SUPSI

High Throughput fs Laser Machine

Francesco Impaziente – 16/06/2022

FemtoSurf Project

FEMTOSURF

Main objective

Develop an **high-throughput fs laser machine** with a solid state 200 W-level laser with parameters suitable for **metal surface patterning** applicable in different industrial areas.

PHOTONICS 21

PHOTONICS PUBLIC PRIVATE PARTNERSHIP

The FemtoSurf Project has received funding from the **European Union's Horizon 2020** Research and Innovation Programme under Grant Agreement No. 825512. This project is funded by one of the call under the **Photonics Public Private Partnership** (PPP).

Principles of Laser Surface Structuring

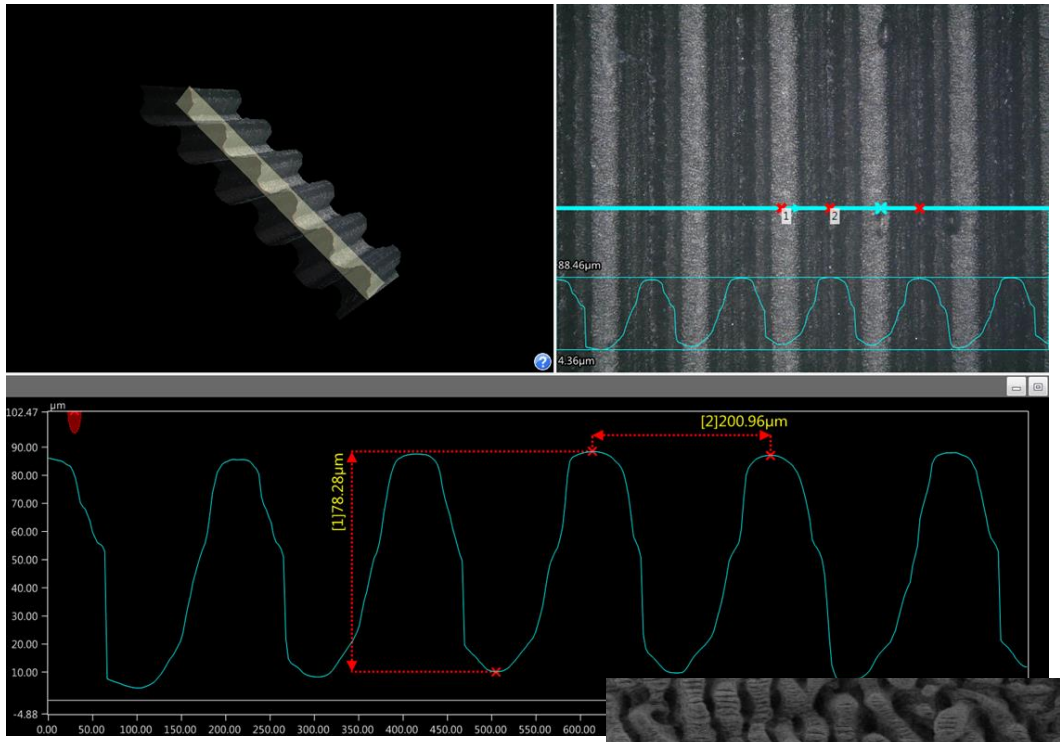
Laser surface structuring can be used to **enhance various properties** of surfaces or even **induce new properties**:

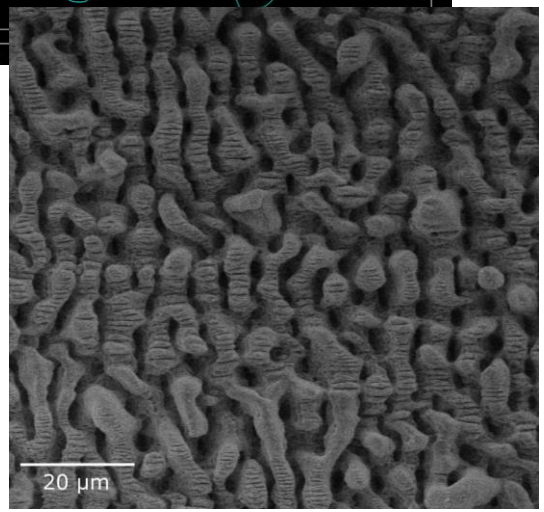
- Friction reduction/lubricant retention
- Roughness modification
- Hydrophobicity/hydrophilicity
- Marking

The method is based on a very short pulse duration and high laser peak fluence. It allows structuring almost all classes of materials with ultra-high precision and without the occurrence of noticeable heat-affected zones.

- Ablation of a **periodic pattern**

- Generation of **nano-structured ripples**, due to material remelting





Applications of Laser Surface Structuring

Ship building

Anti-fouling surface structures on ship propellers.

Massive decrease in **fuel consumption** and **maintenance** of ships.

Tool manufacturing

Reduce the overall **friction between components** in machining operations by surface patterns.

Patterns can be created to **guide lubricant** to specific places of the machining setup

Enhance the **lifetime** of machining tools.

Healthcare

Change the surface properties of titanium implants, which determine **repulsion or adhesion to living tissue**.

Improvement of **functionality** and **longevity** of **orthopaedic implants**.

Aviation

Surface patterns enhance **self-cleaning properties** of aeroplane and spacecraft components.

Reduce the overall friction between components under heavy load.

Enhance the **lifetime** and, in turn, profitability in aerospace sector.

Limitations of Laser Surface Structuring and FemtoSurf solutions

High processing time, only small parts can be processed in reasonable time

Only **simple shape** surfaces can be processed

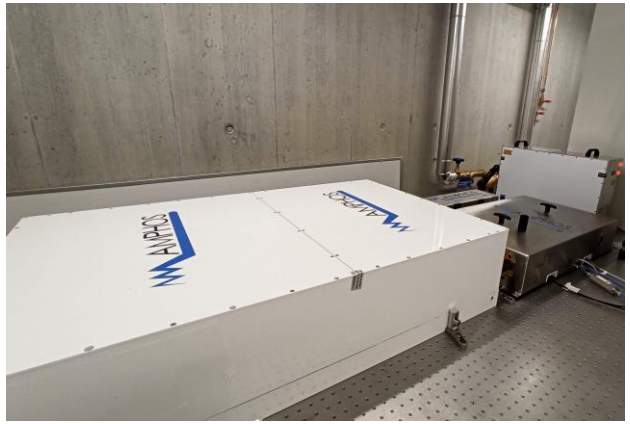
Stitching errors in processing surfaces larger than the scanner's FOV

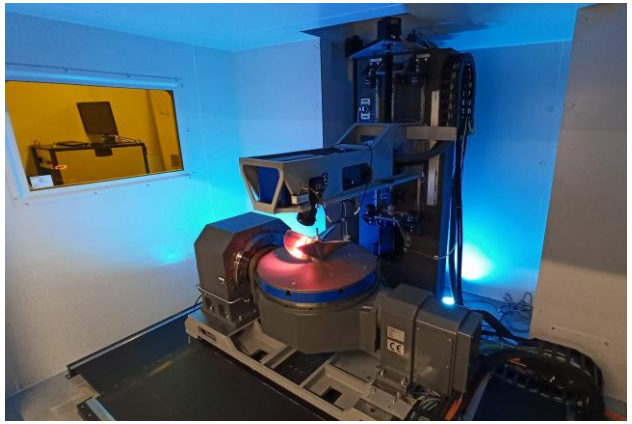
FemtoSurf Solution

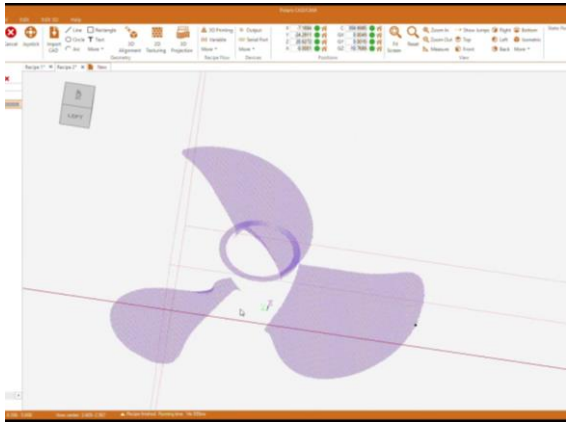
Laser with **higher power** enables processing with **higher speed**

5 mechanical axes machine with **3 optical galvo-axes**

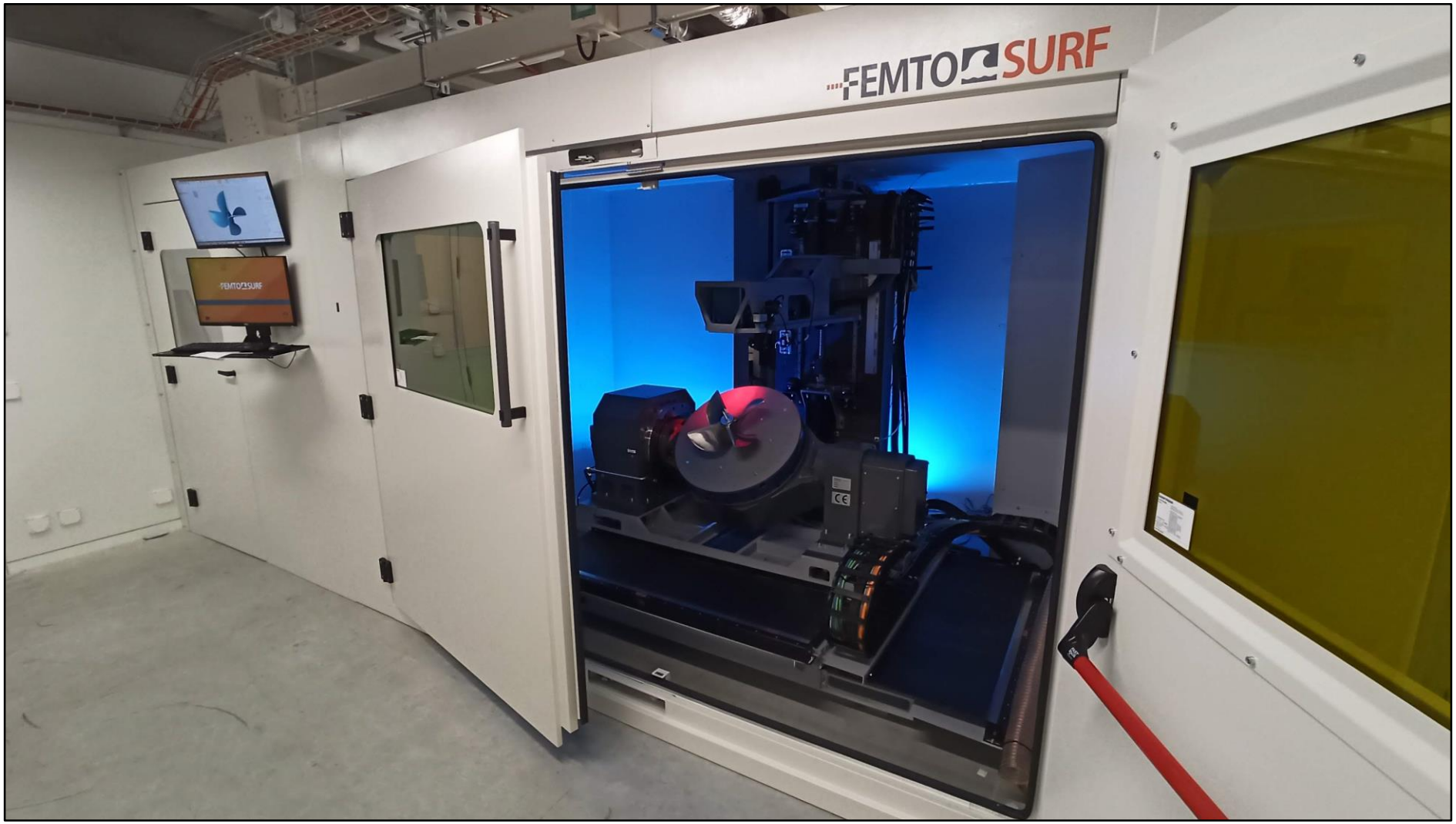
Interpolation of the 8 axes to generate an **IFOV**



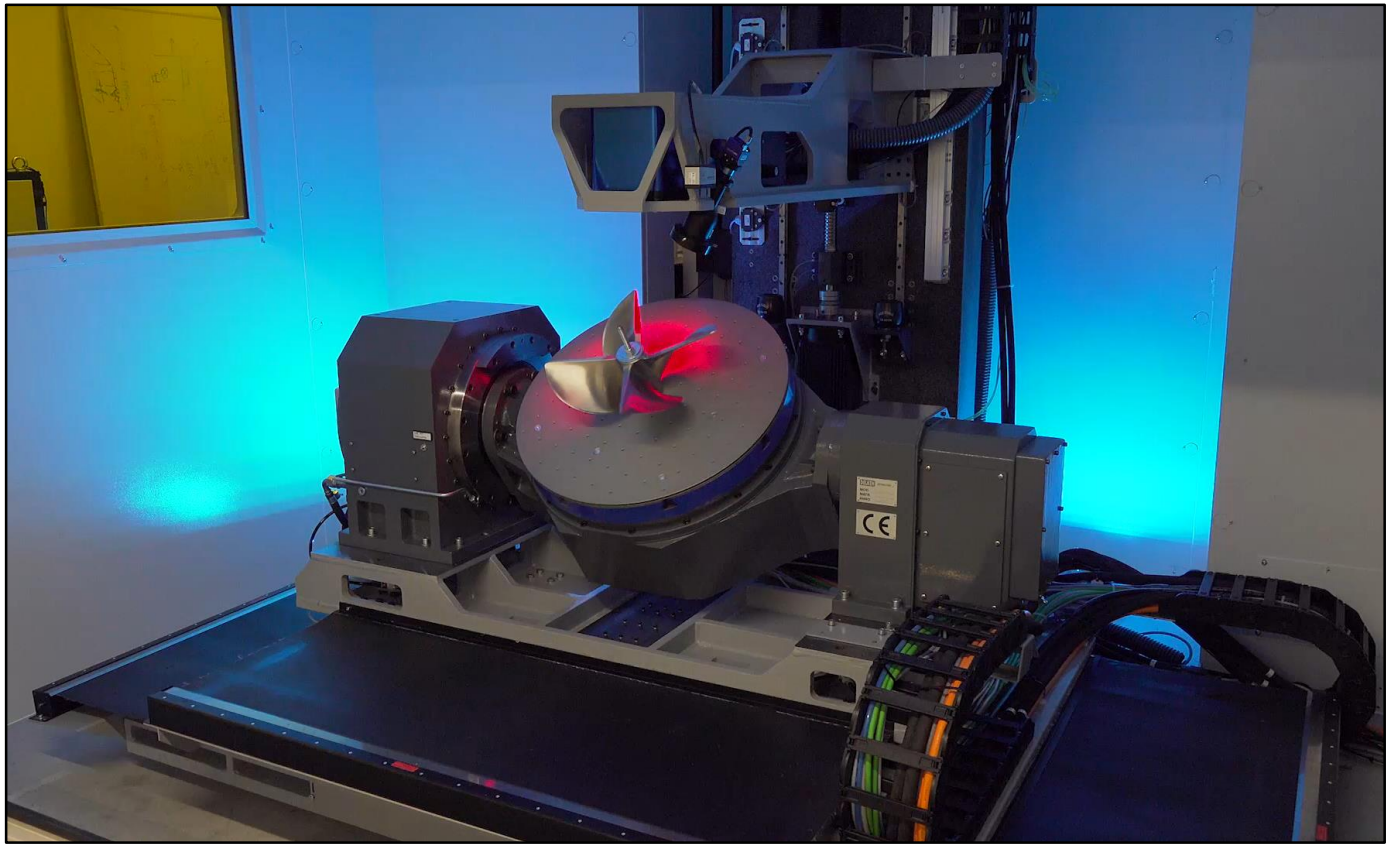




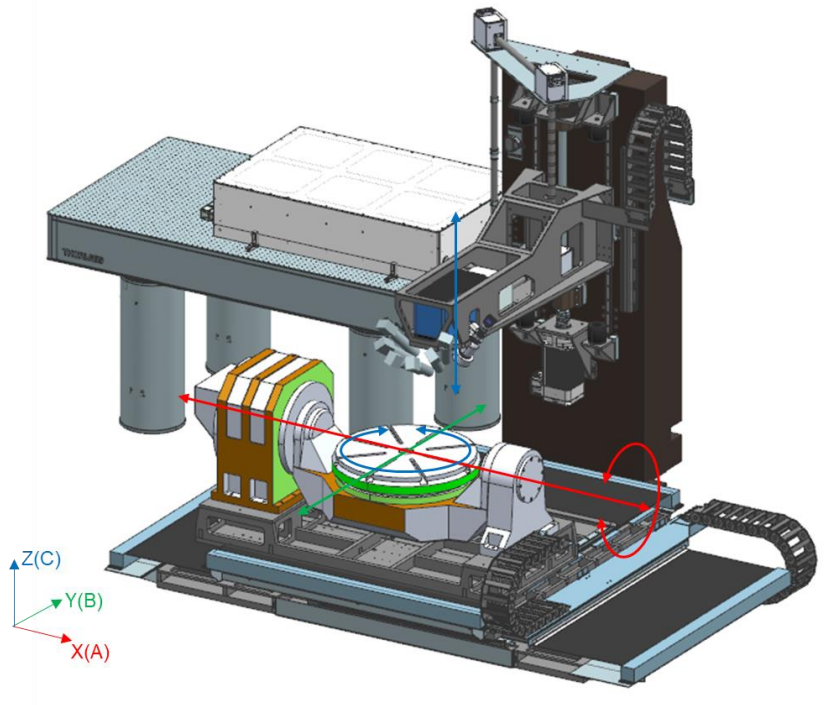
FemtoSurf machine



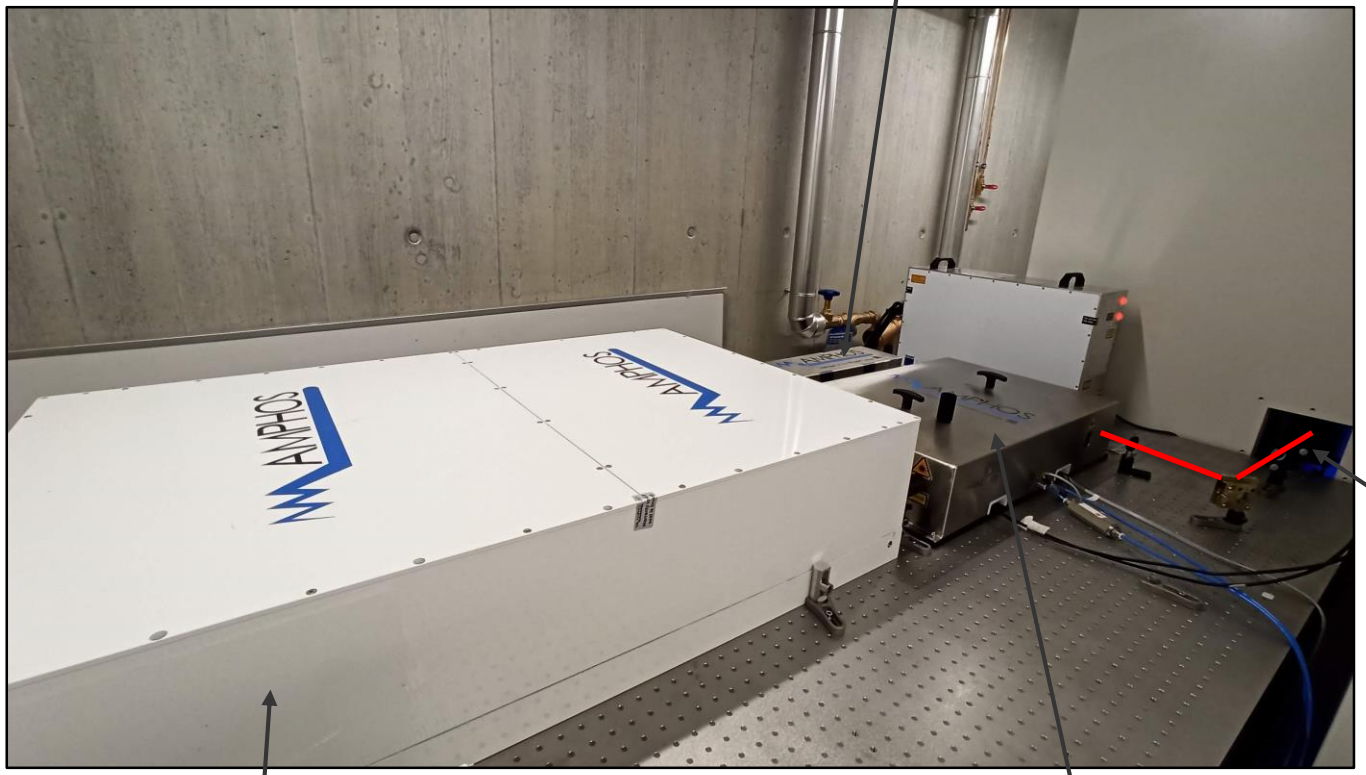
FemtoSurf Machine's properties



FEMTOSURF	Technical data
5 mechanical axes X, Y, Z, A, C	
3 optical scanner axes Gx, Gy, Gz	
Working volume	*600 mm x 600 mm x 300 mm*
Beam delivery system	*Free-space with 3D galvo-scanner*
Rotary Strokes	*A ±100 deg* / *C ±Inf*
Acceleration of all axes	*0.5 m/s^2*
X, Y, Z resolution	*0.01 µm*
A,C resolution	*0.0005 deg*
Weight	*6000 kg*



FemtoSurf Laser



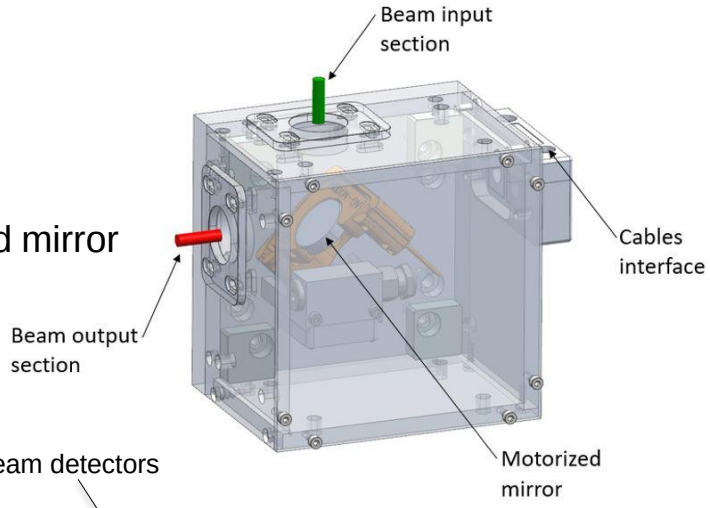
FEMTOSURF	Technical data

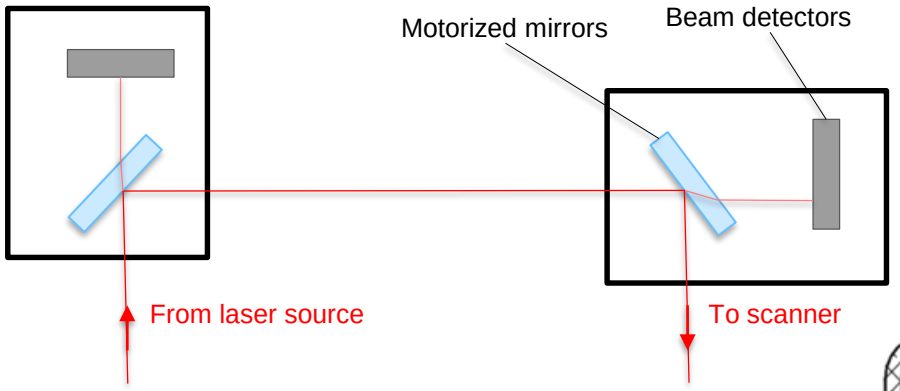
Laser properties	
Wavelength	*1030 nm*
Power	*220 W*
Repetition rate	*500 kHz - 40 MHz*
Max. Pulse Energy	*0.44 mJ*
Pulse duration	*900 fs*
Focalized beam diameter	*25 μm*
Working distance	*200 mm*

FemtoSurf Optical Chain

Self-alignment system:

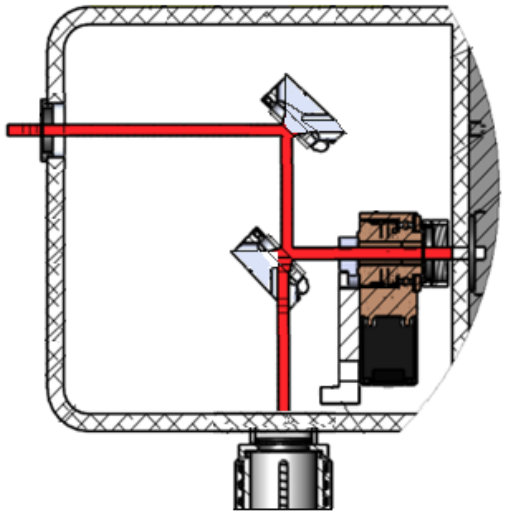
- 4 mirror box with motorized mirror
- 4 CCD beam detectors



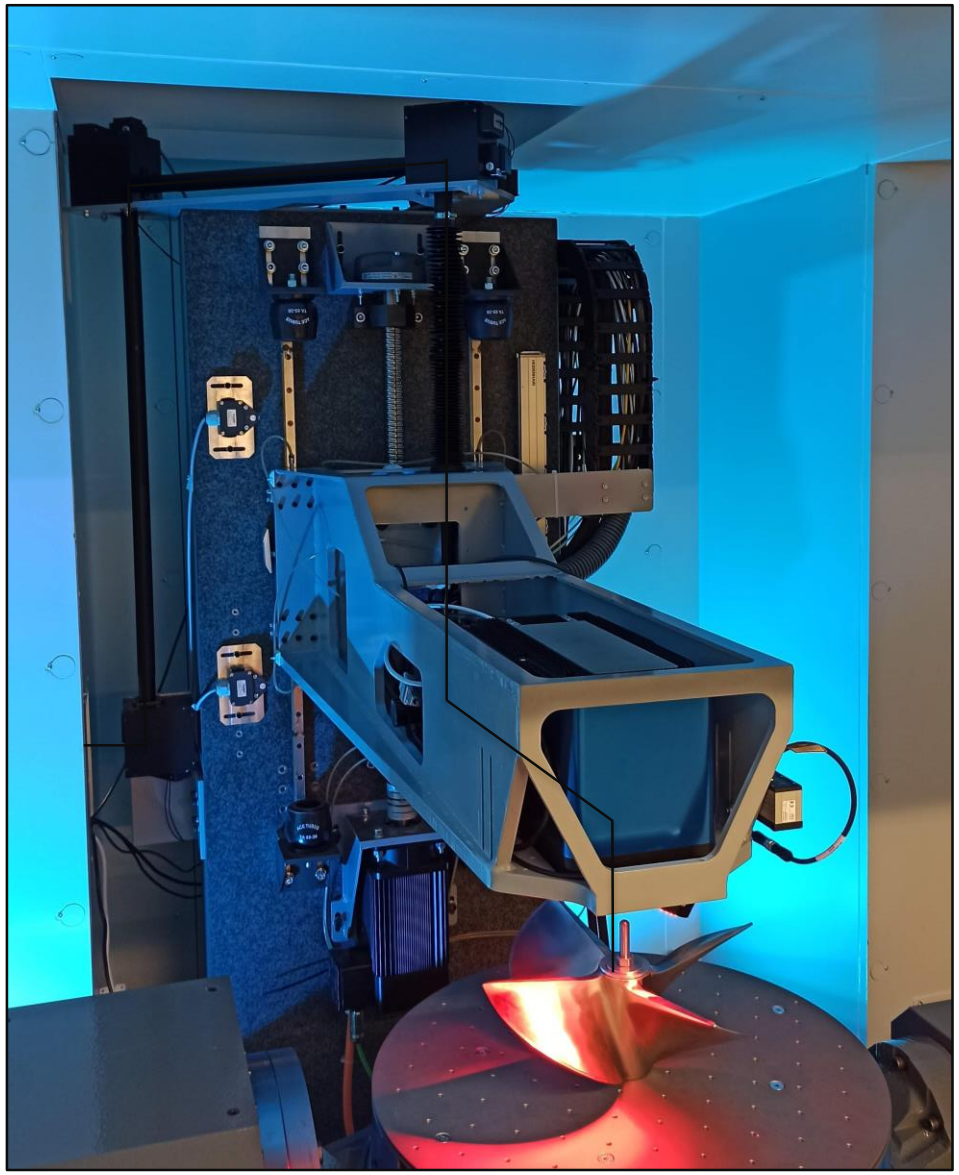


Pre-scanner box:

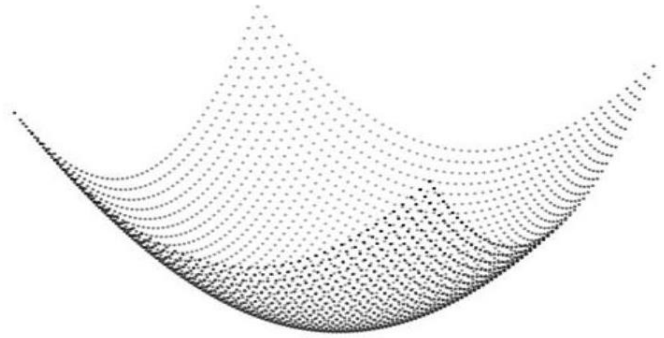
- 1 power meter
- 1 lambda/2 plate for polarization adjusting



Scanner: - 3 axes scanner, without F-theta lens.
Accurate 3D calibration needed



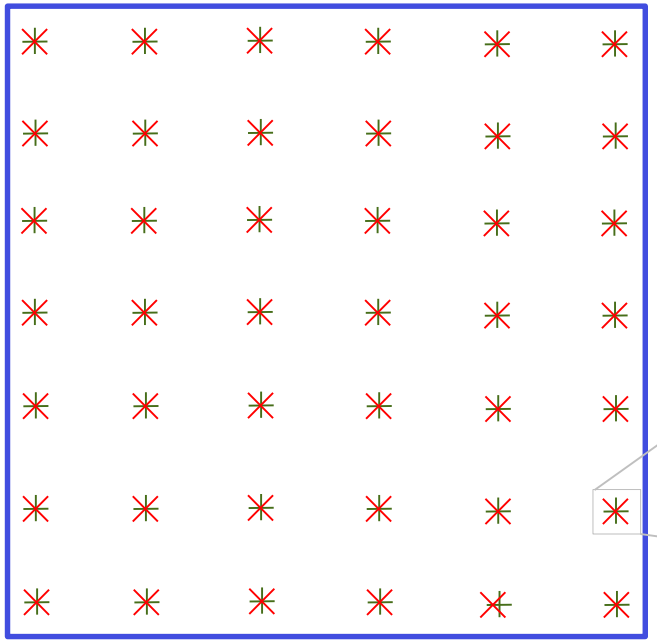
Scanner calibration



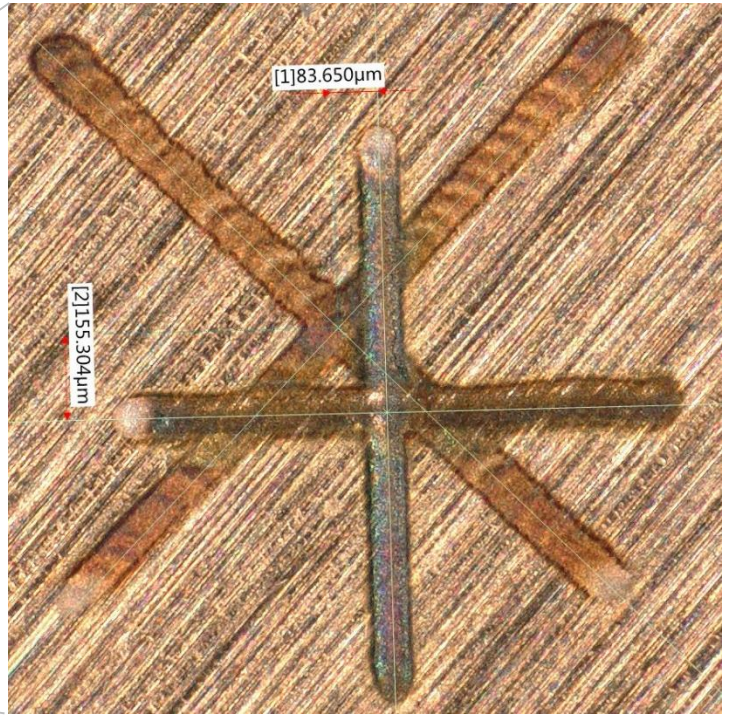
Scanner without a f-theta lens ⇨ Paraboloid on-focus surface

Set up the FemtoSurf **field flattening algorithm**:

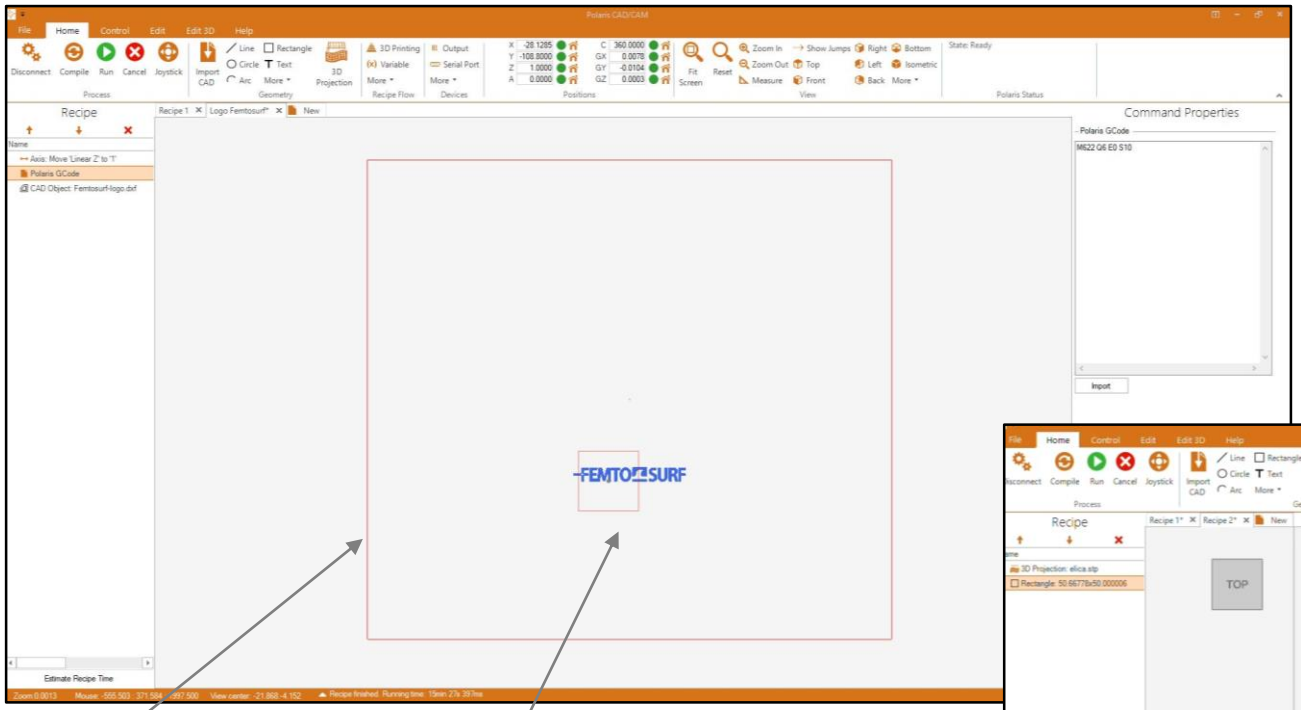
1. Mark the green crosses moving the mechanical axes (stationary galvo axes)
2. Mark the red crosses moving the galvo axes (mechanical axes stationary)
3. Repeat the operation for 3 different heights
4. Measure the X and Y offset error and enter the values on the control platform



Total scan area



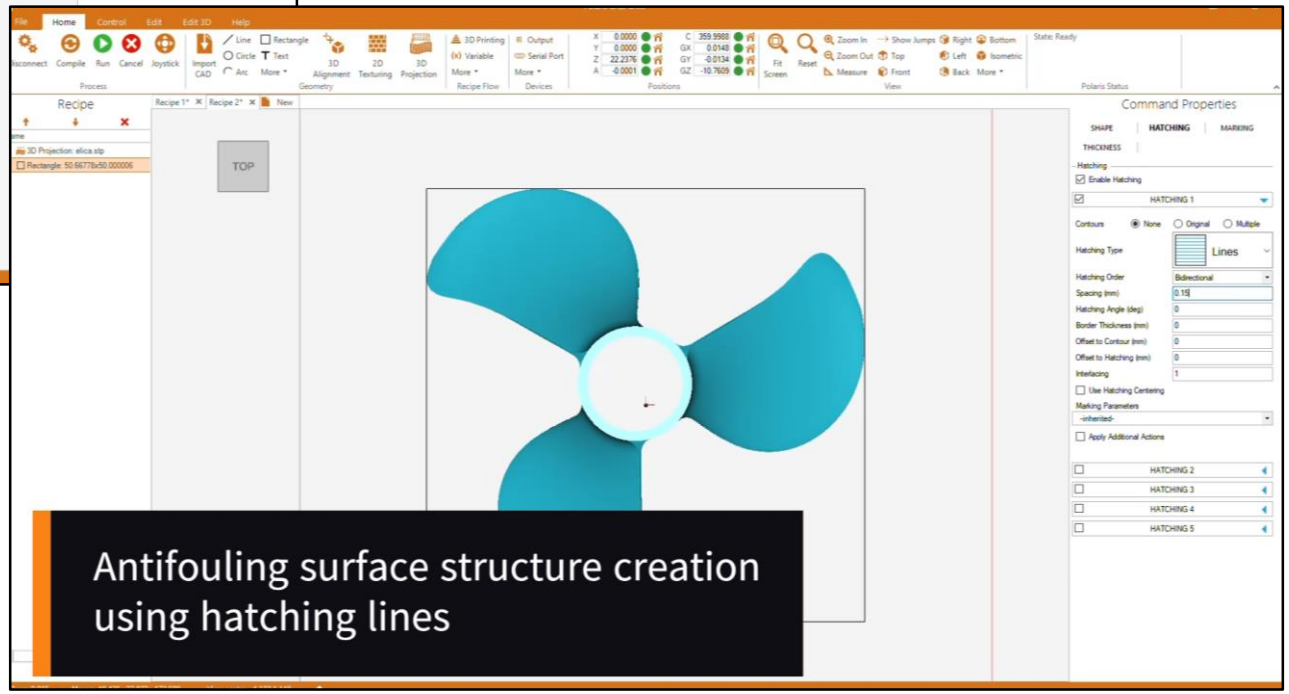
FemtoSurf CAD-CAM software



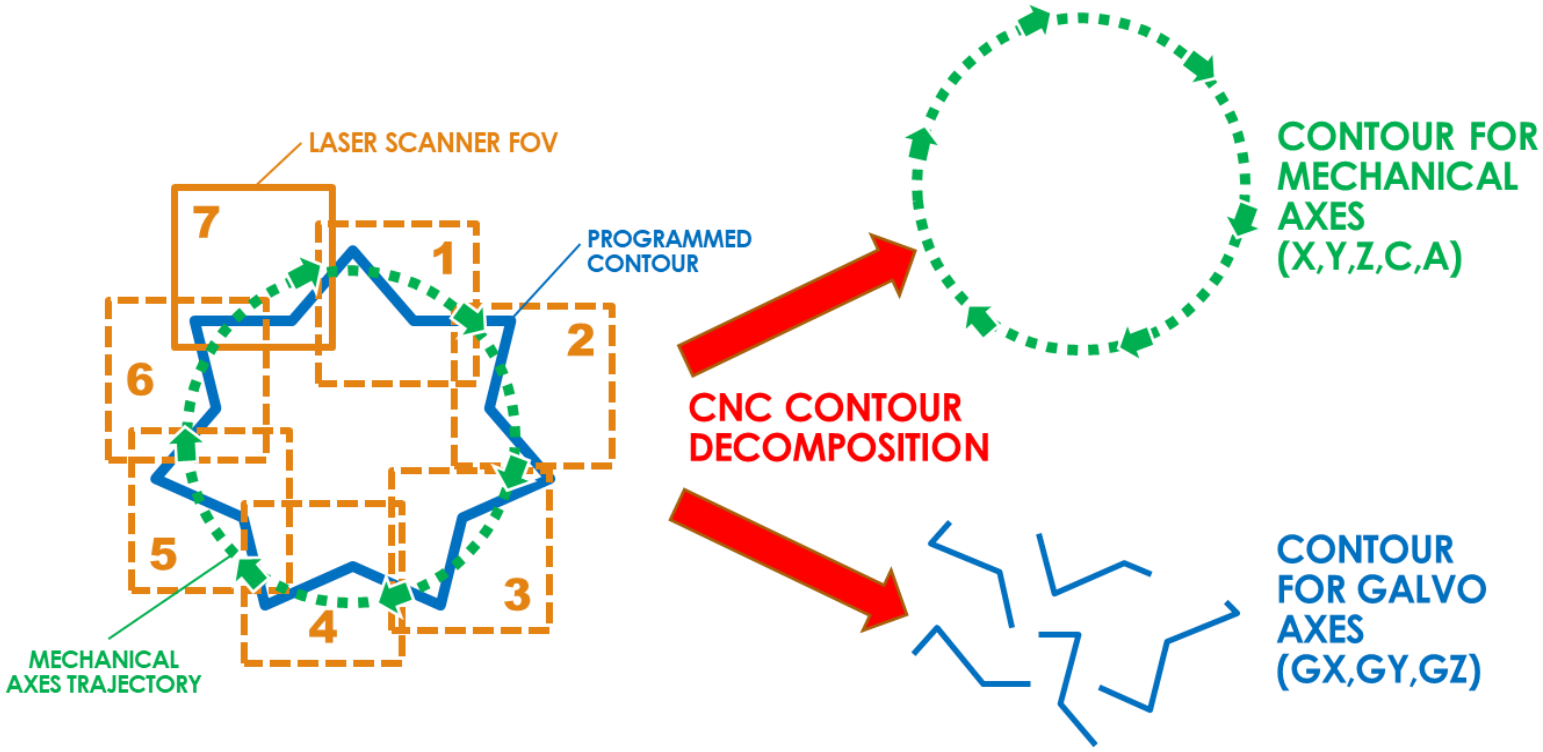
Total working area
600x600mm

Scanning area
80x80mm

Part program generation for processing of propellers



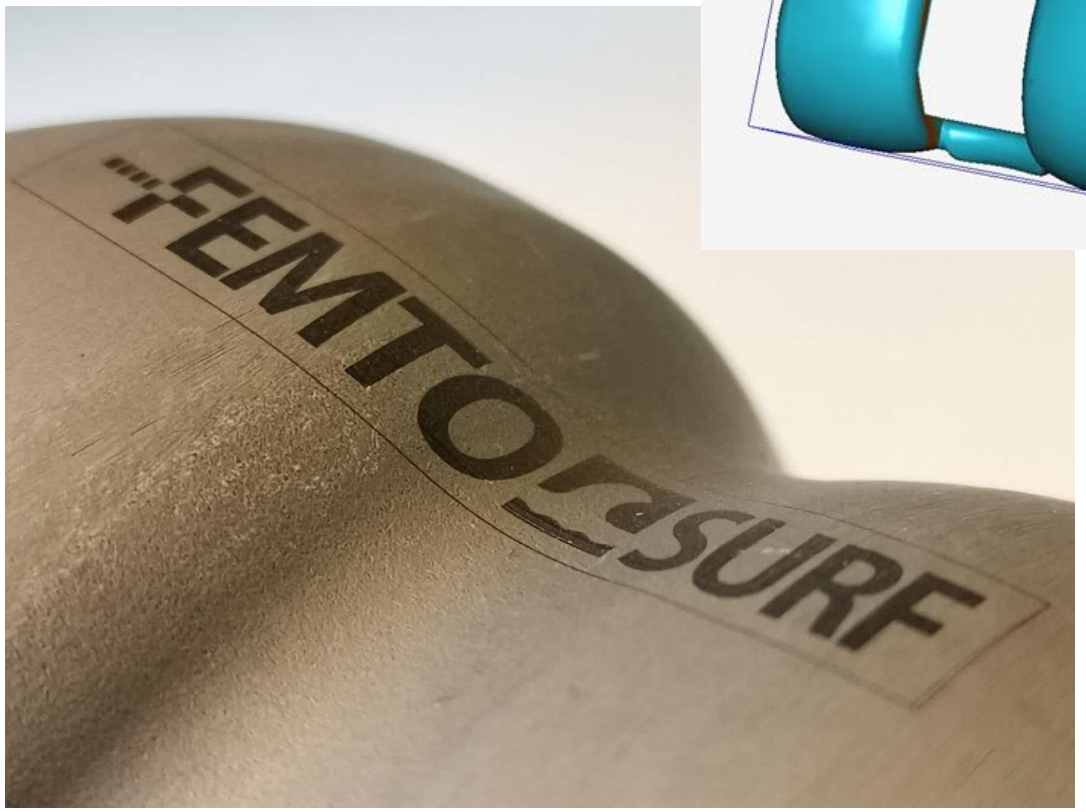
Infinite Field of View with 8 axes interpolation

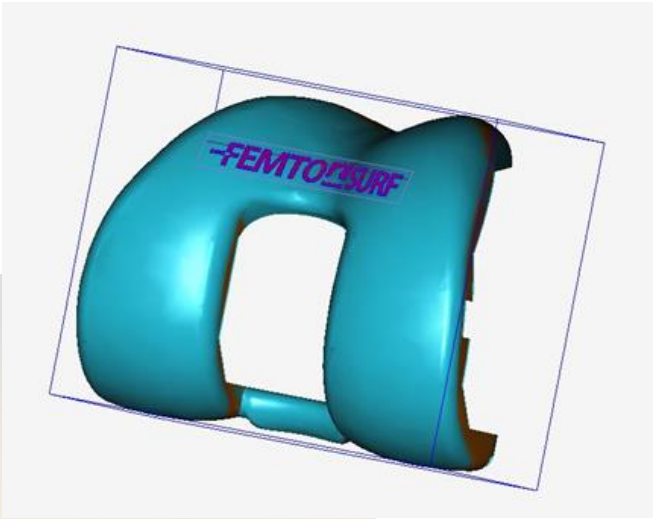


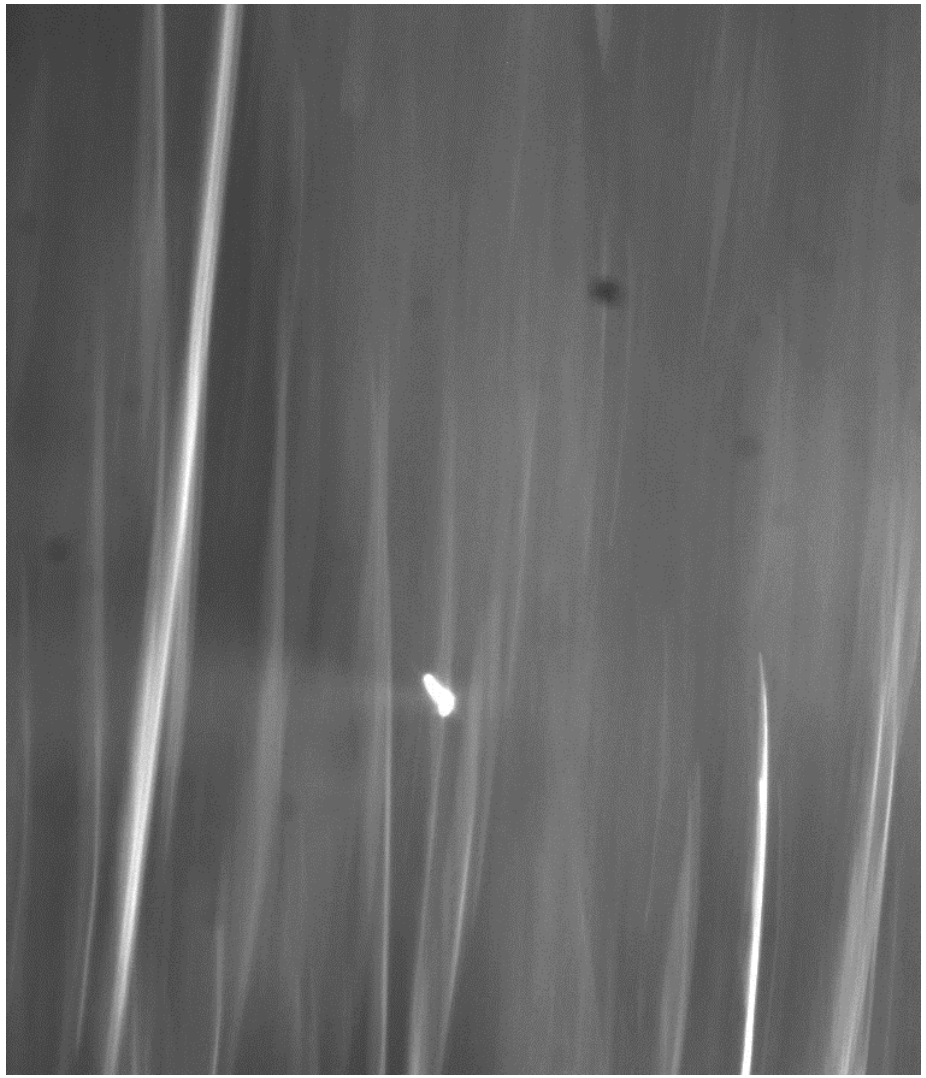
Laser processing with IFOV

Titanium implant with complex geometrical shape

Marking as «**focus-test**», with speed of **3 m/s**







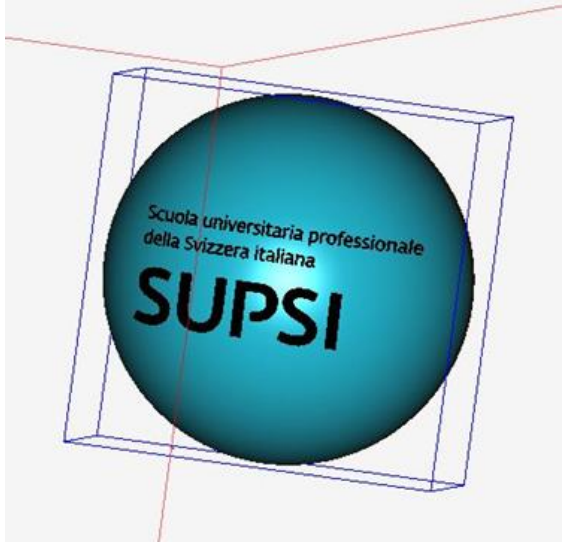
Laser processing of a highly reflective chromed sphere

Marking test on small components.

Speed of 3 m/s

Grid and SUPSI logo on a spherical surface with 25 mm diameter

Minimize the incident angle to avoid radiation reflection

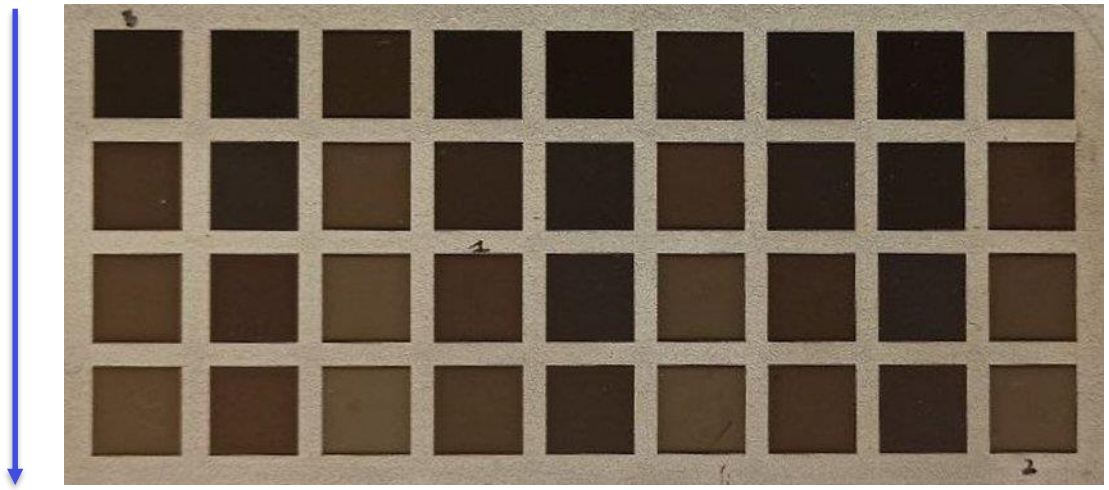


Experimental campaign for hydrophobicity of stainless steel

DoE for optimizing recipe for hydrophobicity of **stainless steel**.

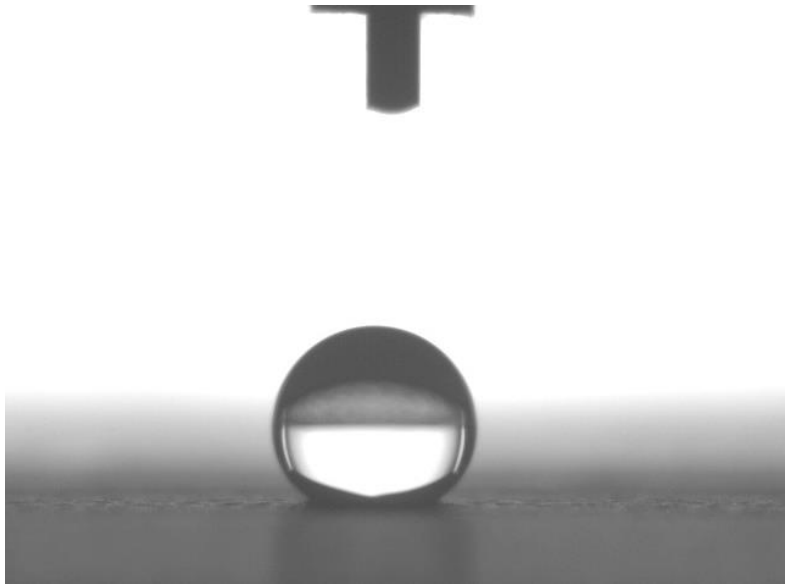
Goal: Find a good trade-off between processing time and hydrophobicity.

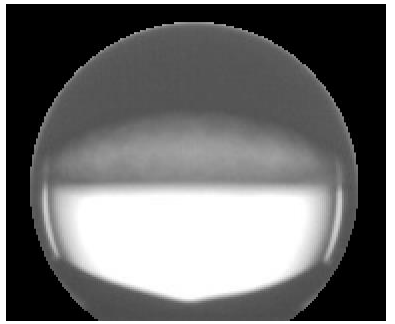
Hatching Distance



Scanning speed

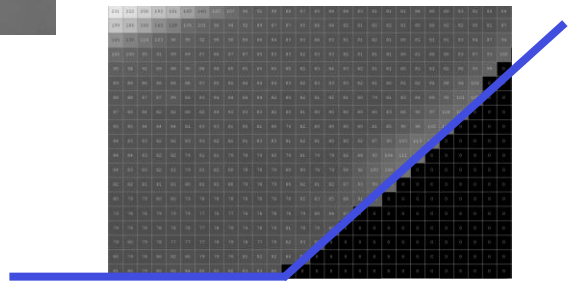
Each sample has been tested measuring the static contact of distilled water on the tested surface.





Analyse Pixel Image to get Contact Angle

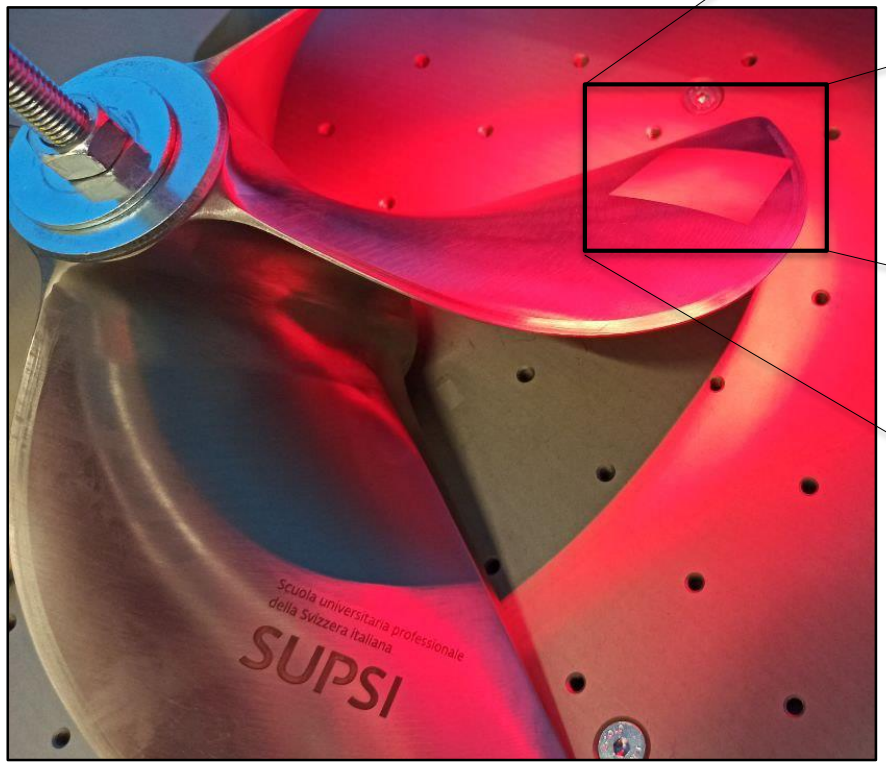
Selected Process Parameters Set
Power: 200 W
RR: 1 MHz
Speed: 3 m/s
Hatching Distance: 15 microns
Bidirectional lines, X, Y



Contact Angle: 141.5 °

Processing of the propeller with the selected set of process parameters

First test of surface structuring of a propeller's blade using an **IFOV program** (June 2022).



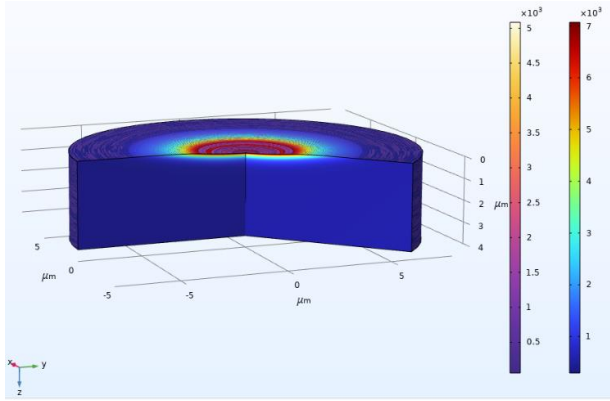
A complete propeller will be functionalized. It will be tested by end-user to valuate **hydrophobic property**.

FemtoSurf: Conclusions and future applications

FemtoSurf represents a **novel machine** solution for **fs laser processing** of big parts and batches of small parts with high working throughput.

Future developments in **increasing the throughput** for fs laser based industrial processes.

Future developments in **process simulations** with multi-physics programming.

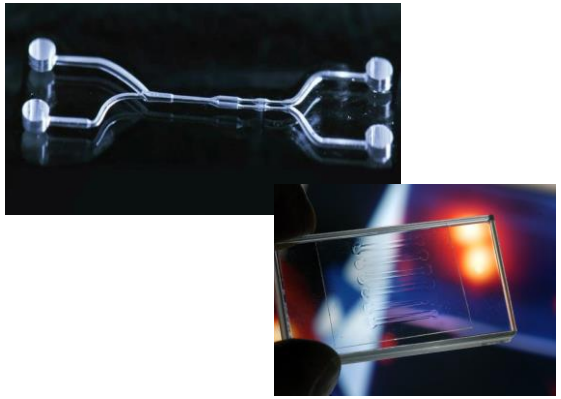


Metals

- Surface structuring
- Cutting and drilling of thin films

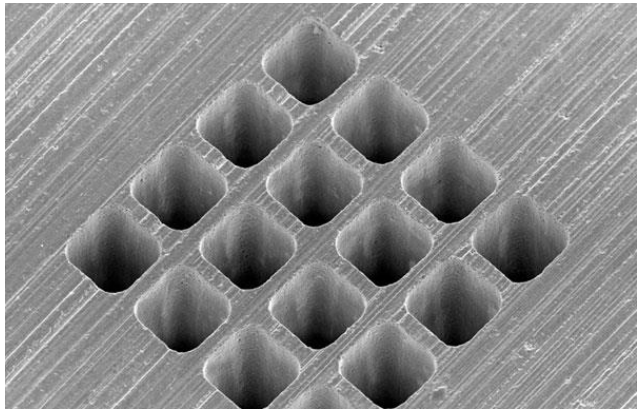
Glasses

- Cutting and drilling of glass substrate
- Selective laser etching
- Anti-reflective coating on glass components
- Laser welding



Ceramics

- Cutting and drilling of ceramic plates



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Thank you for your attention

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LE MONDE DE LA HAUTE PRÉCISION