# A new concept for automotive battery boxes manufacturing

## OCT with ALO4: controlled and precise tactile laser welding

**Nataliya Deyneka Dupriez & Philip Marben**

The design of battery boxes must meet multiple strict requirements, including crash resistance, stability, and water and gas tightness. Laser welding with filler wire is the preferred joining technology for production of battery boxes. An OCT system has been integrated into the ALO4 tactile processing head for intelligent highly automated and precise process monitoring and quality control. With high welding speeds and stable process control, the combination of ALO4 with OCT enhances production efficiency and ensures outstanding seam quality.

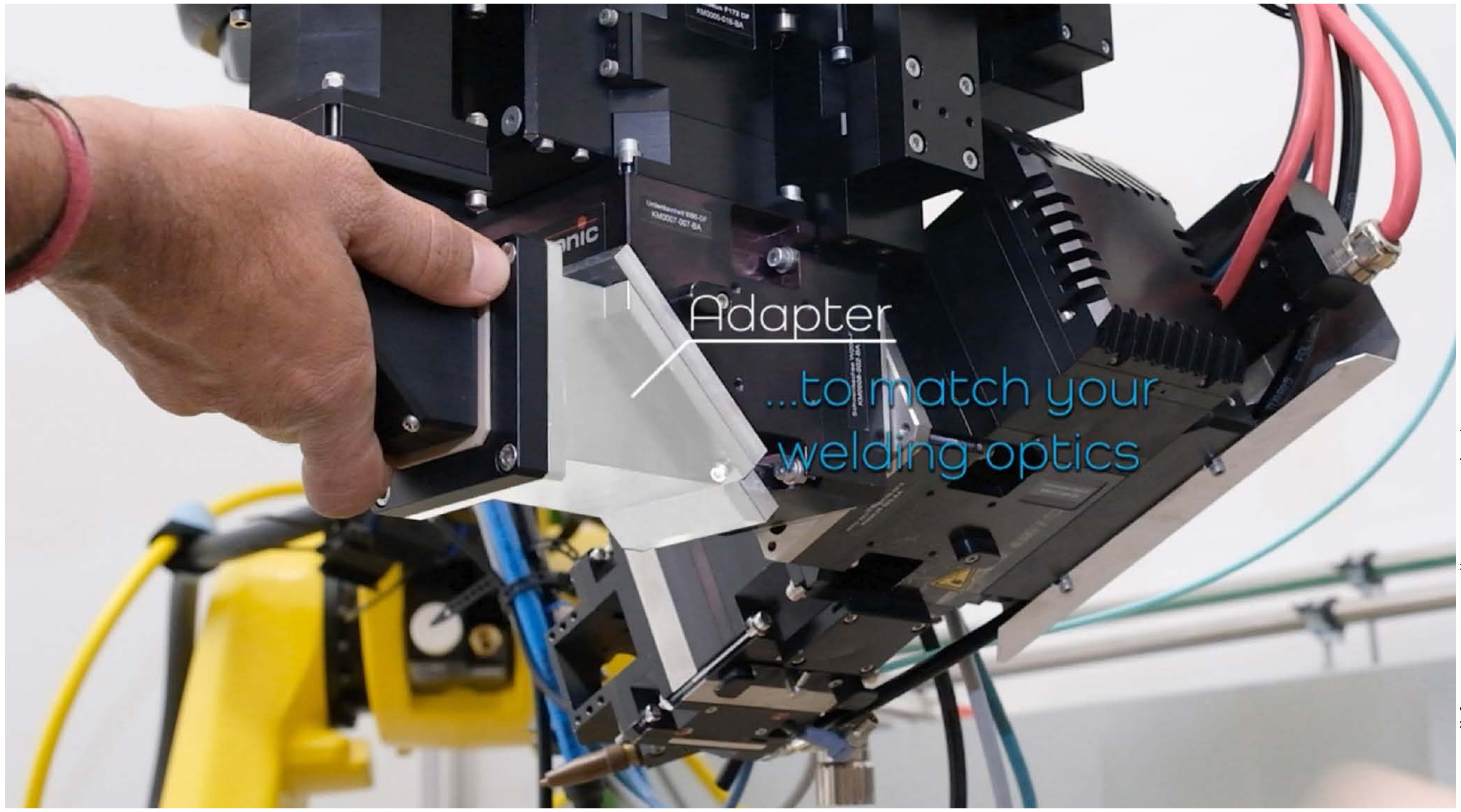


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Fig. 1 The video (online version of this article) shows how the OCT SCANNER is mounted to the ALO processing head

Laser welding offers exceptional precision, automation and rapidity making it the perfect technology for accurate and efficient joining of large volumes. During laser welding the processing laser is automatically guided along the component by SPS-controlled 2D or 3D optics with or without filler wire. Tactile laser welding with filler wire has emerged as a highly effective joining technique, offering advantages like lower heat input, and particularly accurate and tight seams. The addition of filler wire has proven to be the most effective way to control microcracks and boost joint strength.

In order to improve the tactile laser welding accuracy and efficiency, Lessmüller Lasertechnik developed several laser processing monitoring techniques. One of them is the WELDEYE high-speed camera system that allows real-time visualization of surface topography and the identification of key quality characteristics.

However, with optical coherence tomography (OCT) online monitoring, it is possible to modify the processing position and parameters during the process based on the measurement data, ensuring consistent process control that eliminates the need for post-production quality examination. The ability to make adjustments during the process significantly reduces process time and material waste, increasing overall efficiency [2, 3]. Developed by Lessmüller Lasertechnik, OCT can be also successfully applied for the welding with oscillating laser beam [4].

Lessmüller Lasertechnik and Scansonic, both manufacturers of laser processing systems and sensors and long-established cooperation partners, offer the concept for fast and efficient tactile laser welding: Scansonic ALO optics with Lessmüller Lasertechnik OCT (Figs. 1, 2). The seam tracking and quality assurance with OCT compensates for component tolerances and ensures consistent process control and outstanding seam quality. The ALO4, Scansonic's newest processing generation in its market leading ALO product line, is demonstrating its value in mass production of most automotive manufacturer. Equipped with numerous elaborated features, the processing optics are even more flexible to use and optimized for the automated welding process. ALO4 is ideally suited for all applications where uncompromising accuracy is required, even for complex contours, such as in the field of e-mobility – for safety-relevant battery boxes.

The battery is the core of a modern electric vehicle, with range closely tied to the vehicle's weight. Consequently, manufacturers are increasingly adopting high-strength aluminum alloys for battery carriers. In high-volume production, aluminum battery trays are commonly used for high-range vehicles (more than 250 km per charge), while steel structures are preferred for lower-range models. In contrast, low-volume production often relies on composite or multimaterial structures. Aluminum alloys were selected to produce lighter and cost-effective battery trays.

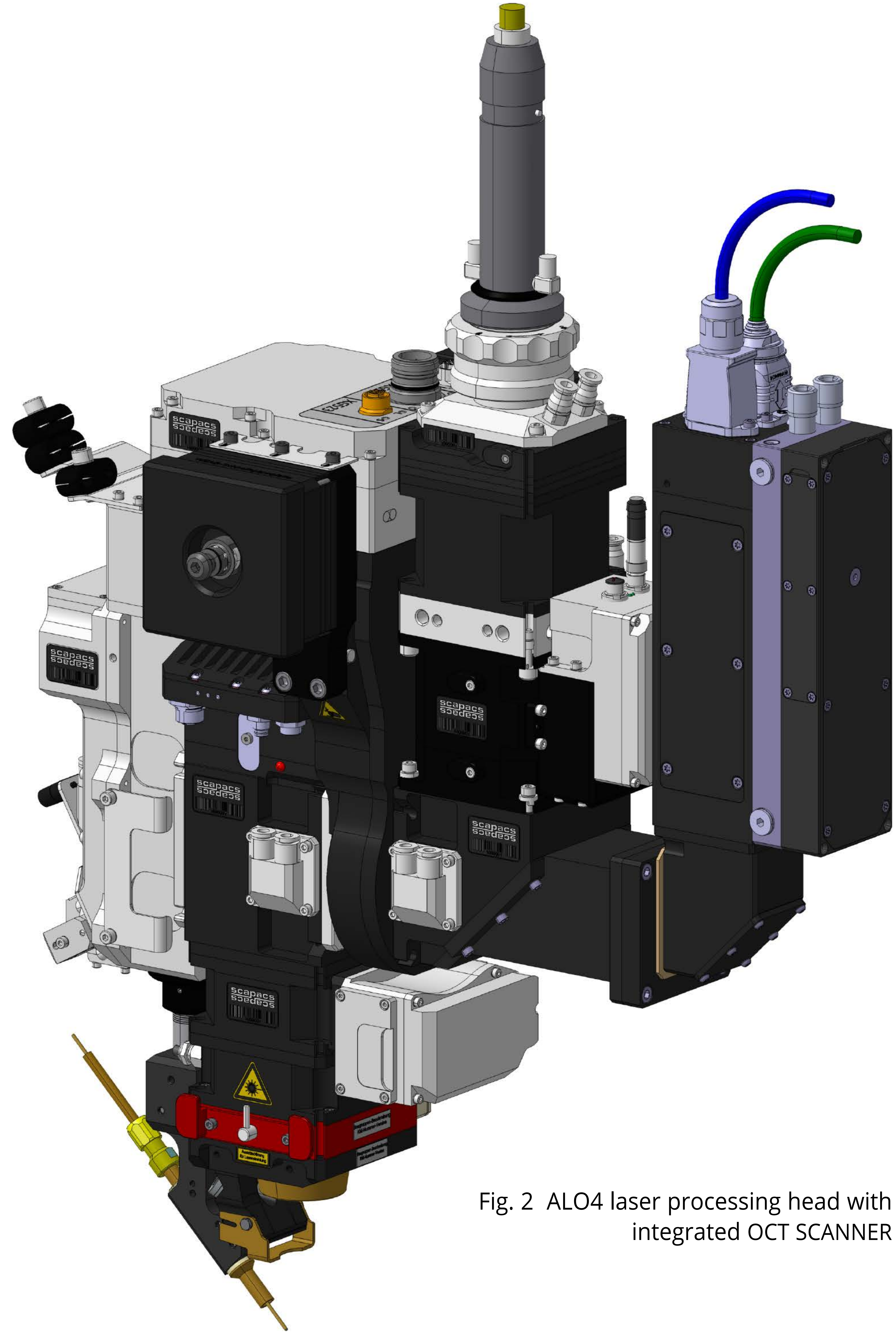

Fig. 2 ALO4 laser processing head with integrated OCT SCANNER

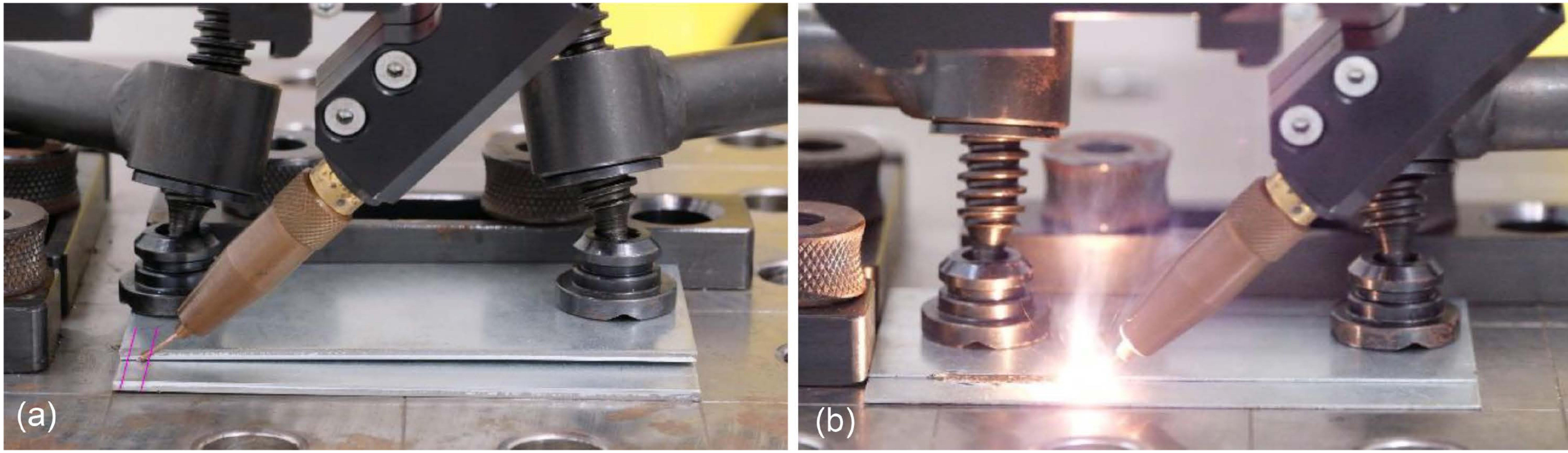


Fig. 3 (a) OCT pre- and post-process scans (magenta lines) for high precision process control during tactile laser welding with ALO4 (b)

Serving as the interface between the vehicle's underbody and the battery pack, battery boxes not only affect vehicle dynamics but also play a critical role in safety. They must withstand high mechanical demands and mitigate fire risks, making them crash-relevant components. Aluminum alloys offer a cost-effective and lightweight solution. However, their tendency to suffer from hot cracking presents significant challenges for welding technology. Manufacturing of the battery boxes must meet multiple stringent requirements: water and gas tightness, optimal strength, absence of cracking and warping, crash resistance, stability, balanced weight distribution, etc. Ultimately, choosing the right materials and joining processes for battery boxes is a complex task that must balance technical performance – such as weight, strength, and sealing – with manufacturing costs.

As production volumes increase, reducing cycle times becomes even more critical. In battery box manufacturing, the laser fully demonstrates its strengths as a tool – thanks to lower energy input, higher speed, and increased flexibility. Given the challenging material properties and high technical demands, tactile laser welding with filler wire ensures crack-free weld seams while the joining of the complex geometry has to be precisely controlled. Scansonic has developed a range of solutions for these applications and offers the appropriate optics from its ALO4 portfolio while Lessmüller Lasertechnik OCT ensures exact control over the joining process for the elaborated geometries involved in battery box.

## Tactile laser welding with the ALO4

ALO4 represents the next generation of automated tactile laser welding, ensuring precision and reliability during battery box production delivering repeatable welding results. ALO4-L (Long) is designed for particularly complex geometric configurations to create weld seams even in tight spaces within the battery box. ALO4-F is the product of choice for pin seams while ALO4-O combines the advantages of tactile welding with those of beam oscillation for thick sheets such as covers of battery boxes. The commonality of all ALO4 optics: Their precise energy input minimizes heat buildup, preventing warping of the components.

The ALO4 processing system features a modular design that enables customized configurations and seamless expandability throughout its entire lifecycle, providing tailored solutions for diverse applications. Enhanced drive dynamics and increased torque allow for 90° swivel axis angles during processing, making it ideal for continuous operation under high mechanical loads. Integrated 3D weight compensation and force control ensure precise wire contact pressure regulation and enable full 360° processing. The system features automatic horizontal focus tracking, temperature monitoring, and position control.

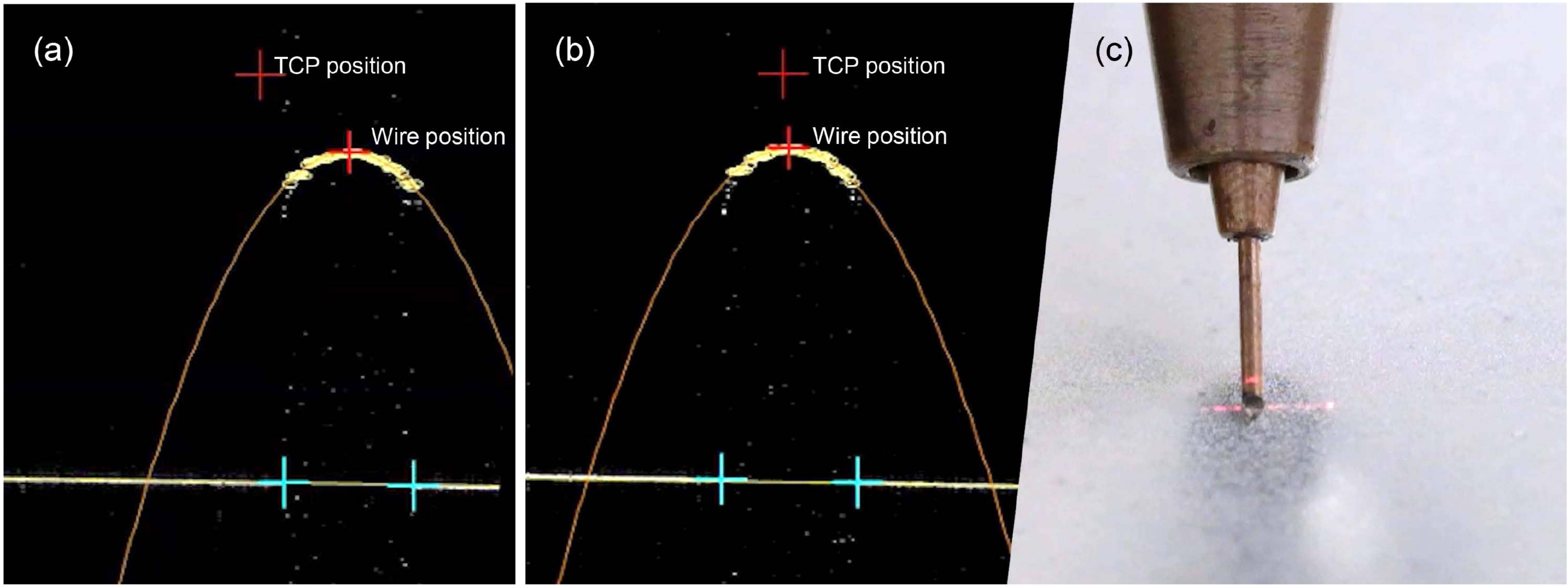

Fig. 4 Motorized lateral wire position adjustment with help of OCT: (a) filler wire misaligned; (b, c) filler wire adjusted. Description of the OCT images: OCT measurement points at the wire tip, surrounded by the yellow circles, are fitted with the parabola; the wire edges are marked with the blue crosses; the TCP and filler wire positions are marked with the red crosses.

An integrated force sensor and telescopic arm compensate for height tolerances. Both right-hand and left-hand applications can be realized. This means that a single optics can process different components in the same laser cell. Optional integration of external functions such as wire feeders, media control, quality assurance systems, and direct laser source control simplifies handling.

## Integration of the OCT into the ALO4

OCT is seamlessly integrated into the ALO4 processing head for the precise real-time post-process control [1] and for the automated filler wire position adjustment.

The OCT runs tested on the following optics: ALO4, ALO4basic, and ALO-L. The OCT SCANNER is mounted to the ALO4 processing head through the specially developed OCT adapter (see Fig. 1).

In the processing laser heads the OCT measuring beam is usually directed to the workpiece surface coaxially to the processing laser beam in order to evaluate the processing area. The ALO4 processing laser path contains two deflection mirrors. The adaption of OCT to ALO4 must ensure the premium OCT signal quality. The OCT adapter is mounted on the ALO4 deflection module containing the deflection mirror, which must efficiently transmit the OCT measuring beam (wavelength: 820 – 860 nm). To achieve this, the ALO4 deflection module is equipped with a specialized 'OCT mirror' (IQFO mirror: infrared laser / QA system / front OCT). This ensures that the OCT signal quality remains unaffected by the swiveling axis, maintaining high measurement accuracy.

To achieve the best performance, the OCT measuring beam has to be reflected as much as possible by the coupling deflection mirror. Therefore, in combination with 'OCT mirror' a DFS mirror was used for the non-swiveling coupling deflection mirror.

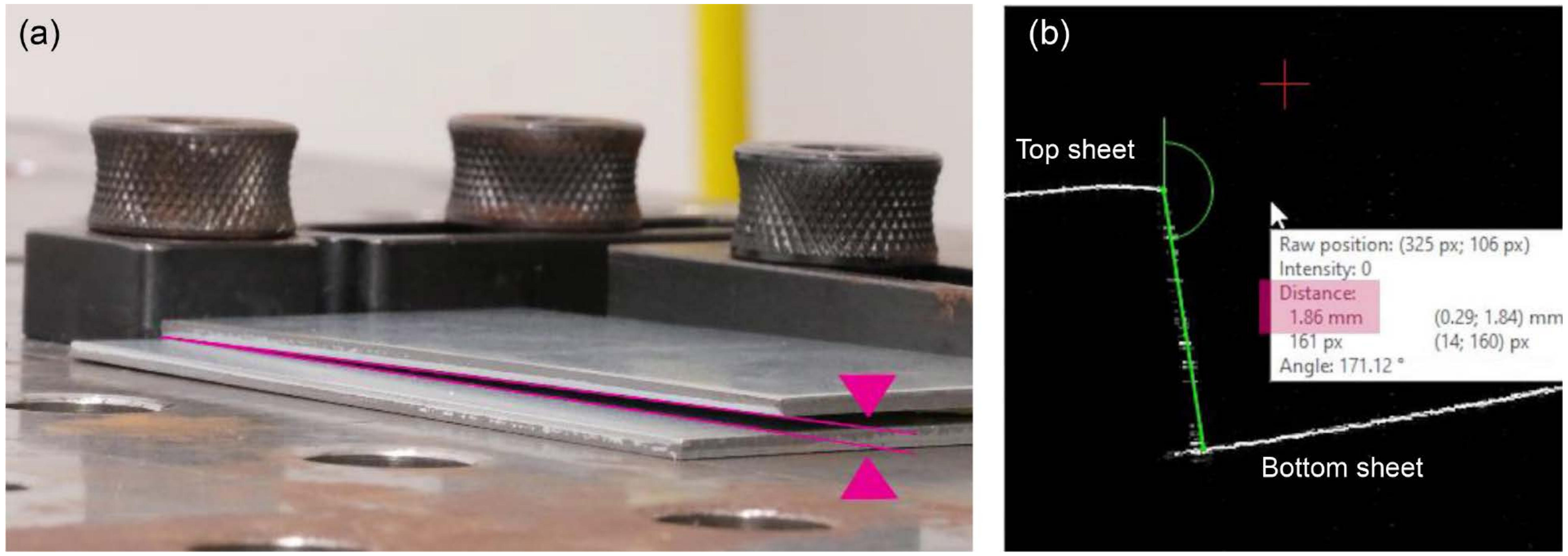


Fig. 5 A photograph (a) and OCT image (b) of the overlap joint with the gap (video online). The distance from the upper side of the bottom sheet to the upper side of the top sheet can be measured with OCT so that the gap can be assessed if the thickness of the top sheet is known.

OCT measurements are also possible with a double focus module. To adjust the orientation of the OCT scan line to the actual rotation, the OCT system receives the current angle of rotation from ALO4 via a fieldbus. The control units of OCT and of ALO4 are separate.

The aim of the setup is to perform wire misalignment compensation and to record and analyze the seam topography during processing.

The OCT SCANNER deflects the measuring beam 2 mm in front of and 10 mm behind the tool center point and performs two subsequent scans across the joint (Fig. 3).

OCT records every weld seam with OCT video and a comprehensive data set while continuously monitoring process parameters. All recorded OCT height data are put in accordance with the process data. This enables early detection of production faults preventing costly rejects.

Additionally, all recorded data are available at all times for the purposes of predictive maintenance. Through the user interface, operators can visualize the optics' positioning in the workspace and monitor the joining process outside the laser cell.

## Application examples

The system offers wire misalignment compensation, eliminating the need for rework and extending the range of applications in highly automated production systems.

Filler wire is continuously pressed into the joint via the swiveling axis, positioned in the laser focal point and melted. OCT scans across the wire tip and evaluates the filler wire tip position and offset to the tool center point (TCP) position (Fig. 4). With help of the ALO motorized lateral module, the filler wire could be shifted to the TCP. This means that the filler wire remains directly at the laser's focus and is guided over the seam with consistently high accuracy.

Some tests were carried out and the following are the results. For aluminum welding, the following standard settings were applied. A fillet weld at the overlap joint was executed with an SA angle set to 30° to ensure an optimal OCT measurement signal. The laser power was 5 kW, the welding speed was maintained at 3 m/min, and filler wire speed was kept at 3.5 m/min while the shielding gas (argon) was supplied at a rate of 10 l/min in a direct flow.

## Nataliya Deyneka Dupriez

Nataliya Deyneka Dupriez studied metal physics at the National Technical University of Kyiv before completing her doctorate in solid-state physics at the University of Ulm. After several years of academic research in material science, she joined Lessmüller Lasertechnik as a technical writer in 2015.

Dr. Nataliya Deyneka Dupriez,
Lessmüller Lasertechnik GmbH, Gollierstr. 12,
80339 Munich, Germany
phone: + 49 89 3609 0480, fax: +49 89 36090 4829
e-mails: service@lessmueller.de,
nd@lessmueller.de
Web: www.lessmueller.de

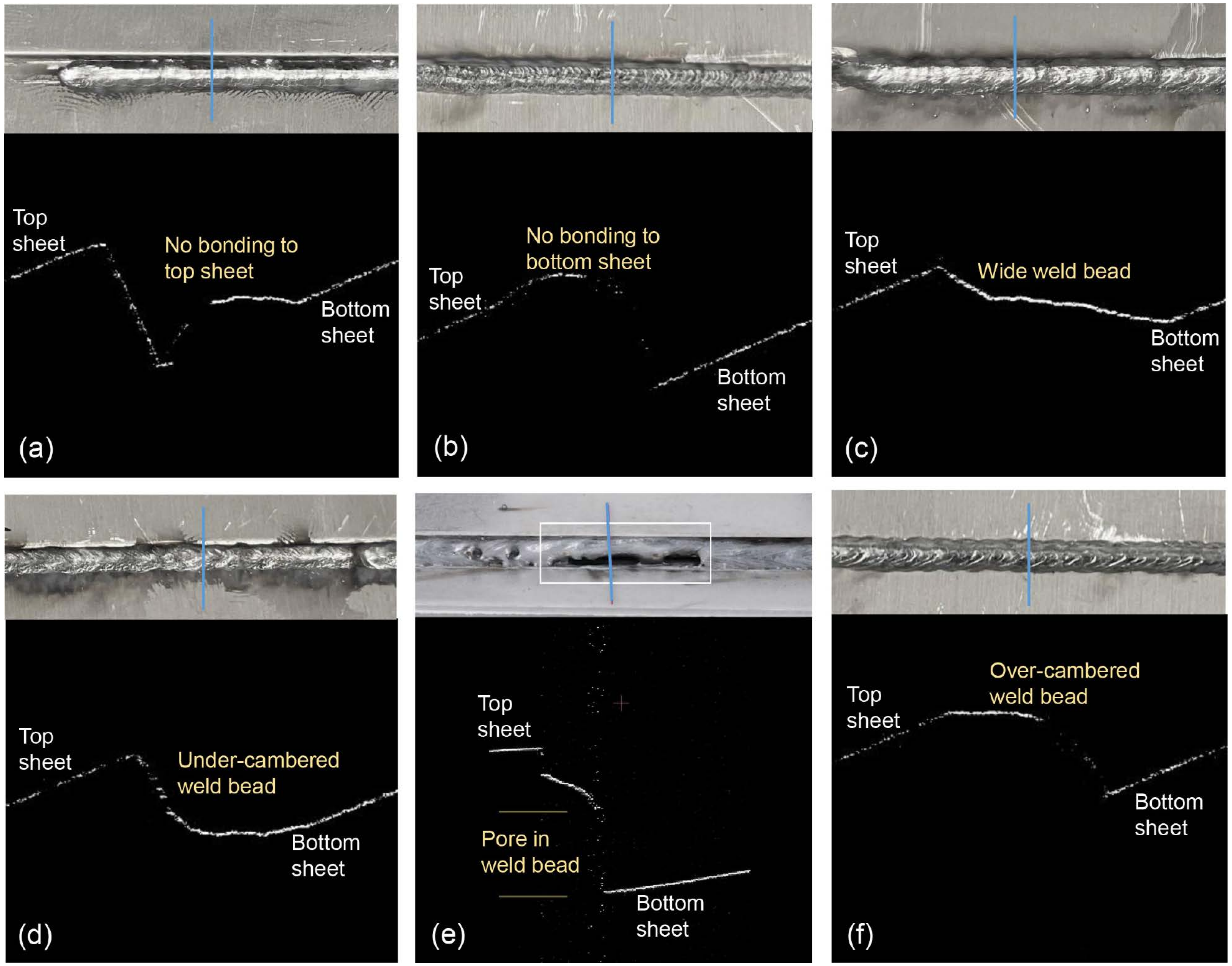


Fig. 6 OCT images of the single scan across the weld bead during real-time postprocess evaluation of the seam topography and defects with OCT: (a) no bonding to the top sheet; (b) no bonding to the bottom sheet; (c) widening of the weld bead; (d) under-cambering; (e) pore; (f) over-cambering. OCT images are superimposed with the corresponding photographs of the weld bead, where the vertical magenta lines represent the OCT scan path.

Gaps between the top and bottom sheets can be measured using OCT (Fig. 5). It was found that gaps of 0.7 mm can be compensated for during welding with the filler wire, while it was not possible to bridge gaps of over 1 mm.

Several typical process errors during welding were simulated and OCT measurement results were documented (see some example images in Fig. 6). When the processing laser spot was shifted towards the bottom sheet, the edge of the upper sheet was fully visible in the OCT image as it was not melted and there was no bond to the upper sheet (Fig. 6a). A bonding faults caused by the shift of the laser spot towards the upper sheet or by the reduced laser power (to 4 kW) can also be identified by OCT (Fig. 6b). Increasing the laser power to 7 kW led to a widening of the weld bead, which can be clearly recognized in the OCT image (Fig. 6c). Deviations in the seam geometry such as over-cambering and under-cambering can be observed in the OCT image as a result of an increased (to 6 m/min) or decreased (to 1.5 m/min) welding wire speed (Figs. 6b, d).

A similar under-cambering of the weld bead was also detected when no filler wire was present. Defects such as pores (Fig. 6e) can also be analyzed to check whether their size is within the specified tolerance range. The weld depth could not be measured due to the pure OCT signals from the keyhole.

## Philip Marben

Philip Marben is product owner for the tactile laser processing optics of the ALO4 product family at Scansonic MI. He received his MSc degree as industrial engineer from Otto von Guericke University, Magdeburg. He started at Scansonic in the in-house laser laboratory where he gained in-depth knowledge and understanding of laser processing challenges.

Philip Marben, Scansonic MI GmbH,
Schwarze-Pumpe-Weg 16, 12681 Berlin,
Germany; phone +49-912074-10;
e-mail: info@scansonic.de,
Web: www.scansonic.de

The ALO4 with OCT offer several advantages, ensuring high-quality and efficient welding at high welding speeds. It helps prevent weld defects and incomplete welds thus minimizing production stops and downtimes. With OCT technology, optimal quality assurance is achieved, excellent weld formation, and stable process control, resulting in the highest seam quality.

## Conclusion and outlook

Tactile laser processing guarantees excellent welding quality at high joining speeds. The welding process of battery boxes can be significantly improved by combining tactile laser welding with filler wire and real-time evaluation of the topography of the processing area with OCT, enabling higher welding efficiency while minimizing manufacturing costs. The OCT height measuring instrument can be seamlessly integrated into the ALO4 optics. This was developed in co-operation between Lessmüller Lasertechnik and Scansonic and ensures that every weld seam is a quality seam. The ALO4-OCT system allows the recording of OCT and process data in real time for comprehensive quality control by capturing the seam topography, detecting faults and performing beam-wire alignment in order to achieve optimum welding results.

Further tests have to be done to demonstrate the feasibility of the Lessmüller Lasertechnik OCT integration into the Scansonic ALO4-F and ALO4-O optics. The ALO4-F processing optics guarantees optimal component accessibility. The ALO4-F, equipped with specialized laser beam deflection and an adapted wire feeder, enables welding of corner joints in battery boxes by reaching into hardly accessible corners, making it suitable for welding both steel and aluminum battery boxes. The ALO4-O laser processing head was specially designed for difficult to access geometries for use in the production of battery cases and combines tactile seam tracking with the laser beam oscillation that increases the joint cross section. Thus, customer-specific solutions can be developed which reliably functioning in serial production.

## Lessmüller Lasertechnik

As one of the leading experts in laser process monitoring, Lessmüller Lasertechnik offers standard and customized solutions for live process monitoring and control of industrial laser processing, all developed, designed and manufactured in house and installed worldwide: the innovative OCT with more than 200 installations for flexible, precise, and reliable seam tracking, depth measurement and seam inspection, allowing a step forward in faster, more accurate and effective production; the proven WELDEYE with over than 800 systems, and the economical WELDCHECK for process monitoring.

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## Scansonic

Scansonic provides systems and solutions in the fields of laser welding, laser brazing, laser cutting, and laser hardening, as well as optical sensing and process monitoring systems. With innovative solutions and one of the world's most advanced laser application centers, the company supports customers in the automotive, rail vehicle, and energy industries in implementing highly precise and reliable processes. Scansonic MI is the global market leader in laser-based, tactile joining systems for body-in-white applications. The company is part of Berlin Industrial Group (B.I.G.), with approximately 360 employees.

**www.scansonic.de**
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