Tailored melt pool shape and temperature distribution by a dual laser beam LMD-w process

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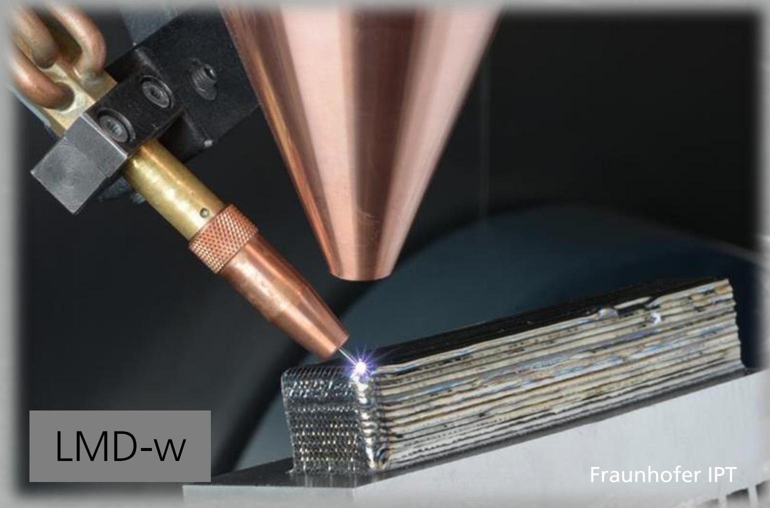
Motivation



Applications

- Additive Manufacturing of parts and features
- Coating
- Repair
- ➢ Application markets: mobility, energy, mechanical engineering, tools

Wire-based Laser Metal Deposition (LMD-w)

- Small heat input
- High material efficiency
- Easy handling of filler material
- Small risks for health
- Low contamination of machines and production environment

[BEYE95, SYED05, KAIE12, BAMB18, NGO18]

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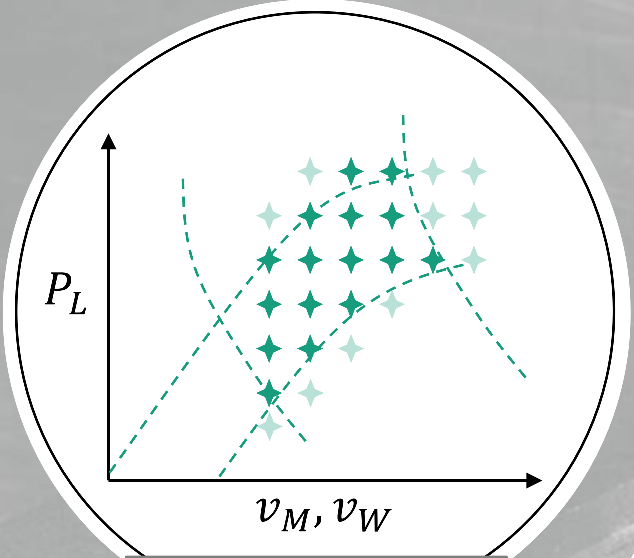
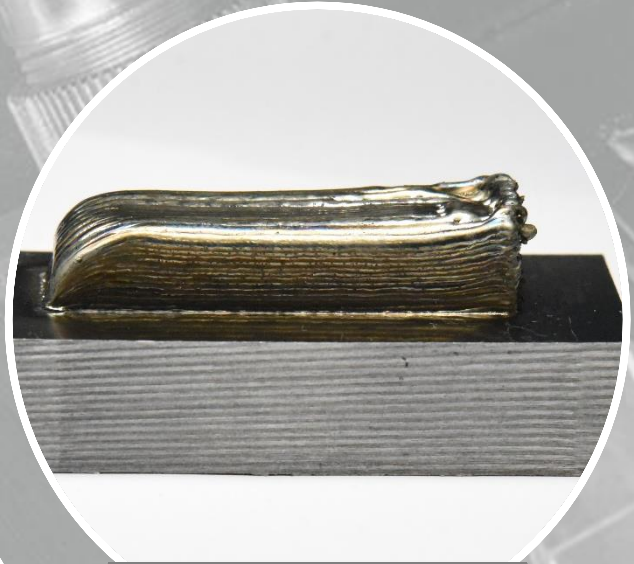
LMD-w with lateral wire feed – challenges

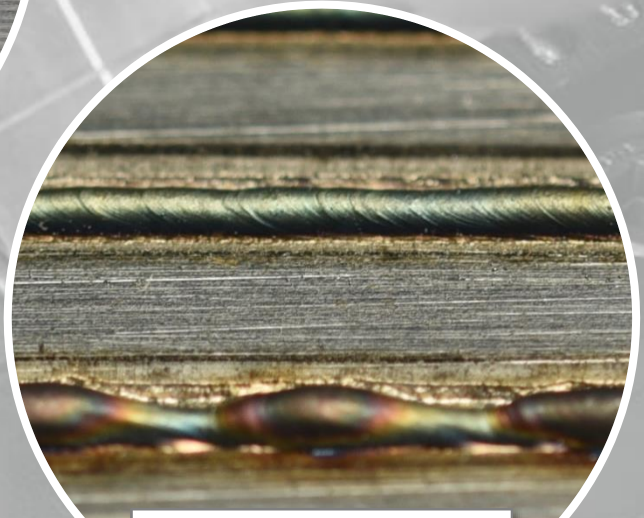


Small process window

Process instability



Insufficient surface quality



Insufficient reproducibility

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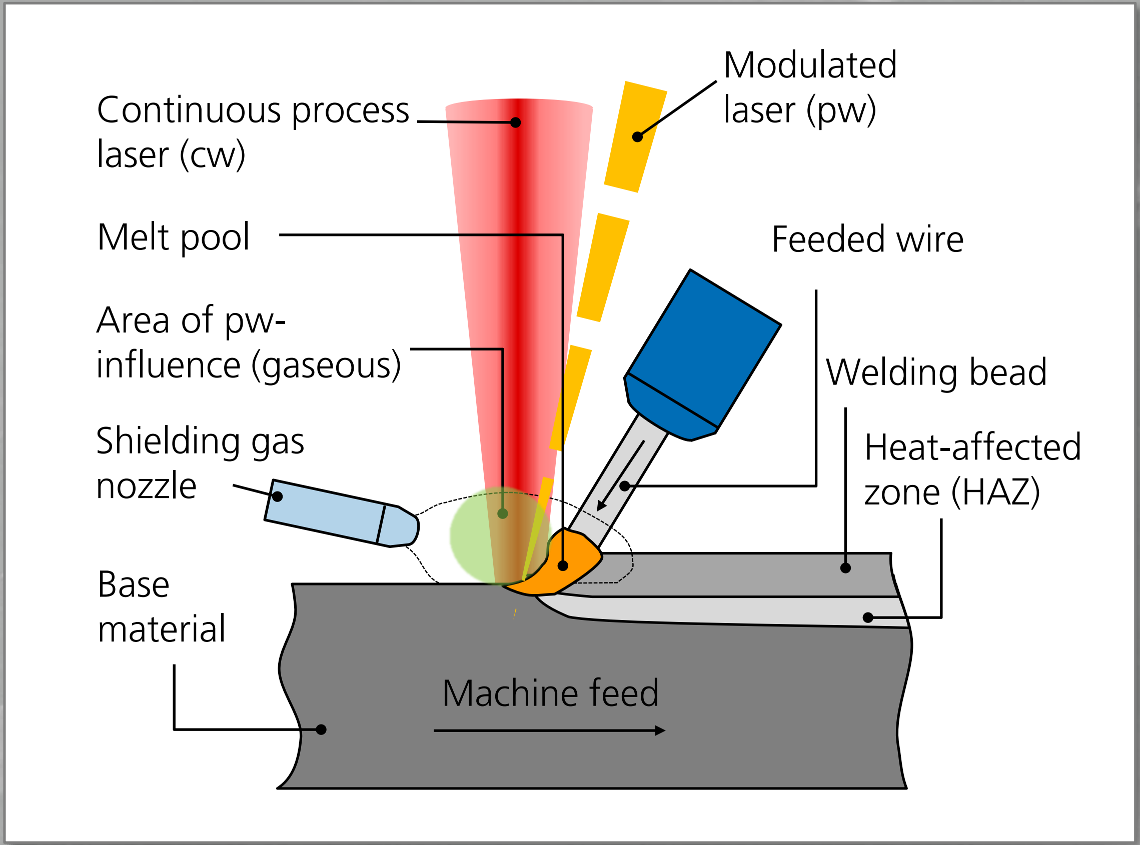
Dual beam process – principle and potential



cw = continuous wave, pw = pulsed wave

Effects

- Modification of absorption behavior
- Influence on welding bead geometry
- Enlargement of stable process window

Potential

- Specific temperature adjustment
- Reduction of surface waviness and roughness
- Process stabilization

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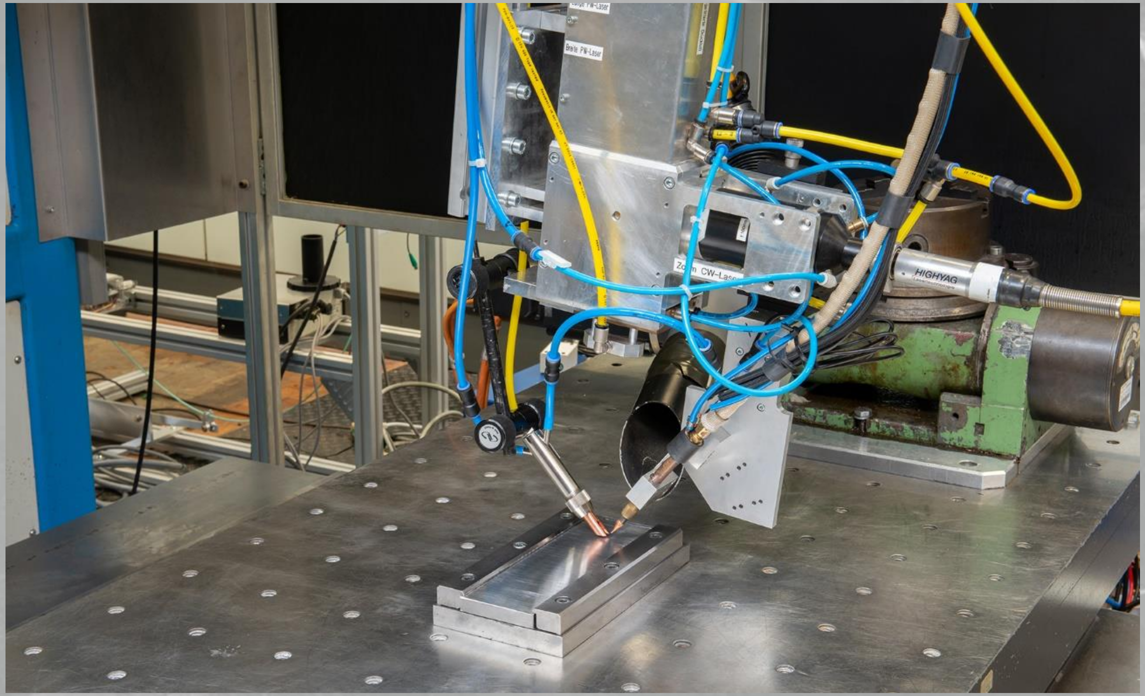
Dual beam process – principle and potential



Used laser sources:

- Modulated beam: Edgewave IS20I-ET
- Continuous beam: Laserline LDF 5000-40

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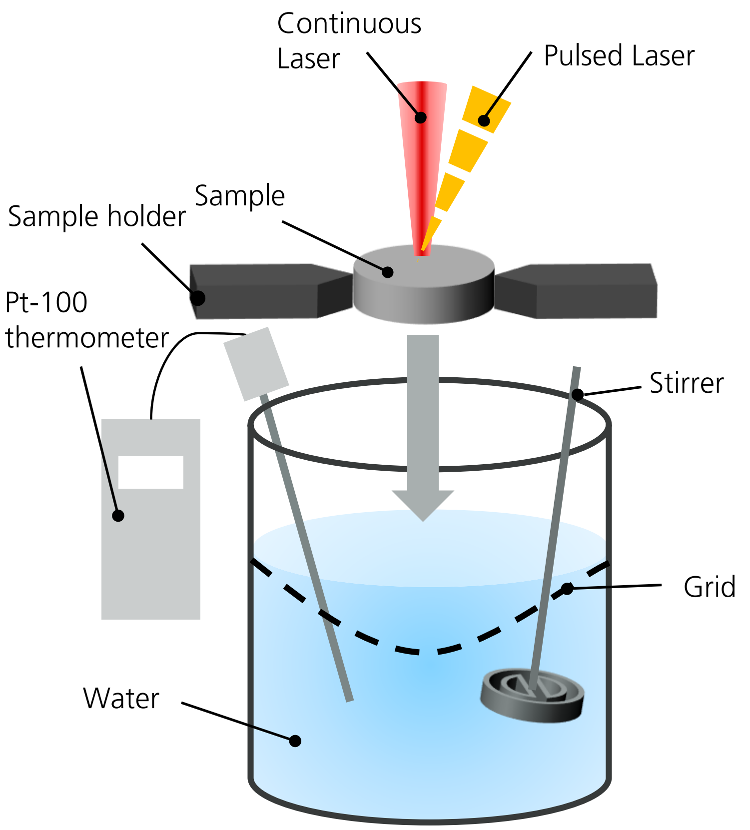
Modulated laser influence on absorption (I/II)

Calorimeter-like test stand



- Laser processing of the samples during 40 s (cw constant: 400 W, pw variated)
- Dropping the sample into an isolated water vessel
- Measuring the water's temperature raise until stagnation
- Determination of the absorbed energy
- Calcuation of the effective absorption coefficient (cumulated pw+cw power)

Dependency of absorption on the modulated laser radiation

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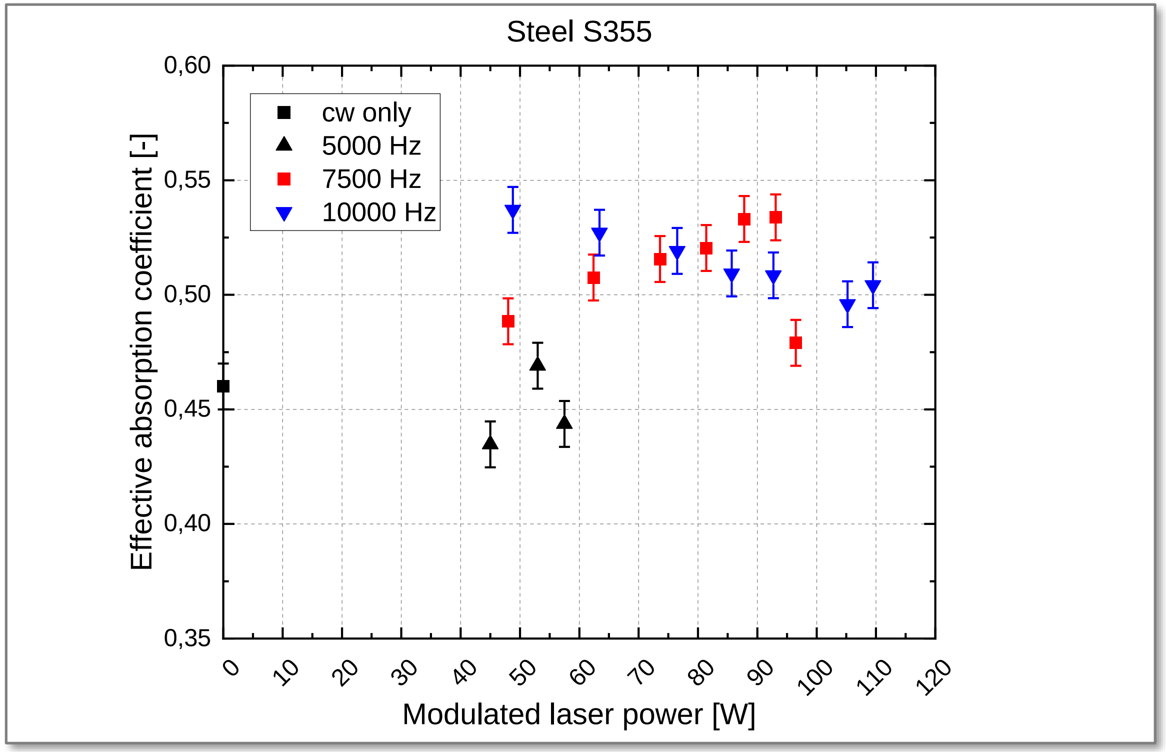
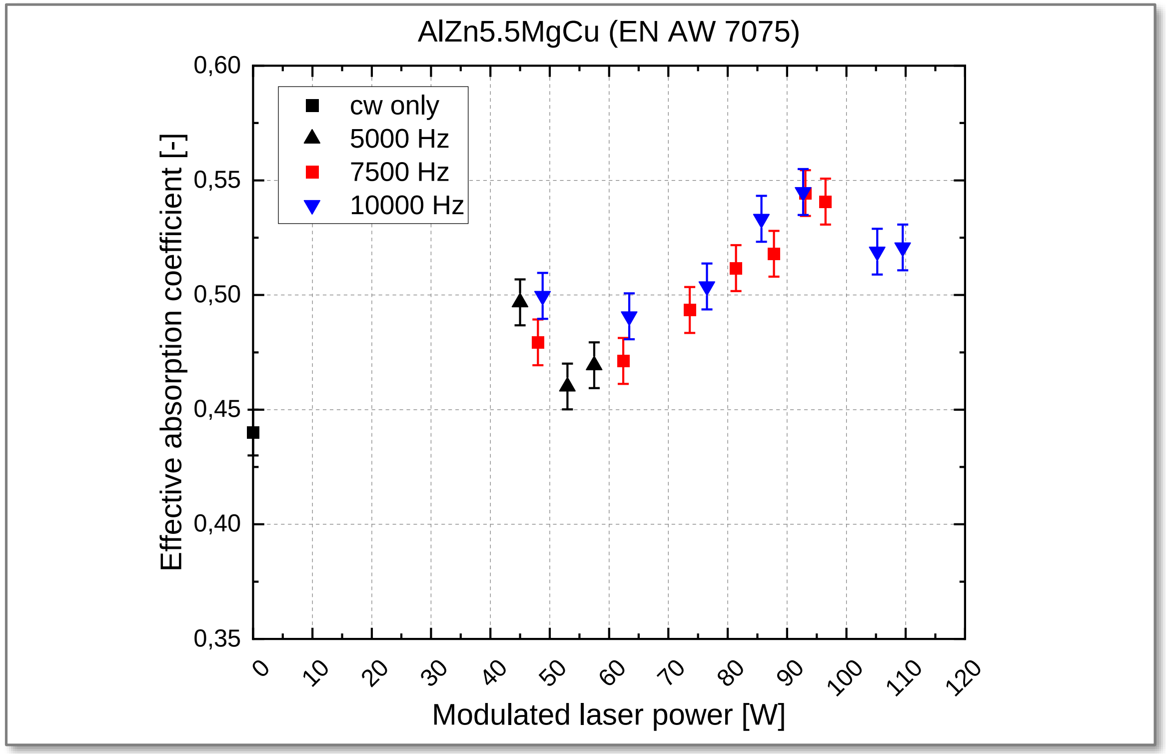
Modulated laser influence on absorption (II/II)





- The vapor created by the modulated laser has a significant influence on the global absorption
- Local minimum at intermediate powers and a decrease at high powers are observed
- Explanation possible by dissipation in the plasma (collision-based and collision-free effects) [Cui et al., 2013]

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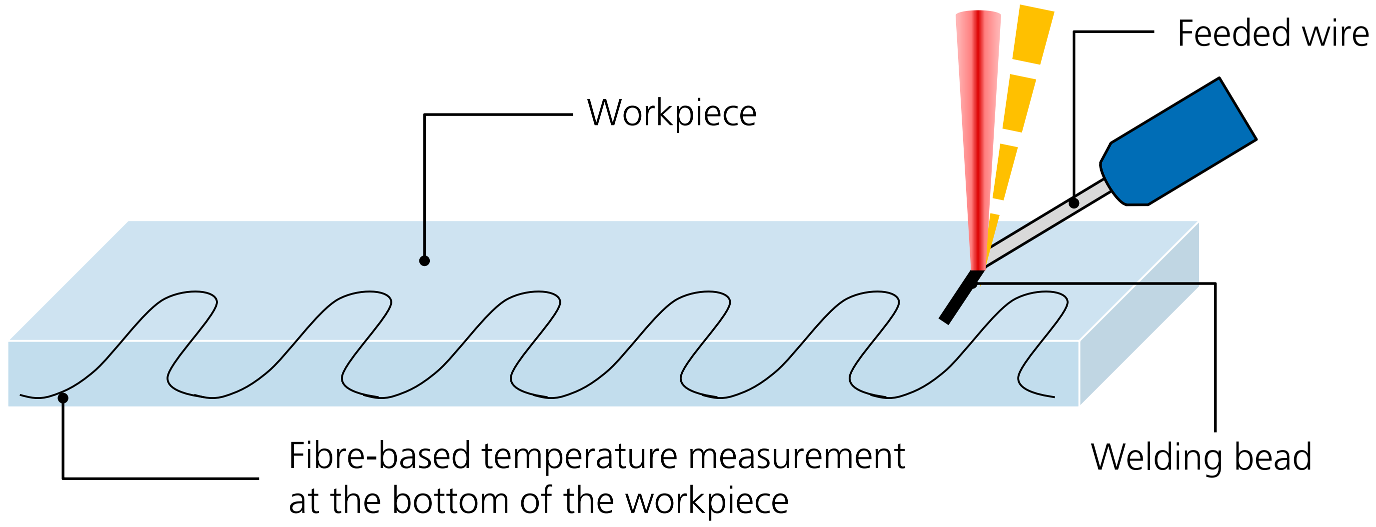
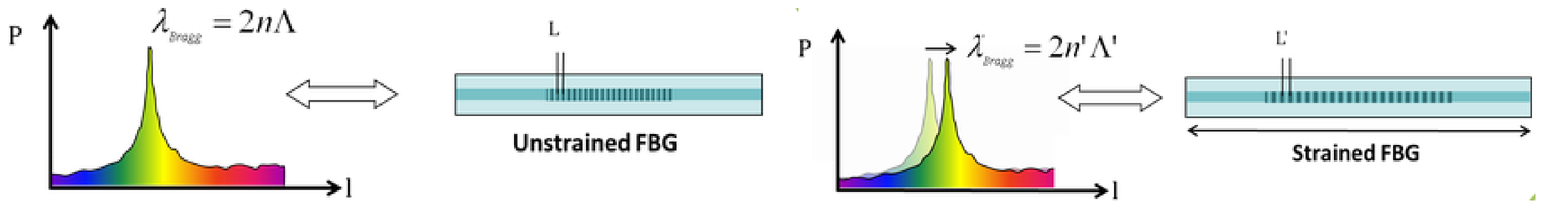
Modulated laser influence on workpiece temperature (I/III)

- Study of the workpiece temperature as a function of the pulsed laser parameters
- In-situ optical fiber-based temperature measurement via measurement of the fiber strain (**O**ptical **B**ackscattering **R**eflectometry, OBR)
- Strain measurement possible thanks to a periodic modulation of the refractive index in the fiber (**F**iber **B**ragg **G**rating, FBG)
- Comparison of maximum strains/temperatures and of the heat propagation behavior





Source: fbgs.com

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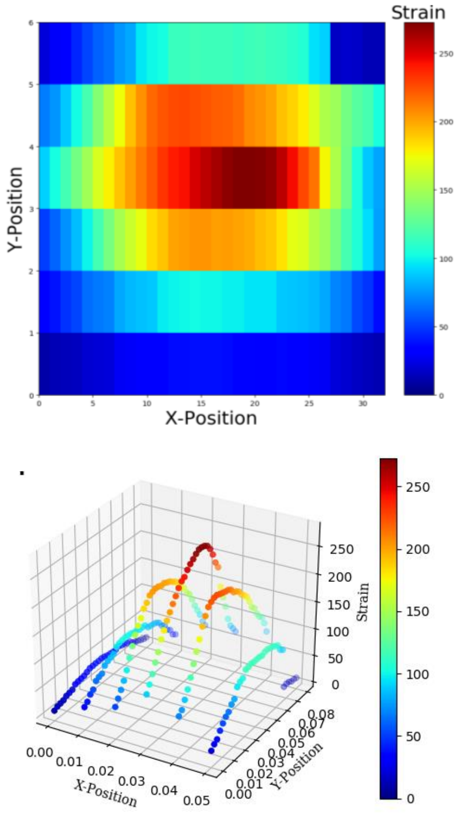
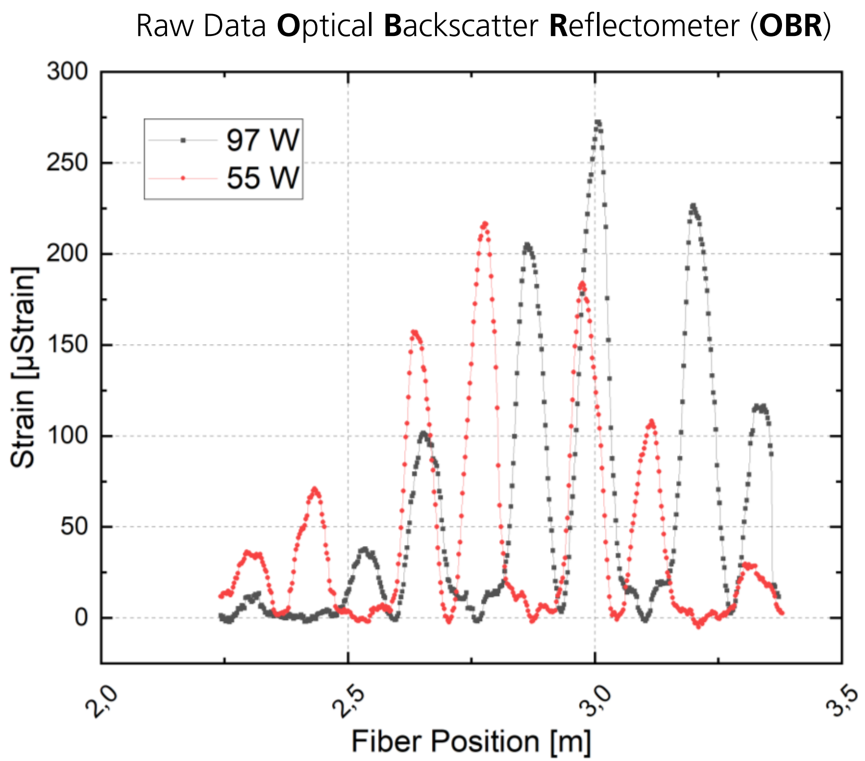
Modulated laser influence on workpiece temperature (II/III)

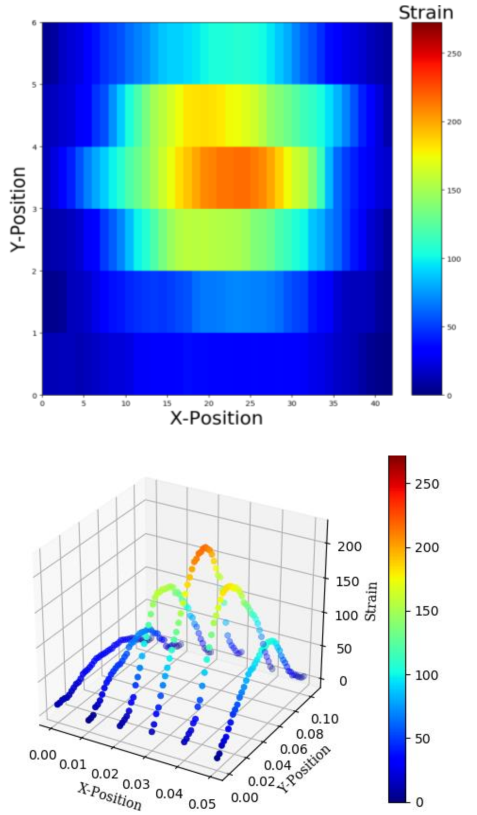
97 W





- cw: 2800 W
- pw: 7500 Hz

55 W



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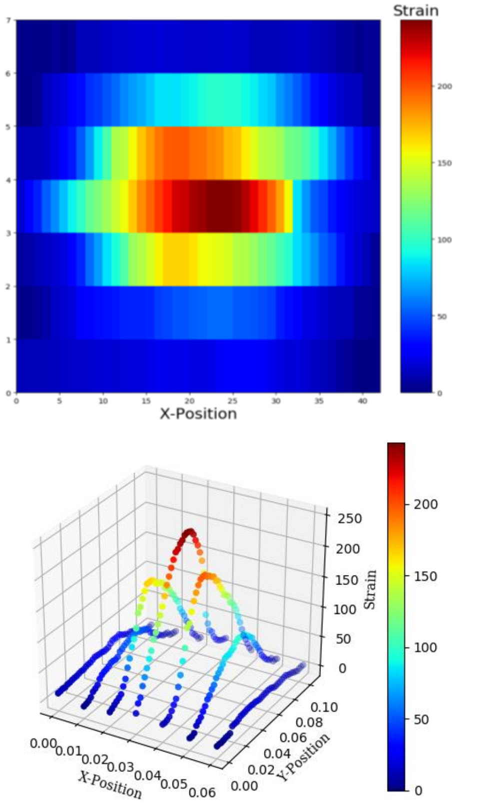
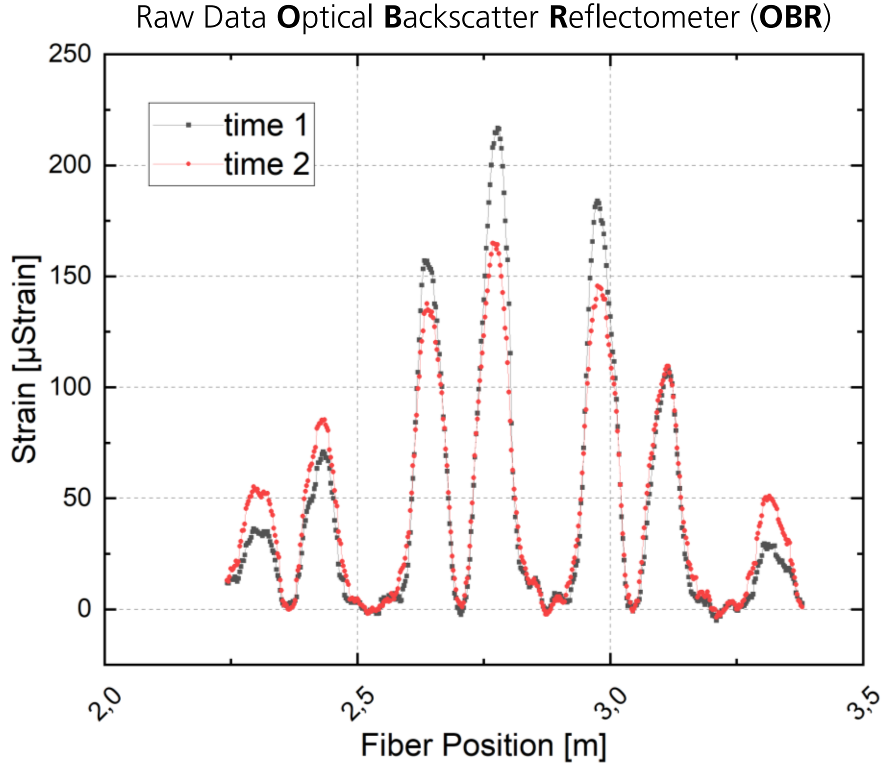
Modulated laser influence on workpiece temperature (III/III)

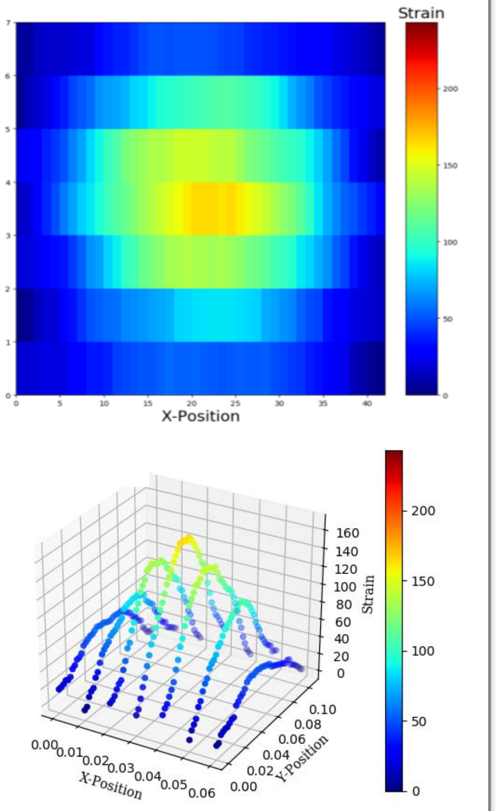
Time 1





- Δt~10 s
- cw: 2800 W
- pw: 7500 Hz / 55W

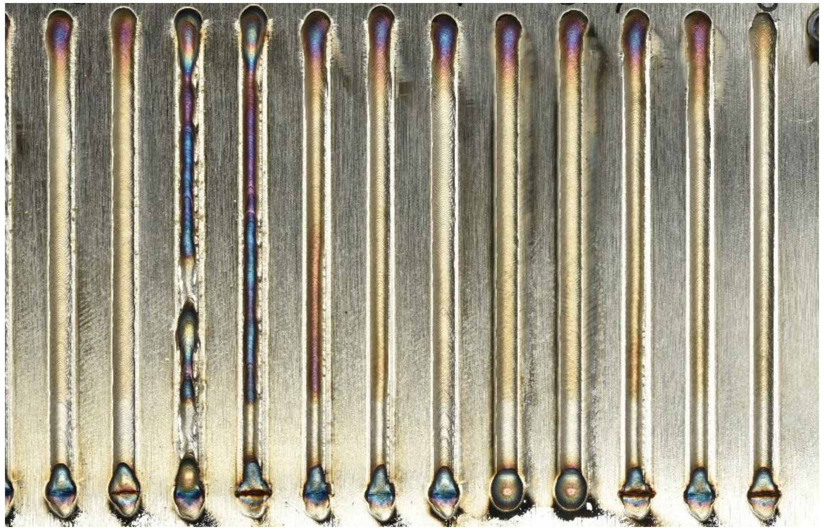
Time 2



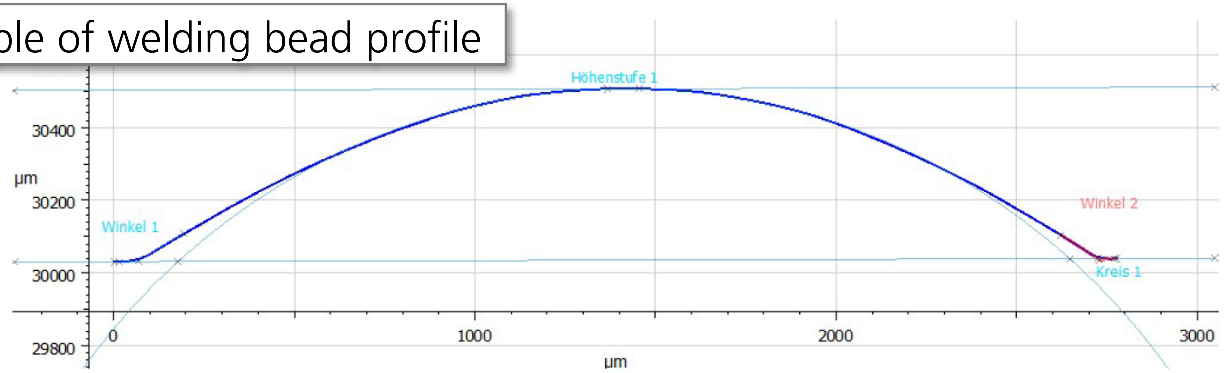
Tailored melt pool shape and temperature distribution by dual laser beam LMD-w

Modulated laser influence on welding bead geometry (I/V)

- Deposition experiments (tool steel QuFe13 on S355)
- Constant parameters:
  $P_{L,c}$ = 2400 W
  v_M = 1100 mm/min
  v_W = 1600 mm/min
- pw parameters variated (frequency and power)
- Repetition to ensure reproducibility
- Surface characterization by depth-of-field measurement (Alicona G5)
- Evaluation of bead roughness and cross section



Example of welding bead profile



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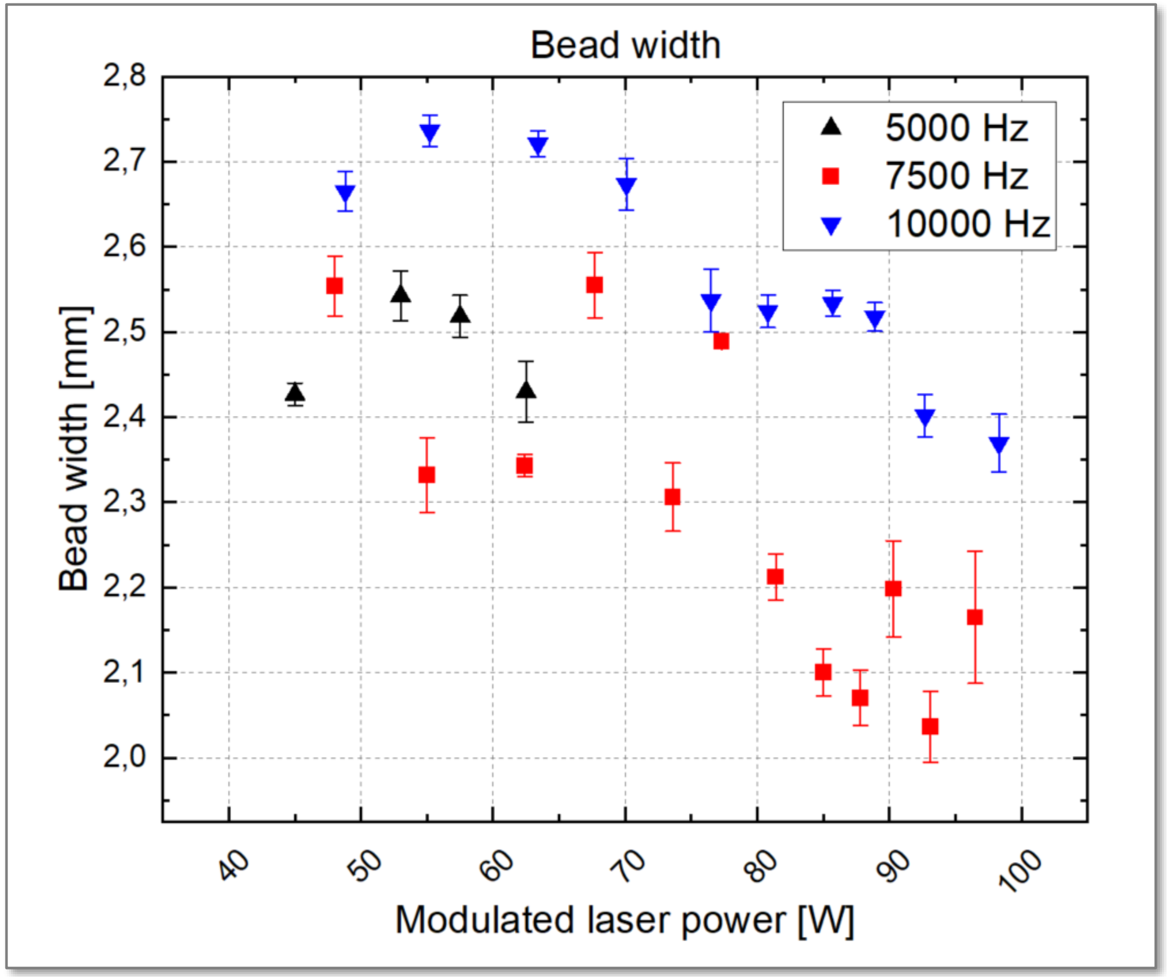
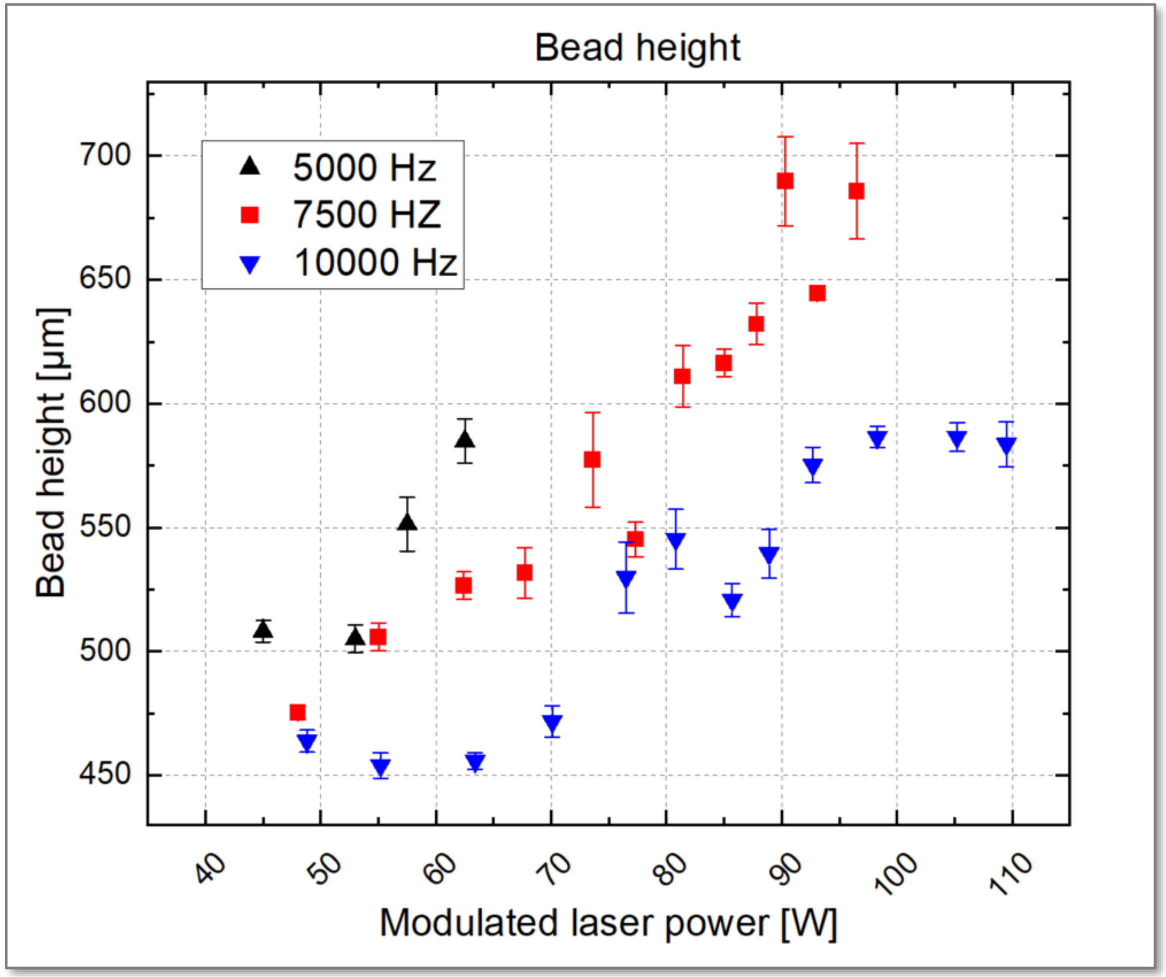
Modulated laser influence on welding bead geometry (II/V)





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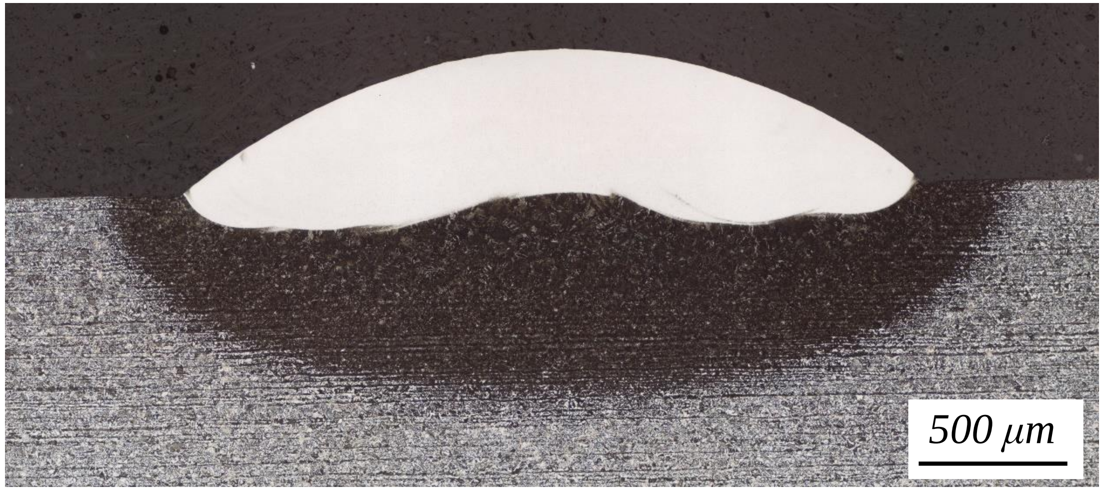
Modulated laser influence on welding bead geometry (III/V)



$P_{L,c}$ = 2400 W, v_M = 1100 mm/min, v_W = 1600 mm/min

f_P = 10000 Hz, $P_{L,m}$ = 49 W

f_P = 10000 Hz, $P_{L,m}$ = 110 W

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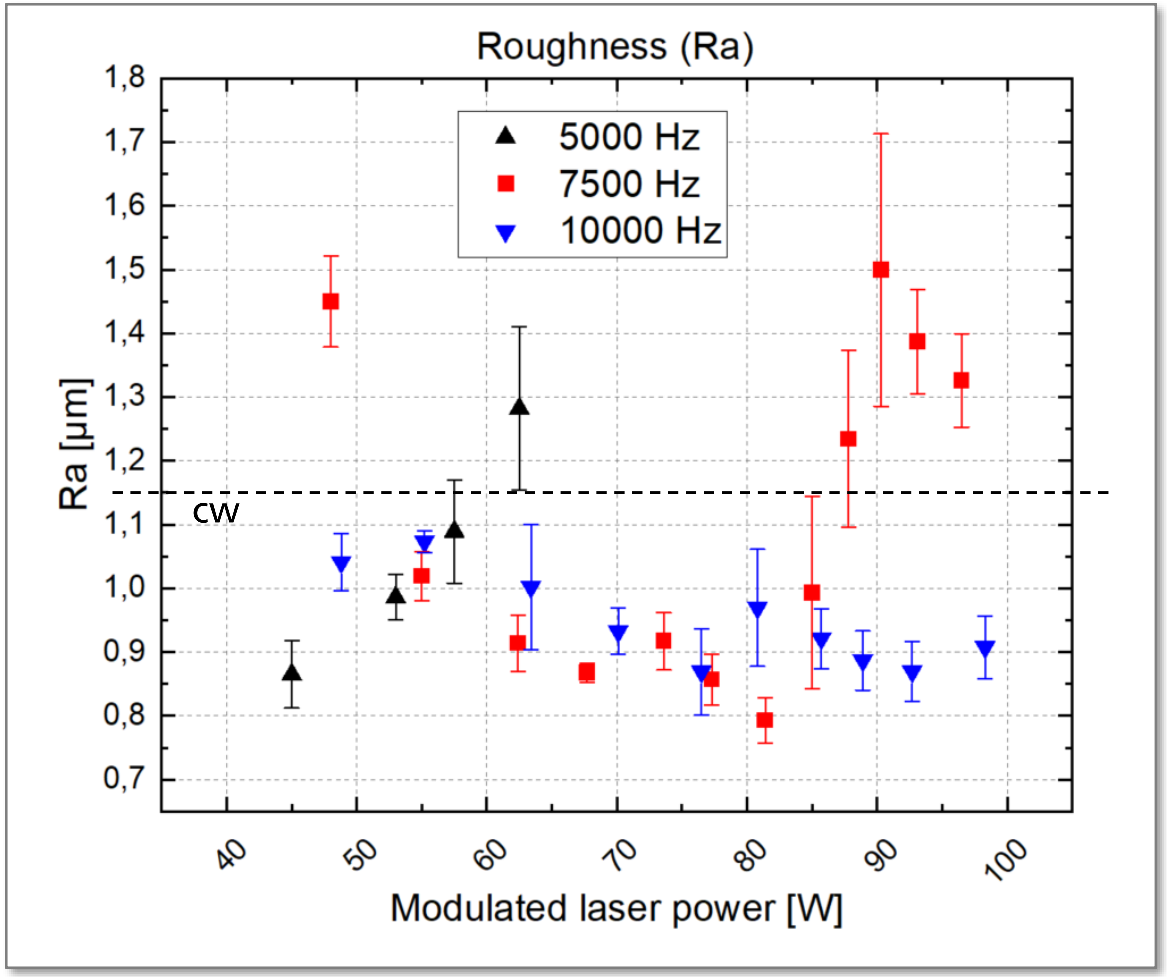
Modulated laser influence on welding bead geometry (IV/V)



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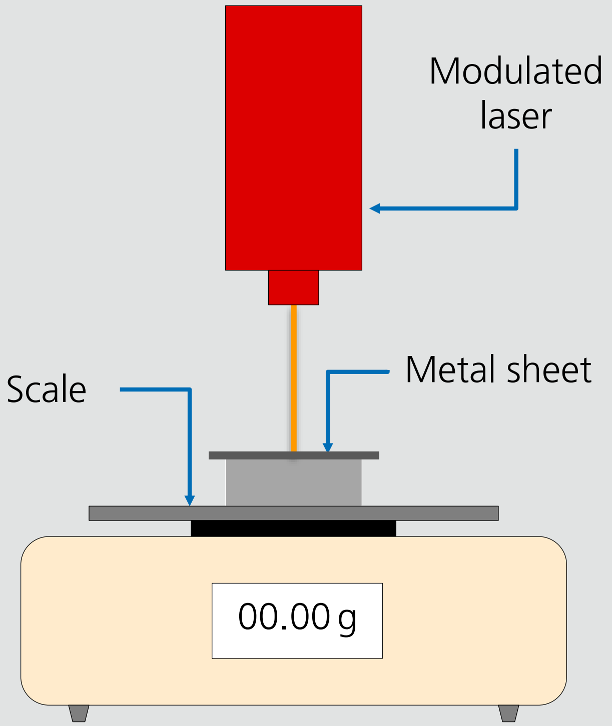
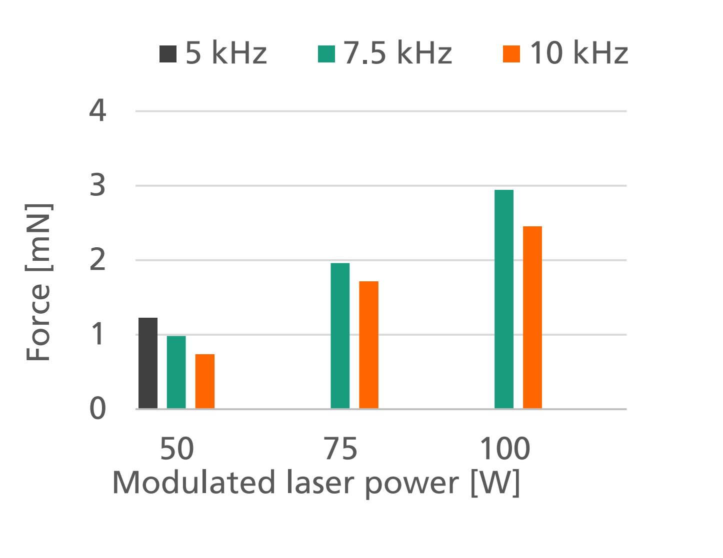
Modulated laser influence on welding bead geometry (V/V)

- The bead geometry is strongly influenced by the evaporation-induced forces
- The stronger the forces, the higher and the narrower the welding beads
- At lower forces, the surface is smoothed; at higher forces, R_a increases as the liquid material is stirred up

Force measurements [Bergs et al., LiM 2019]





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Summary and conclusion

- Analysis of the modulated laser influence in a dual laser beam LMD-w process
- Identification of two main effects
  - Modification of the energy input / workpiece temperature (absorption-related)
  - Modification of the melt pool shape (force-related): welding bead cross section and roughness control
- The absorption coefficient can be increased by about 20 %
- The welding bead height and width can be tailored by a factor of maximum 2
- The welding bead surface roughness can be reduced

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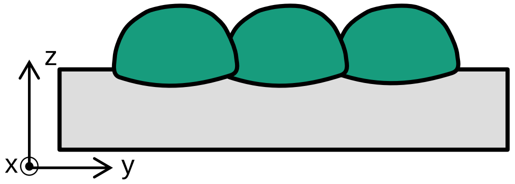
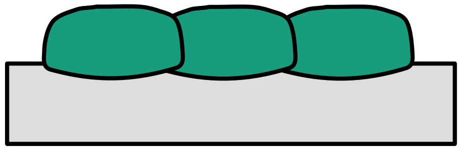
Outlook

only cw

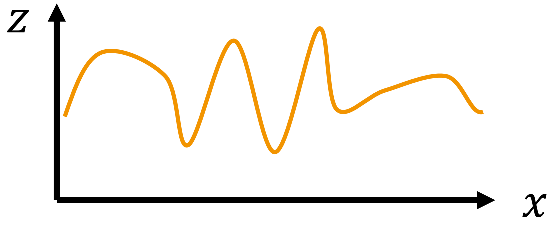
pw + cw

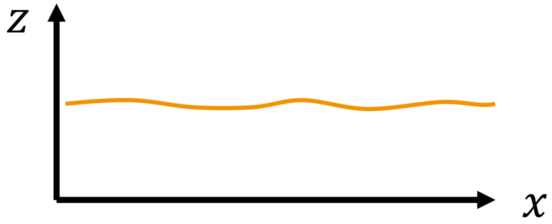
Use advantageous bead cross sections to reduce surface waviness



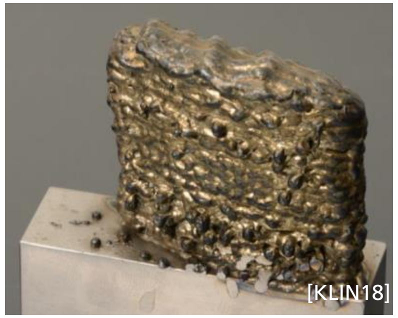


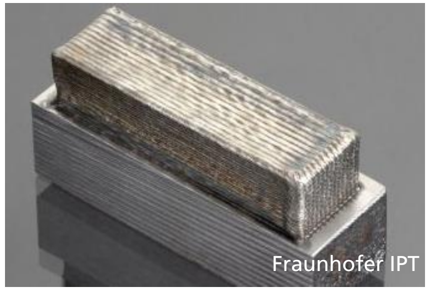
Reduce surface roughness by the modulated laser





Increase process stability and quality in 3D LMD-w





Contact

Thank you for your attention!

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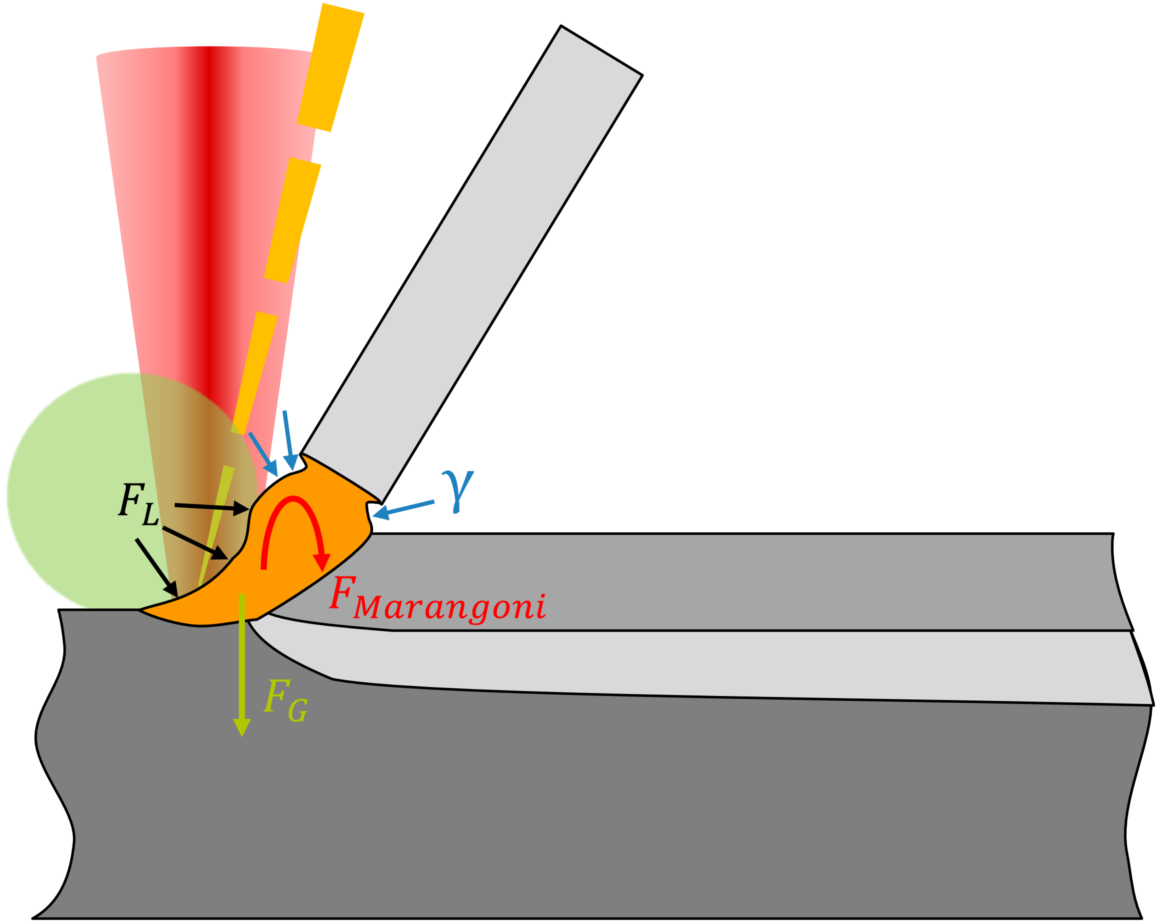
Backup

Wt.%	C	Si	Mn	Mg	Cr	Cu	Mo	Ti	Ni	Zn	Fe	Al
S355 J0	0.2	0.55	1.6	-	-	0.55	-		0.01	-	Bal.	-
QuFe13 (Quada)	0.25	0.5	0.7	-	5.0	-	4.0	0.6	-	-	Bal.	-
EN AW 7075	-	0.4	0.3	2.5	0.23	1.5	-	0.2	-	5.5	0.5	Bal.

Backup



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