FEMTOSURF

Surface treatments using ultra-short pulse femtosecond laser

Public Summary

D5.4 Final sensing system configuration and validation

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Disclaimer

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Introduction

The instrumental feature of the FemtoSurf machine refers to the capability to target performance thresholds under the energy efficiency, product quality, productivity, and process quality perspectives. These targets are only possible with a set of sensing systems able to combine its scanning data, monitor and harmonize that data to retrieve important and valuable information before and after the FemtoSurf machine's 3D surface texturing process. Work package 5 is dedicated to implement these advanced quality control measures with different macro-scale to nano-scale metrology systems for fully digitalized process monitoring and control needed to ensure defect-free manufacturing processes.

To achieve these goals, the project partners Heliotis and Ramteid provided three needed vision-based sensing components and integrated those into two metrology solutions: The so-called *outside* and the *inside* metrology solution.

Outside metrology solution

The first solution is called the *outside* metrology solution. This solution consists of the following three core components:

1) a KUKA robot provided by SUPSI,
2) an Artec 3D Space Spider scanner as first sensing system provided by Ramteid,
3) an enhanced Heliotis H8 white-light interferometry system.

The final lab-setup at Heliotis for this metrology system is shown in Figure II.

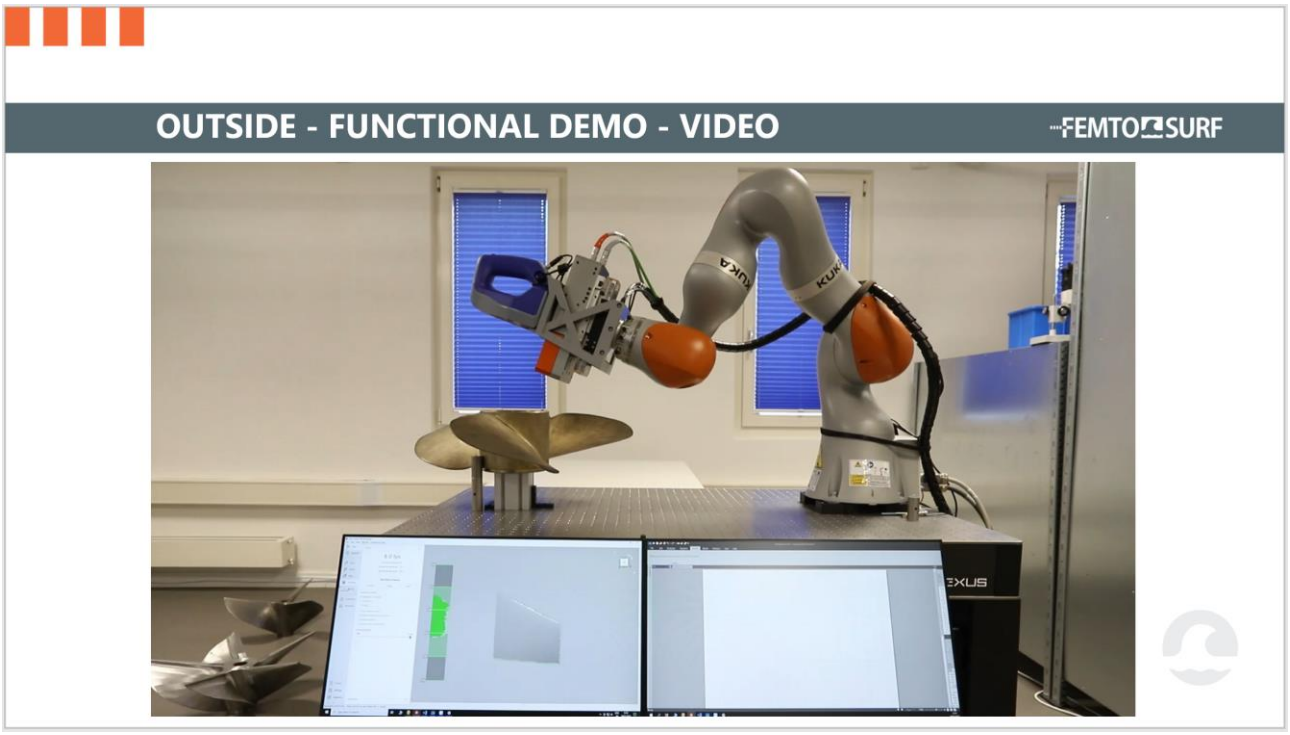

Figure II: Functional demo of outside scanning solution @ Heliotis.

Validation of the important system requirements of the *outside* solution:

1) **Important robot features:**

   Capable of hosting the weight of the two sensing systems and accompanies infrastructure at high accurate repositioning accuracy. Reachability for all use-case parts, ranging from boat propeller size to dental implant size.

   Validation result: The selected KUKA robot model fulfills all required features.

2) **Important macro sensing system features:**

   3D scanning precision, resolution, and accuracy better than 100 microns. Light weight, compact, self-containing, robot mountable. SDK/API available for software integration. Not sensible to vibrations of the robotic arm.

   Validation result: The selected commercial 3D scanner Artec 3D Space Spider fulfills all required features without any need of hardware modifications.

3) **Important nano sensing system features:**

   Texture scanning resolution and precision for the FemtoSurf designed surface texture pattern, instrument reachability for large and small use-case parts. Not sensible to vibrations of the robotic arm.

   Validation result: The Heliotis H8 was selected with an updated image sensor. An additional linear axis was a needed enhancement. With these updates and enhancements and suitable optics, the Heliotis system is able to fulfill all required features, even mounted on the robot.

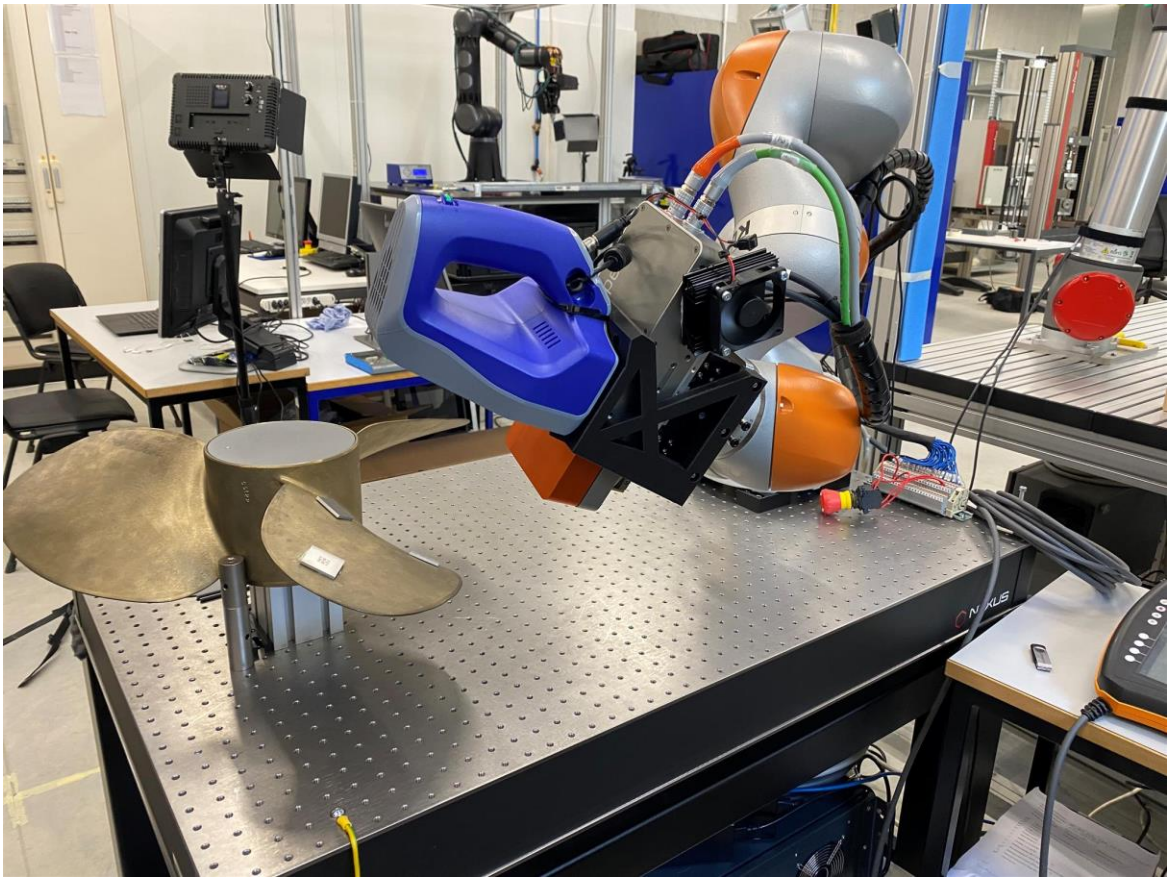

Figure III: Final installation of outside solution @ SUPSI.

Inside metrology solution

The second sensing solution is called the *inside* metrology solution. This solution consists of the following two core components:

1) A custom 3-arm delta gantry structure for providing three degrees of freedom (3DoF) for XYZ movements developed by Ramteid for 2) hosting a camera constellation of up to five high-performance and high-resolution industrial vision cameras also provided by Ramteid.

Photos during the functional validation in the final setup directly on the FemtoSurf machine's cantilever head at SUPSI for this metrology system are shown in Figure IV.

Figure IV: Final installation of inside solution @ SUPSI.

Validation of the important system requirements of the *inside* solution:

1) **Important gantry & motion features:**

   XY-axes to cover of at least 10cm by 10cm. Z-axis movement of at least 20cm. High-precision, zero-vibration Z-axis movement during scan process. Positional repeatability.

   Validation result: The custom-developed gantry structure conforms to all enclosure limitations and the delta movement motion system fulfills all reachability and operational requirements.

2) **Important camera constellation features:**

   Same spot focus of all cameras. High-data transfer rate of all cameras in parallel. Illumination support. Low weight. Low infrastructure and cabling needs.

   Validation result: The custom developed camera constellation fulfills all requirements.

Calibration token

Ramteid and SUPSI developed a calibration token (see Figure V). This calibration token is used for acquiring all six dimensions of freedom of the part consisting of the three planes of motion and three axes of rotation with multiple same-time shots from the cameras of the camera constellation attached to the FemtoSurf machine cantilever head.

Figure V: Calibration token.

Validation of the *outside* metrology solution

The outside scanning solution was tested with a selected ROLLA propeller having three calibration tokens attached and both metrology systems in parallel on the robot:

1) With the H8 from Heliotis, the corners of the calibration patterns (see Figure VI, left) and the corners of the tokens itself were scanned, beside selected surface areas (to be compared before and after FemtoSurf 3D laser texturing / processing).

   The validation of the H8 for surface texture scanning was successful: standard H8 scanning functionality can be used on the robotic solution without any degradation of the retrieved scanning result data in contrast to a stationary set-up of the H8.

2) Using the Artec 3D scanner provided from Ramteid, the full propeller blade was scanned (see Figure VI, right) including the calibration tokens.

   The validation of the Artec 3D scanner for macro-object scanning and calibration token detection was successful: The gathered 3D topology and texture data is precise enough for scan-to-CAD comparisons and for calibration token border & corner detection with sub-pixel interpolation techniques, which is important for the coordinate system referencing on the machine itself with the inside sensing solution.

This validation of FemtoSurf's outside sensing solution shows: the integrated robotic solution fulfills all requirements.

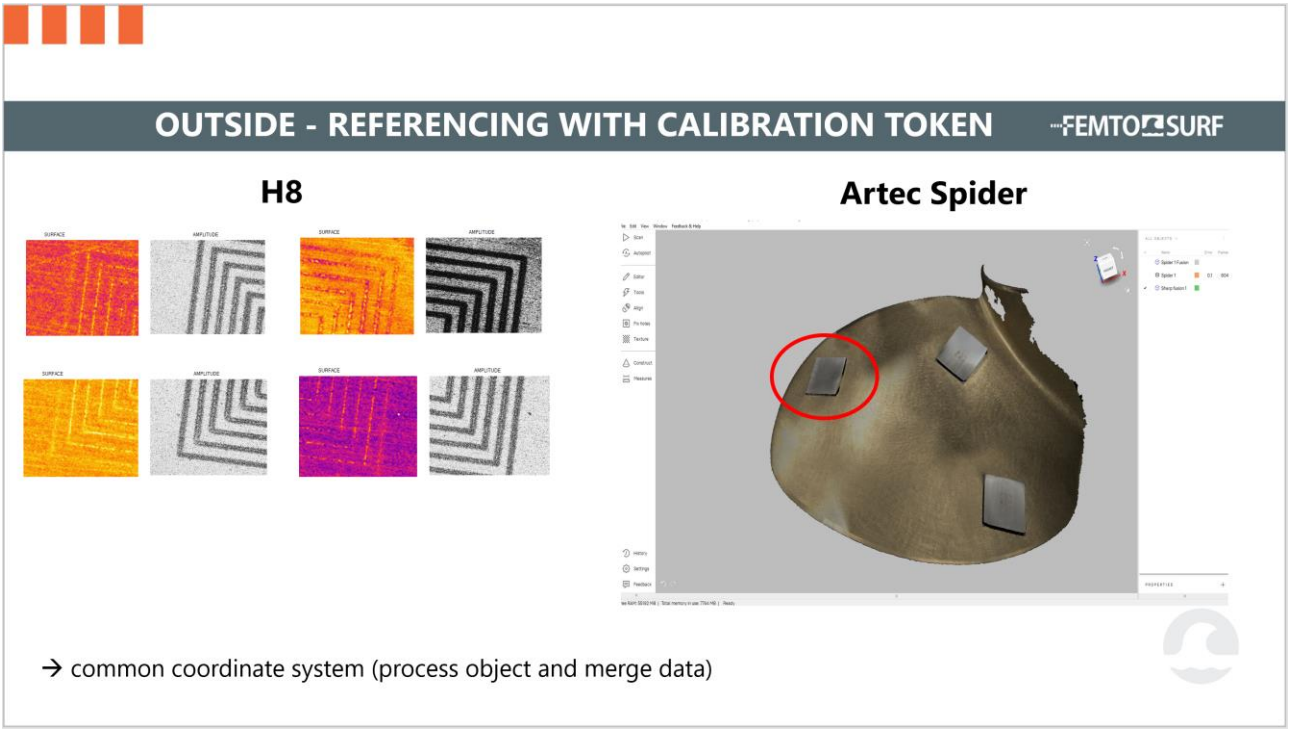

Figure VI: Calibration token scans with H8 (left) and Artec 3D Space Spider (right), ROLLA propeller with calibration tokens attached.

Validation of the *inside* metrology solution

The most important functionality of the inside metrology solution is the high-precise measurement and referencing of all six degrees of freedom for at least three calibration tokens either directly attached to or textured onto large use-case objects itself. This is performed with sub-pixel computational methods bases on the image sensor's outstanding optical resolution of about 2 microns by 2 microns in physical space (near the optical border at 1 micron) for each monochrome pixel digitized at up to 12-bit resolution.

For dental implants or tiny AEREA use-case objects which are too small for hosting the calibration tokens, the tokens are attached to or textured onto a mounting plate.

Figure VII shows the overview image (on the left) and the detail image of the calibration token center spot (on the right) taken with the center camera of the camera constellation attached to the FemtoSurf machine's cantilever head targeting a calibration token lying on the machine's rotary table.

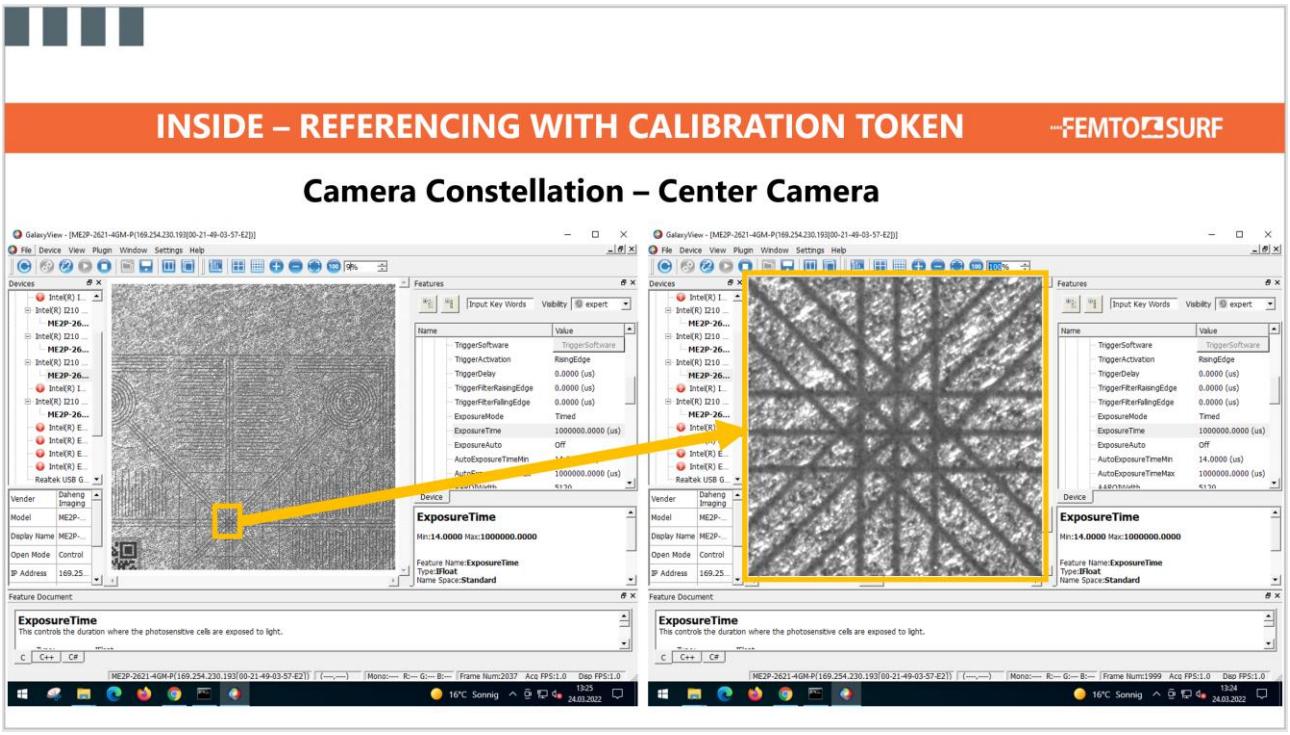

Figure VII: Calibration token scan on FemtoSurf machine with center camera of camera constellation.

The validation of FemtoSurf's inside sensing solution shows that the camera constellation fulfills all requirements.

Conclusion

With the validated features of both, the outside and the inside, metrology solutions in combination with the calibration token as a relational and calculational basis for combining the different coordinate systems of the integrated sensing systems, all known use-cases of the FemtoSurf machine should be supported at the required resolution and precision and, thus, achieve all defined requirements.

List of Acronyms

European Commission	EC
Deliverable	D
Task	T
Work Package	WP
Project partner Heliotis	HELIOTIS
Project partner Ramteid	RAMTEID
Project partner Femtika	FEMTIKA
Project partner SUPSI	SUPSI
Project partner Rolla	ROLLA
Project partner Aerea	AEREA
Hardware	HW
Software	SW
Computer Aided Design	CAD
Gigabit Ethernet Vision	GEV
Gigabit Ethernet	GIGE
Gigabit Ethernet Vision	GigEVision
Heliotis HeliInspect H6 metrology system	H6
Heliotis HeliInspect H8 metrology system	H8
Megapixel	MP
Three dimensions of freedom	3DoF
Six dimensions of freedom	6DoF
Data consisting of X-, Y- und Z-coordinates	XYZ