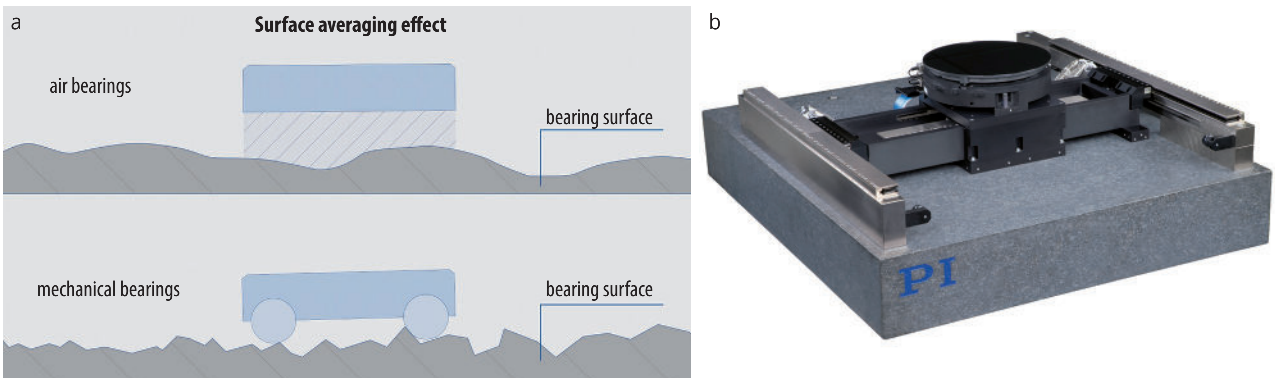


Fig. 3 Comparison of air bearings and mechanical bearings (a). Wafer dicing requires high accuracy. The permissible tolerances along the travel range amount to only a few micrometers per meter. An air bearing planar stage, which is driven by linear motors, is a suitable positioning system for such applications (b). (Sources: PI)

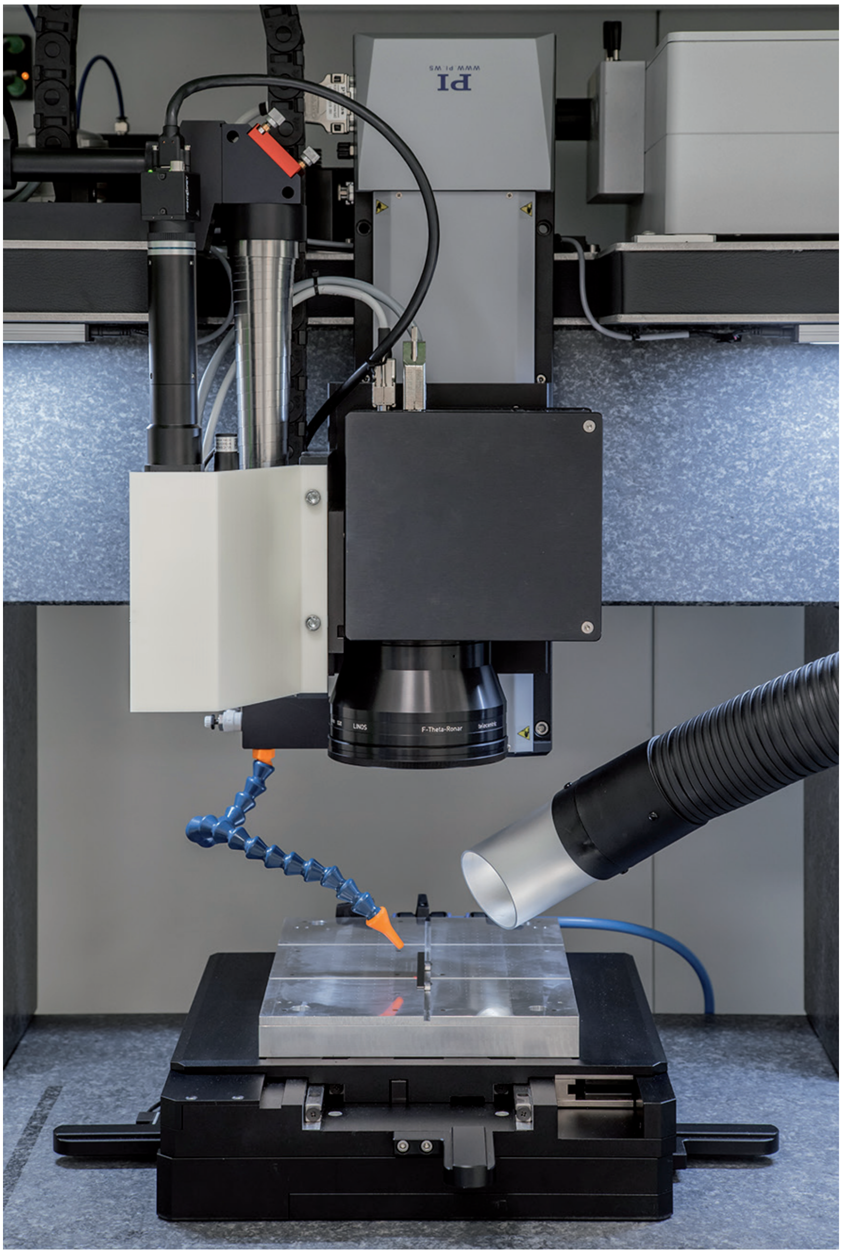


Fig. 4 Multiaxis setup comprising linear motor-driven Model 731 XY planar stages (8 × 8″ travel) and screw-driven Z stages from Physik Instrumente, and a galvanometer scanner from Scanlab for laser marking precision components at high speed. (Source: PI)

repeatability of 0.1 µm. The stage can handle loads of 50 lbs. (**Fig. 4**).

EtherCAT laser-control module and HMI

Tying motion and laser source together used to be complex, but a special EtherCAT-capable laser control module now allows direct control of the laser source, increasing both precision and throughput.

EtherCAT is a modern, cost-efficient, open, real-time Ethernet-based fieldbus system. Short for 'Ethernet for Control Automation Technology', it is used by control and system engineers as a robust, high-speed, real-time network for machine control solutions. The flexibility of the fieldbus system and the precise synchronization of all network devices has helped EtherCAT to gain popularity on a global base. In high-performance applications, exact synchronization is a critical factor. The LCM EtherCAT slave module by ACS (offers a broad range of functions, including digital pulse modulation for dynamic power control, output impulses or gating signals (on/off signals) that are synchronized to positions along a two to six-dimensional motion path or programmable operation zones. ACS nodes are synchronized by applying the EtherCAT distributed clocks (DC) mechanism, supporting short cycle times – 1 msec, 0.5 msec, 0.25 msec and 0.2 msec (at 1, 2, 4 and 5 kHz).

The LCM module controls virtually any laser via universal electrical interfaces. In addition to the high-speed laser signal output, the module is also equipped with a special lock system, an error input, and an enable output. Eight digital I/Os are also available for laser-specific functions. The challenges during the development of a robust and scalable laser processing or micromanufacturing machine platform can be solved much better and faster with this type of laser module. Good HMI platforms can provide further simplification (**Figs. 5a/b**). This particularly applies to optimizing the accuracy and repeatability of laser control for motion, and for developing the associated software. Machine developers, system integrators, and users benefit equally from this because it results in higher machine performance and reduced expenditure on development.

Company

Physik Instrumente L.P. (PI)

is a leading manufacturer of nanopositioning, linear actuators and precision motion-control equipment for photonics, nanotechnology, semiconductor and life science applications. PI has been developing and manufacturing standard and custom precision products with piezoelectric and electromagnetic drives for over 40 years. The company has been ISO 9001 certified since 1994 and provides innovative, high-quality solutions for OEM and research. PI has a worldwide presence with 10 subsidiaries and over 750 staff.

www.pi-usa.us

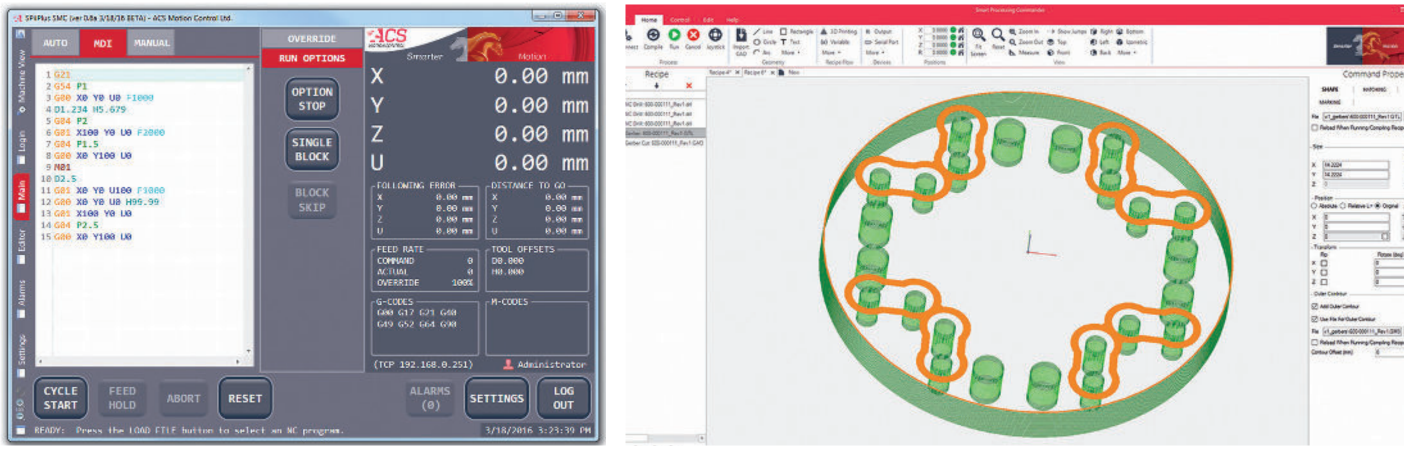


Fig. 5 The user interface (Human Machine Interface, HMI) is an important subsystem of the machine and normally falls into one of two classifications: there are 'CNC style' HMIs that import and execute machine-coded programs (typically G code) created by a CAM software post processor (left). Another type is an integrated graphical interface. Some HMIs allow the import and processing of CAD files and offer integrated functionality for post processing of the CAM data (right; sources: ACS Motion Control)

Scanning process for large areas and workpieces – virtually infinite field of view

Simple implementations of galvanometer scanners and positioning systems do not operate simultaneously but sequentially, dividing large areas into smaller segments stitched together. Large areas with many small details cannot be marked efficiently in this way. Smaller details require high acceleration and large areas require longer travel ranges. A multistage approach is recommended, separating the trajectories for smaller, lighter, and therefore faster positioning systems with shorter ranges, and for larger, heavier, and relatively slower motion components with longer travel ranges.

Basically, laser marking then functions in a similar way to human writing. The arm, as a slow musculoskeletal system, provides gross manual dexterity while the hand and fingers accurately form the individual letters, which corresponds to the motion of the galvanometer scanner.

Analogous to this, the motion patterns from the X/Y stage and scanner are synchronized by a controller and run simultaneously during scanning. This process enables the efficient marking of large areas with many small details, and therefore increases the throughput.

Higher processing accuracy is achieved when compared to the traditional process because smaller laser beam deflection angles have a positive effect on optical errors. Stitching errors are also eliminated at the same time.

Summary

The combination of advanced motion controllers and highly accurate and dynamic positioning stages gives an edge to systems integrators and laser processing equipment manufacturers. Engineers, such as those at PI and ACS, are constantly working on better solutions, and can now offer world-class automation platforms that exceed current standards for quality and throughput.

Physik Instrumente L.P.

Stefan Vorndran,
VP Marketing
16 Albert St., Auburn, MA 01501;
phone: 508-832-3456,
fax: 508-832-0506;
e-mail: stefanv@pi-usa.us;
Web: www.pi-usa.us