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## Development of Environmental Barrier Coatings on Ceramic Matrix Composites assisted by LASAT (Laser Shock Adhesion Test)

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► **To cite this version:**

Guillaume Cottin, Vincent Guipont, Vincent Maurel, Emine Bakan, Robert Vassen, et al.. Development of Environmental Barrier Coatings on Ceramic Matrix Composites assisted by LASAT (Laser Shock Adhesion Test). HT-CMC, Sep 2019, Bordeaux, France. hal-02185840

**HAL Id: hal-02185840**

**<https://minesparis-psl.hal.science/hal-02185840>**

Submitted on 2 Dec 2020

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# Development of EBC on CMC assisted by LASAT (Laser Shock Adhesion Test)

## COLLABORATIVE WORK

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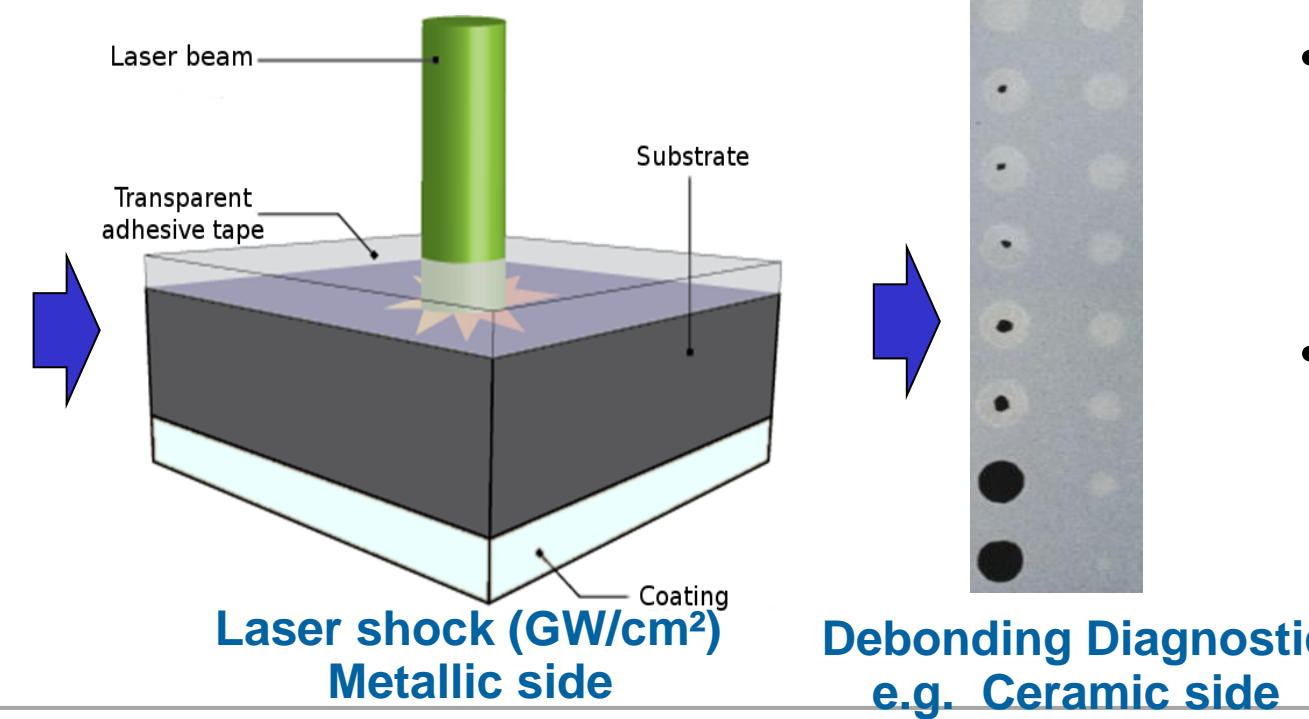


## CONTEXT: Laser-driven debonding → Interface strength of ceramic coatings

### LASAT: Laser Shock Adhesion Test



LASAT facility



#### • Saga –Thales Laser :

- maximum energy: 2J
- pulse duration: 5.2 ns
- wavelength: 532 nm

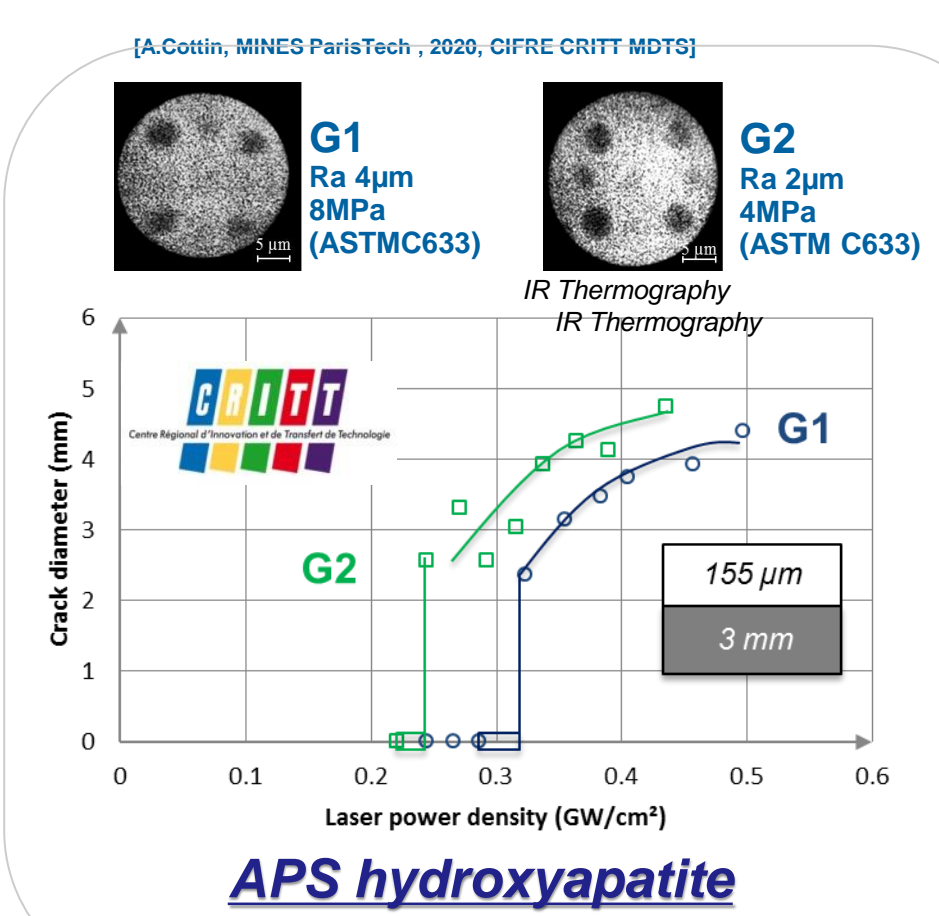
#### • Two settings parameters are:

- Irradiated area diameter,  $\phi_{laser}$
- Laser energy, J
- laser fluency (power density), 0,1 → 10GW/cm<sup>2</sup>

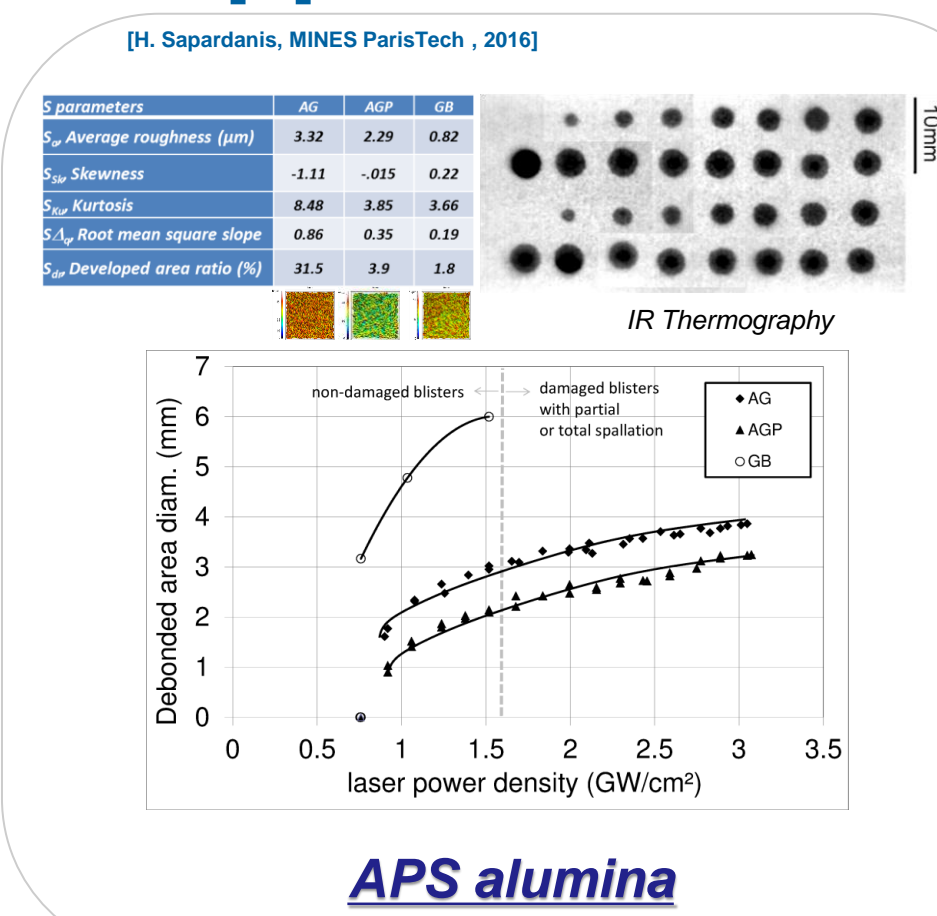
#### For coating system:

- Substrate thickness
- Coating thickness
- Failure threshold / LASAT 2D curves
- **No specific geometry**
- **No contact, Local assessment**

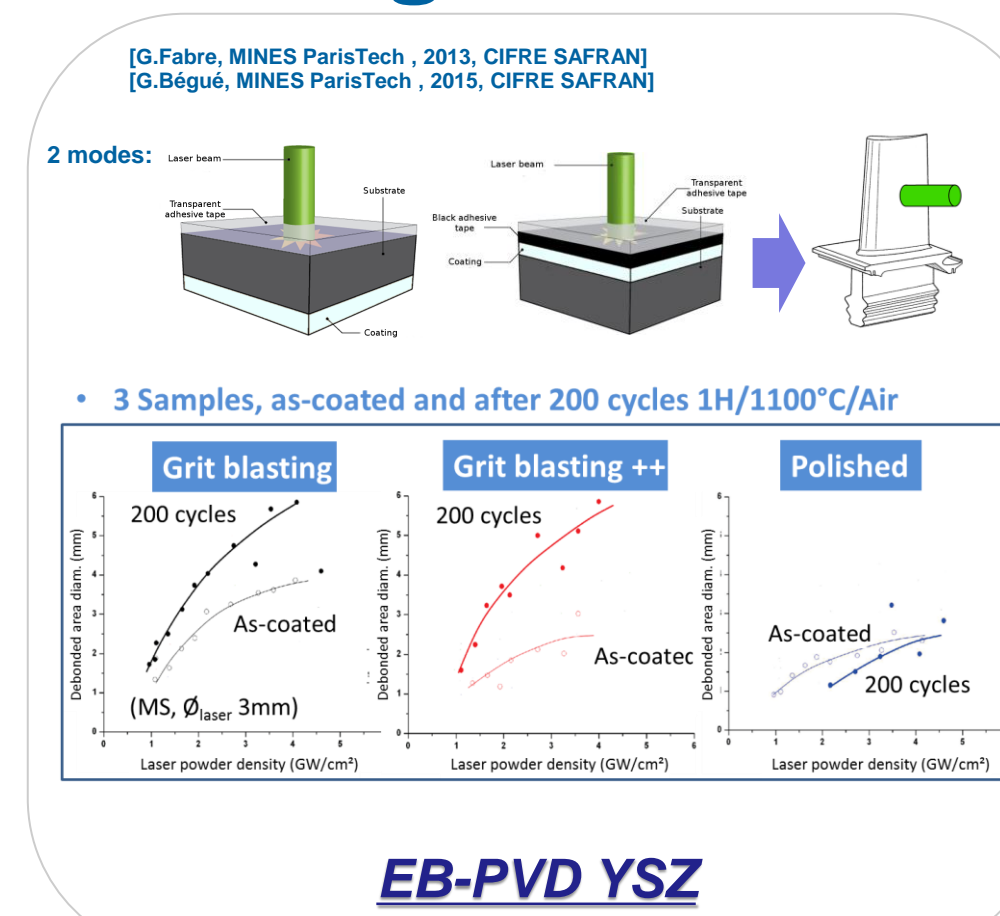
## BACKGROUND: LASAT applied to ceramic coatings on metallic substrates



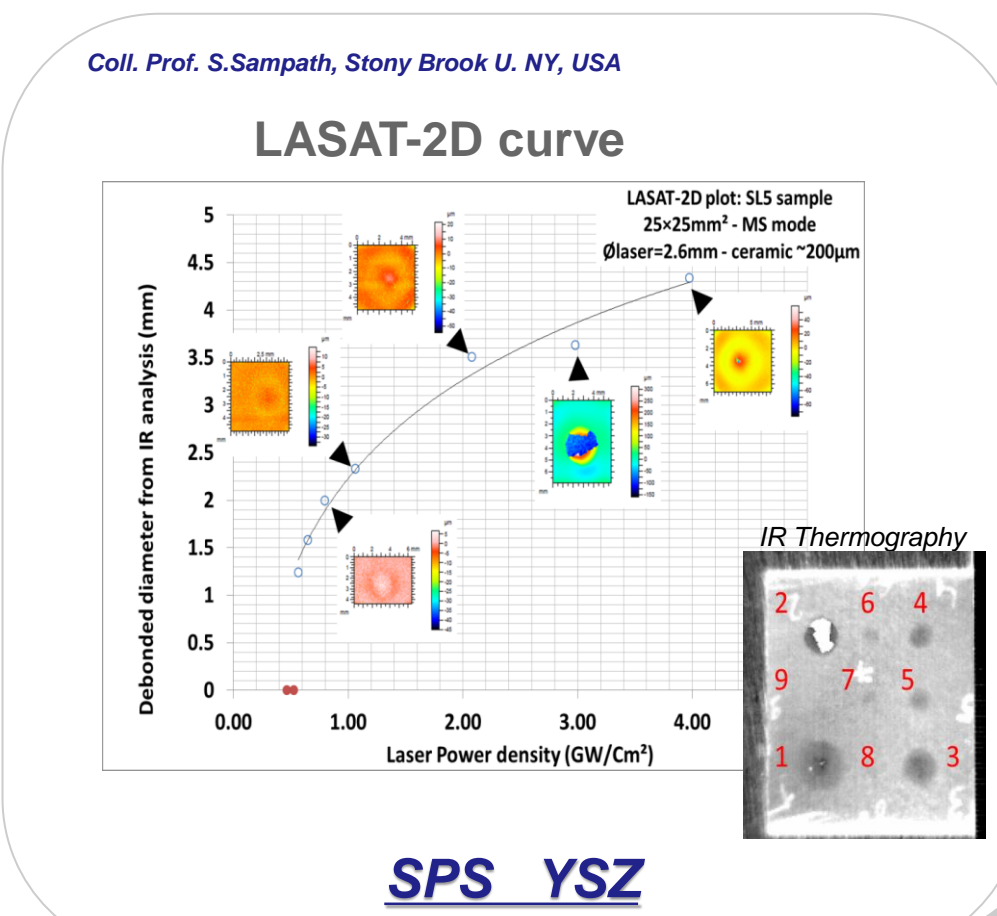
APS hydroxyapatite



APS alumina

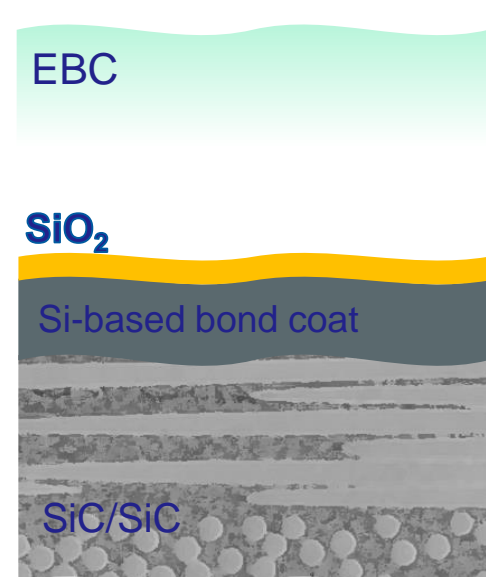


EB-PVD YSZ



SPS YSZ

## OBJECTIVES



Development of Plasma Spray Multilayered Environmental Barrier Coatings on CMCs

LASAT applied to EBC?  
→ Assessment of interface strength of CMC/EBC

- Dense layers
- Minimal CTE mismatch with CMC
- High water vapor resistance oxides e.g. Yb<sub>2</sub>Si<sub>2</sub>O<sub>7</sub> for SiC/SiC

## MATERIALS AND PROCESSES

### Spraying experiments

Sample	Dimensions	SiC/SiC	Si	Yb <sub>2</sub> Si <sub>2</sub> O <sub>7</sub>	Plasma
Sample 1	#1 25x25 mm <sup>2</sup>	3.4 mm	115 μm	109 μm	APS
Sample 2	#2 25x25 mm <sup>2</sup>	3.4 mm	92 μm	123 μm	HV-APS

### LASAT experiments

- $\phi_{laser}$  = 3.1 mm / P = 2 → 5 Gw/cm<sup>2</sup>
- Confinement : water, adhesive tape
- with/without protective tape
- Metallic side (MS) or ceramic side (CS)

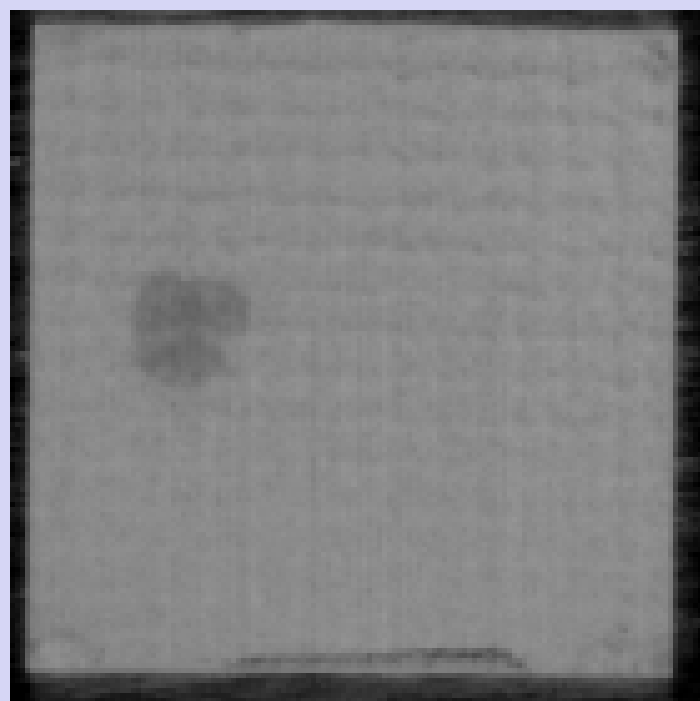
### Diagnostics:

- Optical top-surface image
- IR camera / substrate @50C
- Cross-section / OM

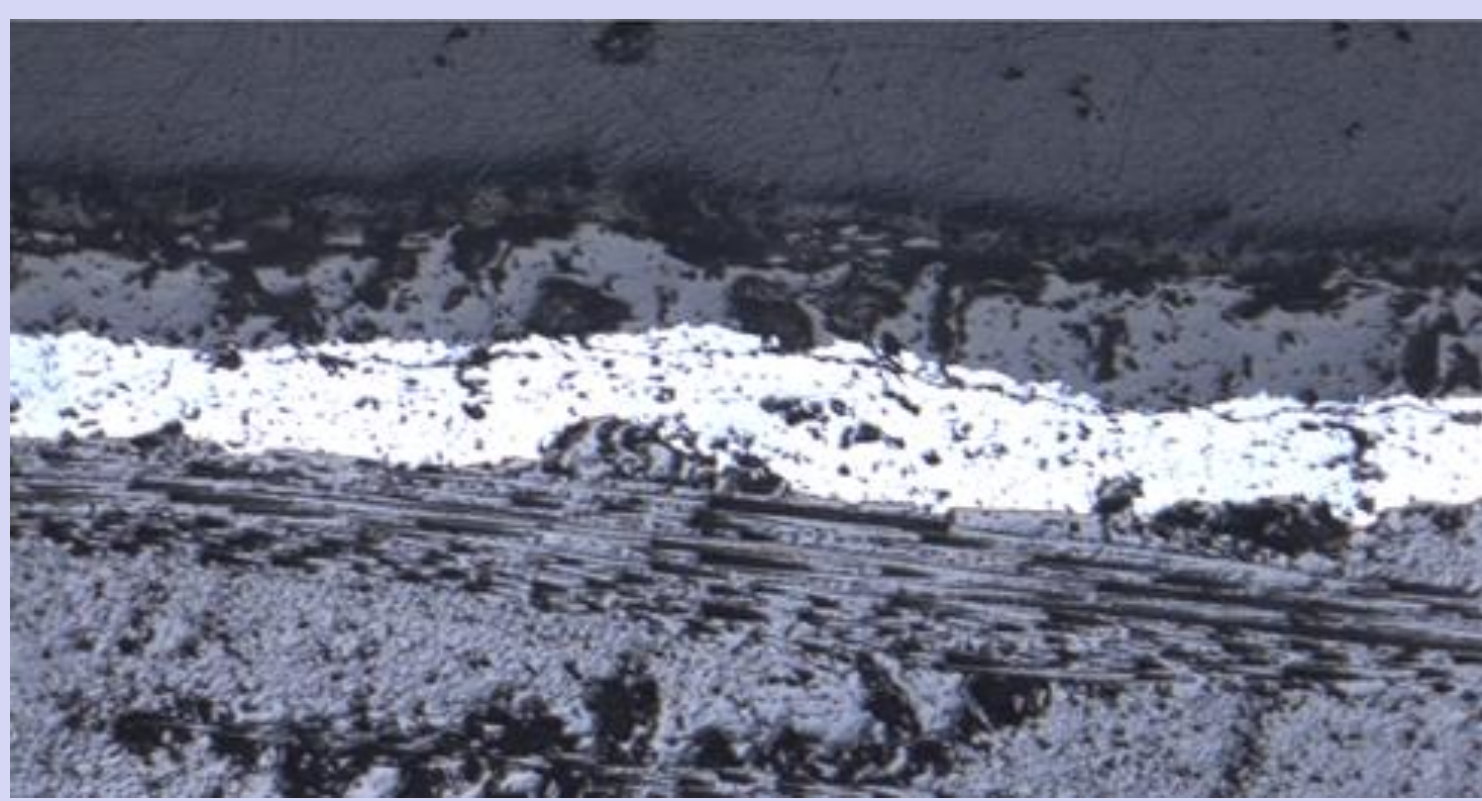
## HIGHLIGHTS

### 1. LASAT can be applied to CMC/EBC

- IR image ceramic top-surface
- 5 GW/cm<sup>2</sup>
- MS mode



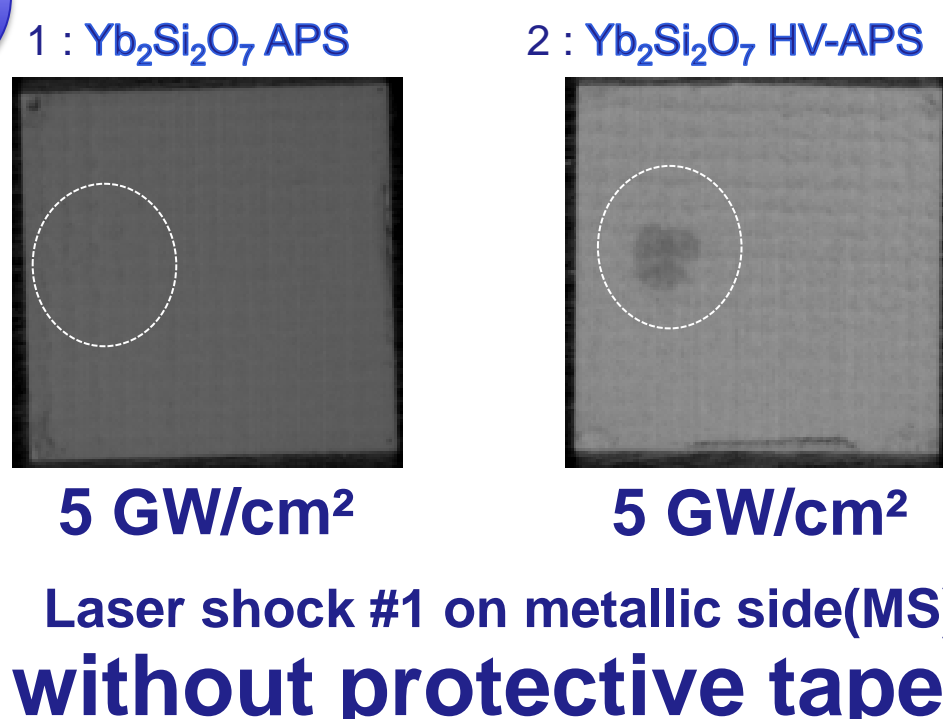
### 2. Laser-induced crack is located within the Si layer (HV-APS sample)



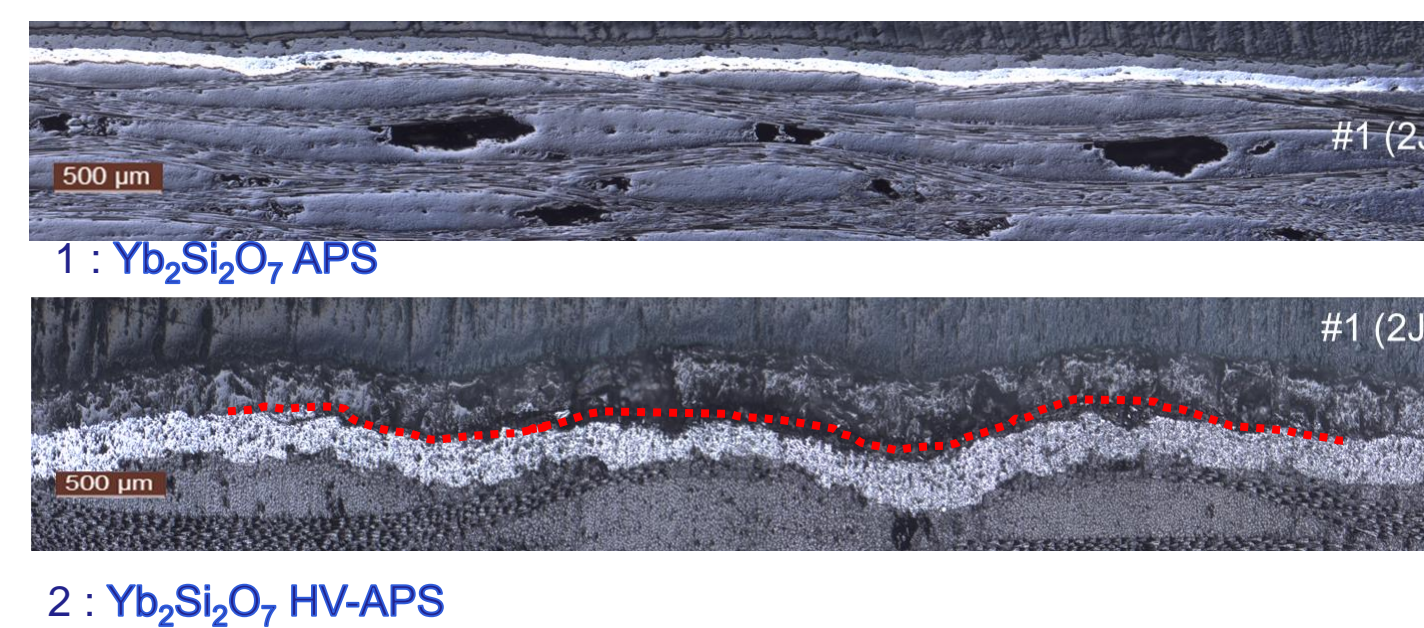
### 3. LASAT on ceramic side is applicable

## MAIN RESULTS

### 1 IR image ceramic top-surface

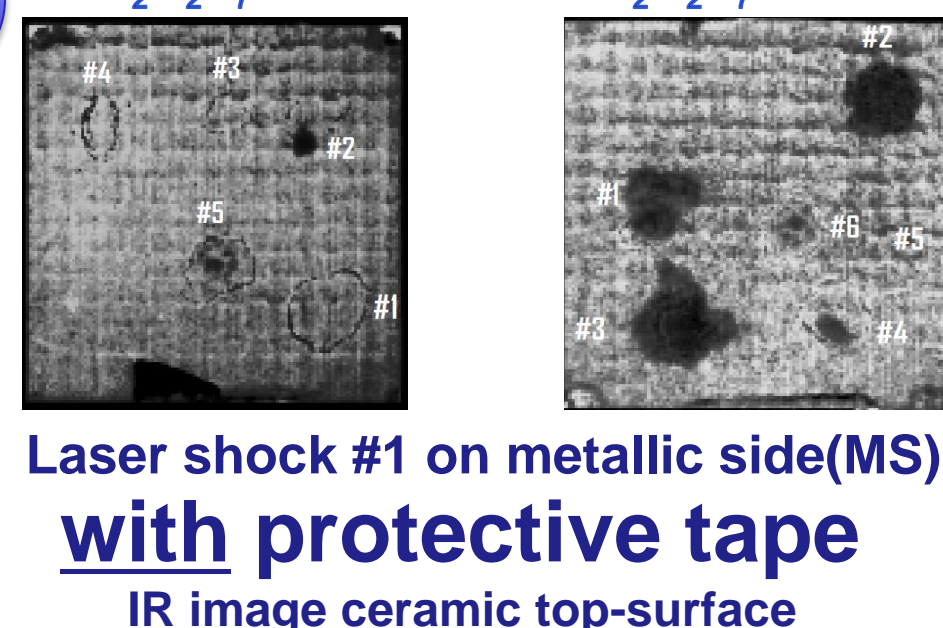


Laser shock #1 on metallic side (MS) without protective tape

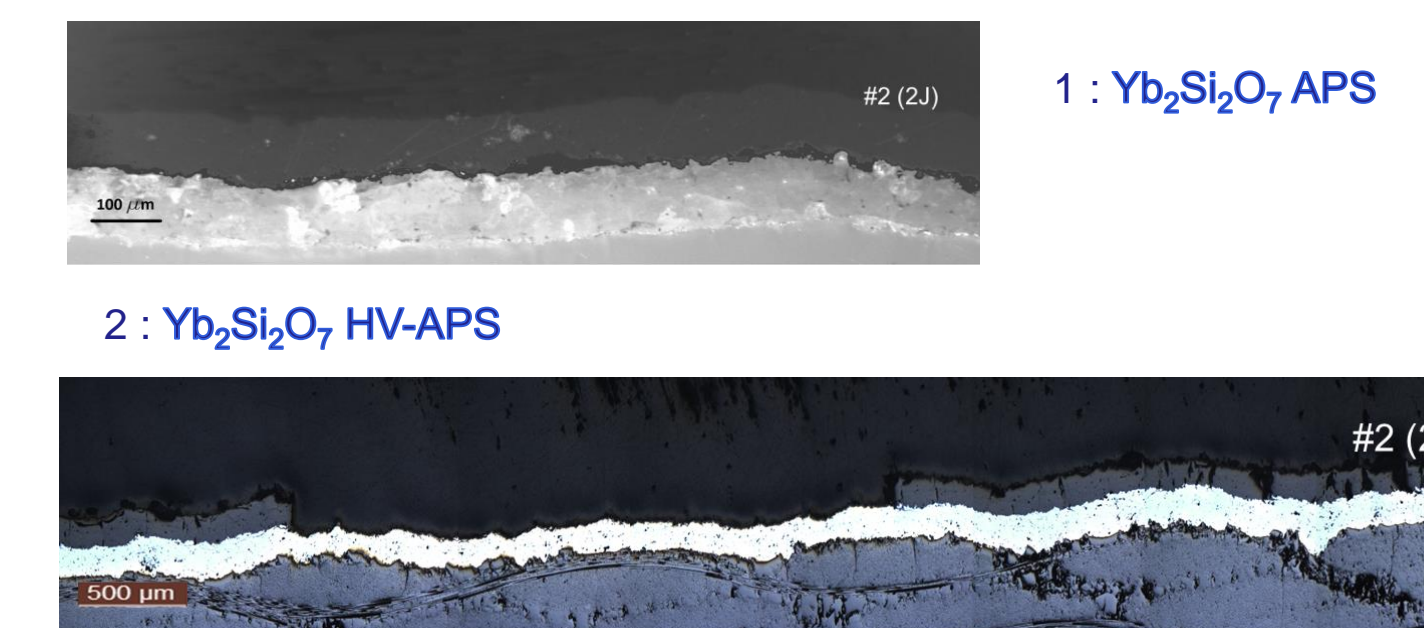


- Debonding occurred only for HV-APS sample
- IR imaging is applicable, not optical imaging
- Pores are evidenced within CMC substrate

### 2 Yb<sub>2</sub>Si<sub>2</sub>O<sub>7</sub> APS and HV-APS

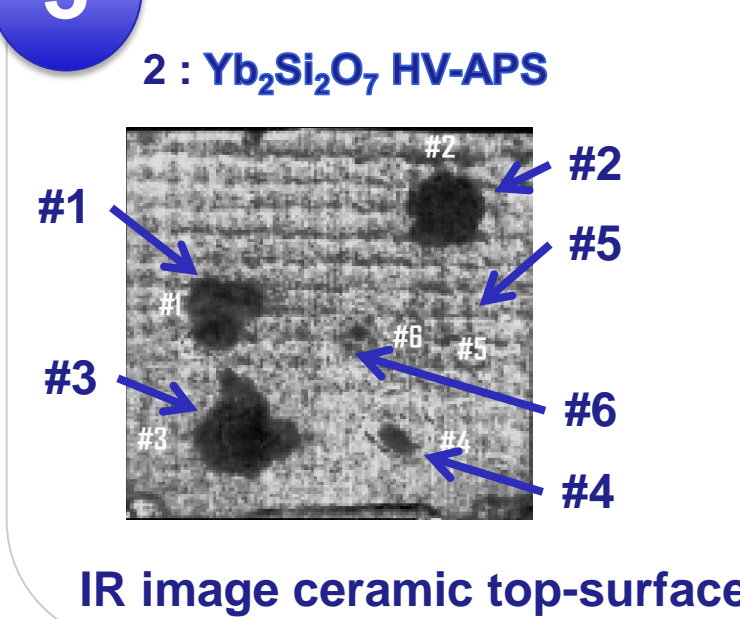


Laser shock #1 on metallic side (MS) with protective tape  
IR image ceramic top-surface



- Small crack in case of 1 : Yb<sub>2</sub>Si<sub>2</sub>O<sub>7</sub> APS
- Spallation in case of 2 : Yb<sub>2</sub>Si<sub>2</sub>O<sub>7</sub> HV-APS
- IR imaging is applicable for small crack
- Protective layer and water increase laser-induced input pressure

### 3 Yb<sub>2</sub>Si<sub>2</sub>O<sub>7</sub> HV-APS



IR image ceramic top-surface

	Side	GW/cm <sup>2</sup>	Damage	Laser shock conditions
#1	CMC	5,1	Crack 5 mm	Without protective tape + transparent tape
#2	CMC	4,8	spallation	With protective tape + water
#3	CMC	3,7	spallation	With protective tape + water
#4	CMC	2,5	Crack 1.2 mm	With protective tape + water
#5	CMC	1,9	Crack 0.8 mm	With protective tape + water
#6	EBC	4,9	Crack 0.5 mm	With protective tape + water

- Crack size is decreasing with laser energy
- Crack located Si/Si near Yb<sub>2</sub>Si<sub>2</sub>O<sub>7</sub> coating
- LASAT with CS mode is applicable

## CONTACT

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## CONCLUSIONS

- LASAT can be applied to CMC/EBC systems involving SiC/SiC -Si-Yb<sub>2</sub>Si<sub>2</sub>O<sub>7</sub>
- HV-APS 25x25 mm<sup>2</sup> sample exhibited a conventional behaviour upon LASAT → LAST 2D curves can be envisaged
- IR imaging can be advantageously envisaged for a non destructive assessment of the interfacial damage
- MS or CS modes can be envisaged, the use of a protective layer is preferred
- The weakest and lowest toughness interfacial zone seems to be located within the Si layer after deposition
- The presence of large pores within CMC may have attenuated the propagating shockwave in case of the APS sample

