Intelligent Power Control for Quasi-Simultaneous laser welding

Saara Ruotsalainen VTT

LASER World of PHOTONICS

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

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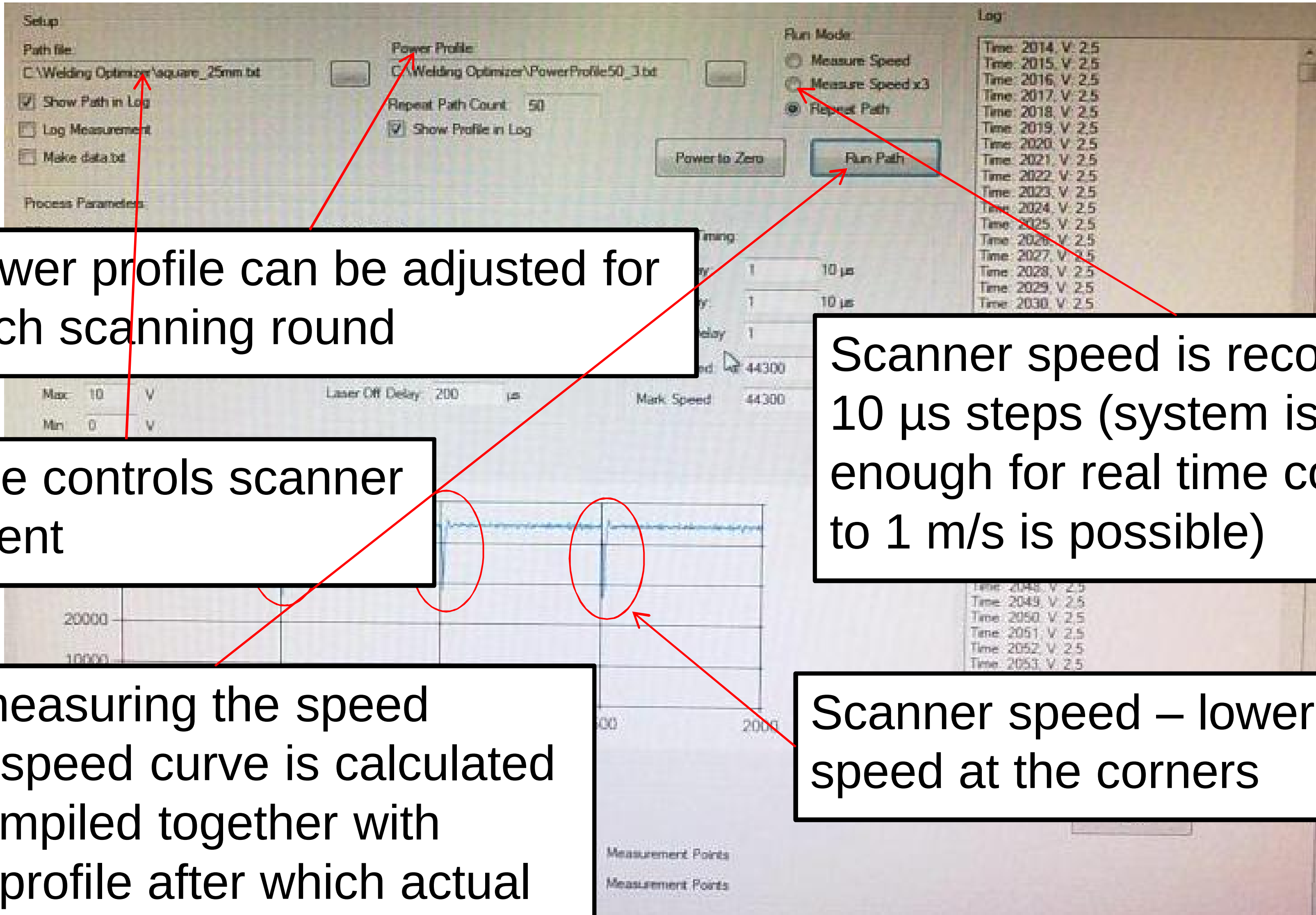
What is Intelligent Power Control = IPC ?

- Intelligent Power Control is method to vary the laser power during the welding at different stages of welding
- IPC-program is software developed at VTT during the Polybright project
- IPC-program use National Instruments DAQ device for measuring the scanner speed and calculating laser powers
- Two different method to adjust the laser power which can also be used at the same time
  - Can be used in the quasi-simultaneous welding for adjusting the different laser power level for each scanning round
  - Can be used in the laser welding for adjusting the laser power depending on the actual speed of the scanner for example to decrease the laser power in the corners to achieve same heat input and avoid over burning

IPC software



Power profile can be adjusted for each scanning round

Scanner speed is recorded in 10 µs steps (system is not fast enough for real time control, up to 1 m/s is possible)

Software controls scanner movement

After measuring the speed power-speed curve is calculated and compiled together with power profile after which actual welding can be done

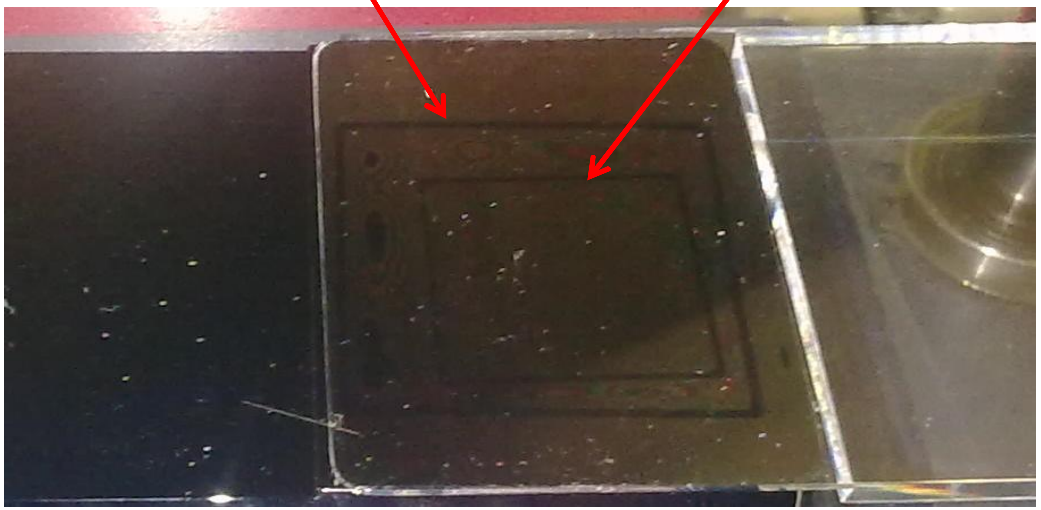
Scanner speed – lower speed at the corners

Verification of IPC concept with thermal imaging

- Scanlab Intelliscan 10 with f160 with DOE provided M60 by Leister
- SPI 100 W fiber laser
- National Instrument DAQ
- IR Camera CEDIP TITANIUM 560BB (wavelength range 1.5-5.1µm)
- VTT IPC software
- Power steps – different power at different stages
- Power correction in corners

Verification of IPC concept with thermal imaging - welding configuration

- 1 mm black and transparent polycarbonate (Makrolon 2405) samples
- Samples are prewelded and measurement made from inner rectangle
- Thermal camera could not ”see” through 12 mm clamping glass → prewelding is used
- System is not calibrated for polymers (emissivity is not known) → temperatures measured are not actual, but temperature difference can be seen



Verification of IPC concept with thermal imaging - Laser "speed"

- Laser used was 100 W SPI fiber laser from year 2005
- Current mode of laser was used which enables us to adjust power really fast
- Laser can change the power in needed time

Analogue Current Mode

The response time $\Delta\tau$ 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

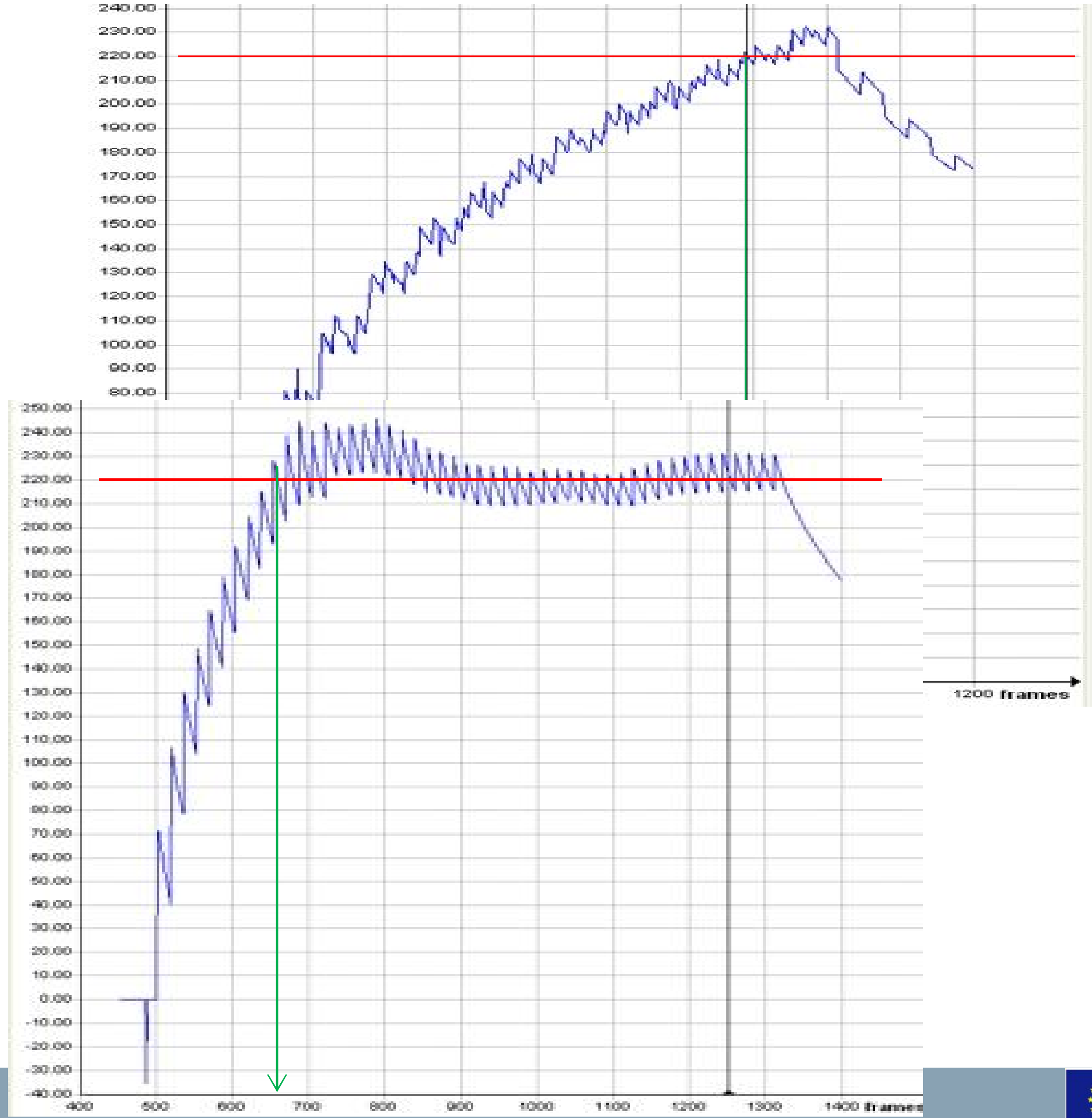
$\Delta\tau$ = Time taken for output power to reach steady state (+/- 1%)

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

How does it work? - Different powers at different stages of the welding

- In **traditional QSLW** the laser power is constant and the temperature of the weld is increased evenly

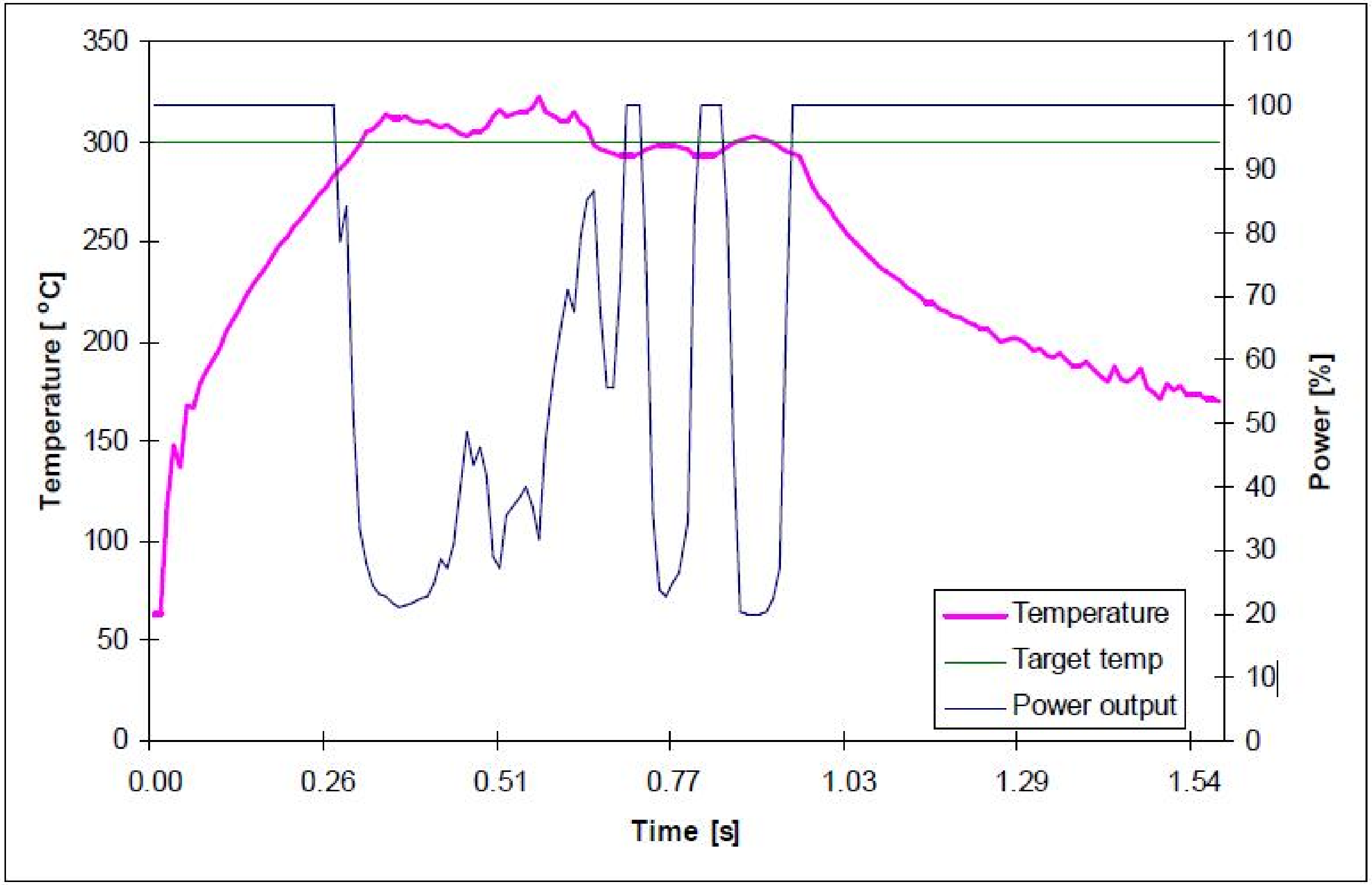
- With **IPC** higher power can be used at the beginning of the welding to achieve molten state, after that power is decreased and temperature can be kept constant
- With IPC-software power can be adjust for each scanning round



Different powers at different stages of the welding

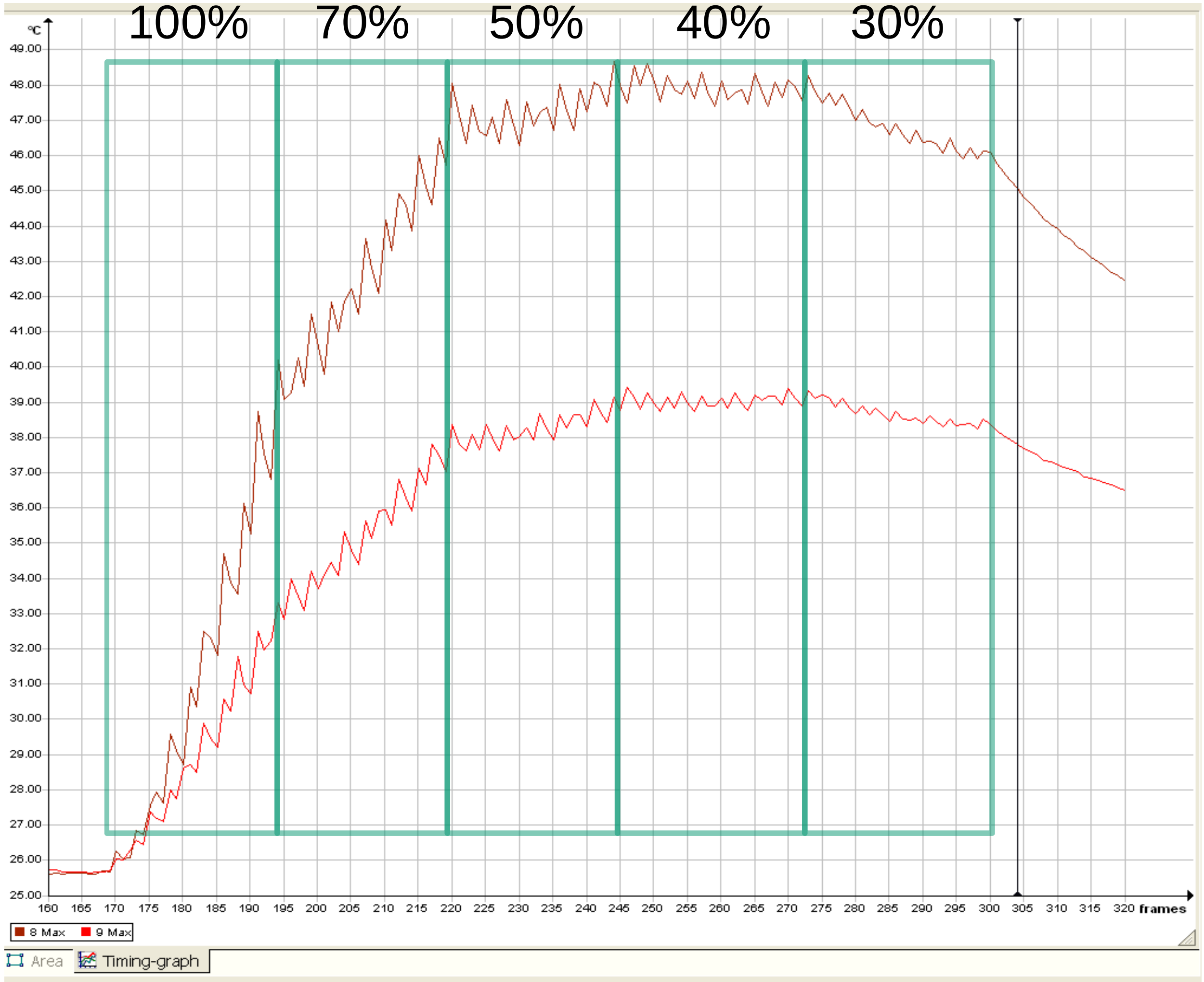
- Power curves for different scanning rounds can be record by using pyrometer or can be found by testing

- **Pyrometer** is set to measure one point in the weld
- Pyrometer controls the laser power
- Power output curve can be used in IPC



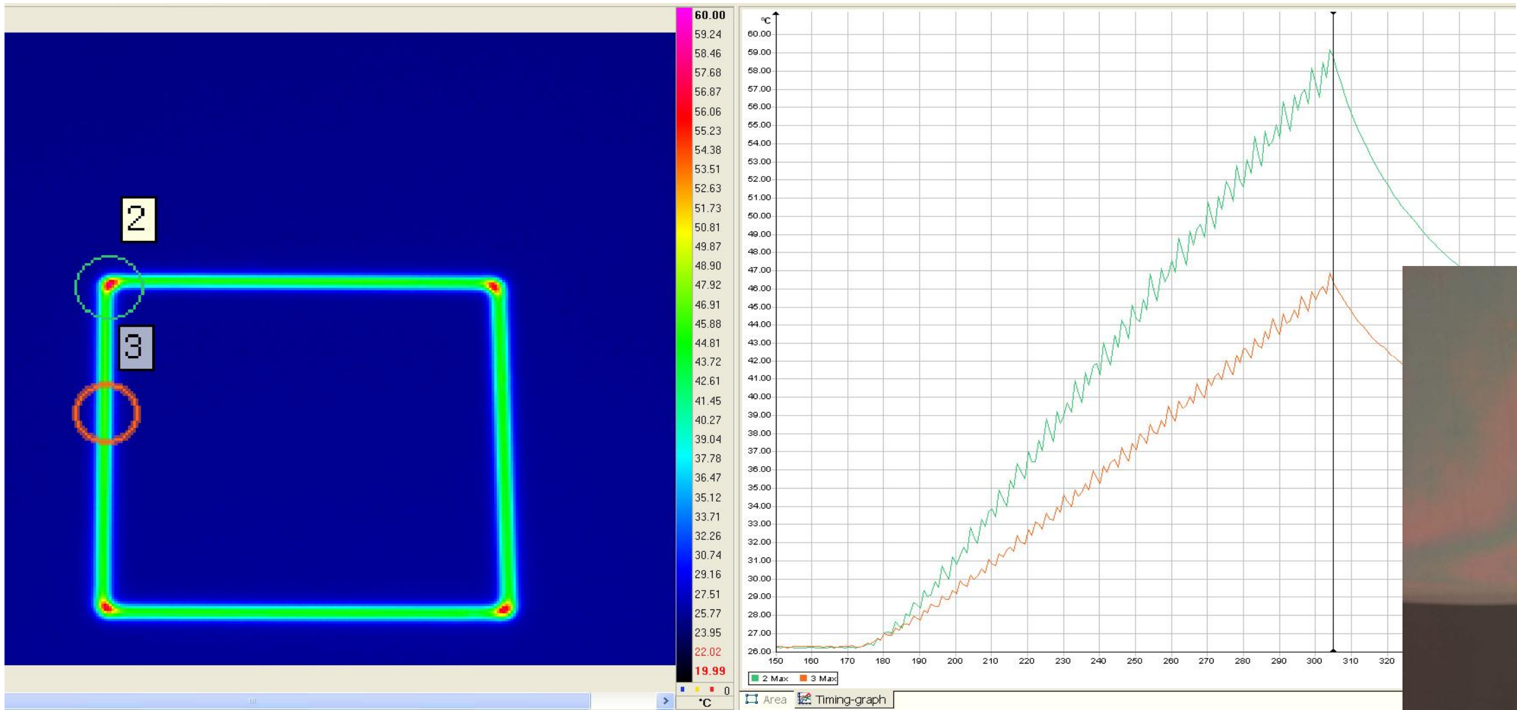
Different powers at different stages of the welding

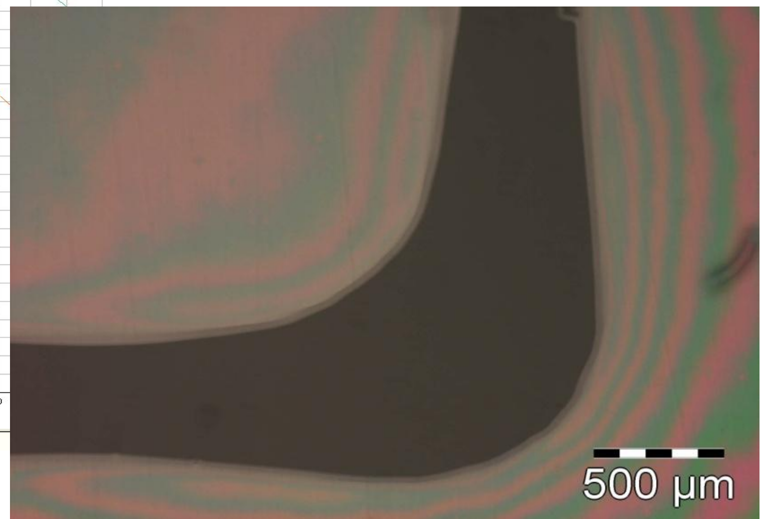
- Power level set by testing
- 5 different stages for power
- First stage (100 %) should be longer to achieve the melting stage faster



Verification of IPC – traditional QSLW

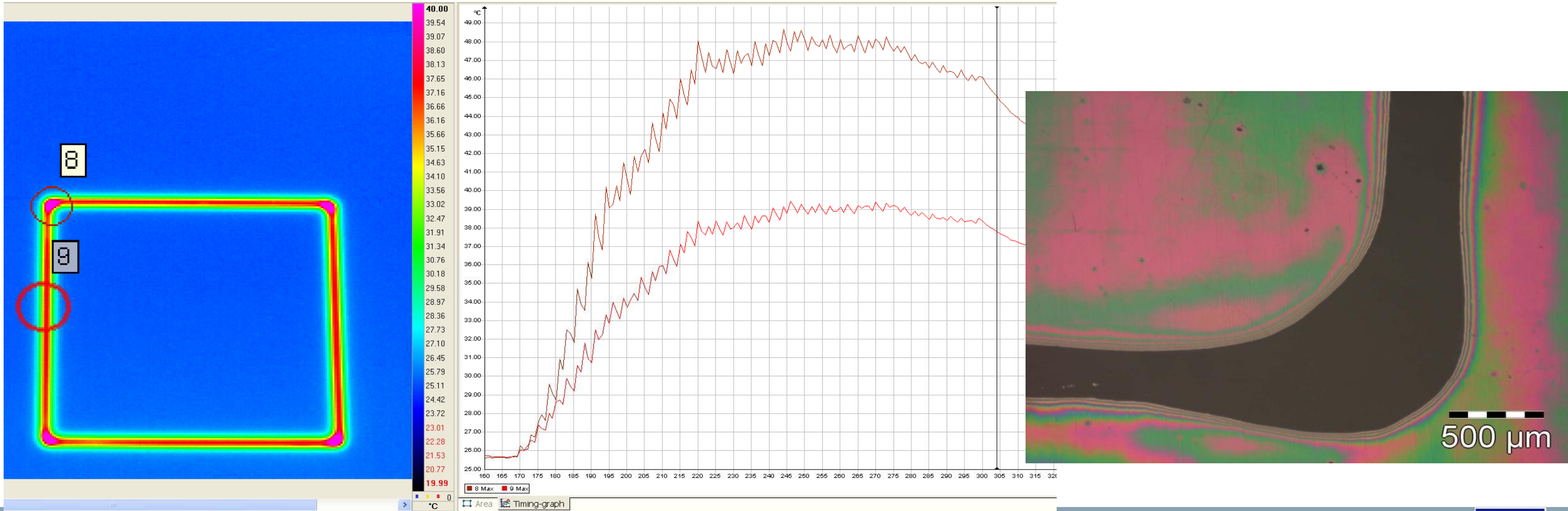
- With traditional QSLW the temperature is increased evenly
- Corners get hot and width of the weld is wider in the corners (macrograph)
- Difference in corners to straight lines is evident
- Laser power 50 W, welding speed 10 m/s, 50 scan





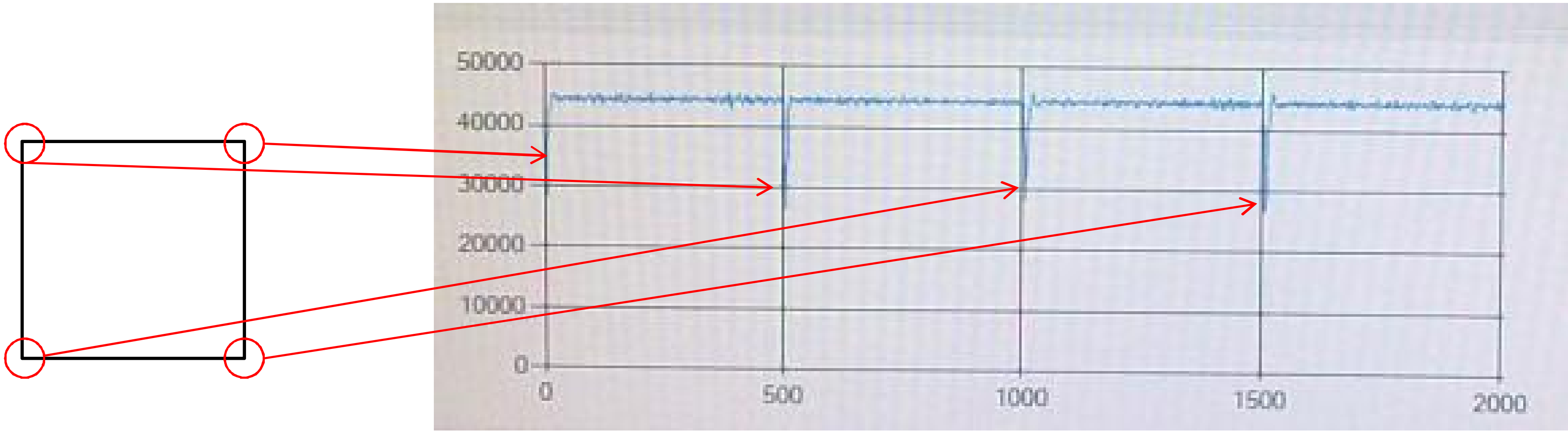
Verification of IPC - Different powers at different stages

- With IPC the temperature increased faster in the beginning
- Corners get hot because no corner correction was used and width of the weld is wider in the corners (macrograph)
- Power steps: laps 1-10 100%, 11-20 70%, 21-30 50%, 31-40 40%, 41-50 30%
- Welding speed 10 m/s, 50 scan



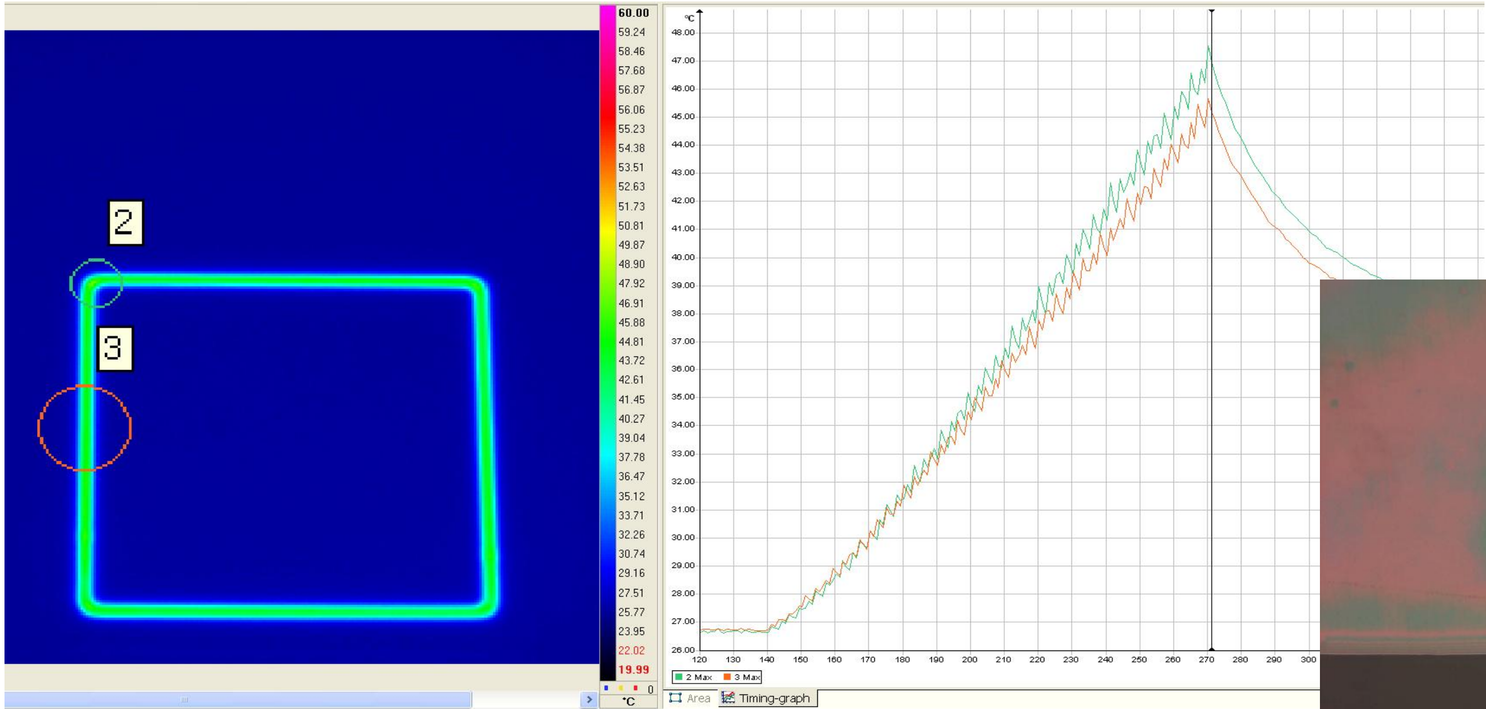
How does it work? – Different powers with different speeds

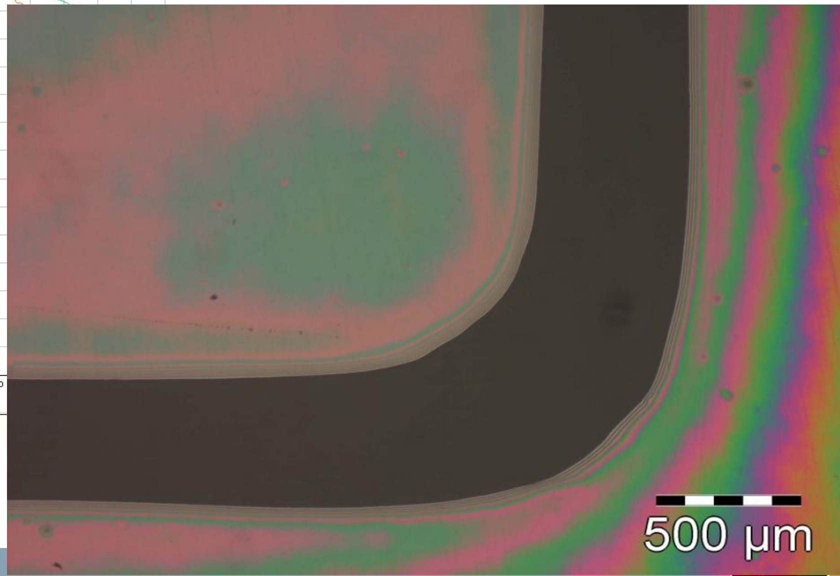
- The actual speed of scanner is recorded with IPC software
- Software measures three rounds to eliminate errors
- After measuring the laser power is calculated according to the actual speed. Upper and lower power values can be set.
- Actual welding is done with calculated powers



Verification of IPC - QSLW + corner correction

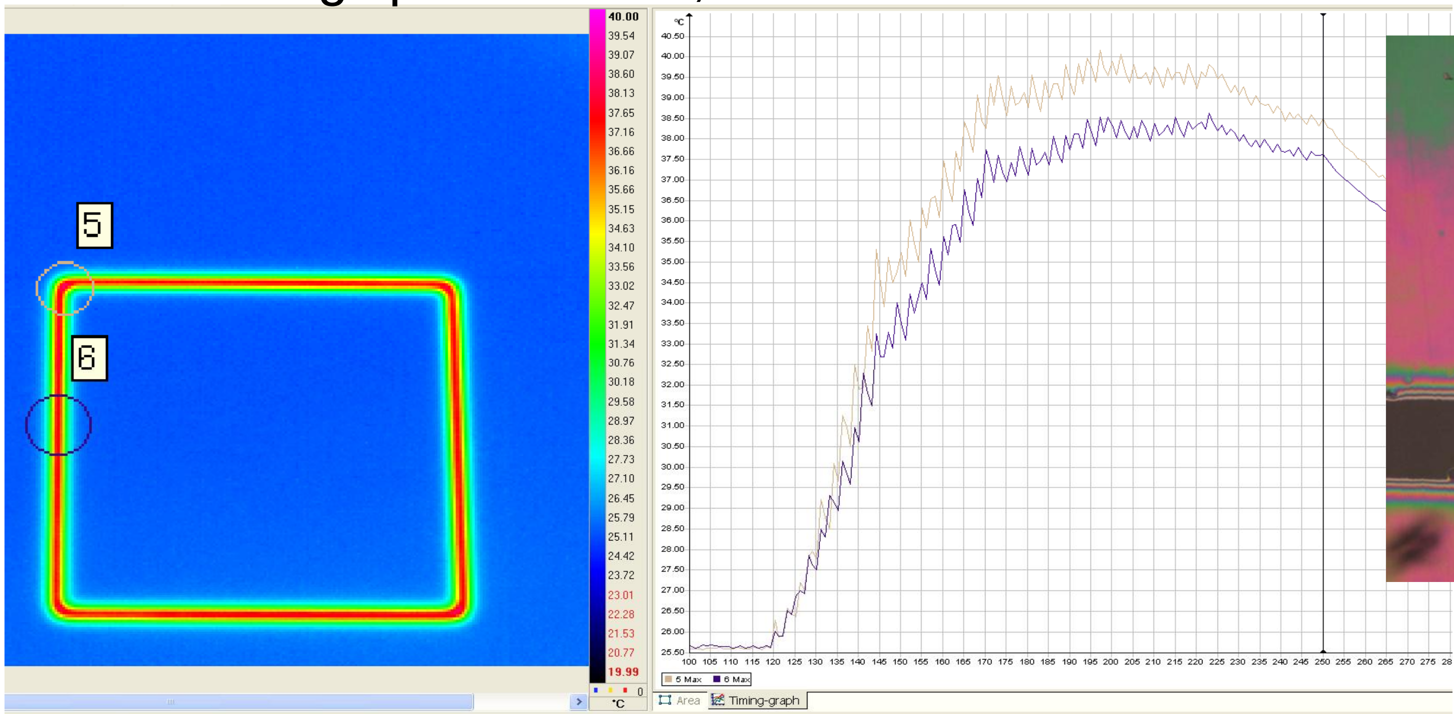
- QSLW with corner correction – no overheating in the corners
- Laser power from 0 - 50 W, welding speed 10 m/s, 50 scan

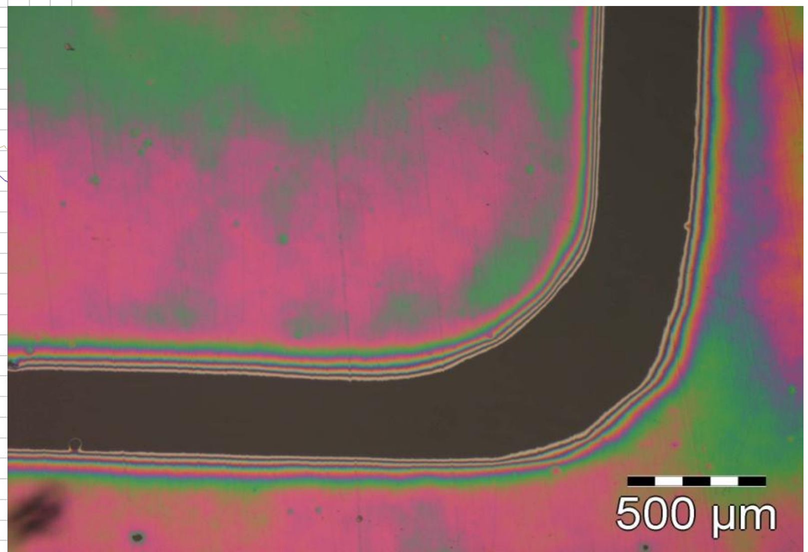




Verification of IPC - Different powers at different stages + corner correction

- Temperature increased faster in the beginning of the welding cycle
- Almost same temperature in corners
- Corners could be compensated even more so that temperature would be the same in corners also.
- Laser power from 0 - 80 W in the corners and different rounds: laps 1-10 100%, 11-20 70%, 21-30 50%, 31-40 40%, 41-50 30%
- Welding speed 10 m/s, 50 scan





Conclusion

- With IPC weld can be kept longer time in melt phase should increase melt mixing and welding times can be decreased
- With IPC corners can be kept at good temperature level, no overheating → burning or wider weld
- In the sharper corners the advantage of IPC is bigger
- High speed thermal imaging provides pretty good tool for weld verification during welding for R&D purposes. High cost of such camera might not be suitable for production
- IPC concept based to the cheap National Instruments DAQ + VTTs developed IPC software which should give integrators an advantage over their competitors

Thank you for your attention!