Extending the Process Limits of Laser Polymer Welding with High-brilliance Beam Sources – POLYBRIGHT

Alexander Olowinsky

LASER World of PHOTONICS

Laser Polymer Welding – Recent results and future prospects for industrial applications in a European research project

Munich, Germany

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Outline

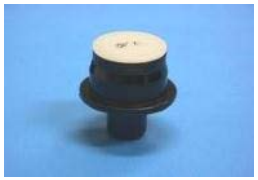
- Introduction
  - Motivation and aims
  - Process requirements
- The POLYBRIGHT Project
  - The consortium
  - Project organization
- Experimental results –current status
  - Computer simulation of the polymer welding process
  - New laser sources
  - Welding results using material adapted laser wavelengths
- Summary and Outlook

Laser Polymer Welding
Industrial Applications in Automotive













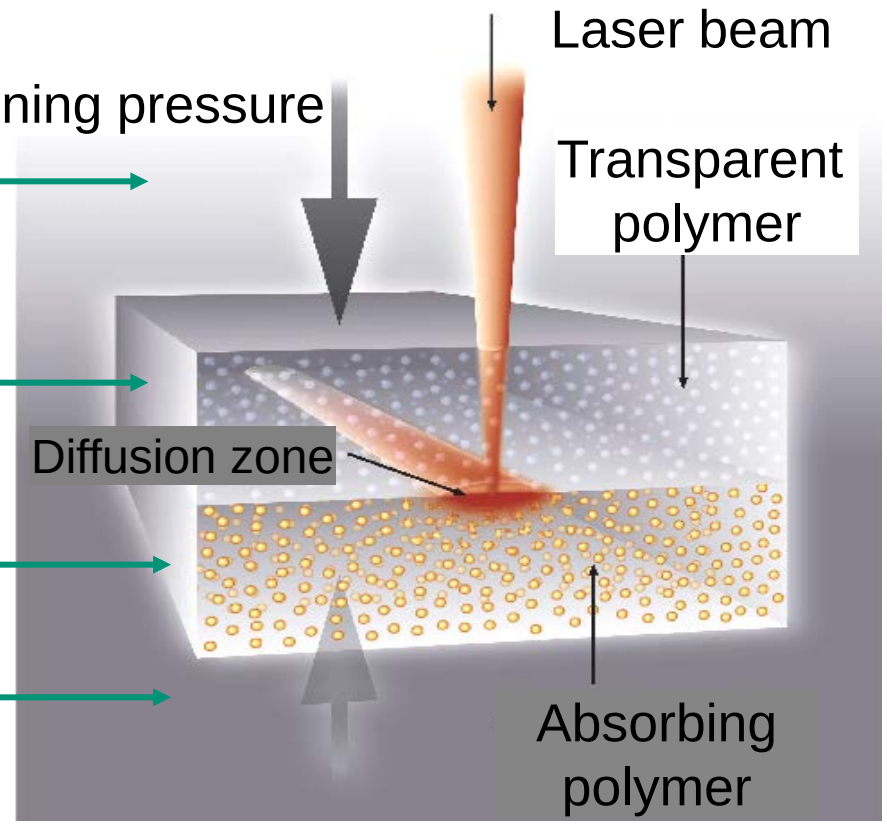




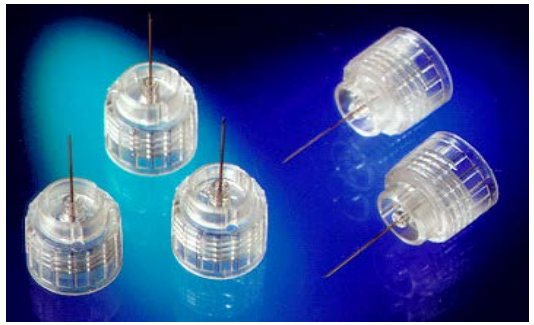

Laser beam transmission welding

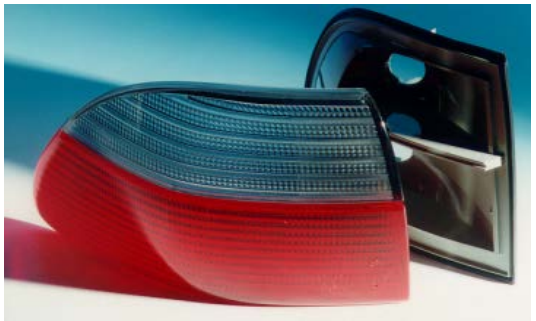
Process basics

- Wavelength
- Intensity distribution
- Beam quality
  - Reflection coefficient
  - Transmission coefficient
  - Scattering
  - Material thickness
- Optical penetration depth
- Thermal properties
  - Polymer compatibility
  - Surface contact



Motivation and aims



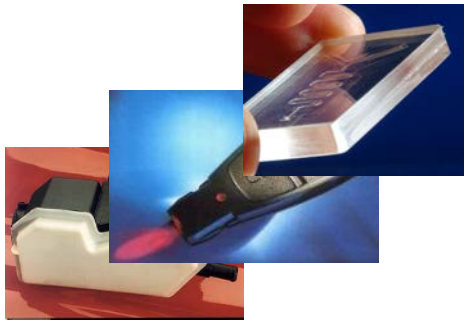


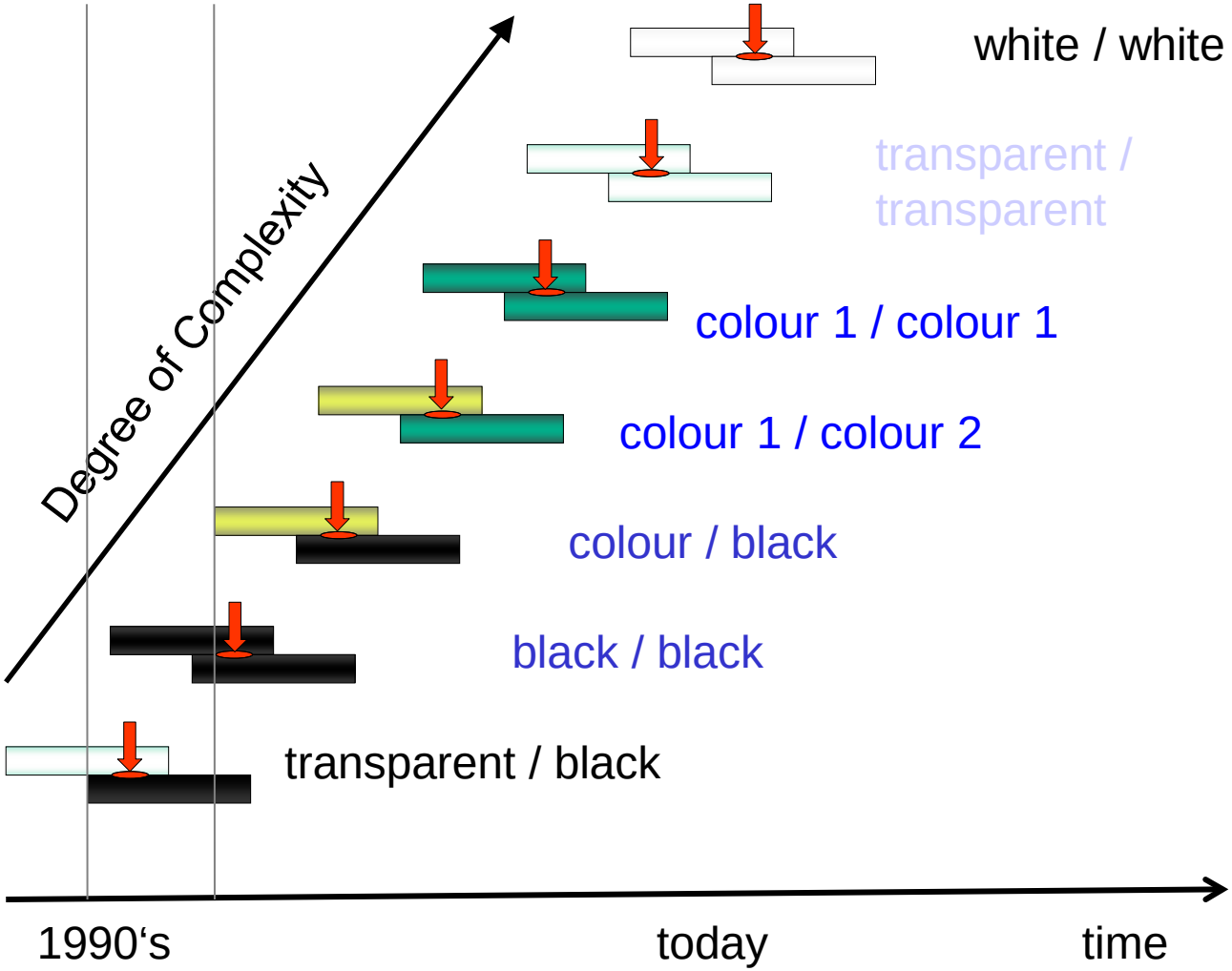
Process related disadvantages

- Material limitations – requirement to match the optical properties of the joining partners for the laser welding process . Furthermore, only few materials combinations are possible for welding dissimilar plastics
- Shape limitations – currently most of the welding contours are restricted to flat, 2D surfaces
- High investment – the cost for complete laser welding systems is still high for many applications compared to other joining methods
- Lack of know-how or conservative attitude in the product development process

Degree of Complexity

- Transparent / black standard configuration
- Changing colours influencing the process:
  - Transmission
  - Absorption
- Additives (GF etc.)



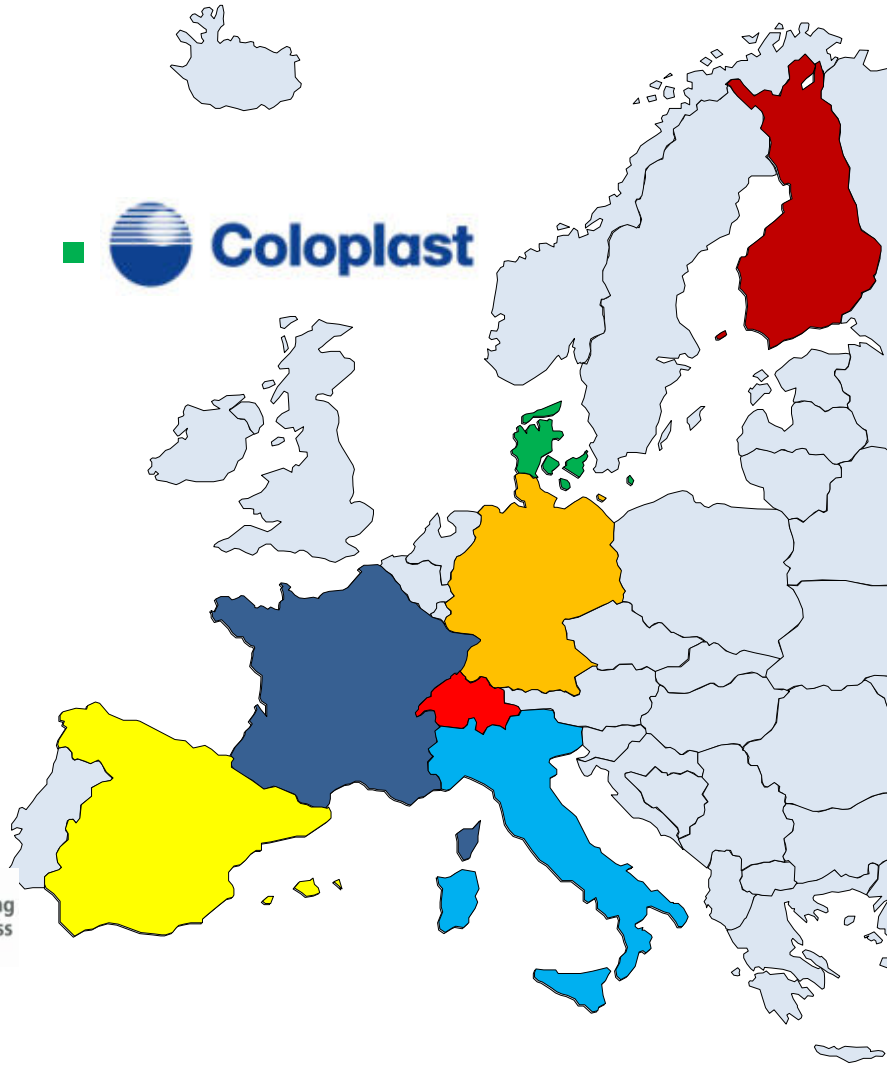


Motivation and aims - Project objectives

- Development of high power high brilliance lasers with new wavelengths in the range of **1500 - 1900 nm**. Laser power up to **500W**
- **Innovative beam manipulation systems** for optimum energy deposition in the welding area
- **New** laser polymer joining **processes** based on advanced thermal management concepts
- **New machine concepts** for the high speed and flexible laser manufacturing
- Enabling **new applications** for laser polymer welding by enhancement of the process performance and new joint configurations

The POLYBRIGHT Project Partners

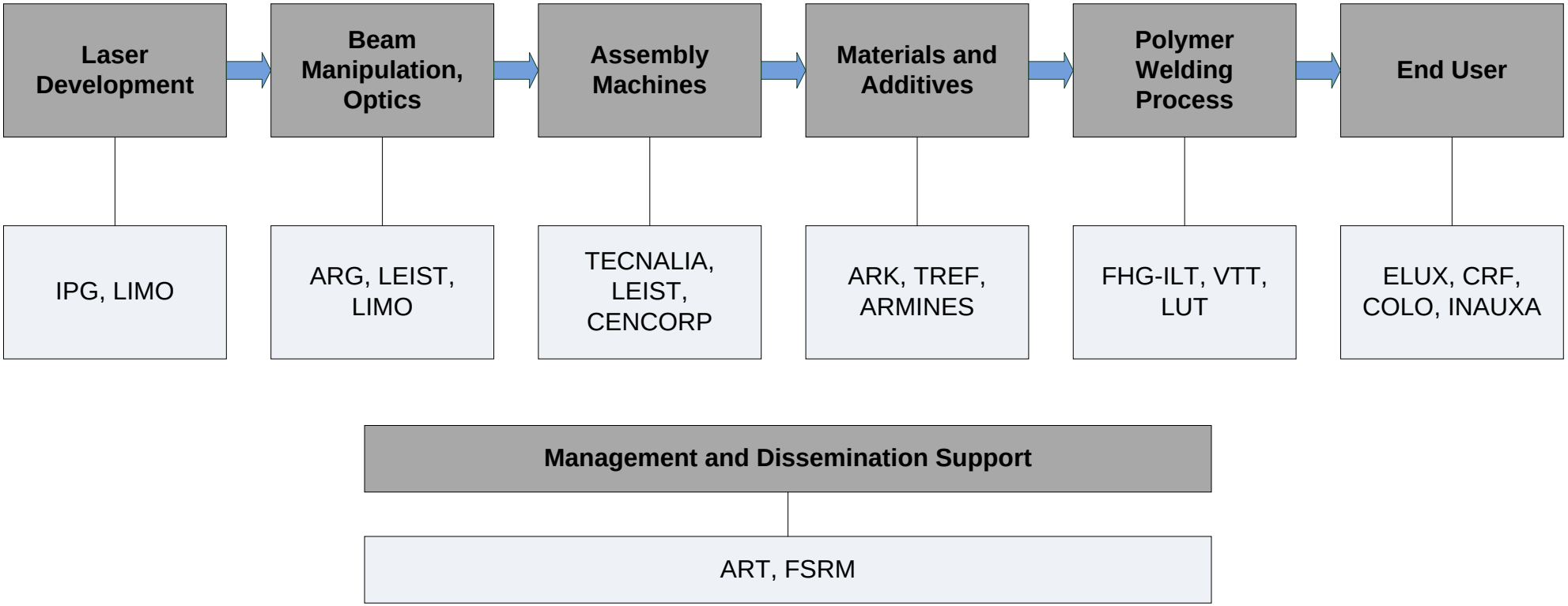
- Fraunhofer ILT
- Fraunhofer LBF
- TREFFERT
- IPG LASER
- LIMO Lissotschenko Mikrooptik
- ARGES
- ARMINES
- ARKEMA The world is our inspiration
- ARTTIC
- tecnalia Inspiring Business
- inauxa
- Coloplast



- cencorp
- VTT
- Open your mind. LUT. Lappeenranta University of Technology
- LEISTER
- fsrm CROSSROADS OF MICROTECHNOLOGY
- Electrolux
- CRF CENTRO RICERCHE FIAT

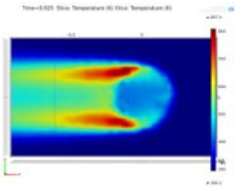
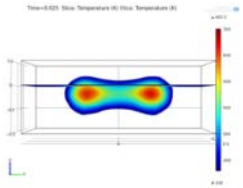
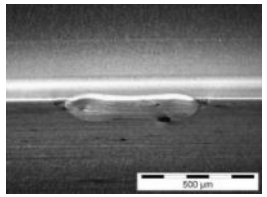
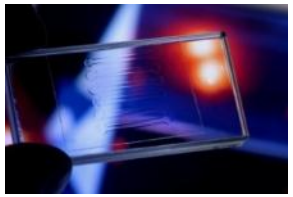
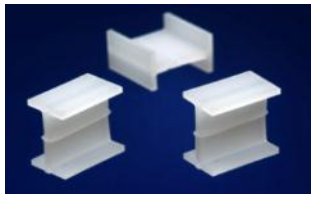
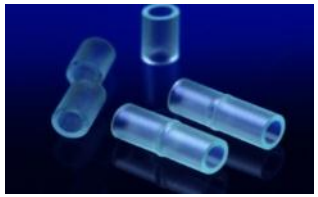
The POLYBRIGHT Project - The consortium

Process Chain Plastic Part Welding



Flexible, robust and fast-adapting laser beam welding

- Development of a computer model for the investigation of various thermal management concepts
- Realization of an intelligent power control for welding of polymers in order to enable a larger process window
- Investigation of new laser welding processes with higher quality and higher speed such as Transmission Welding by an Incremental Scanning Technology (TWIST), Remote Welding for polymeric components or Quasi-simultaneous welding with advanced power control
- Welding of transparent polymers with new laser wavelengths and new weld joint configurations relevant for developments of new products

TWIST®- Concept

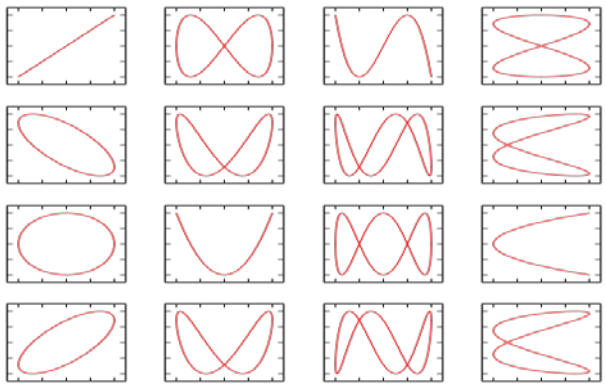
Transmission

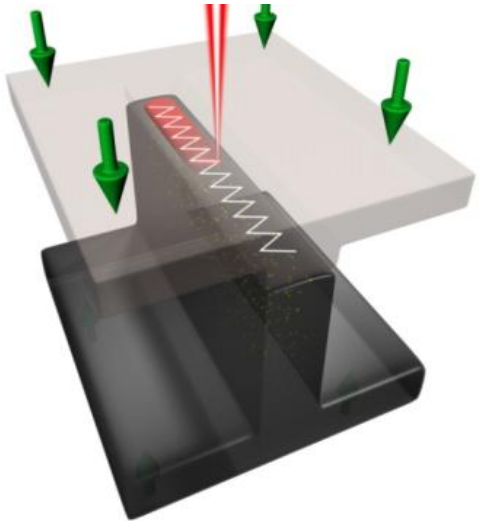
Welding

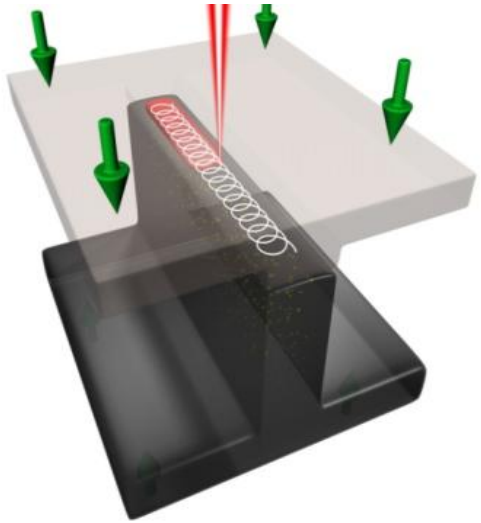
Incremental

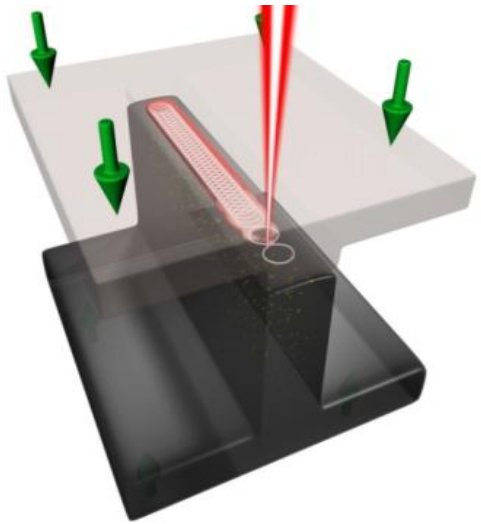
Scanning

Technique









TWIST®- Concept

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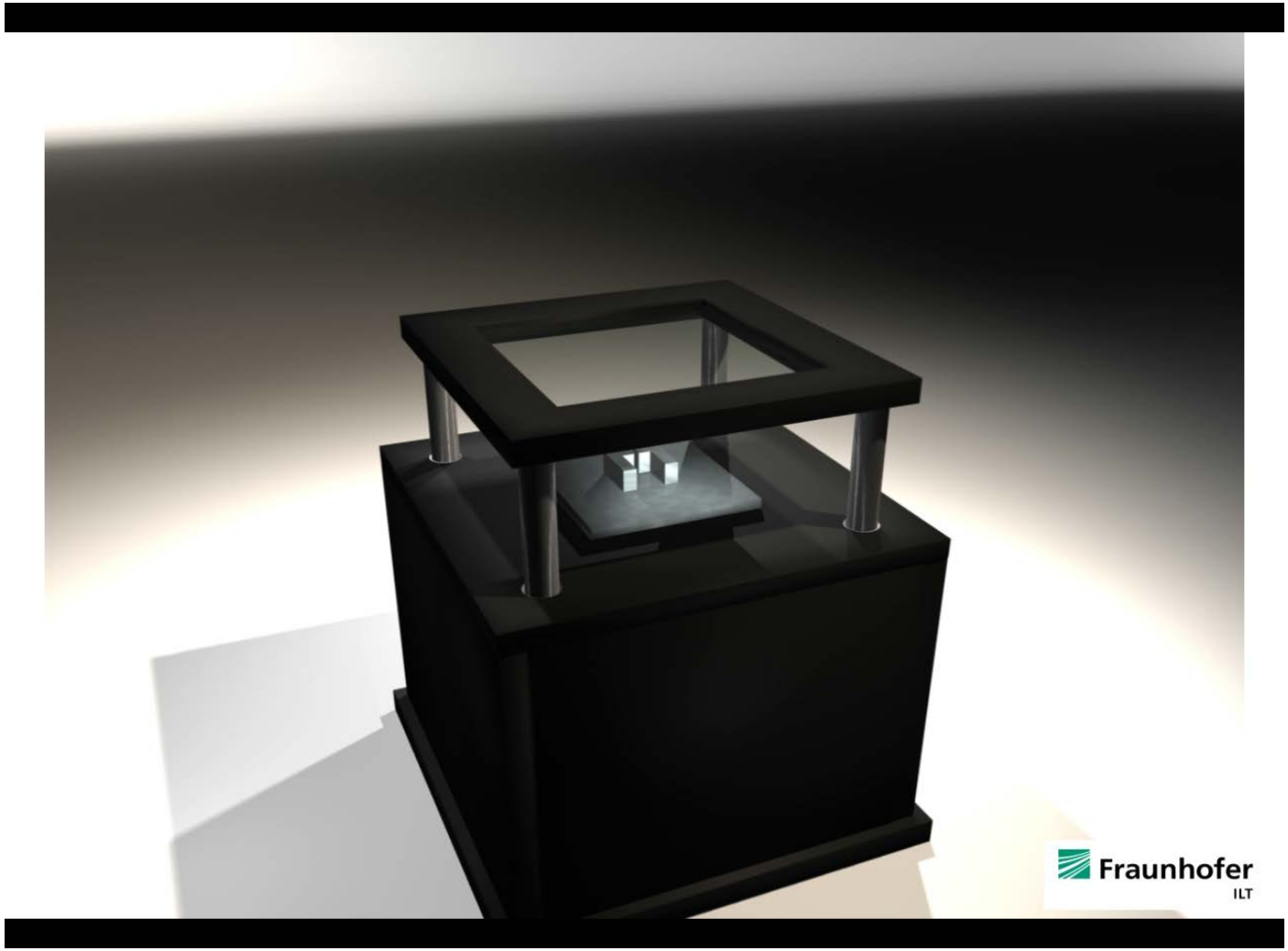
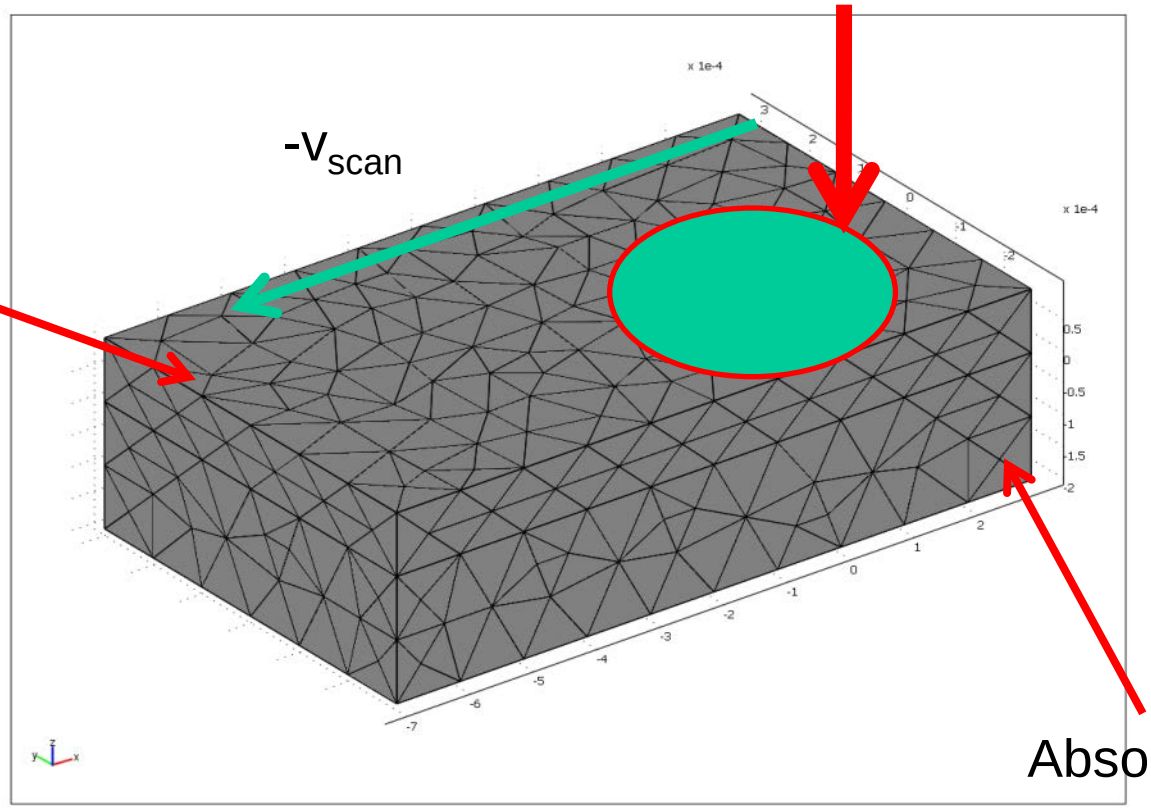


Computer simulation of the polymer welding process

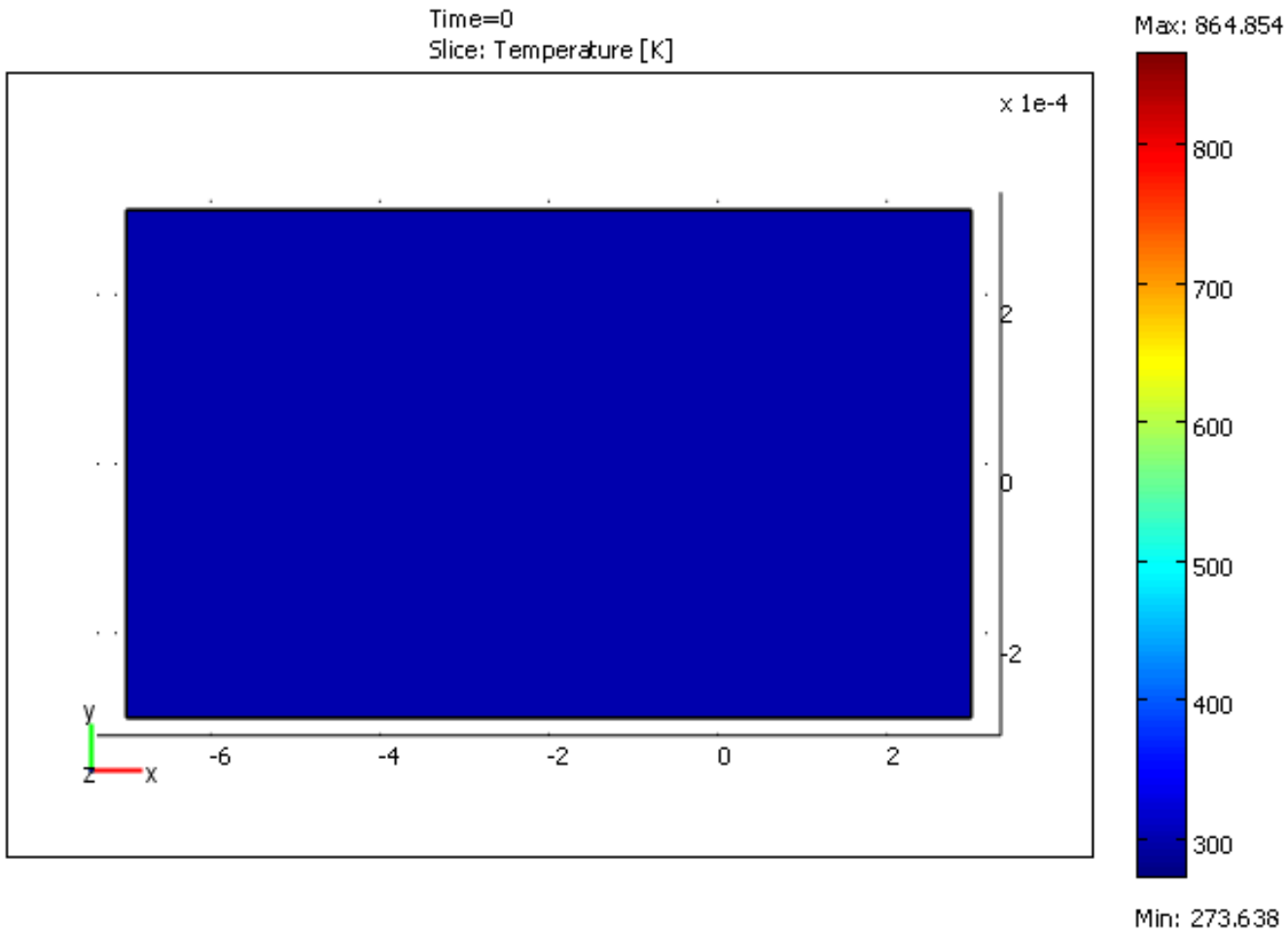
Absorbent and transparent joining partners (dabs= 200 µm, dtra= 100 µm) in thermal contact

Transparent part



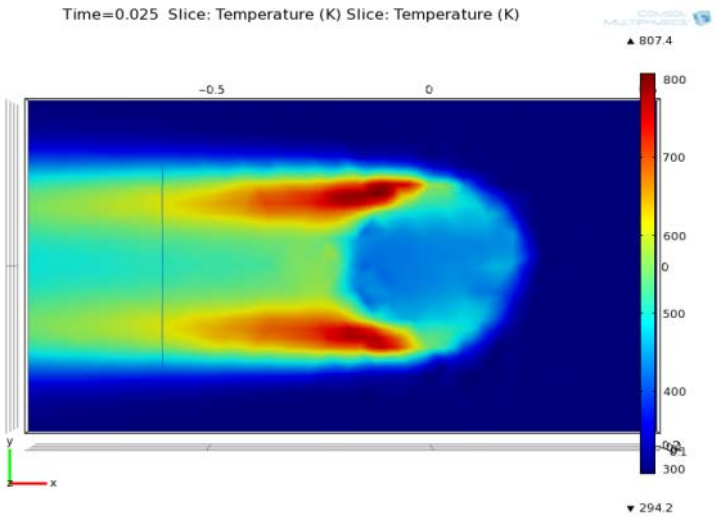
Absorbent part

Computer simulation of the polymer welding process

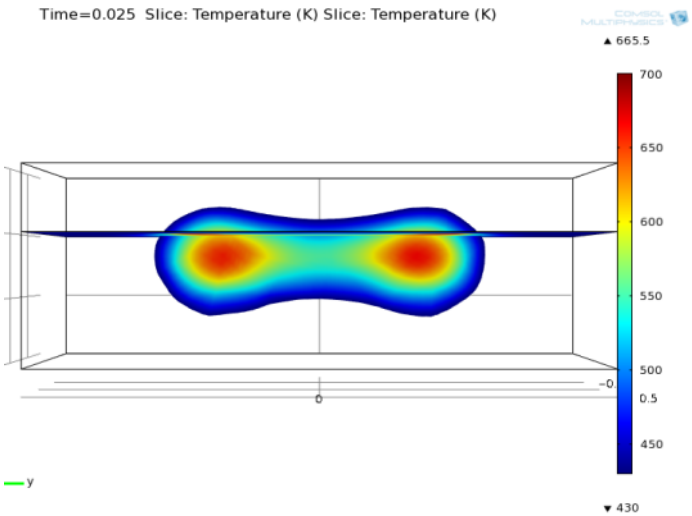


Computer simulation of the polymer welding process

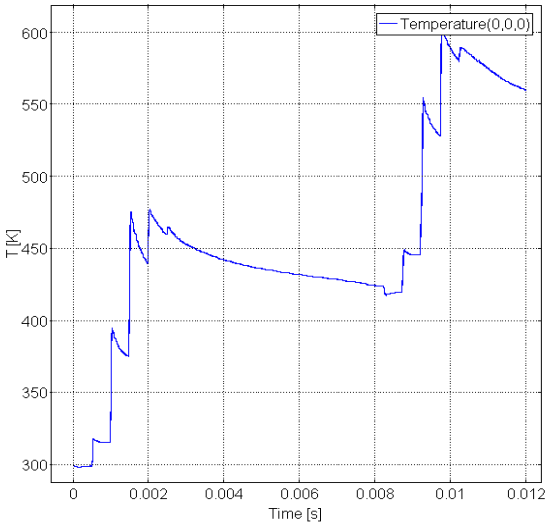
Top view - welding area



HAZ in cross section



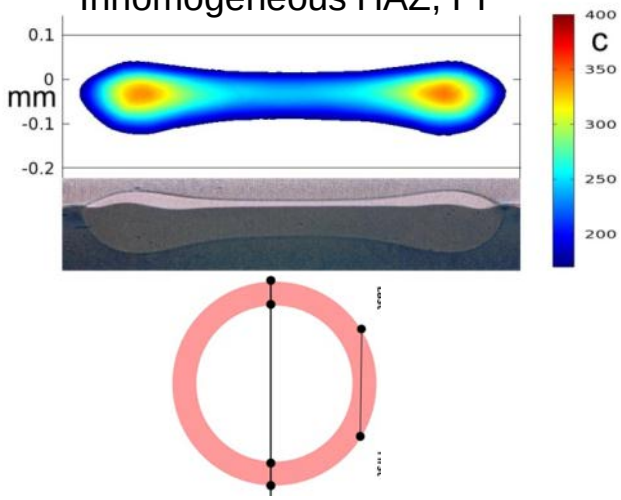
Temperature profile



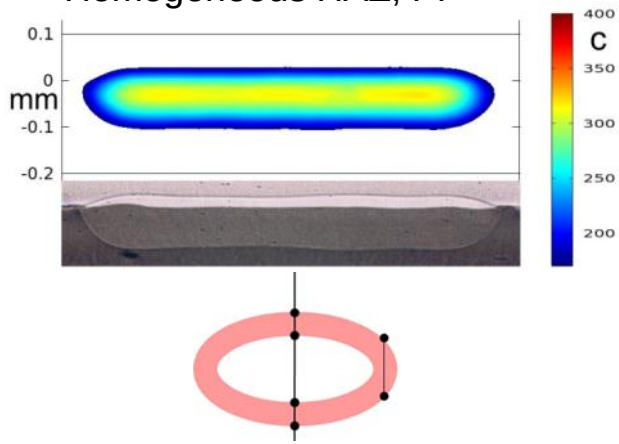
Computer simulation of the polymer welding process

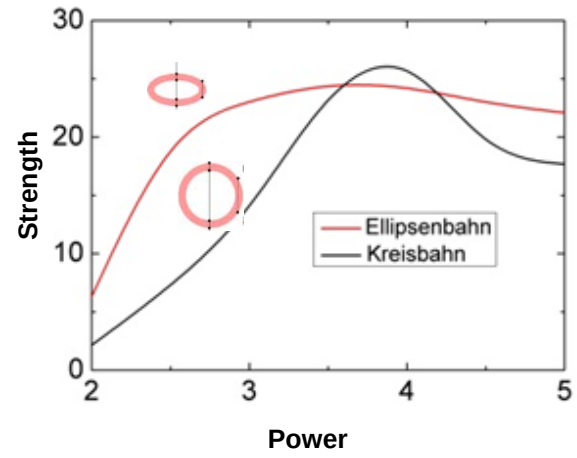
Comparison between circular and elliptical modulation

TWIST Circle 0,8mm
Beam 80 µm
Feed 50 mm/s
Rotation 2000 Hz
Inhomogeneous HAZ, PP



TWIST Ellipse 0,8/0,2mm
…
…
…
Homogeneous HAZ, PP

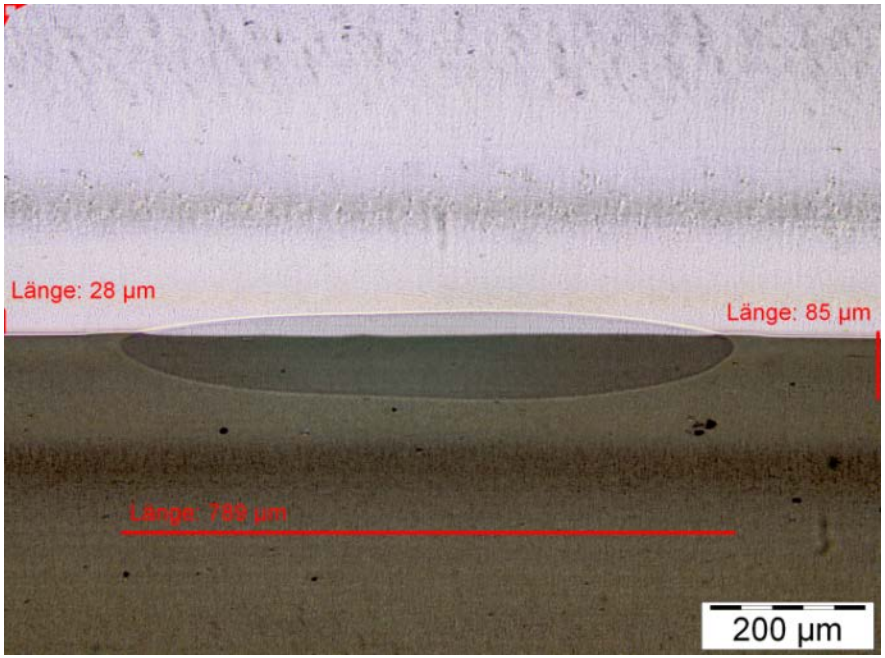




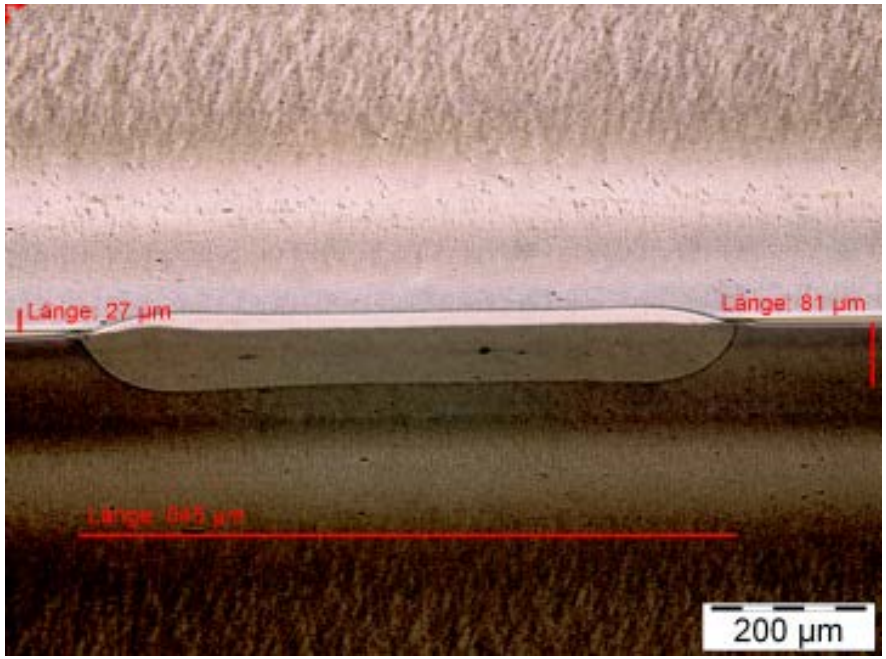
Experimental verification of simulation

Comparison Contour welding - TWIST welding

Contour v=ct.



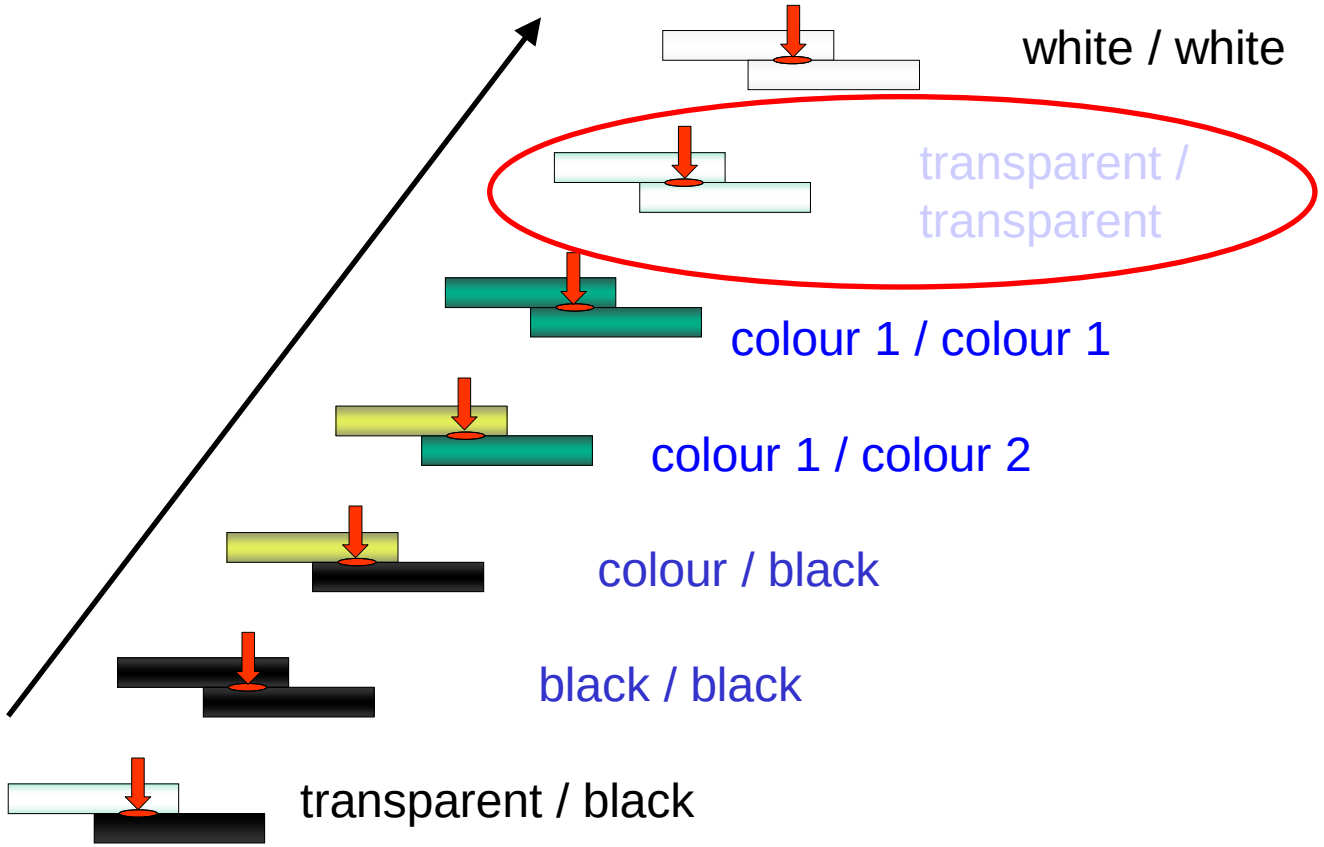
Elliptical shape v=ct.



TWIST welding: heat effective zone is homogeneous

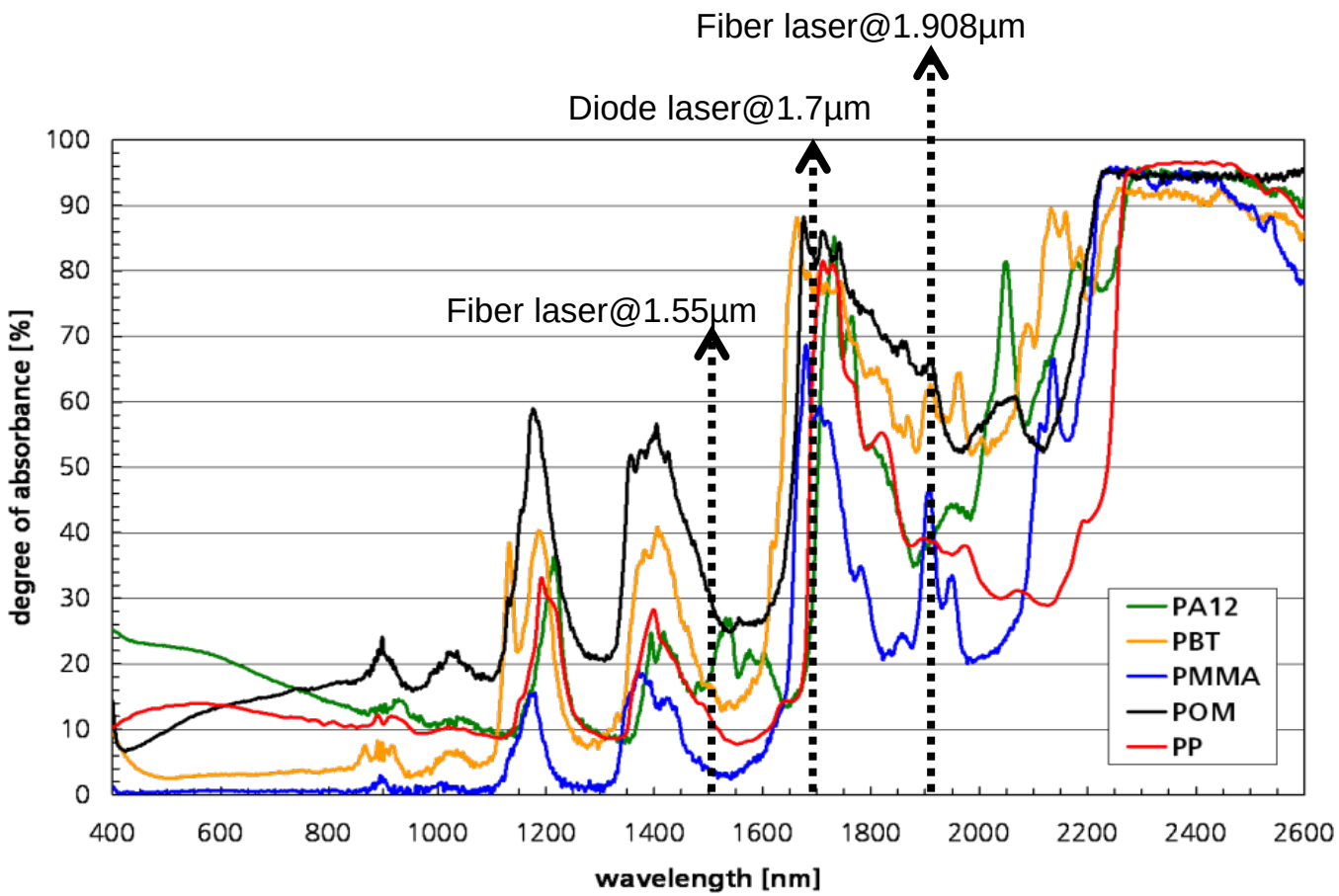
Welding results using material adapted laser wavelengths

- Transparent / black standard configuration
- Laser transparent additives allow colourisation of upper joining partner
- IR-absorber allow coloured lower joining partner
- No additional additive needed



Welding results using material adapted laser wavelengths

- Transparent in VIS
- Intrinsic absorption in infra-red
- Absorption band aroused by harmonic oscillation of molecular groups of the polymer chains
- Optical properties of thermoplastics highly dependent from wavelength in IR-Area and molecular structure



Material thickness d = 2mm

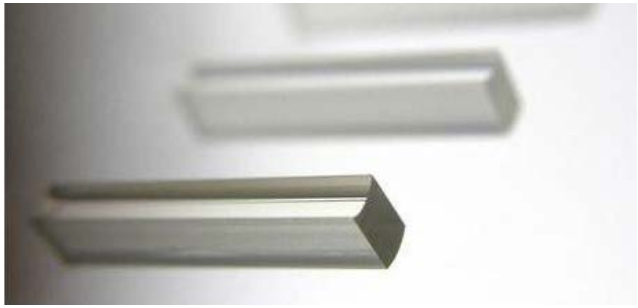
Available new laser sources

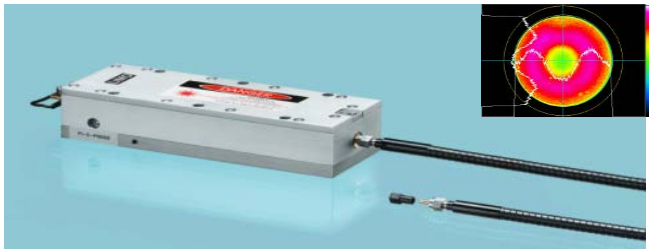
IPG:

- 120 W Erbium doped Fiber Laser (1.5 µm wavelength)
- 120 W Thulium doped Fiber Laser (1.9 µm wavelength)
- 500 W Erbium doped Fiber Laser (1.5 µm wavelength)

LIMO:

- 20 W diode laser (1550 nm wavelength) with 400 µm fibre
- 80 W diode laser (980 nm wavelength) with 400 µm fibre with M-shape beam profile
- 20 W diode laser (1640 nm wavelength) with 400 µm fibre





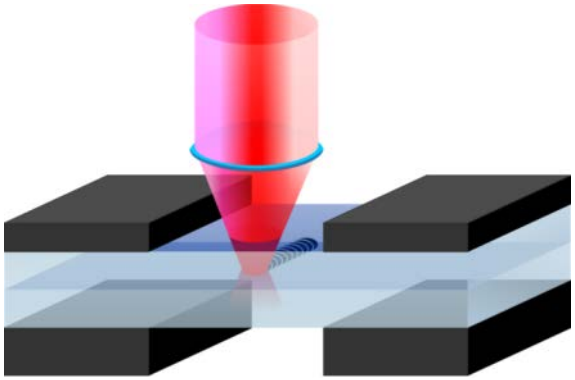
Welding results using material adapted laser wavelengths

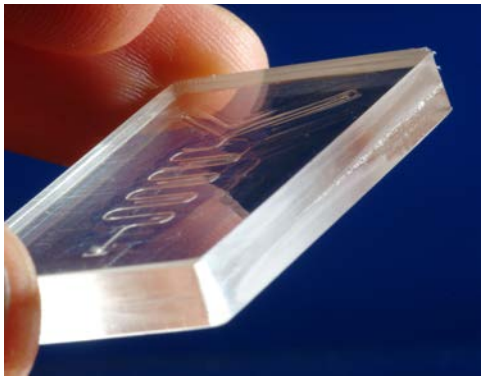
Concept

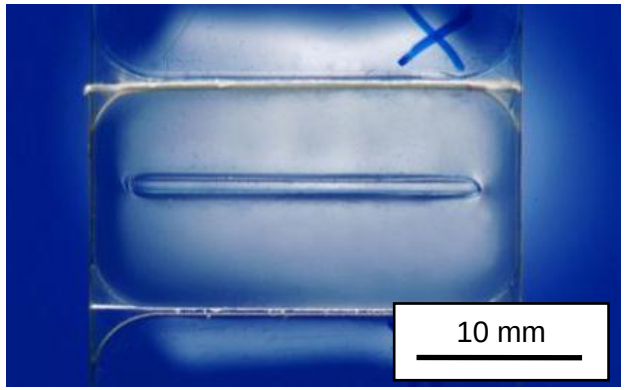
- Adjusted wavelength of laser source
- High numerical aperture optics

Result

- Low intensity on surface but high intensity in welding area
- Temperature exceeds melting point only in welding area







Material thickness d = 2mm

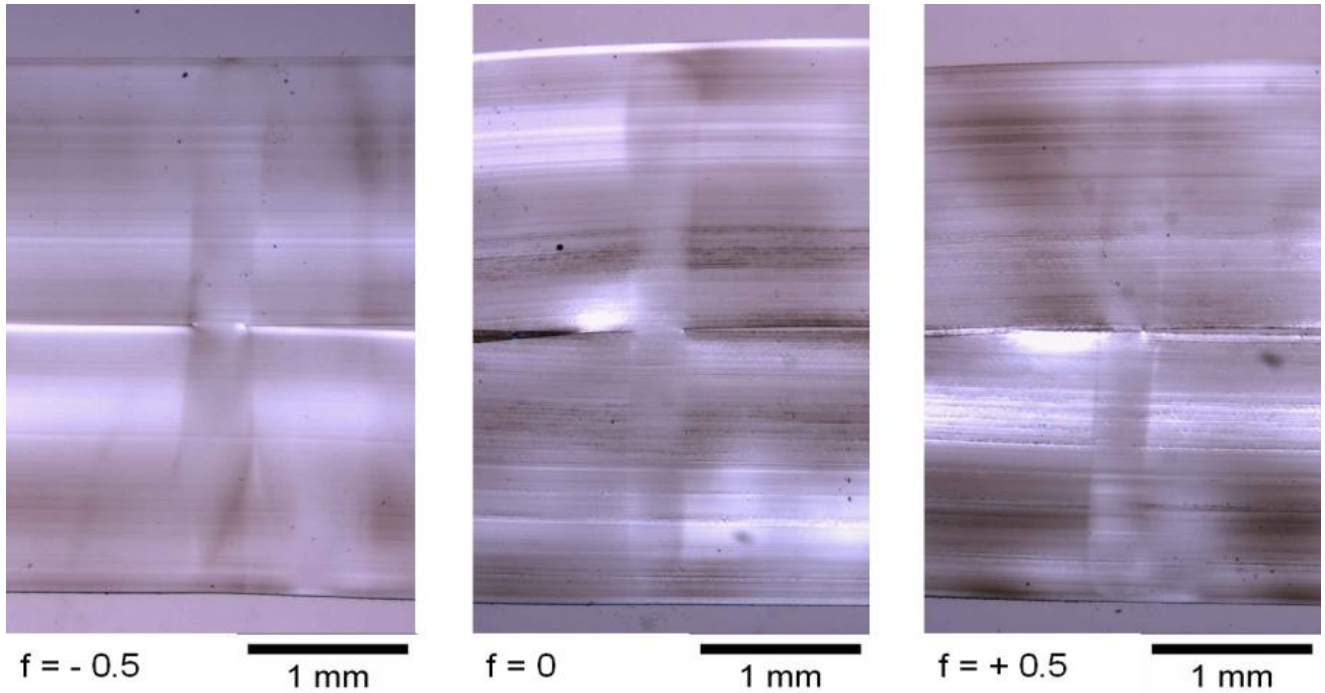
Welding results using material adapted laser wavelengths

Variation of focal position

- Fiber laser @1.55µm
- Laser power: P= 100 W
- Feed rate: v= 2 m/min

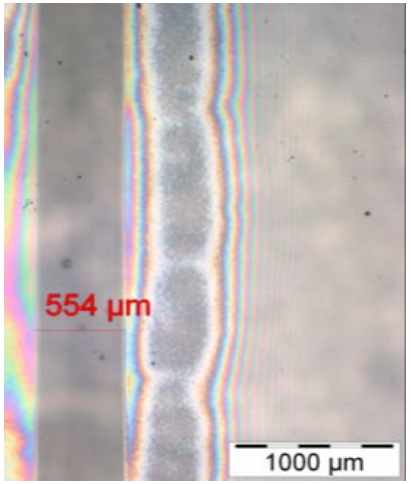
Results:

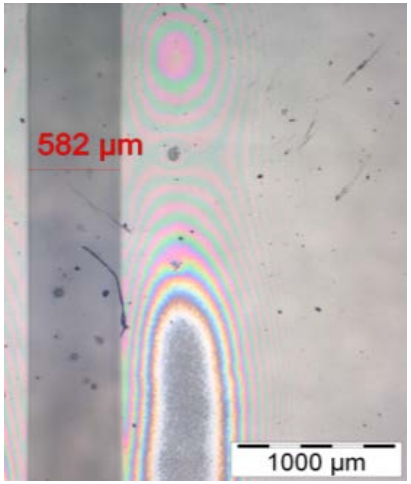
- Optimal setting prevents melting of surface and deliver smallest width of heat affected zone
- No further limitation of depth of heat affected zone

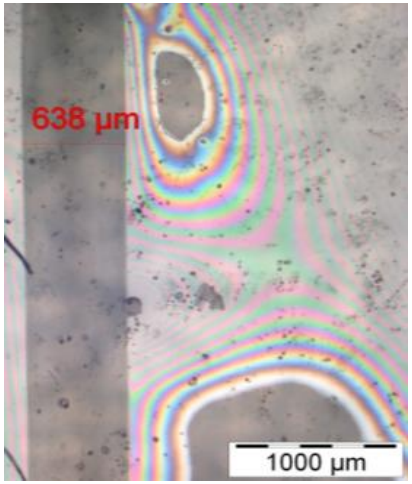


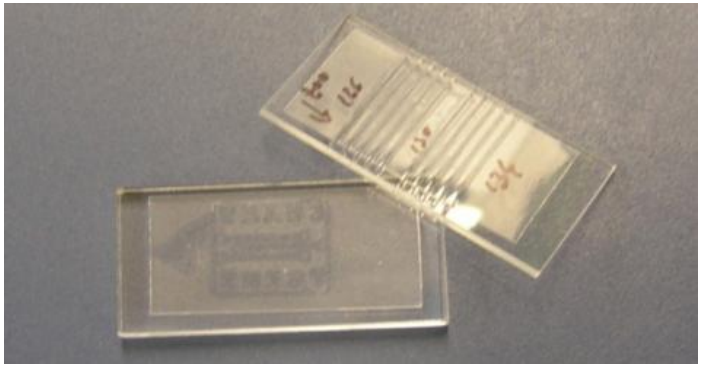
Welding results using material adapted laser wavelengths

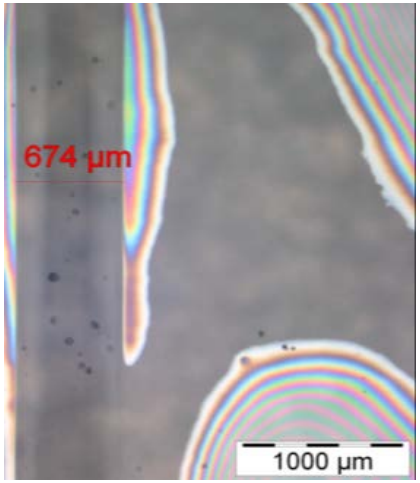
- Diode laser @1.7µm
- Material - PMMA
- Laser power: P=20/ 22.5/ 27.5/ 32.5/35W
- Feed rate: v= 1.5 m/min

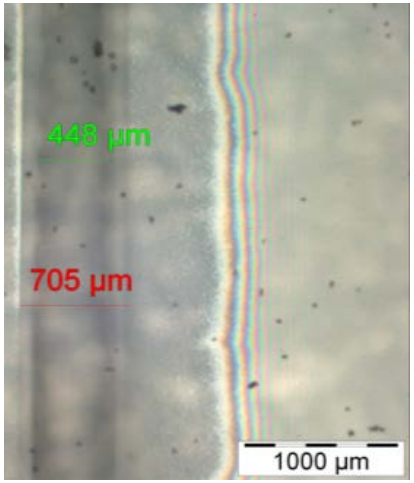






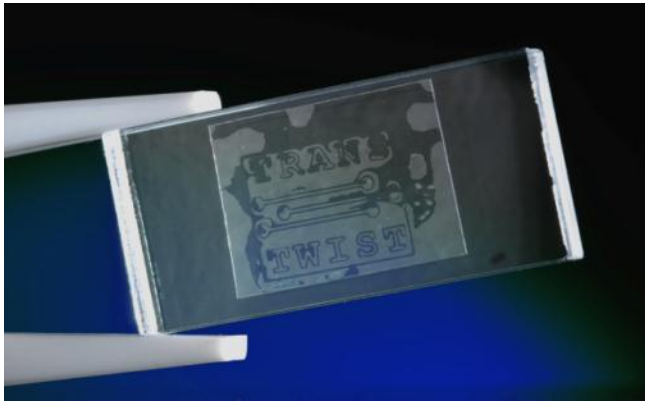


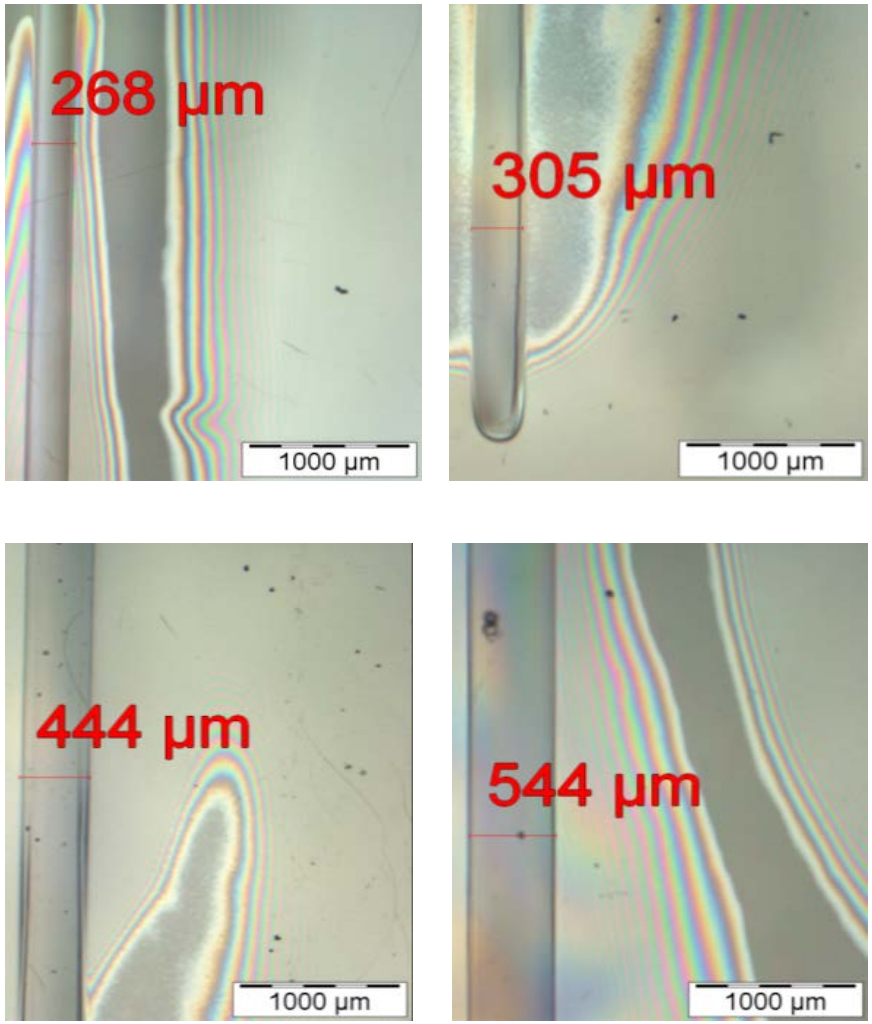




Welding results using material adapted laser wavelengths

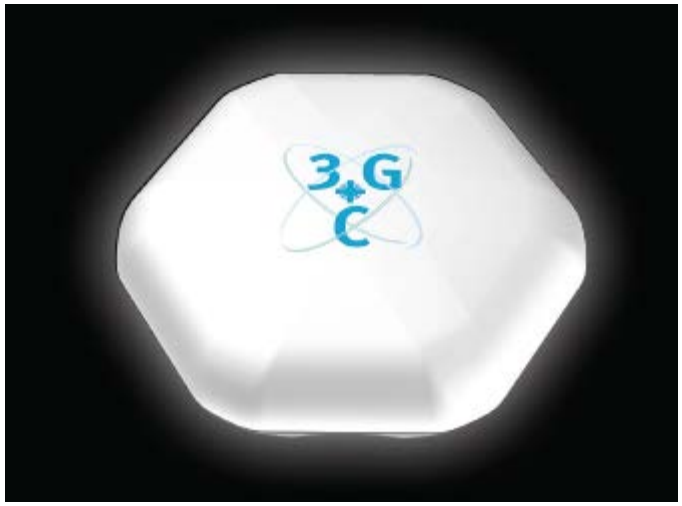
- fiber laser @1.908µm
- Material - PMMA
- Laser power: P= 16.6/ 25/ 25/ 33.3 W
- Feed rate: v= 3 m/min
- Oscillation parameters:
  f= 2000 Hz
  A= 0.075/ 0.1/ 0.15/ 0.2mm

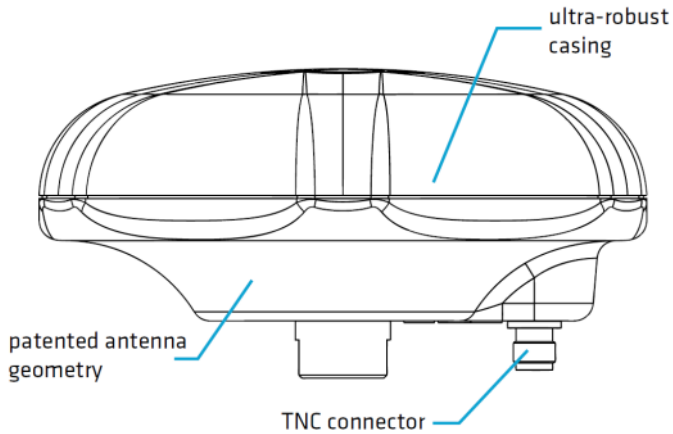


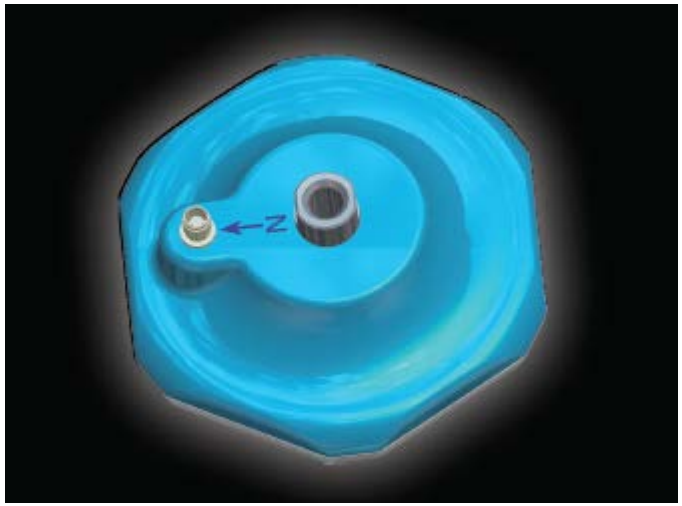


From research to market – an industrial application example

- Four constellation GNSS antenna
- Galileo | GPS | Glonass & Compass
- Rugged housing
- Hermetic sealing needed
- Varying colours







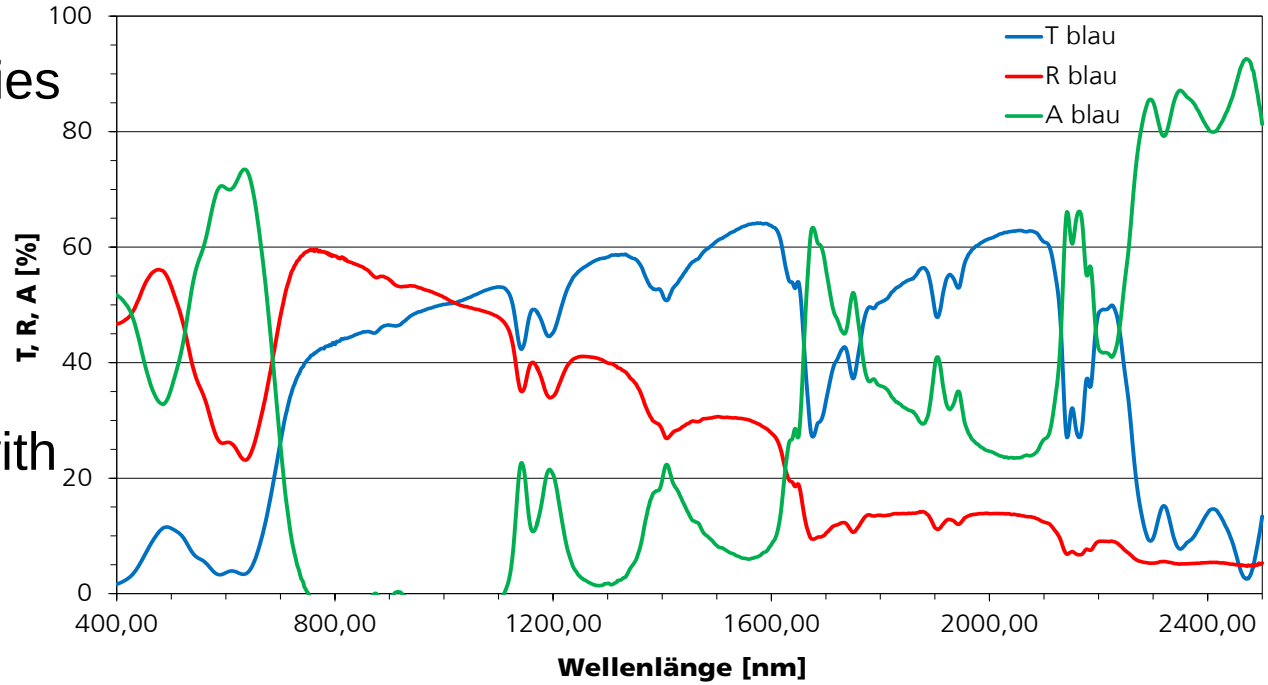
navXperience

Optical properties ASA blue laser transparent

- Strongly wavelength dependent optical properties
- Reflexion decreases with increasing wavelength:

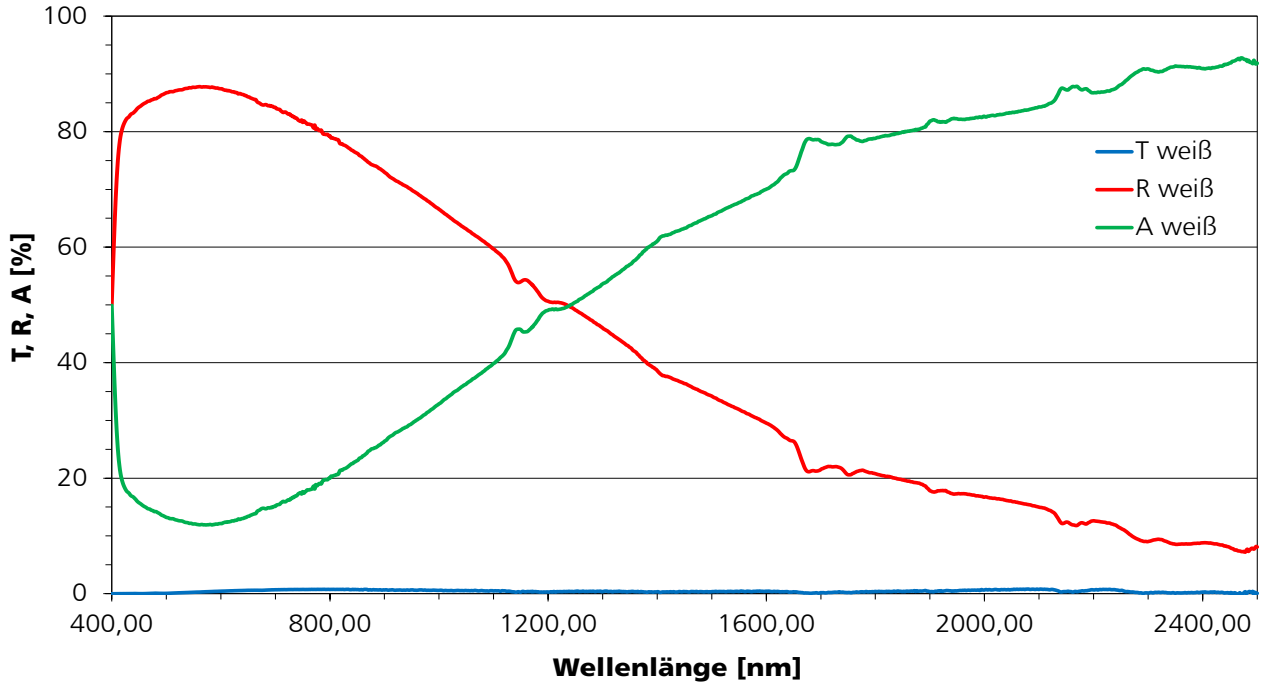
  53% @ 940 nm
  30% @ 1550 nm
- Transmission increases with increasing wavelength:

  48% @ 940 nm
  63% @ 1550 nm



Optical properties ASA white laser absorbing

- Wavelength depending properties determined by filler additives
- Very high reflectivity in the visible spectrum
- Strong decrease of reflectivity with increasing wavelength:
  71% @ 940 nm
  32% @ 1550 nm
- Optical penetration depth:
  222 µm @ 940 nm
  176 µm @ 1550 nm



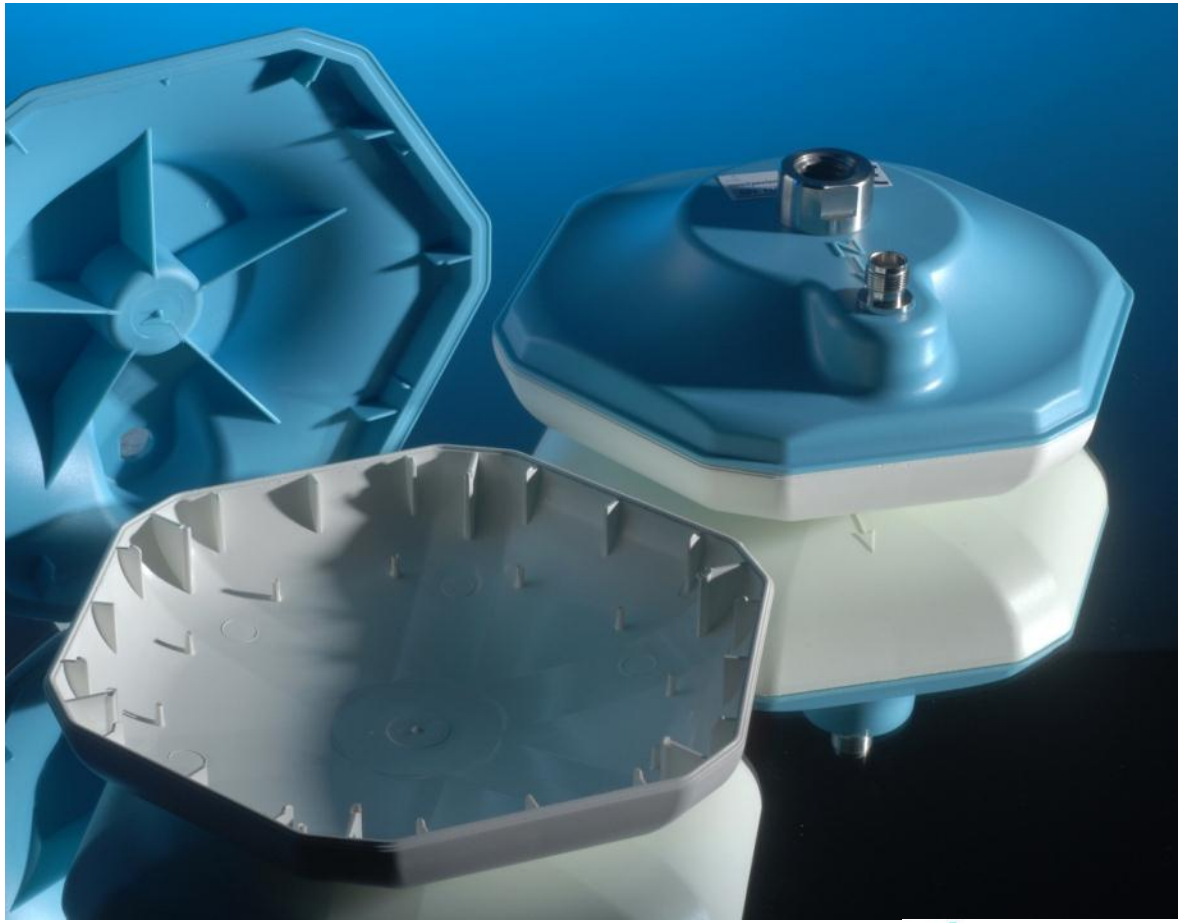
Welding of GPS antenna housings

Requirements:

- Invisible weld seam
- Hermetic sealing
- No thermal and mechanical load of the antenna components inside
- Burst pressure 2.5 bar

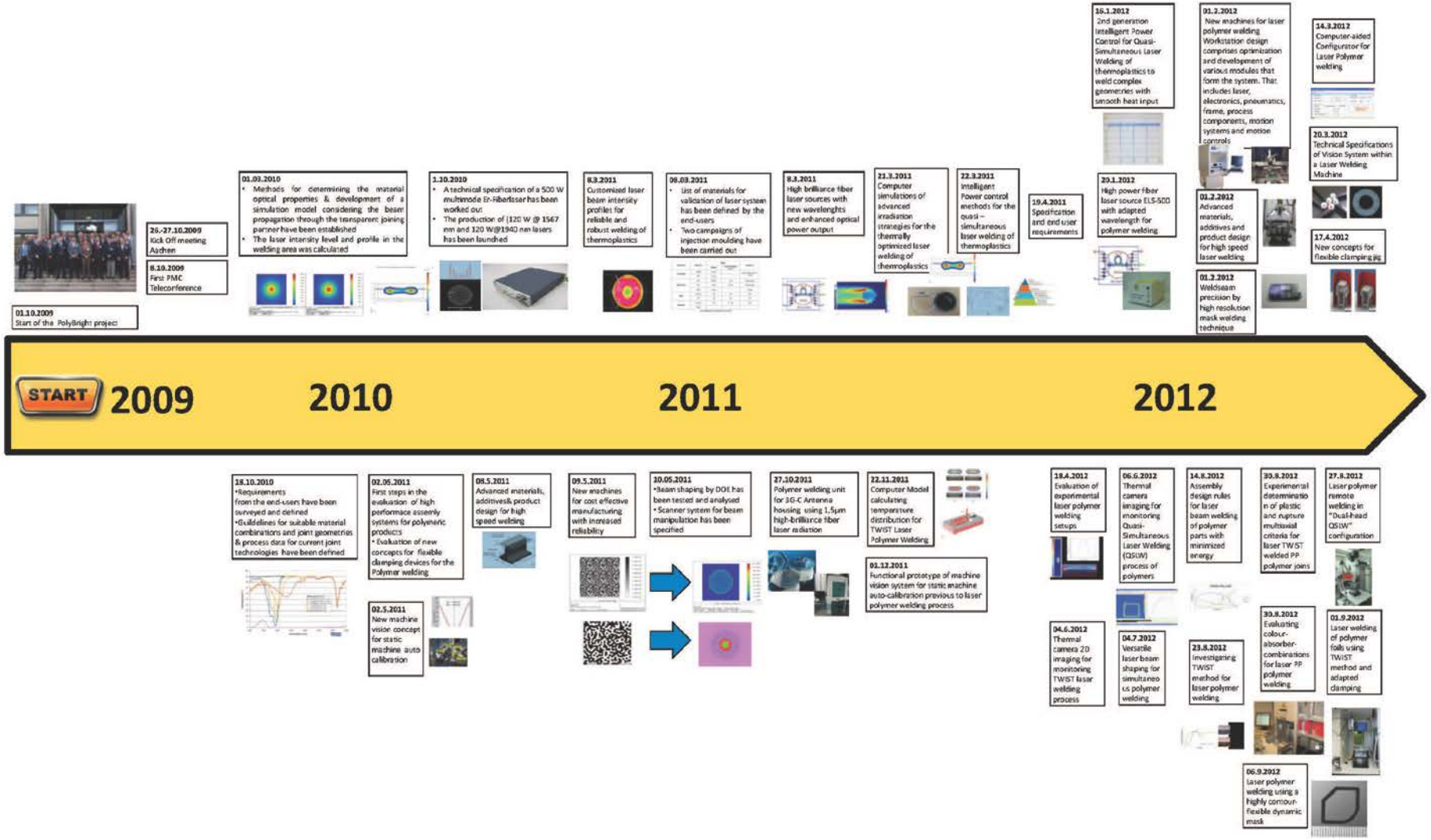
Result:

- Fiber laser 1550 nm
- TWIST-welding with:
  Laser power: 25 W
  Feed rate: 25 mm/s
  Frequency: 2000 Hz
  Amplitude: 0,2 mm
  4-times multi-pass welding

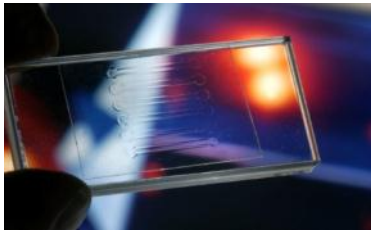


navXperience

Project Timeline



Summary and Outlook



Industrial applications require:

- **High Quality** – through robust polymer assembly with high reproducibility and minimum waste
- **Flexibility** – by minimizing time and investment for product change on the manufacturing line
- **Productivity** – by high speed processes with joining times < 1 second
- **Cost reduction** - reconfigurable machines and high yield production, new laser systems and peripherals
- **New products** - simplified product design and highly integrated products , material independent welding processing, new designs

Thank you for your attention!

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Dr.-Ing. Alexander Olowinsky

Fraunhofer Institute for Laser Technology

Steinbachstraße 15

D-52074 Aachen, Germany

Phone: +49 (0) 241 89 06 -491

Email: alexander.olowinsky@ilt.fraunhofer.de

More information : www.polybright.eu

More Information

- Website: www.polybright.eu
- Booth here: Fraunhofer-Gemeinschaftsstand Hall C2/330
- K2013 in Düsseldorf: 16.-23. October 2013 Hall 070 Booth No. 70C03

- Diode laser module, 1640 nm, 20W, Fiber 400µm (LIMO)
- High-NA focussing optics: D_{foc}=0,26mm, z_R=0,3mm (ILT)
- xyz linear axes 400mm on granite base
- Machine housing and clamping device