Laser Impact Welding – Process Introduction and Key Variables

Huimin Wang
Deijan Liu
Geoff Taber
John Lippold and
Glenn S. Daehn

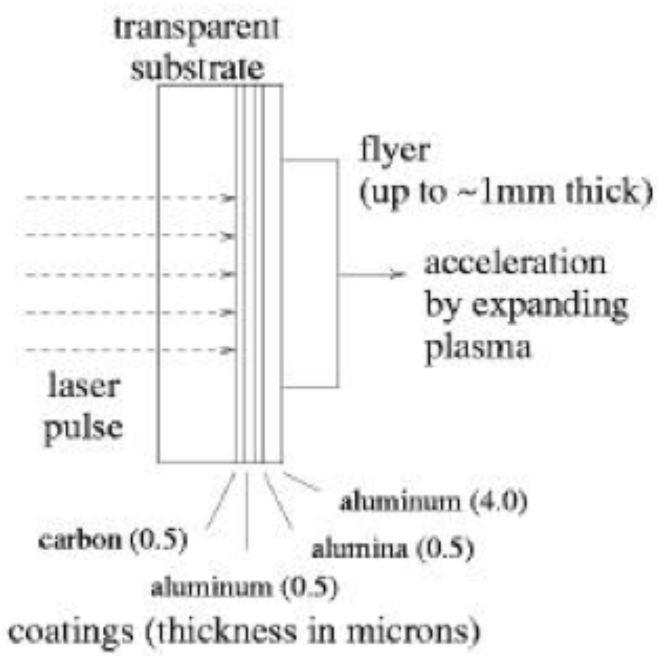
Department of Materials Science and Engineering
The Ohio State University, Columbus, Ohio, USA

Support: NSF-IUCRC CIMJSEA, Medtronic, Intelligent Manufacturing Initiative, Alcoa Foundation.

overview

- Laser Driven Flyers
- Characteristics of the OSU System
  - Laser
  - Diagnostics
  - Automation
- Examples from:
  - Ni – Ni for fundamentals
  - Al flyer to Cu with more practical mindset

background – pulsed energy & lasers



Considerable work on **laser driven flyers** in US National Labs between about 1990 and 2000.

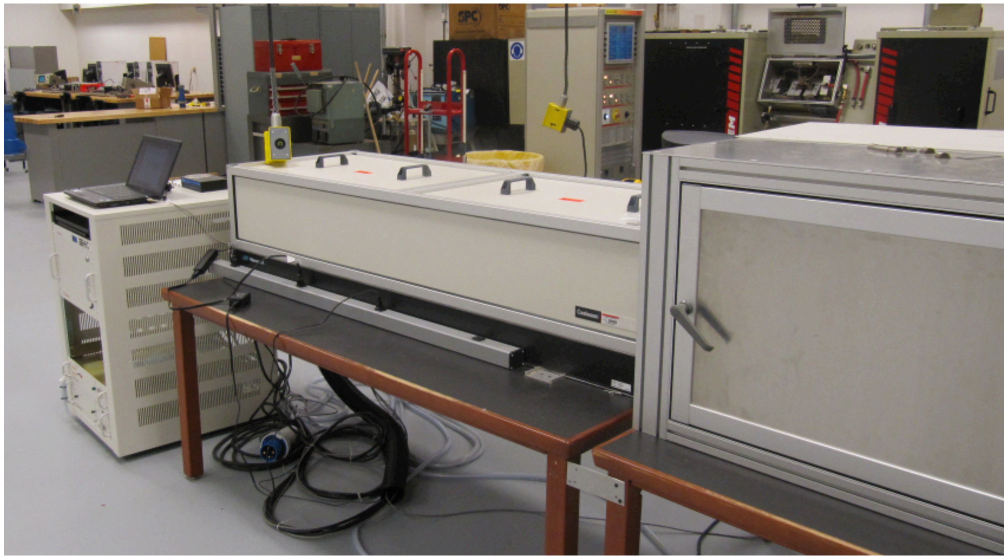
Velocities over 1km/second in thin flyers.

Swift, D. C., Niemczura, J. G., Paisley, D. L., Johnson, R. P., Luo, S. Review of Scientific Instruments, 2005.

past work on laser flyers

Researchers	Laser Pulse	Flyer	Velocity/efficiency	Comment
Lawrence & Trott 1993	Variety of data used		high values possible.	Excellent early theoretical analysis
Kadono et al, 2000	20 J, 249 nm, 30 ns.	Ta	>10 km/s, ~1.8% efficient	believe short wavelength, long duration give efficiency.
Greenaway, 2003	10 mJ, 1060 nm, 9ns	2μm thick, 1mm dia,	4 km/s,	Auffwar ablation layer gives better efficiency, metal used not clear. Efficiencies up to 25%.
Gu et al 2004	90 mJ, 1060 nm, 10ns	10μm, 0.8mm dia, Al foil	1.2 km/s	No ablation layer.
Swift et al 2005	1054 nm, 600 ns, range of E; 5-20 J.	50-250 μm Cu foils, 4-6 mm dia	Velocities in ~200 m/s range, effecincies ~1-3%	concludes confined ablation has much higher efficiency, used PMMA substrate.
Cogan et al 2005	1064 nm; 10 ns pulses 20 -110 mJ	0.5 - 9 μm Al films, ~1mm	**Efficiencies up to 45%**	shows very high efficiency in converting to kinetic energy.
Miller 2009	10 ns pulses. Typically 1 J energy	3 mm Cu flyers	**Velocities to 1 km/s. Efficiencies near 50%**	Shows high efficiency with no coupling layer

laser Impact Welding System



System Specifications

Energy	3.0 J
Wavelength	1064 nm
Pulsewidth	8.1 ns
Repetition rate	10 Hz
Energy Stability	< 2%

Continuum Genus Laser Impact Welding System: Nd-YAG based, Upgradeable to 8 J.
Light shaft is about 2.4 meters long (8 ns).

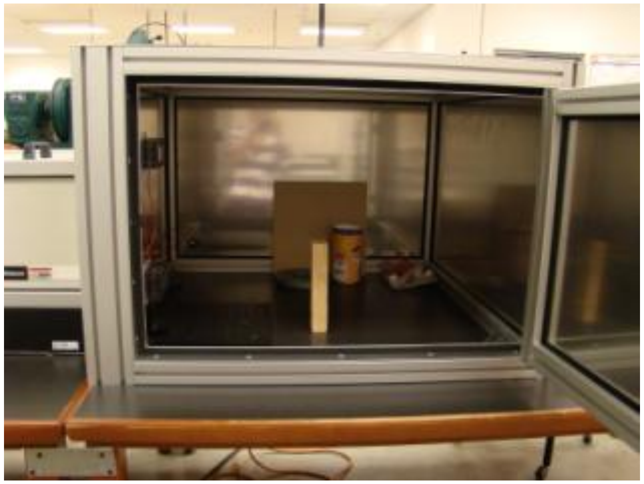
laser impact welding system

← Control System

Experimental Bay →

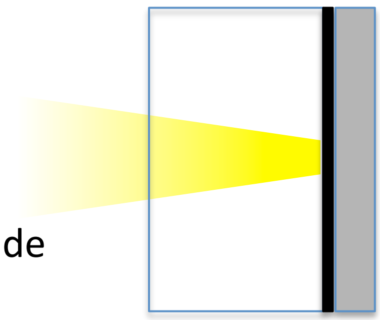
System classified as Class I laser system, as light only accessible in closed bay.

Bay open (below)

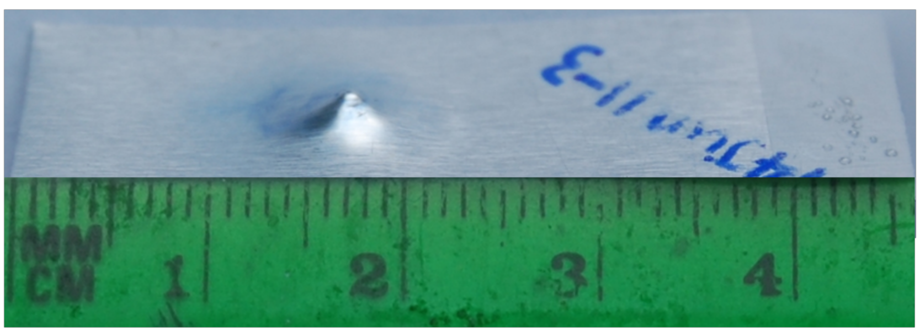


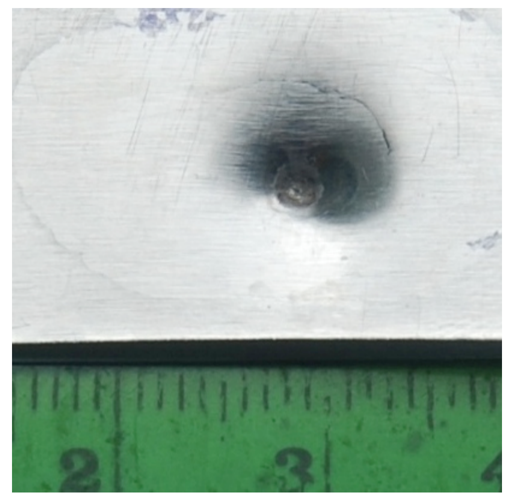
launch of 150µm thick aluminum

Glass, ink, flyer

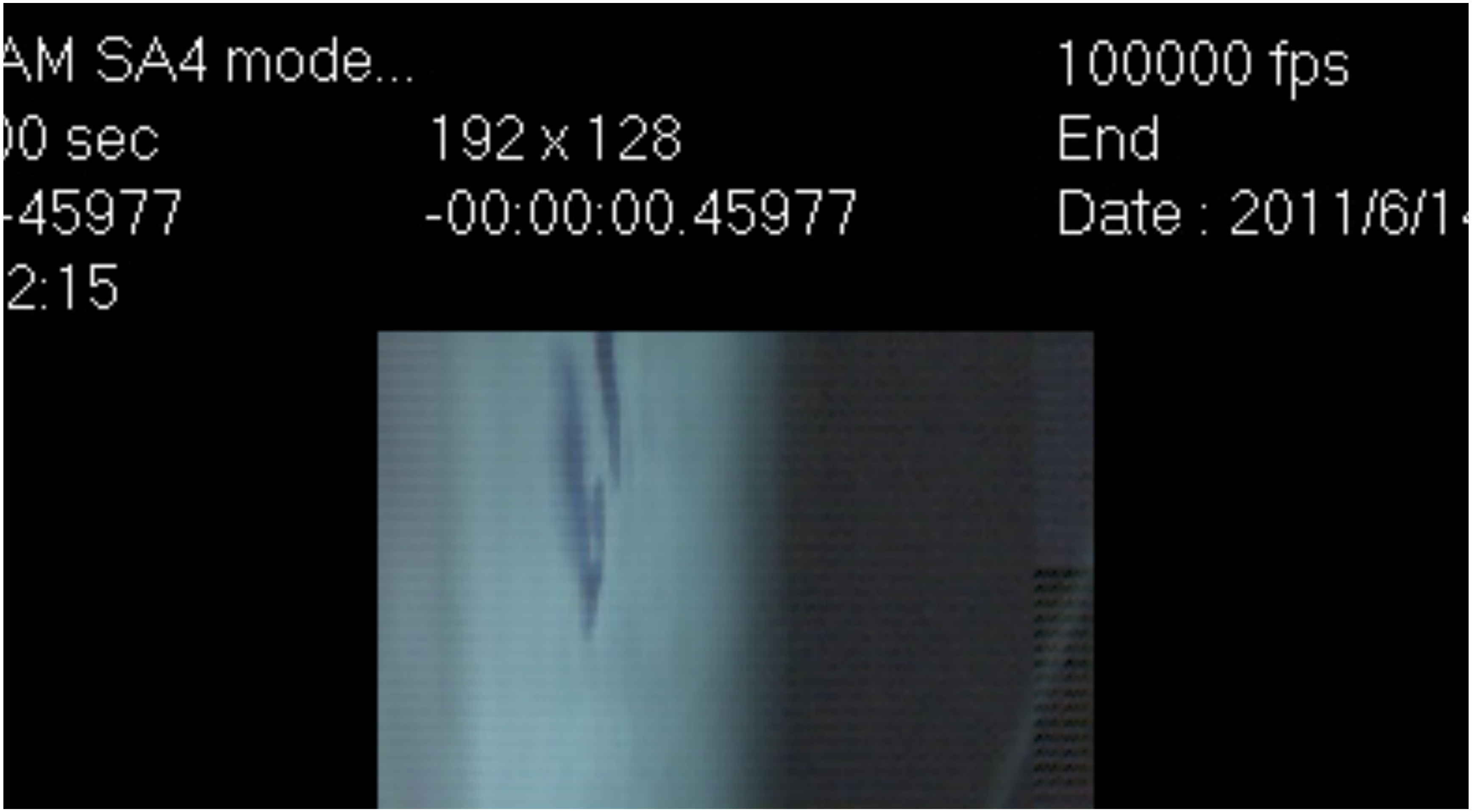


- Materials
  - Backing plate: "Pearl" microscope slides 1.0-1.2 mm thick
  - Ablative layer: Sharpie black marker ink, applied to glass slide
  - Flyer plate: 150µm AA1100, 16mm×45mm foil,
    attached to ablative layer with super glue- coated side of glass slide
- Laser: 3 J, 8 ns
- dimple dimension on the plate: 2mm diameter





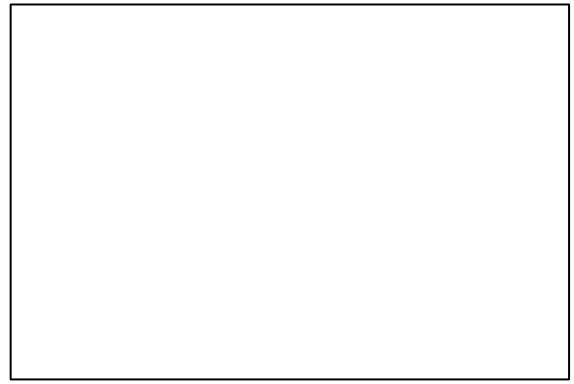
flyer launch 150µm aluminum



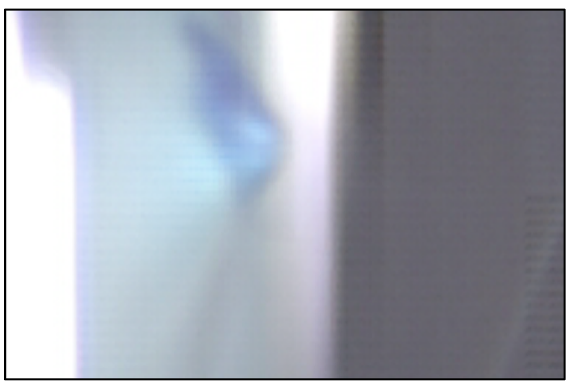
Collaboration with Medtronic and Scott Terry

Images from high speed sequence

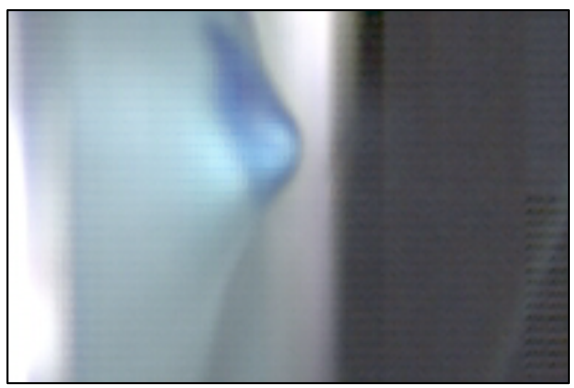
t= - 50µs flash-lamp



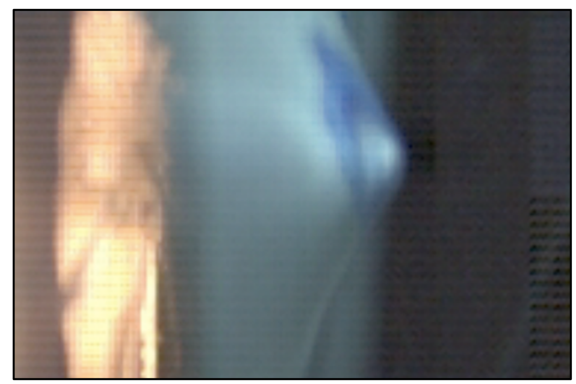
t= 0 laser pulse



t= 10µs



t= 20µs

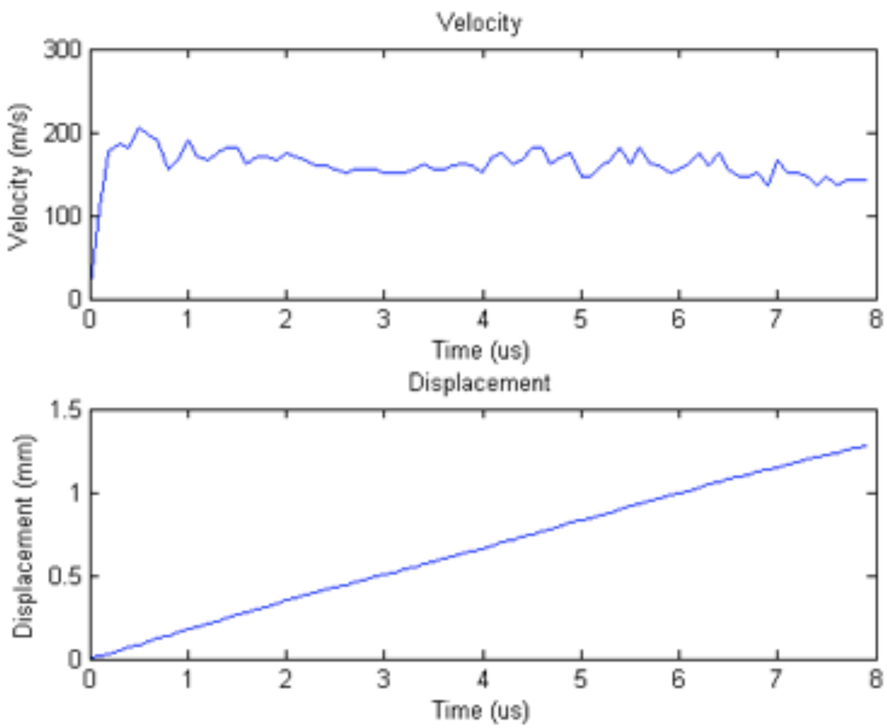


t= 200µs

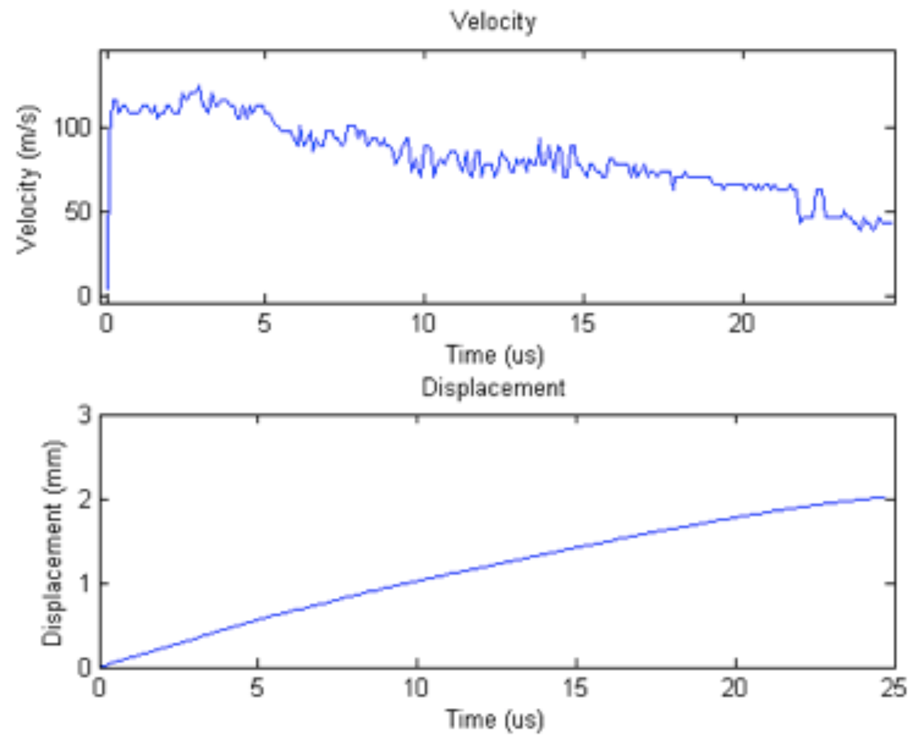
LSP Experiments

635 µm thick Aluminum, 4 mm wide
Launched with 6.5 J laser pulse
3mm diameter area

Water confining medium V_{max} ~200 m/s



Celo-Tape confining medium V_{max} ~120 m/s



<u>Peak velocity in about ~10µm displacement!</u>

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Experiments in collaboration with LSP Technologies, Dublin, Ohio.

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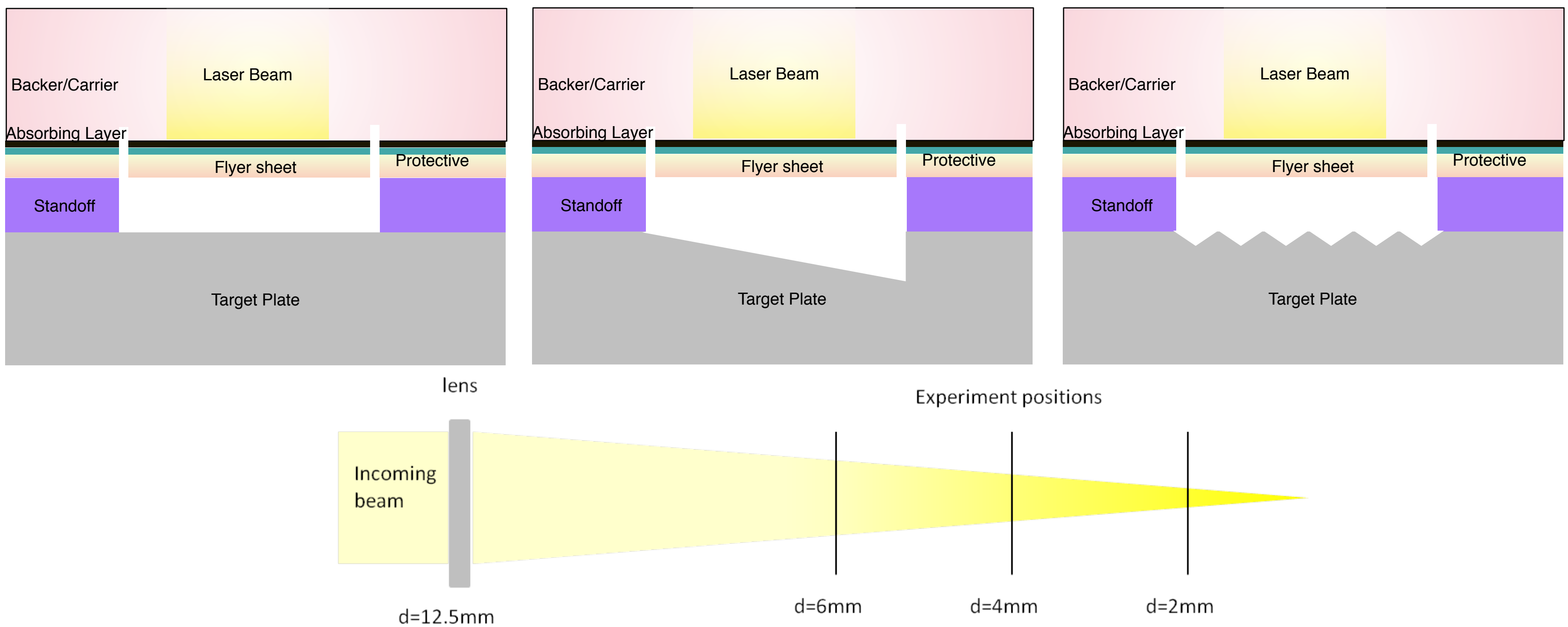
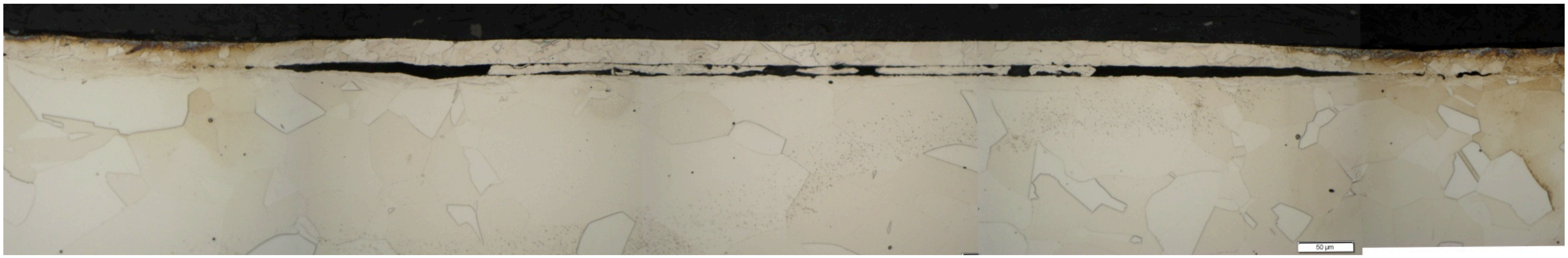
collision welding methods

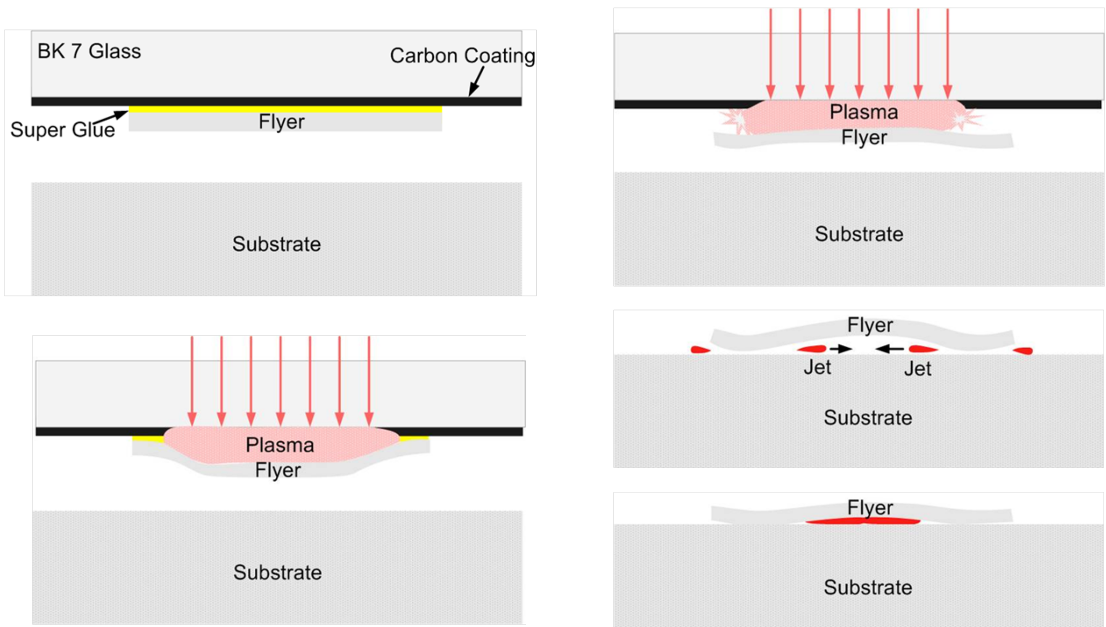
- **Degrees of Freedom**: Pulse Energy, Pulse Width, Beam Diameter, Energy Distribution, Substrate, Flyer, Geometry, etc, etc.



Ni on Ni – disk flyer – morphology

Weld interface of 50 µm Ni201 to Ni201 using a flat-launch geometry. 3mm circular flyer.





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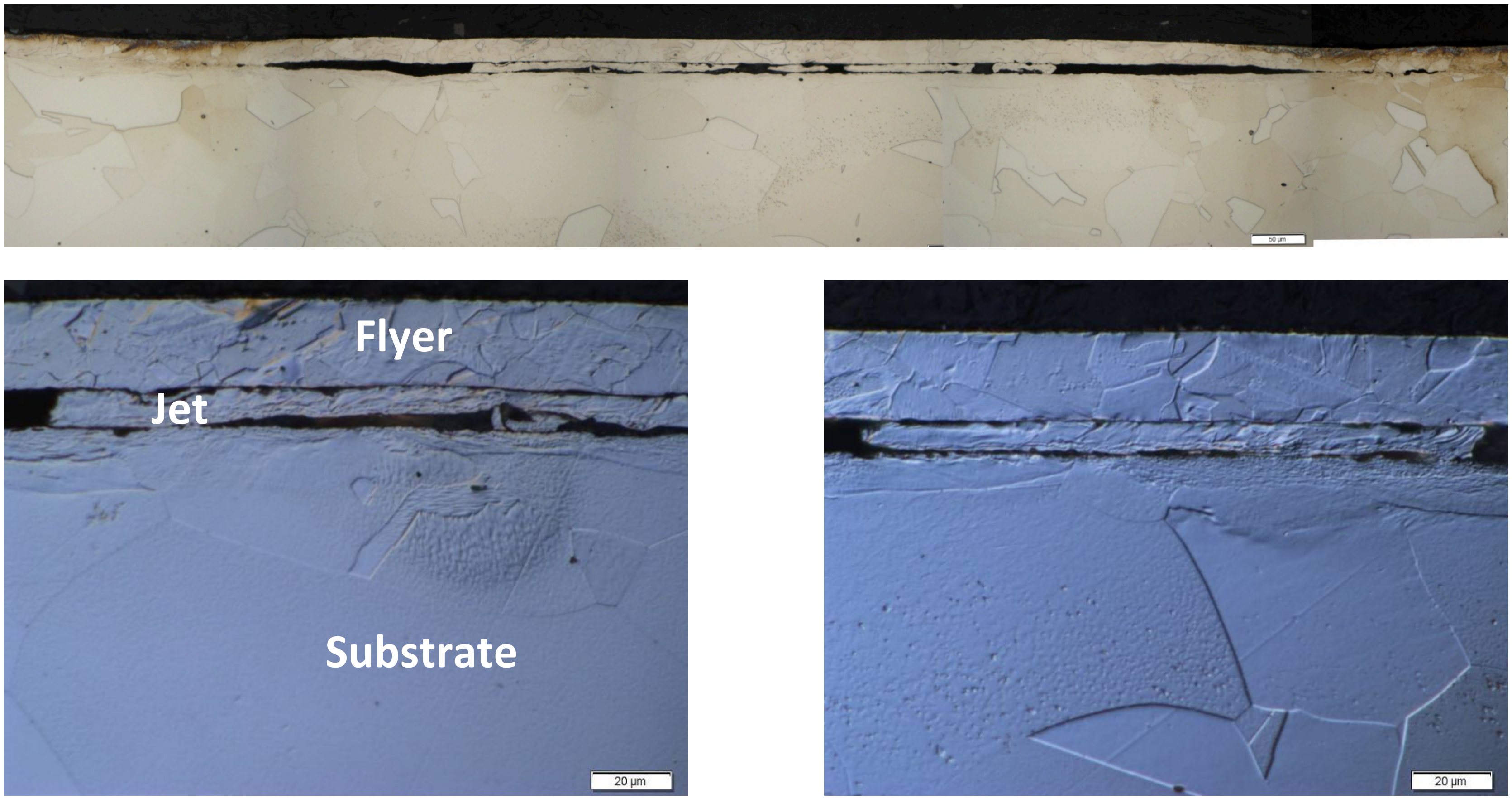
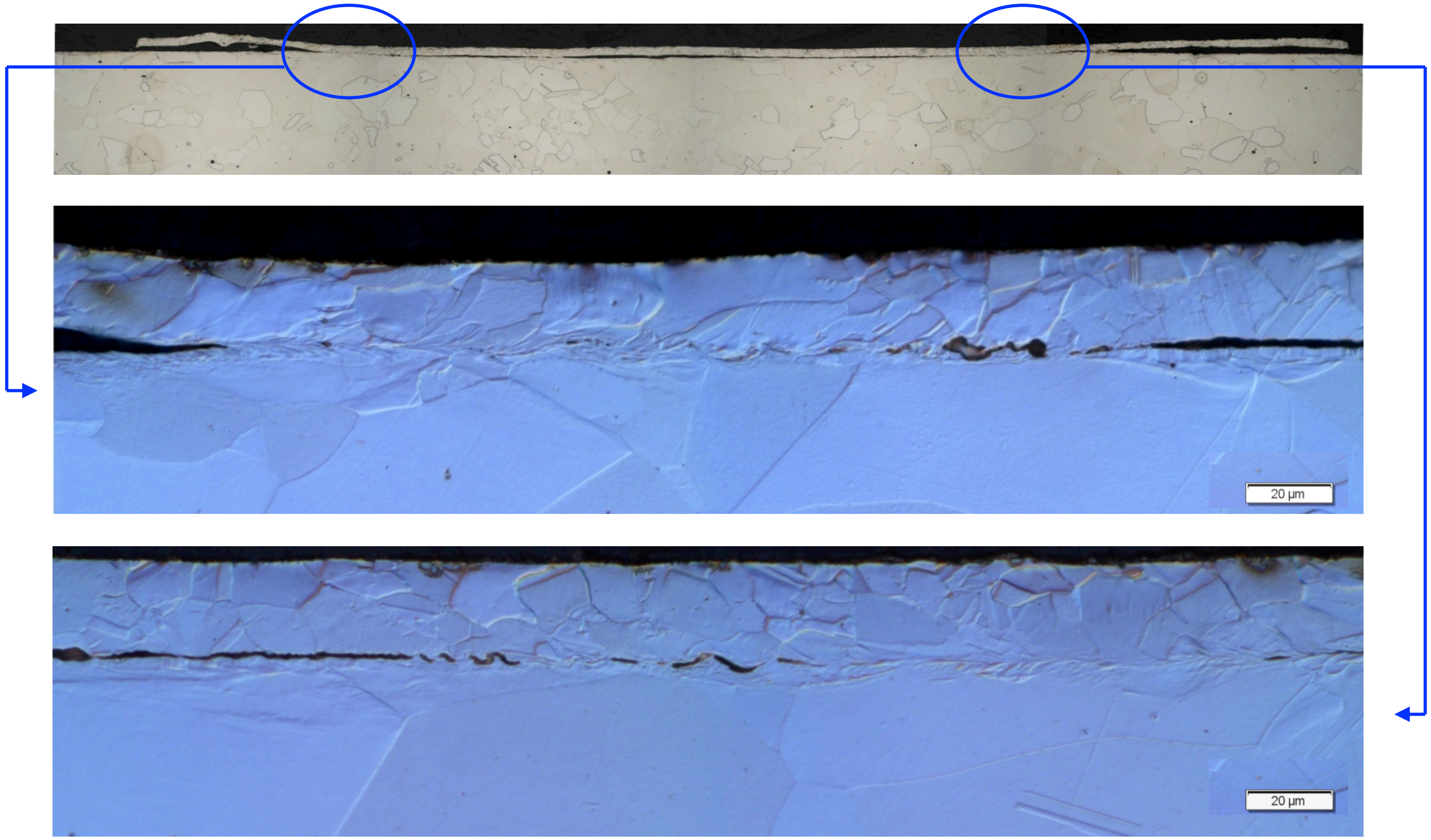
jetting in Ni-Ni collisions

(Flyer:50μm)



Jet enclosed in between the flyer and substrate was often observed.

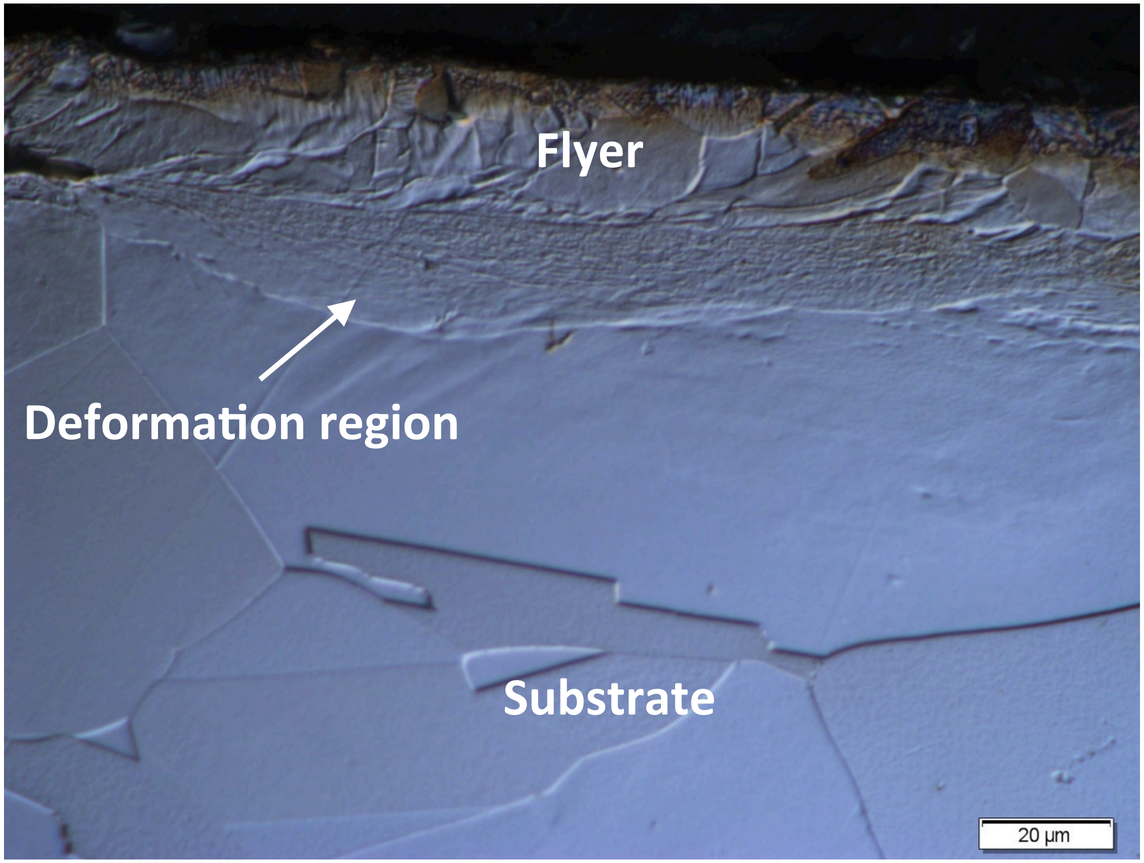
wavy interface (Ni-Ni)



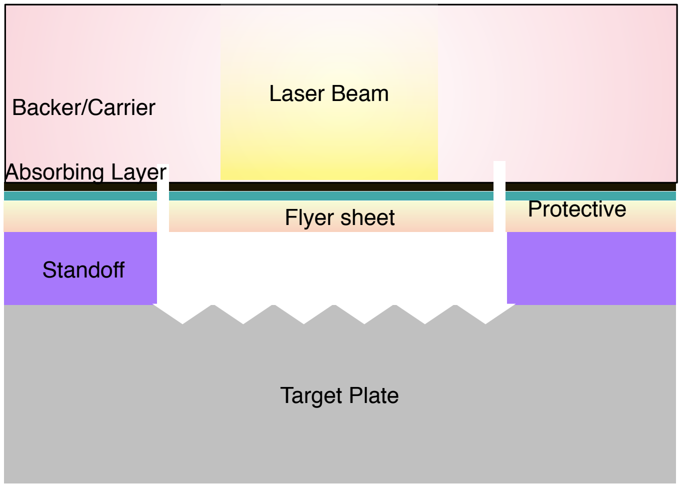
(Flyer:25 μm)

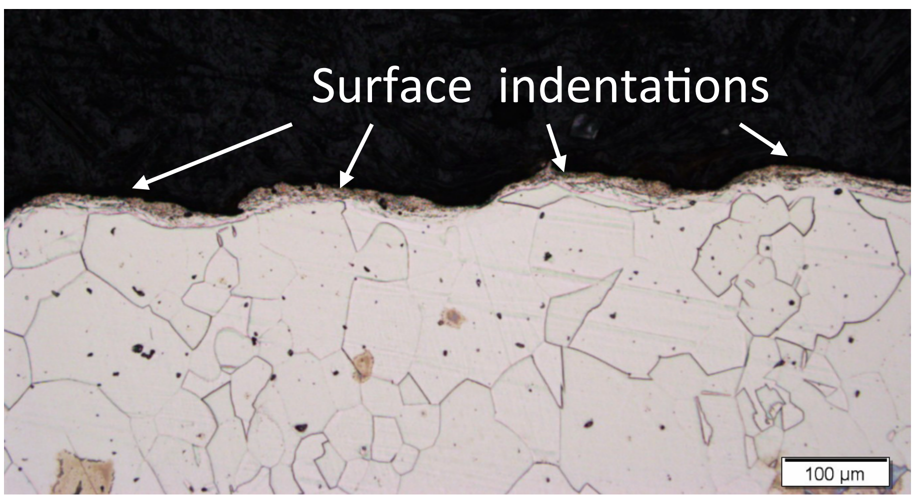
severe local plastic deformation

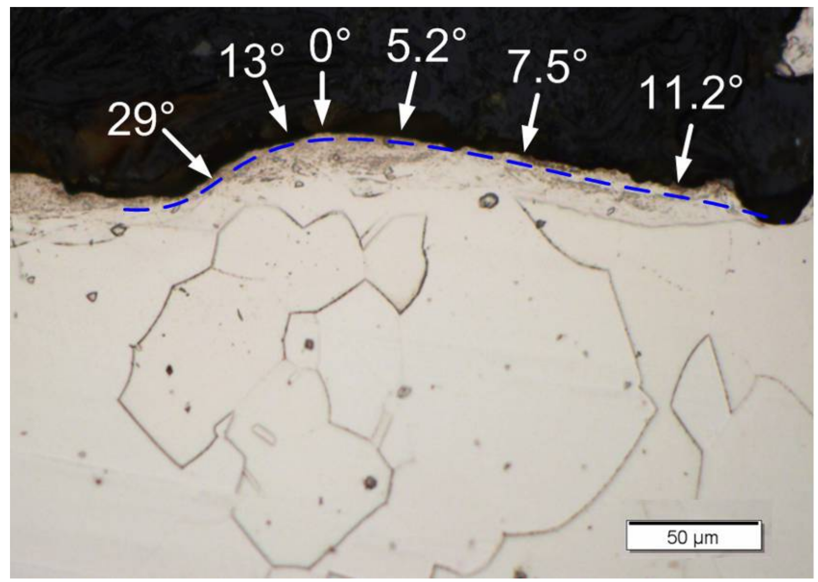
(Flyer:25 μm)



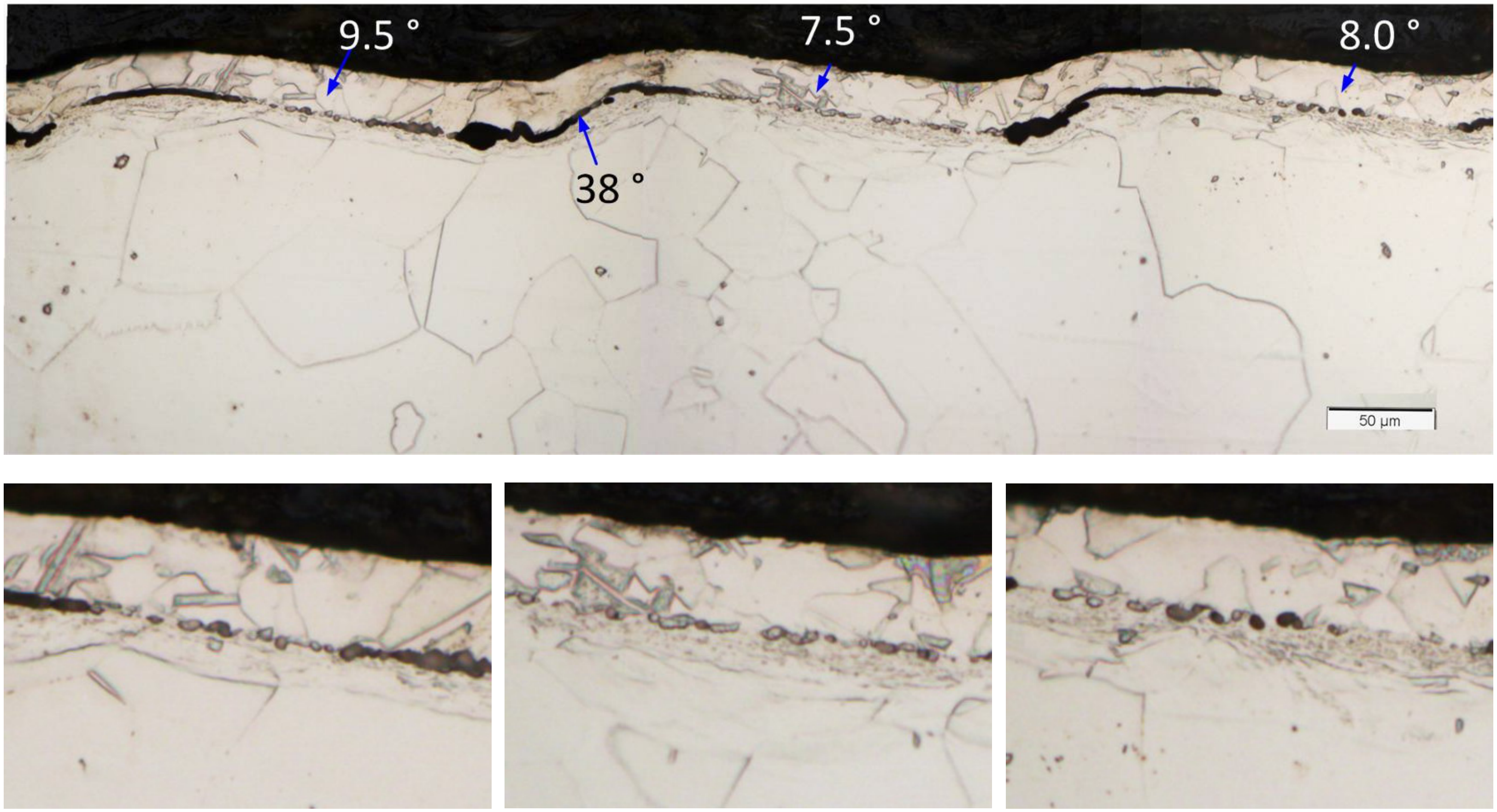
impacting serrated surfaces…







result – large bonded area (Ni-Ni)



A proper impact angle range for nickel may be 7 to 9 degrees.

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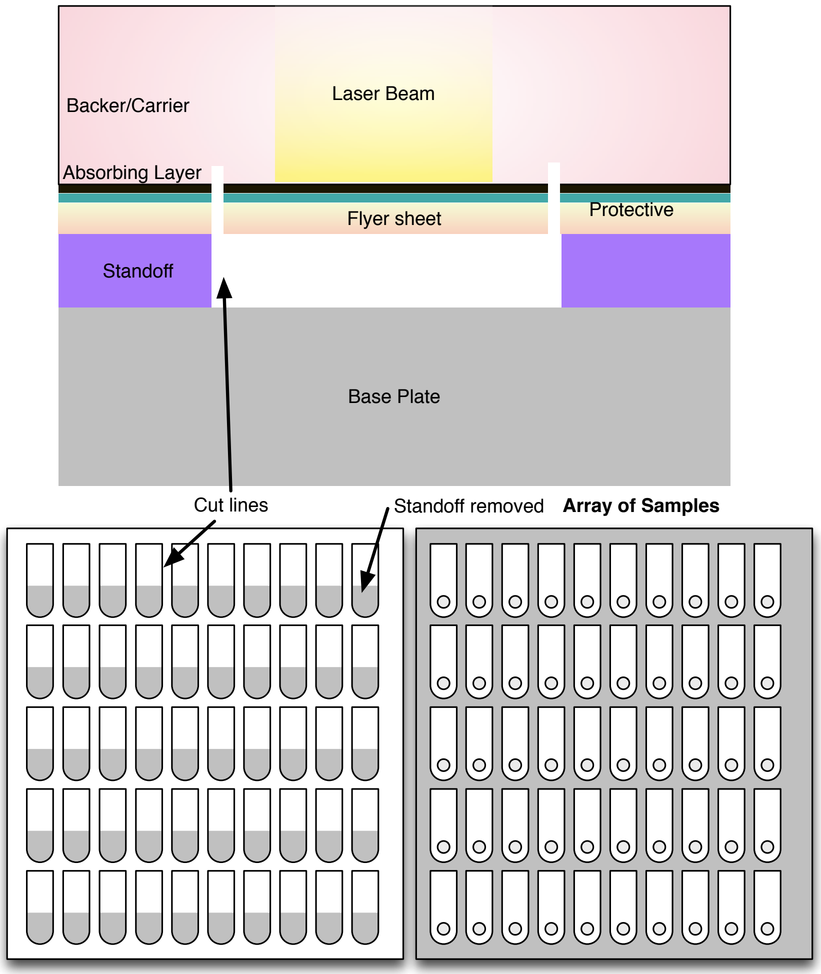
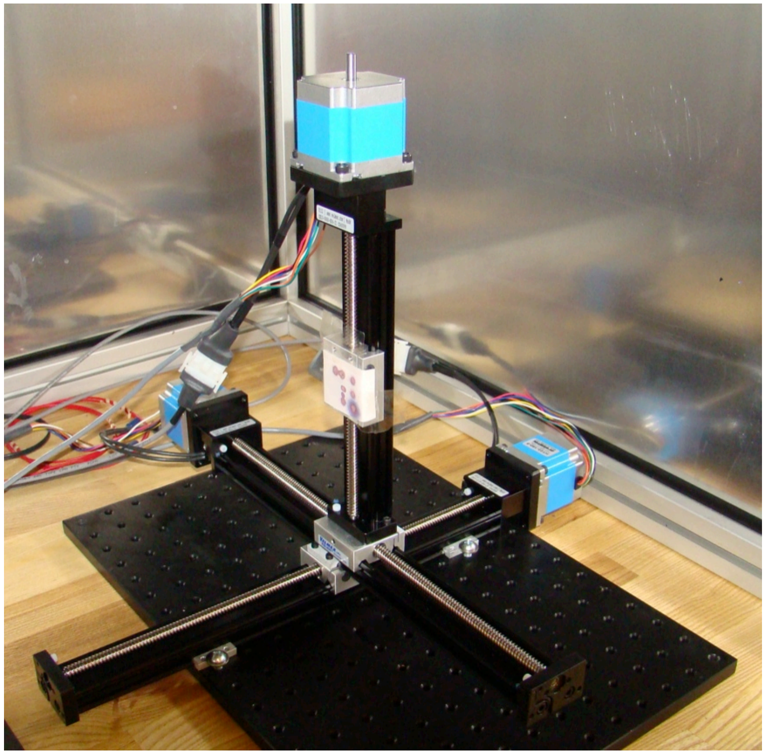
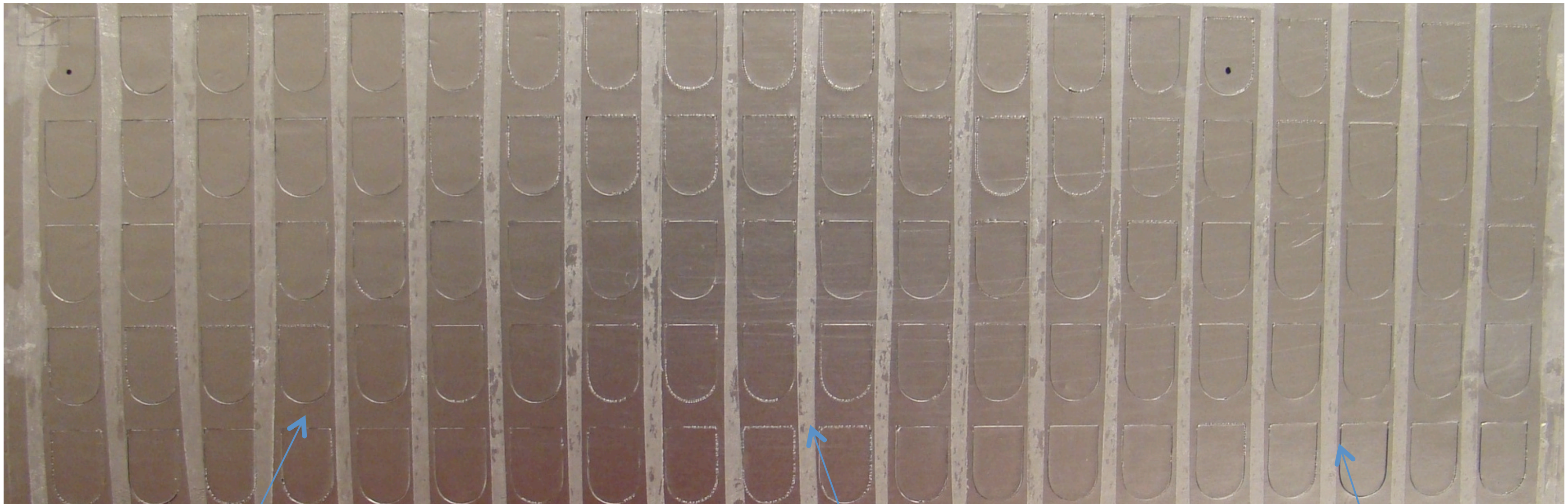
automation


Laser Beam
Backer/Carrier
Absorbing Layer
Flyer sheet
Protective
Standoff
Base Plate
Cut lines
Standoff removed
Array of Samples



target fabrication



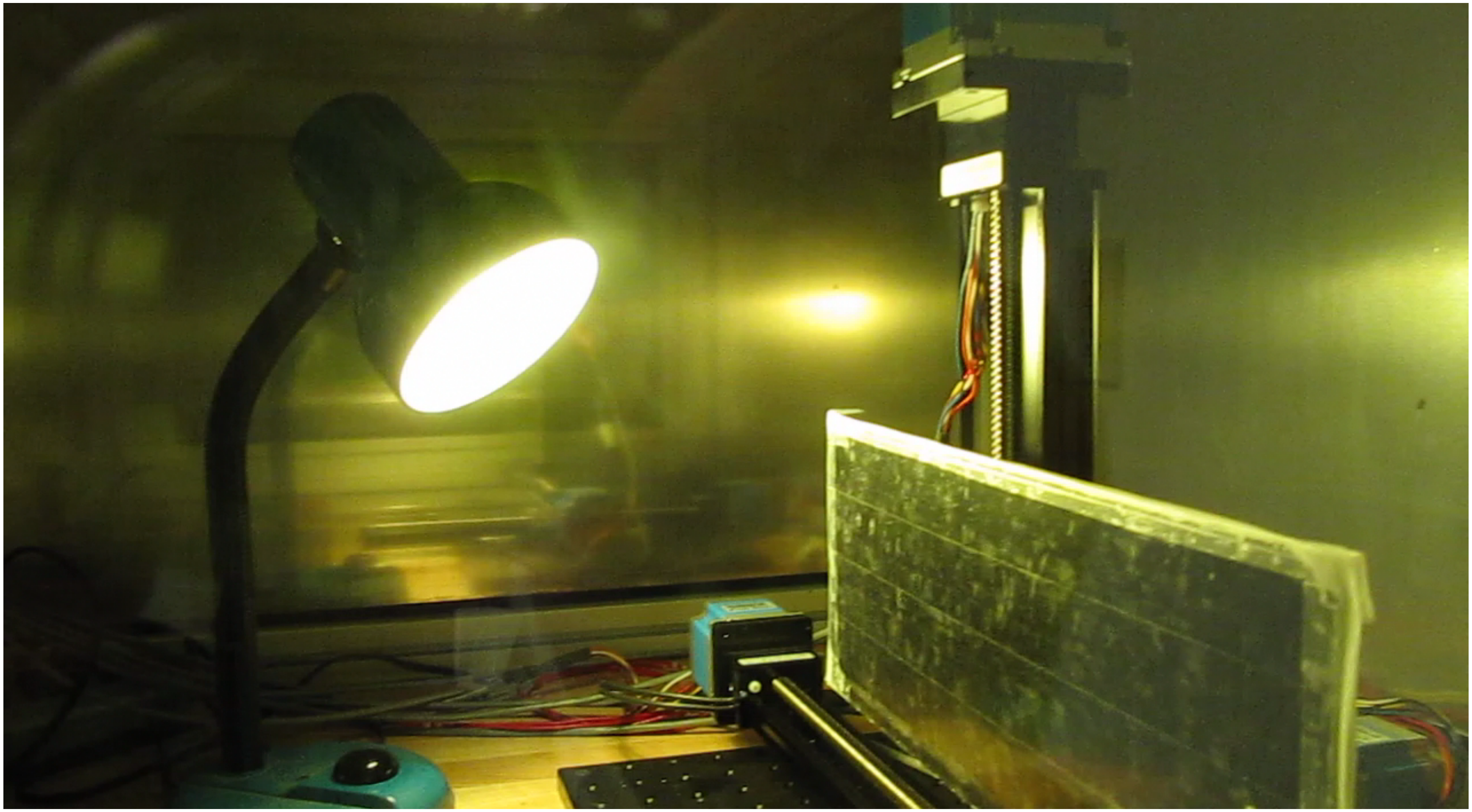
Flyer: Al1100- 25 µm

Standoff: double sticky tape-100 µm thick

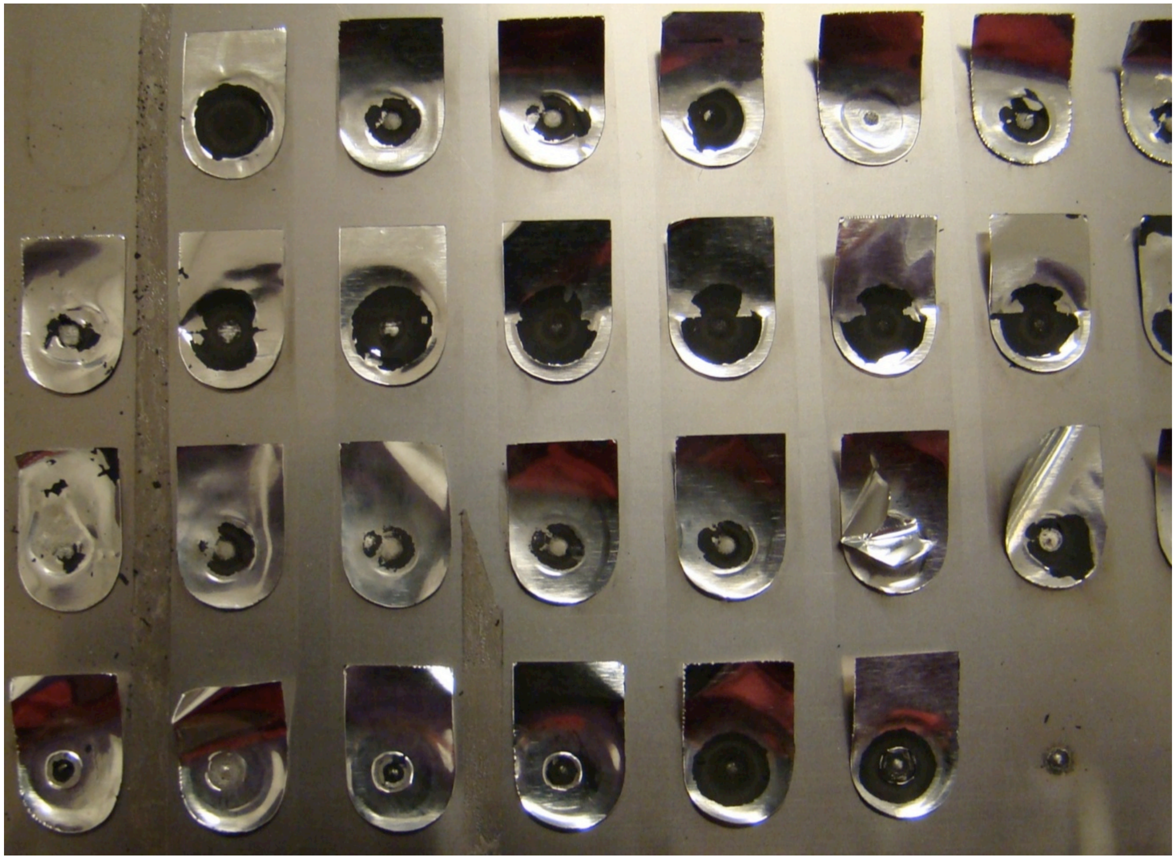
Cut line – Contour cutter

1. Back side of flyer painted with black RUST-OLEUM Enamel, glued to 0.5 mm polycarbonate.
2. Tape provides good attachment between flyer and target and standoff.

motion and welding at 1 Hz

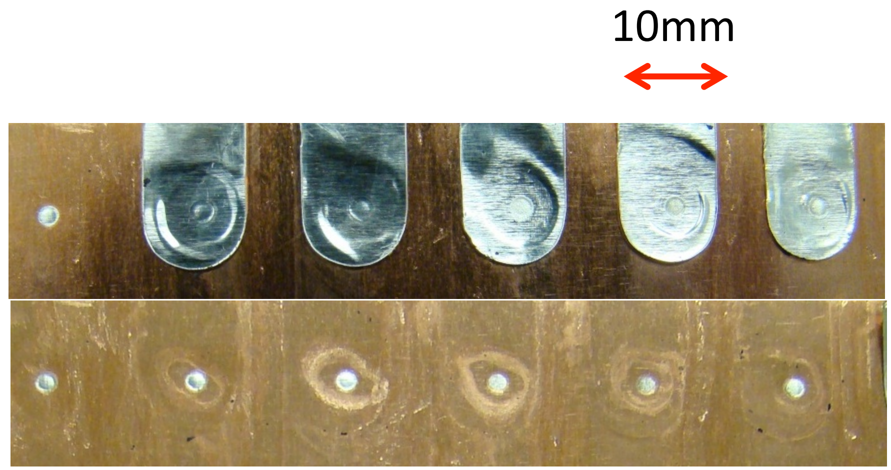


completed welds



Few tabs get lost in separating pack.

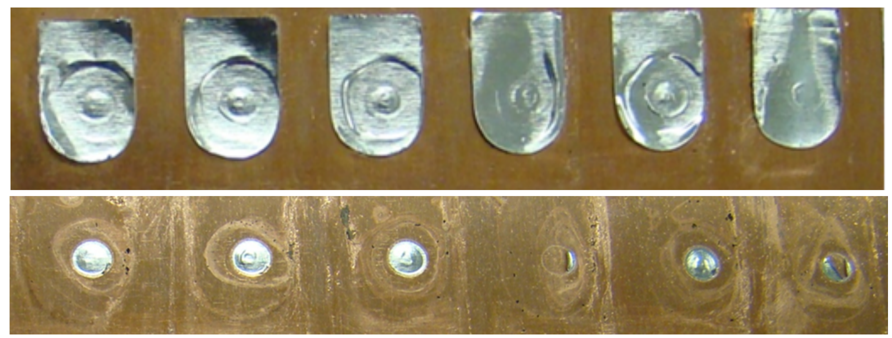
Al-Cu Results



<u>2mm spot size</u>

Avg. peel strength 3.1 Nt

St. Dev. 0.6 Nt

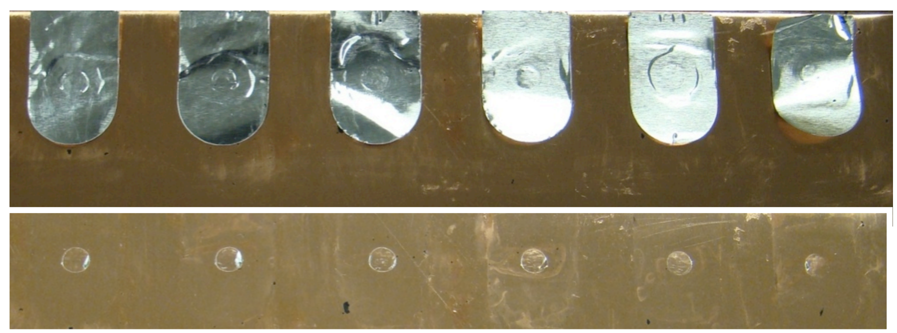


<u>4 mm spot size</u>

Avg. peel strength 4.1 Nt

St. Dev. 0.9 Nt

25 µm Al foil
3 Joule pulse
100 µm standoff
Flat geometry



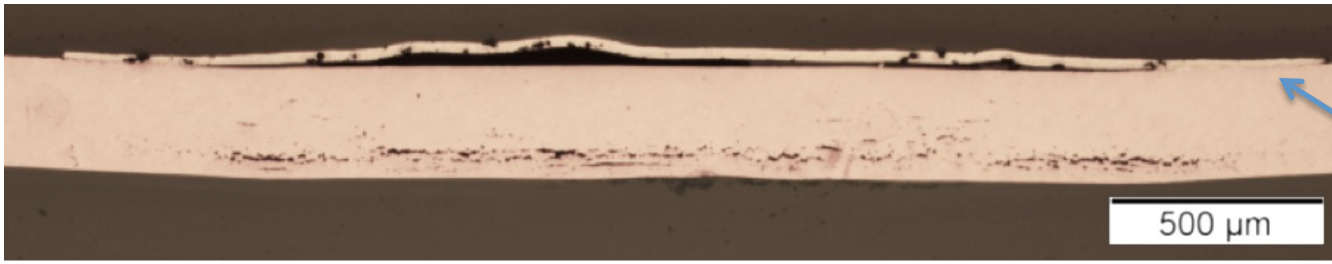
<u>6 mm spot size</u>

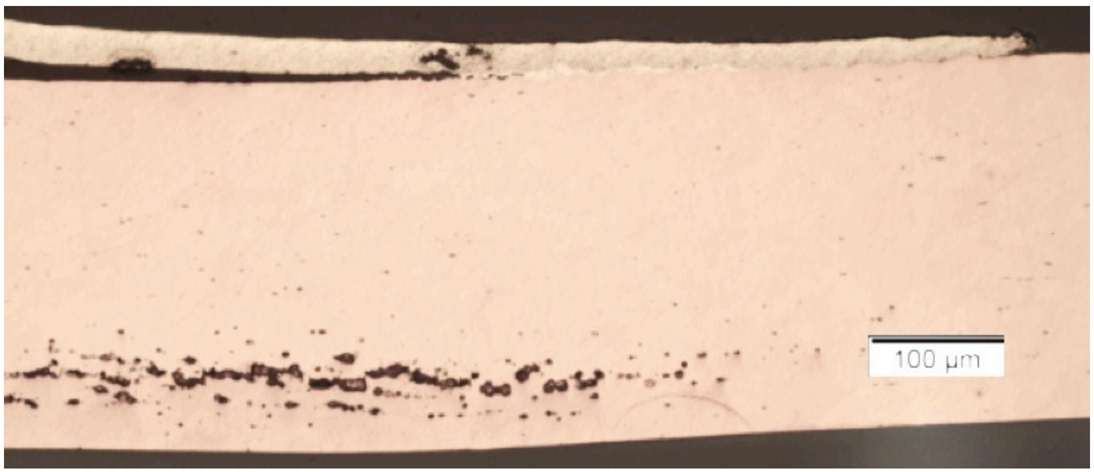
Avg. peel strength 4.75 Nt

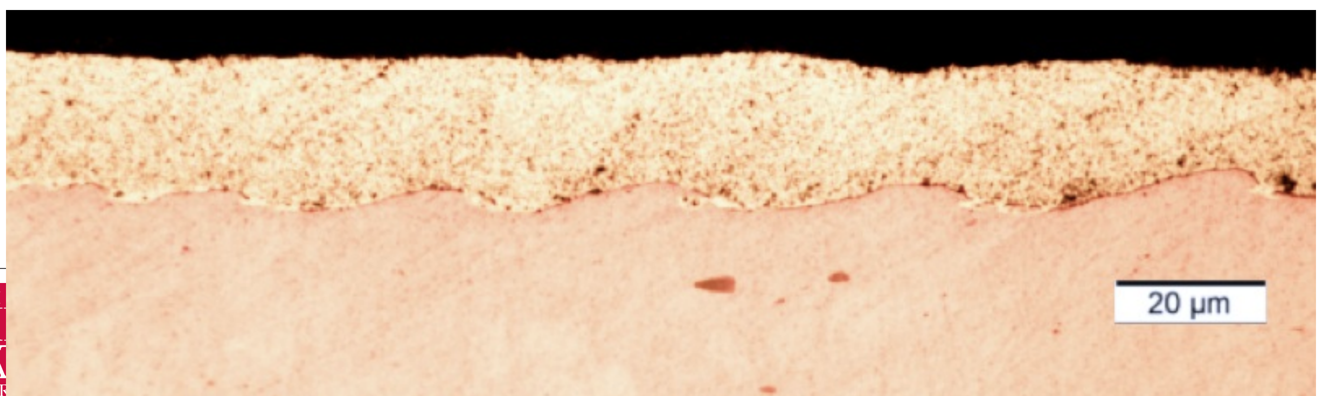
St. Dev. 1.0 Nt

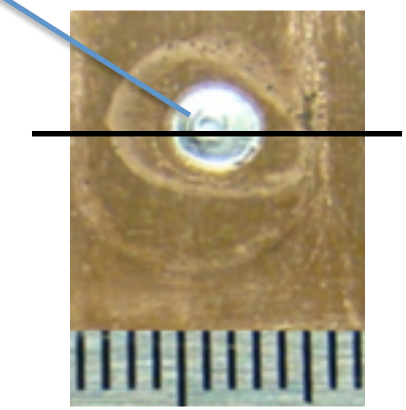
4-probe conductivity being developed…
Preliminary: 6mm has lowest resistance, 2mm- highest

Al flyer, Cu target structure









4mm diameter spot

conclusions

- Laser impact welding of thin metal foils is very practical and effective.
- High production rates are easily achieved (10 Hz).
- In addition to welding, forming and cutting can also be carried out at short length scales.
- Sample preparation is key to making the process practical.

H. Liu et al. / Optics & Laser Technology 44 (2012) 1987–1991

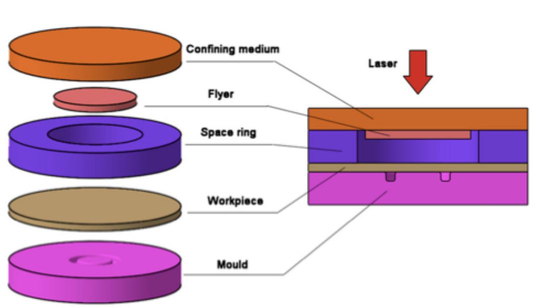
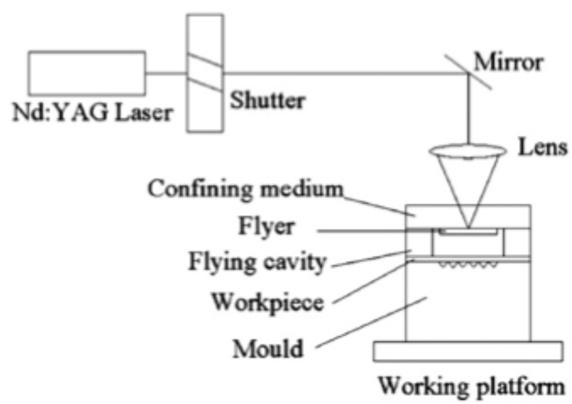
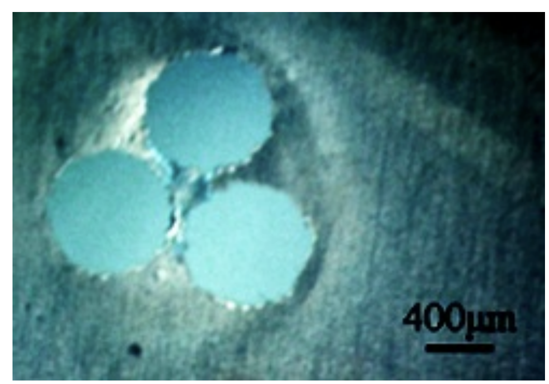


Fig. 1. Schematic diagram of the novel micro-embossing.





Examples from Hiu et. al., Jiangsu University (2012).