# Laser-based welding in lightweight construction

## Two new optical methods improve the weld seam in hairpin manufacturing and joining plastics to metal

LMB Automation was engaged in two collaborations with research institutions and industry partners to improve laser welding under certain conditions, to overcome the limitations of fixed bifocal optics, and to implement the process on automotive parts.

The laser beam tool has become an integral part of modern production, and the requirement for improved efficiency and new potential applications is continuously growing. With new fields of application, component geometries and materials, the conventional optics with limited movement and limited beam shaping options are often no longer able to guarantee a flawless welding result. Such applications include, for example, the joining of thermoplastics and metal as structural components in vehicle construction, and the welding of hairpins in electric motors. For this reason, the LMB laser specialists have developed two new concepts with partners that can be used to positively influence the melt pool through more flexible control and more precise power distribution. With the twin-weld process, better mixing in the melt pool is achieved so that gaps can be bridged more quickly. MULTISPOT allows the intensity distribution within a laser focus to be varied locally and temporally. The performance can then be precisely adapted to the weld geometry and material properties.

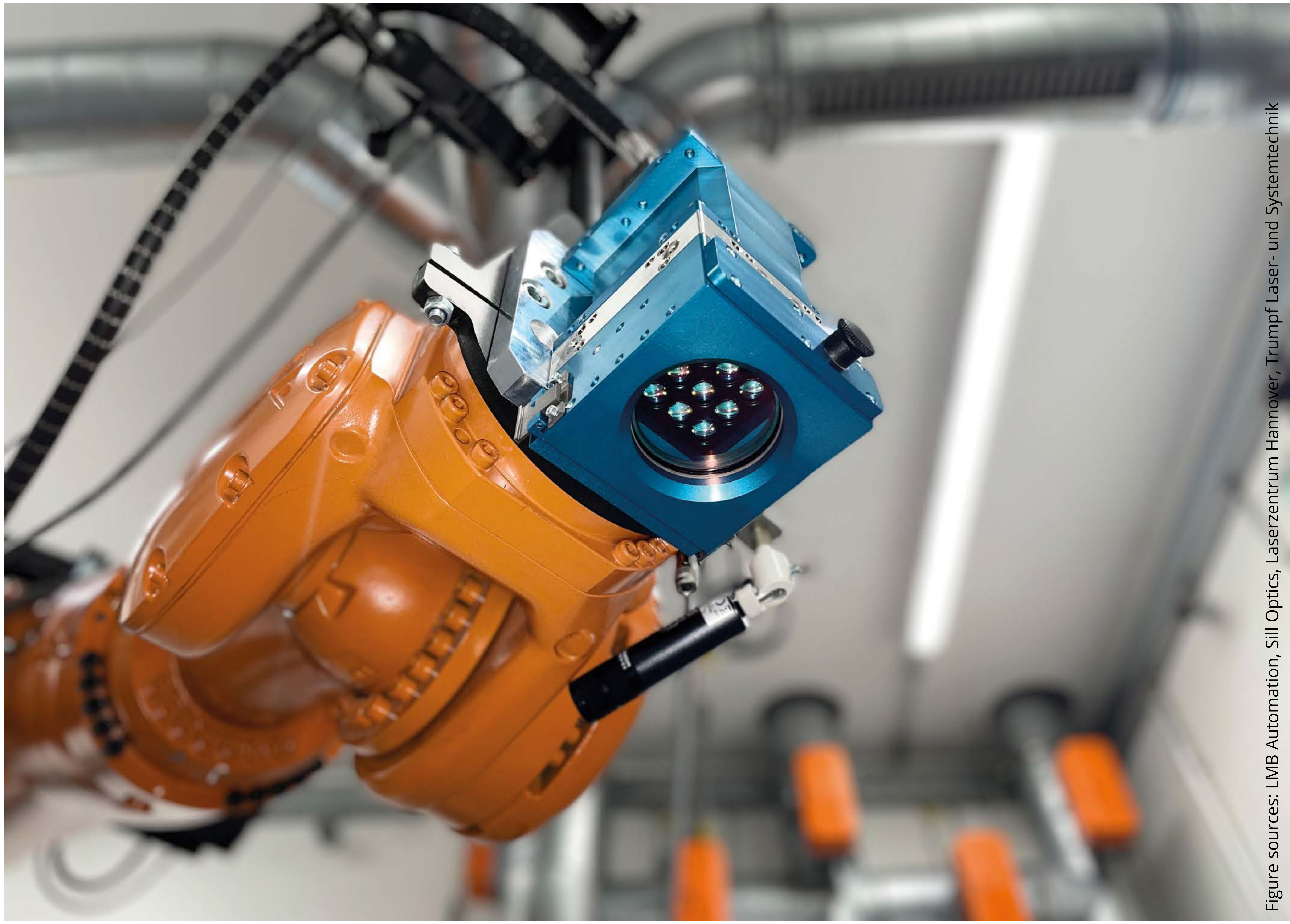

Figure sources: LMB Automation, Sill Optics, Laserzentrum Hannover, Trumpf Laser- und Systemtechnik

The optics use a matrix of 3 × 3 laser diodes that can be individually controlled, which enables variable intensity distribution in the laser focus

"The laser is an established tool in manufacturing," says Peter Schlüter, managing director of LMB Automation. "Despite its versatility and characteristics, it has a few stumbling blocks that can be overcome through adaptations and continuous further development." Not all laser beams are the same: the shape of the beam influences product quality by affecting power density, the cutting width, melt pool dynamics and heat influence. The beam can be focused, expanded, or divided as required. Particular attention should be paid to the melt pool, which affects the geometry, strength, and microstructure of the joint and therefore the quality of the weld seam. The better this dynamic can be controlled with optimized optics, regardless of the location and time, the sooner typical problems such as cracks, pores, splashes, undercuts or insufficient penetration in the keyhole can be avoided.

## LMB Automation

Since 1994 LMB Automation has been offering solutions for laser-based material processing of various materials and components. The three applications welding, cutting and marking are covered. In addition, since 2000, the company has been developing industrial production systems – as stand-alone models or part of a production line – in which the laser is the defining tool. These are completely designed, constructed, assembled and adapted to the special requirements of the customers at the company site. In addition to lasers with different powers, manual workstations, multi-axis systems and robots are used for in-house contract manufacturing. R&D projects are also being implemented together with partners in photonics and universities. The company currently employs 55 people.

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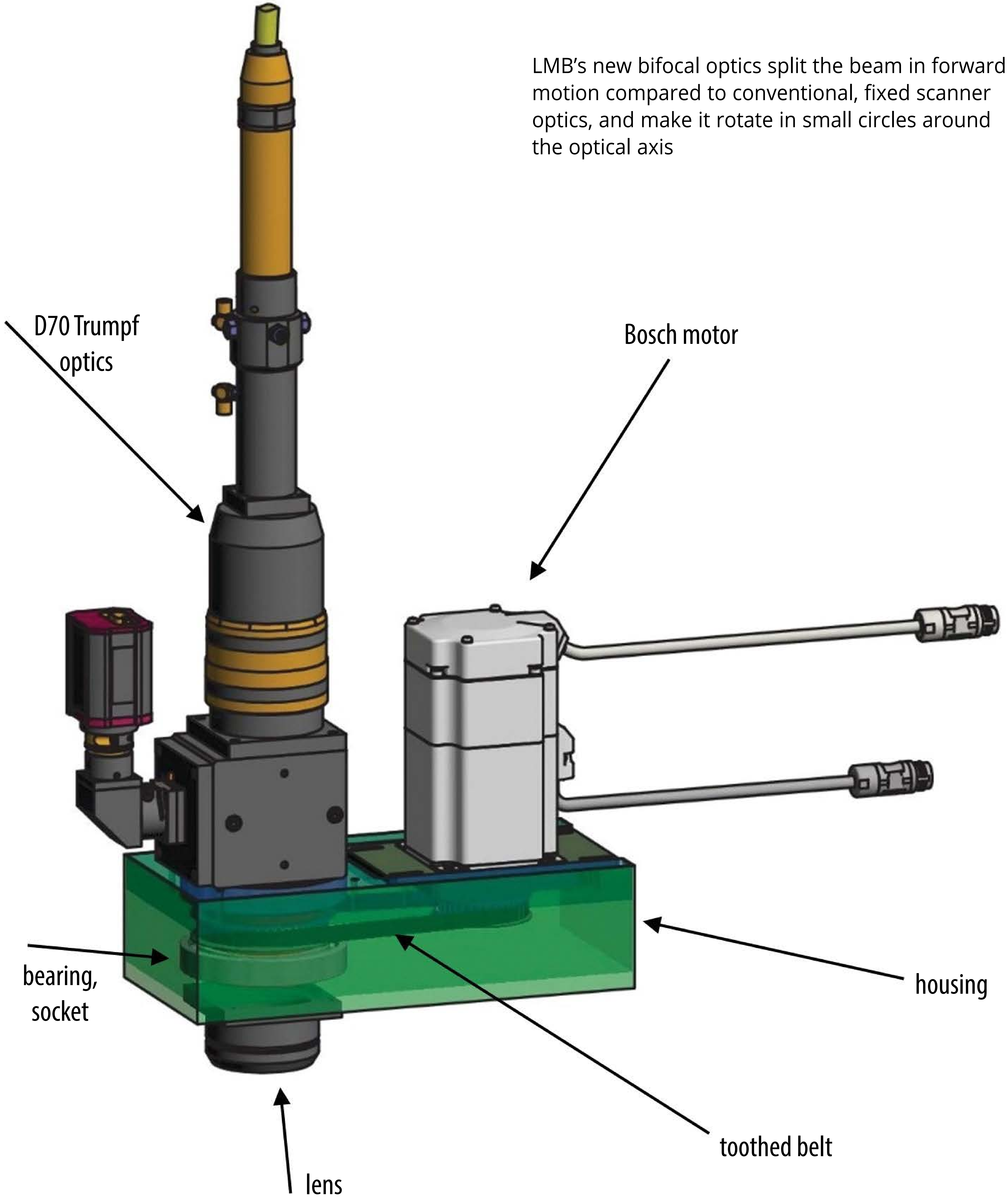
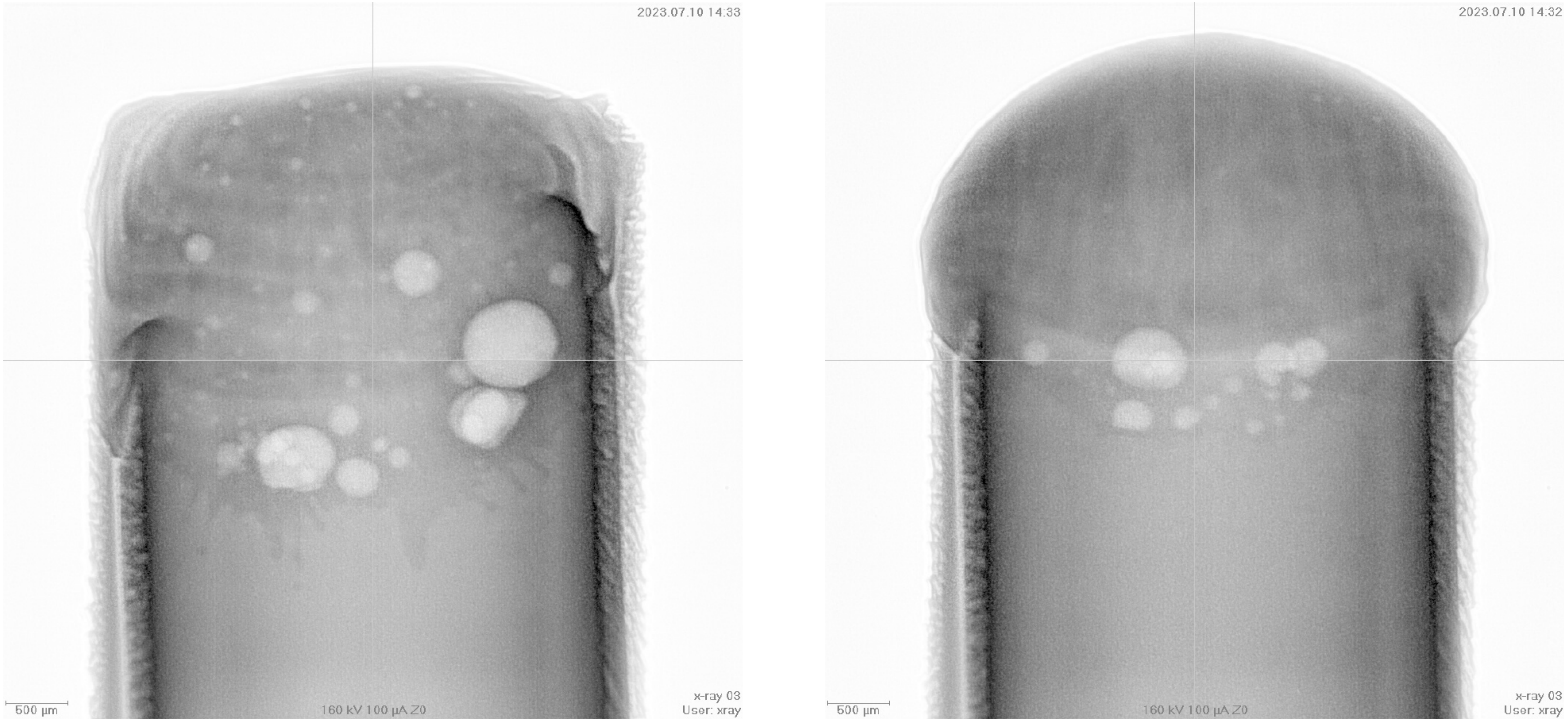
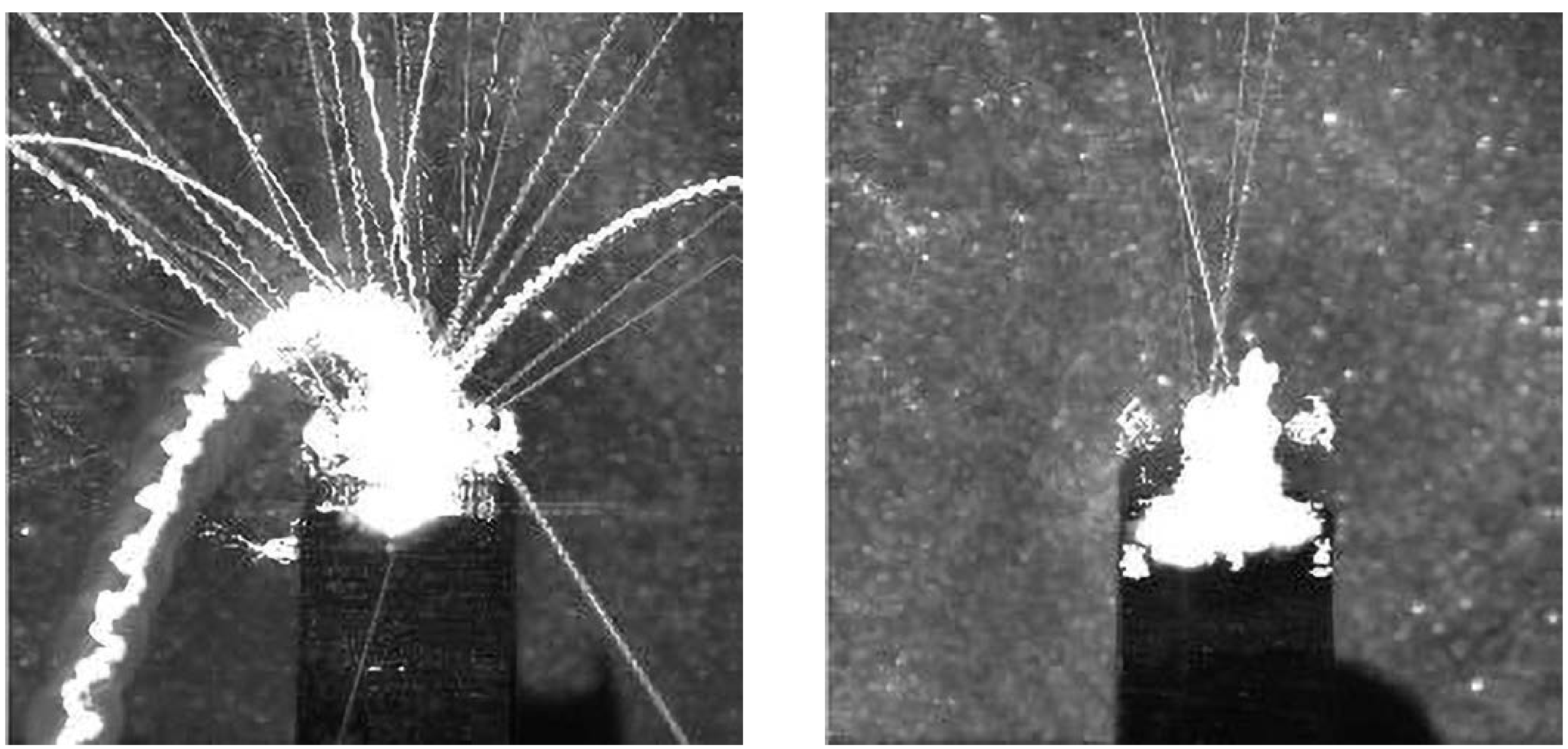
LMB's new bifocal optics split the beam in forward motion compared to conventional, fixed scanner optics, and make it rotate in small circles around the optical axis





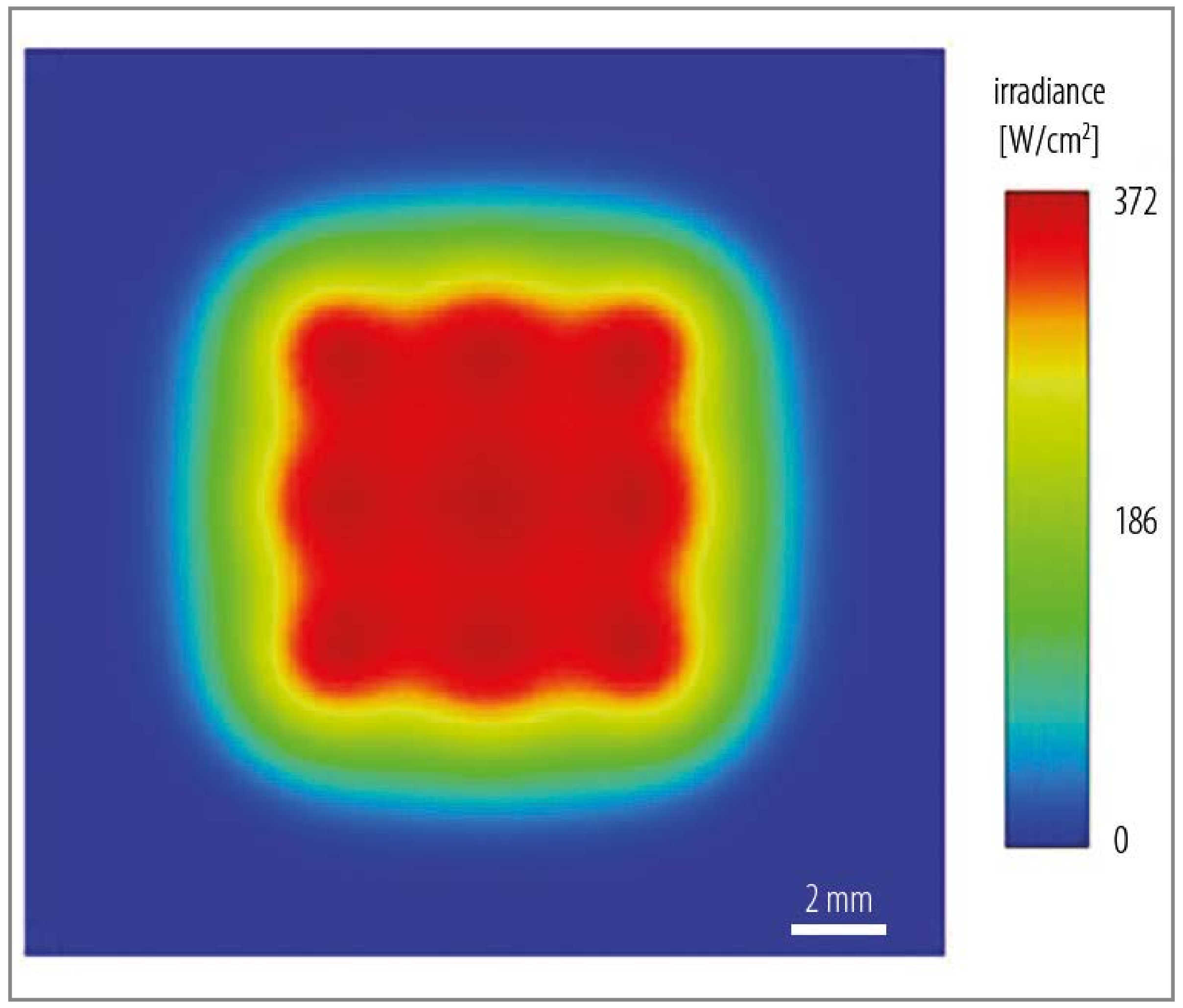
The higher rotation speed of the bifocal optics significantly reduces the frequency of pores in the upper part of the weld seam


Since copper components in particular are very prone to spatter, the heated material is quickly melted and pressed into the contour so that it cannot escape from the keyhole upwards in the first place.

## Structure of optics with rotating components

A typical case in which the combination of a difficult material and insufficient flexibility of the optics can lead to problems is the welding of the copper joints that are made in the hairpins in stator production. The viscous molten copper leads to pronounced process dynamics, which causes the material to spray very quickly. For production, however, a process with as little splash as possible is necessary because no ejected material must get into the stator. To ensure this, LMB uses an adapted bifocal optic in the twin-weld process, which additionally splits the beam in forward motion compared to conventional, fixed scanner optics, and allows it to rotate in small circles around the optical axis. “In the melting area, the two partial beams form two keyholes to ensure that the molten material is better mixed and pressed into the gap by the rotational movement,” explains Schlüter. The weld seam gains strength as a result. At the same time, the pitch and rotation ensure that the time span when crossing a reference point is halved compared to just one focus point, thereby accelerating the entire welding process.

With the combination of a high rotation speed and flexible optics, the Twin Weld process makes it possible for the first time to process all contours with these optics. This would not even be possible with fixed bifocal optics. In addition, the higher rotation speed significantly reduces the number of pores that occur at the top of the weld. “Since copper components in particular are very prone to spatter, we wanted to prevent this. We achieve this by quickly melting and pressing in the heated material so that it cannot escape from the keyhole,” says Schlüter.


Each of the individual optics is powered by its own laser diode. The advantage is that, for example, in a contour when cornering, the outer area in focus can be given a higher beam power and the inner area with a reduced beam power.

## Laser optics to join plastics with a wide seam

Thermoplastics represent a new challenge for laser welding. They are increasingly being used as structural components in lightweight construction. Although laser welding of plastics is not new, it is mainly used to create relatively narrow weld seams, for example in microfluidic applications. For structural components on the other hand, large connection areas between the individual components are required to ensure sufficient power transmission. Wider weld seams are necessary than can be achieved with standard optics in order to achieve higher strength and tightness when welding different plastics as well as plastics with metals. "In principle, homogenized laser focal points can be used to produce wide weld seams," remarks Schlüter. "However, studies have shown that the high process temperatures when joining with a large laser focus at a small diameter lead to partial internal overheating of the material." The main reason for this is the severely limited or non-existent ability to vary the intensity distribution within the required large laser beam spot by changing the location and duration during the joining process. This is where the new MULTISPOT welding head comes in, which LMB developed together with six partners as part of an 'SME innovative' project. The optics use a matrix of 3 × 3 laser diodes that can be individually controlled, which enables variation of the intensity distribution within the laser focus. Each of the individual optics is supplied by its own laser diode. The outer area in focus can be exposed to a higher beam power and the inner area to a reduced beam power. This allows the welding process to be adapted much more precisely to the welding geometry and material properties.

## Information

### Project Twin-Weld

LMB has developed the so-called twin-weld process with the aim of overcoming the limitations of fixed bifocal optics. By splitting the laser beam and rotating the optics, gaps can be bridged better and the weld seam quality can be improved. This has been demonstrated by initial results when welding various materials. Currently, rotating bifocal optics are being further researched through practical experiments in a joint development project with the University of Bochum. In addition, the mode of action is simulated with the help of a mathematical model to be able to provide information on the parameters in advance for new applications.

### Project MULTISPOT

In order to implement the complex task, it was necessary to work together with specialists in individual departments. In the MULTISPOT project, funded by the German Federal Ministry of Education and Research, implementation was achieved with four SMEs, a research institute and two associated partners. The distribution of tasks was as follows: the LZH (Laserzentrum Hannover) was responsible for the process and software development. The development of the diode unit was carried out by Neolase in cooperation with Coherent. The construction of the special optics was carried out by Sill Optics. A special measuring device was developed by Primes to carry out the necessary measurements of intensity distribution. The task of LMB Automation GmbH was to integrate all the necessary components, including the cooling, into an optical head and prepare them for use on a robot. Application samples for testing were provided by Volkswagen.

## Interaction of plastic and metal in lightweight construction

These optics have shown particular promise in the welding of plastic with metal, which is being used ever more frequently in vehicle construction for doors or interiors for example. “In the tests, the load-bearing element was a sheet metal frame to which a plastic cladding was to be attached for protection and, above all, to reduce weight,” reports Schlüter. At the same time, the weld must achieve high strength and be tight so that no moisture reaches the frame. To prepare for the process, the joining surfaces of the metal part were first roughened with a different laser system. Subsequently, both components were pressed together and the metal was heated with the new MULTISPOT welding head. With an input of 100 W per diode, a total of 900 W could be used to melt the pressed plastic at the contact surface to form the hot metal. Thanks to the adjustable intensity distribution, the melt flowed evenly into the textured areas without heat loss, resulting in a particularly homogeneous and stable seam.

Both optics are currently being used for more in-depth application tests in prototype setups to find out how the intensity distribution and the melting behave with different geometries and materials. The aim is to gain important insights into how the structure and operating costs can be optimized in future by adjustments. For LMB, both projects showed that constant questioning and further development of established concepts pays off: “It all started with a simple question: how can the efficiency of the laser be improved when it is inserted into the workpiece? The end result is two practicable and forward-looking optical techniques that can make the laser tool more versatile, and ultimately make lightweight construction fitter for the future,” Schlüter sums up. ■

**LMB Automation GmbH**
Peter Schlüter
Schmölestraße 13
58640 Iserlohn
Germany
phone: +49 2371 152100
fax: +49 2371 152190
e-mail: info@lmb-gruppe.de
Web: www.lmb-gruppe.de