ICHSF 2018 INTERNATIONAL CONFERENCE ON HIGH SPEED FORMING

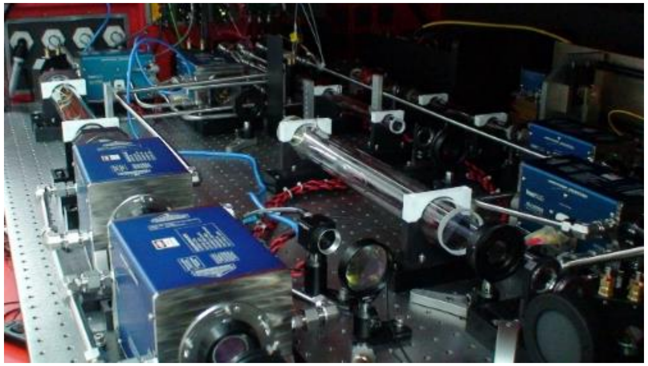
Laser Impulse Generation

Parameter Effects and Applications

Stan Bovid | LSP Technologies, Inc. | Director of Materials Research

$1 to $3.5 Billion

1 mW to 10 PW



Laser Application Type	Power Output
Hardening	5kW/cm2
Cutting	200 KW/cm2
Welding	1 MW/cm2
Drilling	100 MW/cm2
Impulse Generation	10 GW/cm2

Why Lasers?

Repeatable, controllable, affordable energy manipulation

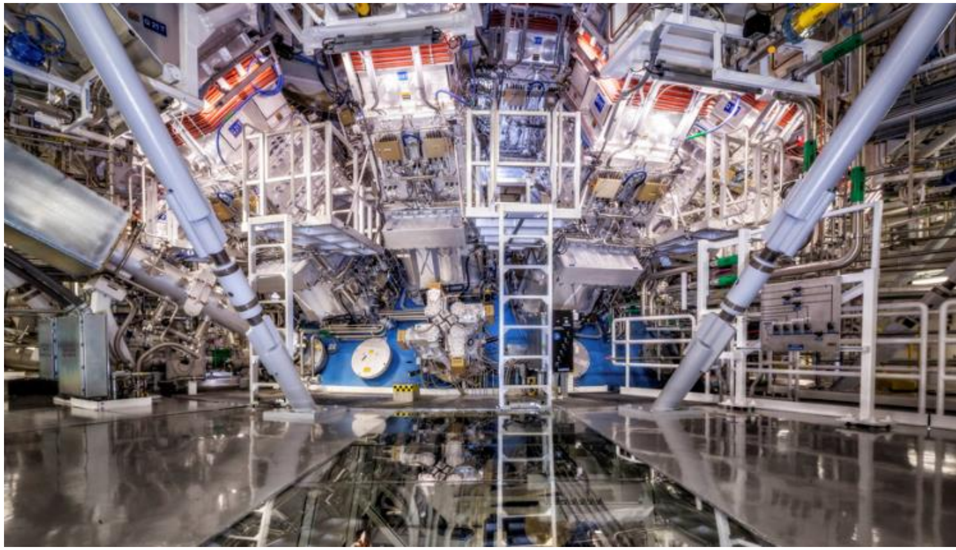
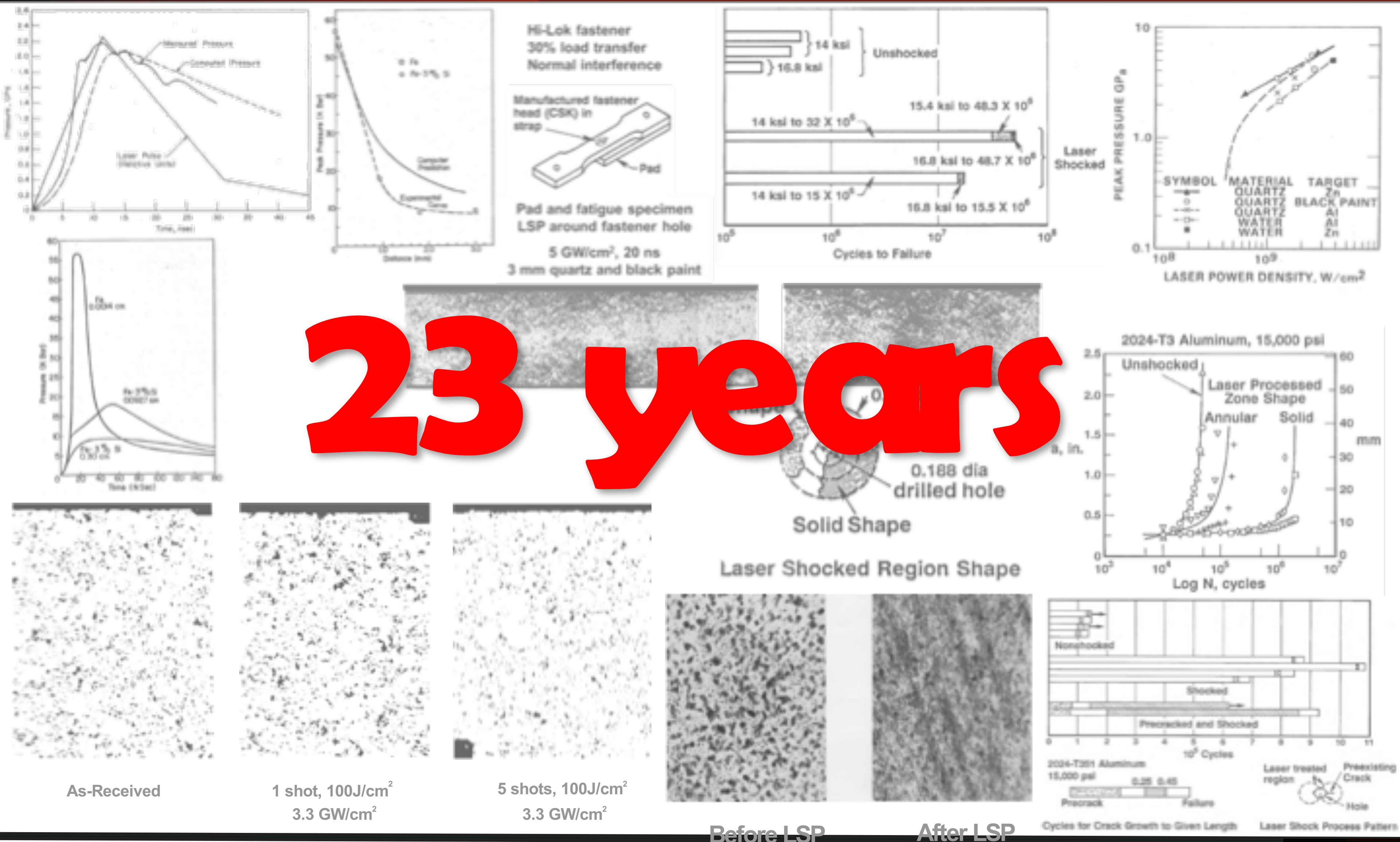


Photo by Damien Jemison/LLNL

LSP Technologies
Role
in
High Energy Laser Processes

LSP Technologies

Building the Technology Foundation



Basement
to
Global

Collaborative Partnerships

ONLY FOR AEROSPACE
NOT THE FIRST
OURS IS FINE
TOO EXPENSIVE
TOO BIG
MORE DATA
NOT STANDARD
NOT INVENTED HERE
JUST A LAB
GOOD ENOUGH
REDESIGN DECISION

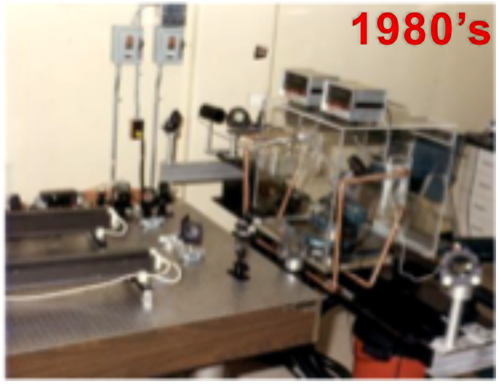
Patient

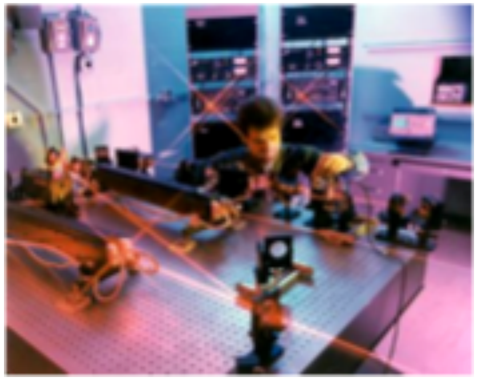
Persistent

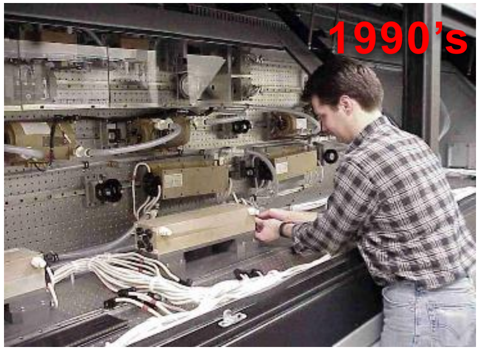
Opportunistic

Laser Impulse Generation

Limited by the Technology of the Time



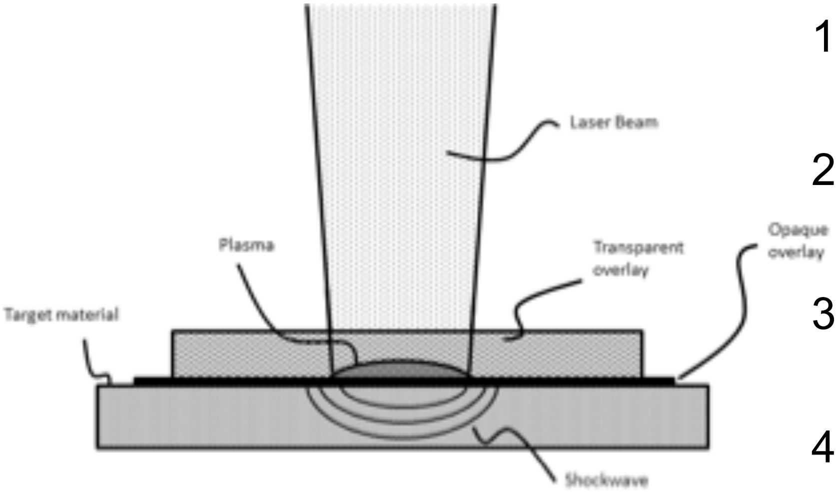




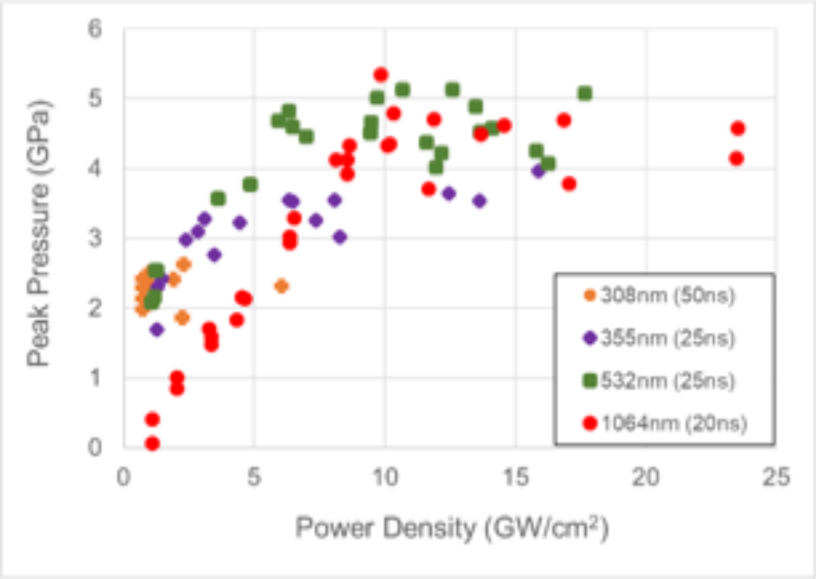
Laser Impulse Process

Laser Impulse Generation

Overview of Confined Ablation



1. Pulsed laser system power in GW/cm^2 scale
2. Target ionized by laser pulse, heated to plasma
3. Plasma confinement for increased pressure
4. Shockwaves generated by pressure spike

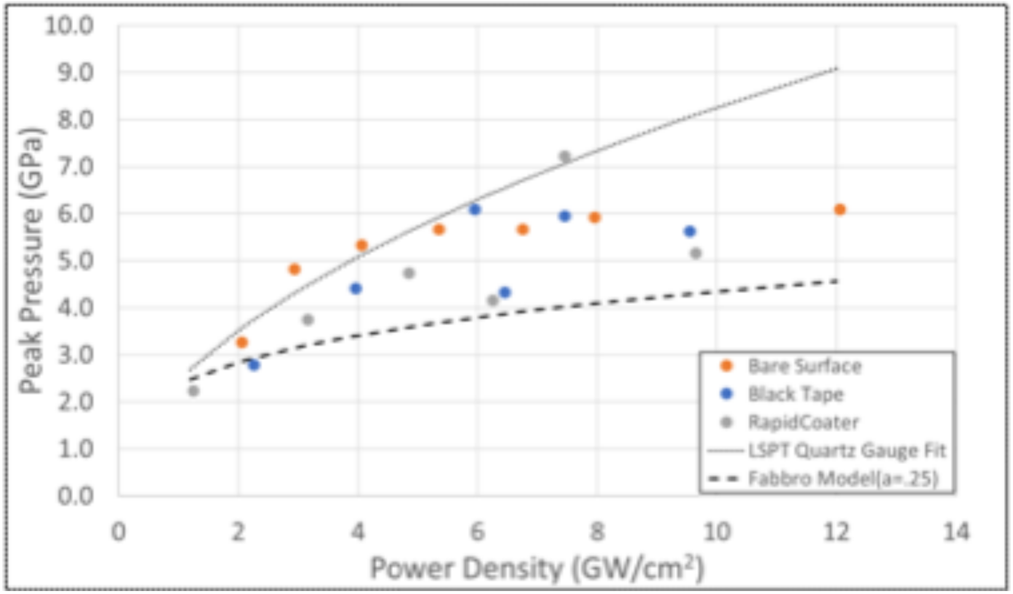


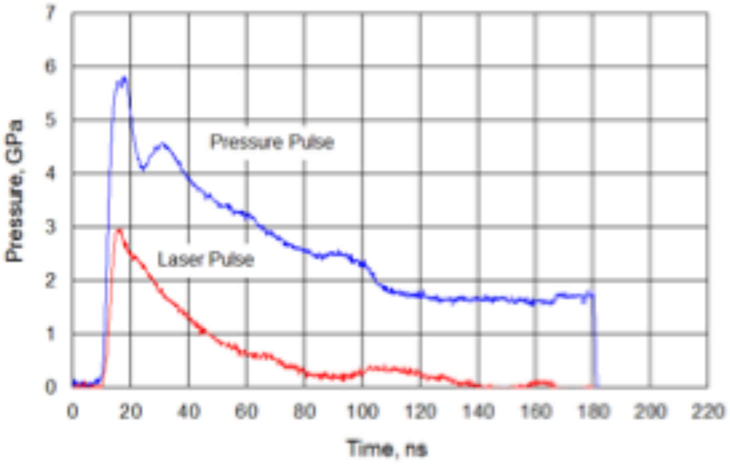
Data per P. Peyre, SPIE Symposium, 1998

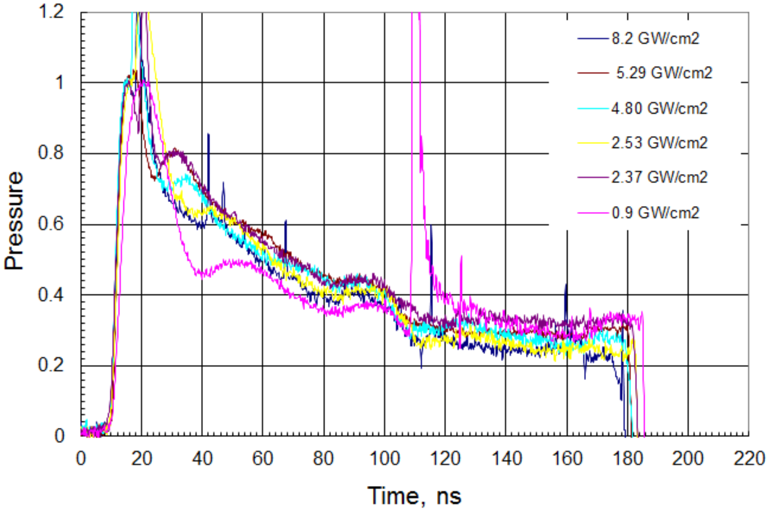
Pressures ~ 10 GPa

Pulse duration ns to us

Areas mm² to cm²





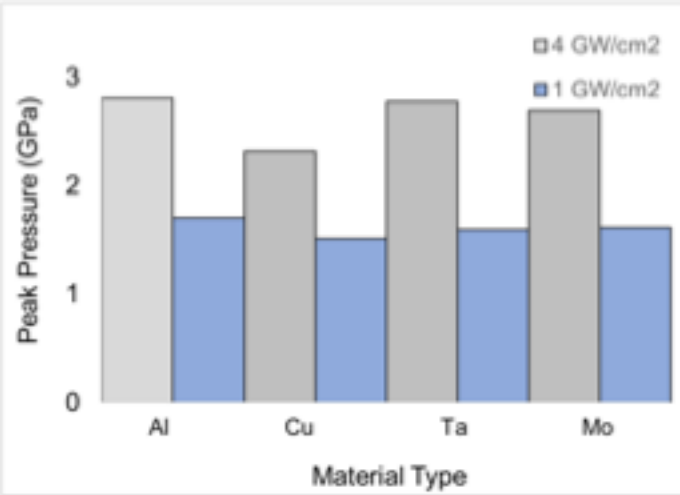


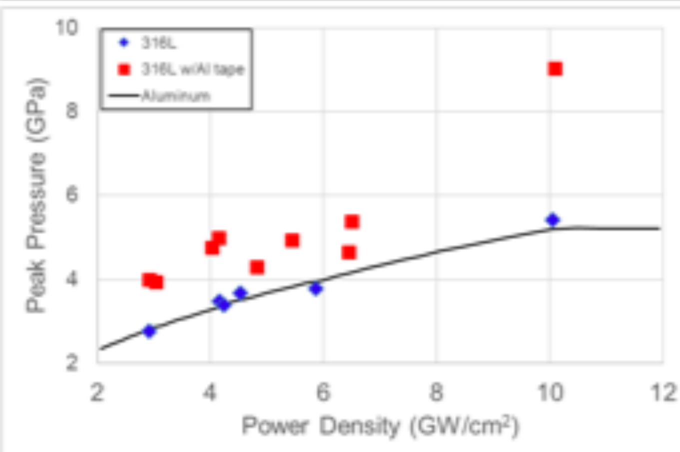
Peak pressure measurements derived from PDV back-surface analysis of 0.020 inch aluminum. Compared to legacy data from quartz gauge work and Fabbro model. (Some pressure attenuation expected in PDV)

Shoulders of Giants

Plus many more scientists from National Labs, Industry and Academia

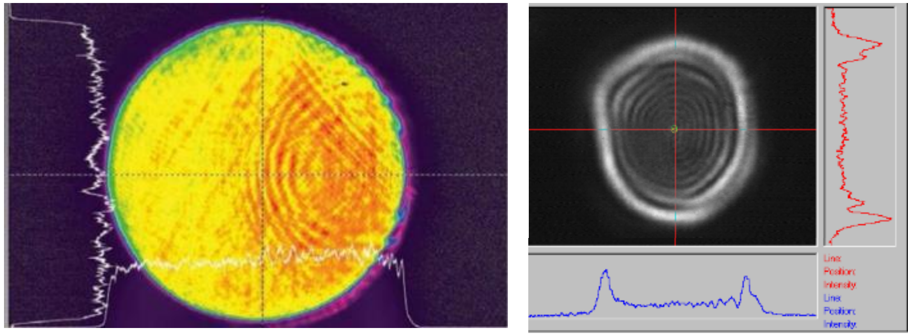
Target Materials and Pressures

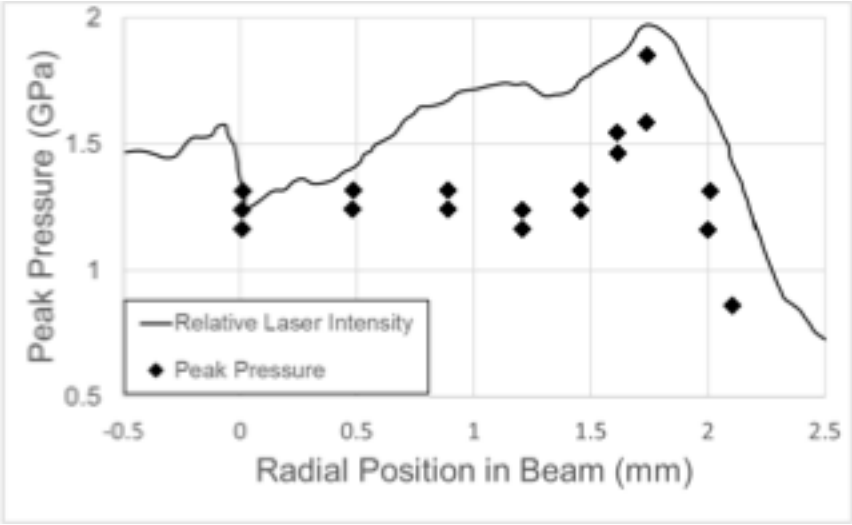




Data per Fabbro, J. Laser Applications, 1998

Spatial Energy vs. Developed Pressure

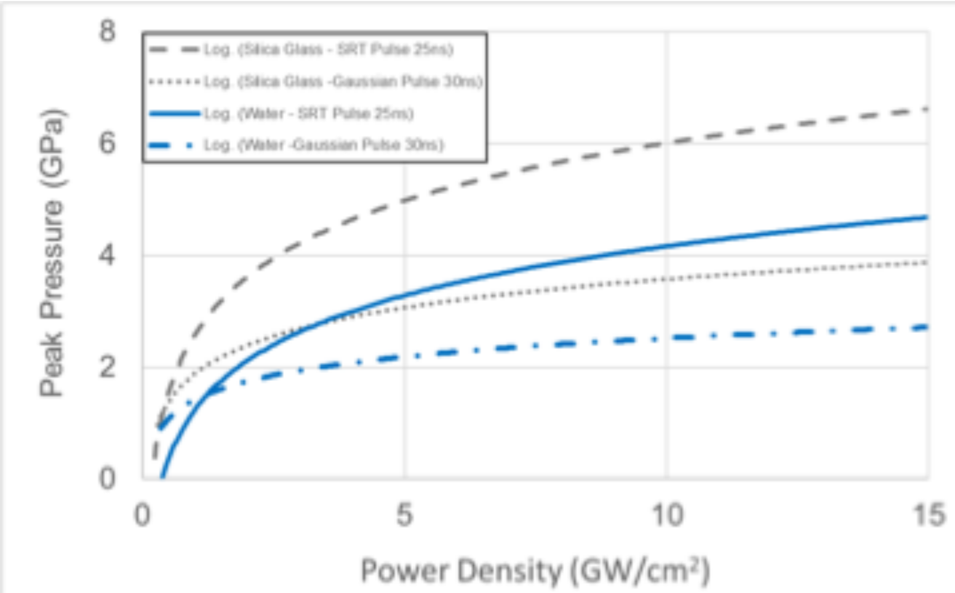




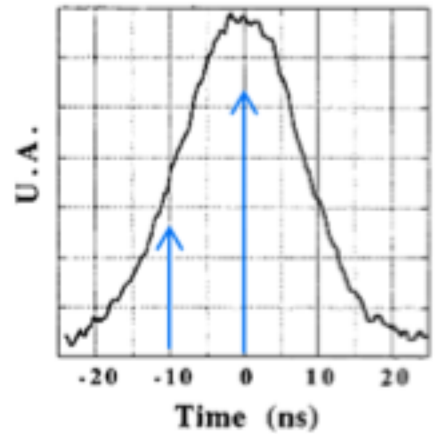
Data per L. Berthe, Dissertation, University of Orsay, 1998

Influences on Laser Impulse Generation

Confining Overlay and Dielectric Breakdown

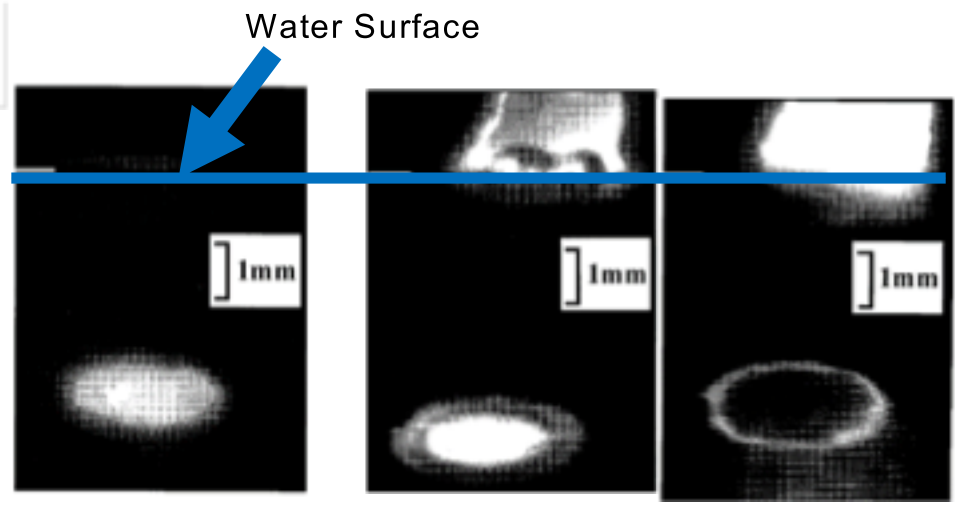


Data per Peyre, Optical and Quantum Mechanics, 1994



DEB depends on:

- Time
- Intensity



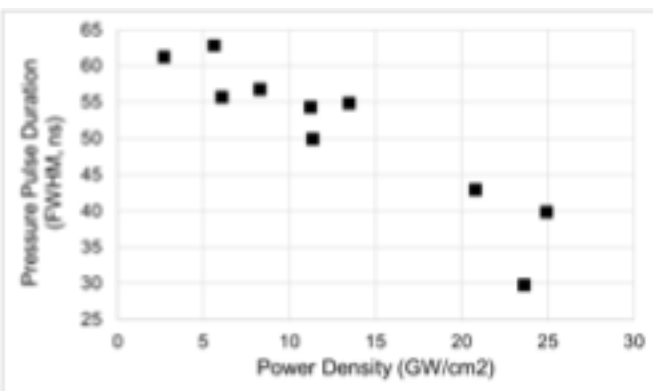
1.8 GW/cm², 0 ns

-10 ns

0 ns

28 GW/cm², 0 ns

From: Berthe, Applied Physics, 1997



Data per Berthe, SPIE, 1996

KEY TAKEAWAYS

Laser impulses are scalable

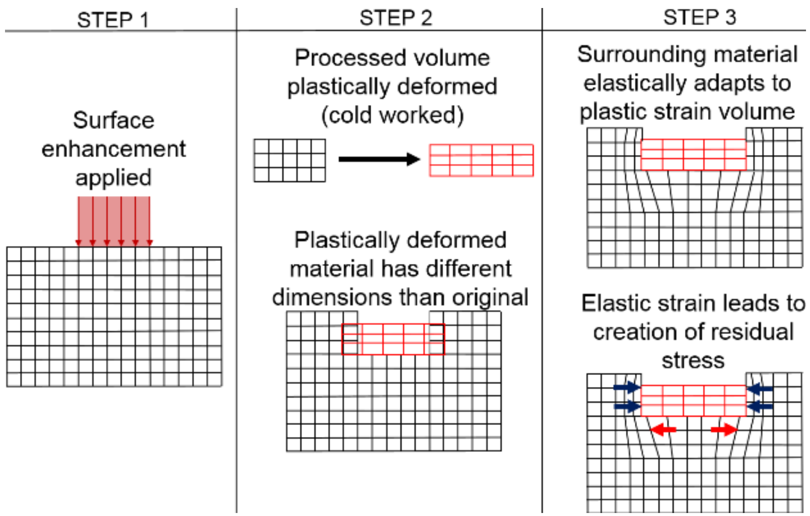
Trade space opportunities for tailoring

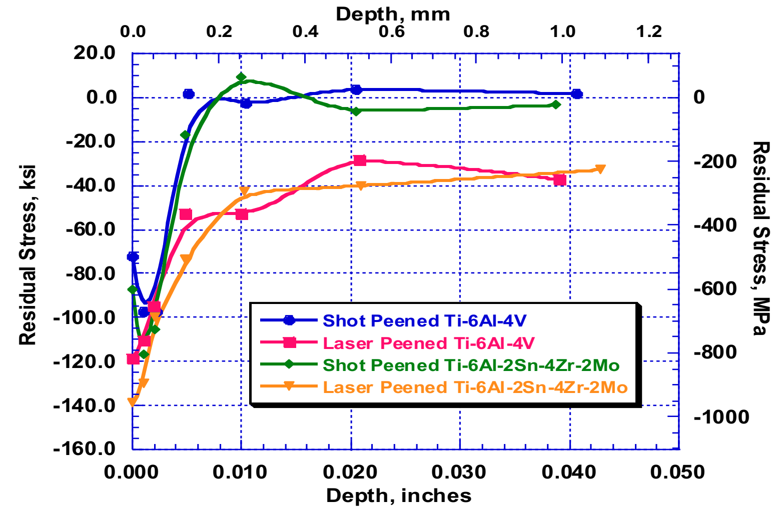
Optimization is application specific

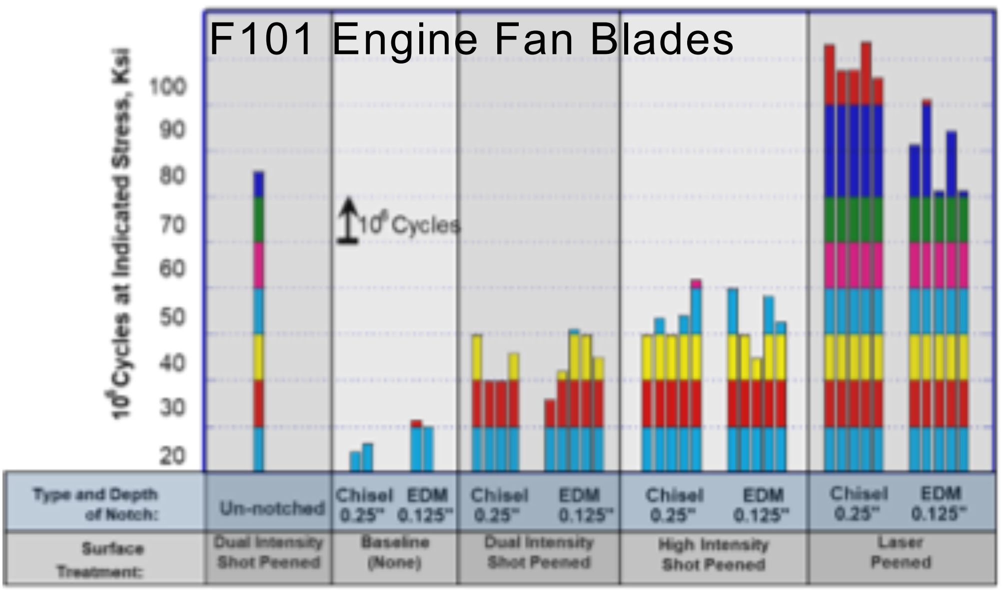
Commercial Applications

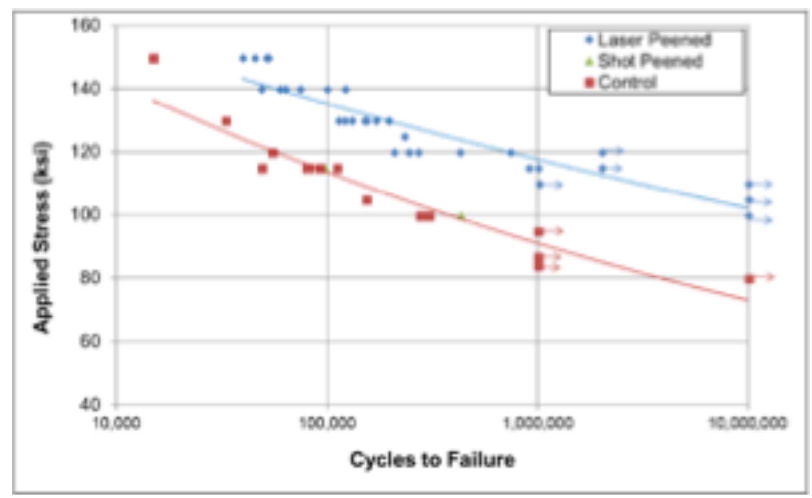
Commercial Usage of Laser Impulse

Laser Peening - Residual Stress & Service life Enhancement





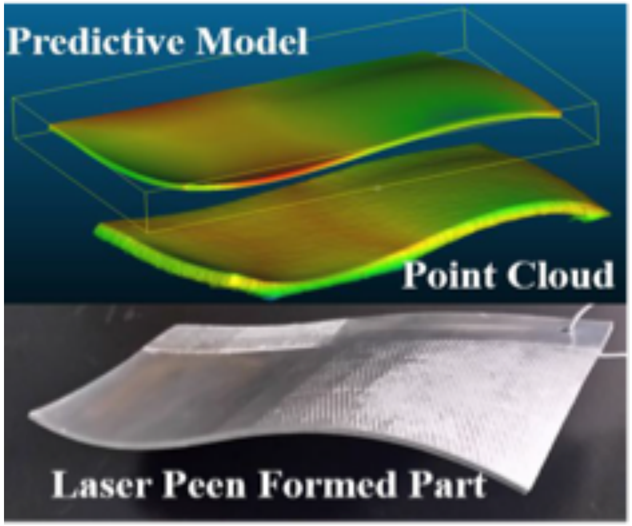


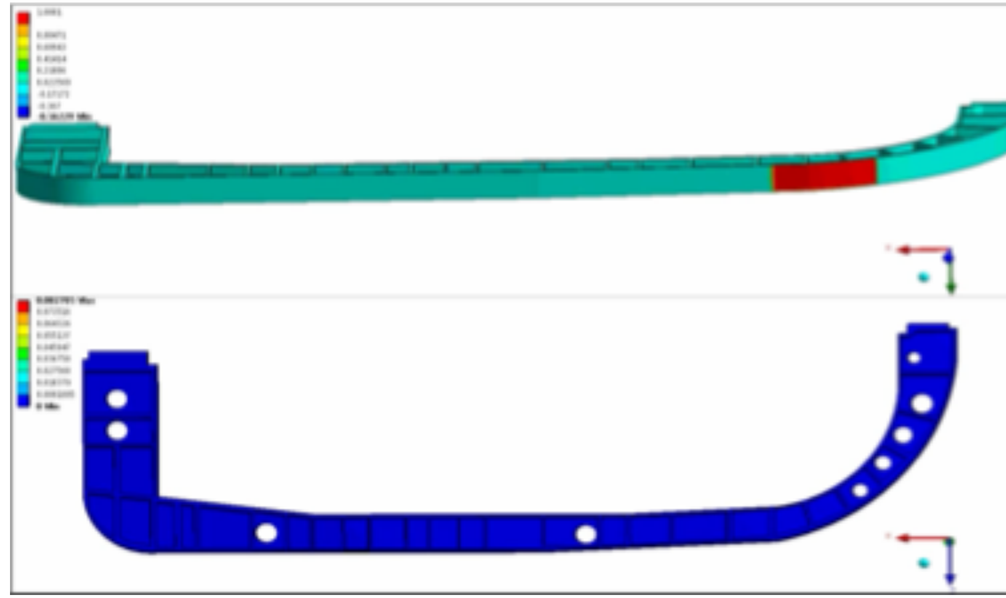


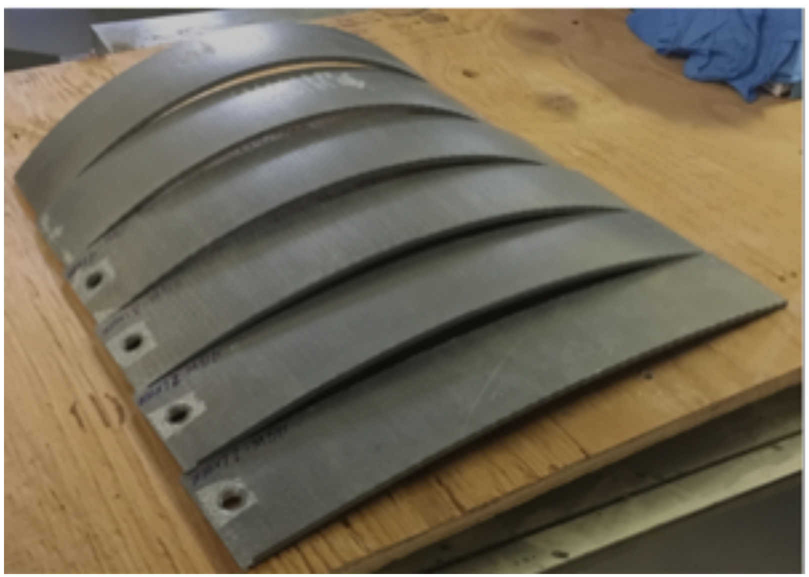
4340 alloy steel bending fatigue

Commercial Usage of Laser Impulse

Laser Peening - Residual Stress : Shape Forming & Correction

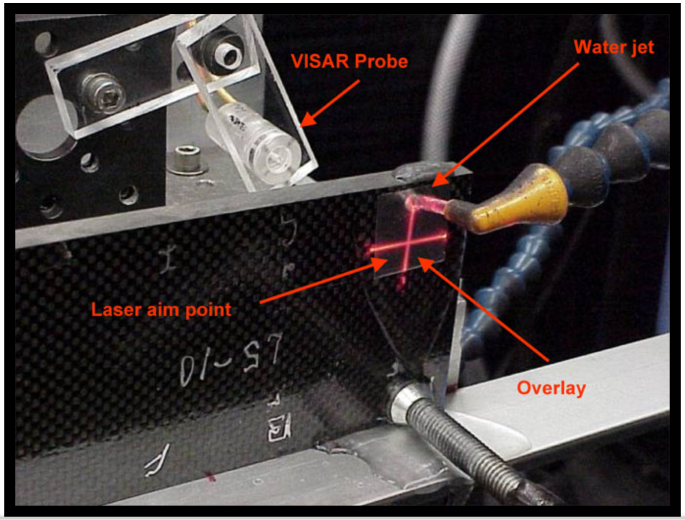






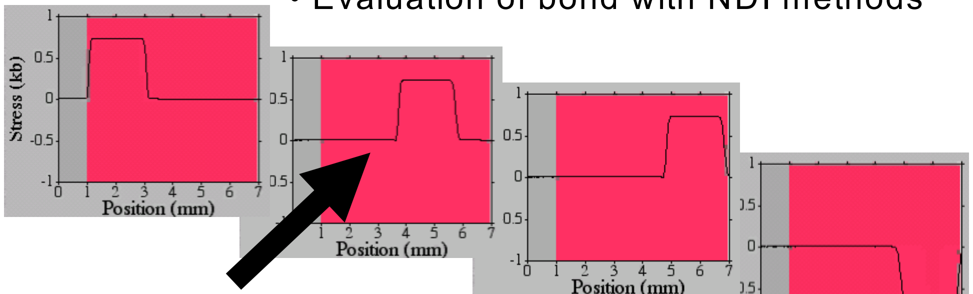
Commercial Usage of Laser Impulse

Laser Bond Inspection - Stress Wave : Bond Integrity Test

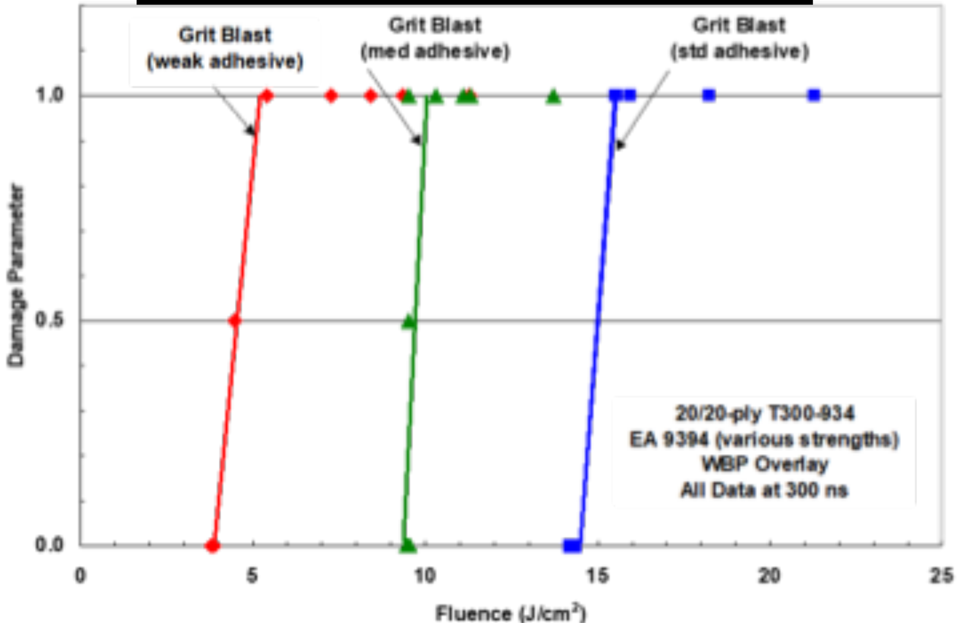


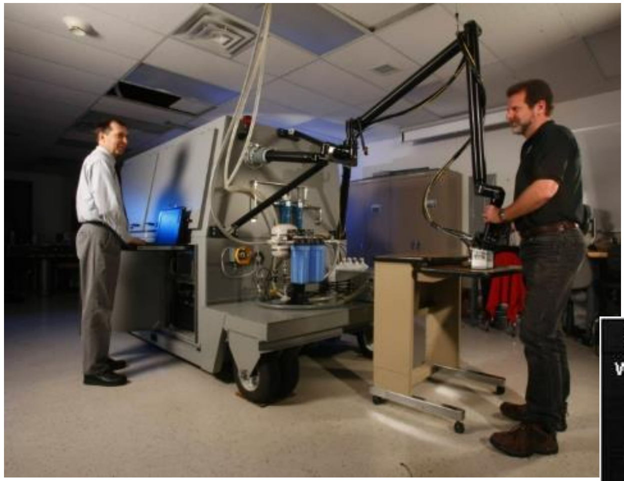
Inspection Process

- Generation of pressure pulse
- Propagation of pulse
- Evaluation of bond with NDI methods



Propagation of pressure pulse





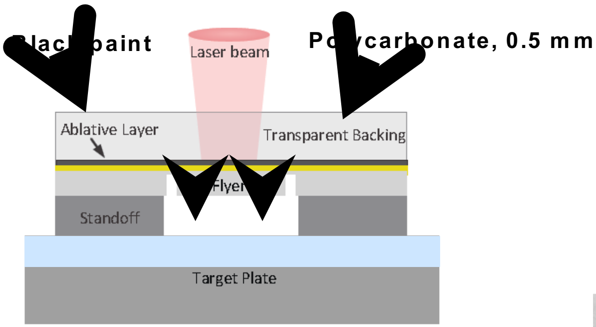
Data per Bossi, J. Materials Evaluation, 2009

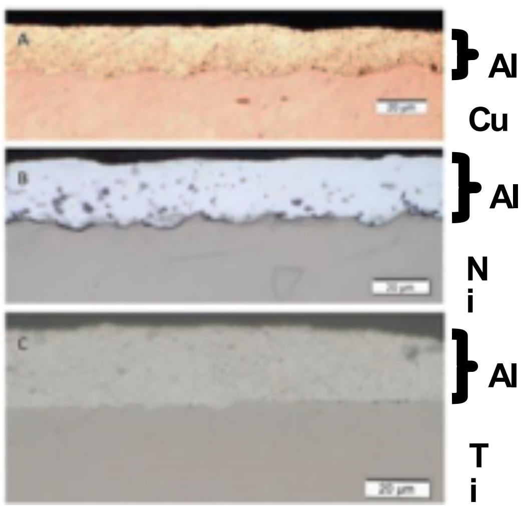
Developing Applications

Developing Uses of Laser Impulse

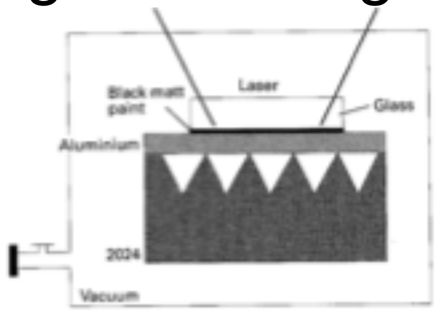
Joining Applications

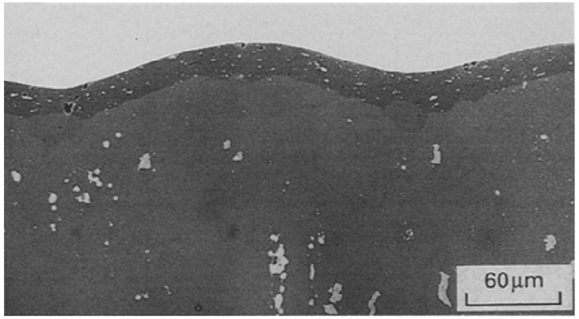
Laser Impact Welding & Cladding

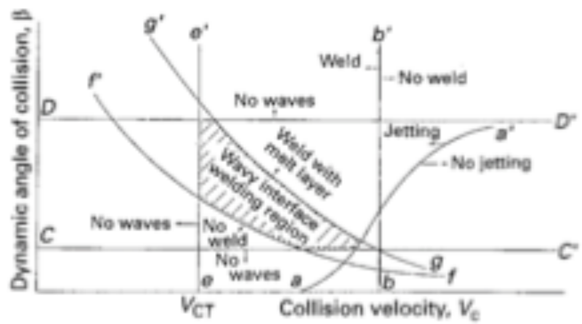




Images per D. Liu, Welding J, 2013

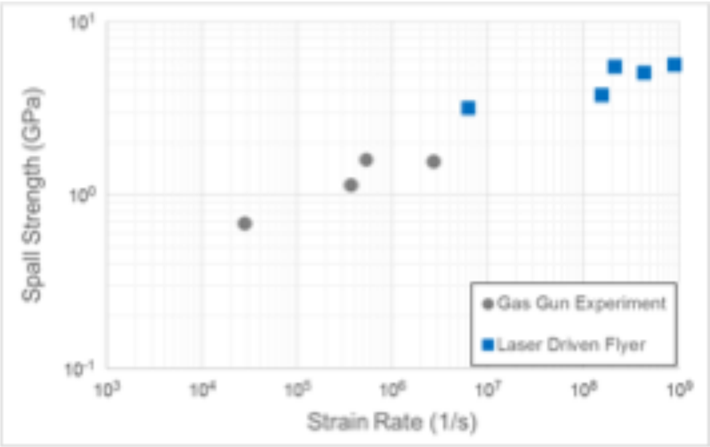




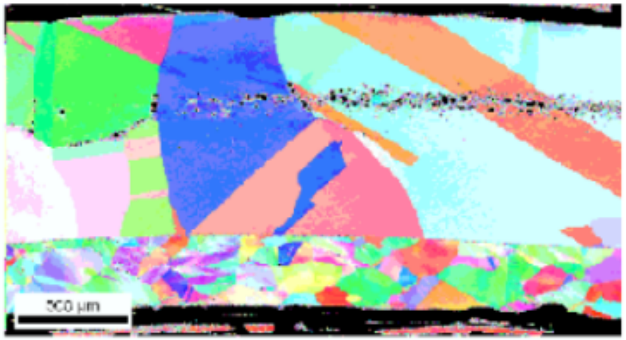


From: Dubrujeaud, Jo Mat Sci Letters, 1994

Laser Driven Flyers

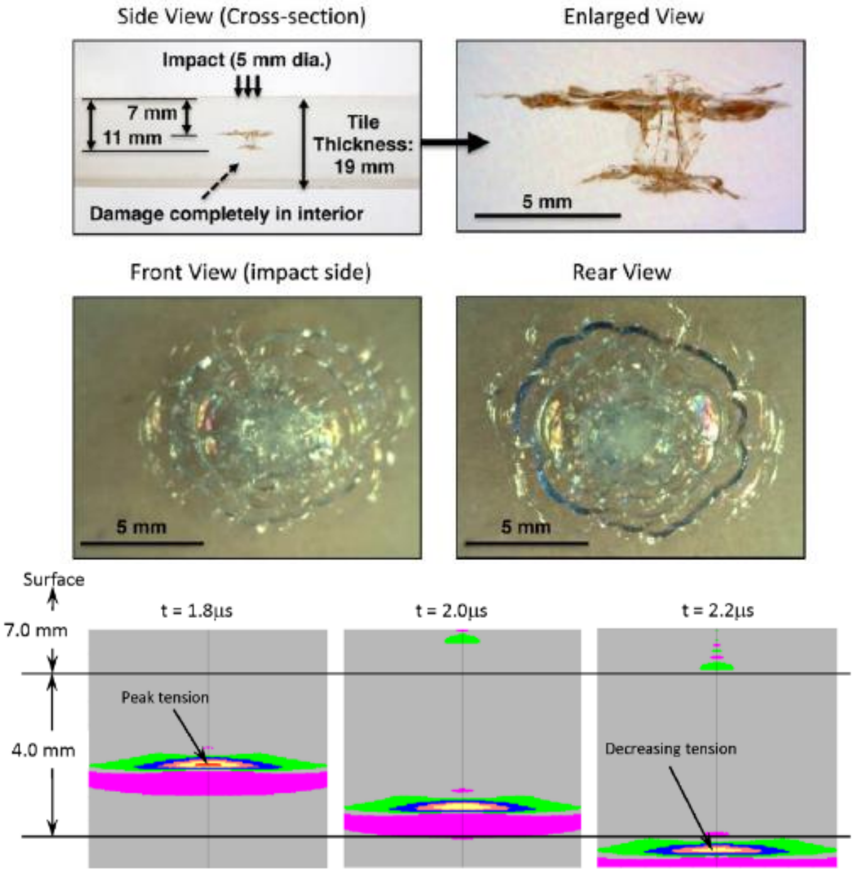


Copper spall strength based on strain rate



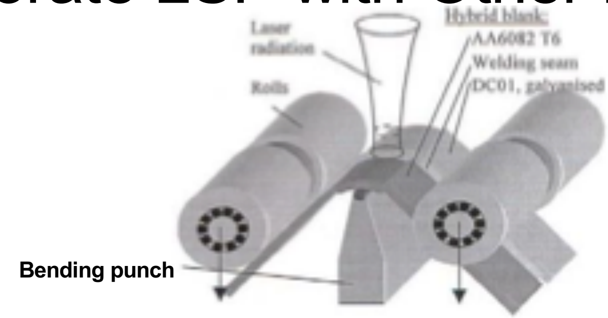
From Luo, SPIE Conf, 2008

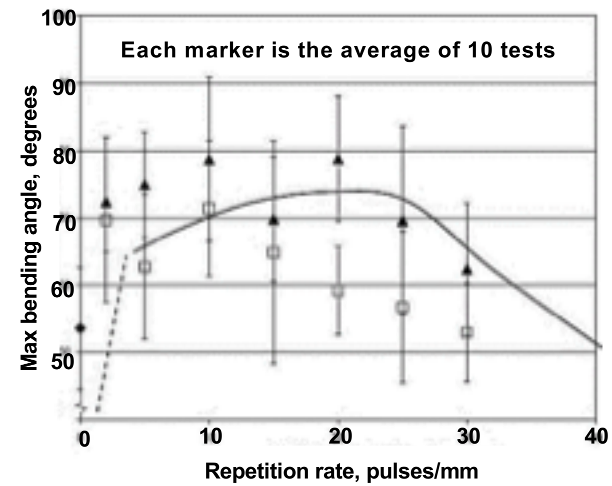
Strength Testing



From Holmquist, Intl. Jo App Glass Science, 2014

Incorporate LSP with Other Processes

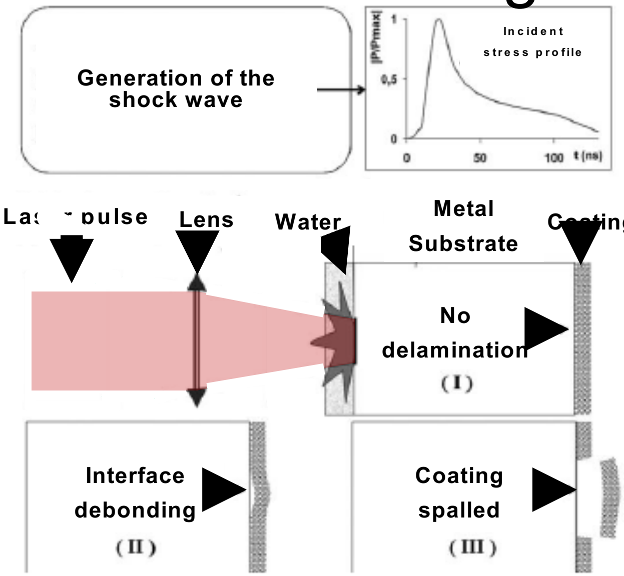


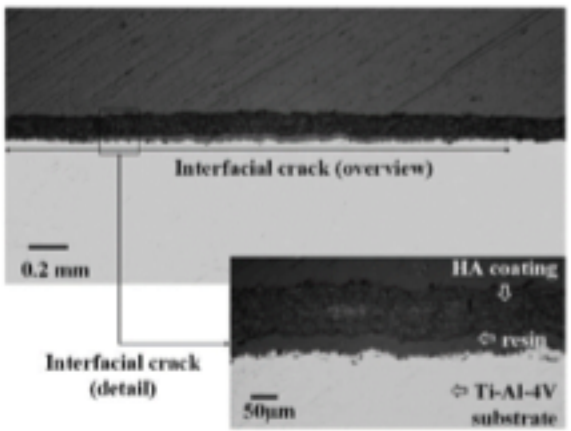


- Test without laser peening
- Test with laser peening, no water overlay
- Test with laser peening , water overlay

From: Niehoff, Proc 2nd Int Conf on Deformation Processing and Structure of Materials, 2005

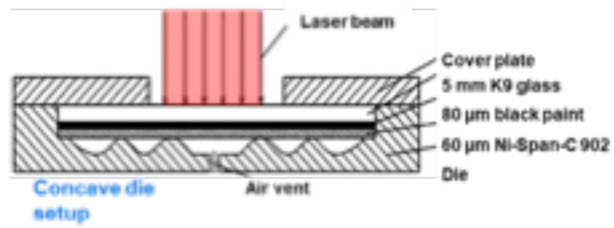
Adhesion Testing



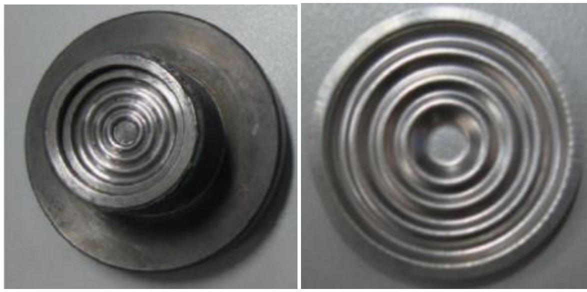


From: Guipont, Biomed Res A, 2010

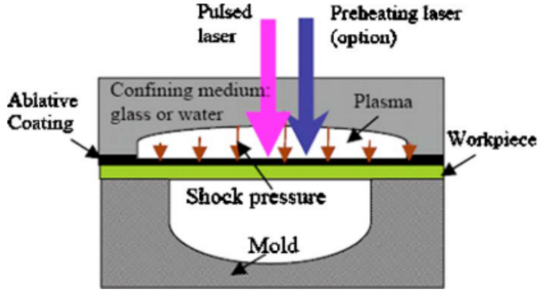
Direct Forming Capabilities



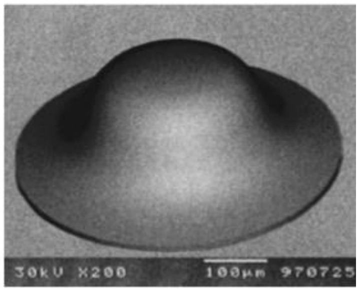
From: Jiang, Optics and Laser Tech, 2013

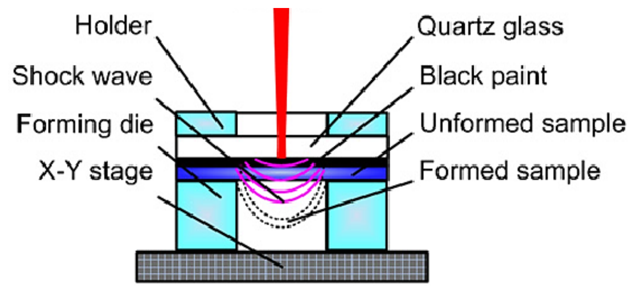


Forming die **Formed piece**

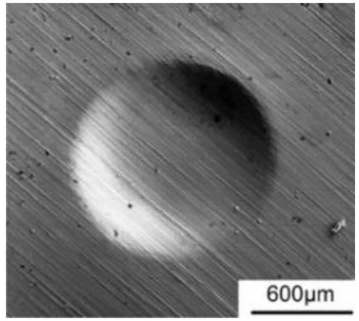


From: Cheng et al., J Applied Physics, 2007





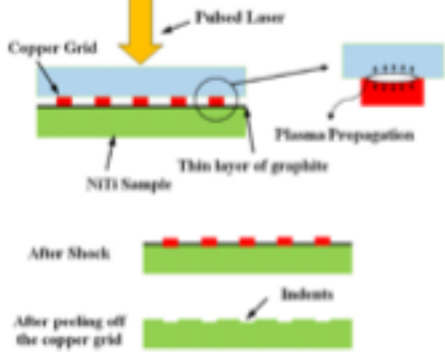
From: Zheng, Int J Mach Tools & Manuf, 2010

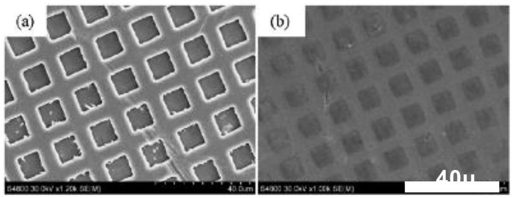


Developing Uses of Laser Impulse

Lab-scale Applications

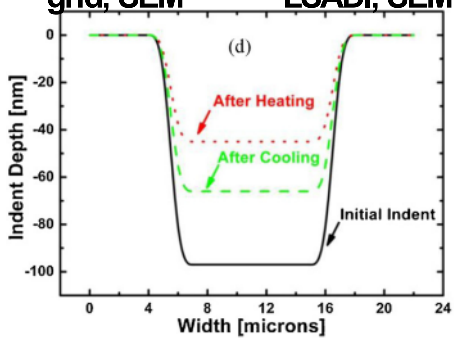
Imprinting and Marking





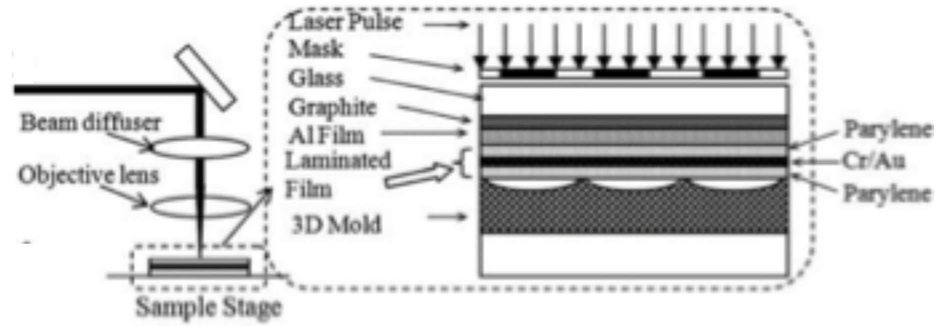
Copper grid, SEM

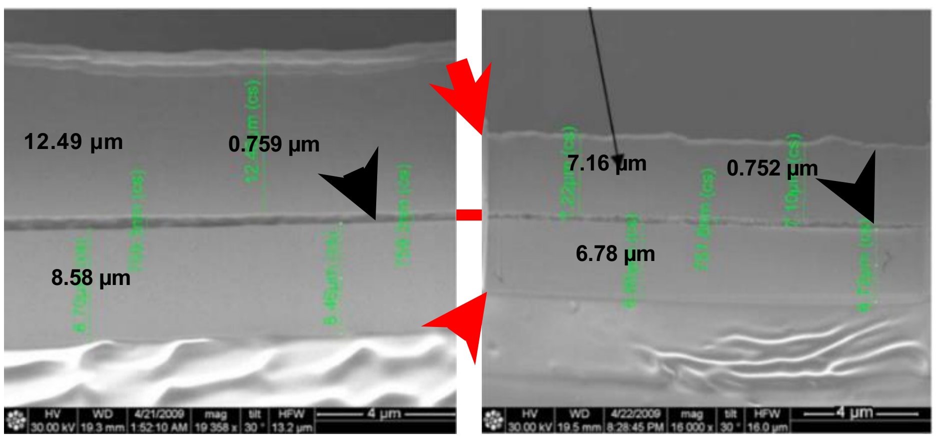
NiTi after LSADI, SEM



From: Ye, Appl Surf Sci, 2012

Contouring of Films





3D focused ion beam tomography layer thicknesses before and after laser shock forming at 0.25 GW/cm^2

From: Yu, Applied Physics Letters, 2009

KEY TAKEAWAYS

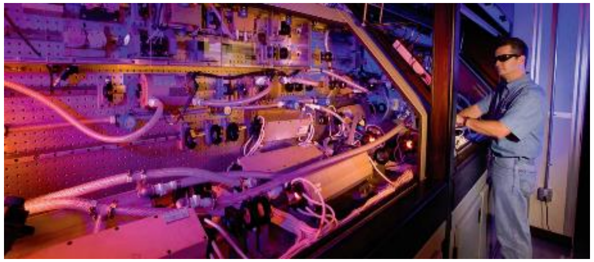
Laser impulses are versatile

Research and development is plentiful

Opportunities and Challenges in Laser Impulse Generation

High energy density research facilities/equipment

Accessibility beyond Omega, NIF, Vulcan, Trident, etc.

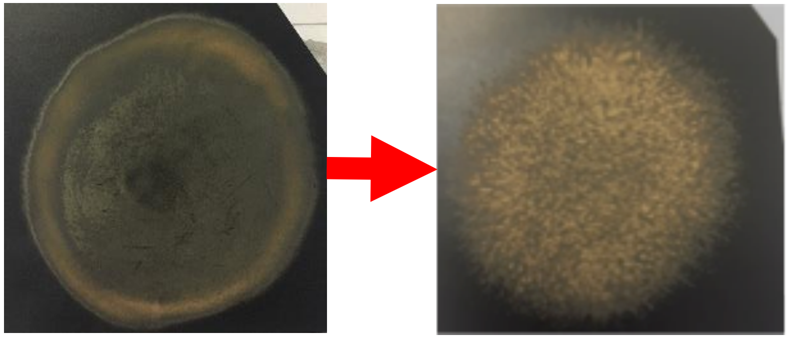


Enhanced understanding of laser – plasma – stress wave interactions

(2015 Review of the Inertial Confinement Fusion and High Energy Density Science Portfolio: Volume I – May 2016)

"The codes and models themselves are not capturing the necessary physics to make such predictions with confidence….

There are areas of physics that are not well understood or not properly captured in models, codes, and current simulation approaches."



Simplified laser beam shaping and delivery tools

Minimize energy losses

Tailor temporal and spatial for application optimization

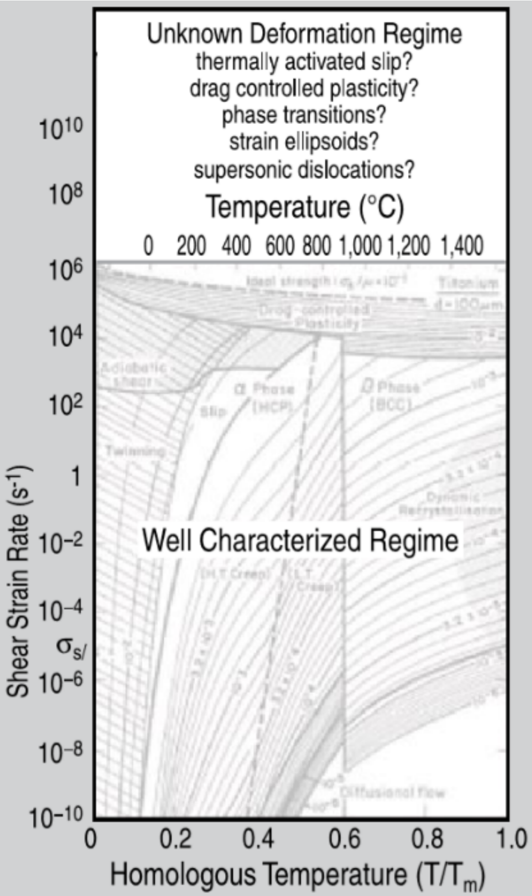


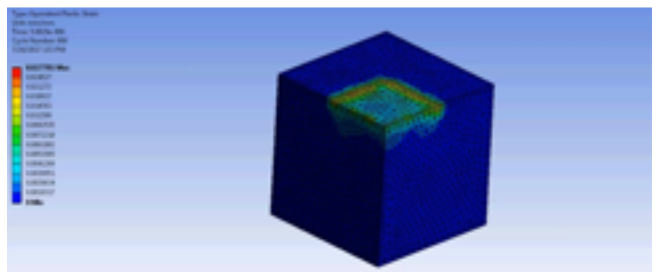
Figure 1. The Weertman–Ashby map of strain rate vs. temperature and unknown regime.

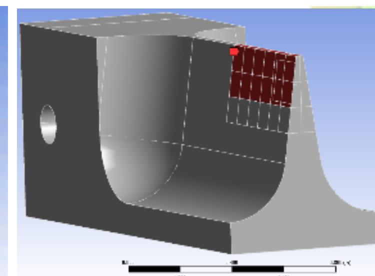
From: Meyers, JOM, 2010

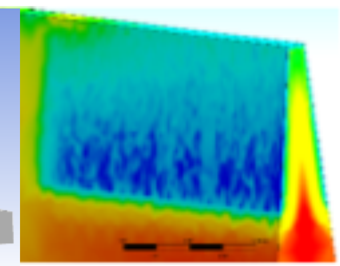
Further understanding of high-strain rate plasticity mechanisms

Unified modeling approaches

- Multi-scale validation, availability



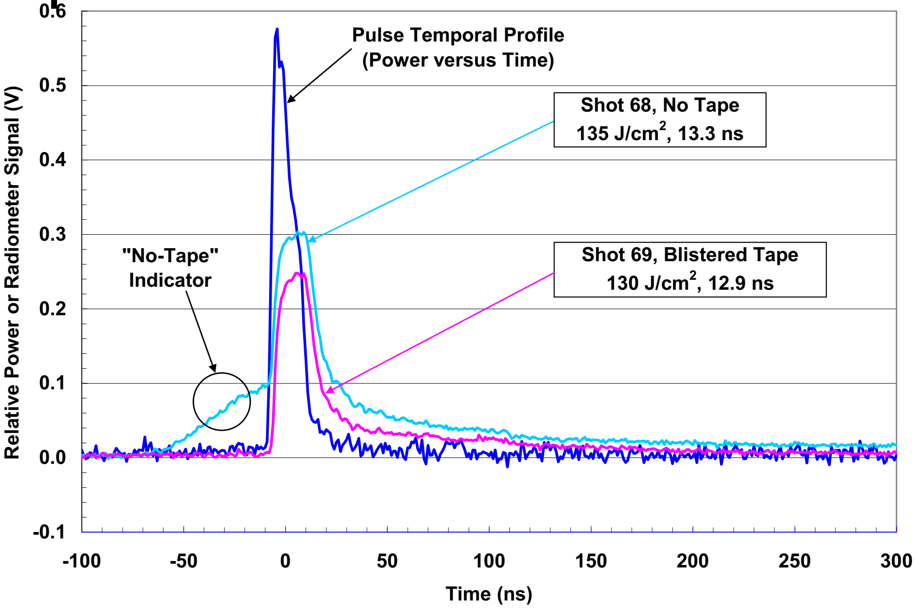




Optimized process parameters for specific applications

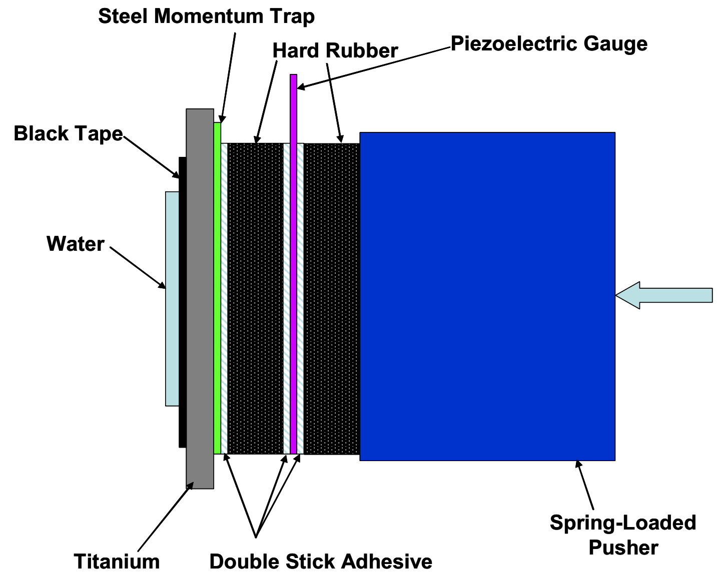
Non-destructive quality measurements for process and materials

- Ensure process completeness
- Standardize laser – process performance with more direct pressure measurements



Comparison of radiometer records with and without tape

Data Developed with USAF Funding



THANK YOU FOR THE OPPORTUNITY TO SHARE

Questions?

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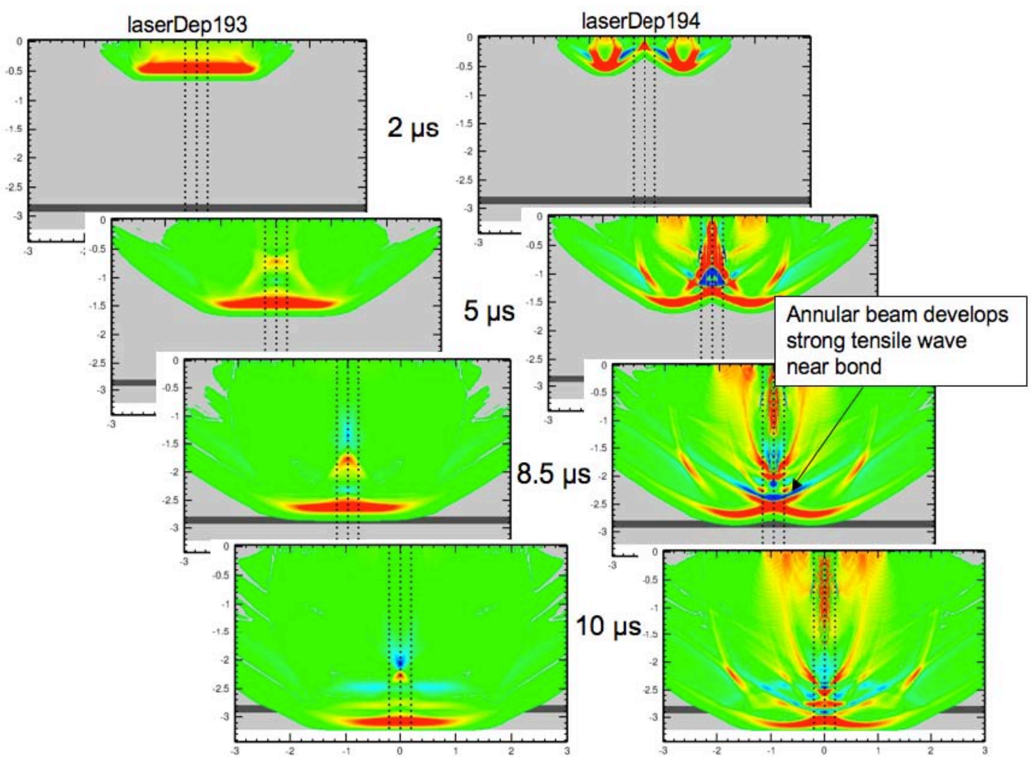
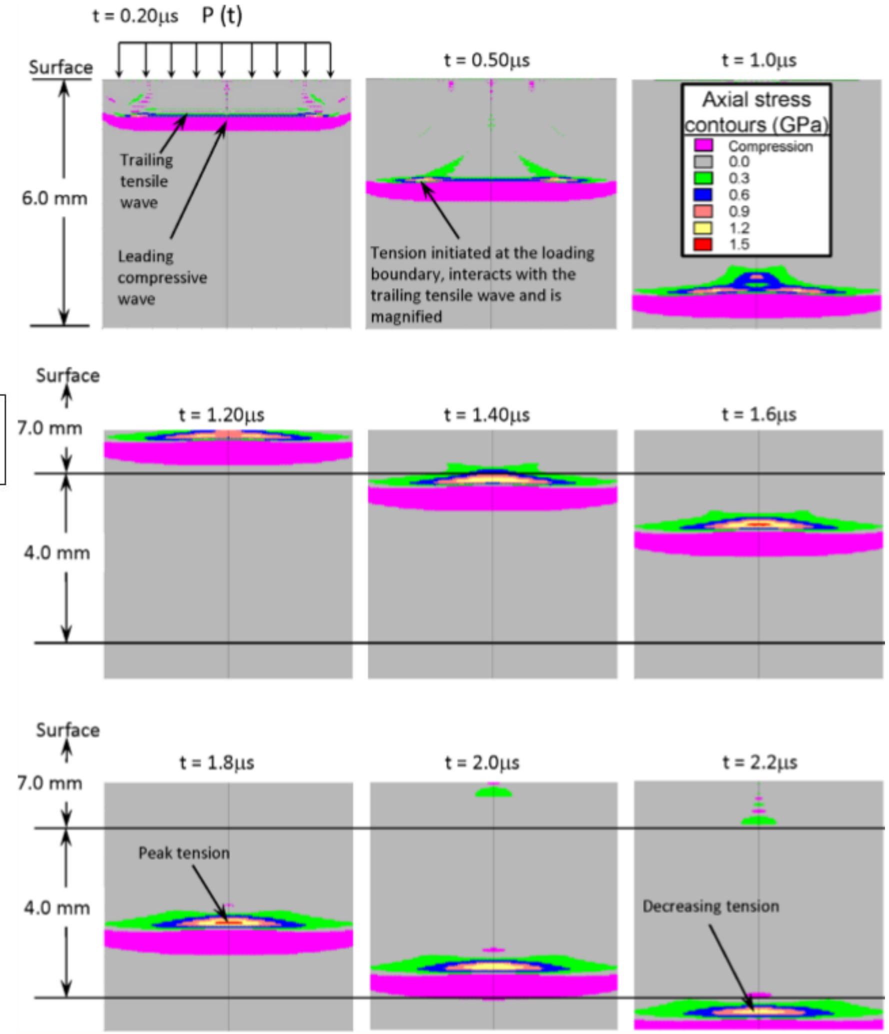
614-718-3000x415

Laser Driven Shockwaves

Models of Shock Process



CTH Hydrocode



From Holmquist, Intl. Jo App Glass Science, 2014

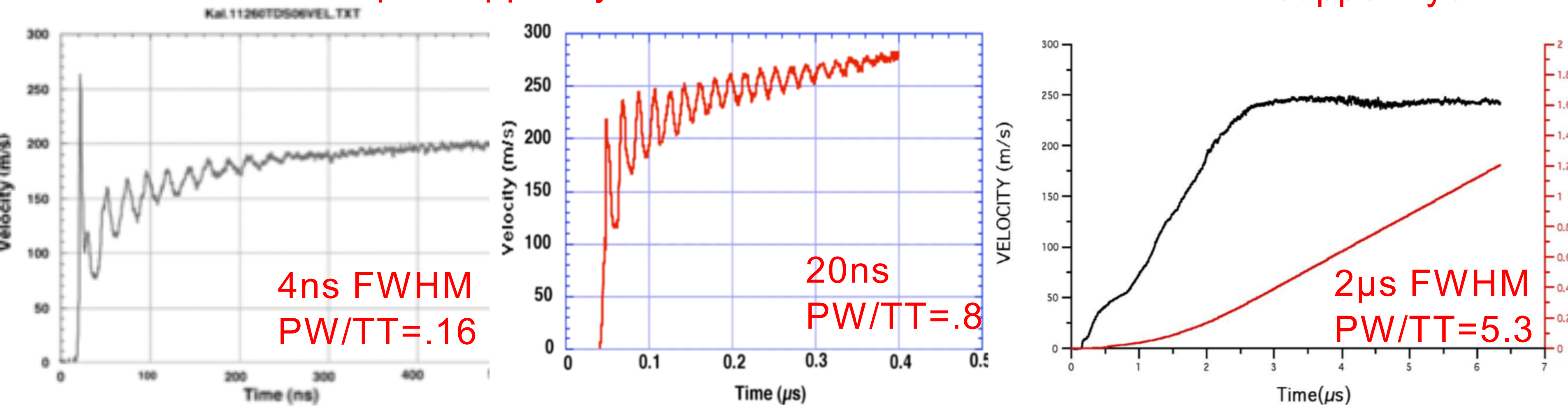
EPIC Hydrocode

Laser Flyer / Welding & Cladding

Optimization Potentials

50 µm copper flyer

2mm copper flyer

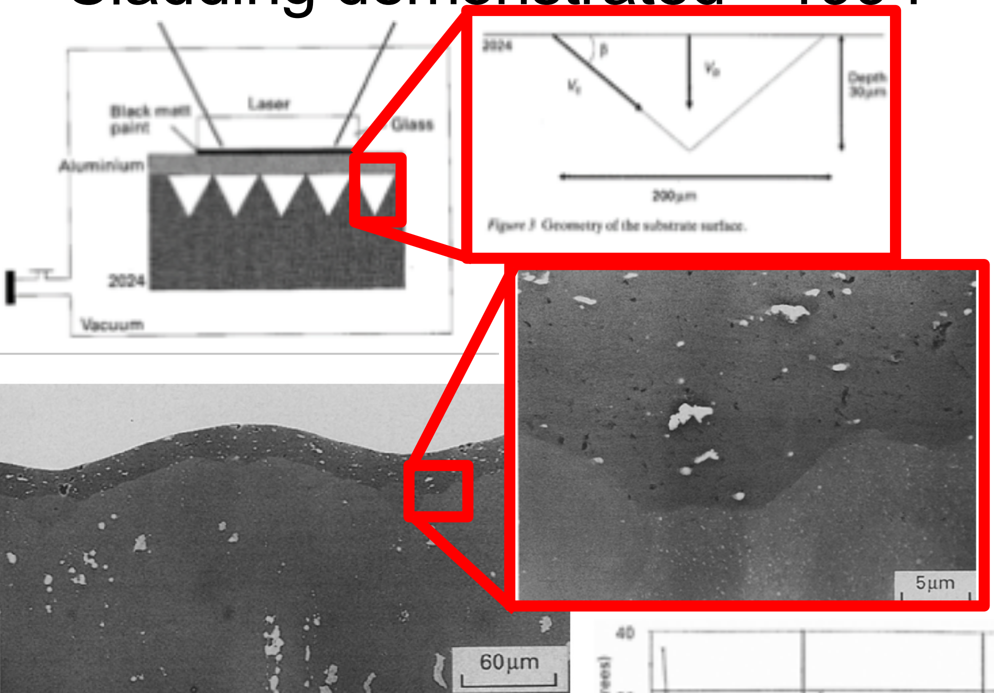


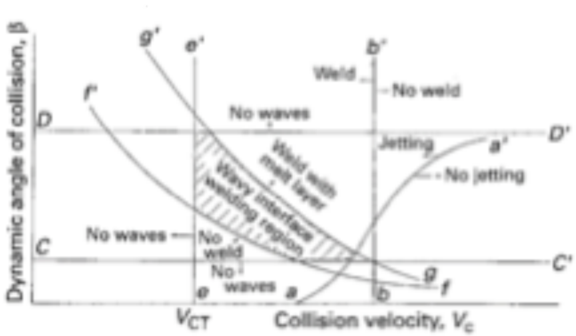
From: Paisley, Proc. of SPIE, 2006

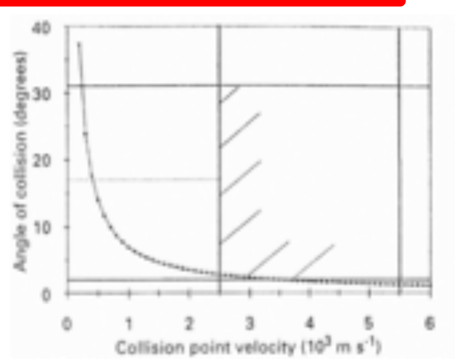
Research shows for optimization:

1. Uniform acceleration when FWHM > 1-5x roundtrip travel time of shock in flyer
2. Thicker materials (0.25mm – 2mm) require lasers with >30J and 100ns FWHM pulse
3. Coatings can enhance performance

Cladding demonstrated - 1994

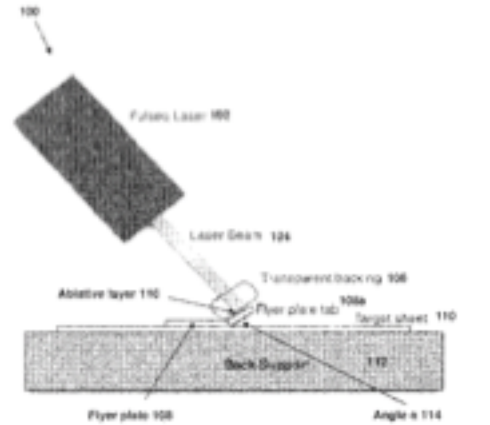




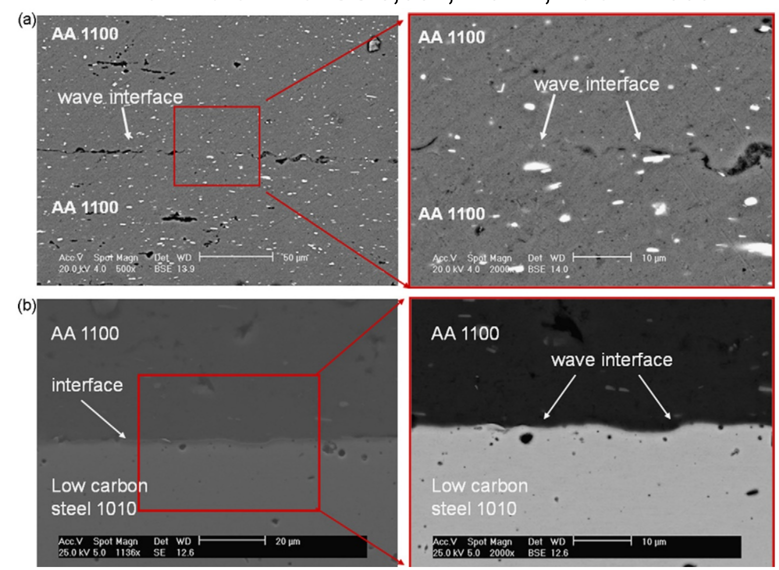


From: Dubrujeaud, Jo Mat Sci Letters, 1994

LIW Patent and Process



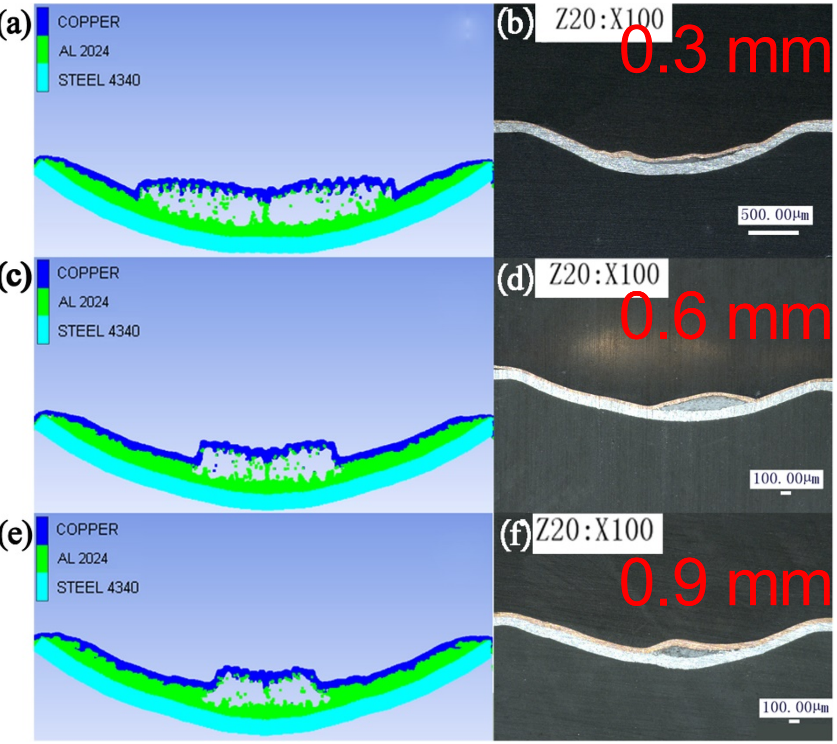
From Patent No. US 8,084,710 B2, Daehn 2009.



From Zhang, Jo Mat Proc Tech, 2011

Laser Impact Welding

Impact of standoff distance



From: Wang, Optics & Lasers in Eng, 2016