New wavelength-dependent femtosecond pulsed LASER cleaning: A case study with stones of different provenance locality, Portugal

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Abstract: Laser cleaning techniques have been considered amongst the most impactful contributions of Physics towards the restoration of stonework. Contamination and deterioration products in stones eliminated by laser-assisted techniques is a new and promising development that may highlight the use of laser cleaning methodology in this sector. This research work reports on studies aimed to evaluate the use of ultrafast femtosecond (fs) pulsed lasers for the removal of contaminants on significant stone surfaces with different locality from Portugal. A series of studies have been carried out to assess the controlled laser cleaning parameters using two different laser systems: a 238 fs pulsed UV laser with emission at 343 nm and a 228 fs pulsed n-IR laser with emission at 1030 nm. In both cases, line scan pulse mode was employed to explore contaminant removal efficiency while, at the time, assessing the degree of damage produced to the underlying original substrate surface. Adequate repetition-rate generation, wavelength-dependent absorption and materials thermal properties are amongst the parameters considered, and the main results obtained will be presented and discussed in an effort to evaluate the potential that these new types of lasers offer towards an increased cleaning efficiency of stones with deteriorated surfaces.

Keywords: femtosecond laser; short pulse; stone; cleaning; restoration;

LIGHT FOR ART

New wavelength-dependent femtosecond pulsed LASER cleaning: A case study with stones of different provenance locality, Portugal

SUPERVISOR:

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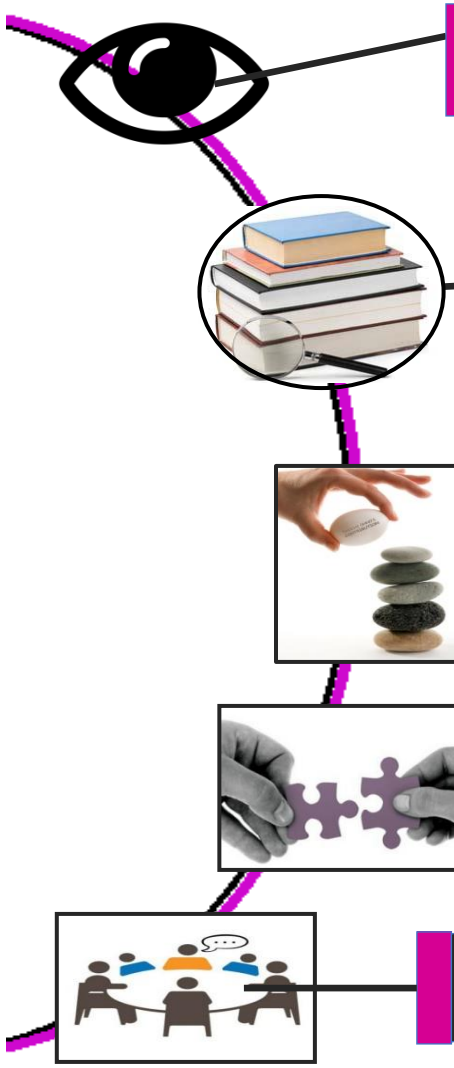

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Md Ashiqur Rahman

Predoctoral Investigator
Spanish National Research Council (CSIC: INMA)

Academic Endeavors

Marie Sklodowska Curie PhD : H2020-MSCA- ITN- ED-ARCHMAT
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University of Evora (Portugal), University of Rome La Sapienza (Italy) & Aristotle University of Thessaloniki (Greece)

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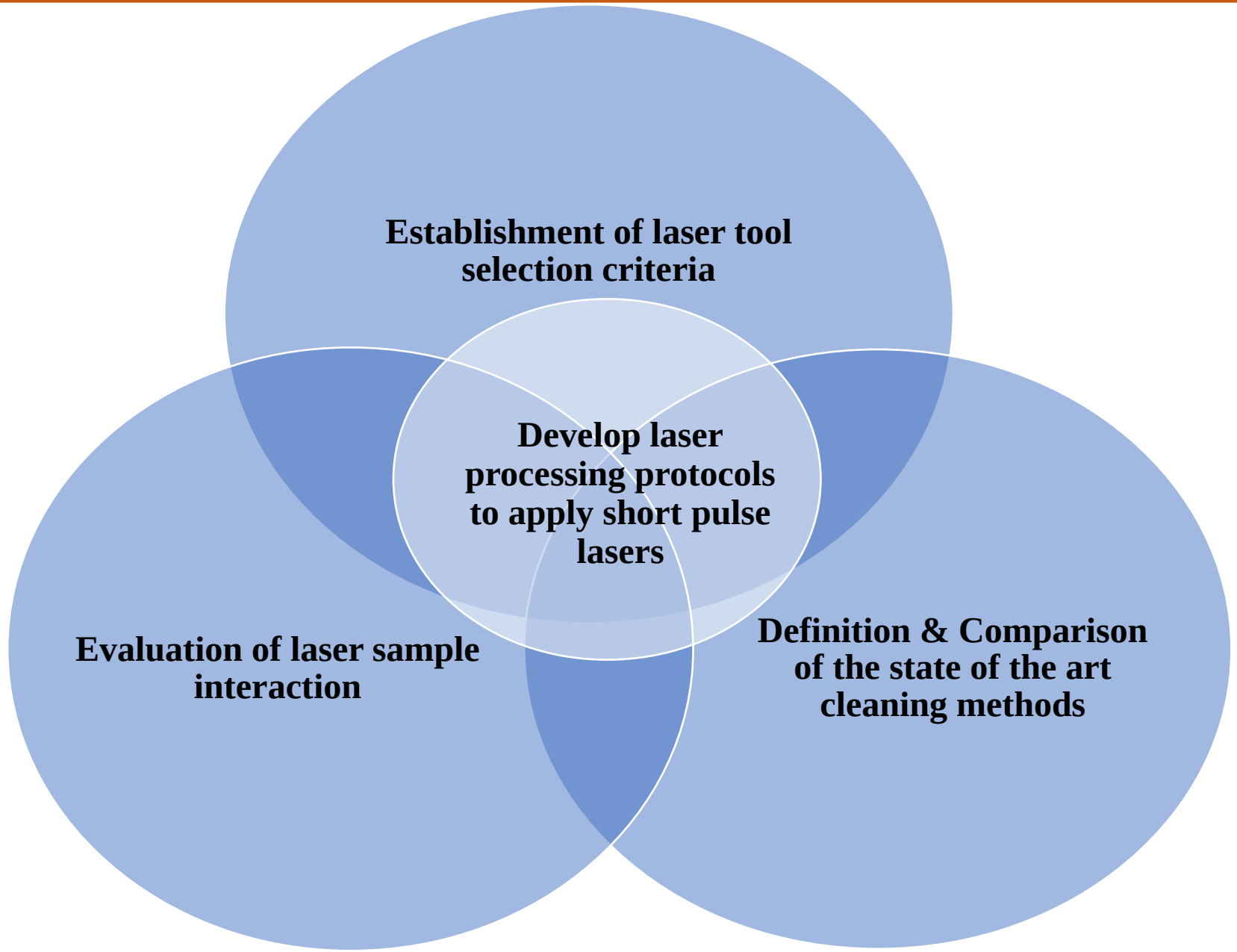
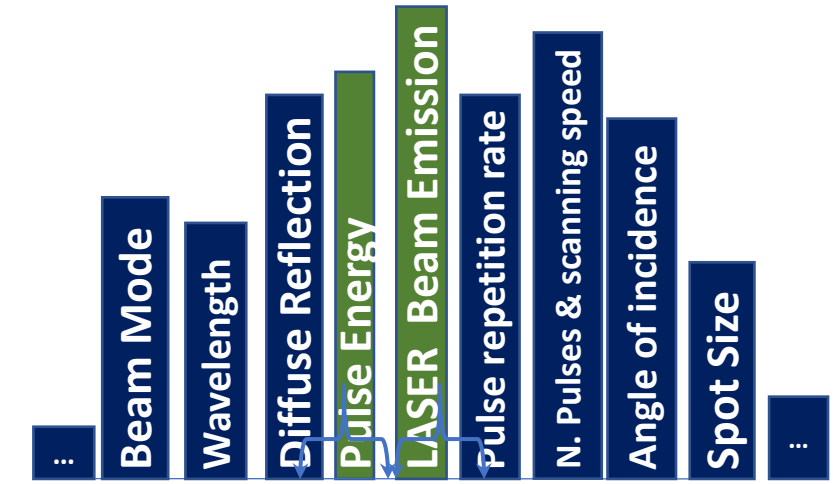
Project Description and Objectives



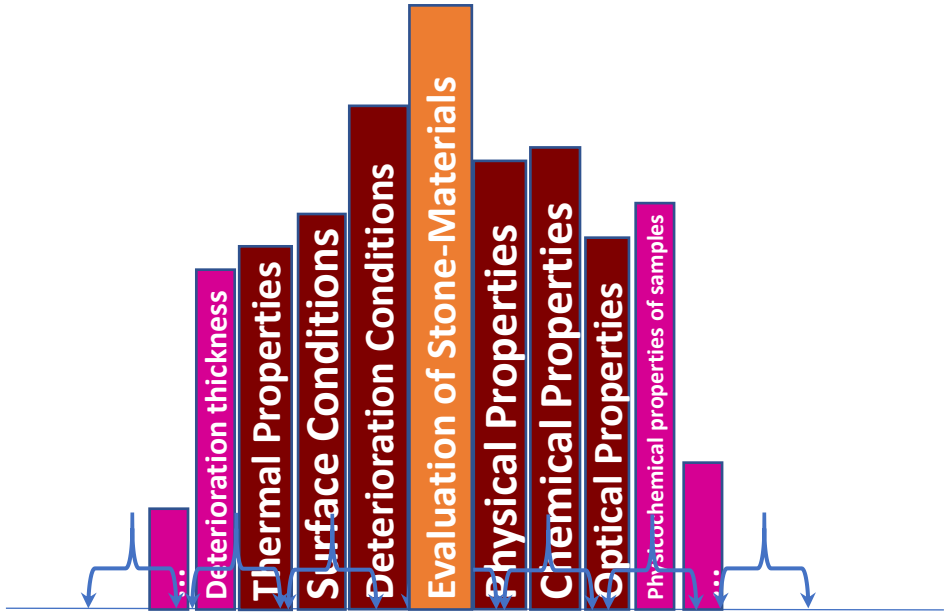
Controlled LASER methodology design



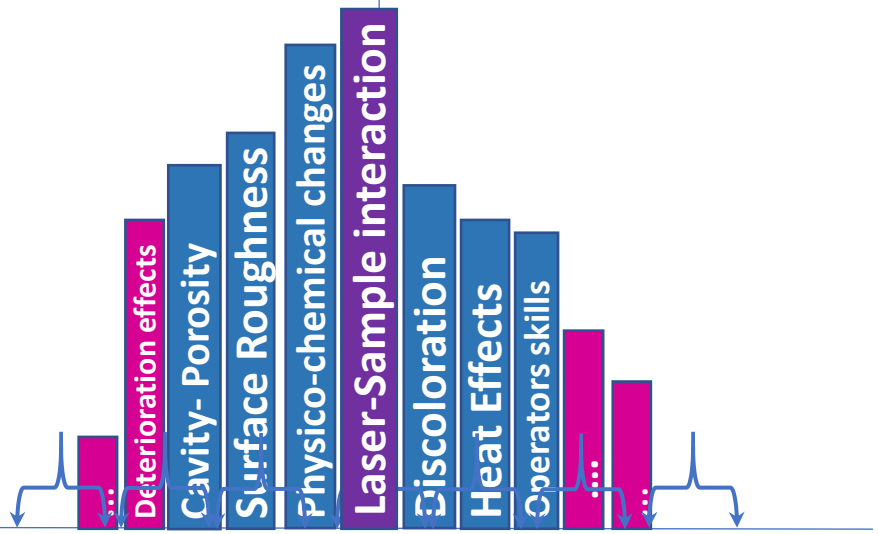
If newly controlled LASER methodology works perfectly, then will go for large scale research

Analyze the possibilities that the new short pulse lasers open in CH conservation.

Evaluation of Stones and artifacts

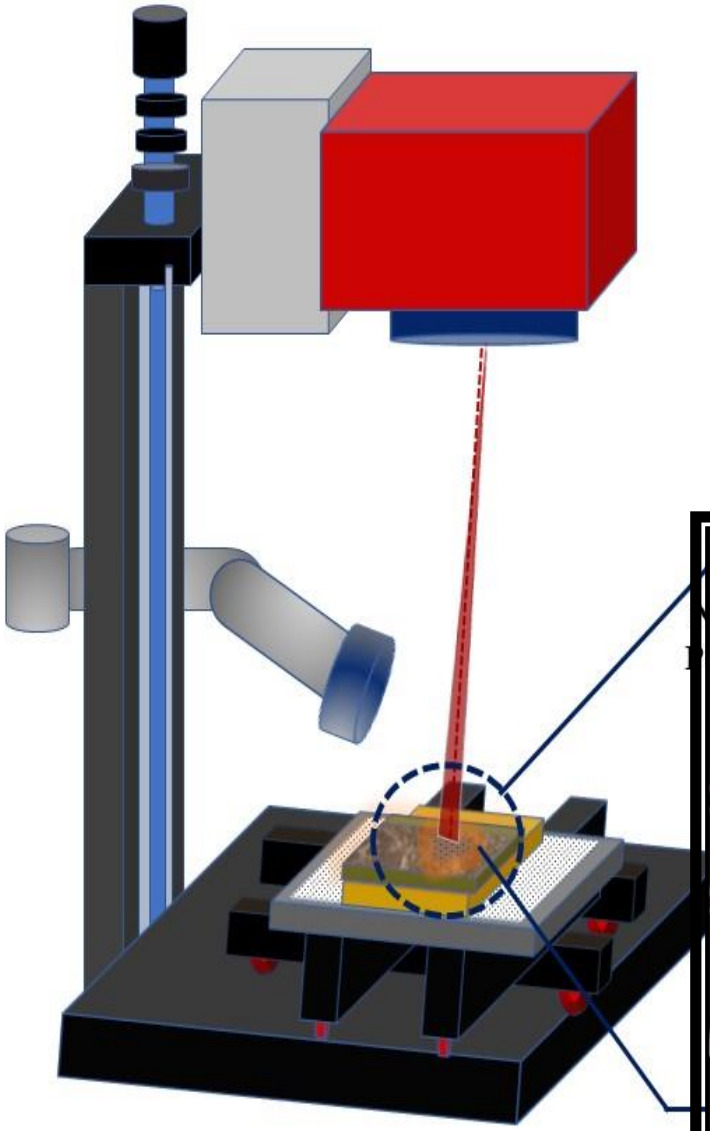


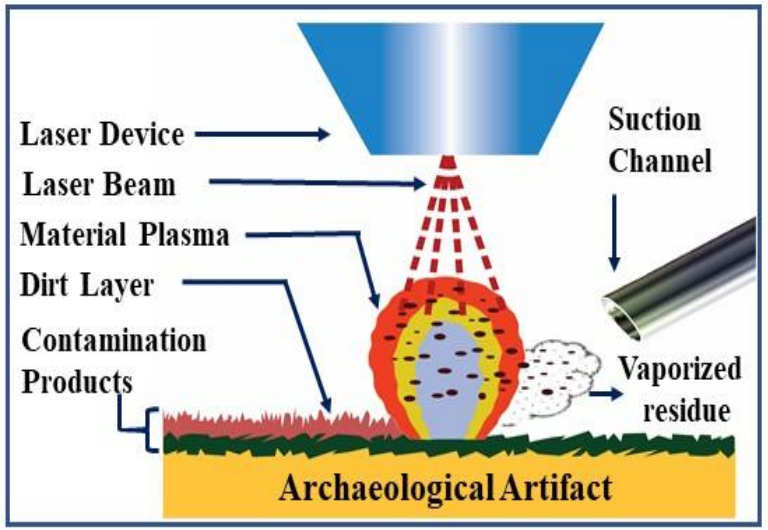
Evaluation of laser sample interaction (laser emission parameters and the material physicochemical properties)

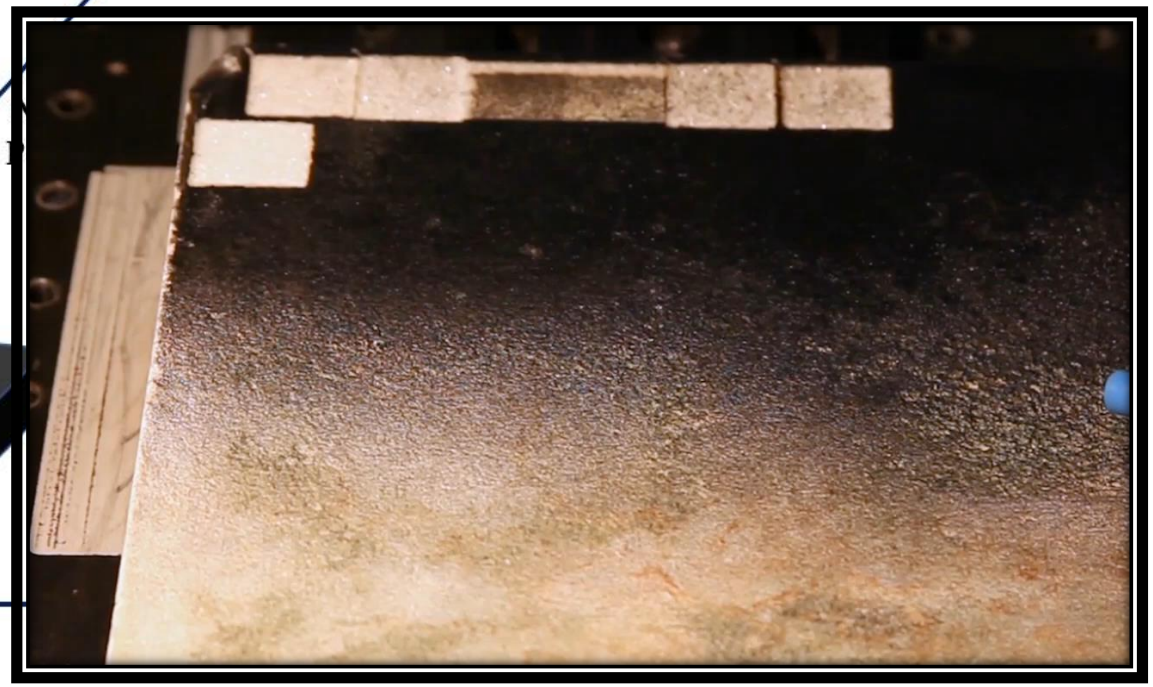


Evaluation of Laser- Sample Interaction

How does laser cleaning works?







“Moca Créme” Limestone. Provenance locality: Santarém, Alcanede

Grey Granite Provenance locality: Portalegre, Santa Eulália

“Vidraço” Limestone. Provenance locality: Leiria, Alcobaça

White Estremoz Marble with pink veins, slab surface oblique to foliation. Provenance locality: Vila Viçosa, Lagoa

White Estremoz Marble with well-defined foliation parallel to the slab surface. Provenance locality: Estremoz

Samples Description

White Estremoz Marble, slab surface oblique to foliation. Provenance locality: Estremoz

White Estremoz Marble with blueish aleatory veins, “Pele de Tigre” variety (Tiger Skin variety). Provenance locality: Vila Viçosa, Lagoa

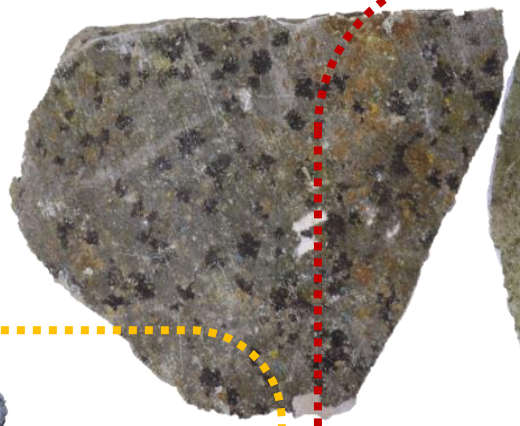
White Estremoz Marble with pink veins, slab surface oblique to foliation. Provenance locality: Vila Viçosa, Lagoa

Cream Estremoz Marble, slab surface oblique to foliation. Provenance locality: Vila Viçosa, Lagoa

Samples Description

“Moca Créme” Limestone. Provenance locality: Santarém, Alcanede

Grey Granite Provenance locality: Portalegre, Santa Eulália

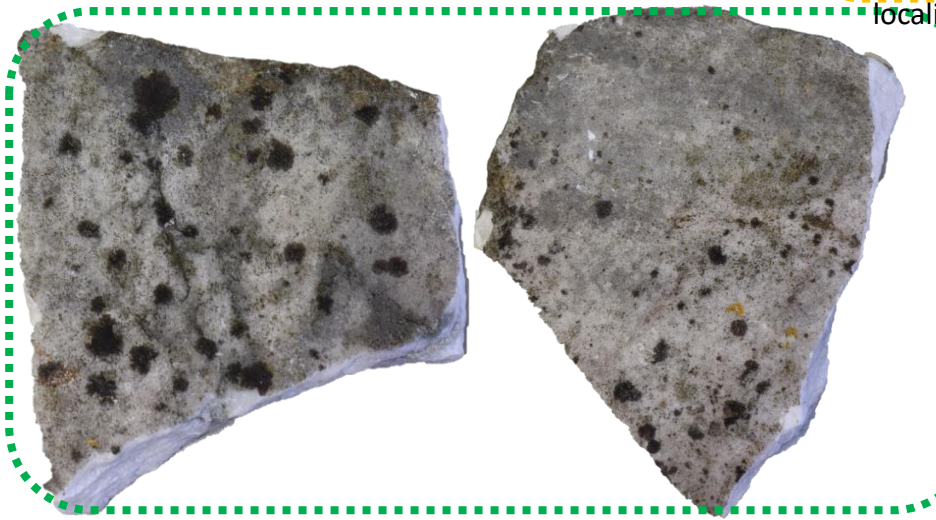


“Vidraço” Limestone. Provenance locality: Leiria, Alcobaça

White Estremoz Marble with pink veins, slab surface oblique to foliation. Provenance locality: Vila Viçosa, Lagoa

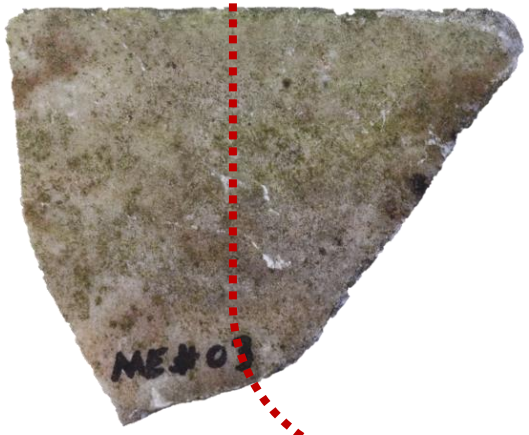
White Estremoz Marble with well-defined foliation parallel to the slab surface. Provenance locality: Estremoz

White Estremoz Marble, slab surface oblique to foliation. Provenance locality: Estremoz



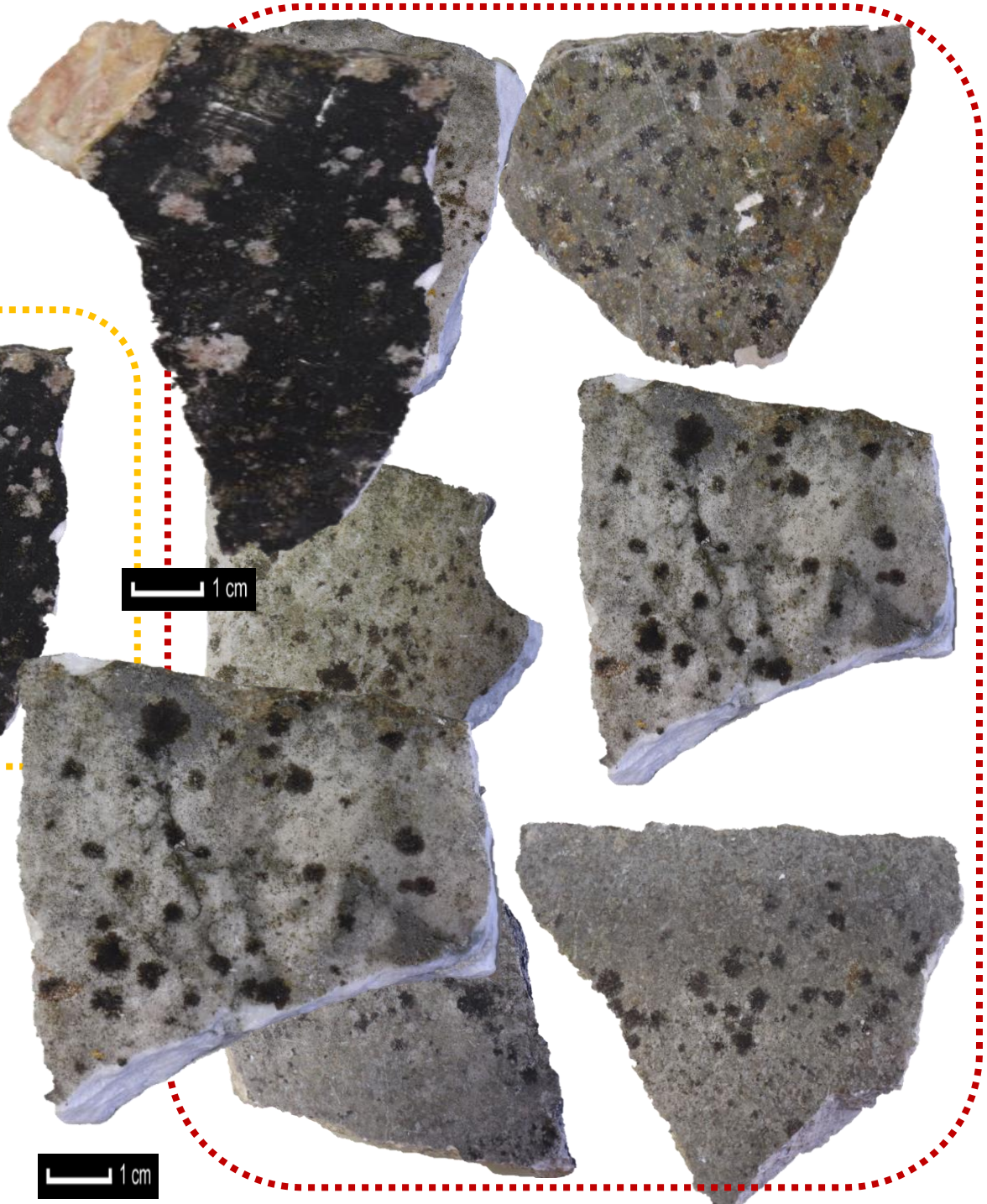
White Estremoz Marble with blueish aleatory veins, “Pele de Tigre” variety (Tiger Skin variety). Provenance locality: Vila Viçosa, Lagoa

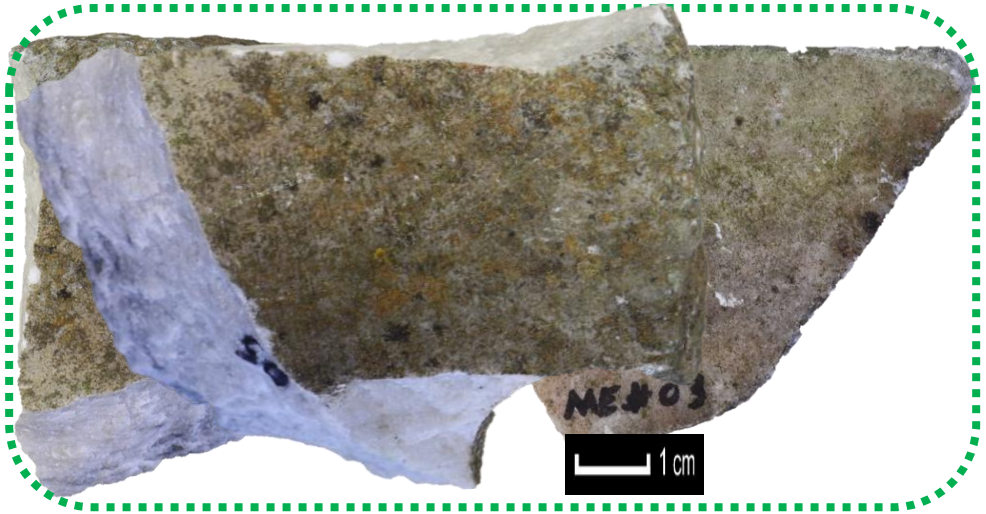
White Estremoz Marble with pink veins, slab surface oblique to foliation. Provenance locality: Vila Viçosa, Lagoa

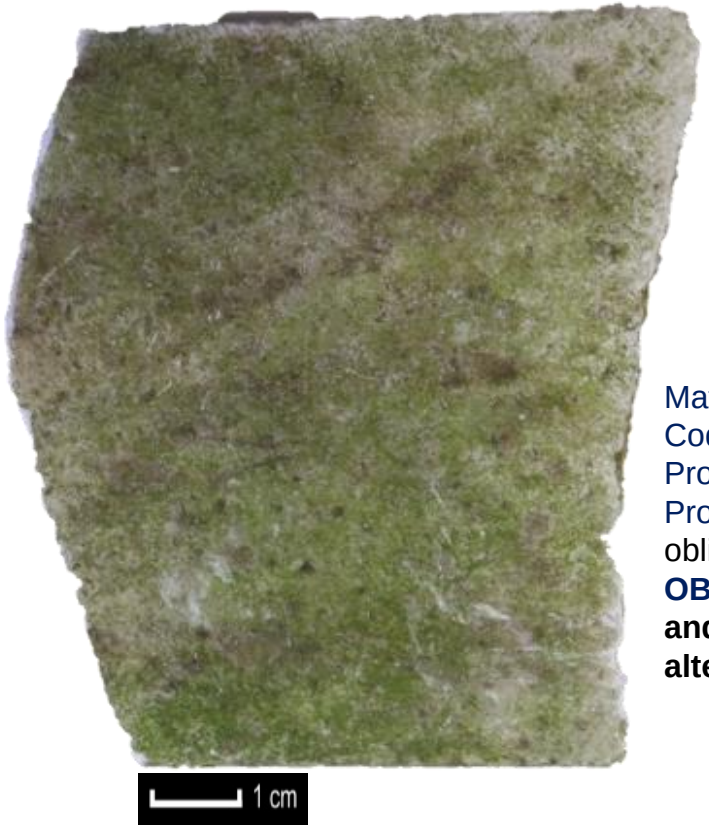


Cream Estremoz Marble, slab surface oblique to foliation. Provenance locality: Vila Viçosa, Lagoa

Sample

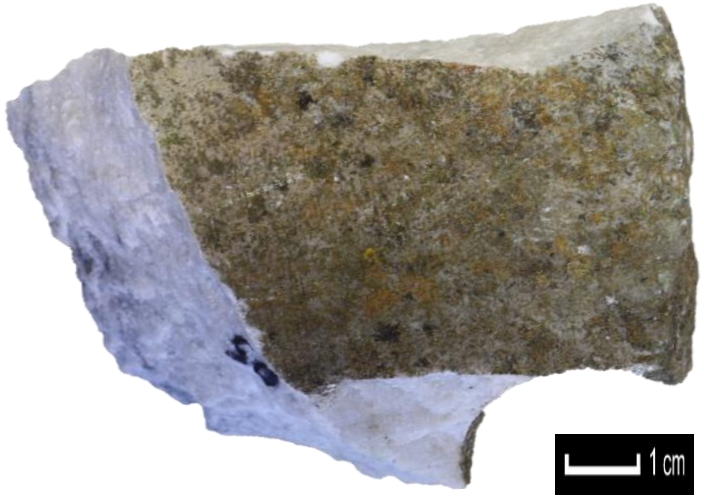






Material: Marble
Code: **White Estremoz Marble**
Provenance locality: Vila Viçosa, Lagoa
Problems: with pink veins, slab surface oblique to foliation.
OBJECTIVE: Remove bio-colonization and clean the surface stains without altering the surface.

Material: Marble
Code: **Cream Estremoz Marble**
Provenance locality: Vila Viçosa, Lagoa
Problems: Slab surface oblique to foliation.
OBJECTIVE: Remove bio-colonization and clean the surface stains without altering the surface.

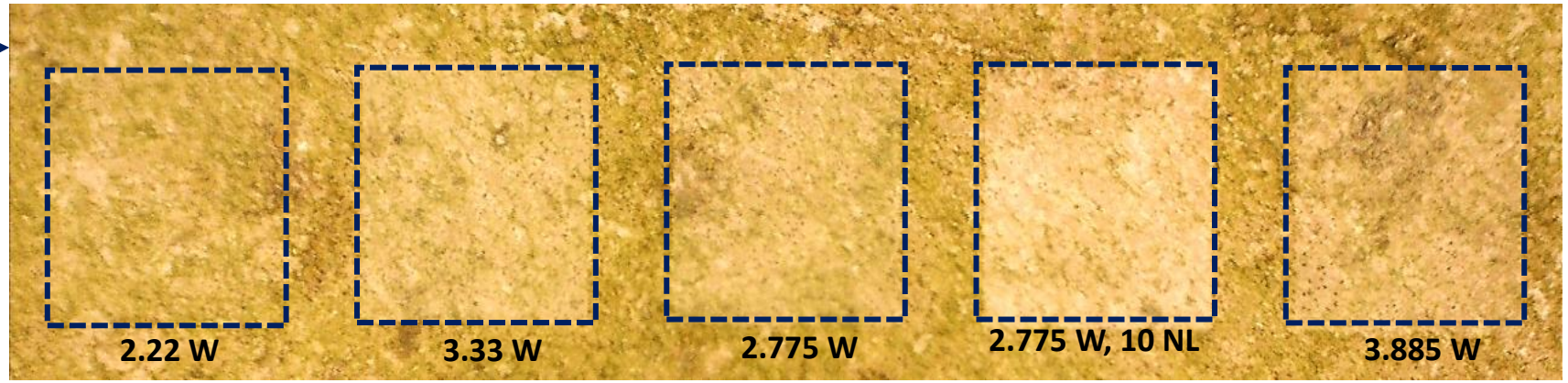


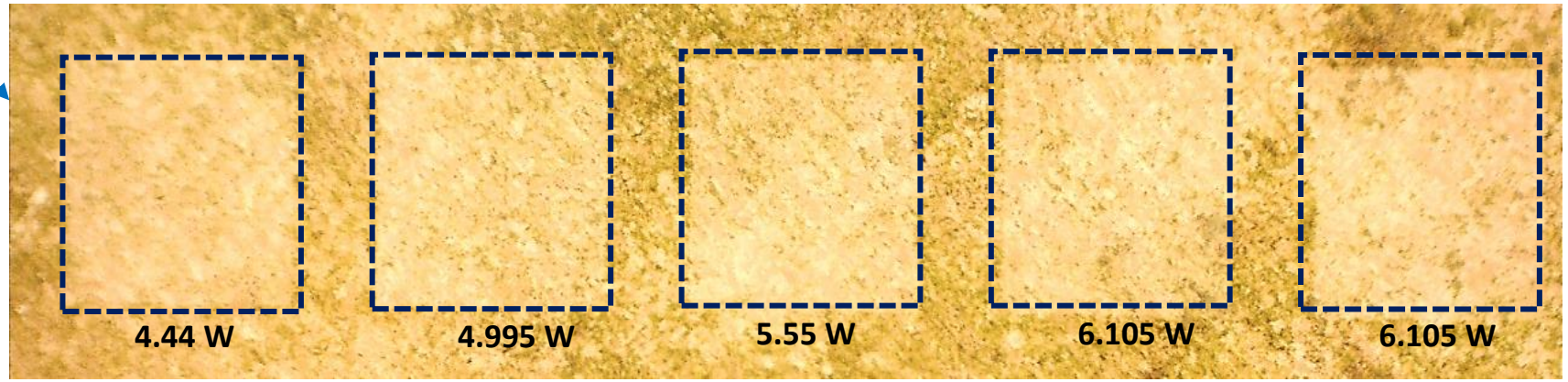
Material: Marble
Code: **White Estremoz Marble with blueish aleatory veins, “Pele de Tigre” variety (Tiger Skin variety).**
Provenance locality: Vila Viçosa, Lagoa
Problems: Slab surface oblique to foliation.
OBJECTIVE: Remove bio-colonization and clean the surface stains without altering the surface.

Material: Marble
Code: **White Estremoz Marble**
Provenance locality: Estremoz
Problems: Slab surface oblique to foliation.
OBJECTIVE: Remove bio-colonization and clean the surface stains without altering the surface.

Case Studies: White Estremoz Marble

Laser type	P_{max} (W)	l (nm)	t_p (fs)	f_p (kHz)	D_b (µm)	Mark speed (mm/s)	Spacing between lines (µm)
fs UV	11.1	343	238	200	30	150	15

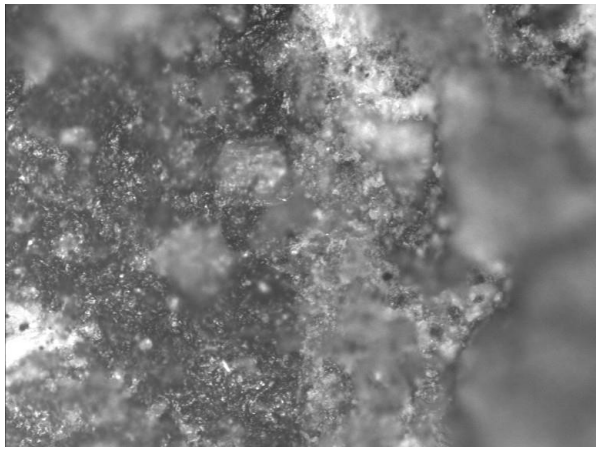




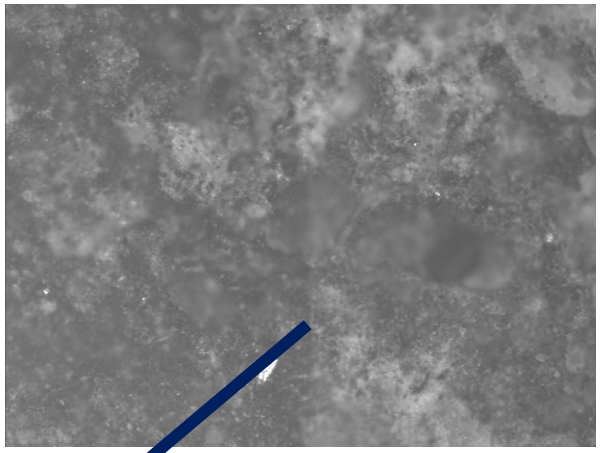
200KHz (/20ppd), 15µm, 150mm/s, NL:1

Case Studies: White Estremoz Marble

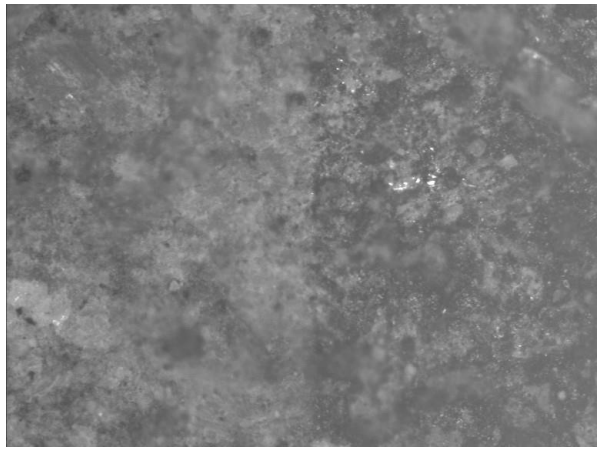
2.22 W



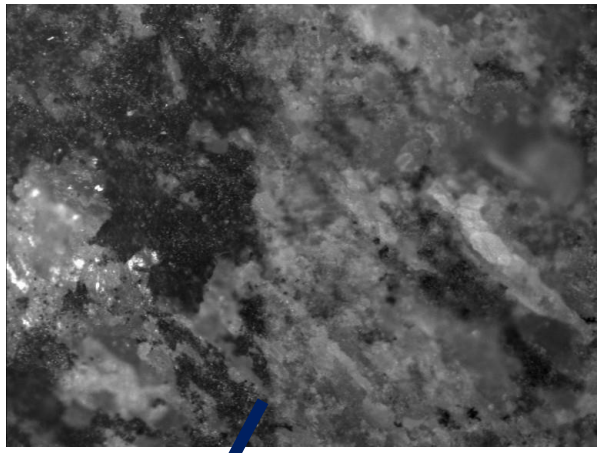
2.775 W



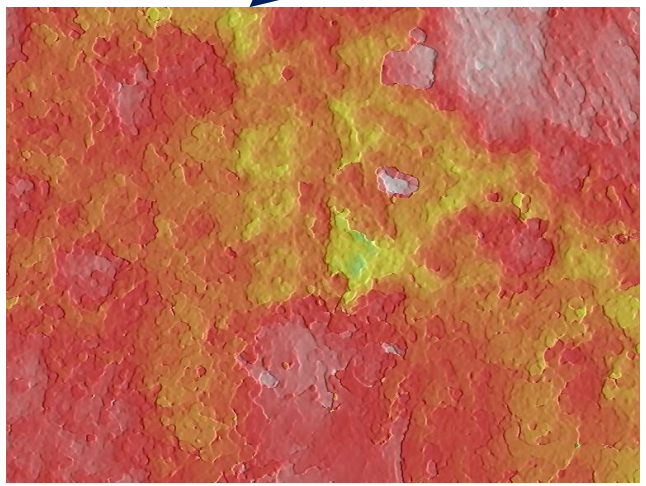
3.33 W



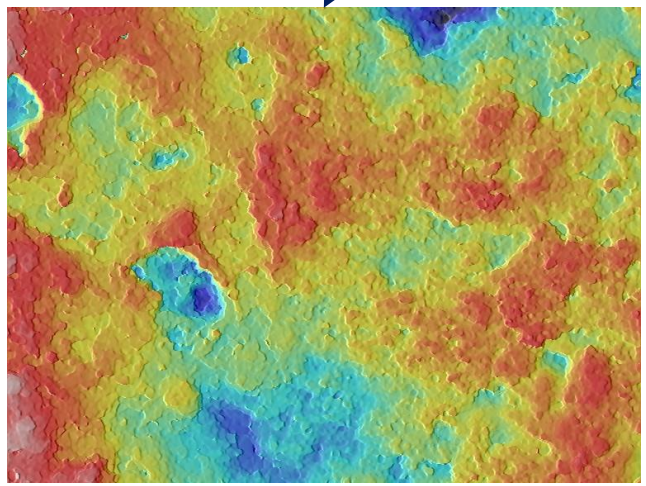
5.55 W

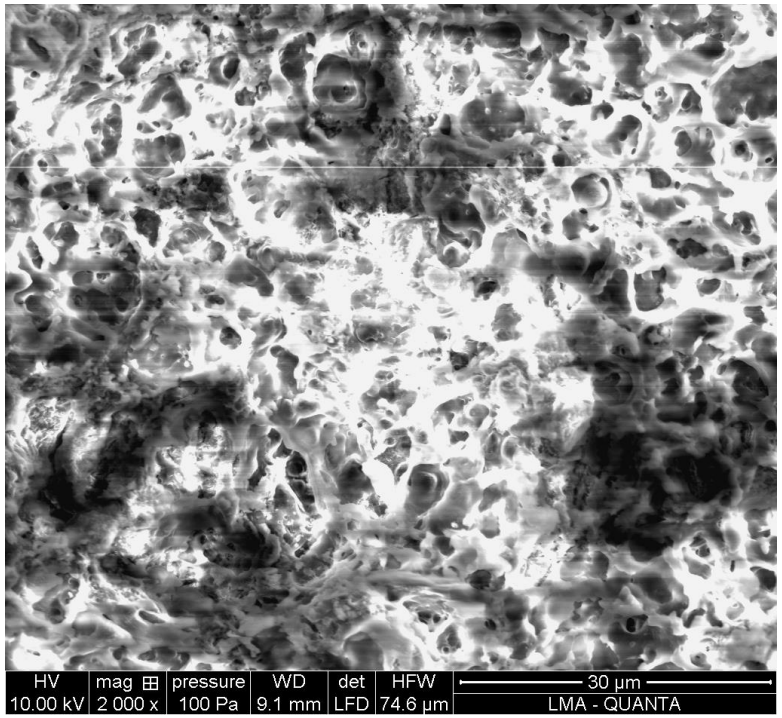


Confocal microscopy images correspond with the original laser treated and uncleaned area

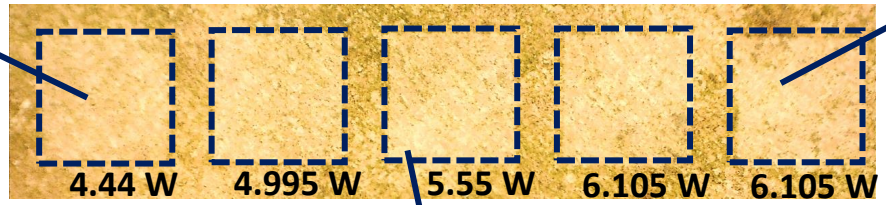


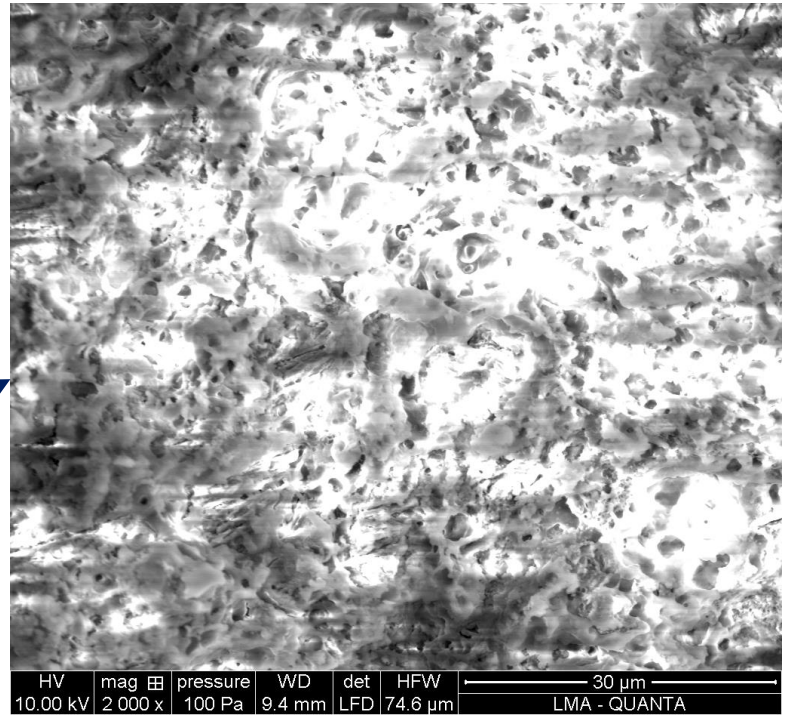
Tomography images from Confocal Microscopy correspond with the original laser treated and uncleaned area

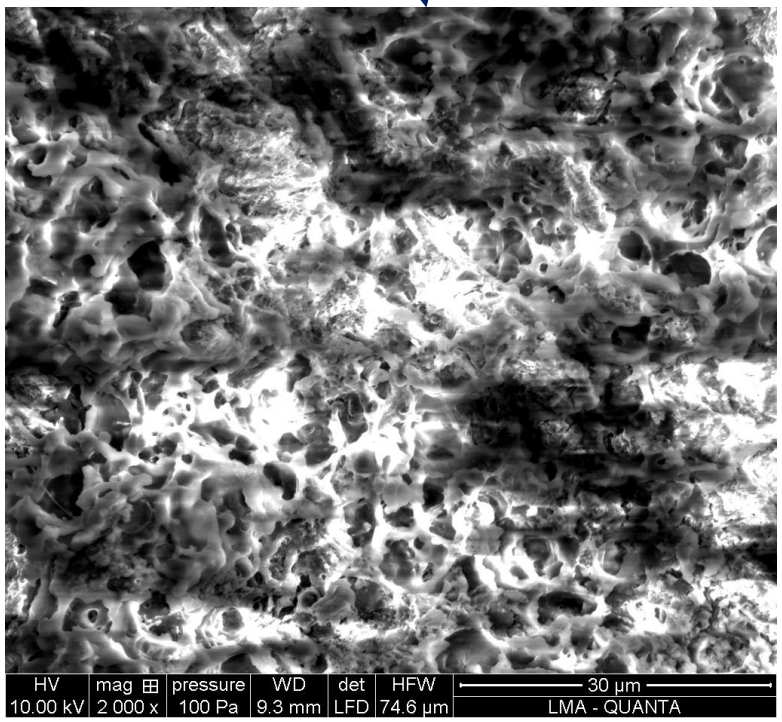




200KHz (/20ppd), 15µm, 150mm/s, NL:1



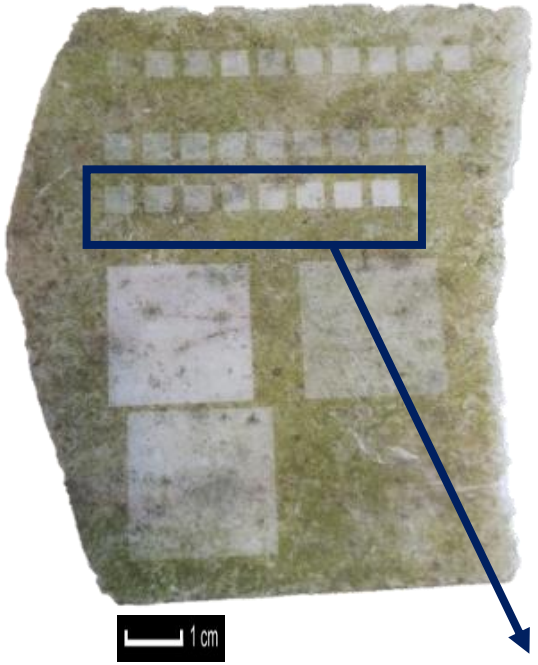




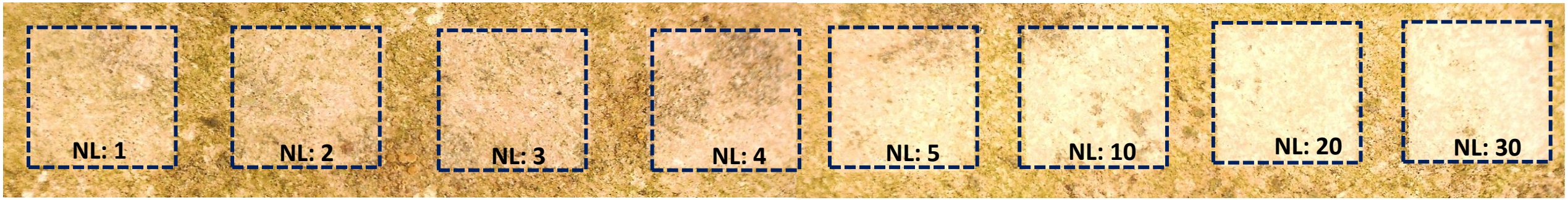
SEM images correspond with the original laser treated area

Case Studies: White Estremoz Marble

Laser type	P_{max} (W)	l (nm)	t_p (fs)	f_p (kHz)	D_b (µm)	Mark speed (mm/s)	Spacing between lines (µm)
fs UV	11.1	343	238	200	30	150	15

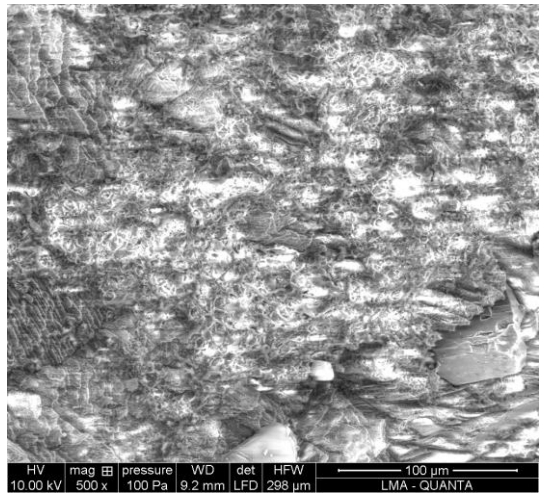


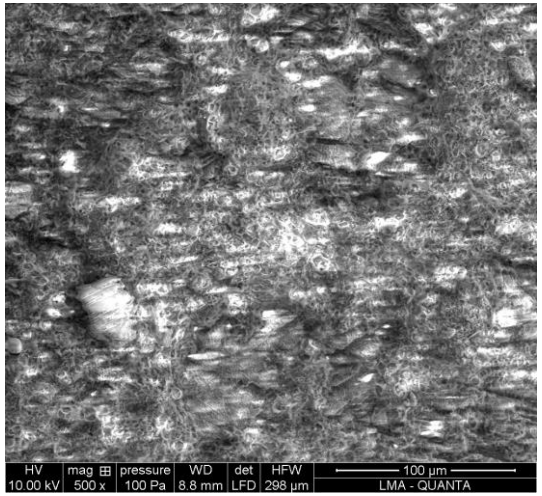
2.775W, 200KHz (/20ppd), 15µm, 150mm/s

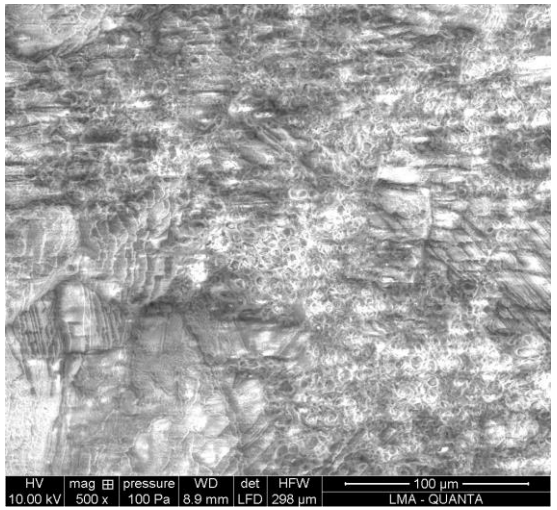


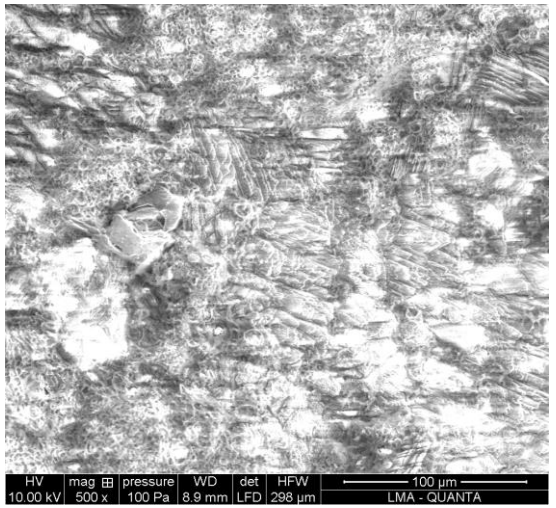
Case Studies: White Estremoz Marble

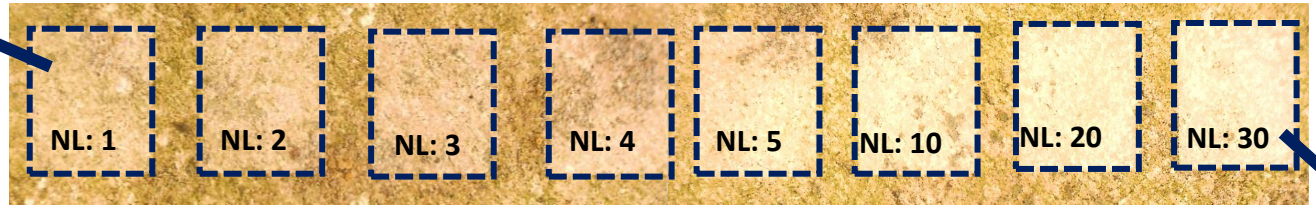
2.775W, 200KHz (/20ppd), 15µm, 150mm/s

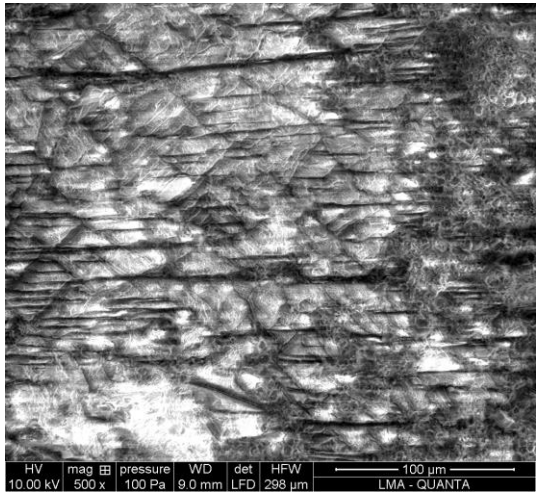


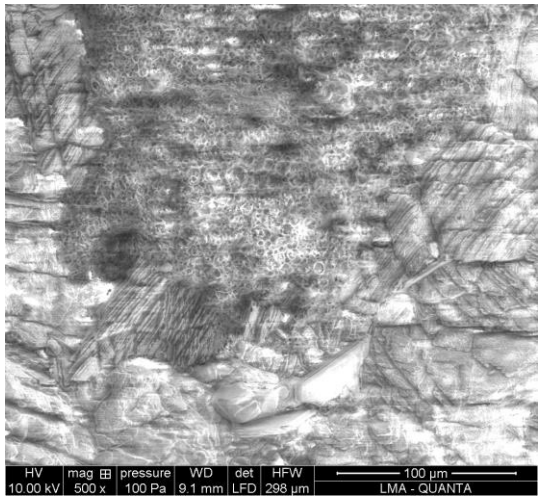


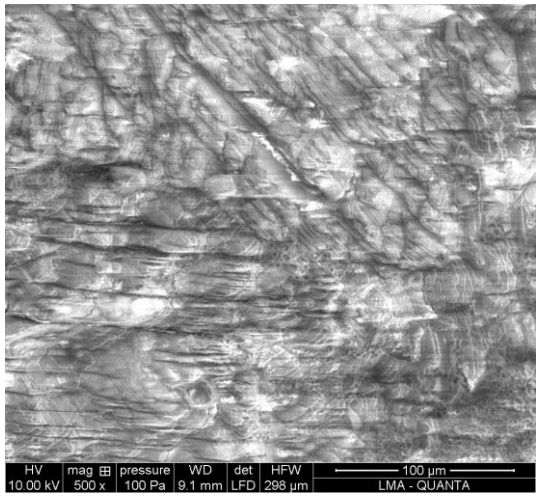


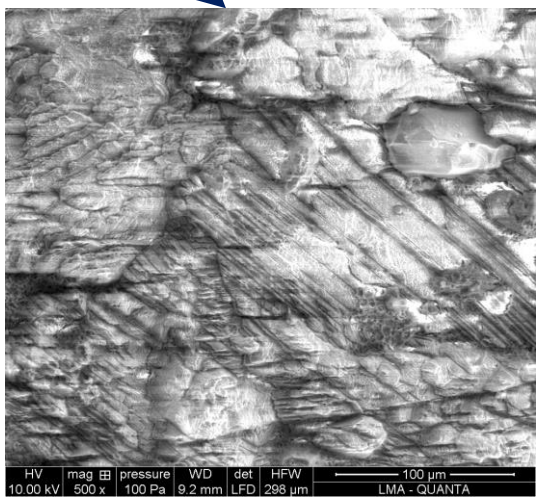




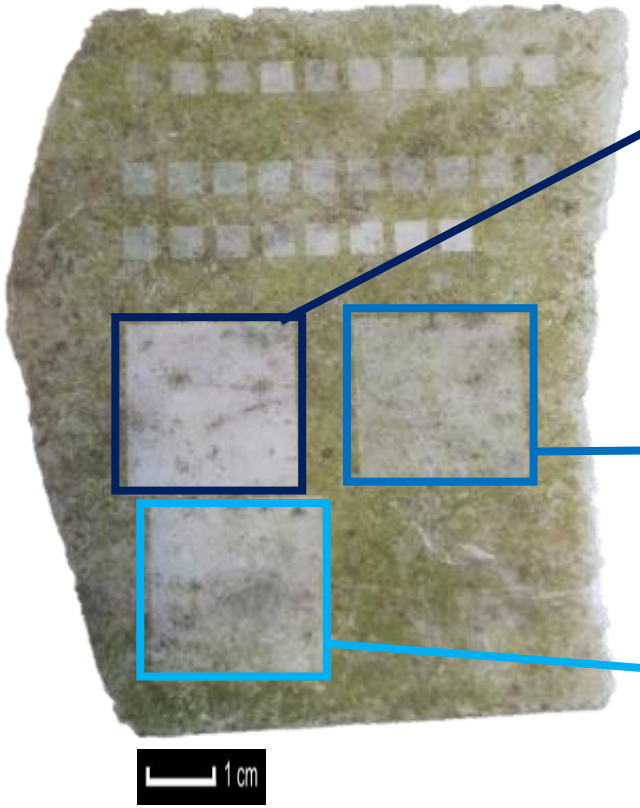


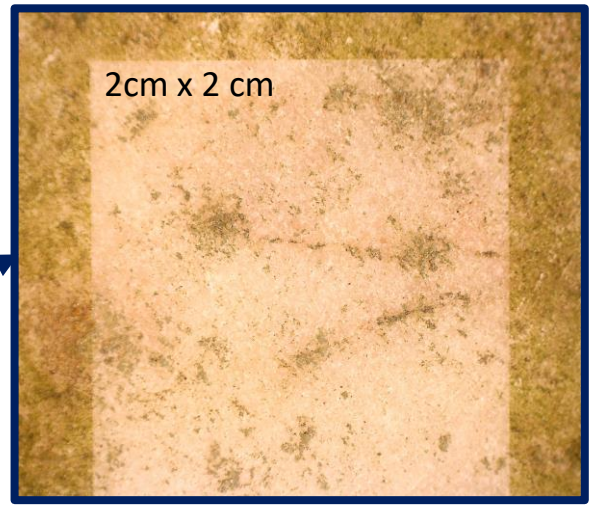






Case Studies: White Estremoz Marble





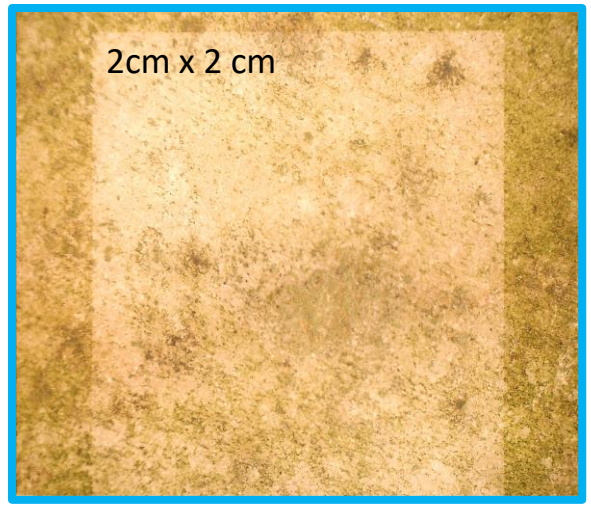
Fluence: 1.96 J/cm2
Irradiance: 8247.525 GW/cm2

2.775W, 200KHz(/20ppd), 15µm, 150mm/s, 10 nL

Fluence: 1.96 J/cm2
Irradiance: 8247.525 GW/cm2

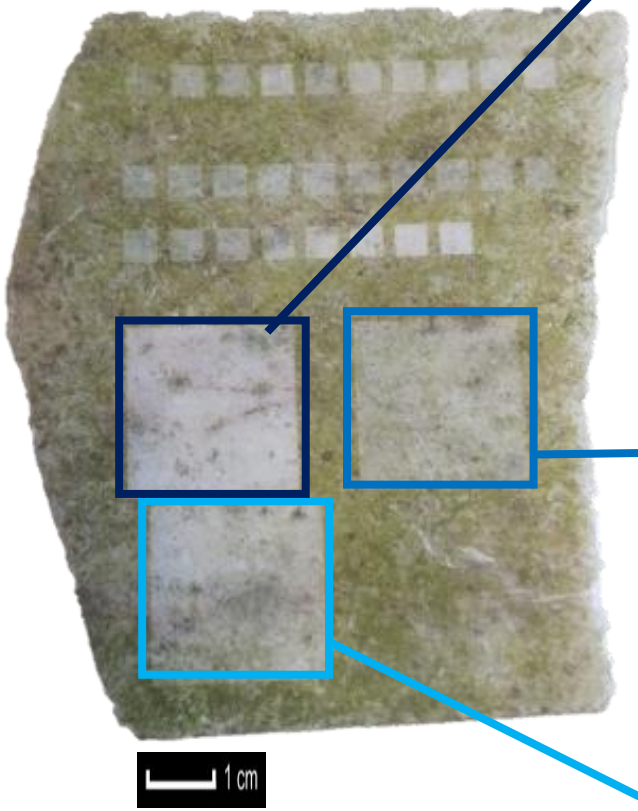
2.775W, 200KHz(/10ppd), 30µm, 600mm/s, 10 nL

Fluence: 2.36 J/cm2
Irradiance: 9897.030 GW/cm2



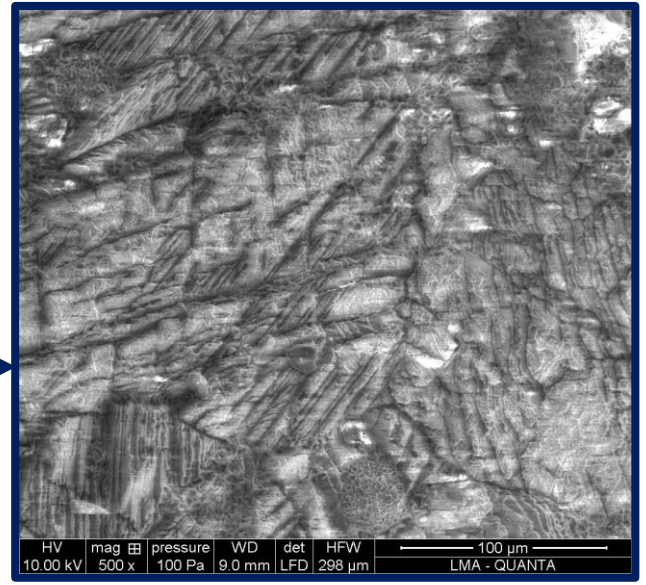
3.335W, 200KHz(/10ppd), 30µm, 600mm/s, 10 nL

Laser type	P_{max} (W)	l (nm)	t_p (fs)	f_p (kHz)	D_b (µm)	Mark speed (mm/s)	Spacing between lines (µm)
fs UV	11.1	343	238	200	30	150	15



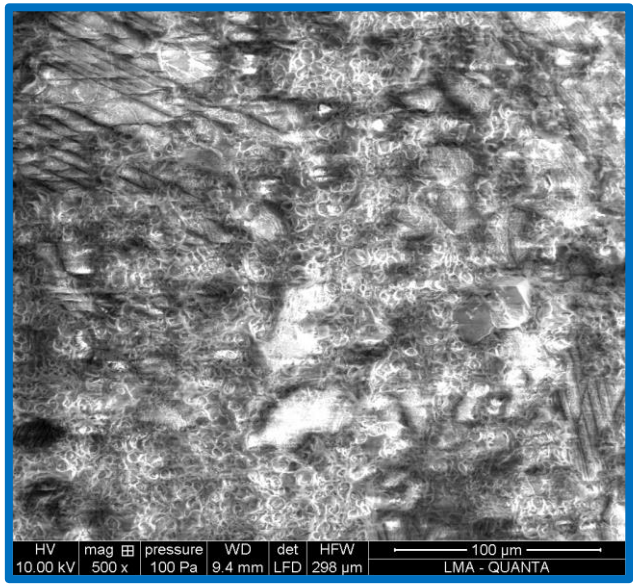
2cm x 2 cm

2.775W, 200KHz(/20ppd), 15µm, 150mm/s, 10 nL



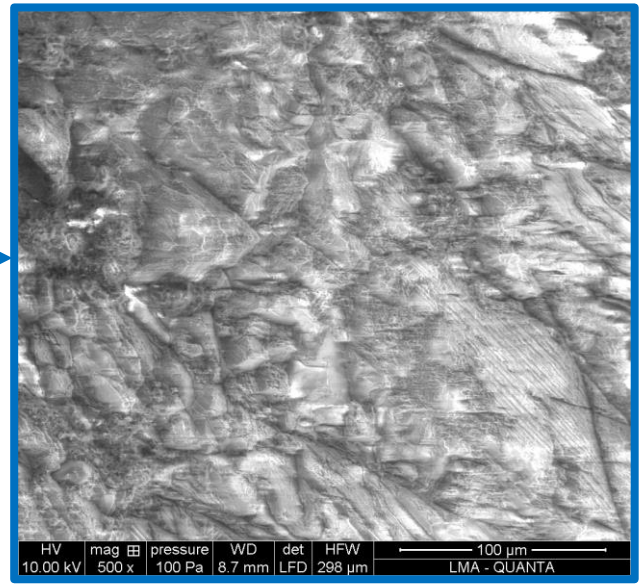
2cm x 2 cm

2.775W, 200KHz(/10ppd), 30µm, 600mm/s, 10 nL



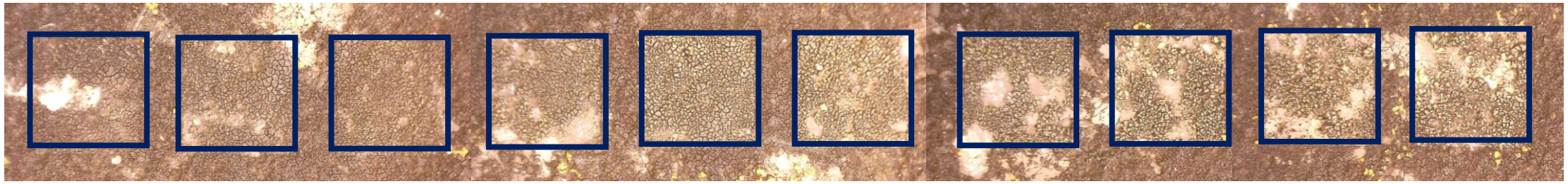
2cm x 2 cm

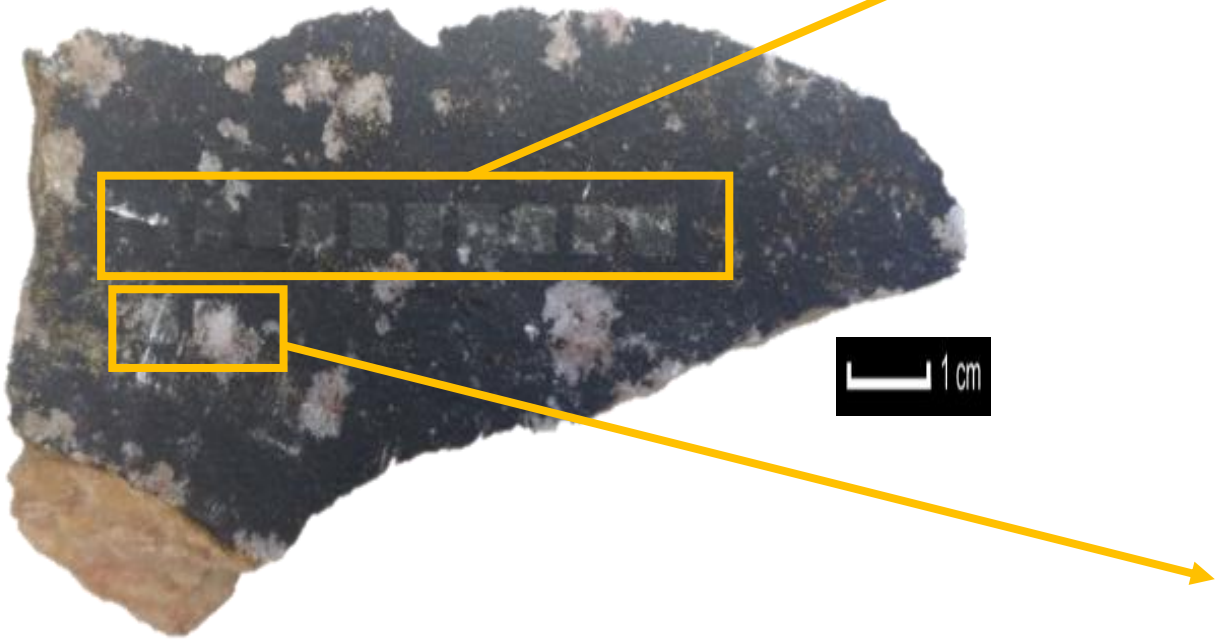
3.335W, 200KHz(/10ppd), 30µm, 600mm/s, 10 nL

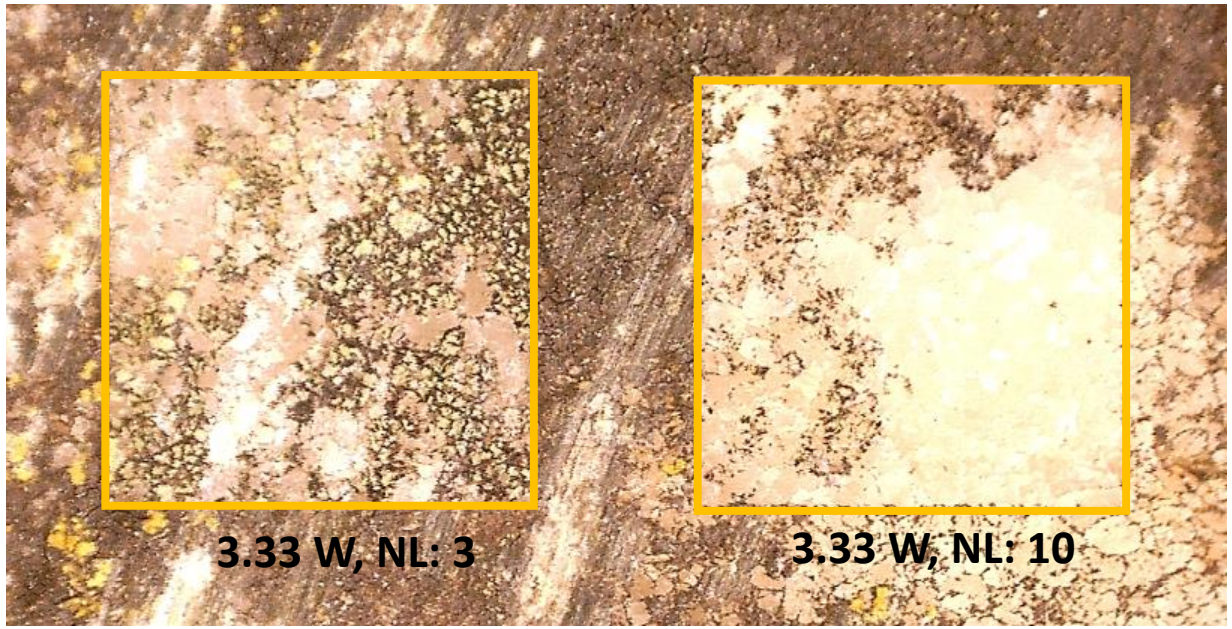


SEM images correspond with the original laser treated area

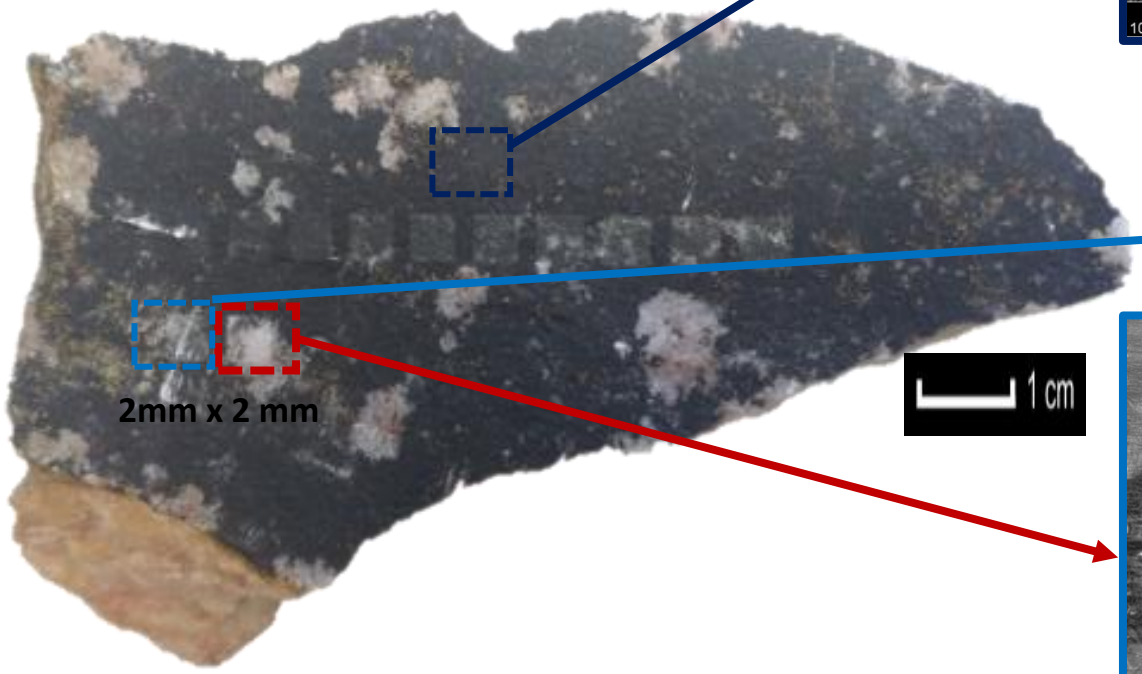
Case Studies: White Estremoz Marble

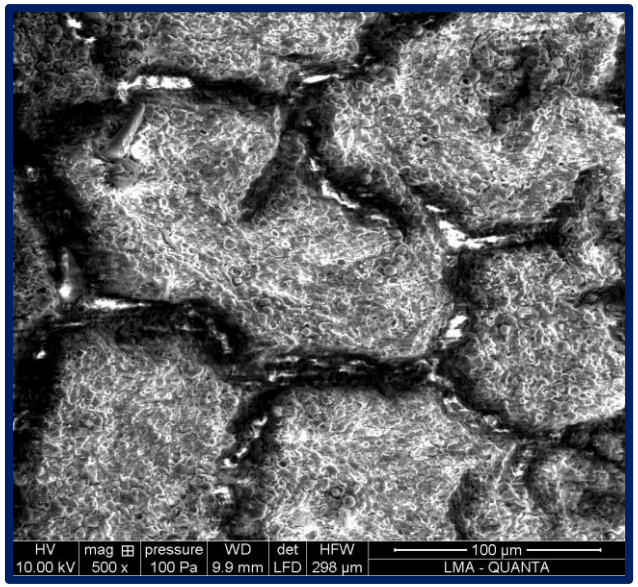


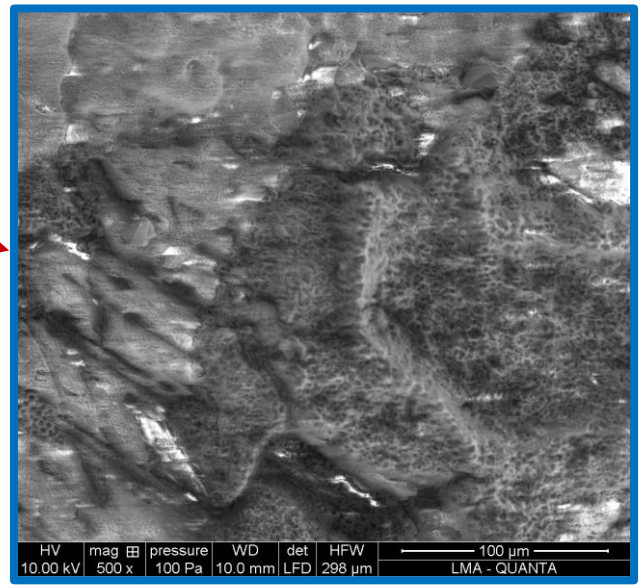


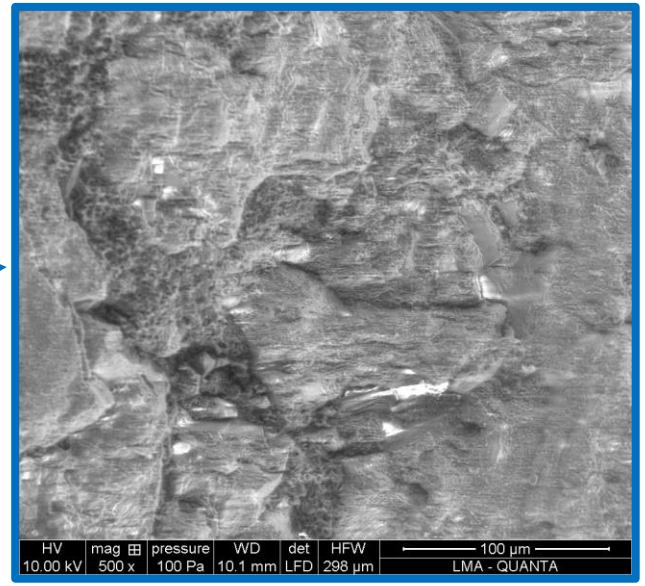


SEM images correspond with the original area and laser treated area

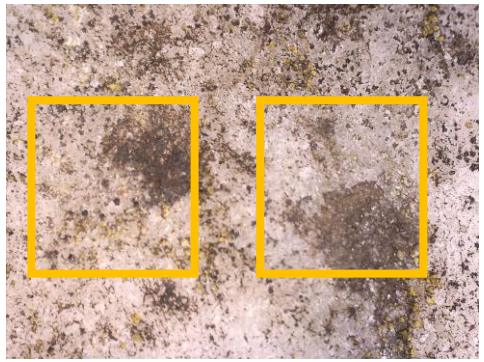




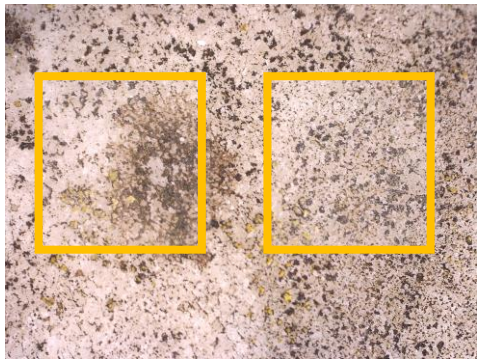




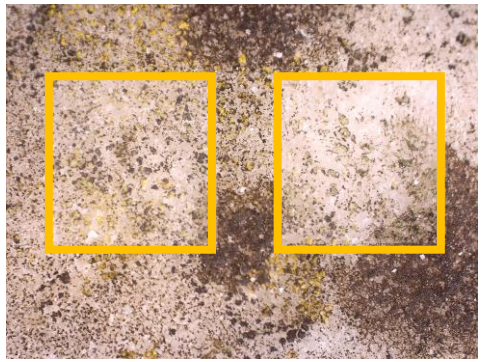
Case Studies: Cream Estremoz Marble



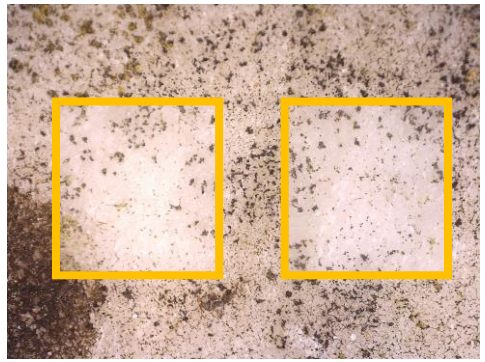
2.22W 2.775 W



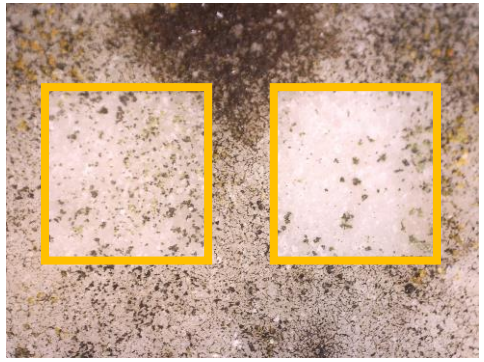
3.33 W 3.885 W



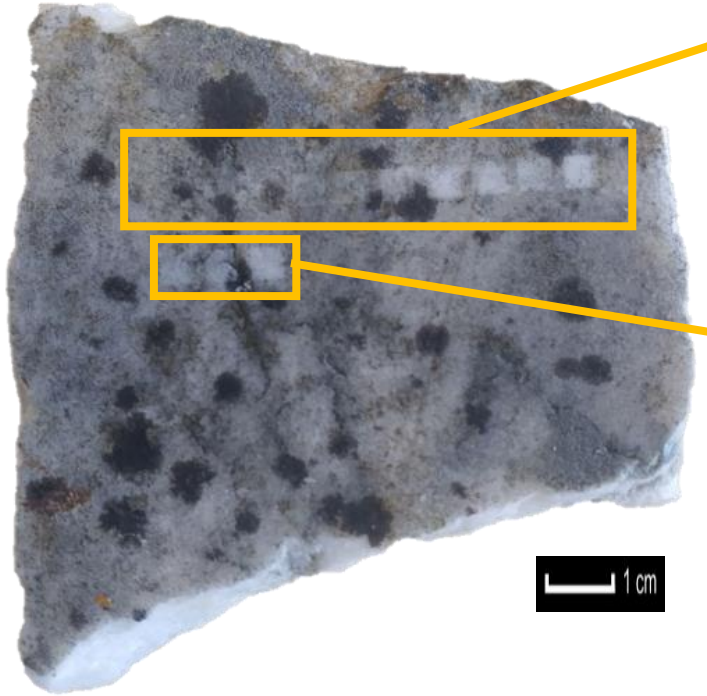
4.44 W 4.995 W



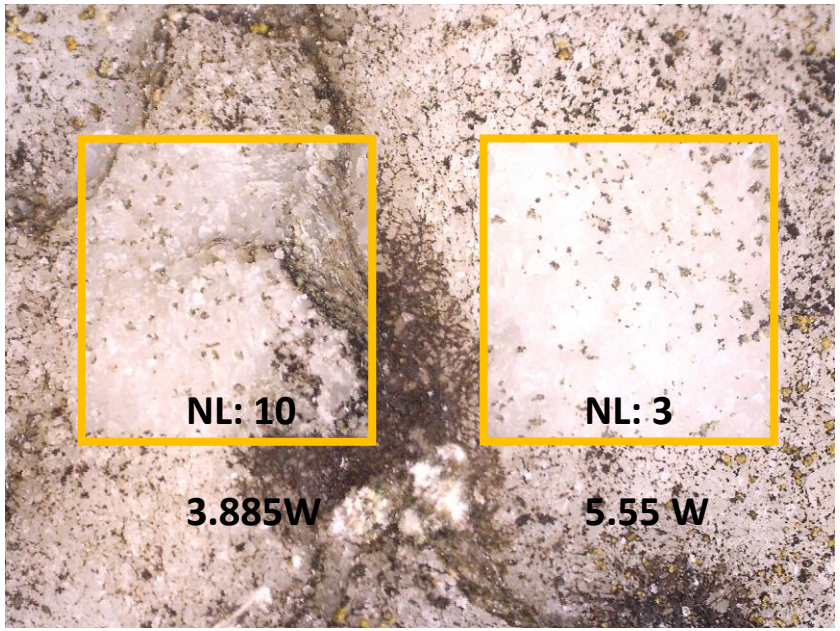
5.55 W 6.105 W



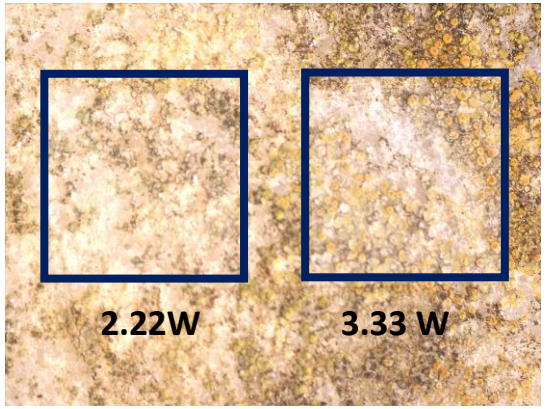
6.66W 7.215 W

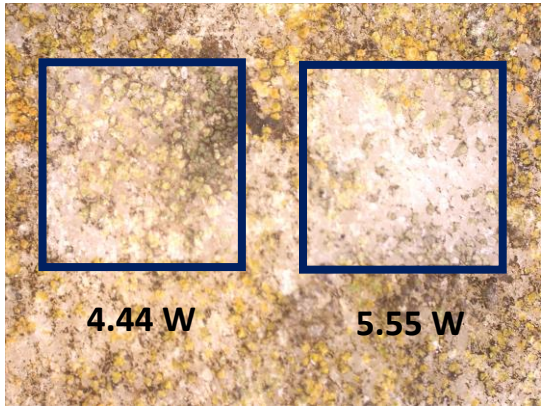


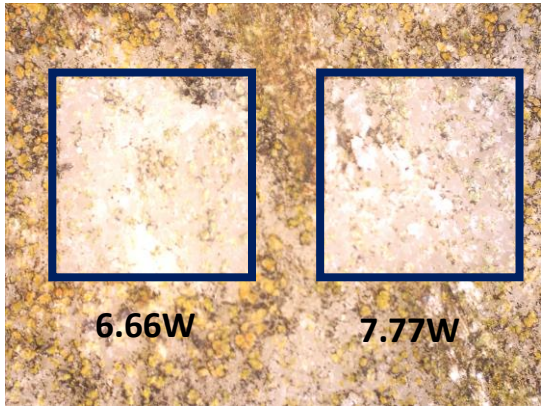
200KHz(/20ppd), 15µm, 150mm/s, NL:1

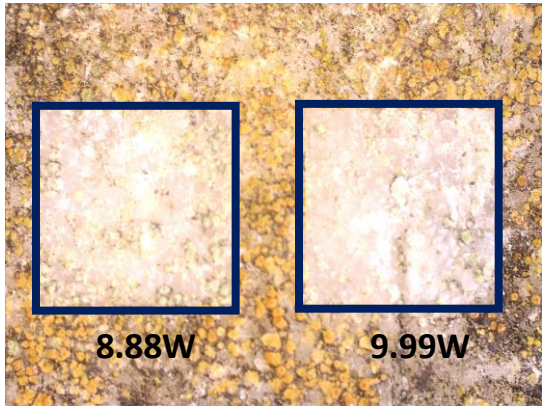


Case Studies: Cream Estremoz Marble

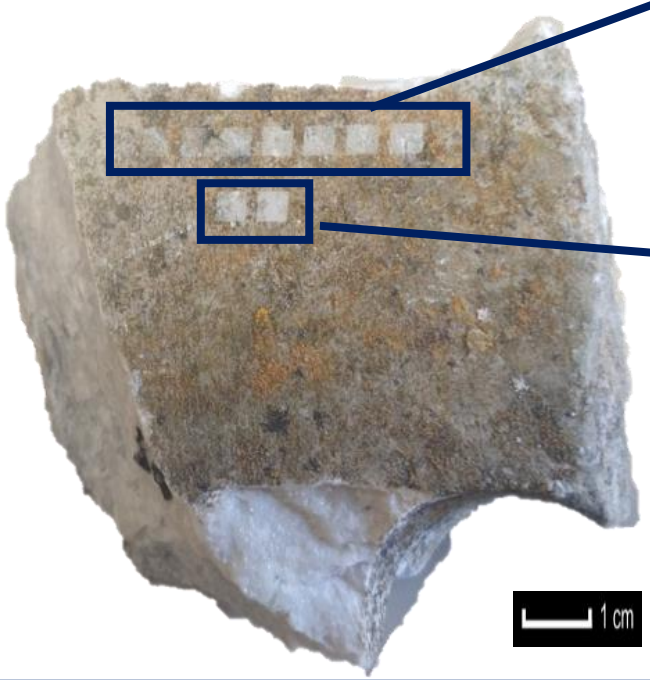


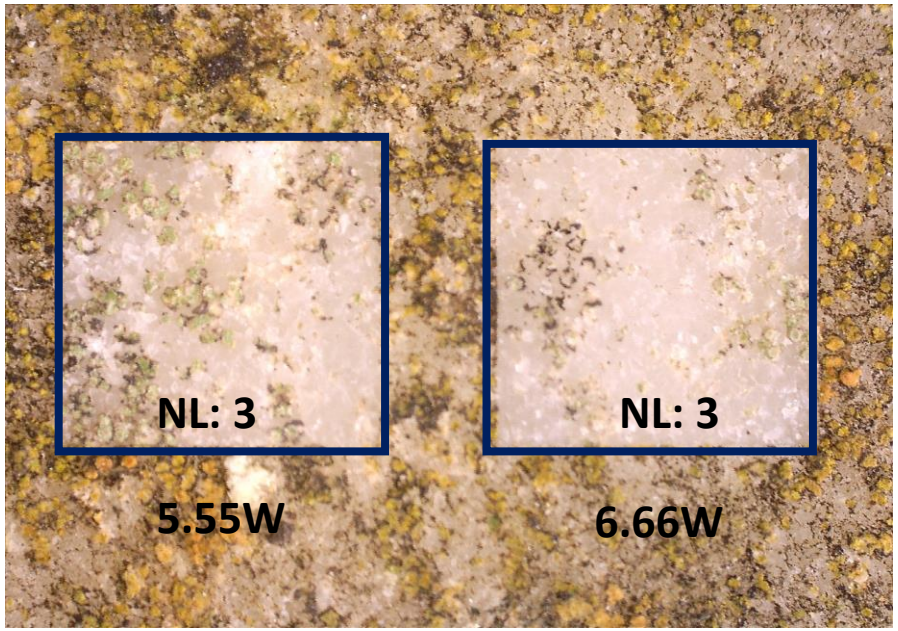






200KHz(/20ppd), 15µm, 150mm/s, NL: 1





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CSIC Consejo Superior de Investigaciones Científicas

INMA Instituto de Nanociencia y Materiales de Aragón

ICT

Universidade de Évora

ED-ARCHMAT

European Commission

A H2020-MSCA-ITN-EJD GA 766311

Discussions..

Q. & A.

Keeping the Lights on:

Yesterday,
Today &
Tomorrow…

ashiqur@unizar.es