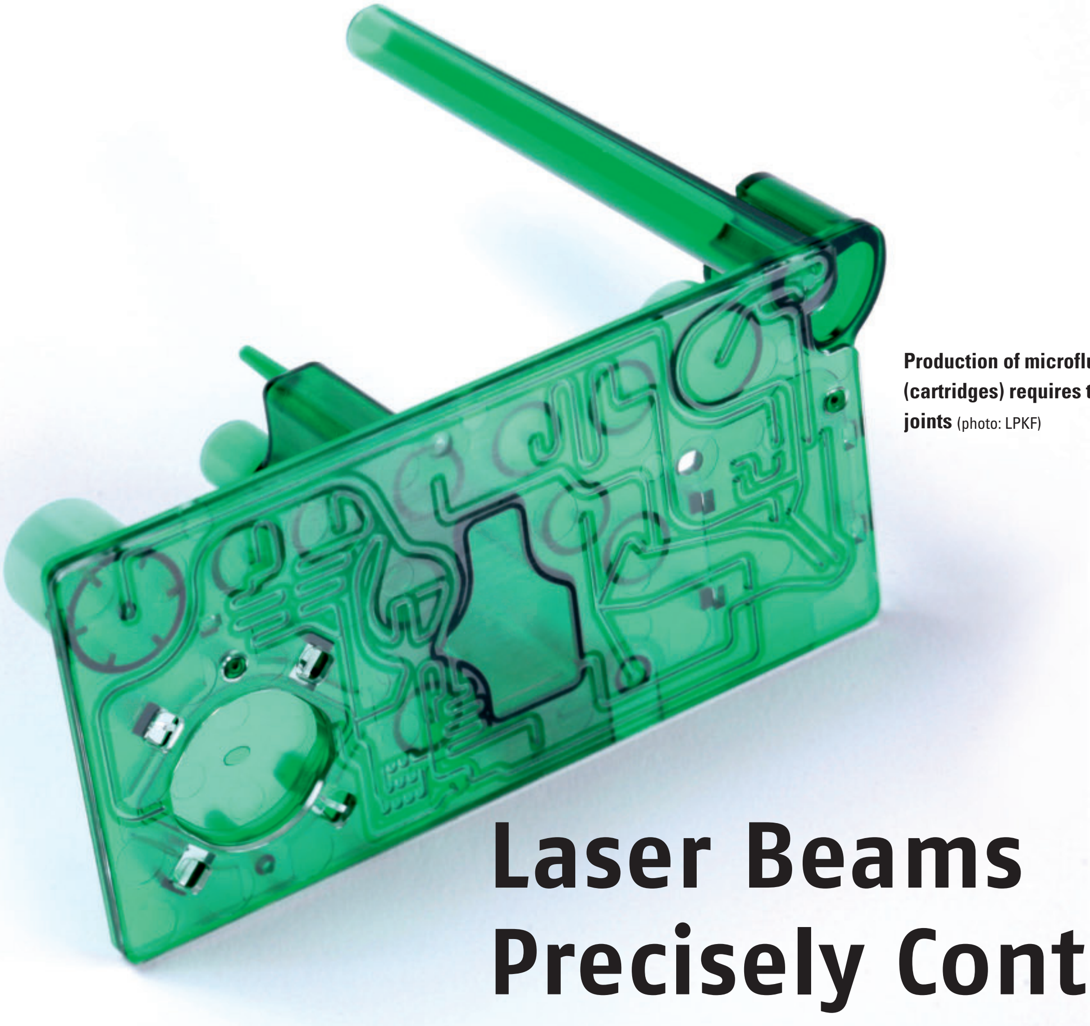

Production of microfluidics components (cartridges) requires the finest welded joints (photo: LPKF)

Laser Beams Precisely Controlled

Welding. Previously mainly diode lasers were used as beam sources for welding plastic. The spectrum of plastic welding has been expanded enormously thanks to advances in the field of fiber lasers.

FRANK BRUNNECKER ET AL.

Fiber lasers have found a permanent place in materials processing, telecommunications and spectroscopy as well as in medical engineering. Essential to the success of fiber lasers is the development of special glass fibers. Due to their excellent beam quality, fiber lasers are alongside of the diode laser as complementary sources.

Function of the Fiber Laser

The fiber laser is a type of solid-state laser in which an optical fiber serves as the active medium (Fig. 1). As with other types of laser fiber lasers have an active medium, a resonator and a pump for excitation. The amplifier medium – a special optical fiber – gets its properties from doping with rare earths such as ytterbium, erbium, neodymium and thulium. It is normally optically pumped, usually by diode lasers.

Most high performance fiber lasers are based on a fiber core with two envelopes (double clad fibers). The doped fiber core is used for reinforcement. The coherent fiber laser light propagates along the fiber core.

The outer coating adds additional energy to the fiber. The pump light necessary for stimulation is inserted along the inner mantle. It interacts with the doped fiber core and leads to strengthening of the fiber laser (Fig. 2). This configuration allows conversion of the multi-mode radiation of the pump light (typically from diode lasers) into single-mode radiation from the fiber laser. The beam quality of the optical system is thus improved.

The pump light is coupled to the inner mantle and guided by the fiber geometry. There is efficient interaction with the doped inner core. The fiber core in the form of a thin wave guide has a lower refractive index than the inner coat. This

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Fig. 1. Fiber laser welding module for plastic compounds (photo: nLight)

structure enforces the very high beam quality of the actual fiber laser. It ensures focus on a very small focal spot at a low angle of incidence.

The advantages of fiber lasers over conventional laser systems are:

- Flexible beam guiding. Since the light is already in a fiber, it can be simply focused on the work piece to be machined with a dynamic focusing element.
- High output power. Performance levels up high in the kilowatt range have been demonstrated.
- High beam quality. The waveguide properties allow focusing the light on a diffraction-limited spot.
- Compact design. Fibers are naturally very flexible. Even long active fibers can be wound on small sized spools (coiling).
- Reliability. Fiber lasers are mechanically robust structures, extremely reliable and provide maintenance-free operation over the entire lifetime of the product.
- Efficiency. The high power efficiency of the lasers leads to low operating costs over the entire life span.

In relation to various performance criteria fiber lasers proved superior to competing technologies. The beam quality of the fiber laser is nearly diffraction-limited. The result is a beam parameter product (BPP) of less than 0.5 mm-mrad, so it is much better than diode-pumped solid state lasers, CO_2 lasers and direct diode laser technology. With regard to efficiency and cost – including follow-on costs – fiber lasers are superior to conventional lasers. Yet the application always determines the choice of the most suitable type of laser (Table 1).

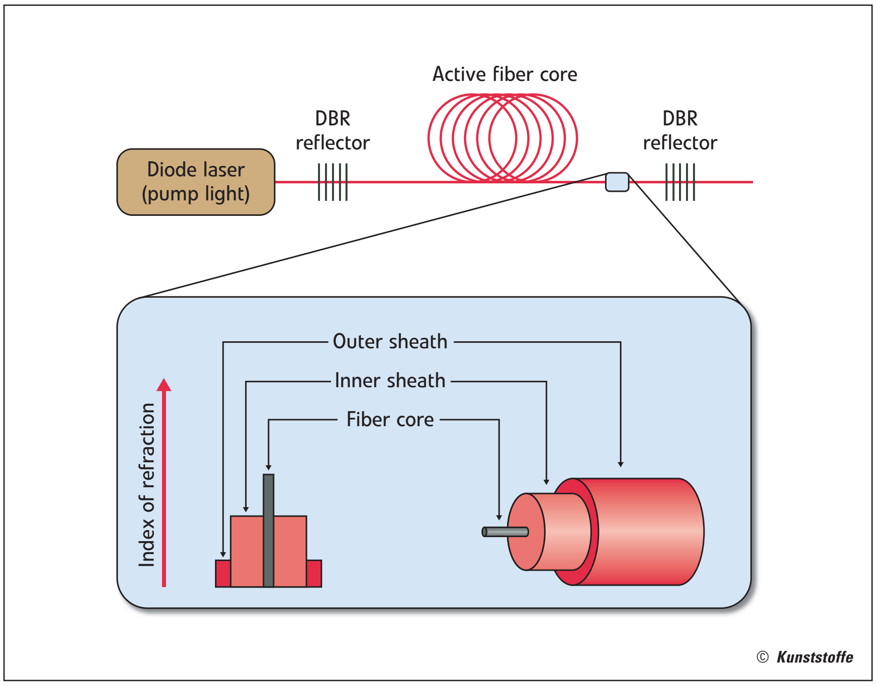

Fig. 2. Principle design of a fiber laser and the internal structure of the active fiber. The diode laser module provides the pump light while the DBR gratings (mirror) define the longitudinal resonator cavity (figure: nLight and Optotools)

For the Finest Seams

Until now mainly fiber-coupled diode lasers have been used for laser welding of plastics. This is due to the high energy efficiency compared to conventional solid-state lasers such as NdYag lasers as well as the beam profile sufficient for most fields of application. However, diode lasers encounter limits when it comes to very fine seams. Thus great effort is needed to produce a very small spot diameter with corresponding energy density with a diode laser. For fiber lasers this is readily available due to the high beam quality.

The application fields of the fiber laser in conjunction with laser welding of plastics are many and range from automotive technology to the consumer area. Wherever thin welds are required for functional reasons or as a design component, the fiber laser is the answer.

The production of microfluidic components for medical devices (Title photo) is a special example of the potential applications of fiber lasers in conjunction with laser welding of plastics. At Medtec Europe 2009 in Stuttgart, Germany, LPKF Laser & Electronics AG presented a specialized plastic welding machine for the manufacture of microfluidic components (Fig. 3). A powerful fiber laser is integrated into this apparatus to produce ▶

Fig. 3. The compact laser welding system of type LQ-MF Vario is designed specifically for microfluidics and medical applications (photo: LPKF)

	Ytterbium-doped fiber laser	Diode-pumped solid stateYAG	CO_2 laser	Direct diode laser
Beam quality at 100 W [mm-mrad]	< 0.5	0.5–1	10	10–20
Efficiency	35 %	25 %	10–15 %	50 %
Cost [EUR/W]	165	55	40	80
Wavelength	1.1 µm	1.06 µm	10.6 µm	0.8–1.06 µm

Table 1. Comparison of performance of ytterbium-doped fiber lasers (Yb doped), YAG lasers, CO_2 lasers and direct diode lasers (OEM Modules) (source: nLight and Optotools)

welds in the micrometer range. In the contour welding process the laser is moved with one rotation per weld over the parts to be joined. In this application seam lengths of several meters are not uncommon. Optimal geometry-based clamping techniques and carefully chosen process parameters such as laser power and speed make for a stable welding process.

The process surveillance capabilities are similar to those when using a diode laser. This is where tools such as burn detection (detection of burns caused by foreign inclusions in the polymer and impurities) or pyrometry or camera surveillance and a joint holder are used.

Another area of application for fiber lasers is so-called clear-clear connections. There are two identical polymers joined together. Through precise injection of laser energy from fiber lasers into the weld surface both parts reach the molten state only there. Due to the clamping pressure polymer chains diffuse into the opposite joint part and a continuous material connection is achieved. Thus laser absorbing additives are eliminated in the plastics laser welding process – an important criterion in medical diagnostics.

Fiber lasers expand the application range of laser plastic welding enormously. The hygienic and particularly gentle process will continue to gain market share and replace traditional joining methods. ■

THE AUTHORS

DIPL.-ING. FRANK BRUNNECKER, born in 1977, is director of the division of plastic welding at LPKF Laser & Electronics AG, Erlangen, Germany.

RENÉ GEIGER, born in 1976, is a development engineer in the division of plastic welding at LPKF, r.geiger@lpkf.de

STEFFEN REINL, born in 1972, works as a sales manager at Optotools GmbH, Heilbronn, Germany; steffen.reinl@ optotools.de

KIRK PRICE, born in 1977, is product development manager at nLight Photonics, headquartered in Vancouver, Washington, USA; kirk.price@nlight.net

Contact: info@laserquipment.de