Mikrofügen mit Faserlasern durch prozessangepasste Strahlmodulation

Precision fiber laser joining with process adapted beam modulation

EPMT2010

Lausanne, June 10th, 2010

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Fraunhofer-Institute for Laser Technology

Fraunhofer ILT

OUTLINE

- Metal Welding
  - Definition of micro welding
  - Making use of the potential of high brilliance
  - Fields of application
- Polymer Welding
  - Functional principle
  - Polymer welding with high brilliance laser sources
- Summary

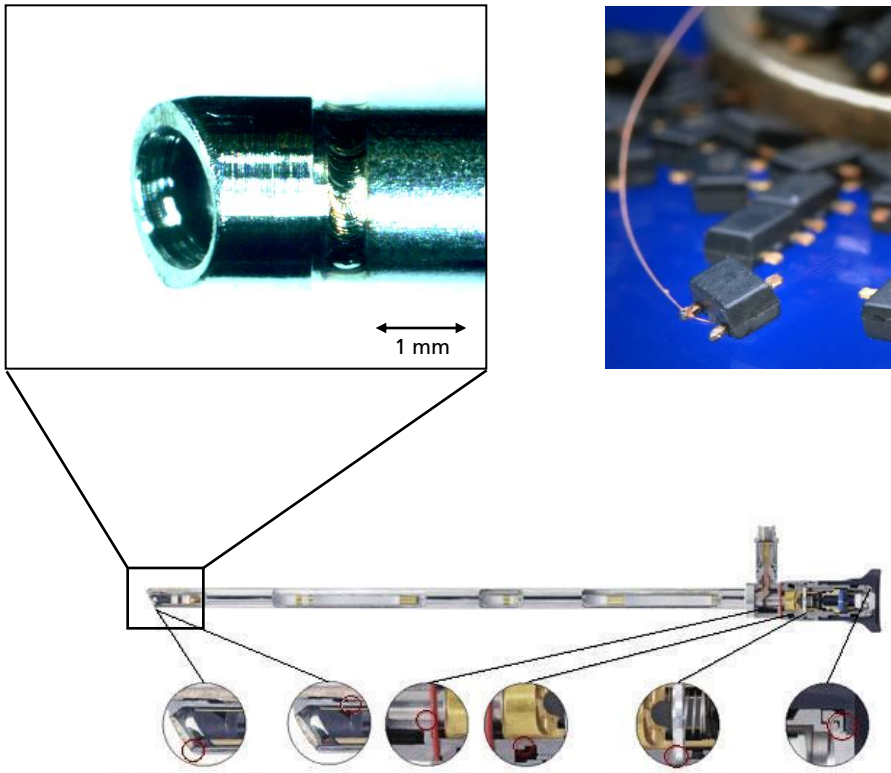
Definition of Laser Micro Welding

Spatially

- Component Size: One Dimension << 1 mm
- Spot or Seam Welds, Weld Width < 500 µm

Temporally

- Welding Time: 1 - 100 ms

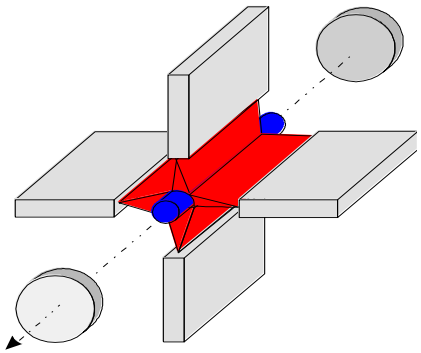


Joints and Connectors

Source: Olympus Winter&Ibe

Solid State Laser Beam Sources
Functional principles

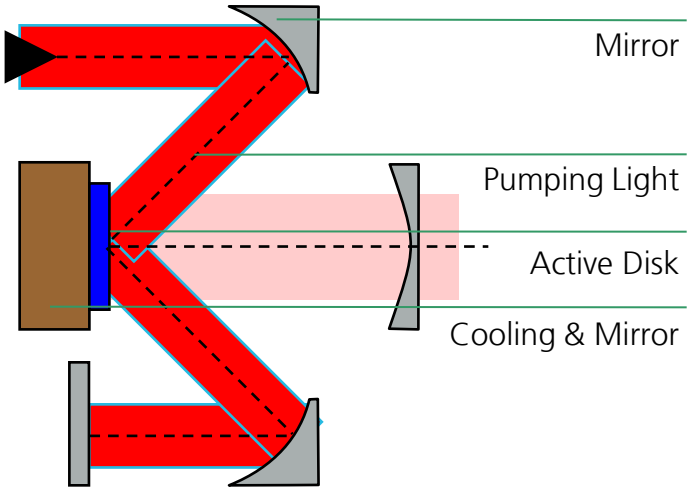
Rod Laser



Focus Diameter:

100 – 400 µm

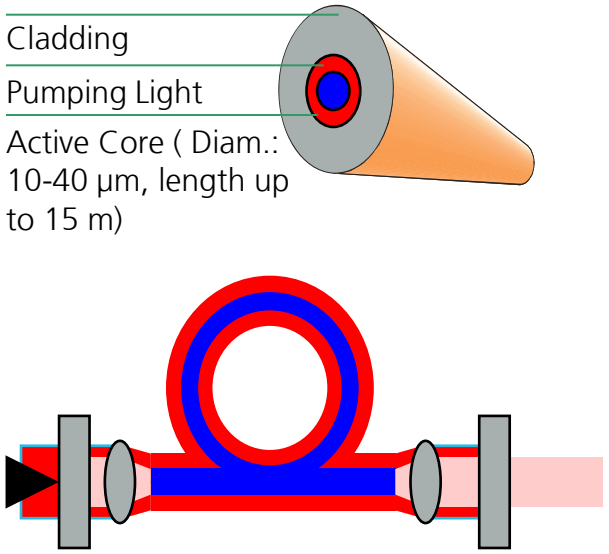
Thin Disk Laser



Focus Diameter :

50 – 100 µm

Fiber Laser



Focus Diameter :

10 – 50 µm

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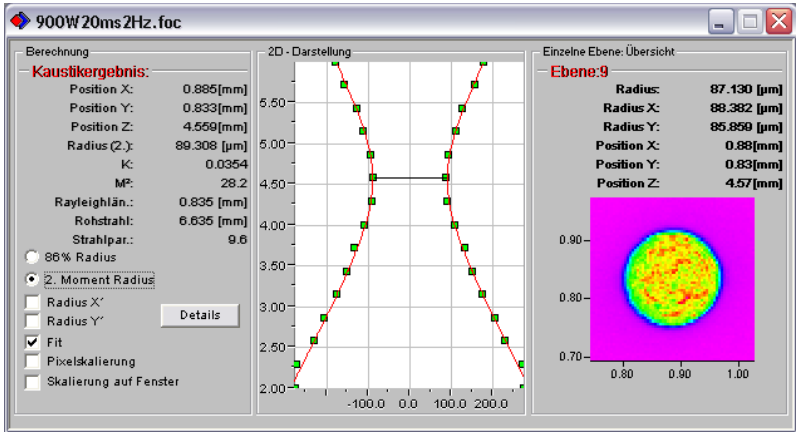
Laser Beam Source
Pulsed Nd:YAG Laser

Source	HL 62P
Laser Medium	Nd:YAG
Wavelength / nm	1 064
Mode of Operation	Pulsed
Max. Output Power / W	3 000@10ms
Beam Guide	Fiber
Focal Length / mm	80
Focus Diameter / µm	180
Rayleigh Length / µm	835



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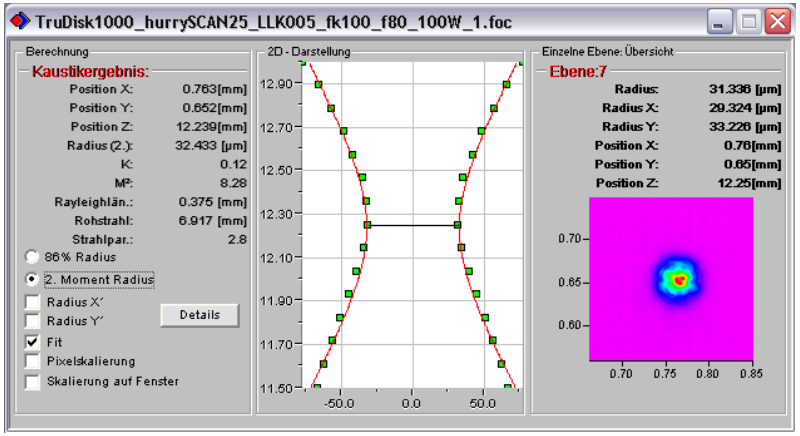
Laser Beam Source
Thin Disk Laser

Source	TruDisk 1000
Laser Medium	Yb:YAG
Wavelength / nm	1 030
Mode of Operation	cw
Max. Output Power / W	1 000
Beam Guide	Fiber
Focal Length / mm	80
Focus Diameter / µm	60
Rayleigh Length / µm	375



Source: Trumpf

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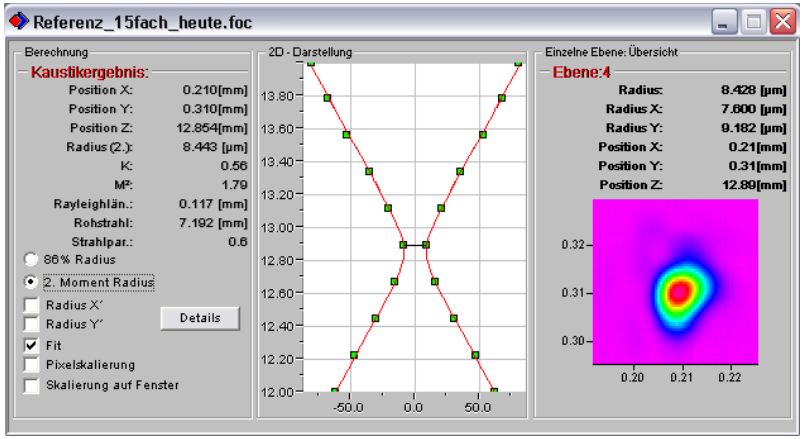
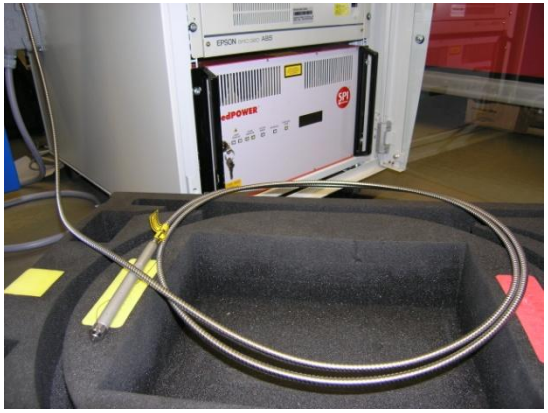
Laser Beam Source
Fiber Laser

Source	SPI 200 C
Laser Medium	Yb:Glass
Wavelenght / nm	1 075
Mode of Operation	cw
Max. Output Power / W	200
Beam Guide	Fiber
Focal Length / mm	80
Focus Diameter / µm	20
Rayleigh Length / µm	117





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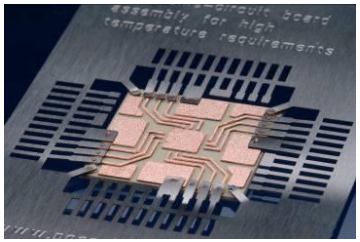
Fields of Application

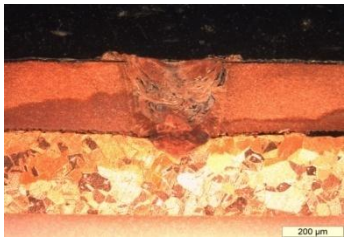
Automotive
- Electric Contacts

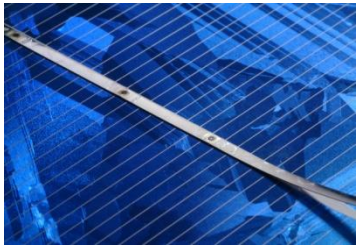
Micro Mechanics
- Mechanical Contacts

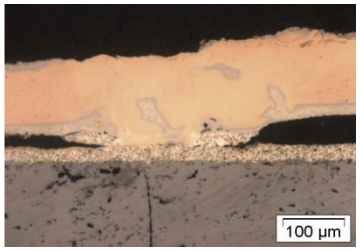
Medical Engineering
- Electric Contacts, Seals

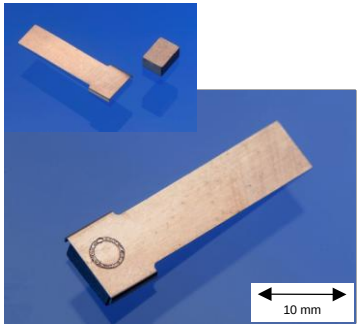
(Consumer-)Electronics
- Electric Contacts

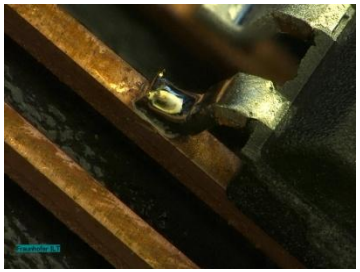












- Overlap- and butt joints
- Wire connections
- Highly reflective materials
- Limited welding depth

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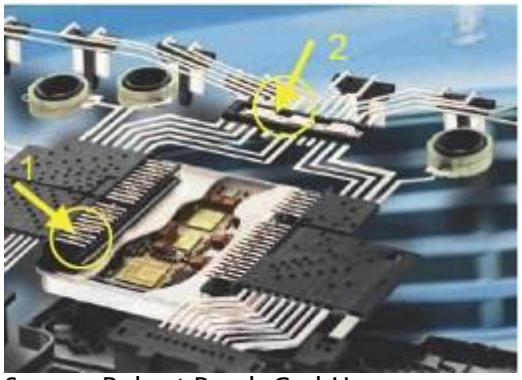
Spot Welding

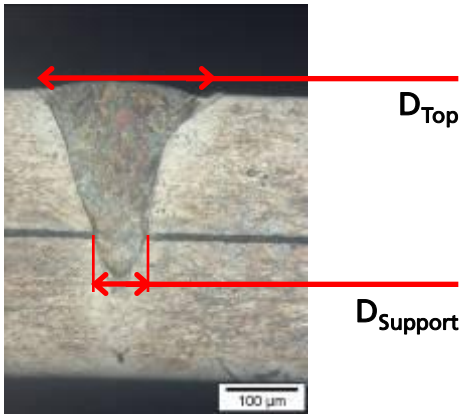
- Electronic Components
- High Throughput
- Controllable Weld Properties

Common Problems with Spot Welding

- Small Supporting Joint Diameter
- Sensitive to Depth Variation
- Porosity due to Melt Pool Overheating



Source: Robert Bosch GmbH



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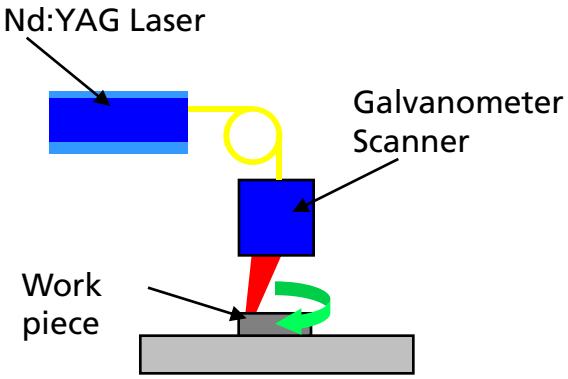
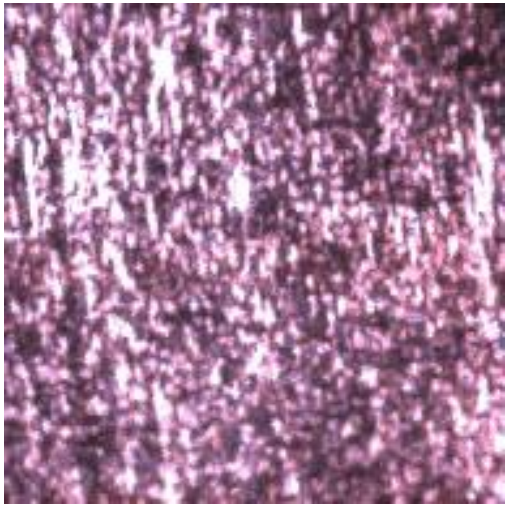
Micro Ring Welding



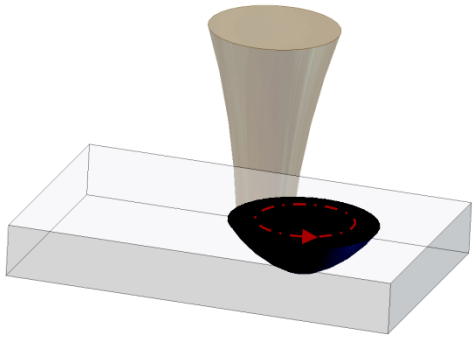
- Multiple Revolutions
- Ring Diameter ~ Beam Diameter
- Overlapping Irradiation Pattern

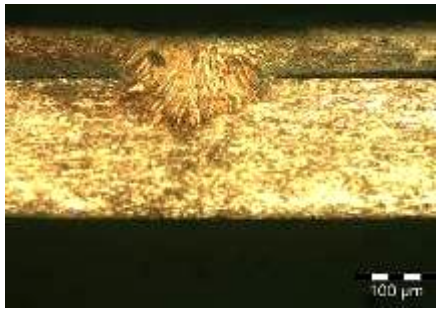


P = 3.75 kW

2w = 400 µm

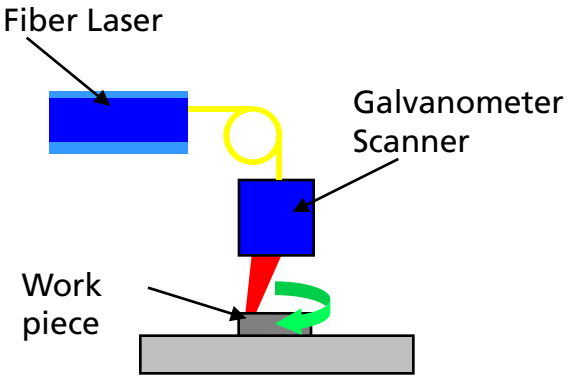
D_{circle} = 300 µm



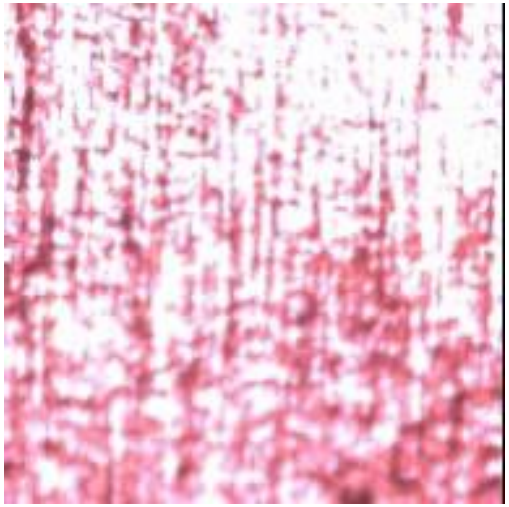


Fraunhofer ILT

Micro Ring Welding



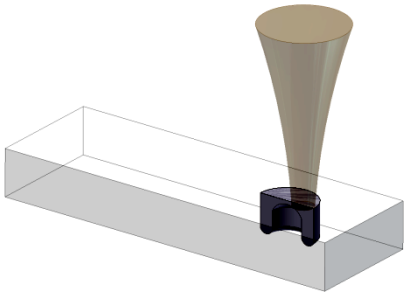
- Multiple Revolutions
- Ring Diameter > Beam Diameter
- Non-Overlapping Irradiation Pattern

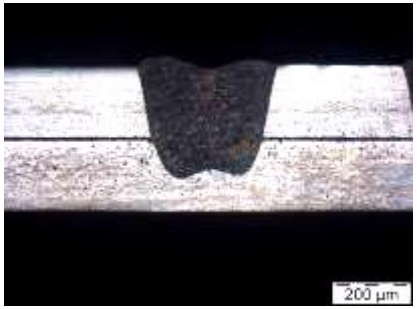


P = 100 W

2w = 30 µm

D_{circle} = 500 µm





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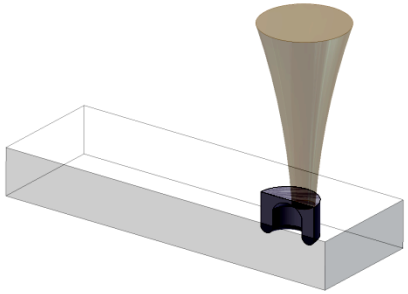
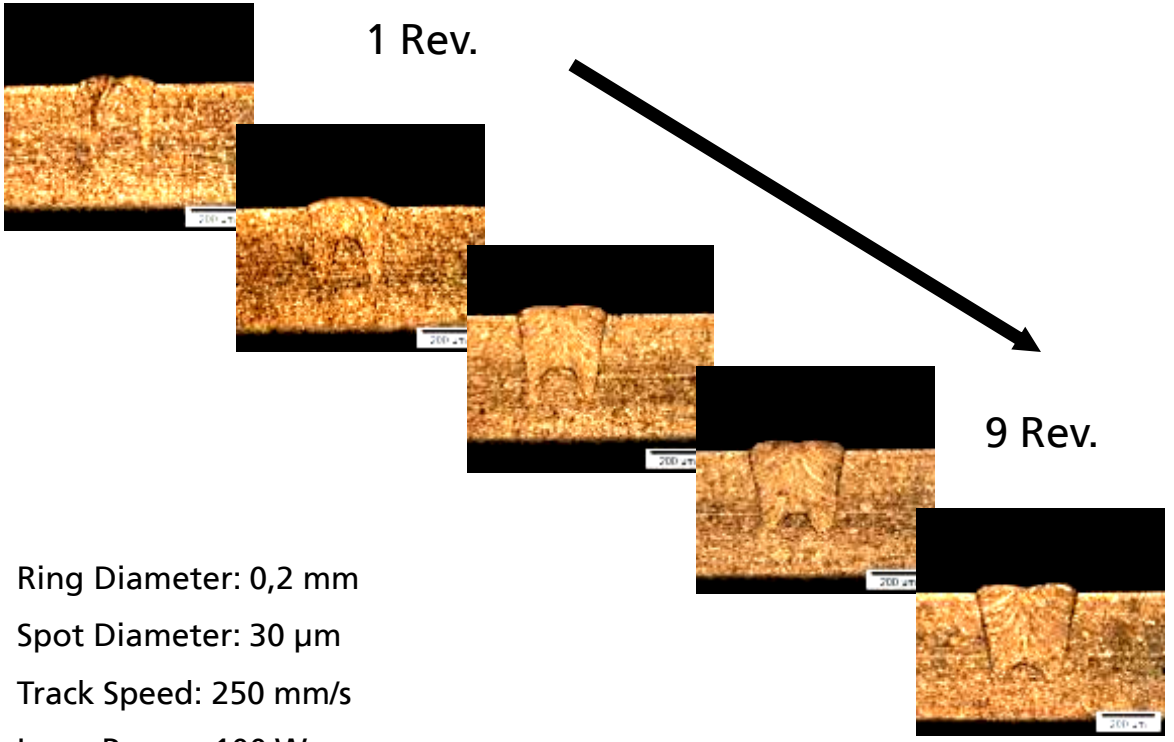
Micro Ring Welding
Melt Pool Formation





- Peripheral Depth: Path of the Laser Beam
- Central Depth: Heat Accumulation

Ring Diameter: 0,2 mm

Spot Diameter: 30 µm

Track Speed: 250 mm/s

Laser Power: 100 W

Material: Stainless Steel, t = 500 µm

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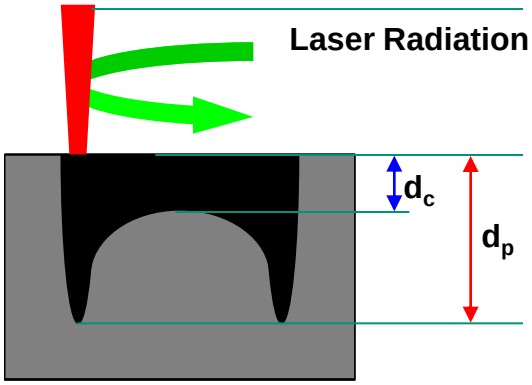
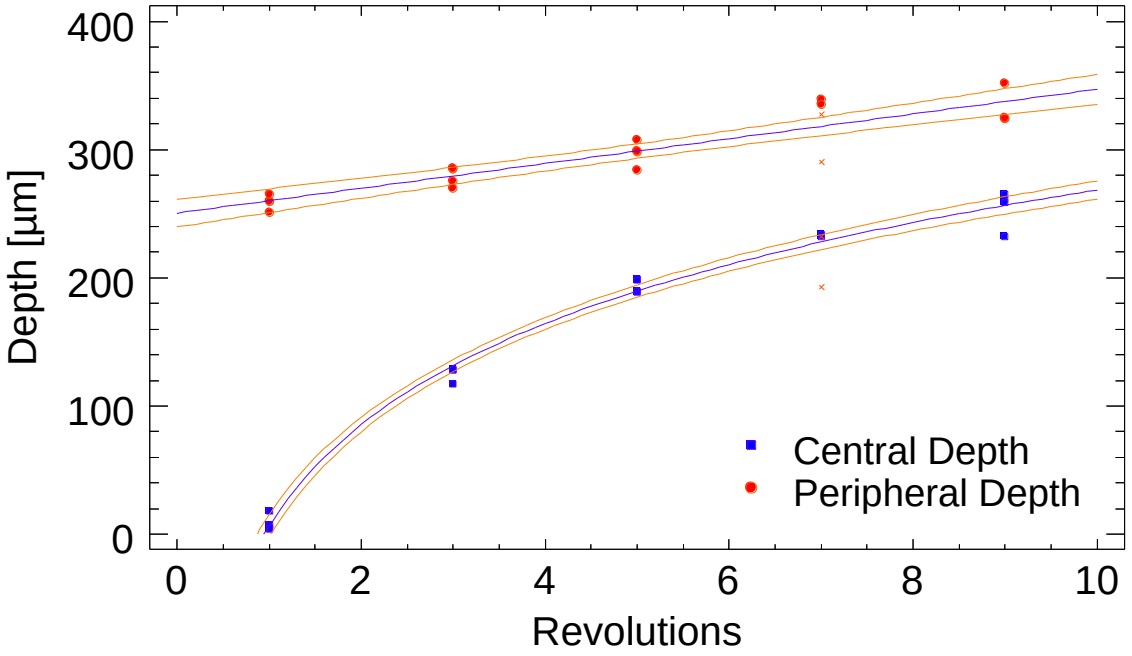
Micro Ring Welding
Melt Pool Formation



- Peripheral Depth: Linear increase
- Central Depth: Logarithmic increase



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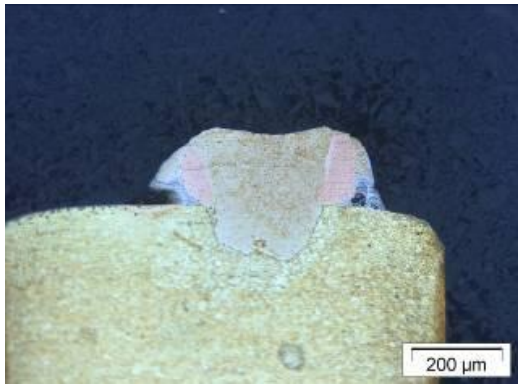
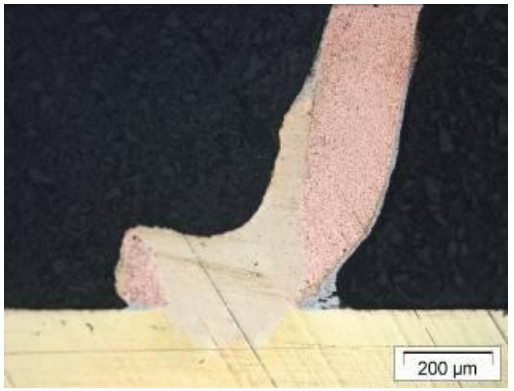
Micro Ring Welding
Welding of Electronic Components





Welding of SMDs

- Contact size: 0,5 mm²
- Material thickness: t = 0,2 mm
- Ring Diameter: 0,3 mm

- No porosity
- Cylindrical melt pool
- High supporting joint diameter

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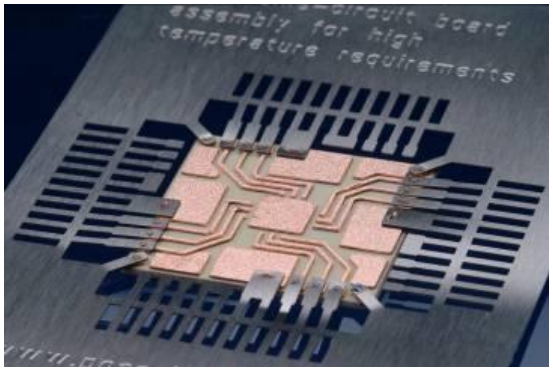
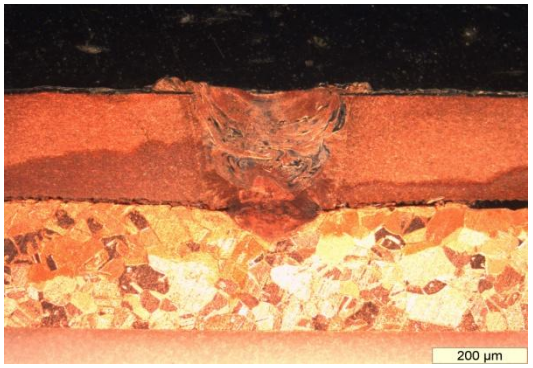
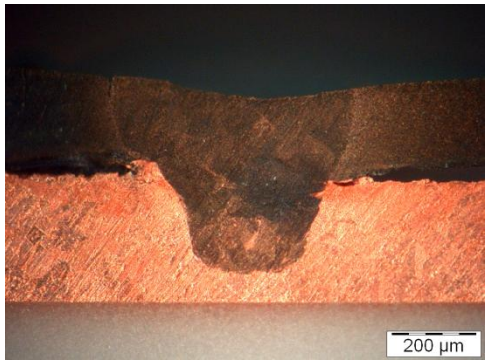
Micro Ring Welding
Welding of Metal Coated Ceramic Substrates







Welding of DCBs

- Contact size: 1 mm²
- Leadframe: t = 0,2 mm
- Cladding: t = 0,3 mm

Spot welding

- 2w = 180 µm
- P = 1,3 – 2,5 kW (Peak)
- T_h = 5 – 10 ms
- E_p = 5 – 10 J

Ring welding

- 2w = 20 µm
- P = 320 W
- T_h = 18 ms
- E_p = 5,8 J

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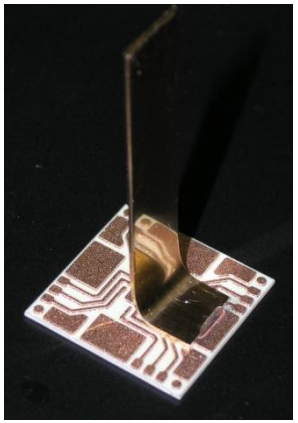
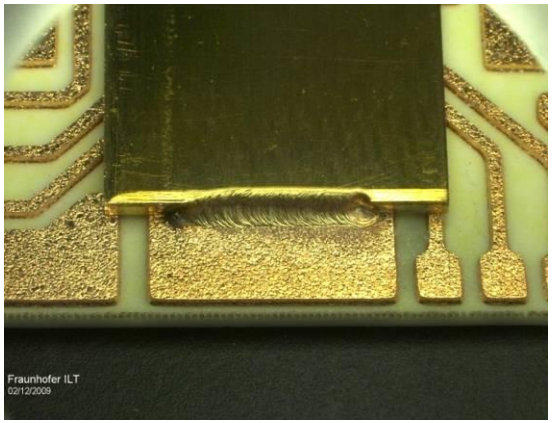
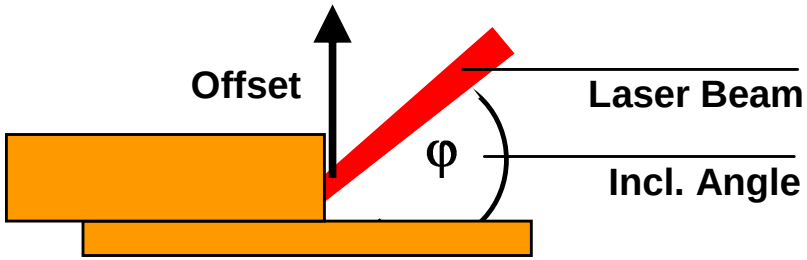
Micro Ring Welding
Fillet Welds with moving rings







Sample:

- DCB: Cu-Clading t = 0,3 mm
- Contact Fin: CuSn6, t = 0,8 mm
- Overlap Weld not reliable due to material thickness
- Fillet Weld by Spatial Power Modulation

Parameters:

P = 500 - 700 W

S = 0.2 – 0.6 mm

V_f = 30 mm/s

A = 0,3 mm

f = 1 000 Hz

α = 20 °

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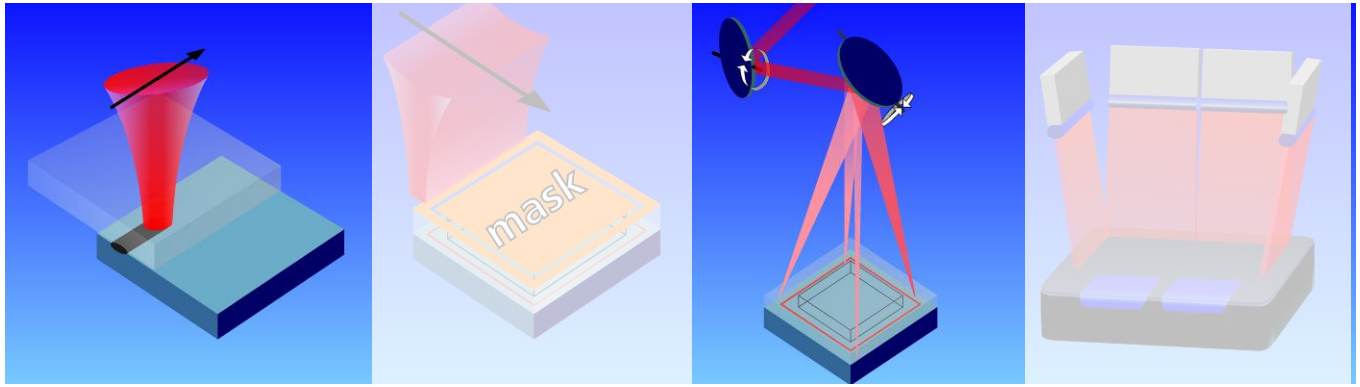
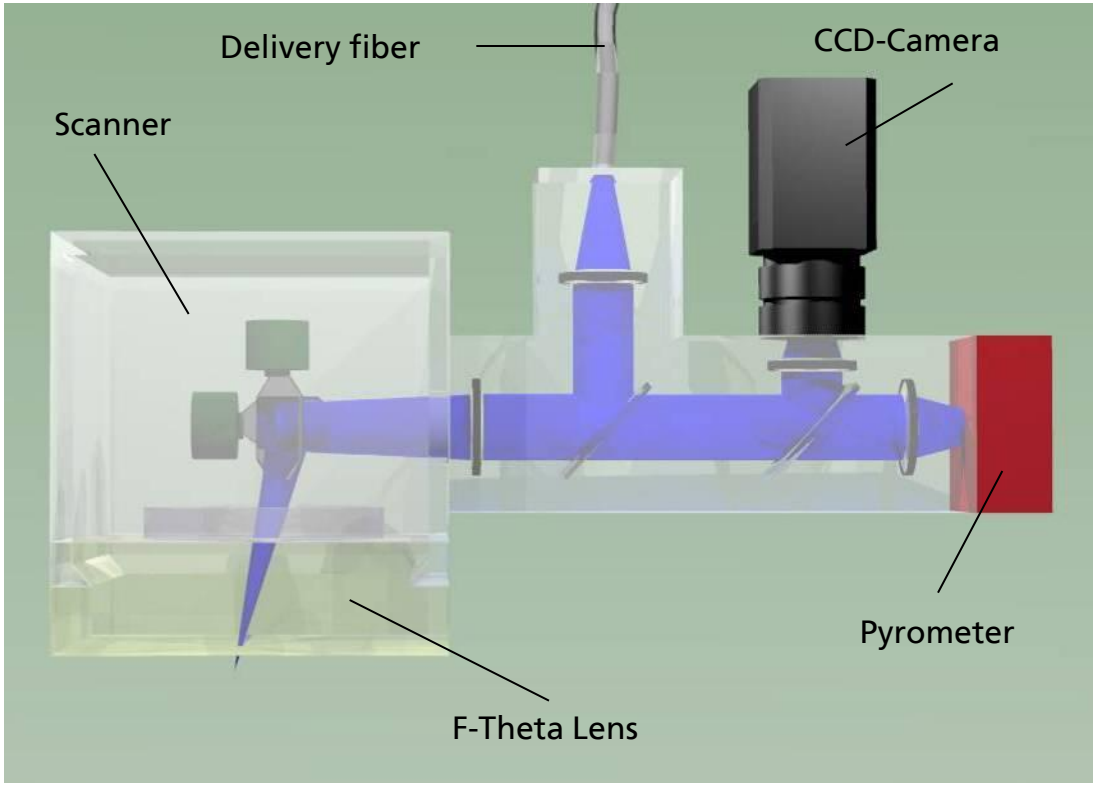
Polymer Welding

Laser Sources and Welding Techniques



	Contour	Mask	Quasi-simultaneous	Simultaneous
Laser source	HPDL / Nd:YAG/Fiber	HLDL	HPDL / Nd:YAG / Fiber Laser	HPDL
Spot diameter [µm]	> 200 / 20 / 10	50 x 40000	> 200 / 20 / 10	-
Laser power[W]	< 200	< 300	> 200	> 200
Feed rate [m/min]	< 25	< 10		-
Interaction time [ms]	> 1	> 2,5	> 0,002	> 50

Polymer Welding with Galvo Scanners



TWIST® – a new welding process

Transmission

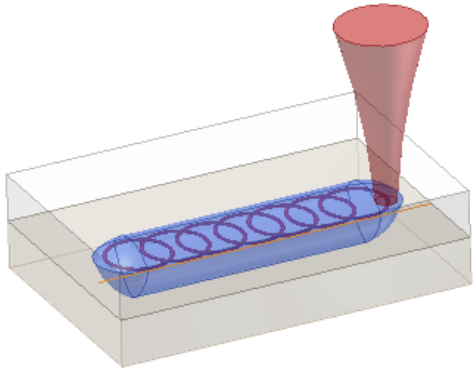
Welding

Incremental

Scanning

Technique

- Superposition of linear feed with high dynamic movement



$$\begin{cases} x(t) = v \cdot t + r \cdot \cos(2 \cdot \pi \cdot f \cdot t) \\ y(t) = r \cdot \sin(2 \cdot \pi \cdot f \cdot t) \end{cases}$$

TWIST® – a new welding process

Irradiation pattern

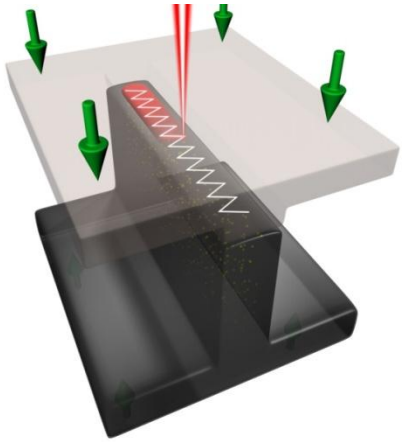
Transmission

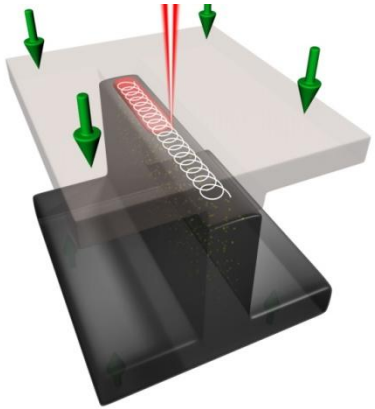
Welding

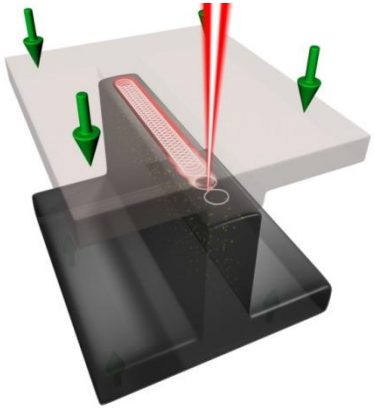
Incremental

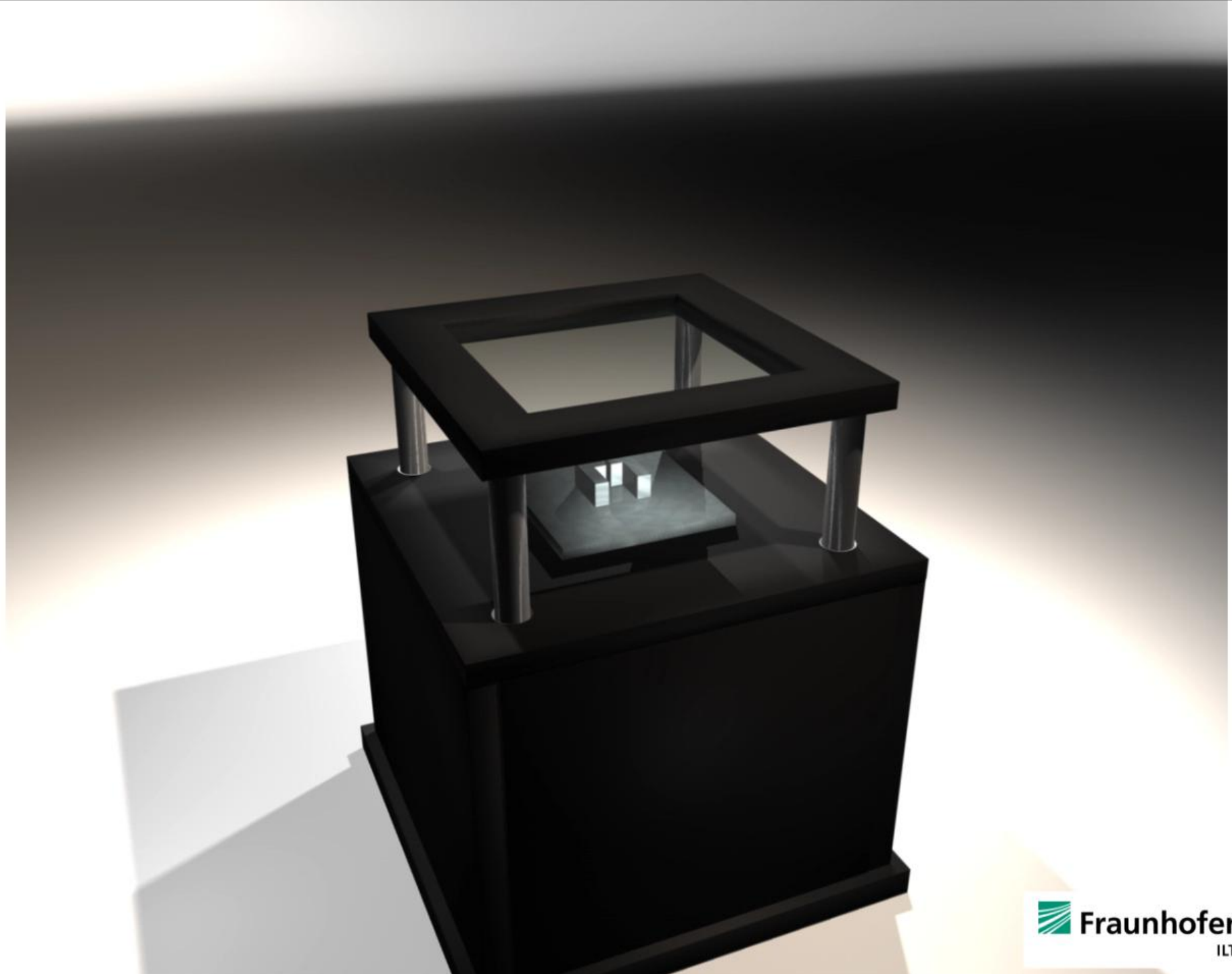
Scanning

Technique









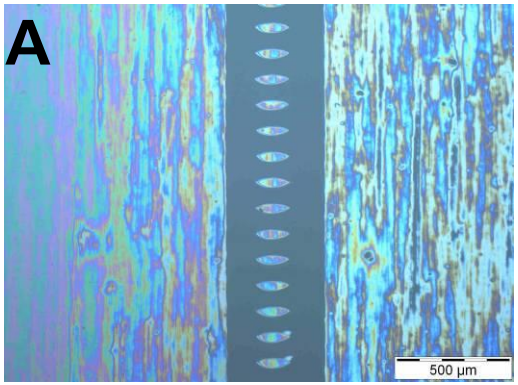
Fraunhofer
ILT

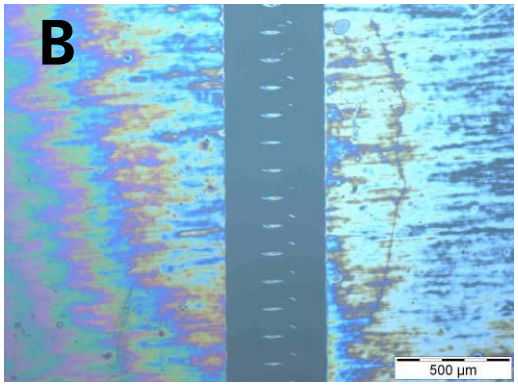
Weld Seams

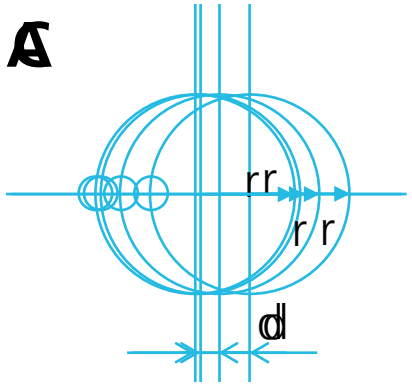
A) P= 3,6 W
v= 70 mm/s
r= 0,2 mm
f= 600 Hz

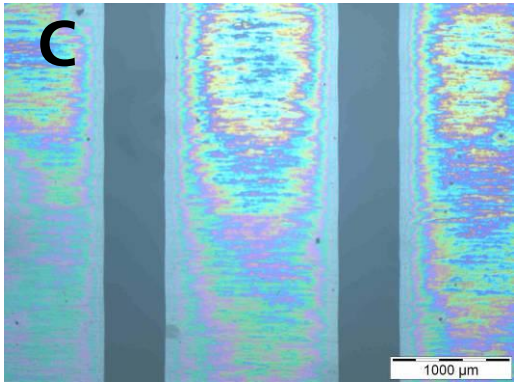
B) P= 3,6 W
v= 50 mm/s
r= 0,2 mm
f= 400 Hz

C) P= 3,6 W
v= 20 mm/s
r= 0,2 mm
f= 400 Hz









Fraunhofer ILT

Cross Sections of the Seams

- Welding of Polypropylene (PP) plates

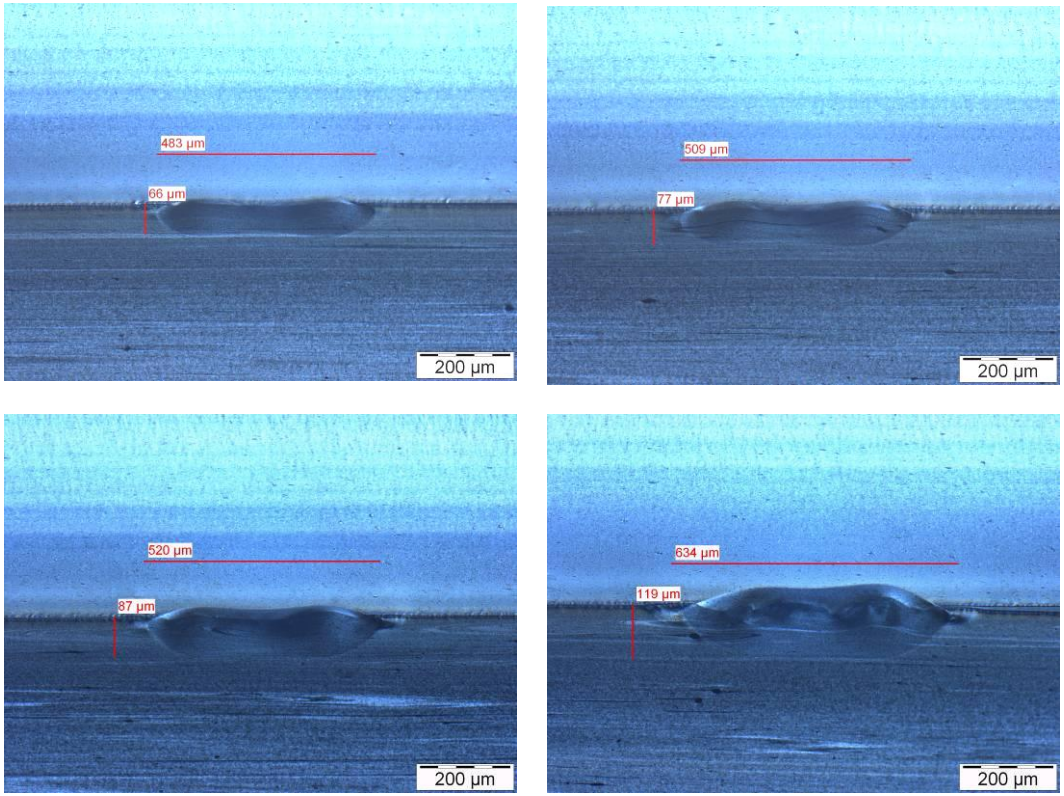
Material properties:

- Thickness d= 1 mm
- 0,5 wt% carbon black

Process parameters

A) P= 2,5 – 5 W
v= 50 mm/s
r= 0,225 mm
f= 1800 Hz

Weld seam width – 500 µm



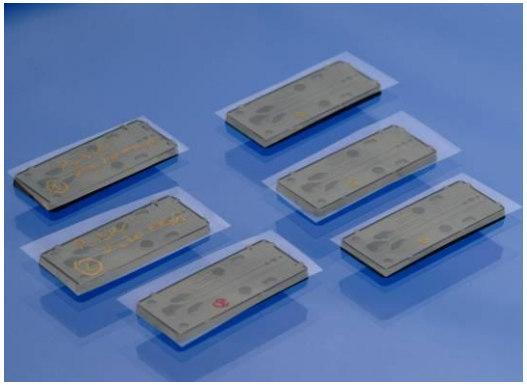
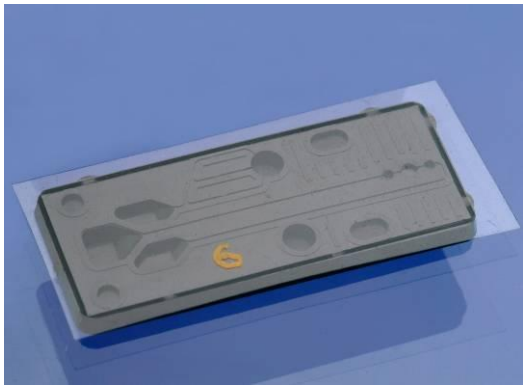
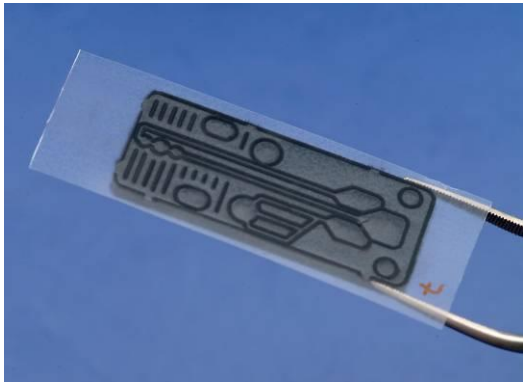
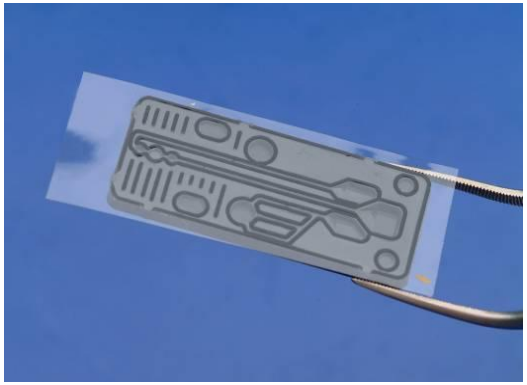
Fraunhofer ILT

Application for TWIST

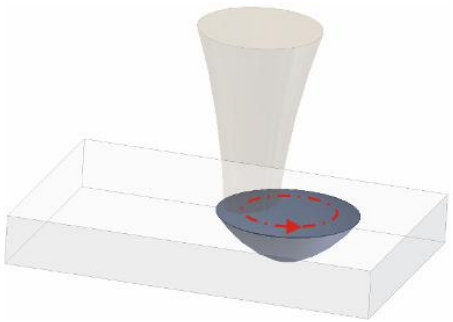
Micro fluidic device
- PMMA or PP

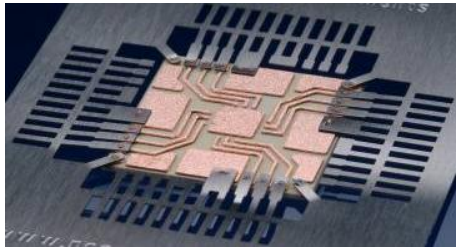
Cover (75 µm)
-PMMA or PP

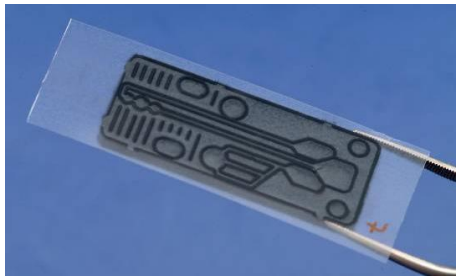
P= 1,4 - 6,6 W
v= 50 - 300 mm/s
d_0= 70 µm
d_{weld}= 100 to 500 µm

Summary







- New processes with high reproducibility and stability
  - SHADOW® Micro Ring Welding:
  - TWIST® – Ultrafine welding of Polymers
- Improvement of weld quality avoiding splatters and craters
- High controllability of weld depth
- High Welding Speed for High Throughput
- Further decrease of the focal diameter to achieve smaller weld seams
- Temporal and spatial modulation of the laser power to avoid material degradation

Thank you for your attention
Merci pour votre attention

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