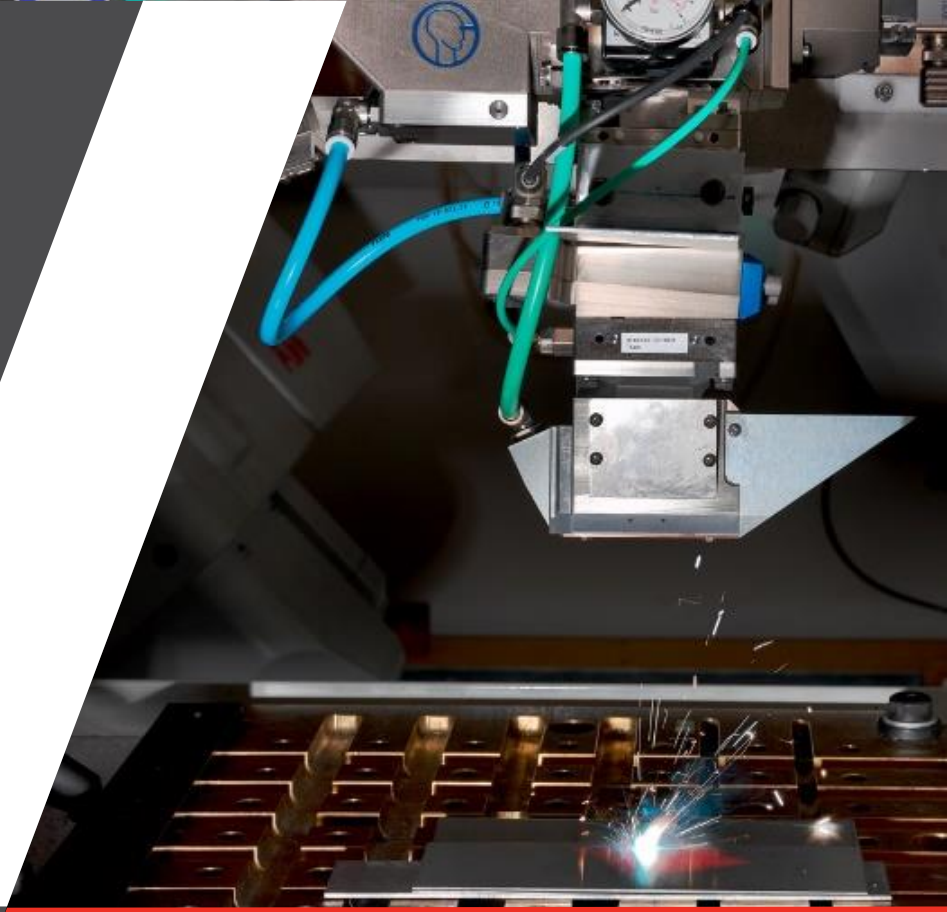
Advances in Laser Welding Using Beam Shaping Bolster Green Transport Future

Lasers4MaaS - Laser-as-a-Service



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21st October 2024

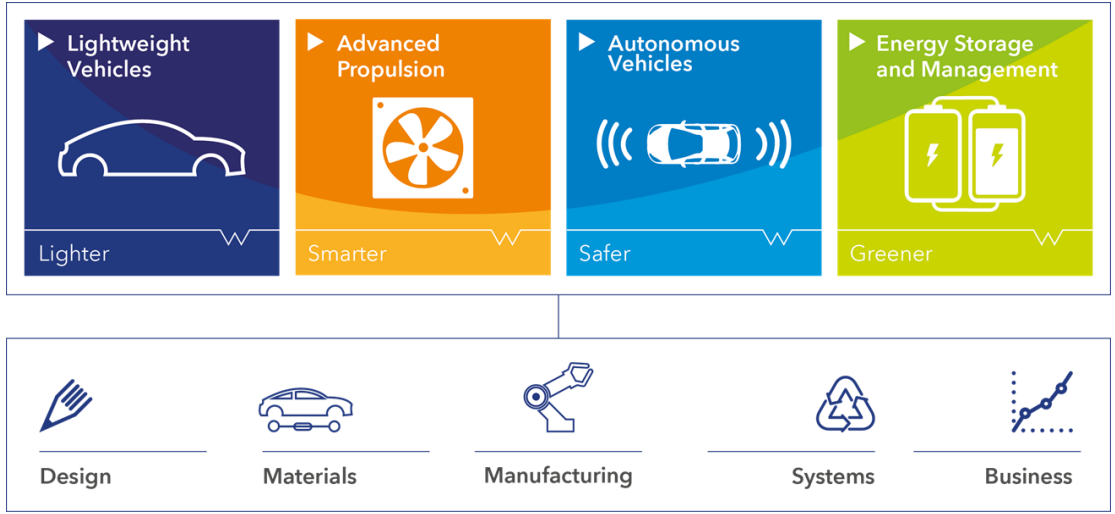
EPIC Online Technology Meeting on Industrial Laser Processes for Automotive and Electro Mobility

WMG THE UNIVERSITY OF WARWICK

WMG, The University of Warwick

- WMG is an academic department at The University of Warwick
- WMG is also founding member of the HVM Catapult
- Ethos:
  - Support the growth and success of the UK manufacturing industry
  - Bridge the gap between concept and commercialisation (TRL 3 to 7)
  - Accelerate and de-risk technological innovation

Current focus at WMG: Low Carbon Mobility



Laser Beam Welding Lab at WMG

Our expertise:

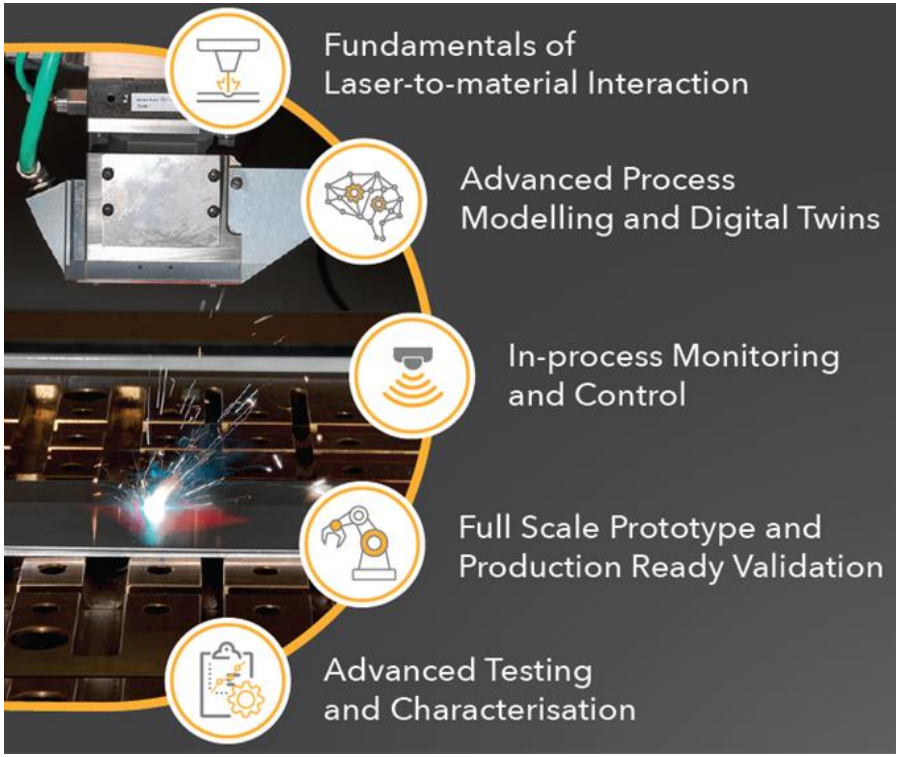
- Later-to-material interaction
- Multi-physical modelling, quality control
- Process scale-up from concept to full scale prototype
- Advanced testing and weld characterisation

Our capability:

- State-of-the art facility with lasers and advanced optics
- Tooling design/process simulation, including robotics cell
- Quality control enabled by state-of-the-art sensors

Success stories:

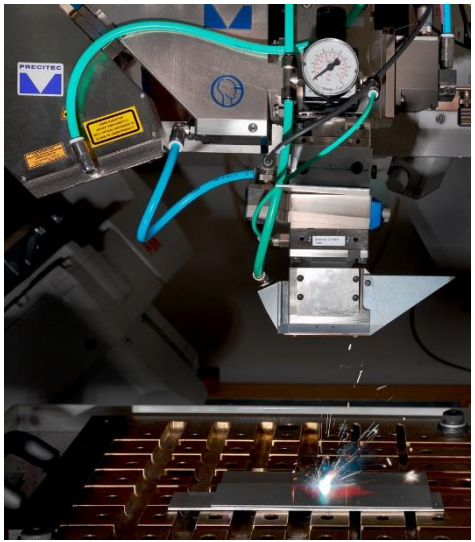
- INNOVISTA award for remote laser welding process
- Laser welded battery enclosures using recycled aluminium
- Impact of beam shaping to material response



Laser Beam Welding Lab at WMG

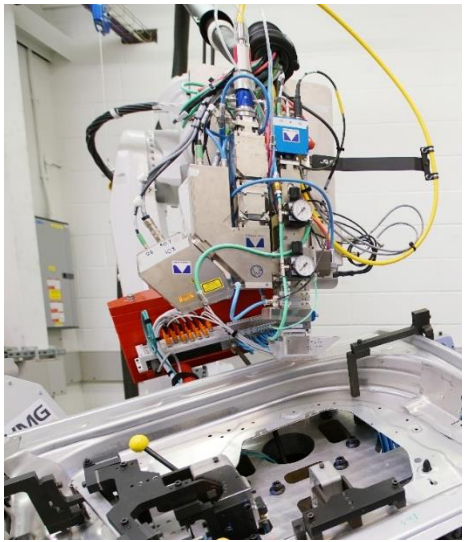
Our work cuts across the entire research and innovation cycle including
fundamental research (TRL 3/4), **applied research** (TRL 5/6) and **technology development** (TRL 7)

Fundamental research



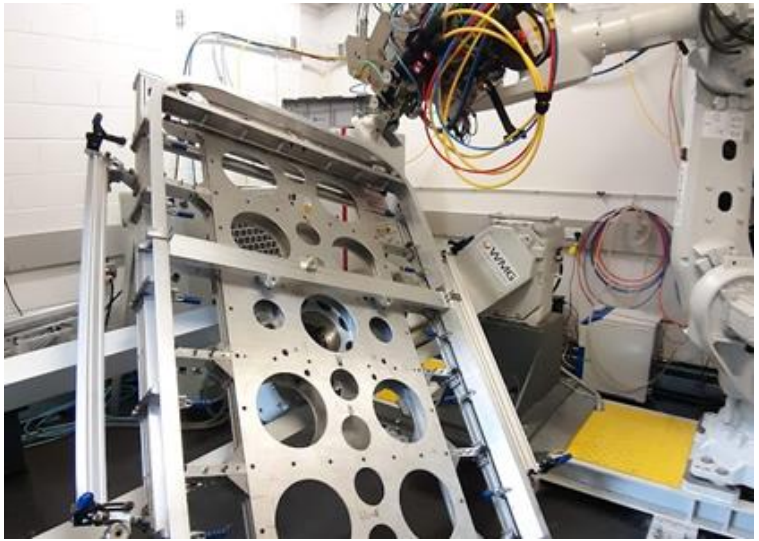
TRL3/4

Applied research



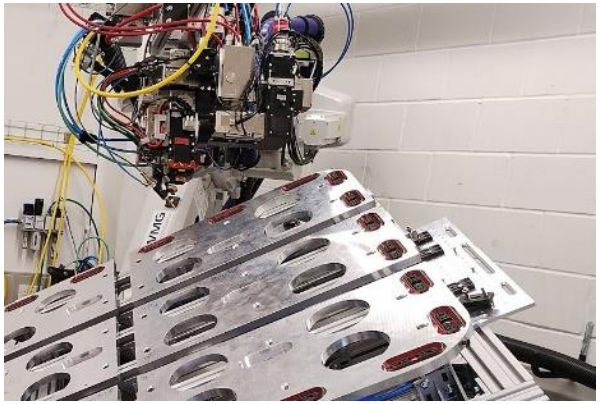
TRL5/6

Full scale prototype

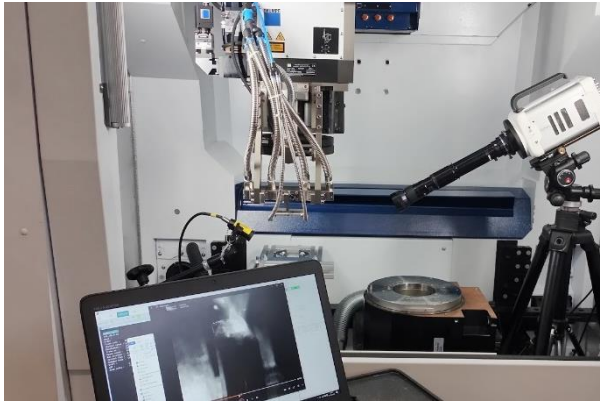


TRL7

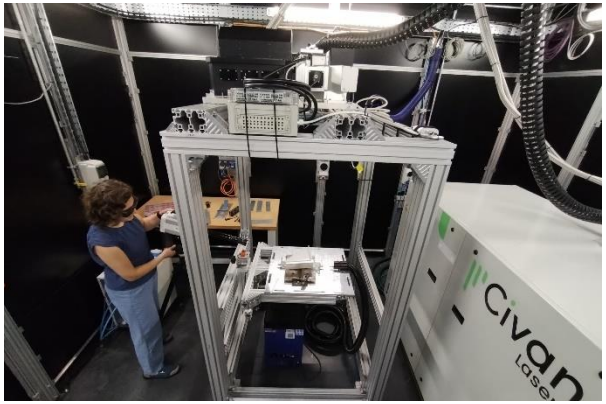
Laser Beam Welding Lab at WMG



Robotics Laser Beam Welding



4-axis CNC Laser Beam Welding



Laser Welding with Dynamic Beam Shaping

Laser systems: LASERLINE LDF 6000; COHERENT ARM FL10000; TRUMPF Brightline 6000; Manual handheld laser (1.5kW with wire feeder); CIVAN 14 kW with dynamic beam shaping

Welding heads: Precitec Weldmaster (1D wobbling head with motorised collimator); K-lab 200 (2D scanner/manual collimator). Scansonic ALO4-O/ALO4 (2D wobbling with seam tracking and spot-in-spot module); Scansonic RLW-S (2D scanner/auto collimator); TRUMPF PFO (2D scanner/auto collimator); SmartMOVE (2D scanner)

In-process sensors: high speed camera; IR camera; photodiodes; OCT; XARION ultrafast optical microphone

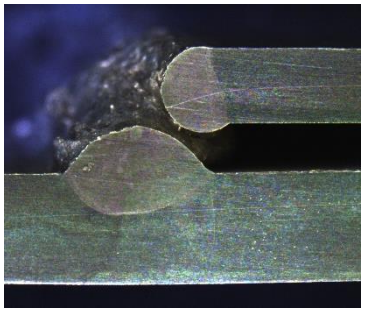
Diagnostic kits: PRIMES power and focus meter

Simulation suites: Flow3D; Comsol Multiphysics

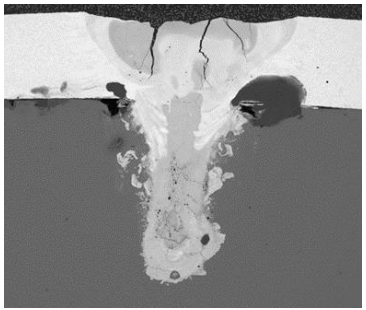
Production at scale for automotive e-mobility

What is the industry asking for?

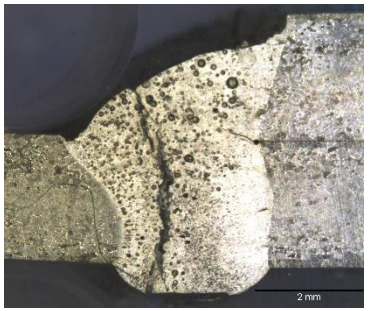
- Novel welding/de-welding strategies
- Solutions for new material combinations
- CAPEX reduction
- Need for zero-defects
- Up-skilling and new skillsets
- …



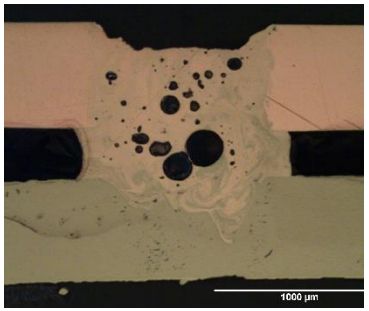
Lack of connection



Micro-cacks and intermetallics



Centreline cracks

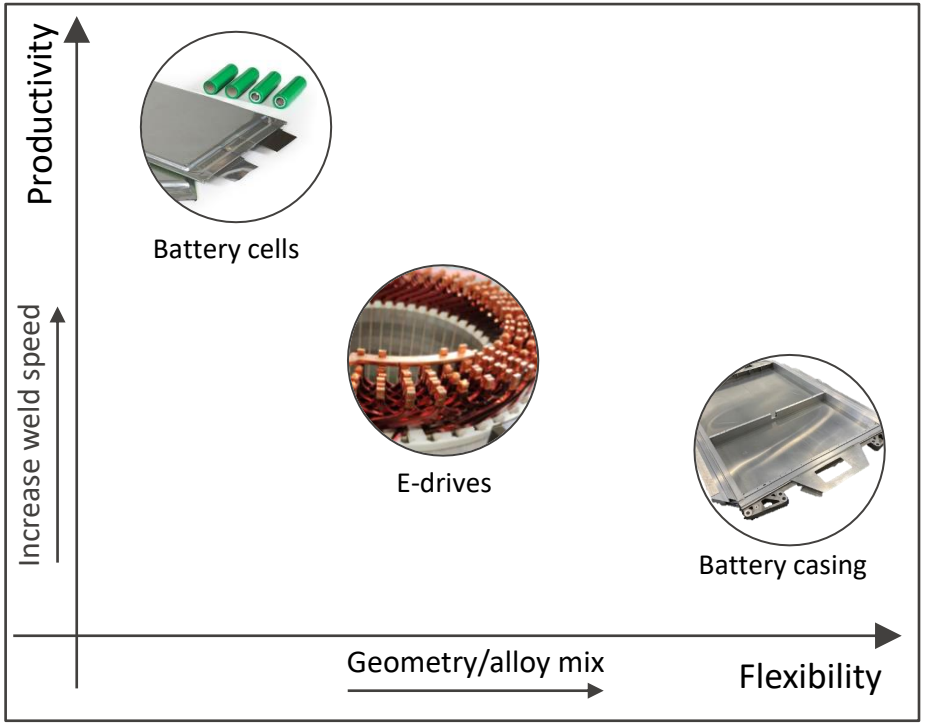


Distributed pores

Production at scale for automotive e-mobility

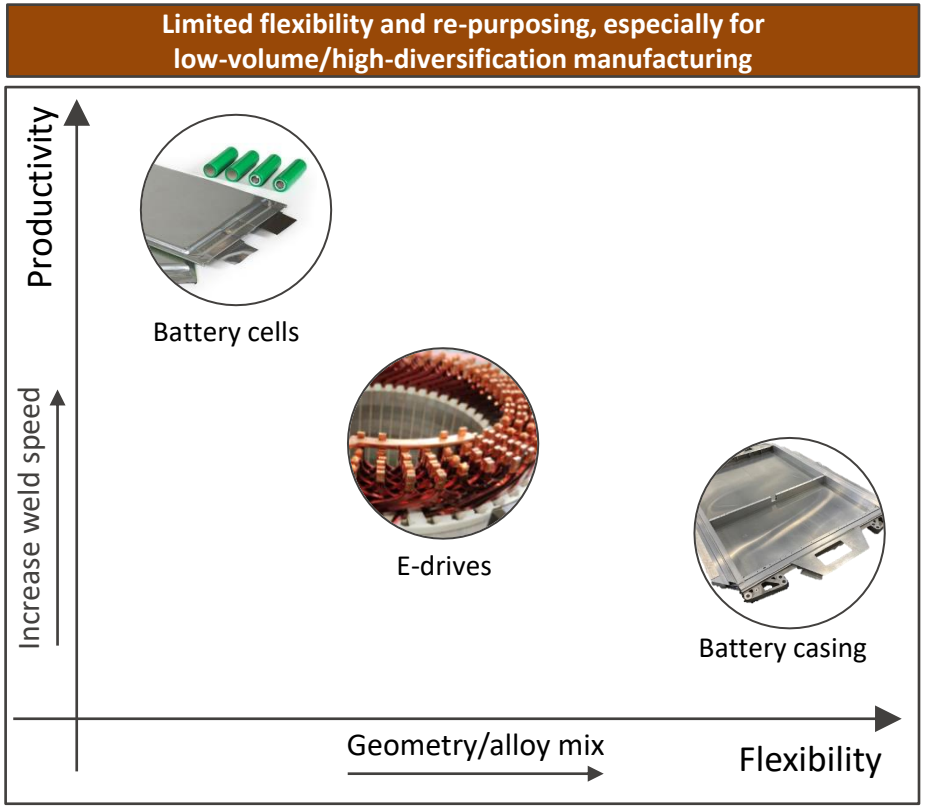
What is the industry asking for?

Limited flexibility and re-purposing, especially for low-volume/high-diversification manufacturing

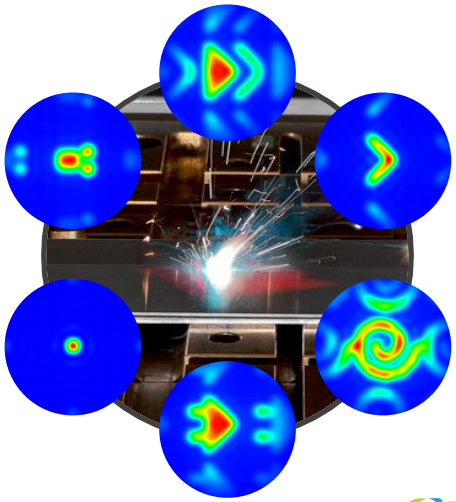


Production at scale for automotive e-mobility

What is the industry asking for?



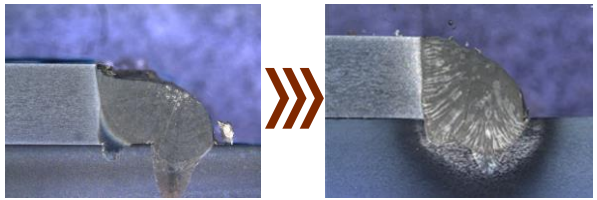
- No doubt that laser is a universal tool, however, so far different lasers for different applications
- **A productivity-driven approach tends to jeopardise the full flexibility of advanced laser welding**
- Can we capitalise on latest advances in laser beam shaping (time and space modulation of beam intensity)?



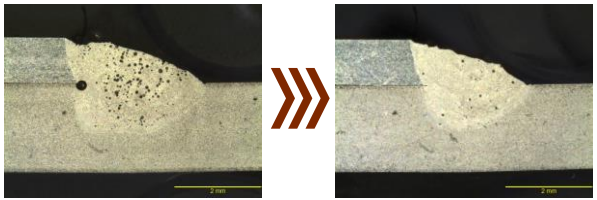
Advances in Laser Welding

Laser Beam shaping

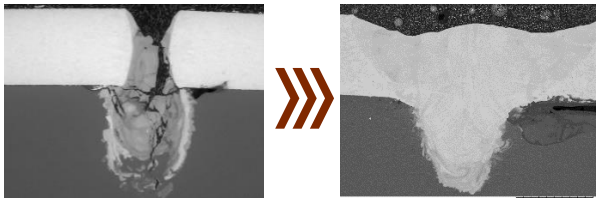
Weld profile
- Control of weld profile
- Enhanced part-to-part gap bridging
- Enlarged process window



Keyhole and molten pool dynamics
- Reduction of weld porosity/spatters
- Control material mixing
- Increased welding speed



Microstructure
- Tailored microstructure
- Control of weld cracks
- Control of phases/intermetallic formation



- For years, laser welding systems have provided fixed output beam profiles

- Laser beam shaping makes use of a static beam (no movable parts) or wobbling beams to tailors the heat input in time and space, during solidification

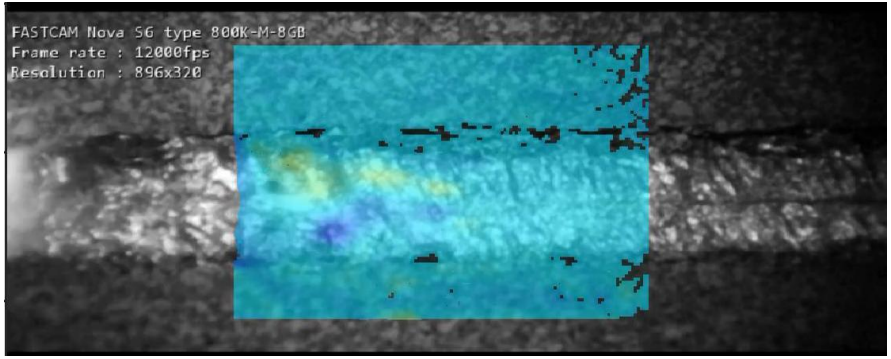
  … hence, great opportunity to unlock the **full flexibility of advanced laser welding systems**

Laser Beam shaping

Autogenous laser welding of 6xxx series aluminium

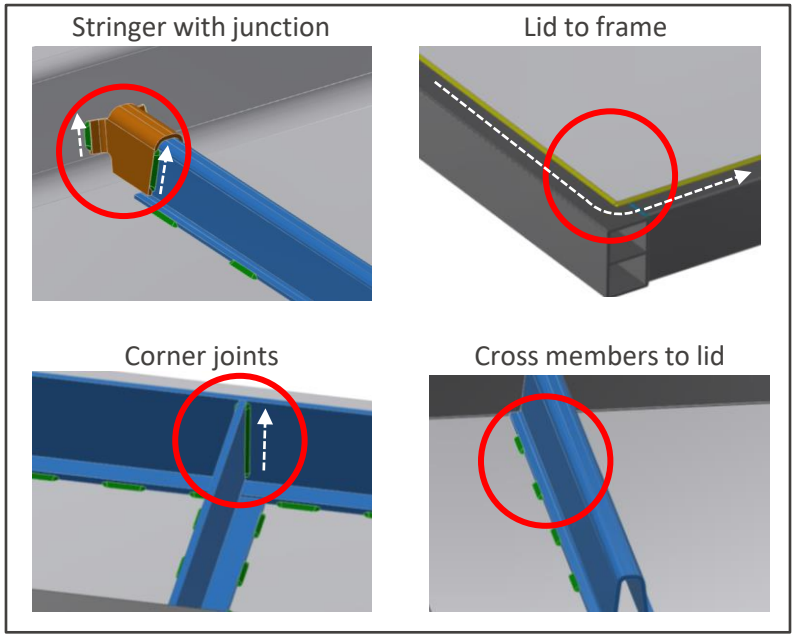
Statements:

- Higher range vehicles generally have aluminium battery trays
- Aluminium 6xxx series is hot crack sensitive
- State-of-the-art use filler wire in conjunction with laser: complex
- Industry demands new advances for autogenous laser-only processes



**example of centreline crack during autogenous laser welding*

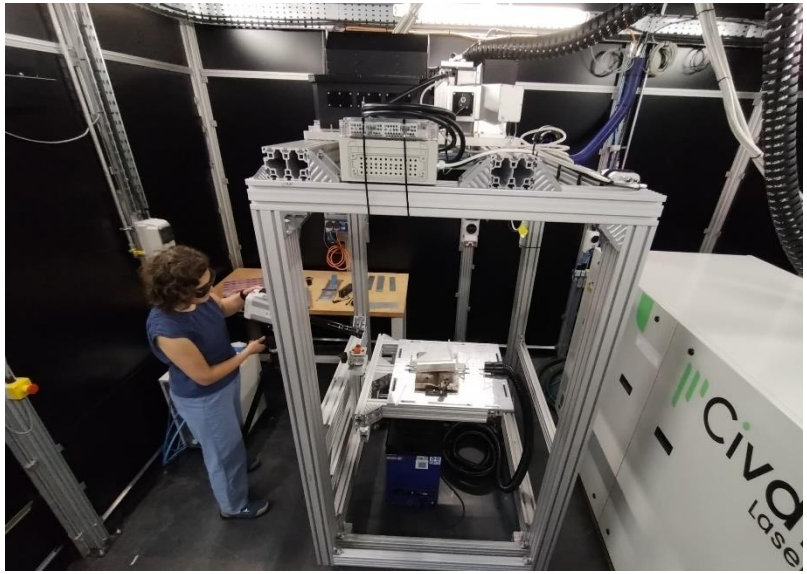
Examples of applications of laser beam welding



Laser Beam shaping

Autogenous laser welding of 6xxx series aluminium

Testing CBC-OPA CIVAN dynamic beam shaping



- AA6061 overlap weld: 0.4 mm to 0.8 mm
- Full penetration weld

CIVAN OPA6

- Total power: 14 kW
- Pre-focussed beam: 1.5 m focal length
- Smallest spot diameter: ~120 µm
- Total area covered by laser on focus : ~1.5 mm

2D Scanner – SmartMOVE SH30G-ME-LD

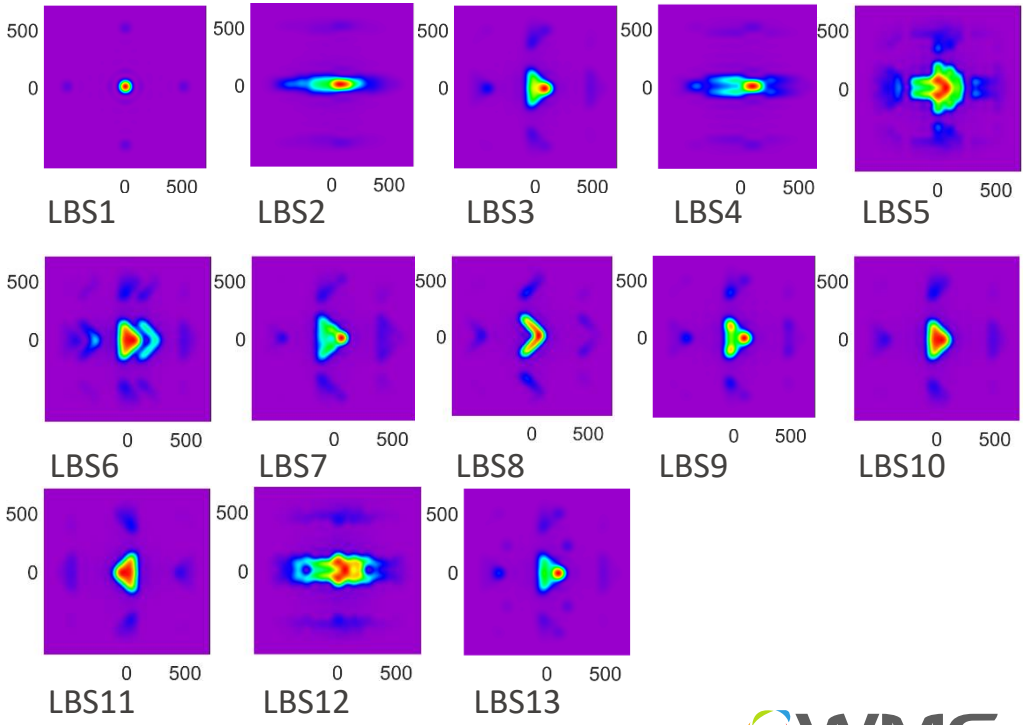
- Working envelop: 800 mm diameter
- Stroke limits: +/-18°
- Total laser power: 11 kW
- Autofocus option enabled by the dynamic beam shaping
- Auto-path alignment enabled by the dynamic beam shaping
- Co-axial camera available
- Option to integrate third-party sensors (LWM, etc.)
- Closed-loop control between scanner and CIVAN source

Laser Beam shaping

Autogenous laser welding of 6xxx series aluminium

Testing CBC-OPA CIVAN dynamic beam shaping

Beam shape ID	Laser power (W)	Welding speed (mm/s)	Shape Frequency (kHz)	No of points/ time (ns)
Reference	3000	110	1000	1
LBS2	4000	110	1000	33
LBS3	3600	110	1000	20
LBS4	3900	110	1000	24
LBS5	3800	110	1000	28
LBS6	3700	110	1000	24
LBS7	3700	110	1000	20
LBS8	3700	110	1000	10
LBS9	3700	110	1000	22
LBS10	3600	110	1000	20
LBS11	3600	110	1000	20
LBS12	3900	110	1000	25
LBS13	3600	110	1000	20

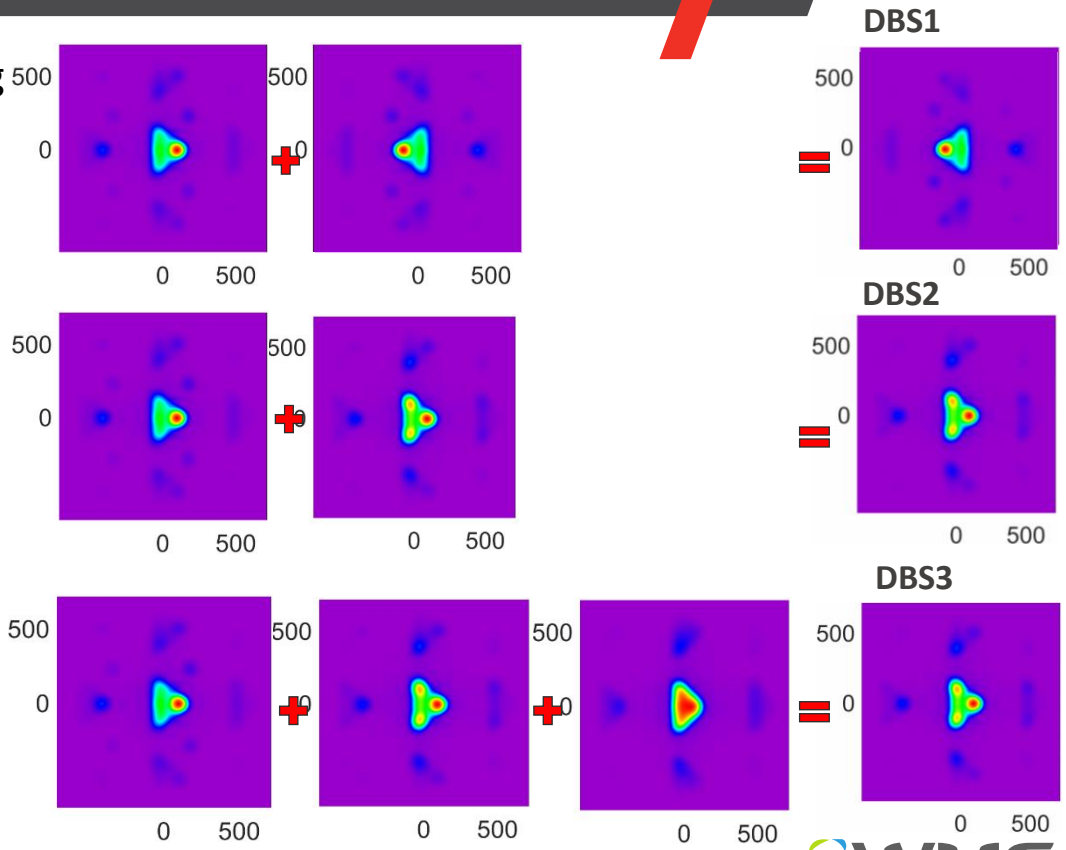


Laser Beam shaping

Autogenous laser welding of 6xxx series aluminium

Testing CBC-OPA CIVAN dynamic beam shaping

Beam shape ID	Laser power (W)	Welding speed (mm/s)	Shape frequency (kHz)	Sequence frequency (Hz)
DBS1-1	3700	110	1000	1000
DBS1-2	3700	110	1000	200
DBS1-3	3700	110	1000	100
DBS2-1	3700	110	1000	1000
DBS2-2	3700	110	1000	200
DBS2-3	3700	110	1000	100
DBS3-1	3700	110	1000	1000
DBS3-2	3700	110	1000	200
DBS3-3	3700	110	1000	100



Laser Beam shaping

Autogenous laser welding of 6xxx series aluminium

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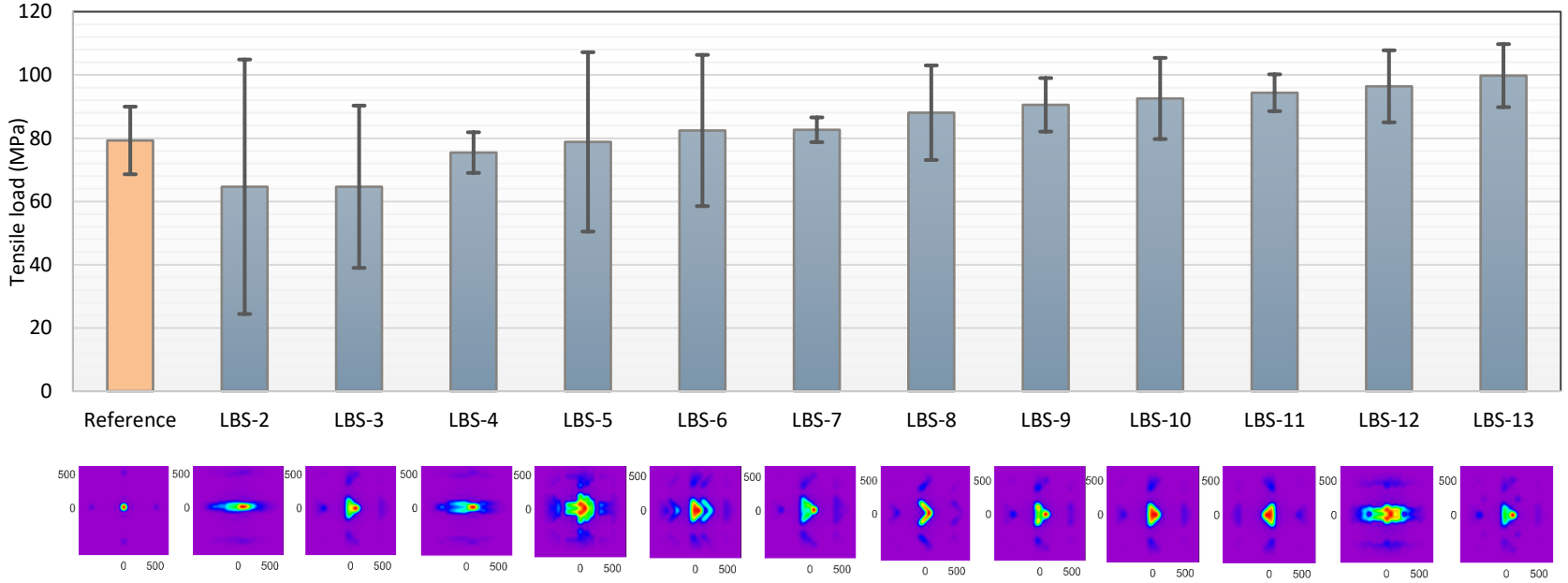

AA6061 overlap weld: 0.4 mm to 0.8 mm; full penetration weld

Venkat et at. "Fast thermal cycling during laser welding of AA6061 alloy with dynamic beam shaping in the MHz regime to control solidification cracking", under review, 2024

Laser Beam shaping

Autogenous laser welding of 6xxx series aluminium

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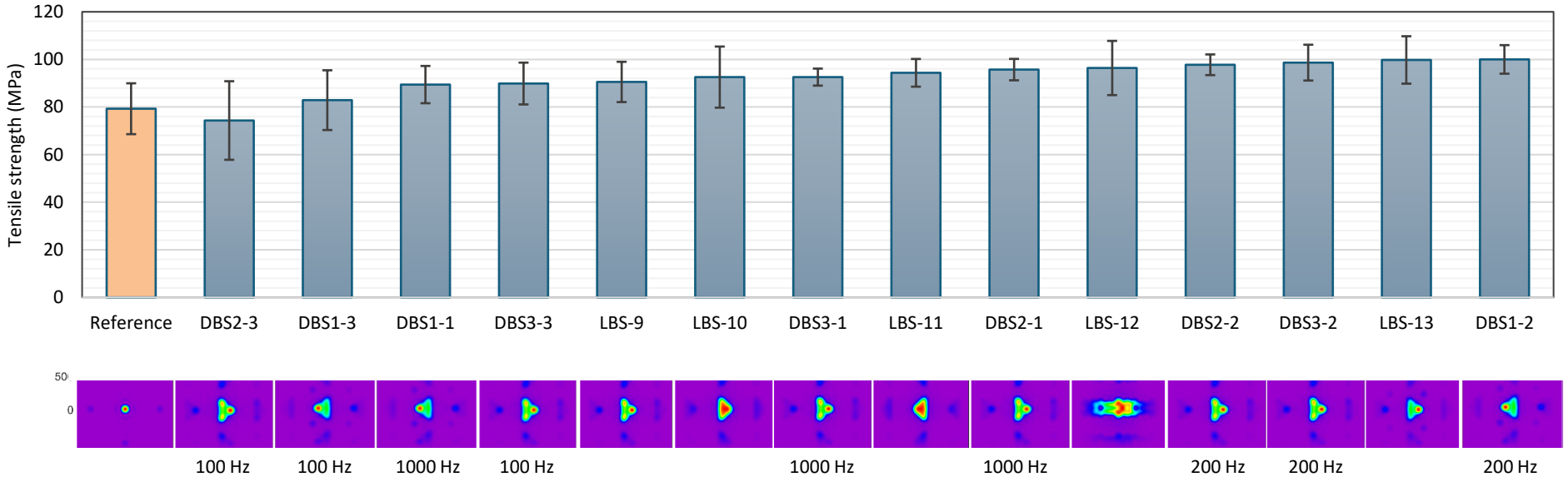

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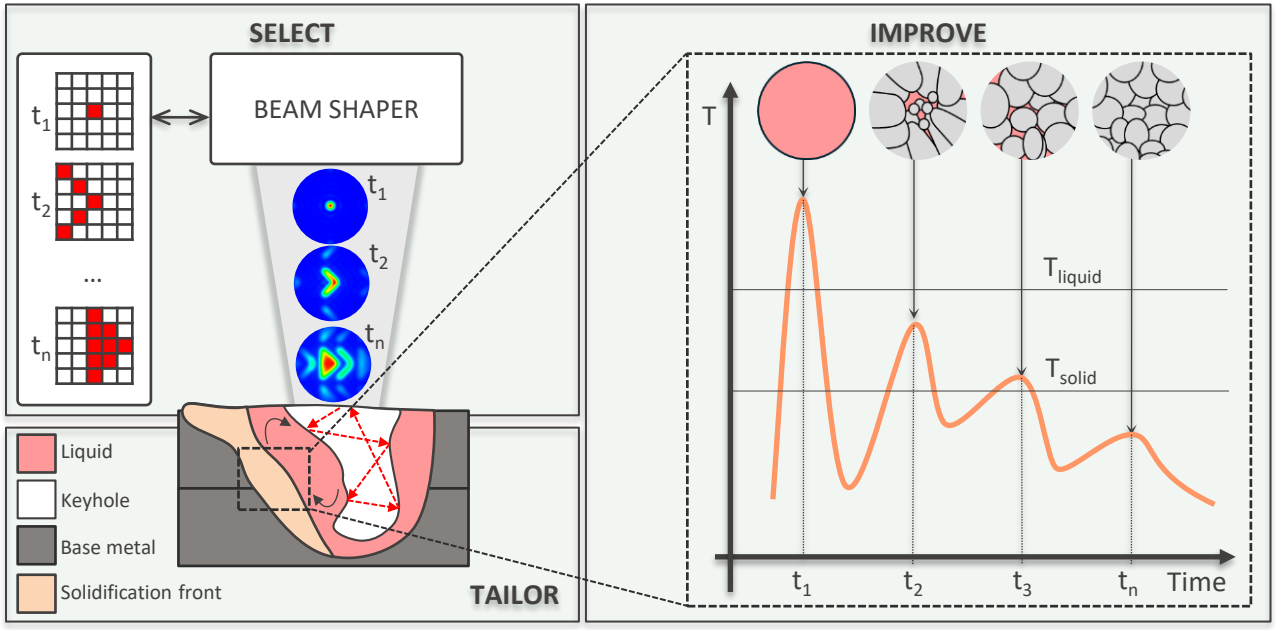
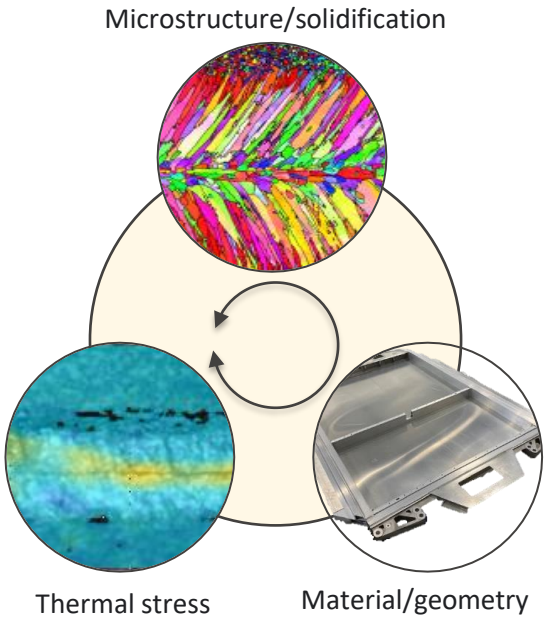
Laser Beam shaping

Which beam shape/sequence produces the optimal weld properties?





- **The challenge**: more flexibility translates to more complexity during the process development
- Need for a holistic approach (multi-physics, multi-scale,…)

Conclusions

The potential of beam shaping moving forward

Potential for **servitisation**: manufacturers will be able to build products on-demand, without the need of re-investment in new equipment, thereby enabling rapid **repurposing**

- Reconfigurability challenge 
- Acceptance challenge 
- Connectivity challenge 
- Controllability challenge 

Conclusions

The potential of beam shaping moving forward

Potential for **servitisation**: manufacturers will be able to build products on-demand, without the need of re-investment in new equipment, thereby enabling rapid **repurposing**

- Reconfigurability challenge 
- Acceptance challenge 
- Connectivity challenge 
- Controllability challenge 

What can we do for you?

Lasers4MaaS - Laser-as-a-Service Digital Platform with Dynamic Beam Shaping for Acceleration of Smart, Decentralised and Sustainable Factory of the Future

Funded by the European Union

This project has received funding from the European Union's HORIZON-CL4-2024-TWIN-TRANSITION-01-03 under grant agreement No 101178719. Project kick-off Jan 2025.

What can you do for us?

- Discuss challenges in laser welding where controlled thermal cycling via beam shaping may help to improve functional properties
- Become member of the “Industrial Advisory Board” of Lasers4MaaS

Thank you, any questions?

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