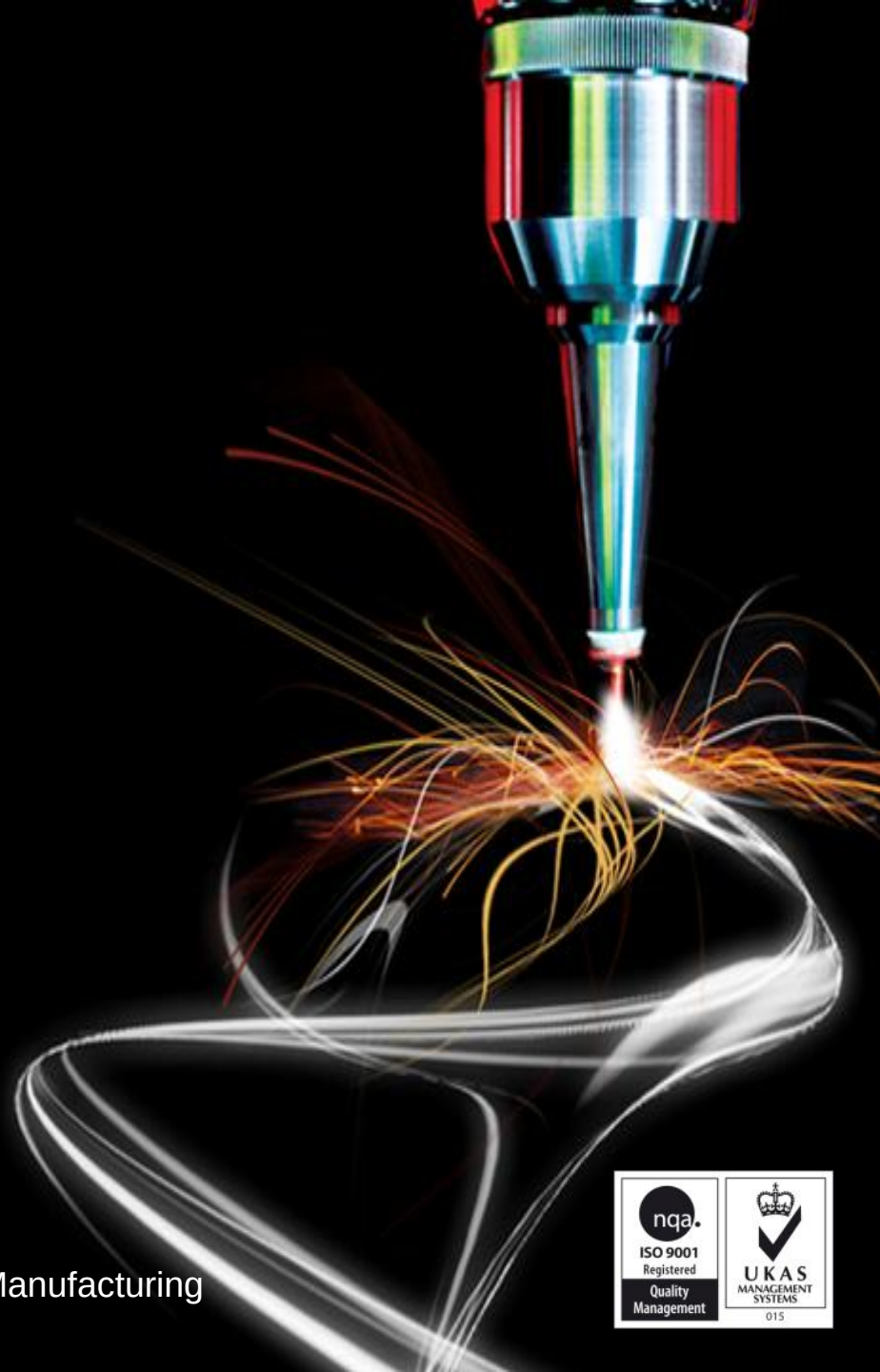
SPI® Lasers



Marking | Cutting | Welding | Micro Machining | Additive Manufacturing

nqa. ISO 9001 Registered Quality Management

UKAS MANAGEMENT SYSTEMS 015

# Nanosecond Laser Welding of Dissimilar Metals and Foils

Daniel Capostagno, Adam Rosowski,
Jack Gabzdyl, Michael Duka

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# Welding with ns Pulsed Fiber Lasers

1. **Introduction**
2. Lasers for welding
3. Thin metal ns pulsed laser welding
4. Dissimilar metal „welding“
5. Joining of battery cells
6. Summary

# ns Pulsed Fiber Lasers

- Proven industrial tool for:
  - Marking
  - Engraving
  - Cutting
  - Surface texturing
  - Thin film patterning
  - Cleaning

**All based on ablative material removal processes**

# ..using the right tool for the job.

Welding and joining represents a paradigm shift for ns lasers.....

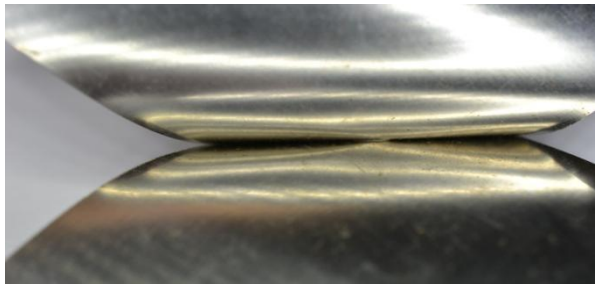
**Need to think differently....**

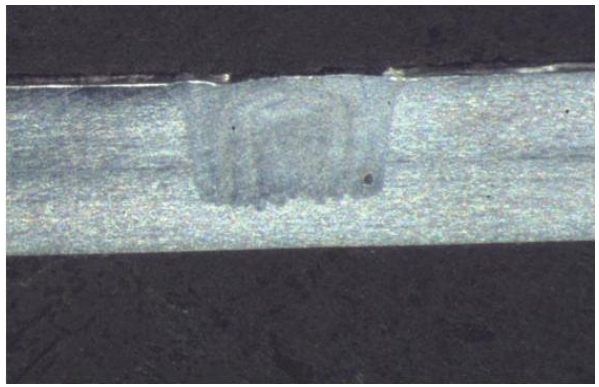
# Micro joining of foils

**Problem** — Reliable joining avoiding over penetration

**Challenge** — Avoiding distortion and warping

**Solution** — Control of heat input by beam mode shaping.



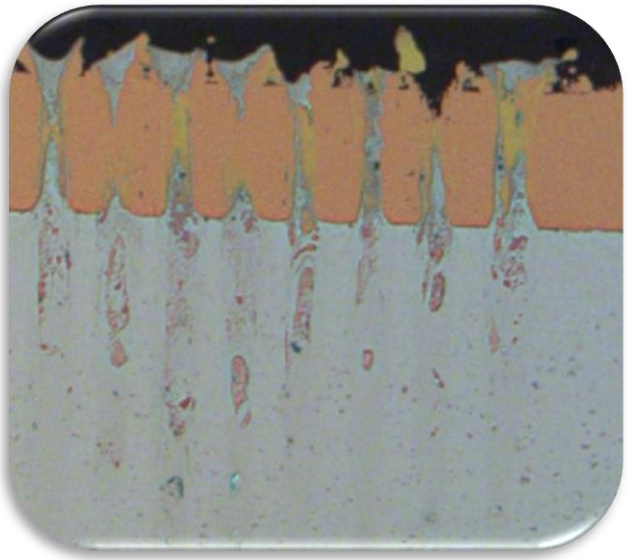


# Micro joining of metals

**Problem** — Reliable joining of thin section dissimilar materials

**Challenge** — Overcome the problems of brittle inter-metallics

**Solution** — Novel ns welding process not based on large weld pool



# Welding with ns Pulsed Fiber Lasers

1. Introduction
2. **Lasers for welding**
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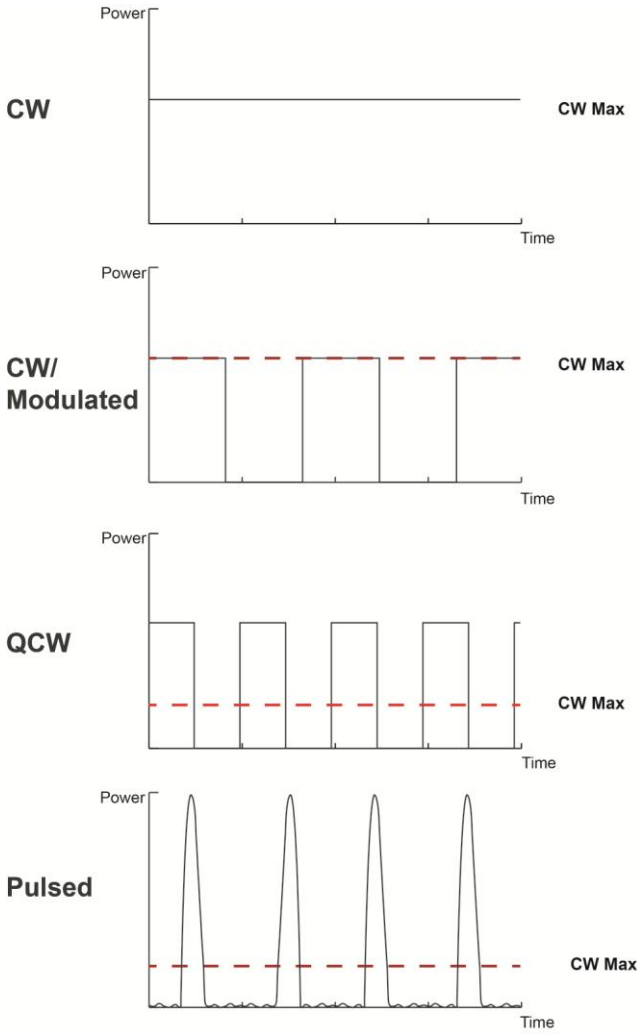
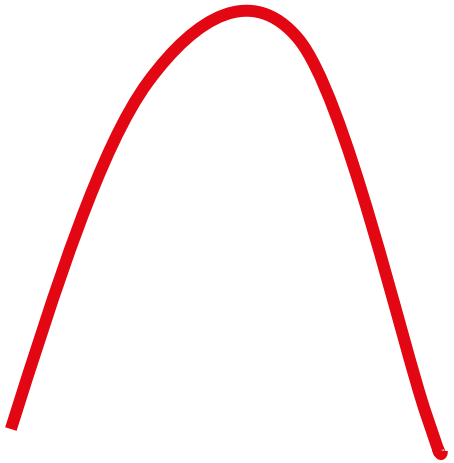
# Lasers for welding

- **CW Lasers**
  - Laser measured by power – able to provide continuous stable laser output at rated power
- **CW/Modulated Lasers**
  - Lasers that produce a gated output with the maximum power being the CW limit
- **QCW Lasers**
  - Able to produce ms pulses at higher peak powers at reduced average power than their continuous duty operation
- **Pulsed Lasers (ref FLP Nd:YAG)**
  - Producing short high peak power pulses with low average power.

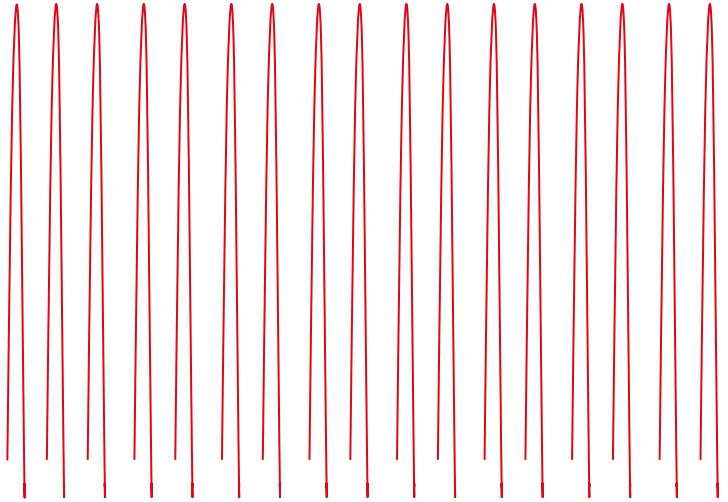


# FLP Nd:YAG vs ns



**OLD (FLP Nd:YAG)**

- 6-10kW peak power
- ms pulse duration
- >J pulse energy
- <1kHz Rep Rate
- <15% DF
- <100W average power

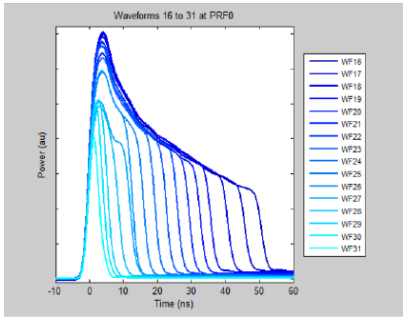


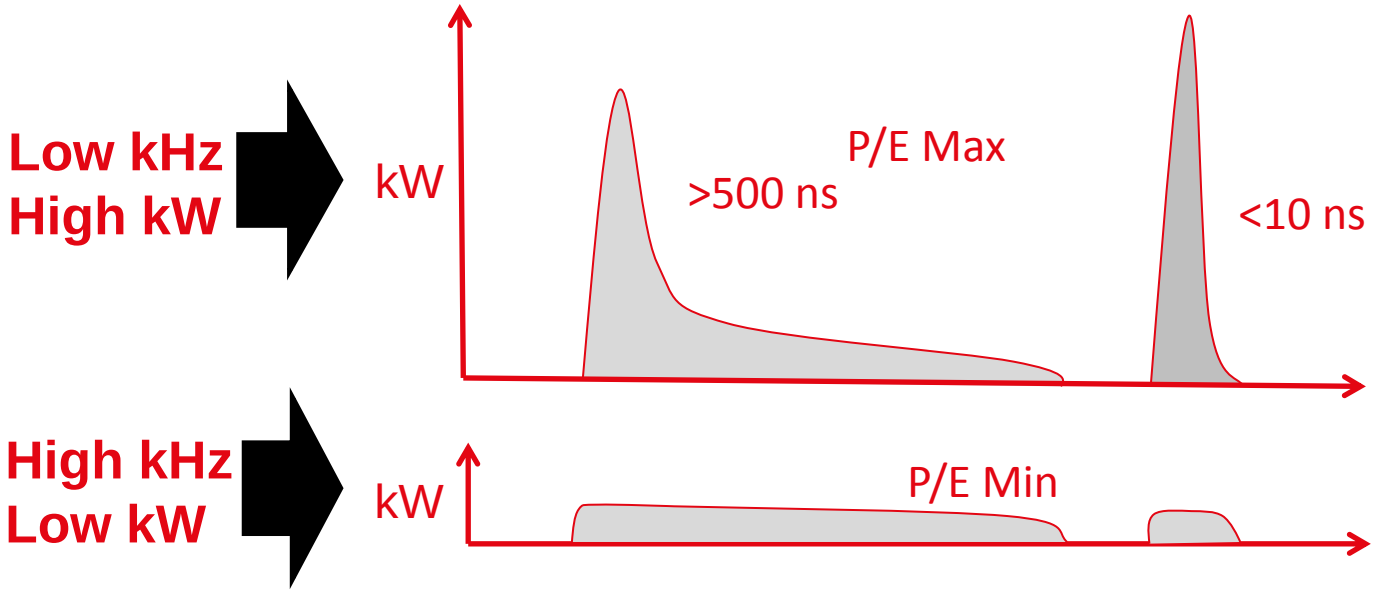
**NEW (ns Joining)**

- 6-10kW peak power
- ns pulse duration
- <mJ pulse energy
- >100kHz Rep Rate
- <15% DF
- <100W average power

# PulseTune Waveforms

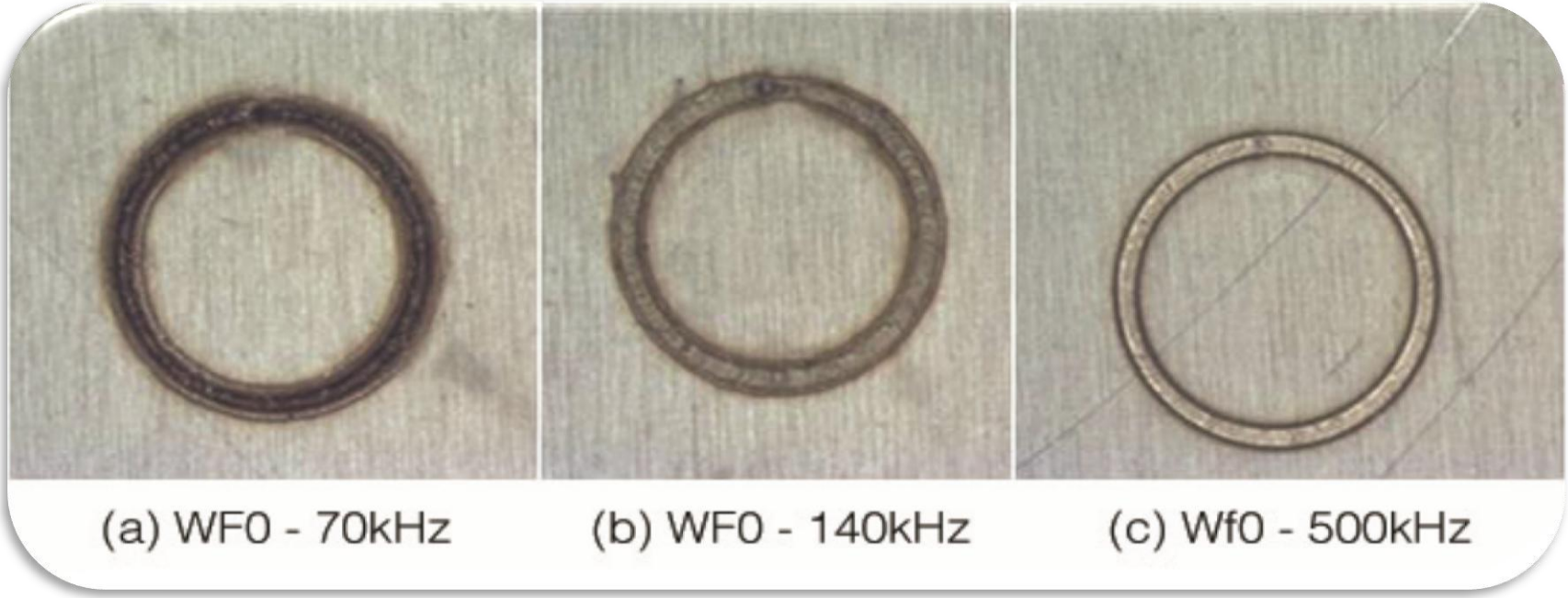
- Flexibility in ns lasers in optimising pulses to match application requirements.



# Metallic welding using ns pulses

- Use pulse waveforms & frequency to tune parameters from vaporisation/melt ejection to melt generation.




70W, 1mJ
>10kW peak,
<2% duty.

70W, 0.5mJ
>2kW peak,
<4% duty.

70W, 0.15mJ
>500W peak,
<15% duty.

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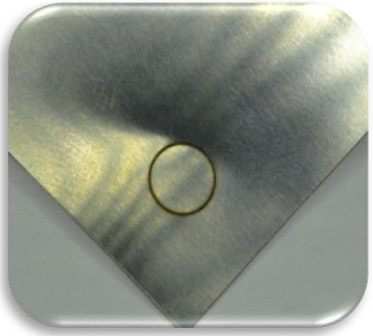
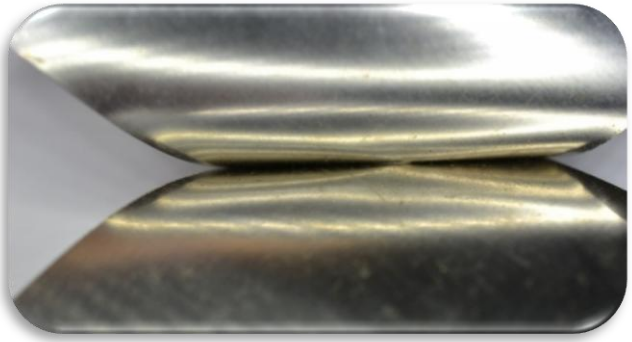
# Lap welding in stainless steel

- 304 SST 150µm sheets welded in lap configuration
  - Parameters - 70W  100mm/s -  6mm Ø welds.

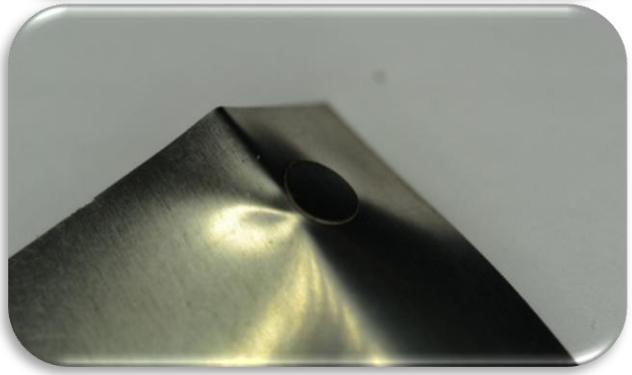


Top weld view
no cover gas



Weld under
manual peel
stress

Bottom weld view
full penetration

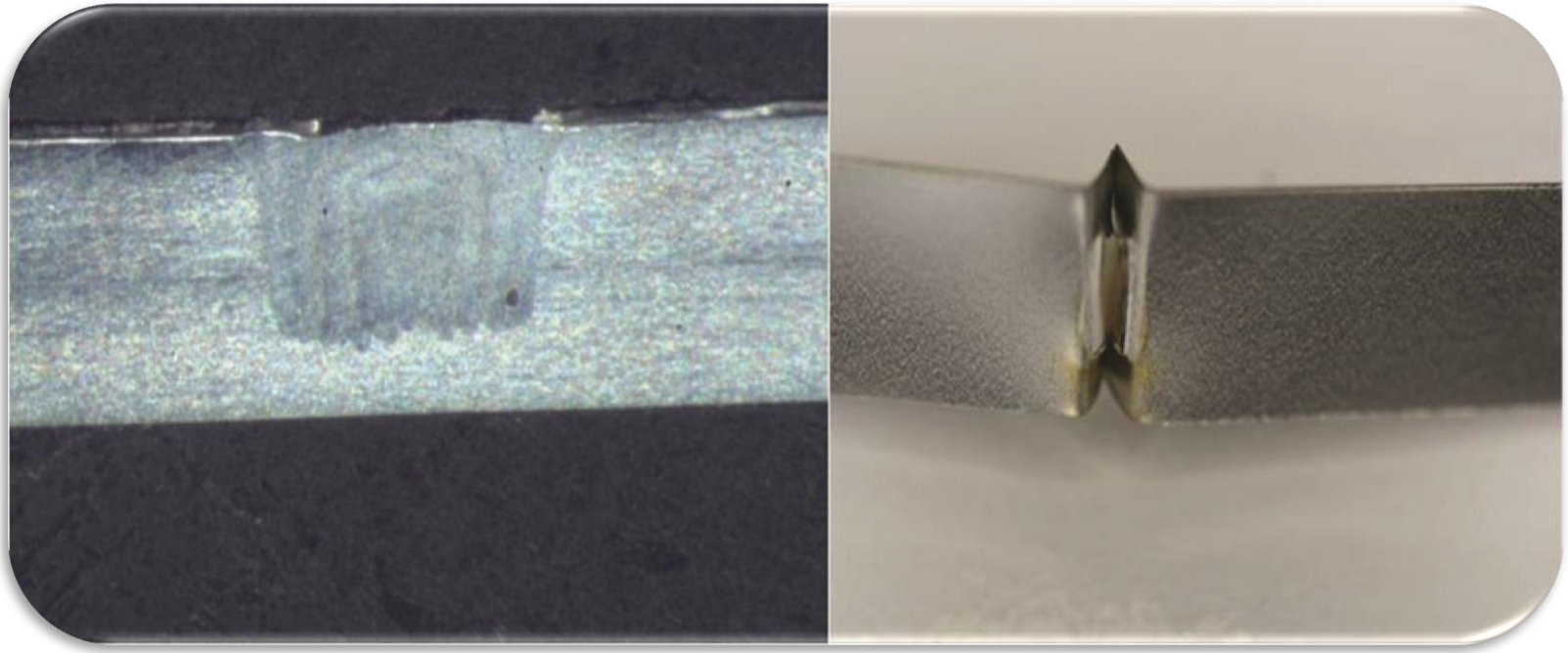


Failure mode
at weld
interface

Similar results were achieved in 250µm sheets at 50% welding speed.

# Weld strength

- These welds really strong enough for serious applications.



Tests completed on stainless steel to stainless steel welds show shear strength for two 1mm welds in a full 0.5mm lap weld to be > 224 lbs. In one case with a 180 degree peel test on a linear weld 5mm long and 1mm wide, the part yielded at 241 lbs.

# HDD welding

- Stake weld to hold parts + continuous seam with wobble
  - Using 70W EP-Z.

# Butt Welding

- Can make good butt welds in similar materials
  - 70W EP-Z using wobble technique in 200µm stainless steel

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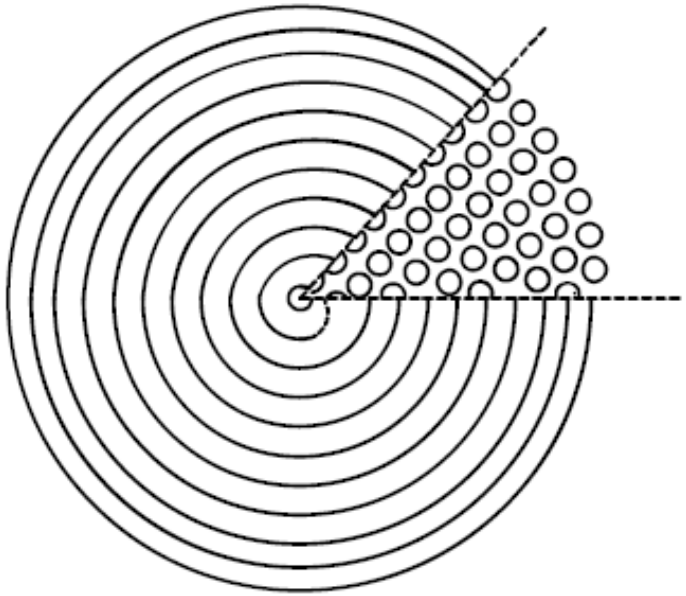
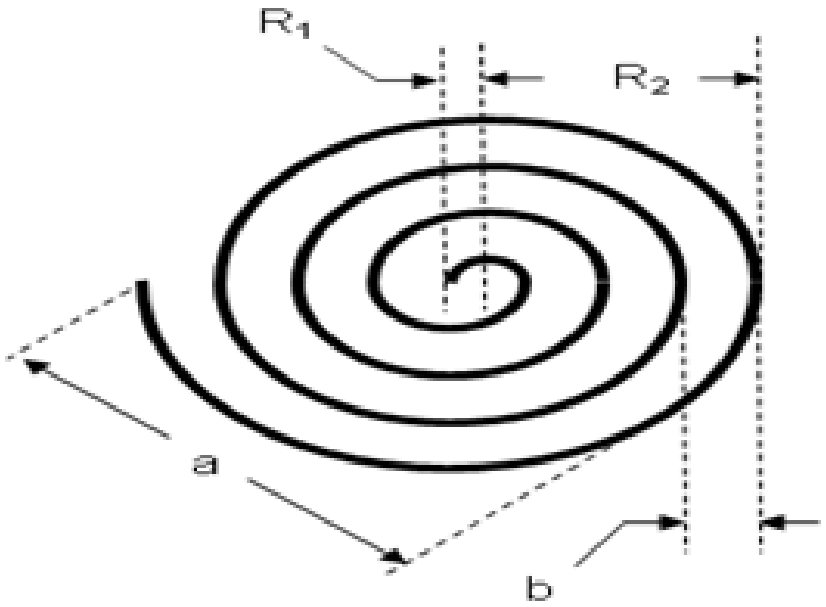
# Welding exotic materials

- Focus on ability to weld bright metals
  - Range of material types and dissimilar combinations
  - Using novel weld configurations..

# ns Pulsed Spot Welds

- Method for making spot welds.



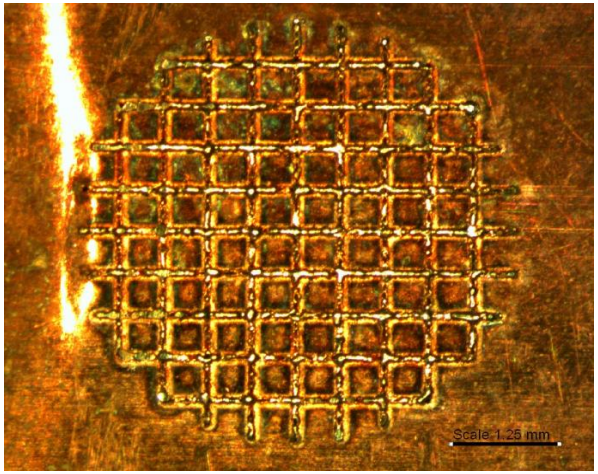



Spatially overlapping spots >98% linear fill separated by 50% the $F_s$ on the rise radius.

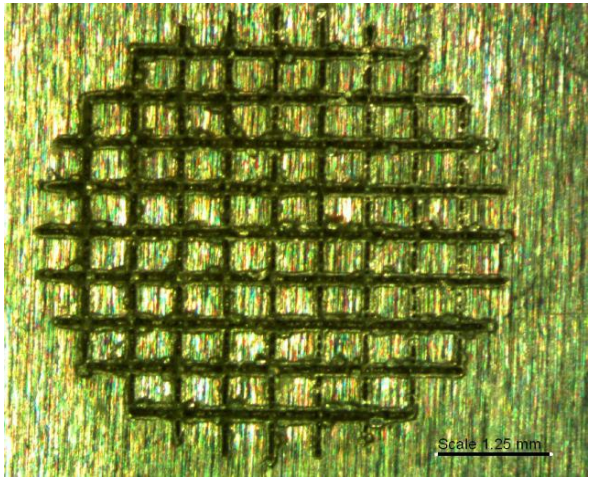
$R_1$, Inner Radius, 0.02mm
$R_2$, Outer Radius, 0.5mm
a, Ramp, 3mm
b, Rise, 0.02mm

# Grid patterns

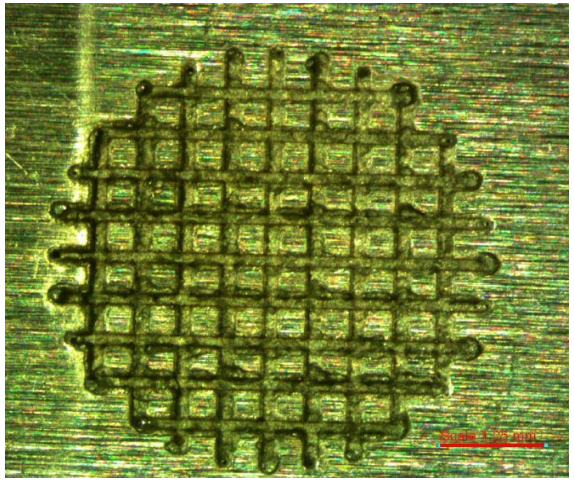
- Fast and flexible applicable to multiple material combinations




Copper on Supper Alloy




Aluminium on brass

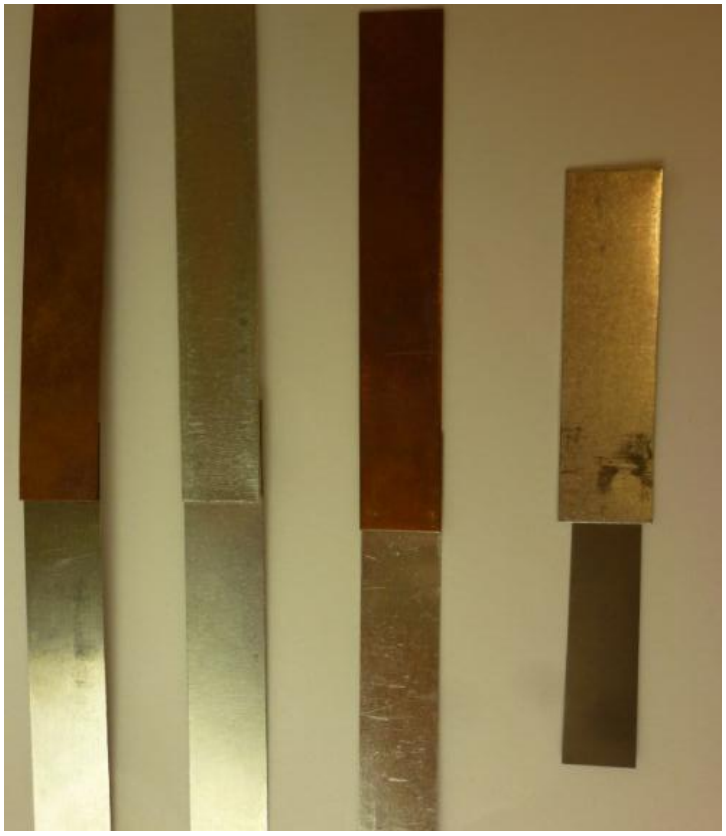


Aluminium on Copper

# Control of heat input.....

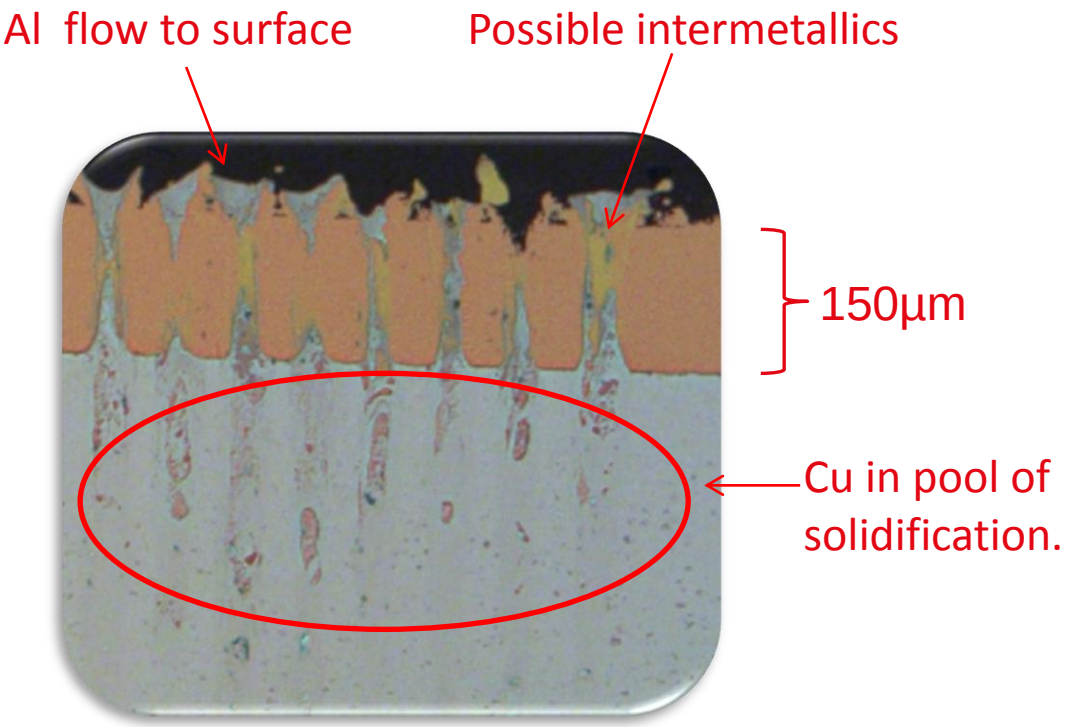
- No witness marks on wide variety of material combinations!

Combinations
Left to Right:
SS-Cu
SS-Al
Al-Cu
Ti-Al



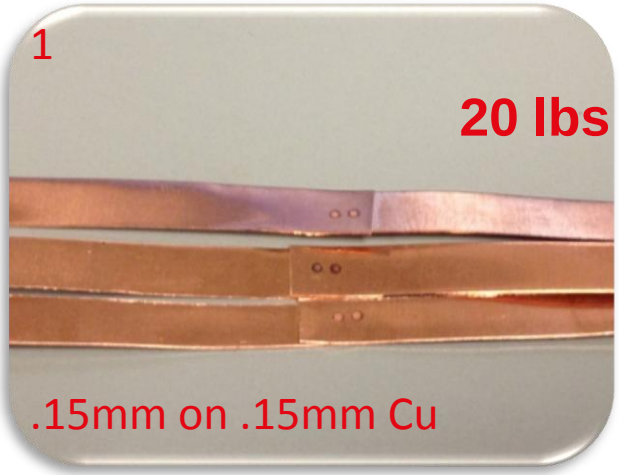
# Metallurgically interesting Cu/Al

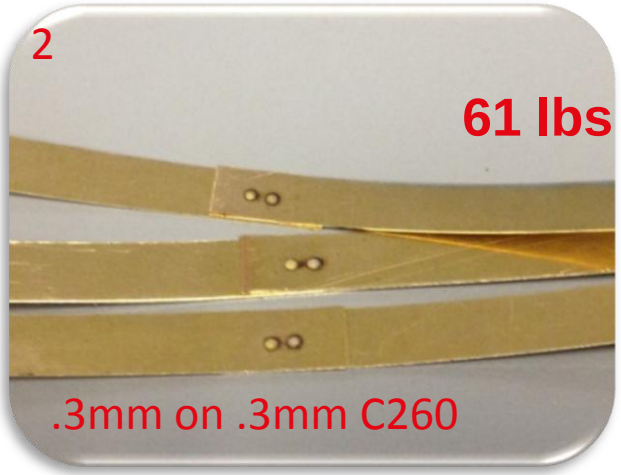
- Spot welds do not show characteristic form of conventional pulsed spot welds
- More closely resembles multi-staking

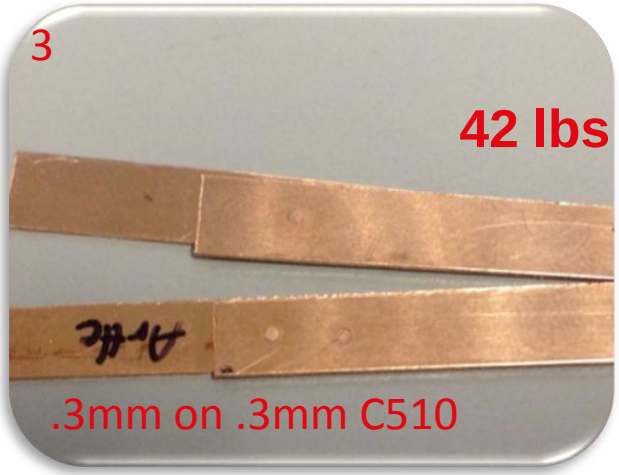


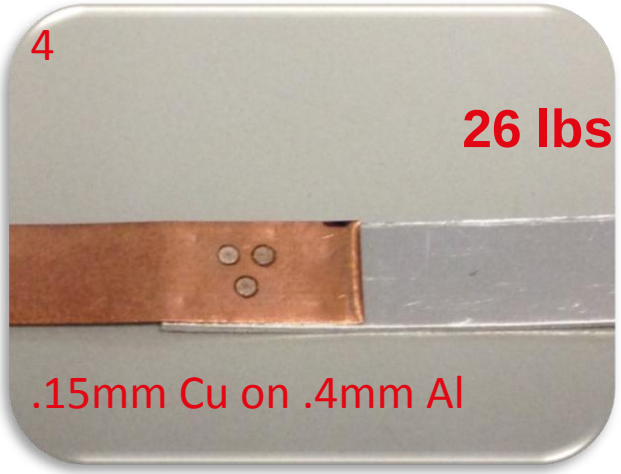

WF 36, 520ns, 70 KHz

# Tensile weld strength



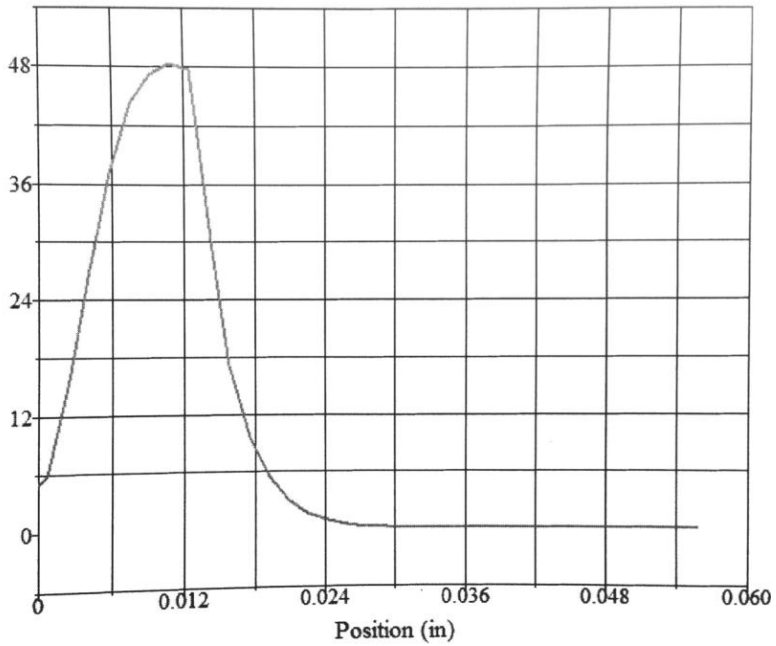



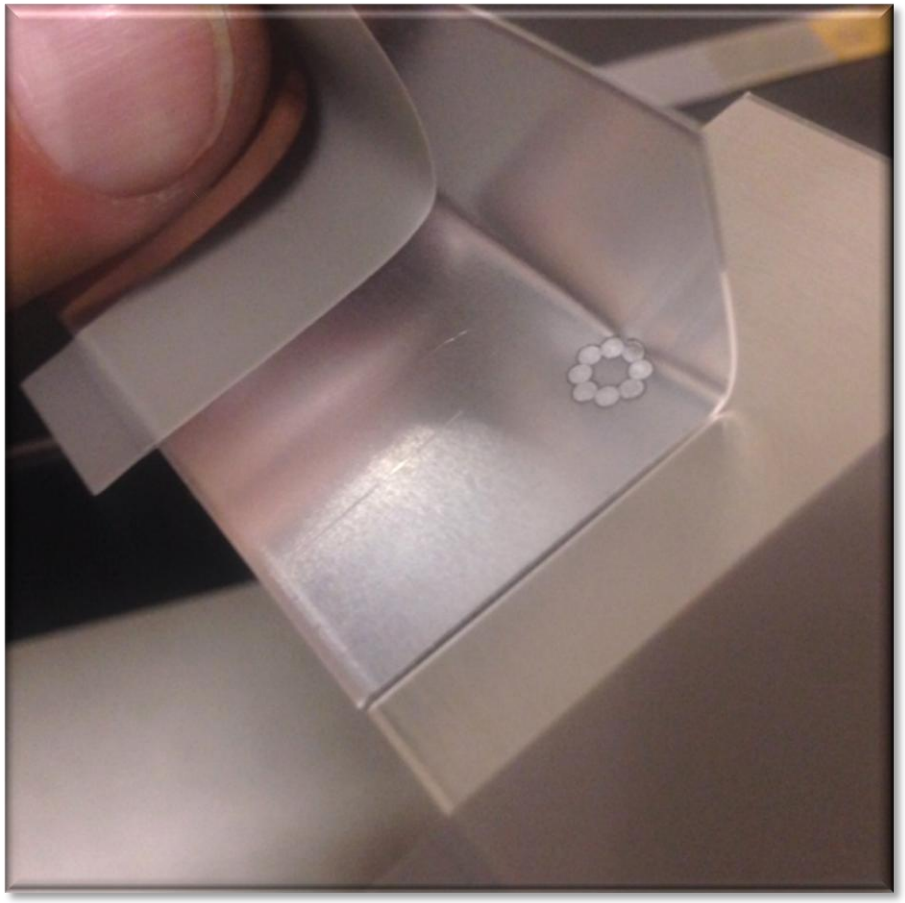
# Pull test results

- With a cosmetic pass
  - Reduced surface porosity with bright finish
  - Increased joint strength to 48lbs on 150 um copper.



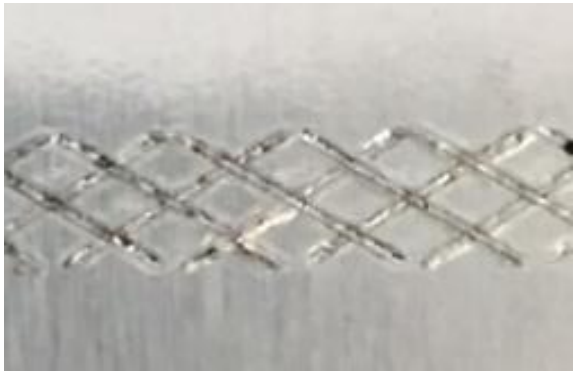
# Peel strength.....

Different configurations can yield improved results



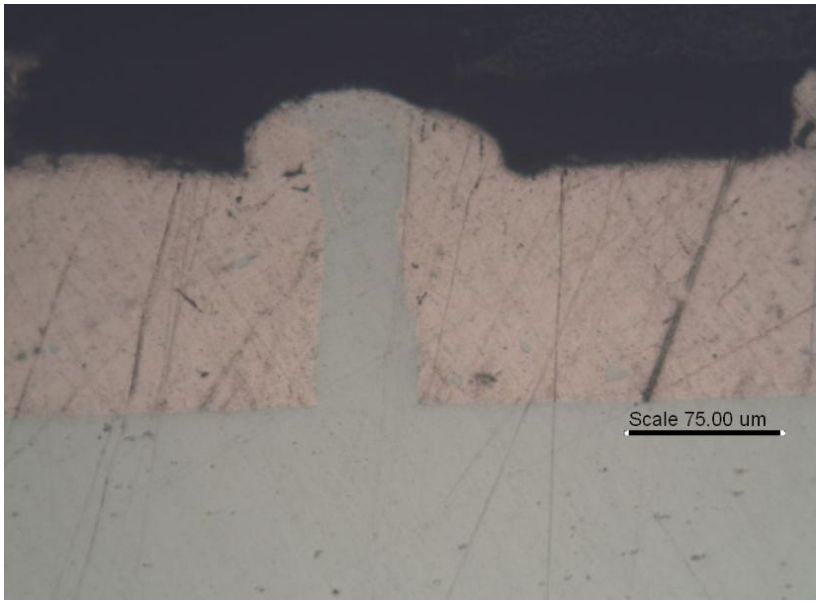
# Weld geometry flexibility

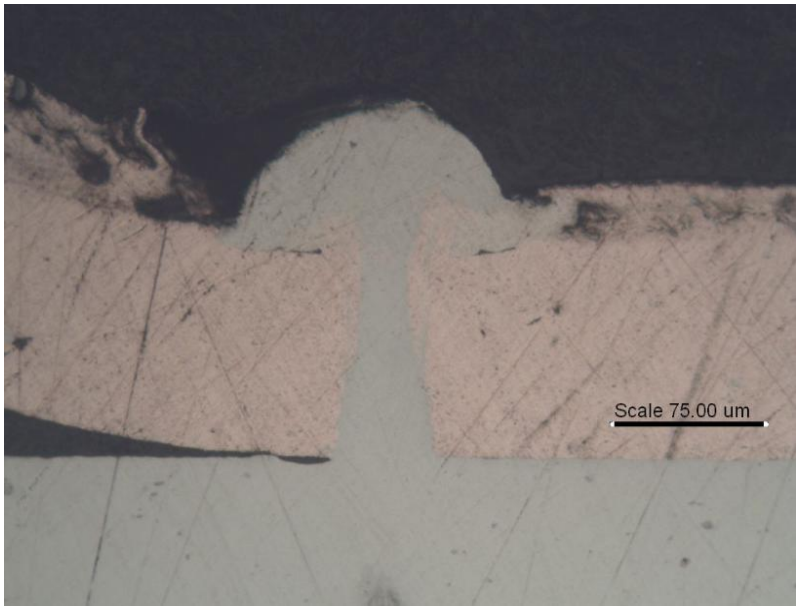
- Opens up the possibilities to design for purpose
  - Electrical conductivity
  - Pull strength
  - Penetration and nugget shape
  - Available space
  - Heat input (witness marks)



# Copper to Aluminium

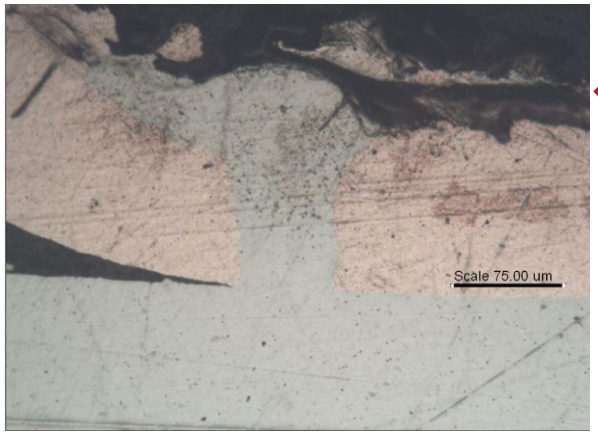
- Single pass with 70W HS-H
  - Laser made “Metal Rivet”!
  - Aluminium flows through copper layer – no signs of inter-metallic layer



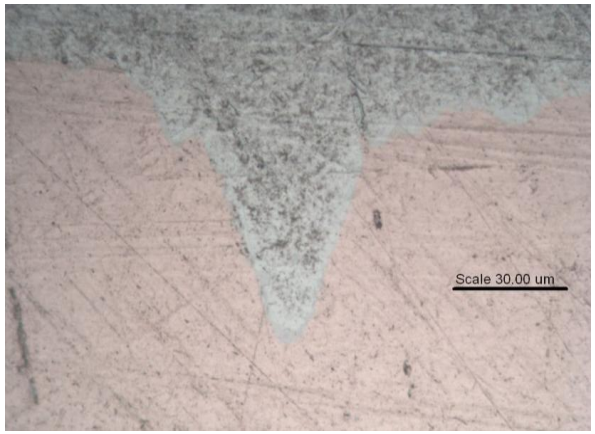
# Dissimilar combinations

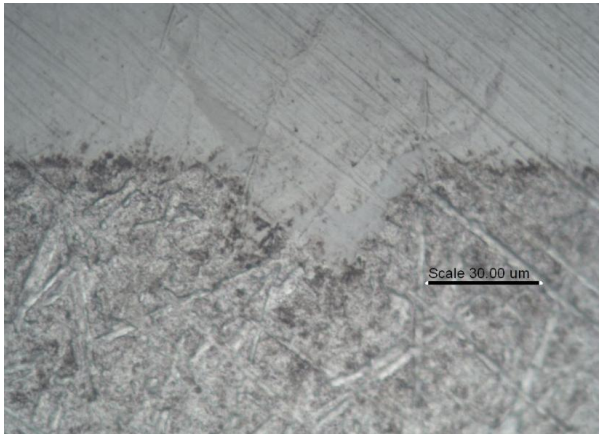
- Various dissimilar micros




Cu/Al

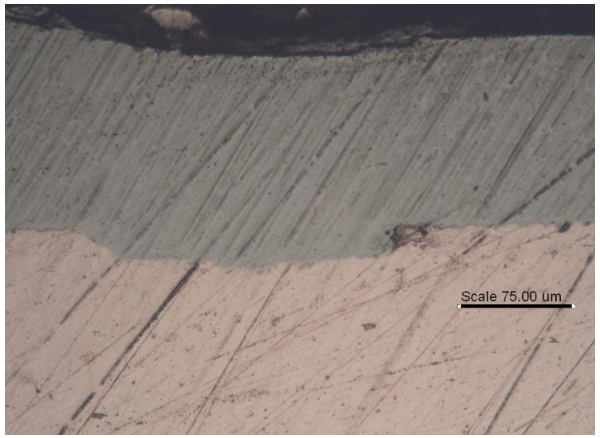
Al/Cu



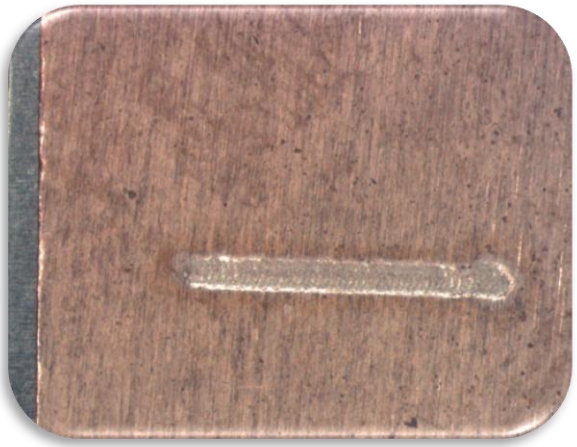

SS/Al

Ti/Cu

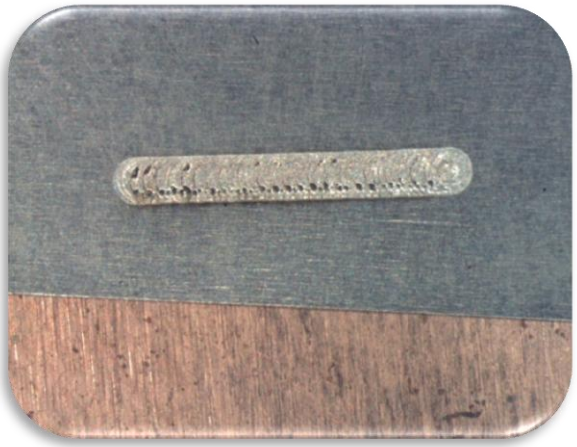


# Seam welding

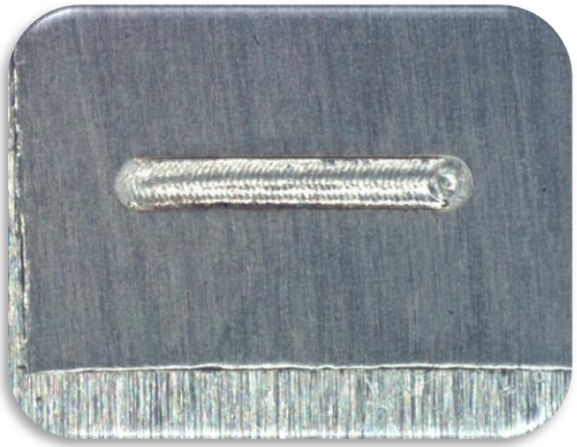
- Wobble welding offers width control in lap welding of dissimilar combinations



Cu - Al



Al - Cu



SS - Al

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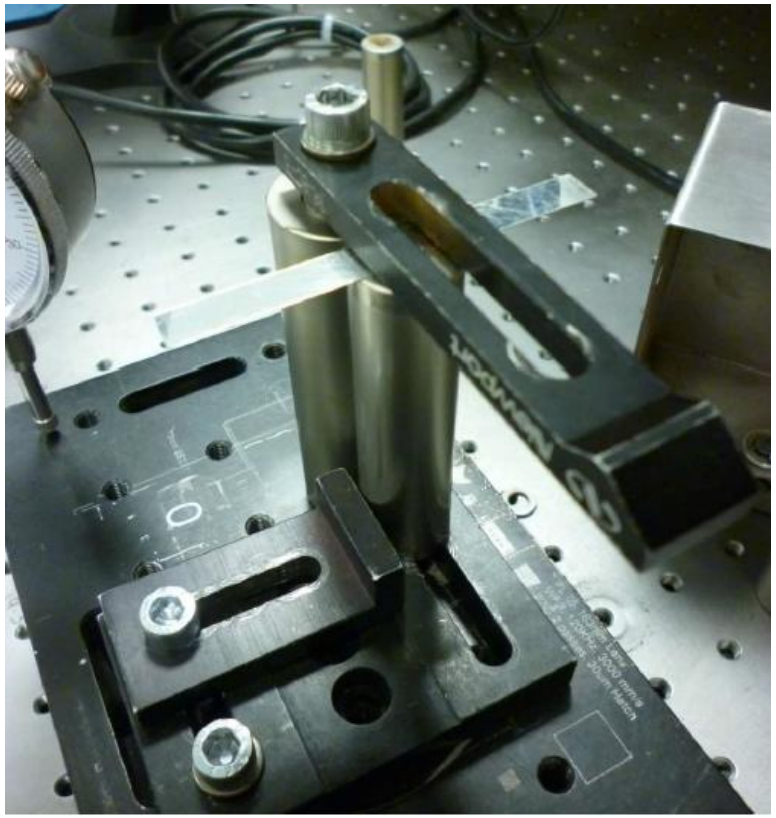
# Joining of battery cells

- Requirement to weld copper/aluminium tabs to cells
- Using scanner + 100W EP-Z
- Basic fixturing
  - Good contact required.
  - Shielding gas as appropriate to material combinations.



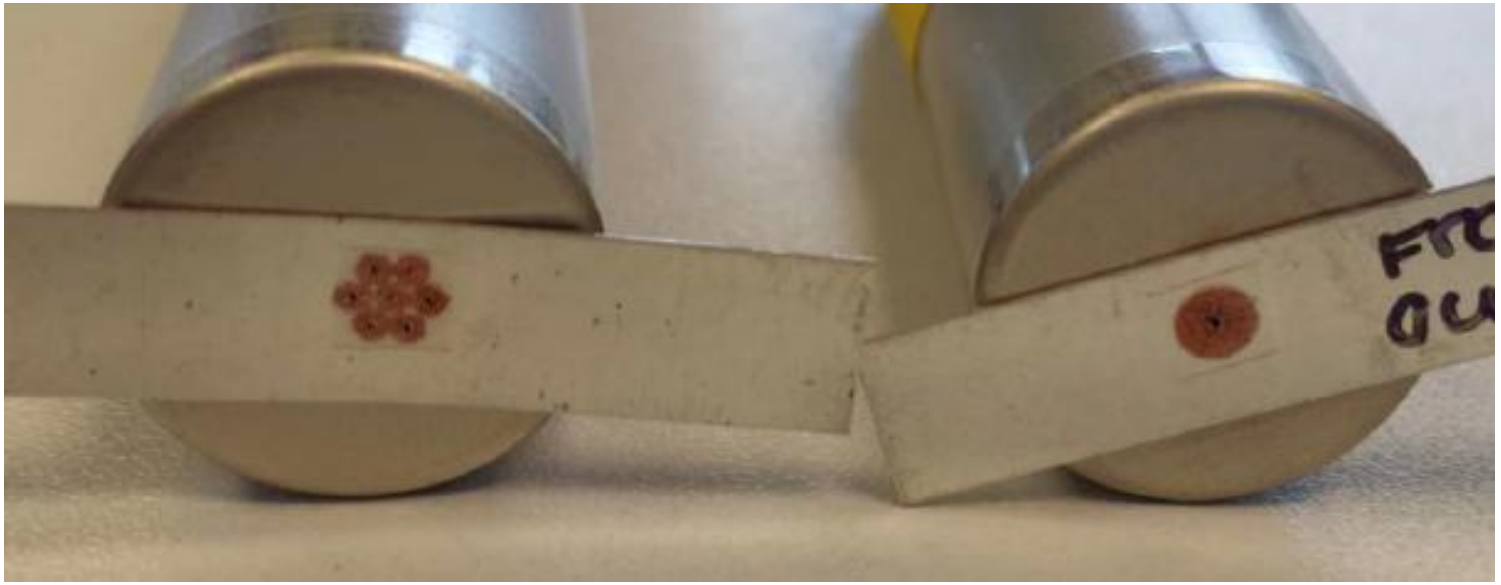
# Heat input control

- Objective is to produce strong welds with no burn through or witness marks



# Evaluation of joint design

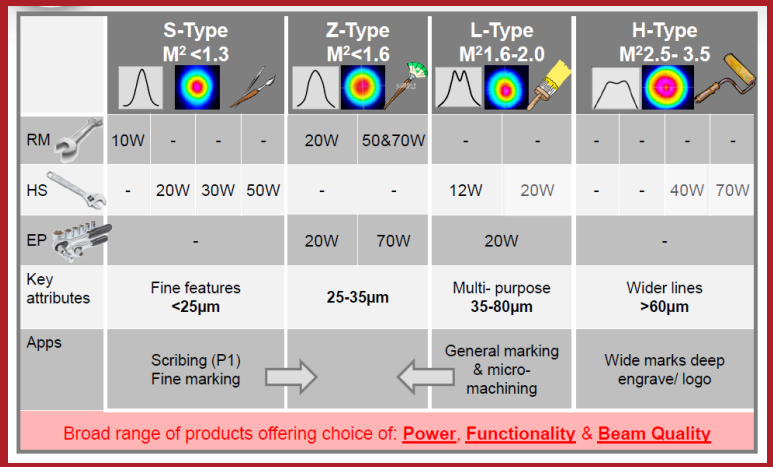
- Single large area spot vs multiple spots
  - Roughly same  contact area time to process
  - Multiple spots proved to be stronger + gave more control over penetration depth



# Summary

- **ns pulsed lasers offer a flexible solution with multi process capability**
- **new welding potential particularly for dissimilar metals**
- **enhanced thermal input control**
- **new joint design possibilities**
- **tailored beam quality options offer the right tool for the job**

Patent No:
WO2016128704
WO2016128705
Other patents pending



# Versatility of G4