ESSIAL has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 766437.

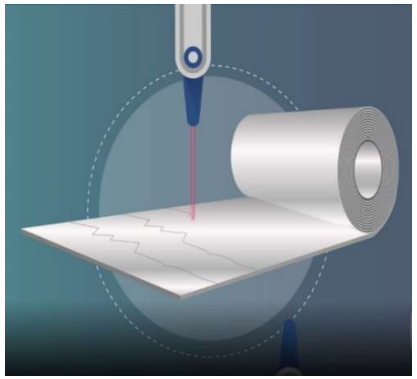
ESSIAL

# Thank you for your attention!

## ESSIAL FINAL PROJECT INFODAY

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

FINAL EVENT ESSIAL – ULS-AMS : 11/07/2022



# ESSIAL

## *Electrical Steels Structuring Insulating and Assembling by means of the Laser technologies*

**O. Maloberti (UNILASALLE Amiens, Project Coordinator)**

# AGENDA

**09:30 – INTRODUCTION & PRESENTATION OF ESSIAL**

- *Speaker UNILASALLE, Olivier Maloberti*

**10:00 – IMPLEMENTATIONS FOR POWER ELECTRONICS INDUCTANCES AND TRANSFORMERS**

- *Speaker UNILASALLE, Olivier Maloberti*
- *Speaker MULTITEL, Julien Dupuy*
- *Speaker ANDALTEC, Jesús Castillo*
- *Speaker EREA, Johan Bleumers*

**11:45 – APPLICATION METHOD FOR DEMONSTRATORS AND ELECTRICAL MACHINES**

- *Speakers JEUMONT Electric, Préscillia Dupont & Maxime Ployard*

*LUNCH*

**14:00 – VISIT OF THE FACILITIES**

**16:00 – Q&A AND CLOSING SESSION**

# AGENDA

**09:30 – INTRODUCTION & PRESENTATION OF ESSIAL**

- *Speaker UNILASALLE, Olivier Maloberti*

**10:00 – IMPLEMENTATIONS FOR POWER ELECTRONICS INDUCTANCES AND TRANSFORMERS**

- *Speaker UNILASALLE, Olivier Maloberti*
- *Speaker MULTITEL, Julien Dupuy*
- *Speaker ANDALTEC, Jesús Castillo*
- *Speaker EREA, Johan Bleumers*

**11:45 – APPLICATION METHOD FOR DEMONSTRATORS AND ELECTRICAL MACHINES**

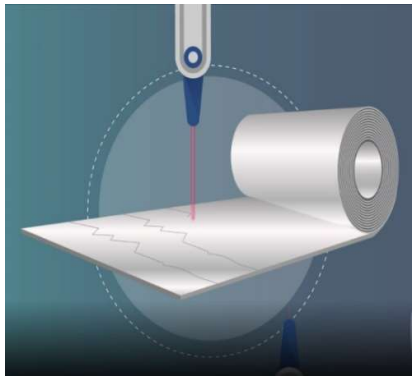
- *Speakers JEUMONT Electric, Préscillia Dupont & Maxime Ployard*

*LUNCH*

**14:00 – VISIT OF THE FACILITIES**

**16:00 – Q&A AND CLOSING SESSION**

FINAL EVENT ESSIAL – ULS-AMS : 11/07/2022



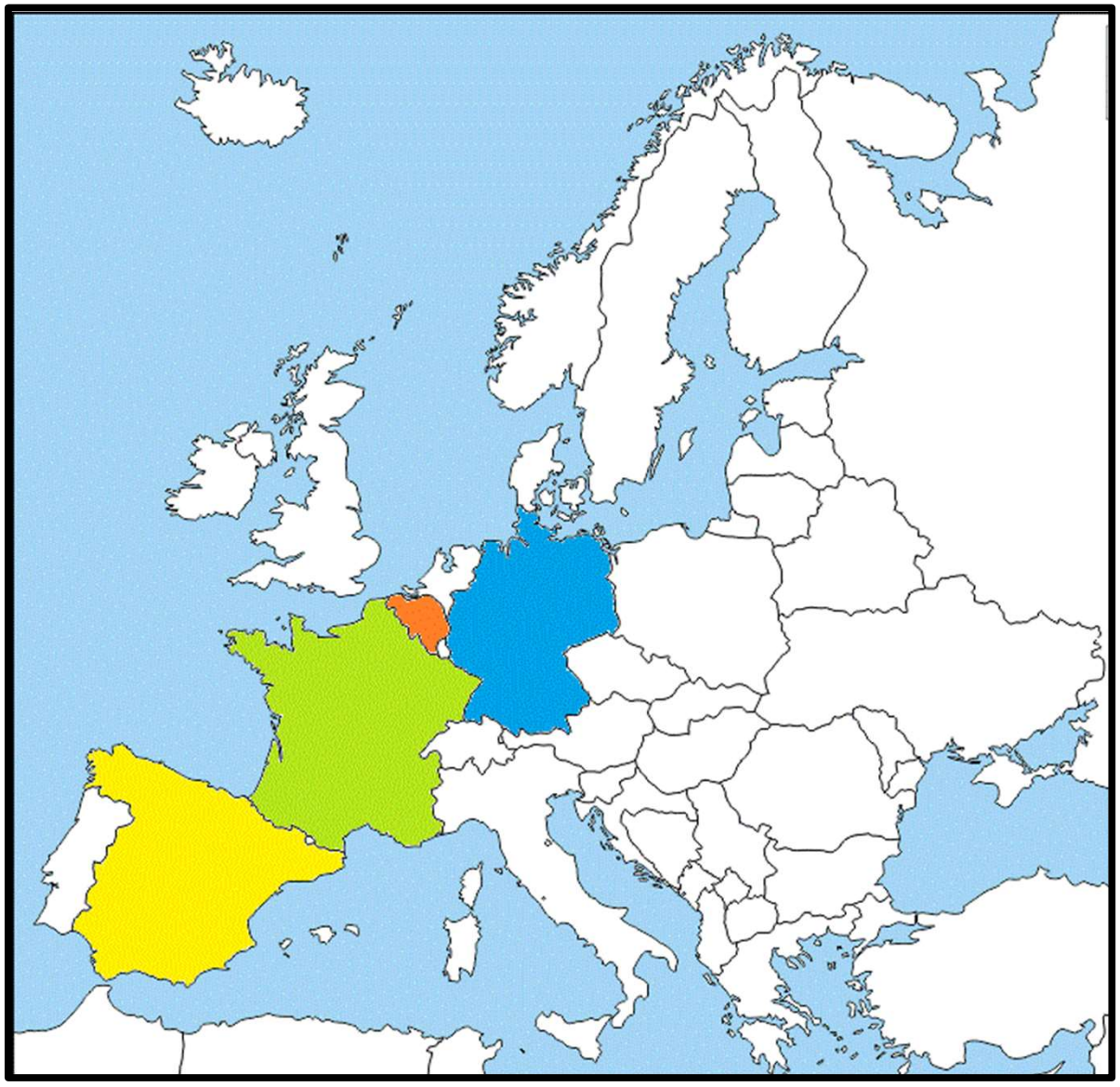
# ESSIAL

## INTRODUCTION AND PRESENTATION OF ESSIAL

**O. Maloberti (UNILASALLE Amiens, Project Coordinator)**

# CONTENTS

# Project Consortium - Organization – partnership



**4 countries in EUROPE:**

France: 6 partners
Belgium: 4 partners
Spain: 2 partners
Germany: 1 partner

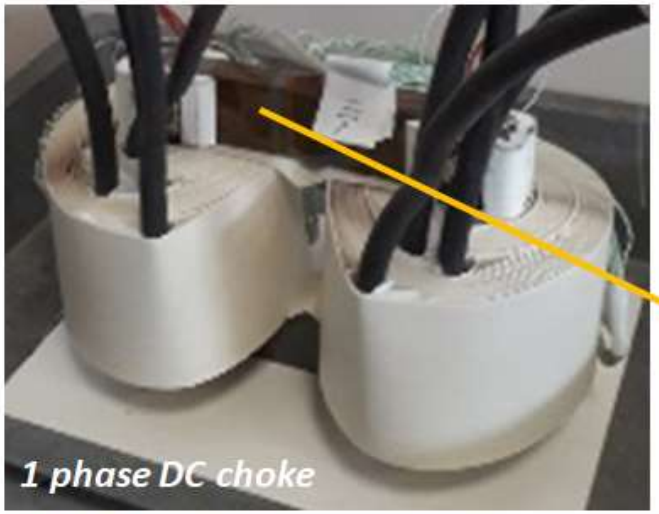
5 universities/laboratories
4 Research centers/latforms
4 industries
2 SMEs

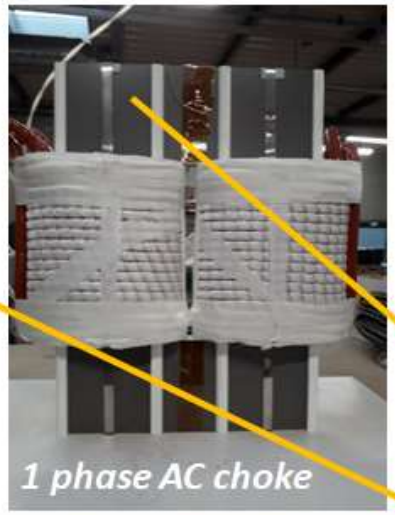
**Coordinator:**
UNILASALLE AMIENS

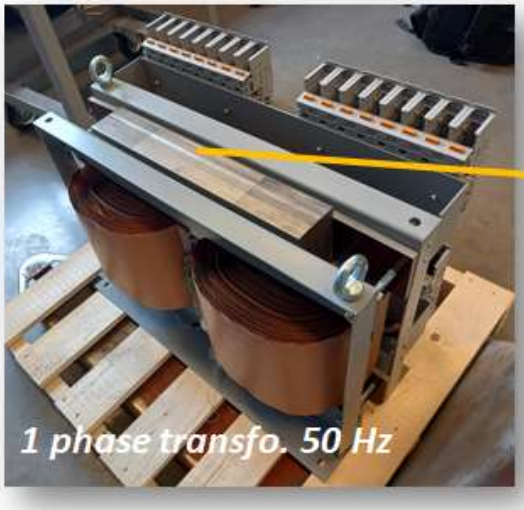
**BUDGET = 5 M€ (13 partners)**
**~ 100 k€ / partner / year**

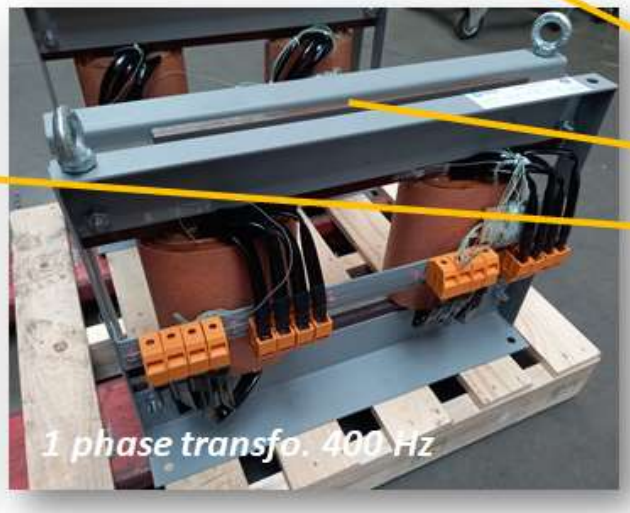
UniLaSalle Amiens
Symade UniLaSalle
UniLaSalle Institut Polytechnique

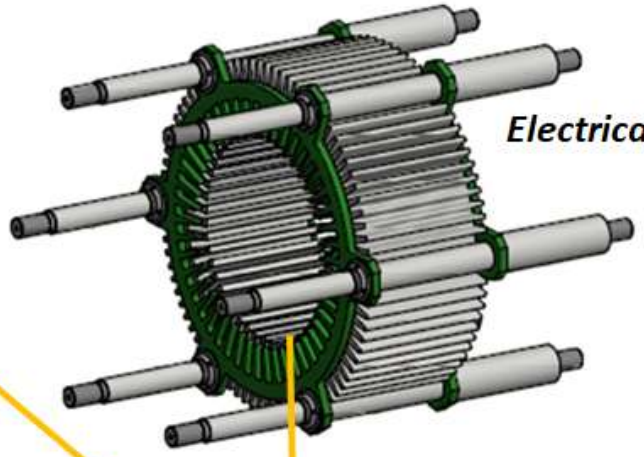
# Context – Electrical machines and magnetic circuits

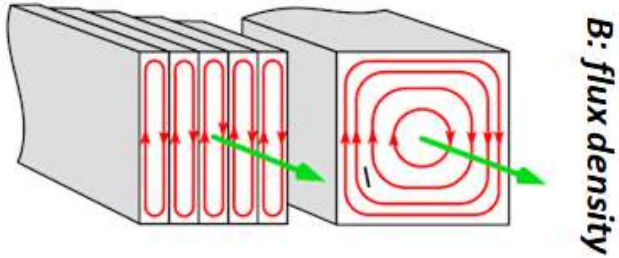



Laminated stack of electrical steels

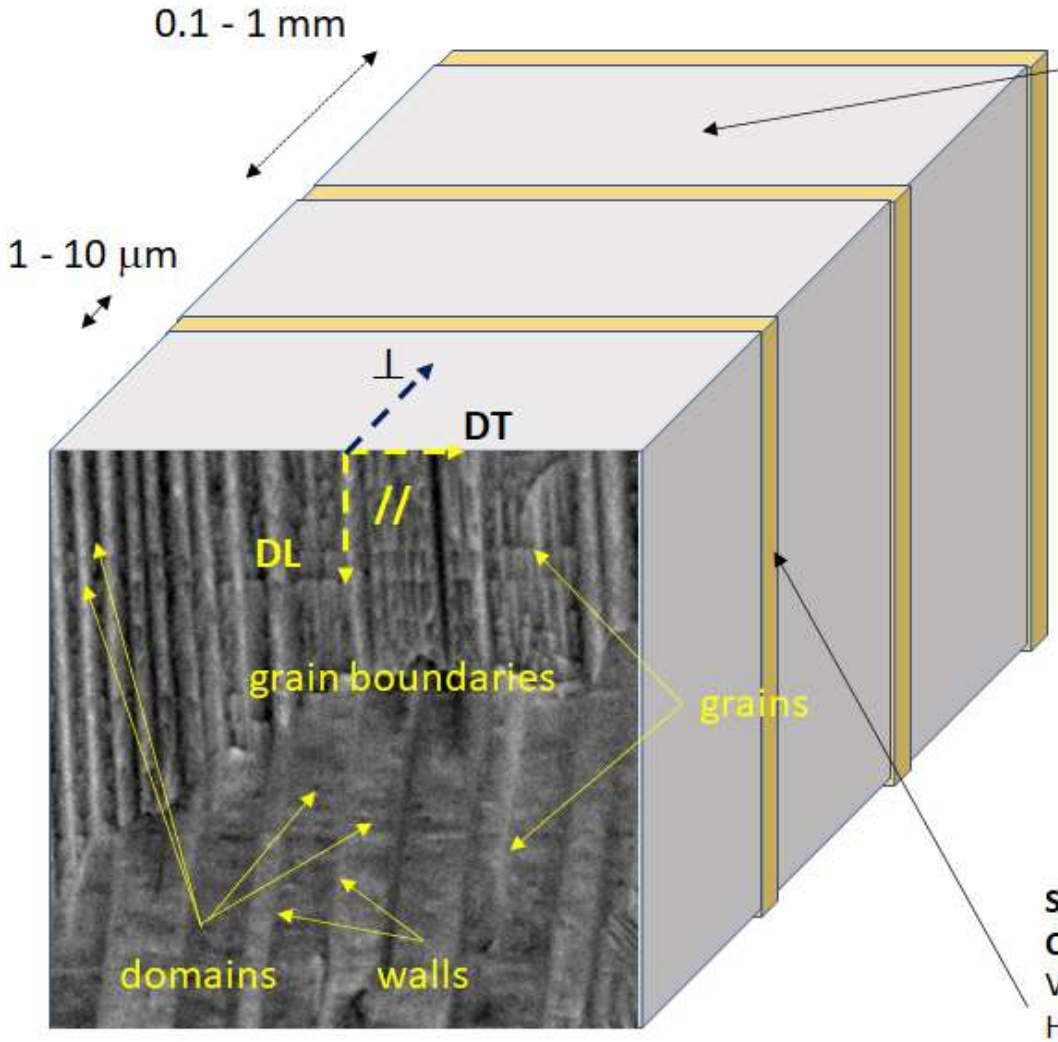
- Non Grain Oriented Electrical Steels
- **Grain Oriented Electrical Steels**
- Special alloys

UniLaSalle Amiens

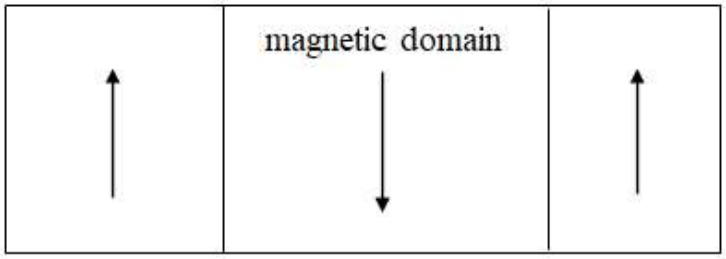
Symade UniLaSalle

UniLaSalle Institut Polytechnique

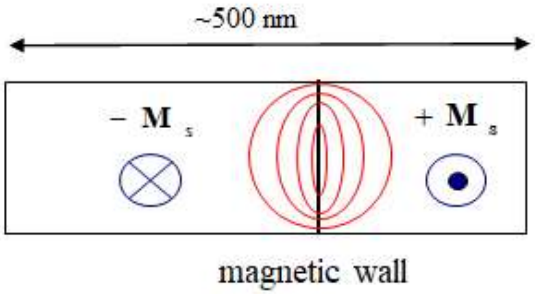
# Context – Magnetic Circuits, Cores and Materials




**Soft ferromagnetic alloy:**
**Fe, Ni and Co based**
High // magnetic permeability
Low // & ⊥ electrical conductivity
Fine and free magnetic structure

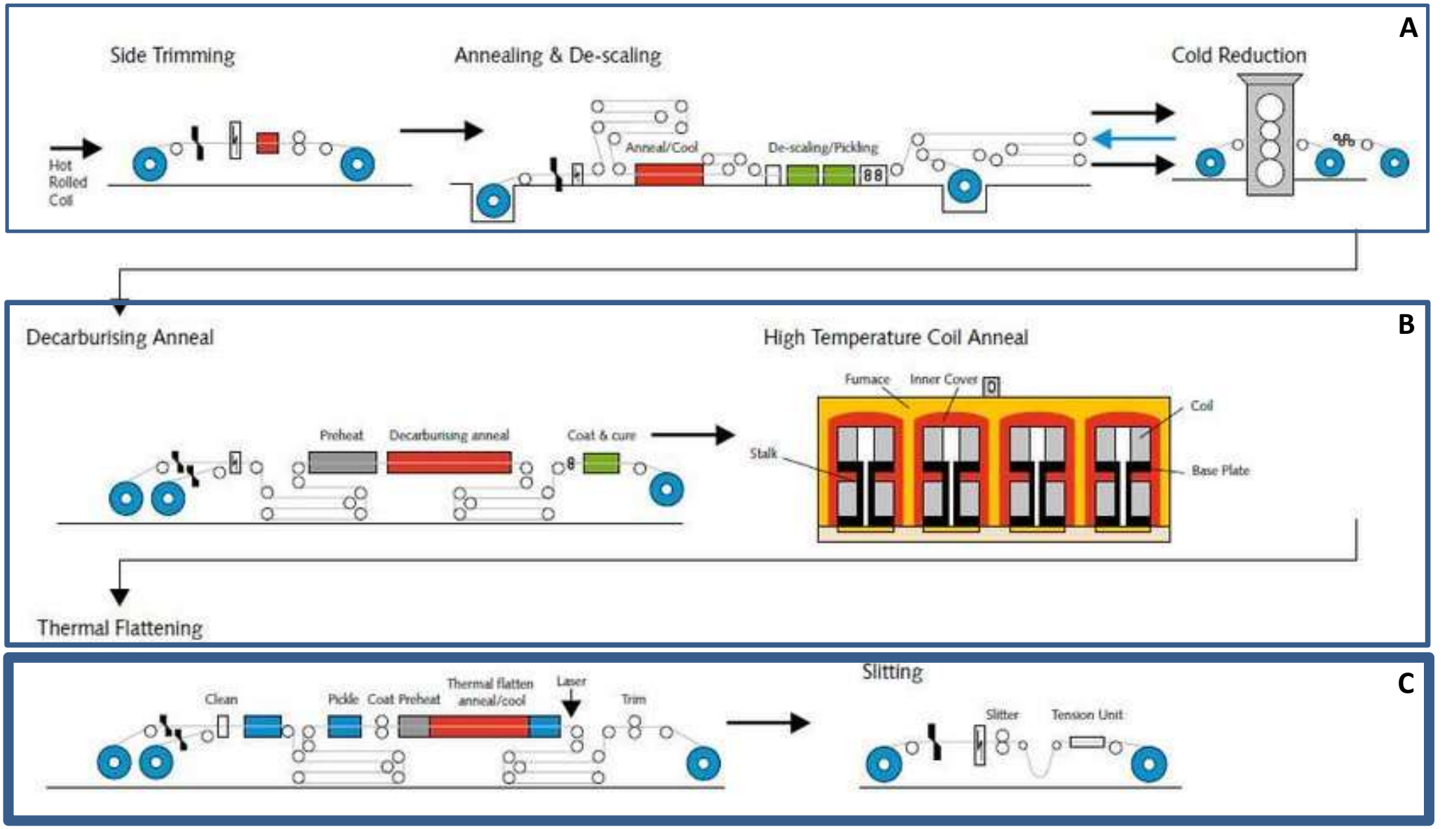



**Micro. Currents**
**Walls motion**




**Synthetic Insulating resin:**
**Organic or inorganic based**
Very high ⊥ electrical resistivity
High // magnetic permeability
Good thermal resistance

# Context – Electrical steels production line



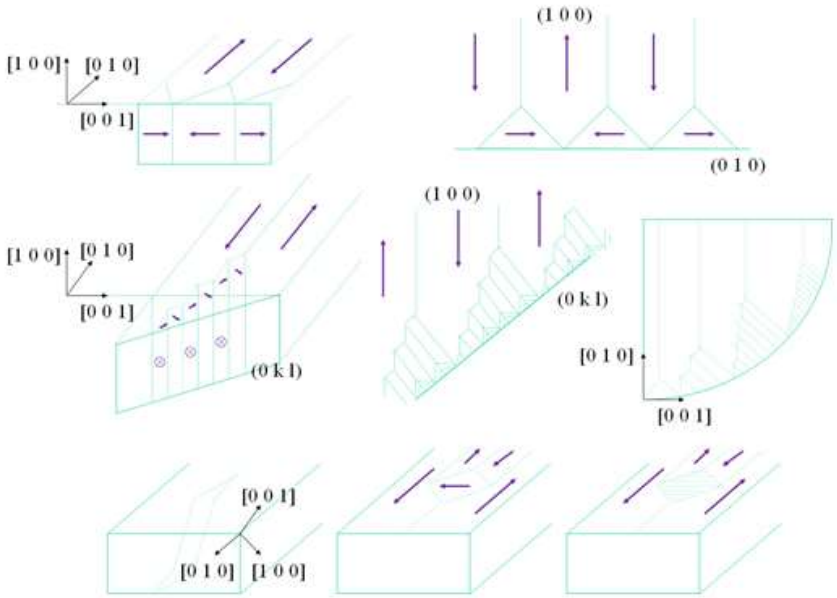
# Context – Material properties

## Materials properties

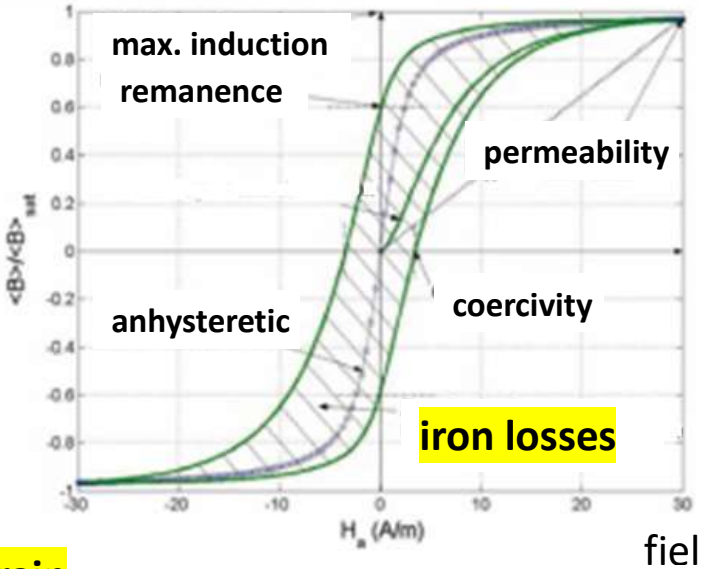
**Magnetic structures**

**Magnetic properties (hysteresis loop)**

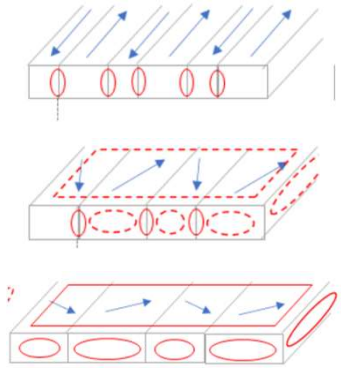
**Mechanical properties (butterfly loop)**




induction

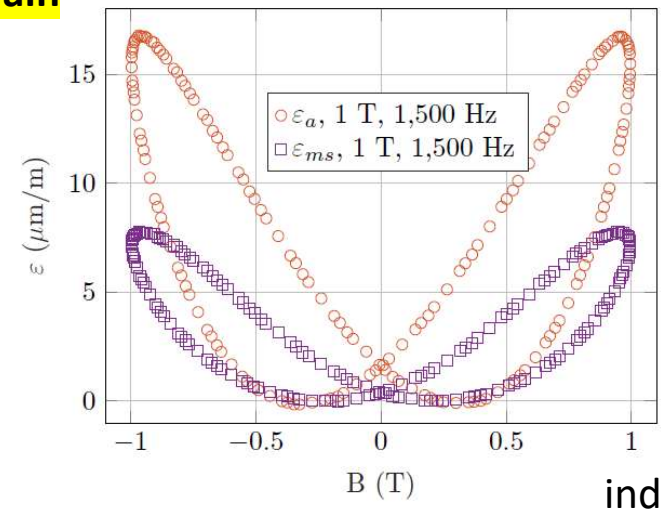


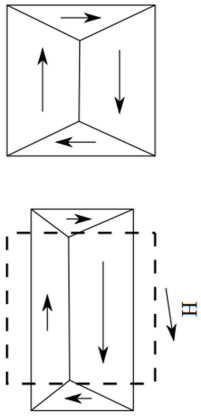

*Walls motion*



field

**strain**




*Magneto-striction*

induction

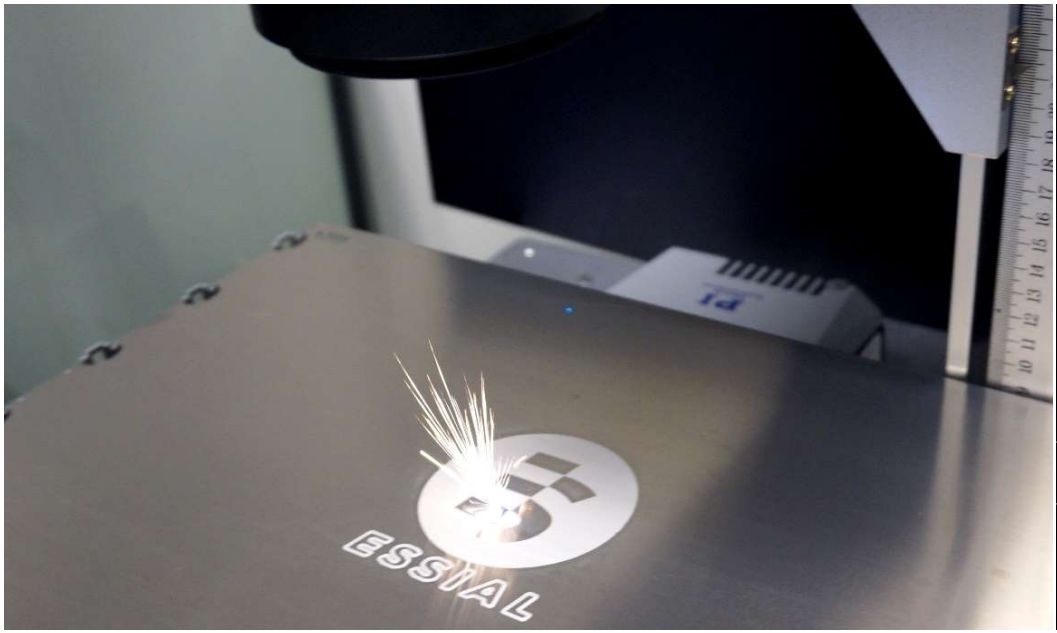
# Context – Surface Laser Treatments

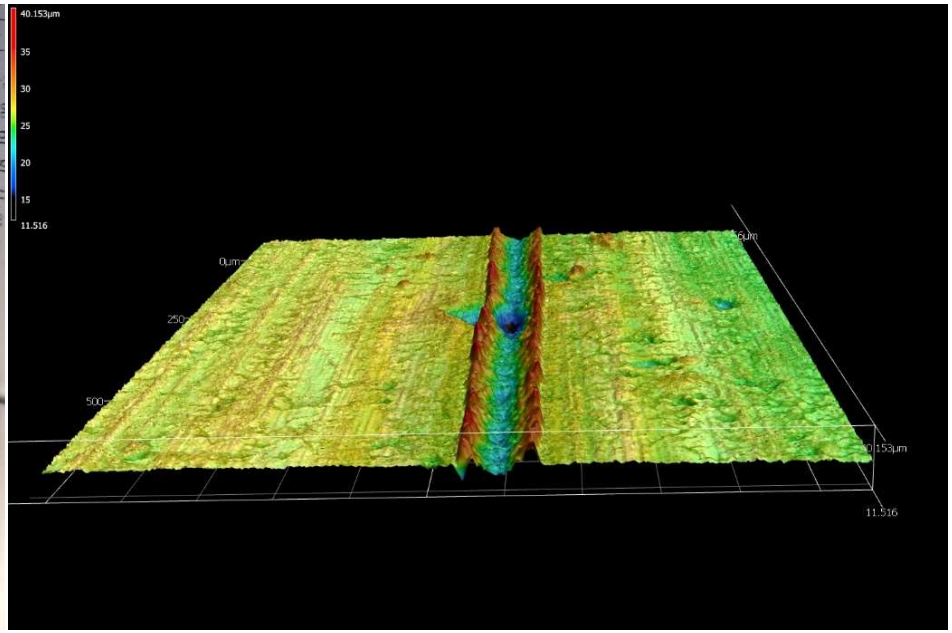
Challenge 1: Improving performances through **surface functionalization**

Challenge 2: Functionalities achieved **without addition of raw materials** (life cycle assessment, reuse, recycling)

Challenge 3: Technologies should be adaptable and **up-scalable**

Challenge 4: **Limit the additional cost to 10%**



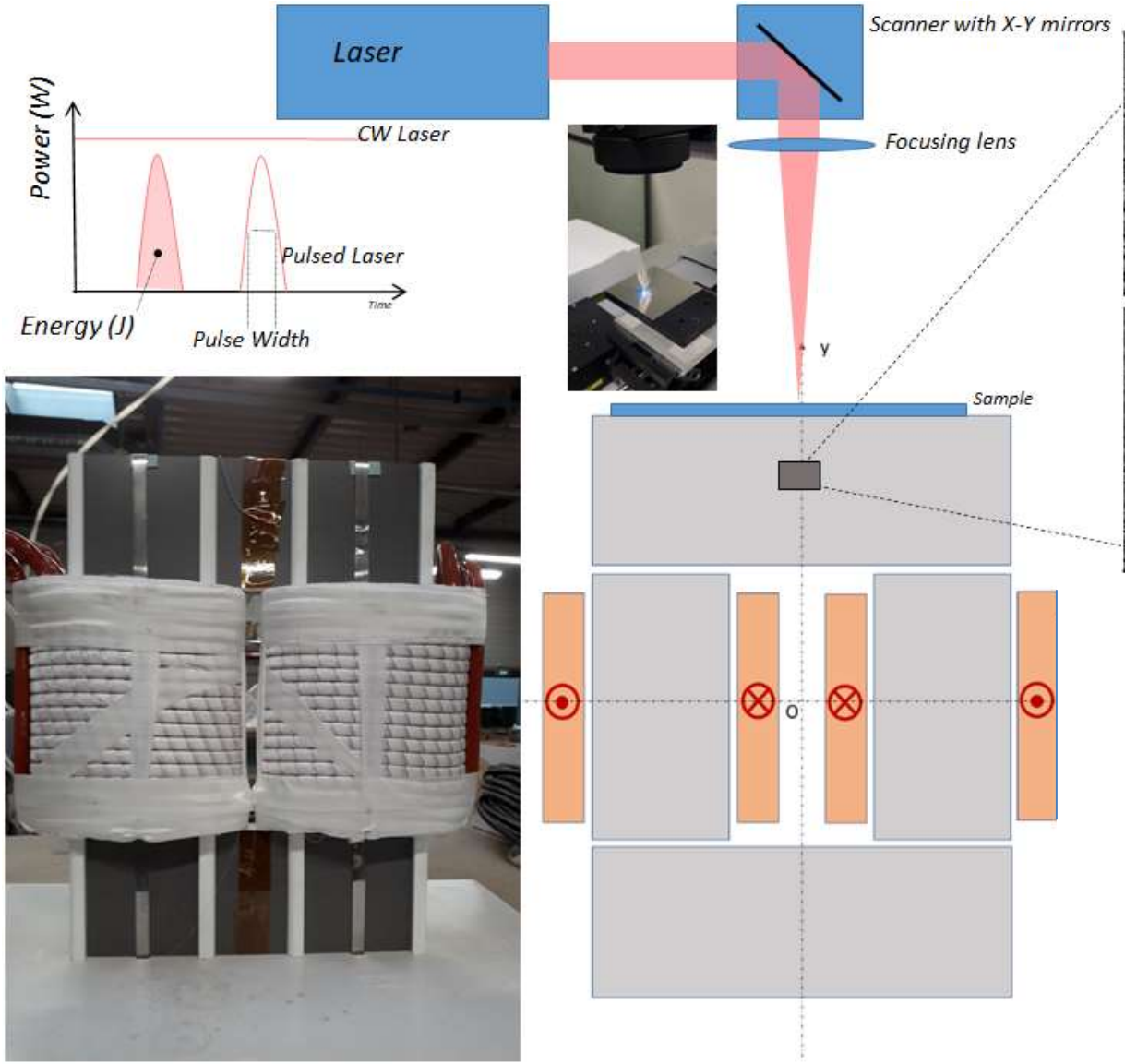



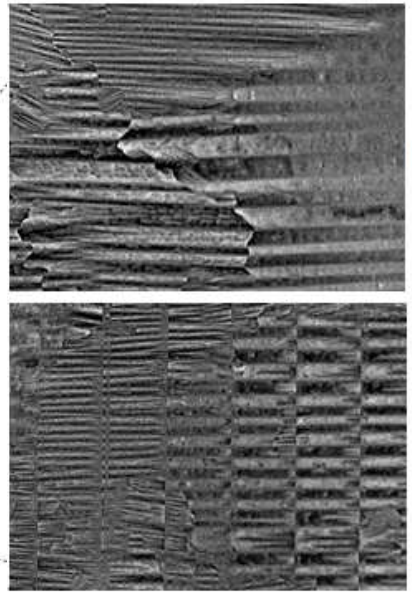

UniLaSalle Amiens

Symade UniLaSalle

UniLaSalle Institut Polytechnique

# The Project: from the material to the products & vice versa

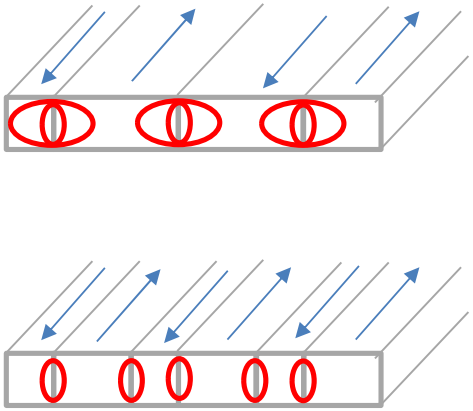


BEFORE

domains refinement

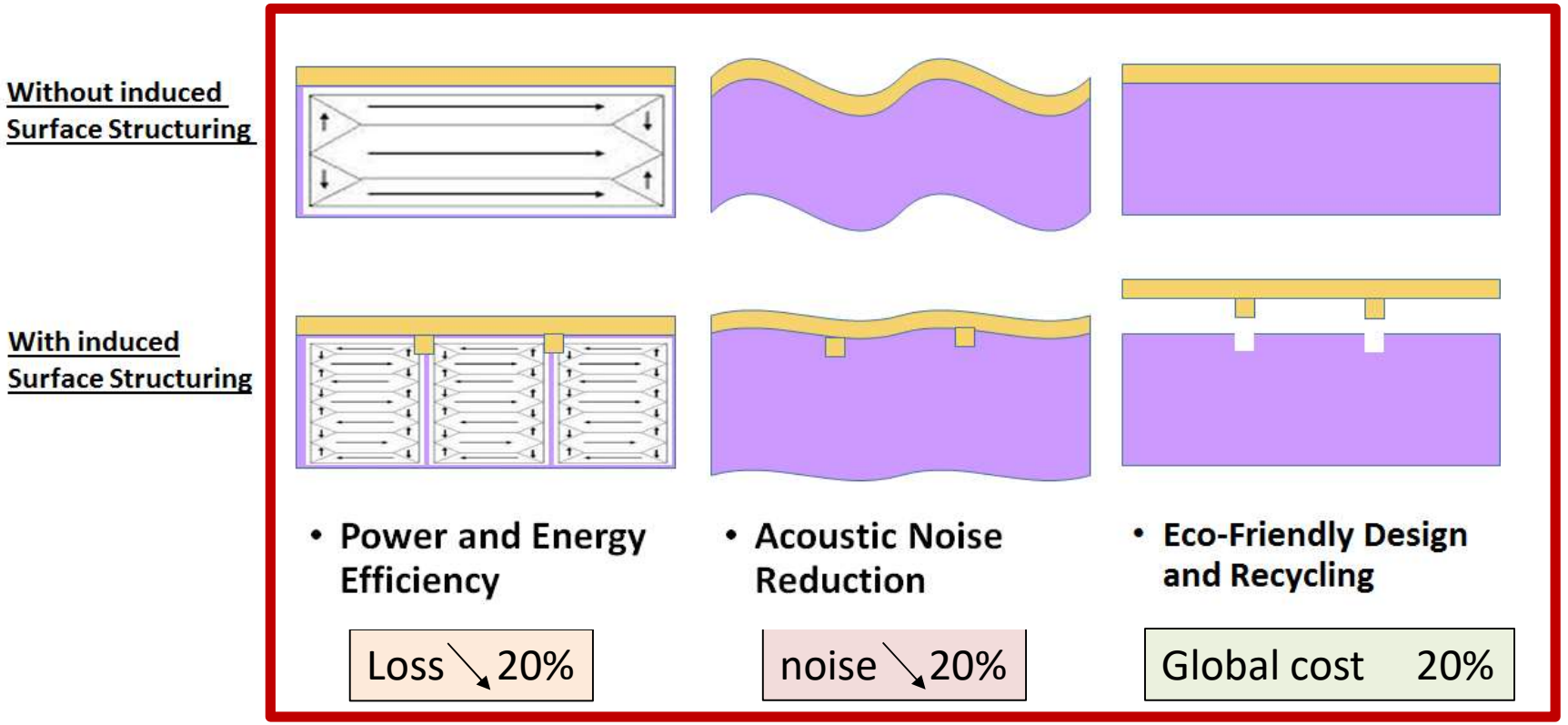
AFTER



domains refinement

# Main GOALS & STAKES of the ESSIAL Project

- **Energy Efficiency of Energy Conversion** inside magnetic circuits
- **Noise pollution reduction emitted** by electrical components
- **Separation and recycling factor enhancement** of different materials






UniLaSalle Amiens

Symade UniLaSalle

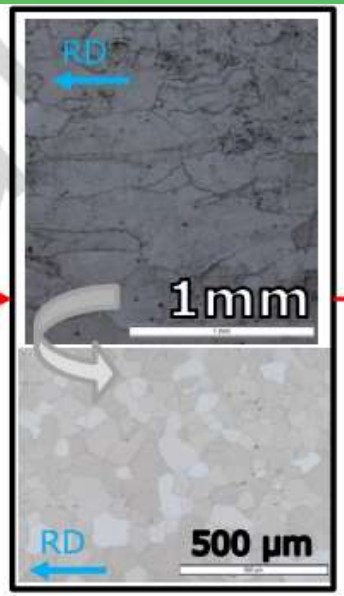
UniLaSalle Institut Polytechnique

# Development of metallurgical steps at the lab. scale

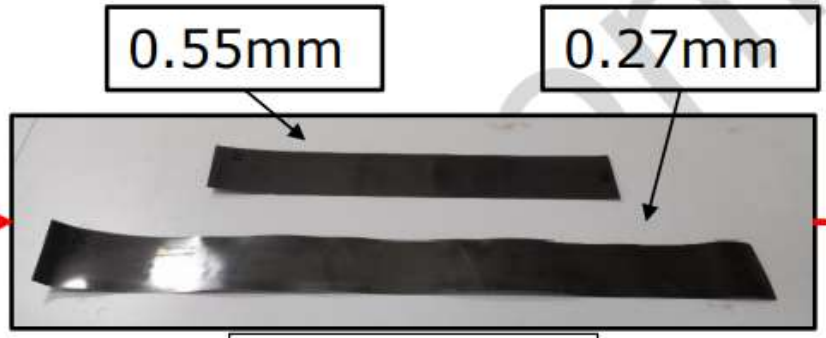
Vacuum Induction Melting

Block cutting

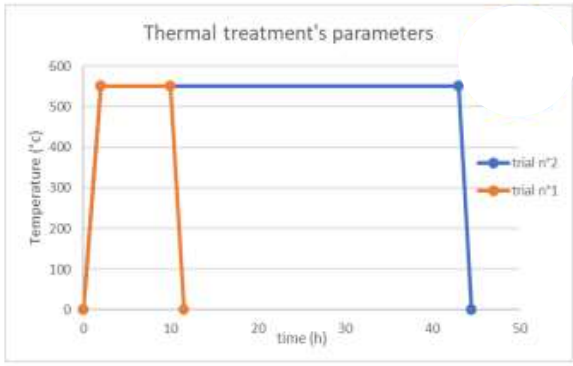
Hot rolling




Annealing study




Cold rolling study




| trial | carbon content (ppm) |
|---|---|
| initial | 166 |
| trial n°1 | 86 |
| trial n°2 | 54 |
| trial n°3 | 23 |

Decarburizing study

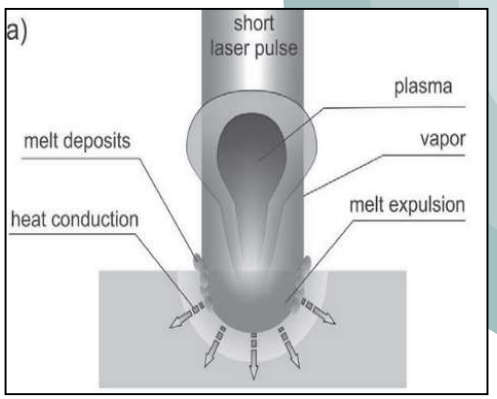
UniLaSalle Amiens

Symade UniLaSalle

UniLaSalle Institut Polytechnique

# Introduction of Pulsed Surface Laser Treatments

## History of the domains refinement techniques

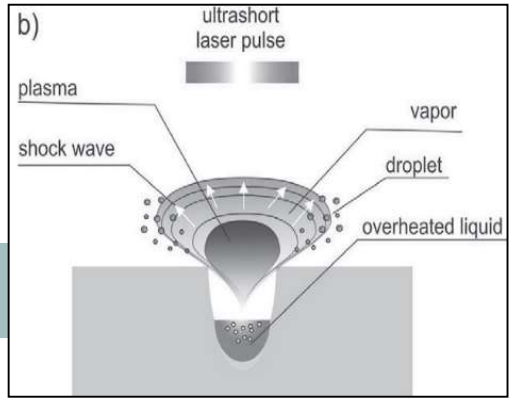



Mechanical Scratching

Continuous Laser (CWL)

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

**Ultra-Short Pulse Laser (USPL)**




Main criteria to qualify the surface treatments of electrical steels :

i. **Power loss** reduction factor – energy efficiency

ii. Permeability increase factor – **easiness to be magnetized**

iii. **Vibration and noise** reduction factor – noise pollution reduction

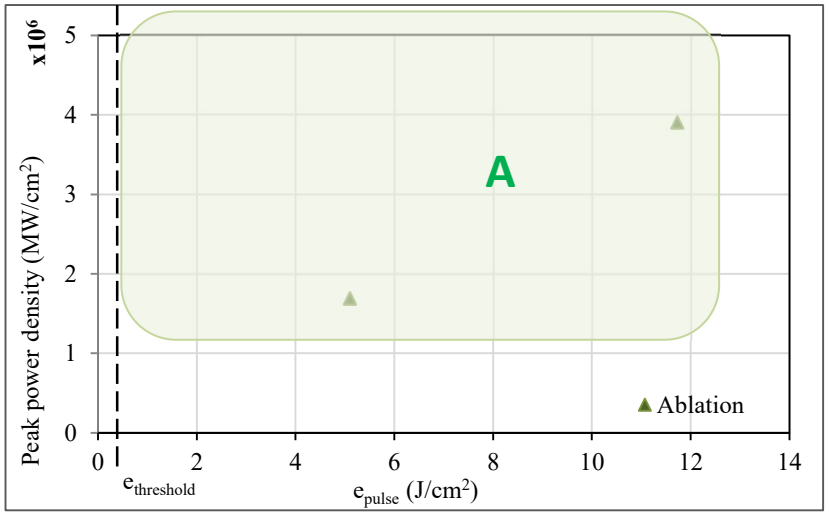
iv. **Process speed, supervision and cost** – upscaling for industrial lines

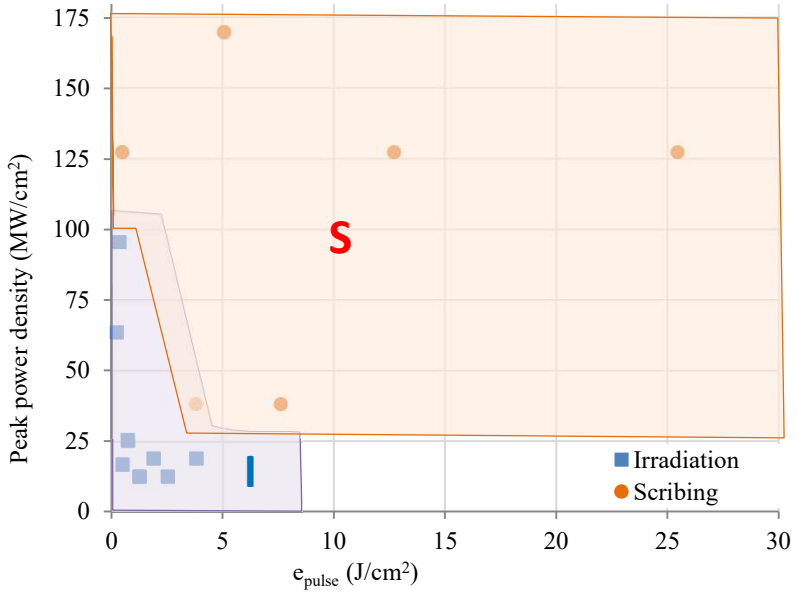
UniLaSalle Amiens

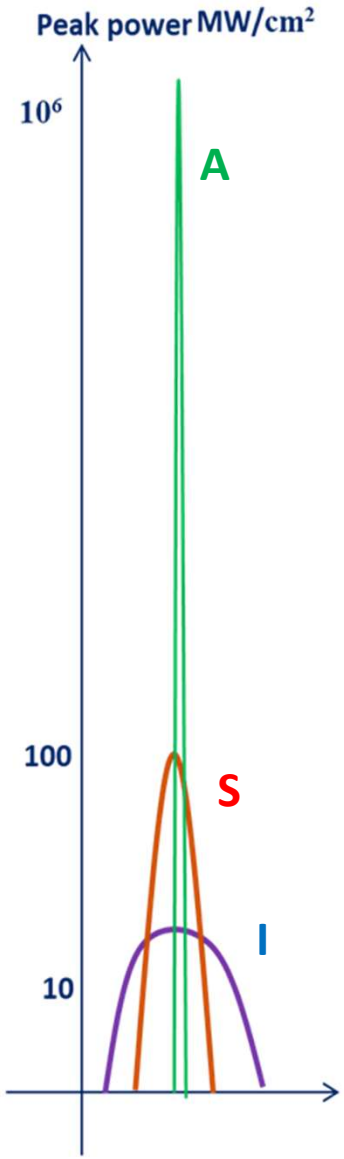
Symade UniLaSalle

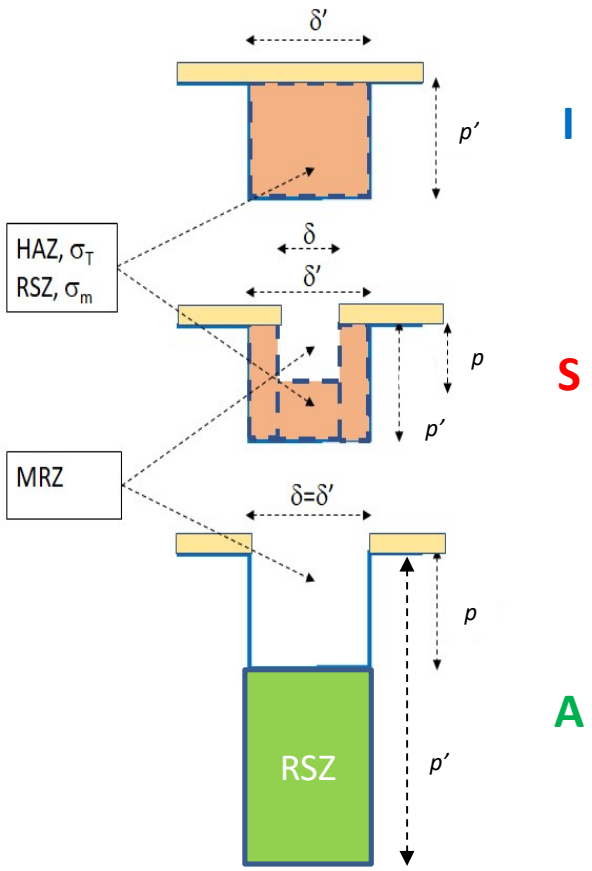
UniLaSalle Institut Polytechnique

# Laser Irradiation – Scribing – Ablation



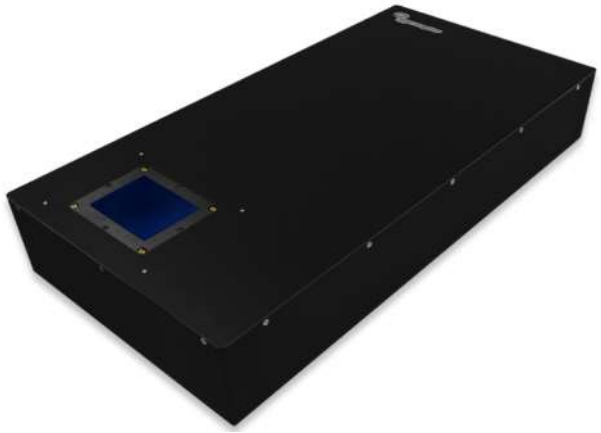

***p: groove ablation depth***
*RSZ: Residual Stress Zone*
*with **strong shock wave pressure***

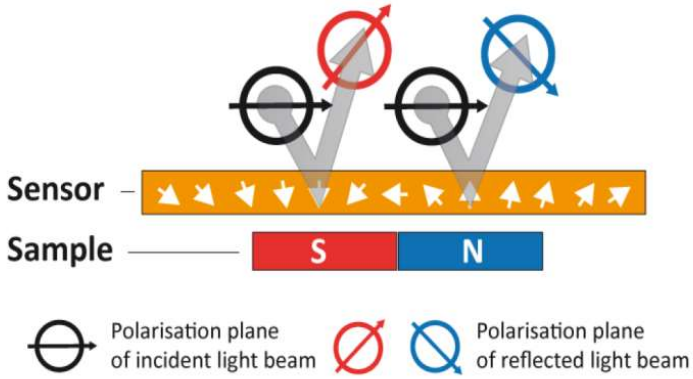
UniLaSalle Amiens — Symade UniLaSalle — UniLaSalle Institut Polytechnique

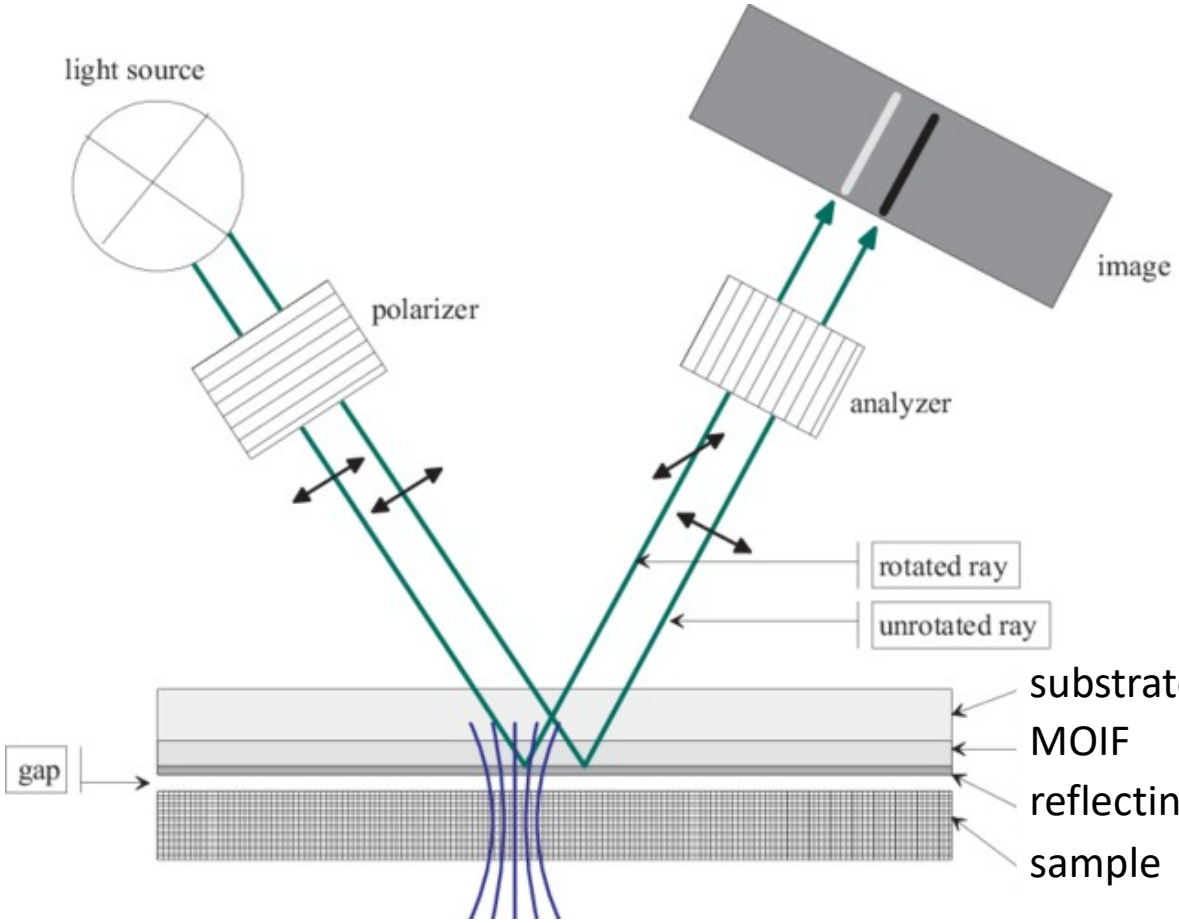
# Introduction of Imaging Techniques - MOIF

## Magnetic Optical Indicator Film technique - MOIF

MOIF





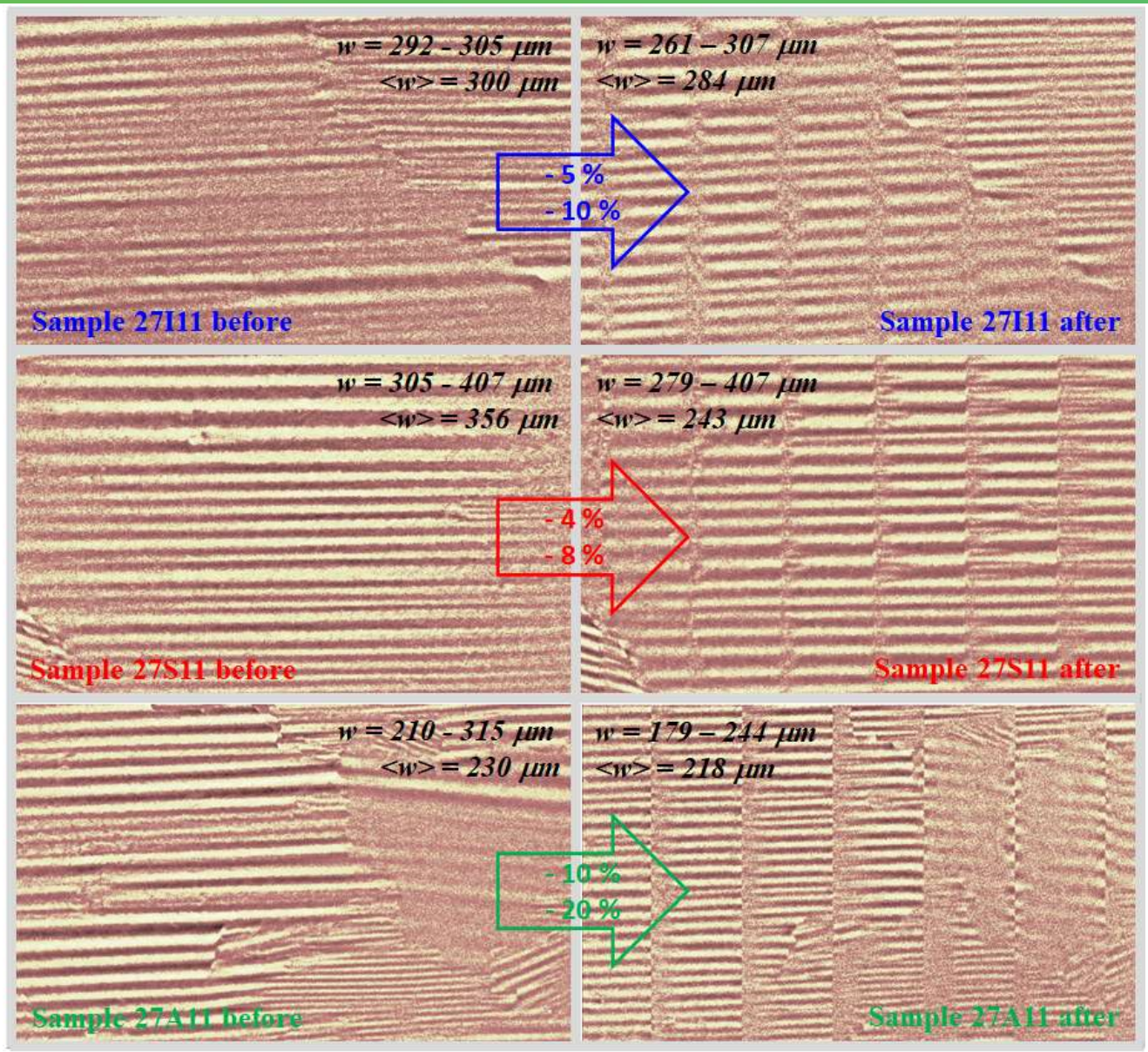



# Microscopic imaging of GOES magnetic structure – MOIF - ISA


## IRRADIATION
- 7,5 % refinement

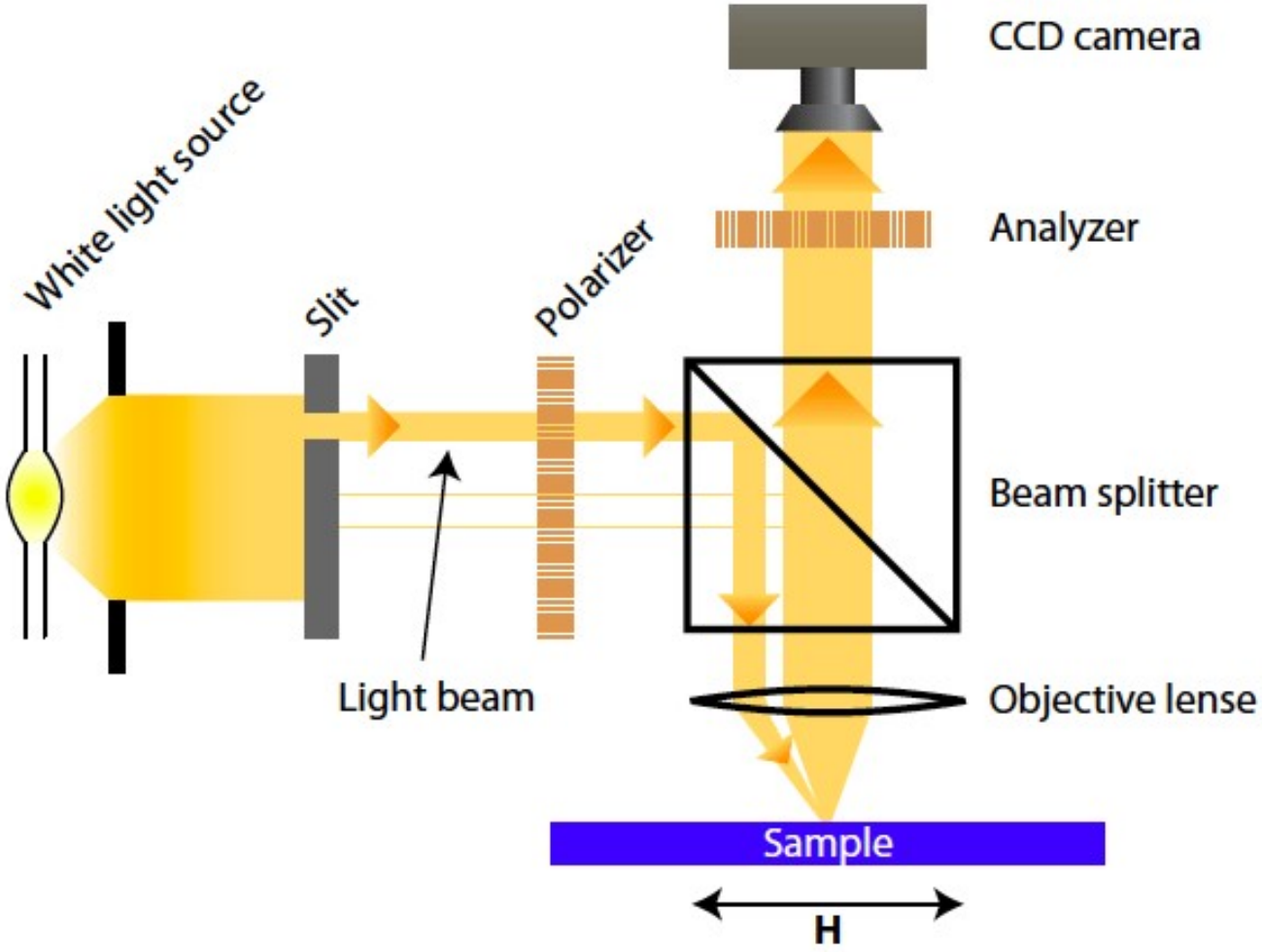
## SCRIBING
- 6 % refinement

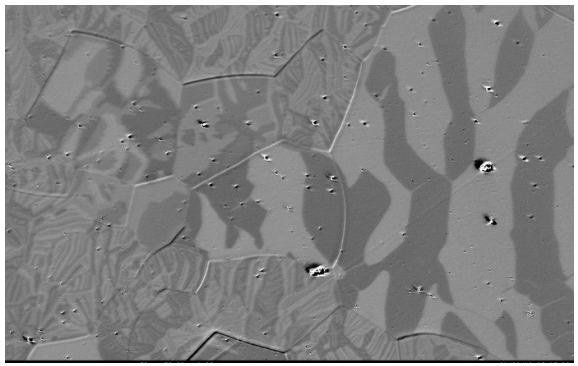
## ABLATION
- 10 % refinement



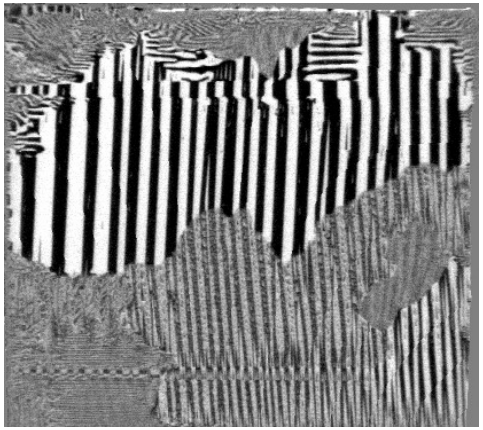
# Introduction of Imaging Techniques - MOKE

## Magnetic Optical Indicator Film technique – dynamic MOKE

*MOKE image of NGOES steel*

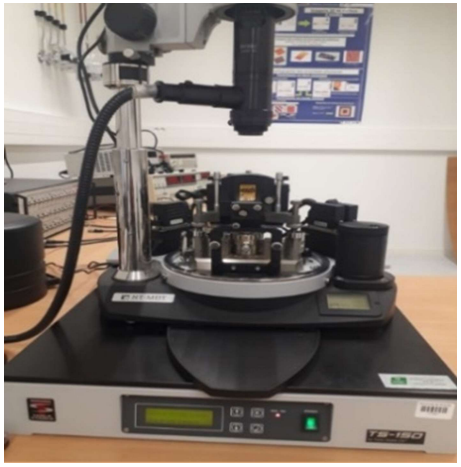


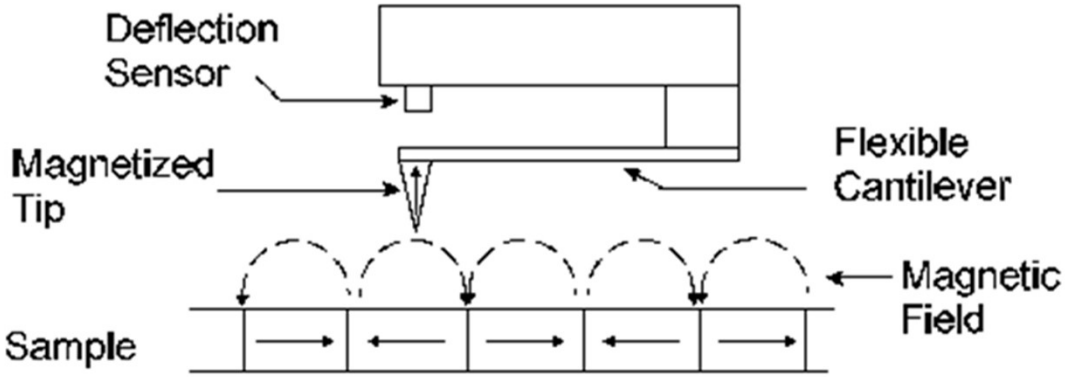
*MOKE image of GOES steel*

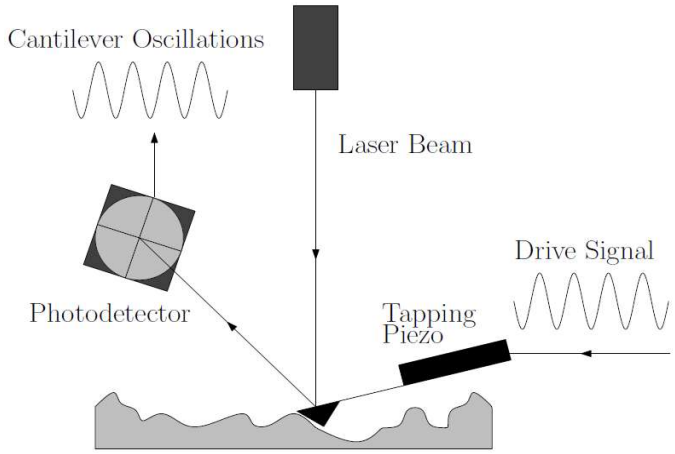
# Introduction of Imaging Techniques - MFM

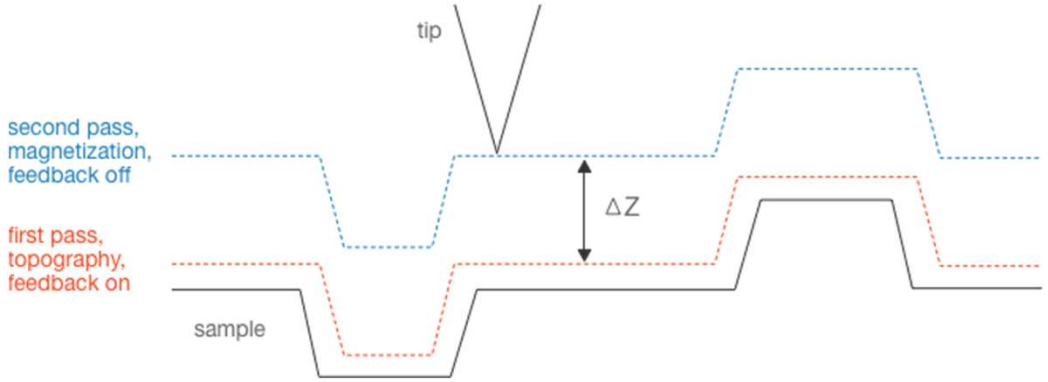
## Magnetic Force Microscope - MFM

MFM



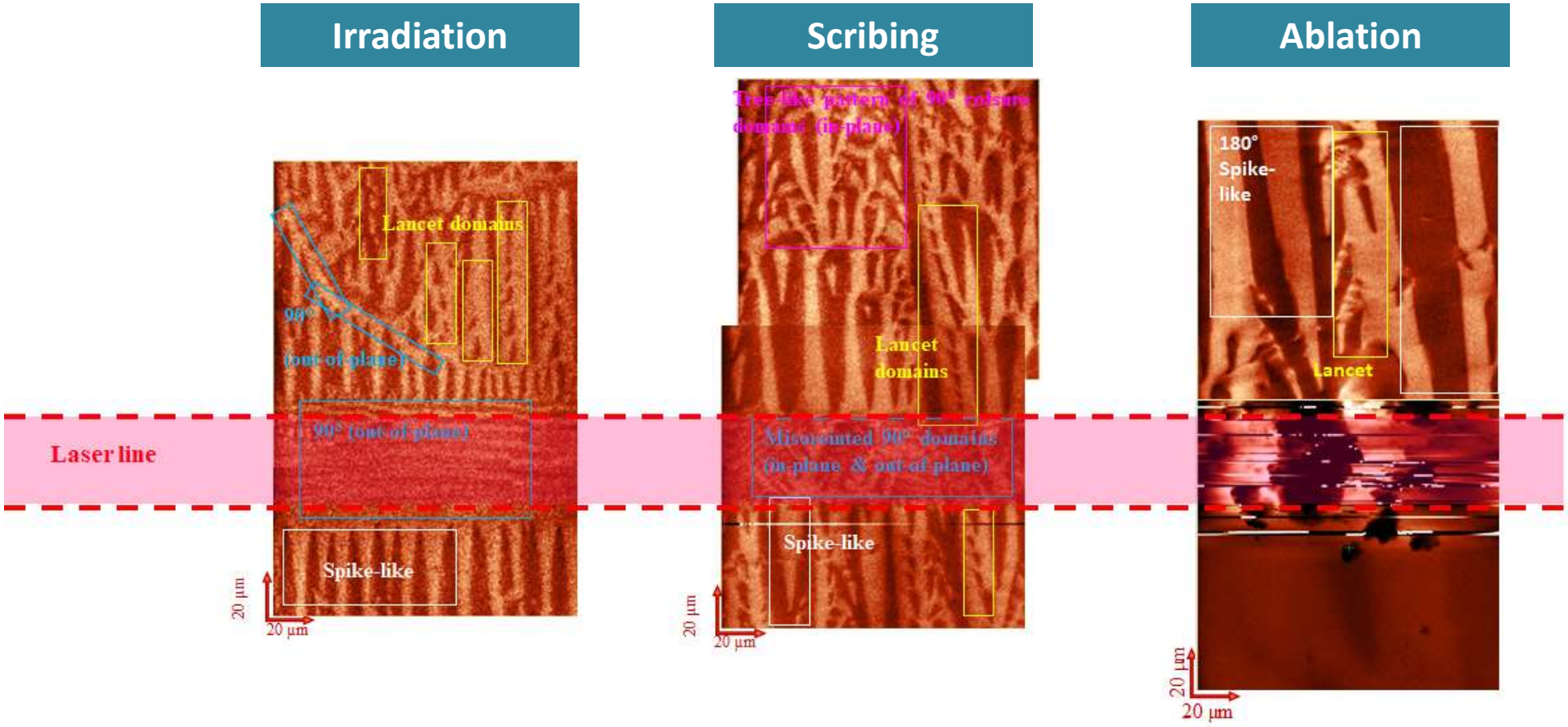



# Microscopic imaging of GOES magnetic structure – MFM

**MFM: High resolution ~ 120×120 µm²**


**Sample GO XXM-XX:** 10×10 mm²; Polished, Images after laser treatment close to the laser spots




UniLaSalle Amiens

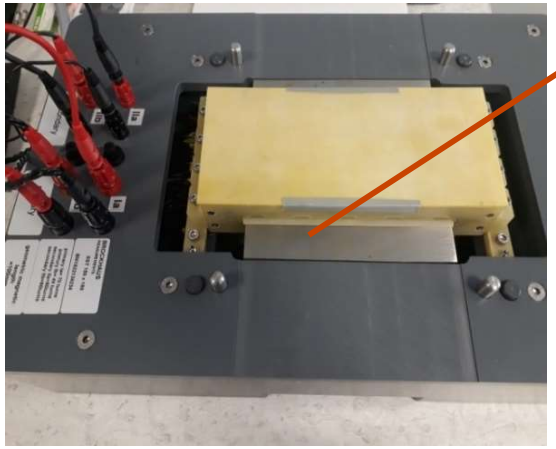
Symade UniLaSalle

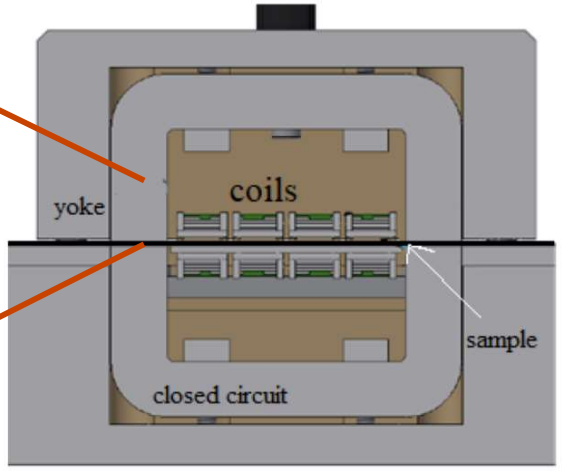
UniLaSalle Institut Polytechnique

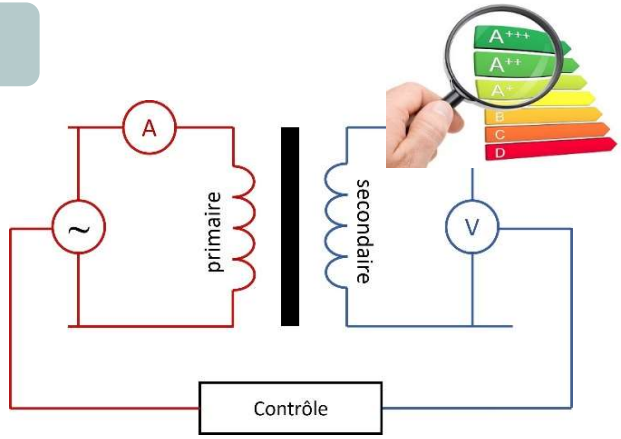
# Introduction of Equipements for magnetic measurements

## Single Sheet Tester (SST)

(BROCKHAUS measurement)



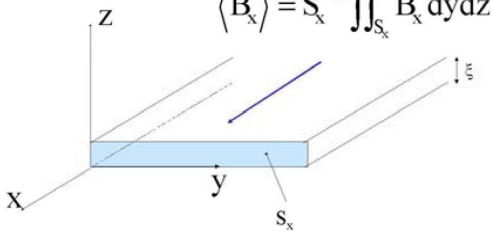




$I \propto H$ *(magnetic field)*

$V \propto -\frac{dB}{dt}$ *(time variation of induction)*

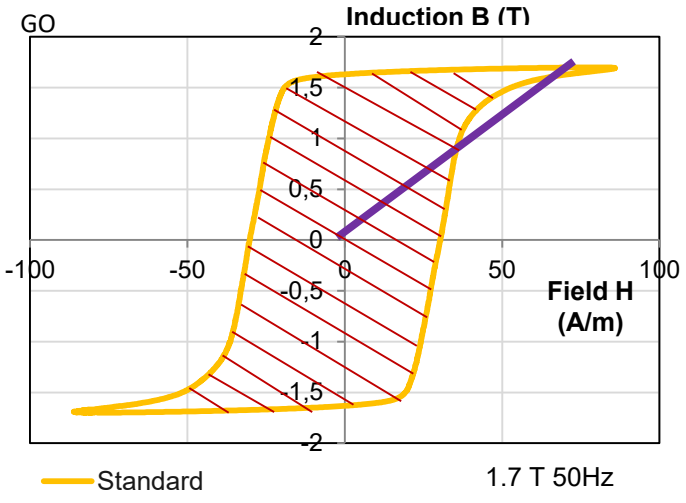
## Hysteresis loops

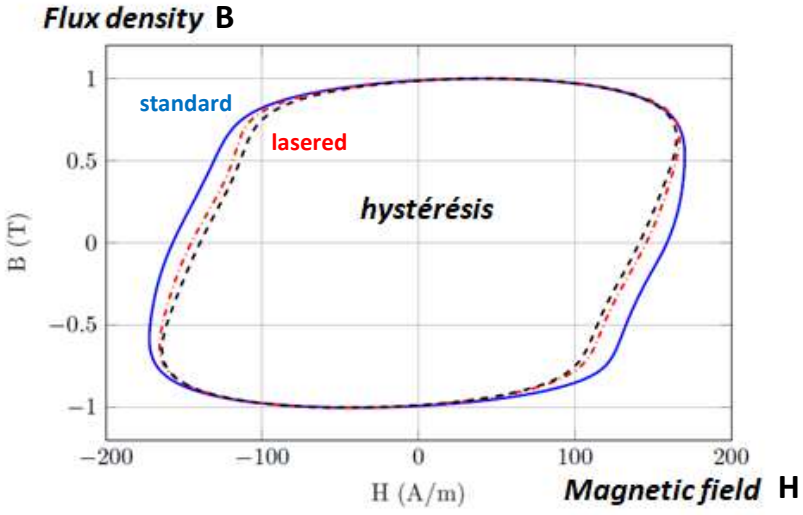
$$\langle B_x \rangle = S_x^{-1} \iint_{S_x} B_x \, dydz$$




iron losses

magnetic permeability




UniLaSalle Amiens

Symade UniLaSalle

UniLaSalle Institut Polytechnique

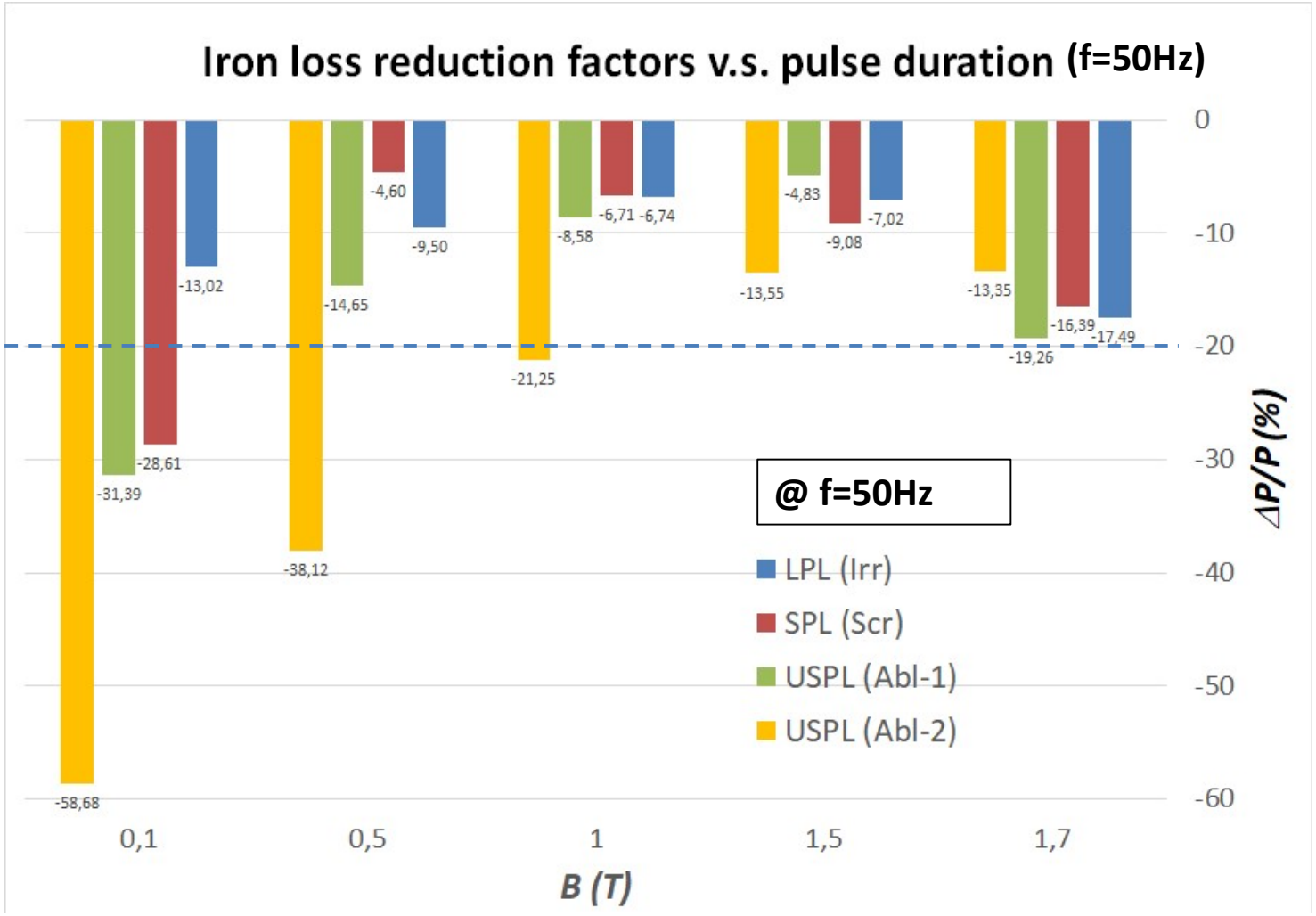
# Unidirectional power loss reduction under laser treatment


Best loss reductions

GOES 0,23 mm tick.

Comparisons with the same samples before and after laser treatment.

| 1,7T 50Hz | LPL (%) | SPL (%) | USPL 1 (%) | USPL 2 (%) |
|---|---|---|---|---|
| 0,23 | -17,5 | -16,4 | -19,3 | -13,4 |
| 0,27 | -15,3 | -11 | -15,3 | -15,4 |




Permeability Constraint: $J_{800}$ > 1,77 T 1,80 T 1,74 T > 1,7 T

UniLaSalle Amiens

Symade UniLaSalle

UniLaSalle Institut Polytechnique

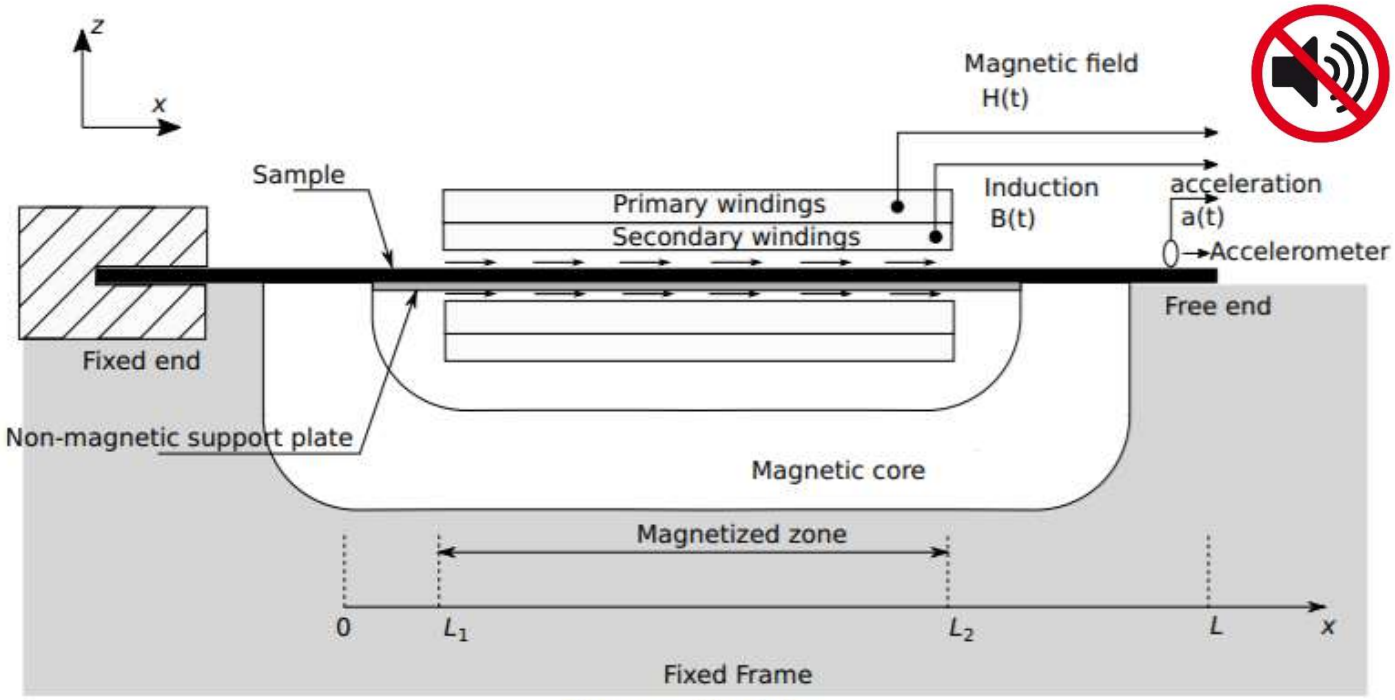
# Introduction of Equipements for vibration measurements

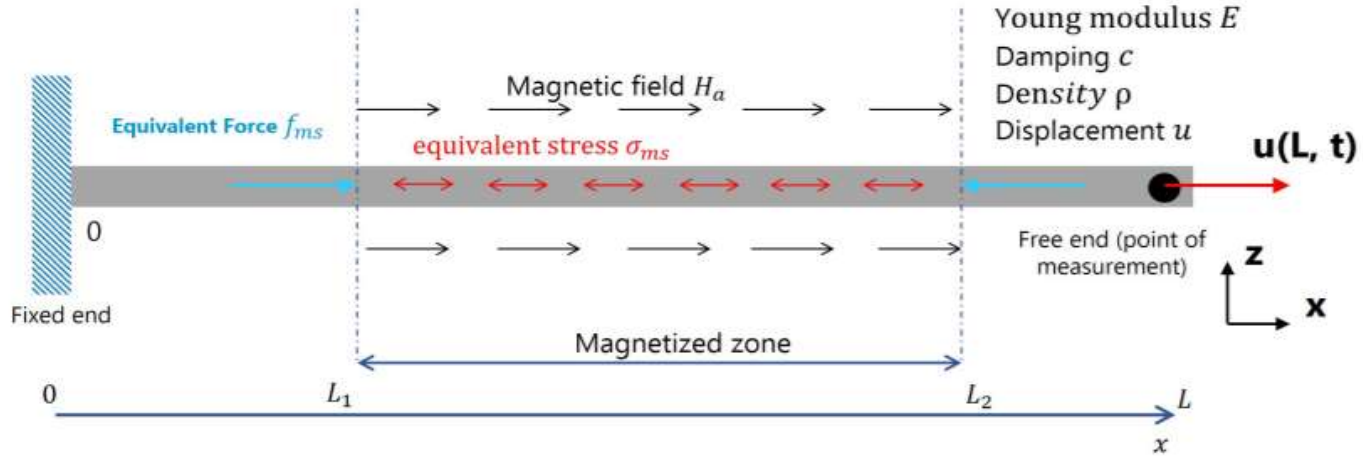
**Magneto-mechanical measurements system**

Synchronously

Electromagnetic:
Field H
Flux density B

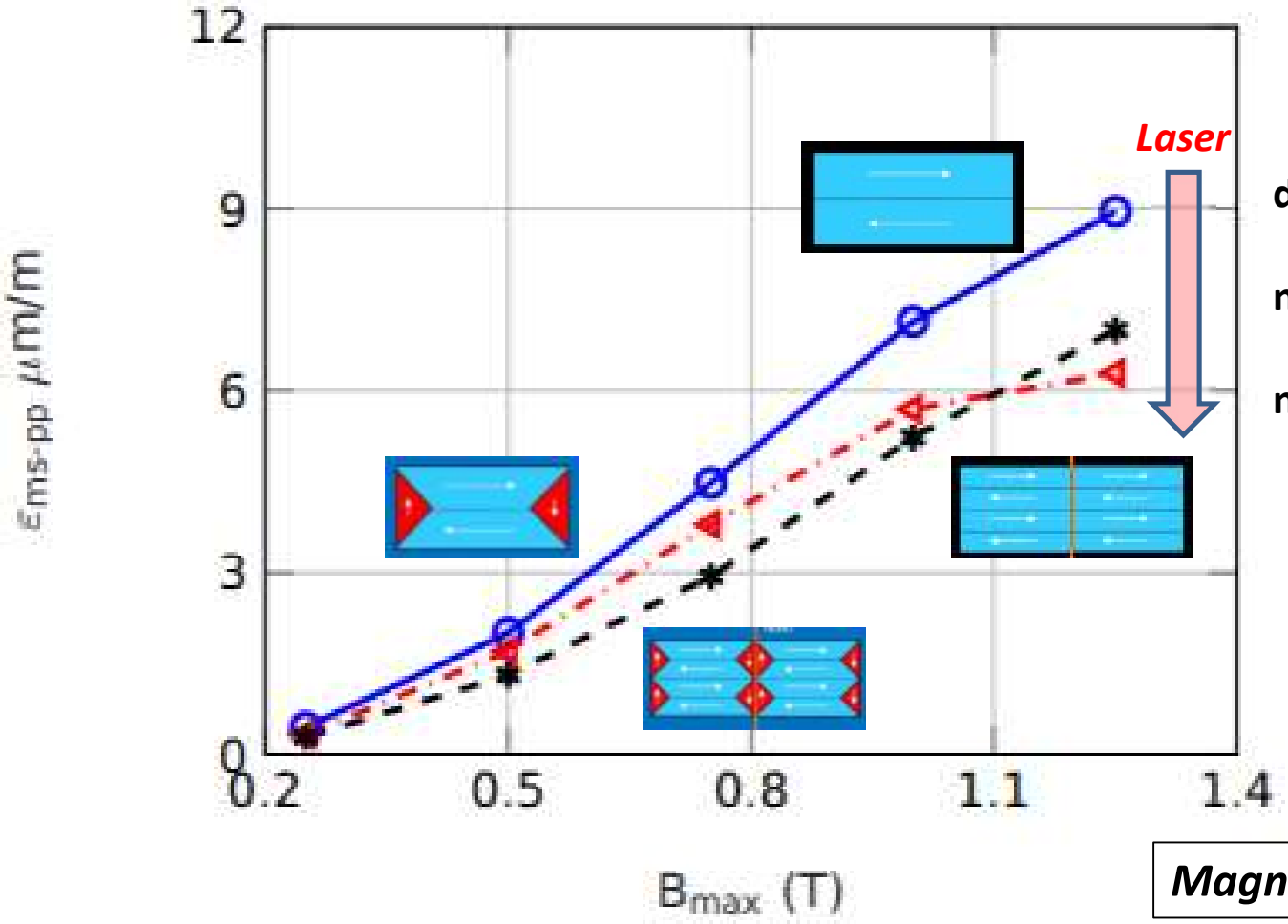
Mechanical:
Acceleration of sample end



# Magnetic induced vibration source weakening

***Magnetic induced strain***
***Magneto-striction***




***Magnetic Flux density***

dε/ε ~ -30 %

noise ∝ ε'² ∝ (fε)²

noise reduction ~ - 3 dB

Figure – Peak-To-Peak vs Induction at 1,500 Hz. [ Ref. 1 face 2 faces]

UniLaSalle Amiens

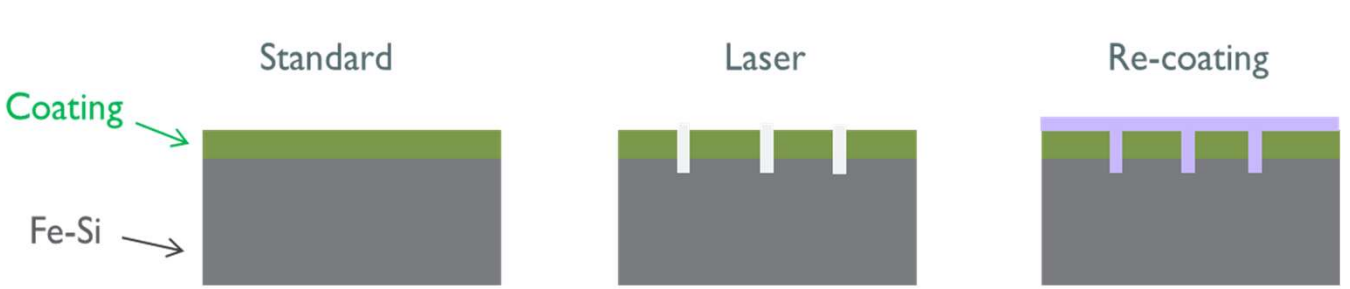
Symade UniLaSalle

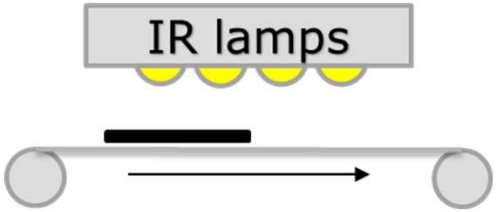
UniLaSalle Institut Polytechnique

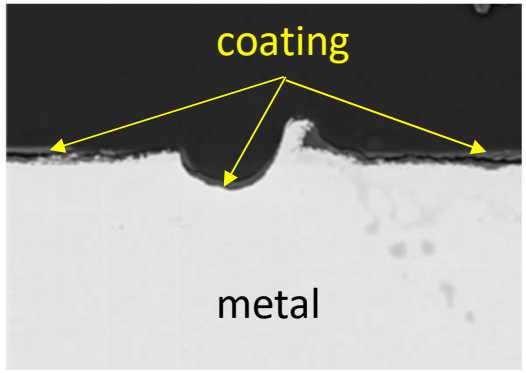
# Coating process ≠ oxydation, corrosion, short circuits




SPRAY COATING




UniLaSalle Amiens

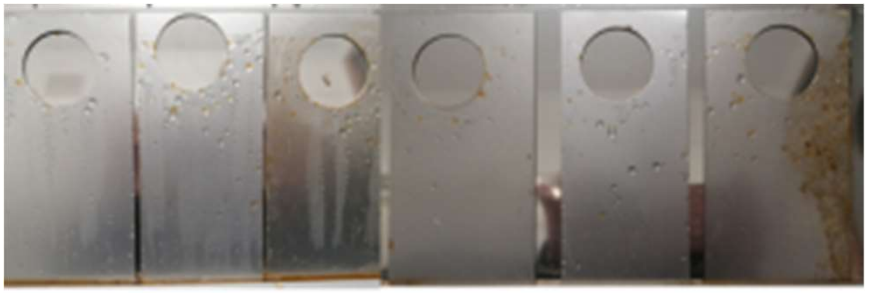
Symade UniLaSalle

UniLaSalle Institut Polytechnique

# Corrosion and insulation properties measurements

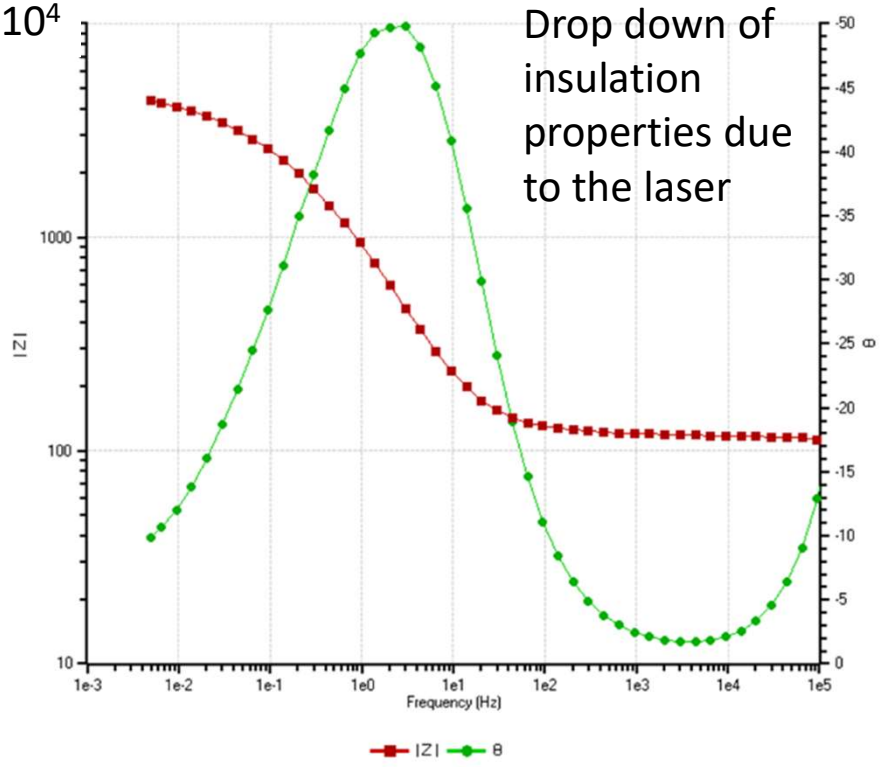
Corrosion in QCT test if no protection after the laser

Adjustment of deposition parameters for protecting coating



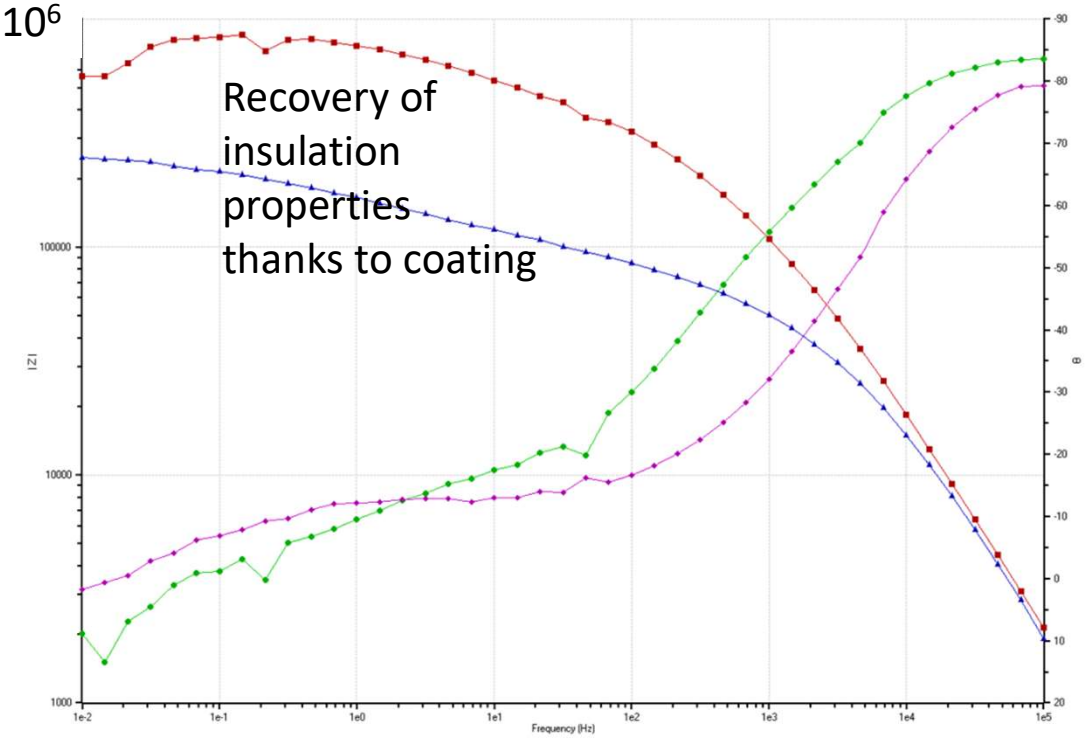
$10^4$

Drop down of insulation properties due to the laser




$10^6$

Recovery of insulation properties thanks to coating

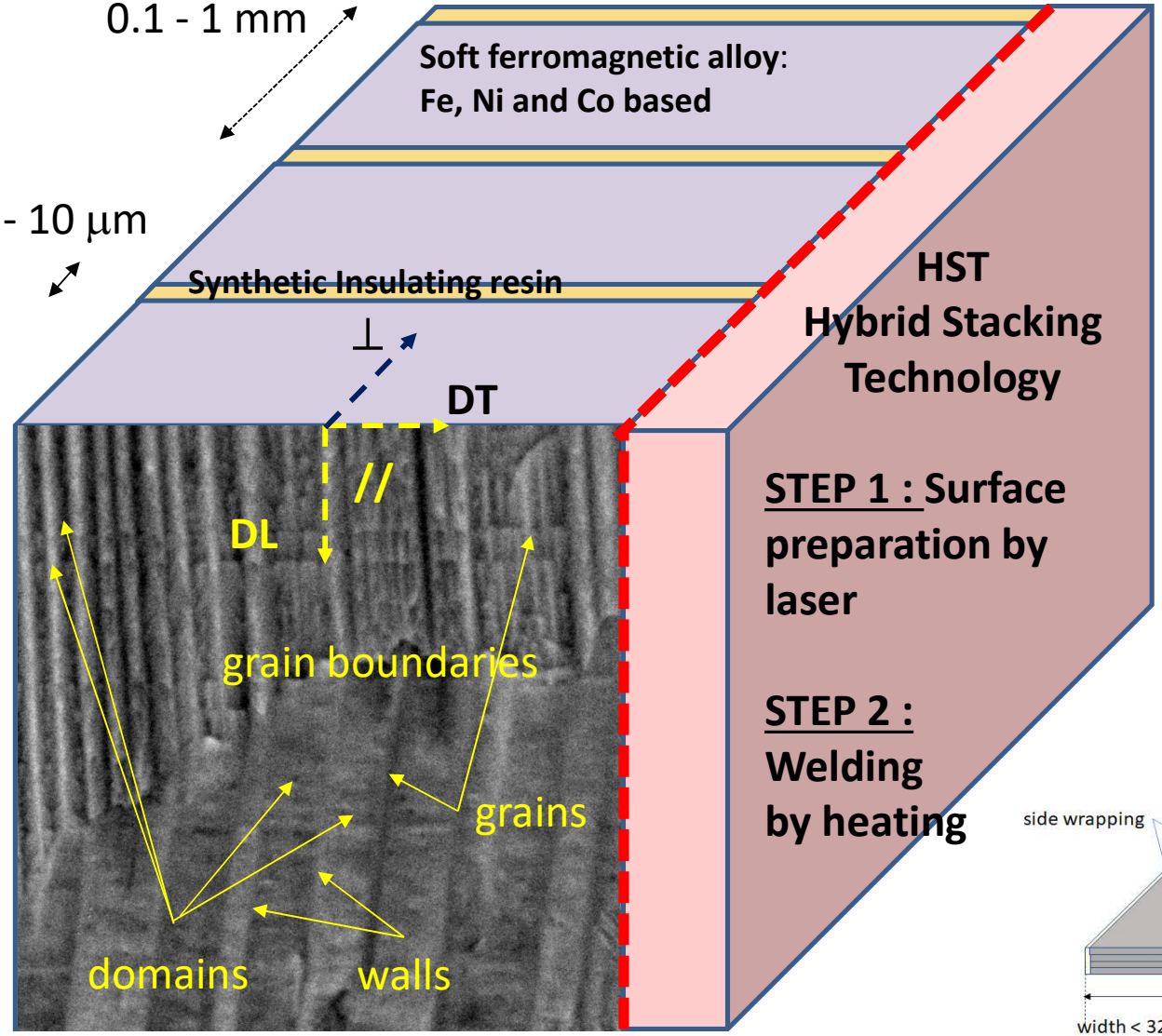



UniLaSalle Amiens

Symade UniLaSalle

UniLaSalle Institut Polytechnique

# Introduction of Laser Hybrid Joining



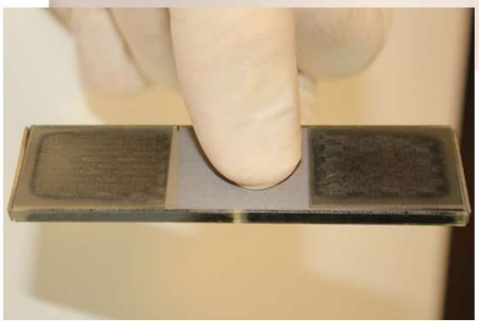

**HST**
**Hybrid Stacking Technology**

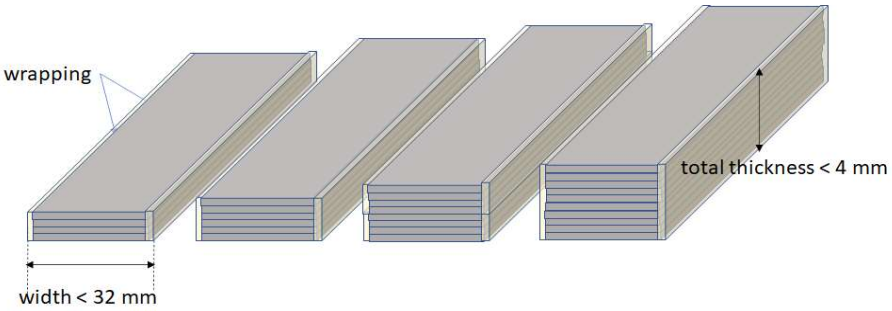
**STEP 1 : Surface preparation by laser**

**STEP 2 : Welding by heating**

STEP 1

STEP 2



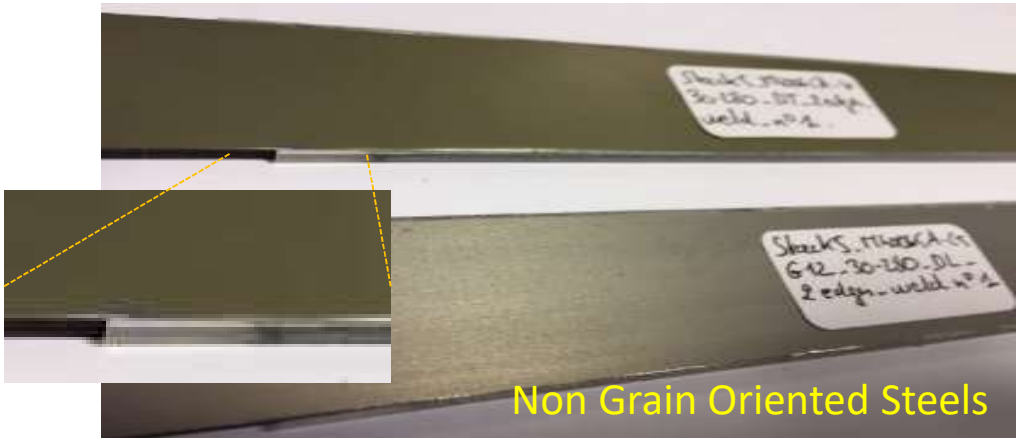



UniLaSalle Amiens

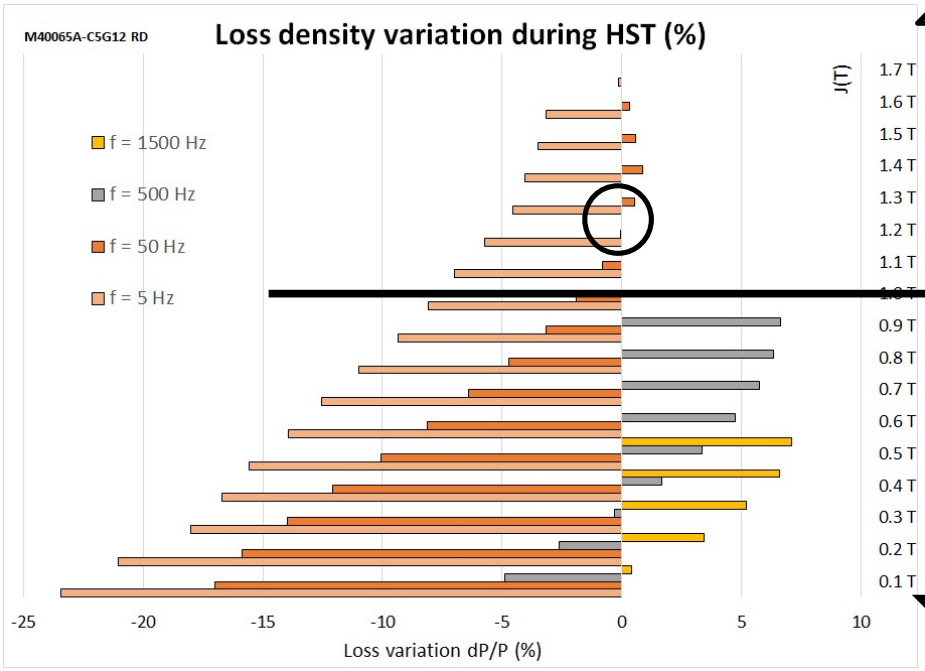
Symade UniLaSalle

UniLaSalle Institut Polytechnique

# Impact of laser joining process on magnetic performances

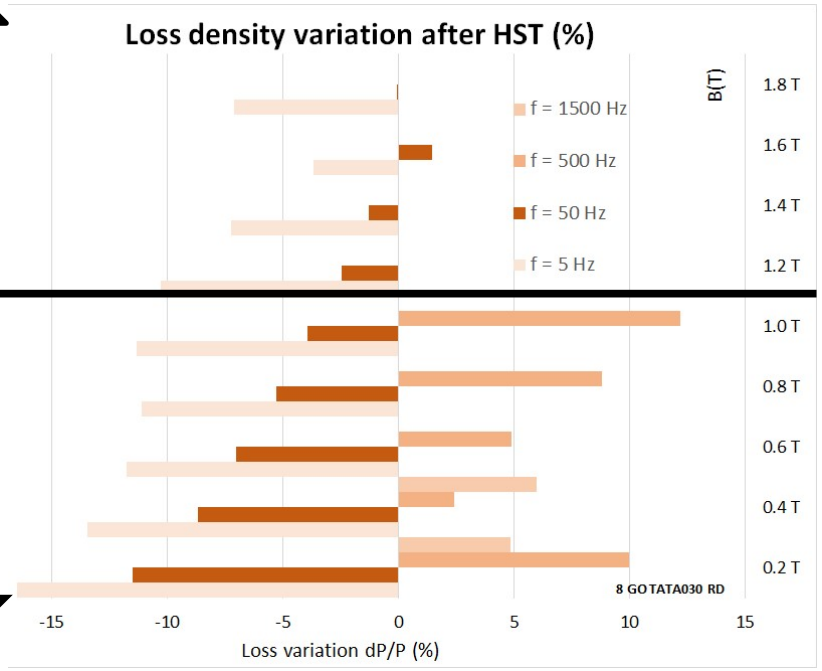







transformers

inductors




Flux density B(T)

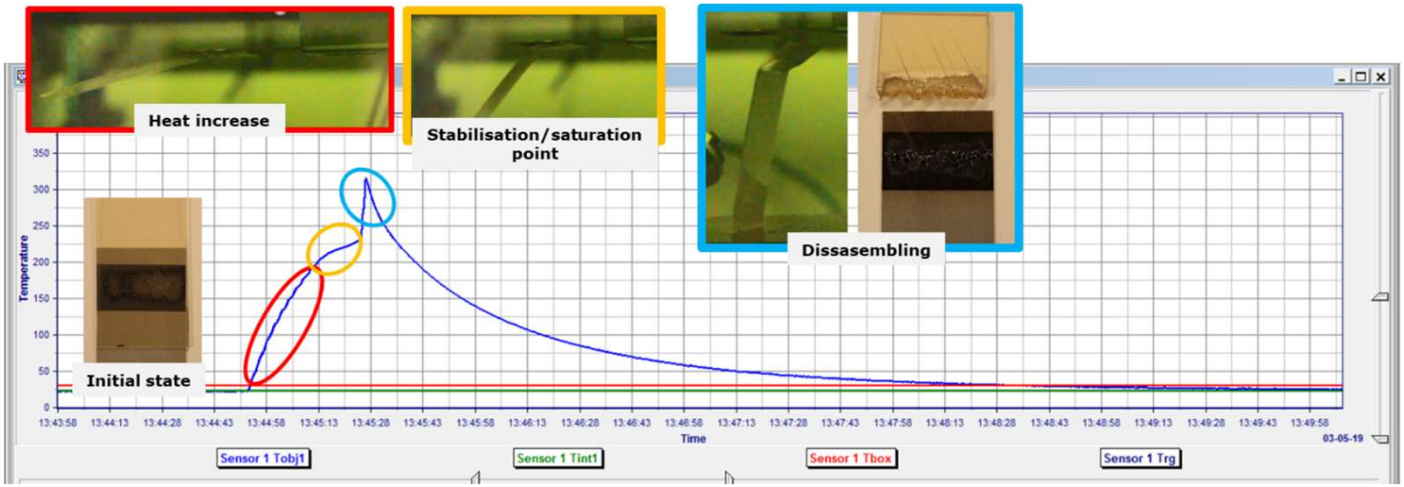
UniLaSalle Amiens

Symade UniLaSalle

UniLaSalle Institut Polytechnique

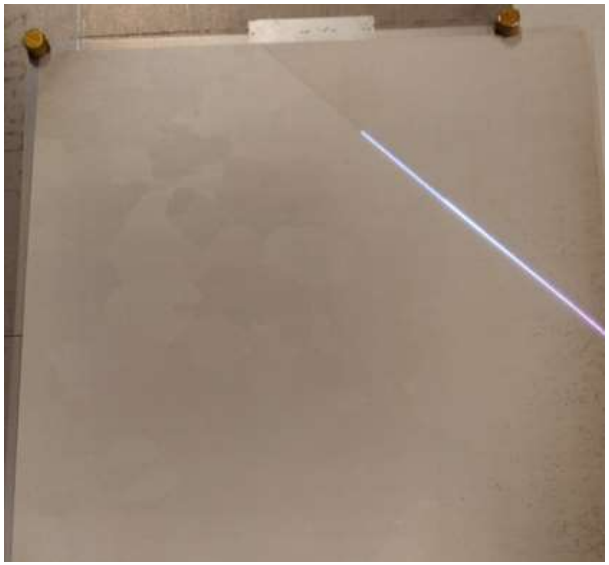
# Disassembling of stacks and separation of materials

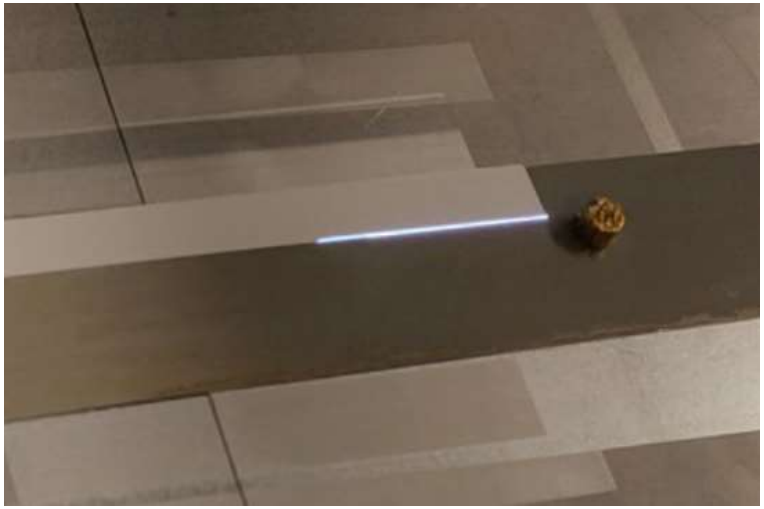
LASER DISASSEMBLING

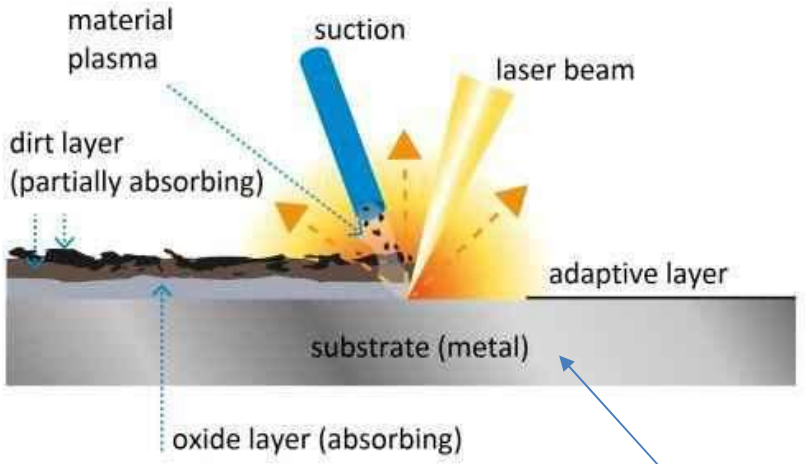



HEAT GUN DISASSEMBLING

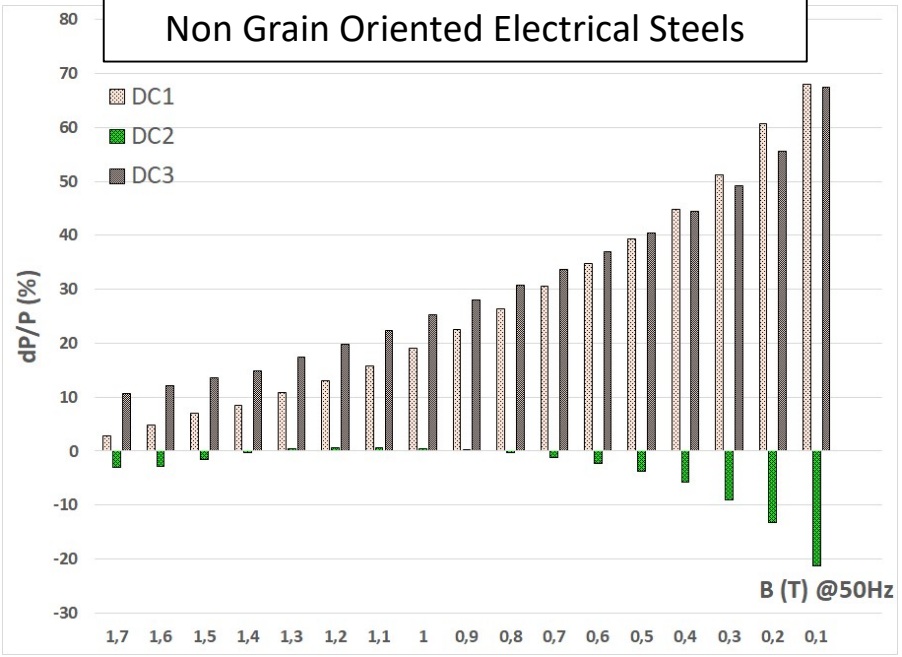
# Surface cleaning and re-use of materials








Non Grain Oriented Electrical Steels




UniLaSalle Amiens

Symade UniLaSalle

UniLaSalle Institut Polytechnique

# Conclusion – Main Results


- 10 % < magnetic losses < - 35 %

- 1,5 dB < magnetic noise < - 20 dB

90 % < recycling / re-use rate < 100 %

1 year < ROI < 7 years

# AGENDA

09:30 – INTRODUCTION & PRESENTATION OF ESSIAL

- *Speaker UNILASALLE, Olivier Maloberti*

**10:00 – IMPLEMENTATIONS FOR POWER ELECTRONICS INDUCTANCES AND TRANSFORMERS**

- *Speaker UNILASALLE, Olivier Maloberti*
- *Speaker MULTITEL, Julien Dupuy*
- *Speaker ANDALTEC, Jesús Castillo*
- *Speaker EREA, Johan Bleumers*

11:45 – APPLICATION METHOD FOR DEMONSTRATORS AND ELECTRICAL MACHINES

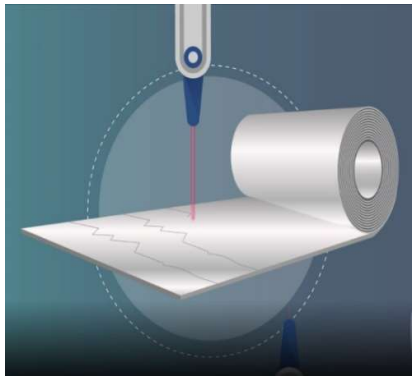
- *Speakers JEUMONT Electric, Préscillia Dupont & Maxime Ployard*

*LUNCH*

14:00 – VISIT OF THE FACILITIES

16:00 – Q&A AND CLOSING SESSION

FINAL EVENT ESSIAL – ULS-AMS : 11/07/2022



# ESSIAL

## IMPLEMENTATIONS FOR POWER ELECTRONICS INDUCTANCES AND TRANSFORMERS

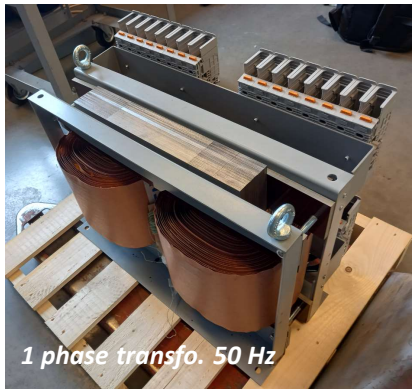
**O. Maloberti (UNILASALLE Amiens, Project Coordinator)**

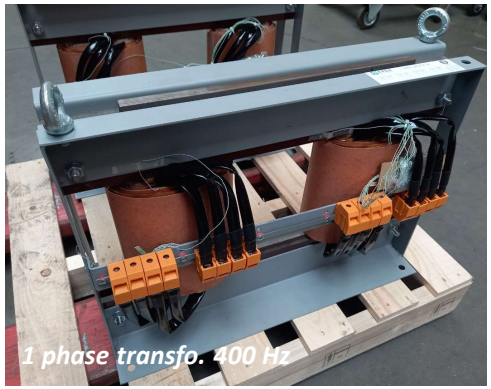
UniLaSalle Amiens · CRM GROUP · IRT M2P Institut de Recherche Technologique Matériaux Métallurgie et Procédés · Multitel Innovation Centre · Université de Picardie Jules Verne · uc3m Universidad Carlos III de Madrid · EREA Transformers erea · energy · engineering

JEUMONT Electric Groupe Altawest · matikem de l'idée au marché · andaltec Centro Tecnológico del Plástico · Fraunhofer IPT · lasea Precision Laser Solutions · euronovia

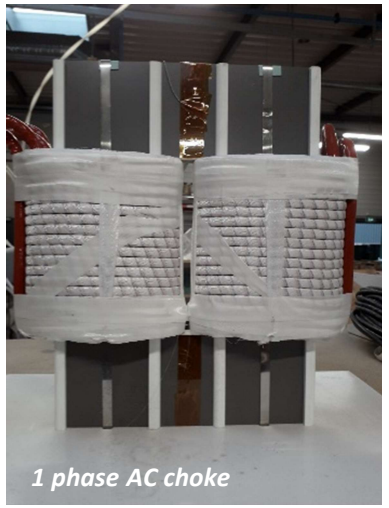
UniLaSalle Amiens · Symade UniLaSalle · UniLaSalle Institut Polytechnique

- **Voltage transformers (inverters, distribution …)**
  - AC 1Ph and 3Ph transformers
  - **0,27 mm GOES**


*1 phase transfo. 50 Hz*

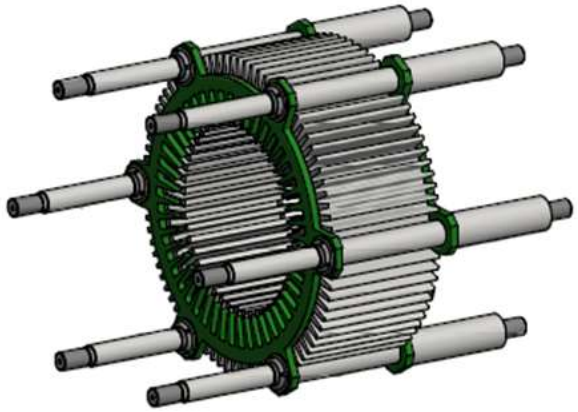

*1 phase transfo. 400 Hz*

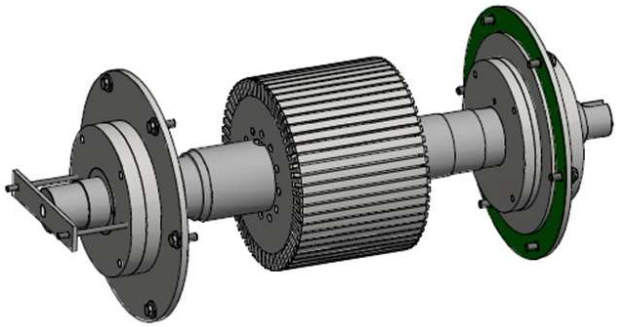
- **Output filters, DC & AC inductors**
  - AC 1&3Ph-AC choke **0,23 mm GOES**
  - DC choke, **0,23 & 0,3 mm GOES**

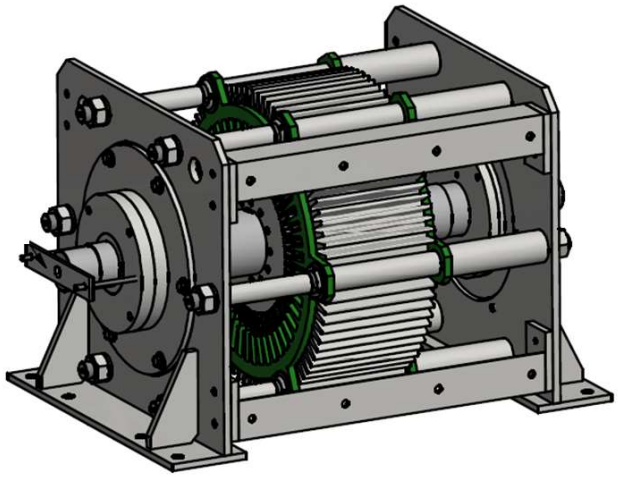

*1 phase AC choke*


*1 phase DC choke*

- **Rotating electrical machine**
  - 4 or 8 poles machine ~ 400 kW
  - **0,65 mm NGOES or 0,3 mm HiB GOES**







# CONTENTS

Upscaling – Process speed increase

LAB.

$f_r$ =10kHz

**v=5 mm/s**

FAB.

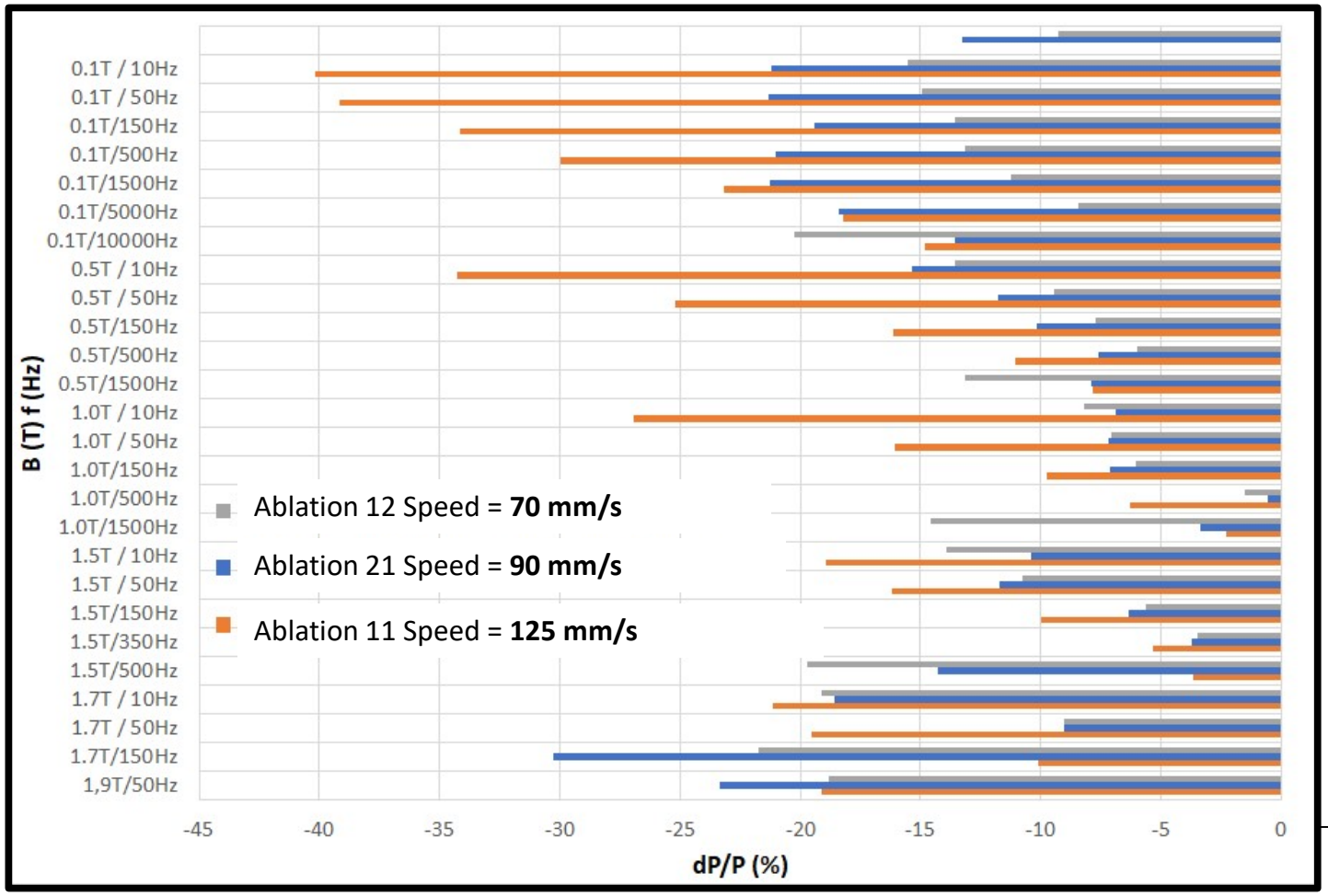
$f_r$ =100kHz

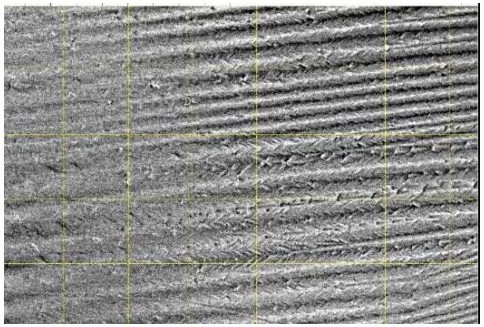
**v=90 mm/s**

IND.

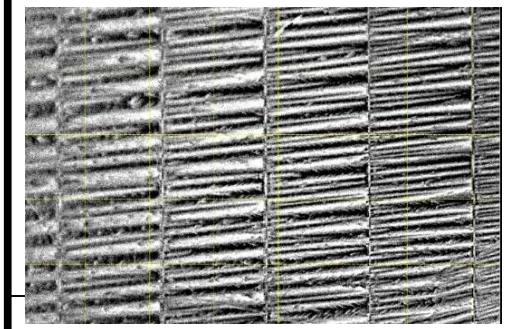
$f_r$ =330kHz

**v=125 mm/s**

Laser



UniLaSalle Amiens

Symade UNIVERSITY UPSCALING UniLaSalle

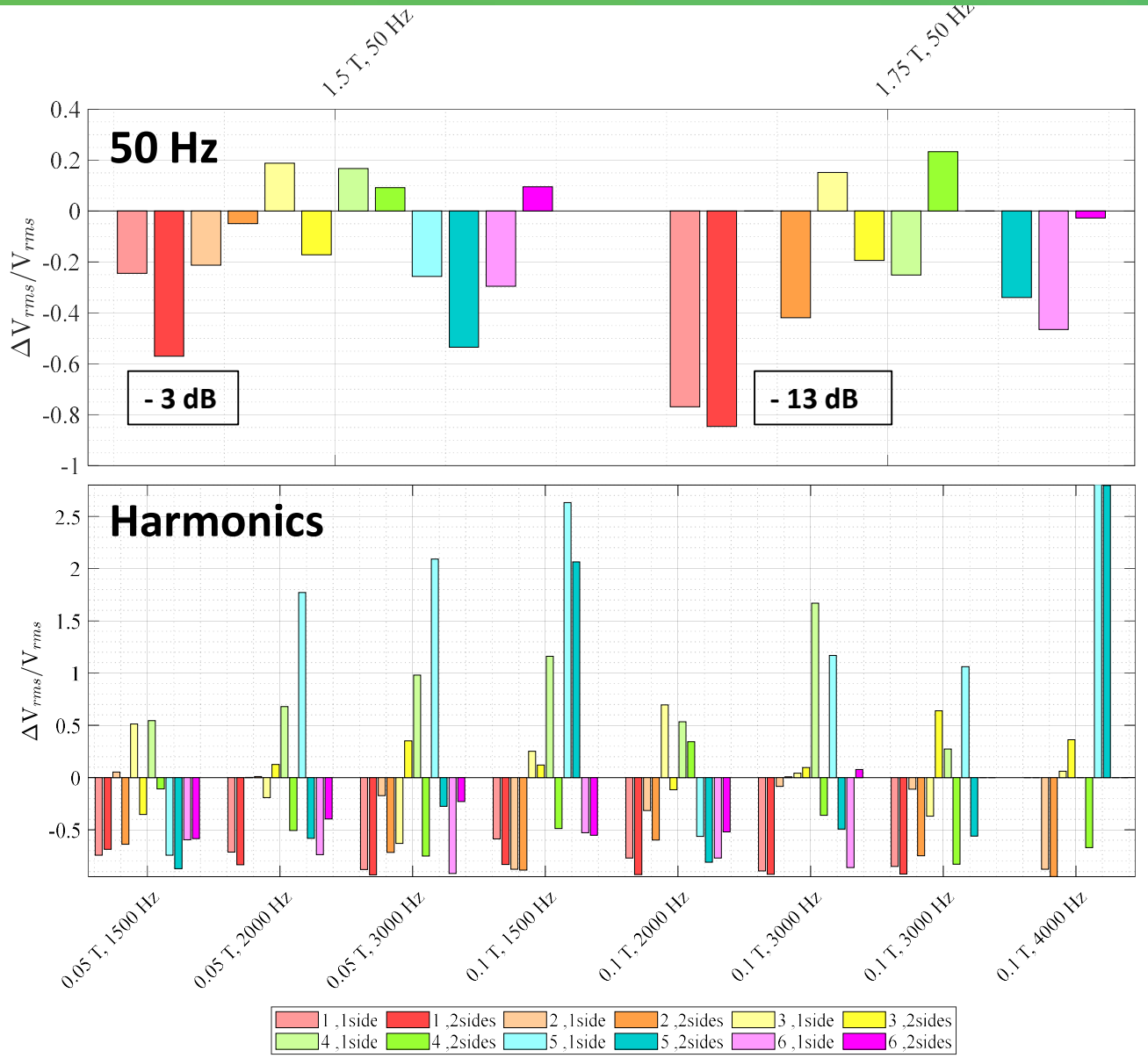
UniLaSalle Institut Polytechnique

# Optimization at high speed for magnetic noise reduction

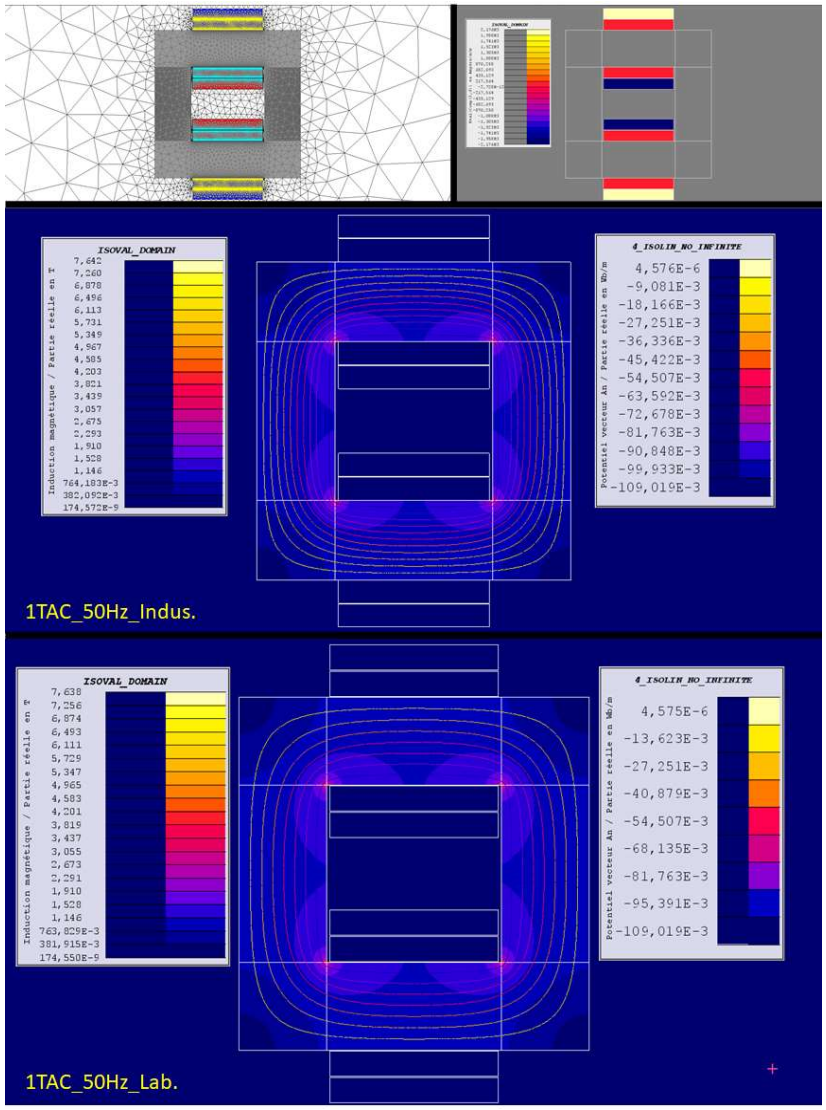
PATTERN 1
1. Ablation 2 70 mm/s
2. Ablation 1 70 mm/s

PATTERN 2
3. Ablation 1 70 mm/s

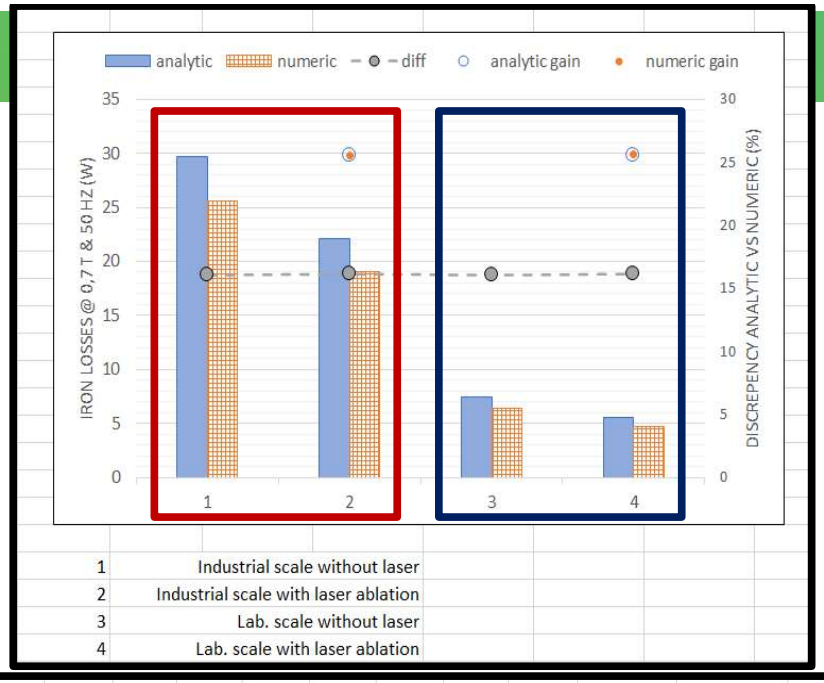
PATTERN 3
4. Ablation 1 70 mm/s
5. Ablation 2 90 mm/s
6. Ablation 1 75 mm/s



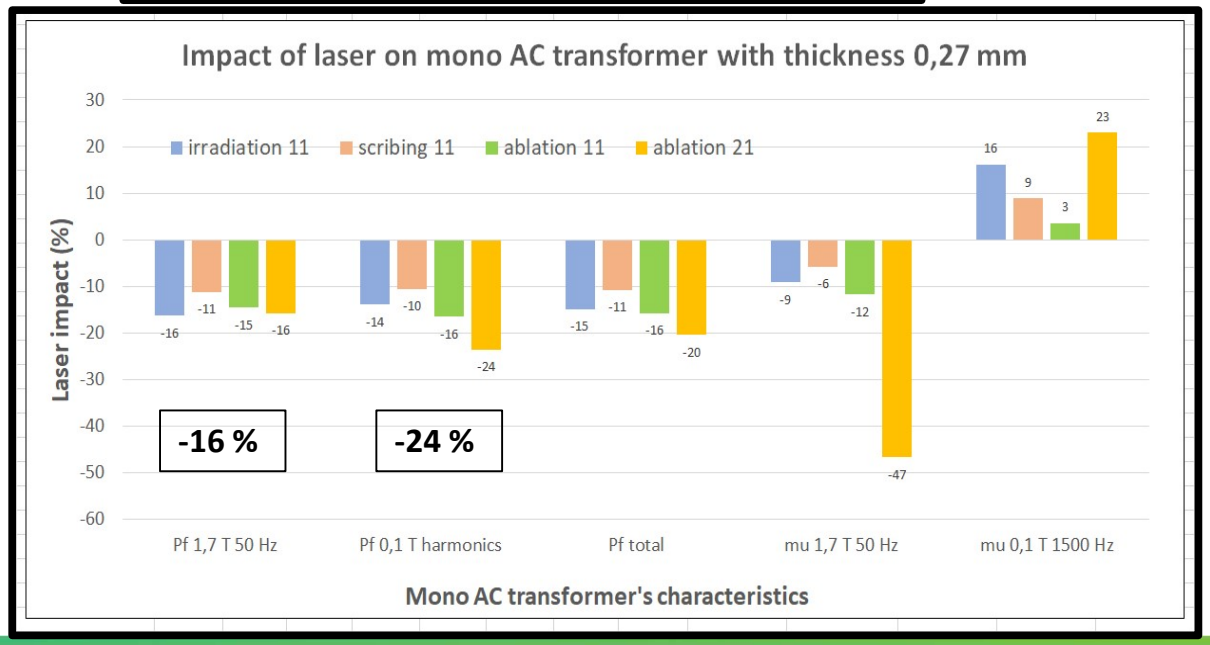
# Design of transformers




Industrial sclae




Lab. sclae

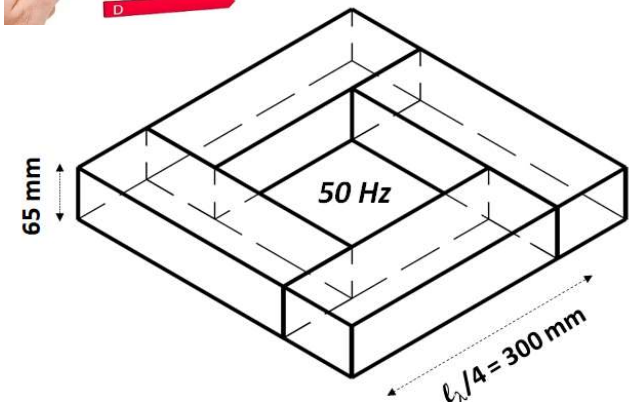


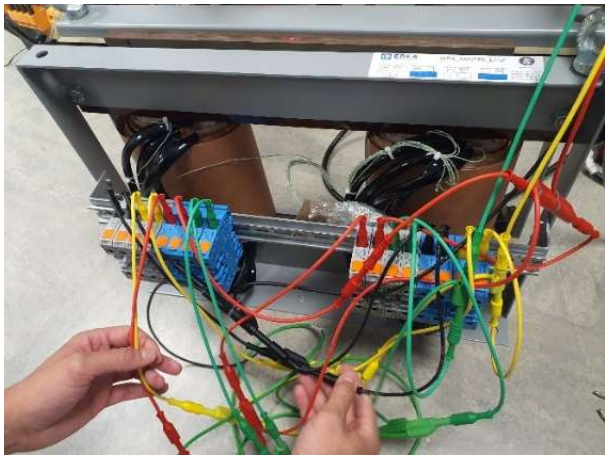

UniLaSalle Amiens

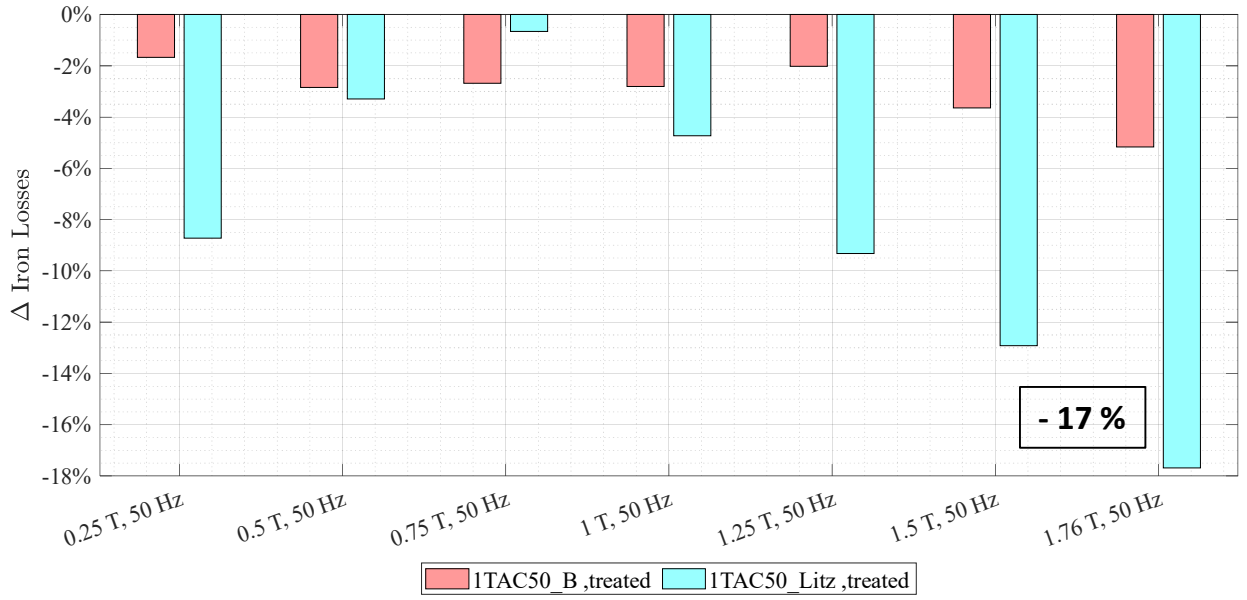
Symade UniLaSalle

UniLaSalle Institut Polytechnique

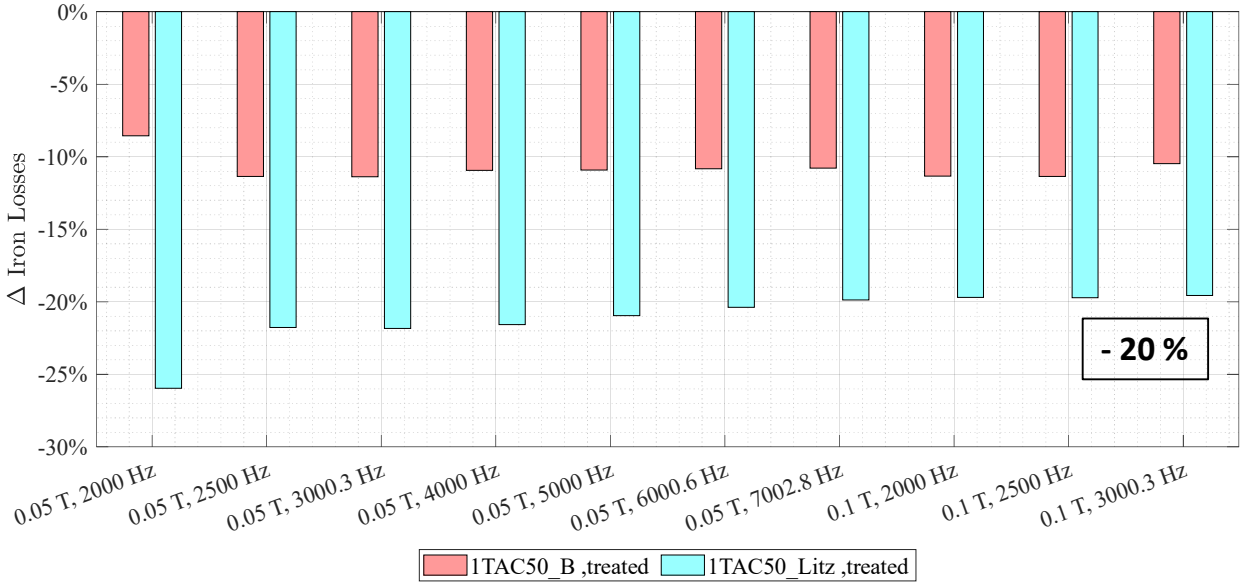
# Prototyping of transformer at the lab. – loss measurements




Fundamental



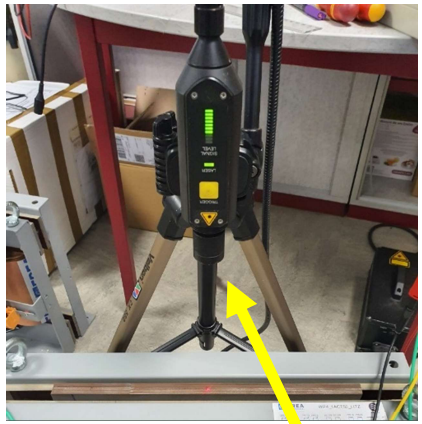

Harmonics

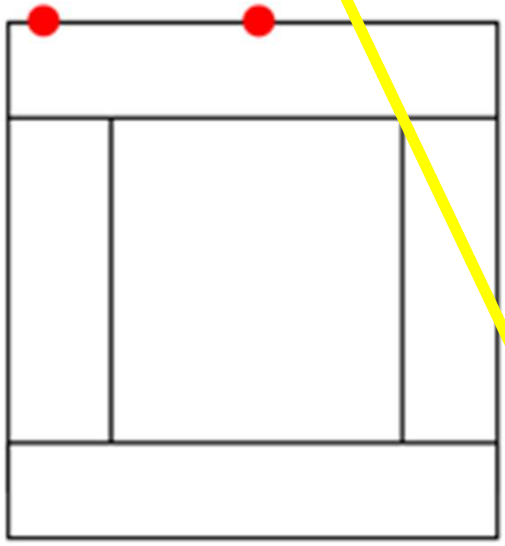
UniLaSalle Amiens

Symade UniLaSalle

UniLaSalle Institut Polytechnique

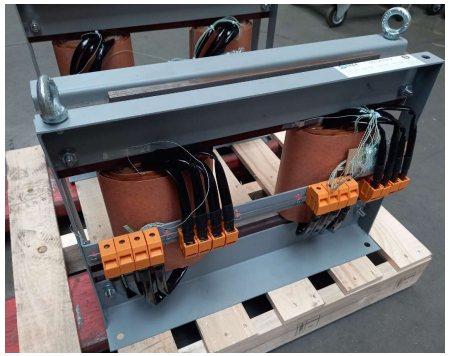
# Prototyping of transformer at the lab. – vibrations measurements

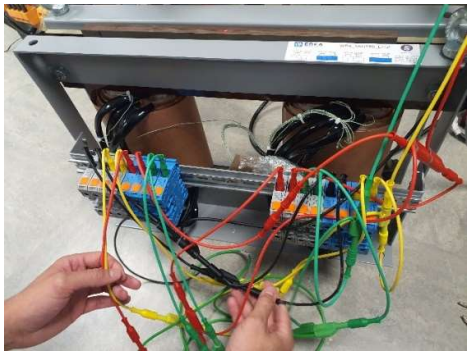


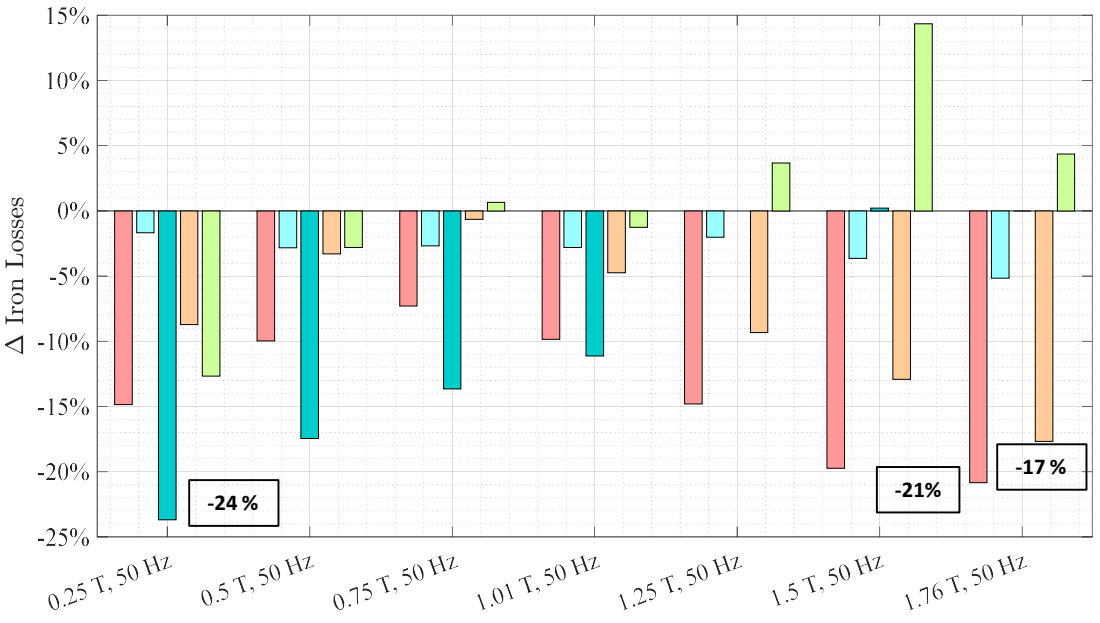


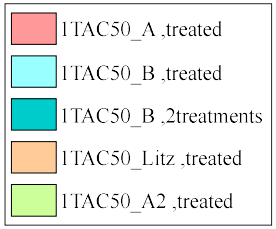
Measurement positions for the velocity using the laser vibrometer.

# Prototypes – transformers at the lab. scale (surface laser treatments)

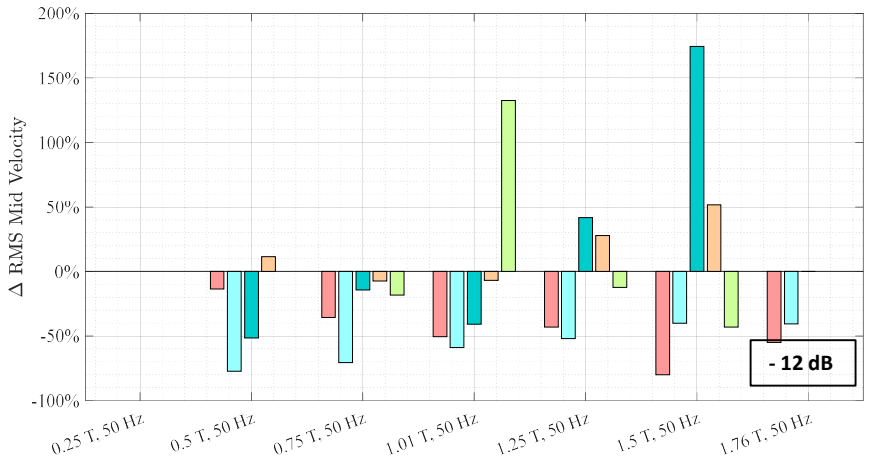





Loss Reduction

Noise Reduction

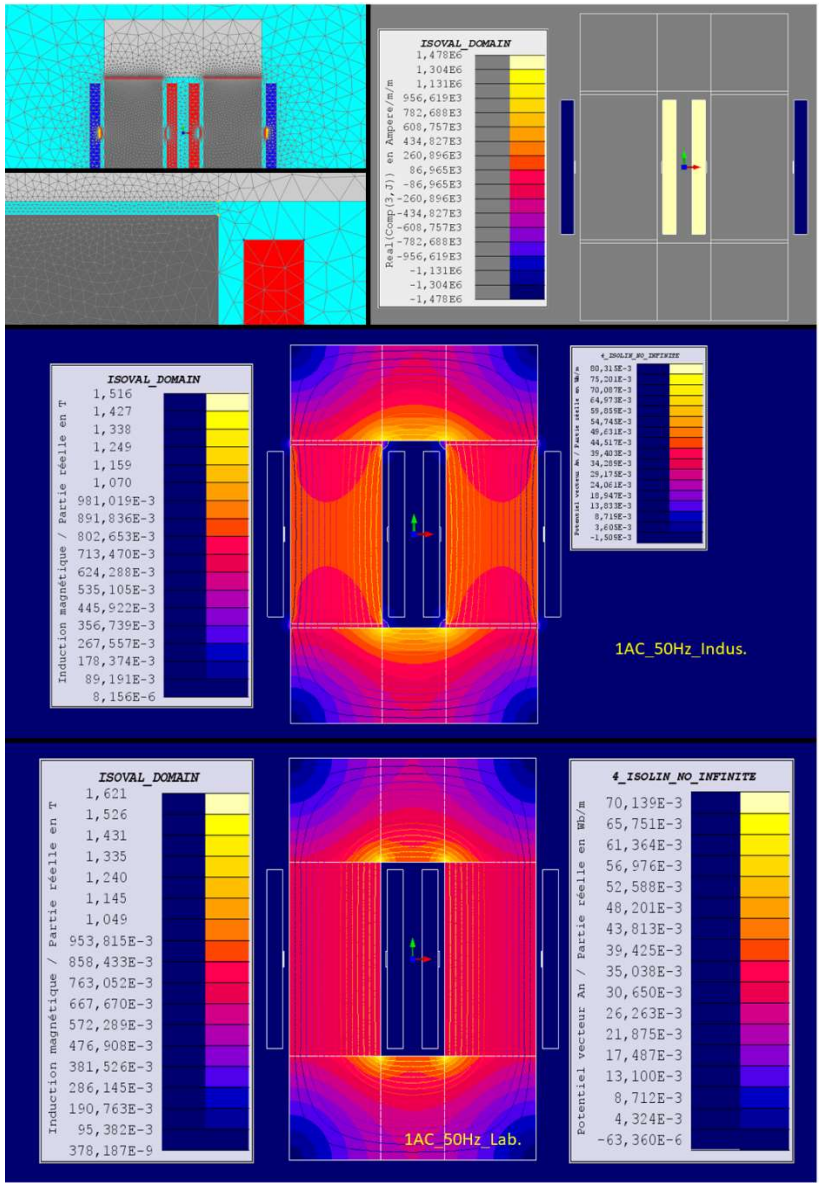



UniLaSalle Amiens

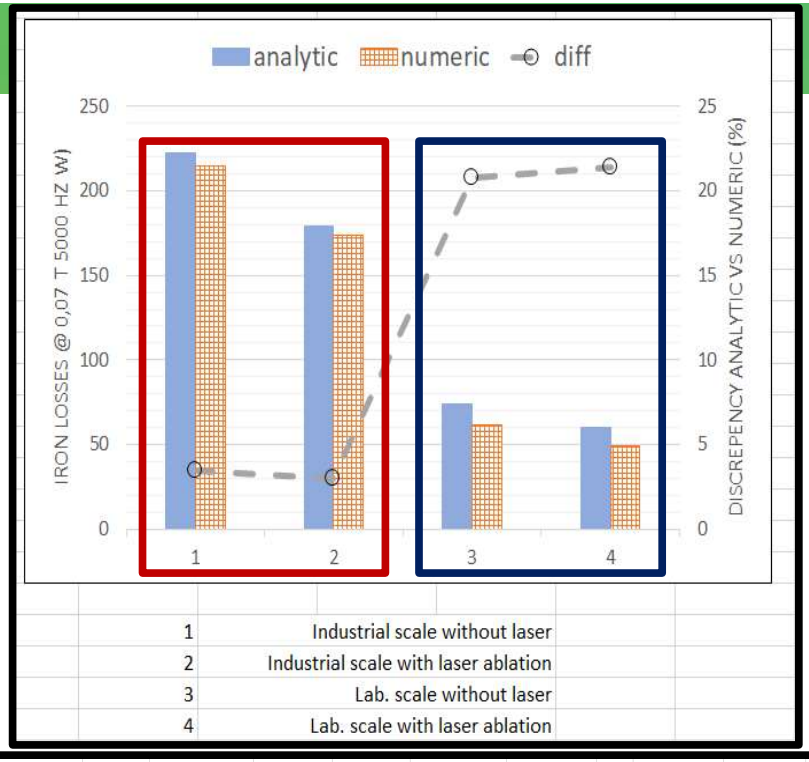
Symade UniLaSalle

UniLaSalle Institut Polytechnique

# Design of inductors

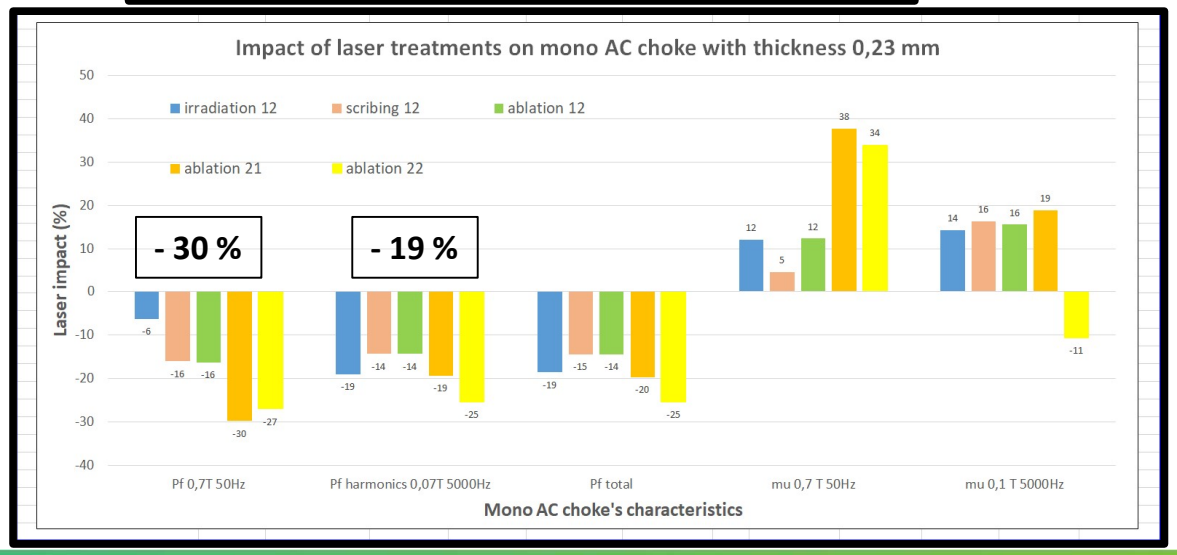



Industrial sclae





Lab. sclae

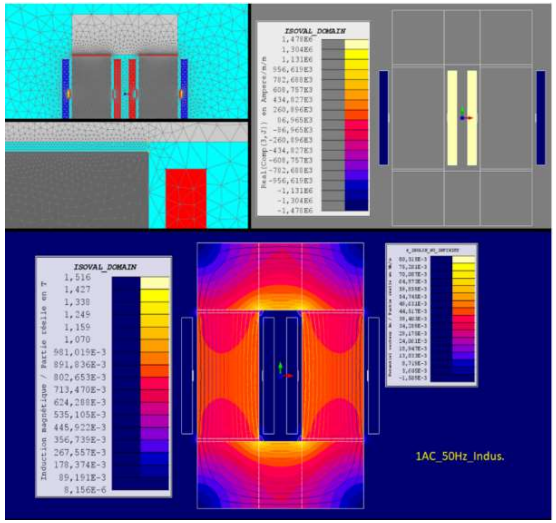


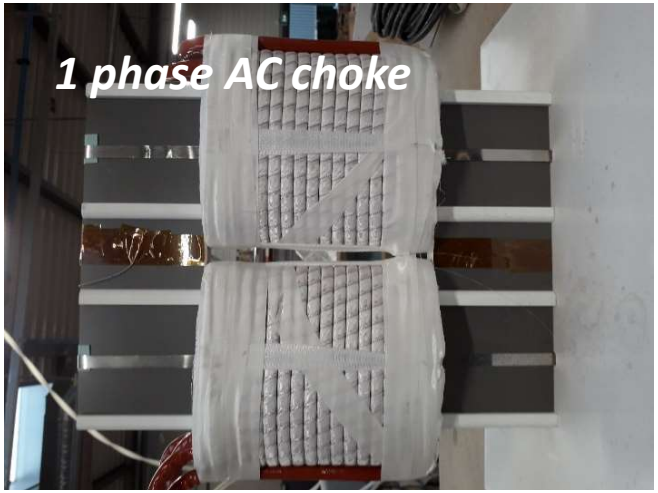

UniLaSalle Amiens

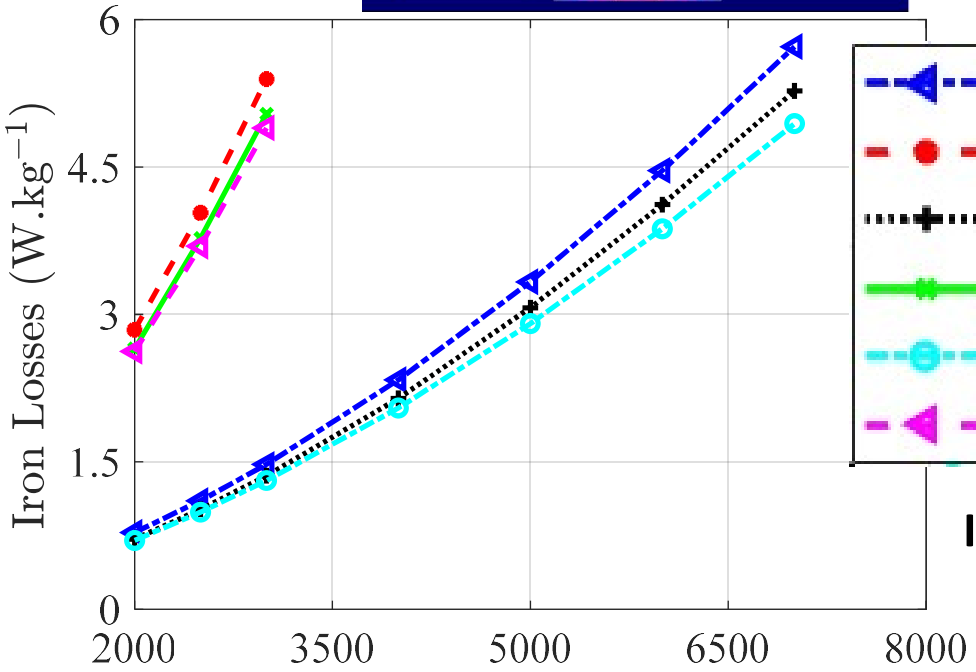
Symade UniLaSalle

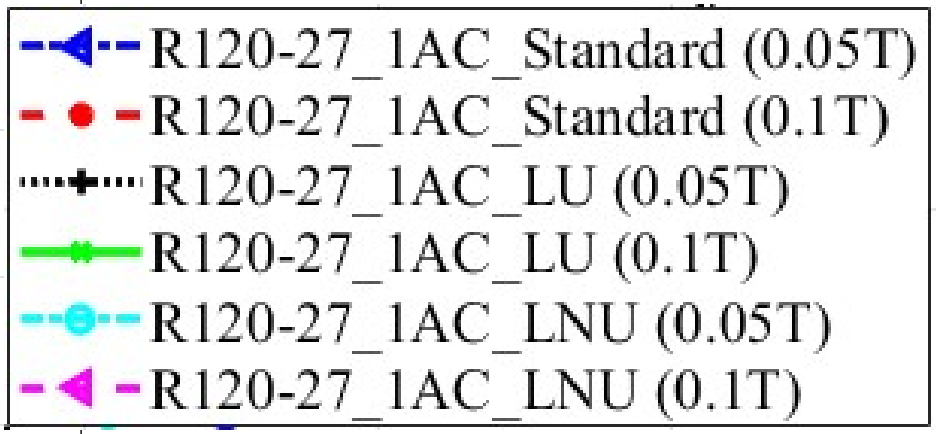
UniLaSalle Institut Polytechnique

# Prototypes – AC chokes WP4 (surface laser treatments)


**Iron losses of harmonics decrease up to 20 %**

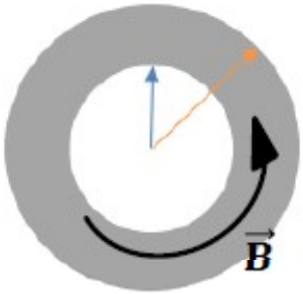
UniLaSalle Amiens

Symade UniLaSalle

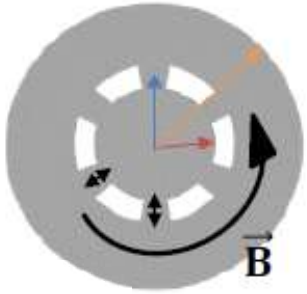
UniLaSalle Institut Polytechnique

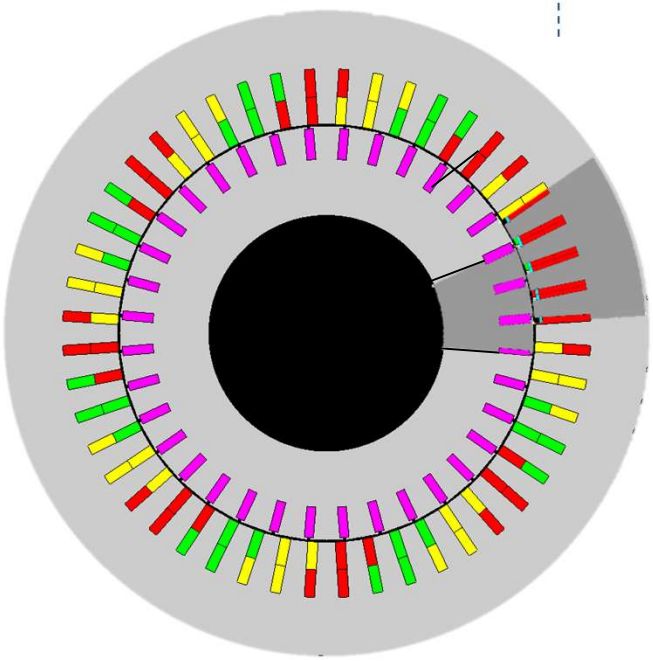
# Proof of concept and prototypes – Electrical machines

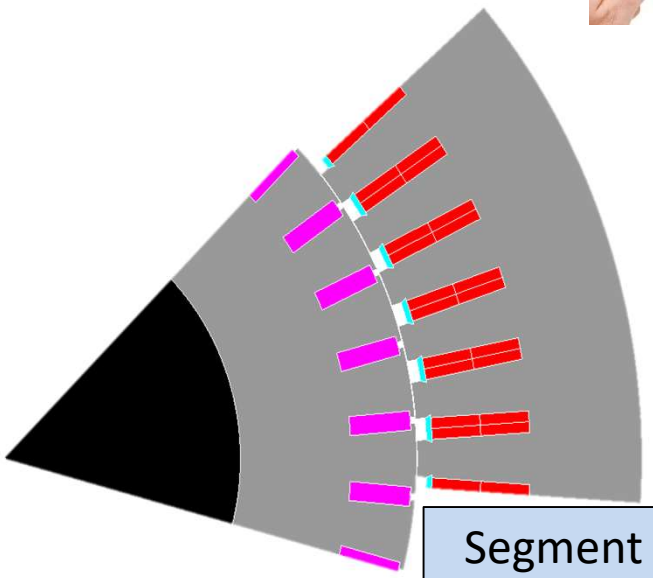
SIMPLE RING CORE




TEETHED RING CORE



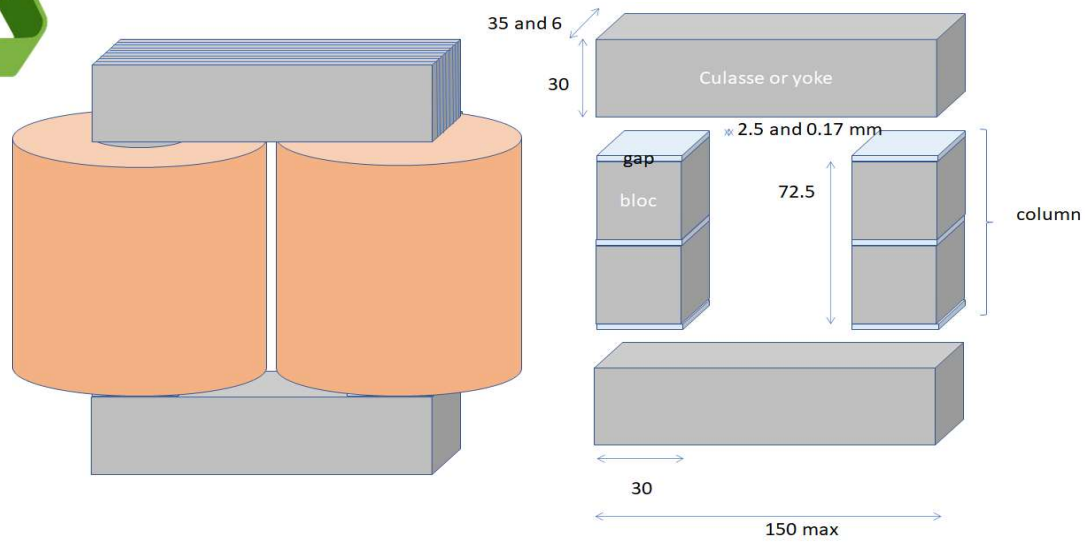



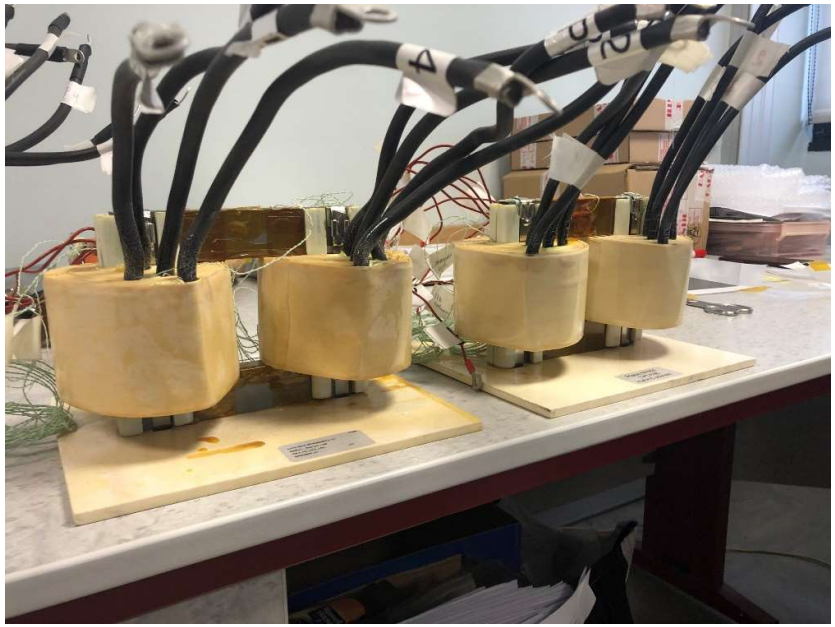


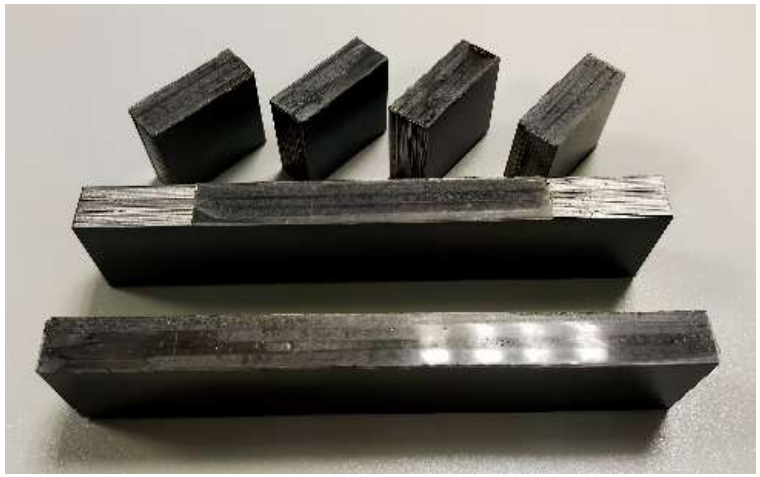
Segment Scale Model SSM

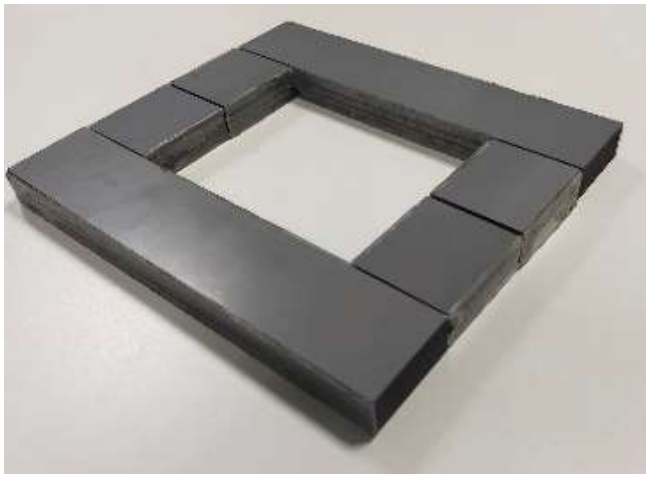
| | NO steel grade | | GO steel grade | |
|---|---|---|---|---|
| [W] | **M400-65A** | **M330-35A** | **Non treat 0.3mm** | **Laser teat 0.3 mm** |
| Losses | **1118** | **892.** | **910** | **730** |

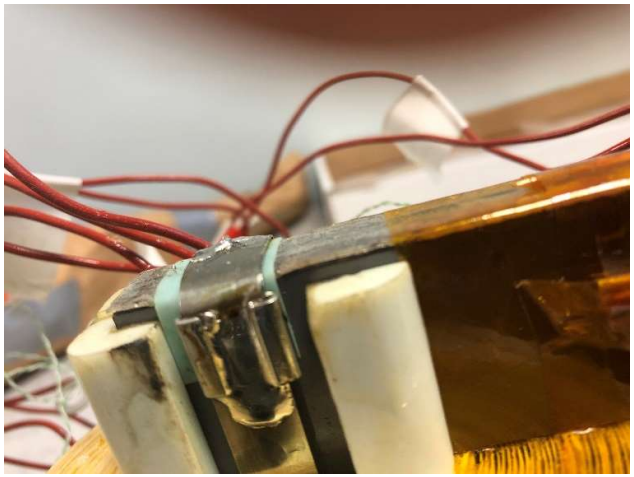
# Proof of concept and prototypes – Hybrid Joining of a DC choke









UniLaSalle Amiens

Symade UniLaSalle

UniLaSalle Institut Polytechnique

# Life Cycle Cost analysis – ROI laser cost vs loss reduction

## Metallurgists

| Cost and ROI calculation for R2R speed of 5 m/min | | | |
|---|---|---|---|
| *thickness (mm)* | *process time (s/kg)* | *cost (€/kg)* | ***ROI (years)*** |
| 0,23 | 6,82 | 0,334 | **1,70** |
| 0,27 | 5,81 | 0,285 | **1,35** |
| 0,3 | 5,23 | 0,256 | **1,11** |

## End-Users

| Process Speed: 500 mm/s, Laser Power = 100 W | | | | |
|---|---|---|---|---|
| **Process Time (h)** | **Energy consumption (KWh)** | **Laser treatment +equipment cost (€/h)** | **Laser treatment process cost (€)** | **ROI (years)** |
| **1-ph AC inductor (350 A / 230 VAC, 35 kg magnetic core)** | | | | |
| 4,52 | 0,45 | 34,21 | 154,7 | **5,23** |
| **3-ph AC inductor (270 A / 400 VAC, 100 kg magnetic core)** | | | | |
| 9,03 | 0,9 | 34,28 | 309,67 | **6,98** |
| **1-ph AC transformer 400 Hz (23 kVA / 30 kg magnetic core)** | | | | |
| 0,94 | 0,09 | 34,16 | 32,18 | **1,63** |
| **3-ph AC transformer 400 Hz (60 kVA / 50 kg magnetic core)** | | | | |
| 1,73 | 0,17 | 34,17 | 59,01 | **2** |

# AGENDA

**09:30 – INTRODUCTION & PRESENTATION OF ESSIAL**

- *Speaker UNILASALLE, Olivier Maloberti*

**10:00 – IMPLEMENTATIONS FOR POWER ELECTRONICS INDUCTANCES AND TRANSFORMERS**

- *Speaker UNILASALLE, Olivier Maloberti*
- *Speaker MULTITEL, Julien Dupuy*
- *Speaker ANDALTEC, Jesús Castillo*
- *Speaker EREA, Johan Bleumers*

**11:45 – APPLICATION METHOD FOR DEMONSTRATORS AND ELECTRICAL MACHINES**

- *Speakers JEUMONT Electric, Préscillia Dupont & Maxime Ployard*

*LUNCH*

**14:00 – VISIT OF THE FACILITIES**

**16:00 – Q&A AND CLOSING SESSION**

ESSIAL has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 766437.

ESSIAL

# Thank you for your attention!

## ESSIAL FINAL PROJECT INFODAY

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