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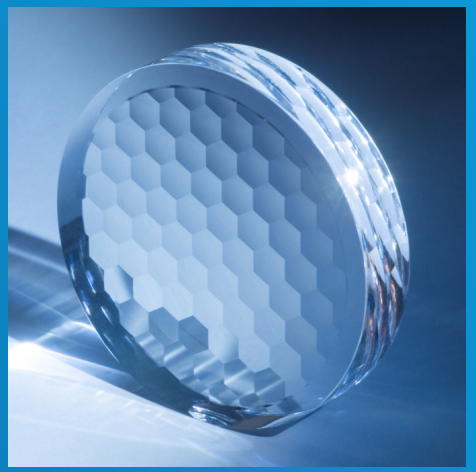
How Laser Welding can be improved by freeform beam shaping optics.



HQ Dalgety Bay, Fife, Scotland

US Center, Sahuarita, Arizona

Dr Emma Modrate 03-Nov-2024

PowerPhotonic

PowerPhotonic

- **Head Office Based in Dalgety Bay**
- **Opened new site in Sahuarita in 2022**
- **55 staff over both sites**
- **Been manufacturing optics since 2004**
- **Its our birthday year**

Freeform design and manufacture - Welding

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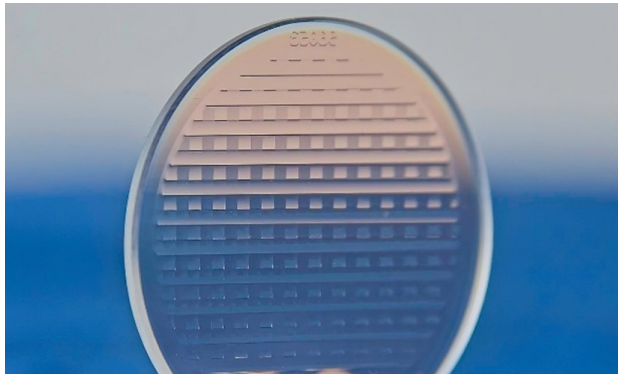
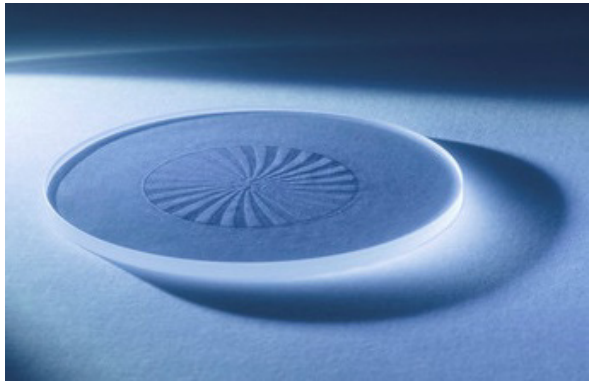
Freeform beam shaping to enhance laser welding

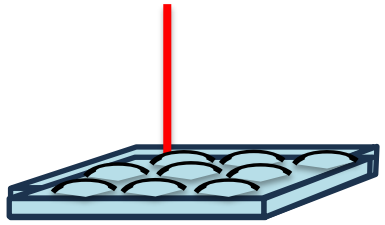
- Requirements – Strength, precision, efficiency
- Challenges – Spatter, Material differences, cracking, brittleness, porosity.

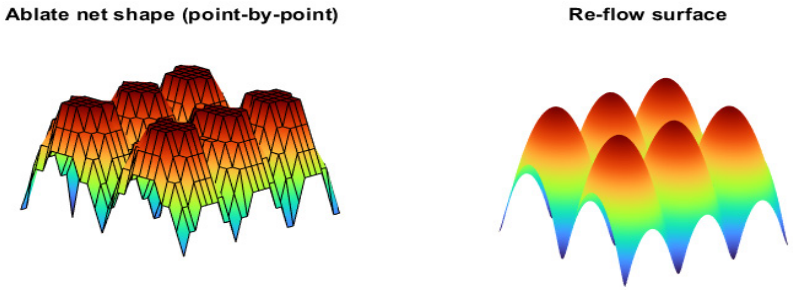




Laser direct-write fabrication in fused silica

- Laser machining process creates gross form
- Laser reflow creates ultrasmooth optical surface
- Very low roughness = very low scatter = very high efficiency
- Fabrication of truly freeform optical surfaces





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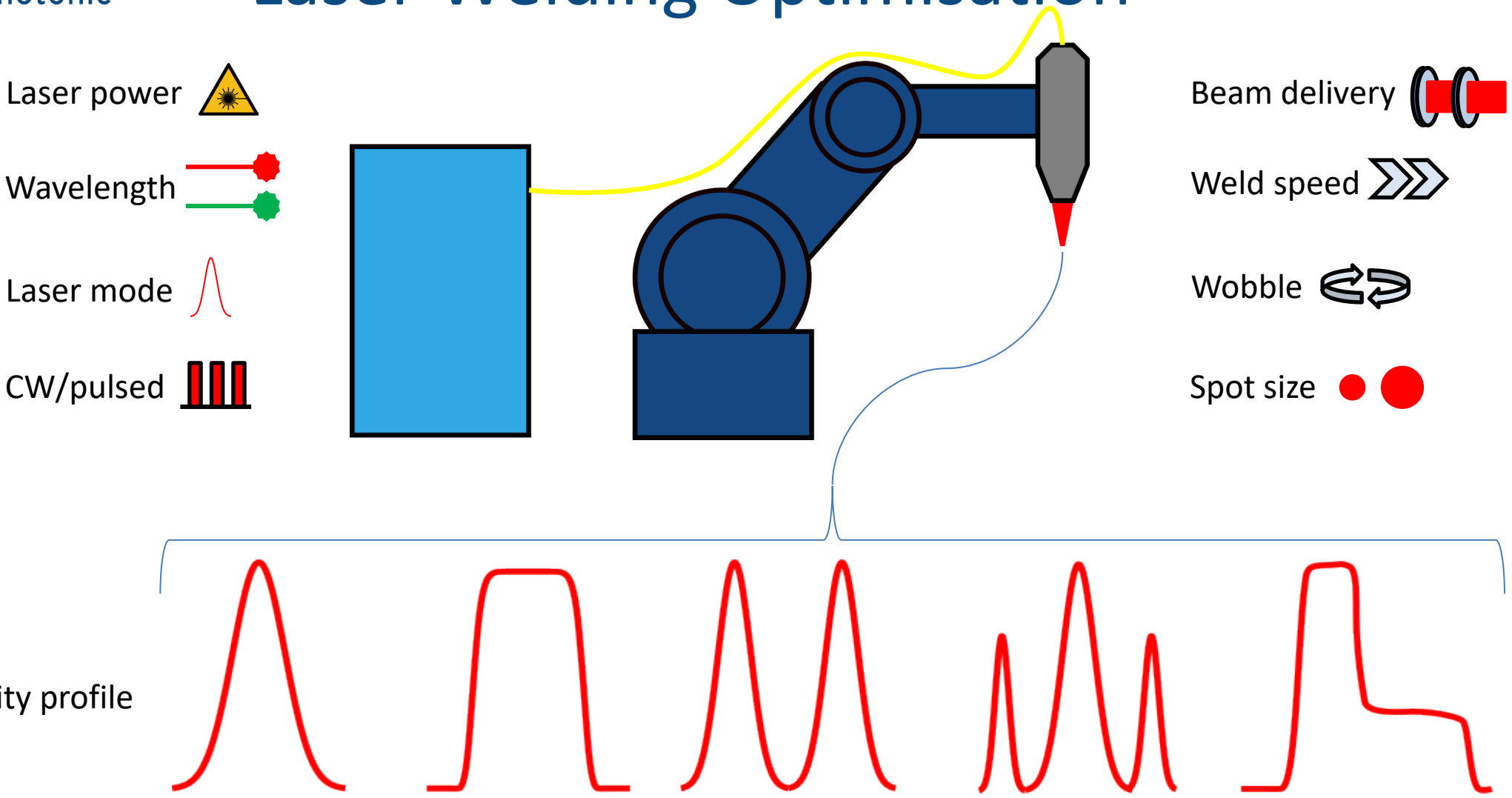
Laser Welding Optimisation



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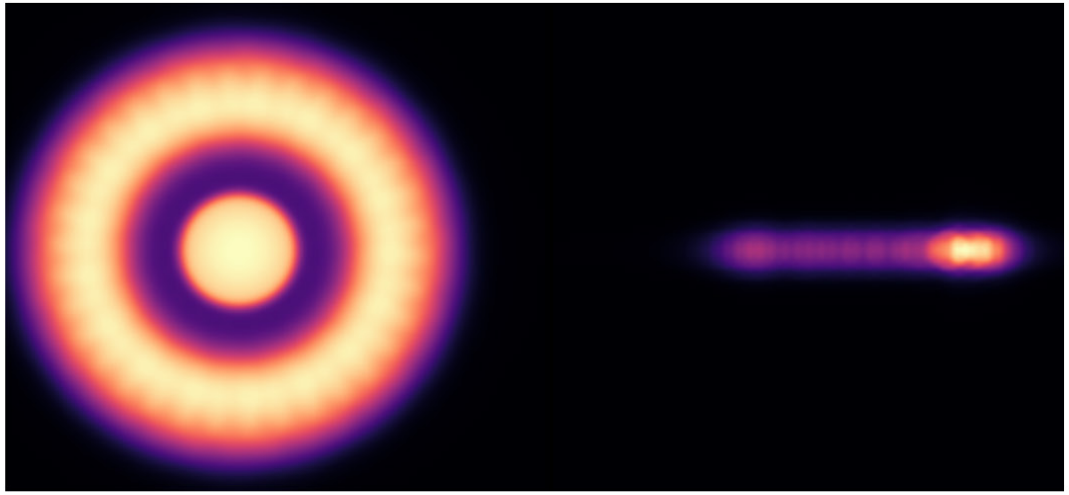
Possible Welding Beam Shapes



PowerPhotonic Core:Ring Beam Shaper

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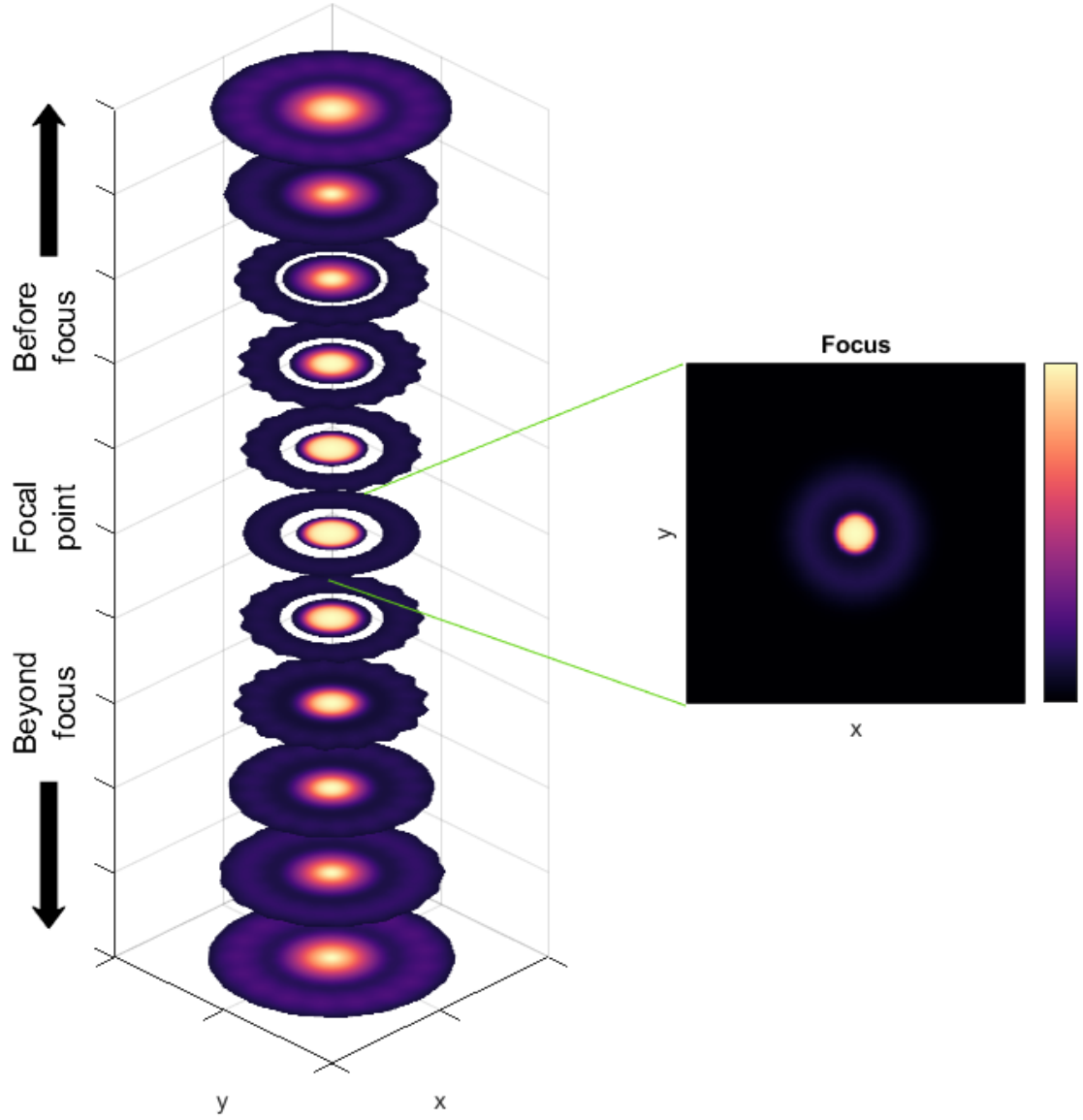
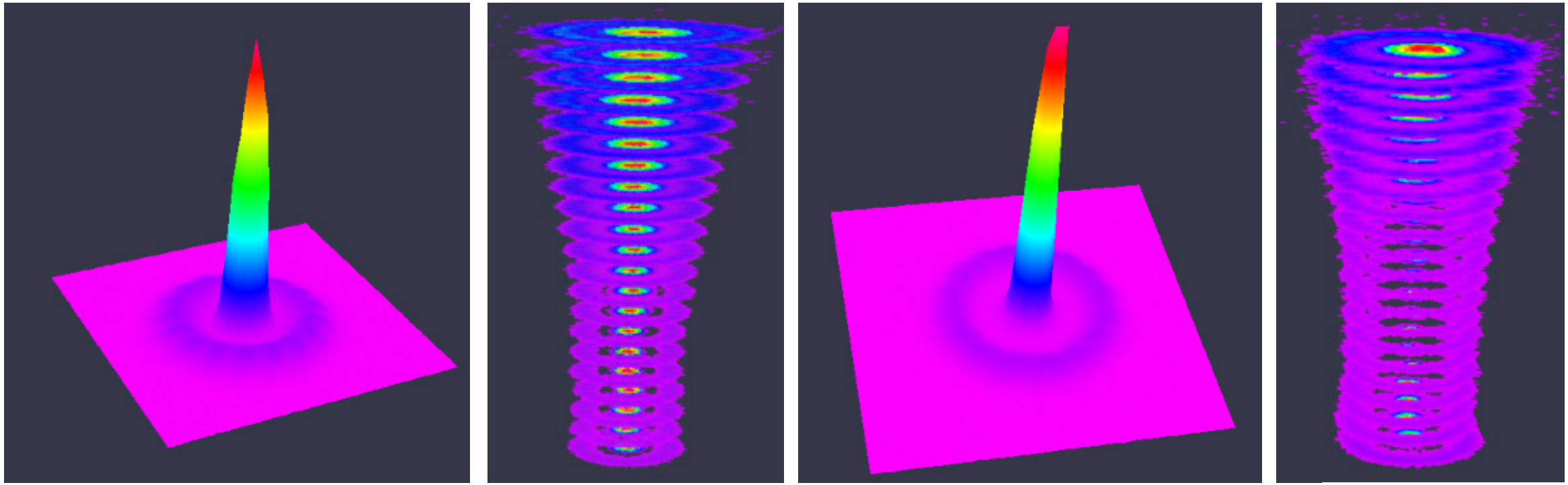
- **Core & ring profile at focus *and* through caustic**
- **Central core of intensity generates the keyhole**
- **Surrounding ring influences the melt pool**
- **Customisable parameters**
  - Ring size
  - Core size
  - Core:ring intensity ratio



PowerPhotonic Core:Ring Beam Shaper - Measured

PowerPhotonic



Parameter	Value
Primary spot size (FWHM)	~ 0.2 mm
Ring size (D4σ)	900 / 1200 µm
Power ratio (Power in ring vs primary spot)	50%

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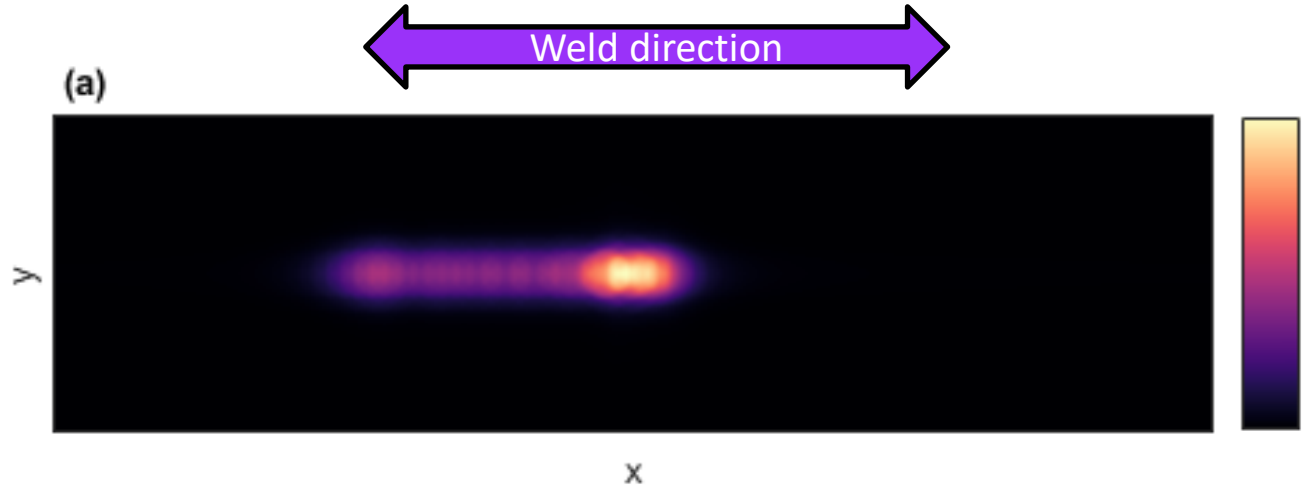
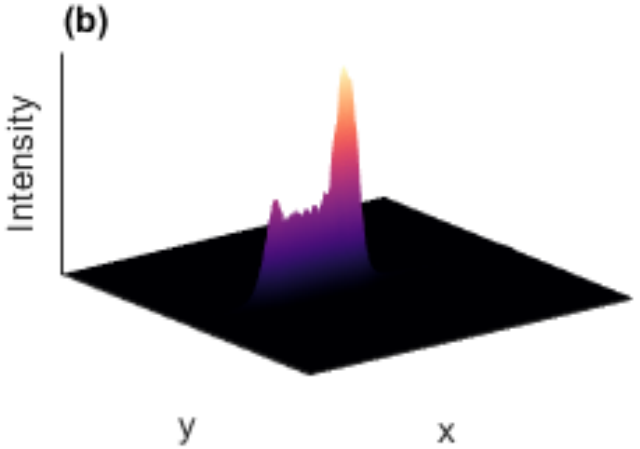
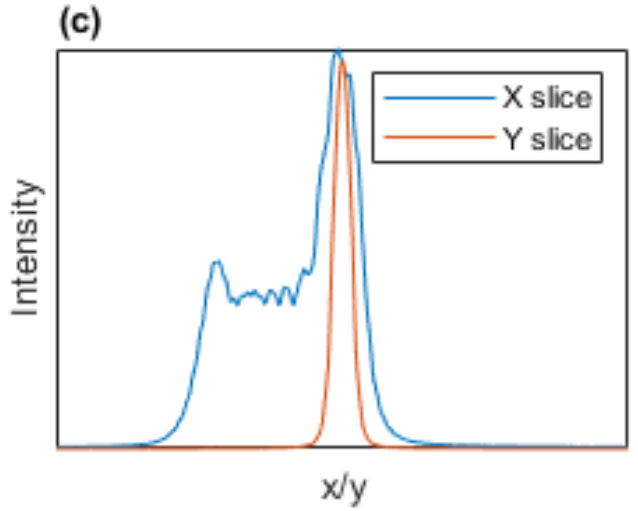
Tailshaper

- **Asymmetric profile – matches welding direction**
- **Primary spot – provides the power to generate the keyhole**
- **Power “tail” follows (or leads) the main spot**

  Influences thermal gradients in the welding process







Tailshaper Customisation Options

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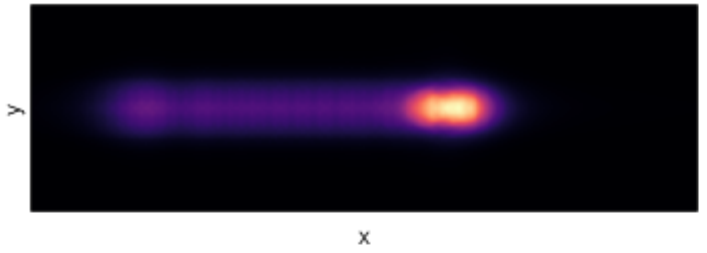
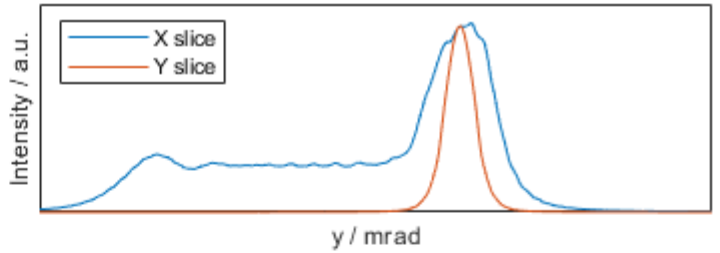
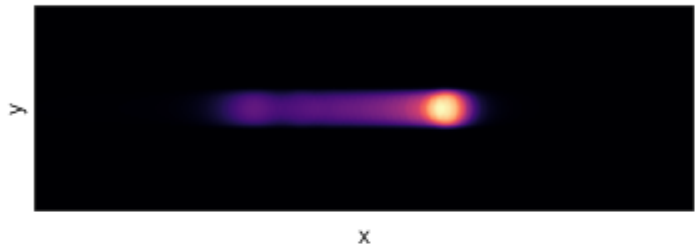
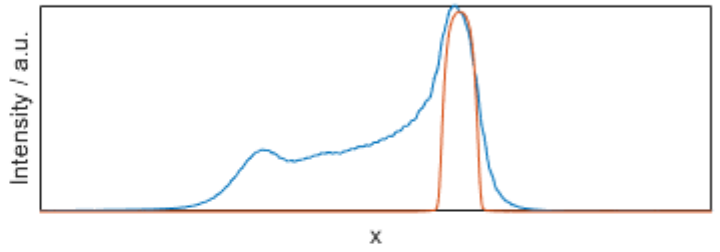
Customisable parameters

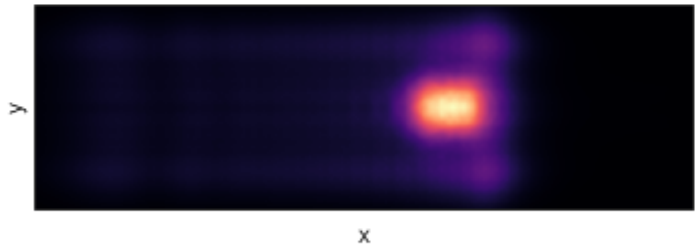
- Tail length & width
- Tail profile
- Tail direction(s)
- Primary spot size
- Primary spot shape
- Primary spot profile

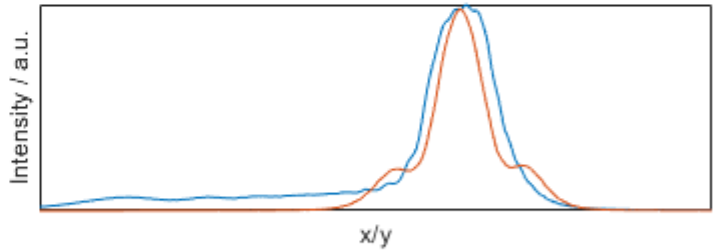


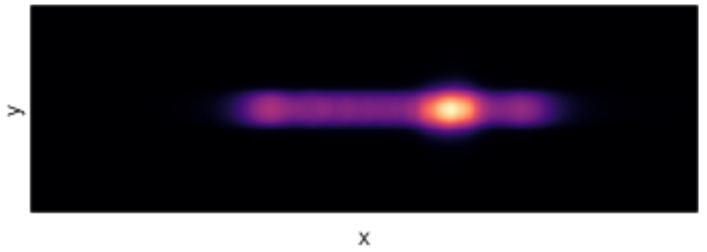


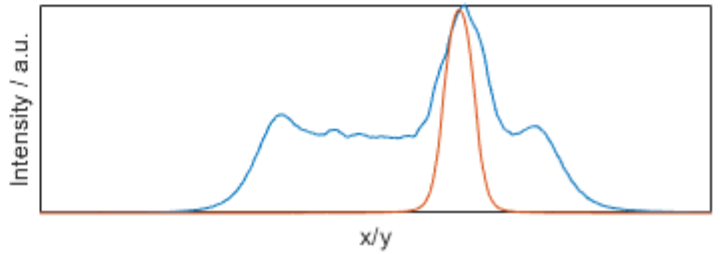












Tailshaper Functional Measurement

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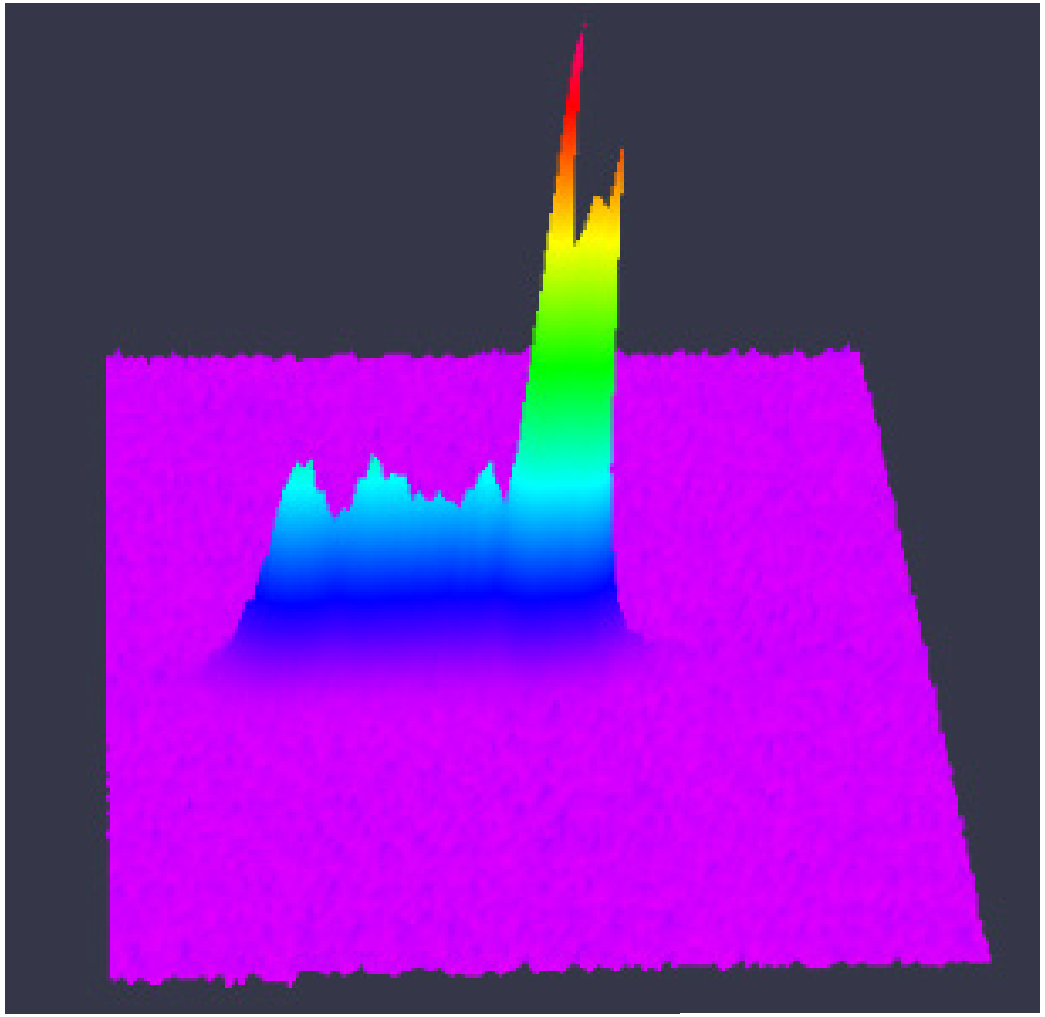
Parameter	Value
Primary spot size (FWHM)	1 x 0.3 mm
Tail size ($1/e^2$)	3.5 x 0.3 mm
Tail intensity (Relative to primary spot)	30%



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Case Study: Autogenous Welding of Aluminium 6082

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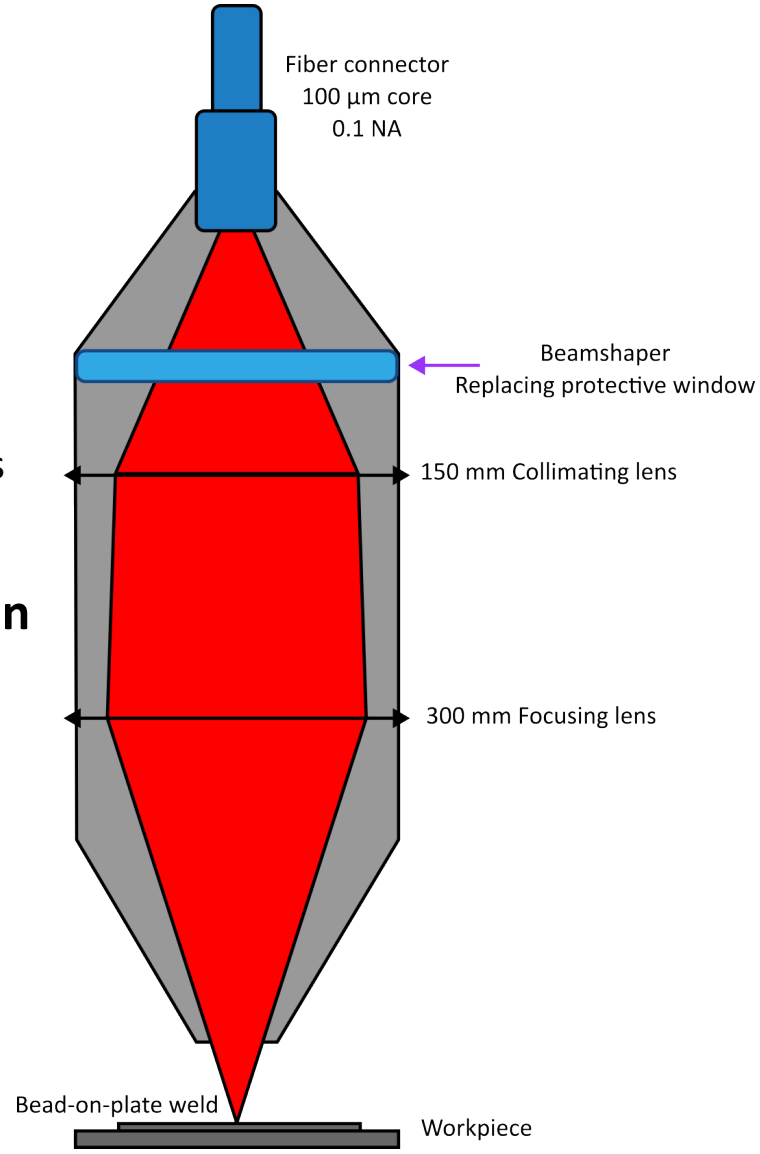
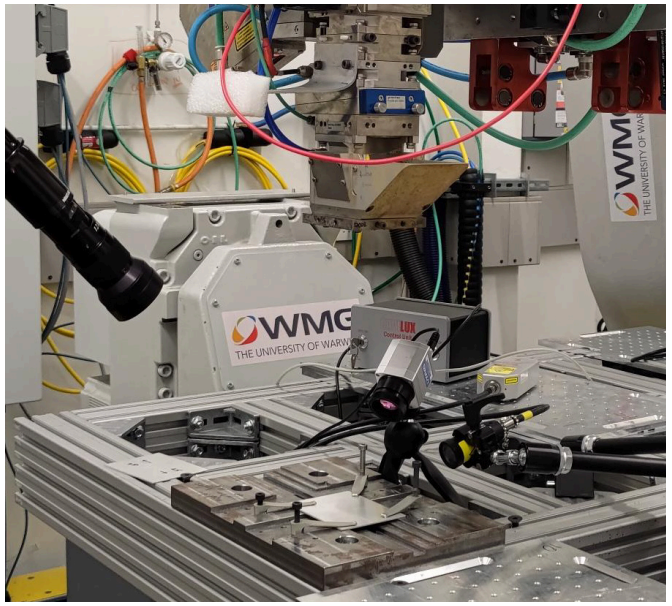
- **Common material for car bodies**
- **Challenging to weld**
  Sensitive to cracking, complex & wasteful process
- **Implement beam shaping to achieve an autogenous process**
  No filler wire, no shield gas. Laser only.





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- Alex Griffiths
- Mark Wilson
- Lewis Johnstone
- Callum Wreford
- Venkat Vivek Pamarthi
- Tianzhu Sun
- Qamar Hayat
- Pasquale Franciosa

Unshaped Welding

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Weld speed	25 mm/s
Power	1.4 kW

Welding

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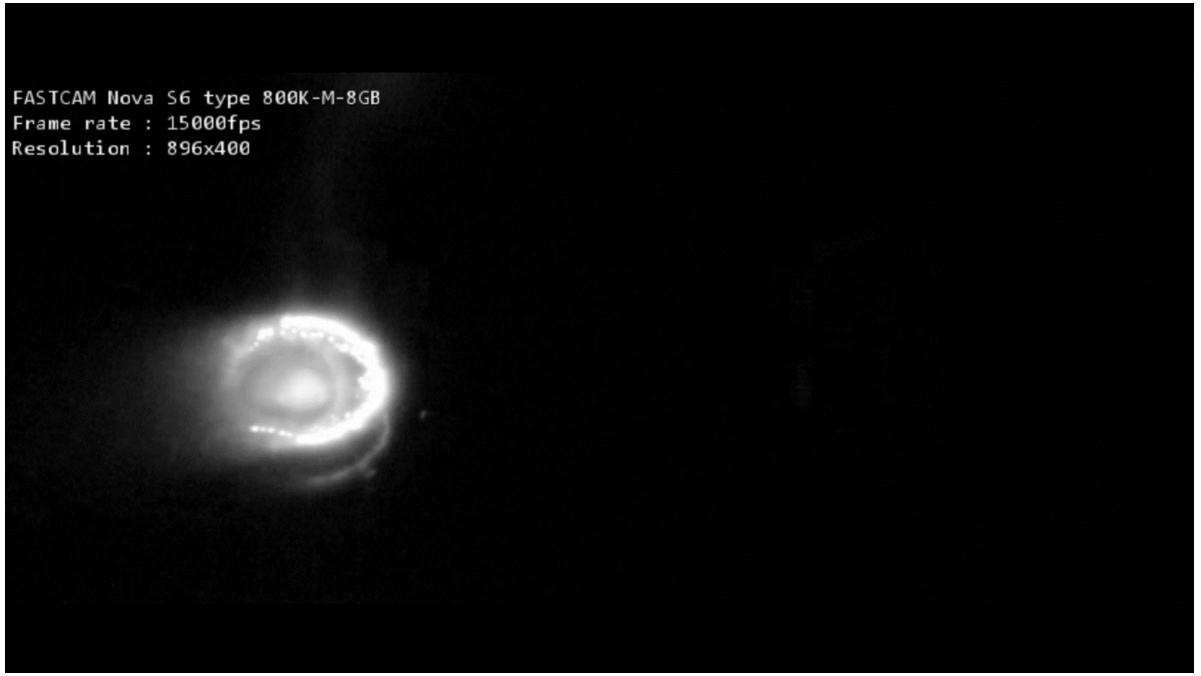
1200 ring



Weld speed	25 mm/s
Power	1.4 kW

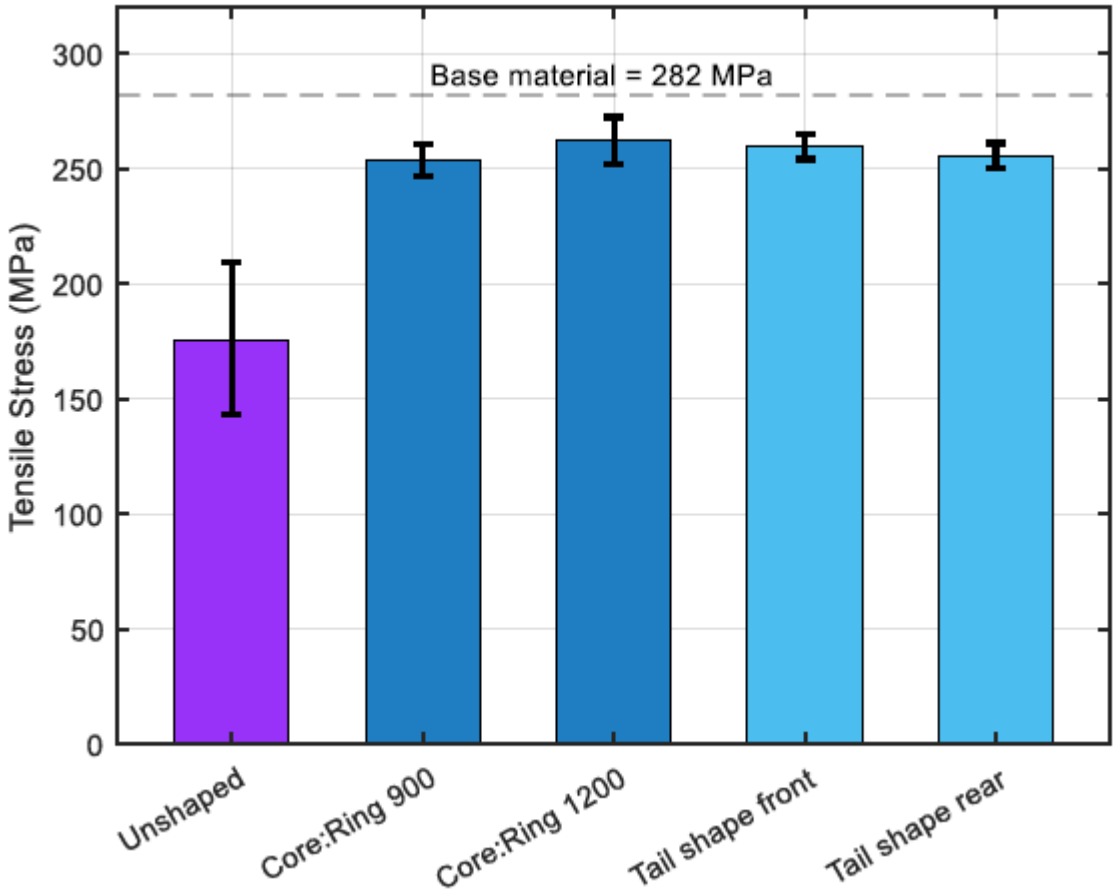
Tail forward – pre-heating

Weld speed	25 mm/s
Power	4 kW

Tensile Stress

- **Welding with the unshaped spot has lower tensile strength**
  Prone to cracking due to central grain structure

- **Core:ring shaper and Tailshaper welds both show increased tensile strength**
  Finer microstructure, with more favourable grain orientation



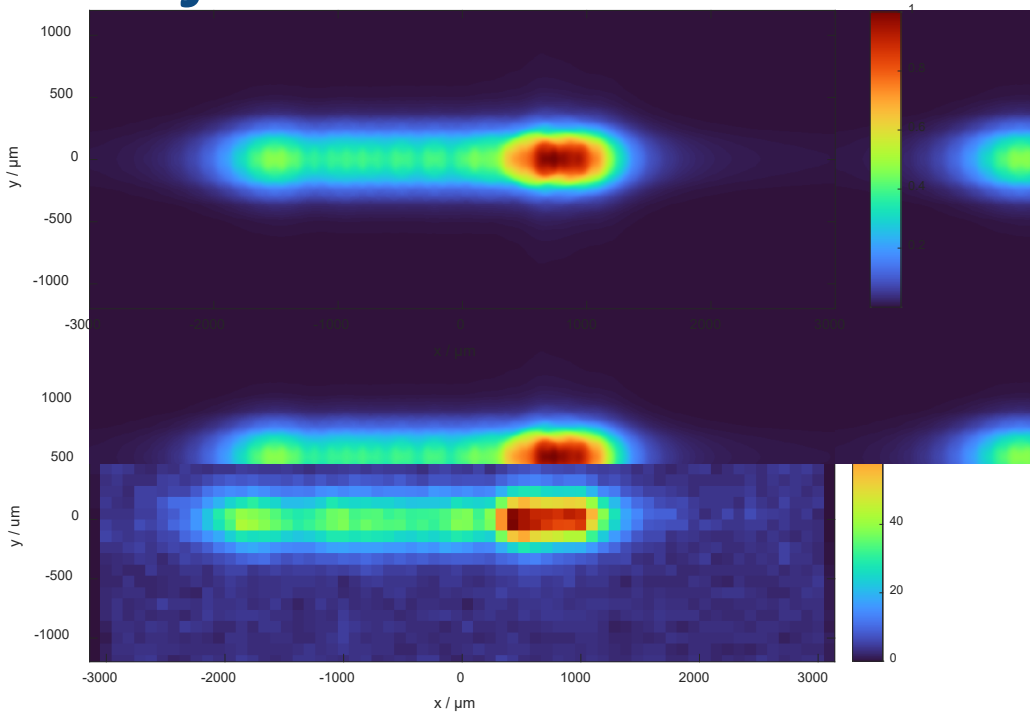
Conclusion to Project

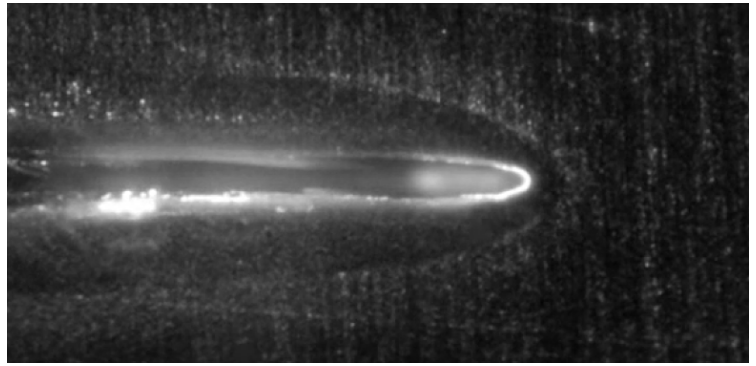
- **Optimised beam shapes improve laser welding performance**
- **PowerPhotonic beam shapers provide freeform beam shapes with low system complexity**
- **Beam profiles can be tailored to influence melt pool size, shape and dynamics**
- **Demonstrated 40% increase in weld strength with beam shaping**

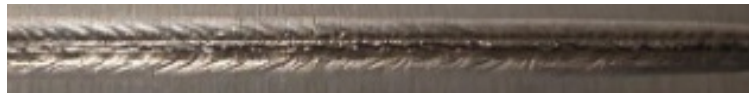
Modelled

Measured

Applied







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Next Steps

- **Innovate Grant – Soni-Shape Laser (https://sites.google.com/view/soni-shape-laser/home)**

- **Developing some new beam shapes for welding and collaborating with partners.**

Thanks

PowerPhotonic

- **Dr Alex Griffiths (Lead Engineer, PowerPhotonic)**
- **Dr Persephone Poulton (Product Development Engineer, PowerPhotonic)**
- **WMG – Dr Pasquale Franciosa**

- **Everyone here for listening.**

Any further questions please contact

emma.modrate@powerphotonic.com