COMPOSITE LASER ABLATION FOR SURFACE PREPARATION (CLASP) & DERIVATIVES

MAKING LIGHT WORK OF COMPOSITE BOND PREP

Presenter: **Matt Schulz**

Laser Research Engineer

Laser Manufacturing Technology Development Team

matthew.schulz@udri.udayton.edu

University of Dayton Research Institute

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Overview

- UDRI & Research Team Background
- USPL Lasers
- CLASP
- RoboCLASP
- USPL Laser Depaint

Introduction – University or Dayton Research Institute (UDRI)

- Established in 1956
- Performs basic and applied research, engineering services, testing, & technology transition
- Fully supported by external sponsors
- Integral part of the University; reinforces UD's mission
- Over 800 research staff (250+ at WPAFB)
- Among all colleges and universities:
  - 1st in the U.S. for materials R&D

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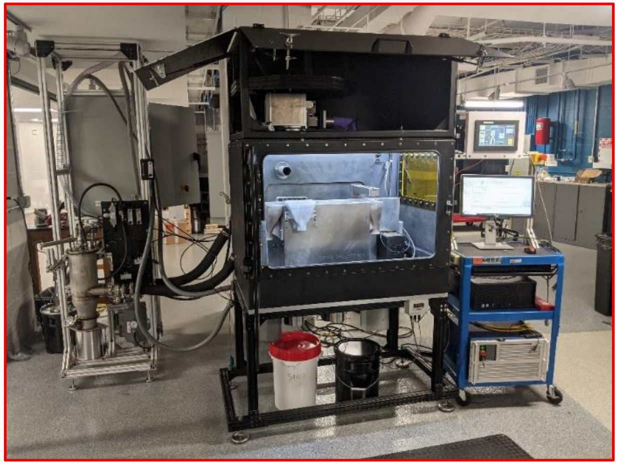
Additive & Laser Manufacturing Technology Development Group

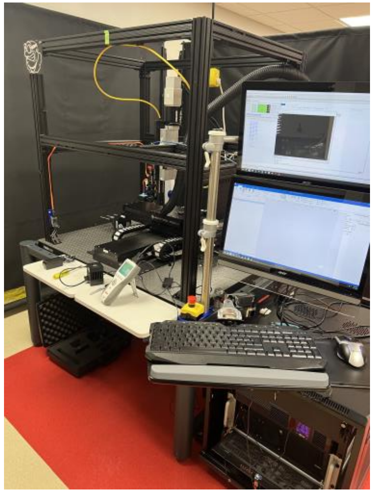
- 30+ person (20 FTE, >10 interns) research group that can rapidly mobilize to deliver Additive Manufacturing, Laser Manufacturing, and Application-driven solutions.
  - **Laser Manufacturing Technology Development**
    - Ultra-fast laser system development
    - Laser-material interaction
  - **Laser Powder Bed Fusion Additive Manufacturing**
    - Next Gen. Machine design and innovation
    - Operates AFRL Novel AM Lab (RXCM)
    - In-situ Laser Process Monitoring
    - AM Materials Science and Testing
  - **Photopolymer AM**
    - Application driven
  - **Advanced Applications**
    - Rapid application development across all UDRI technologies



Unique Ultra Short Pulse Length (USPL) Laser Capabilities

LMTD TEAM

- **Laser Manufacturing Technology Development**
  - 9 full time engineers
  - 4 + rotating interns
- **Expertise**
  - Laser material interaction
  - Remote sensing and process control
  - Custom laser workstation design and production
  - Technology Accelerator
  - Low → High TRL Quickly
  - On staff mechanical engineers
  - On staff computer scientists



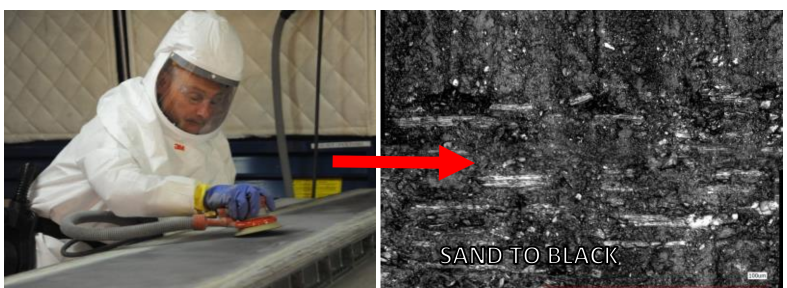
LASER SOURCES

- **20W Amplitude FS laser**
  - Mobile fiber launch cart
- **20W IPG FS laser**
  - On 5+3 axis workstation
- **30W IPG NS laser**
  - Direct focus workstation
- **50W Amplitude FS laser**
  - With harmonic generator
- **100W Amplitude FS laser**
  - Hybrid LPBF
- ***<u>300W Amplitude FS</u>***
  - *<u>Installed Feb 2024</u>*
- **1kW NS / 6kW CW IPG**
  - Single scanhead selectable source

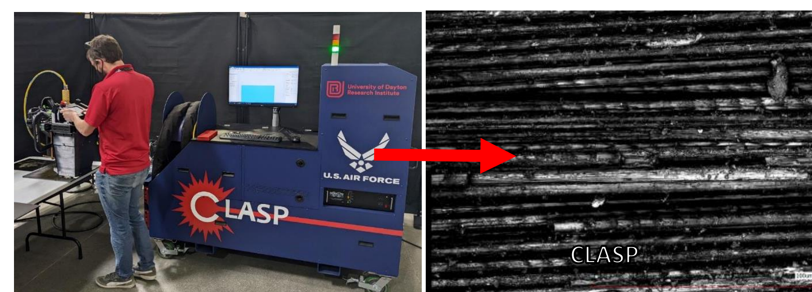
What is CLASP?
Composite Laser Ablation for Surface Preparation

- Composite bond preparation can be a complicated process depending on the application. Current methods of hand sanding (Sand-to-Black) have many challenges:
  - Variable efficiency by operator
  - Requires multiple steps to ensure preparation for bond is complete
  - Manually intensive
  - Time consuming

"I hate sanding"
Everyone, Everywhere



Ronnie Gadola, 574th Composite Repair Flight sheet metal mechanic, sands an F-15 torque box assembly in a new sanding booth in Bldg. 169. U. S. Air Force photo by Ray Crayton Jr



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Brief USPL (Ultra Short Pulse Length) Laser History

- 1st laser was operational in **1960**

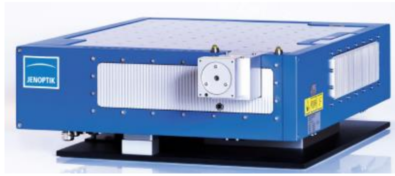
  Light
  Amplification by
  Stimulated
  Emission of
  Radiation

- 2001: 1st femtosecond (USPL) laser for a nonscientific application

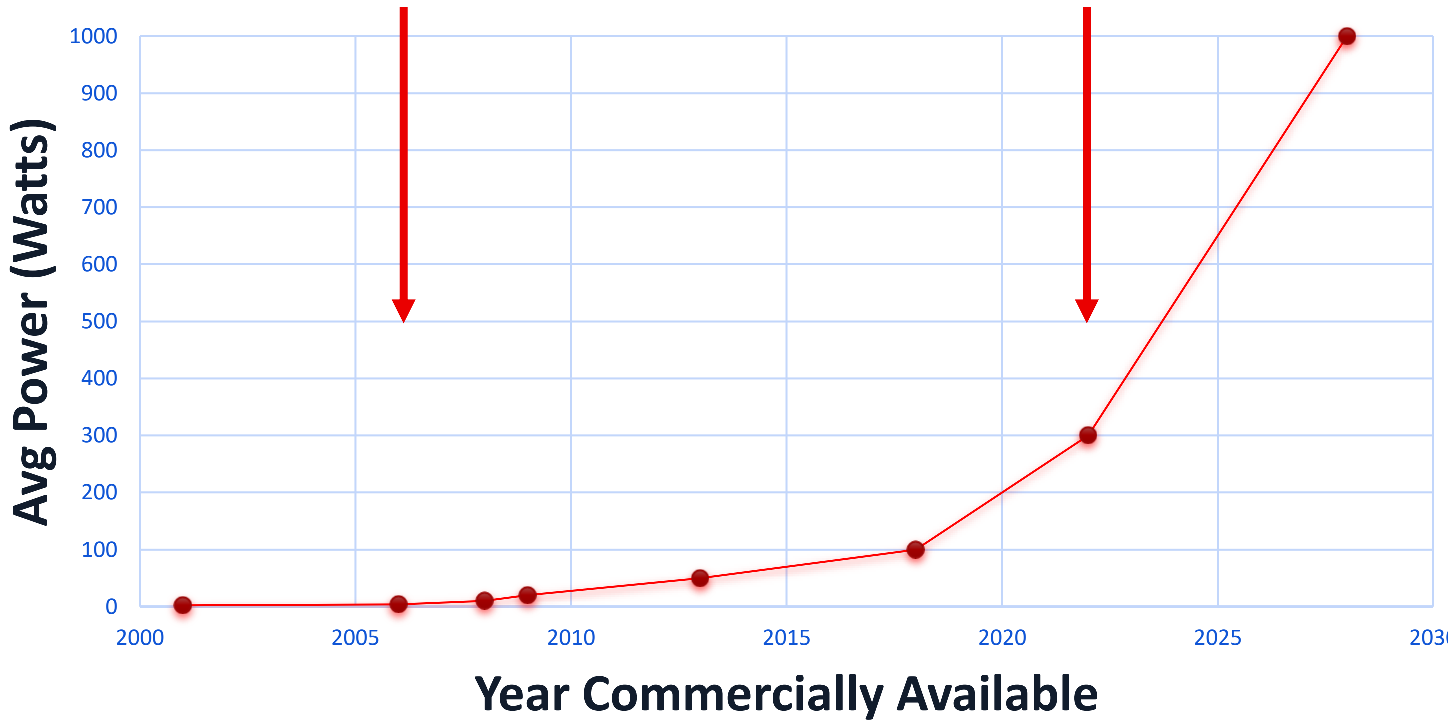
Goldfinger: James Bond Film **1964**

USPL Laser Average Power Over Time

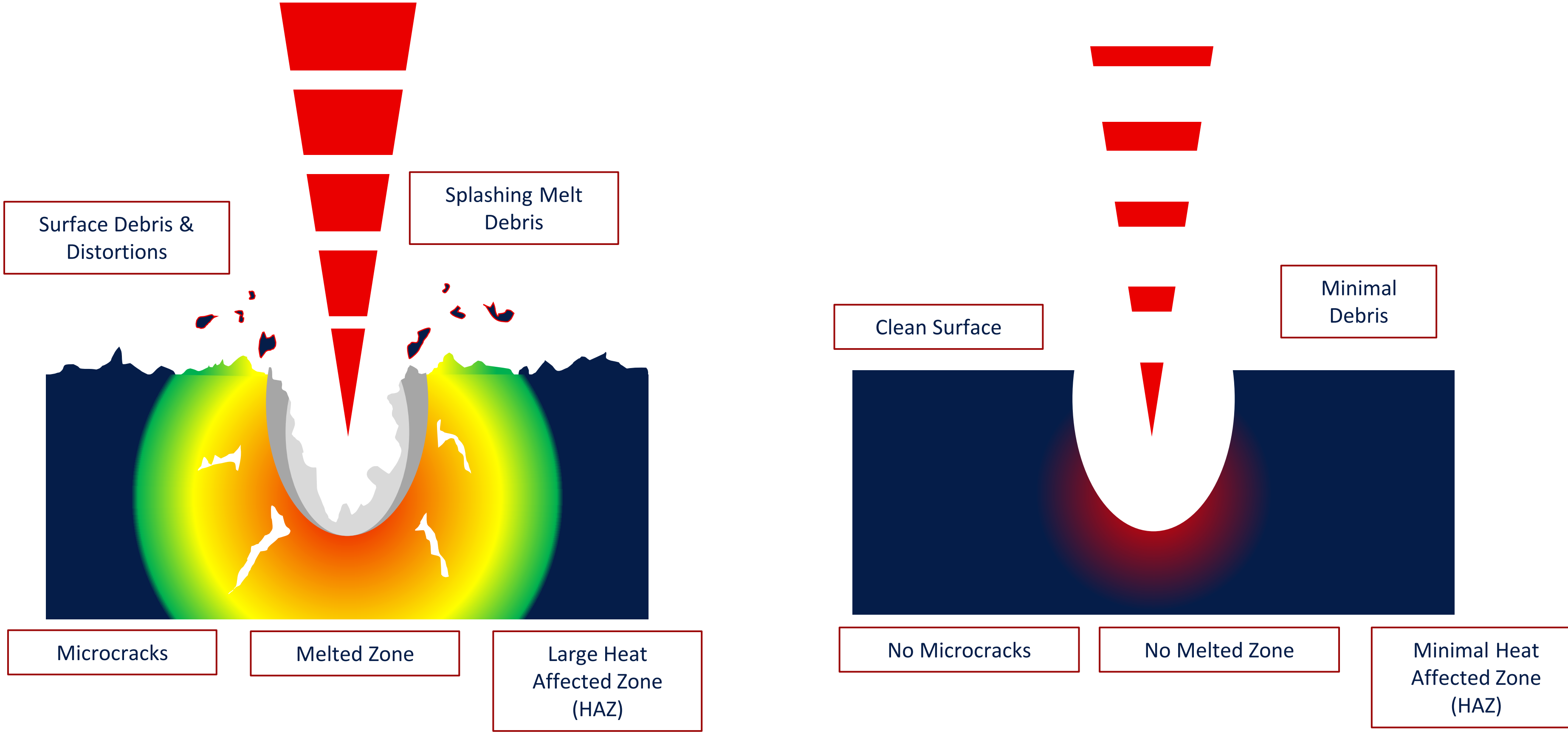
4W JenLas D2.fs
JENOPTIK



300W Tangor
Amplitude



Long Pulse Laser vs Ultra Short Pulse Laser Ablation



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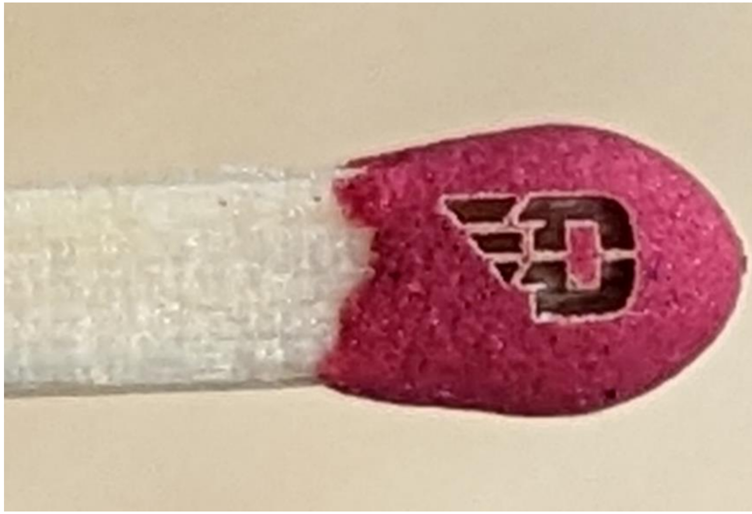
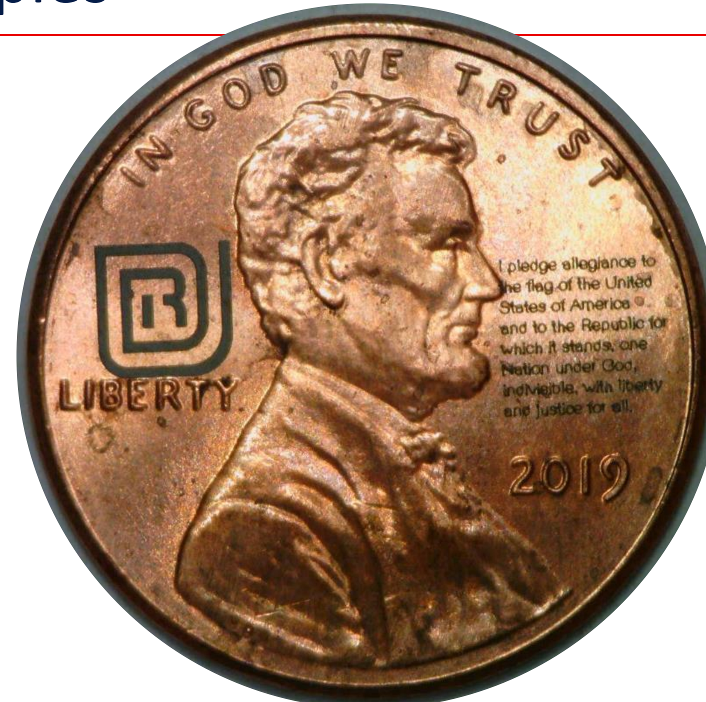
USPL Laser Micromachining Examples

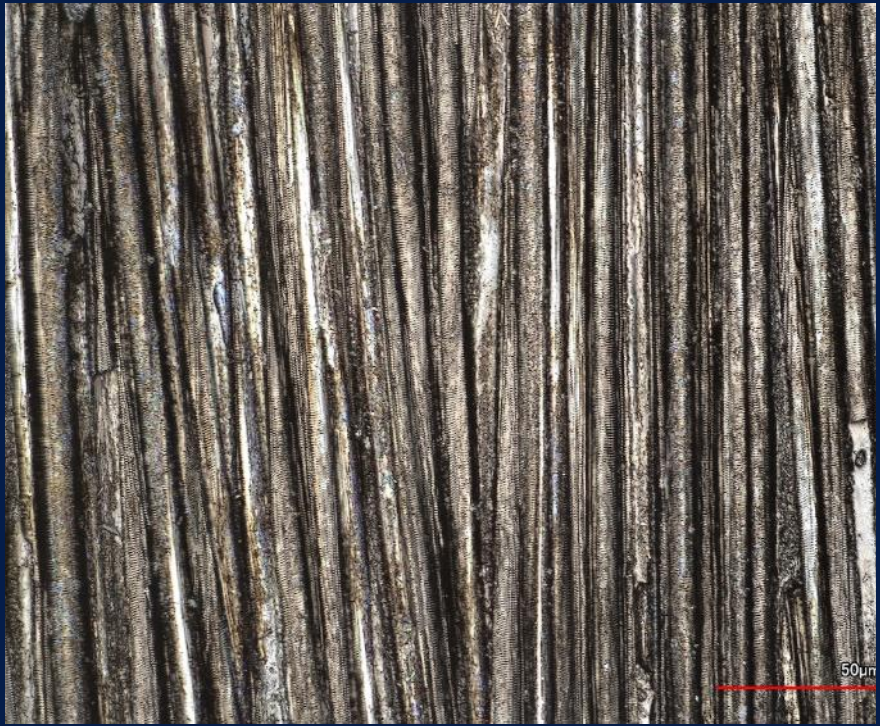




- USPL when done correctly is an athermal process
  - Requires laser material expertise and system design experience to develop a manufacturing solution
- Custom sensing & controls are often needed for deployment of solution

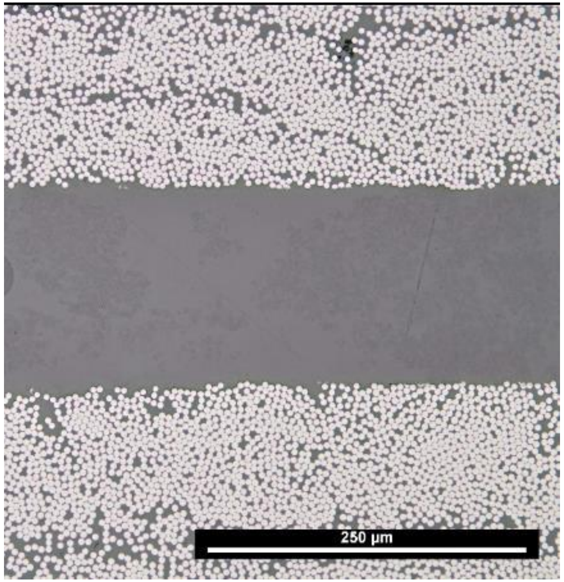
Confocal data: Sand to Black vs CLASP

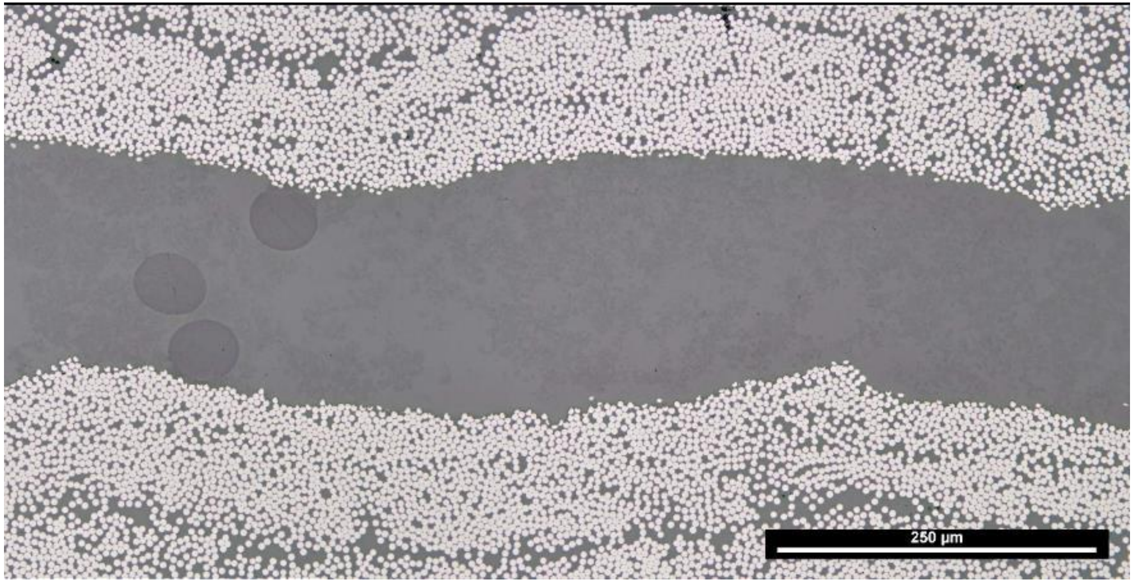
Sand to Black



CLASP

Cross-sectional Analysis- Bondline





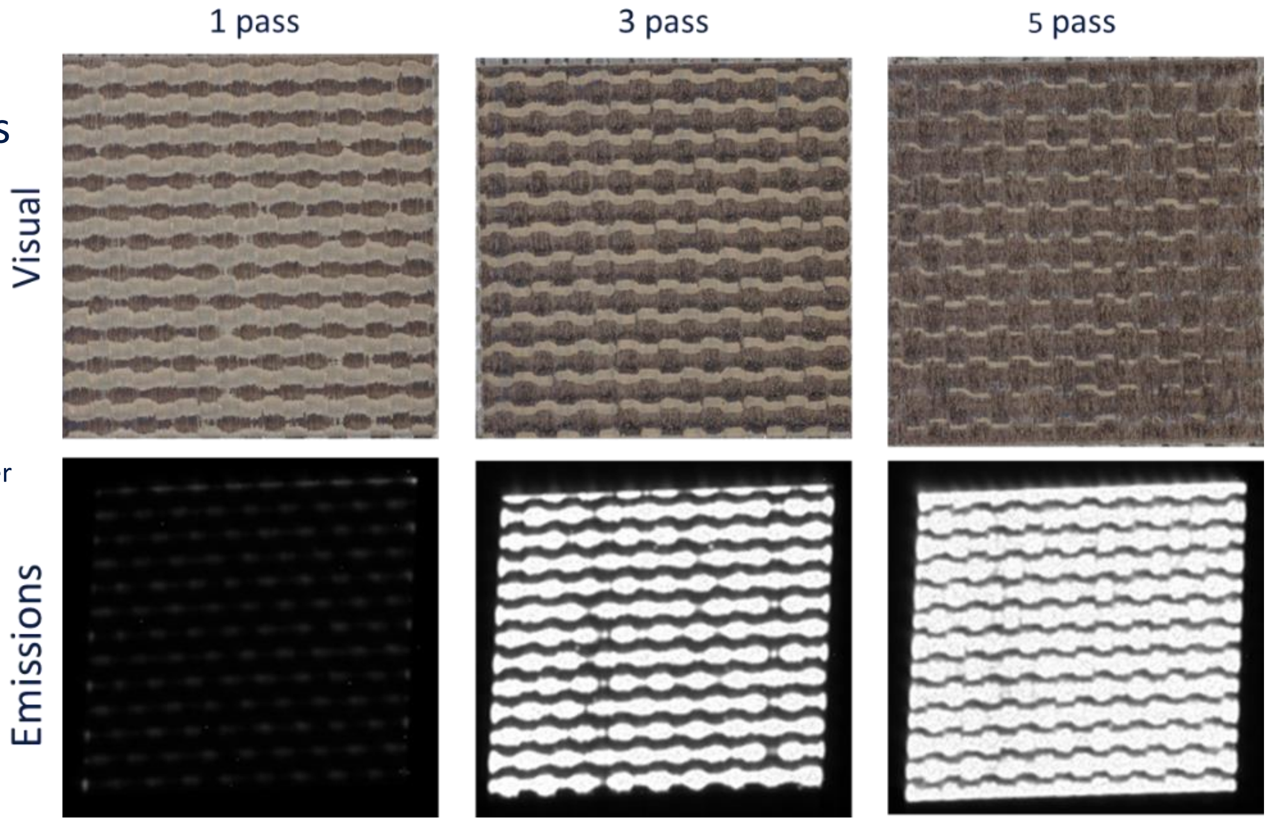
Traditional Sanding

100% CLASP resin cap removal

CLASP leaves the contours of the fibers from the peel-ply intact, with less fiber damage overall

Macro Closed Loop Control: Tape PMC Emissions QA Study

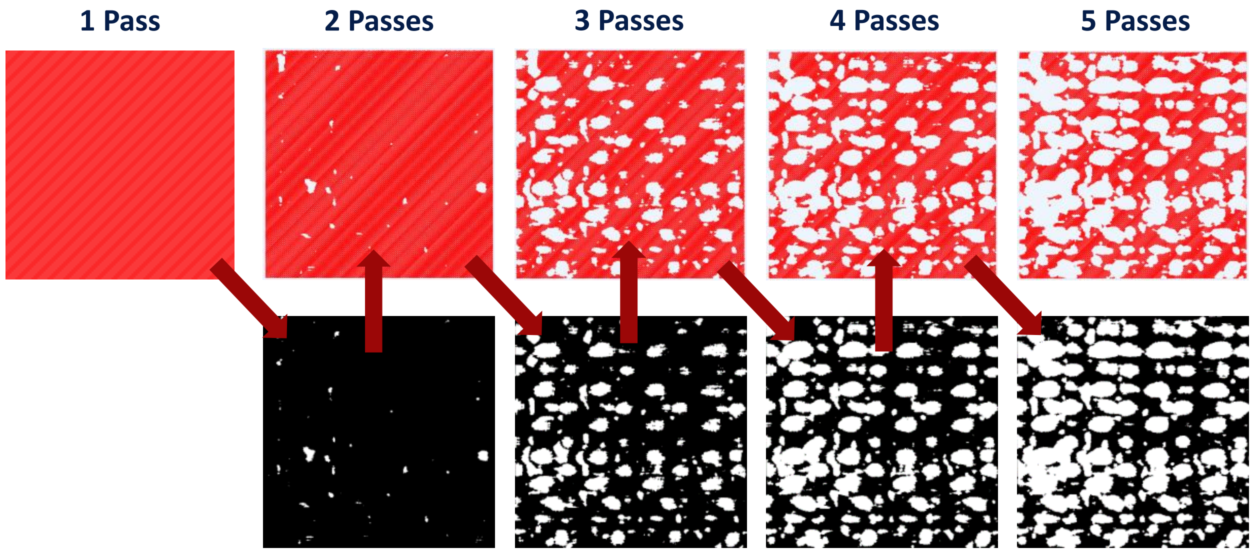
- Viewing emissions of the Carbon Fiber
  - Can see where resin remains with higher contrast than visual
  - Useful for fast closed loop feedback
  - Processing with 100% laser coverage
- Enables less damage and makes a more efficient process!



Micro Closed Loop Processing

- Taking data from the emissions, feed a dxf for the next pass
- Reduces processing time up to 50% depending on number of passes
- Homography required to correct for lens distortion

DXF files with vectors in DMC software



Emissions data filtered

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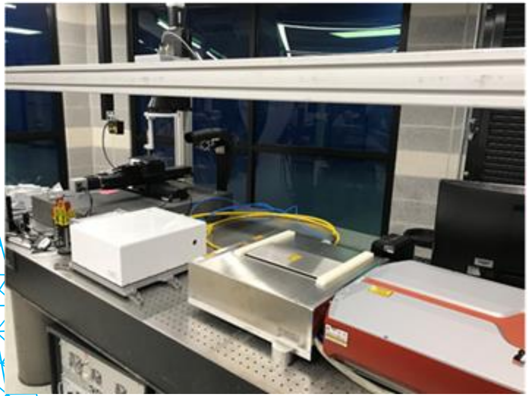
CLASP Cart Timeline

Dec 2020



Bench-top demonstration

Apr 2021

CLASP Cart Rev 1

Nov 2021

CLASP Cart Rev 2

CLASP Cart-Rev 3 April 2022

- **Enabling technologies**
  - 20W Femtosecond Laser
  - Up to 20m Hollow Core Fiber
- **Key Features**
  - Pick n Place Processing
  - Galvanometer based end effector
    - 6”x6”x6” focal range
  - In-situ cameras
  - HEPA processing exhaust
- **System Maturation**
  - System is deployed to a manufacturing facility
  - Commercialization effort with Albers Aerospace in progress

User Pull & Next Steps

- **What are our customers asking for?**
  - More power/faster processing
    - Targeting large area processing (50ft+)
      - Robotic | Gantry Integration
    - 60W laser source option for commercial product
  - More fiber coupling options
    - UV, higher power/energy capability, more flexible/durable
  - Lighter weight
    - Handheld processing ***(2D Feasibility Shown)***
    - Small form factor lasers
- **Next Steps**
  - Robotic Integration- RoboCLASP ***(Funded)***

CONTINUING EFFORT: ROBOCLASP

ROBOTIC INTEGRATION OF CLASP

"ROBOTS ALLOW OUR EMPLOYEES TO WORK SAFELY, FASTER, AND AT LESS COST" DENNIS MUILENBURG

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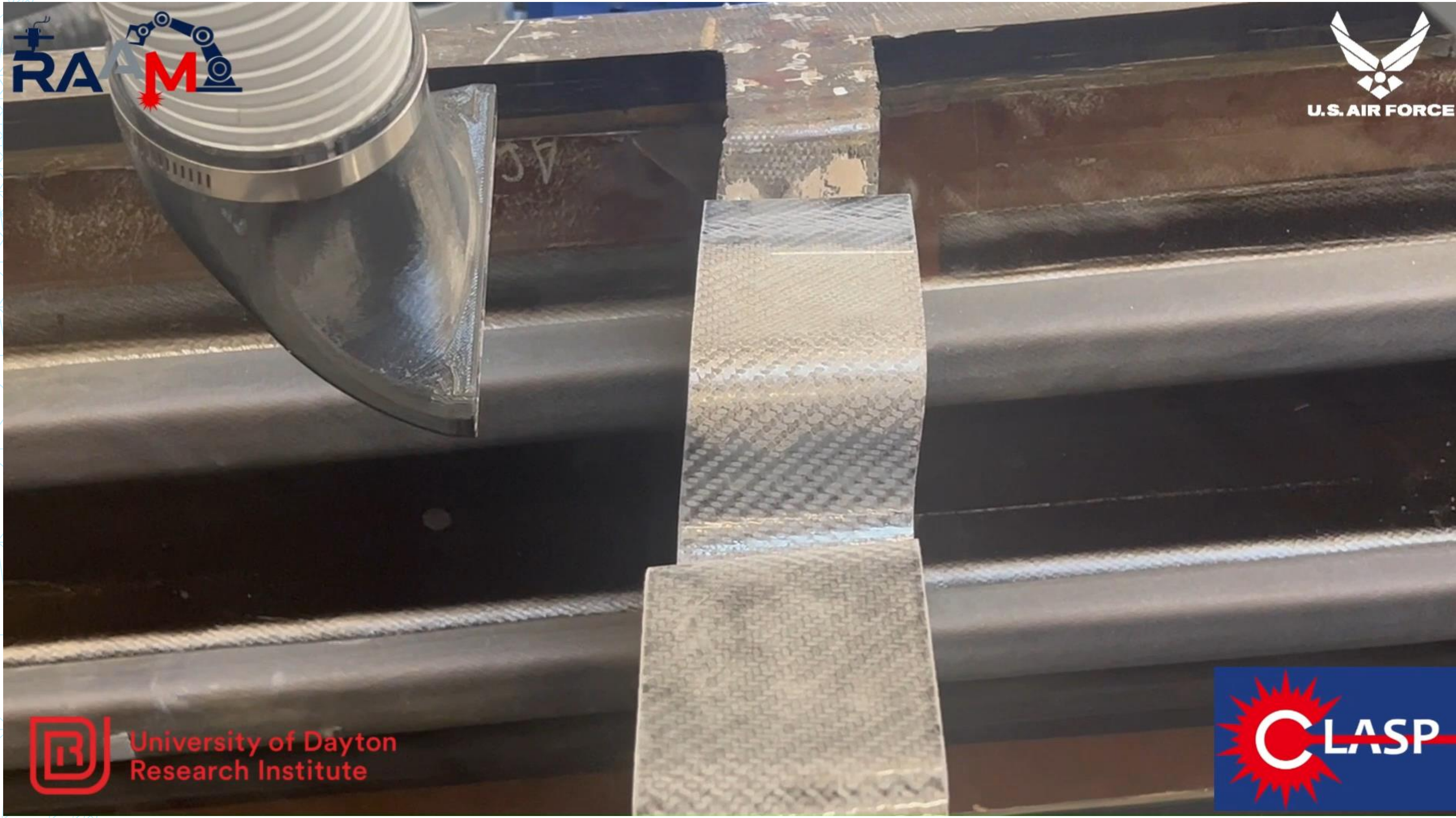
RoboCLASP Video (2 min)



RoboCLASP Next Steps

- Current Process
  - Macro manual alignment
  - 20W Laser Source
  - R&D Size End Effector
  - Automate path planning with Pick N Place processing
  - Scan geometry → Laser Process → In-Situ Monitoring + Closed Loop Control
- Next Steps
  - Automated macro alignment
  - 300W Laser Source
  - Production size end effector (for confined spaces)
  - Continual processing with monitoring, closed loop feedback control

World's 1st USPL laser with a hollow core fiber integrated into a robotic end effector for a commercial application

R&D Gen1 End Effector

USPL LASER DEPAINT / COATING REMOVAL

CONTINUING THE WAR ON SANDPAPER

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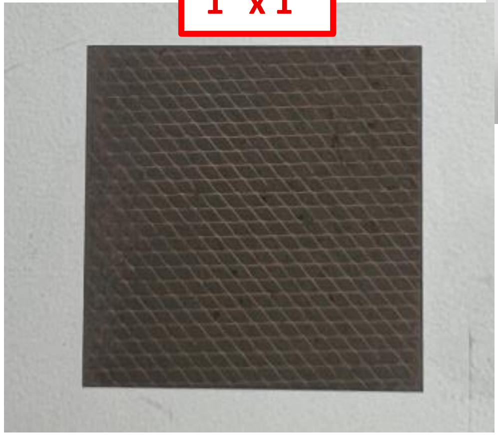
F-16 Horizontal Tail Spar Depaint

- A probe experiment was performed on a piece of F-16 horizontal tail spar with copper mesh lightning strike protection.
- Epoxy basecoat & a white polyurethane topcoat

- Topcoat removed
- Copper mesh uncovered
- No special operating conditions
- Current process is manual abrasion or chemical depaint

1" x 1"



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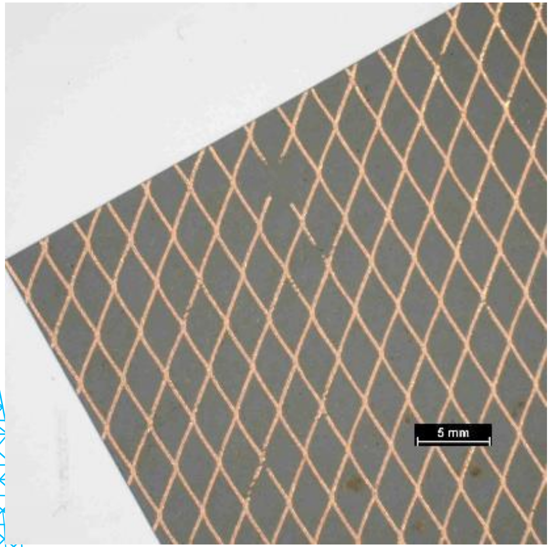
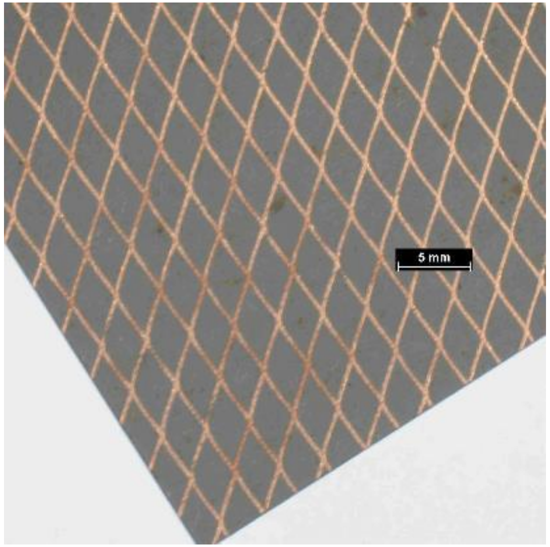
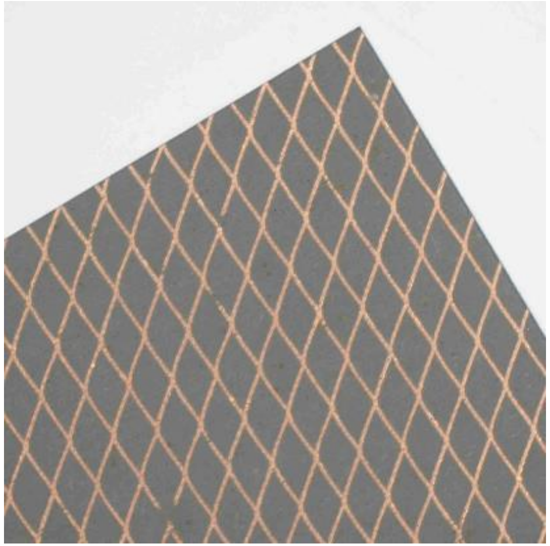
F-16 Horizontal Tail Spar

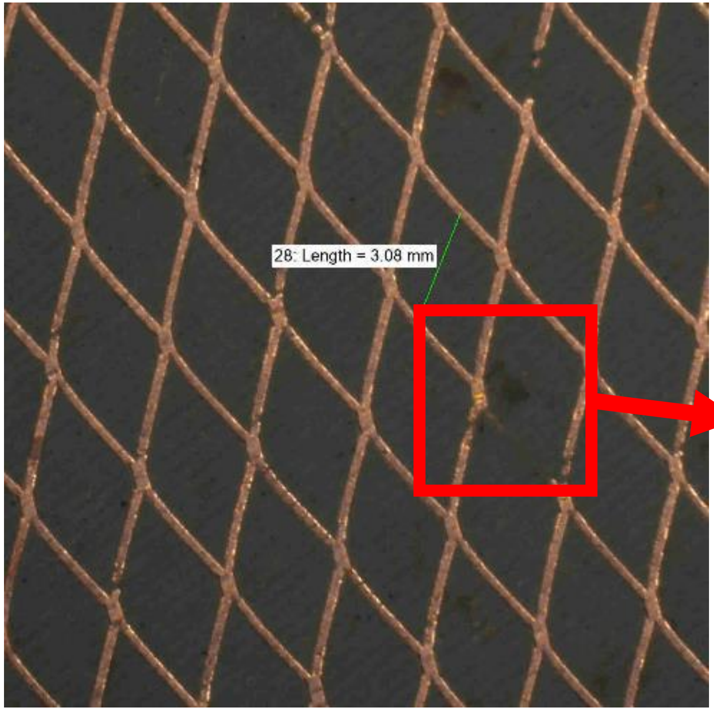
No Paint Color Limitations with USPL Lasers



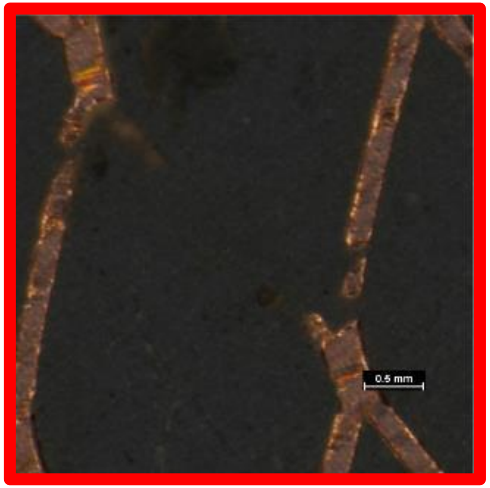




F-16 Horizontal Tail Spar



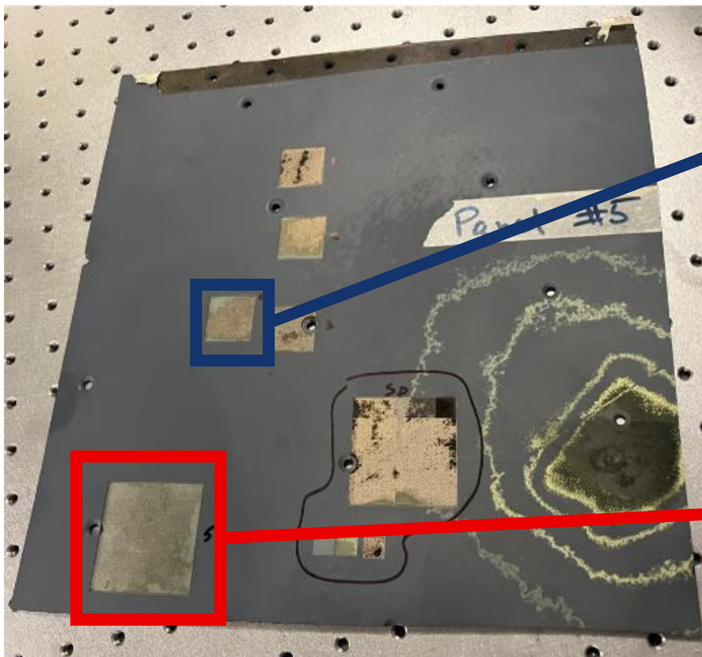
- No copper mesh was removed from the component
- Copper mesh is under the resin

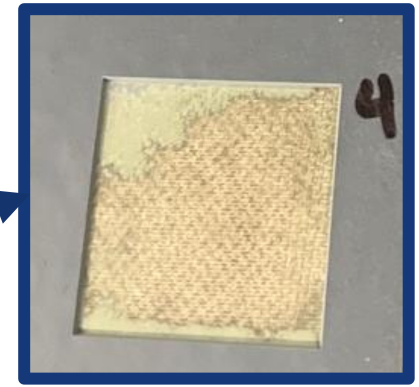


Initial unoptimized laser parameters prove processing time is scalable to at least <10 sec/inch^2

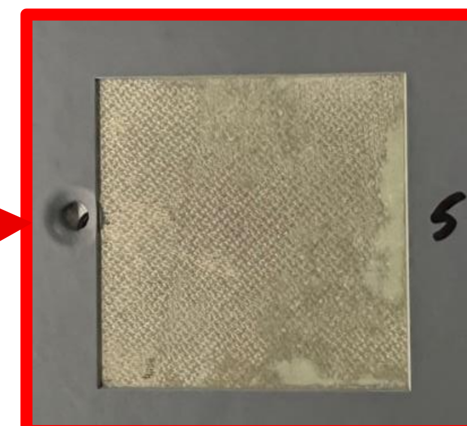
F-16 Composite Wing Component

- Cut-up F-16 Composite wing component
- Goal: Ablate paint & stop on peel ply

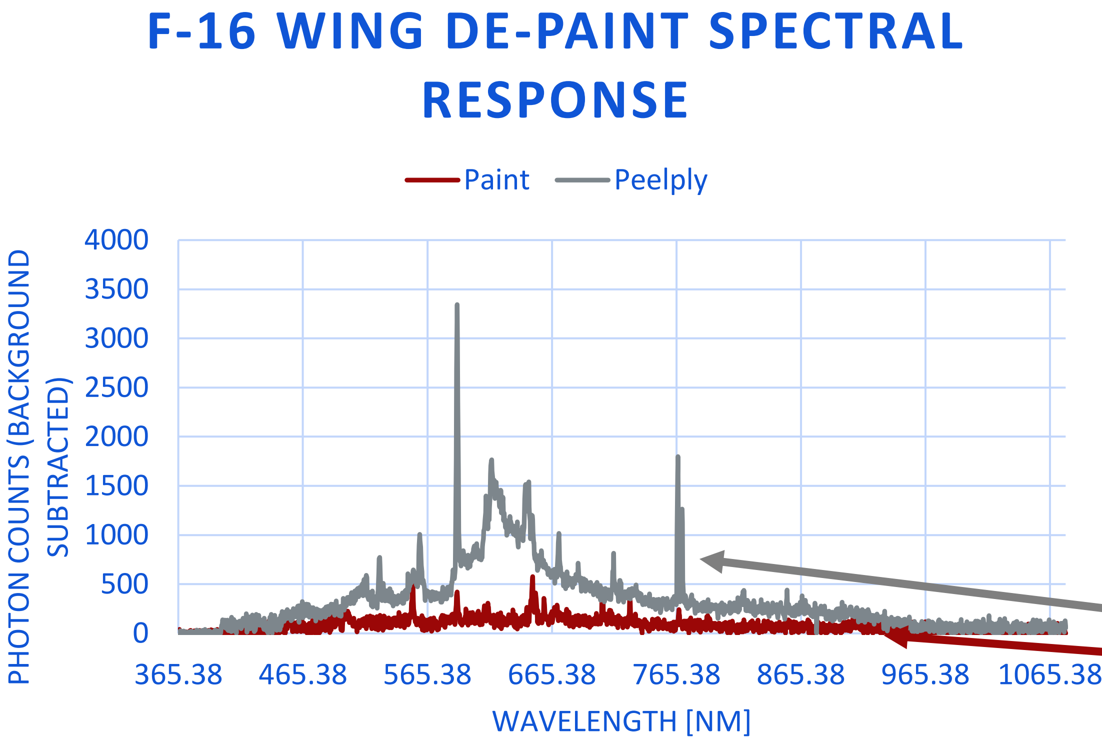


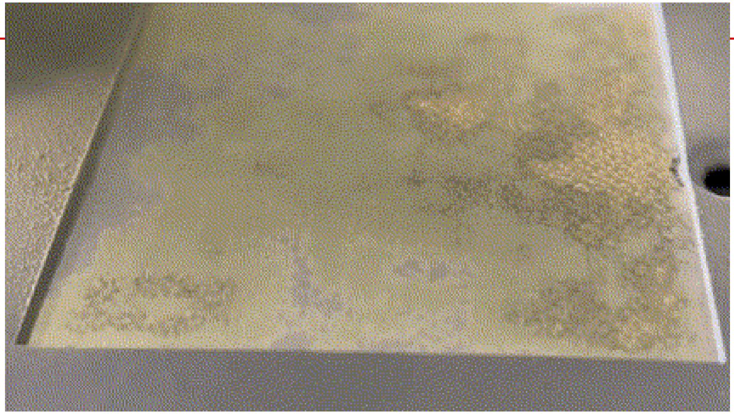


Cross-part airflow for debris management not-optimized

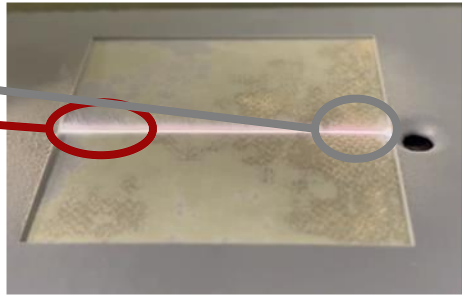


F-16 Composite Wing Component



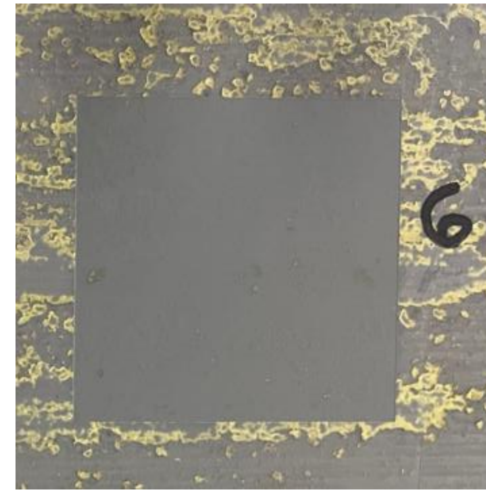


2”x2” area



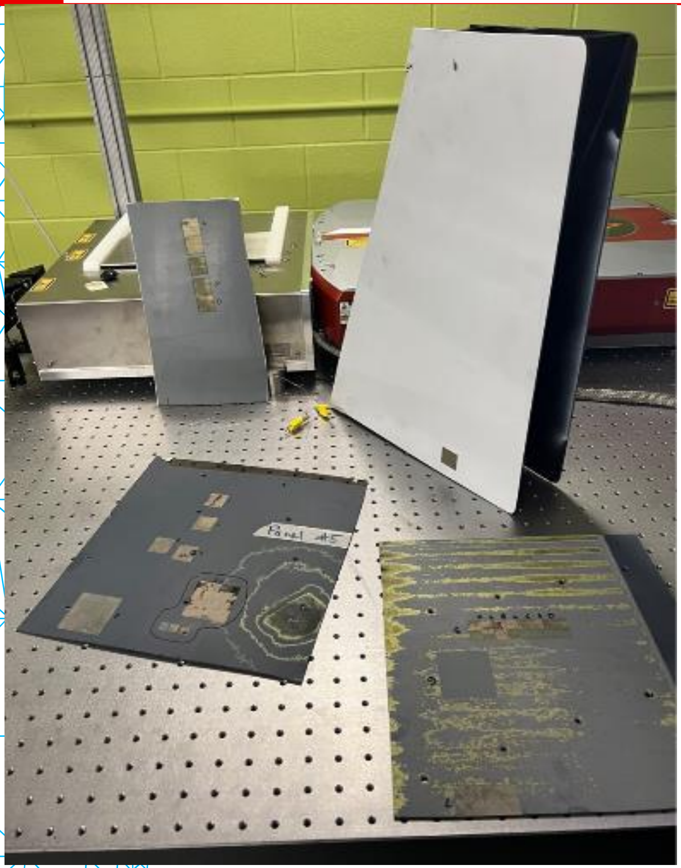
F-16 Composite Wing Component

- Goal: Demonstrate USPL laser on “flaky” substrate caused by CW laser processing
- Single pass using USPL workstation

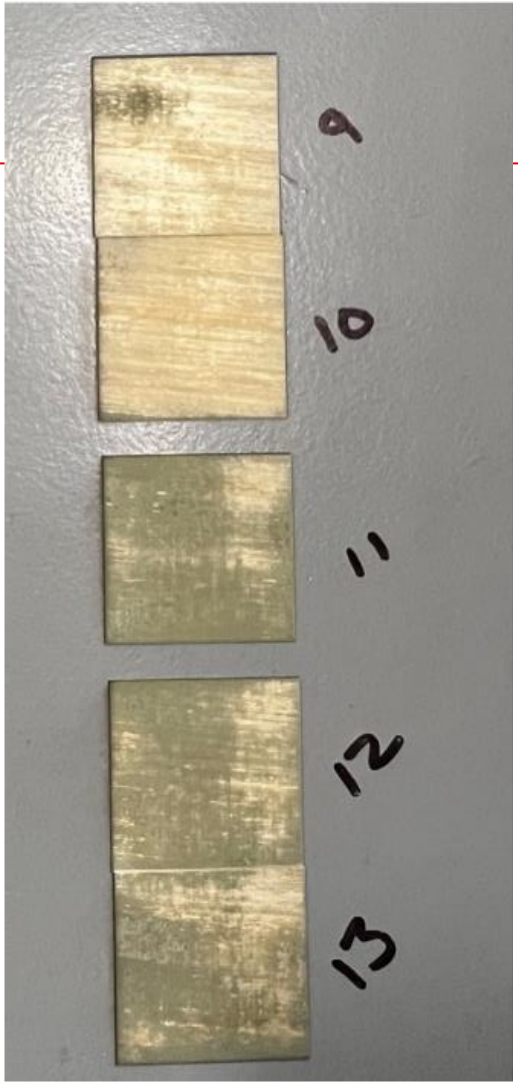


- Goal: Demonstrate pattern to pattern gap control
- A-B Gap: ~500µm
- B-C Gap: ~80µm
- C-D Gap: ~0µm

F-16 Wound Radome USPL



- Goal: Ablate paint & stop on substrate without damage
- Experiment 10 performed down to substrate no visible damage



Conclusion, Next Steps

- **Feasibility Success**
  - De-painting of composite substrate has been proven on supplied materials and several others
- **Next Step**
  - USPL laser technology can be used for de-painting across a variety of material, coating combinations
  - The team is interested in proving feasibility in new and emerging material sets
  - Looking for platform, application with that can benefit from USPL laser de-paint.

QUESTIONS

UDRI Engineering Contacts

matthew.schulz@udri.udayton.edu (Laser Research Eng)
jared.speltz@udri.udayton.edu (CLASP Team Lead)
michael.pratt@udri.udayton.edu (RoboCLASP Team Lead)
christopher.taylor@udri.udayton.edu (Laser De-paint)

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