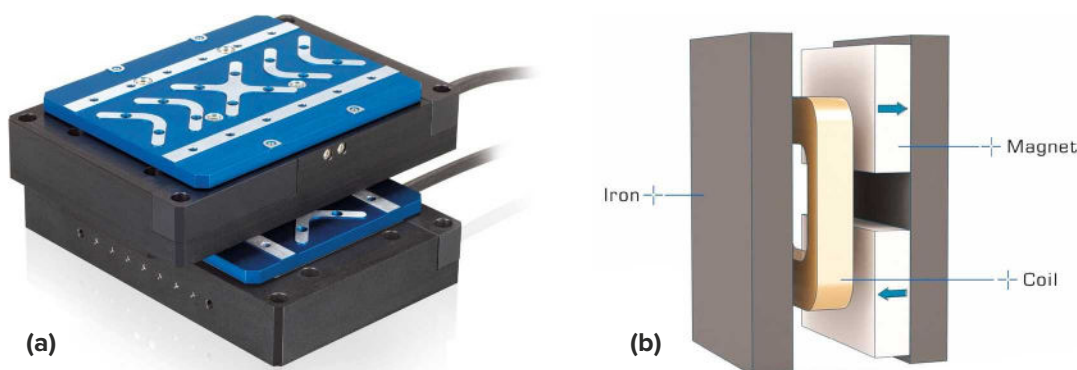


Dynamic positioning systems and advanced motion controllers are increasing throughput in laser material processing applications

STEFAN VORNDRAN, VP MARKETING, PHYSIK INSTRUMENTE (PI),
AND MARKUS SIMON, HEAD OF SYSTEM CONSULTING, PI MICOS

Lasers are used for a wide variety of applications—such as cutting, drilling, welding, marking or structuring—in many industrial sectors to optimise manufacturing processes and satisfy the need for the ever-increasing quality of components. This is especially true for the semiconductor and electronics industries, since their requirements for accuracy and speed are higher than most. As far as throughput and precision are concerned, laser power is usually not the limiting factor. Gains in productivity and quality tend to be achieved through dynamic positioning systems, advanced motion controllers and software, as well as high-speed communication and synchronisation between motion platforms, laser controllers and beam steering units.



► **Figure 1:** (a) Linear motor stages featuring highly dynamic electromagnetic direct drives such as the one shown are used to scan and position diamonds in the XY plane for laser-engraving. (b) The operating principle of a voice-coil motor. ►

Engraving diamonds

A laser is often used for engraving codes or serial numbers into diamonds to certify their authenticity (figure 1). A multi-axis, dynamic positioning system uses a linear motor stage featuring a highly dynamic electromagnetic direct drive to scan and move the diamond in the XY direction. Another linear motor stage is used to position the laser objective in the vertical direction. Three-phase linear motors and voice-coil drives for shorter travel ranges up to 1 in. are well established for high-speed positioning and scanning. They afford high accelerations and velocities as well as virtually unlimited service life due to their non-contacting delivery of force. Scanning frequencies in the 10 Hz range are feasible for short travel ranges.

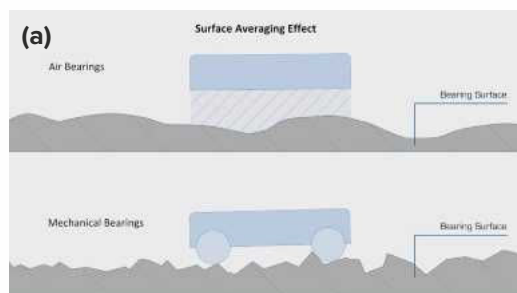
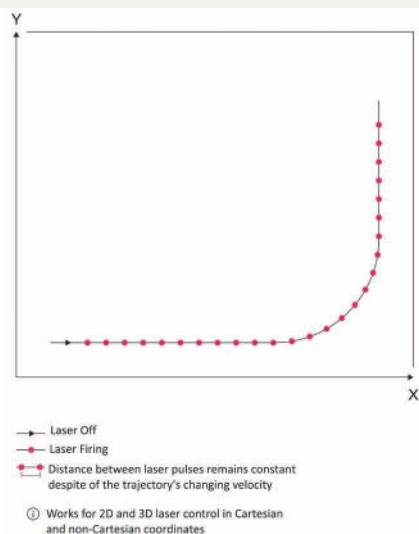
Guiding precision in the sub-micron range is ensured by crossed roller bearings and direct-measuring. Integrated linear encoders provide the required position resolution and repeatability (the most favourable linear encoders available can resolve motion to below 1 nm). An advanced motion controller triggers the laser, dependent on both position and speed, matching positioning system and laser exactly to each other when

running complex patterns, circles or sharp edges. An optimised algorithm in the controller synchronises the motion of the workpiece and the laser pulses so that the shape, size and gap between adjacent points remain constant (figure 2).

Dicing semiconductor wafers

The dicing of semiconductor wafers also demands a dynamic positioning system. The cutting width must remain constant, and deviations along the programmed path must be limited to a few micrometres per metre to avoid damage of individual dies during the cutting process. A positioning system such as the Physik Instrumente (PI) A-322 Plglide HS planar air bearing stage is suitable for such applications (figure 3).

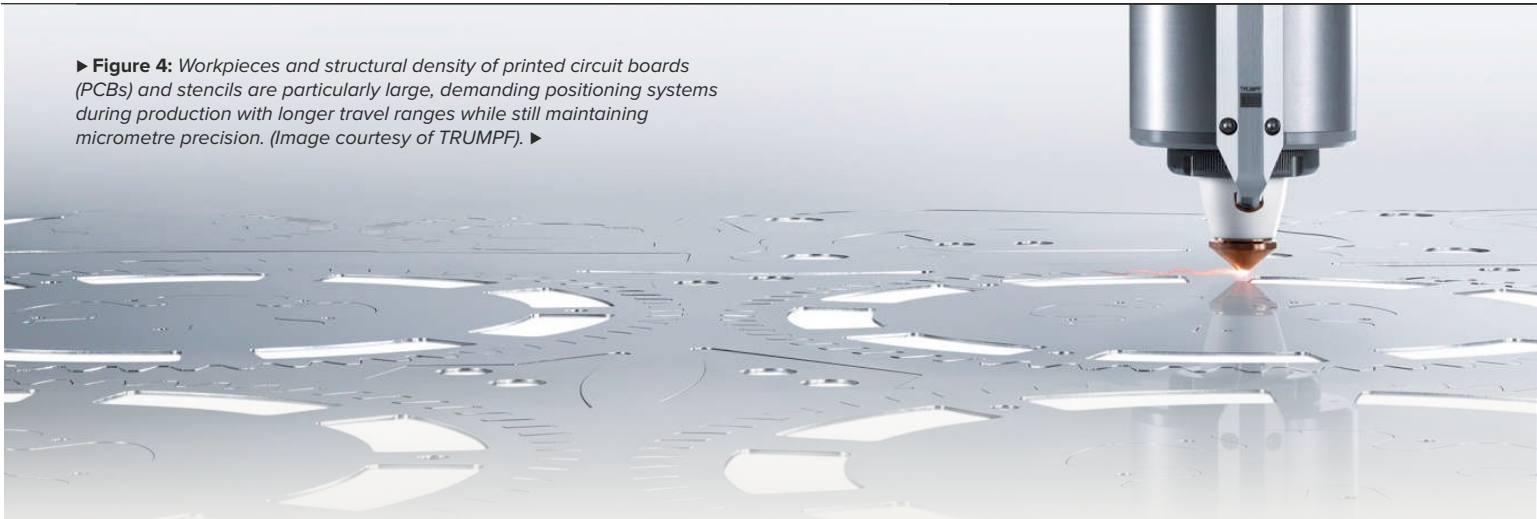
► **Figure 2:** An optimised algorithm in the advanced motion controller synchronises the motion of the workpiece and the laser pulses, so that the gap between adjacent points and their size remains constant. ►



► **Figure 3:** (a) A comparison of air bearings and mechanical bearings. (b) Wafer dicing requires high accuracy. The permissible tolerances along the travel range amount to only a few micrometres per metre. A planar air bearing stage, which is driven by linear motors, is a suitable positioning system for such applications. ►



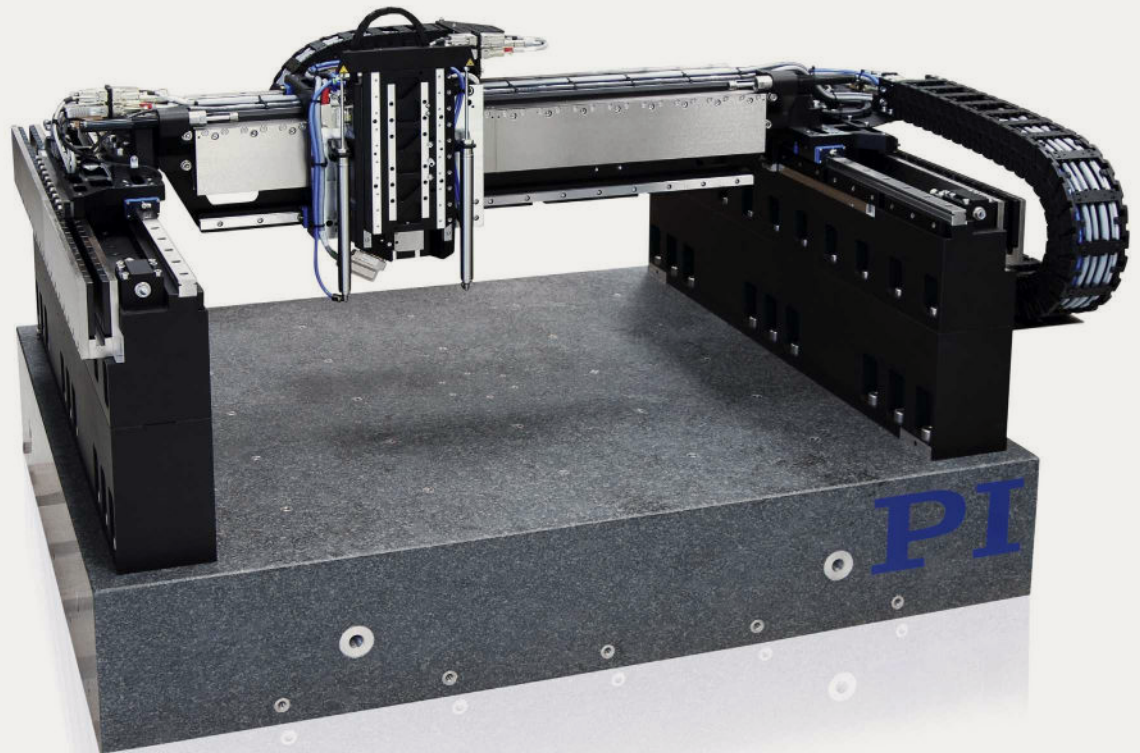
► **Figure 4:** Workpieces and structural density of printed circuit boards (PCBs) and stencils are particularly large, demanding positioning systems during production with longer travel ranges while still maintaining micrometre precision. (Image courtesy of TRUMPF). ►



An air bearing stage replaces mechanical contact with an air film, eliminating friction, particle generation and wear. The A-322 Plglide is driven by sine wave commutated, three-phase, ironless linear motors, providing accelerations of 20 m/s². The lack of friction allows for better geometric performance and motion with very high-speed constancy. Ironless linear motors are non-cogging, providing smoother motion and higher resolution to 1 nm and below. The combination of air bearings, ironless linear motors and linear encoders maximises throughput and precision.

Producing stencils and printed circuit boards

The requirements for producing and processing printed circuit boards (PCBs) and stencils are similar (figure 4). However, PCBs and stencils are comparatively much larger in terms of size and structural density, thus demanding a positioning system that offers longer travel ranges.



► **Figure 5:** Gantry systems, with their high stiffness yet low inertia motion platforms, keep the workpiece stationary and move the laser head/optics instead. (Image courtesy of PI). ►

► **Figure 6:** The combination of SCANAhead control technology and galvanometer scanners with digital encoders enables scanning heads in the excelliSCAN series to provide excellent dynamics and precision. (Image courtesy of SCANLAB). ►



The most suitable approach is a gantry positioning stage, since it affords high stiffness but has a relatively low-inertia motion platform (figure 5). The part being produced or processed is kept stationary, and the laser head and the optics move freely. Cable management and operation are optimised so that vertical motion axes, autofocus sensors and the laser feed can be integrated. The absolute-position measurement achieved renders the typical initialisation/homing process unnecessary, allowing for higher efficiency.

Laser marking dials

Multi-axis positioning systems can incorporate galvanometer scanners. A galvanometer is a high-dynamics moving-coil motor. In modern galvanometer scanners, a low-inertia mirror is driven in closed loop to position a laser beam at high speed, precision and repeatability.

The use of two galvanometer scanners in a single positioning system allows for steering of the laser beam in two dimensions (figure 6). Typical scan angles are in the range of ± 20 degrees. This leads to good results in terms of dynamics and precision if, for example, dials are to be written onto functional components.



Measuring dynamics of capped MEMS?

Your solution is Polytec



Analysis of encapsulated MEMS

MSA Micro System Analyzers from Polytec provide state-of-the-art analysis for the characterization of vibration and topography properties of micro-structures. Now, our latest IRIS technology delivers more insights than ever before, measuring even encapsulated MEMS sensors and actuators. Benefit from highest amplitude resolution, real-time response capability and wafer-level test integration.

Learn more:
polytec.com/msa650



► **Figure 8:** The Ethernet for control automation technology (EtherCat) slave control module of the laser control module (LCM) series offers a broad range of functions. It can control virtually any laser via universal electrical interfaces. (Image courtesy of ACS Motion Control). ►



A linear-motor-driven, cross-roller XY positioning stage can extend motion in the XY direction (figure 7). This stage features optical linear encoders, allowing it to achieve minimum incremental motion as low as 0.02 μm and a repeatability of 0.1 μm , and can handle loads of 50 lbs.

EtherCAT laser control module and human machine interface

Tying motion and laser source together used to be complex, but an Ethernet for control automation technology (EtherCat) laser control module (LCM) allows for direct control of the laser source, thus increasing both precision and throughput.

EtherCAT is a modern and cost-efficient, real-time, Ethernet-based fieldbus system that is used by control and system engineers to provide a robust, high-speed, real-time network for machine control solutions. The flexibility of the fieldbus system and the precise synchronisation of all network devices has helped EtherCAT gain popularity globally.

Exact synchronisation is a critical factor in high-performance applications. The EtherCAT LCM is a slave module from ACS Motion Control offering a broad range of functions, including digital pulse modulation for dynamic power control and output impulses or gating signals (on/off signals) that are synchronisable to positions along a two- to six-dimensional motion path or programmable operation zones (figure 8). ACS nodes are synchronised by applying the EtherCAT distributed clocks (DC) mechanism supporting short cycle times, namely 1, 0.5, 0.25 and 0.2 msec (1, 2, 4 and 5 kHz, respectively).

The LCM module controls virtually any laser via universal electrical interfaces. In addition to a high-speed laser signal output, the module also affords a special lock system, an error input and an enable output. Eight digital inputs and outputs (I/Os) are also available for laser specific functions. The challenges during development of a robust and scalable laser processing or micromanufacturing machine platform can be solved much more satisfactorily and quickly using this type of laser module.

► **Figure 8:** The Ethernet for control automation technology (EtherCat) slave control module of the laser control module (LCM) series offers a broad range of functions. It can control virtually any laser via universal electrical interfaces. (Image courtesy of ACS Motion Control). ►



A linear-motor-driven, cross-roller XY positioning stage can extend motion in the XY direction (figure 7). This stage features optical linear encoders, allowing it to achieve minimum incremental motion as low as 0.02 μm and a repeatability of 0.1 μm , and can handle loads of 50 lbs.

EtherCAT laser control module and human machine interface

Tying motion and laser source together used to be complex, but an Ethernet for control automation technology (EtherCat) laser control module (LCM) allows for direct control of the laser source, thus increasing both precision and throughput.

EtherCAT is a modern and cost-efficient, real-time, Ethernet-based fieldbus system that is used by control and system engineers to provide a robust, high-speed, real-time network for machine control solutions. The flexibility of the fieldbus system and the precise synchronisation of all network devices has helped EtherCAT gain popularity globally.

Exact synchronisation is a critical factor in high-performance applications. The EtherCAT LCM is a slave module from ACS Motion Control offering a broad range of functions, including digital pulse modulation for dynamic power control and output impulses or gating signals (on/off signals) that are synchronisable to positions along a two- to six-dimensional motion path or programmable operation zones (figure 8). ACS nodes are synchronised by applying the EtherCAT distributed clocks (DC) mechanism supporting short cycle times, namely 1, 0.5, 0.25 and 0.2 msec (1, 2, 4 and 5 kHz, respectively).

The LCM module controls virtually any laser via universal electrical interfaces. In addition to a high-speed laser signal output, the module also affords a special lock system, an error input and an enable output. Eight digital inputs and outputs (I/Os) are also available for laser specific functions. The challenges during development of a robust and scalable laser processing or micromanufacturing machine platform can be solved much more satisfactorily and quickly using this type of laser module.

Good human machine interface (HMI) platforms can provide further simplification (figure 9). This especially applies to optimising the accuracy and repeatability of laser control for motion, and 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.

Scanning process for large areas and workpieces

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 higher

accelerations and large areas require longer travel ranges. A multi-stage approach is therefore recommended, separating the trajectories for smaller, lighter and faster positioning systems with shorter travel ranges, and for larger, heavier and slower positioning systems with longer travel ranges (figure 10).

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 XY stage and scanner are synchronised by a controller and run simultaneously during scanning. This process allows for efficient marking of large areas with many small details, thereby increasing throughput. As smaller laser beam deflection angles have a positive effect on optical errors, a high processing accuracy is achieved and stitching errors are eliminated.

Summary

The combination of dynamic positioning stages and advanced motion controllers is highly advantageous for systems integrators and laser processing equipment manufacturers. PI and ACS engineers are constantly seeking better solutions and are committed to the development of automation platforms that deliver exceptional quality and throughput. ●

Physik Instrumente
www.pi-usa.us



► **Figure 9:** The human machine interface (HMI) is an important subsystem of the machine and normally falls into one of two classifications. First, and as shown above, there is the CNC style HMI that imports and executes machine-coded programs (typically G code) created by a CAM software post processor. Second, and as shown below, there is the integrated graphical interface. Some HMIs allow importing as well as processing of CAD files and offer integrated functionality for post-processing of the CAM data. (Images courtesy of ACS Motion Control). ►

