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High-Resolution 3D Sensors for Automated Inspection of Microstructures and Surfaces

“Measure what is measurable and make measurable what is not so.”

- Galileo Galilei

3D Topologies hold a lot of details

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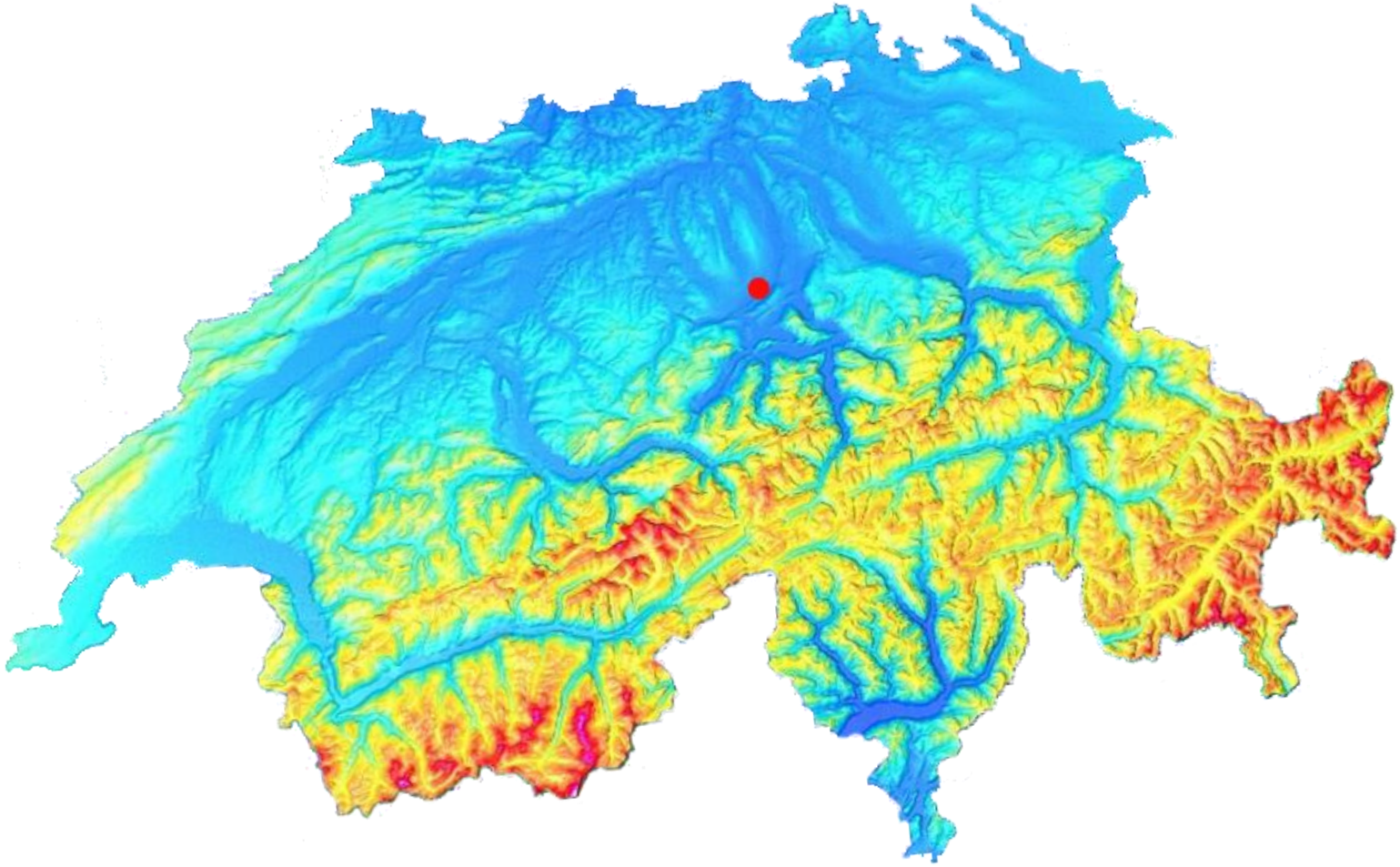
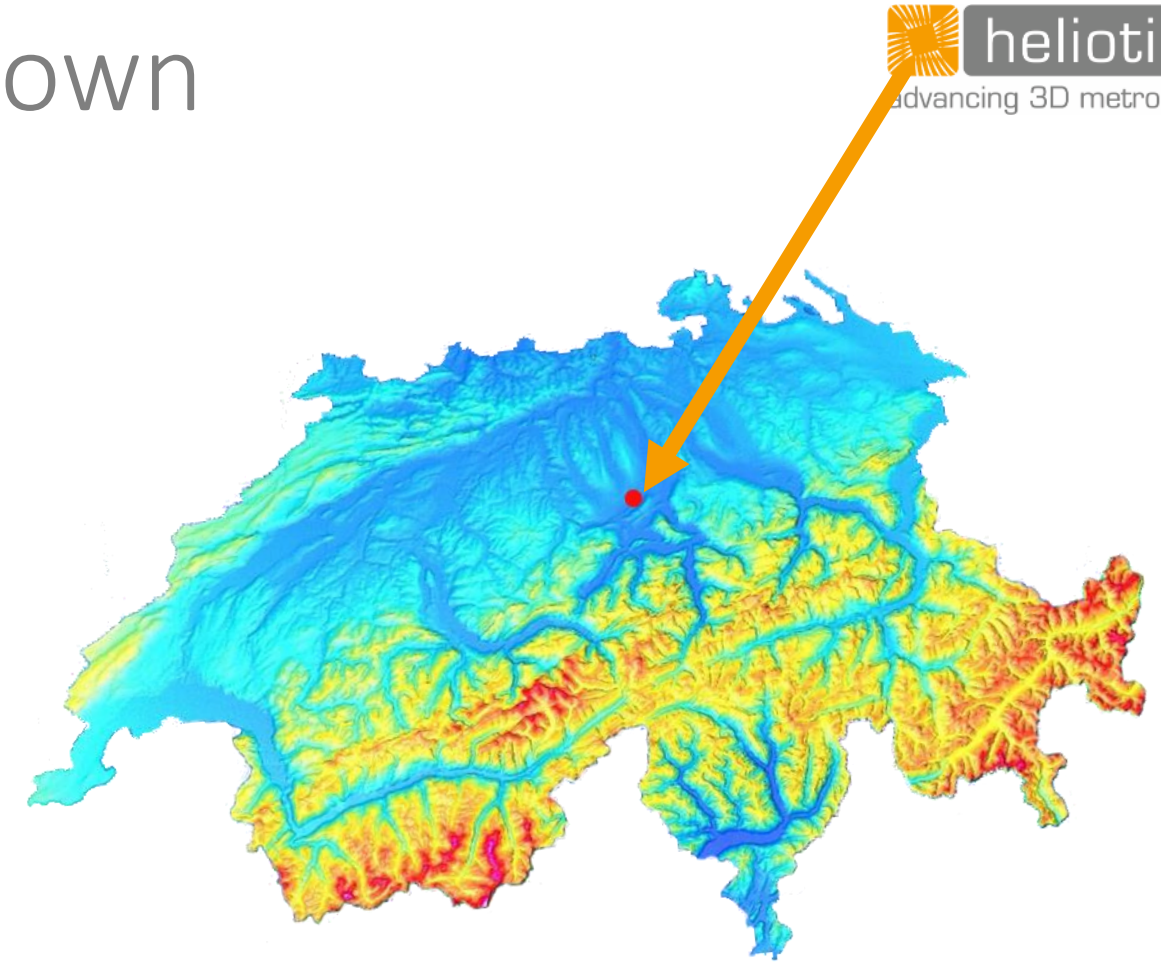


Switzerland

- North/South: 220 km
- West/East: 348 km
- Area: 41’285 km^2
- Lowest point : 193m asl.
- Highest point: 4636 m
- Area above 2000m : 23%
- Mountains > 4000m : 48

Source: swisstopo

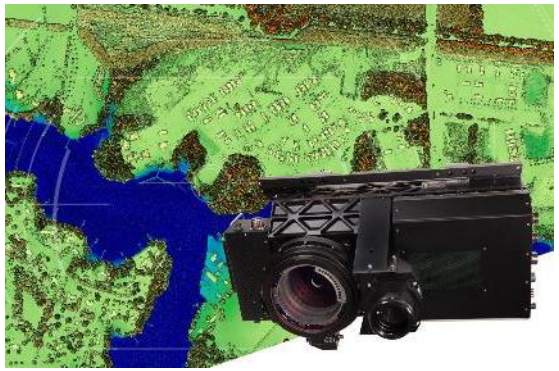
Now, scale the model down by 1 : 100 000 000 => 1km becomes 10um



Then, the heliInspect H8/H9 can measure in one FOV the entire 3D topology

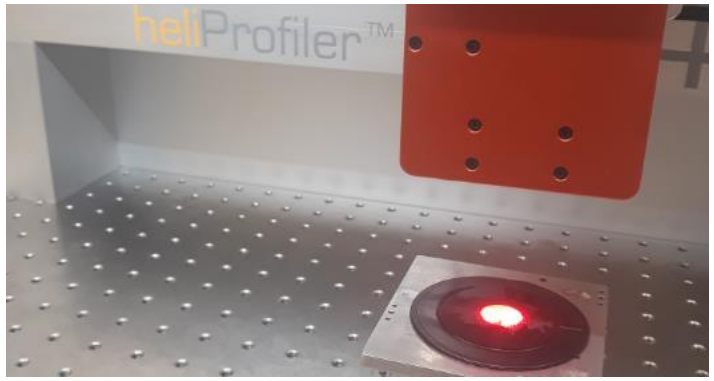
- in less than 100 ms
- with a real-world resolution of 350 m x 350 m
- with a real-world height uncertainty of 0.4 m

Actually, this has been done …



1. The terrain of Switzerland was measured optically with a Leica Topographic LIDAR Sensor

2. The topology was machined optically into metal via fs-Laser and molded into black plastic



3. The miniature topology was measured optically with the industrial White Light Interferometer heliInspect H6

Heliotis – Advancing 3D Metrology

Specialized in 3D metrology for precision applications

- in-house R&D
- in-house assembly and quality assurance
- application-specific designs

White Light Interferometry

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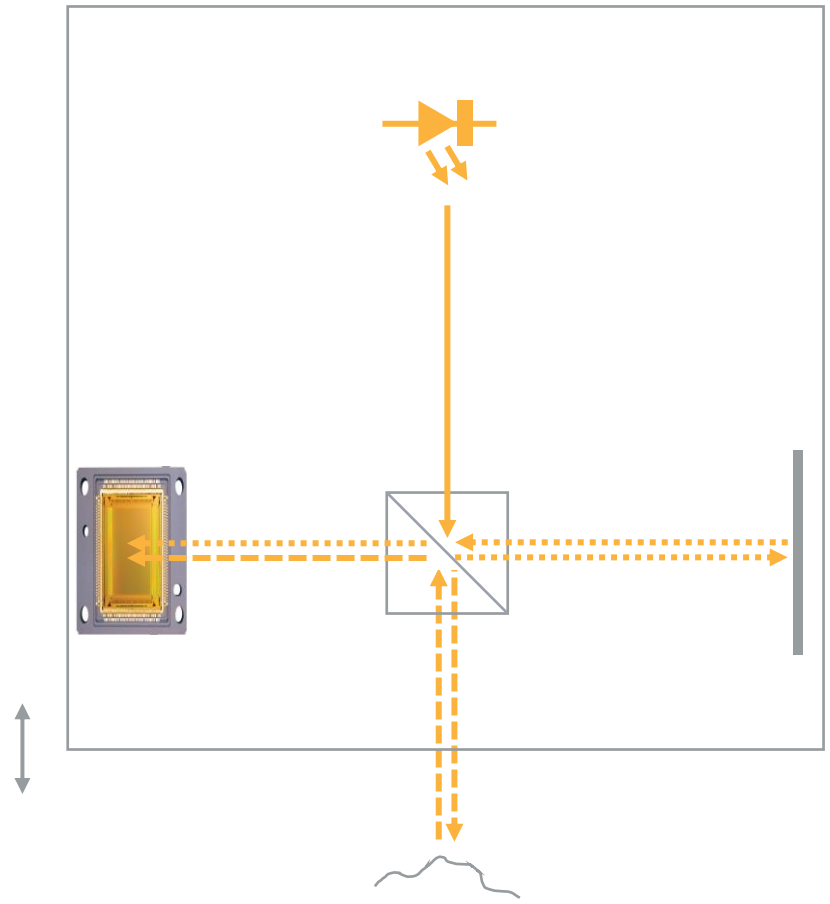

Characteristics of White Light Interferometry

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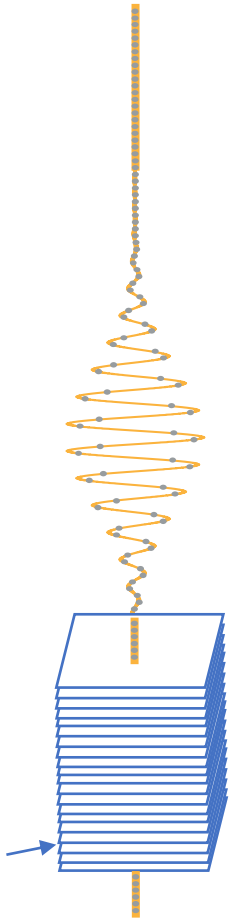
Advantages

- nanometer resolution (interferometric)
- applicable to all surfaces (specular, matt, transparent)
- can do tomography
- can measure deep boreholes (no shadowing effect)

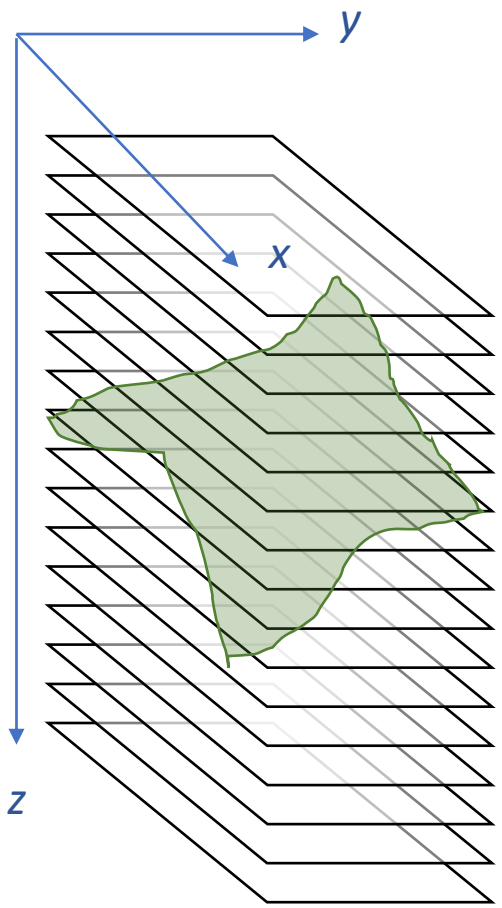


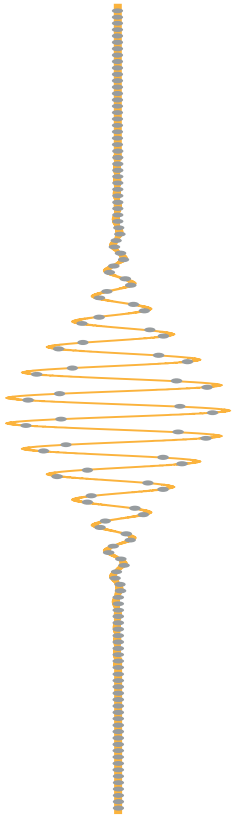
Challenges

- very data intensive / slow
- signal dynamic high

one full image every λ/8
dz ~ 80 nm

Speed Requirements for the Camera





Example:

vertical range: 1 mm
acquisition time: 100 ms
=> scan speed 10 mm/s

LED @ 640 nm
=> sampling distance: 80 nm

} 125’000 fps

Data rate

1Mpix, 16bit ⟹ **2 Tbit/s**

➔ **Limitation: acquistion & data transfer**

In-Pixel Signal Processing
Plus, FPGA-Based Post Processing

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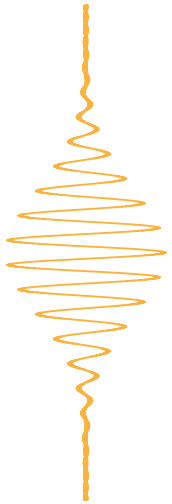

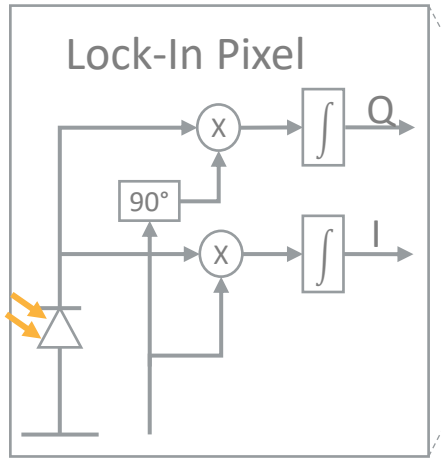

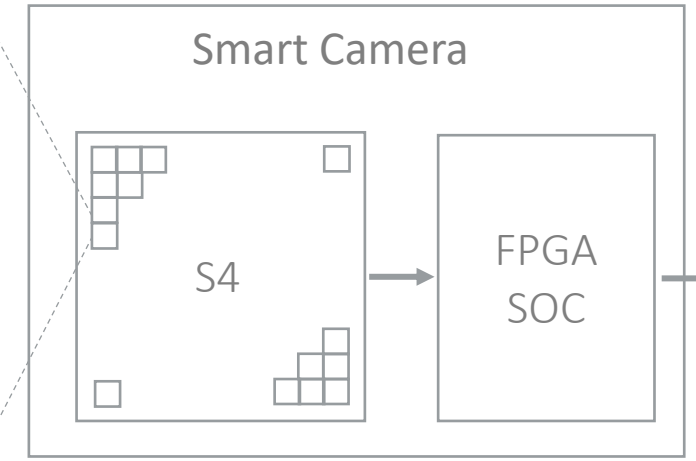

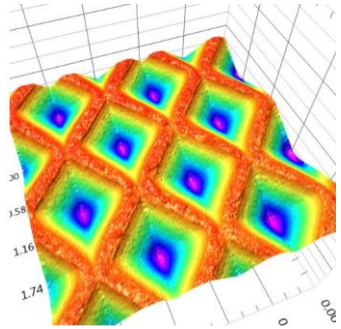

temporal intensity interferogram → analog volumetric (interferogram samples) → digital (10bit) I/Q volumetric data (interferogram envelopes) → digital (32b) surface (height map)

277 billion samples/s → 2 x 1.6 giga raw voxels/s (5800 frames/s) → 44 Mbit/s

Core Competencies in Deep Tech

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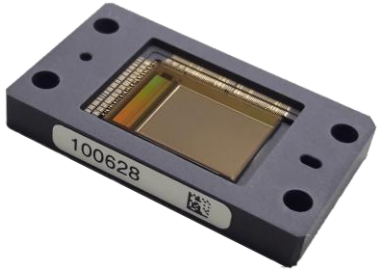


CMOS Image Sensors

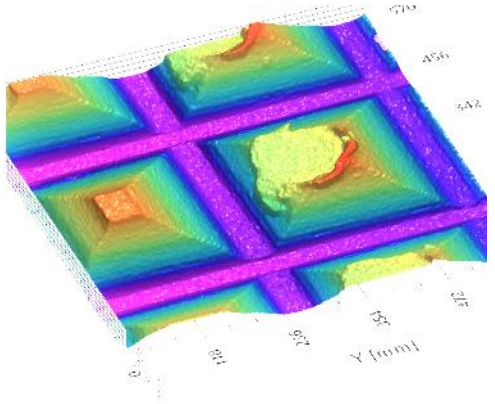
- ASIC development
- pixel-IP
- high-speed interfaces
- fabless
- testing inhouse

Embedded High-Speed Cameras

- high-density PCBs
- FPGA algorithms
- embedded Linux apps
- standard based interfaces

Opto-Mechanics

- optics simulations
- CAD engineering
- sourcing
- assembly (ISO 5)
- testing



3D Image Processing

- Halcon, Matrox, Aurora Vision, Neurocheck, C++, C#, LabView, Python

High Precision Industrial 3D Inspection = Precision x Speed

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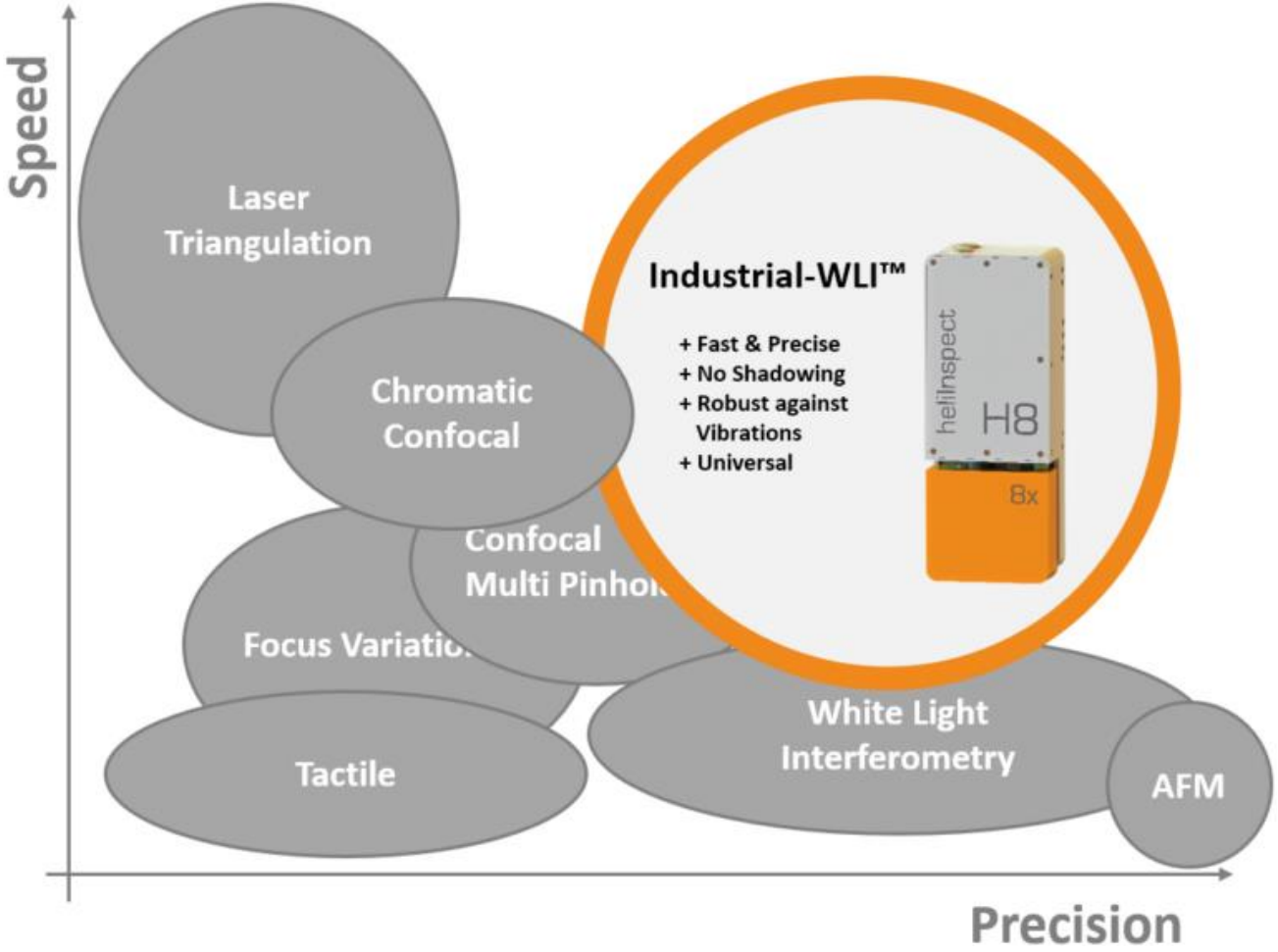
Industrial WLI™ H8 / H9

- geometry
- defects
- planarity
- layer thickness
- surface quality
- transparent materials
- mirroring surfaces



Interferometric Repeatability
No vibration cancelation required

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VLSI Standards Incorporated

NIST FEDERAL INFORMATION SECURITY EDUCATORS FISSEA

PTB
Physikalisch-Technische Bundesanstalt
Nationales Metrologieinstitut

Standard	Step height	Measured Repeatability	Mode
VLSI /NIST	9.9 nm	0.3 nm	Phase
VLSI /NIST	99.6 nm	0.4 nm	Phase
VLSI / NIST	4.5 um	0.004 um	Envelope
VLSI / PTB	201.603 um	0.044 um	Envelop
PTB	899.941 um	0.063 um	Envelope

Where are these sensors used?

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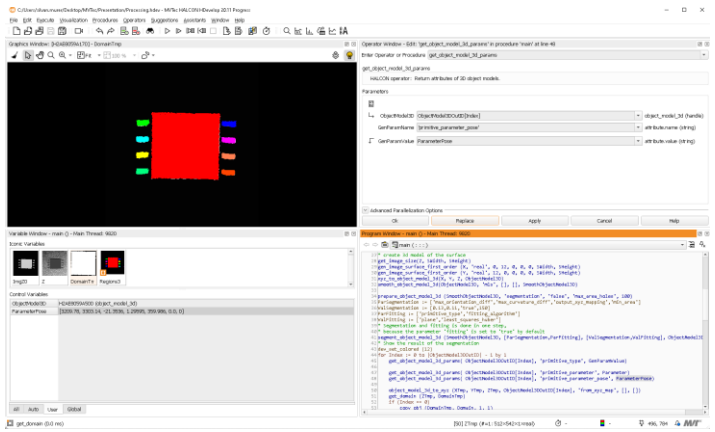

OEM Partners

- inspection machines
- 3D-metrology vendors
- medical diagnostics
- forensic equipment

Vision Integrators

- defect detection
- process control
- geometry
- layer thickness
- surface quality

Machine Builder & Producers

- automotive
- electronics
- medical technologies
- watch industry

Measurements on glass with nanometer accuracy

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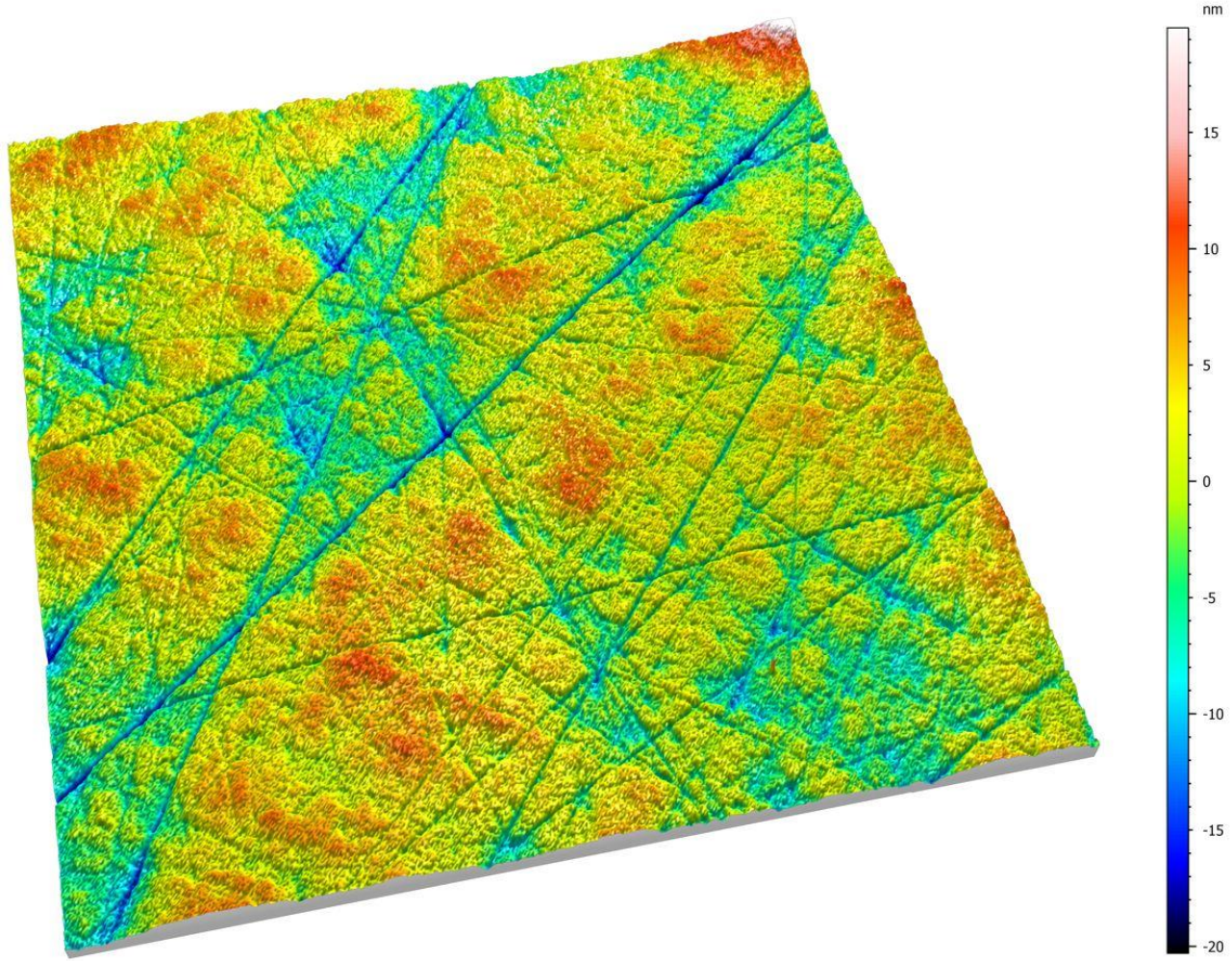
Proprietary phase algorithms for exceptional height resolution

Roughness measurement < 0.2 nm



Micro-Patterning with 3 kW femtosecond laser

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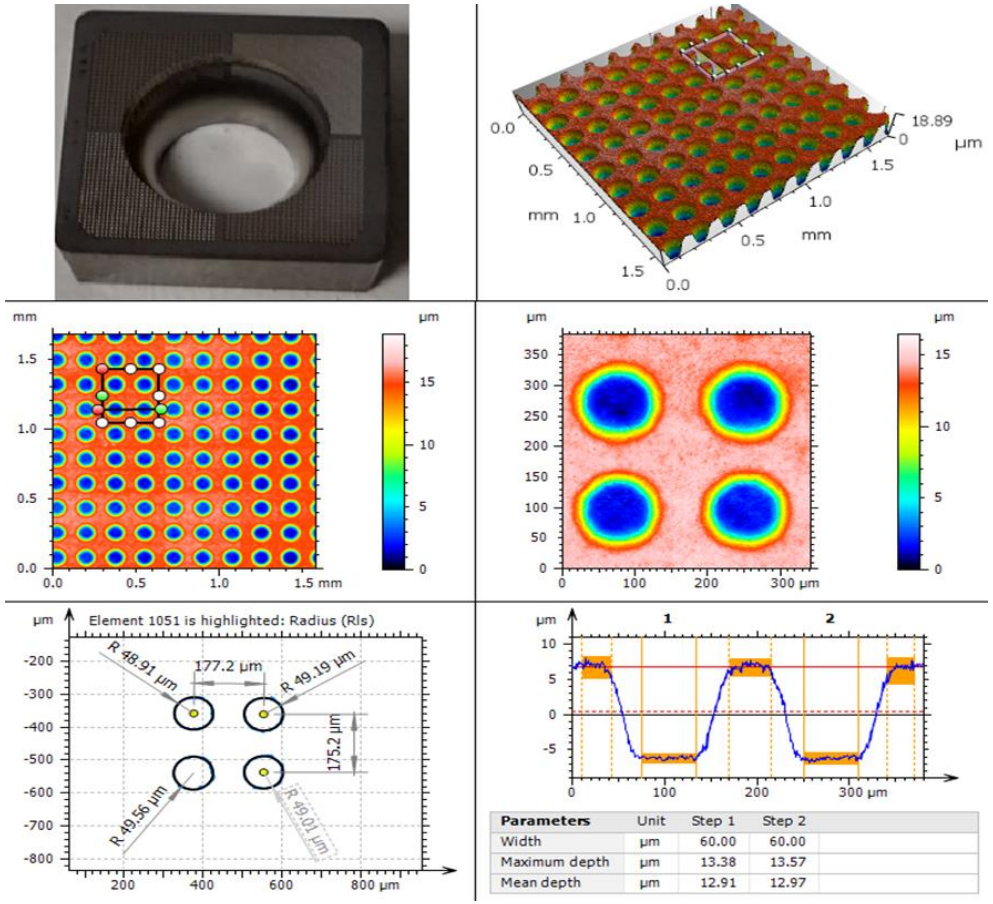
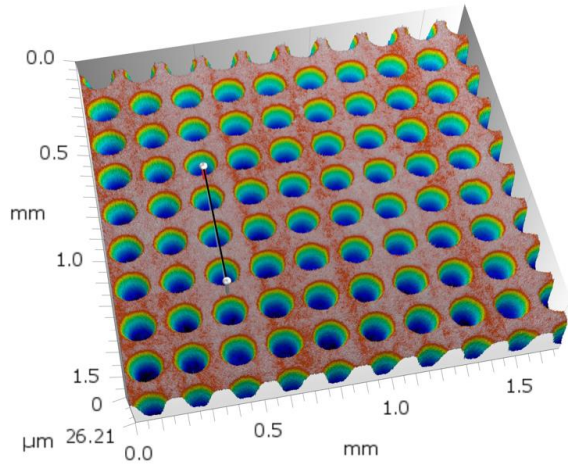
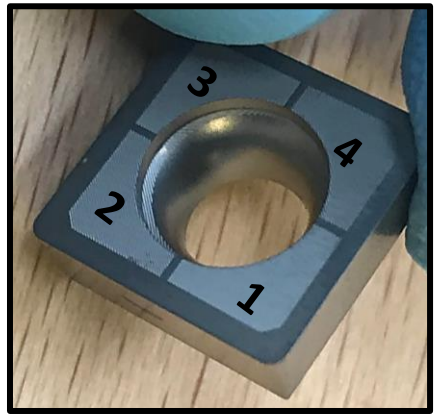
FEMTOSURF







These micro-features are laser textured on the surface of the cemented carbide lathing insert to reduce the cutting forces, and friction between tool rake face and chip during the machining process. It also has shown that it the dimples and grooves can promote hydrodynamic regime transition on the tool's cutting face and hence improving tool life/service performance.

Roughness measurement of laser processed surfaces

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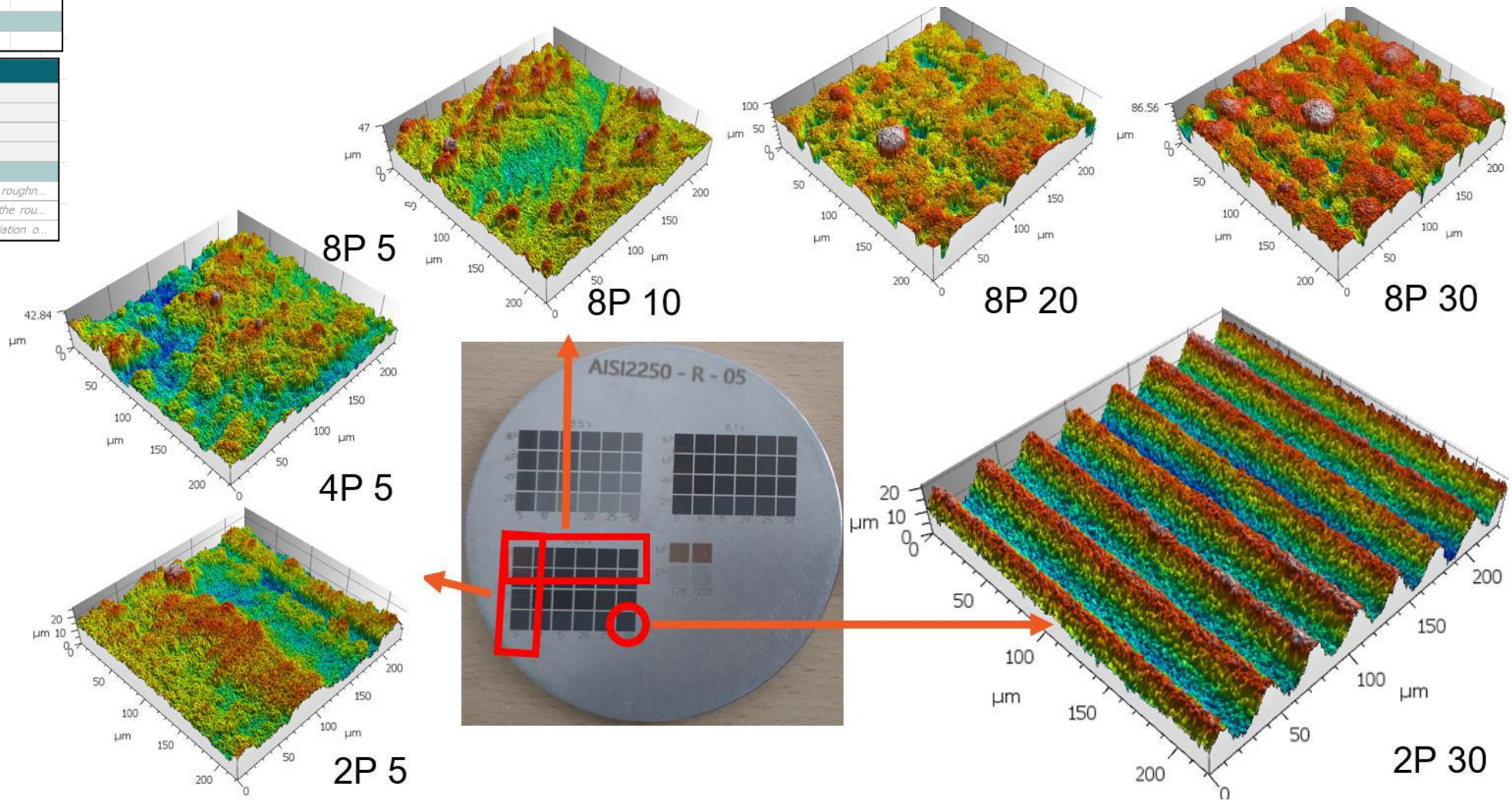
FEMTOSURF

ISO 25178 - Roughness (S-L)			
S-filter (λs): Robust Gaussian (order 0), 0.8 µm			
F-operation: Leveled (TLS), Angle 0.03278°, -0.002131°			
L-filter (λc): Robust Gaussian (order 0), 0.1 mm			
Height parameters			
Sq	4.029	µm	*Root-mean-square height*
Sa	3.207	µm	*Arithmetic mean height*
Spatial parameters			
Sal	5.157	µm	*Autocorrelation length*
Functional parameters (volume)			
Vv	5.975	µm³/µm²	*Void volume*
Functional parameters (stratified surfaces)			
Sk	9.009	µm	*Core height*

ISO 4287 - Roughness (S-L)			
F-operation: Leveled (TLS), Angle 0.0008209°			
S-filter (λs): Robust Gaussian (order 0), 0.8 µm			
L-filter (λc): Robust Gaussian (order 0), 0.1 mm			
Evaluation length: All λc (18)			
Amplitude parameters			
Rv	7.311	µm	*Maximum valley depth of the roughn...*
Ra	2.960	µm	*Arithmetic mean deviation of the rou...*
Rq	3.677	µm	*Root-mean-square (RMS) deviation o...*



Silver paste inspection on solar cells

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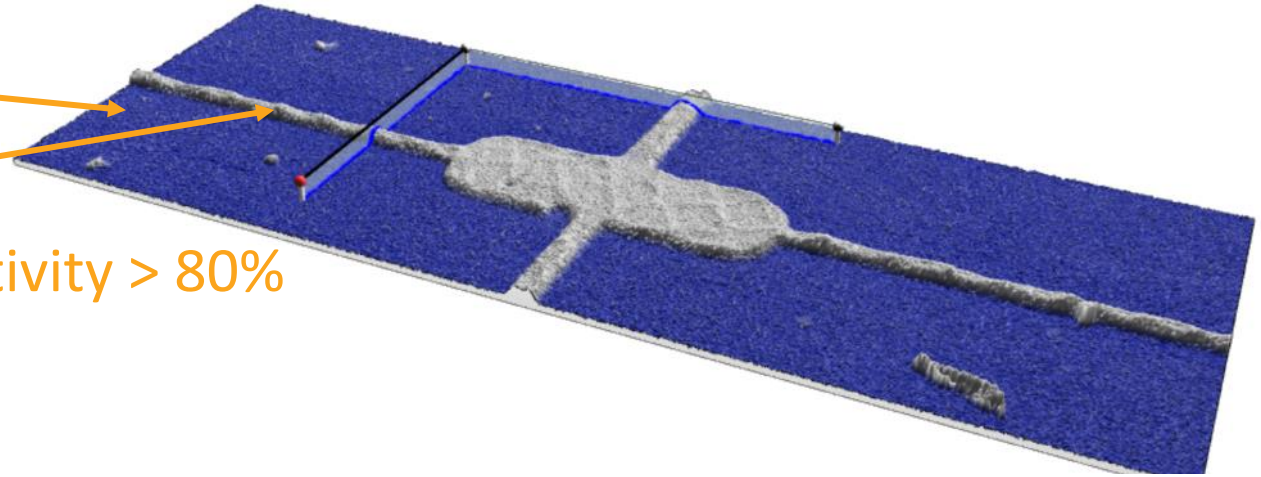
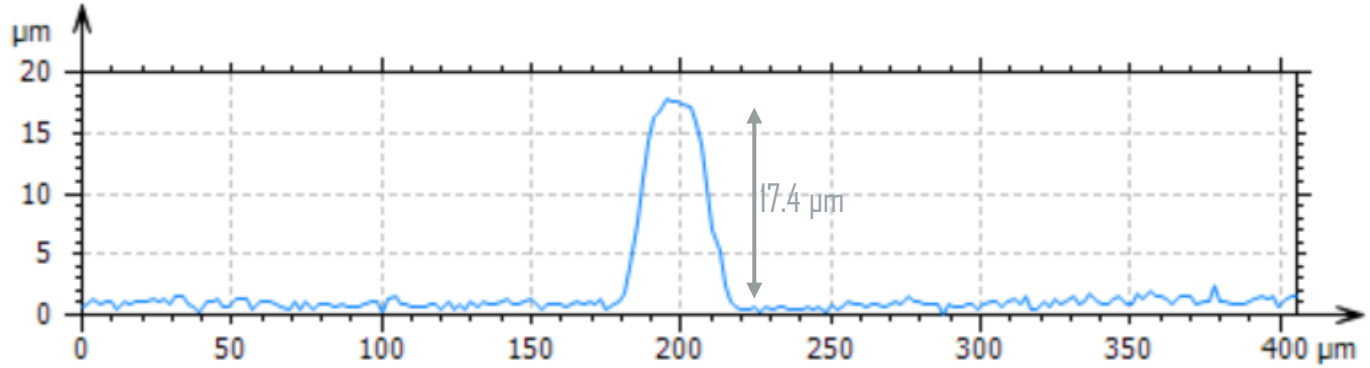
reflectivity < 0.1%



reflectivity > 80%



Edge defects on a gear

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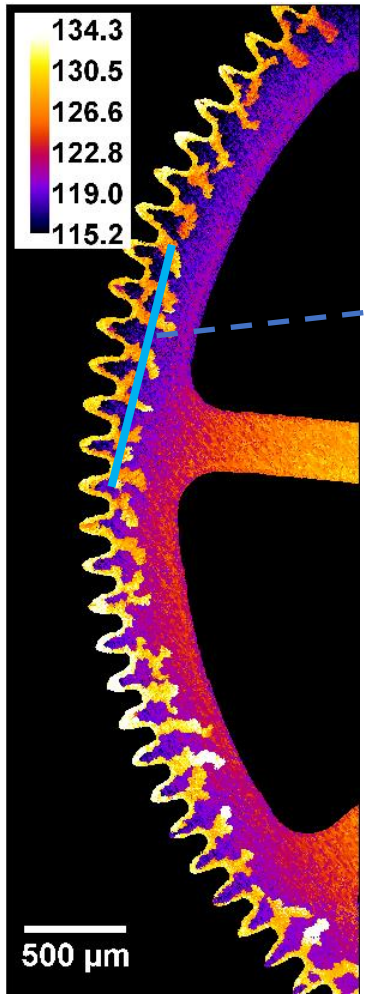

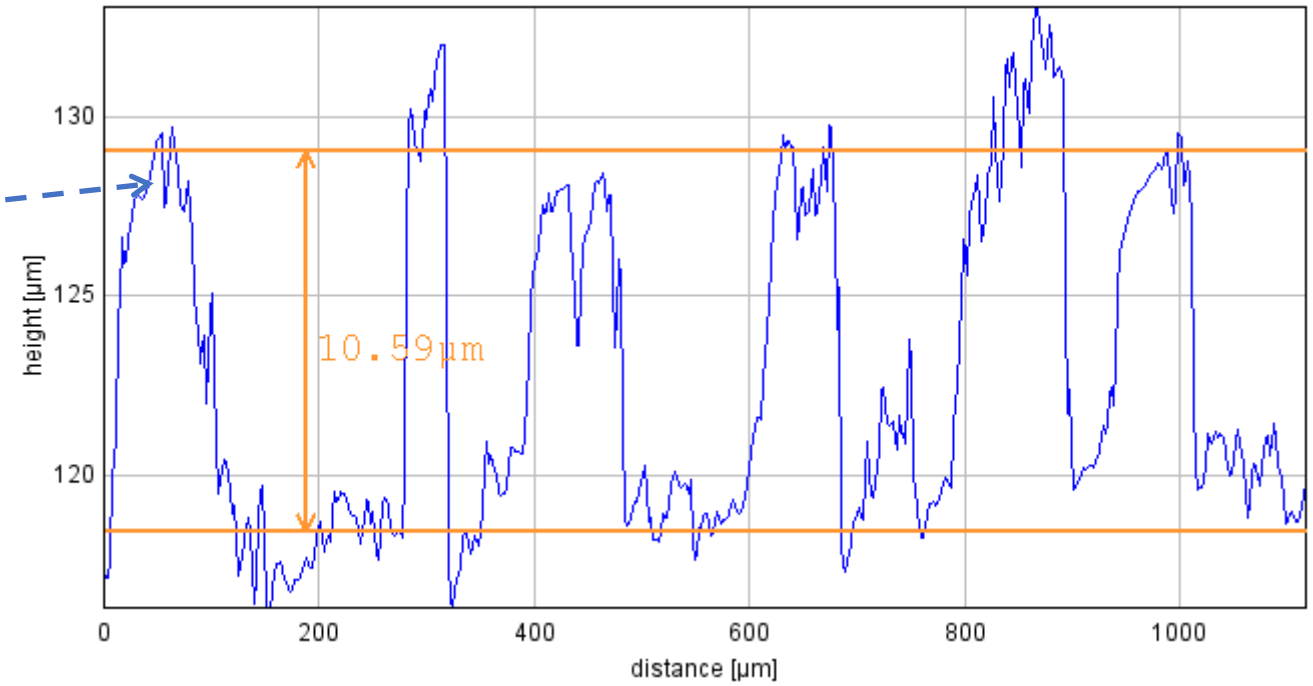

Quantitative height measurement
With sub-micron resolution

Combination of Laser & Metrology

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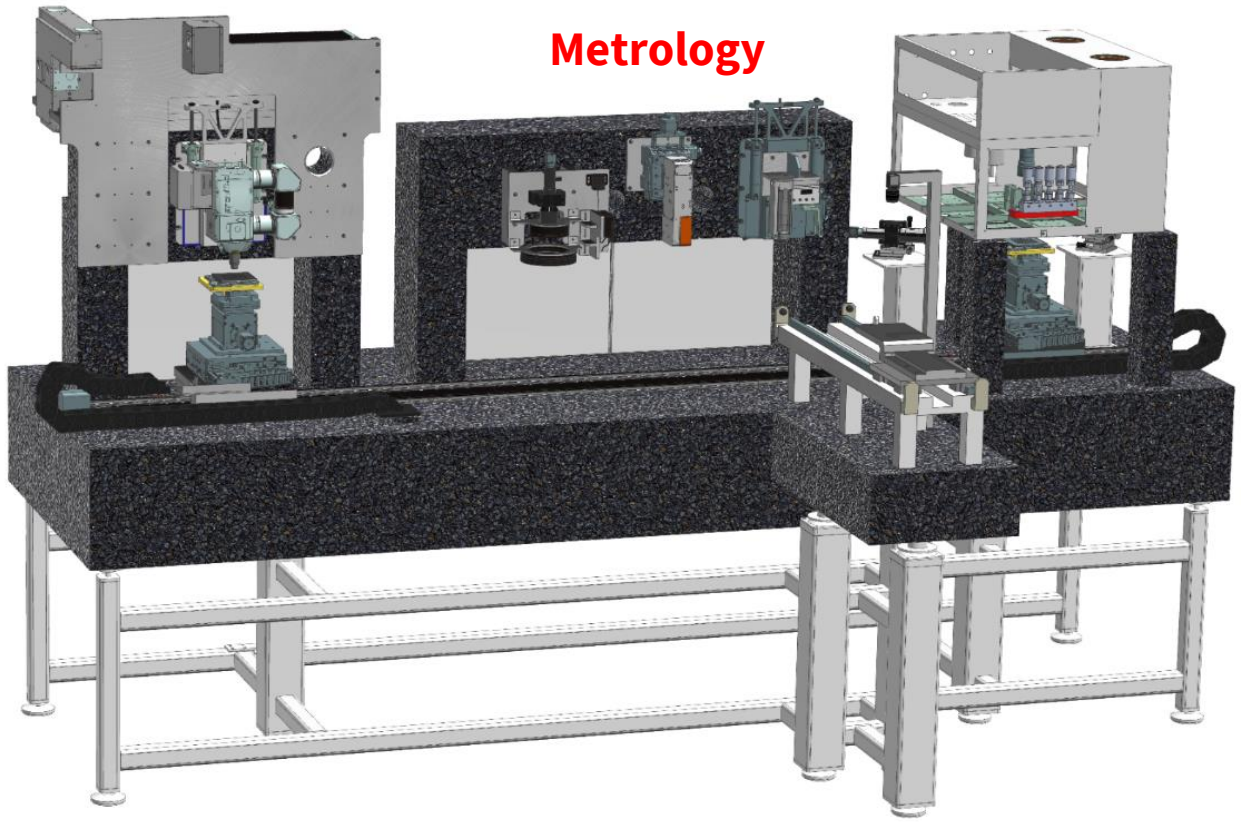
MESOMORPH

- **Laser cutting/welding**
- **2 Photon Polymerisation (2PP)**

Selective Area Direct Atomic Layer Processing **(SADALP)**

Metrology



Measurement of Atomic deposition

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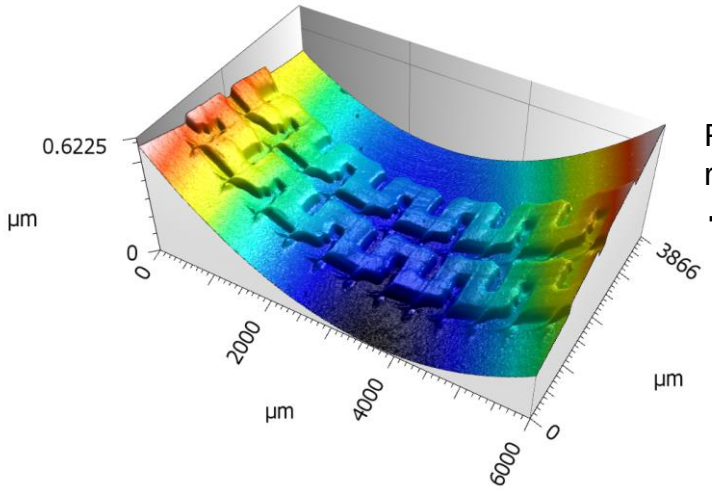
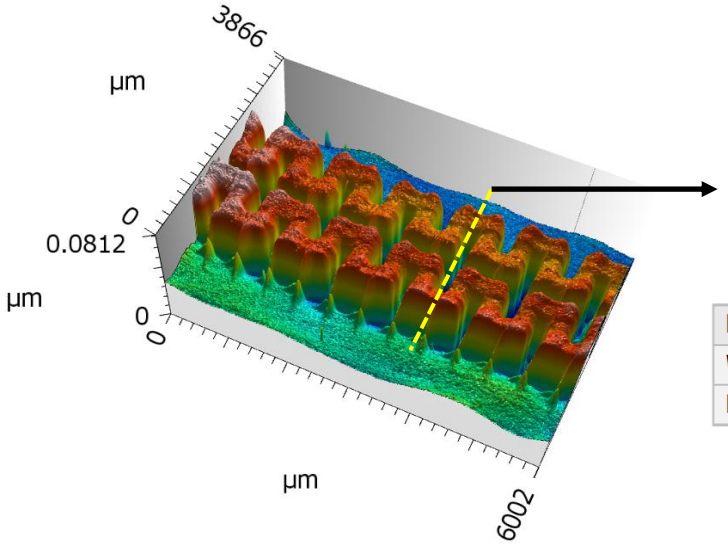
MESOMORPH

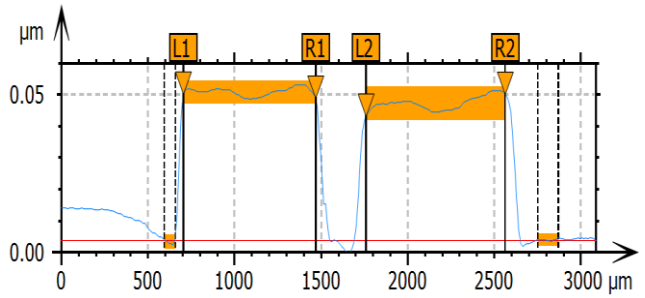
Aspects:

- Few **nm** thin SADALP deposition → can we measure this?



Form removal →

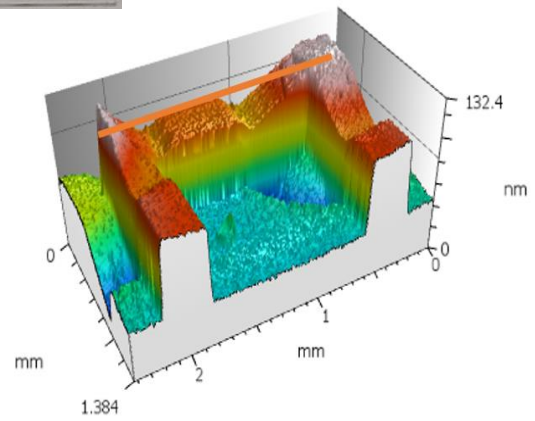


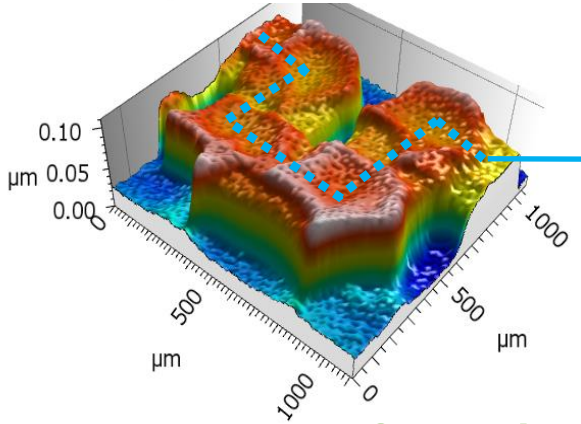


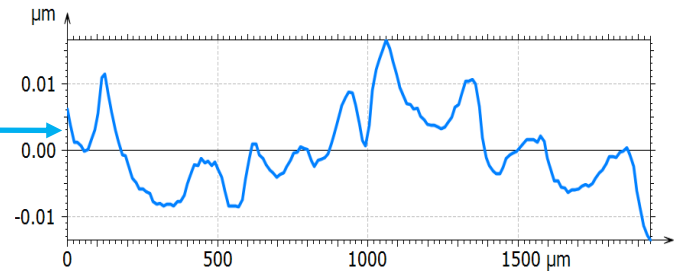
Parameters	Unit	Mean	Step 1	Step 2
Width	µm	804.0	786.4	821.6
Mean height	µm	0.04545	0.04727	0.04362

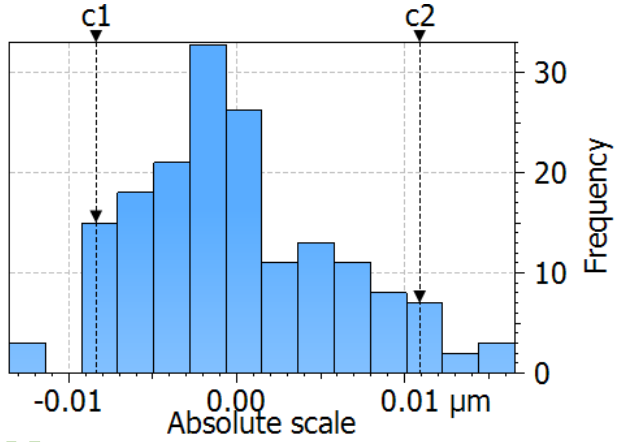
Nominal: 50nm

Correct dimension!









Defects/print quality inspection: OK

Inspection of glass laser welding

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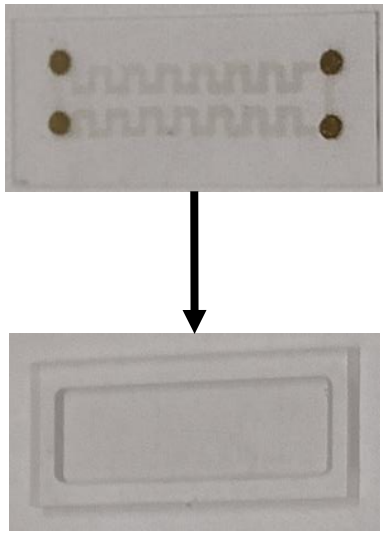
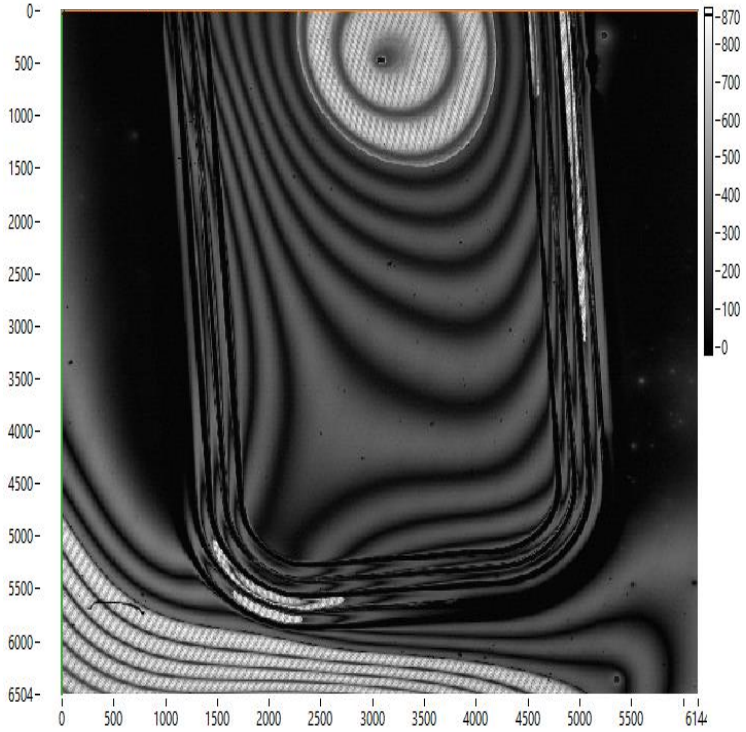
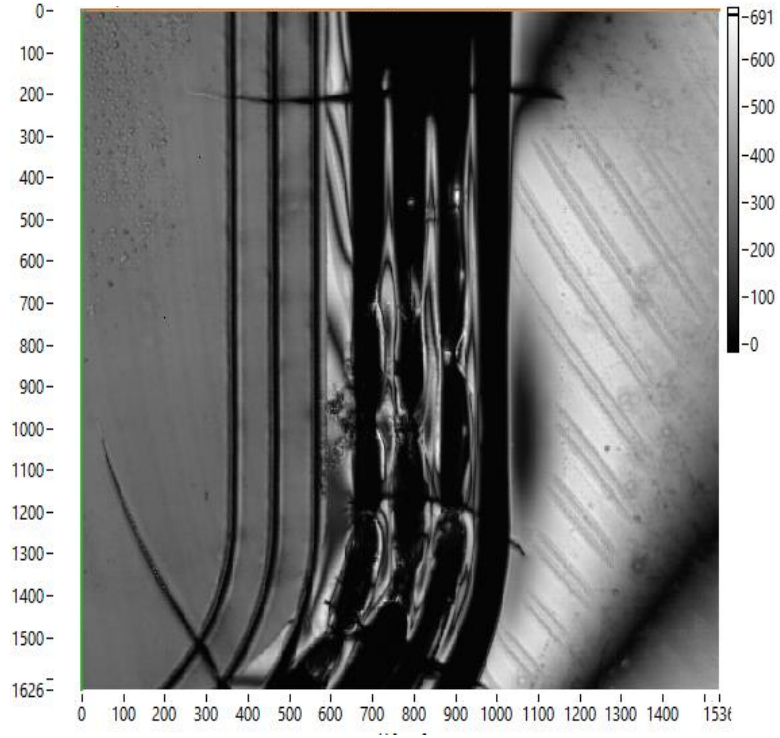
MESOMORPH

Aspects:

- Glass welding and imperfections → can we measure this?
- WLI is tomographic and detects interfaces where optical index changes







Laser glass welding cracks : OK

Measurement of 2PP printed structure

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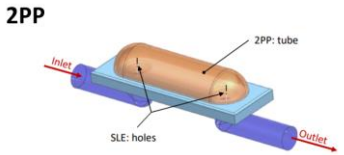
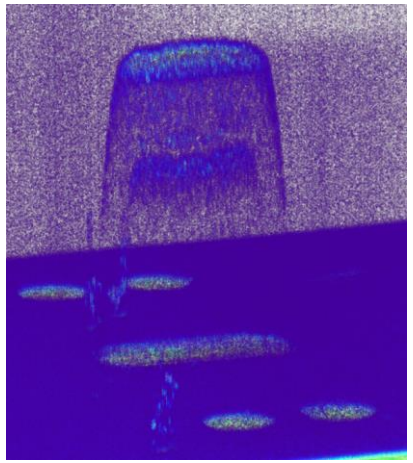
MESOMORPH

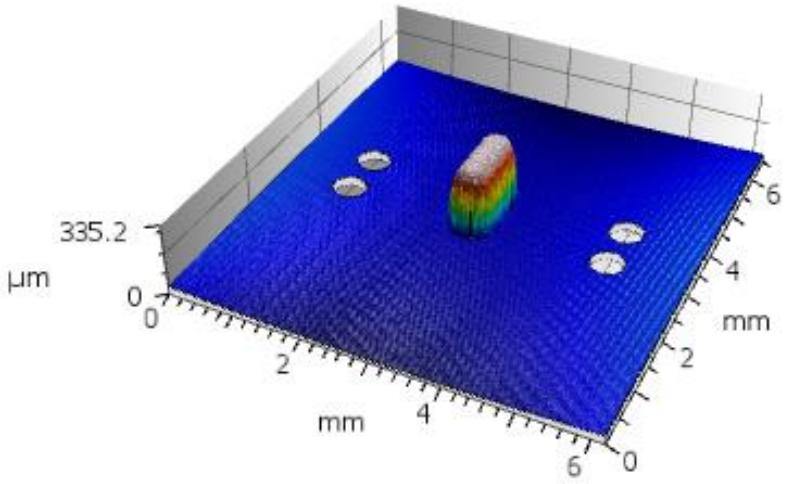
Aspects:

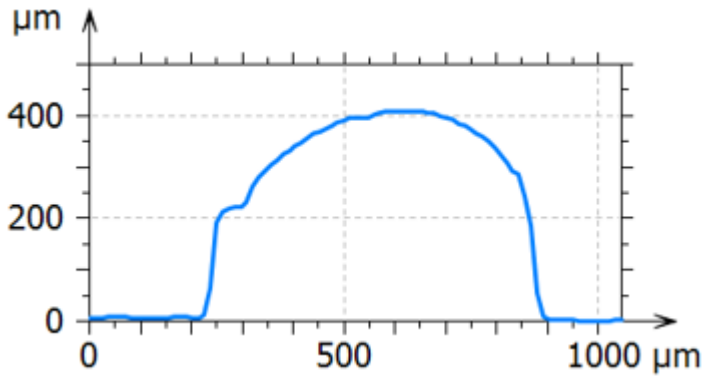
- 2 Photon polymerization cavity → can we measure this?
- WLI → tomographic



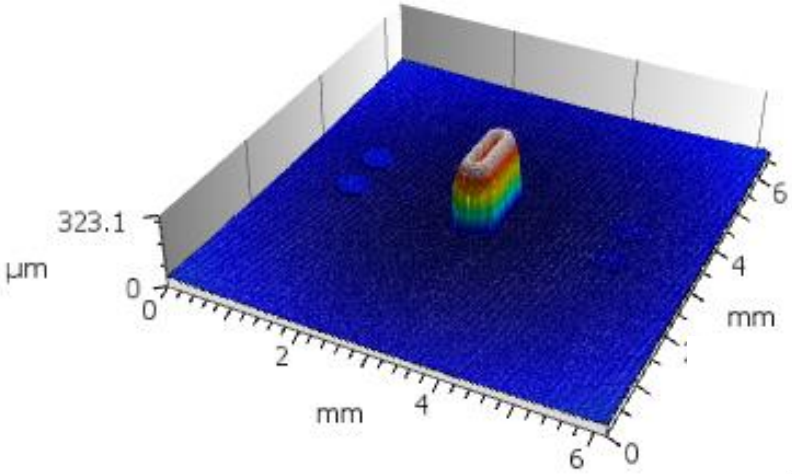


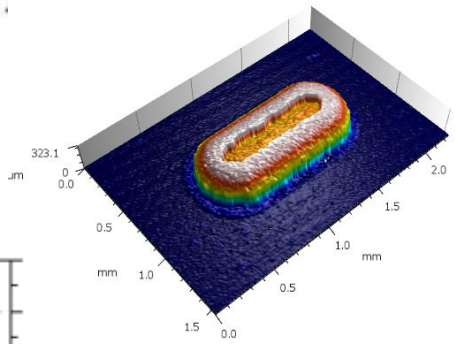
First surface -- **Height**

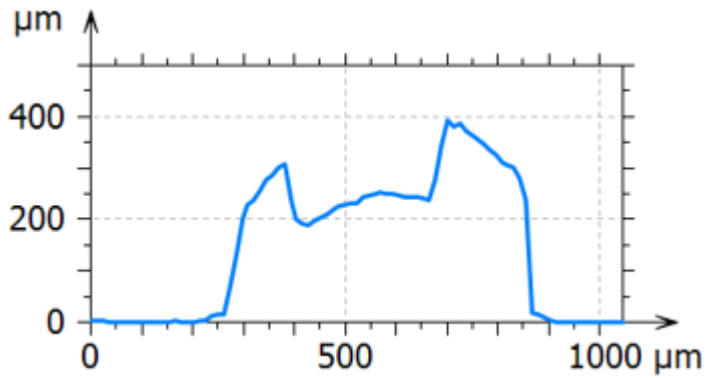




Last surface – wall thickness







If you want to learn more

Visit
www.heliotis.com

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web@heliotis.com

Contact me
Patrick.Lambelet@heliotis.com