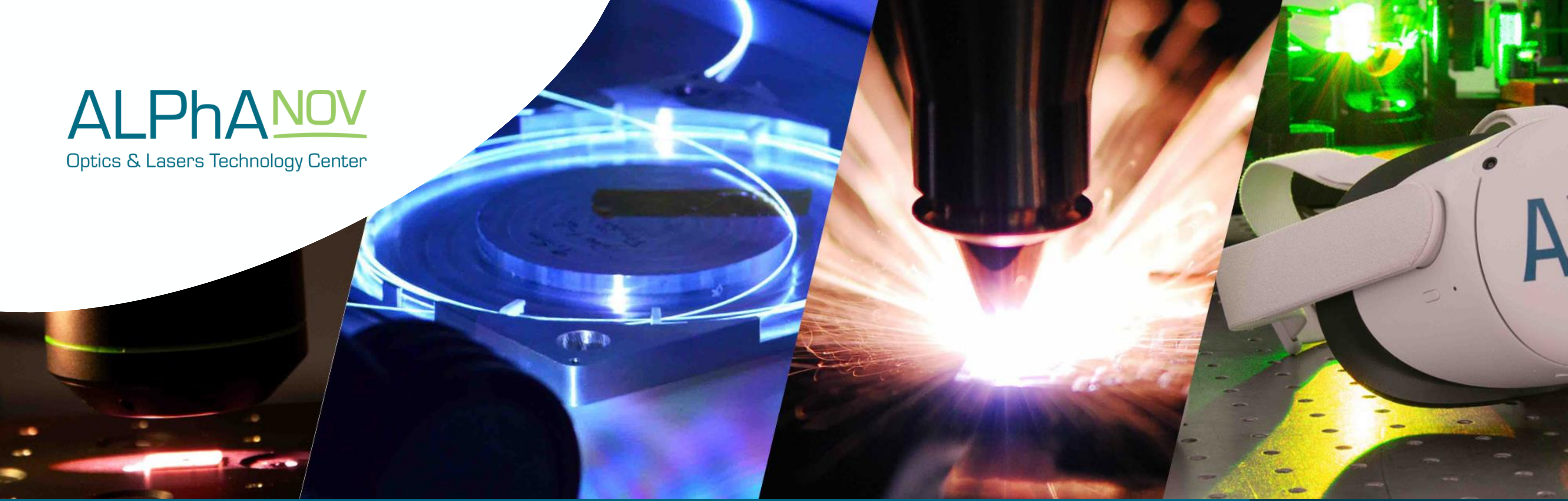
ALPhANOV
Optics & Lasers Technology Center



Laser structuring of functional surfacing: high-resolution meets high throughputs

EPHJ, 13/06/2024

Marc Faucon

Head of
Laser Processing Dpt.
ALPhANOV

MINISTÈRE DE L'ENSEIGNEMENT SUPÉRIEUR, DE LA RECHERCHE ET DE L'INNOVATION

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

RÉGION Nouvelle-Aquitaine

ALPHA RLH

cnrs

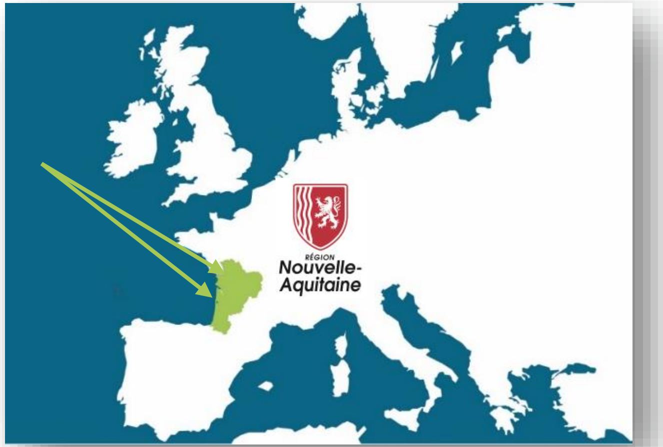
université de BORDEAUX

cea

CRT centre de ressources technologiques

ISO 9001:2015 BUREAU VERITAS Certification

ALPhANOV Facts & Figures



2007 Foundation

120+ Employees

2 Shared facilities
Joint R&D projects

20+ Running collaborative projects
(supported by the European Union, the state, national organism and the Nouvelle-Aquitaine Region)

12 Patents
incl. 7 in co-ownership, all are licensed or exploited

25 Start-Up
supported over the past 15 years

1 200+
People trained by the PYLA training center each year

8.2 M€
Turnover 2022

More than 2 500 Customers/partners accumulated
From labs to SME and large companies worldwide

ALPhANOV
Optics & Lasers Technology Center

Aeronautics, Defence and Space, Security

Biotechnologies, Pharma and Health

Industry 4.0

Sustainable Development

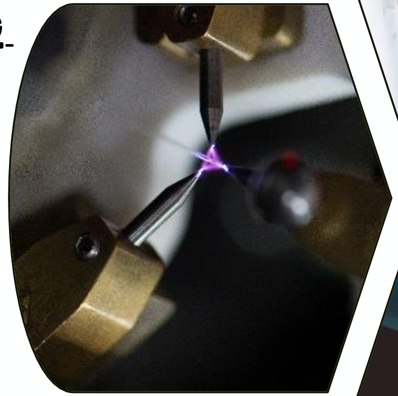
ALPhANOV's Departments

Laser sources & components

Innovative laser sources
Integration of PC fibers
Optical components

Photonics Systems

Integrated circuit test-bench
Opto-electronic systems
Opto-mechanical systems
Integrated machines



Trainings

Technical trainings on optics and lasers
VR-based training support development

Laser Processing

Feasibility studies
Industrial scale-up of laser processes
Technology transfer

Surface Functionalization

DEF Methods to *combine the properties of a bulk material with specific surface properties* which can be changed and tailored according to the environment the material must withstand

Standard techniques

The industry of surface treatment still mostly relies on the use of:

- **Toxic chemicals** and **wet acid baths** with use of **large amounts of water**
- Multi-steps processes which are far from being eco-friendly and represents a **health risk** for many workers

United Nations 2030 Agenda
17 Sustainable Development Goals

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Surface Functionalization

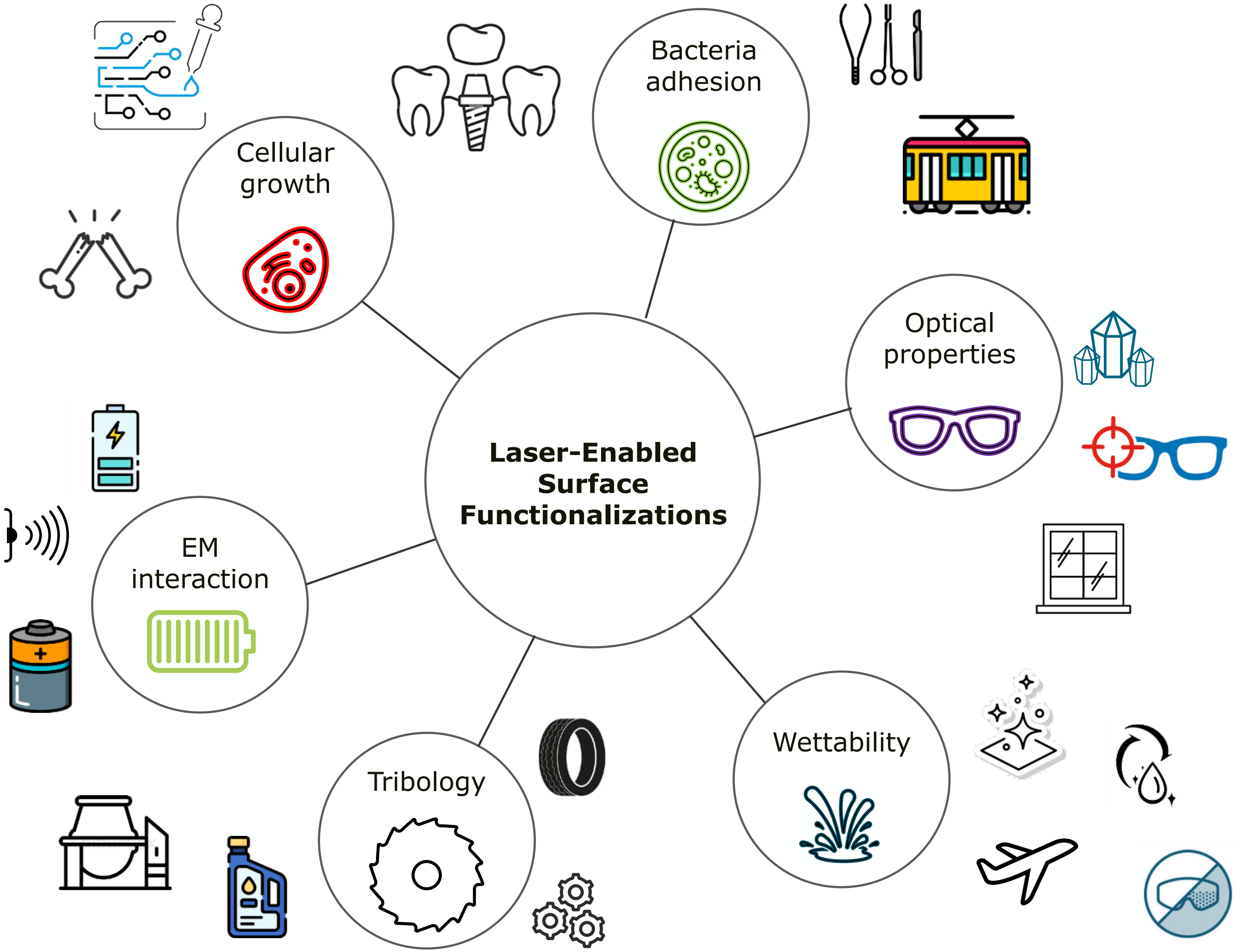
Methods to *combine the properties of a bulk material with specific surface properties* which can be changed and tailored according to the environment the material must withstand

Laser-based techniques

- Laser–based surface functionalization is **intrinsically sustainable** and versatile
- Laser methods do not **employ any toxic chemical** compounds and do not require the use of **any amount of water** during the process
- Laser methods can be applied to basically **all materials**, from metals to dielectrics and polymers
- Final products are intrinsically **easier to recycle and re-use**

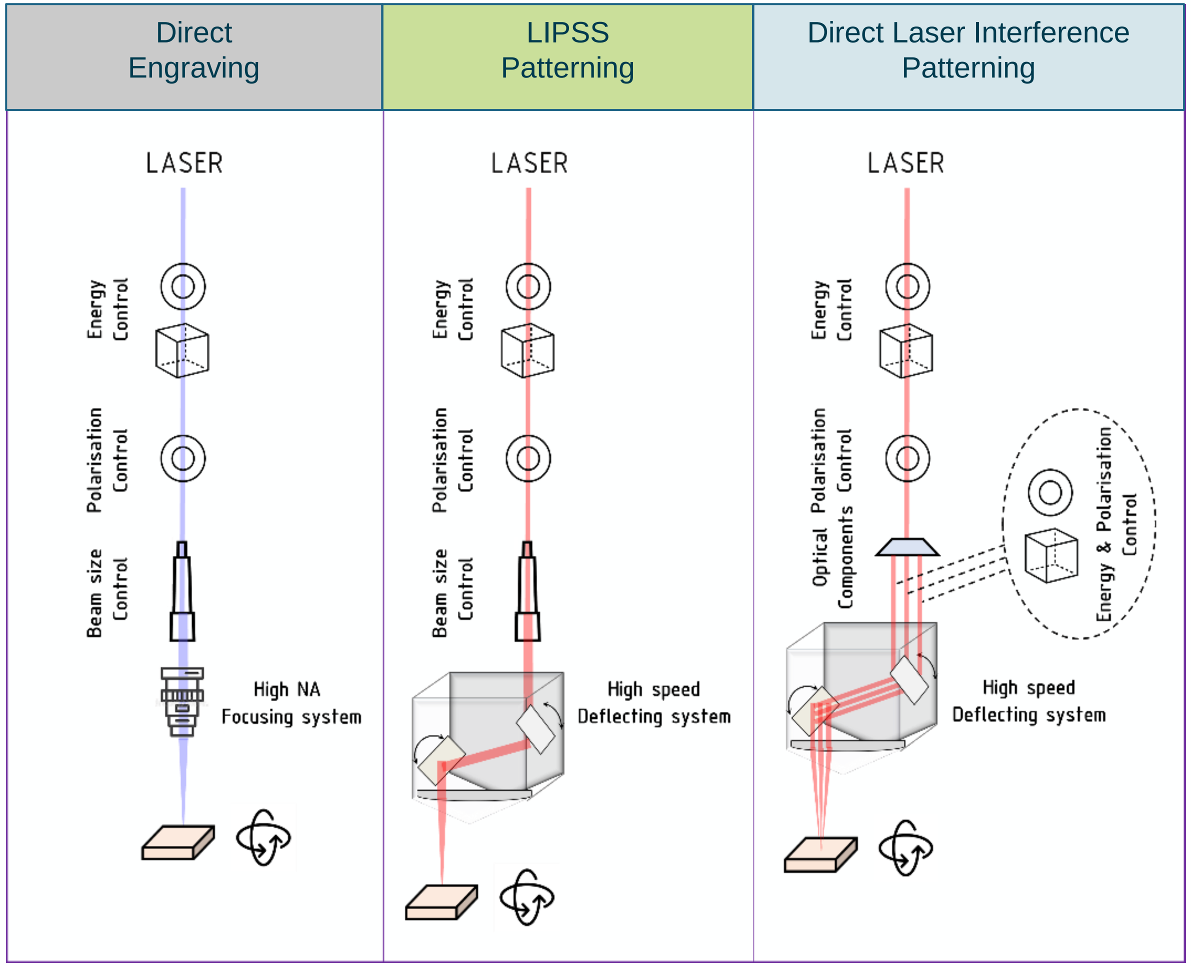
15 m long laser-functionalised coil @<15 min/m^2

Laser-enabled Surface Functionalization



Laser-enabled Surface Functionalization

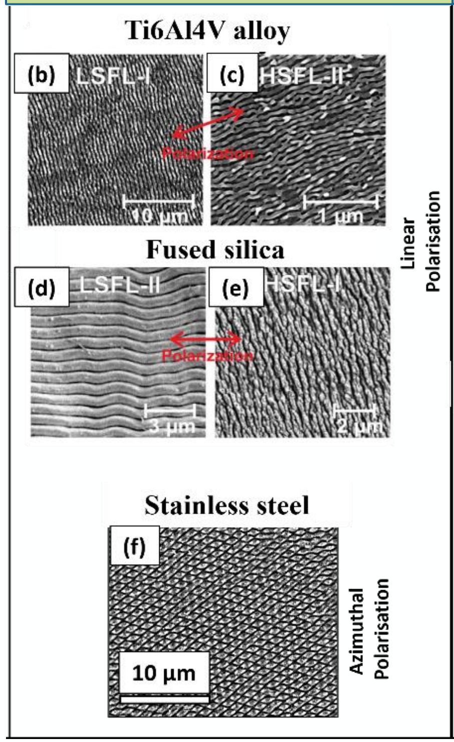
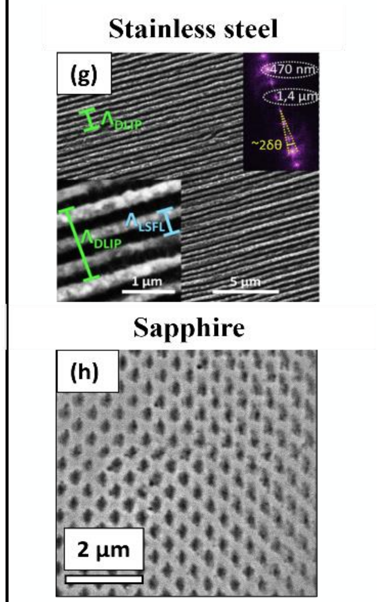
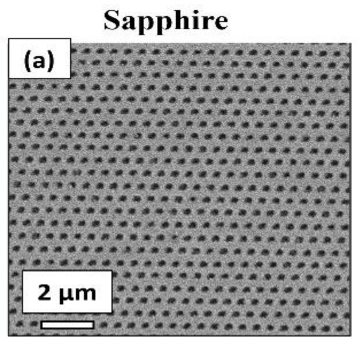
Ultrafast laser texturing allows the *generation of specific nano/micro-structures* on the material surface which provide the surface with tailored functionalities



Gemini et al., Journal of Japan Laser Processing Society, 29, 11 (2022)

Laser-enabled Surface Functionalization

Ultrafast laser texturing allows the *generation of specific nano/micro-structures* on the material surface which provide the surface with tailored functionalities

	LIPSS Patterning	Direct Laser Interference Patterning	Direct Engraving
			
Feature sizes	100s nm - 10s µm	100s nm - <10 µm	100s nm - 100s µm
Choice of Topography	✔	✔	✔
Process Throughput	✔	✔	✖
Choice of Material	✖	✔	✔

LIPSS Patterning X

2020-2024

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862100

Innovation Ecosystem to accelerate the industrial uptake of advanced processes to manufacture *nano-enabled industrial and consumer products* as well as the necessary testing capabilities to *demonstrate nano-enhanced goods features*

Broad Project Objective 1:
Open Innovation Test Bed

Broad Project Objective 2:
Upscaling Facilities

Broad Project Objective 3:
Testing Facilities

Broad Project Objective 4:
Case Studies

Broad Project Objective 5:
Nano-safety, regulatory support, LCA, RMS

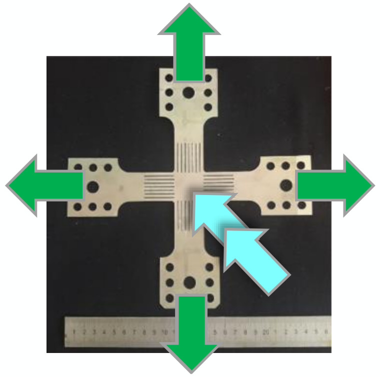
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862100

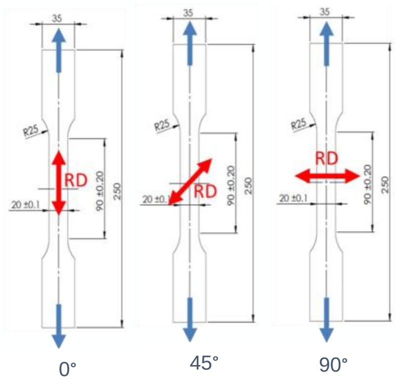
LIPSS Patterning X

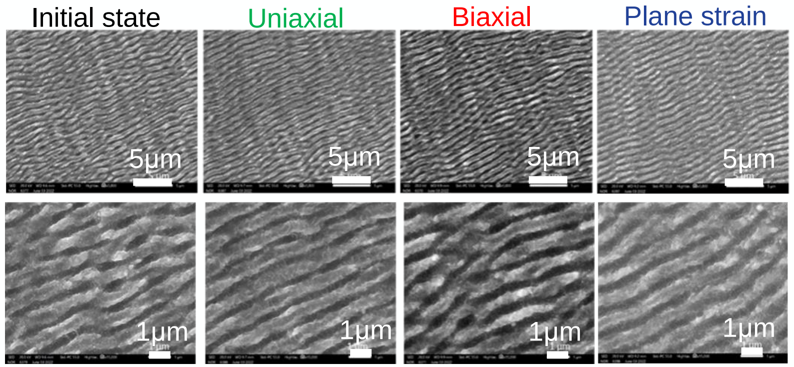
2020-2024

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862100

Five sets of mechanical tests:
Tensile –uniaxial, biaxial, plain strain- and deformation tests, Fatigue resistance







Maximum stress to failure

Material	$\sigma_{f\,1E6}$ [MPa]	$\sigma_{f\,1E5}$ [MPa]
LIPSS	518	553
REFERENCE	524	556

17 March 2023

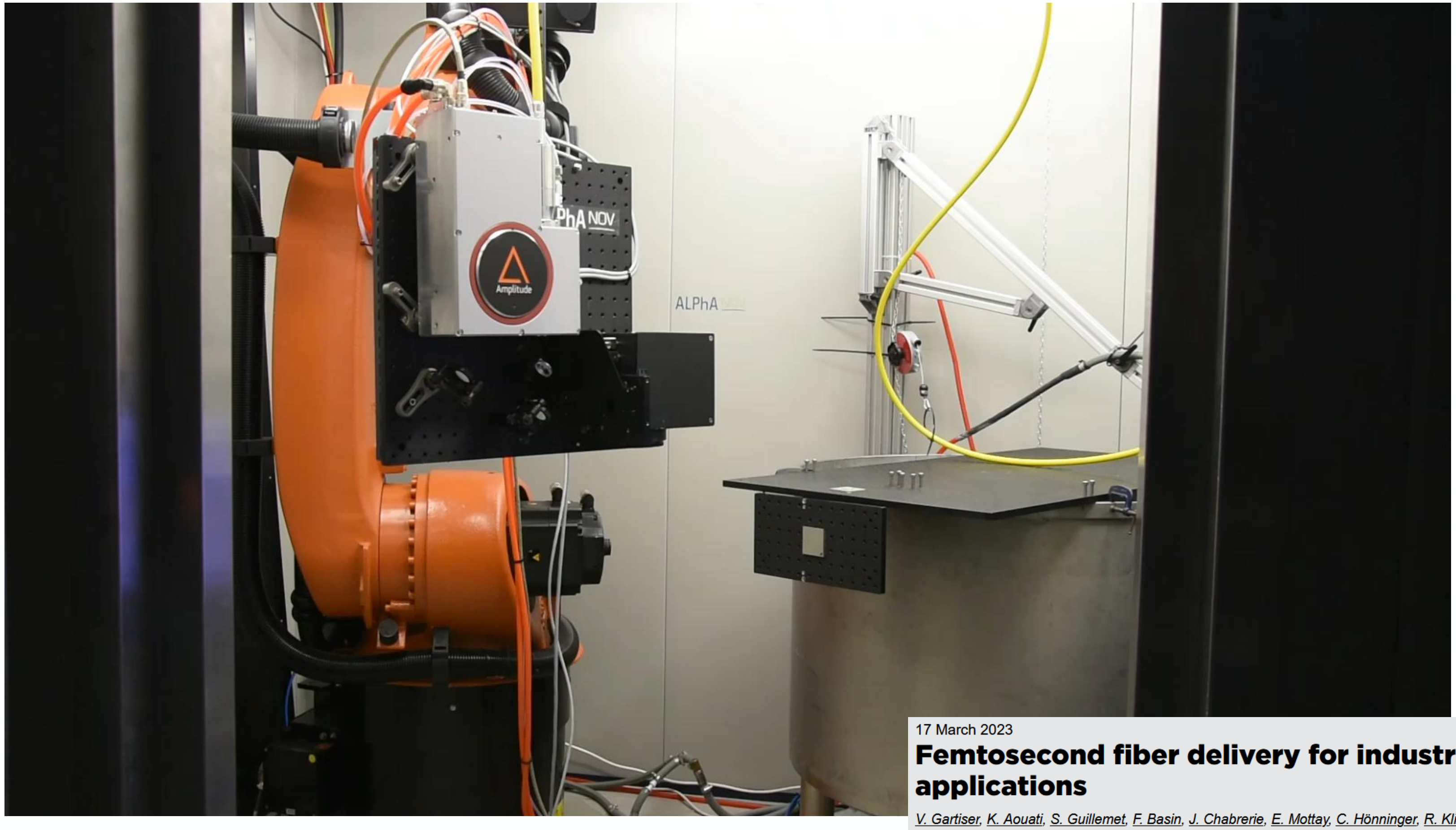
Forming of metal sheets textured by LIPSS

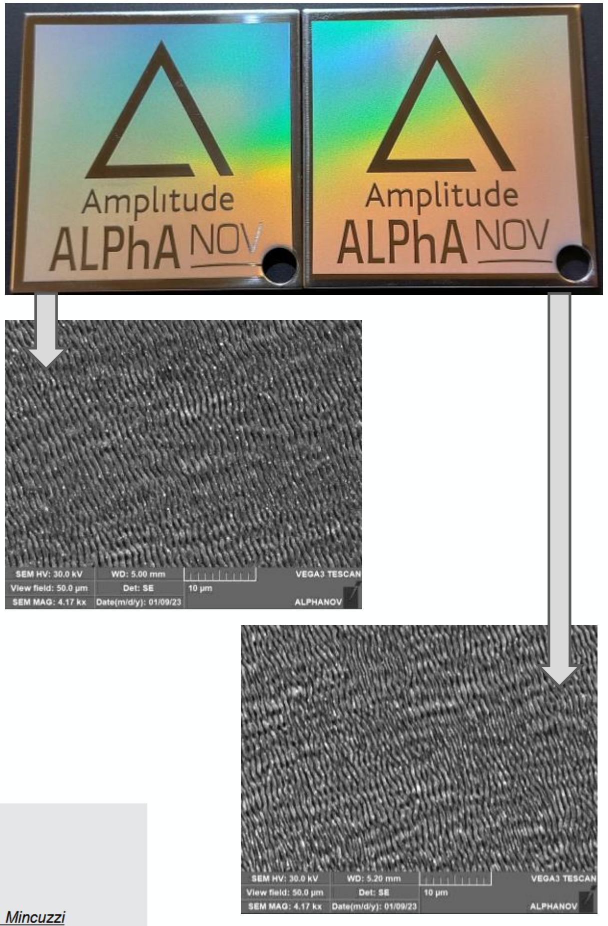
G. Mincuzzi, Sylwia Rzepa, Sergi Parareda Oriol, A. Bourtereau, L. Gemini, M. Faucon, R. Kling

Author Affiliations +

Proceedings Volume 12409, Laser-based Micro- and Nanoprocessing XVII; 124090R (2023)
https://doi.org/10.1117/12.2649763
Event: SPIE LASE, 2023, San Francisco, California, United States

LIPSS Patterning X





17 March 2023

Femtosecond fiber delivery for industrial applications

V. Gartiser, K. Aouati, S. Guillemet, F. Basin, J. Chabrerie, E. Mottay, C. Hönninger, R. Kling, G. Mincuzzi

Author Affiliations +

Proceedings Volume 12411, Frontiers in Ultrafast Optics: Biomedical, Scientific, and Industrial Applications XXIII; 1241102 (2023) https://doi.org/10.1117/12.2650326

Event: SPIE LASE, 2023, San Francisco, California, United States

DLIP X

GIGAGREEN

2022-2026

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101069707

Towards the sustainable giga-factory: developing green cell manufacturing processes

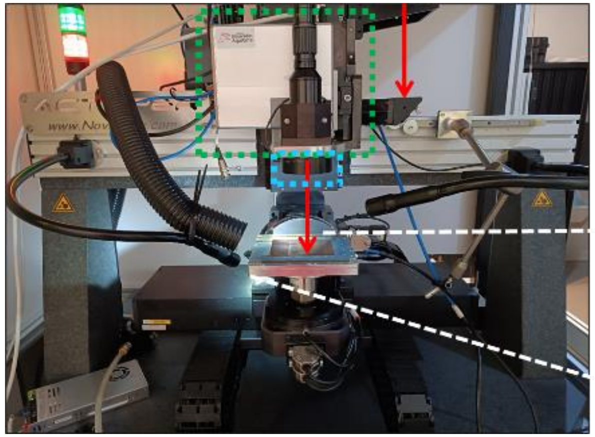
Specific needs
Elimination of NMP as organic solvent due to its toxic nature and its expensive recovery system
Less expensive and environmentally friendly solvents
Optimised wet coating technologies
Innovative dry processing techniques
Implementation of "Design to Manufacture" (DtM) notion
Digitalisation in manufacturing techniques
Solutions and/or standarised approaches to ensure safety

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101069707

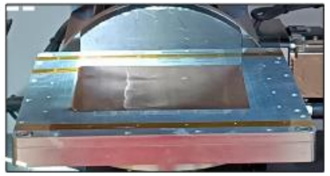
1 Laser functionalization of **charge collectors (Al, Cu)** to improve adhesion and improve electrical performance

Increasing the contact area by maximizing the ratio of total surface area to projected (nominal) area with increase of Sdr>50%

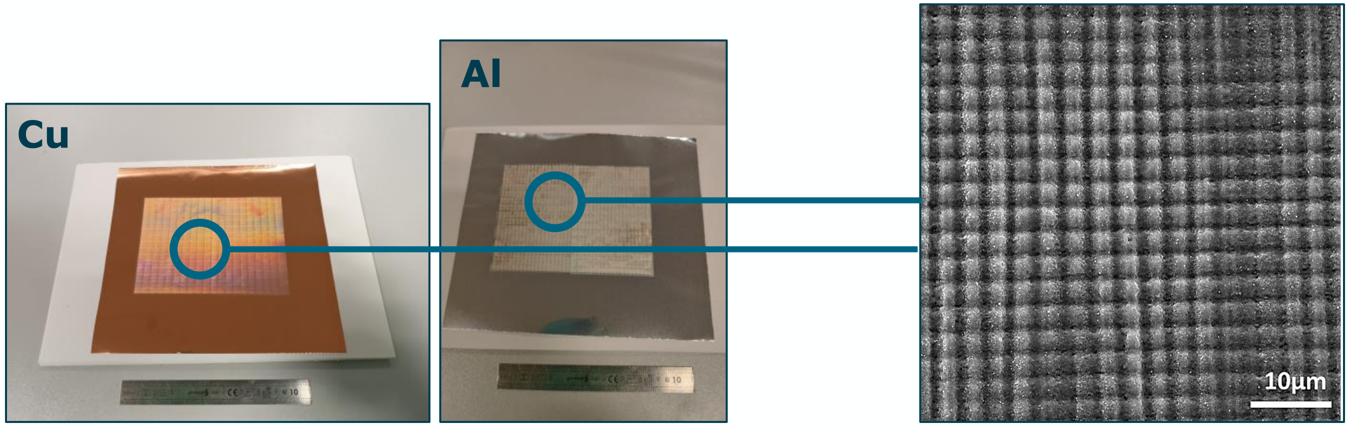
Sdr (Developed Interfacial Area Ratio) = percentage of the definition area's additional surface area contributed by the texture as compared to the planar definition area

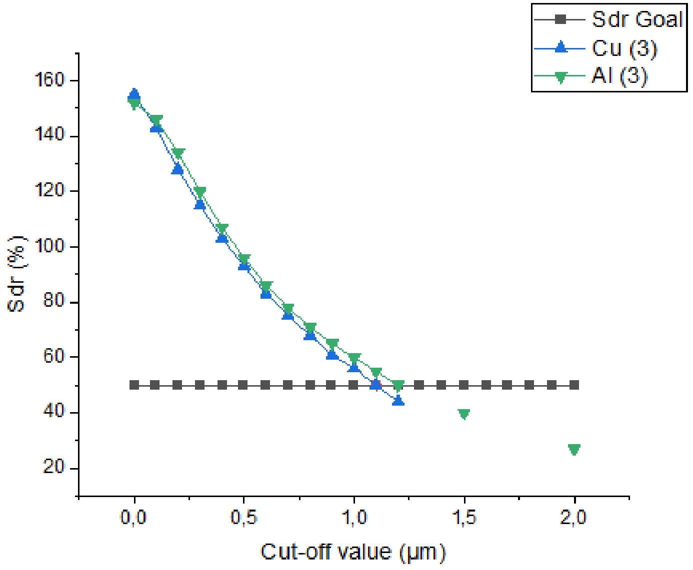


Tangerine (20W)
λ 1030 nm
τ 300 fs



15µm Cu foil hold by vacuum





AN

DLIP X

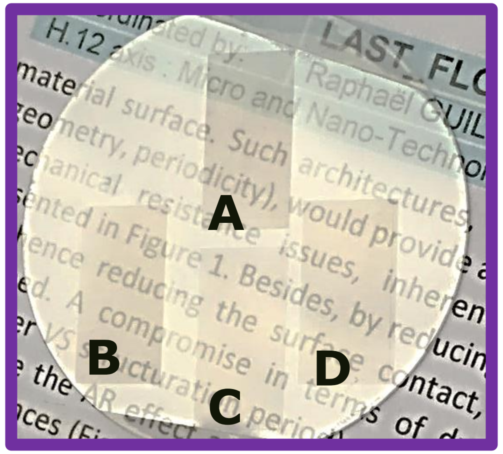
FunGlass

Fraunhofer IWS

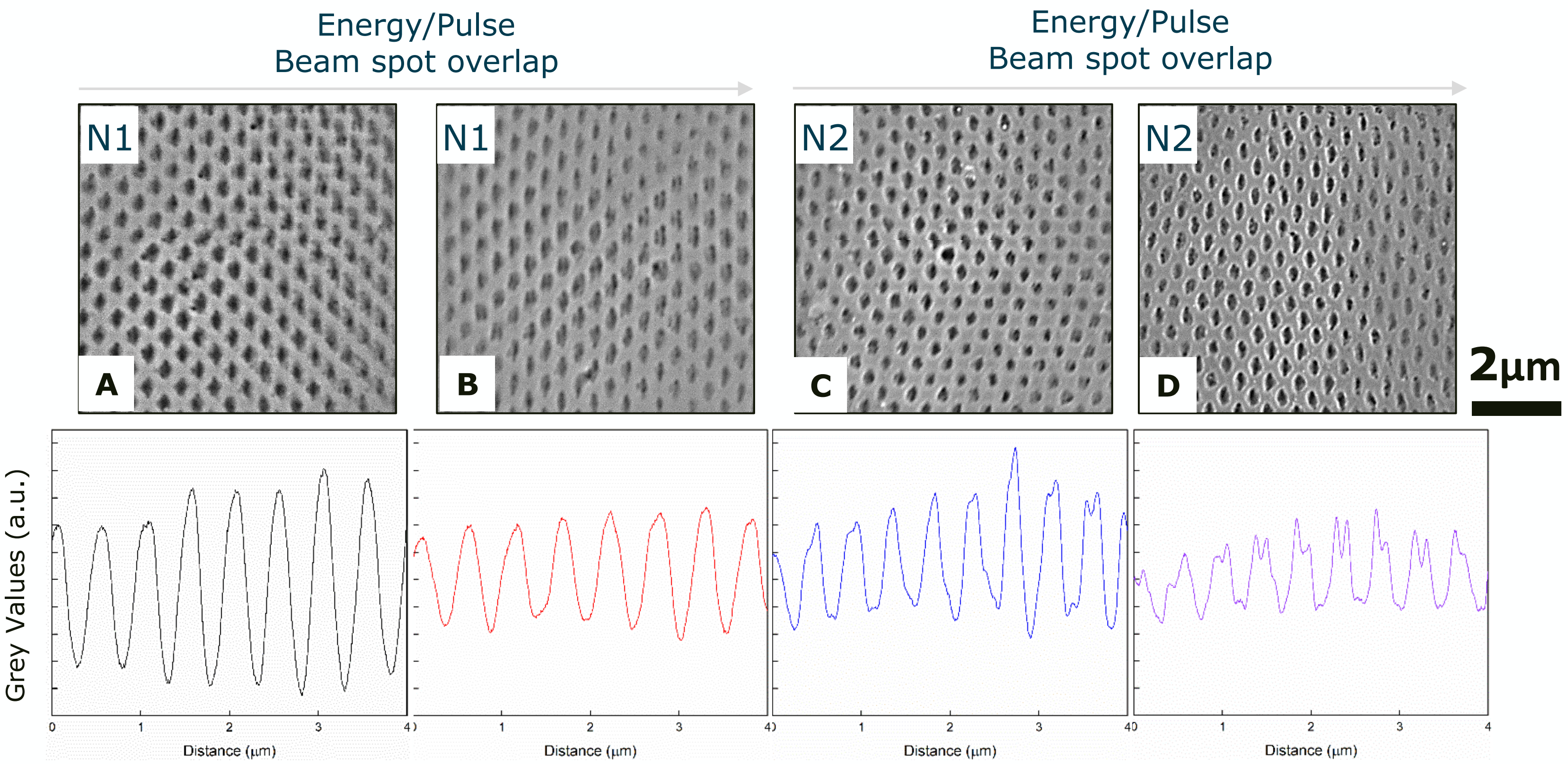
FUSION BIONIC

RÉGION Nouvelle-Aquitaine

Pulse duration ≈ 10 ps
Wavelength ≈ 343 nm
beams = 4
Repetition Rate = 2 kHz
Motion control : motorised stages



Sapphire



P ≈ 500nm
D ≈ 247±23nm

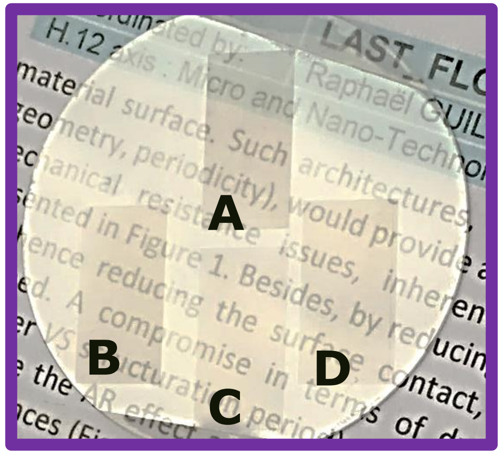
P ≈ 530nm
D ≈ 229±23nm

P ≈ 448nm
D ≈ 212±19nm

P ≈ 452nm
D ≈ 215±16nm

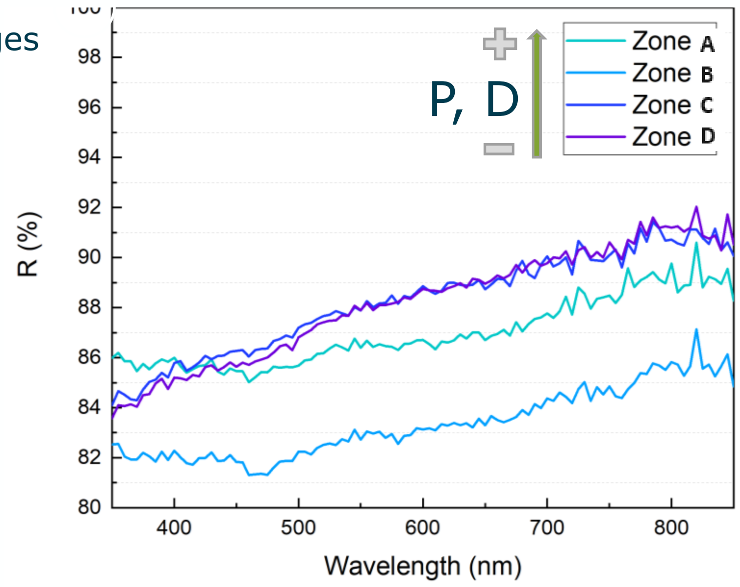
DLIP X

Pulse duration ≈ 10 ps
Wavelength ≈ 343 nm
beams = 4
Repetition Rate = 2 kHz
Motion control : motorised stages



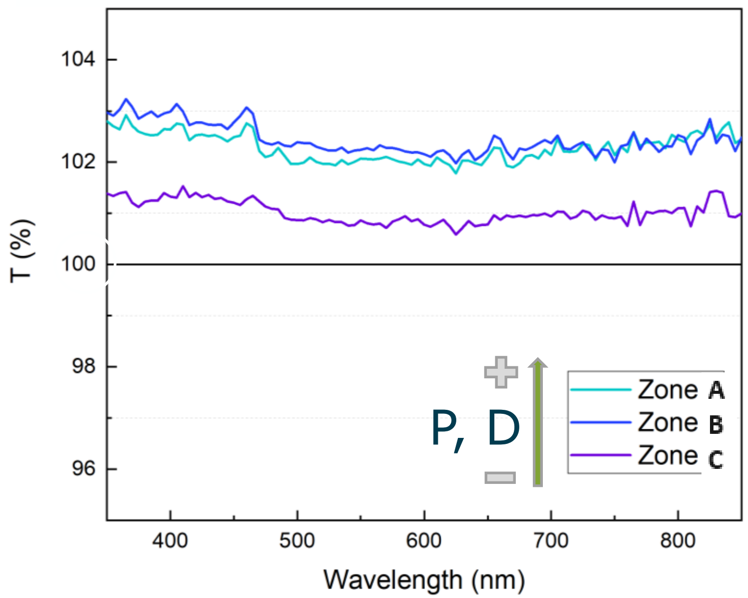
Sapphire

Relative specular reflection



Decrease of relative specular reflection at 8°

Relative transmittance



Increase of relative transmittance

- The decrease of specular reflection is linked to an increase of the transmission up to 3%
- Laser-treated sapphire presents an anti-reflective effect in visible spectrum

DLIP X

Surface functionalisation of transparent materials: high-throughputs meet high resolutions

Laura Gemini, Aurelien Sikora, Laura Loi, Girolamo Mincuzzi, Marc Faucon, Rainer Kling

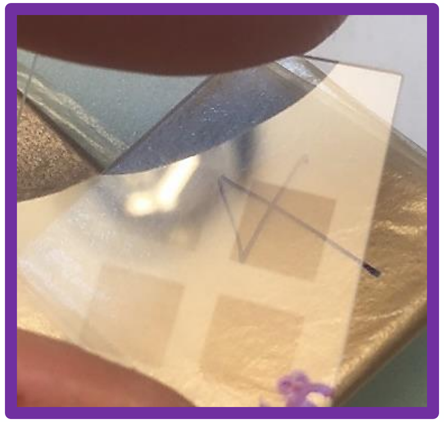
Author Affiliations +

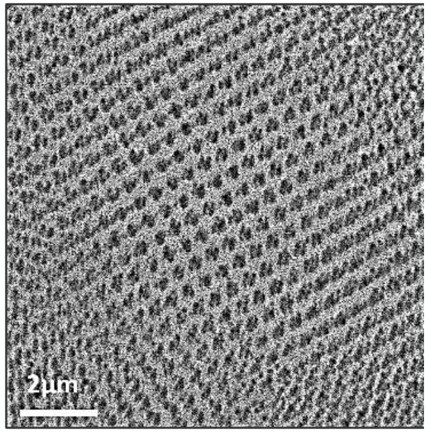
Proceedings Volume PC12408, Laser Applications in Microelectronic and Optoelectronic Manufacturing (LAMOM) XXVIII; PC124080C (2023) https://doi.org/10.1117/12.2648757

Event: SPIE LASE, 2023, San Francisco, California, United States

Fused Silica

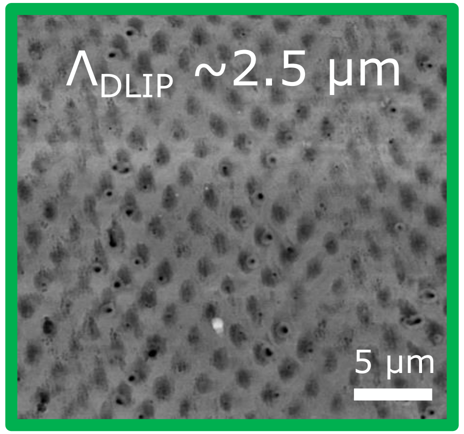
Pulse duration ≈ 10 ps
Wavelength ≈ 343 nm
beams = 4

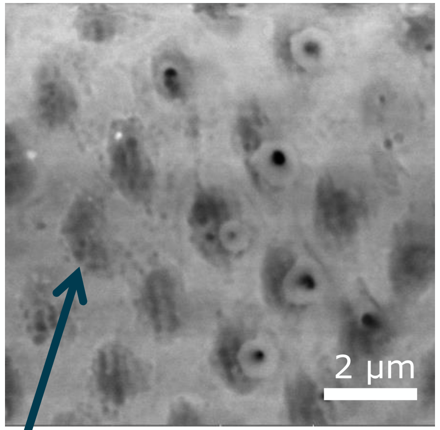




Periodicity ≈ 550nm
Diameter ≈ 305nm

Pulse duration ≈ 10 ps
Wavelength ≈ 532 nm
beams = 4



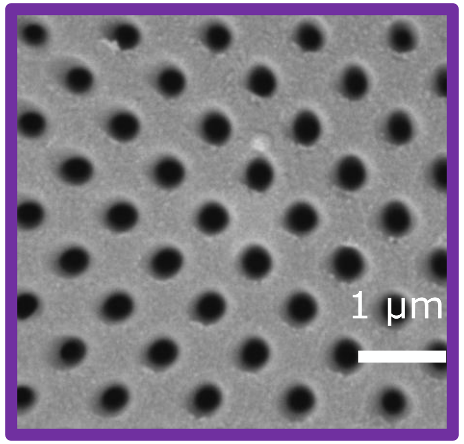


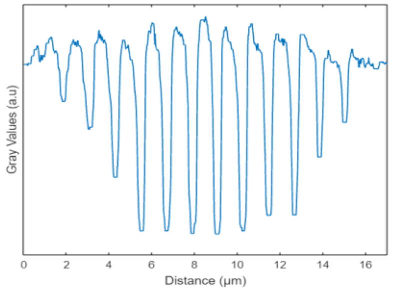
Periodicity ≈ 2.5µm
Diameter ≈ 1µm

Nanostructuring

PC

Pulse duration ≈ 350 fs
Wavelength ≈ 343 nm
beams = 4





Periodicity= 1.2 µm
Diameter= 335 ± 34 nm

Fraunhofer IWS

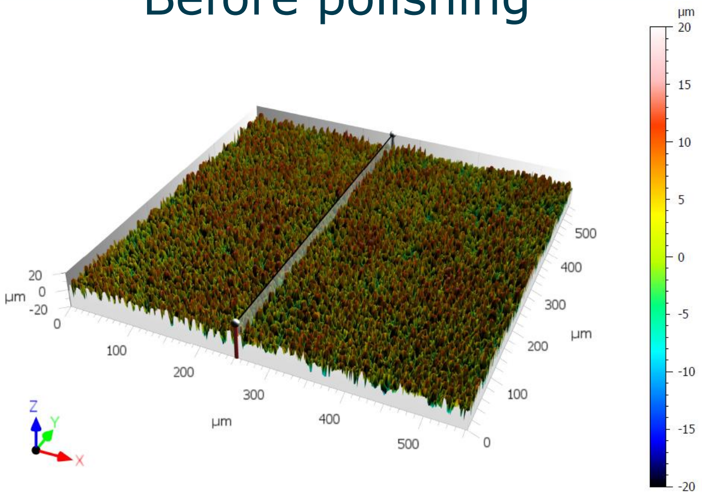
FUSION BIONIC

High throughput, Laser finishing and functionalization! X

LAMIPoC

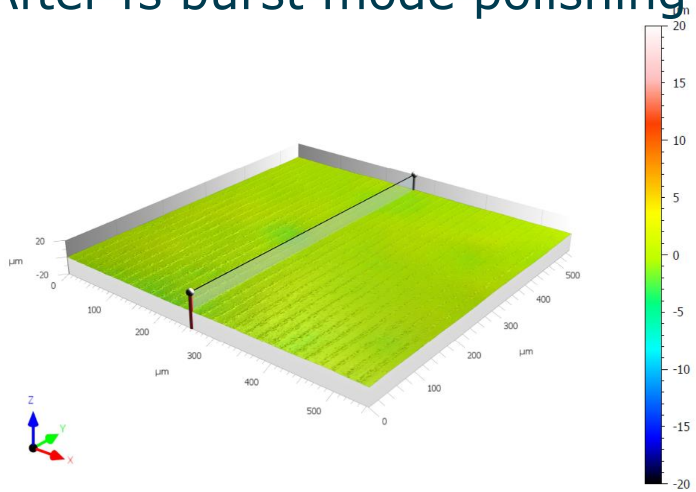
EURORÉGION
EUROESKUALDEA
EURORREGIÓN
NOUVELLE-AQUITAINE • EUSKADI • NAVARRE
AKITANIA BERRIA • EUSKADI • NAFARROA
NUEVA AQUITANIA • EUSKADI • NAVARRA

Before polishing



ISO 25178 - Primary surface		
F: [Workflow] Leveled (LS-plane)		
S-filter (λs): None		
Height parameters		
Sq	5.444	µm
Ssk	0.2068	
Sku	2.275	
Sp	26.52	µm
Sv	12.60	µm
Sz	39.12	µm
Sa	4.496	µm

After fs burst mode polishing



ISO 25178 - Primary surface		
F: [Workflow] Leveled (LS-plane)		
S-filter (λs): None		
Height parameters		
Sq	0.4390	µm
Ssk	-0.1054	
Sku	2.892	
Sp	1.794	µm
Sv	1.884	µm
Sz	3.678	µm
Sa	0.3484	µm

$T_{Polishing}$ = 110 s/cm²

x15 Sp (Maximum peak height)
x7 Sv (Maximum pit height)
x11 Sz (Maximum heihg)
x13 Sa (Arithmetical mean height)

Continuous laser polishing: 200µm < HAZ < 1000µm [1]
Nanosecond laser polishing: 20µm < HAZ< 150µm [1]
Femtosecond laser polishing: non-observable < HAZ < 7.5µm

[1] Gisario, A. and al; Int J Adv Manuf Technol 120, 1433–1472 (2022)

Take Home Messages!

Laser surface functionalization works!

- Tailoring surface properties on a large variety of materials for a wide range of applications by selecting suitable laser processing technique
- Achieving process throughputs which are already competitive for several industrial sectors (<15min/m^2)
- Limitations:
  - Adapting integrated systems and machines to manufacture large 3D parts to precision and resolution needed for fs laser processing
  - Improving mechanical and chemical stability of laser-enabled surfaces by hybrid functionalisation processes (non-toxic nano-coatings)

Thank you for your attention!

ALPhANOV
Optics & Lasers Technology Center

Marc Faucon

marc.faucon@alphanov.com