Title	Pyrometer control for quasi-simultaneous laser welding
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Citation	APPOLO Workshop "Online Monitoring in Laser Processing", 5 June 2015, Lappeenranta, Finland Lappeenranta University of Technology (2015)
Date	2015
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Business from technology

PYROMETER CONTROL FOR QUASI-SIMULTANEOUS LASER WELDING

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APPOLO Workshop ”On-line monitoring of laser processing
June 5th, 2015. Lappeenranta

Outline

- Motivation
- Background
- Experimental procedure
    - Equipment
    - Materials used
- Results and discussion
- Conclusions
- Future work

Motivation

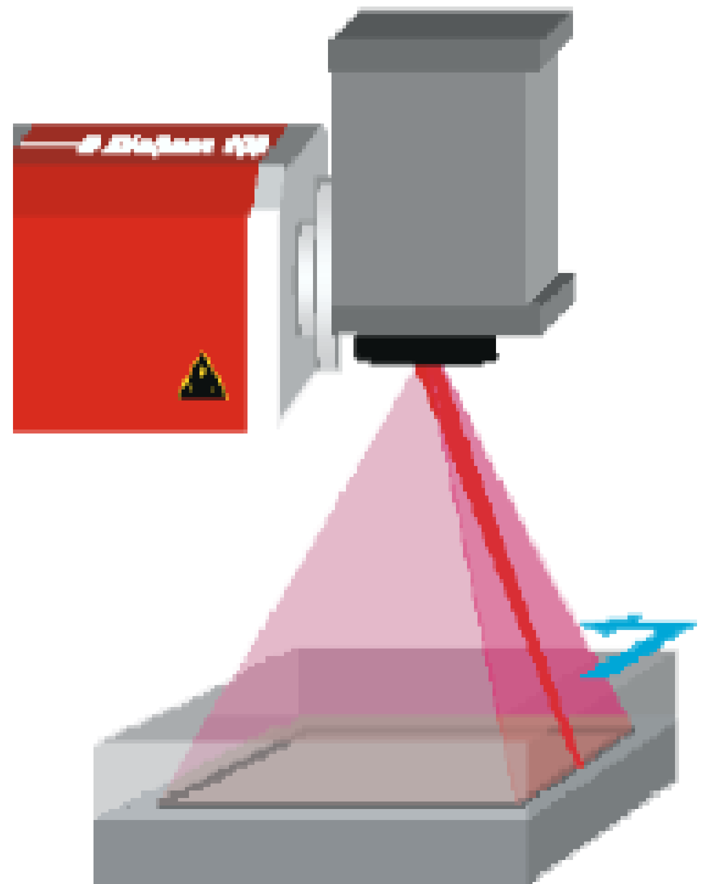
- Use of polymers is constantly increasing
- Weight reduction
  - Cost saving
  - Environmental footprint
- High quality and fast assembly method needed
- High brilliance lasers give new aspects to laser polymer welding

- => Traditional methods based on laser welding can be further optimized

Background

- Pyrometer control for contour welding has been used for a long time
- Some studies exist also about using pyrometer in quasi-simultaneous laser welding (QSLW)

- This paper tries to enlarge traditional QSLW parameter window by using pyrometer to extract the optimal power vs time curve. This curve can be used with signal to analog conversion card in real production to utilize the full potential of each laser.

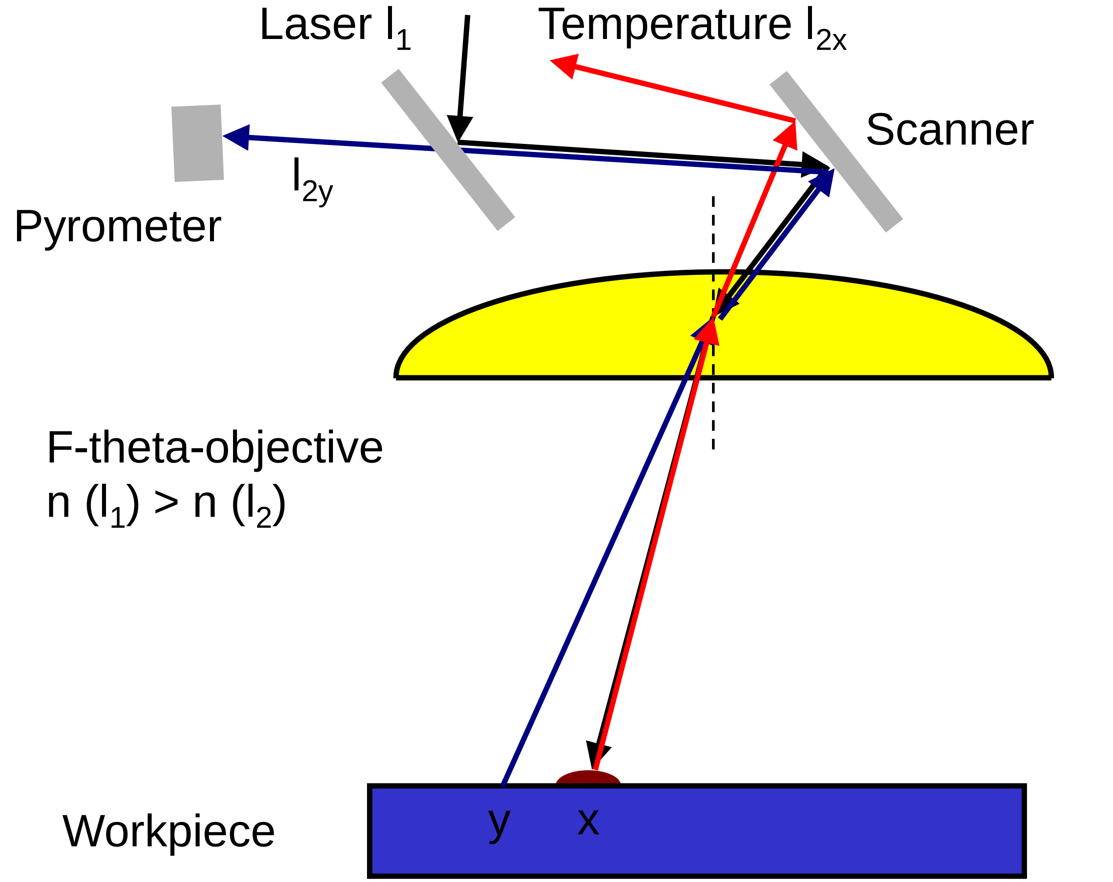


Quasi-simultaneous laser welding

Challenge: Chromatic aberration of F-theta-objectives

- Refractive index of lenses is function of the wavelength
- Standard f-theta objectives are developed for one wavelength
- No position synchronization of pyrometer signal and laser spot especially in the outer area of the scan field

-> Chromatic corrected f-theta-objective needed



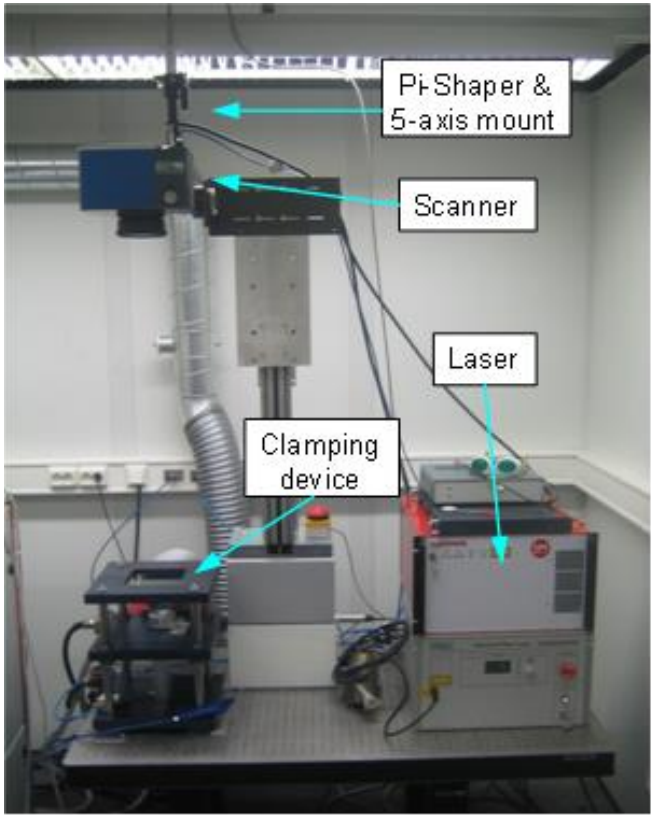
One example scanner system DILAS DL.S20P

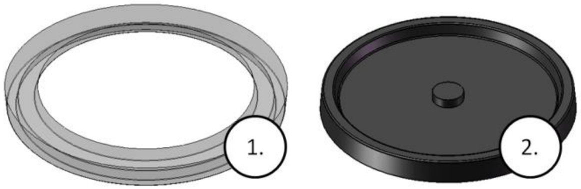
Colour corrected F-theta objective

- Laser wavelength 980 nm
- Pyrometer wavelength 1800 – 2100 nm
- Optical output power < 300 W
- Focal length 262 mm
- Working field 140 x 140 mm^2
- Aperture 20 mm
- Costs ca. 40000 €

Experimental procedure

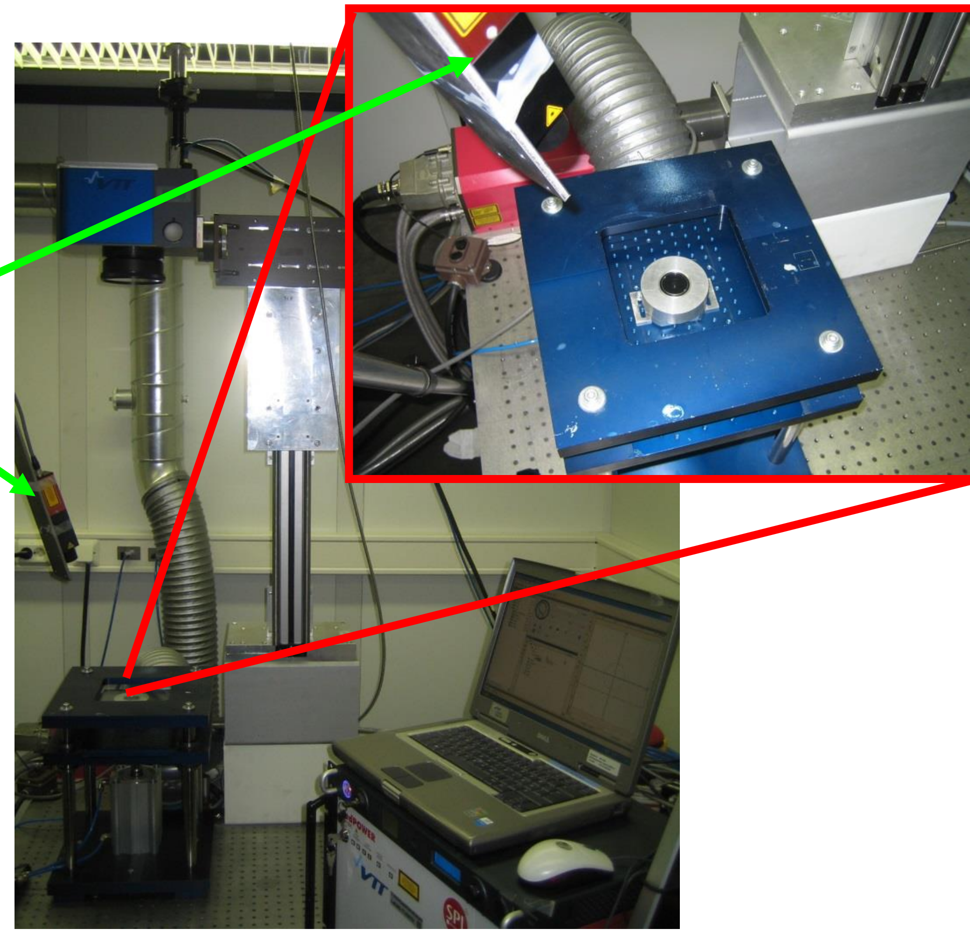
- Quasi-simultaneous welding setup
  - SPI 100W CW fiber laser
  - Scanhead with f825 f-theta
  - Beam shaper: Pi-shaper (transforms the beam to top-hat mode)
  - Clamping unit
- Beam quality K ~ 0.2 with Pi-Shaper
  - without K ~ 0.91
- Material Polycarbonate from Bayer
  - Makrolon 2405
  - Clear and black





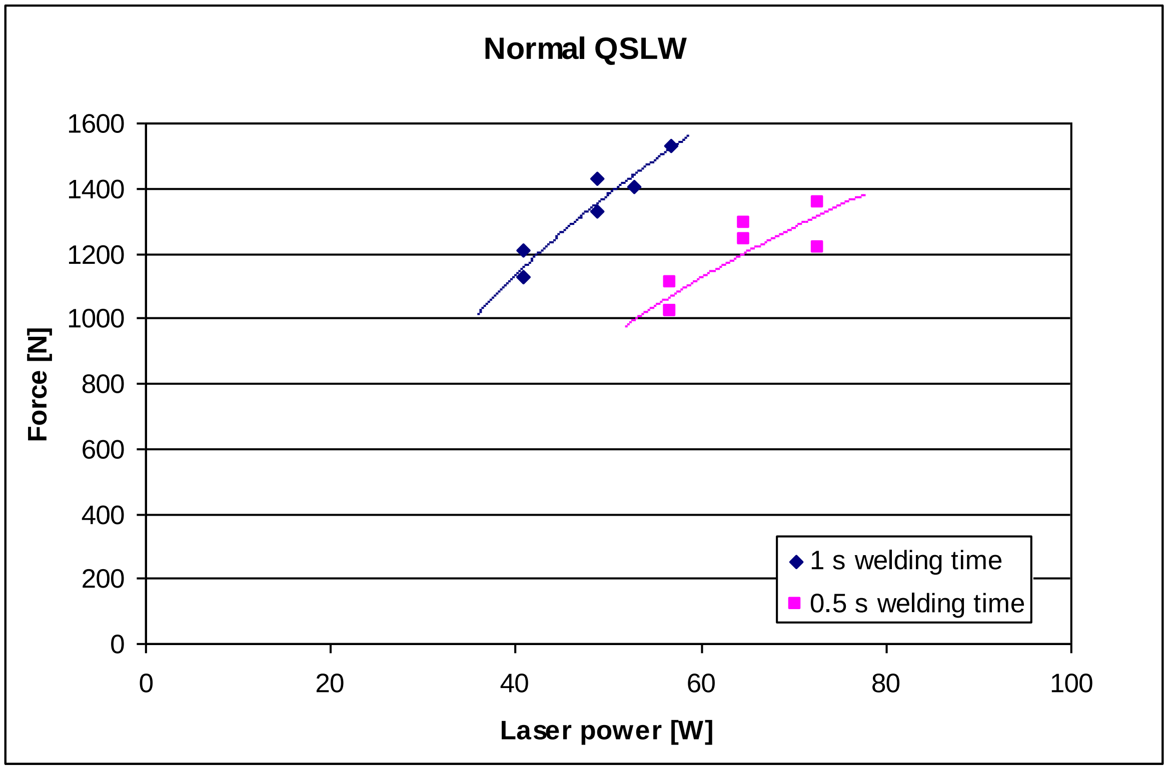
Experimental procedure

- Pyrometer setup
  - Identical to quasi simultaneous except pyrometer controls the laser power
  - Dr Mergenthaler pyrometer on single point on weld



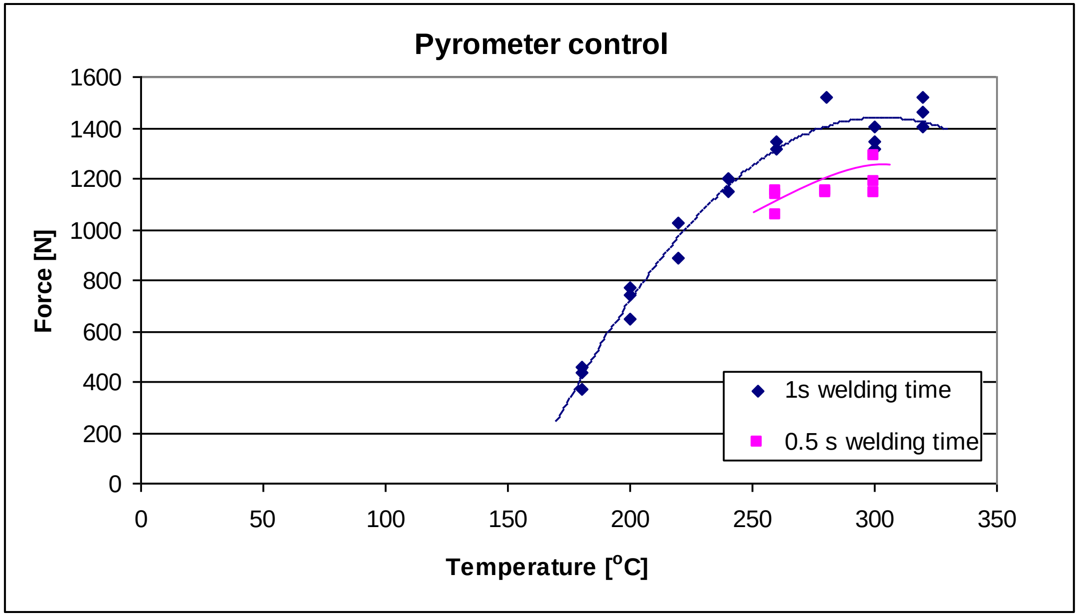
Traditional quasi-simultaneous welding results (weld strength)

- Used powers at 1 s welding time 50, 60 and 70W
- Used powers at 0.5s welding time 70, 80 and 90W
- Weld length 100 mm



Pyrometer controlled QSLW

- With pyrometer controlling laser power one can achieve the optimal conditions for material with simple test series.
- Relative temperature around 300 ^{o}C seems to be optimal -> see tensile tested sample



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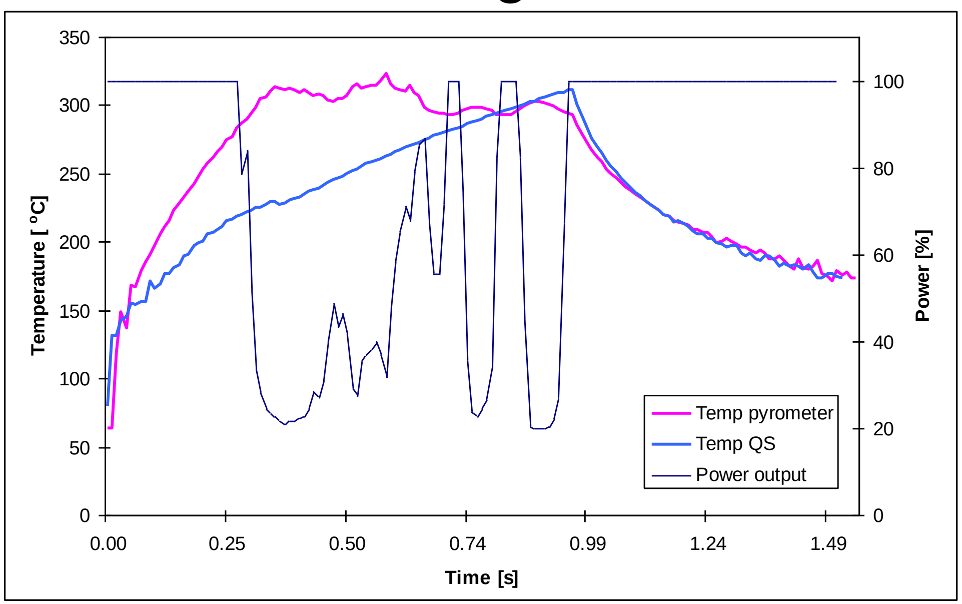
Lappeenranta University of Technology

Traditional QSLW vs with pyrometer QSLW

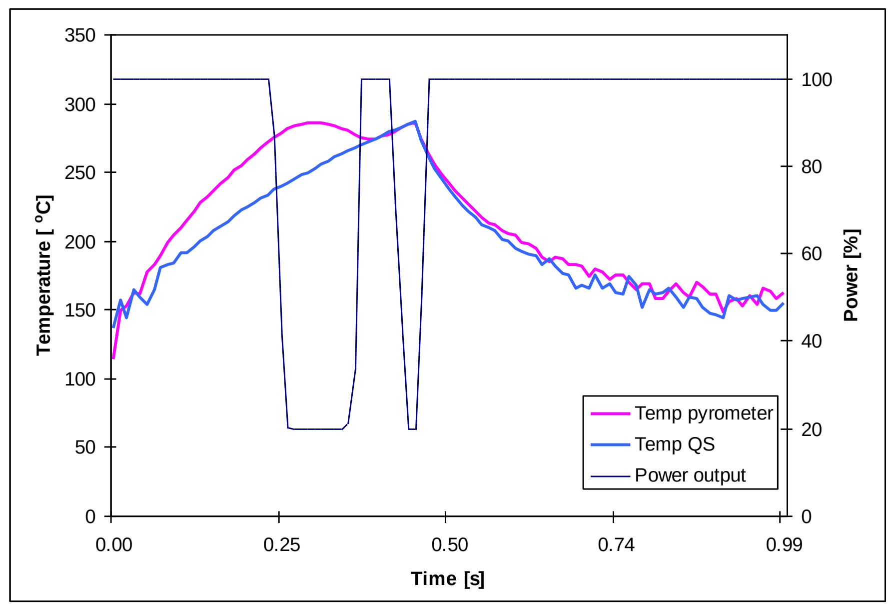
Higher average power would enable us weld faster with the same parameter window using correct power curve

Temp QS= temperature without pyrometer
TEMP pyrometer = temperature with pyrometer

1 s welding



0,5 s welding



IPC?

- IPC = Intelligent power control
  - Variable laser power in different stages of weld
  - welding power is set by the actual scanner speed.

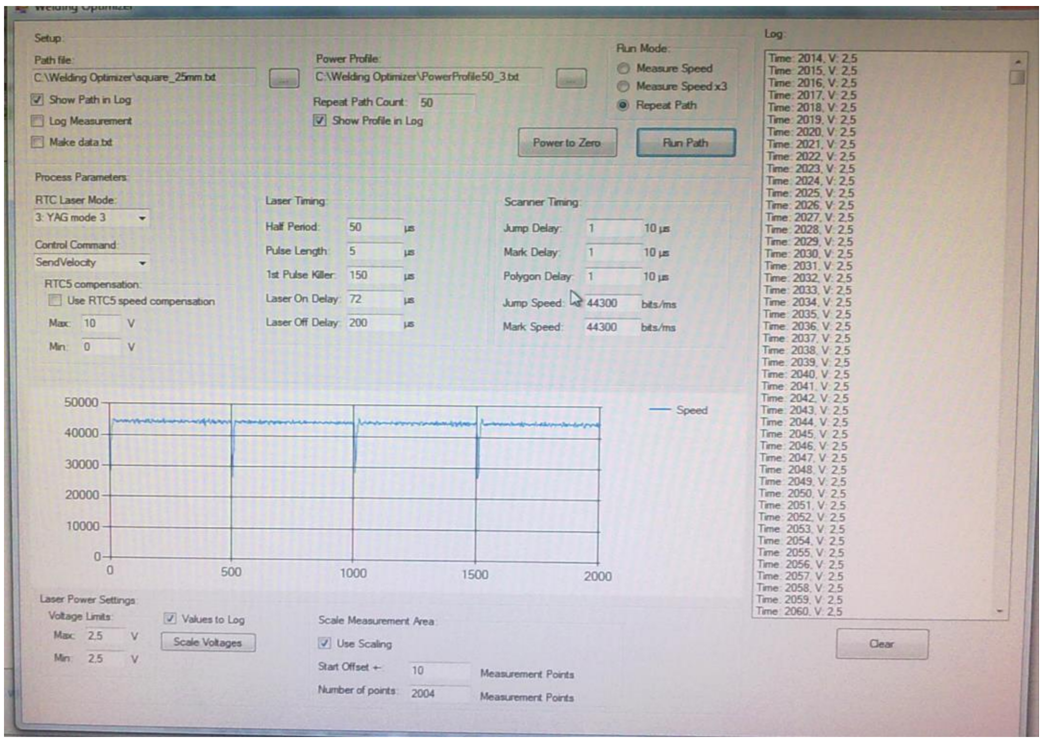
$\Rightarrow$ in corners where scanner speed is lower the laser power is also lower => same heat input in each point on weld

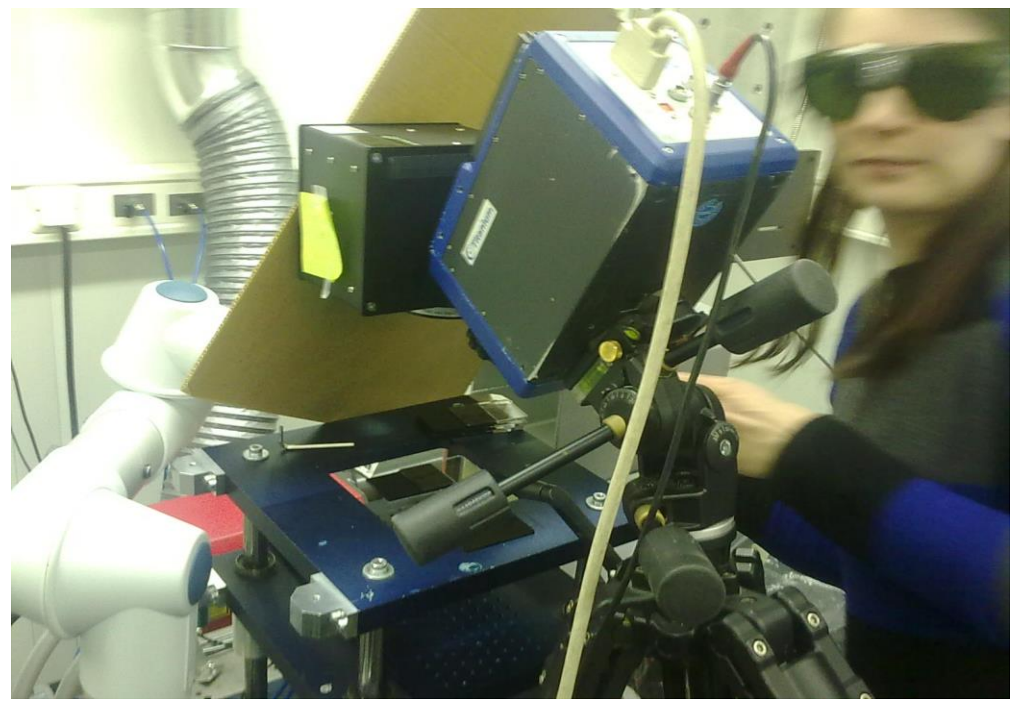
This is not done in real-time since system is not fast enough

Scanner speed is first recorded and then power curve compiled together with IPC after which actual welding can be done

Verification of IPC concept with thermal imaging

- Scanlab Intelliscan 10 with f160 with DOE provided M60 by Leister
- IR Camera CEDIP TITANIUM 560BB (wavelenght range 1.5-5.1µm)
- VTT software and 2nd generation IPC
  - Power correction in corners
  - Power with first 10 laps 100%, laps 11-20 70% power, laps 21-30 50% power, laps 31-40 40% power and last 10 laps (41-50) 30% power. This could be optimized more





Laser power is adjusted according to scan speed

- Laser is ”old” SPI fiber laser (2005)
- This current mode enables us to adjust power really fast.

Analogue Current Mode

The response time Δτ of the system in open loop current control mode to step changes in the external voltage setpoint ΔV should be measured for +ve and -ve step changes in the external setpoint.

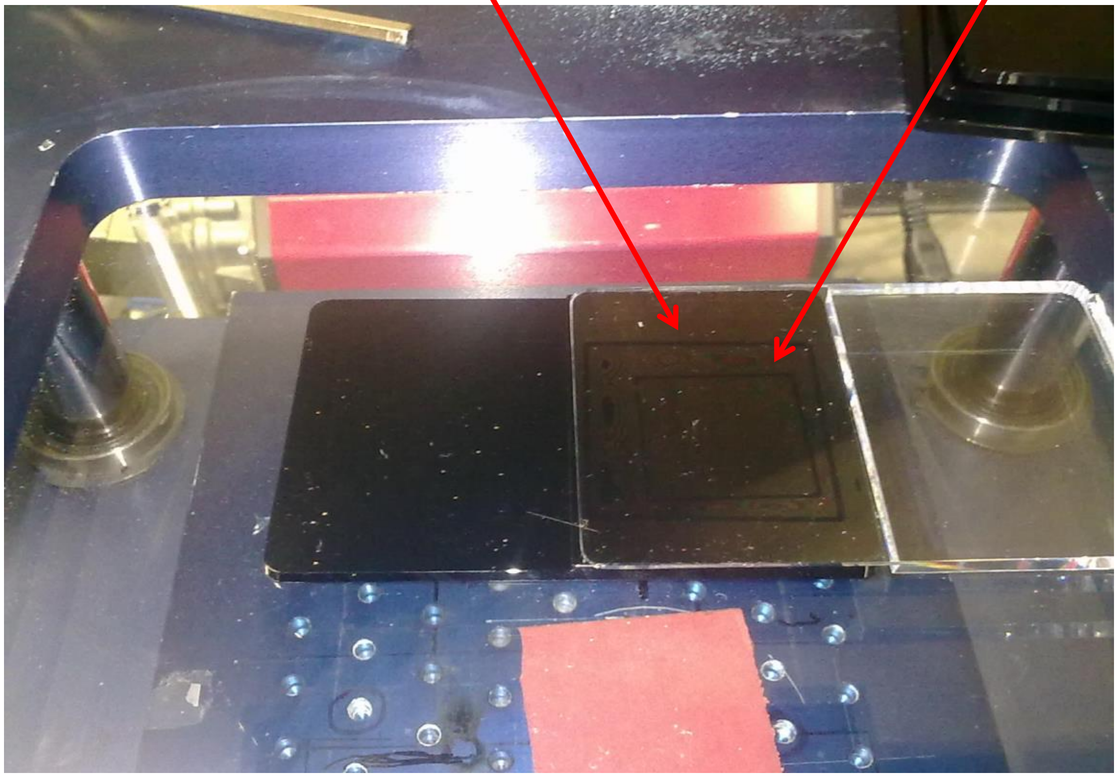
ΔV = Final Voltage Vf (power) setpoint - Initial voltage Vi (power) setpoint

Δτ = Time taken for output power to reach steady state (+/- 1%)

Vf	Vi	ΔV	Δτ	Trace
Volts	Volts	Volts	μS	
10	9	-1	3.17	Fig 16
10	8	-2	3.15	Fig 17
10	7	-3	4.43	Fig 18
10	6	-4	3.35	Fig 19
10	5	-5	3.44	Fig 20
10	0	-10	26.82	Fig 21
0	10	+10	7.96	Fig 22
0	9	+9	7.38	Fig 23
0	8	+8	7.08	Fig 24
0	7	+7	7.26	Fig 25
0	6	+6	6.09	Fig 26
0	5	+5	5.47	Fig 27

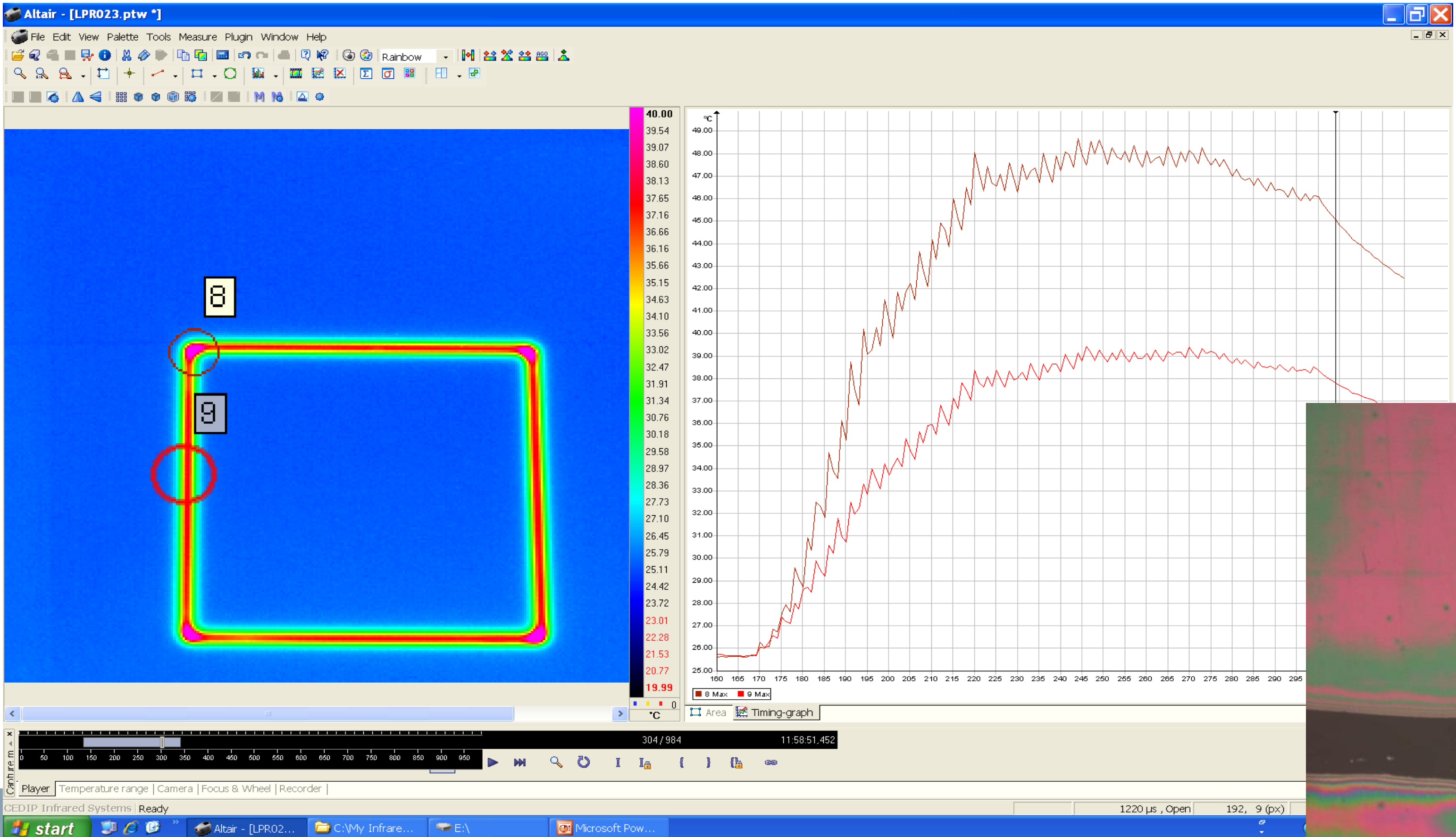
Welding configuration

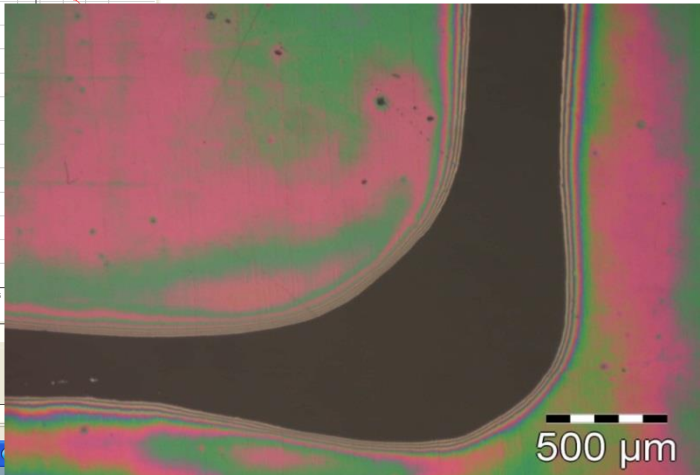
- Samples are prewelded and measurement made from inner rectangle
- Thermal camera could not ”see” through 2mm plate and that is why prewelded samples needed to be used since partners cannot be clamped with window
- Actual temperatures not measured. Only relative ones aqcuired
- Material PC Makrolon 2405 1mm clear and black



Traditional QSLW with IPC 80W

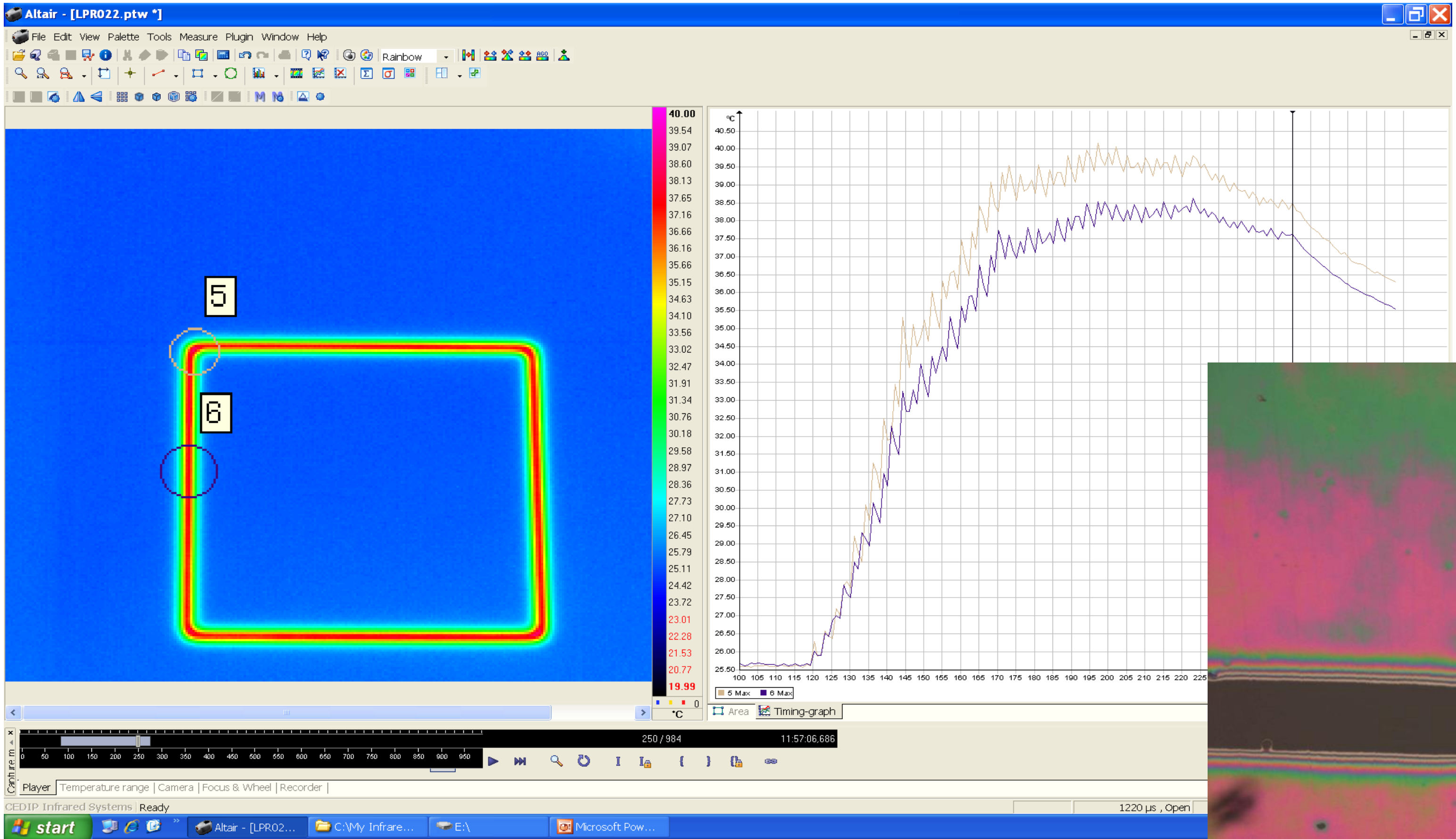
- Corners are much hotter than weld otherwise which makes corners hotter and weld is not equally wide

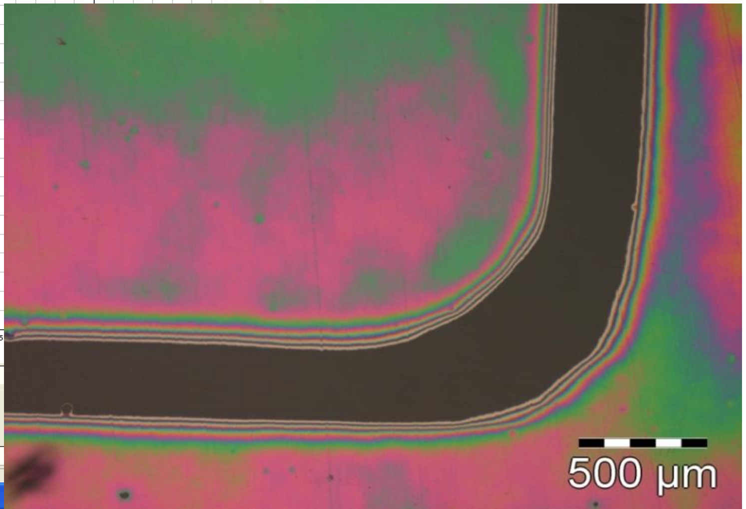




Welding of 1mm PC with 2nd generation IPC 0-80W

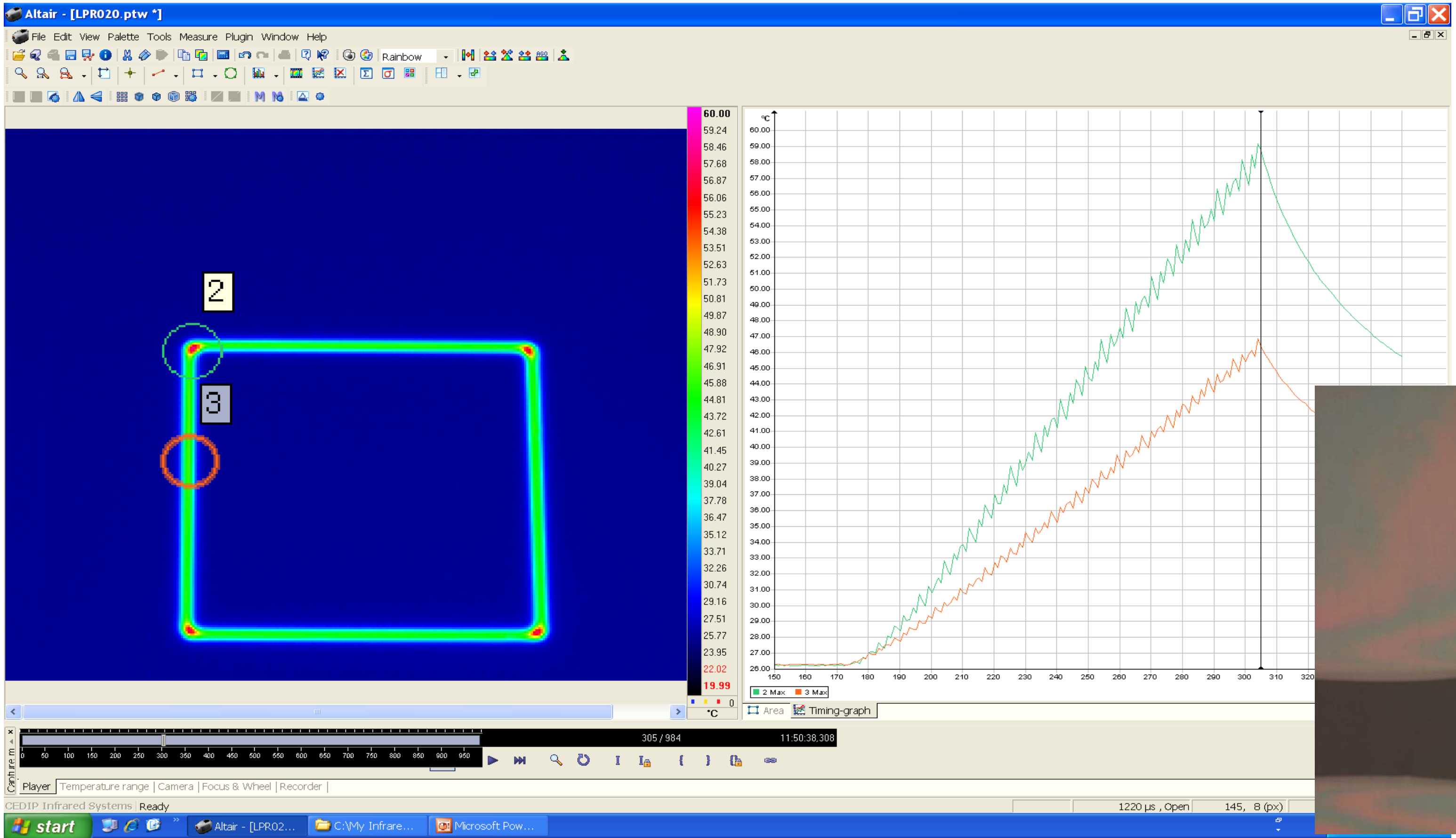
- Almost same temperature in corners. Actual welds made using 1mm PC makrolon 2405.
- Using this system corners could be compensated even more so that temperature would be the same in corners also.
- Real welds made during imaging

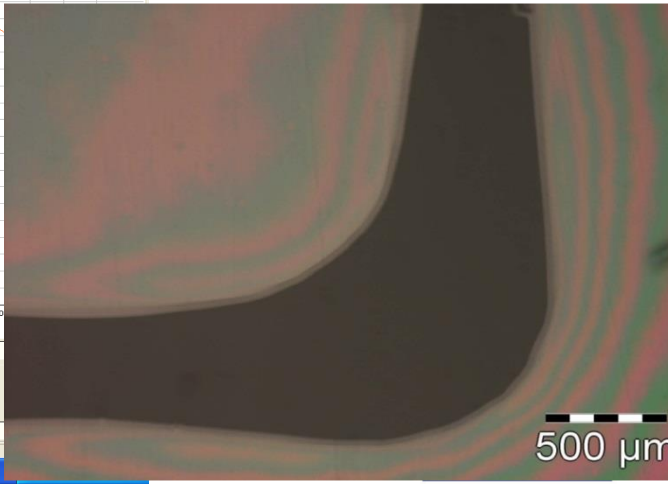




20 QSLW 50W

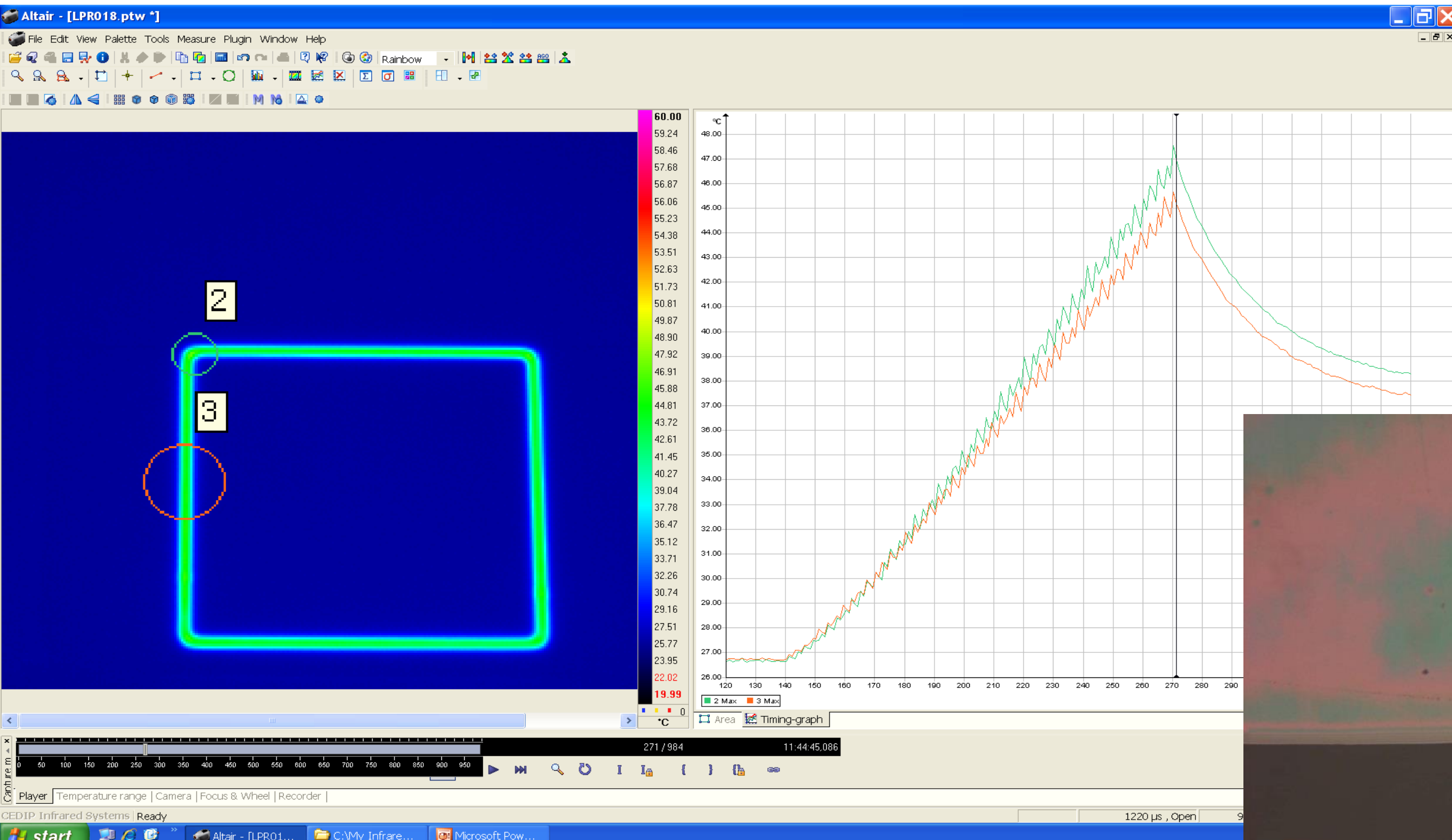
- Traditional QSLW works well but corners get hot and macrograph shows this. Difference in corners to straight lines is evident

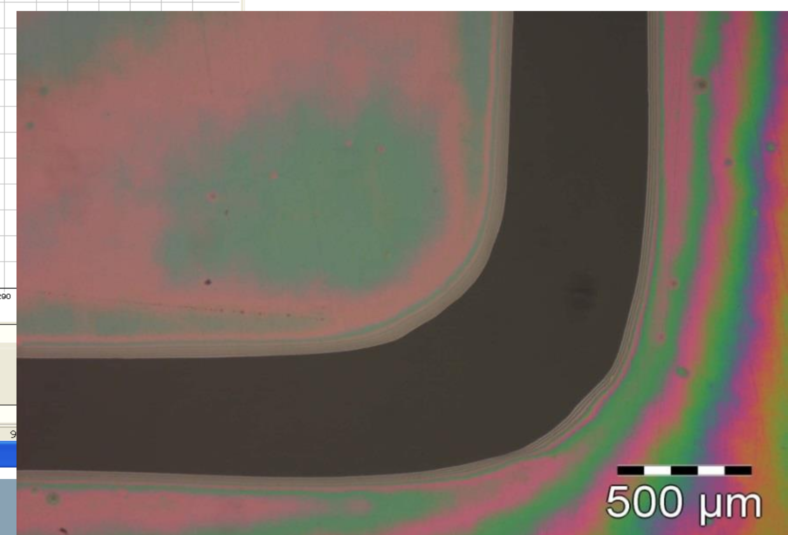




18 QSLW + corner correction 0-50W

- QSLW with corner correction with gives good weld





Conclusion

- 2nd generation IPC works well with 5m/s and 10m/s. At 10m/s the resolution is 10µm. Actually better since in corners the speed is not 10m/s
- Corners can be kept at good temperature level
- Fast heating+long stay at wanted temperature can also be realized with IPC concept

Conclusion

- Idea of broadening parameter window works well
- 2nd generation IPC works well with 5m/s and 10m/s. At 10m/s the resolution is 10µm. Actually better since in corners the speed is not 10m/s
- Corners can be kept at good temperature level
- Fast heating+long stay at wanted temperature can also be realized with IPC concept

Thanks to

- Polybright project consortium
- Project full title**: Extending the process limits of laser polymer welding with high-brilliance beam sources**
- Grant agreement no**.: 228725**
- www.polybright.eu


Thank you for the attention