IMPLEMENTATIONS FOR POWER ELECTRONICS INDUCTANCES AND TRANSFORMERS LASER PROCESSES

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ESSIAL FINAL PROJECT INFODAY 11/07/22

MULTITEL, R&D and Innovation Center

Mons

Tournai

Non profit organization ~ 70 persons
4 R&D DEPARTMENTS and one service oriented department (ERTMS)

Applied Photonics
Lasers and optical sensors

[Physics]

Signal and image processing

[Intelligence]

Human Machine Interface
[Instrument]

Networking
[Connectivity]
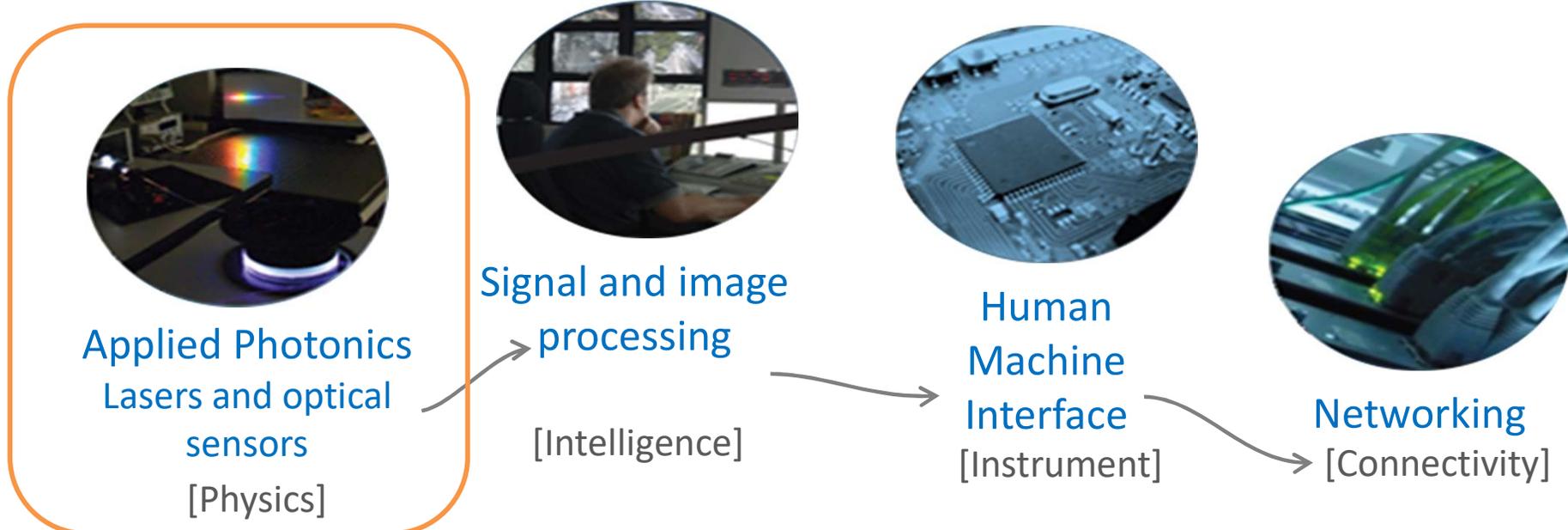
MULTITEL, APPLIED PHOTONICS DEPARTMENT
At a glance...

15 engineers and PhD   Two clean rooms   Multidisciplinary

Fiber lasers	Fiber optic sensors	Laser micro processing	Biophotonics	Terahertz
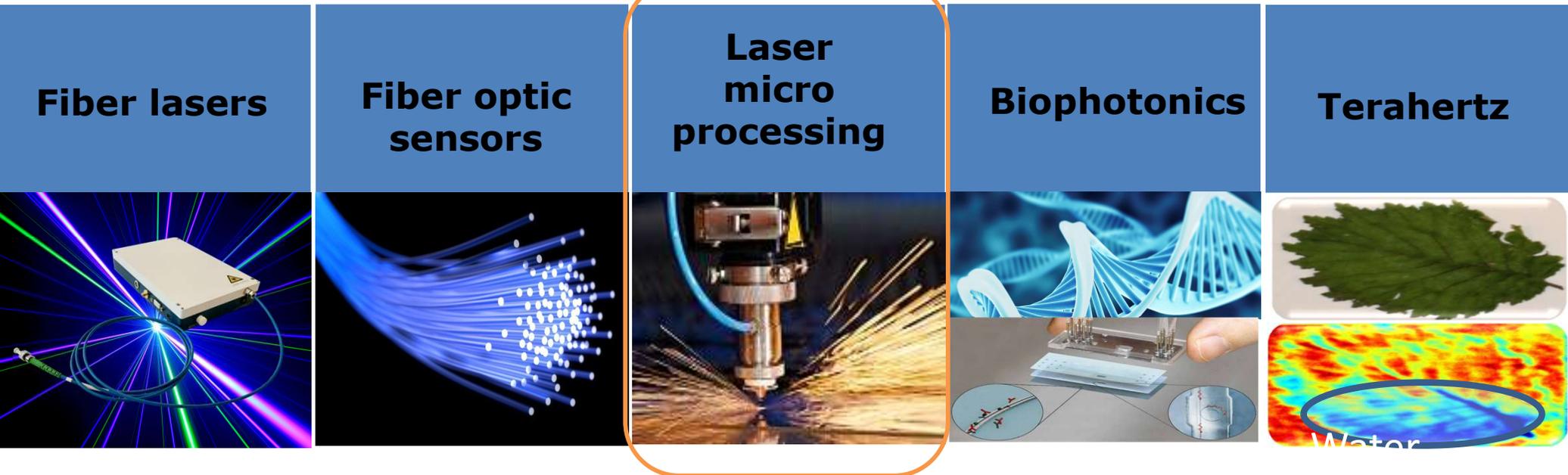
Main objectives of Multitel within ESSIAL

WP2 : Manufacturing processes
Surface laser texturing (capabilities, analysis and new processes)

WP4/WP5 : Proof of Concept
Produced advanced laser treatments on Electrical steel for electrical machines
prototypes

Why a laser treatment on Electrical steel?

- Objective: to improve the electrical and magnetic performances of transformers and motors by acting on the material.

➔ Domains refinement: laser surface treatments allowing an orientation or an improvement of the magnetic domains of the steel for:

Active/Rotating machines
motors (Rotor + stator)
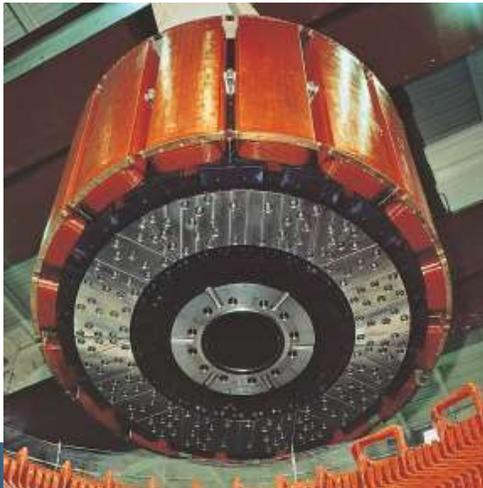
Passive machines
Inductances/chokes
Power Transformers
Torus
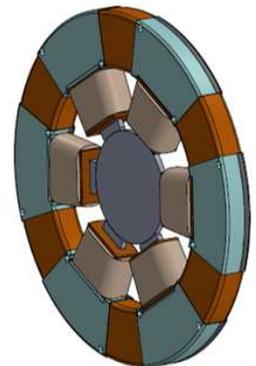
Laser processes – SOA & definitions

History of the domains refinement techniques

Mechanical Scratching

Continuous Laser (CWL) <- Common treatment in siderurgy

Long Pulse (LPL), Short Pulse (SPL) Lasers

Ultra-Short Pulse Laser (USPL)
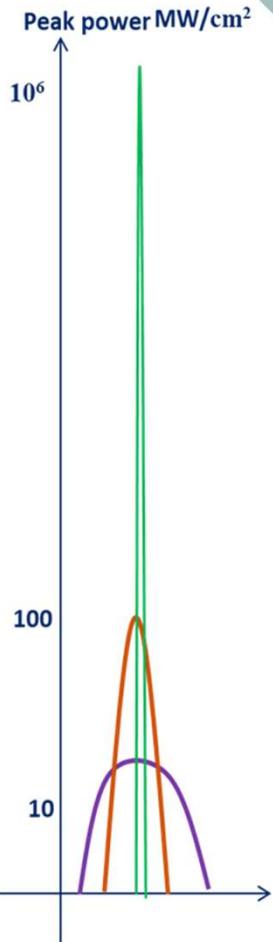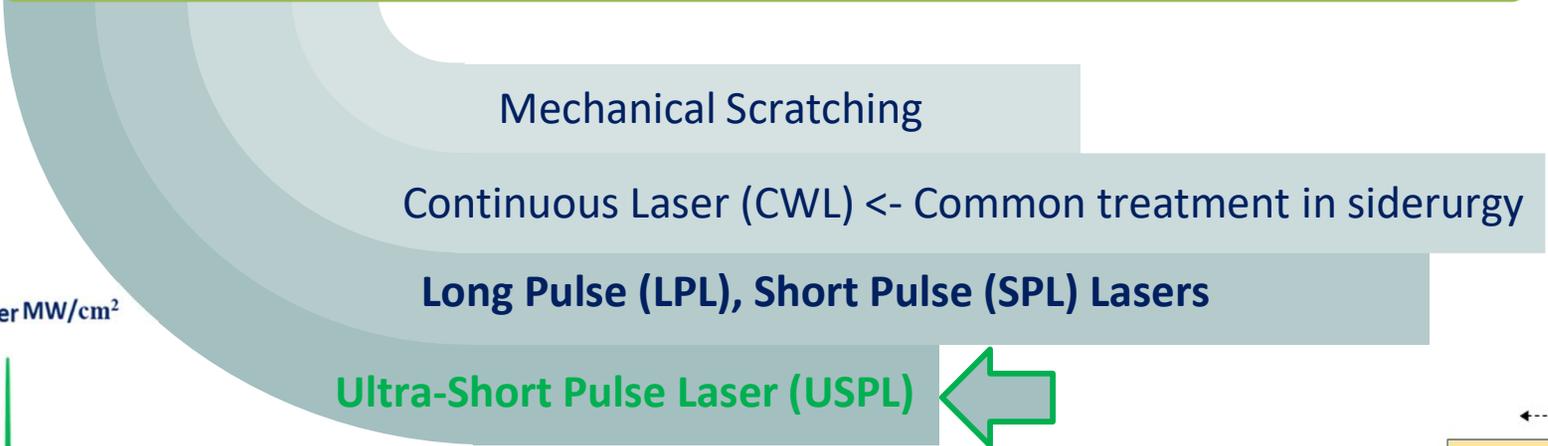
A: USPL process called ablation (Femtosecond)

S: SPL process called scribing (Nanosecond)

I: LPL process called irradiation (>100ns to CW)
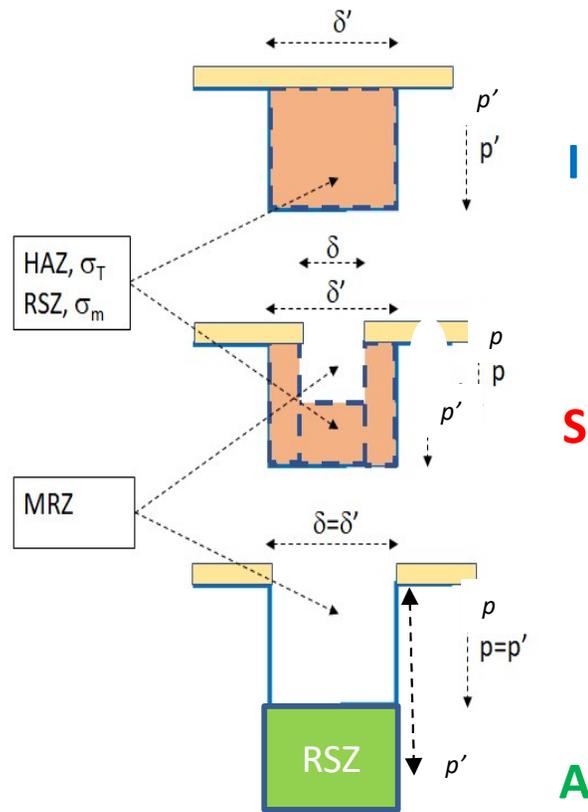
Patterns, experiments and classifications

Laser treatments

Electrical Steel Metal sheet properties

OM0

- Laser types
  - ✓ CW (Irradiation)
  - ✓ ns pulsed (Irradiation /Scribing)
  - ✓ fs pulsed (Ablation)

- Power/Energy vs scribing speed

- Pattern (design , direction)

Impact →

- **Surface morphology**

- Magnetic domains size

- Power losses

- Permeability

- Magnetic noise

OM0   J'ai juste ajouté "magnetic noise"
Olivier MALOBERTI; 2022-07-10T18:11:43.044

Patterns, experiments and classifications
Impacts of Laser surface Treatments

Steel Characterization Laser treatments Tests Workable for end-users

Metallurgy
(SEM, EBSD …)

Optics
(confocal Microscope …)

Magnetics
(SST, MOIF, MOKE)

Coating
(SEM, XRD, EIS …)

Scanning Electron Microscopy (SEM)
Electron Backscatter Diffraction(EBSD)

Single sheet tester (SST)
Magneto-optical indicator film (MOIF)
Magneto-optic Kerr effect (MOKE)
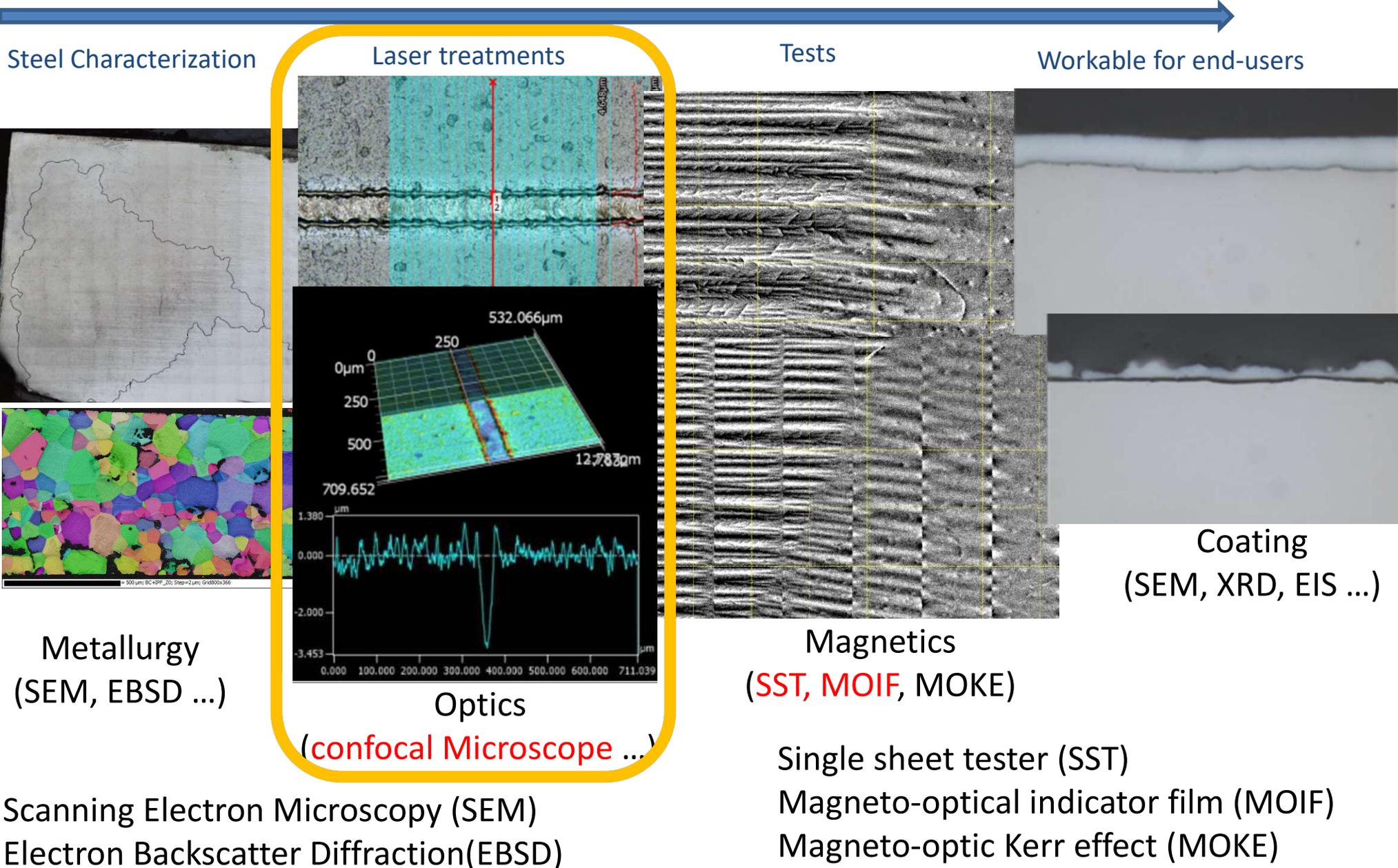
Surface Morphology Analysis of laser texturing on electrical steel

Tool : 3D confocal laser microscope
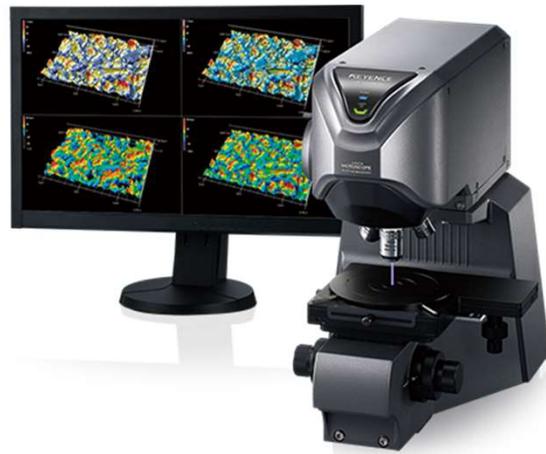
1 optical image
(obj 10x or 20x →Magnification x240-x480)

1 3D reconstruction

1 profile analysis
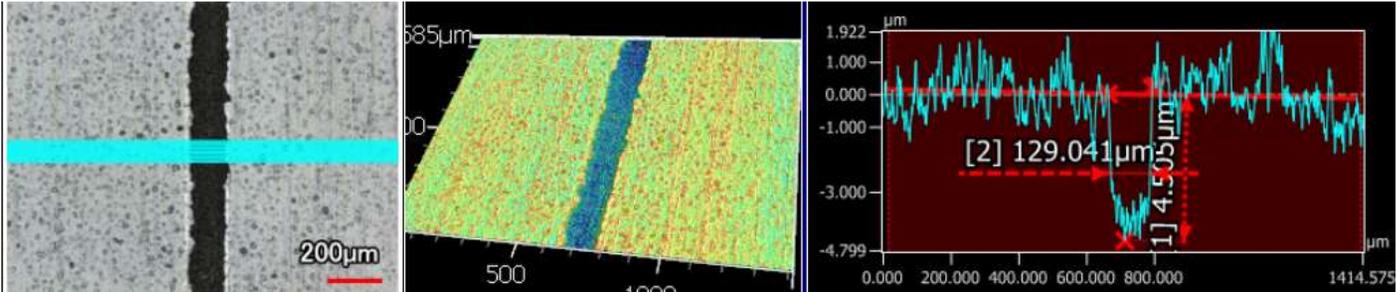
GO 23MOH sample with a fs laser scribed line (ablation 500fs)

Criterias

→We measure line width and depth/relief of the laser scribed line and around it
We eliminate laser parameters which cause
- Surface deformation (Thermal deformation)
- Relief at the edge OR in the laser scribing (melted material)
- Droplets
Relief >2μm eliminated: we have to stack the electrical steel sheets for the proof of concept

Laser processes for samples surface treatments

Patterns : Depending of the steel grades and application

Lines // & ⊥ to the rolling direction

pitch 0,1 to 5mm

Mandatory : >10µm grooves depth and no sheets deformation or bumps >2µm

To compare all the samples and laser process, we have used the same optical configuration and mainly change → pulse width , energy (power) and velocity,
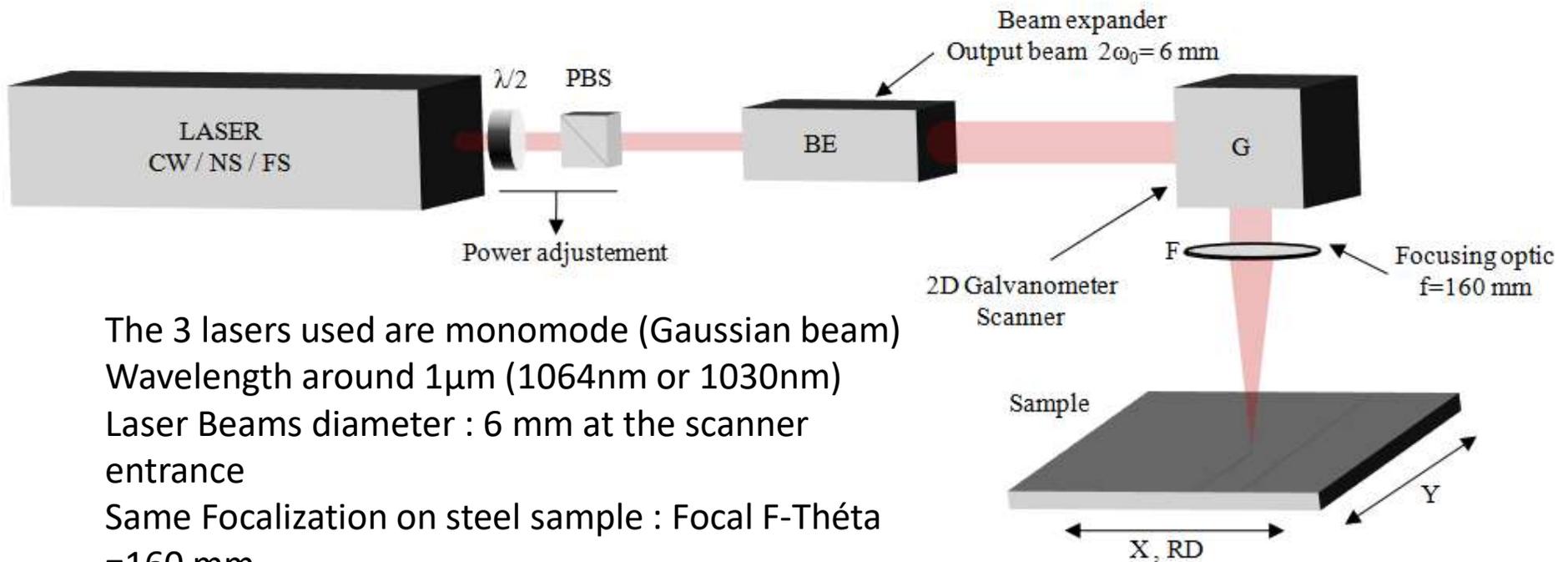
The 3 lasers used are monomode (Gaussian beam)
Wavelength around 1µm (1064nm or 1030nm)
Laser Beams diameter : 6 mm at the scanner entrance
Same Focalization on steel sample : Focal F-Théta =160 mm

Laser spot diameter equal for each type of laser : around 50 µm spot size on the sample

Laser processes - samples surface treatments

1 - IRRADIATION Ex: Laser CW – Power 25 W – Speed 50 mm/s → laser parameter OK
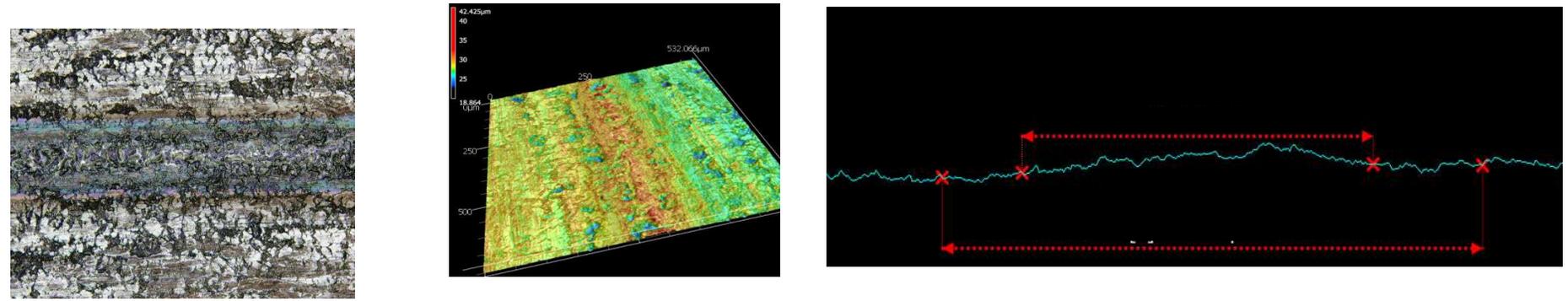
2 - SCRIBING Ex : Laser 100ns – AVG Power 10 W – Speed 50 mm/s → laser parameter eliminated
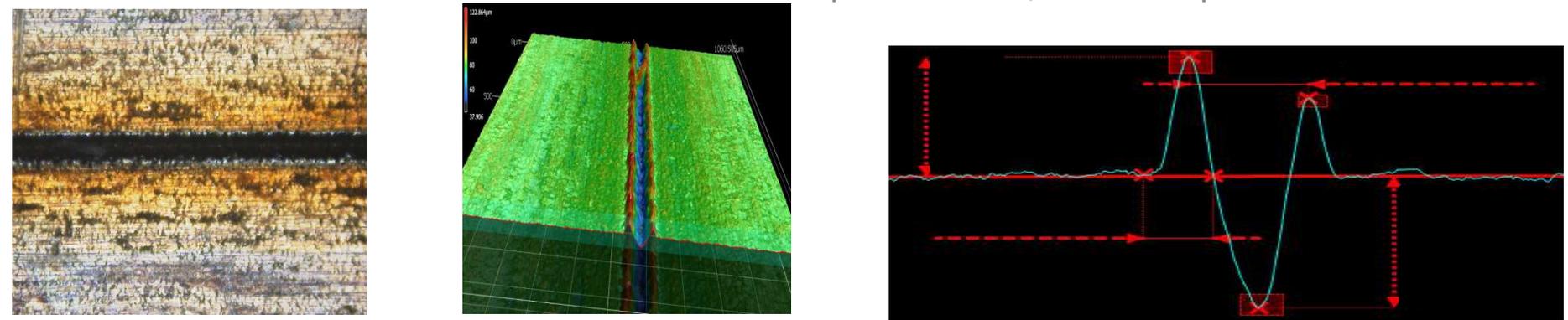
3- ABLATION Ex : Laser USP fs– AVG Power 20 W – Speed >50 mm/s
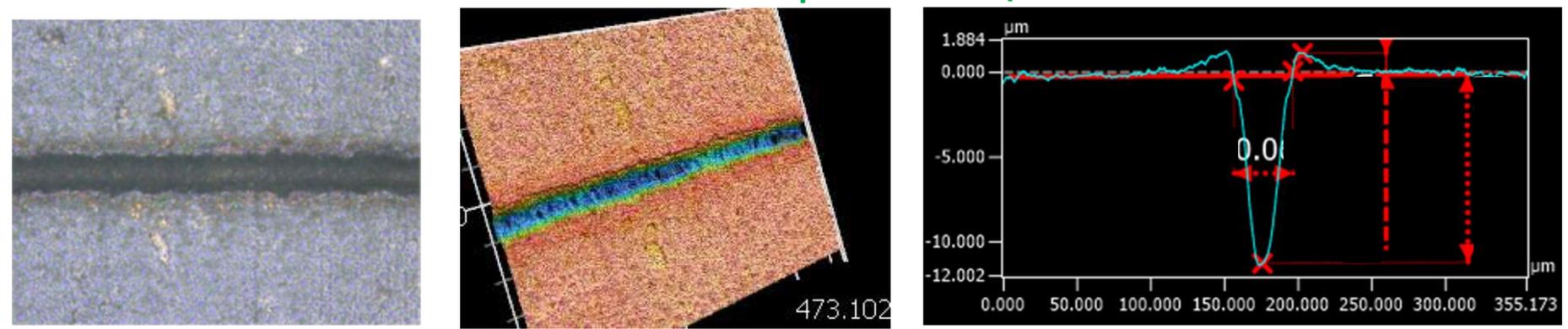
OM0   Inutile de préciser les dimensions des profils ici … en cas de confidentialité

Olivier MALOBERTI; 2022-07-10T18:11:25.163

Ablation issues

- Several reproductibility issues occured with the <u>ablation parameters </u>during tests on GO steels:
  - Steel sheet bending induced by the laser processing
  - Geometry of the grooves (depth vs number of passes and bending)
  - Process speed for numerous samples texturization

- Investigation on the origin of these issues.
- Improvement of the set up
  - USP laser with higher repetition rate and power
  - Correction of the methods for implementations for power electronics inductances and transformers

MATERIAL laser treated for inductances and transformers prototypes:
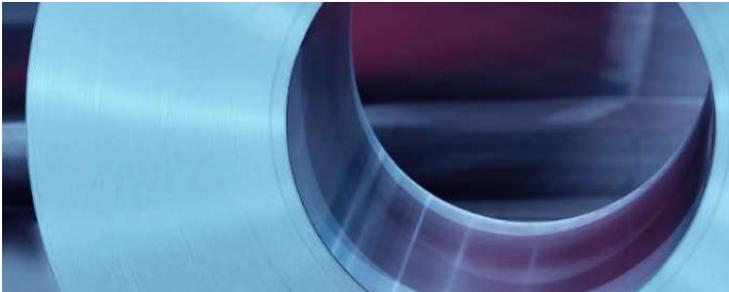
Grain-Oriented (GO) SiFe electrical steel	
Names/Grades	GO R120-27 GO H090-23
Coatings	2.3 μm +/- 0.4 (phosphate/carlite)
Thickness	GO : 0.23 *mm and* 0.27 *mm*
Sample sizes	*187x100 mm* *287x100 mm* *300 x 100 mm*

Laser micromachining set-up for ESSIAL prototypes

IFOV/EFOV Infinite/Enlarged Field of View machine

→ combination and synchronization of X-Y Galvo mirrors and X-Y translation stage to process large surface or multiple samples.

→ 700x700 working area to process samples with a scanner equipped with a télécentric F-thêta Lens,
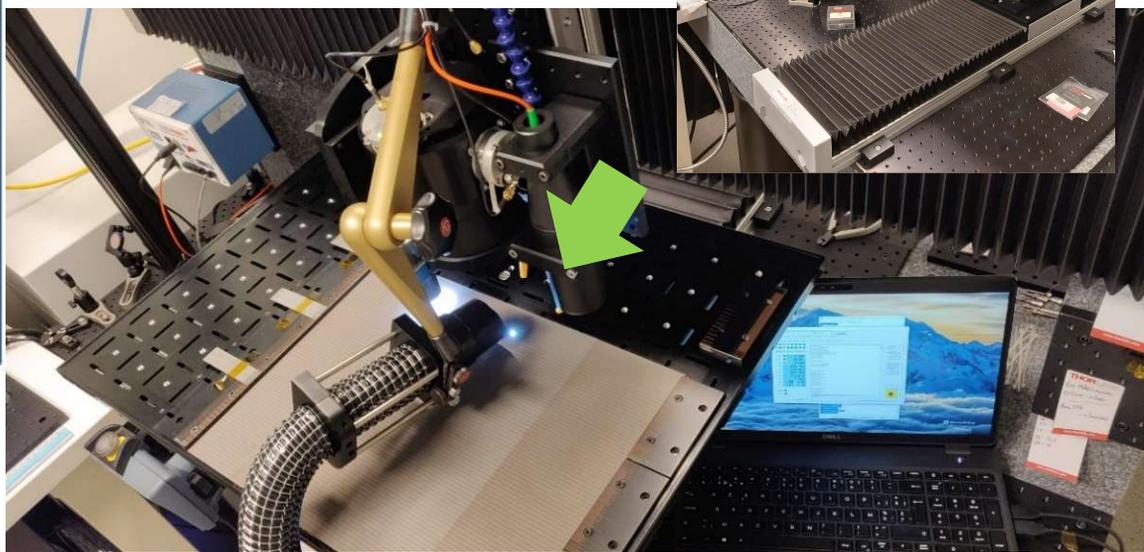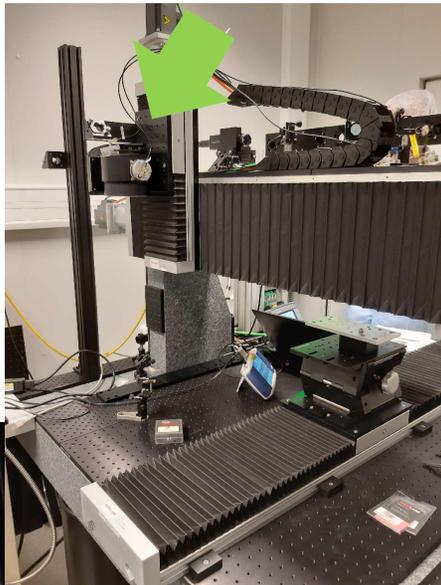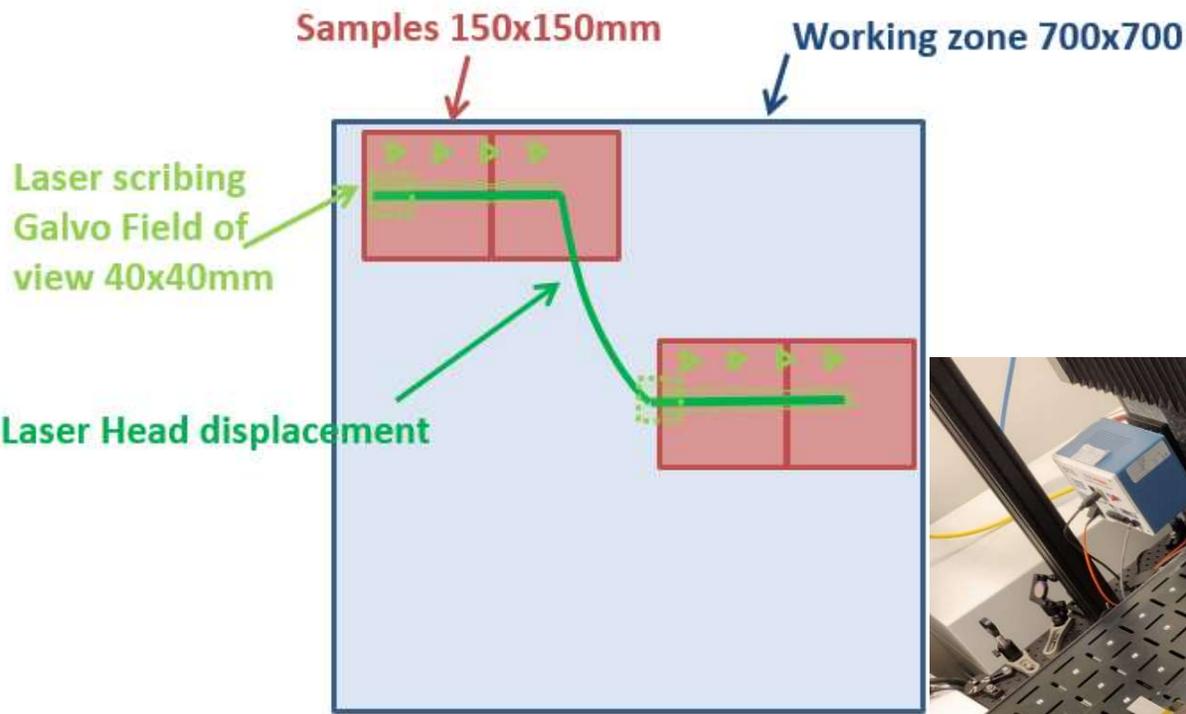
Sheet texturization for inductances and tranformers:
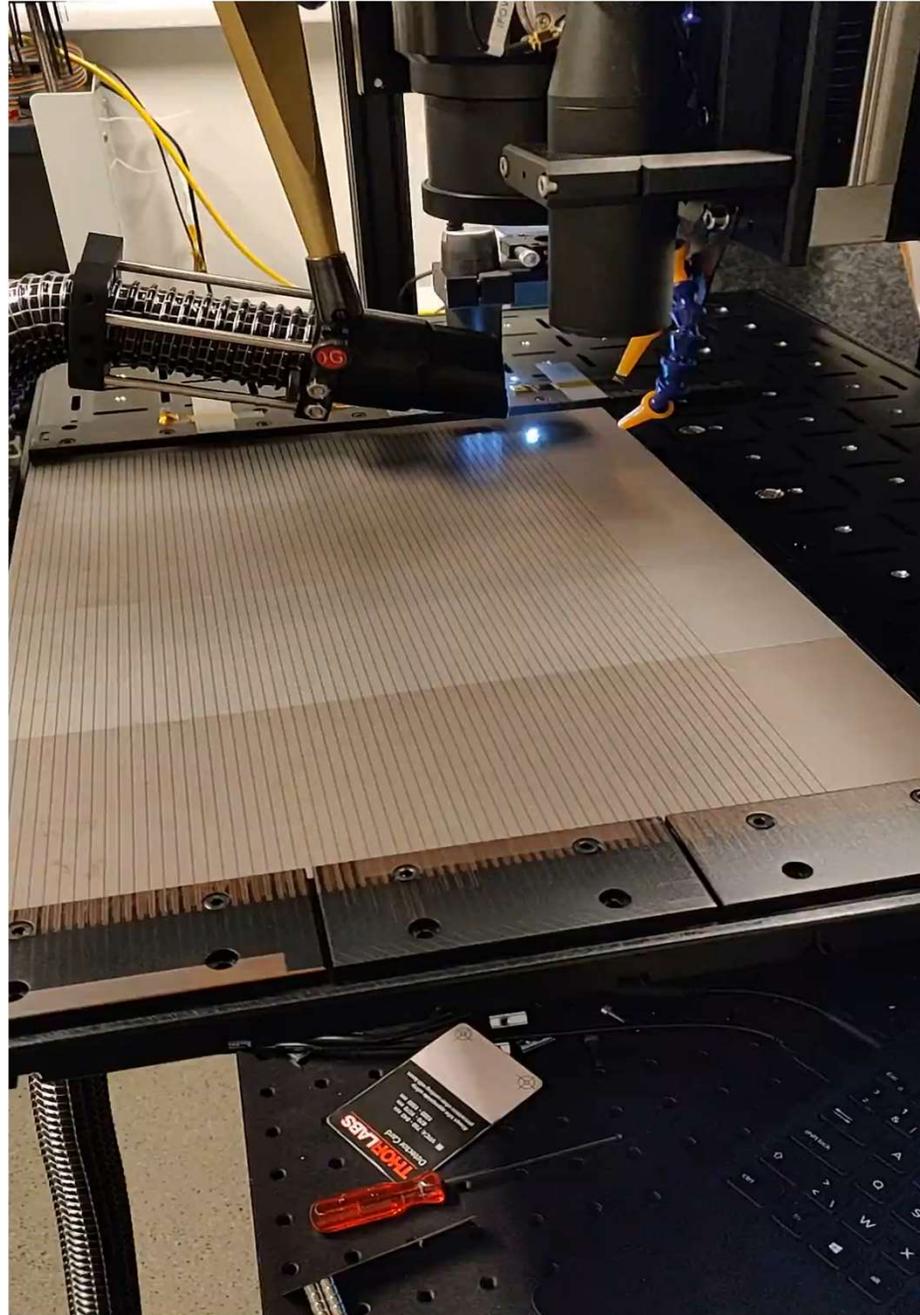
Sheet texturization for inductances and tranformers:

Total of 5 chokes made with 100x287 and 287x100 mm sheets → ~ 1400 sheets laser texturized

      2 steel grades tested

      3 different patterns / laser parameter for grooves
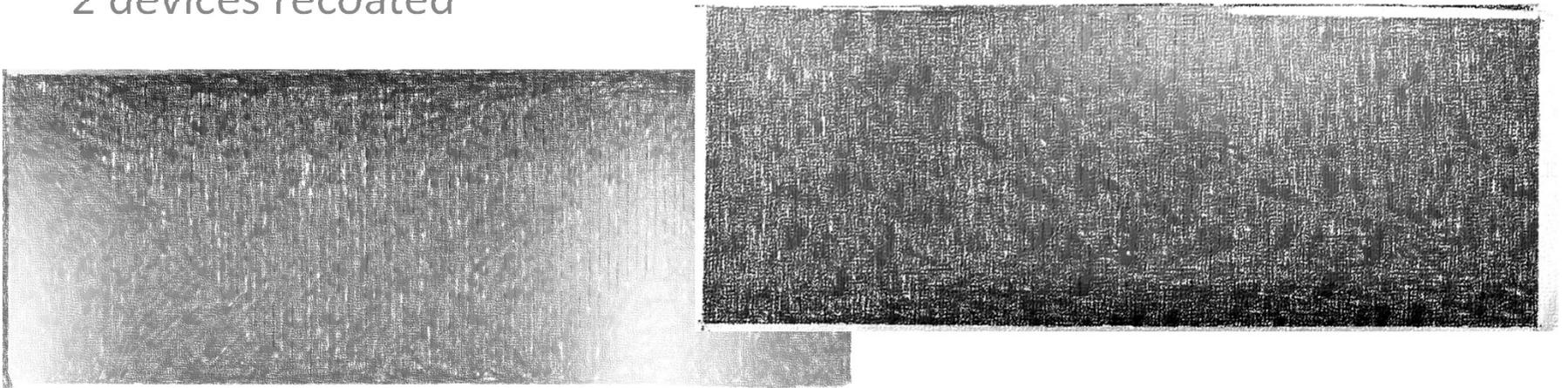
      2 devices recoated

Total of 7 transformers made with 100x300mm sheets → ~ 3120 sheets texturized

      5 Lab scale and 2 industrial scale transformers

      5 different patterns / laser parameter for grooves

      2 devices recoated

PROTOTYPING- IMPLEMANTATIONS
Loss reduction measurements in two AC transformers laser treated

Core Transformer:
4 stacks of 150 sheets
300x100mm

Coming Next

Transformers Manufacturing
Johan Bleumers (EREA)
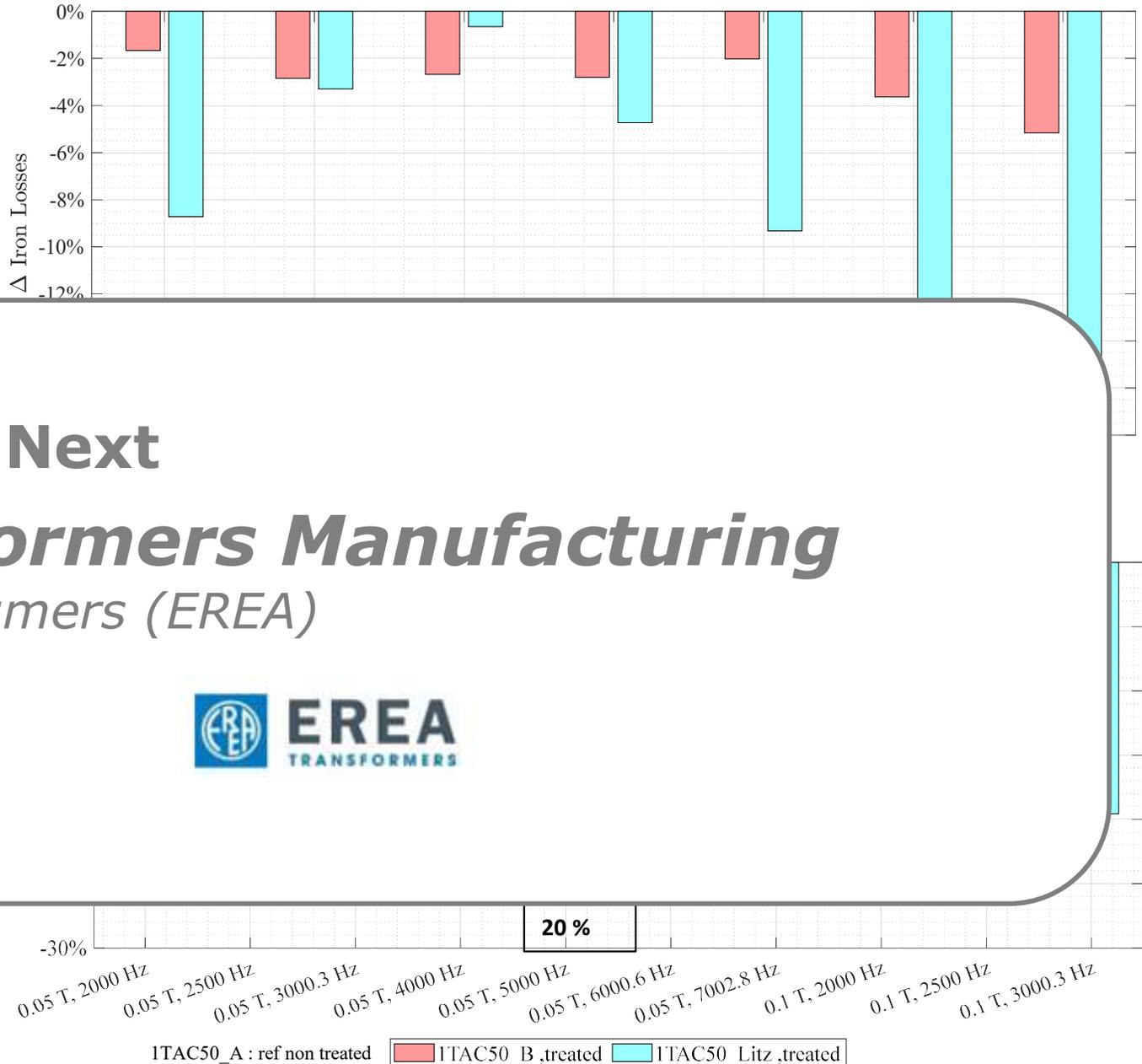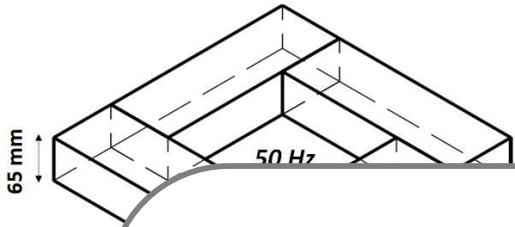
Fundamental 50Hz

Harmonics

1TAC50_A : ref non treated   1TAC50_B ,treated   1TAC50_Litz ,treated

20 %

Others Laser issues for ESSIAL

Non Grain Oriented Electrical steel

Same laser setup/configuration as for ablation process

Grain sizes smaller than 100µm:

Smaller specific patterns for TD and RD

full surface nanotexturation tested and measured
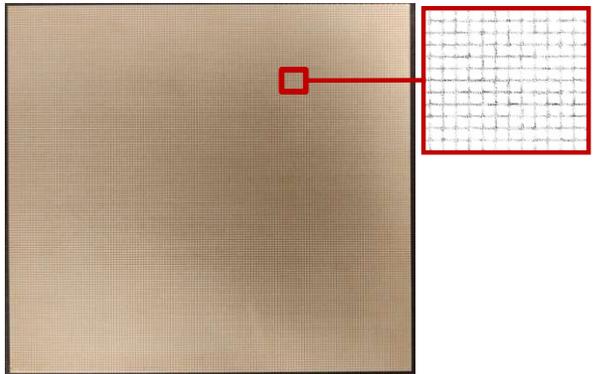
Laser processes on GO for Rotating machines

Mass laser texturization of segments

Specific patterns and laser processes for

rotors, stators, yokes and teeth

Removal- Decoating issues

laser process to remove the coating

Insulation : organic and inorganic

Different thicknesses and hardness

"Eco-friendly" process
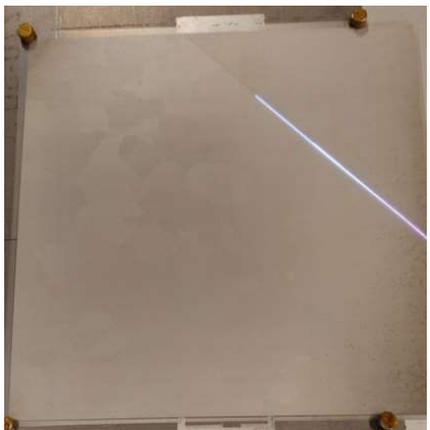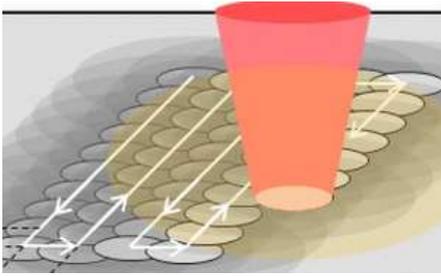
ESSIAL

Thank you for your attention!

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Monday, 11 July 2022 – UniLaSalle, Amiens (France)