Laser transmission welding of Covestro thermoplastics

Increasing use is being made of laser transmission welding to join plastics parts, especially in the field of electronic housings, sensor housings and small containers for liquids. These are precisely the types of applications in which laser transmission welding offers the greatest advantages over other forms of plastics welding.

These advantages include a highly localized heat-affected zone with low heat input plus total freedom from fuzz. The parts being joined are not subject to any mechanical loading and, compared with ultrasonic welding, laser welding offers greater design as well as tight welds, including on large-sized parts with long welds.

Process description

The laser beam passes through the part being joined that is transparent to the beam and arrives at the absorbing part. There, the laser beam is converted into heat through absorption, leading to plasticization. Through the local volume increase that results, contact with the transparent part is established over the full joining surface, and the transparent part is then also plasticized via thermal conduction. This completes the welding of the two parts, which are held in place by a fixing unit (Fig. 1).

The process requires the parts to not only have the standard mechanical, rheological and chemical properties for welding; they also must meet special optical requirements.

The part facing the incident laser beam should have the highest possible transparency in the wavelength range used by the laser source. In addition to this, its reflection and absorption should be as low as possible. The second part must have a high absorption as well as a low level of transmission and reflection. Absorption must not be too high, however, since this will otherwise lead to no more than surface heating. Surface heating will not create any notable volume of melt and can easily cause the plastic to burn. A certain volume absorption is thus required so as to form a cushion of melt, which in turn requires the laser beam to penetrate to a certain depth. The level of absorption should therefore not be too close to 100 % (Fig. 2).

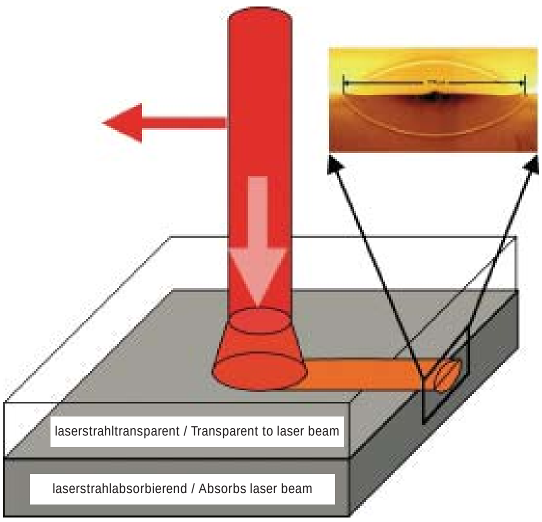


Fig. 1: Principle behind the process, taking the example of contour welding

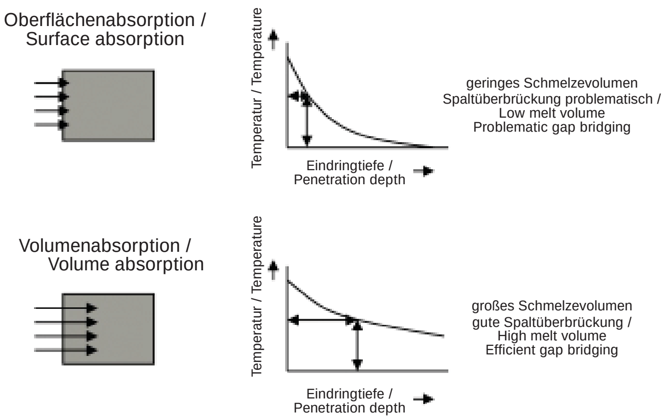


Fig. 2: Absorption behavior of plastics for laser welding

Diode lasers and Nd:YAG lasers are used for the laser transmission welding of plastics. The most important distinguishing feature of these laser types is the wavelength, which is 808 nm, 940 nm or 980 nm in the case of the diode laser and 1064 nm in the case of the Nd:YAG laser. This leads to a number of specific differences in their application, as described below.

The following process variants can be assigned to the basic process principle in Fig. 1:
– contour welding
– simultaneous welding
– quasi-simultaneous welding
– mask welding

In all these variants, the two or more parts being joined are held together by means of an appropriate fixing unit prior to the welding operation.

Contour welding

In contour welding (Fig. 1), the laser beam is run along the joining seam so that local plasticization results. The laser can be moved with a range of different systems:
a) The laser beam is coupled into an optical waveguide which is fixed onto a robot arm.
b) The parts to be joined are fixed to a biaxial table and moved under a stationary laser beam.
c) The laser source is moved by means of a biaxial positioning unit over the parts to be joined.

Since plasticization takes place on a highly localized basis, the precision of the parts to be joined is particularly important. With this process variant, only very small gaps can be bridged with the heat-induced volume increase that results in the absorbing part. The standard travel speeds are between 5 and 100 mm/s as a function of laser power (10 to 100 W currently in use), the material and the wall thickness. The system can be employed very flexibly and is particularly suitable for small or frequently-changing contours.

Simultaneous welding

In simultaneous welding (Fig. 3), laser diodes are positioned above the entire course of the weld seam. This means that the entire seam can be irradiated and plasticized simultaneously.

If the welding unit is equipped with a displacement measuring facility, a defined joining displacement makes it possible to offset tolerances (gaps) between the parts being joined. The welding time is independent of the weld seam length and is between 1 and 5 s depending on the power of the laser. Setting up a system of this type is time-consuming and, depending on the number of diodes required, can be quite cost-intensive. There are limits to the radii and three-dimensional contours that can be formed. In addition to this, a new diode holder is needed for each new component.

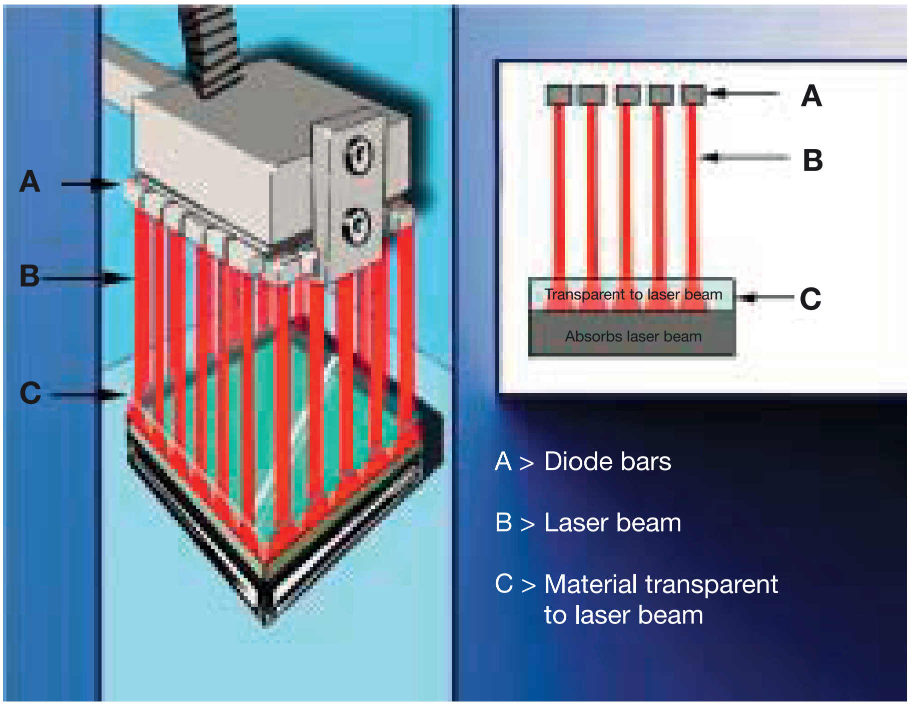


Fig. 3: Principle behind simultaneous welding

Laser diode bars above contour

Entire weld seam irradiated simultaneously

Short process time

Only very large radii possible

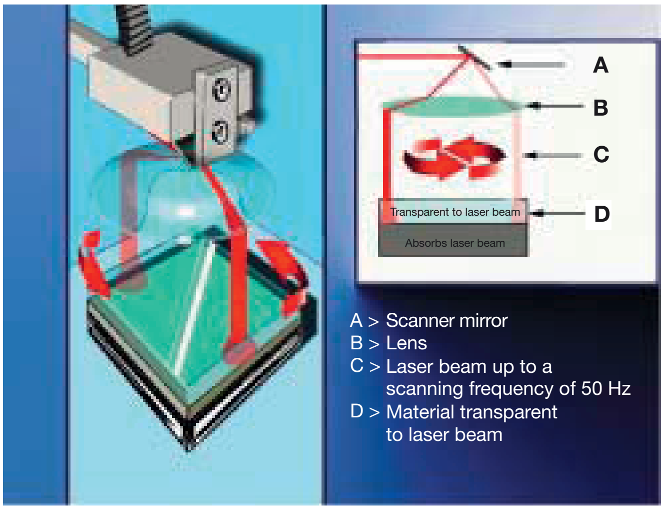
Time-consuming and inflexible setup, for large series only

Welding displacement possible to offset tolerances

Quasi-simultaneous welding

With quasi-simultaneous welding, the entire joining surface is also plasticised at “quasi” the same time. In this case, deflection mirrors are used to guide the laser beam over the surface to be joined at a frequency of up to 50 Hz, a method similar to that used in laser marking. This results in virtually uniform heating of the absorbing material.

With the appropriate set-up, it is possible (in the same way as for simultaneous welding) to offset tolerances with the aid of a joining displacement. Quasi-simultaneous welding will also permit three-dimensional weld profiles and radii to be achieved with virtually no restrictions, since adjustable optics permit height compensation. Because of the high laser capacities of considerably more than 100 W that are required and the stipulation of highly accurate focusing, preference is given to Nd:YAG laser sources here.



Scanner mirror deflects laser beam

Weld seam irradiated in its entirety

Short process time

Welding displacement possible to offset tolerances

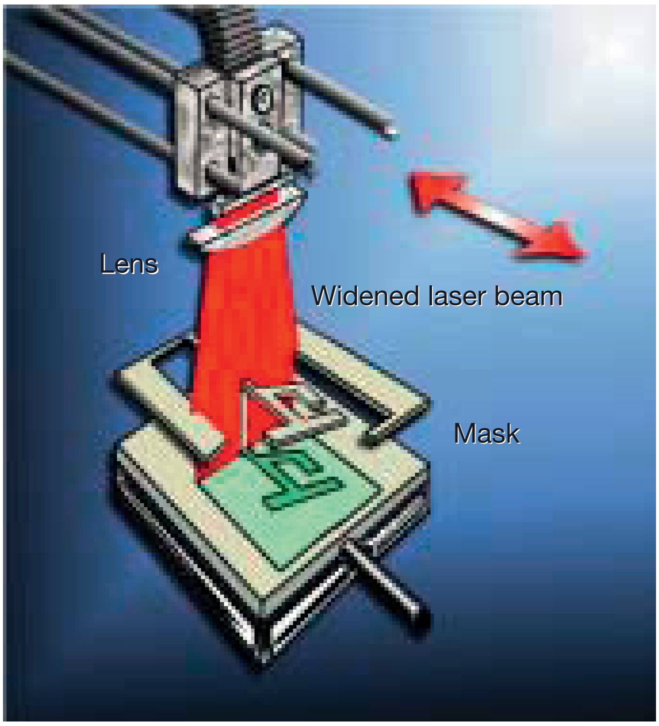
Flexible set-up

Fig. 4: Principle behind quasi-simultaneous welding

Mask welding

In the mask welding process, a laser beam is extended rectangularly far enough to produce a line that can irradiate the entire component width. To ensure that only the weld seam is plasticized, a so-called mask is placed between the radiation source and the component. The mask lets the beam through only in the region of the seam. The laser-beam line is then guided over the part, causing plasticization at the joining surface.

This means that very small contours and narrow weld seams are possible. The type of tolerance compensation possible with contour welding is not feasible in this case.



Laser beam in line form

Entire component width covered

Very small weld width possible

Very small parts with tolerance requirements possible

Problems in gap bridging

Stringent requirements for mask accuracy

Fig. 5: Principle behind mask welding

Influence of the material

When joining parts, there is the question of the uniform visual appearance of the welded component as a whole. While this is not a problem with respect to color for the welding methods used to date, laser transmission welding is problematic in this regard. On the one hand, high transmission is required in the near infrared range, yet on the other hand, identical coloration must be displayed in the visible light range. Figure 6 shows the wavelength ranges of relevance for laser welding.

It is extremely difficult to make a statement on the suitability of specific materials or colors for laser transmission welding, since it is necessary to take into account the distinction between a transparent and an absorbent material, as well as the fundamental influence of the material employed and the wall thickness of the transparent part. Completely different requirements apply in each case. The following experience has been gained so far:

- Colored grades with titanium dioxide tend to display pronounced reflection and are thus not easy to melt.
- Red shades frequently have high transparency due to the proximity of the wavelength to the IR radiation.
- Black materials filled with carbon black have high absorption. The percentage content of carbon black must not be too high, however, since this otherwise poses a risk of purely surface heating.
- Fillers such as glass fibers frequently have a scattering effect that reduces transmission and increases absorption.
- Case-by-case investigations are still essential at present for special colors and filler contents.

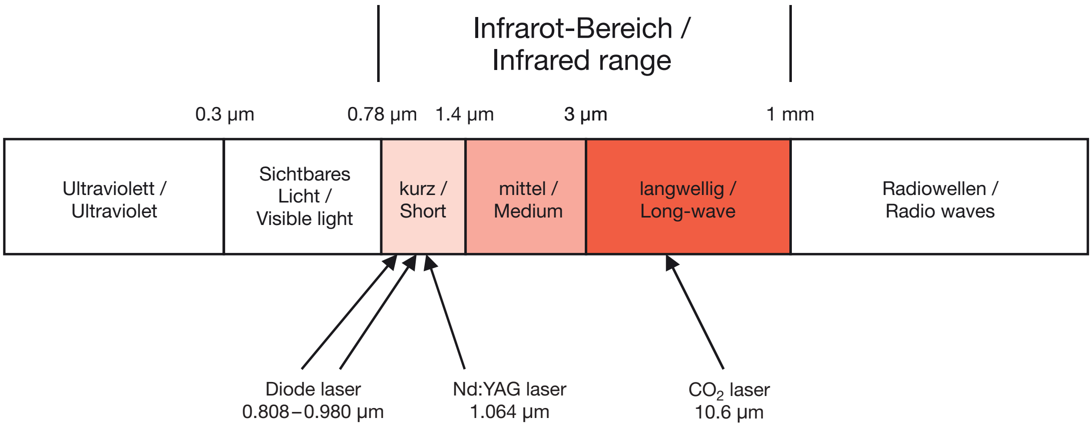


Fig. 6: The wavelengths of laser beam sources

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