

# Laser Bond Inspection (LBI)

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# Presentation Outline

- Introduction to Laser Bond Inspection (LBI) for Adhesively Bonded Composite Materials
- Relative Bond Strength Measurements
- LSPT's Development LBI System
- Validation of Structural Integrity of Bonded Materials by LSPT's Development LBI System
- Summary





# **Introduction to Laser Bond Inspection**

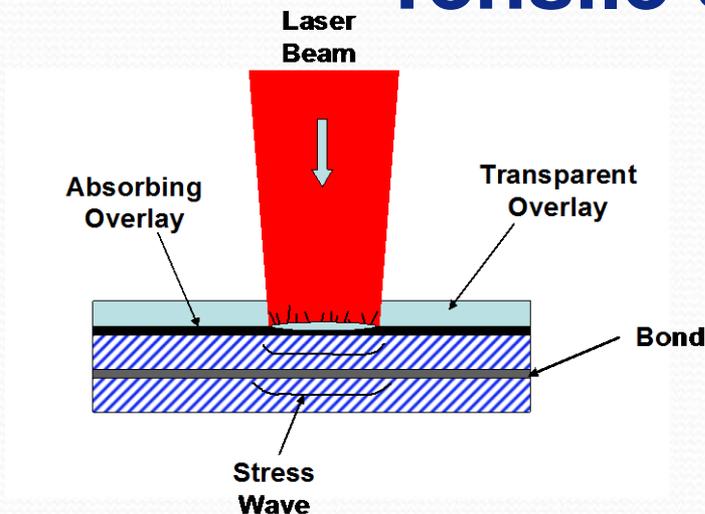


## Reasons to Implement (LBI)

- LBI measures relative bond strength
- LBI detects weak bonds but is nondestructive to strong bonds
- LBI detects kissing bonds
- LBI detects variations in bond strength due to:
  - Surface preparation
  - Adhesive mixing, and
  - Contaminations



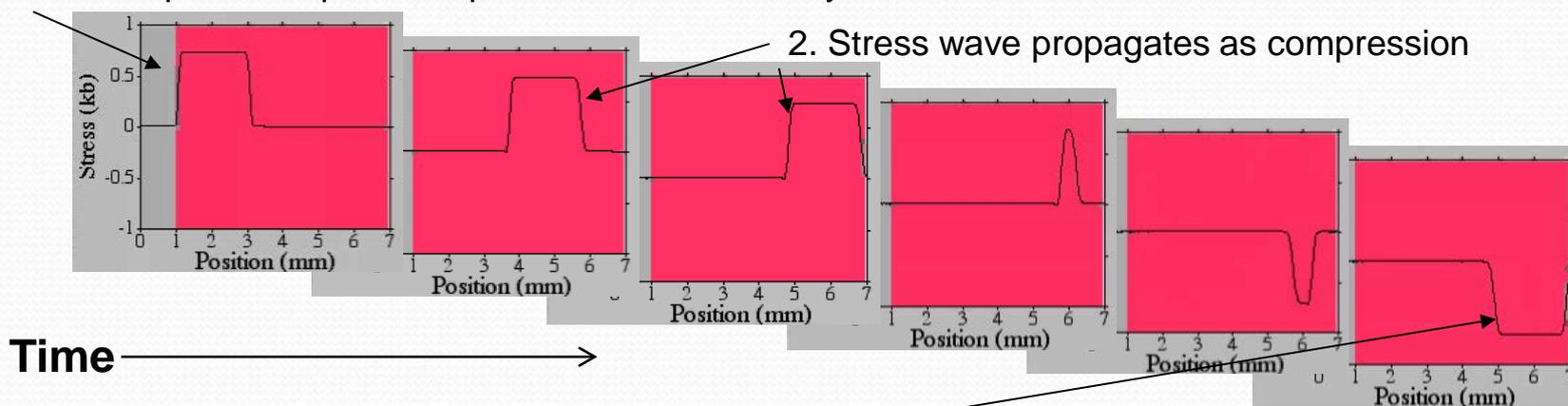
# Tensile Stress Wave



Energy= 5-50 Joules  
Pulse Width=100-300 ns  
Beam Dia.=10mm  
Wavelength=1054nm

1. Laser produces pressure pulse in surface overlay structure

2. Stress wave propagates as compression



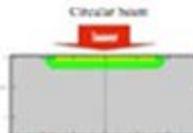
3. Stress wave folds back and propagates as tension wave from a free (back) surface



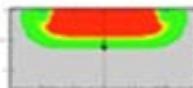
# CTH Code Simulation

19 mm Diameter Laser Beam,  
300 ns Pulse Width (FWHM), and  
13 mm Thick Al Sample

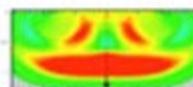
0.3 microseconds



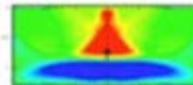
1 microseconds



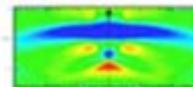
2 microseconds



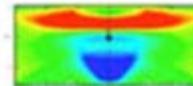
3 microseconds-  
Reflected Tensile



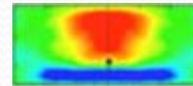
4 microseconds



5 microseconds



6.8 microseconds



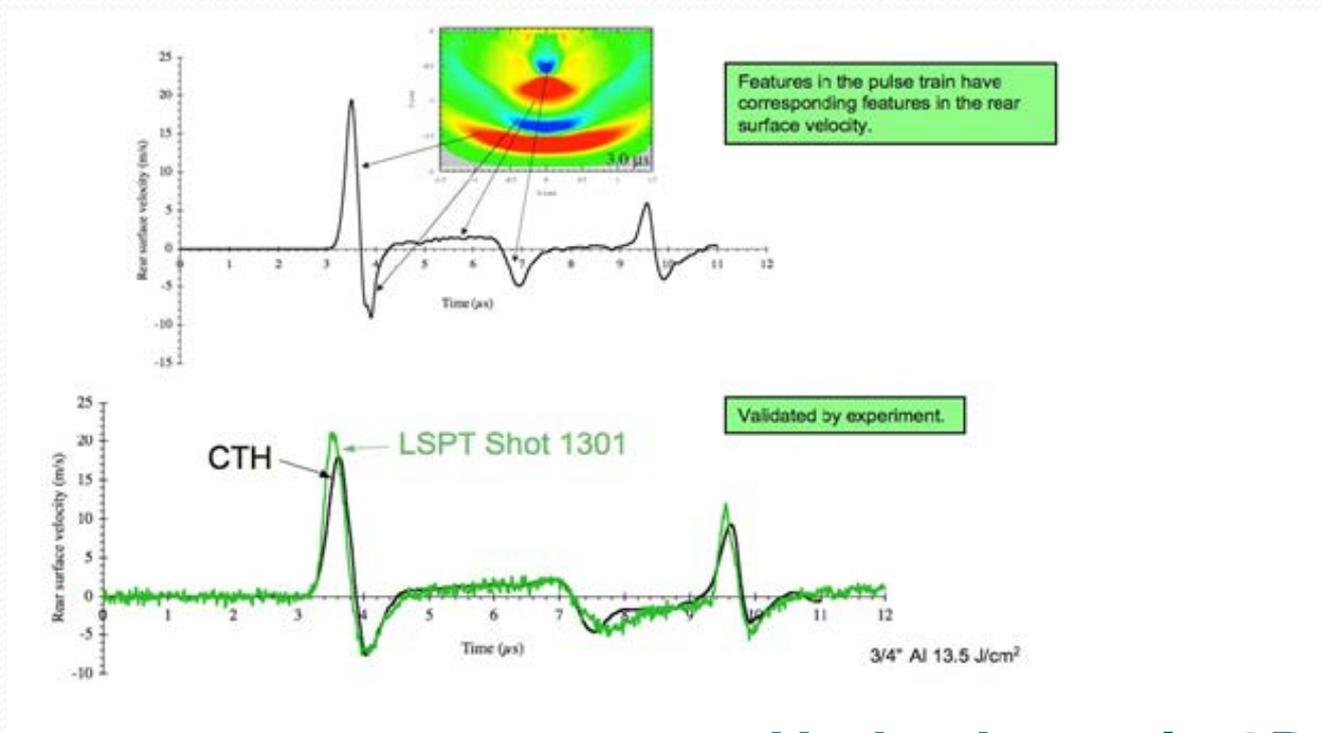
Hydrodynamic 2D Code  
Simulation by Boeing



# Comparison of CTH Simulation with Experiment

Laser Beam Diameter = 19 mm

Aluminum Thickness = 19 mm



Hydrodynamic 2D Code  
Simulation by Boeing

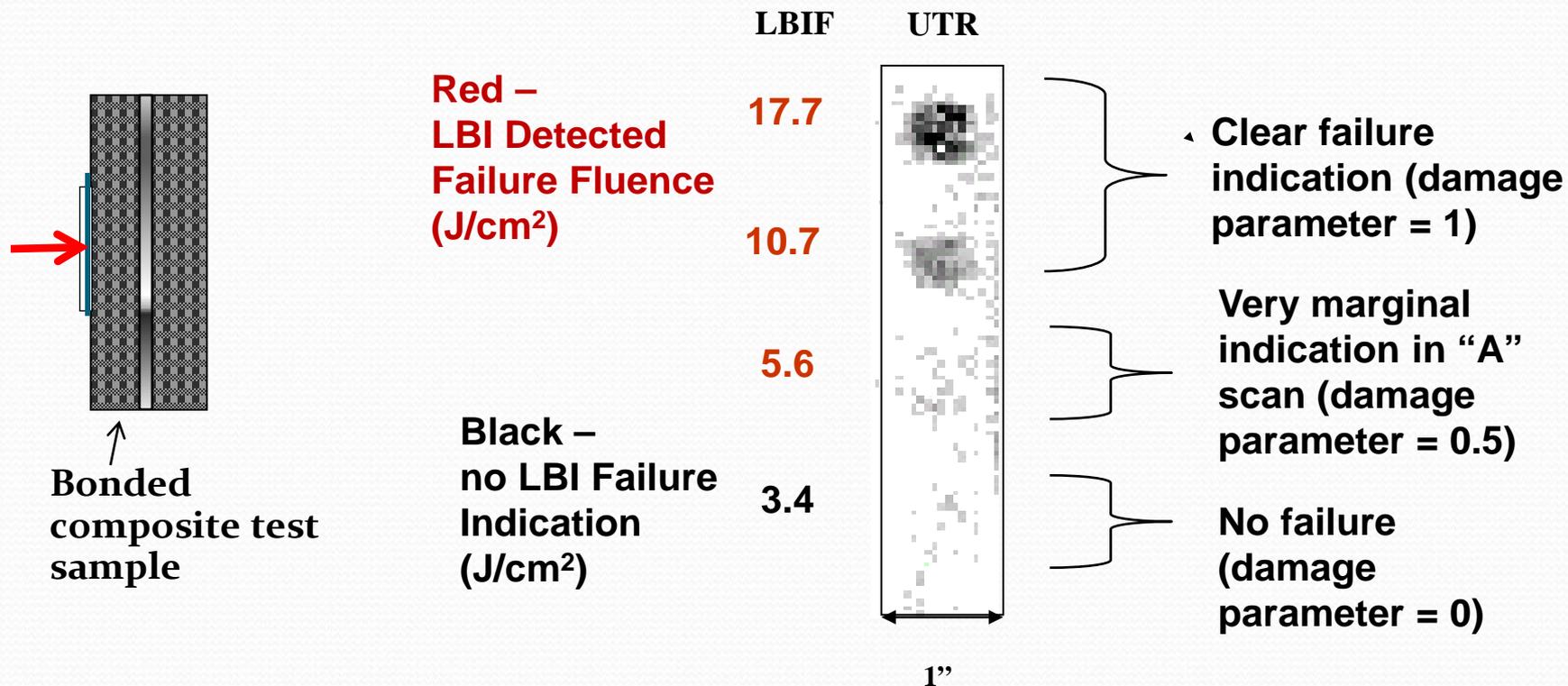


## Summary

- **A forward traveling compressive stress wave produces a reflected tensile stress wave upon reflection at the back free surface**
- **The strength of the tensile stress wave can be selected by varying the energy and/or the pulse width of the laser to fail weak bonds, while strong bonds are unaffected**



# UT Post Examination After LBI



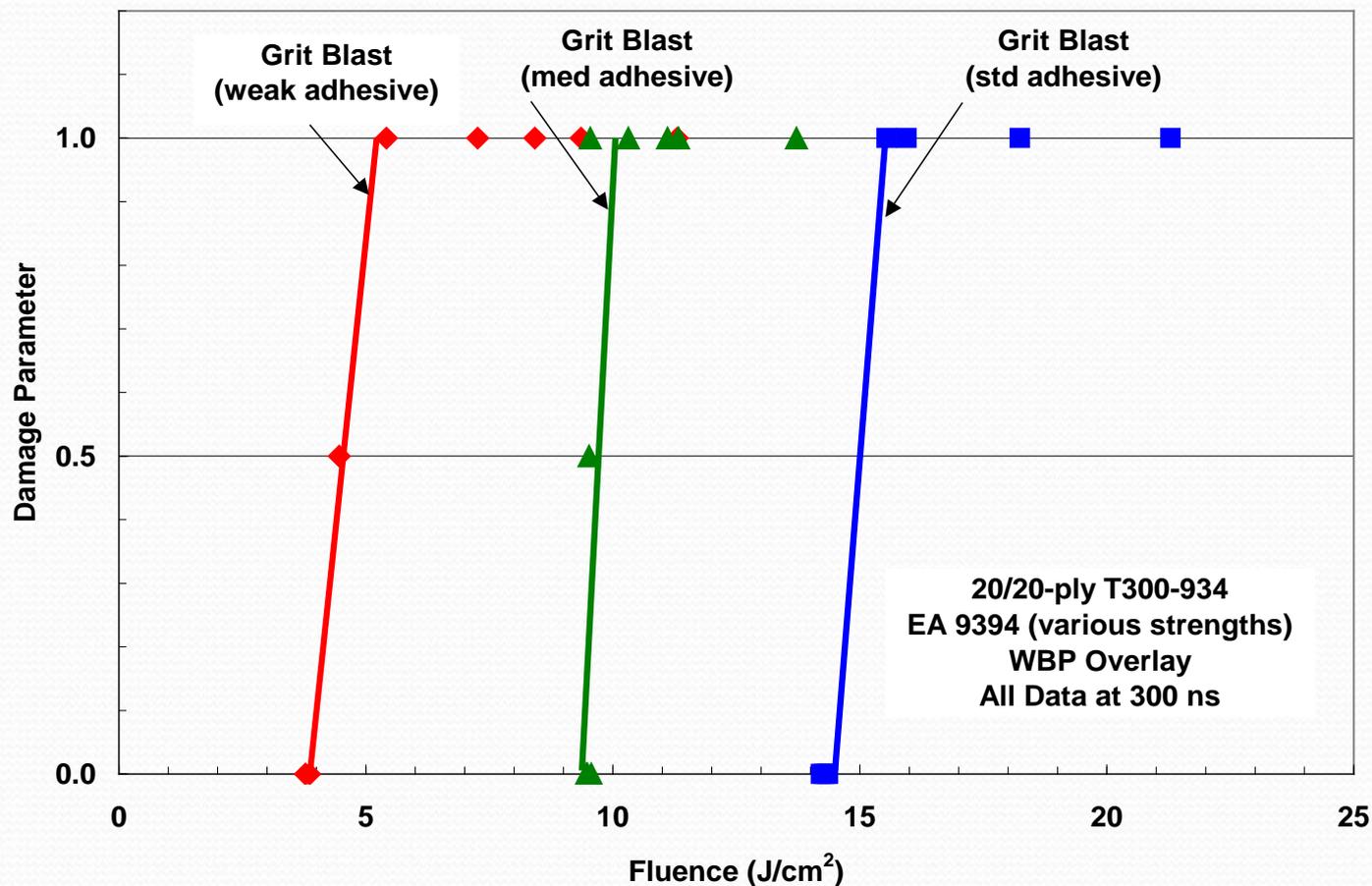


# **Relative Bond Strength Measurements by LBI**



# LBI of a Sample with Three Different Bond Strengths

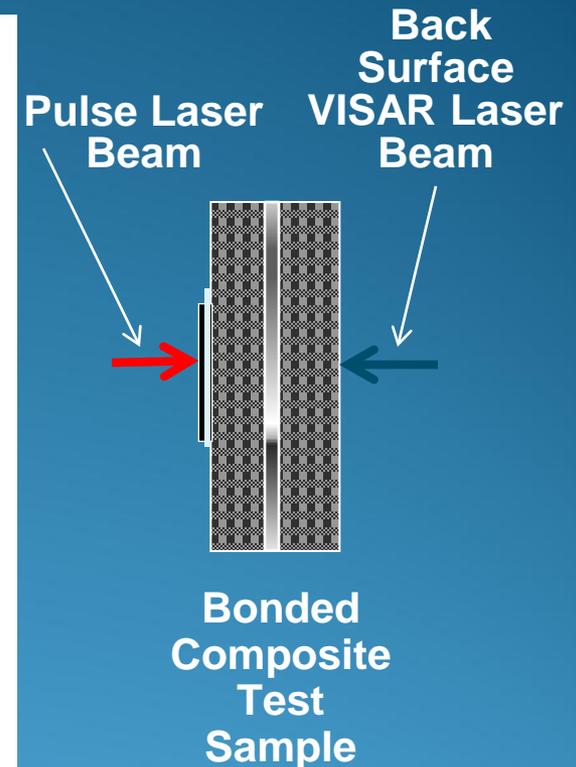
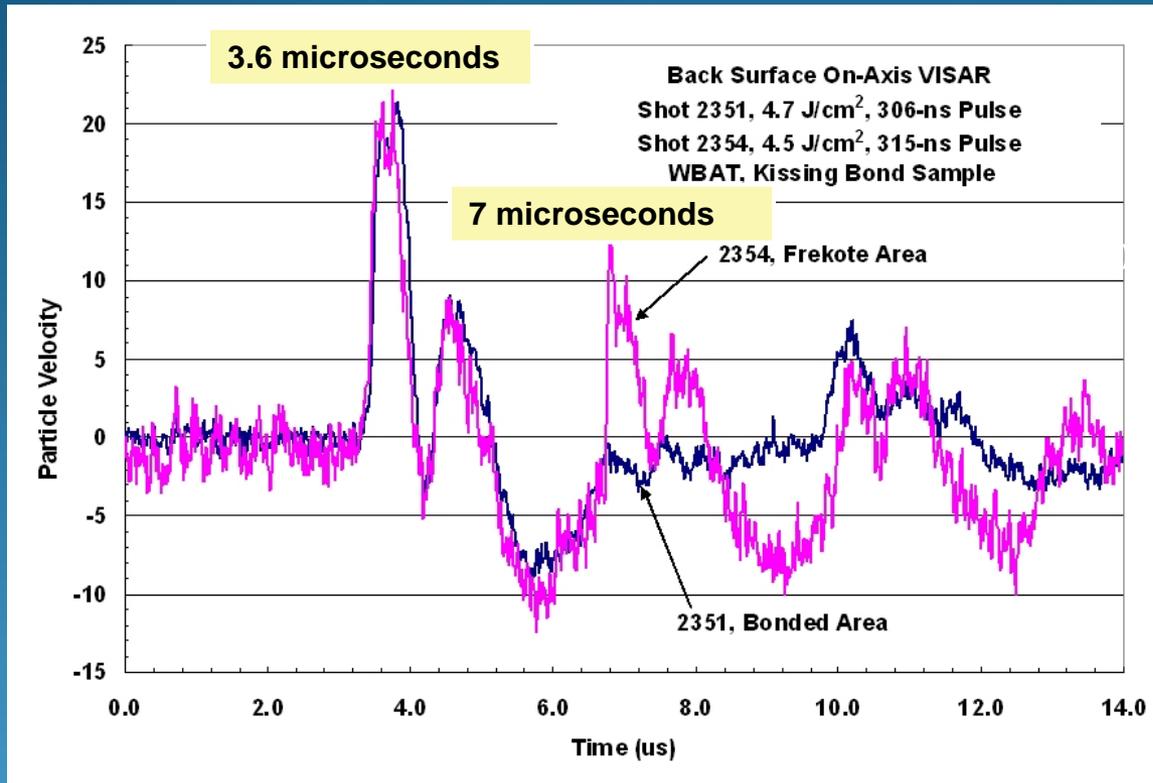
Two-part epoxy adhesive on grit blasted composite surface



From: Materials Evaluation, July 2009, Richard Bossi et al.



# LBI of a Kissing Bond



Detection of kissing bond by VISAR (velocity interferometer system for any surface) at a fluence below the threshold for delamination of the adjacent bonded region.



# **Laser Bond Inspection Development System**



## **LBI Development System Specifications**

- Pulse Energy: 5-50 Joules
- Pulse Width: 100-300 ns
- Pulse Repetition rate: 1/8 Hz
- Wavelength: 1054 nm
- Dimensions: 5.3 x 6.5 x 13 ft (W X H X L)

**LBI System Developed to Inspect a Wide Range of Bonded Structures**



# LBI Development System



ARTICULATED ARM

LASER ENCLOSURE

POWER CORD – 2AWG, 4 WIRE PLUS GROUND

POWER DISTRIBUTION CABINETS

INTERBUS CABINET

PROCESS CONTROLS

PROCESS WATER CONDITIONING

CART

PROCESSING HEAD

OVERALL DIMENSIONS:

WIDTH = 64 INCHES

LENGTH = 157 INCHES

HEIGHT (ENCLOSURE) = 78 INCHES



# Laser Bond Inspection Head

- Eye Safe
- LED indicators
- Overlay Water Removal System
- Modular Design
- Quick Disconnects
- EMAT Sensor



ARTICULATED  
ARM

INSPECTION  
HEAD

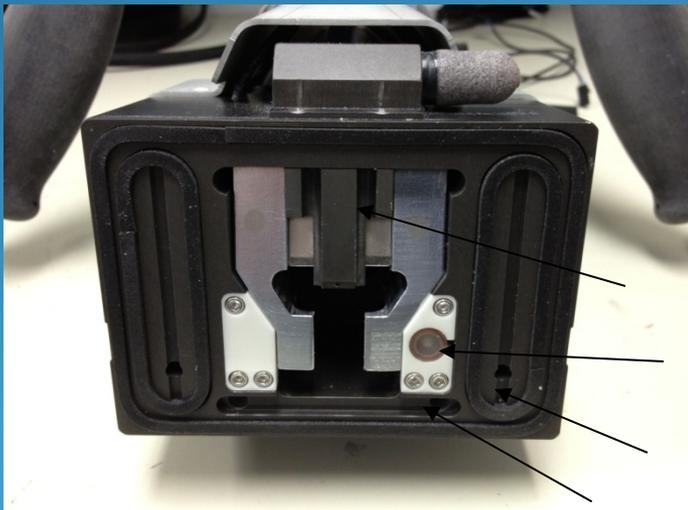
CONTROL  
BUTTON

INSPECTION  
HEAD BASE

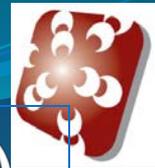
EMAT MAGNET

EMAT COIL

VACUUM HOLD DOWN

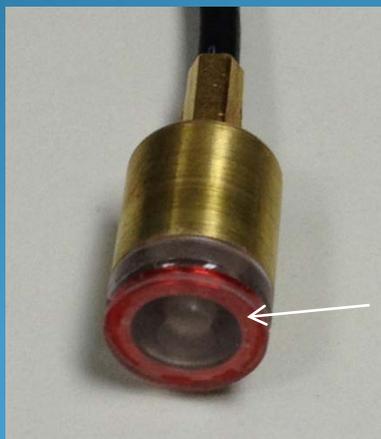


OVERLAY WATER  
EVACUATION

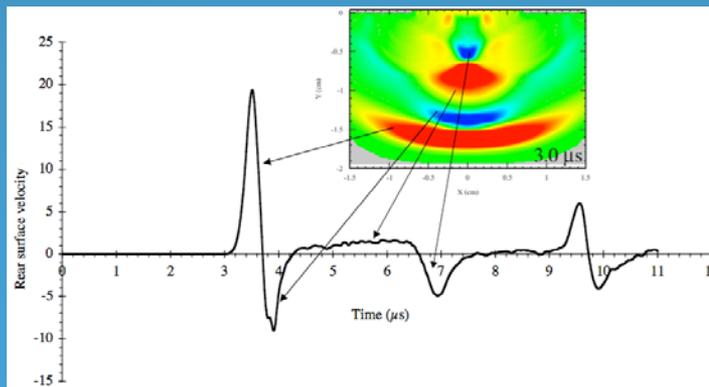
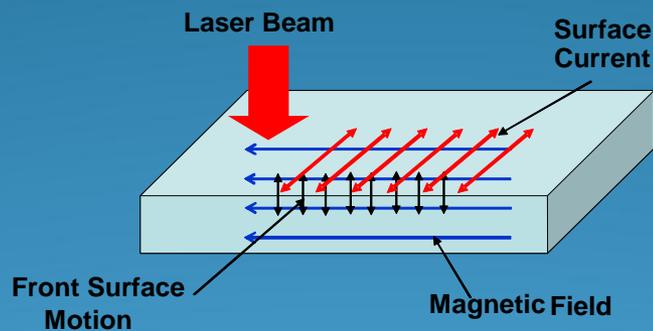
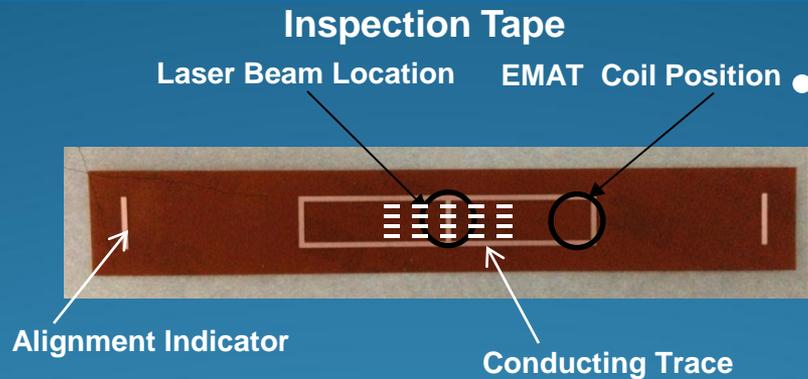


# Electro Magnetic Acoustic Transducer (EMAT)

- Non-conducting composites require a conductive path for EMAT to detect surface motion



Coil



EMAT sensor detects surface motion by electromagnetic induction

- Motion of composite surface through magnetic field induces an electrical current that is picked up by the EMAT coil



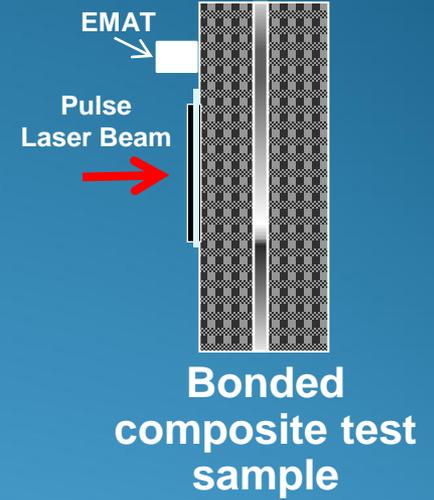
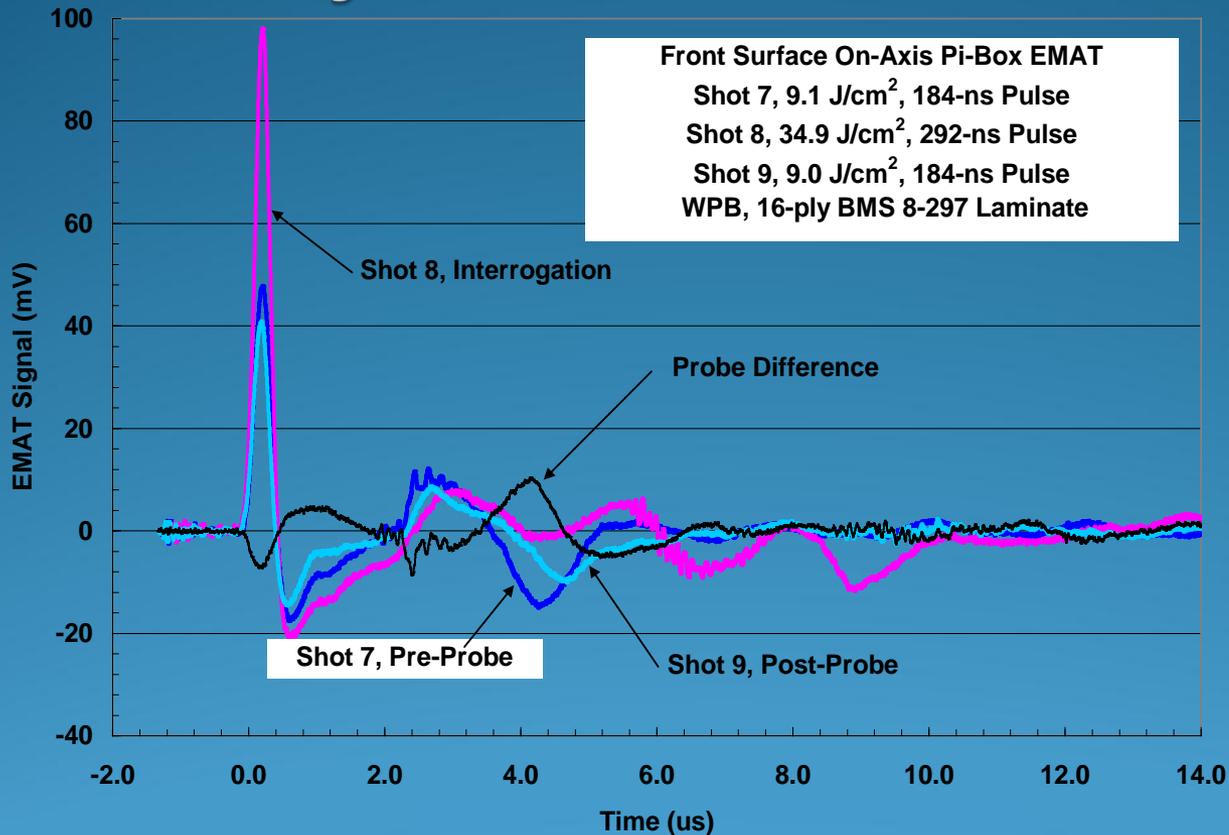
# Low-High-Low LBI by EMAT

## A sequence of three laser pulses is used for bond inspection

- 1) Apply low energy laser pulse to surface of part - not enough energy to damage the bond - record EMAT signal
- 2) Apply high energy laser pulse to surface of part - enough energy to fail a weak bond - record EMAT signal
- 3) Apply low energy laser pulse to surface of part - not enough energy to damage the bond - record EMAT signal
- 4) Compare the two low EMAT signals, if identical then bond is strong, if different bond is weak



# LBI by Front Surface EMAT



EMAT signature above bond failure threshold in BMS 8-297 Laminate



# Laser Bond Inspection Video

**- Laser Bond Inspection -  
Adhesive Bond Strength  
Testing**



# **Laser Bond Inspection Conclusion**



## Summary of LBI

- LBI creates an internal tensile stress wave that tests the relative strength of an adhesive interface in a bonded structure
- LBI detects weak bonds but does no harm to a good bond
- The strength of the stress wave is selected by varying the energy and/or the pulse width of the laser
- LBI can inspect bonded structures that are up to 1 inch in thickness



## LBI Status

- LBI is now being evaluated by major OEMs for large composite structures
- The Boeing Co. has purchased a LBI system for the inspection of bonded structures and has implemented robotic inspection of bonded samples
- LBI system can be configured for an OEM's specific inspection need
- LBI of composite structures is available at LSP Technologies



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