Business from technology

Laser welding of polymers - State of the art and innovative trends Part II - Quasi-simultaneous and Simultaneous welding

1st workshop

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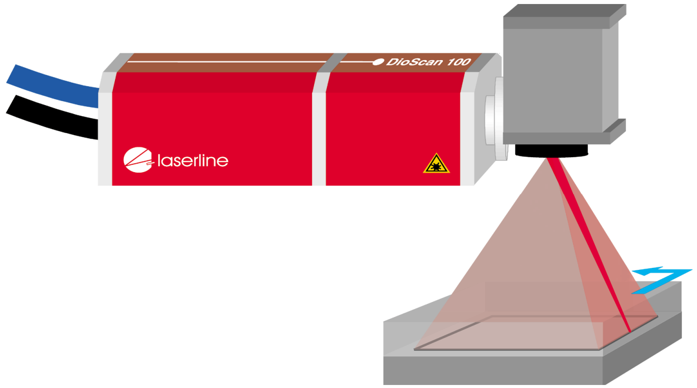
Polymer welding techniques

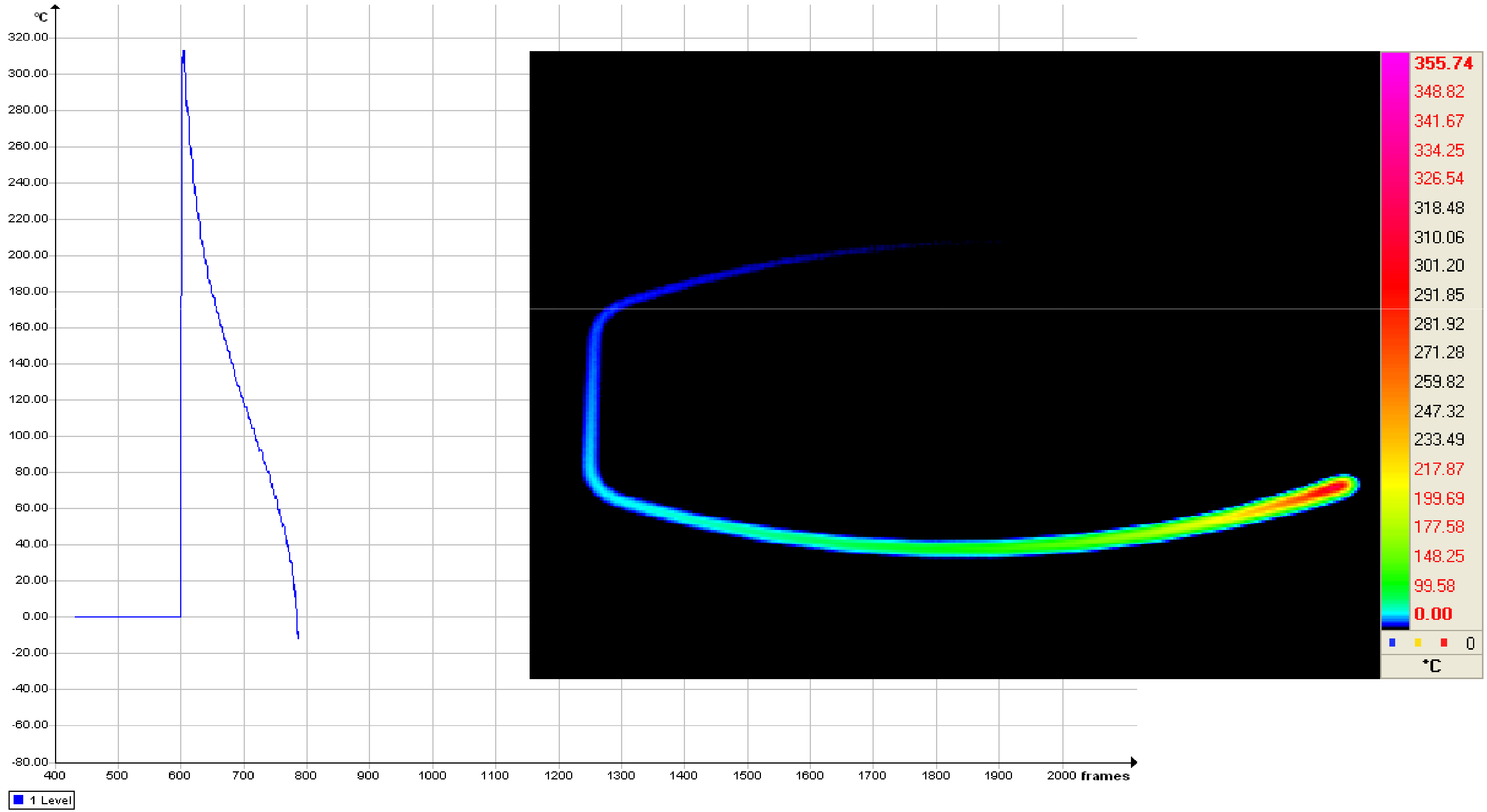
- contour welding
- **quasi-simultaneous welding**
- **simultaneous welding**
- mask welding
- Globo welding
- TWIST

Quasi-Simultaneous Welding

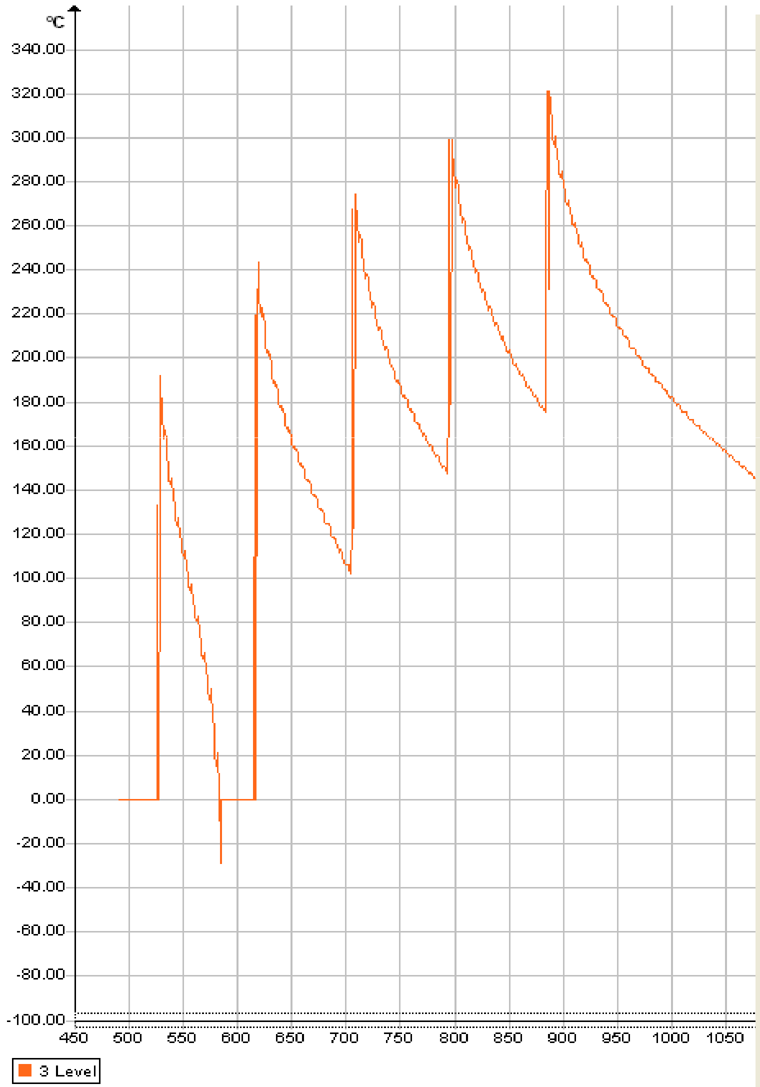
- The laser beam is moved very fast across the work piece several times with scanner mirrors
- The welding path is heated up gradually (low thermal conductivity)
- A quasi-simultaneous melting of the entire welding track occurs
- Very short processing times
- Scanner work field sets the limits for weldable area

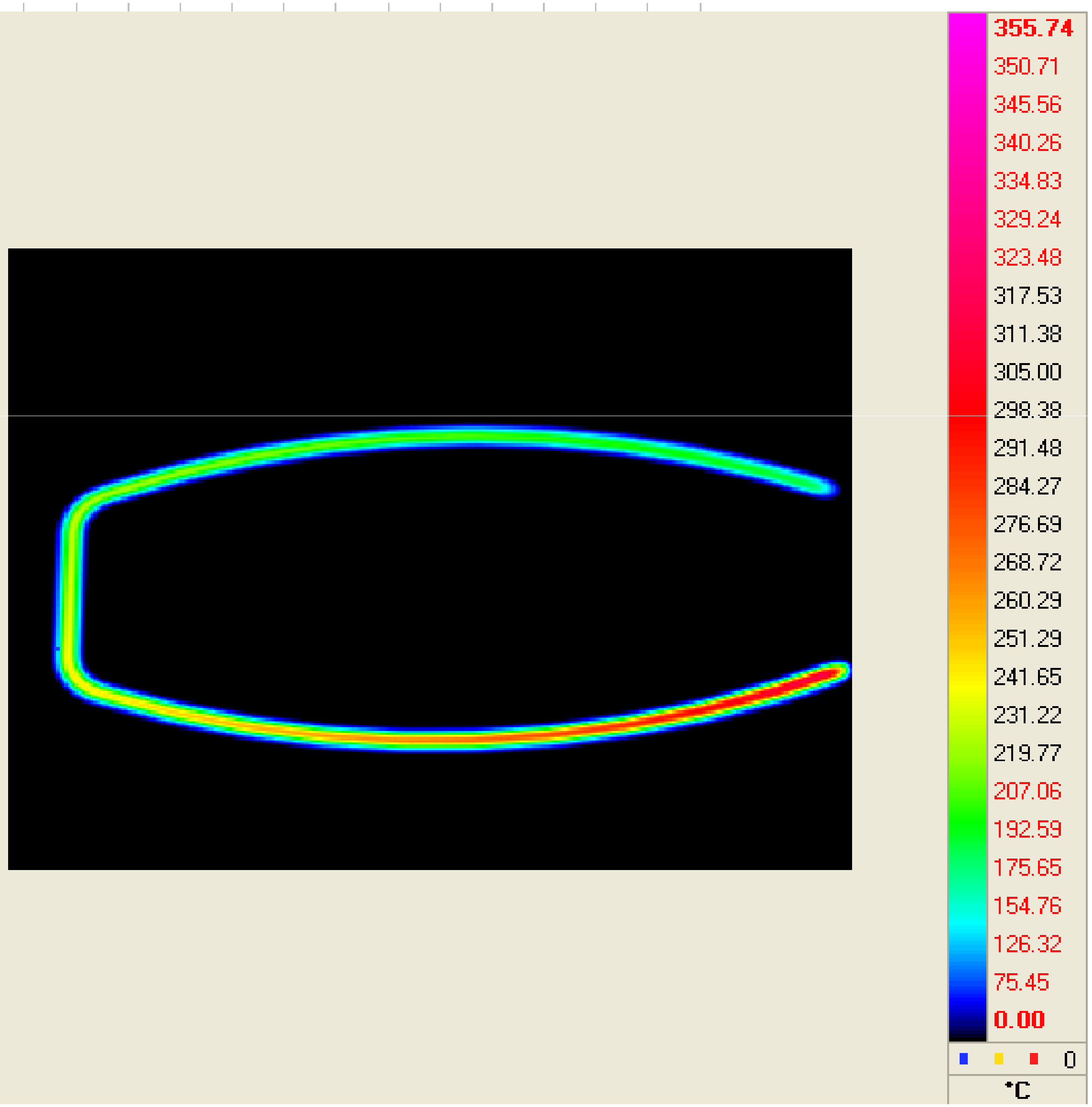


1 scan, 0.1 m/s, 10 W, ~ 1 s

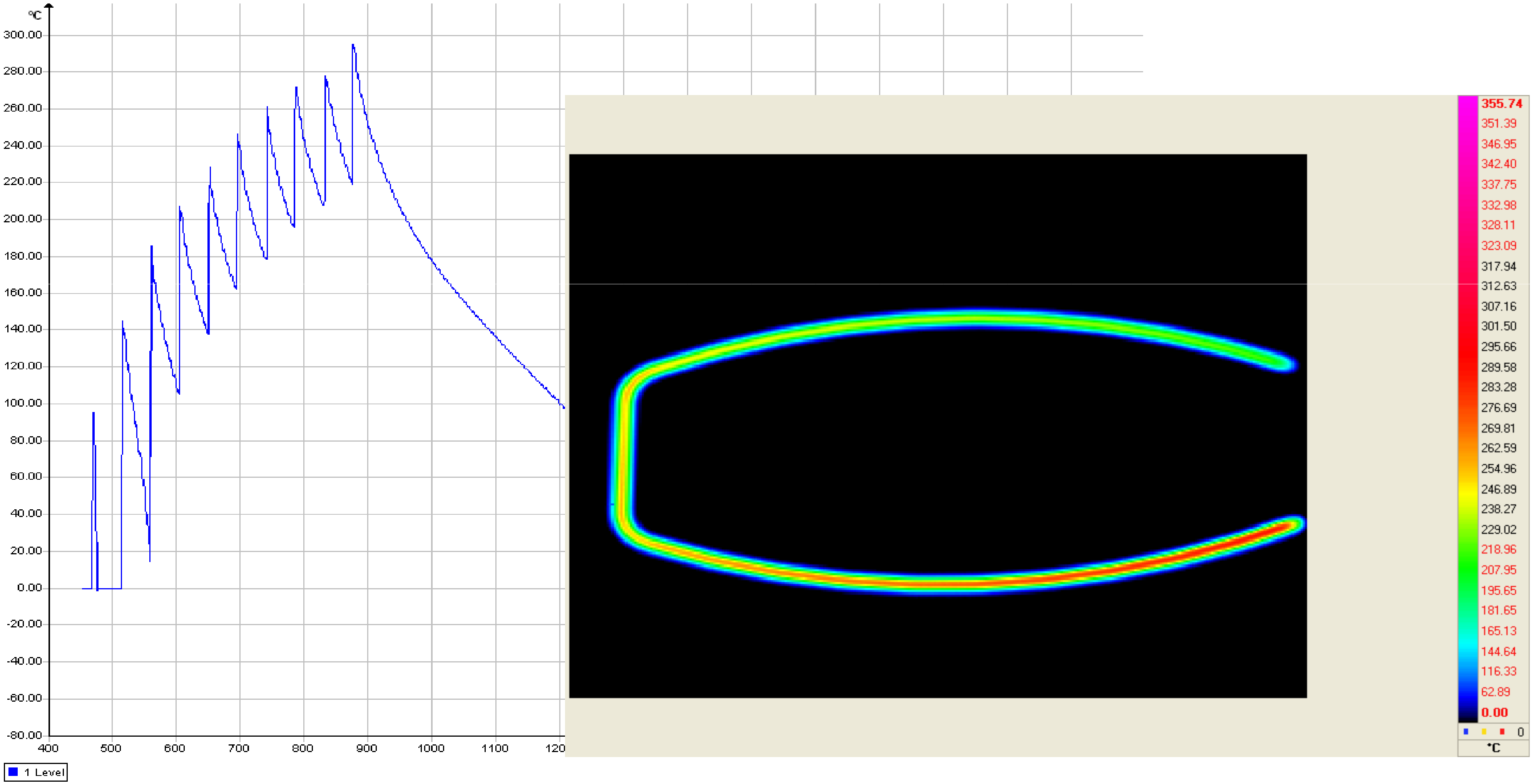


5 scans, 0.5 m/s, 25 W, ~ 1 s

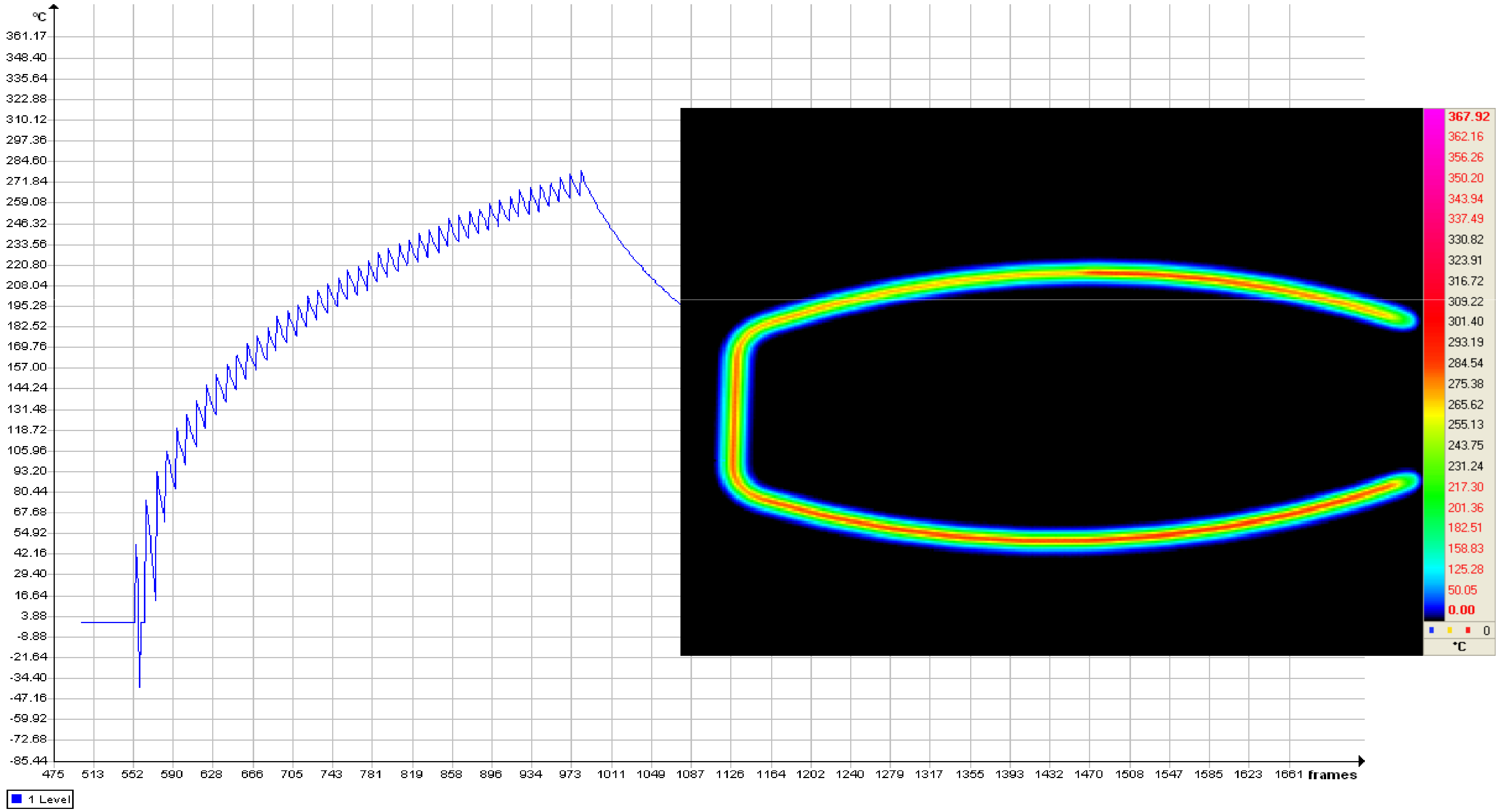




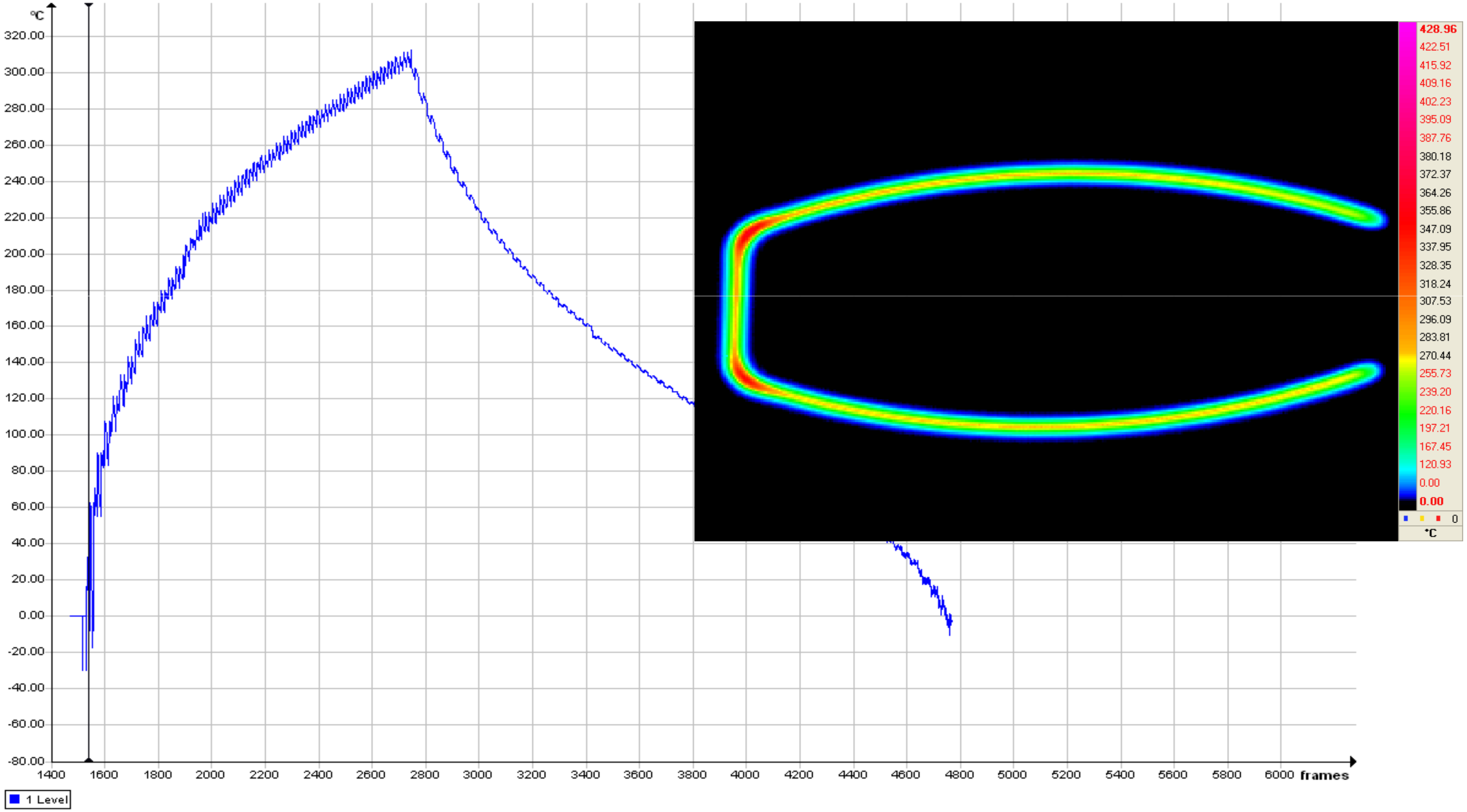
10 scans, 1 m/s, 27 W, ~ 1s



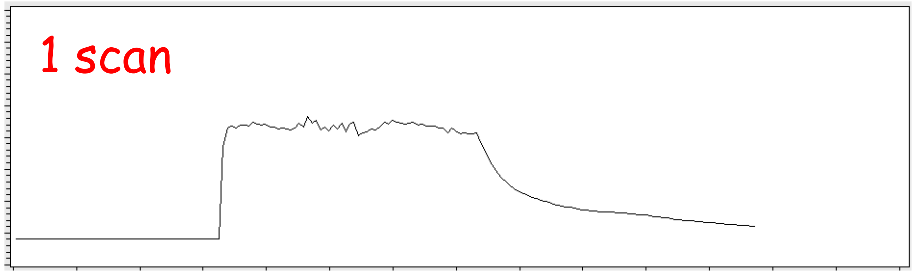
50 scans, 5 m/s, 35 W, ~ 1s

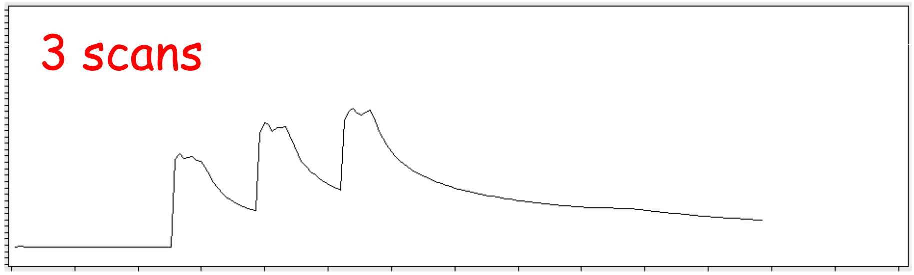


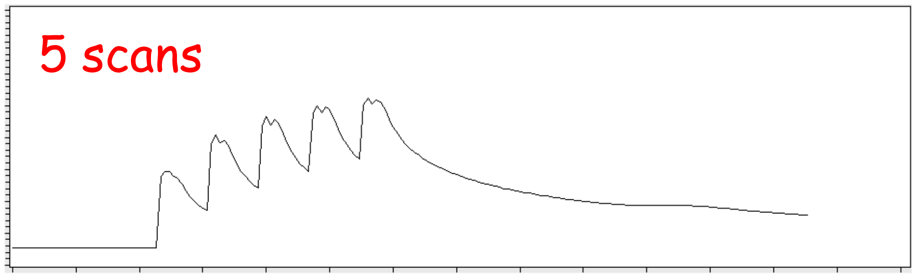
100 scans, 10 m/s, 40 W, ~ 1s

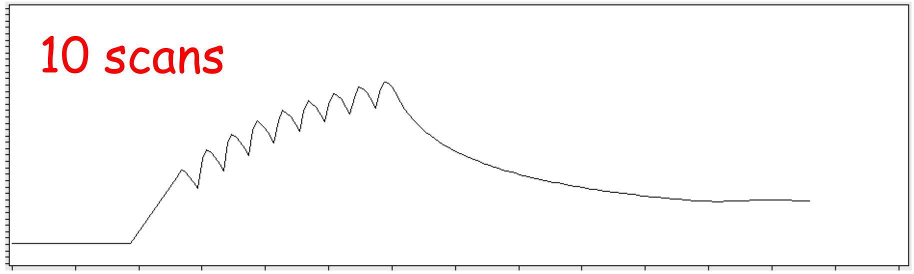


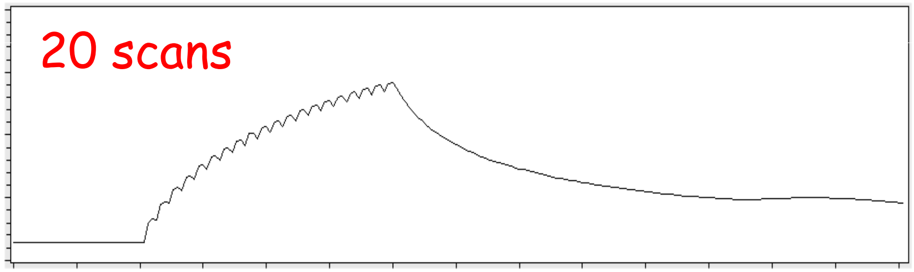
IR Camera Measurements – Temp. vs Time

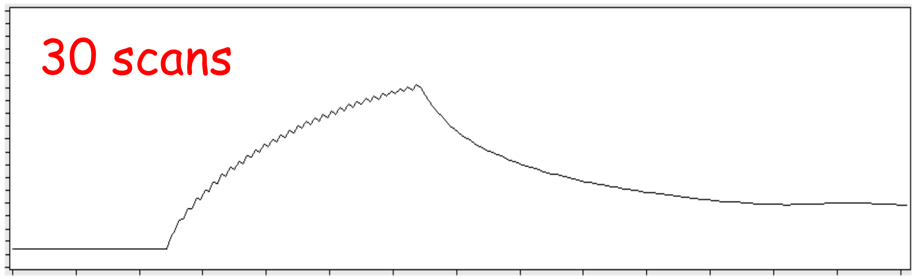


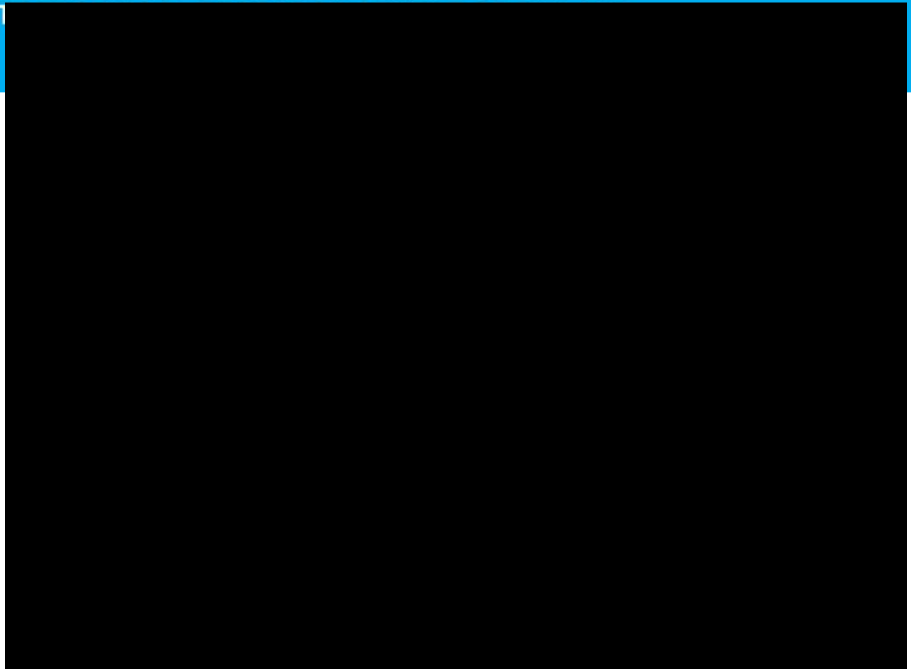


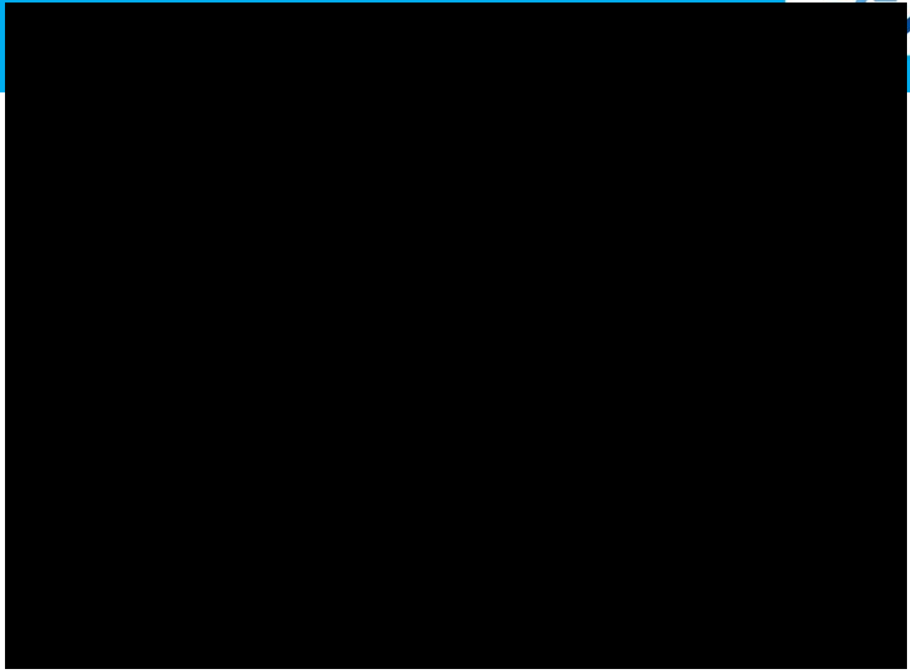




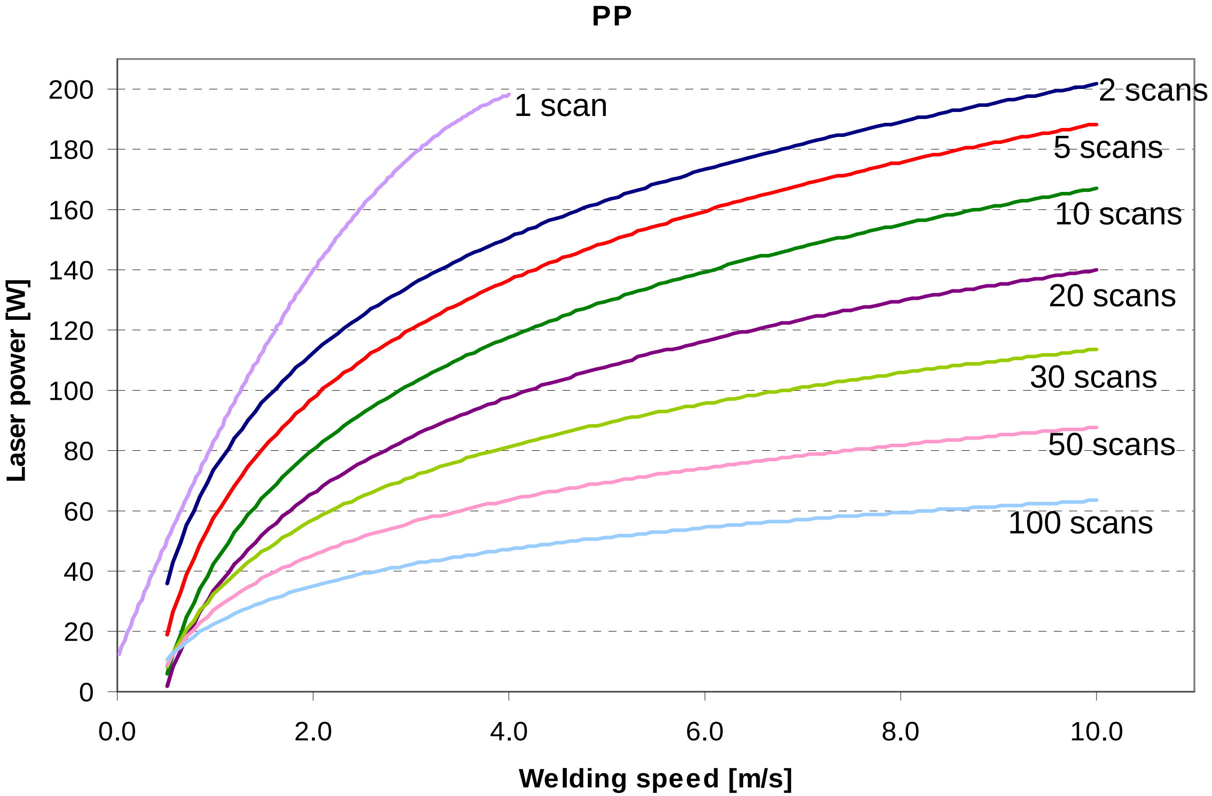






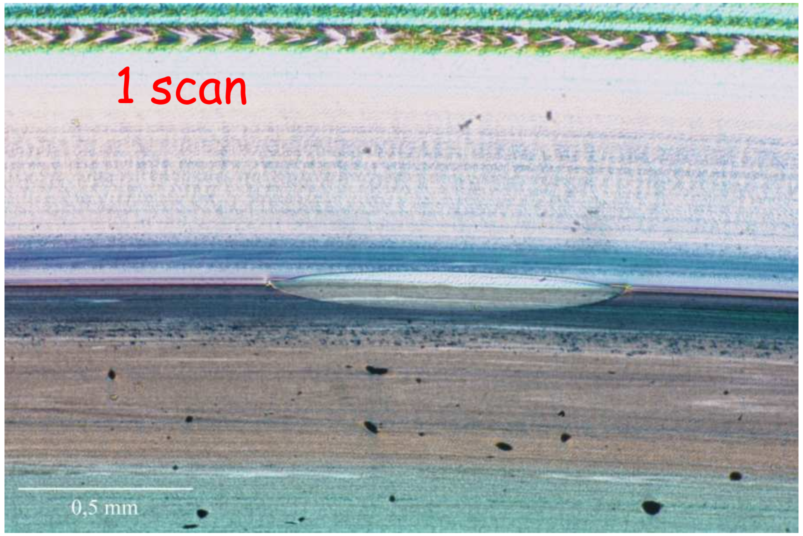


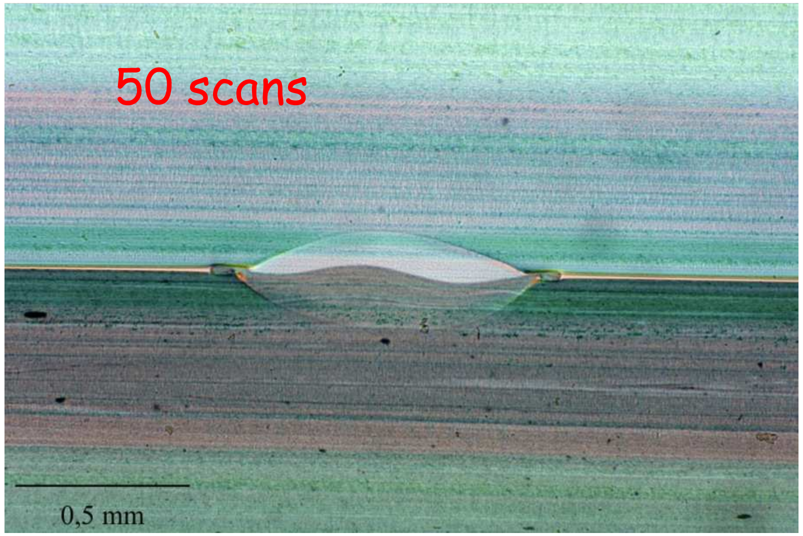
Welding parameters (QSLW- and contour welding)



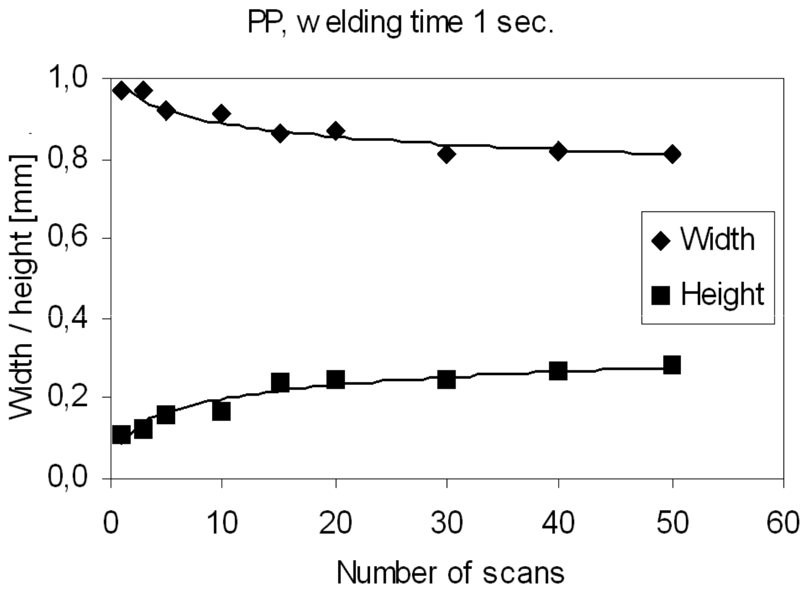
- When welding speed increases with the same amount of scans the needed laser power is higher (shorter welding time)
- When the amount of scans is increased with the same welding speed the needed power is lower (longer welding time)
- Scanning speed, amount of scans and laser power has to be matched together to get good weld properties (wanted welding time and heat input)

Welding Tests – Weld dimensions of PP





The effect of scans to the weld dimension



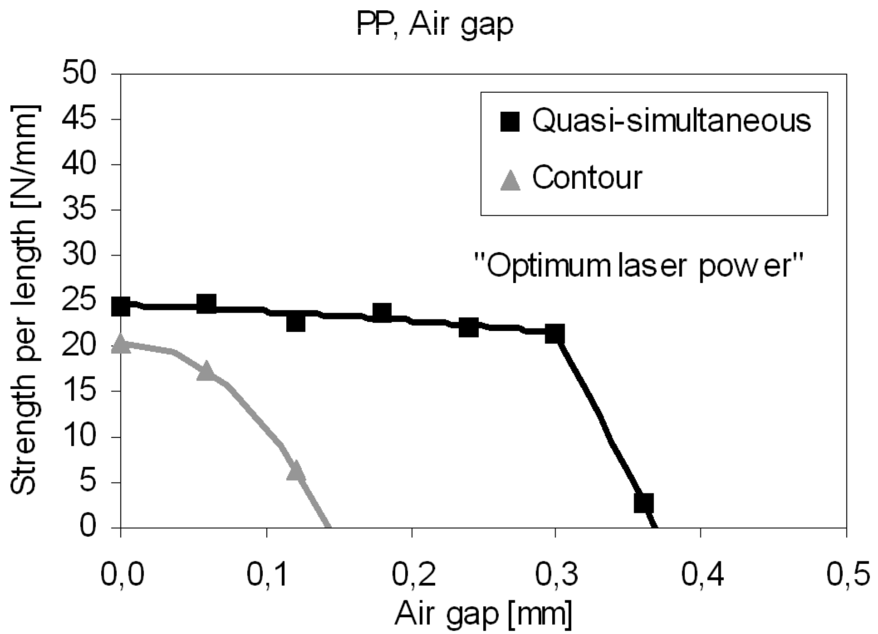
- Wider welds with a low number of scans
- Weld height grows the more times the weld is scanned
  - ⇨more energy is fed in to the center of the weld

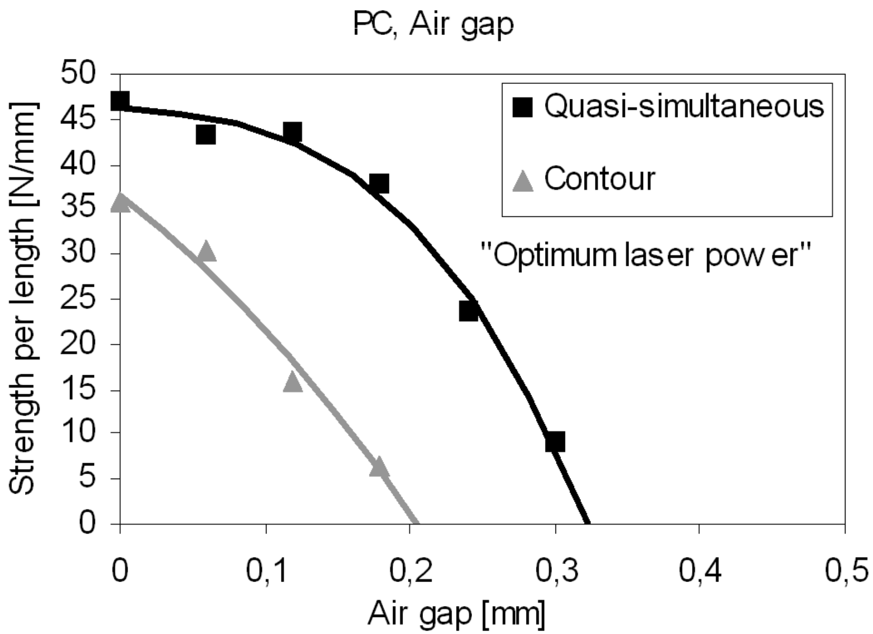
Air Gap Bridging – PP & PC

- Motivation: each mould cavity is unique
  - ⇨ dimensional errors
  - ⇨ air gaps

- Quasi-simultaneous laser welding offers a better air gap bridging ability than contour welding

Quasi-simultaneous: 2 m/s, 50 scans
Contour: 3 m/min
Focal spot size QS & Contour: ∅1 mm



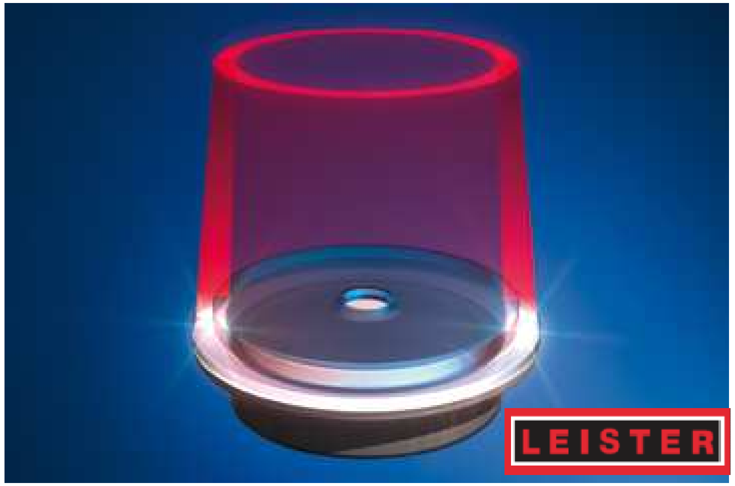


Benefits of QSLW over contour welding

- Quasi-simultaneous laser welding offers stronger welds than traditional contour welding
- Larger air gaps could be bridged with quasi-simultaneous welding then with contour welding
- QSLW offers larger parameter window

Simultaneous welding

- Workpiece and beam are stationary
- If multiple lasers are used they need to be accurately placed (fibers or diodes)
- Beam ”lights” up the whole weld during welding
- Short welding times
- Not flexible
- Simple geometries and high volume production needed
- Diffractive optic is a new way of doing this using fiber laser
- Spatial light modulators might be the next step in simultaneous welding and enable the flexibility



One shot welding

- One shot welding is simultaneous welding using a laser and diffractive optic.
- DOE creates the weld geometry

Why to use diffractive optic?

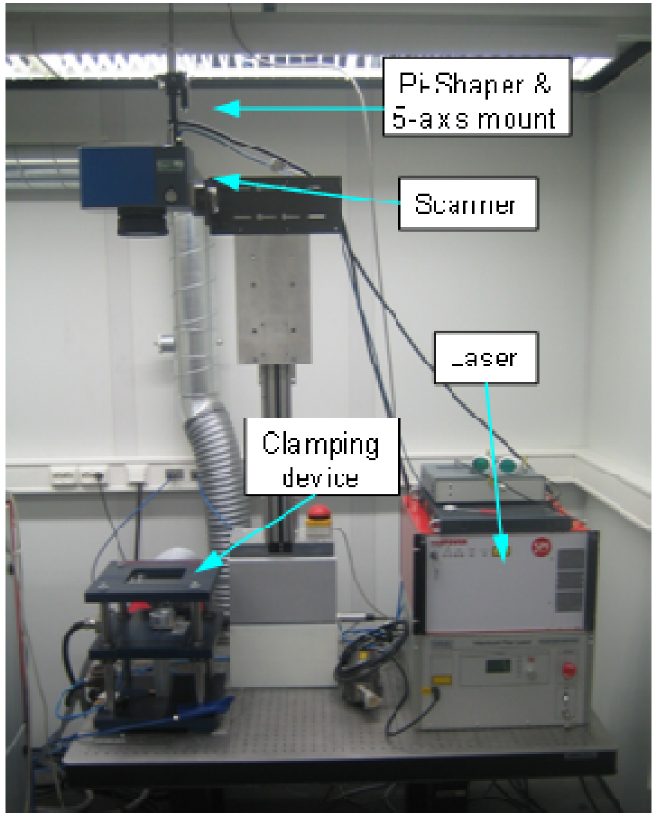
- With diffractive optic one can create what ever geometry from the beam

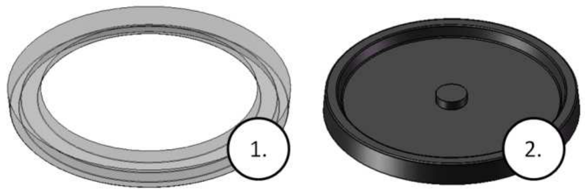
Experiments

Experimental 1/3

- Quasi-simultaneous welding setup
  - SPI 100W CW fiber laser
  - Scanhead with f825 f-theta
  - Pi-shaper
  - Clamping unit

- Beam quality K ~ 0.2 with Pi-Shaper
  - without K ~ 0.91
- Material Polycarbonate from Bayer
  - Makrolon 2405
  - Clear and black



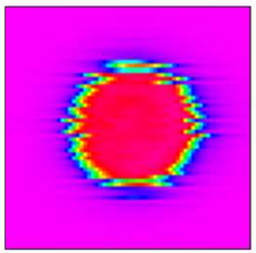


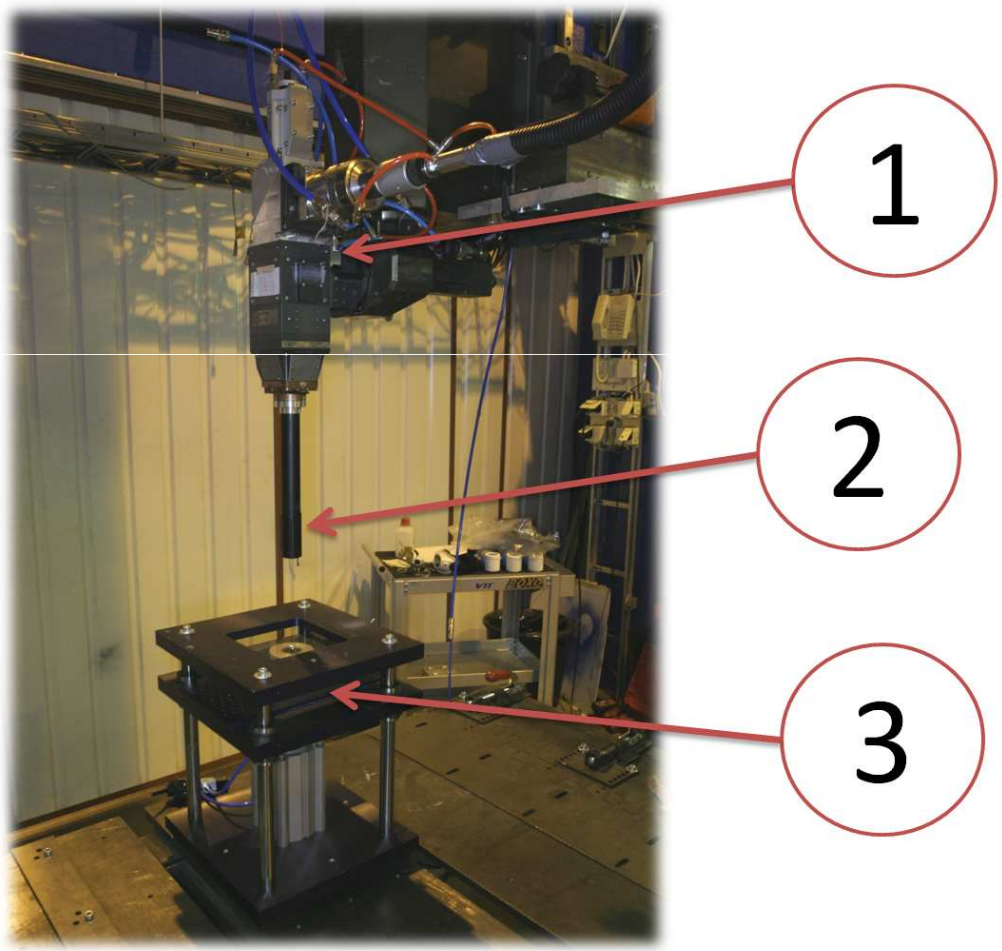
Experimental 2/3

- Simultaneous welding setup
  - IPG YLR-5000-S
  - Precitec YW50 welding head
  - ILV DC-scanner
  - Diffractive optic
- Material and test sample same
  - Makrolon 2405

Caustic Result:

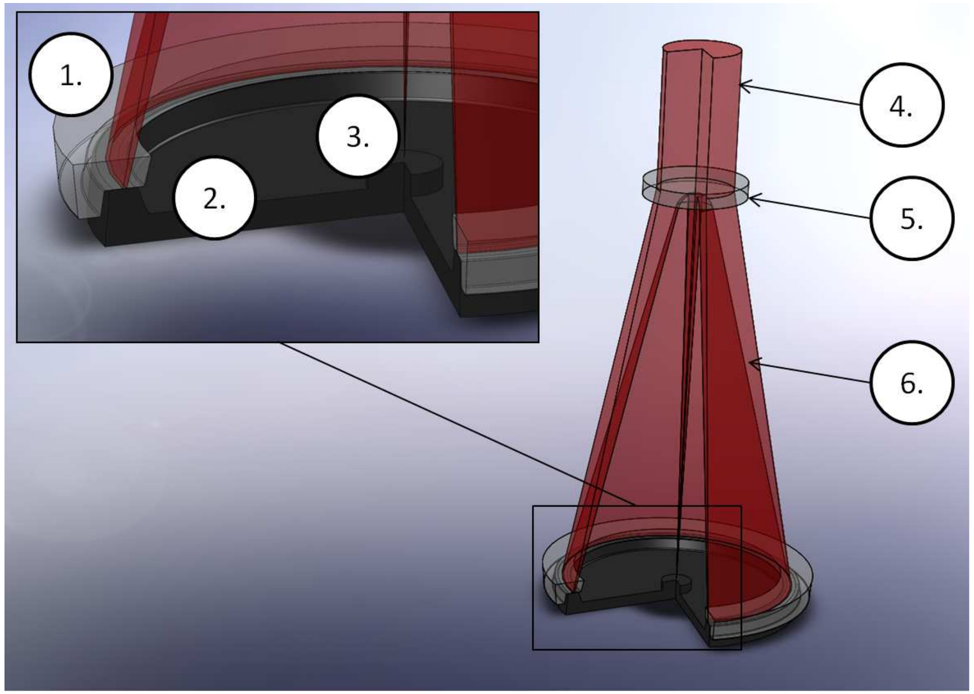
Radius	96.50 µm
K	0.07
M2	13.8
Rayleigh len.	2.00 mm
Raw Beam	9.62 mm
BPP	4.6





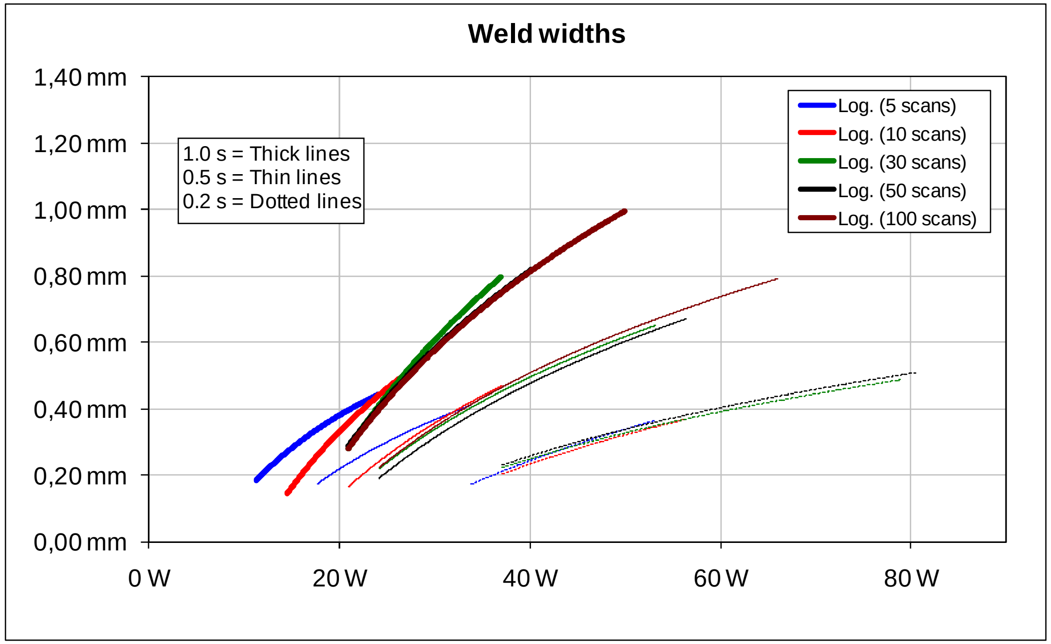
Experimental 3/3

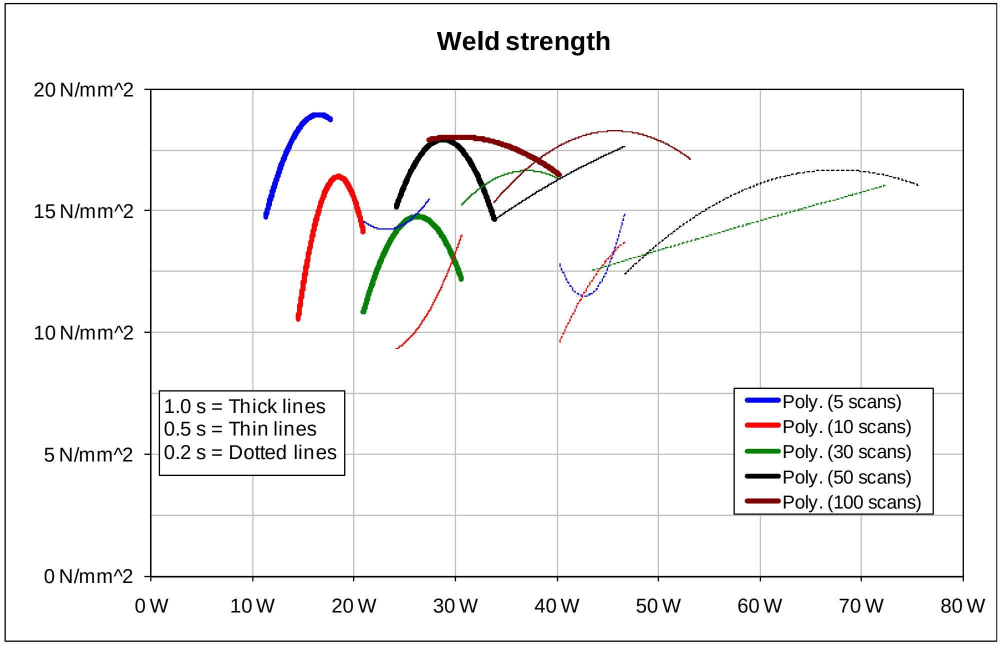
- Diffractive optic creates circle.
- Zeroth mode goes to middle and was blocked away
- High losses due multiple optics -> only ~42% from set power ended to welding



Quasi-simultaneous welding

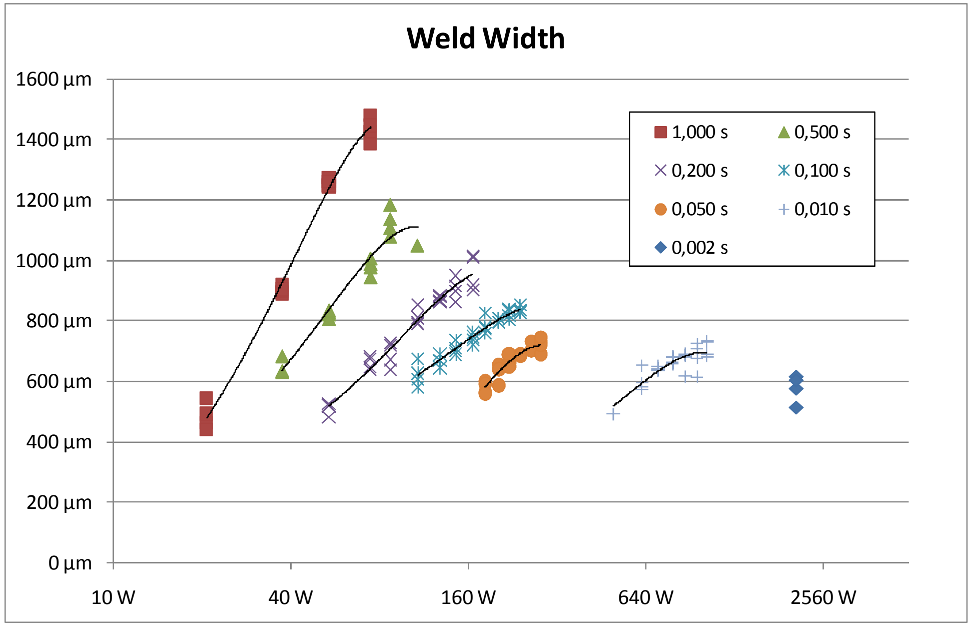
- Results show quite wide welds but strenght of the welds could be better
- The more the scans -> wider the weld
- Welding time does not have a big effect to strenght

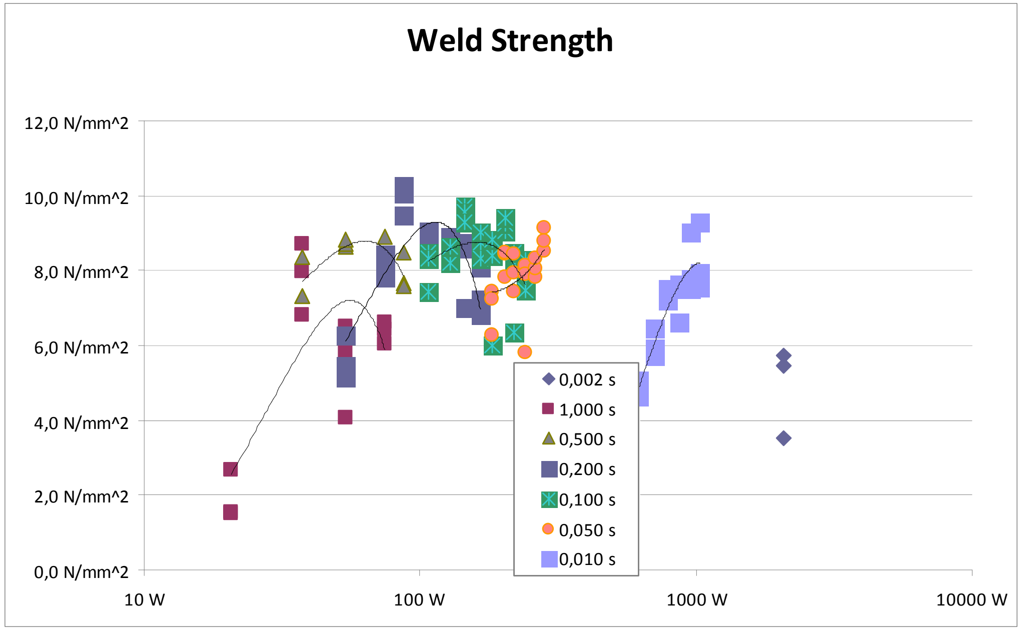




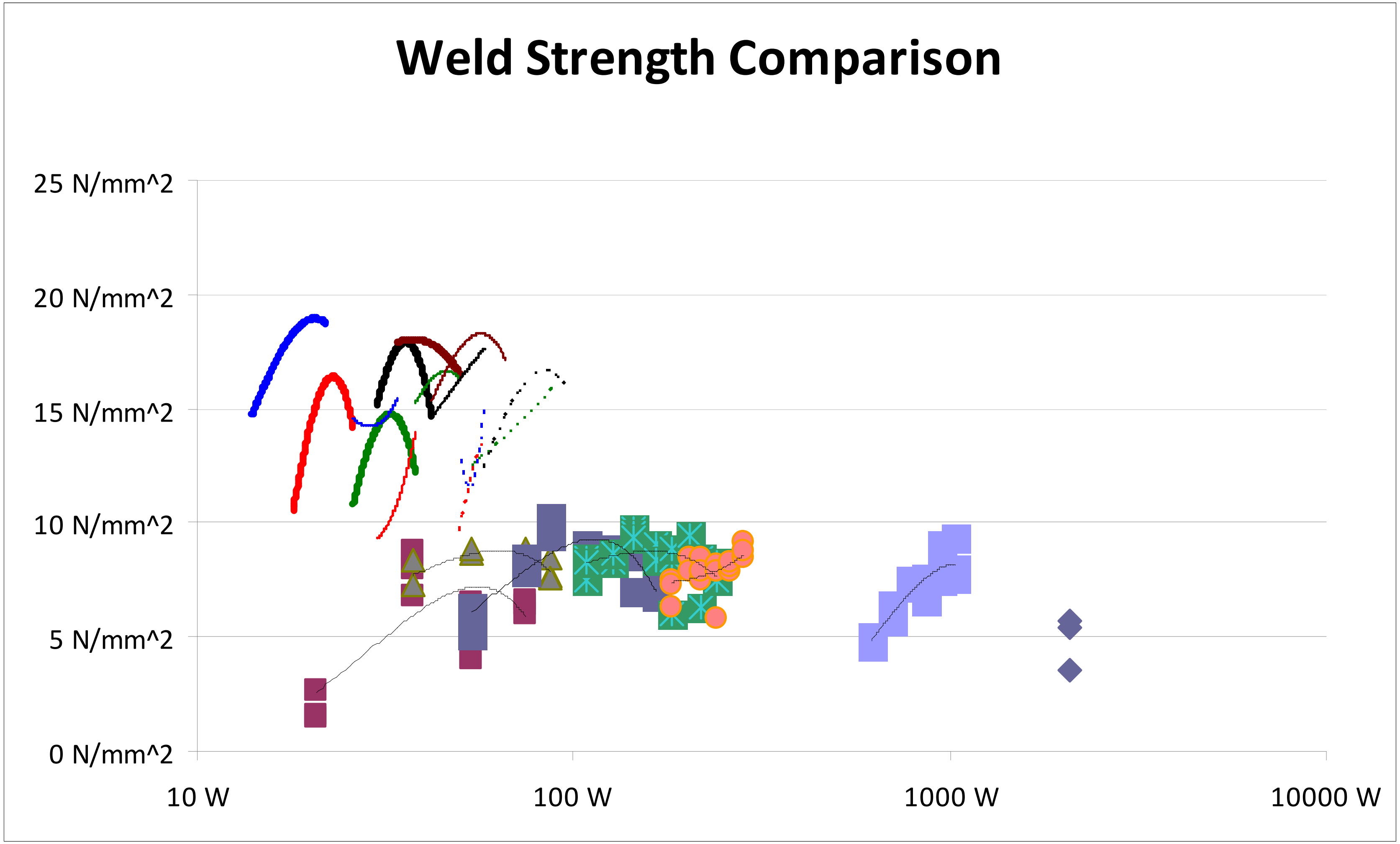
Simultaneous – one shot

- Wider welds with longer welding time
- Welds are a lot wider than DOE design width of 0.2mm





Quasi vs Simultaneous Welding



Conclusion of experiments

- Simultaneous welding gives really good weld strenghts
- No sense using 5kW fiber laser in production.
- 100W laser enables < 1 second welding times which makes it already feasible in production
- Using SLM would enable more flexibility and could be used atleast in testing

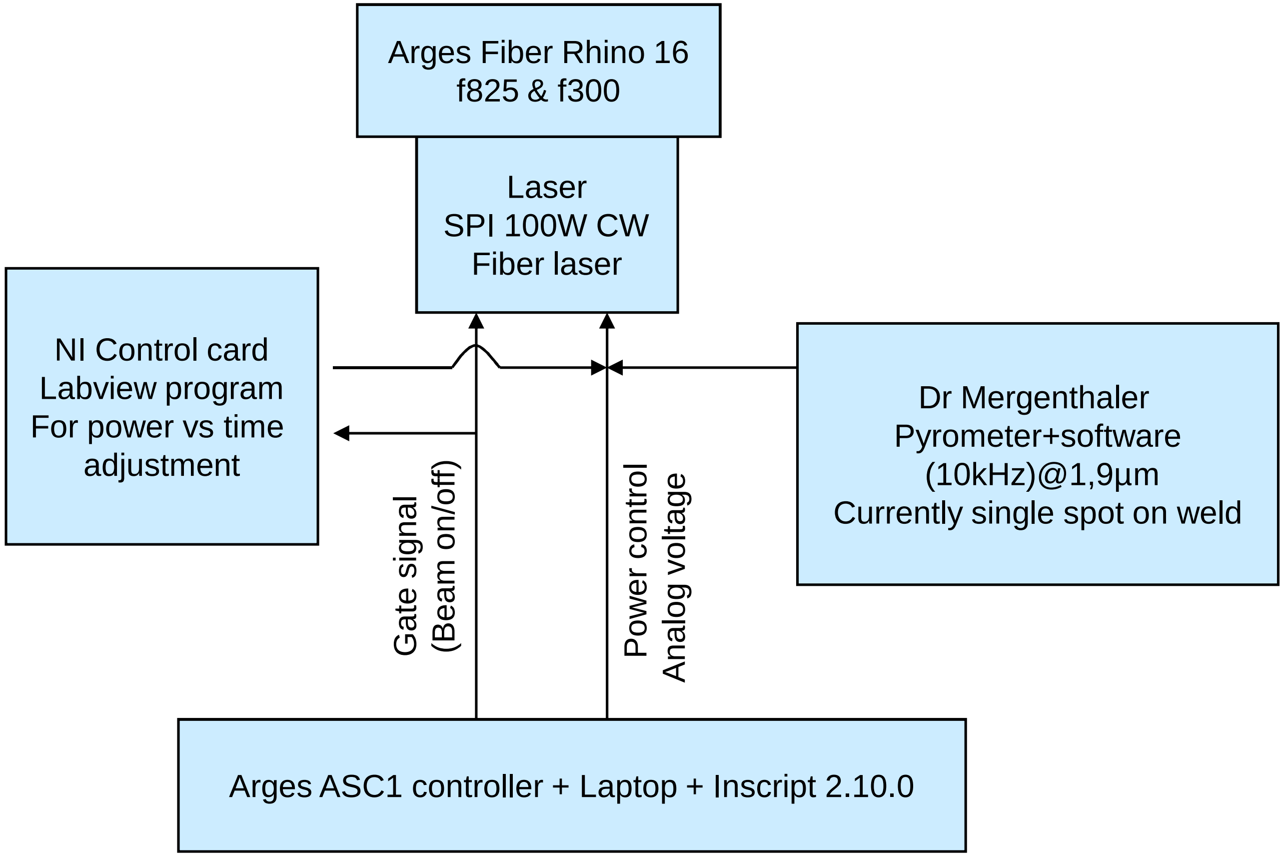
New methods

Intelligent power control

- 1: investigate the high speed movement of the laser beam in order to achieve a gradual heating of the polymeric material and

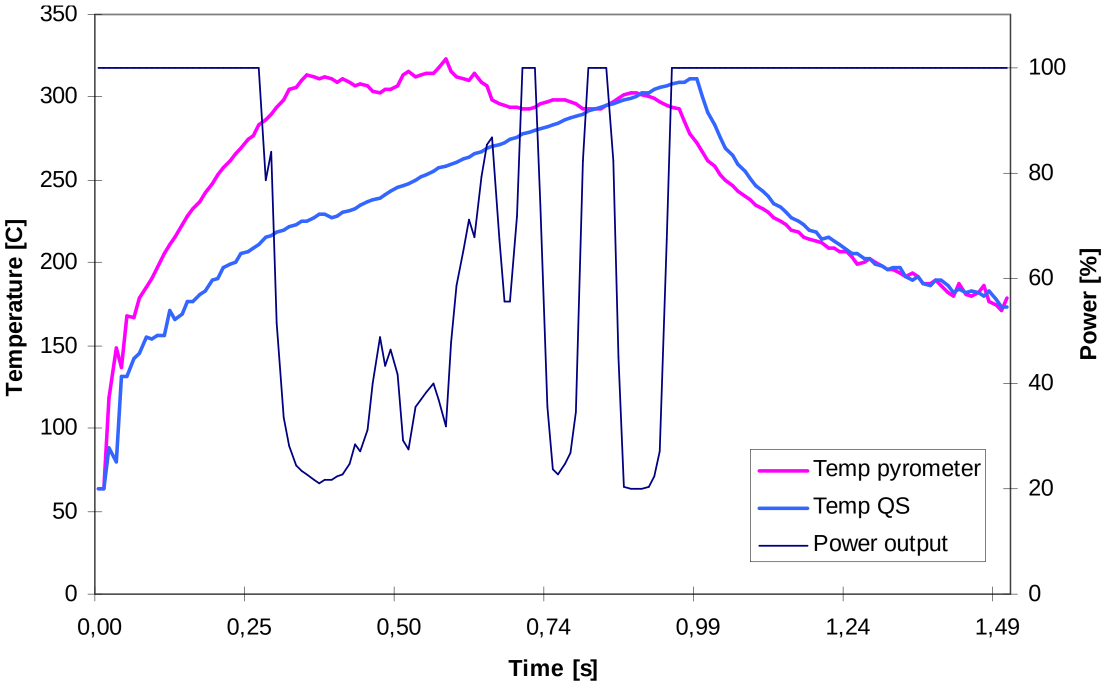
- 2: investigate the optimisation of and intelligent power control on plastics welding to enable larger welding window.
    - This is in this point carried out with implementing new power control method using NI control card to adjust analog power control. In order to get proper power curve to this power control we used a pyrometer setup to extract the basis for power curve. Also experimental way of determining correct curve would be possible but not so feasible.

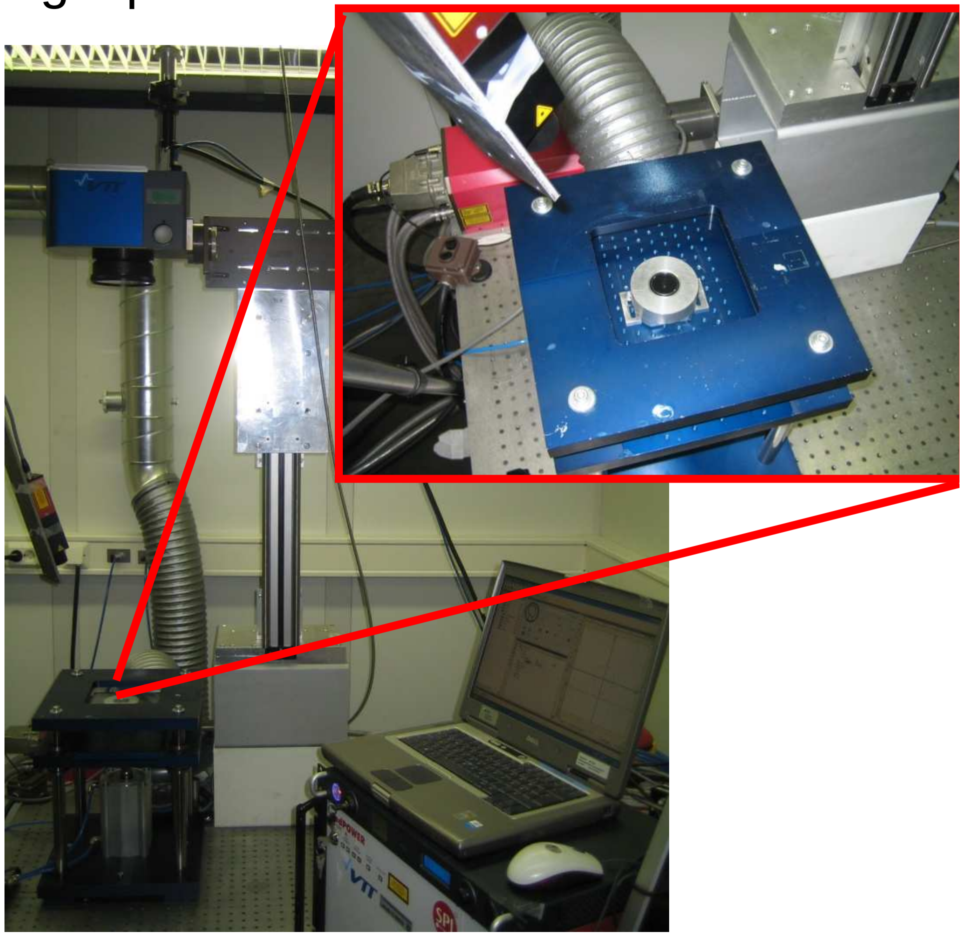
Intelligent power control - schematic



QSLW with pyrometer control vs traditional QSLW

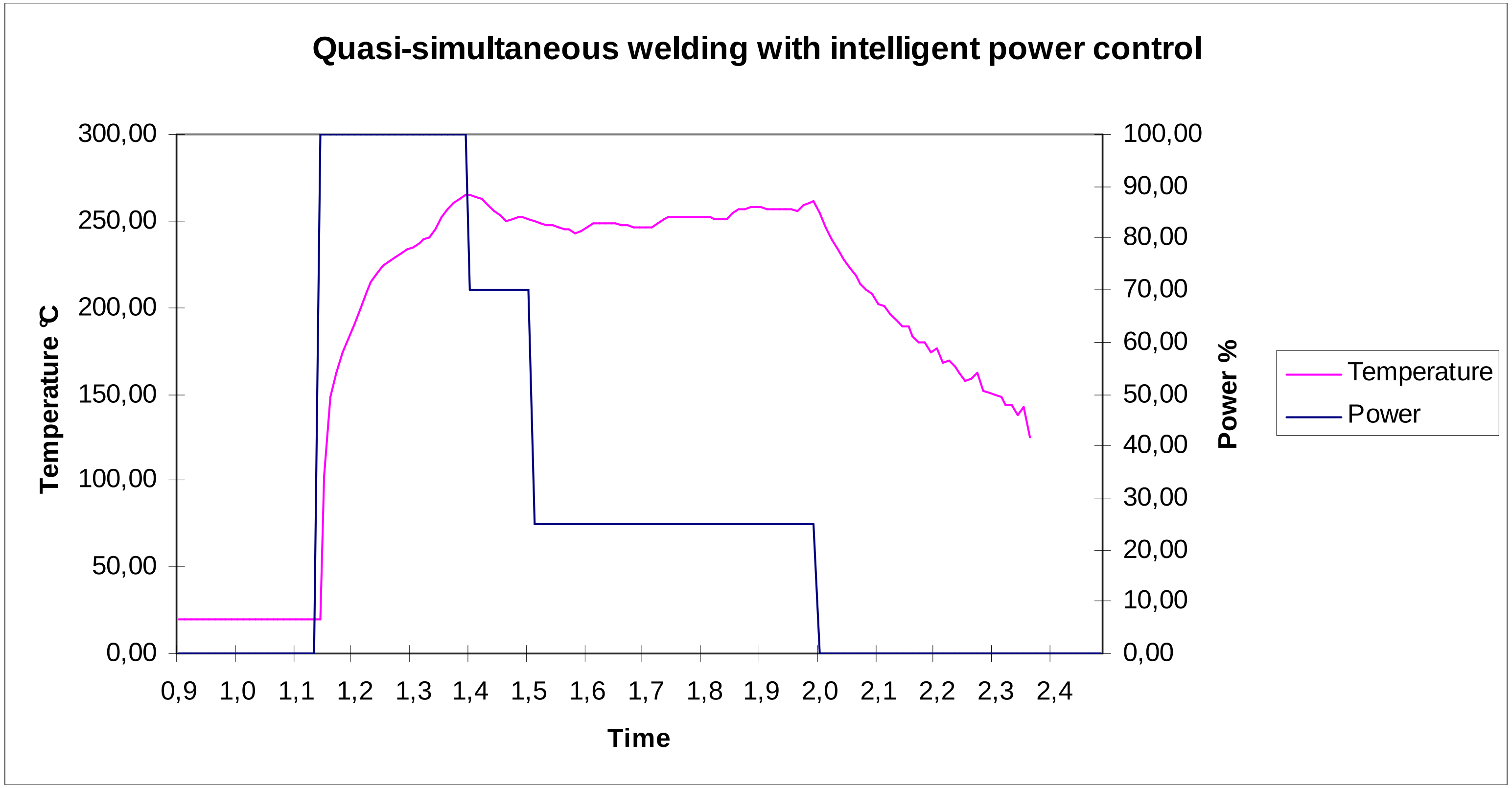
- 10m/s, 100scans,pyrometer on single point





Intelligent power control

- Laser power 100% in start and then sloped down according to text file

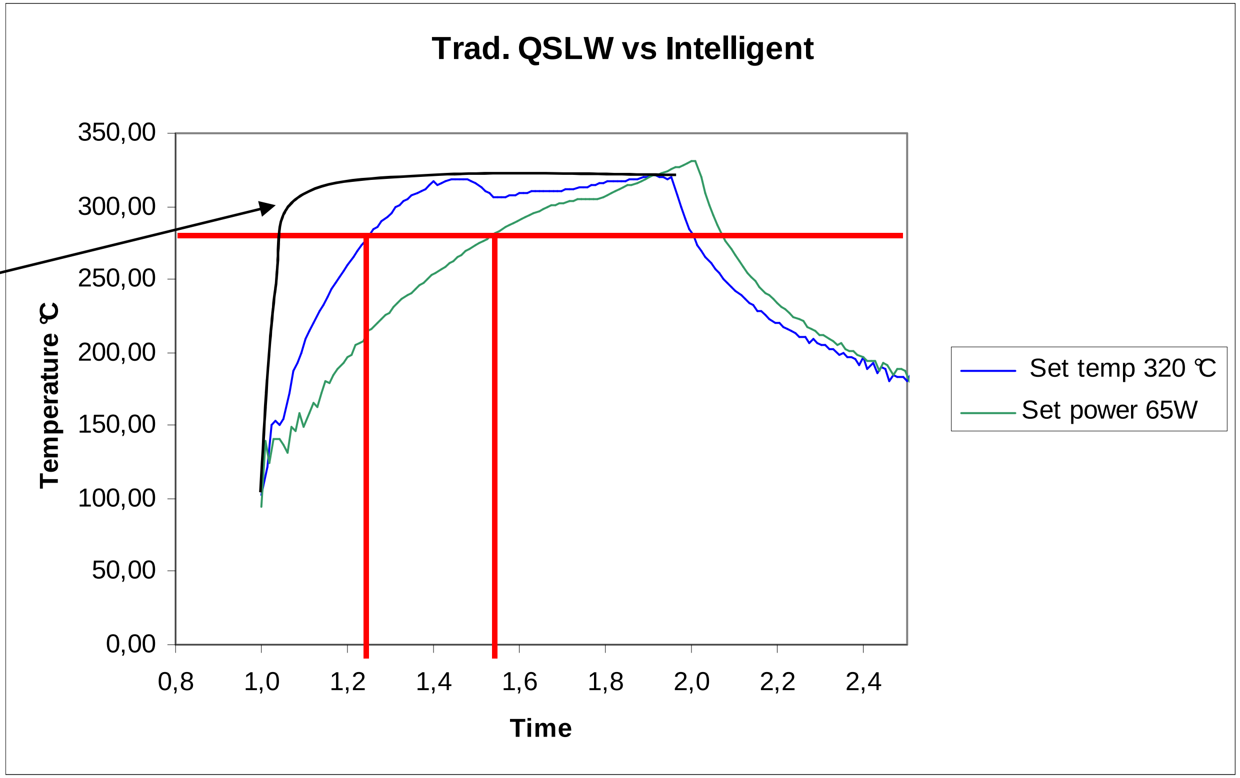


Trad QSLW vs Intelligent

•Intelligent at melt 0.25s after start (insufficent power from laser)

•QSLW at melt 0.5s after start

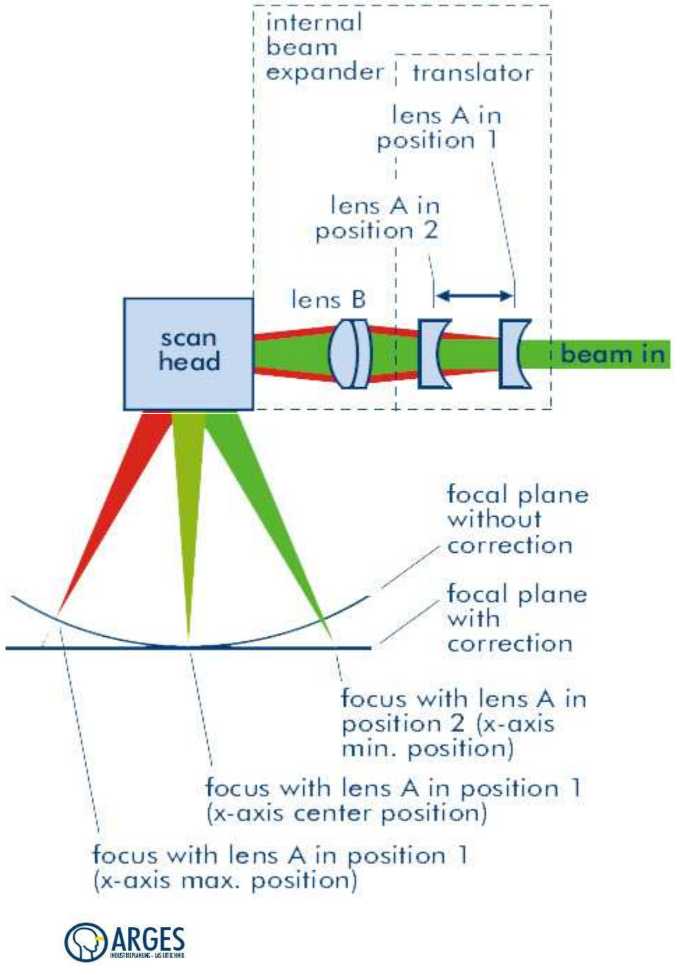
•Higher power laser would even increase time at melt

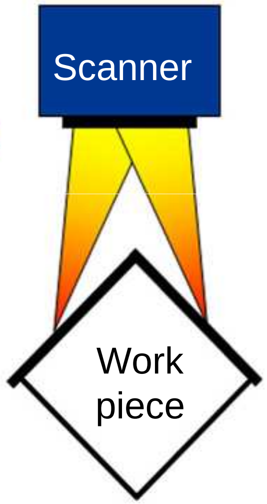


3D welding techniques – quasi-simultaneous welding

3D scanner system

- Focusing lens moves between laser and the galvo mirrors -> z-direction of focal point
- The length of the focal spot movement depends on the focal length and the maximum length of the focusing lens movement
- Welding is actually 2.5D welding
- Clamping device can not cross the joint anywhere on the product

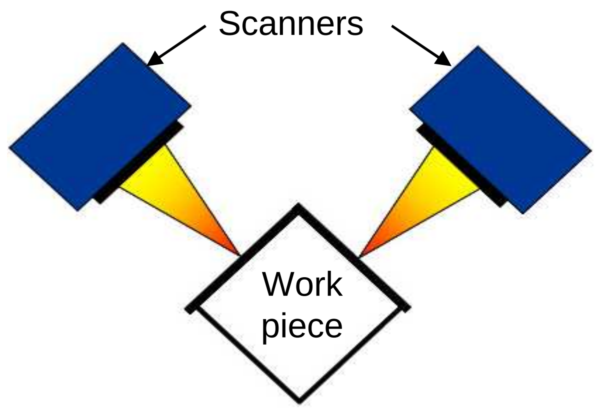


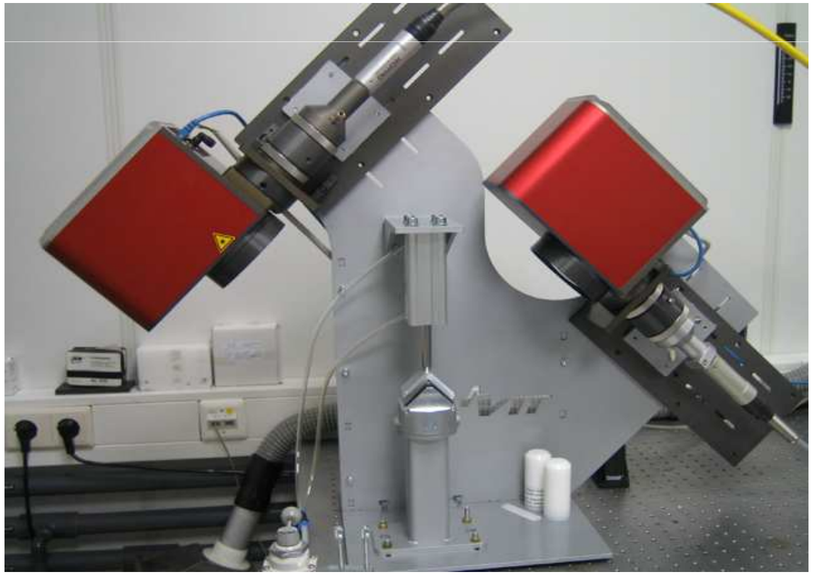


3D welding techniques – quasi-simultaneous welding

Multiple scanner system

- The weld seam is covered with multiple scanners, which are operated in turns such that the welding occurs continuously through entire weld seam
- The more the surface of the weld changes in the z-direction the longer focal length is required
- Faster technique than other 3D q-s techniques ➡ mass-production
- Own laser for each scanner or one laser (higher power) can be divided to various scanners
- Beam comes from multiple direction ➡ the cross of clamping device above the joint are allowed ➡ requirements are not so high

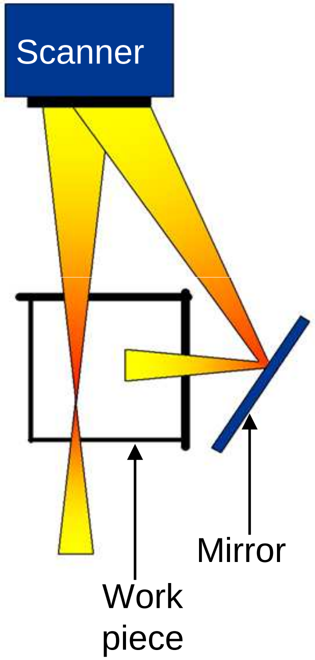




3D welding techniques – quasi-simultaneous welding

Scanner + mirror system

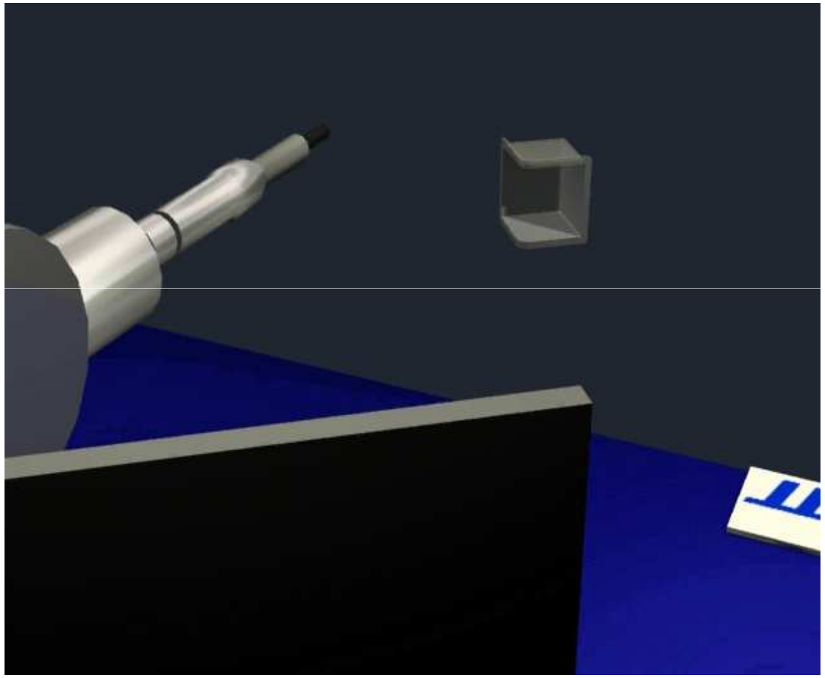
- The beam is reflected via a mirrors to the seam that can't be reached with the 2D scanner such that the welding occurs continuously through the entire weld seam
- The position of the focal spot may vary in the z-direction depending on the size and shape of the product → a very long focal length and a long focal depth are required



3D welding techniques – quasi-simultaneous welding

Scanner + mirror system

- By changing the number of mirrors almost any shape of the part can be welded
- Beam comes from multiple directions
  - the cross of clamping device above the joint are allowed
  - requirements are not so high



VTT creates business from technology