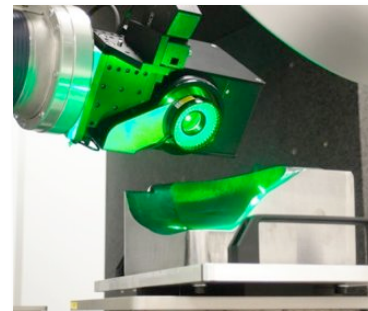
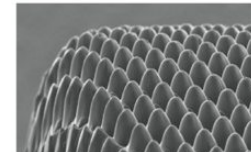
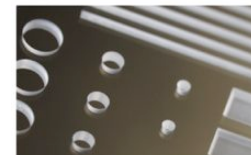
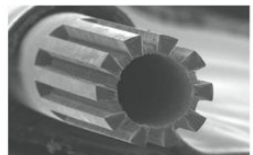


Machine technology for 3D microprocessing of complex curved surfaces

Max Groenendijk, Lightmotif



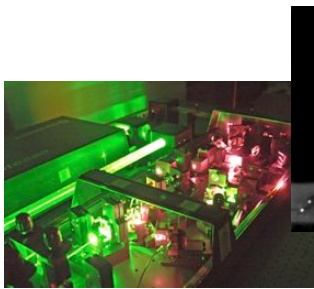
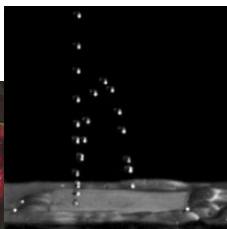
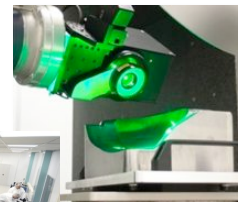
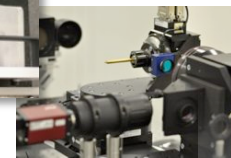
Lightmotif



Company Introduction

Lightmatif

- Spin-off company from the University of Twente, founded in 2008
- ***Ultrashort Pulse Laser Micromachining***
- Offering:
 - Machines for Production and R&D
 - Process and Application Development
- Specialist in surface texturing on 3D curved surfaces



Lightmatif

2003

2006

2008

2009

2012

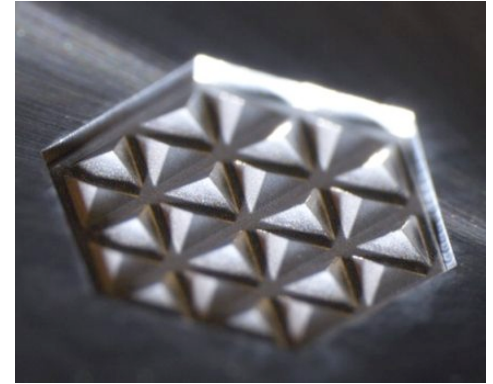
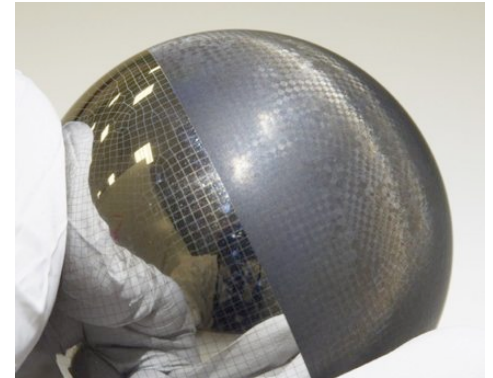
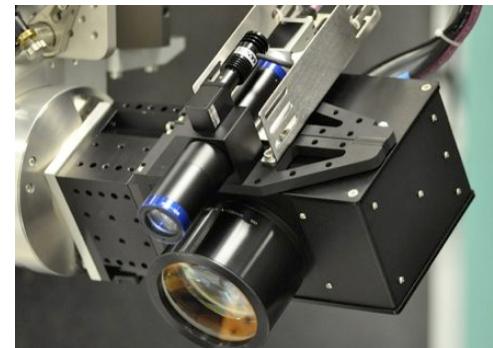
2013

2015

Outline

- Micromachining Examples
- Functional Surface Texturing
- 3D Texturing Technology
- Machine Technology and Control Software
- Summary and Outlook

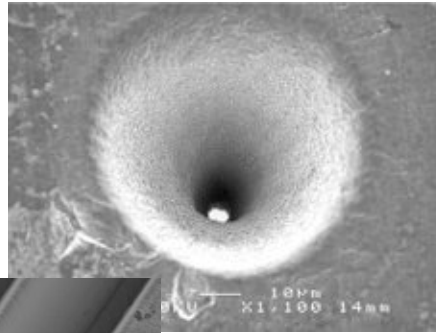
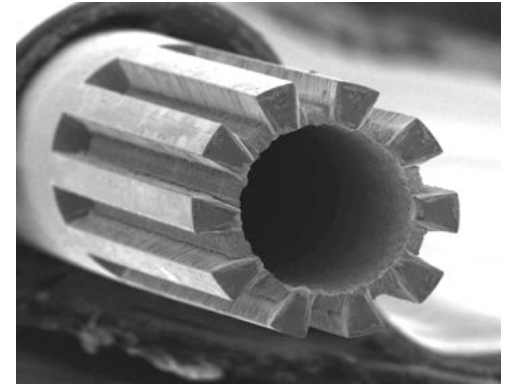
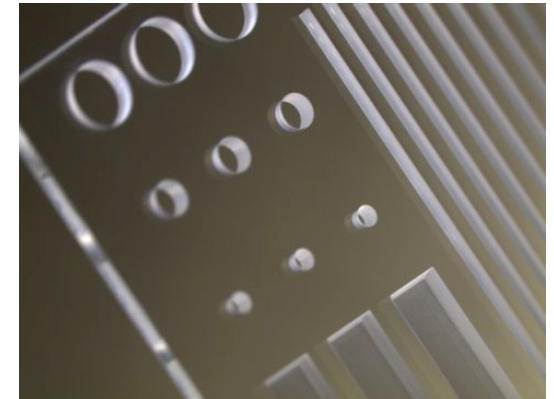
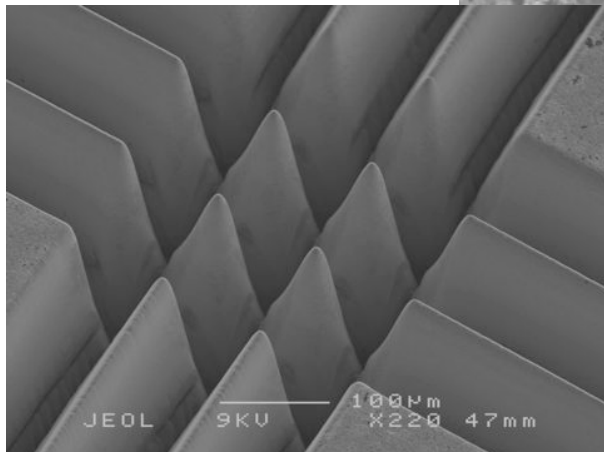
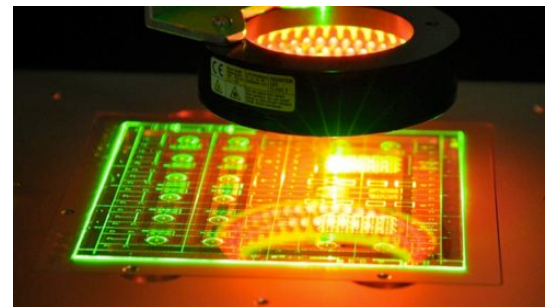
Lightmotif



Micromachining

Lightmotif

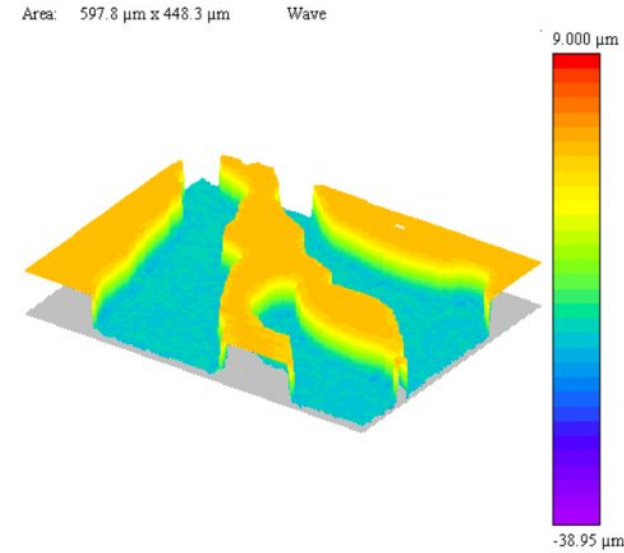
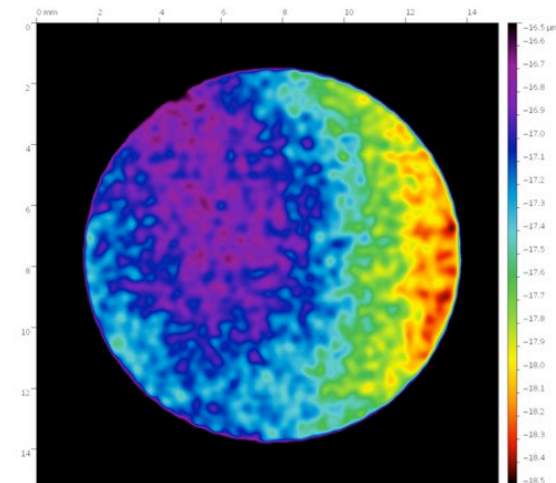
- Accurate machining of all materials
- Direct write, software controlled geometries



Micromachining Alumina



- Round pockets $\varnothing 12,5 \text{ mm}$
- Depth $20 \text{ }\mu\text{m} \pm 0.5 \text{ }\mu\text{m}$ ($\pm 2.5\%$)
- Very sensitive material: 1% variation of laser power results in $\sim 10\%$ variation of depth
- Resulting depth variations are too large, but reproduce

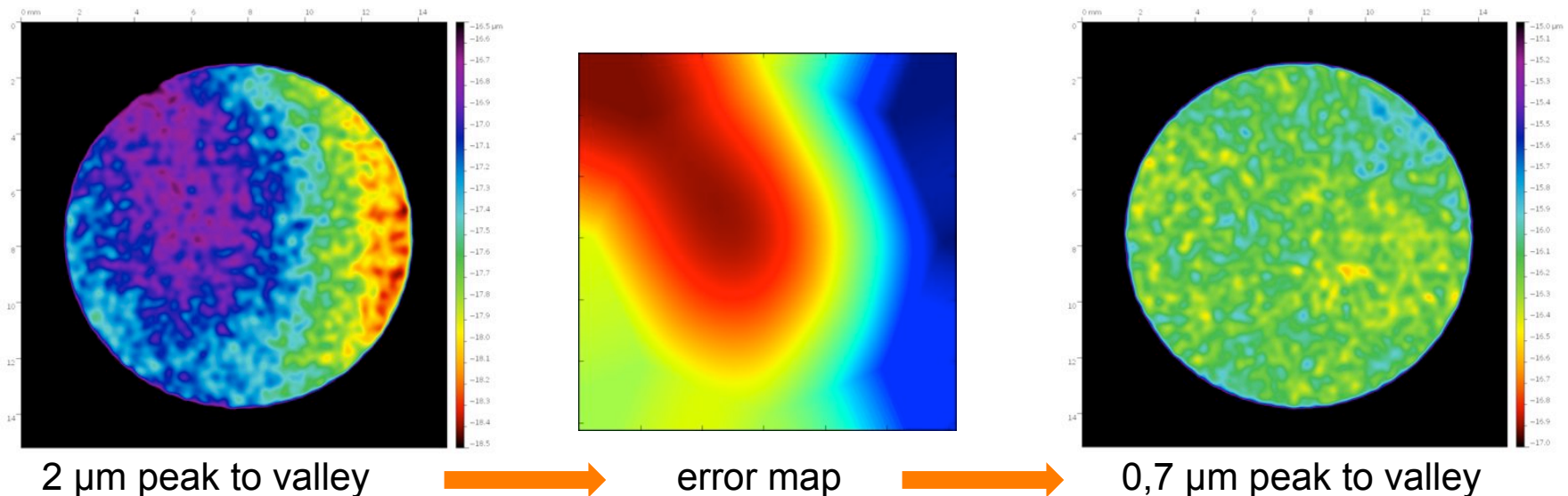


On-the-fly correction

- Measure the depth variations
- Generate error map
- Adjust laser power on-the-fly during machining
- Significant reduction of inherent depth variations

What you need:

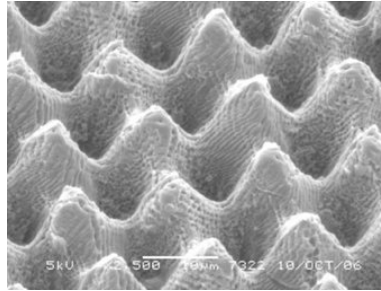
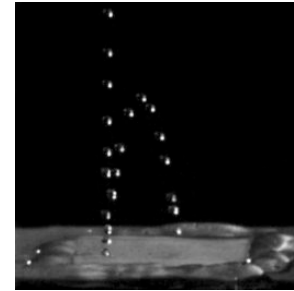
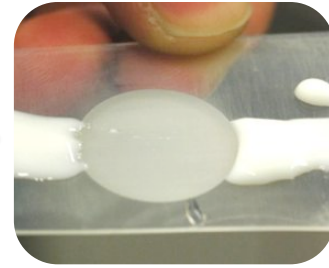
- *Fast modulation of laser power*
- *Ability to implement this strategy in your control software*



Functional Surfaces Textures

Light motif

Wetting

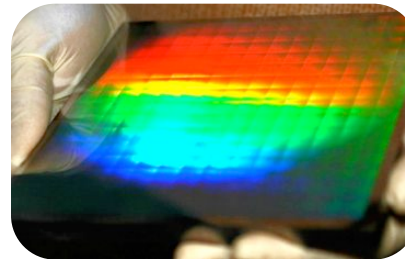


Friction & Lubrication~



*From engine parts
to skin comfort*

Optical effects



*Manipulation of
light*

Biomedical

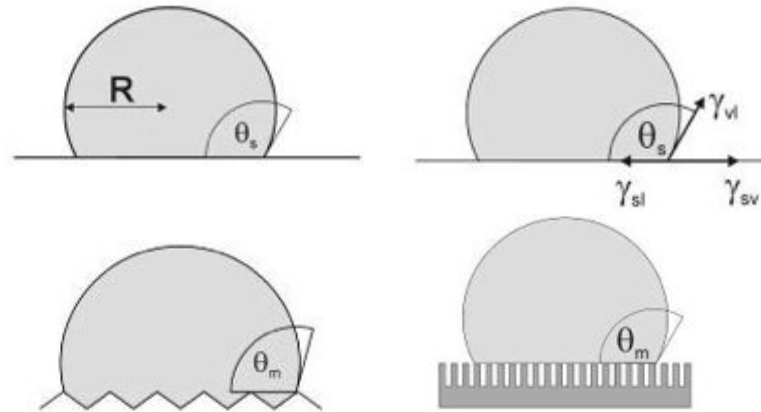
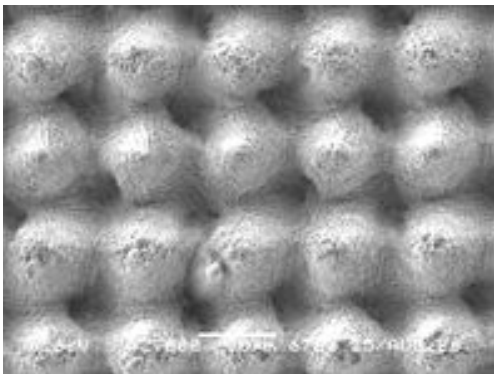


*Manipulation of
cell adhesion*

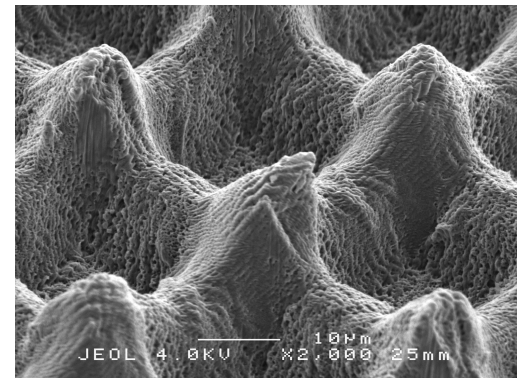
Lotus Effect Surfaces



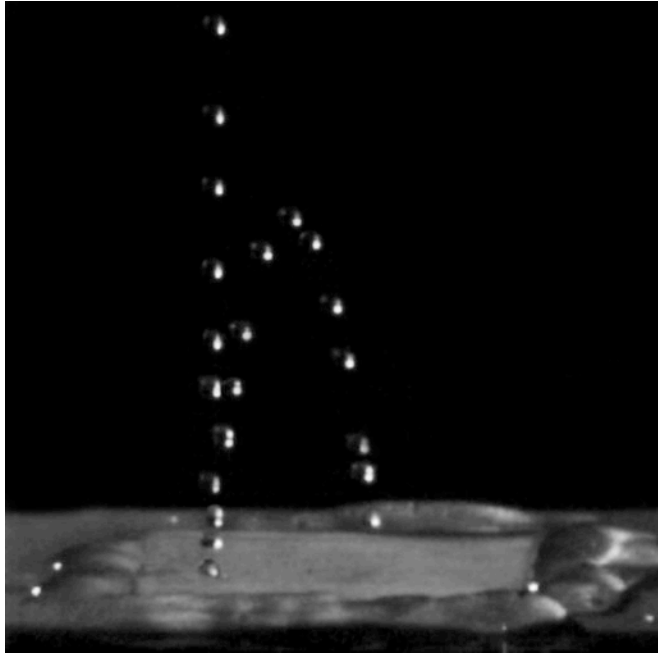
Lotus effect surfaces by
injection moulding into micro-
nano textured moulds



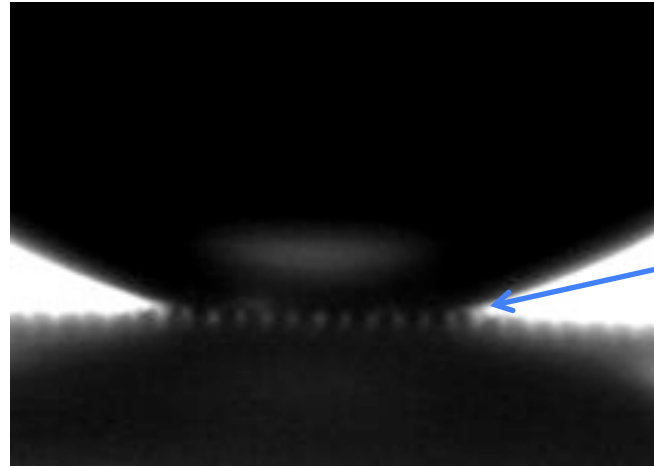
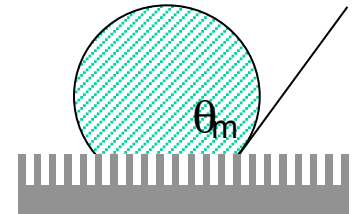
Injection moulding



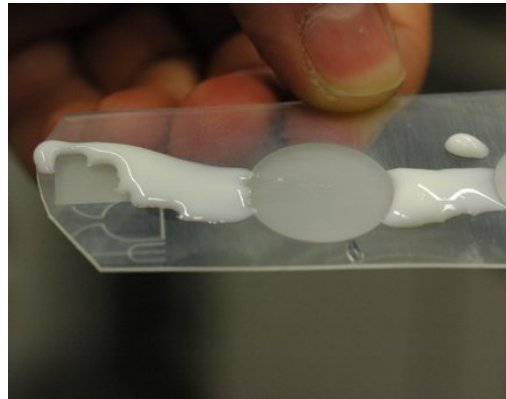
Wetting Properties



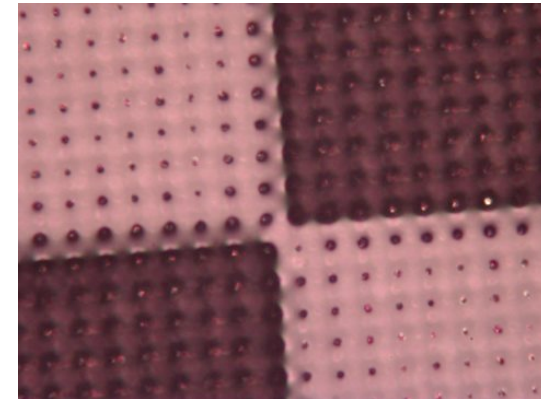
Collage of high-speed recorded images



Partial wetting



'Milk-ophobic' surface, enabled by additional fluor coating on top of our textures



Super hydrophobic and hydrophilic surface

Lubrication

Light motif

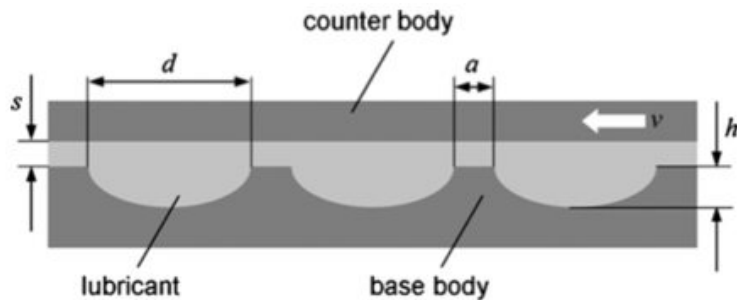


Fig. 7. Scheme of the simulation model.

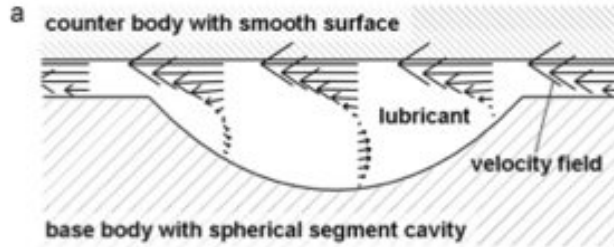
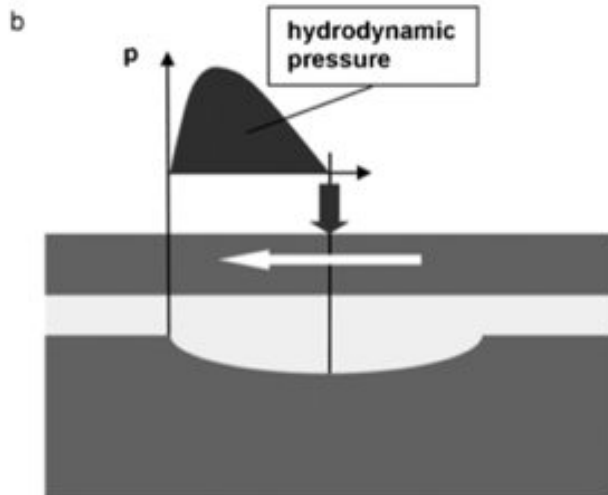
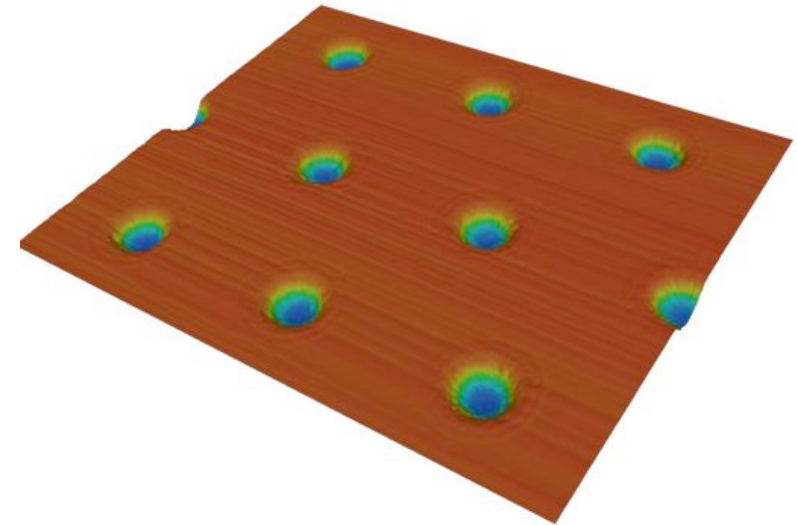


Fig. 8. CFD simulation of lubricant circulation in a microstructure (a); sketch of a micro-structure chamber after [32] (b).

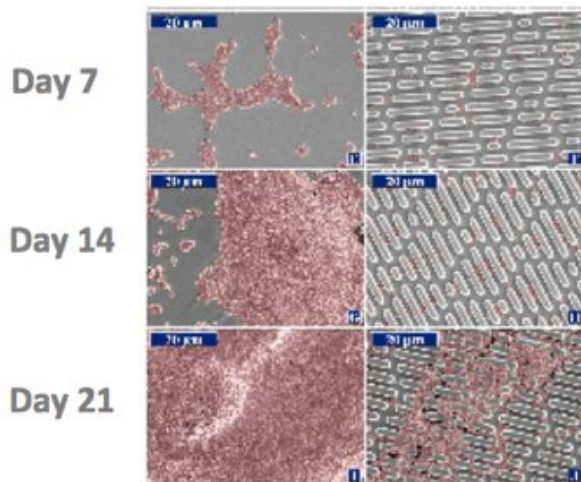


Improve lubrication by dimples:

1. Pressure build up
2. Oil reservoir
3. Wear Particle Trap

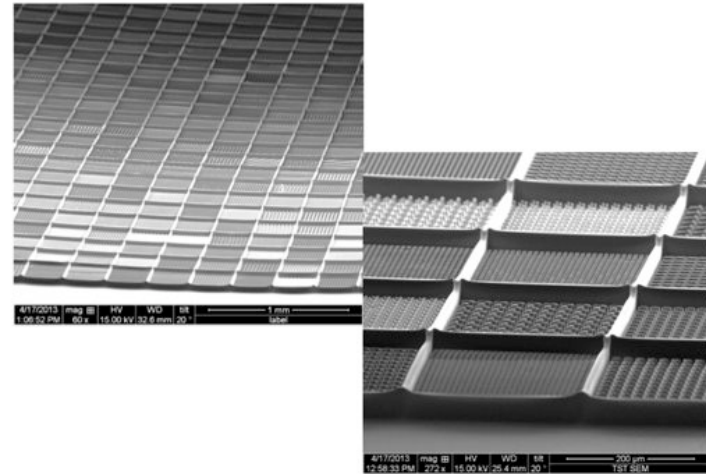
Biological effects

- Cell adhesion and prevention of adhesion
- Stem cell differentiation
- Anti-bacterial surfaces
- ...

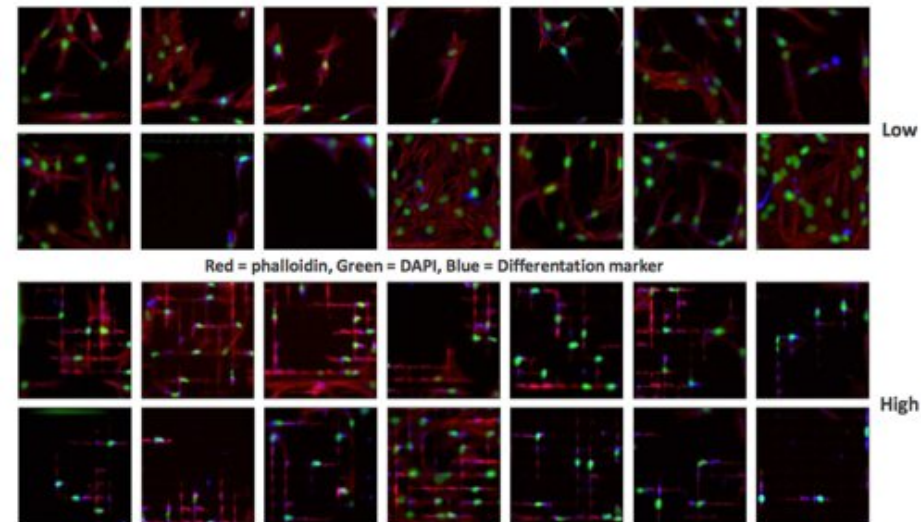


Sharklet™ anti-bacterial surface structures

Light motif



Materiomics cell screening technology to aid topography design



**What textures can we make
with USP lasers?**

100 nm



Width = 2.500 μm

Height = 1.875 μm

Mag = 45.73 K X

Signal A = InLens

Aperture Size = 30.00 μm

High Current = Off

Collector Bias = 300 V

Date: 2 Mar 2012

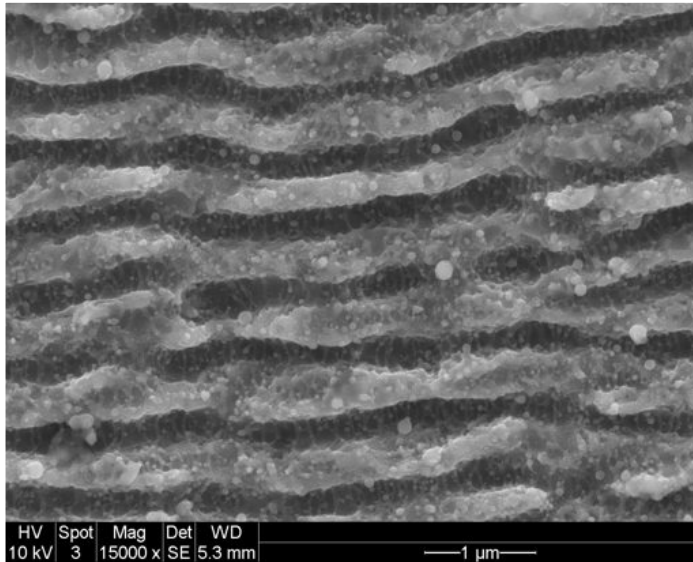
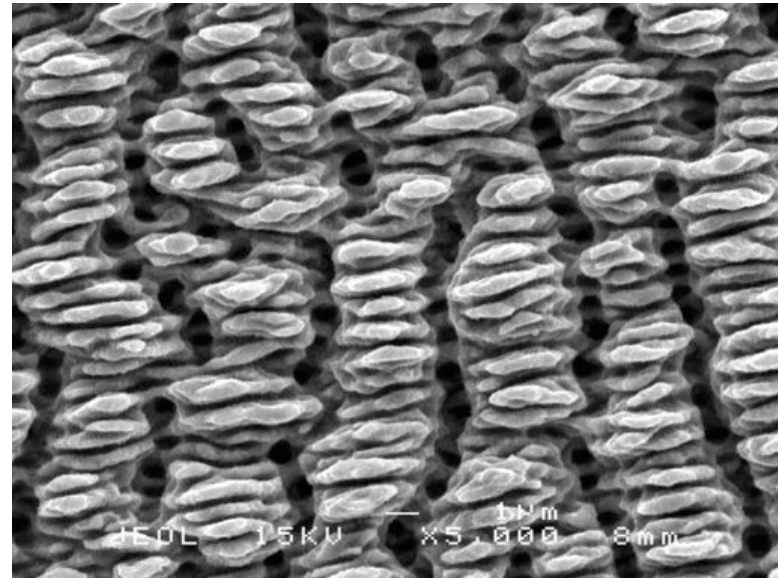
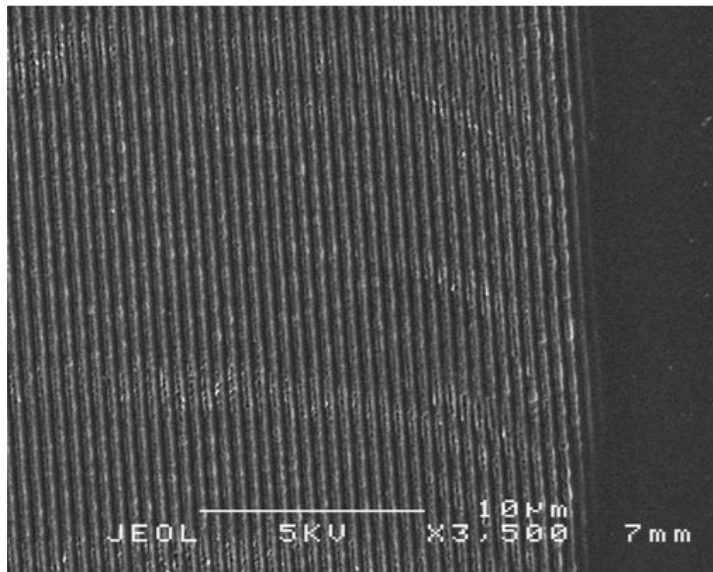
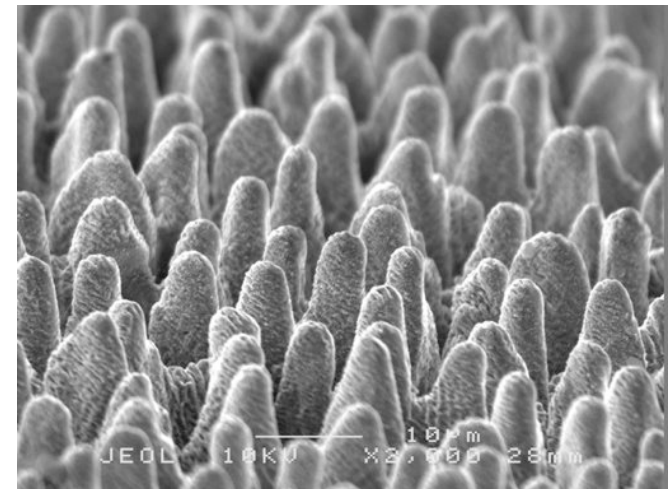
ESB Grid = 0 V

EHT = 5.00 kV

WD = 3.9 mm

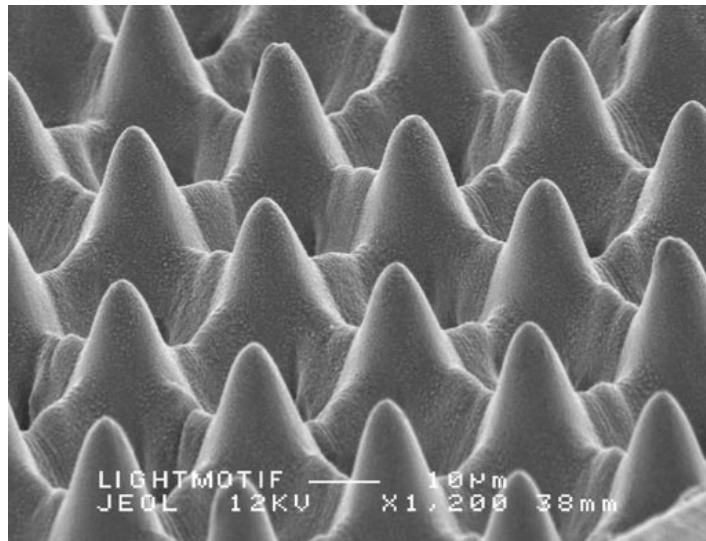
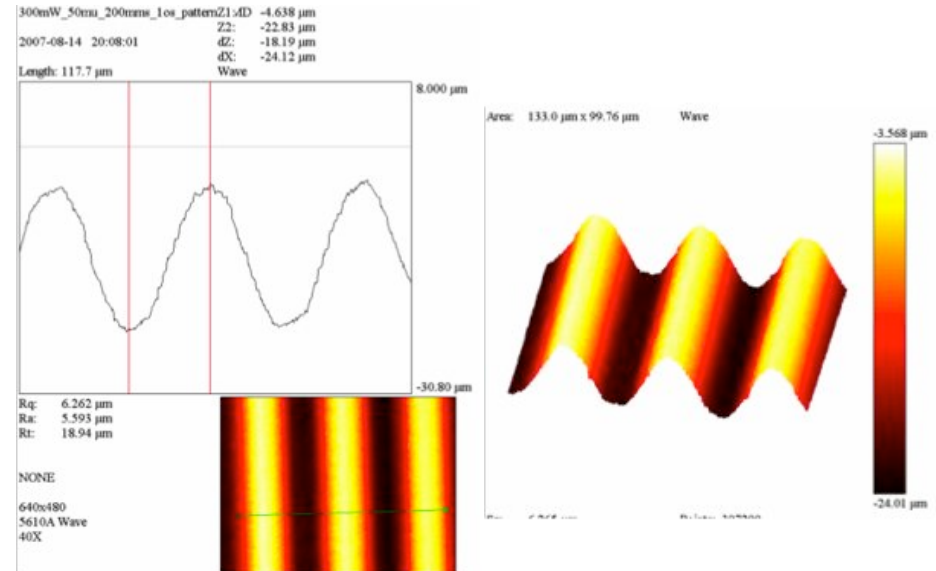
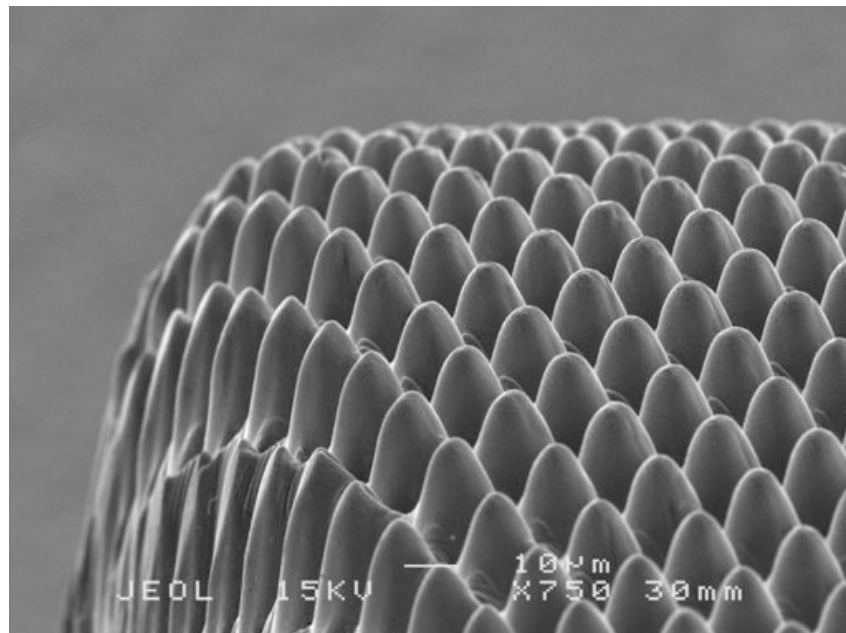
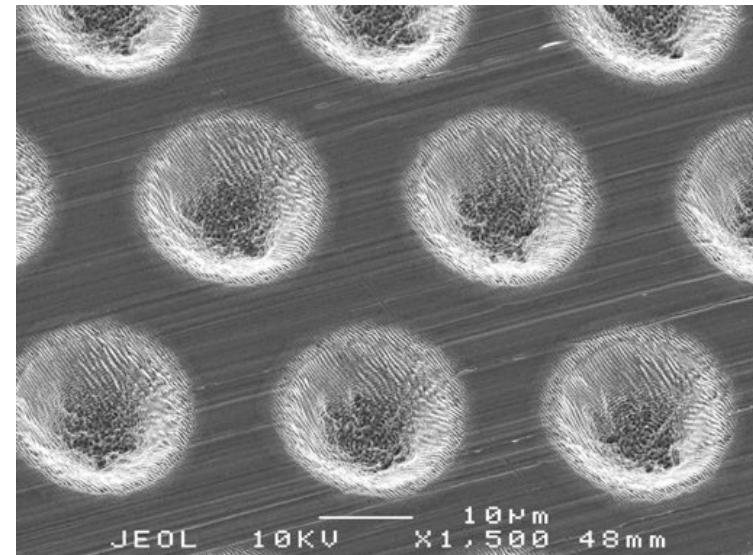
Self organizing textures

Light motif



Direct-Write Textures

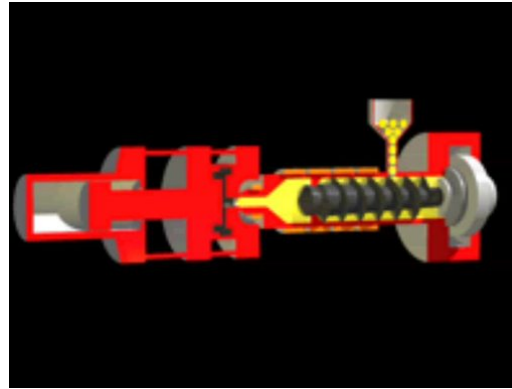
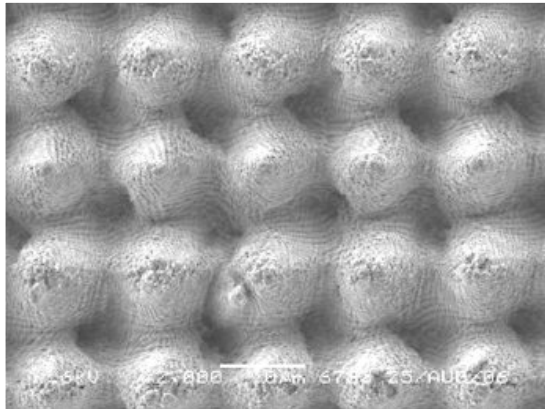
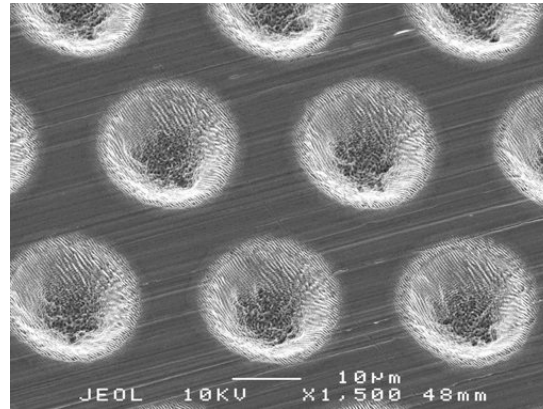
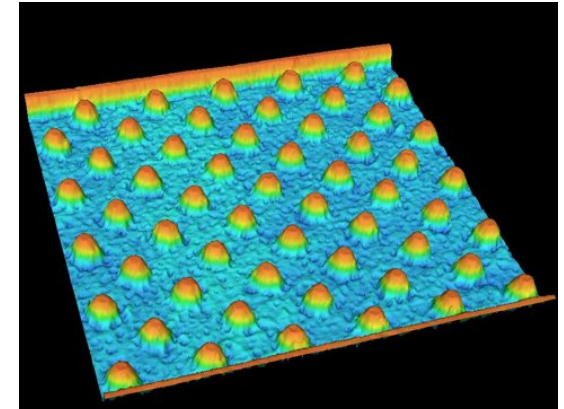
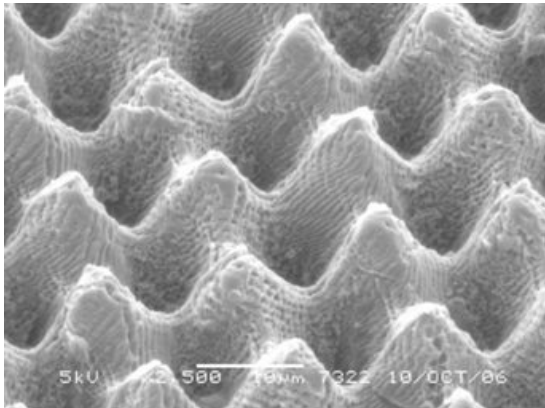
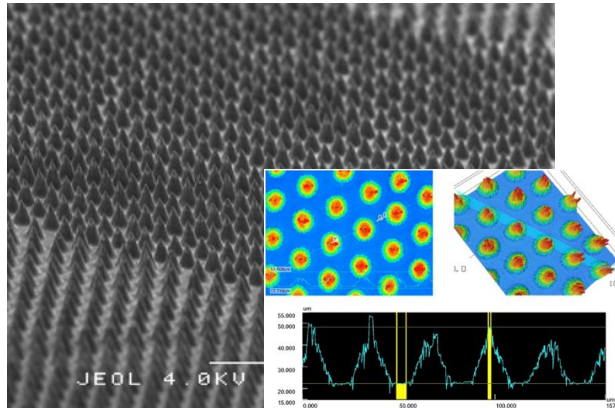
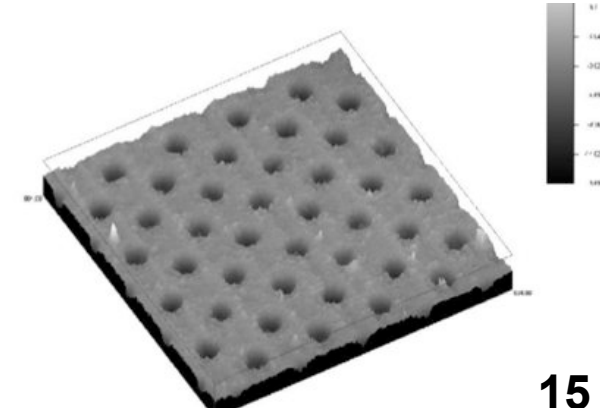
Lightmotif



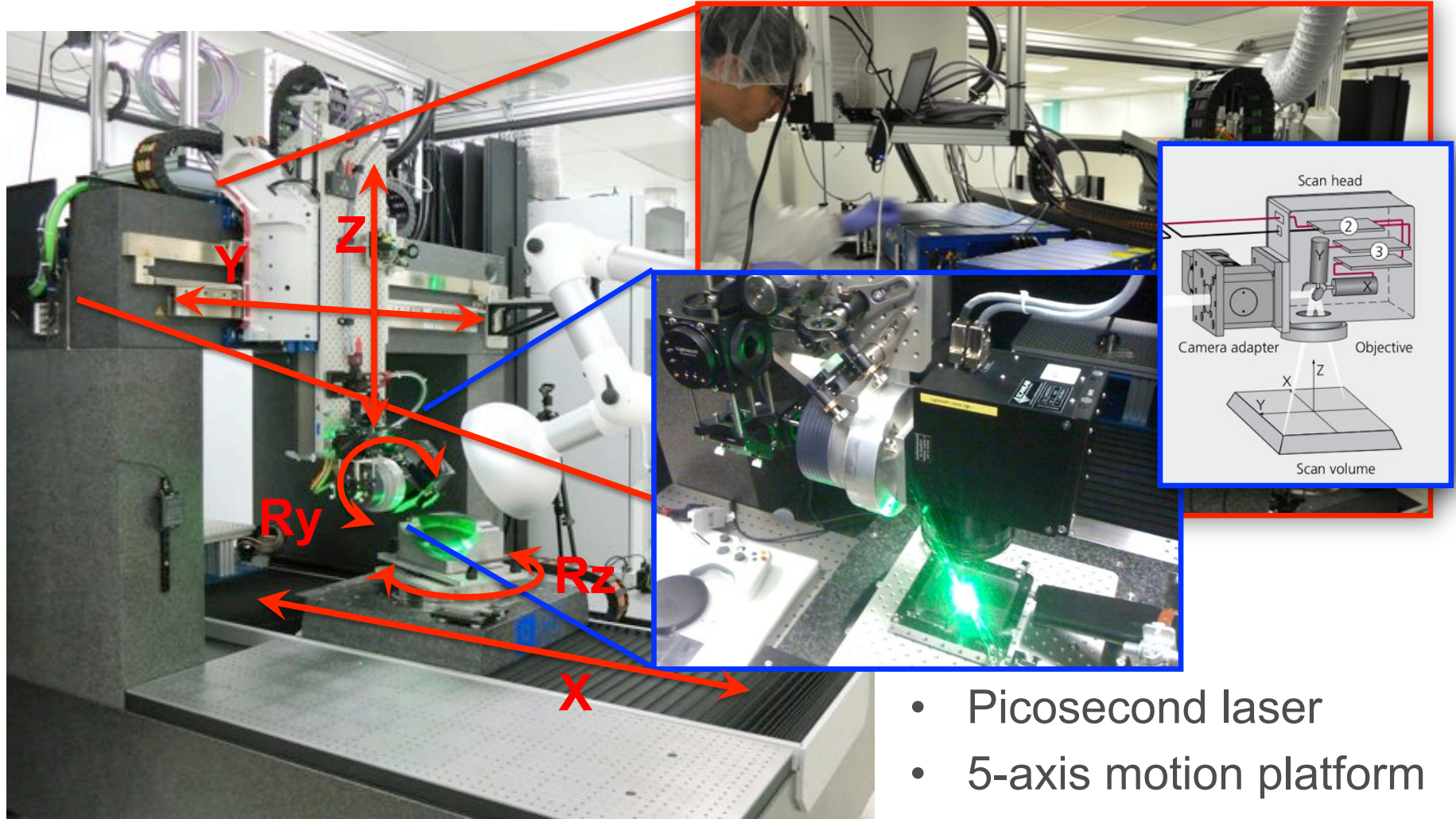
Molded Textures

lightmotif

(Injection)
Molding

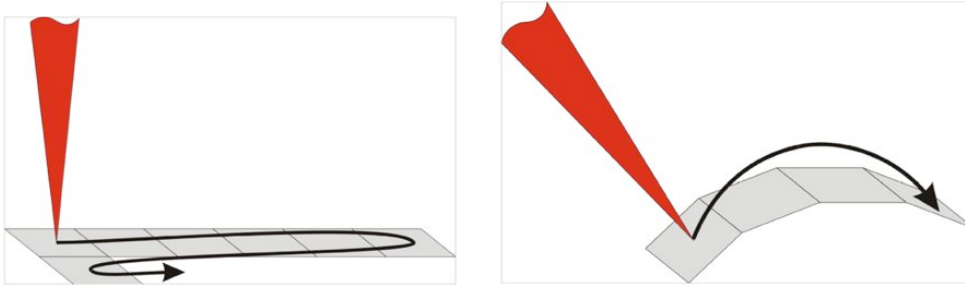


5-axis Laser Micromachining System *Lightmotif*

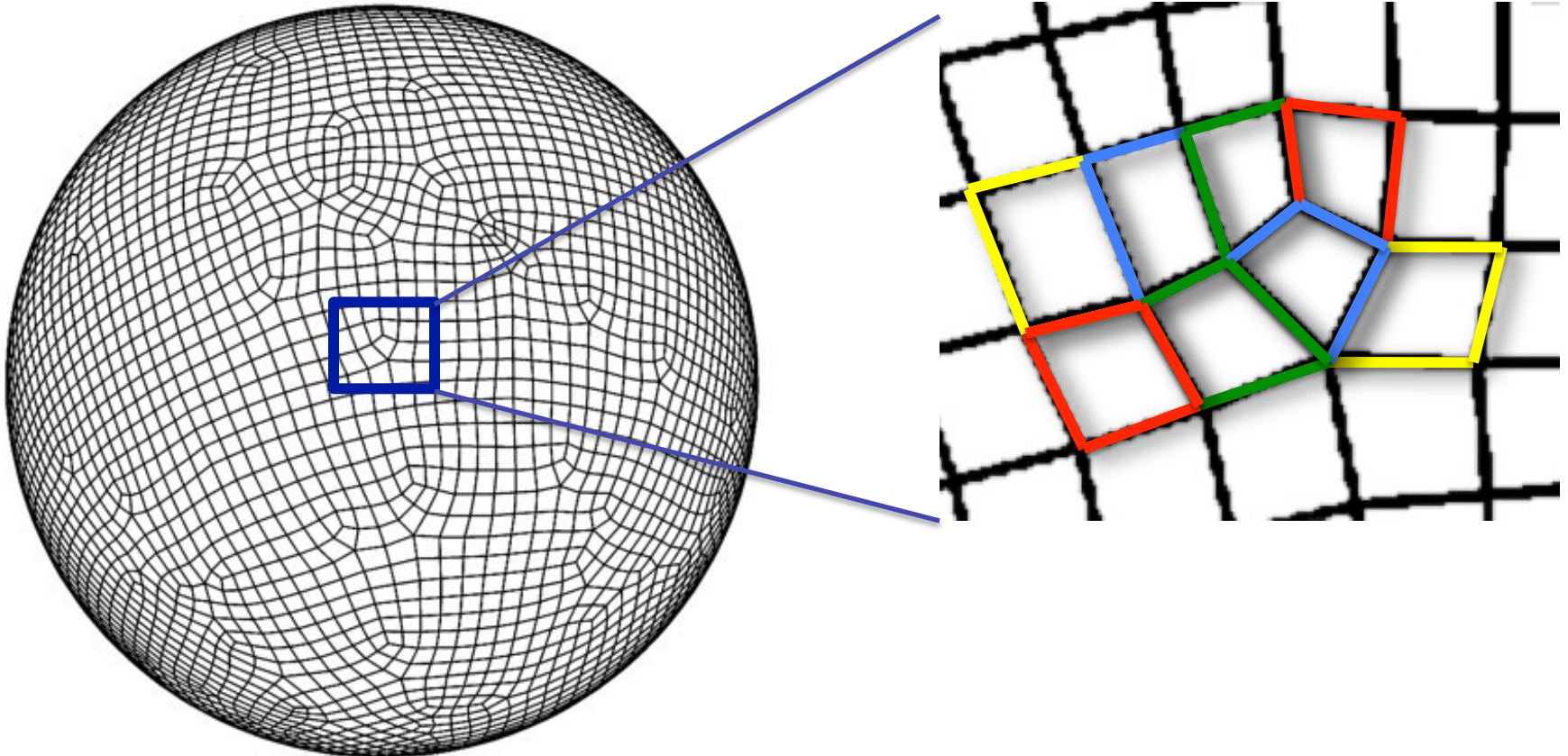


- Picosecond laser
- 5-axis motion platform
- Galvo scanner
- Step-and-scan micromachining

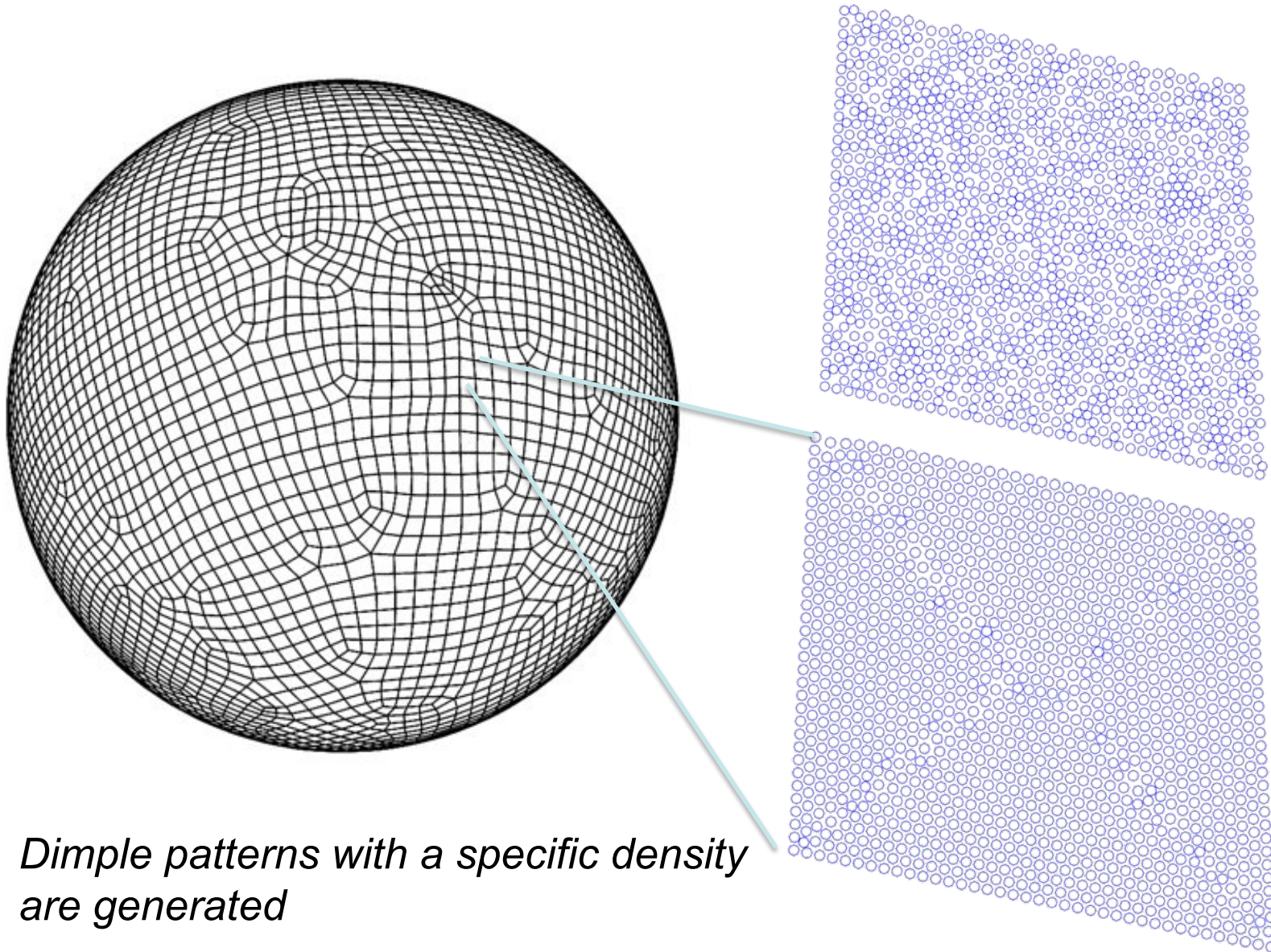
Tiling of Surface



Step and Scan
Approach



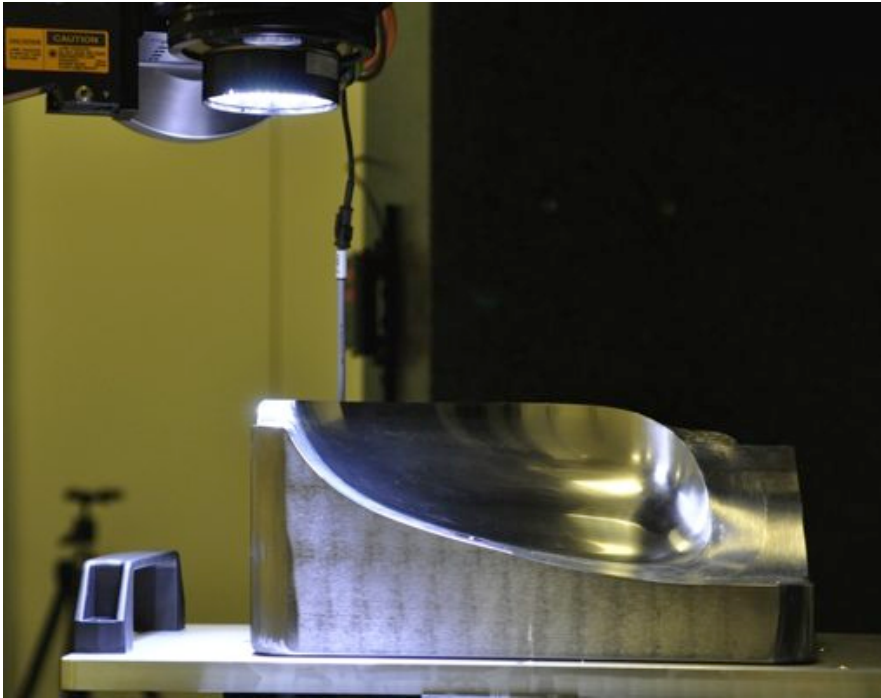
Texture Generation



Dimple patterns with a specific density are generated

Texturing Mirror Cap Mold

FP7 project Nanoclean

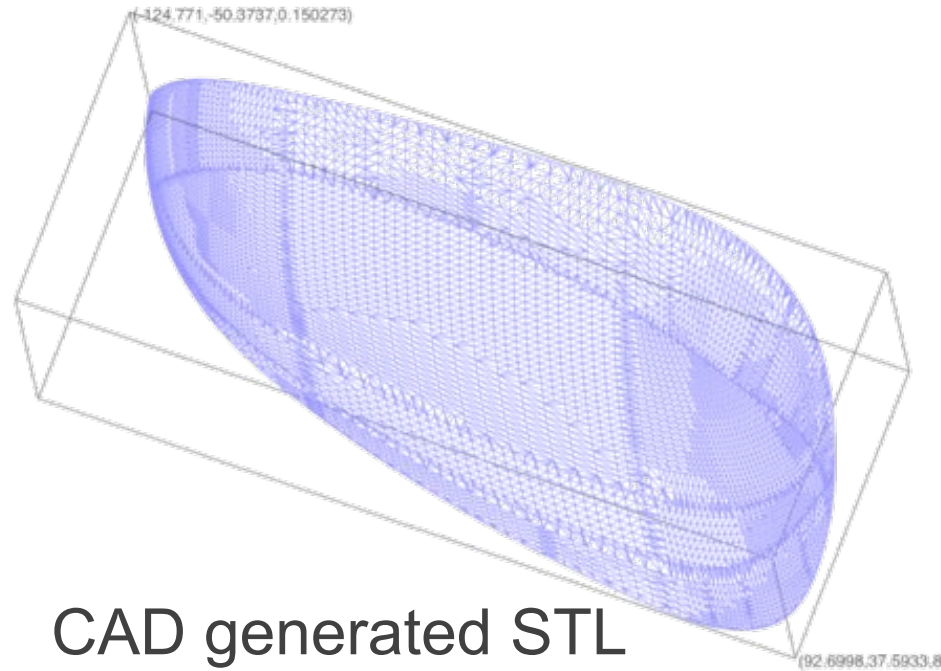


- Demonstrator: Injection mold for car mirror cap
- Goal: obtain a super-hydrophobic effect

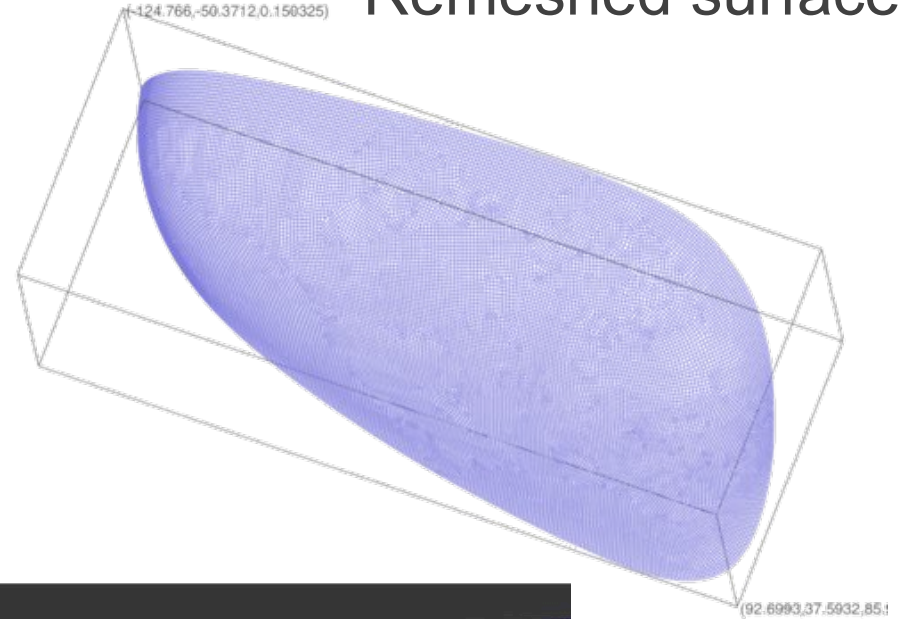
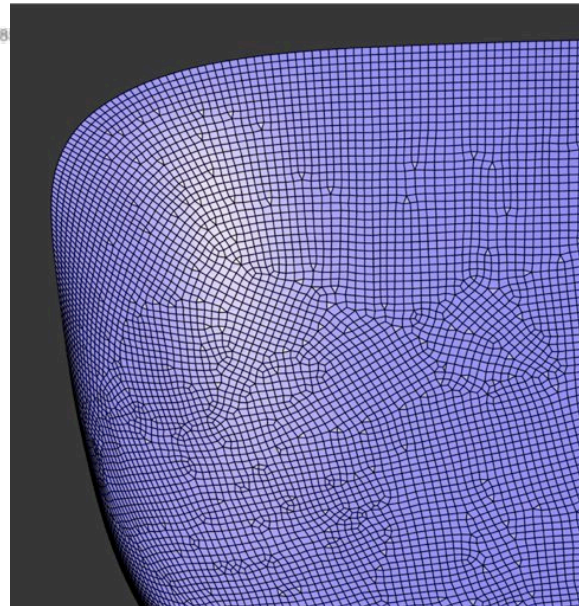


Tiling - Meshing

Remeshed surface

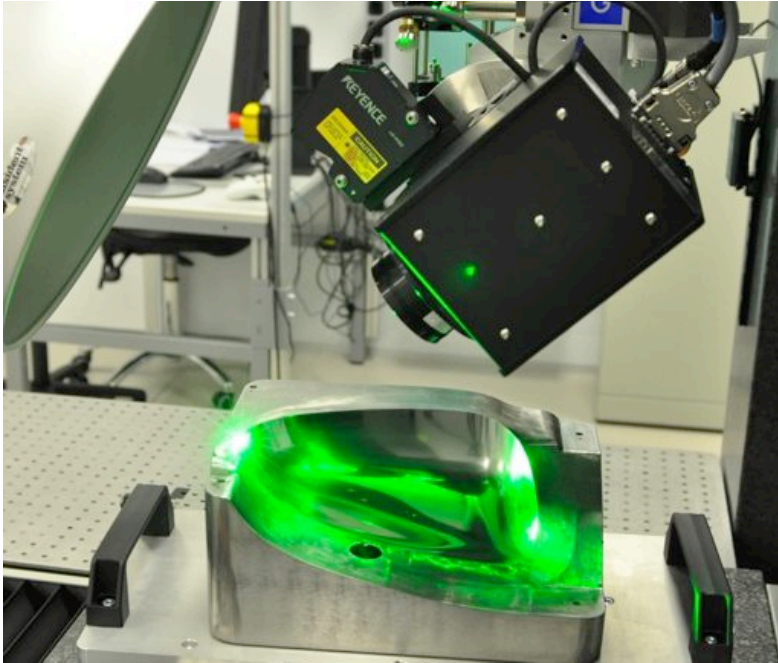
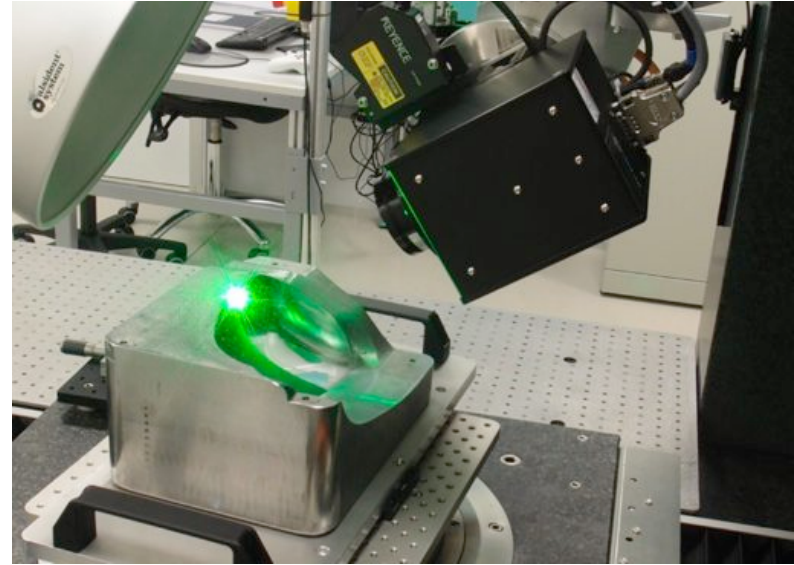
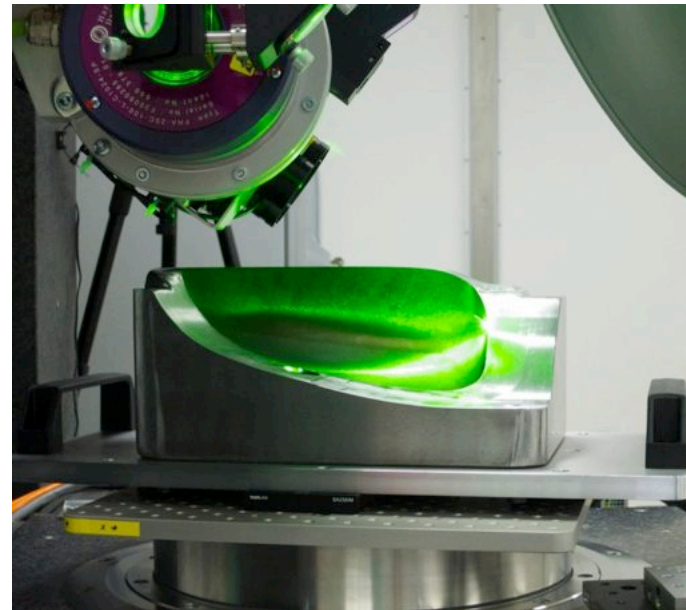


CAD generated STL
surface description



Mold texturing

Lightmotive



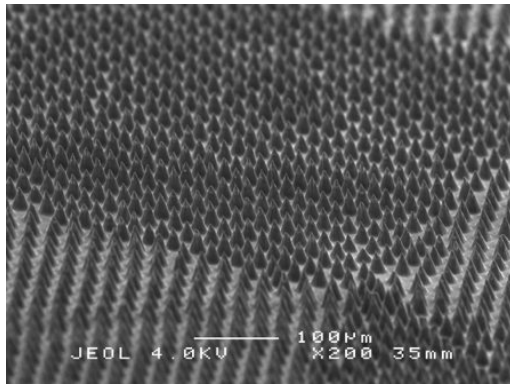
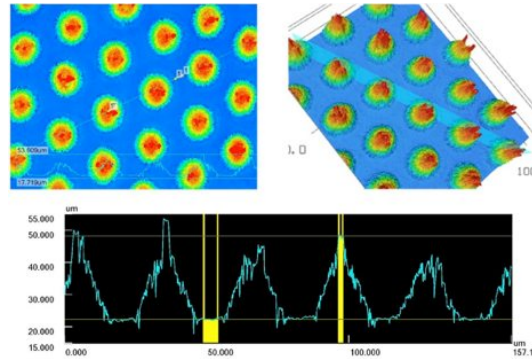
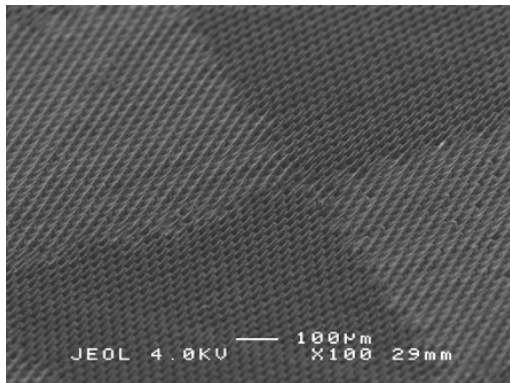
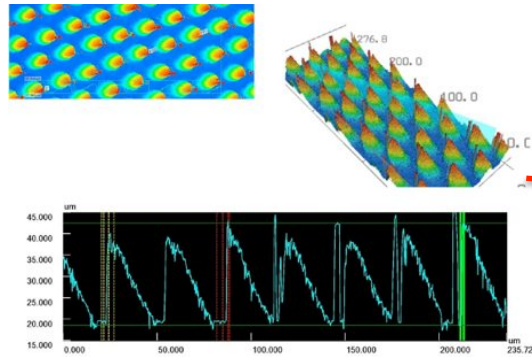
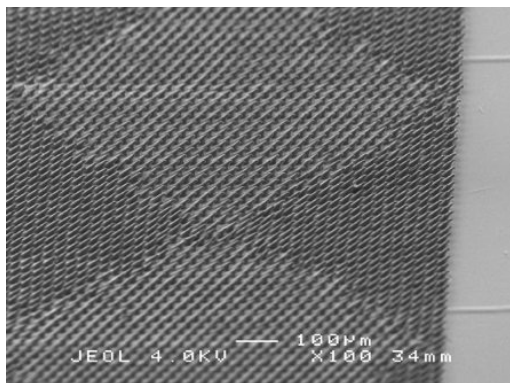
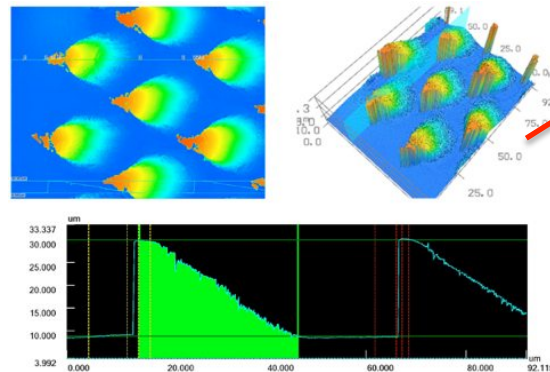
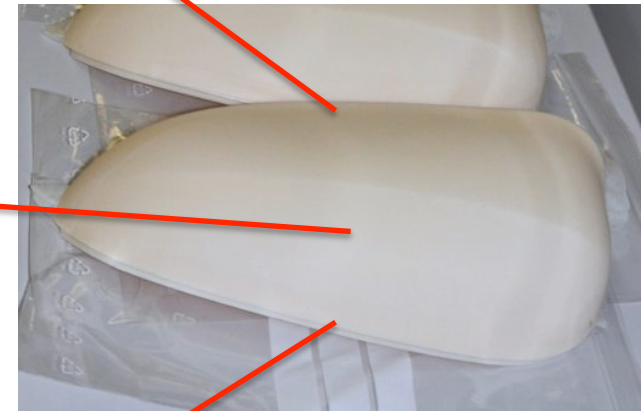
Injection molded mirror caps

Lightmotif

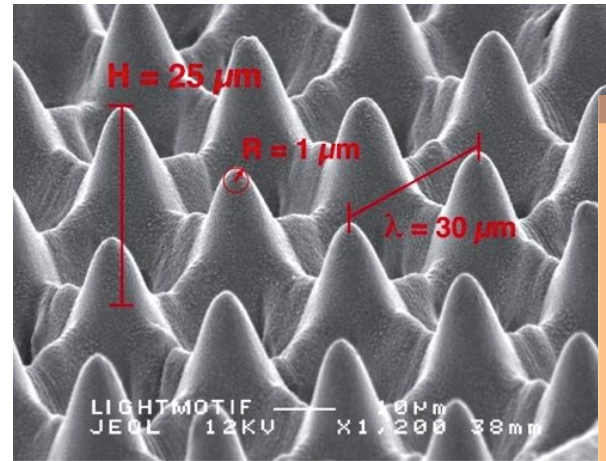
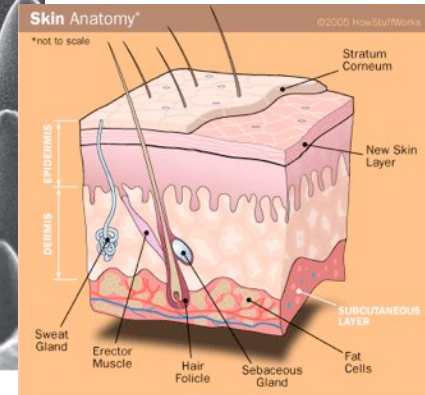


Mold Release

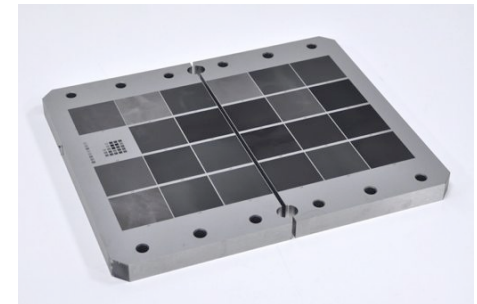
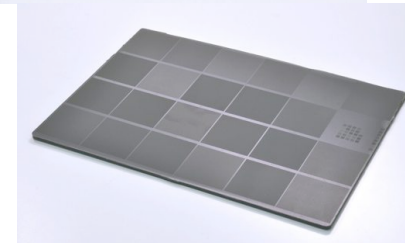
Lightmotif



Inclined pillars to improve mold release



- Development of technology for soft-touch and anti-glare surfaces in car interiors
- 'Soft-touch' effect by reduced skin friction,
- Precisely 'engineered' skin contact surface
- Anti-glare effect by dense and highly diffusing microtextures
- Optimization of texture, process and machine
- Further development towards industrial use of technology



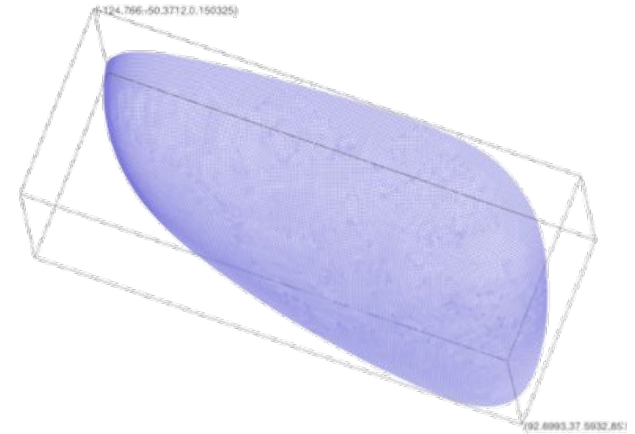
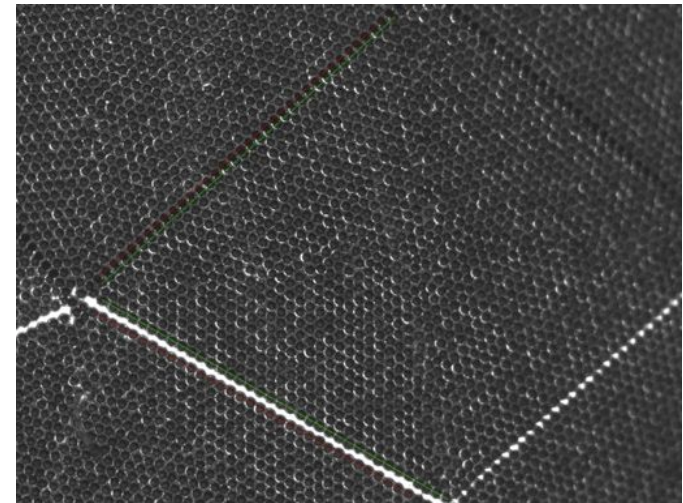
Texturing Challenges

Light motif

- Tiling requires accurate positioning
 - Accurate motion (and beam alignment)
 - Accurate scan field calibrations
 - Compensation of drifts
- Long running jobs require stable laser output power
- Workpiece calibration

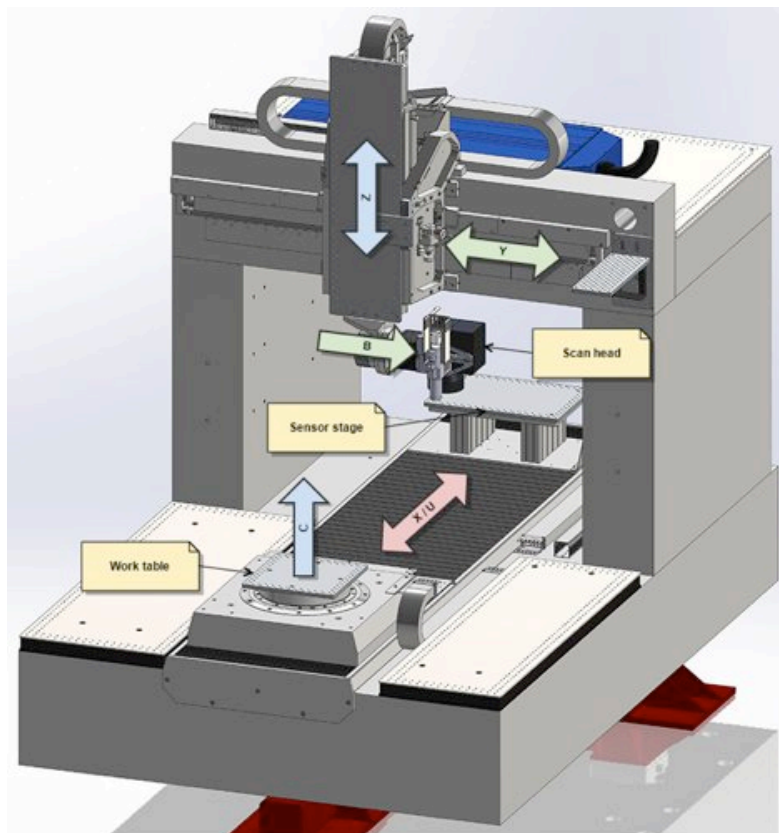
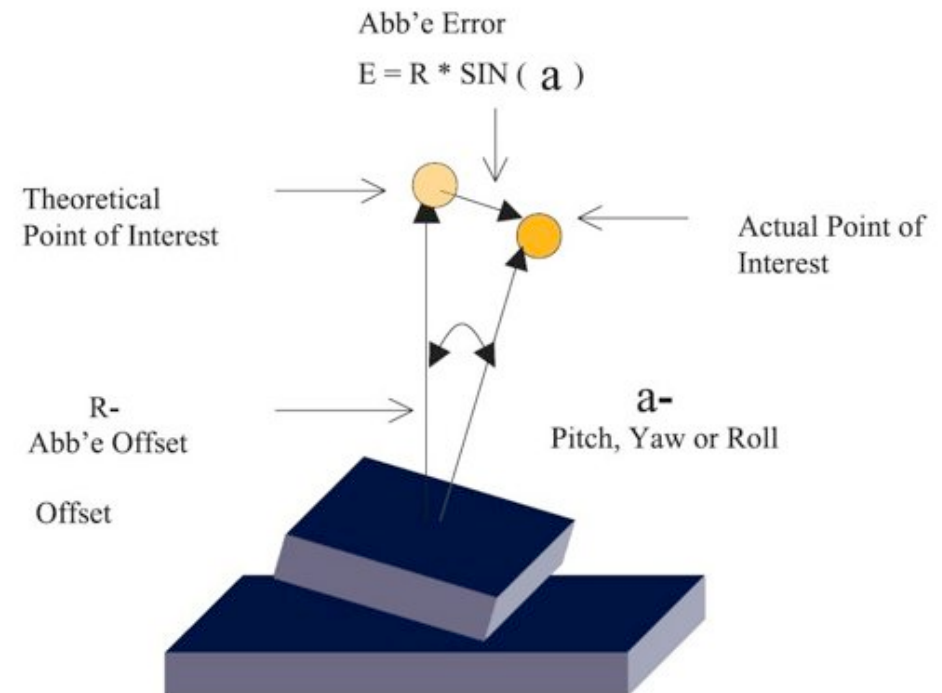
Requires an accurate machine with:

- **Automated scan field calibration**
- **Automated correction of drifts**
- **Automated power calibration**
- **Camera system for alignment**



Motion

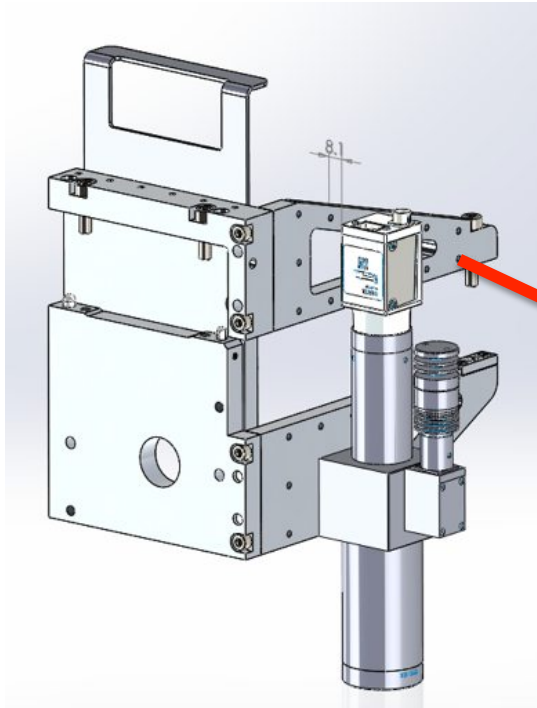
- Split axis system – comparable to CMM – on 9 t granite base
- Suited for high loads (300 kg) and high accuracy
- Air bearings on granite combined with direct-drives
- Sub micrometer repeatability
- Small pitch-roll-yaw, small abbe errors



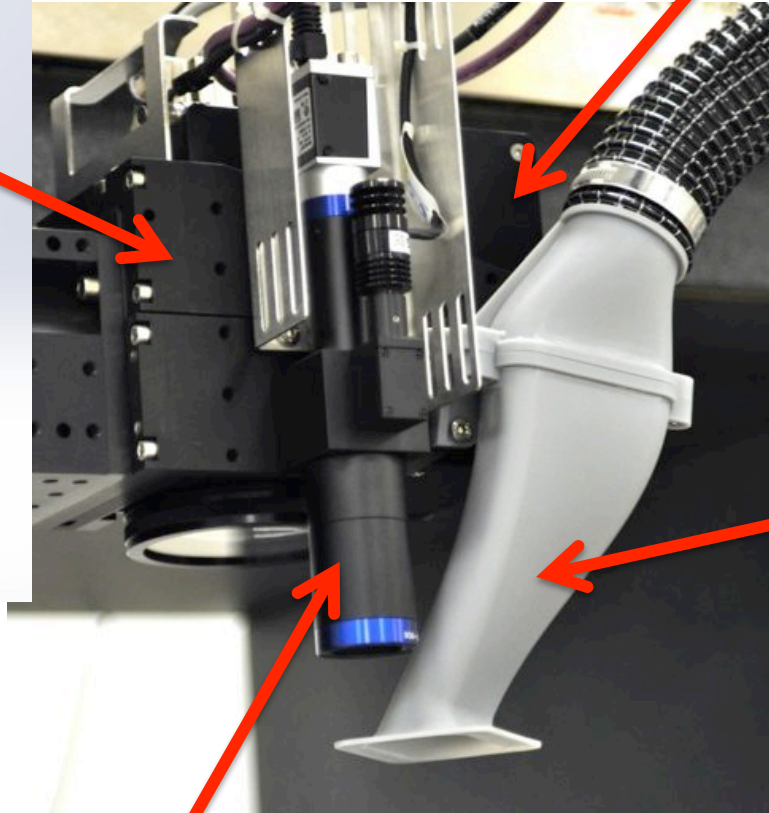
Scan Head Assembly

*Light*matif

Quick Change Adapter



Digital encoder
galvo scanner

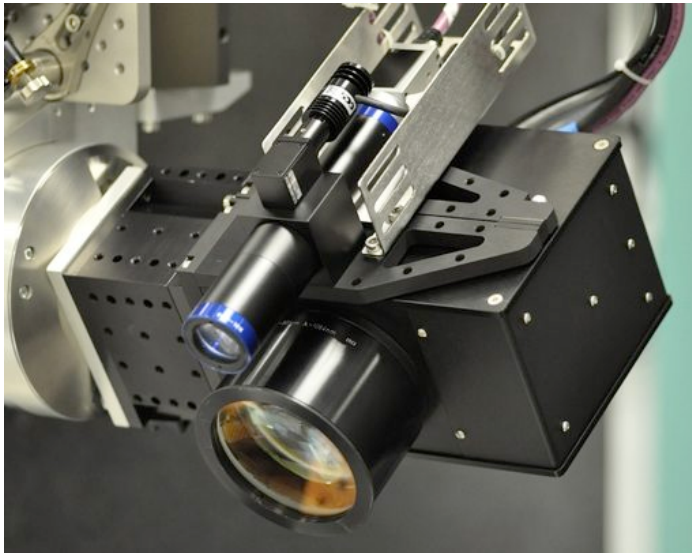
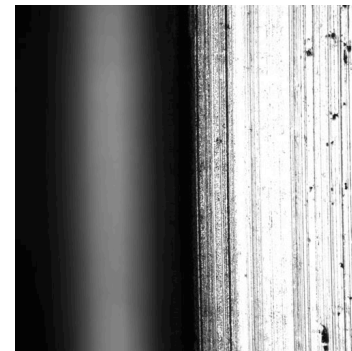
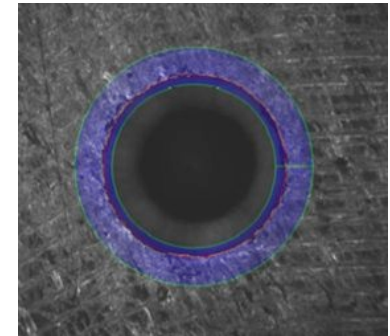


Custom
designed nozzle
for fume
extraction

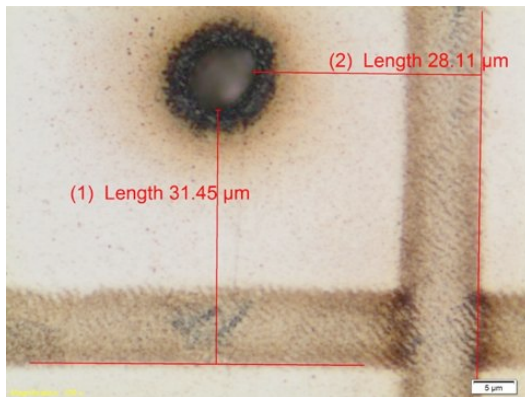
Off-axis camera

Off-axis Camera

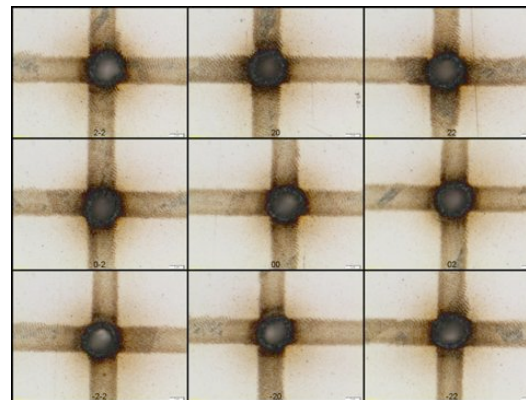
- For system calibration and alignment
- Precise position measurements in the image plane and focus direction
 - 1×1 mm field of view
 - optical resolution of 1.5 μm
 - working distance more than 55 mm
 - small depth of field – enables determining the height of workpieces
- Used in combination with inline camera system



- Sources of static laser spot position errors
 - Pincushion distortion (inherent in two-mirror deflection systems)
 - (Barrel) distortion caused by F-Theta lens
 - Alignment errors of scan head and laser beam
 - Collimation error
- Effect changes when
 - Changing incident beam
 - Unmounting/ mounting the scan head or objective
- Needs to be compensated by a **full calibration** of image field:
 - Measure spot position on a grid of points and generate new correction tables, normally performed manually:



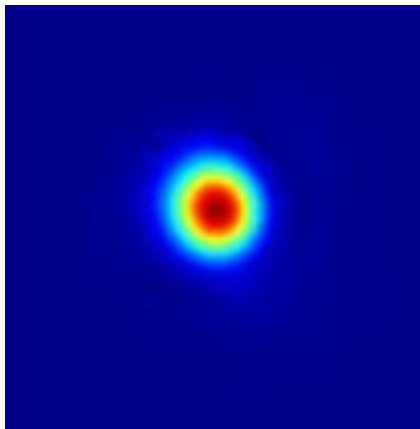
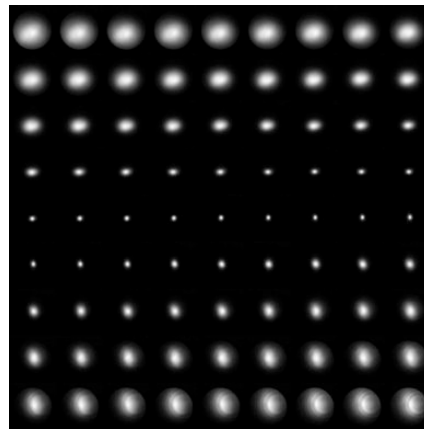
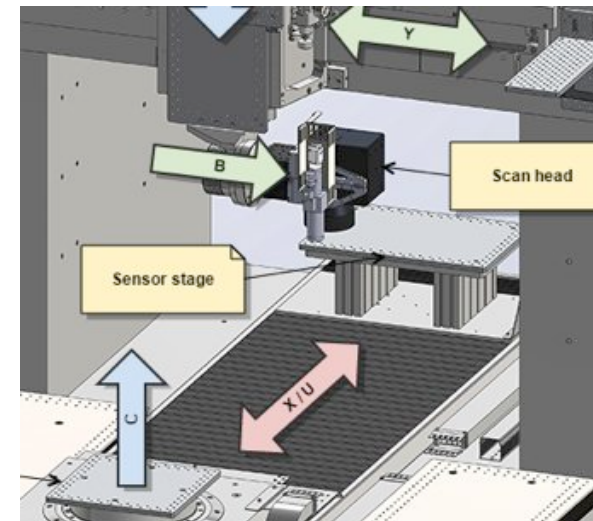
uncalibrated



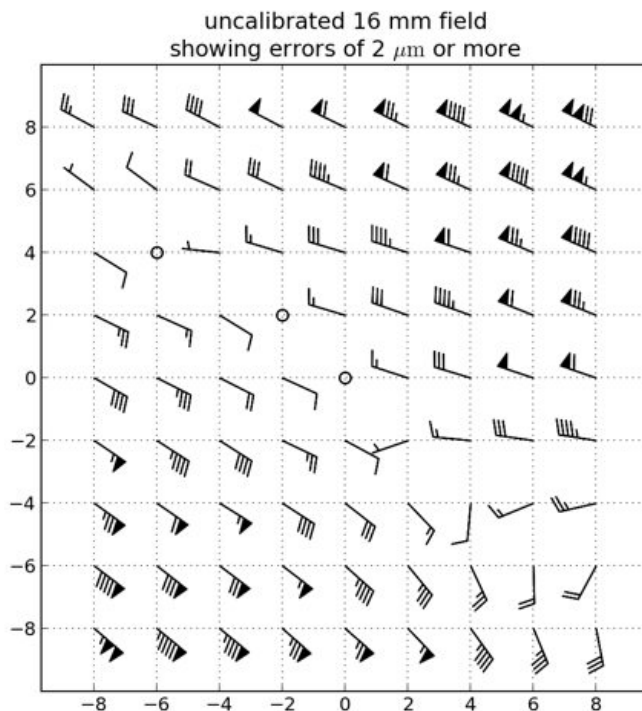
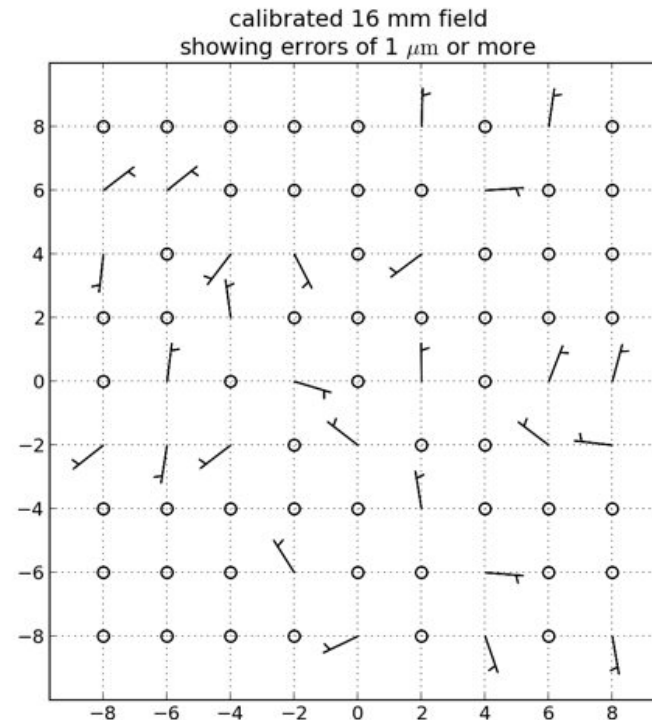
calibrated

- Laser pointing instability, up to 50 μrad (5 μm)
- Drift of scanner system
 - 20 μrad with digital encoders after warm-up (much more with analog encoders)
- These errors cause shift of the image field
- Can be corrected by a **quick calibration**, measuring and updating the scanner home position

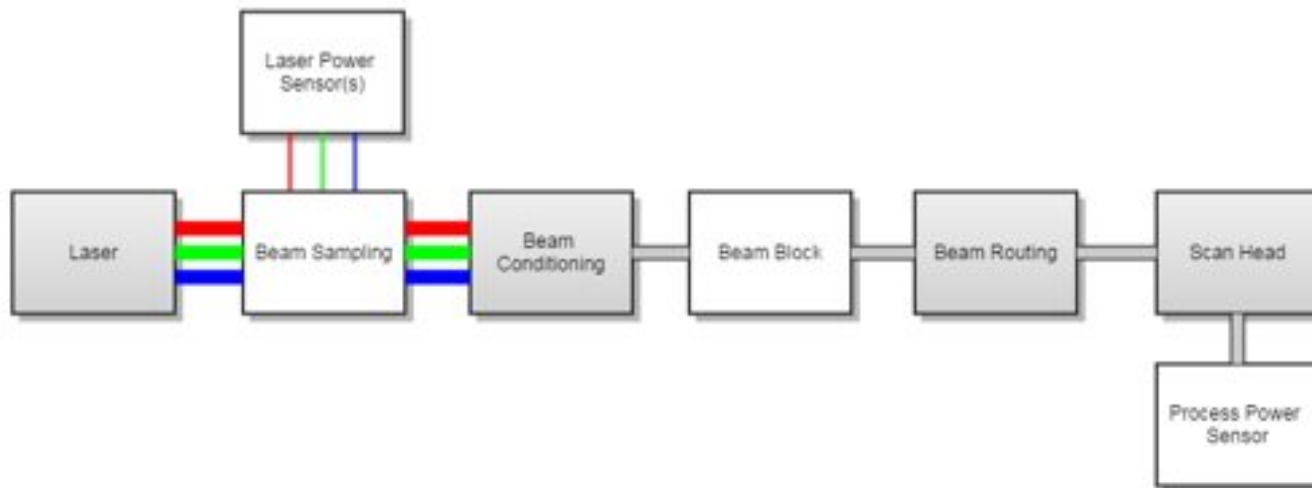
- Based on high resolution imaging and measuring of the focused laser spot, relative to a fixed reference in the machine
- The fixed reference can be imaged by the off-axis camera as well as the spot measurement system
- Enables an **automated full calibration** of the the scan field distortion, as well as measuring the **focus position** in 3D
- Relates the laser spot position to the machine coordinate system
- Also enables an automated **quick calibration** of drifts



- Calibration performed using 81 test points
- Before calibration: errors up to 60 μm
- After automated calibration: (random distributed) errors are less than 2 μm , for the largest part less than 1 μm



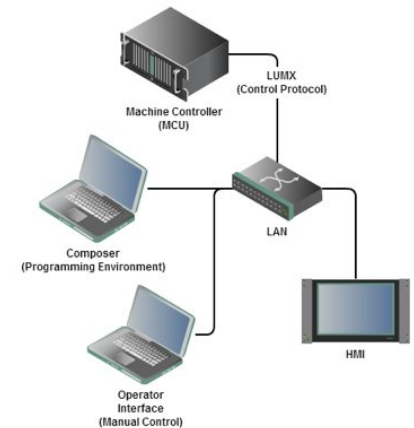
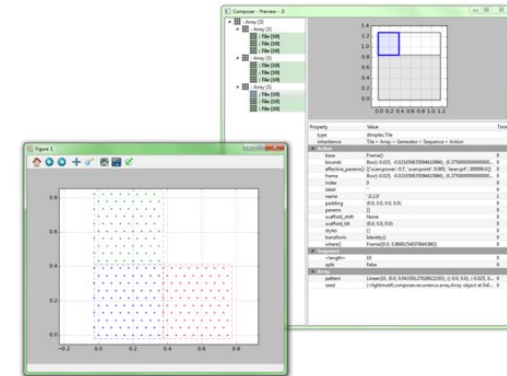
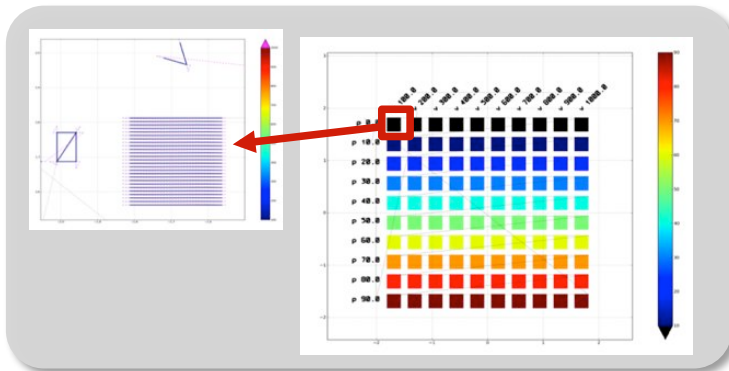
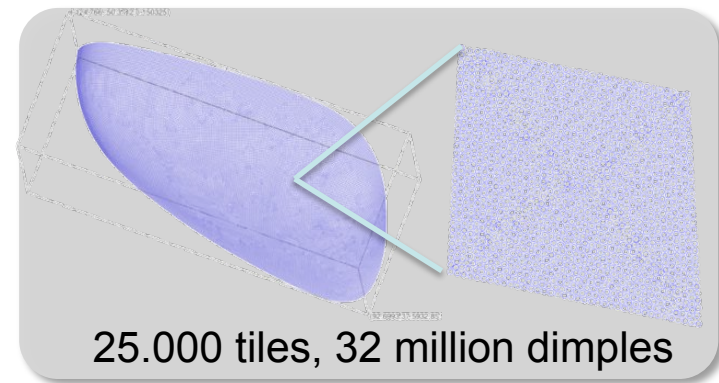
- Integrated power calibration system measures the laser power and system transmission to ensure process repeatability
- Enables to **program the machine in watts** in stead of percentages
 - Always the same power, reduced risk of ‘human errors’
 - Ability to compensate for drift during long jobs/ production
- Source power meters: fast measurements to calibrate the power exiting the laser for its given configuration (e.g. PRF, wavelength)
- Terminal power meter: measures power exiting the scan head for calibrating system transmission



Control Software

Lightmotive

- Job definition using high level programming language
- Programmable control of laser settings (power, repetition rate, burst)
- Graphical job preview and inspection
- Graphical operator interface
- Support for system control by third-party software (C API, Network Protocol)
- Toolboxes for common tasks, e.g. experiment matrices
- Scales to large and complex jobs

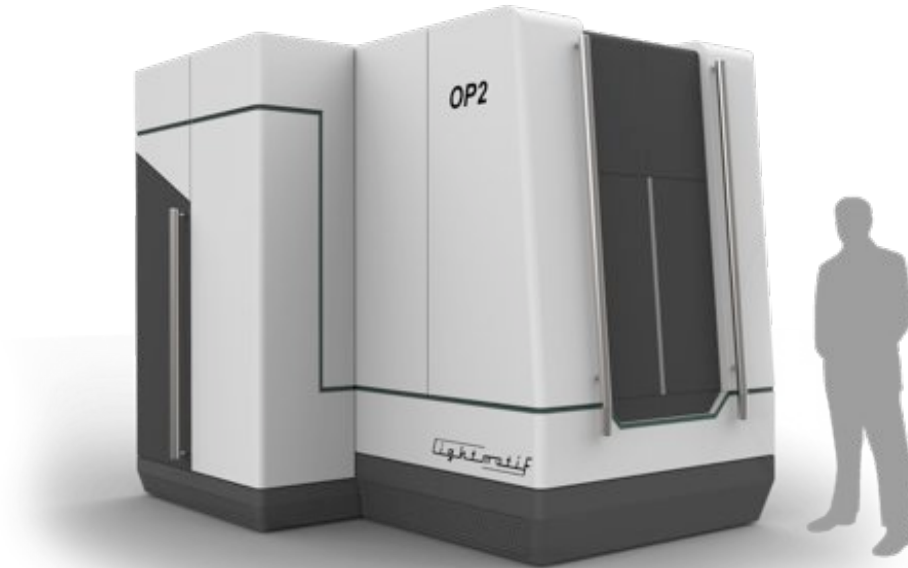
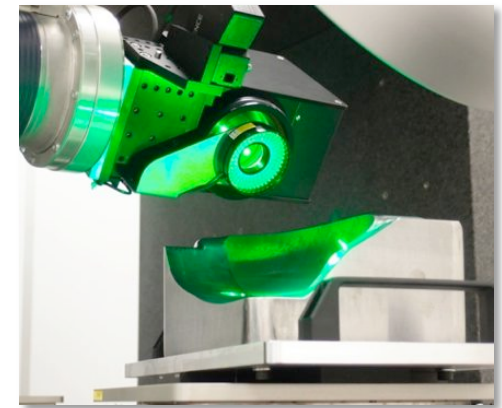


OP2

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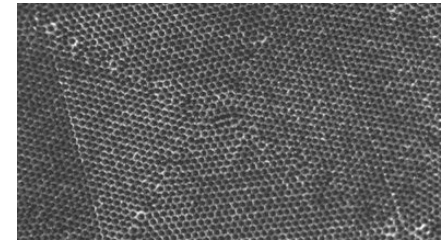
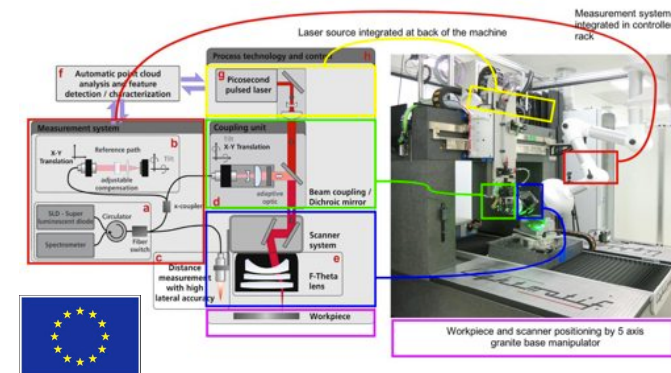
5 axis laser micromachining system

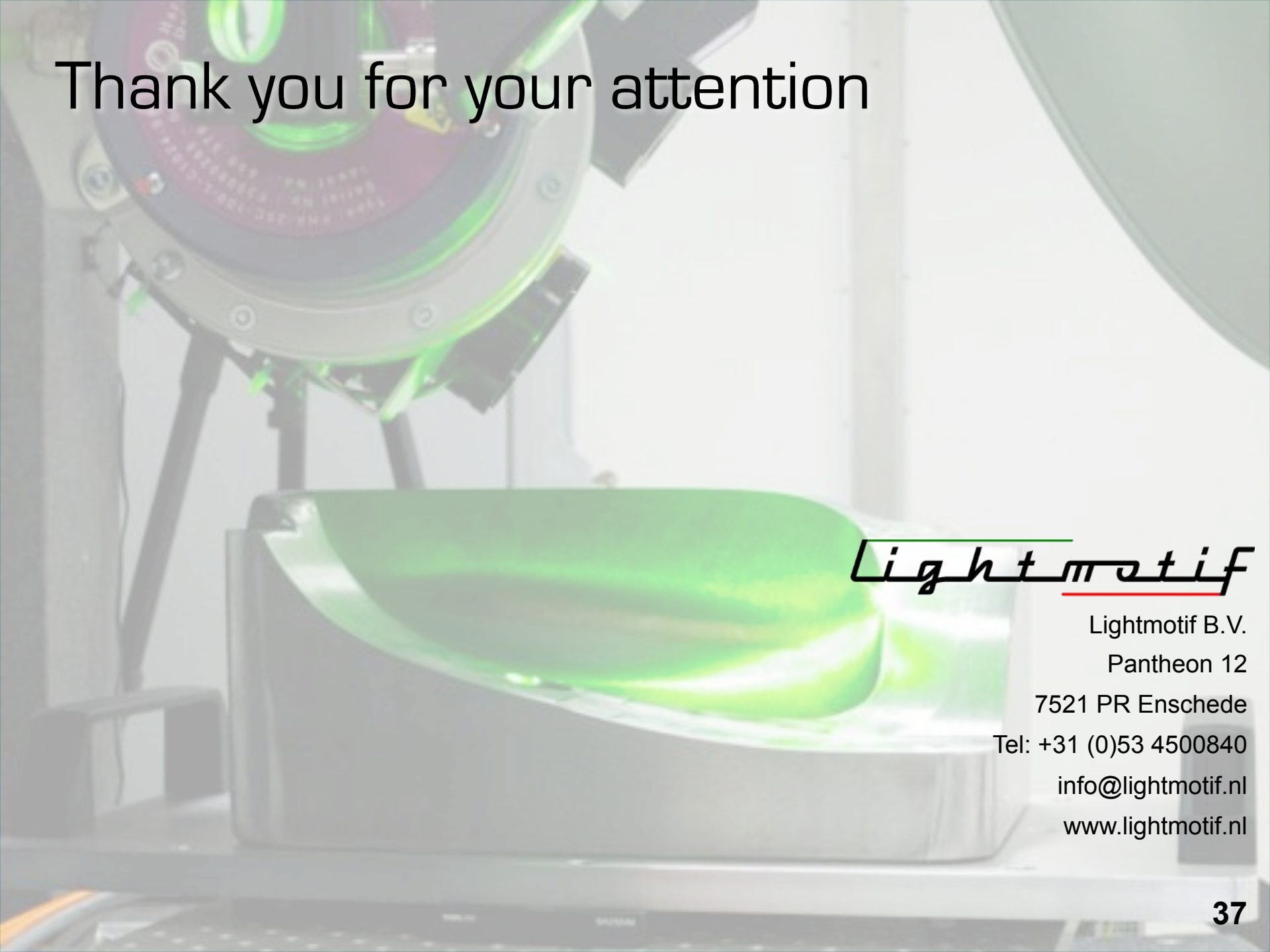
- Picosecond pulsed laser
- High accuracy galvo-scanner
- Air bearing direct-drive stages, sub micrometer repeatability
- 600 x 600 mm working area
- 300 kg load
- Flexible and modular machine concept
- High accuracy step-and-scan micromachining
- High level of automation and sensor integration
- Flexible and scalable control software



Summary and Outlook

- Texturing (micromachining) on 3D curved surfaces enables new applications in various markets
 - Automotive, medical, consumer goods, etc
- Step-and-scan machine technology:
 - Highly accurate 5-axis motion platform
 - Automated scan-field calibration, drift correction
 - Automated power calibration and correction, program your job in watts
- Flexible and scalable control software
- Outlook
 - Adaptive micromachining: automatically adjust micromachining process based on inline measurements
 - Adaptive micromachining platform under development in EU H2020 project ADALAM





Thank you for your attention

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