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SERDP and ESTCP Webinar Series

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  1. Listen to the broadcast audio if your computer is equipped with speakers
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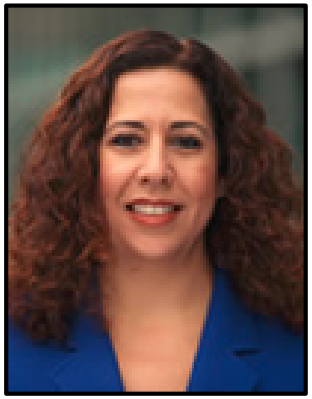
Laser De-Paint and Surface Preparation Mechanism and Technologies

October 19, 2017

Welcome and Introductions

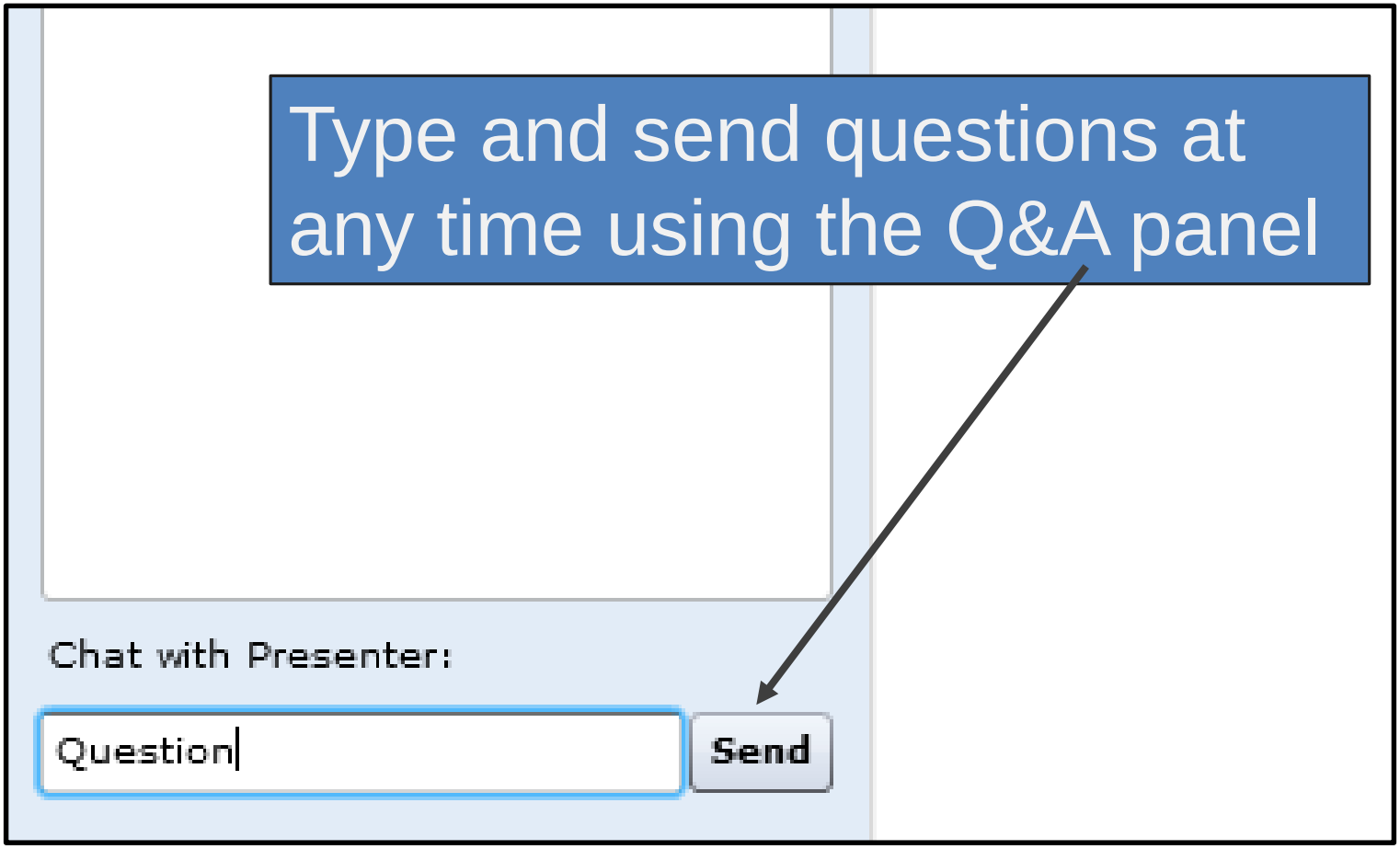


Rula A. Deeb, Ph.D.
Webinar Coordinator

Webinar Agenda

- **Webinar Logistics** (8 minutes)
  Overview of SERDP and ESTCP
  Dr. Rula Deeb, Geosyntec Consultants
- **Laser Technology for Aerospace Applications** (25 minutes + Q&A)
  Mr. Tom Naguy, Air Force Materiel Command, Wright Patterson Air Force Base
- **Laser-Interference Surface Preparation for Enhanced Coating Adhesion and Adhesive Joining of Multi-Materials** (25 minutes + Q&A)
  Dr. Adrian Sabau, Oak Ridge National Laboratory
- **Final Q&A session**

How to Ask Questions



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    - Call into the conference line: 303-248-0285
    - Required conference ID: 6102000
- Submit a question using the chat box

SERDP

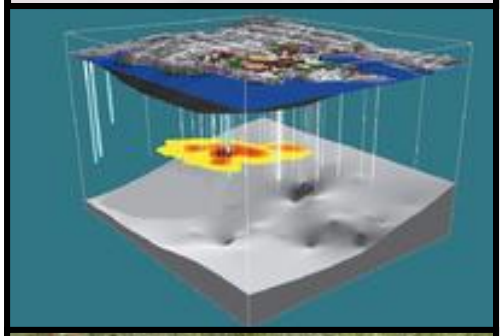
- Strategic Environmental Research and Development Program
- Established by Congress in FY 1991
  - DoD, DOE and EPA partnership
- SERDP is a requirements driven program which identifies high-priority environmental science and technology investment opportunities that address DoD requirements
  - Advanced technology development to address near term needs
  - Fundamental research to impact real world environmental management

ESTCP

- Environmental Security Technology Certification Program
- Demonstrate innovative cost-effective environmental and energy technologies
  - Capitalize on past investments
  - Transition technology out of the lab
- Promote implementation
  - Facilitate regulatory acceptance

Program Areas

1. Energy and Water
2. Environmental Restoration
3. Munitions Response
4. Resource Conservation and Resiliency
5. Weapons Systems and Platforms



Weapons Systems and Platforms

- Major focus areas
  - Surface engineering and structural materials
  - Energetic materials and munitions
  - Noise and emissions
  - Waste reduction and treatment in DoD operations
  - Lead free electronics

SERDP and ESTCP Webinar Series

Date	Topic
November 2, 2017	Platforms for Underwater and Near-Shore Munitions Surveys
November 16, 2017	Building Envelope Technologies
December 7, 2017	Management of Novel Hawaiian Ecosystems

For upcoming webinars, please visit

http://serdp-estcp.org/Tools-and-Training/Webinar-Series

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SERDP • ESTCP SYMPOSIUM

2017 | Enhancing DoD's Mission Effectiveness

A three-day symposium showcasing the latest technologies that enhance DoD's mission through improved environmental and energy performance

- November 28 - November 30, 2017
- Washington Hilton Hotel
  1919 Connecticut Avenue, NW
  Washington, DC 20009
- ***Registration is open***

Laser Technology for Aerospace Applications

Tom Naguy
Air Force Materiel Command
Wright Patterson AFB

Agenda

- Benefits of laser technology
  - Environmental/readiness/capabilities
- SERDP and ESTCP programs
- Future efforts
  - Applications areas
  - Research opportunities
  - Global opportunities
- Conclusions

Why Laser Technology?

Exceeding expectations! Offering numerous benefits…

Increased Mission Readiness

Reduced Environmental Impacts

Decreased Maintenance Costs

Improved Substrate Conditions

Utilized a spiral approach to qualify technology

Mobile robotic systems for full aircraft

Robotic lasers for aircraft components

Handheld laser for small areas

Laser energy safely applied to surface for decomposition and removal of coating into collection system

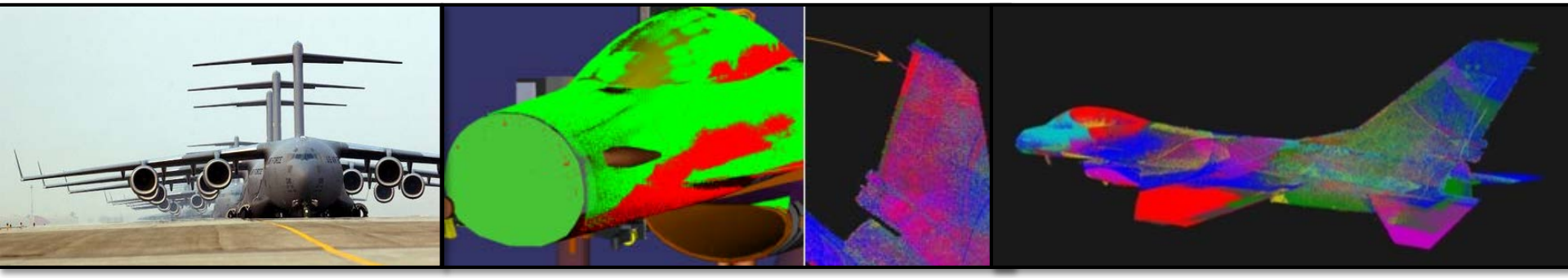
Increased Mission Readiness

Current Operation

- Long de-painting process of 2-4 weeks impacts warfighter readiness
- Limited aircraft throughput

Laser De-Paint Future State

- 50% reduction in de-paint flow days
- Expedited de-paint process improves aircraft availability
- Intelligent aircraft mapping enables maintenance operations such as CBM+ (Conditioned Based Maintenance+)



Get in…Get out! Back in the hands of our warfighters!

Reduced Environmental Impacts

Current Operation

- Carcinogenic working conditions… even in break rooms
- Large amounts of hazardous materials and waste disposal
- Excessive PPE requirements
- Regulatory monitoring and reporting

Laser De-Paint Future State

- Clean, control-room working environment
- No hazardous materials
- 99% reduction in total waste disposal
- Minimal PPE

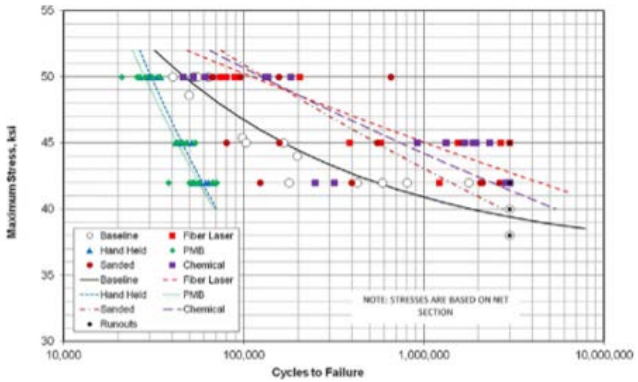
Making our maintainers' jobs safer!

PPE = Personal Protective Equipment

Improved Substrate Conditions

Current Operation

- Substrate damage results due to repetitive, over-time abrasive processes (harsh chemicals, media blasting, etc.)
- Reduces life of weapon system



Laser De-Paint Future State

- Extensive material testing confirms effects of laser de-paint on substrate are comparable to or better than other methods
- Fast processing results in little to no impact on substrate
- Ability to selectively remove coating layers

Improved substrate conditions extend life span of the weapon system!

SERDP/ESTCP Laser Programs and Progress

- *Laser Cleaning and Coating Removal System*
- SERDP-PP-139, 1998 – 2000
  - Scope
    - Focused on large off-aircraft components
    - CO_2 technology (6 kW CW)
    - Automation for multiple parts configurations
  - Identified critical laser and automation requirements!
- Transitioned automation system to ESTCP WP-0526

kW = kilo-watt; CW = Continuous Wave

SERDP/ESTCP Laser Programs and Progress

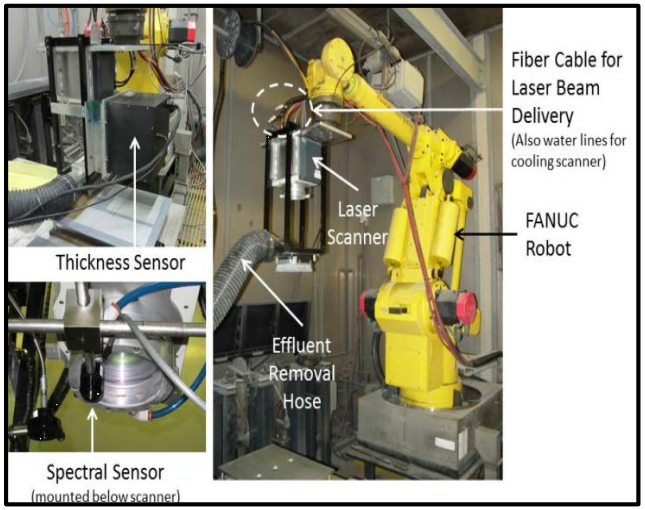
- *Portable Laser Coating Removal System*
  - ESTCP-200027; 2001 – 2005
  - Scope
    - Hand held laser technology
    - Evaluated pulsed lasers Nd:YAG/CO_2/diode
    - Established emissions, human factors requirements, and qualitative and quantitative performance requirements
  - Transitioned to field and depot operations!

SERDP/ESTCP Laser Programs and Progress

- *Robotic Laser Coating Removal System*
  - ESTCP WP-0526; 2005 – 2008
  - Scope
    - Large off-aircraft components using PAR Gantry Robotics – Multi-axis mirrors to deliver beam
    - Automation for complex and multiple components
    - Rofin-Sinar 6 kW CO_2 continuous wave (Next Gen CO_2 Laser!)
    - Demonstarted with KC-135 aircraft coatings
  - Implemented CO_2 Laser technology at Hill AFB!

SERDP/ESTCP Laser Programs and Progress

- *High Speed, Substrate Safe Low Observable Coating Laser Stripping*
  - WP-2146; 2010 – 2015
  - Scope
    - Automated robotic system
    - Evaluated IPG 6kW fiber – CW @ 1070 nm
    - Removal of generic specialty coating systems - selective
    - Identified critical constraints and control issues
      - Real time thickness monitoring, selective stripping, color recognition
  - Technologies are baselined for next generation coming soon!



SERDP/ESTCP Benefits

- Critical laser parameters identified
  - Pulsed and CW beam characteristics
  - Minimum and maximum substrate laser energy to effect coatings removal and no substrate damage
  - Beam energy density optimization
- Automation
  - Critical to high power laser technology adoption)
  - Motion Control technology
    - Gantry vs. fixed vs. mobile
    - Laser Beam Path Programing
    - Color and coating thickness sensors

New Application Frontiers

- Laser de-paint
  - New coating systems/selective stripping
  - Substrate considerations
- Laser surface modification
  - Improve corrosion performance
- Laser bonding
  - Eliminate grit blast/adhesive primers…..
- Laser welding
  - Eliminate welding materials
- Laser fatigue enhancements
  - Eliminate peening materials/minimize surface defects

Research and Development Opportunities with DoD

A few thoughts…….

- Ultrafast pulsed laser technologies
- Lasers with multiple wavelengths/beam characteristics
- Optimized wavelengths for aerospace applications
- Materials and processes that are optimized for laser processing
- Control system technology for robotics and laser application

Global Opportunities

US Department of Defense (organic + contractor support)

$800 Million+

Foreign Military Sales (FMS)

$3 Billion+

Commercial Industries

Huge, Global Market Opportunities!
Each sector alone could exceed $1B!

Conclusions

- Laser technology has demonstrated significant benefits in aerospace de-painting!
  - Automotive and other industries are leading
- Laser technology has potential to expand in many areas
- Research and development of laser technology in support of aerospace manufacturing and sustainment is a new and needed capability

DoD is committed in R&D and applications of laser technologies to support our warfighter!

For additional information, please visit https://serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms

Speaker Contact Information

thomas.naguy.1@us.af.mil; 937-904-0075

Q&A Session 1

SERDP DOD • EPA • DOE | ESTCP

Laser-Interference Surface Preparation for Enhanced Coating Adhesion and Adhesive Joining of Multi-Materials

Dr. Adrian Sabau
Oak Ridge National Laboratory

SERDP DOD • EPA • DOE | ESTCP

Agenda

- Problem statement
- Project objective
- Why lasers for surface preparation?
- Results for laser-assisted surface preparation
- Importance and relevant to ongoing DoD efforts
- Benefits to end-users

Problem Statement

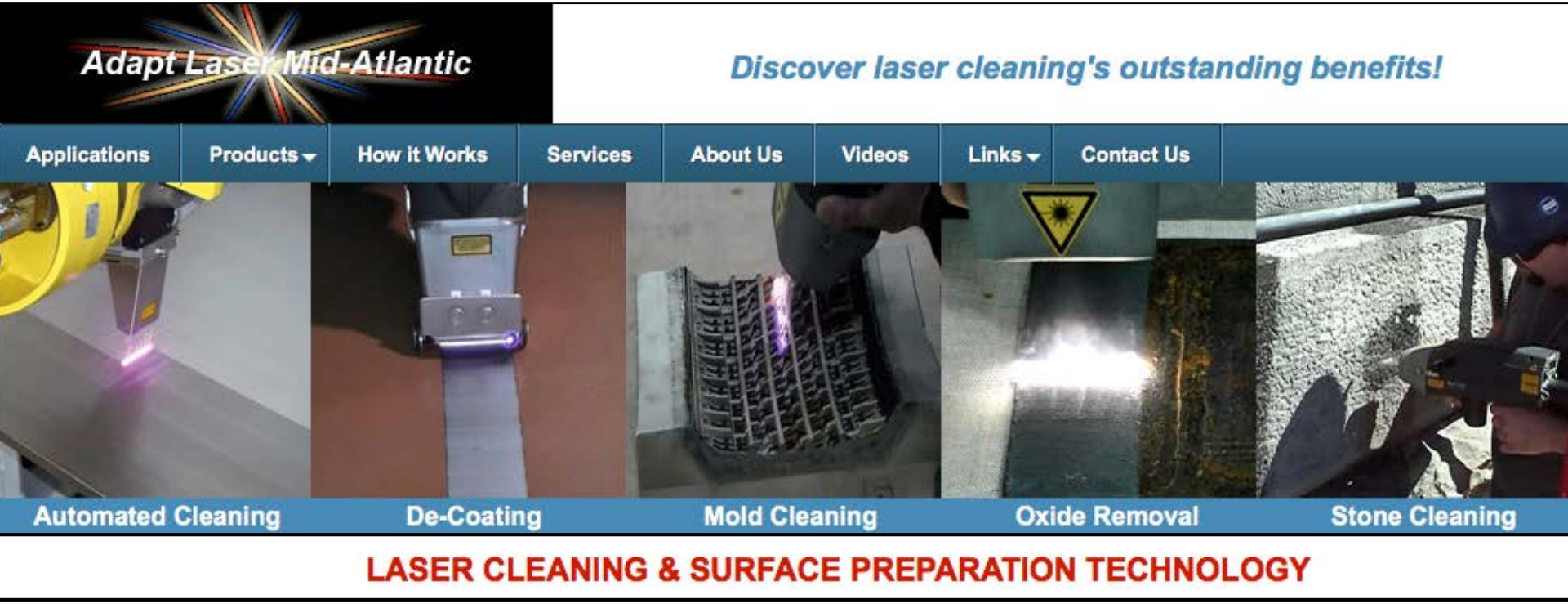
- DoD maintains tens of thousands of aircraft, ground vehicles, and ships
- Corrosion protection is accomplished using multi-step, complex painting/coating processes requiring cadmium, volatile organic compounds, and chromates
  - Annual DoD cost for corrosion protection is >$20 billion
  - Chromate solutions (hexavalent chrome - type I) are highly toxic
- New non-chemical processes for surface preparation would drastically reduce environmental impact, risks, and costs

Project Objective

- Investigate laser-interference structuring techniques as a replacement for chemical conversion coating
  - One-step process
  - Ambient conditions
- Applications
  - Coating systems
  - Adhesive bonding for aluminum and titanium aircraft components

Why Lasers?

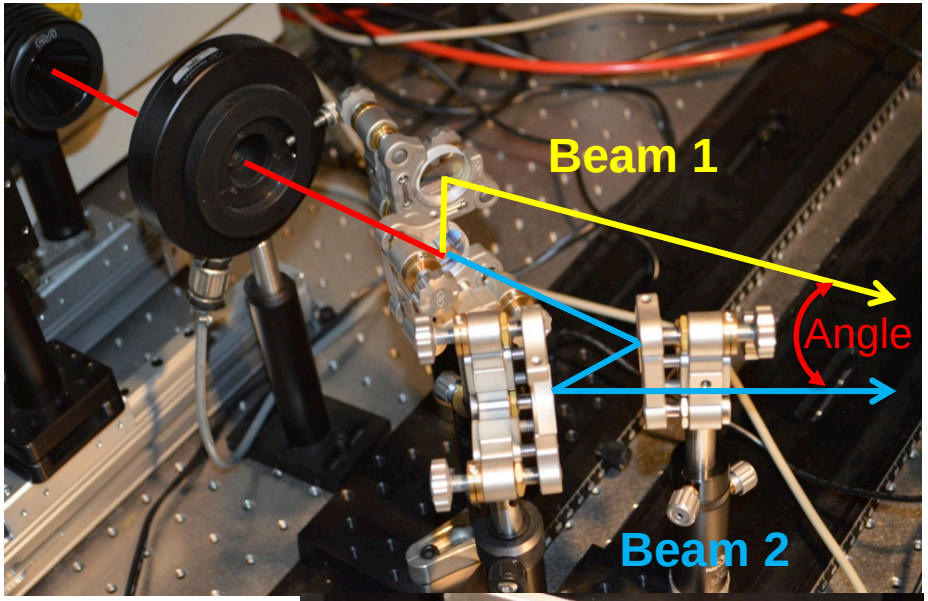
Laser Surface Cleaning is a DoD-Deployed Technology



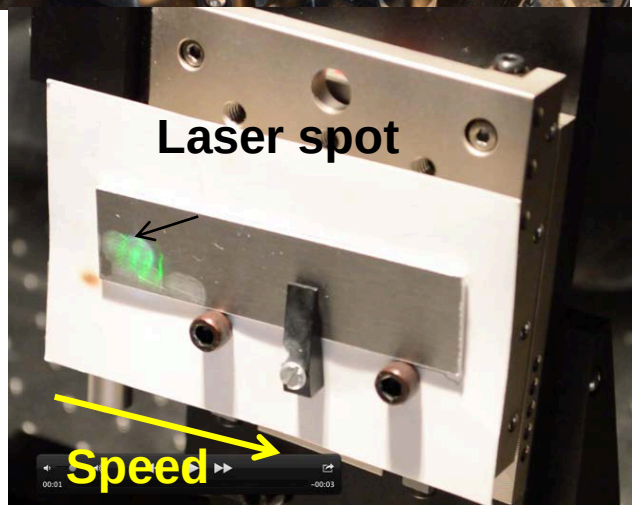
http://www.lasercleanall.com/

Laser Setup for Project

- Q-switched Nd:YAG laser system with an harmonic generator enabling the selection of very sharp wavelengths of 1064, 532, 355, or 266 nm
- Pulse duration 10 ns (heating and cooling rates > 1011 K/s), frequency 10 Hz
- Main variables related to laser-structuring
  - Wavelength
  - Beam angle
  - Spot size
  - Rastering speed



Sample mounted on a translational stage controlled by LabView

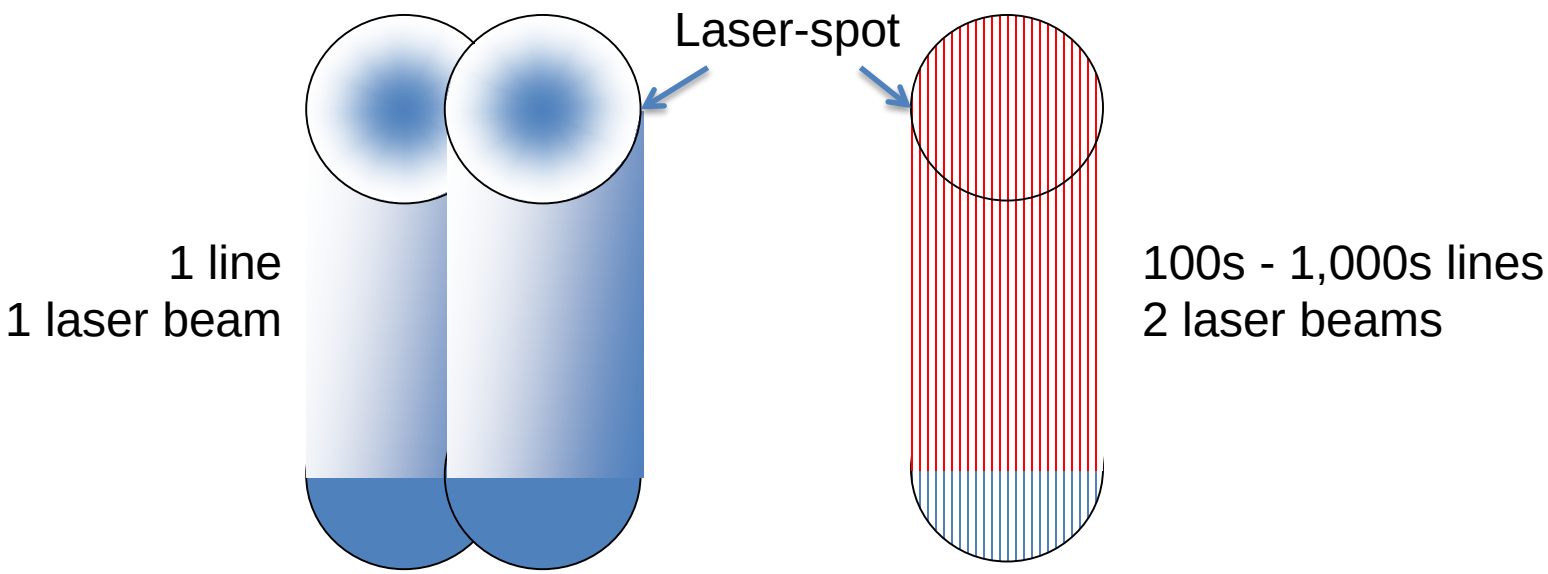


Nd:YAG = neodymium-doped yttrium aluminum garnet; Nd:$Y_3Al_5O_{12}$)

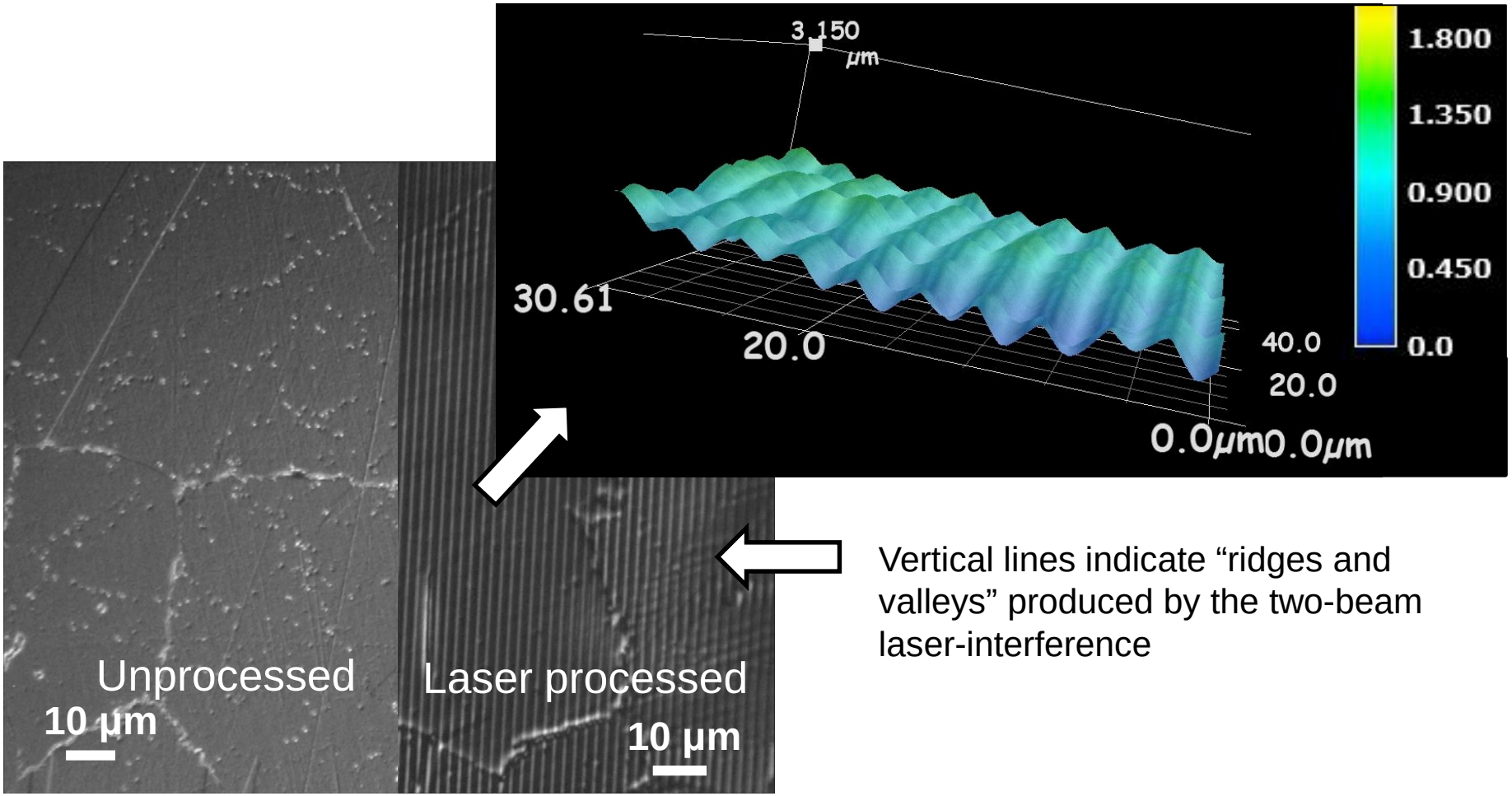
Paradigm Shift

More Structuring at the Same Productivity

Method	Traditional (1 beam laser)	New Laser-Interference (2 or more beams)
Structure	1 dimple per spot	300 to 15,000 mini dimples (pits) per spot
Sizes	500 µm diameter 10 µm depth	0.4 - 20 µm diameter <500 nm depth



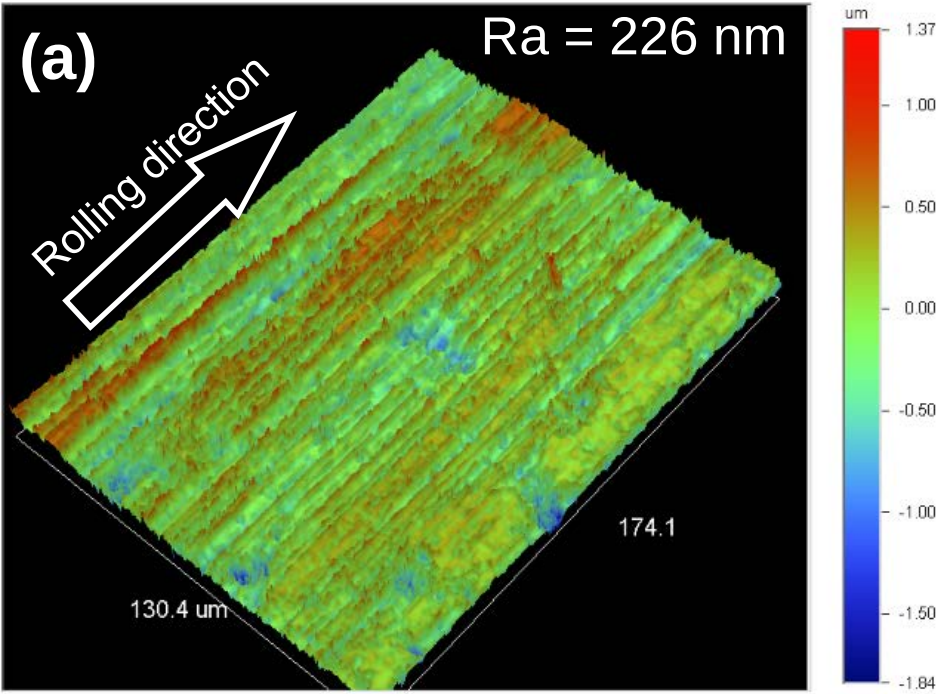
Laser-Interference Patterns for Polished Steel



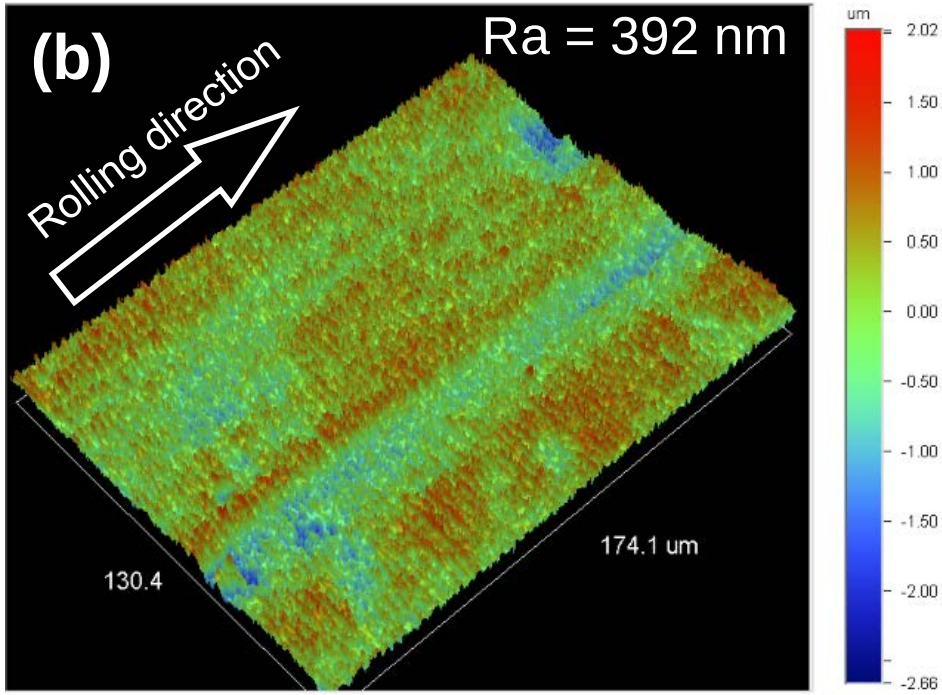
Vertical lines indicate “ridges and valleys” produced by the two-beam laser-interference

Increase in Surface Roughness

As-Received vs. Laser-Interference Structured Surfaces



As-received, unprocessed



Striations normal to rolling direction were produced by laser-interference structuring

Optical surface profile 10 pulses/spot (λ=355 nm, pulse fluence of 1.2 J/cm^2)

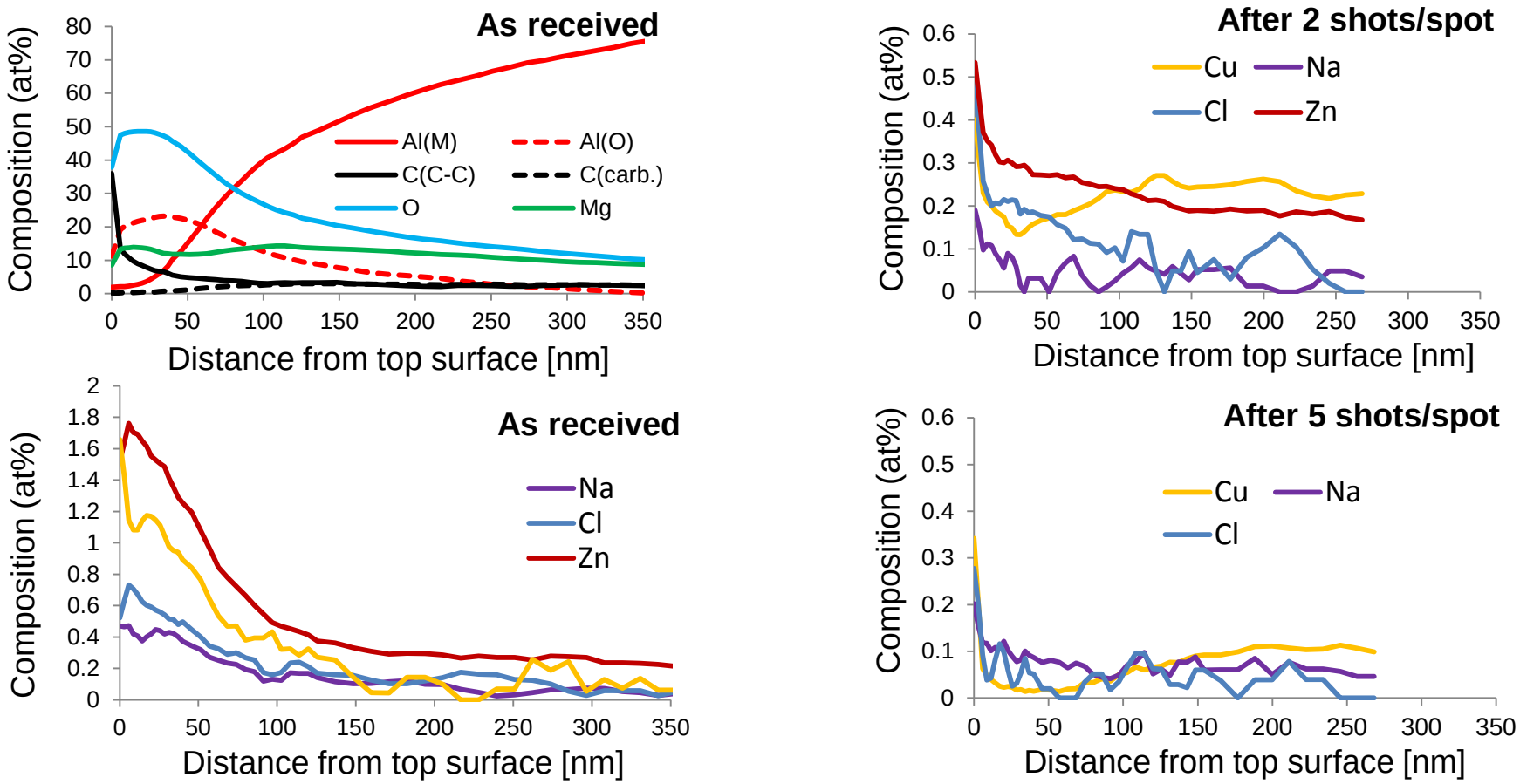
Ra = arithmetical mean roughness

Open Questions

- How effective is laser-interference in cleaning the surface?
- What surface structuring laser-interference can produce?
- How damaging is the laser structuring to the top surface?
- Does laser-interference induce surface cracks, as seen with traditional laser structuring?
- How beneficial is laser-interference structuring for mechanical strength of joints?

Laser-Interference Cleans Surface Effectively

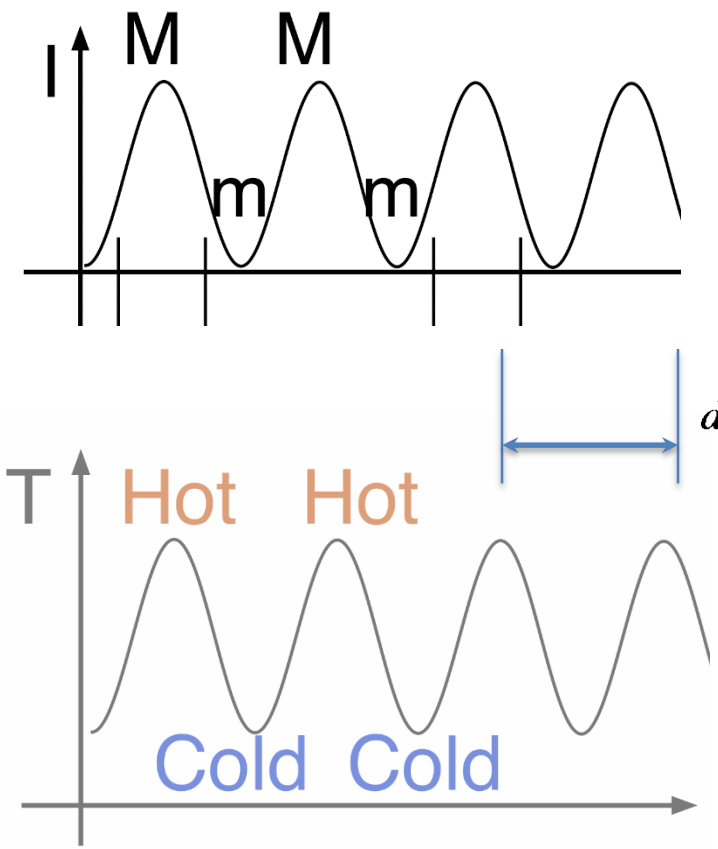
Eliminates the Need For Solvent



Note: X-ray photoelectron spectroscopy was used to investigate the Ar-ion depth profile for Al samples

Submicron Structure Height

Structures can be Line-Shaped for 2-Beam Laser Setup



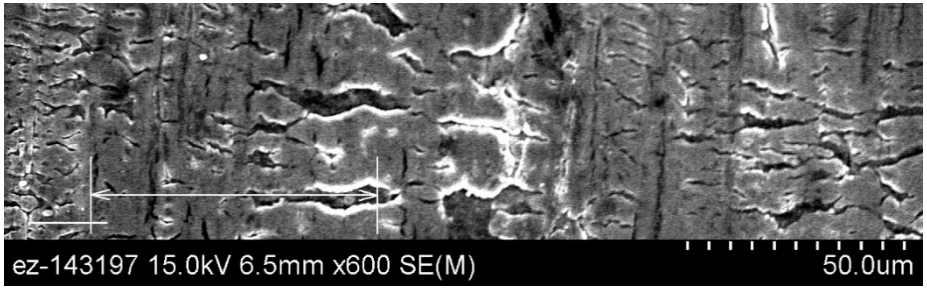
$$d(\lambda) = \frac{\lambda}{2\sin(\alpha/2)}$$

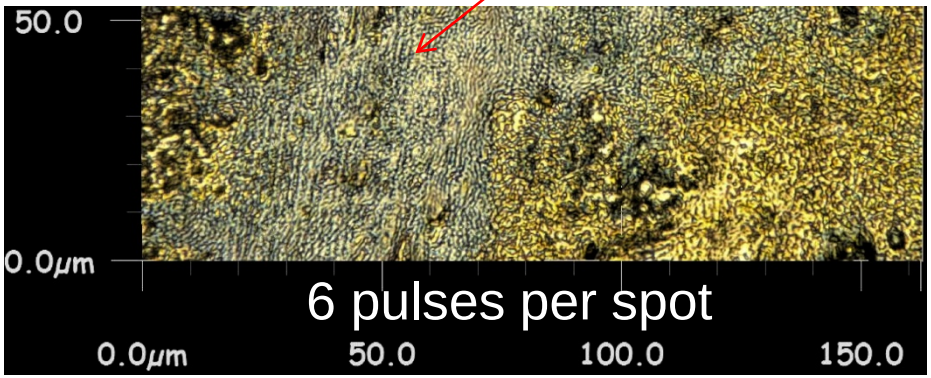
Values for the periodic distance between laser-interference structures, d [nm]

Beam angle [°]	d (355 nm)	d (1,064 nm)
3	6,800	20,300
12	1,700	5,100
36	570	1,700
72	300	900

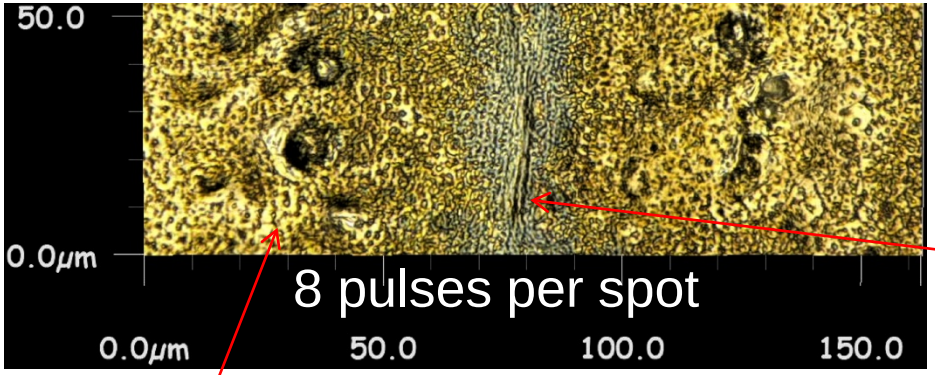
Smoother Laser-Processed Surface

Fewer Surface Cracks and Faults





Structured area



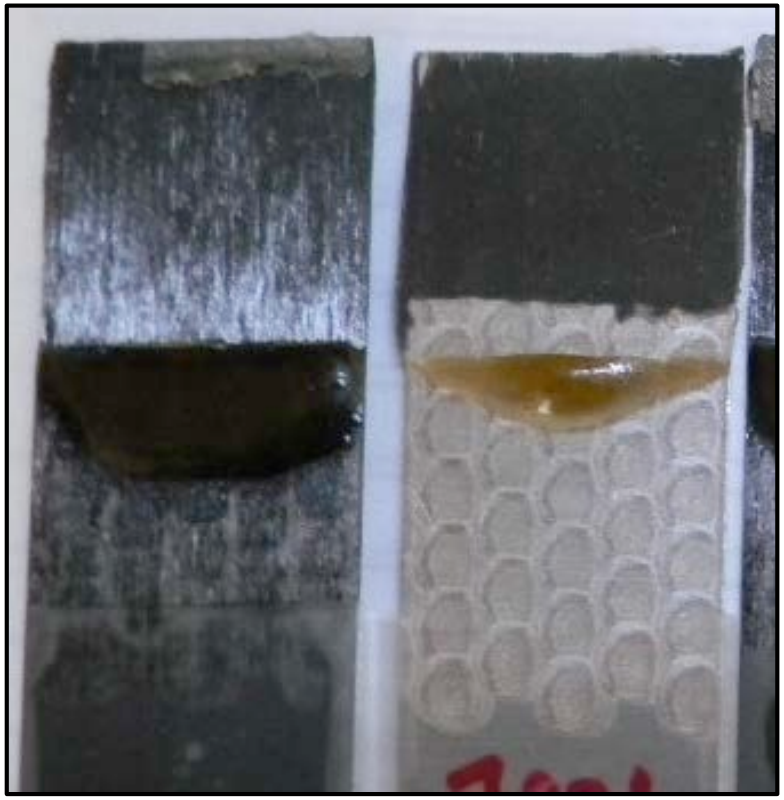
Network patterning at a finer length-scale in the center area (more structuring, less melting)

Web-like network structure (melting)

Note: Results for pulse fluence 1.17 J/cm^2 (Figure 7, Sabau et al. 2016)

Measured Single-Lap Shear Strength

Aluminum and Carbon-Fiber Polymer Composite Joints



Before testing → **After testing**

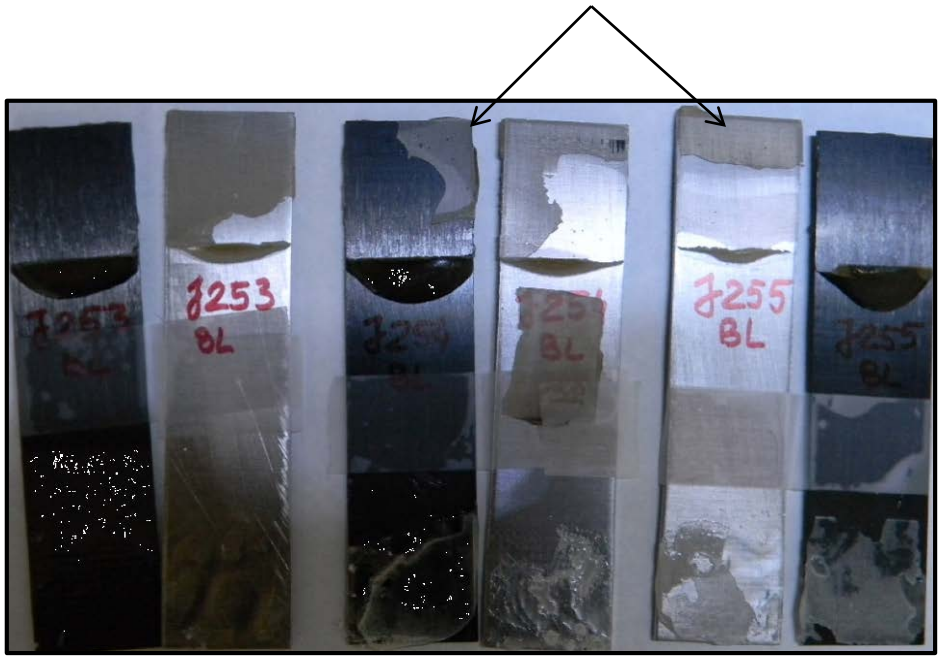
Notes: Data obtained for adhesive DP810 provided by 3M
Results obtained from past project sponsored by Vehicle Transportation Office of DOE

Cohesion Failure of All Baseline Joints

(Fracture of the Adhesive Layer)

- Baseline joints were prepared without "open time" Al
- Composite specimens were prepared without involving laser structuring
  - Abraded using Scotch-Brite™
  - Ultrasonically cleaned using ethanol (5 min)

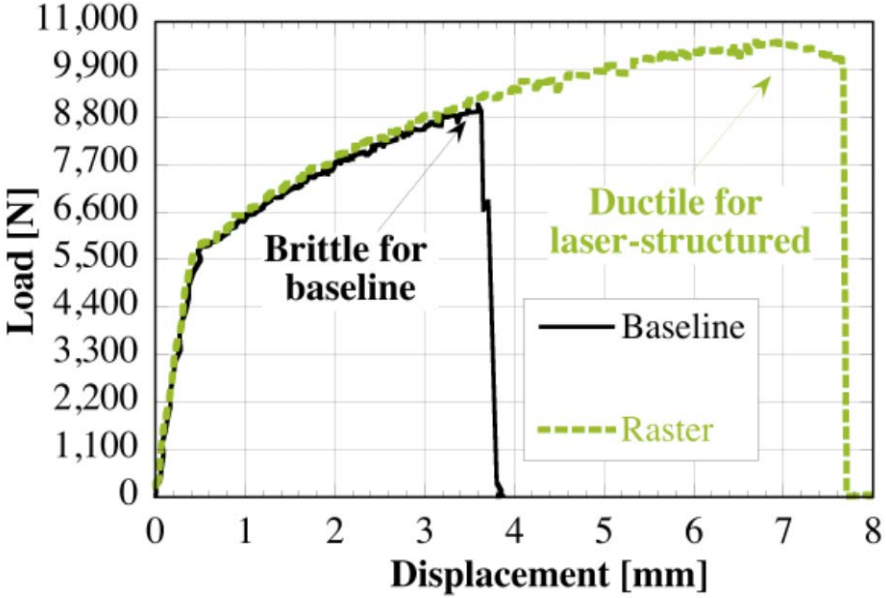
Clean fracture surfaces indicate poor adhesive adherence

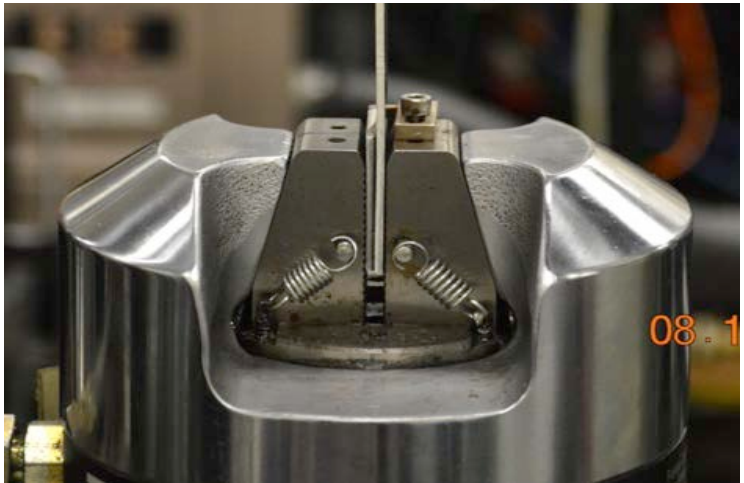


Laser-Structured Joints are More Ductile

Enhanced Bonding of Adhesive to Both Al and CFPC

- Laser structured joints can absorb ~2.5X more energy than baseline joints
- Energy absorbed during the tensile test was 26.3 and 66.8 Joules for the baseline joint and laser-structured joint, respectively





Note: Displacement at maximum load is a direct measure of the energy absorbed by the joint during the shear-lap test

Benefits to DoD and End-Users

- A new non-chemical surface preparation methodology for enhanced coating adhesion and adhesive joining
- New understanding of surface science for laser-interference processing: database and understanding of physical mechanisms for enhanced coating adhesion and adhesive joining

Conclusions

- High potential for non-chemical surface preparation methodology for enhanced coating adhesion
- One-step method provides a larger, non-planar contact area by sub-scale beam size laser-interference structuring
- Eliminates solvent cleaning by removal of mold releases and surface contaminates in one-step
- Increases joint ductility by 2X (crash energy absorbance)

Publications

- Sabau A.S., Greer C.M., Chen J., Warren C.D., and Daniel C., Surface Characterization of Carbon Fiber Polymer Composites and Aluminum Alloys after Laser Interference Structuring, JOM, Vol. 68, pp. 1882-1889, 2016
- Sabau A.S., Chen J., Warren C.D., Erdman D.L. III, Daniel C., Skszek T., and Caruso Dailey M., A Laser Interference-Based Surface Treatment of Al and Carbon Fiber Polymer Composites for Enhanced Bonding, paper LB15-0070, SAMPE Conference and Exhibition, Long Beach, CA, May 23-26, 2016
- Sabau A.S., C.D. Warren, C. Daniel, J. Chen, D.L. III Erdman, Laser Nanostructured Surface Preparation for Joining Dissimilar Materials, Patent application US20160265570, Filed date March 12, 2015
- Sabau, A.S., J. Li, H. Meyer III, C. Daniel, Laser Laser-Interference Surface Preparation for Enhanced Coating Adhesion, Invention Disclosure 201703898, DOE S-138,556, Filed date April 3, 2017

For additional information, please visit

https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/WP-2743

Speaker Contact Information

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Q&A Session 2

SERDP DOD • EPA • DOE | ESTCP

The next webinar is on November 2, 2017

Platforms for Underwater and Near-Shore Munitions Surveys

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Survey Reminder

Please take a moment to complete the survey that will pop up on your screen when the webinar ends

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