In remote laser material machining, focused laser beams are diverted onto the workpiece via highly dynamic adjustment of mirrors known as galvanometer scanners.
In remote laser material machining, a focused laser beam is diverted by rapidly adjustable mirrors known as galvanometer scanners – or scanners for short – and moved highly dynamically along the contour of the workpiece surface to be machined. On account of the distance between the scanner mirrors and the material, the speed of the laser beam on the workpiece can reach several meters per second. The higher the required machining speed, the faster the scanners have to be aligned.

Normally the scanners are controlled by special purpose plug-in PC cards and electronic modules, which control the path movements at the same time. Apart from fast control of the scanners, the main challenges are the monitoring and optimization of the process as well as the interaction with other machine elements. Several movements in the process often have to be coordinated with one another, for example the synchronization of the laser beam movement with a conveyor belt for the material feed. In addition, the process parameters

Productivity increase for laser material machining applications

The Fraunhofer-Institut für Werkstoff- und Strahltechnik (IWS) Dresden (Fraunhofer Institute of Material and Beam Technology) carries out research and development work in the fields of laser and surface technologies. In one application for high-speed laser material machining, the process was optimized using technologies from Beckhoff. Moreover, Fraunhofer IWS Dresden has developed its own EtherCAT module.

This principle has already been implemented in several real systems in a collaboration of Coherent-ROFIN, Karl H. Arnold Maschinenfabrik and Fraunhofer IWS Dresden.

The LMDR system laser scanner in its installed state.
frequently have to be adjusted during running operation in order to ensure constant machining quality.

**ESL2-100 EtherCAT module optimizes laser control**

For better integration of the scanners into automation systems, Fraunhofer IWS Dresden developed a special electronics component—the ESL2-100 module. This enables control of the scanner directly from the machine controller by means of EtherCAT. As a result, the communication among the scanners, the machine controller and peripheral components are optimized with regard to universality, real-time capabilities and synchronicity. “With conventional solutions, the entire contour to be traced often has to be transmitted to the scanner controller in advance. Adjustments during operation are possible only with great difficulty. With the ESL2-100, we now calculate the path movements entirely in the PC-based NC and PLC,” says Peter Rauscher, head of the Laser System Technology Group at Fraunhofer IWS Dresden. “The setpoint and actual values for the scanner movement as well as the status and diagnostic values are communicated between the module and the controller. Interventions in the motion sequence are possible in real-time. The scanners can simply be integrated as motion control axes, for example in the TwinCAT NC automation software.”

**Practical use: Laser treatment of electrical steel sheets**

An application implemented using the ESL2-100 modules is the laser treatment of electrical steel sheets, such as those used for the construction of laminated transformer cores. Thermal stresses are introduced into the sheets by means of laser radiation in order to increase the energy efficiency of the transformers. This Laser Magnetic Domain Refinement (LMDR) was developed collaboratively by Fraunhofer IWS Dresden and a consortium of the companies Coherent-ROFIN and Karl H. Arnold Maschinenfabrik. This method has already been put to use several times in industrial applications. The electrical steel sheet is moved under the laser machining level in the form of belt material. Together with four laser beam sources, 12 scanners as “single axes” are synchronized with a belt feeding speed of up to 140 m/min.

**Meeting high performance and versatility requirements**

The application relied on an Industrial PC from Beckhoff running TwinCAT 3 automation software to achieve control cycle times of < 100 µs. EtherCAT Terminals processed the input signals at up to 100 kHz and switched the laser
The software solution developed by Fraunhofer IWS Dresden for the LMDR runs on a Beckhoff C6650 Industrial PC with EtherCAT as the communication system for the I/Os and drives. Safety-relevant actuators are integrated via TwinSAFE and other fieldbus devices via PROFIBUS.

Beam sources on and off within a few milliseconds. The mechanical forward and infeed axes, implemented with TwinCAT NC and AX5000 Servo Drives, were synchronized system-wide through the distributed clocks functionality of EtherCAT. Communication with further components and machine controllers was implemented with no great effort through the integration of various fieldbus systems using TwinCAT and EtherCAT.

"Leveraging the open, PC-based control concept, we succeeded in combining various components such as laser beam sources, scanners and sensors on a single platform. We also implemented laser control with precise measurement and processing of all relevant process variables for the LMDR. Apart from the real-time applications, we had additional software running on the PC, which reduced hardware expenditures," explains Peter Rauscher. "With the development software, we implemented system-wide configuration, programming, commissioning and diagnostics in a single software project, enabling us to react flexibly to application-specific requirements."

The ESL2-100 module developed by Fraunhofer IWS dynamically adjusts the process parameters and the movement of the scanners, depending on the machining process and belt feed. "The solution we created fulfills the industry’s requirements for high machining speeds with constant machining quality. Ultimately, we were even able to increase machining productivity by more than 15 % as a result," the scientist emphasizes.

**Outlook on further developments**

Future applications will necessitate a modification of the laser beam in order to optimize the machining with different movements, surfaces and materials. "In the future, our system will be able to modify the laser beam movement and control of the laser beam source in real-time – practically as we like," says Peter Rauscher. A new experimental system with Beckhoff technology for the remote laser cutting and welding of metals and non-metals, such as fiber-reinforced materials, has been installed at Fraunhofer IWS Dresden.