Because the laser line is separated into 15 individually controlled line segments with an area of 1.5 mm by 21 mm, the laser beam strikes only the specifically desired welding points on the plastic parts (figure: Limo/Markus-Steur.de)

Simultaneously … in a Single Shot

Joining Large-Area and Transparent Components

Large-area components and transparent, white or beige thermoplastics push process-controlled laser welding to its limits. Now, these limits are no longer an obstacle thanks to enhanced powerful line lasers that deliver outputs in the kilowatt range while also enabling absorber-free laser transmission welding at significantly longer wavelengths.

In addition to point-shaped light sources, the Limo Lissotschenko Mikrooptik GmbH, Dortmund, Germany, now also offers a line diode laser (type: L^3 Limo Line Laser) that generates extremely homogeneous and high-energy lines using patented beam shaping technology. Unlike a round laser beam profile, the line laser processes the entire welding contour simultaneously and uniformly (**Figs. 1 and 2**), thereby achieving faster process speeds. In addition, the laser line's homogeneous intensity distribution, and the laser's continuous wave operation ensure that the process results are consistent. When joining plastics, the laser can be used with several different welding methods, such as mask welding and fully simultaneous welding, for example.

In fully simultaneous welding, the component is welded in a matter of seconds (depending on the type of plastic and the component's wall thickness). This extremely rapid "single-shot" welding technique offers a host of advantages. Warping and thermal stress are drastically reduced. In addition, the line laser's beam can be guided straight to the weld and does not need to be coupled to a fiber. The laser energy in this process is thus applied to the workpiece directly and at an optimized cycle time – with considerably less energy loss. As a result, this method differs greatly from quasi-simultaneous welding, in which the laser beam is moved over the component several times by a laser scanner.

Aside from eliminating the need for motion systems (no relative motion between the component and laser), this method offers the added benefit of a much shorter cycle time. Both of these advantages lower the cost and increase the quality of every weld. That is why a large medical technology company is already using this system to manufacture its plastic perfusion tanks. In addition, fully simultaneous welding with a line laser is also used to produce flat 3-D contours. Unlike standard focal optics with their high-precision processing focal point, the work distances for a line laser only need to conform to a tolerance of ±10 mm.

Creating Complex Welding Systems with Modular Construction

The current demand in the marketplace is for tailor-made system solutions based on a modular design. In addition to "simple" line laser modules, this approach can be used to combine diode lasers to form modularly constructed lines for a wide variety of different production processes. These lines are then able to simultaneously weld large-area plastic components with complex shapes in a matter of seconds. In one example, Limo partnered with a mechanical engineering company to develop a laser concept featuring seven laser modules (**Fig. 3**) for welding fiberglass-reinforced automotive components, with all seven modules controlled synchronously by a single parameter set. This laser creates multiple weld seams of differing lengths on three separate planes on the plastic housing being processed, and it welds the component in 0.5 to 3 seconds.

Another special solution was developed for a different automotive supplier. In this case, the laser line is divided into 15 individually controlled line segments (1.5 mm by 21 mm), which means that the laser beam strikes only the specifically desired welding points (**Title figure**). This sequential laser line (4 kW line laser with a line length of 320 mm and line width of 1.5 mm) reduces energy loss during process control and delivers an impressive 60 % overall efficiency rate.

These examples demonstrate that Limo does more than just manufac- »

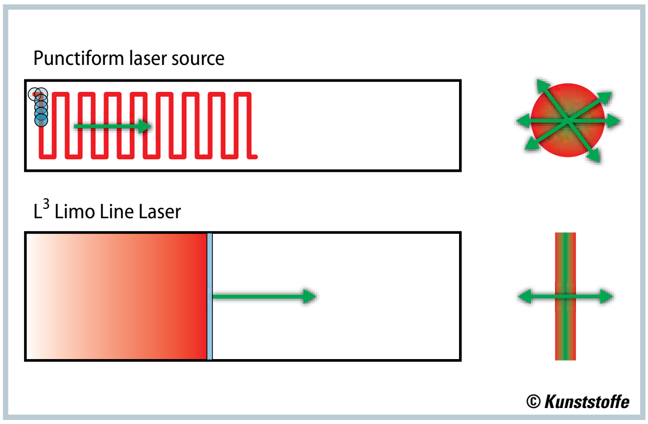

Fig. 1. Unlike point-shaped lasers, which have a round beam profile, line lasers process the entire surface simultaneously and uniformly (figure: Limo)

Fig. 2. L3 Limo Line Laser Technology: Used as an alternative to point-shaped light sources, this line diode laser produces lines characterized by extreme homogeneity and high-energy density thanks to patented beam shaping technology (figure: Limo/Markus-Steur.de)

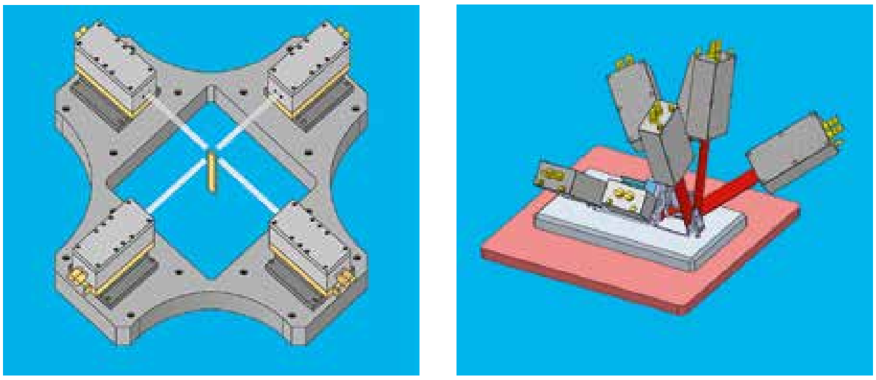

Fig. 3. Modularly constructed line arrays are possible with four or seven laser modules (figures: Limo)

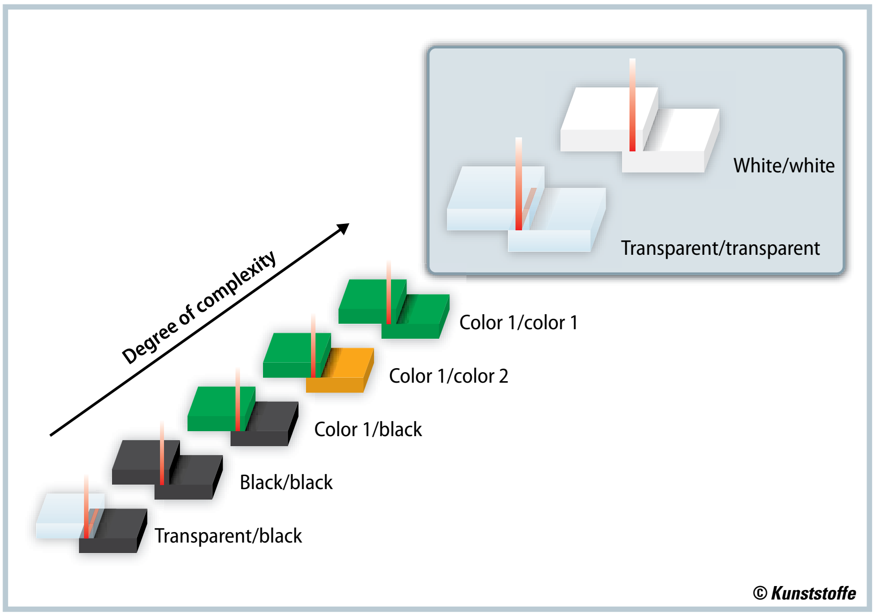

Fig. 4. The absorber effect makes combinations of transparent and black components easy to join with laser transmission welding, whereas the pair white/white is the most difficult (figure: Treffert)

Laser Transmission Welding

In laser transmission welding, plastic pieces that are to be joined are heated and welded virtually simultaneously. In order for this to happen, one component must exhibit high transmittance and the other component must be highly absorptive. Before welding begins, both components are arranged in the desired position, and the necessary joining pressure is applied. Three techniques have established themselves on the market: contour welding, quasi-simultaneous welding and mask welding. These three methods differ in terms of energy application and beam shaping. Yet all three techniques have one thing in common, namely, that relative motion occurs between the components and the laser, and that this motion prevents the simultaneous bonding of all contours that are to be welded together. With fully simultaneous welding and a specially tailored laser seam, this downside is no longer an issue, since all components are welded together at the same time – virtually in a single "shot".

The Authors

Dipl.-Ing. (FH) Frauke Legewie is Account Manager for Cutting & Welding at the Limo Lissotschenko Mikrooptik GmbH in Dortmund, Germany.
Dipl.-Ing. Nikolaus Fecht is a journalist specializing in production technologies of all kinds. He is based in Gelsenkirchen, Germany.

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ture line lasers: It also employs them to develop complete solutions that are fit for industrial use. This means that, by working together with mechanical engineering companies, it is possible to develop tailor-made line laser systems that can be equipped with a powerful and reliable real-time process control system wherever necessary. The quality of this extremely rapid welding operation, in which all joining zones are fused simultaneously, ultimately hinges on this process control. However, the technology can also be integrated into existing production equipment. Systems of this type are already in use at a number of manufacturers and suppliers in the automotive branch.

Based on the wide range of different demands and diverse application possibilities, line lasers have been developed which offer outputs ranging from 10 W to 15 kW and the capability to create individual homogeneous lines featuring geometries with lengths of 1 mm to 350 mm and widths of 0.05 mm to 10 mm, for example.

Laser Transmission Welding without Absorbers

The use of carbon black particles, which are added to plastics as an economical absorber, has proven effective in many different applications. This method is used in the production of automotive components for the engine compartment, which are already black. One well known automotive supplier uses a line laser in series production to join large quantities of black plastic housings for car keys, for example.

In the medical technology industry, where sophisticated material combina-

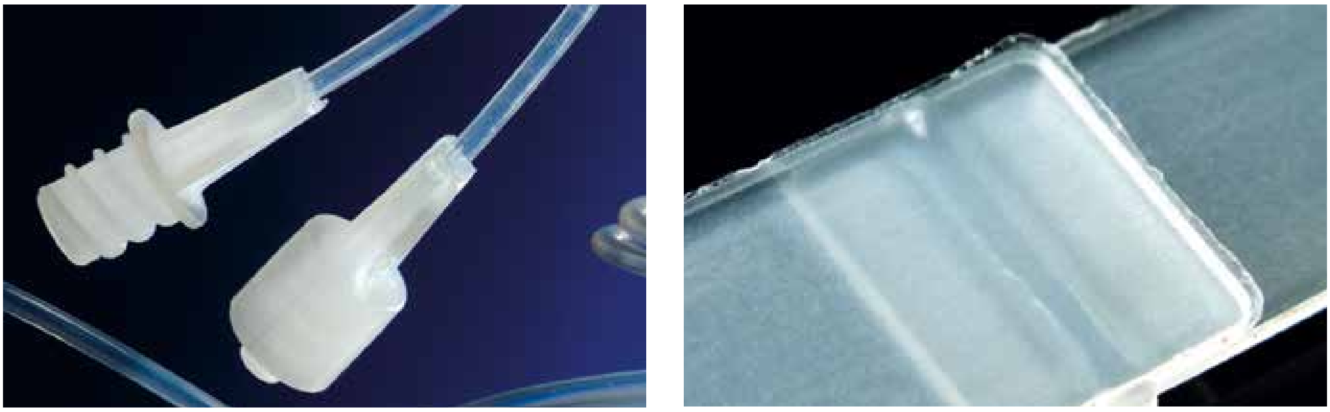

Fig. 5. Using vibration stimulation and absorbance, diode laser systems with a wavelength of 1,470 nm can even heat transparent, white and semi-transparent polymers (figures: Limo, Fraunhofer ILT for the EU-funded PolyBright project)

tions and stricter approval regulations (FDA) are important factors, new laser systems with greater wavelengths are being used that can join plastic components even without the addition of absorbers. These systems play a critical role as adequate direct interaction between the plastic and the laser beam only occurs at wavelengths greater than 1,100 nm. Lasers with wavelengths between 1,400 nm and roughly 2,000 nm are therefore extremely well suited for use in the field of medical technology, on white label products and in microfluidics (e.g., lab-on-a-chip devices). All of these areas involve the joining of transparent, white or semi-transparent thermoplastic components (**Fig. 4**).

In light of this, Limo developed a 150 W line laser with a wavelength of 1,470 nm which is capable of welding together two transparent or two glossy white plastic elements by moving a 12 mm laser line over the joining components (**Fig. 5**). Thanks to sophisticated electronics, the laser transmission welding process can be controlled in real-time when paired with a pyrometer, a sensor for non-contact temperature measurement. For example, if the pyrometer indicates that the temperature is not high enough for welding to occur, the electronic unit can adjust the process by increasing the intensity of the laser beam. In addition, the pyrometer can also be used to document process performance.

Conclusion

The technique of using line lasers for the fully simultaneous welding of plastic parts has proven effective in series production at many manufacturers and suppliers in the automotive industry. This method can also be used to weld larger auto body components made of plastic, GFRP or CFRP. Thanks to product improvements for the utilization of longer wavelengths, enhanced line lasers can now also be used in demanding applications – especially in the medical technology field – for welding transparent, white or semi-transparent plastic parts, such as those made of ABS, PMMA, PA, PC or POM. ■