Modular Solutions for Laser Plastic Welding

precise & concise
clean & green

Plastic parts for welding show a large variety of forms and geometries. To cope with this variety and to meet a wide diversity of customer preferences, our machines are designed in a strictly modular way. The Turnkey machines are configured in our modular design framework according to your requirements. Therefore they are precisely adaptable to the processing of your plastic parts.

All lasers, optics, clamping units, and motion systems from our Modula product portfolio (see page 5-9) are available in the Turnkey systems.

A drawer or rotary table can be selected for the part handling in and out of the machine. With some customer-specific modifications also conveyor systems can be integrated to the Turnkey machines. Our Turnkey machines are delivered fully ready to use. They only need to be connected to an electric power source, and depending on configuration, to compressed air.

Turnkey S

The Turnkey S is the smallest version of the Turnkey machines. It can be set up on a normal work table. Despite its compact design, it is built up in a modular way and can be equipped for all different plastic welding processes with the Modula components. Control system, laser, and cooling are placed in the cabinet on the back side. No separate laser unit is needed.

The welding process can be set up and observed on the touchscreen user interface. Keyboard and mouse can optionally be connected to USB ports on the front of the machine. At the backside, an HDMI port allows the connection of a larger monitor.

For the welding process a small lifting door is opened. For setting up the welding process and for maintenance the complete front cover can be raised providing good access to all components. The drawer for part handling as well as the lifting door can be actuated manually, pneumatically, or electrically. A rotary table is available in both manual or electrical versions.

The Turnkey S can be connected to a local computer network by an Ethernet interface on the backside of the machine. Process data and welding recipes can be both uploaded and downloaded as needed by the user. A secure internet connection can be established for remote services and maintenance.

Configuration shown
- scanner optics
- laser power 200 W
- rotary table
- pneumatic clamping
- pneumatic lifting door

Technical data

Welding area	axes 150 x 100 mm scanner 100 x 100 mm
Laser power	30-200 W
Wavelength	980 nm / 1070 nm / 1725 nm / 1940 nm
Laser class	1 (red pilot laser 2)
Clamping force	2300 N
Stroke distance	20 mm, extendable on request
Drawer	manual, pneumatic, or electrical
Rotary table	diameter 300 mm, manual or electrical
Lifting door	300 x 140 mm, manual, pneumatic, or electrical
Cooling	air (IP20, filter mat)
Ambient temperature	35/40 °C – depending on laser power and duty cycle
Electrical supply	100-240 V, 50/60 Hz, <10 A
Dimensions	520 x 700 x 565 mm, with lamp tower 780 mm
Weight	60-75 kg depending on configuration

Configuration shown
- radial optics
- laser power 40 W
- manual drawer
- pneumatic movement radial optics
- pneumatic lifting door

Configuration shown
- spot optics advanced with pyrometer
- xy axes
- laser power 40 W
- pneumatic clamping
- pneumatic drawer & lifting door

Turnkey M

The Turnkey M is a ready-to-use machine for larger components (up to half a meter). It is designed as a workstation that can be operated in a standing or sitting position. Like the Turnkey S, it has a modular design and can be configured in different versions to suit the workpieces to be welded as well as the customer's requirements.

The laser and the control system are located in the lower part of the Turnkey M, so that in the upper part the welding area with clamping unit, motion system, and optics can be optimally accessed. For setting up the welding area can be reached from the large side doors or from the rear door. All the doors are monitored for safety. The electrical cabinet at the rear side of the lower part of Turnkey M is accessible with two small wing doors and is laser-safe seperated from the welding area. The laser itself in the lower part of the machine is accessible through the lower side doors on the left and right. For welding, only the lifting door at the front is opened and closed.

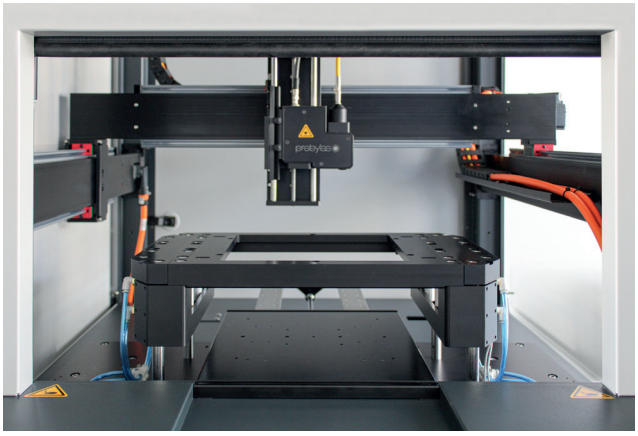
The welding process is set up on the touch screen, which can be tilted according to the height of the operator. A keyboard and mouse can optionally be connected via the USB ports in the operating table.

The drawer for the workpieces and the lifting door can be operated either manually, pneumatically or electrically. The rotary indexing table is available in manual and electric versions.

For connection to a local area network (LAN), the Ethernet interface on the back of the Turnkey M can be used to transfer process data to a server or for remote maintenance via the Internet.

Configuration shown

- spot optics advanced with pyrometer
- laser power 40 W
- xyz axes
- pneumatic clamping
- pneumatic drawer & lifting door



Large welding area up to 470 x 470 mm maximum with axes system including vertical z-axis and large clamping unit.

Electrical cabinet at the back of Turnkey M cooled by air and with two wing doors. Electrical and pneumatic supplies are situated at bottom below electrical cabinet.

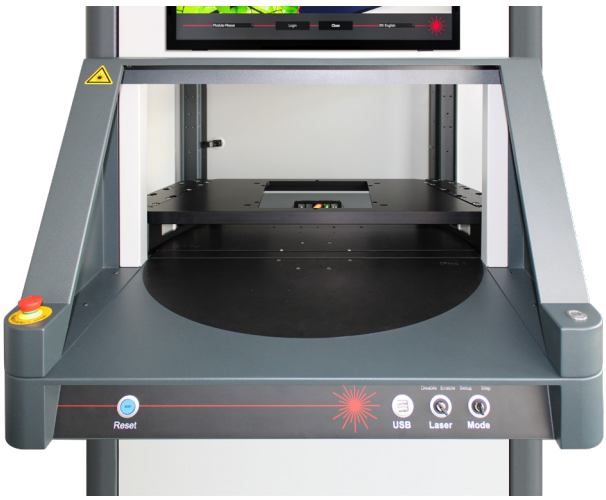
Technical data	
Welding area	axes 470 x 470 mm, scanner 350 x 350 mm
Laser power	30-200 W
Wavelength	980 nm / 1070 nm / 1725 nm / 1940 nm,
Laser class	1 (red pilot laser 2)
Clamping force	up to 7000 N
Drawer	manual, pneumatic, or electrical
Rotary table	diameter 650 mm, manual or electrical
Lifting door	650 x 400 mm manual, pneumatic, or electrical
Cooling	air (IP20, filter mat)
Ambient temperature	35/40 °C – depending on laser power and duty cycle
Electrical supply	100-240 V, 50/60 Hz, <10 A
Dimensions	880 x 1200 x 1950 mm with drawer 880 x 1250 x 1950 mm with rotary table with lamp tower 2170 mm
Weight	about 300 kg depending on configuration

USB ports for memory stick or additional peripherals like mouse or keyboard.

Configuration shown

- scanner optics
- laser power 200 W
- pneumatic clamping
- rotary table
- pneumatic lifting door

Good accessibility to welding area with clamping unit, optics, and motion system by the large side doors.



Large rotary table with wide opened lifting door and clamping unit in the inside position of the rotary table.

For integration in special-purpose machines we offer the same modules separately as you can find in our Turnkey machines. We also provide the necessary support for your internal machine building department or for an external specialist. Laser units and optics are required for any integration. Additionally, we supply clamping units and motion systems. With all relevant modules coming from ProByLas, they can seamlessy work together of an optimal welding process. The machine building department or an external special machine builder only needs to ensure sufficient enclosure including safety and part handling both in and out of the machine.

Laser

The laser unit is the central component of the Modula product family. Besides the laser itself, it is also comprised of the system control, interfaces, and control elements.

On the touch-screen, the welding process is set up and observed during operation. Optionally a keyboard and mouse can be connected to the USB ports as well as a larger screen to the HDMI port on the backside.

The connections for other Modula components as well as the interface for automation carried out by digital and analog inputs/outputs are located on the backside of the laser unit. The safety controls for emergency stop and two-channel interlock can be configured in different ways allowing integration up to the highest Performance Level e according to EN13849 standard.

Technical data

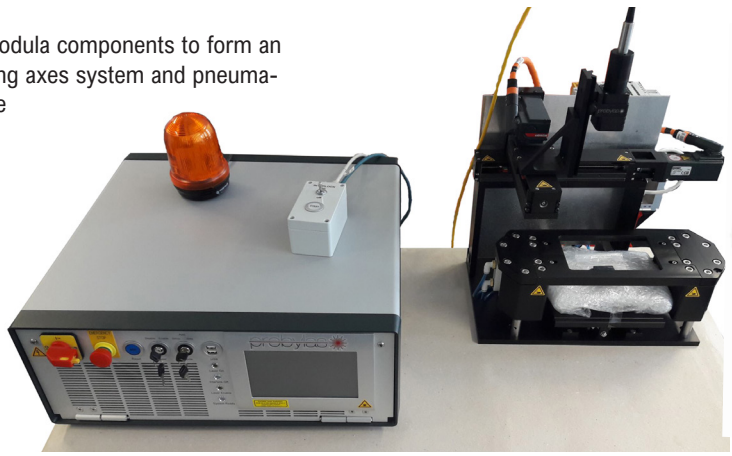
Laser power	30-200 W
Wavelength	980 nm / 1070 nm / 1725 nm / 1940 nm
Laser class	4 (red pilot laser 2)
Air cooling	Protection class IP20 or IP30, optionally with filter mat
Ambient temperature	35/40 °C – depending on laser power, type of air cooling, and duty cycle
Electrical supply	100-240 V, 50/60 Hz, <10 A
Connectivity	Ethernet RJ45 on back side
Dimensions	520 x 430/530 x 215 mm depth depending on configuration

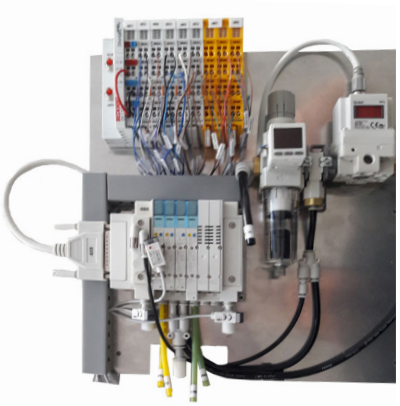
Front view with air vent slots IP30 and pivoting legs

Connections on back side of Modula laser unit

Example of a combination of Modula components to form an open laboratory system including axes system and pneumatics, which are controlled by the Modula laser and control unit.

Configuration shown
- laser power 200 W
- line optics 40 mm long
- xy-axes system
- pneumatic clamping
- pneumatic drawer
- warning lamp





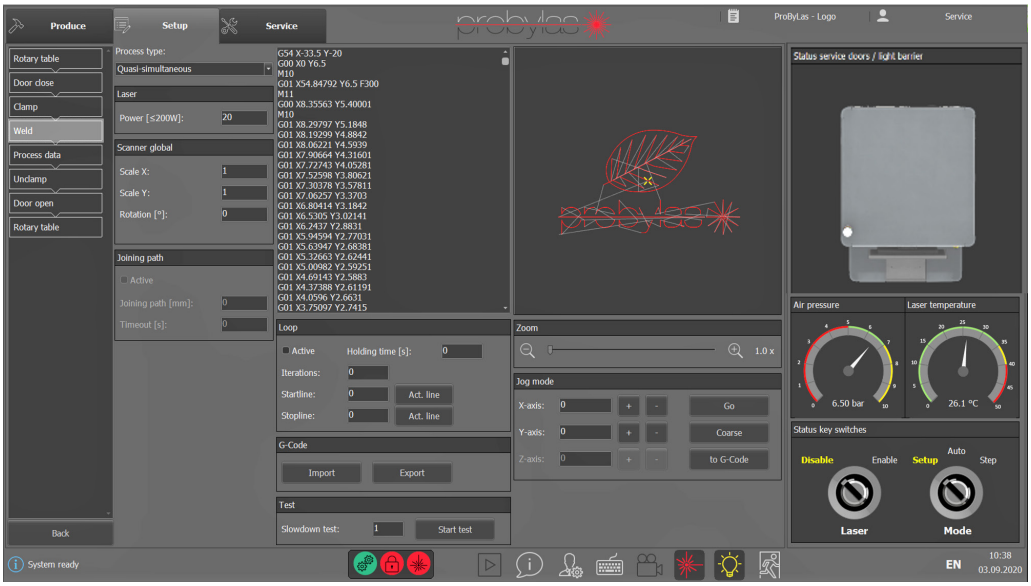
pneumatic cluster on backside

Human machine interface

The user interface can be displayed on the small 7-inch monitor or a separate large monitor plugged into the HDMI connector on the rear. With a larger monitor, an additional column is displayed on the right compared to the small display (see below).

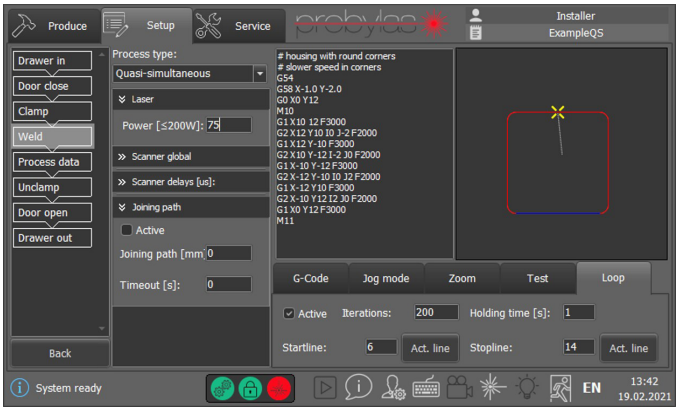
For operation of the user interface 3 different levels of users with independent password can be selected:

- Operator to produce parts
- Installer to set up recipes
- Service for maintenance



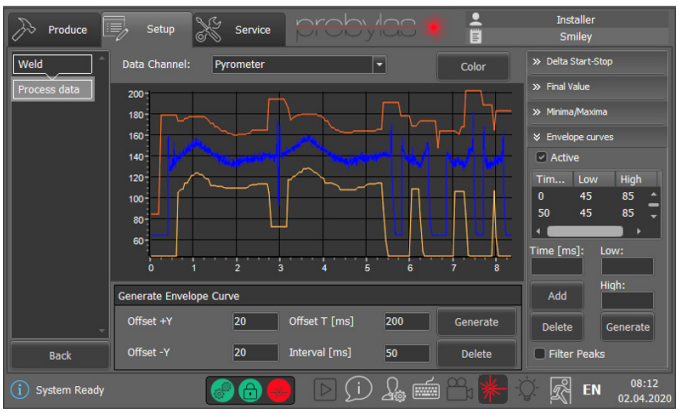
Set up welding recipes

Users who are logged in as “installer“ can create welding recipes as a sequence of single process steps, which are displayed in the left column. The individual process steps are displayed in the main area when selected. In the process step different welding parameters can be selected and set.
The contour for the axes or scanners is programmed as G-code or imported from an external source. The contour is displayed in the right graphic with different colors for movement: without laser in white, with laser in red, and current line of the G-code in blue. Also the current position of the laser is marked with a yellow cross.
Created recipes can finally be released for production.



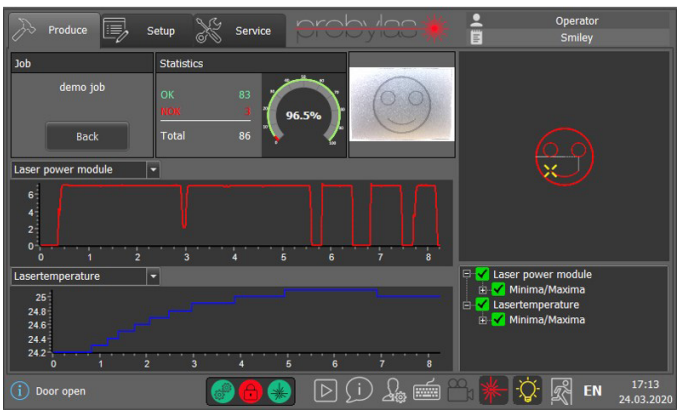
Evaluate and save process data

In the process step, Process Data, the different data channels of measuring sensors can be selected. The individual data channels can be released for the production view and the data recording can be activated.
Various options for evaluating the process data can be selected in the right-hand column, depending on what is most suitable for this data channel. For example, minimum and maximum values can be set for collapse in simultaneous or quasi-simultaneous process type. For pyrometers, envelope curves can be defined for which the measurement signal must stay in between.



Production view

Users who are logged in as “operators“ can only see the production view. They can create and select jobs based on recipes released by the installer. The individual jobs can have a specific batch size or be unlimited.
The production view shows the welding contour with the current position of the laser as well as an evaluation of the previous welds in the same job.
The operator can select two curves of released process data for observation. The created process and quality evaluation is also displayed. In the event of a bad part, the evaluation must be acknowledged before production can continue.



Optics

Similar to the machines, the optics are designed modular as well. Besides the primary employed spot optics, other optics for specific process types can be utilized for special applications. The fiber connector module with collimation lens and the beam shaping elements are connected to the base body from the top and bottom.

Fiber connector & collimation
Depending on the type of laser, different fiber connections are needed.
The collimation lens shapes a parallel beam. With different focal lengths of the lens, various diameters of the laser beam are possible.

Optics base body
For the base body of the optics, a simple version and an advanced version with monitoring of the laser power are available.
The advanced optics can also be equipped with a pyrometer for a temperature reading (100-400 °C).

Beam shaping

Spot diameter
0.5-3.0 mm

Line length
12-60 mm

Filled square or
rectangle

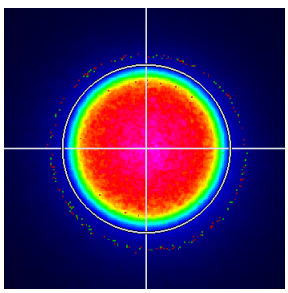
Ring
<50 mm

DOE for
any contour

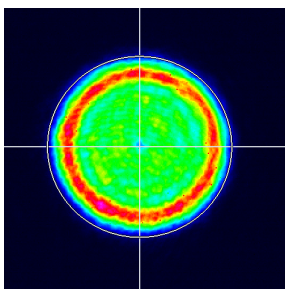
Pro-ball
spot with clamping

Camera module side-mounted on optics for setup and monitoring of welding process

Scanner optics
The scanner is a combination of optics and a motion system. Two pivoting mirrors deflect the laser beam in x- and y-direction. With the small mass and inertia of the moving mirrors, high speeds of several meters per second are possible enabling a quasi-simultaneous process type with multiple contour cylces per second.
The final focusing lens (f-theta) determines the size of the working area, which can measure 100 x 100 mm, 240 x 240 mm, or 350 x 350 mm.
If a fiber laser (1070 nm) is used with the scanner instead of the usual fiber-coupled diode laser (980 nm), other beam profiles can be generated in the working plane, such as the M-shape ideal for plastic welding.



Beam profile flat-top with fiber-coupled diode laser.

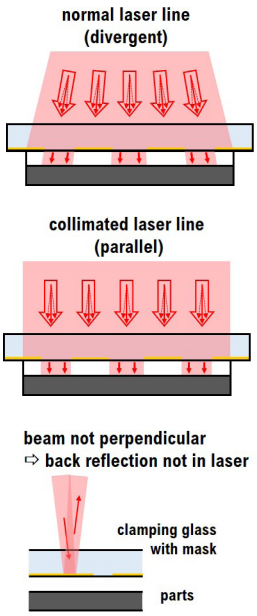


Beam profile M-shape with fiber laser.

Special optics versions

Collimated line optics

The collimated line is a special version of the line optics for mask welding. The laser line is not diverging along the direction of propagation, but remains the same length because the beams run parallel. The geometry of the shadow from the mask onto the workpiece is retained even at larger distances, so that the distortion from mask to welding plane does not have to be precorrected.



Radial optics

Radial optics allow cylindrical workpieces to be welded simultaneously on the circumference as an alternative to rotating the workpieces underneath a spot optic. It is based on a ring optics and additionally has a cone mirror, which reflects the laser beam from the outside to the inside. The workpieces are inserted from bottom into the radial optics

Instead of a clamping unit, a press fit contact must be ensured between the workpieces.

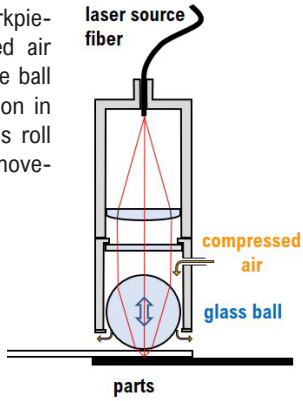
Open radial optics with workpiece and sketched laser beam for lab.

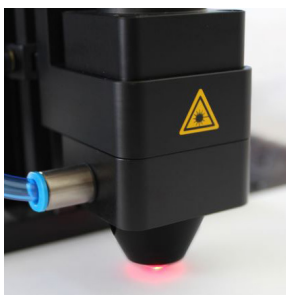
Standard radial optics with closed cylindrical body.

Pro-ball optics

The pro-ball optics allows welding of workpieces without a clamping unit. Typically these applications are flexible foils or technical textiles.

The glass ball focuses the laser beam on one hand and presses the workpieces together by the compressed air behind the ball on the other. The ball moves freely in the air suspension in the cylindrical shaft and can thus roll over the workpieces with the movement of the pro-ball optics.

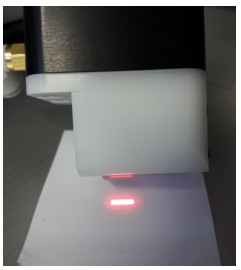


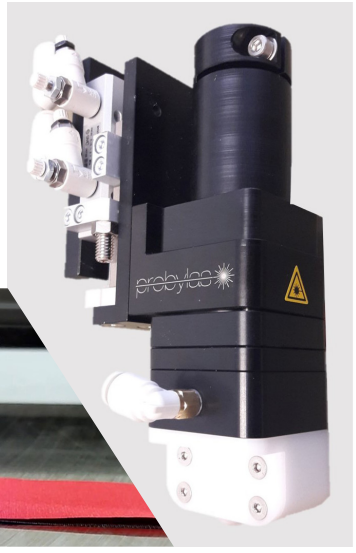


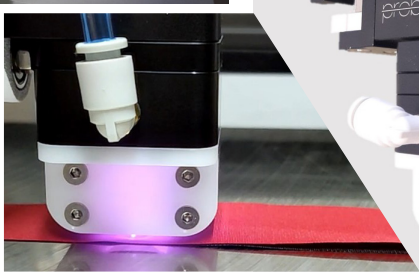
Pro-wheel optics

The pro-wheel optics has a similar design as the pro-ball optics and also a similar application area for foils or technical textiles. The glass wheel can rotate freely in the air bearing during movement and presses the workpieces together.

The laser is formed into a short line that hits the workpieces in the pressure area of the wheel, so that wider weld seams can be produced than with the pro-ball optics. On the other hand, the direction of movement of the pro-wheel optics is limited to straight. Tight curves as with the pro-ball optics are not possible.







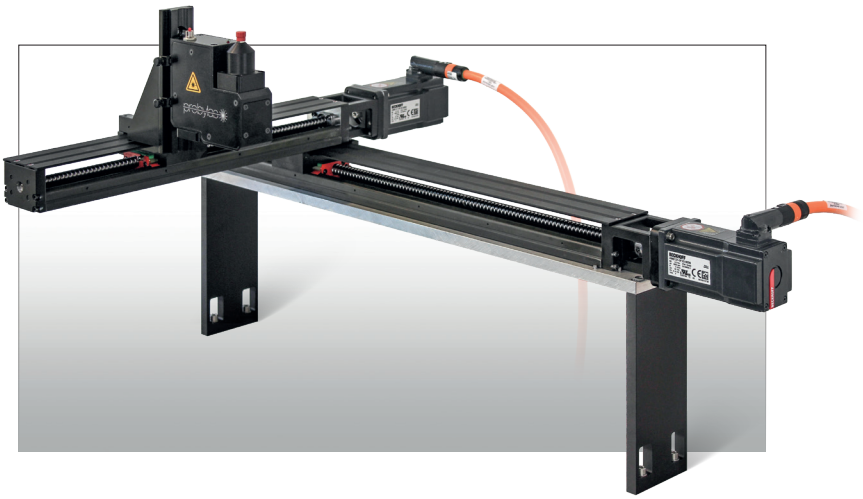
Motion

In order to track the weld contour with the laser beam there are different options of which are closely related to the type of welding process used.

xyz-axes
The optics above can be mounted on an axes system driven by servo motors. Depending on the geometry of the parts and on the welding contour, a single axis may be sufficient or an x-, y-, and z-axis may be combined. The motion control of the axes (numerical control, NC) is integrated in the laser unit.

Rotation axis
For welding the circumference of a cylindrical part, a single servo motor is employed. It can also be combined with a translational axis e.g. along the length of the cylindrical part.

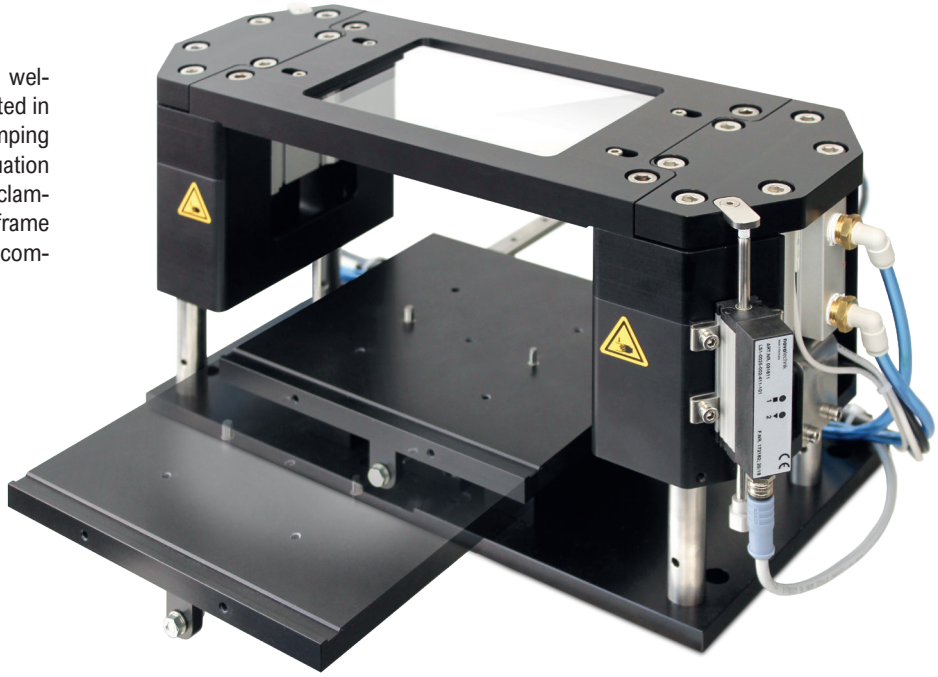
Scanner
The scanner is a combination of optics and motion system and is described in more detail on the previous pages of the optics. With the scanner very fast speeds are possible at several meters per second, as the movement is driven by deflecting mirrors with a small mass and inertia.



Clamping unit

The clamping unit presses the workpieces to be welded against one another. The workpieces are inserted in part-specific cavities on the drawer. The upper clamping plate moves down by pneumatic or electric actuation and presses the workpieces together. The upper clamping tool can be a transparent glass plate, a metal frame with part-specific cutouts for the laser beam, or a combination of both.

For process and quality control the clamping unit can be equipped with travel or force sensors. The clamping travel can be monitored with the distance measurement. In simultaneous or quasi-simultaneous process types, the travel during welding can also be measured, analyzed, or used for direct process control.



Technical data	small clamping unit	large clamping unit	extra-wide clamping unit
Maximum welding area	150 x 100 mm	240 x 240 mm	300 x 240 mm
Maximum width of workpiece	210 mm	300 mm	360 mm
Maximum clamping force	2300 N	7000 N	7000 N
Maximum clamping stroke		20 mm (extendable on request)	
Workpiece/tooling height		55 mm, extendable in steps of 20 mm	
Drawer motion		manual, pneumatic, or electrical	
Clamping actuation		pneumatic (6 bar) or electrical (servo motors)	

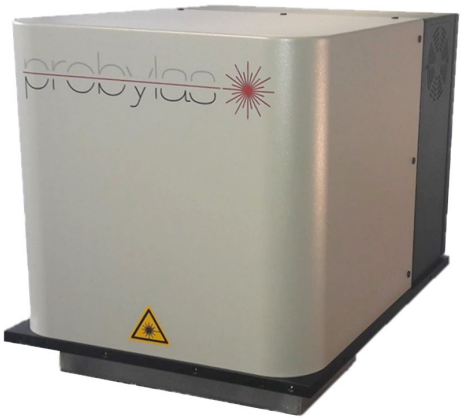
Modula Assembly Inline

The Modula Assembly Inline is a specific combination of a laser unit, a scanner optics, a special clamping unit and a housing for integration onto a transfer system or a larger rotary table. The clamping unit presses on the workpiece carrier and closes it in a laser safe manner, so that the Modula Assembly Inline can be operated without additional laser protection measures.
In addition to the scanner optics, other optics can also be mounted in the Modula Assembly Inline as e.g. for simultaneous welding.

Simple requirements for integration:

- Substructure for the processing unit supporting the employed conveyer system or rotary table that is mechanically rigid enough for the employed clamping forces.
- Workpiece carrier or tooling, which becomes enclosed and laser safe as the upper tooling and the clamping platform of the Modula Assembly Inline come together.
- Interface connection for start trigger and emergency stop signals.

Process cell - with optics and clamping unit



Modula laser and control unit - up to 4 m away from process cell

Technical data	
Welding area	100 x 100 mm
Laser power	40-200 W (wavelength 980 nm, 1070 nm)
Laser class	4 (red pilot laser 2)
Clamping force	up to 2300 N
Maximum stroke	20 mm (extendable customer-specific)
Cooling	air (IP20 filter mat)
Ambient temperature	35/40 °C depending on laser power
Electrical supply	100-240 V, 50/60 Hz, <10 A
Dimensions	Processing unit 330 x 330 x 410 mm Modula laser unit 520 x 430 x 215 mm

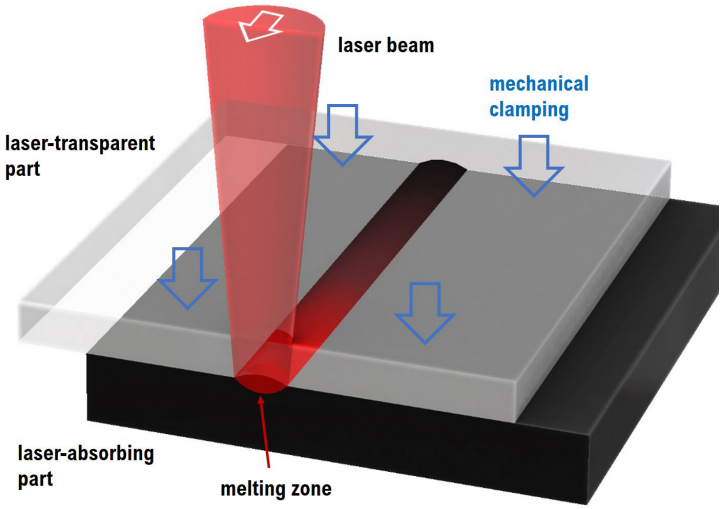
In the welding process the surfaces of two or more plastic parts are melted and pressed together so that the liquid plastic melts mix. When cooling down, the plastic melt solidifies to yield a strong bond. For welding, the plastics must melt when exposed to heat (thermo-plast). Plastics which do not melt when heated, but degrade or disintegrate, cannot be welded (thermo-set plastics).

Process of laser welding

In laser plastic welding the heat to melt the plastic is introduced by a laser directly at the weld seam. The workpieces are already pre-mounted in the final position. The upper workpiece is transparent for the laser, so that at least some part of the laser beam can propagate to the surface of the lower workpiece. This lower part absorbs the laser at the surface, heats up and melts. Due to mechanical clamping pressure, the workpieces are in contact with one another. Both the upper surface of the lower workpiece as well as the lower surface of the upper workpiece plasticize and melt. The two melts mix to yield a strong and solid bond after cooling down.

Advantages

- precisely localized
- shallow melting zone
- little energy needed
- low material strain
- no particles
- no vibrations
- no emissions
- no solvents



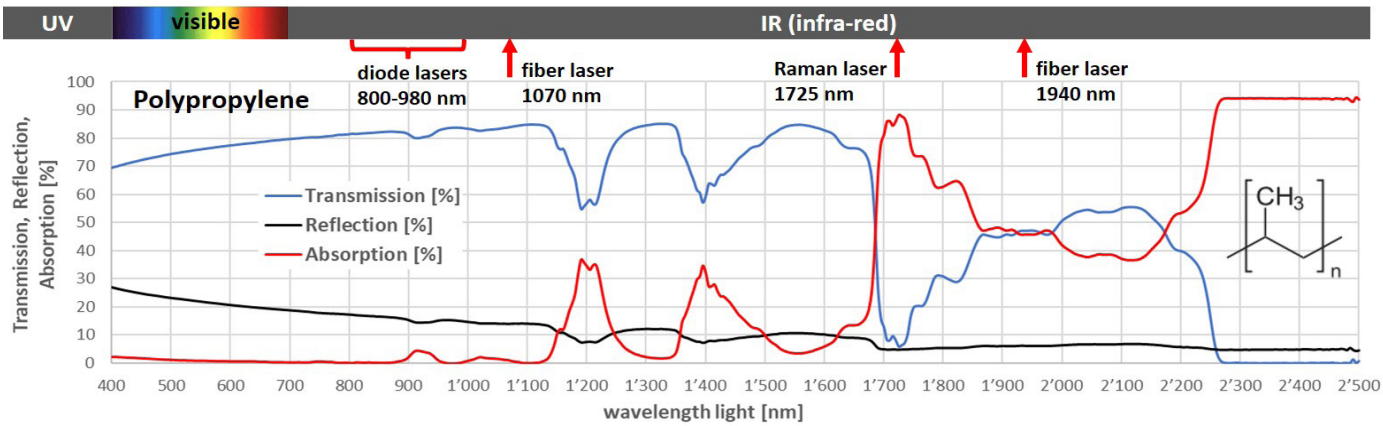
Industries

Based on its technical advantages, laser plastic welding is primarily applied in industries with high quality requirements such as

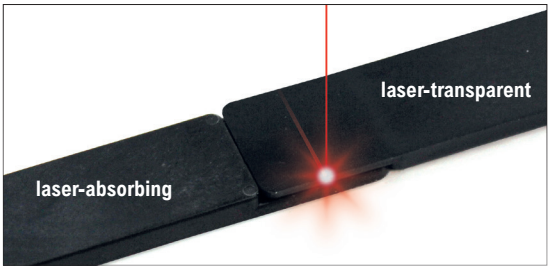
- Medical
- Automotive
- Electronics
- Consumber goods
- Technical textiles

Laser-transparent and laser-absorbing

In laser welding with the classic approach of one transparent part and one absorbent part, the laser wavelengths are in the near infrared range between 800 and 1100 nm. The vast majority of plastics have no absorption of their own in this range, but are transparent or translucent. The absorption is achieved by a colorant added to the plastic. Since the 800-1100 nm range is outside the visible spectrum, the color for the eye and absorption for lasers can be adjusted independently from one another.



Example black-black:
Plastic plate with black colorant, that is transparent to the laser, on a plastic plate that is black absorbing to the laser and eye.



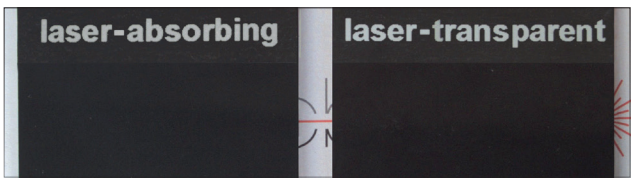


Photo with visible light

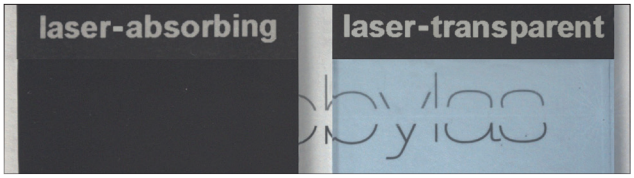
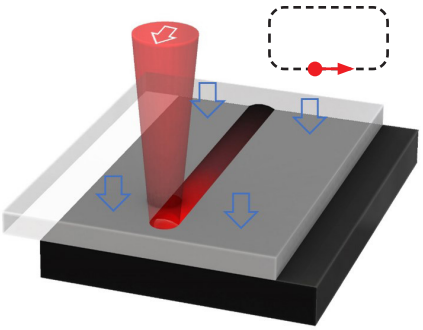


Photo with infrared light

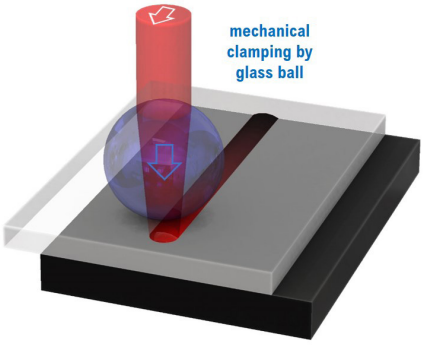
Process types laser plastic welding

There are different process types for laser welding of plastics, which are differentiated according to how the laser beam and laser energy are introduced into the workpieces. Depending on the geometry of the workpieces and the requirements of the joint, one process type may have advantages over other process types. The process types are also closely related to the type of optics and require different amounts of laser power.

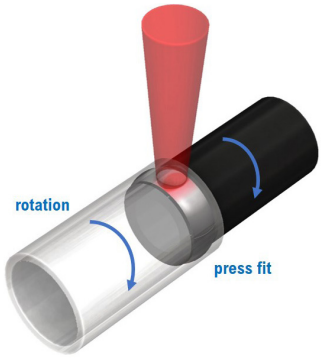
Contour process
The laser is focused to a point with a spot optics and tracks the welding contour once. The plastic melts only locally and solidifies again immediately after the laser beam has passed over the welding point.



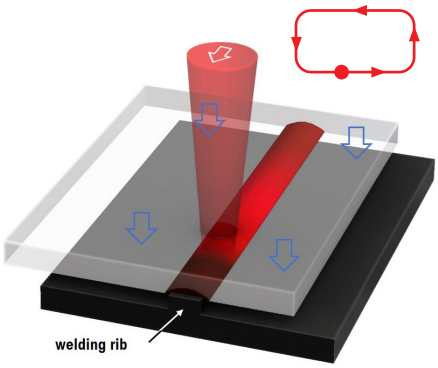
Variation pro-ball or pro-wheel
The laser is focused to a point by a glass ball or glass roller, which also compresses the components at the same time.



Variation rotation
For welding the circumference of a cylindrical part, the workpiece is rotated under the spot optics. The clamping pressure for welding is generated by an interference fit between the workpieces.

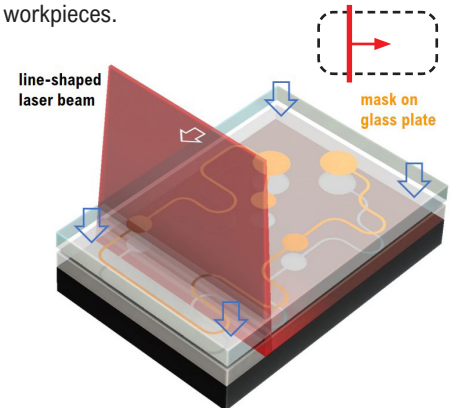


Quasi-simultaneous process
The laser is focused to a spot, which is guided over the welding contour several times per second using scanner optics. The weld seam melts along the entire contour at the same time, so that a rib can melt off.



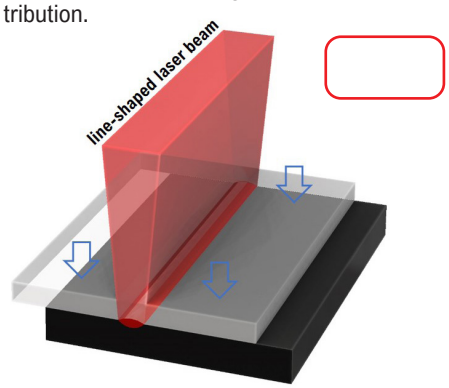
Types of welding process

Mask process
The line-shaped laser beam sweeps over the mask made of a structured reflective metal layer on a glass plate. At all points without a metal layer, the laser hits the weld seam and joins the workpieces.

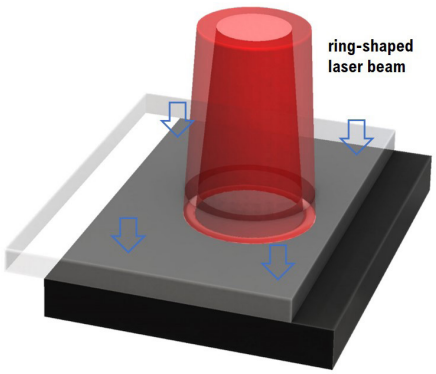


Simultaneous process
A special optics is shaping the beam in the geometry of the weld seam.

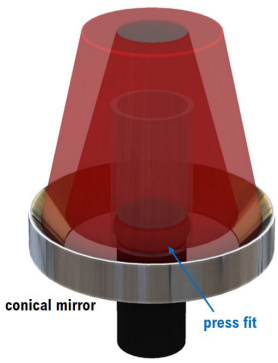
Variation line
A special optical element transforms the laser beam into a homogeneous line distribution.



Variation ring
A special optical element transforms the laser beam into a ring.

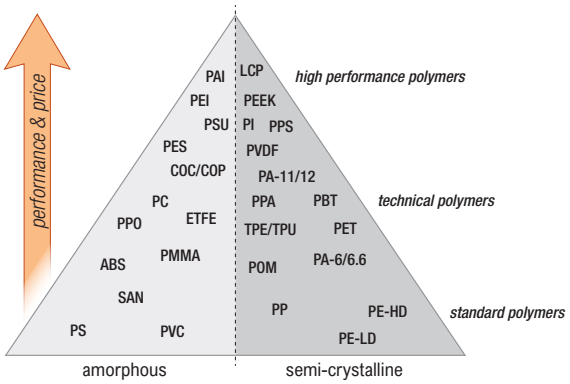


Variantion radial
Laser beam from variantion ring is deflected via conical mirror onto cylindrical parts from outside to inside.



Plastics

In general, all thermo-plastic polymers can be welded. Ideally both parts to be welded consist of the same type of polymer.
Combinations of similar polymers can be welded if the melting temperatures are in the same range and if the polymer melts mix well.



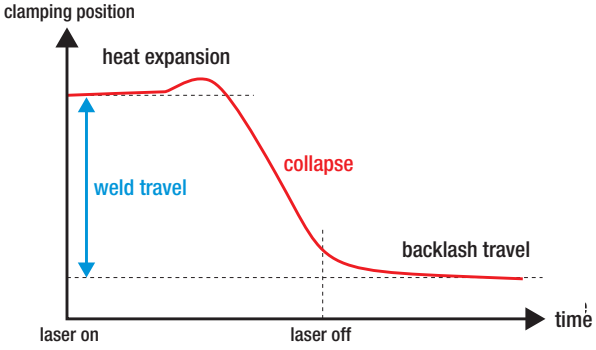
lower part	upper part	PE	PP	EP(D)M	COP	COC	PS	ABS	ASA	SAN	SB	TPU	PVC	PA6	PA6.6	PA11	PA12	PC	PET	PBT	PMMA	POM	PES	PSU	PI	PEI	PAI	PTFE	ETFE	PVDF	PEK	PEEK	LCP
Polyolefins	PE-LD/HD	■	■	■																													
	PP	■	■	■																													
	EP(D)M	■	■	■																			■	■									
Cycloolefins	COP				■	■																											
	COC				■	■																											
Polystyrene and copolymers	PS						■	■			■		■							■	■												
	(M)ABS						■	■	■	■	■	■	■					■	■	■	■	■	■	■									
	ASA							■	■	■	■	■	■					■		■	■		■	■									
	SAN							■	■	■	■	■	■					■		■	■		■	■									
	SB						■	■	■	■	■			■	■			■		■	■												
Polyurethanes	TPU							■	■	■		■		■	■			■		■		■											
Polyvinylchlorids	PVC						■	■	■	■			■					■		■													
Polyamides	PA6										■	■		■	■																		
	PA6.6										■	■		■	■																		
	PA11															■																	
	PA12																■																
Polyesters	PC							■	■	■	■	■	■					■	■	■	■												
	PET							■										■	■	■													
	PBT						■	■	■	■	■	■	■					■	■	■	■		■	■									
Polyacrylates	PMMA						■	■	■	■	■							■		■	■	■											
Polyacetals	POM							■				■								■	■												
Polysulfones	PES			■				■	■	■										■			■	■								■	
	PSU			■				■	■	■										■			■	■									
Polyimides	PI																								■								
	PEI																									■							
	PAI																										■						
Fluoropolymers	PTFE																											■					
	ETFE																												■				
	PVDF																													■			
Polyetherketones	PEK																														■	■	
	PEEK																						■								■	■	
Liquid crystal polymers	LCP																																■

■ good welding
■ possible – tests necessary
■ only in exceptional cases

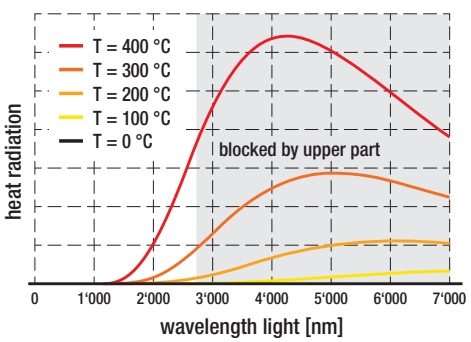
Process and quality control

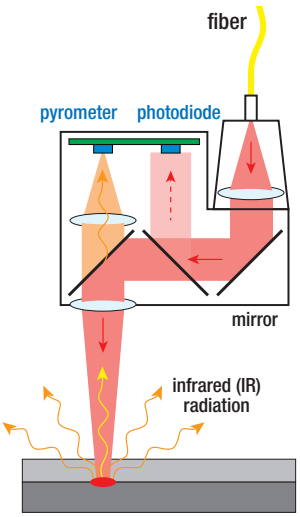
Before, during, and after the welding process, various data can be measured and analyzed for a quality assessment. Besides the laser power measurement, pyrometry for the contour process and weld collapse for simultaneous and quasi-simultaneous processes are frequently applied during welding.

Weld collapse
Depending on the plastic used, a small expansion can be observed before the plastic melts and the collapse of a melt rib starts. After switching off the laser, the travel does not stop immediately as the melt has to cool down and solidify first before the collapse ends.



Pyrometry
A pyrometer detects the heat radiation from the weld seam. As the upper workpiece blocks some part of the heat radiation only a relative temperature signal can be retrieved and not an absolute temperature value.

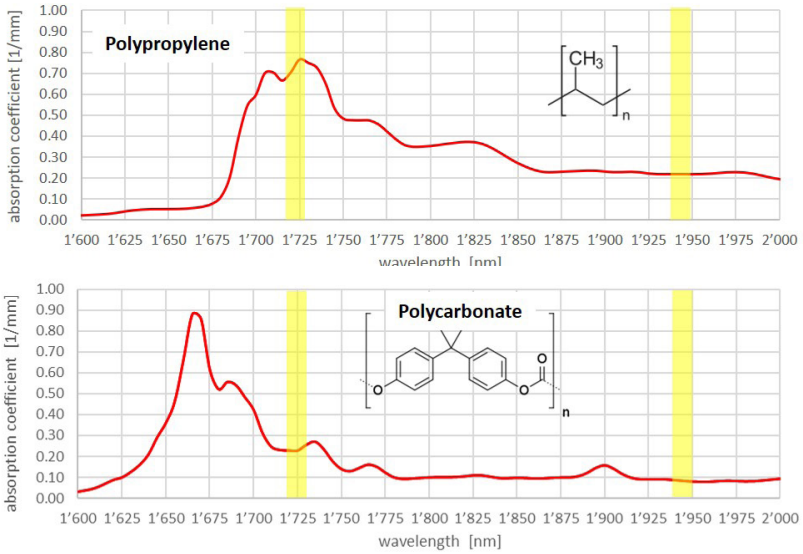




clear-to-clear: long wavelengths

If it is not possible or not desired to add a colorant to the plastic, the wavelength of the laser can be adjusted alternatively. Especially in medical technology applications or in the food industry, this can be important so that the application with a new colorant does not have to be specially certified.

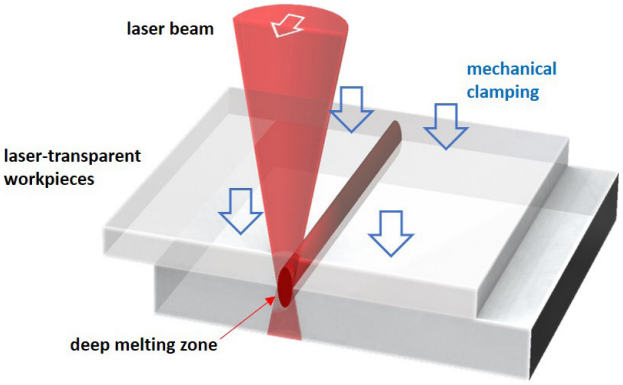
In the range of 1700-2000 nm, most polymers absorb by themselves. The absorption is only weak, so that the laser energy can also penetrate deeper into the material.
The strength of absorption at different wavelengths is given by the type of polymer. Depending on the polymer and thickness of workpieces, it may therefore be advantageous to use either a wavelength of 1725 nm or 1940 nm.
At 1725 nm there is usually a stronger absorption, which is more suitable for thin materials. For thicker materials it can be advantageous to switch to 1940 nm to be able to irradiate deeper into the material.



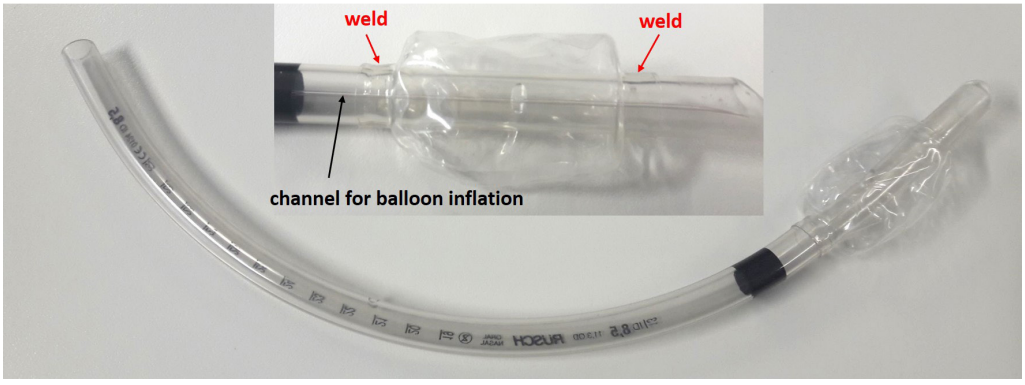
In contrast to classical laser welding, the absorption does not only take place at the weld seam, but already starts at the surface of the upper workpiece and acts over the entire thickness. For thicker workpieces (1-2 mm), the laser beam is therefore strongly focused on the weld seam. In this way, most of the laser energy is still absorbed at the surface, but over a much larger area than at the weld seam. Melting of the plastic thus occurs primarily around the weld seam, but with much greater depth and volume than with conventional laser welding. Accordingly, more laser energy is required and the process is slower.

Advantages
- no colorant necessary
- easier certification in medical application, food, ...

Shortcomings
- process slower
- more energy necessary
- larger melt volume
- more sophisticaled process control
- more expensive laser modules



Since the laser modules at these wavelengths of 1700-2000 nm are also considerably more expensive than at the standard wavelengths of 800-1000 nm, the process variant clear-to-clear with long wavelengths is only used if no admixture of a colorant is possible.



Example of a clear-to-clear welding of balloon on soft PVC tube for artificial respiration

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