Test d’adhérence par choc laser d’assemblages composite pour les besoins aéronautiques

Développements et maturité technologique

Forum ILP – June, 2018

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Presentation Overview

- Why it matters ?
- LASAT history, principle, & methodology
- LASAT Performances
  - Mono pulse results
  - Double pulse solution
  - Symmetrical pulse approach
- Toward industrialization…
- …with remaining open points
- The laser shock applications landscape and trends

Introduction & Methodology

Why it matters ?

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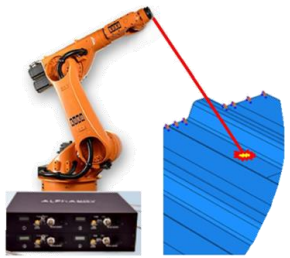
Why it matters ?

Typical A350 bonded assemblies

+ Future programs

Bonding assessment by laser shock adhesion test



Space structures

Production

Main characteristics

- L 10m, R 3m
- Thick (mm → cm)
- Bond depth fixed
- CFRP (IMA/M21E)

Bonded repairs

Main characteristics

- 0.5m × 0.5m, R 3m
- Thick (mm → cm)
- High geometry variabilty
- CFRP (IMA/M21E)

Why it matters

- **Enable structural bonding**

➔ Less fasteners/ “rivetless”: 1. eco-efficiency, 2. lean processes

- Step 1: replace PCS (process control specimen)
- Step 2: Online bonding control (CFRP, hybrid assemblies)

Why it matters

- **Enable structural repair (bigger and rivetless repairs)**

➔ Lighter repairs, more efficient repair

- Step 1: grounded panel
- Step 2: directly on structure

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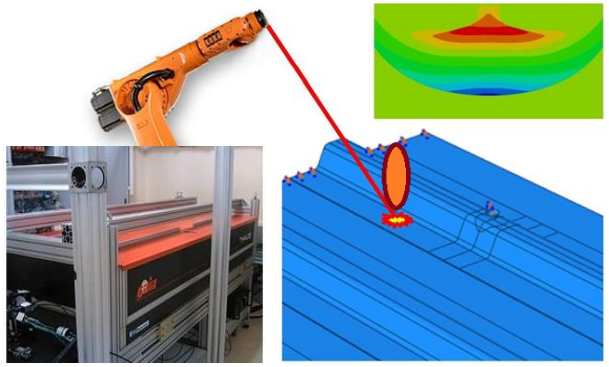
LASAT Brief History



- **1978**: J. L. Vossen, 1st demonstration, **1995**: V. Gupta, 1st patent for metals
- **2000**: E. Auroux, M. Arrigoni, C. Bolis, S. Barradas, thermal barriers, ceramic layers, metals…
- **2009**: D. Laporte, Starting with the thick systems (alu/glue/alu)
- **2009**: M. Perton, E. Gay (SATAC Project)
- **2009**: R. Bossi (Boeing), and LSPT
- **2011-2014:** R. Ecault PhD – ENCOMB Project

First demonstration of discrimination performances
Identification of optimal configurations

- **2012-2015:** D. Courapied , Arcol project
- **2015-2019:** Improving technology maturity

ComBoNDT: Multi-technique project for bonding assessment
COMPOCHOC: LASAT demonstrator expected in 2019
MONARQUE: symmetrical laser shock

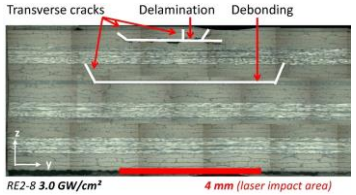
And many others…

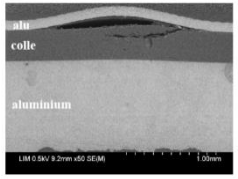
LASAT Principle & Methodology

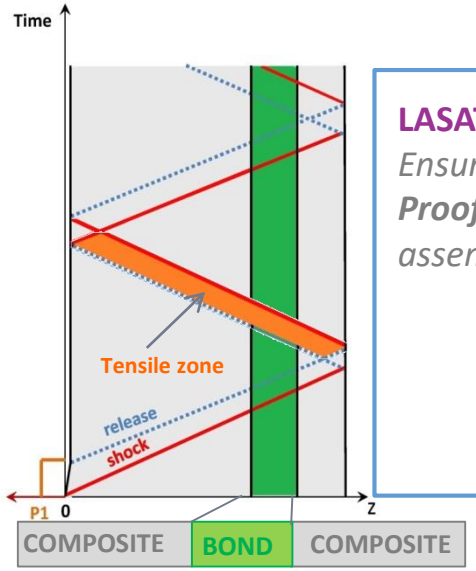
Bond/ interface mechanical characterization

Evaluate bonding strength

Can be used on coupons







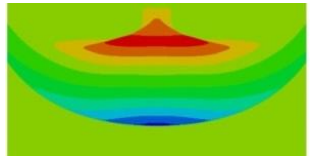
LASAT for bonding assessment

Ensure correct interface/bonding strength

Proof test** (non-destructive for the correct assemblies) → **reveal weak bonding

«Calibration» for the given assembly

Expert dimensioning to identify the best configuration



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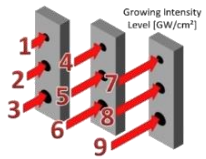
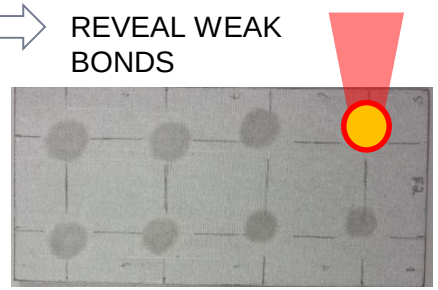


EXP

Laser Shock on target

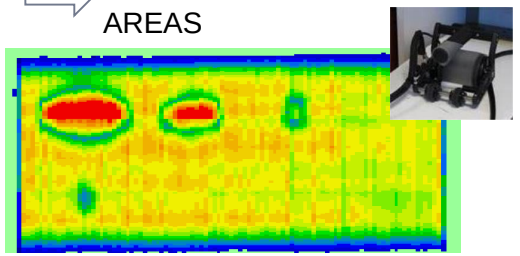
REVEAL WEAK BONDS



Shocks on bonded assembly

Adapted diagnosis

IDENTIFY DISBONDED AREAS



Post-shock ultrasound C-scan

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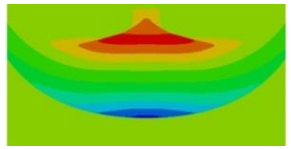
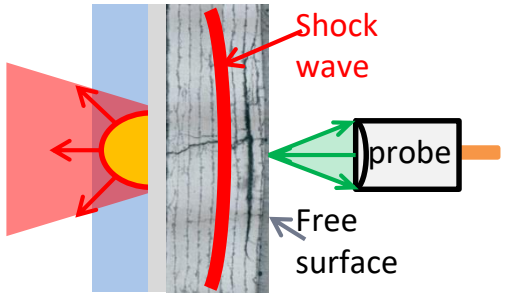
LASAT Tools

NUMERICAL APPROACH

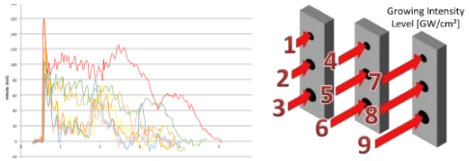
Numerical model validation
Mastering the stresses





EXPERIMENTAL APPROACH

Assembly response characterization
Damage threshold determination



QUANTIFICATION OPTIMIZATION

Nanosecond laser source

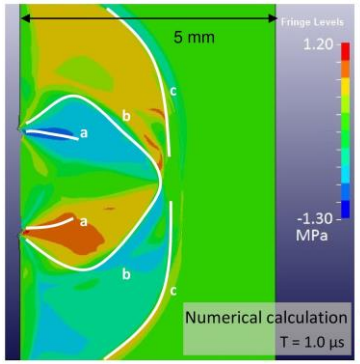
7 ns, 7J, 4mm, GW/cm²

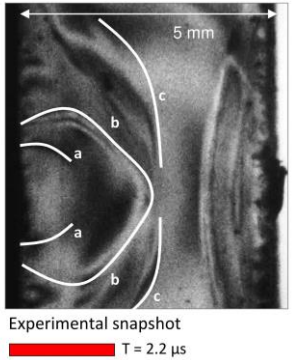
Laser/matter interaction

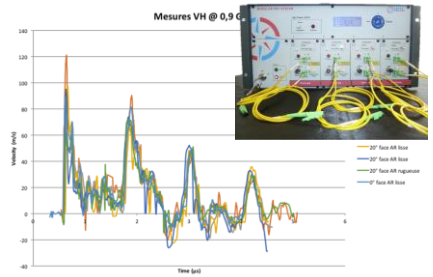
- Esther 1D (CEA)

Mechanics simulation

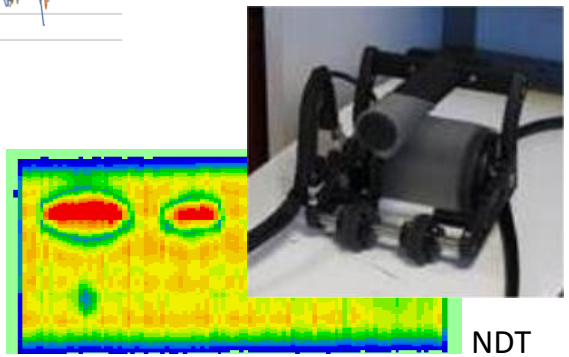
- Homemade 1D code (Hugo…)
- Commercial code with simple model (Dyna, Radioss, abaqus, elastic ortho)
- Commercial code + customized models (strain rate effect, viscosity,…)
- Academic tools (PGD, discrete elements,…)



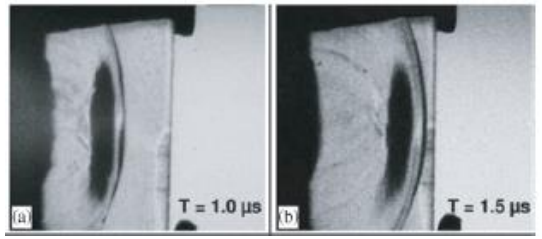




PDV or VISAR



NDT



Shadowgraphy

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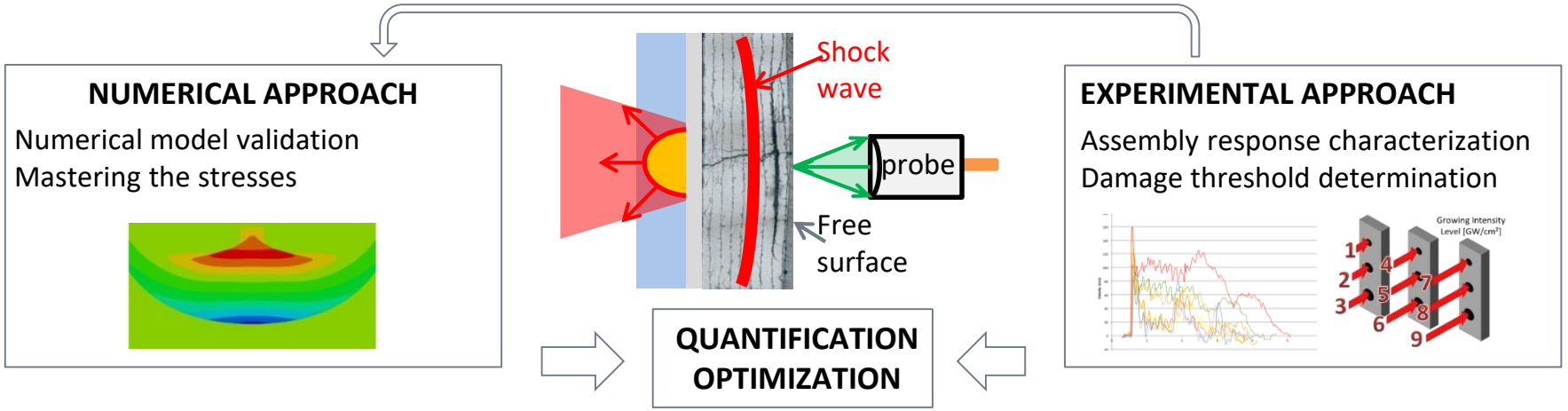
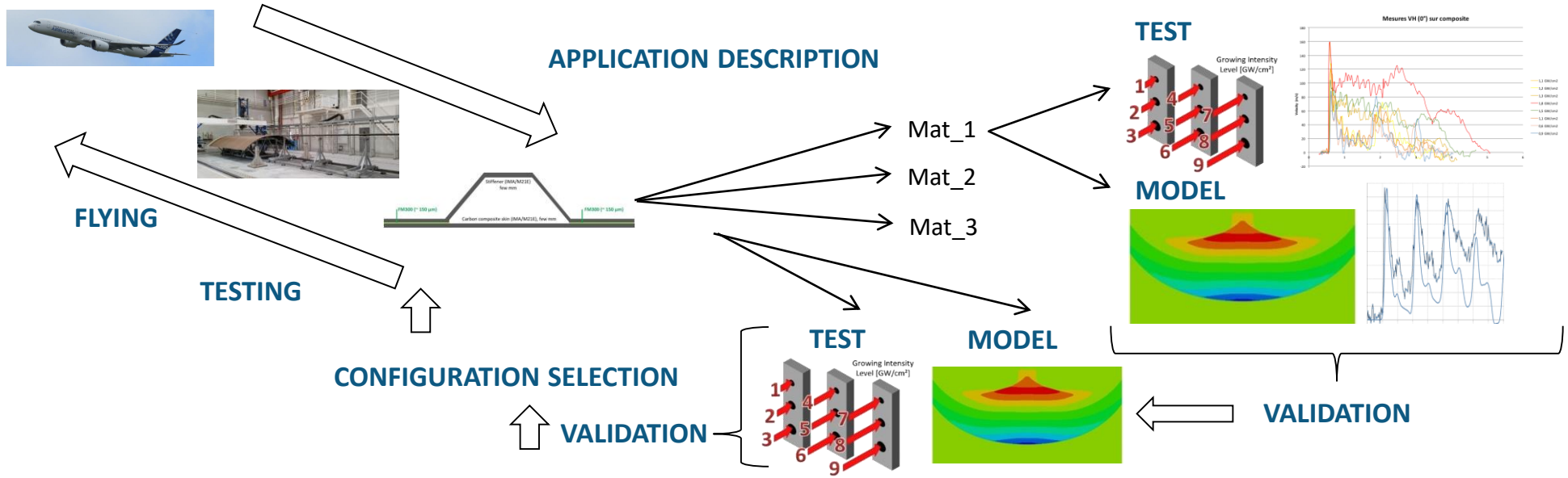
LASAT Methodology & Optimization





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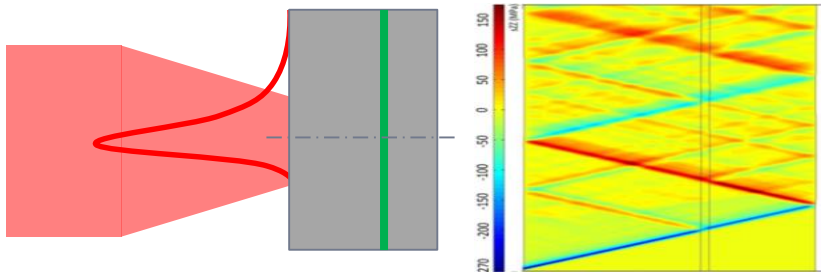
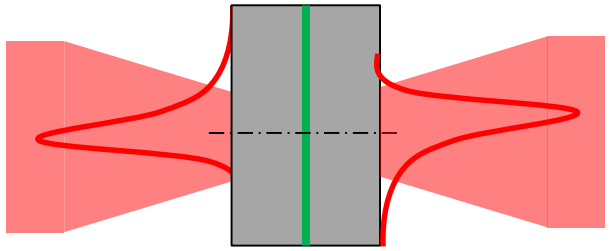
LASAT Configurations

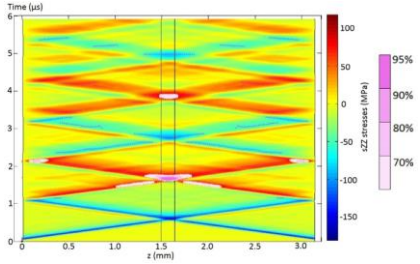
Mono pulse



. ***Historical configuration***
. *Stress distribution mainly depends on laser parameters*
. *Ok for assemblies for which substrates are much stronger than interfaces*

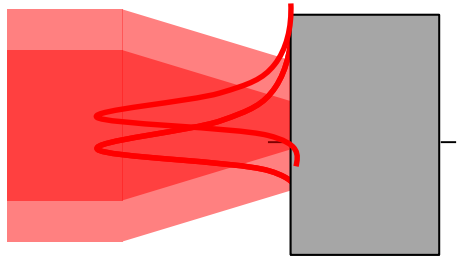
Symmetrical pulses

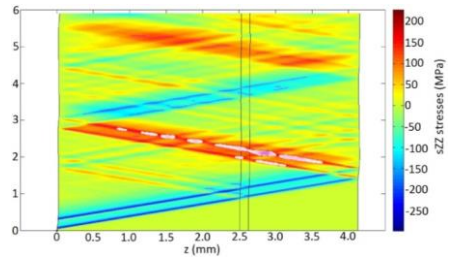




. *Most versatile configuration (Patented)*
. *Stress distribution can be fully adapted to the application*
. ***Production/Repair bonding assessment***
. ***Test of coupons*** *(GIC replacement)*

Double pulses





. *Optimized configuration*
. *Stress distribution can be partially adapted to the application*
. ***In-service bonding assessment*** *(one side access)*

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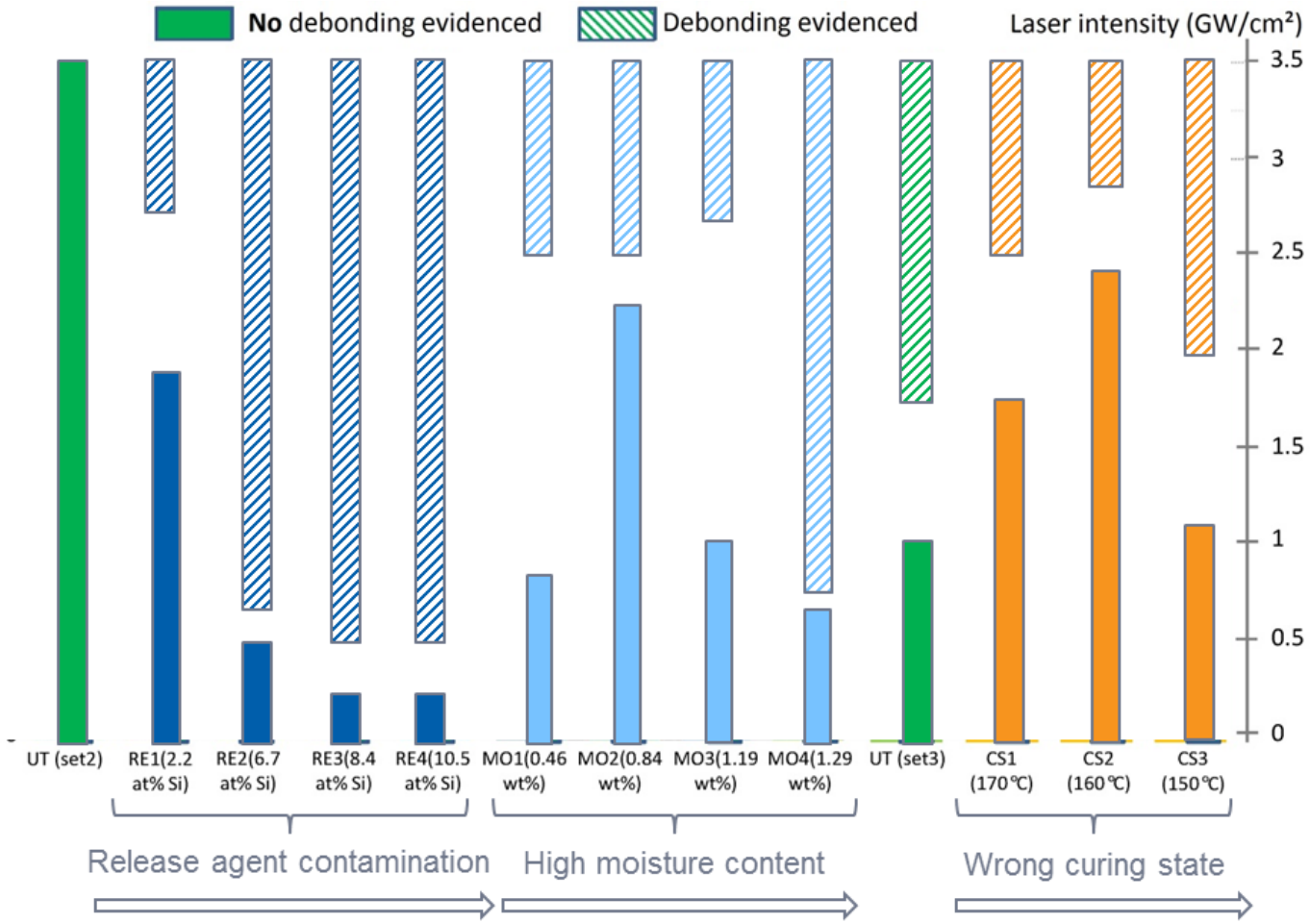
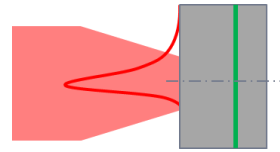
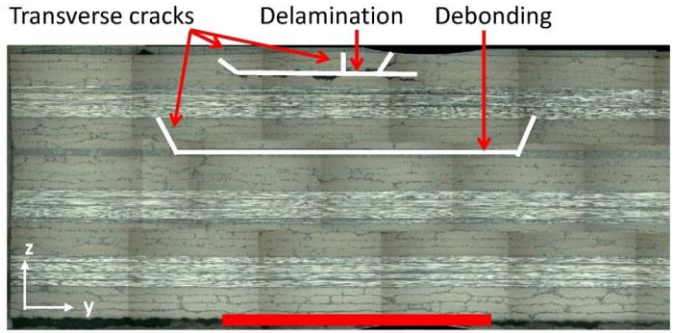
Performances 1/4



T700/M21 – FM300 Assemblies ~ 4mm thickness

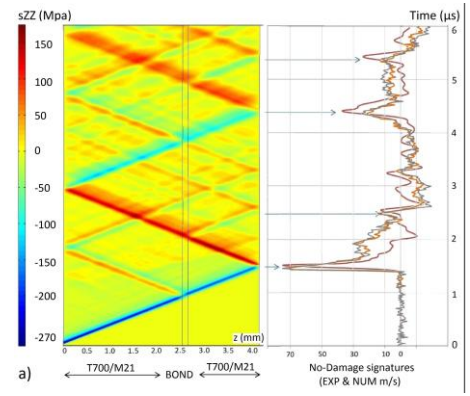


- Material characterization under laser shock
- First discrimination performances



*RE2-8 **3.0 GW/cm²*** *4 mm (laser impact area)*

- Composite delamination
- First numerical validation



- First optimization loop & expected performances

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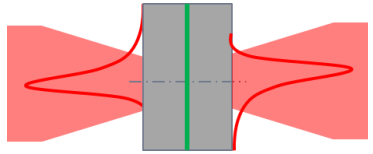
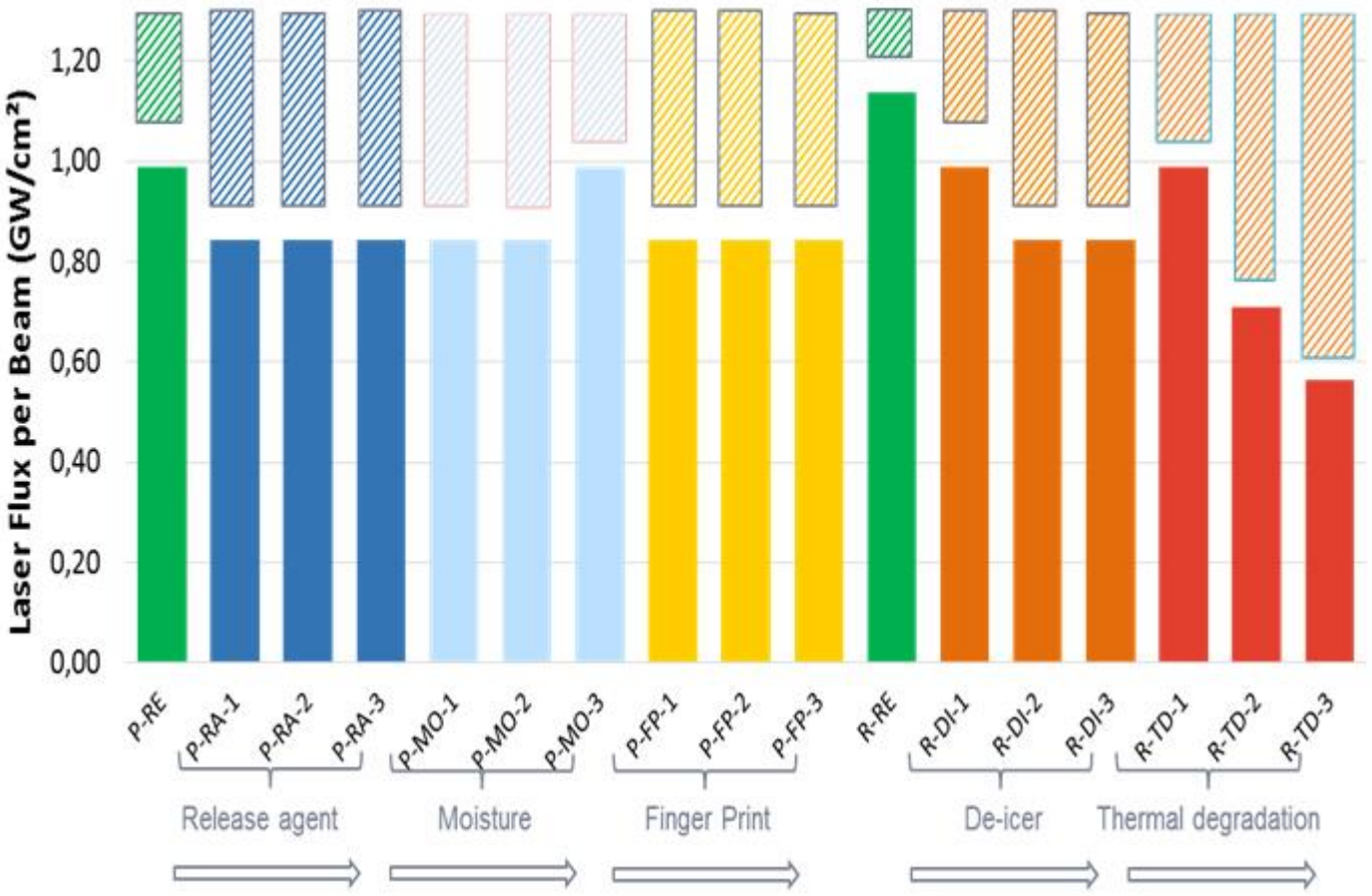
Performances 2/4

M.Sagnard PhD, ComBoNDT





- New contamination tested
- Sharper contamination range tested
- Multiple contamination tested
- Curved & scarfed samples tested

- No more composite delamination

IMA/M21E - FM300 & IMA/M21E - FM300-2M ~ 3mm thickness

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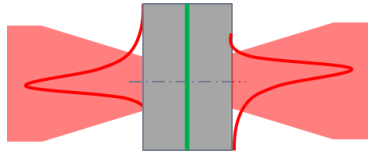
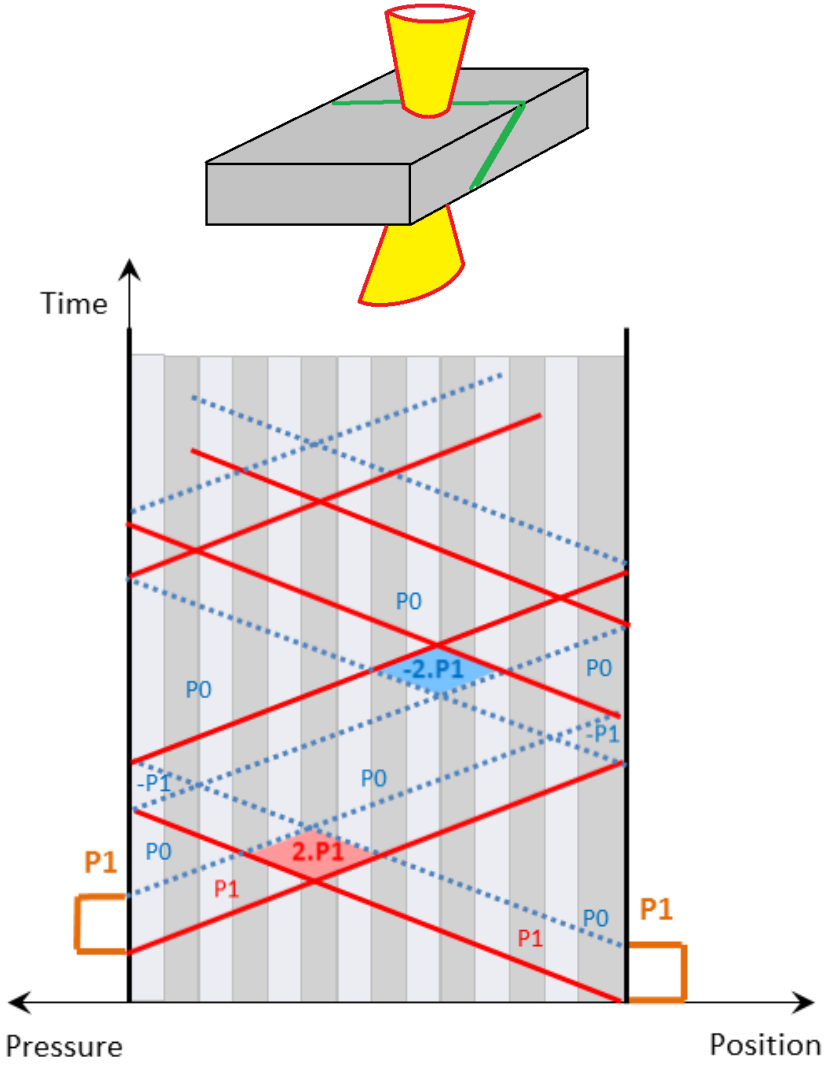
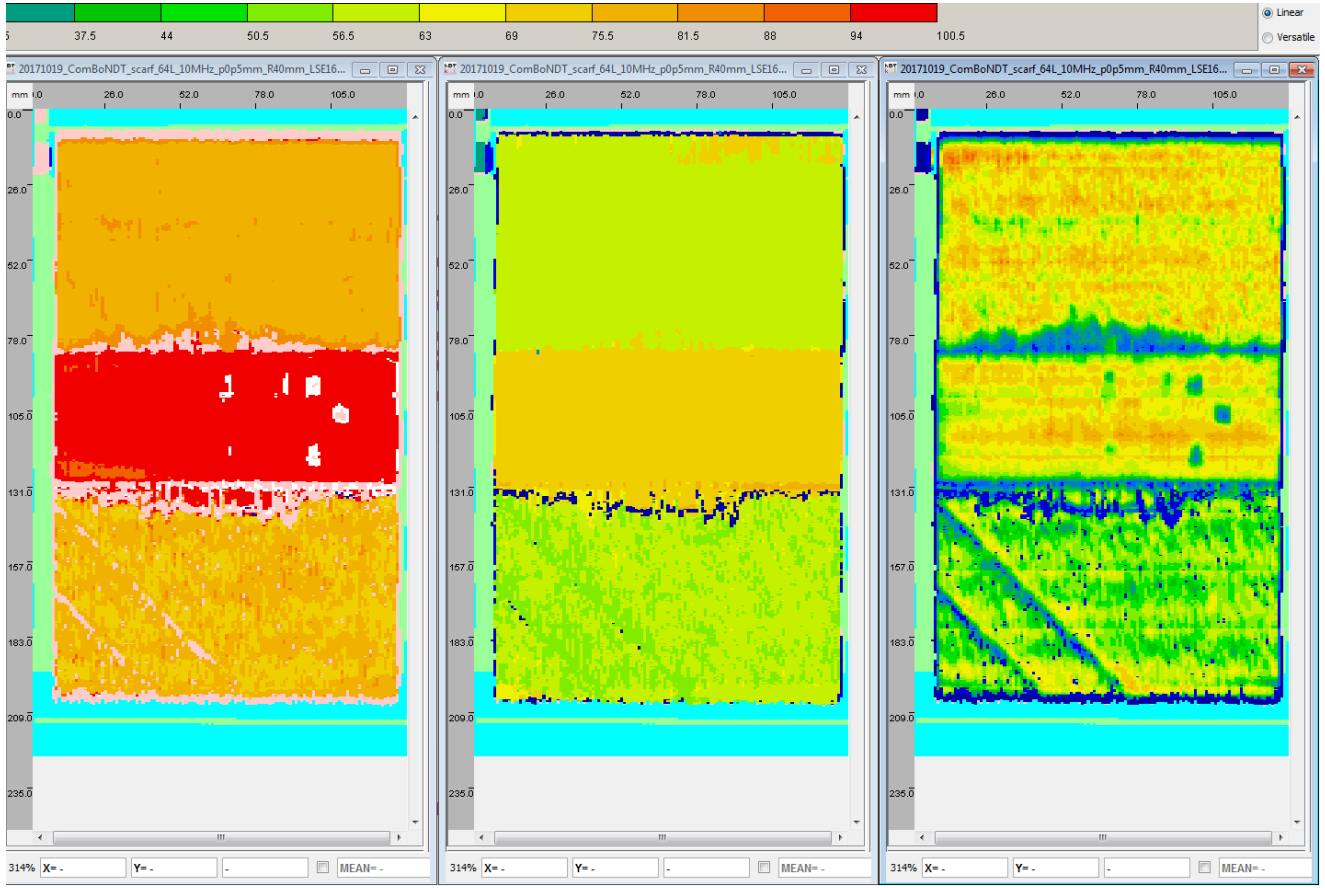
Performances 3/4

M.Sagnard PhD, ComBoNDT







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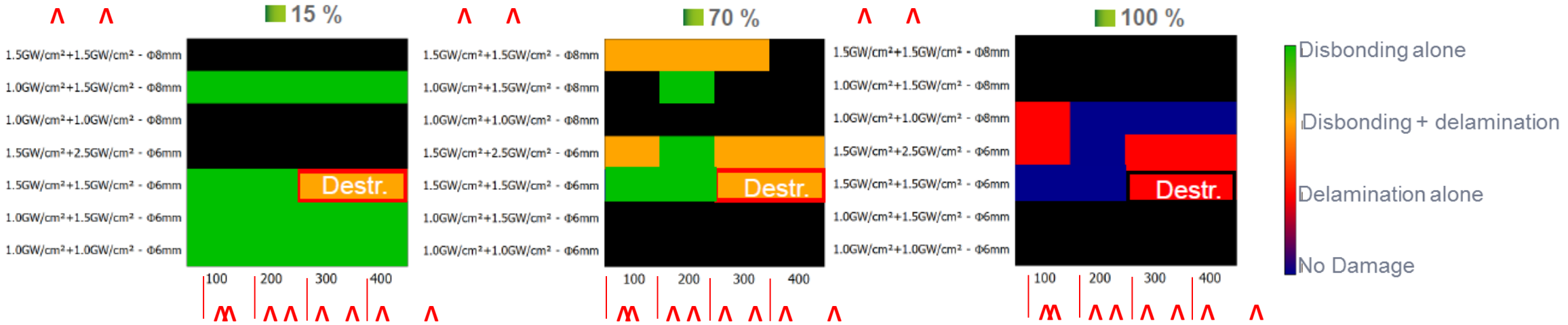
Performances 4/4

S. Bardy PhD, Compochoc



IMA/M21E – FM300 – Assemblies ~ 4mm thickness

- Numerical modeling of laser/matter interaction at low intensity
- Significant development of the time resolved diagnostic (PDV)
- Significant progress on composite modeling to take into account strain rate

To come

Residual mechanical performance assessment by testing post-shock

Prototype assembly for full scale demonstration industrial env.

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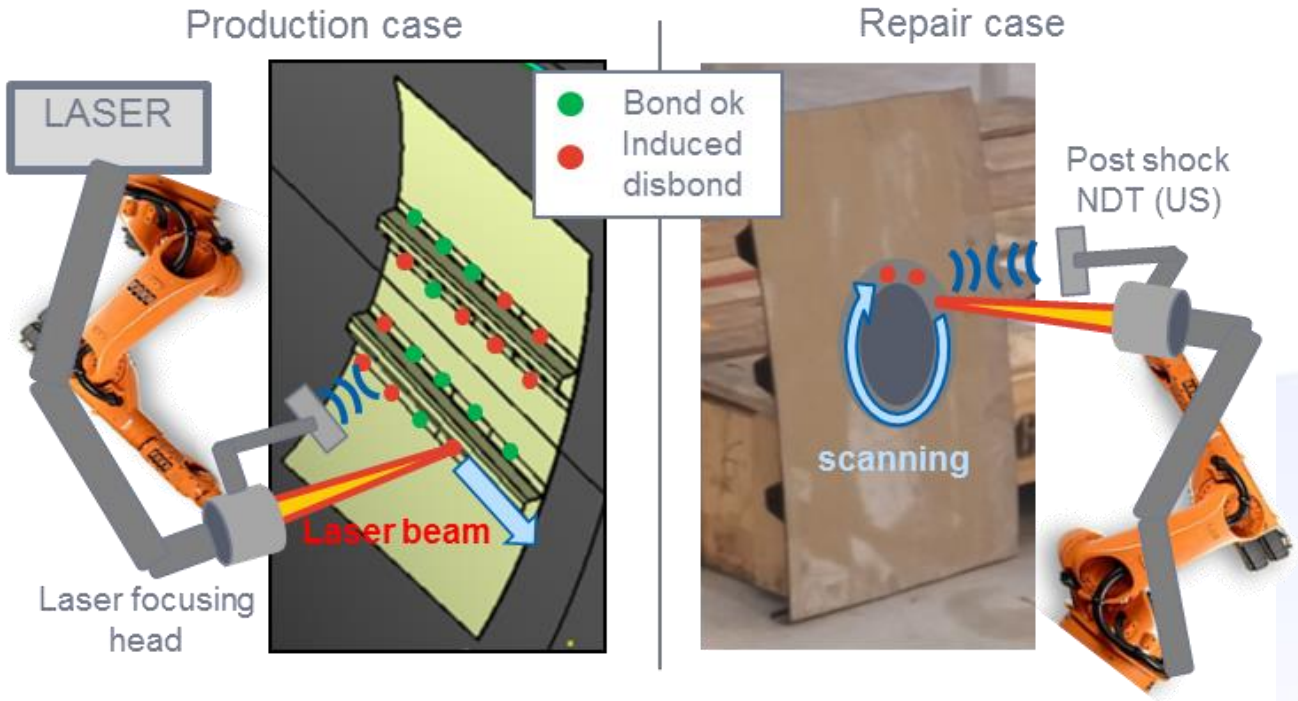
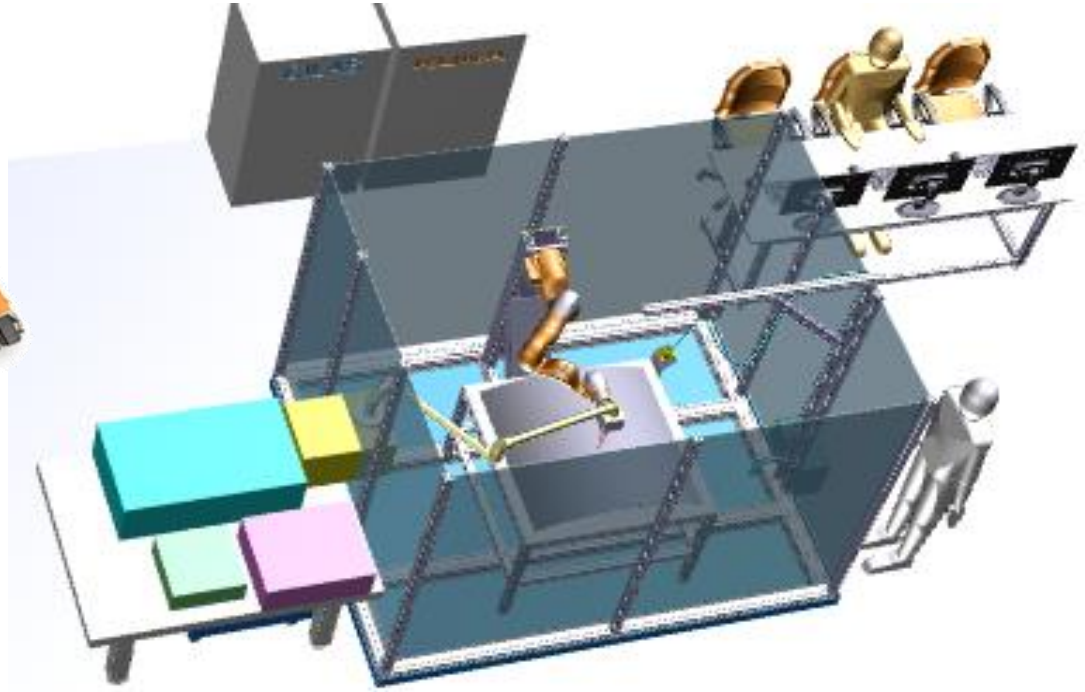
Toward industrialization… 1/3

Compochoc prototype





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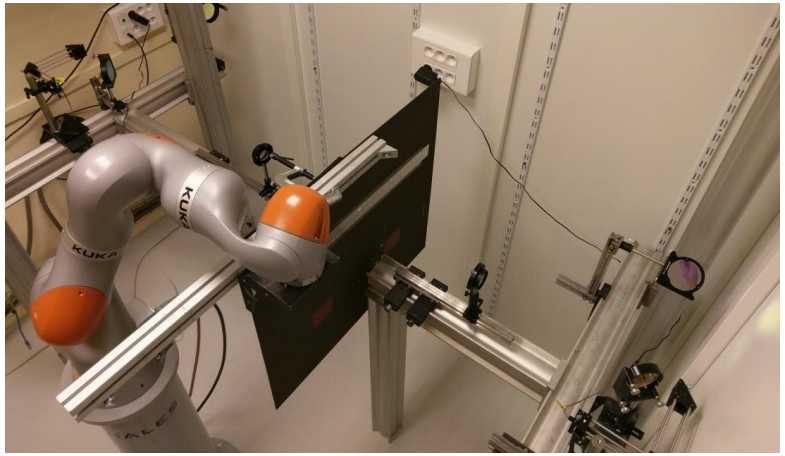
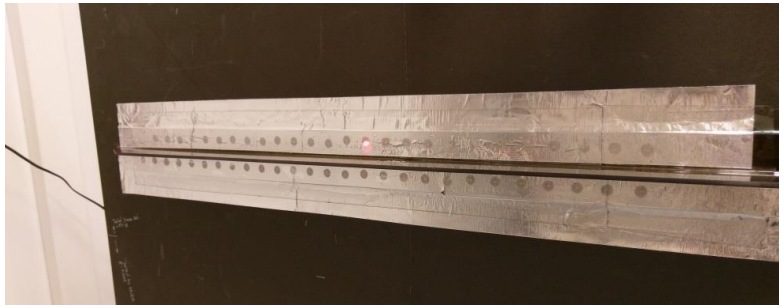
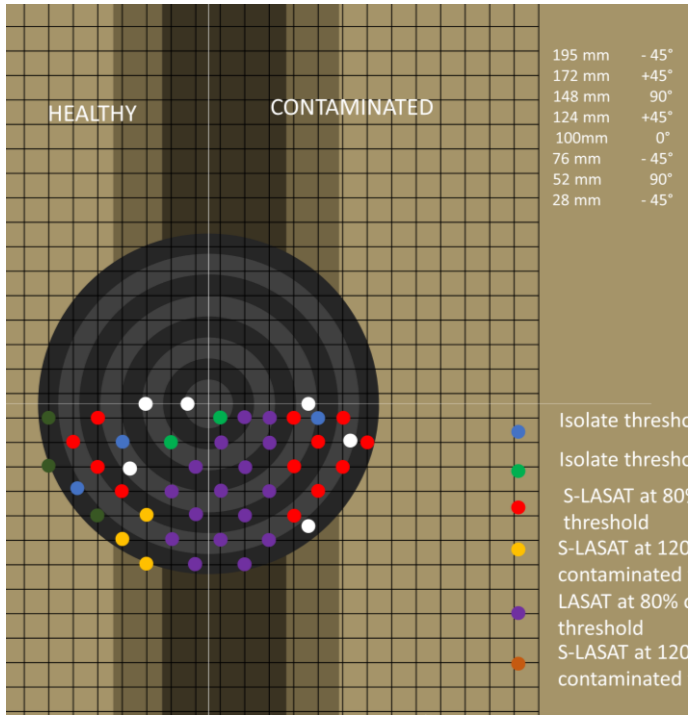
Toward industrialization… 2/3

ComBoNDT full scale demonstration







	Symmetrical config Threshold	Total test shots sym 80%	Opened bond sym 80%
Sound area	0,85GW/cm²	32	0
Contaminated area	0,74GW/cm²	21	21

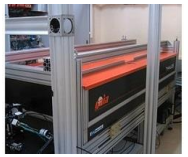
	Symmetrical config Threshold	Total test shots sym 80%	Opened bond sym 80%
Sound area	0,72GW/cm²	8	0
Contaminated area	0,61GW/cm²	8	8

Toward industrialization… 3/3

Hephaistos video

… with remaining open points

Laser source



- Robustness & reliability
- Stability of the parameters
- Repetition rate

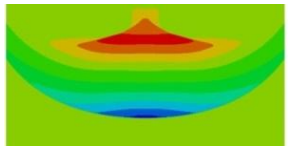
Process

- Solid confinement is a must for some application
- Sensibility to laser parameter deviation on the process performance

Transportation

- Optical arm
- Fiber delivery
  - state of the art 200 mJ
  - 1J target

Modeling



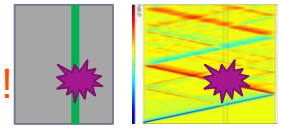
- Progress on phenomena description
- Two speed development necessary:
  1. Pre-dimensioning
  2. Dimensioning + quantification

Diagnostic

- Robustness (PDV, VISAR)
- Single face access
- Automation of the diagnostic (decision making on bond quality)

Expert dimensioning / calibration

Bim !



Bim !

- Sensibility to the damage initiation (for calibration, not for run mode)
- Database management
- Meta Model approaches

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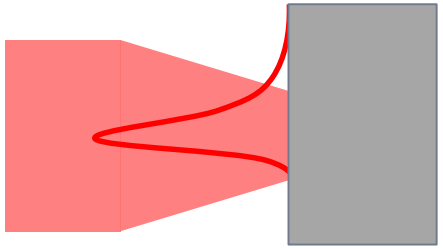
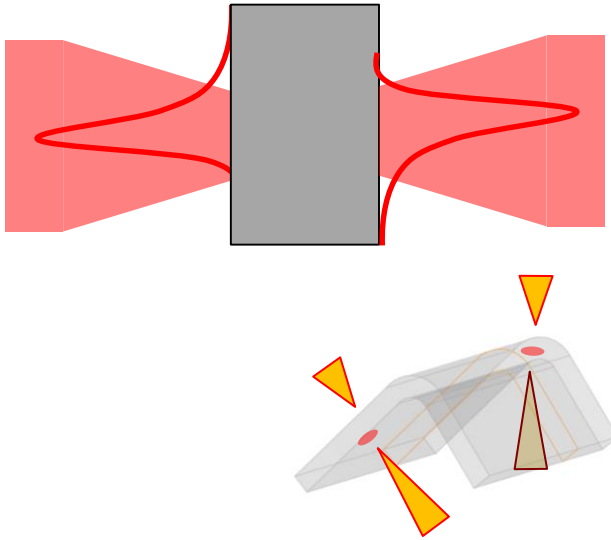
The laser shock applications landscape and trends

Mono pulse



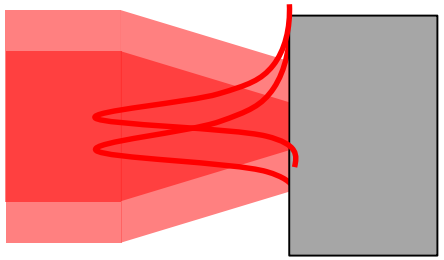
- **LASAT**: metal to metal assembly, metal to composite
  Every assembly where rupture threshold of the substrate is much higher than the one of the interface
- **Laser Shock Peening (LSP)** for fatigue enhancement + life extension

Symmetrical pulses

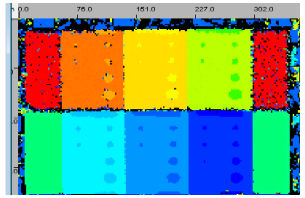


- **LASAT**: when double side access
  Mainly production cases
- **LASAT** : composite to composite
  Every assembly requiring optimization due to weakness of the substrate
- **LASAT**: process control specimen
- **Laser Shock Peening (LSP)** for thin products to master the deformation
- **Selective de-assembling**
- **Calibrated defect generation**

Double pulses



- **LASAT**: when single side access
  Mainly repair cases
- **LASAT** : composite to composite
  Every assembly requiring optimization due to weakness of the substrate
- **LASAT**: repair
- **Laser ultrasounds:** NDT technique for material quality



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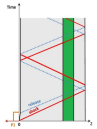
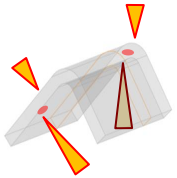
The laser shock applications landscape and trends

LUS

LSP



LASAT



SID (shock induced damage)

Intensity

1 MW/cm² 1 GW/cm² 4 GW/cm² 6 GW/cm²

Energy

30 mJ 200 mJ 1J 7J 10J 25J

Pulse duration

5 ns 20 ns 40 ns 90 ns

Focal spot

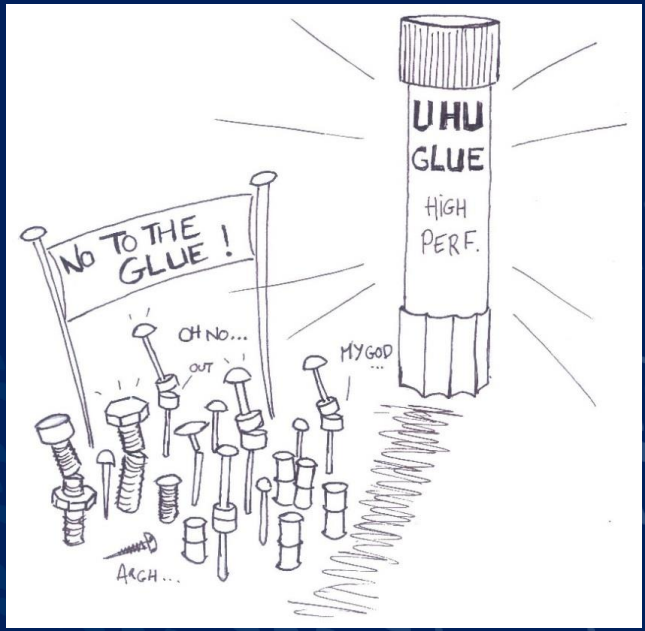
0.5 mm 2 mm 6 mm 10 mm 20 mm

Repetition rate

2 Hz 5 Hz 10 Hz 100 Hz 1 kHz

Fiber state of the art limit

AIRBUS



Thank you

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