»ULTRASURFACE«
ULTRA DYNAMIC OPTICAL SYSTEMS FOR HIGH THROUGHPUT LASER SURFACE PROCESSING

European Commission
Horizon 2020
European Union funding
for Research & Innovation

AGENDA

1. Motivation & goal of the ultraSURFACE project
2. Project relevant technologies
3. Concept & approach
4. First results
5. General information about the beneficiary & role in the project

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Motivation

- Surface processing techniques are widely used in industry
- Laser based processes…
  - … offer high flexibility, precision and quality
  - … offer new possibilities for creating complex surfaces
- The throughput of these processes is often not sufficient for an economic, industrial application
- In the same time:
  Laser sources getting more and more affordable

Goal

Overall goal:

Increase the throughput of laser based surface treatment processes by a **factor of 10**

Project title:

»Ultra Dynamic Optical Systems for High Throughput Laser Surface Processing«

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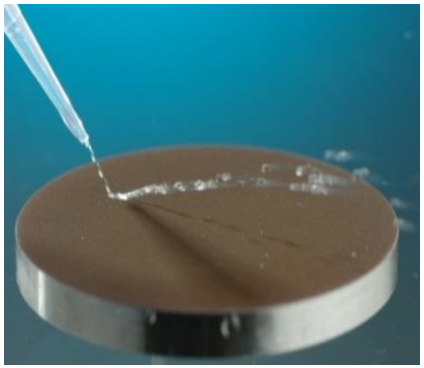
Laser processes
Laser structuring (LS)

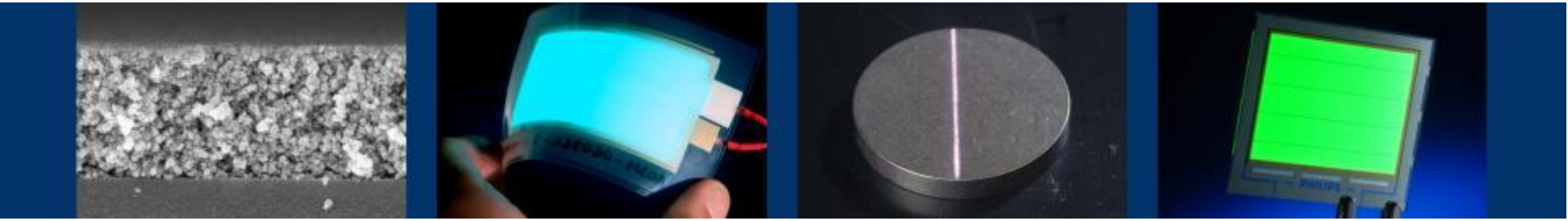
- Achieve small structures in micrometre scale
- With each pulse a tiny amount of material is removed by ablation
- Processing of 3D parts is achieved by sequential processing of tiles
- The low throughput is still limiting this technique to the processing of moulds rather than the processing of the work piece itself / individual parts



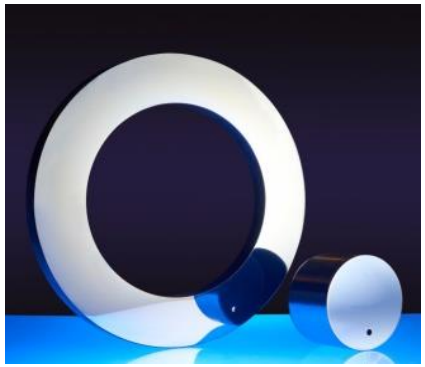
Laser processes
Laser polishing (LP)

- Based on remelting a thin surface layer and smoothing the surface due to the surface tension
- Initial roughness of Ra = 1 – 10 µm can be reduced down to Ra = 0.05 – 0.5 µm
- Process has been adapted to 3D parts for a circular shaped beam profile
- In-house developed 3D CAM-NC process chain allows the processing of complex 3D parts using simultaneous processing
- First industrial applications already showed the potential of this new technology while the throughput is still one of the main limitations

Laser processes
Laser thin-film processing (LT)

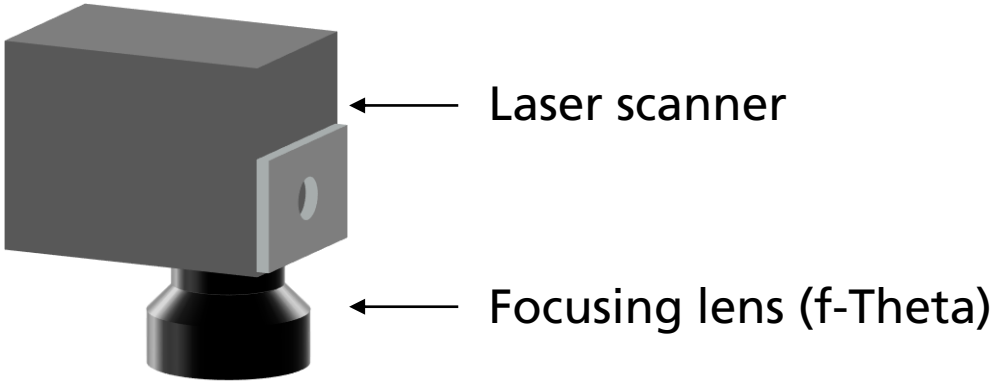


- Tool for improving the performance of technical components e.g. wear, corrosion protection or electrical conductivity
- Often a 2-step process involving the deposition of the film followed by a heat treatment
- Lasers represent a versatile alternative to conventional heat treatment: processing of thermally sensitive substrates, defined local treatment of a component
- In many fields of application requires long processing times and not adapted for complex 3D components yet

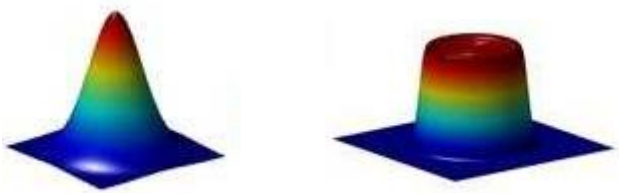


Laser processes
All processes

- A laser scanner is used for a fast (v>10 m/s) beam deflection in 2D/3D

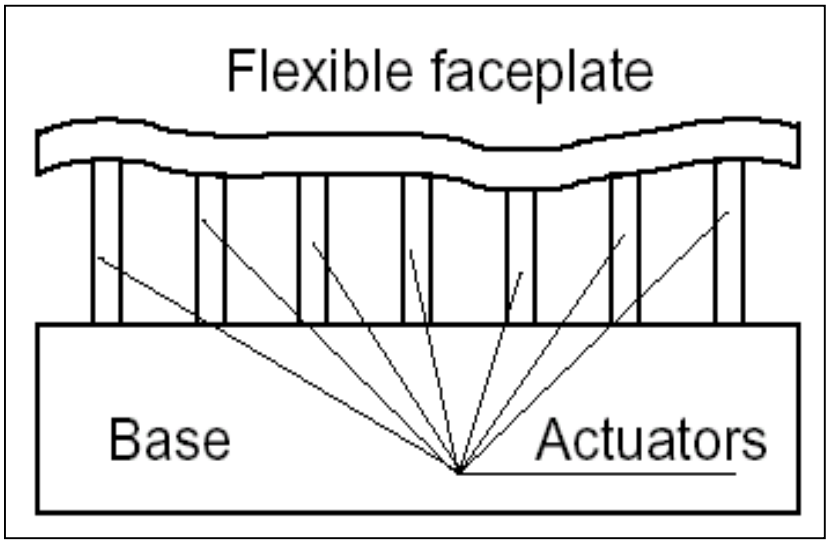


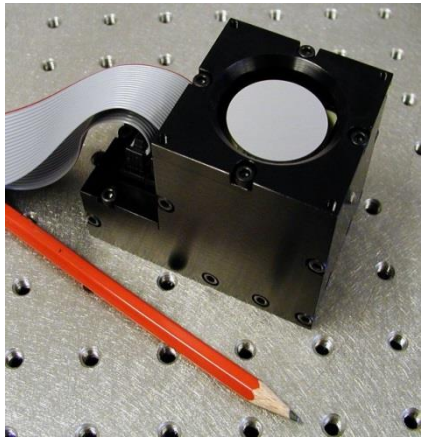
- For almost every application a circular shaped beam profile is used

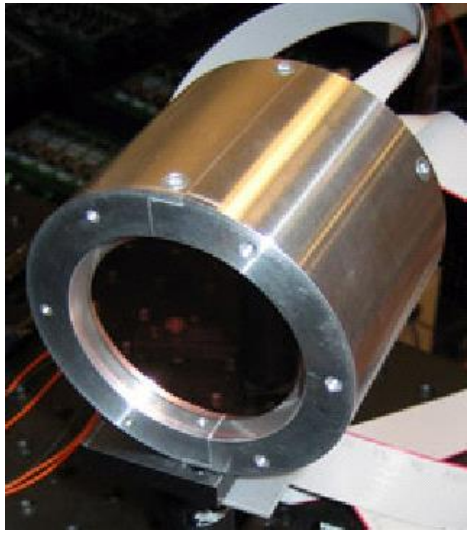


Optical elements
Piezoelectric deformable mirrors (PDM)

- The shape of continuous faceplate is deformed by piezoceramic (PZT) actuators working on transverse piezoeffect

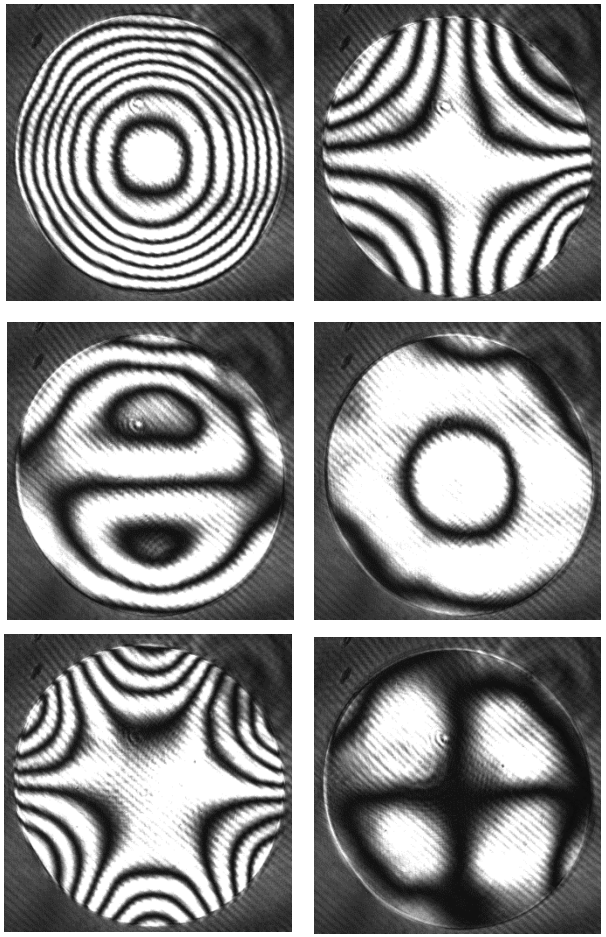






Optical elements

Piezoelectric deformable mirrors (PDM)



- Low cost actuators
- Free edge
- Can be coated with all available coatings (up to 1 kW load)
- Response: 1.5 kHz
- Correction range (8 um per actuator)
- 19 to 109 actuators
- 30 and 50 mm apertures

Optical elements

Diffractive optical element (DOE)

1. Using diffraction and interference phenomenons Holoor designs a special pattern for a desired result

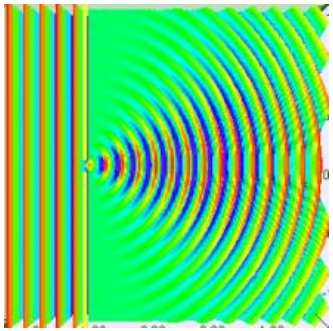


Image by Lookang (Wikipedia)

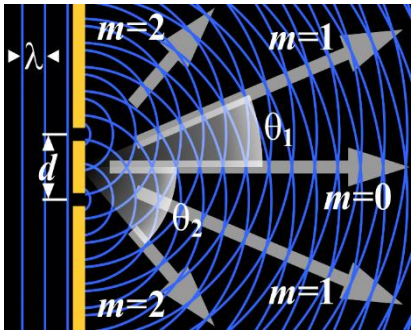
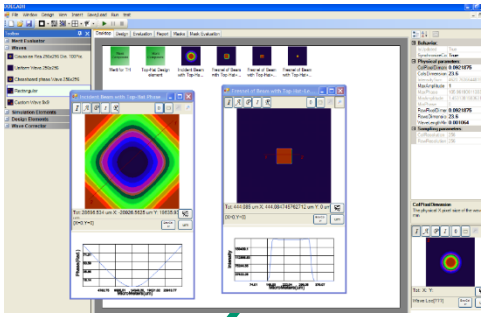
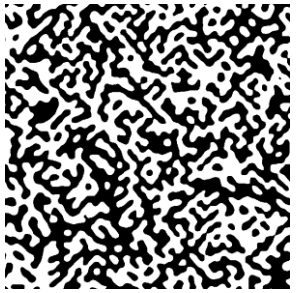


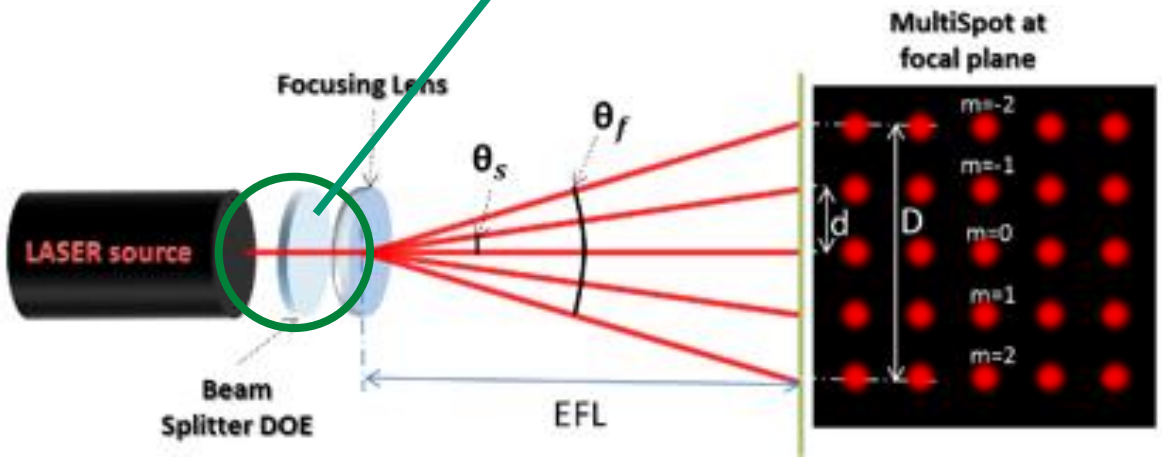
Image by Peo (Wikipedia)

2. The special pattern is applied over a substrate to create the DOE using a lithography process(es)



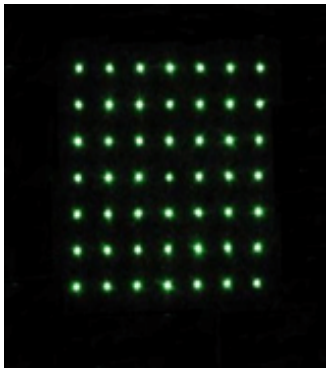
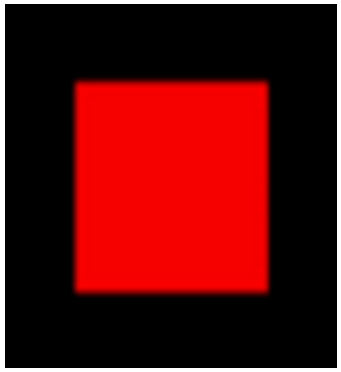
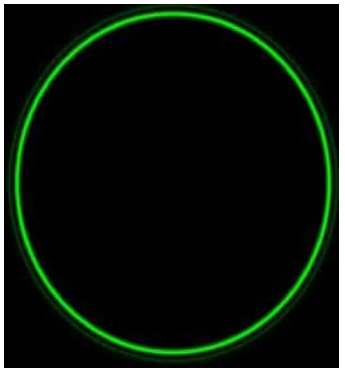
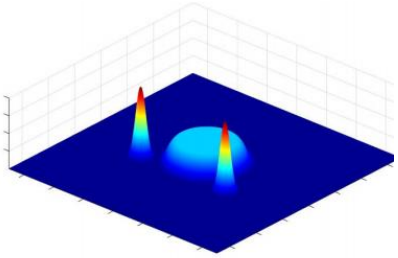
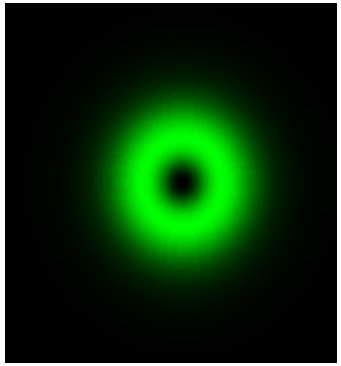
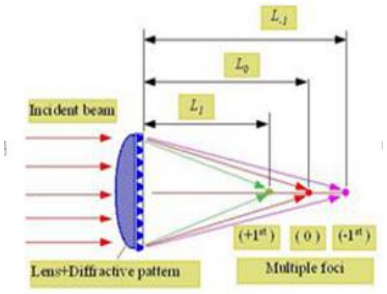


3. The DOE is implemented into a system to achieve desired or improved output



Optical elements
Diffractive optical element (DOE)

- Beam splitting
- Beam shaping
- Beam focal shaping
- Others: sampling, phase corrections

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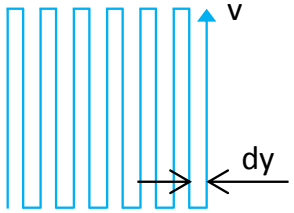
Concept & approach
Increasing throughput

State of the art

Circular or square intensity distributions

Meandering tool path

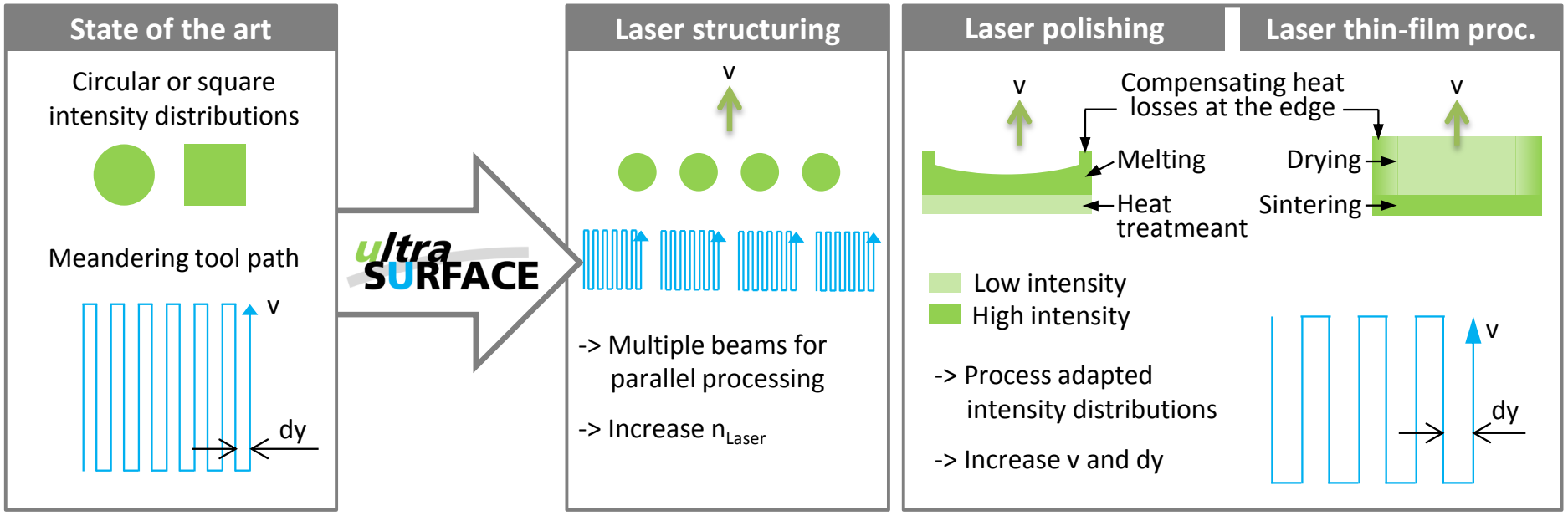


Troughput:

$$TP = \left(t_{npt} + \frac{A}{v \cdot dy \cdot n_{\mathrm{Laser}}} \right)^{-1}$$

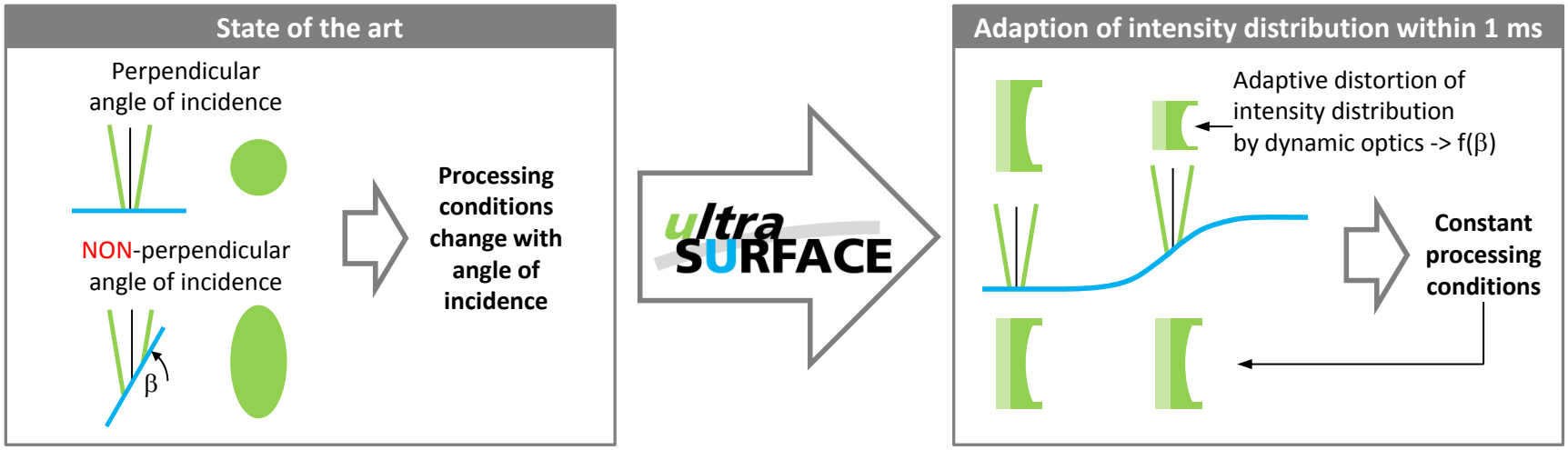
t_{npt}	non-prod. Time	↓
A	Area	
v	Velocity	↑
dy	Track offset	↑
n_{Laser}	# Laser	↑

Concept & approach
Multi-beam, beam-shaping



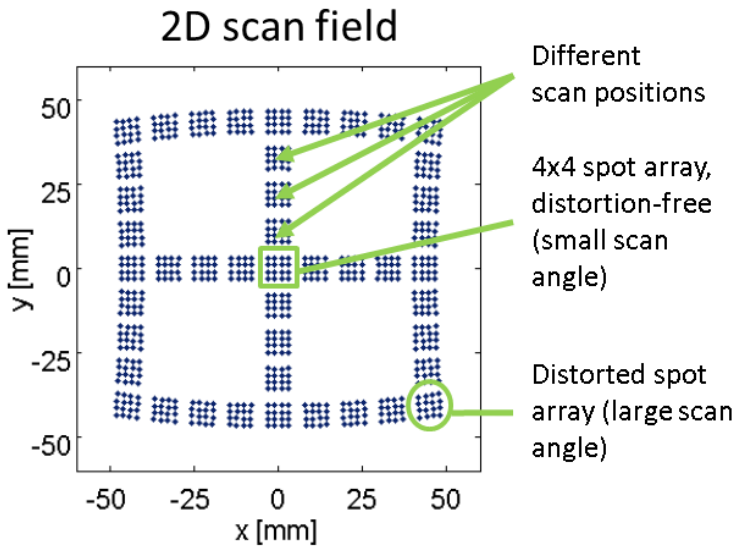
Concept & approach

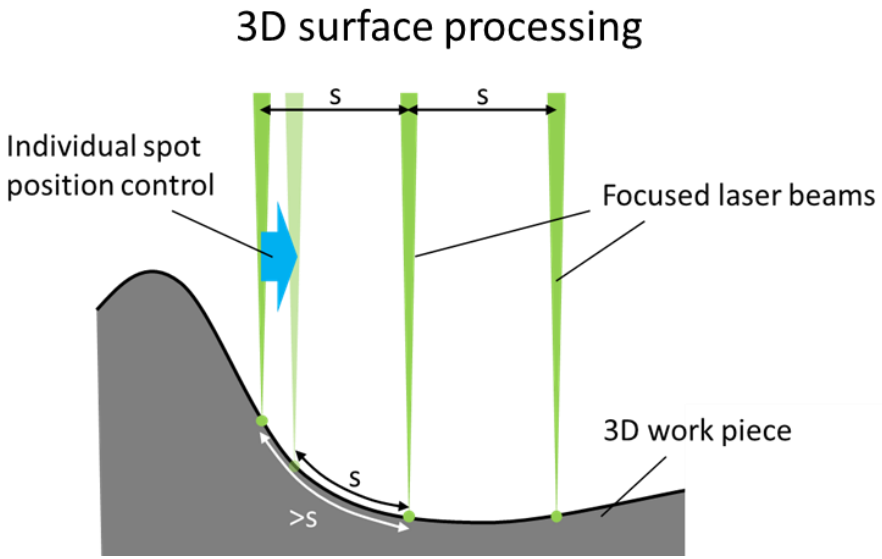
Adaptive beam-shaping for 2D/3D processing



Concept & approach

Adaptive multi-beam positioning for 2D/3D processing





Concept & approach
S.M.A.R.T. objectives

»Ultra Dynamic Optical Systems for High Throughput Laser Surface Processing«

SO1 - Dynamic and flexible beam-shaping optics for laser surface processing

SO2 - Multi-beam optics for parallel laser surface processing

SO3 - Ultrafast synchronisation of optics and machine for 3D processing

SO4 - Validation in industrial scenarios

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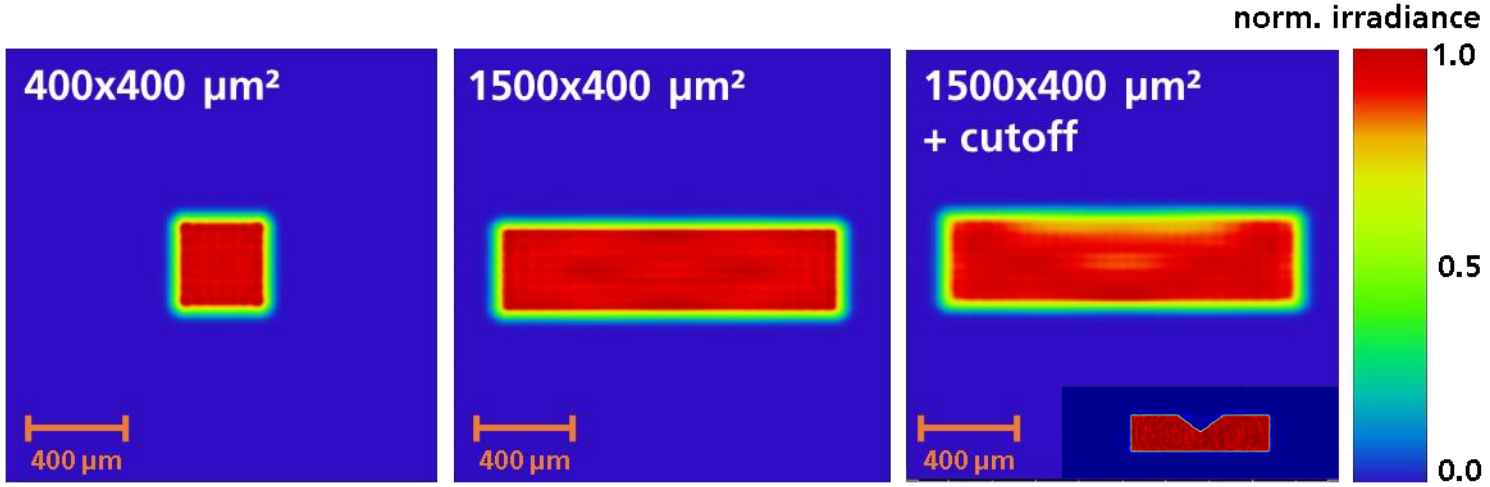
Beam-Shaping Optics (SO1) - Concept

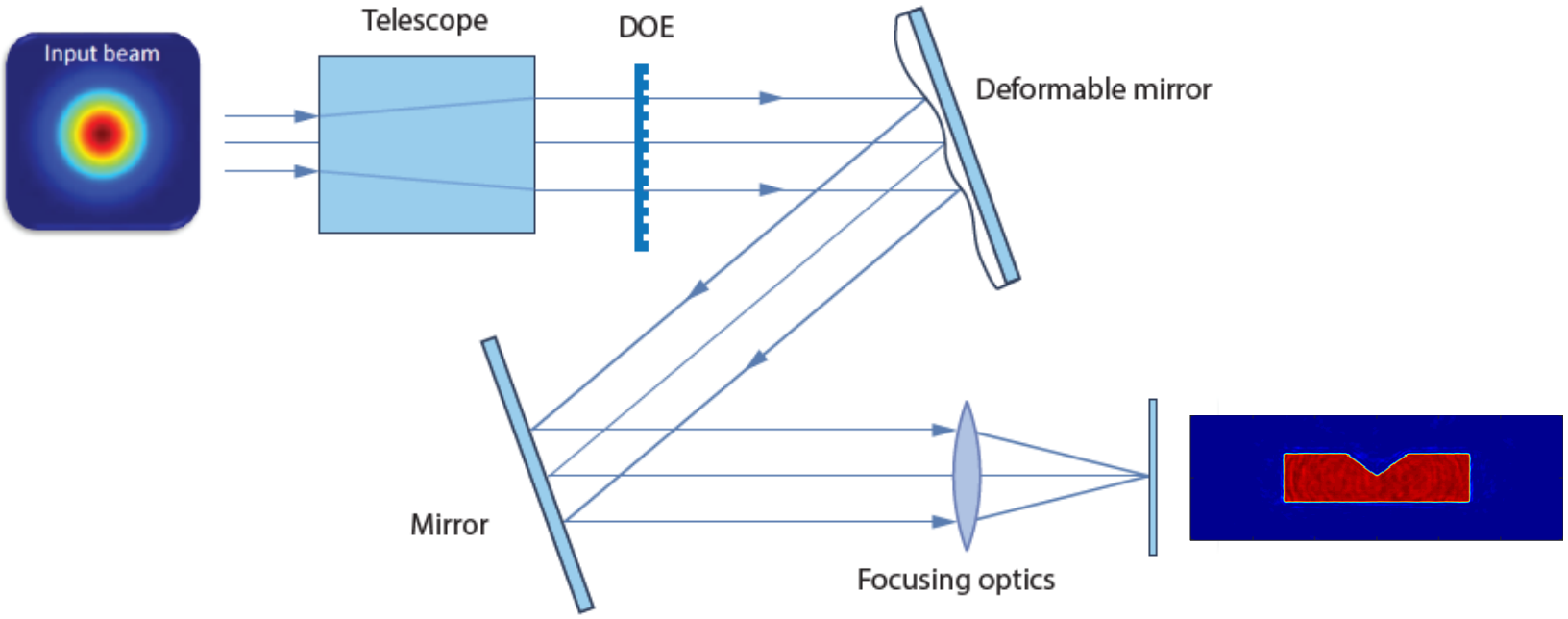
- **Analytical model for deformable mirror (PDM) shape**
  - PDM surface shape is calculated based on actuator voltages and integrated into optical design software
  - evaluation of beam-shaping capabilities of state-of-the-art PDMs
  - results for 79 channel piezo-electric DM (⌀ 50 mm):



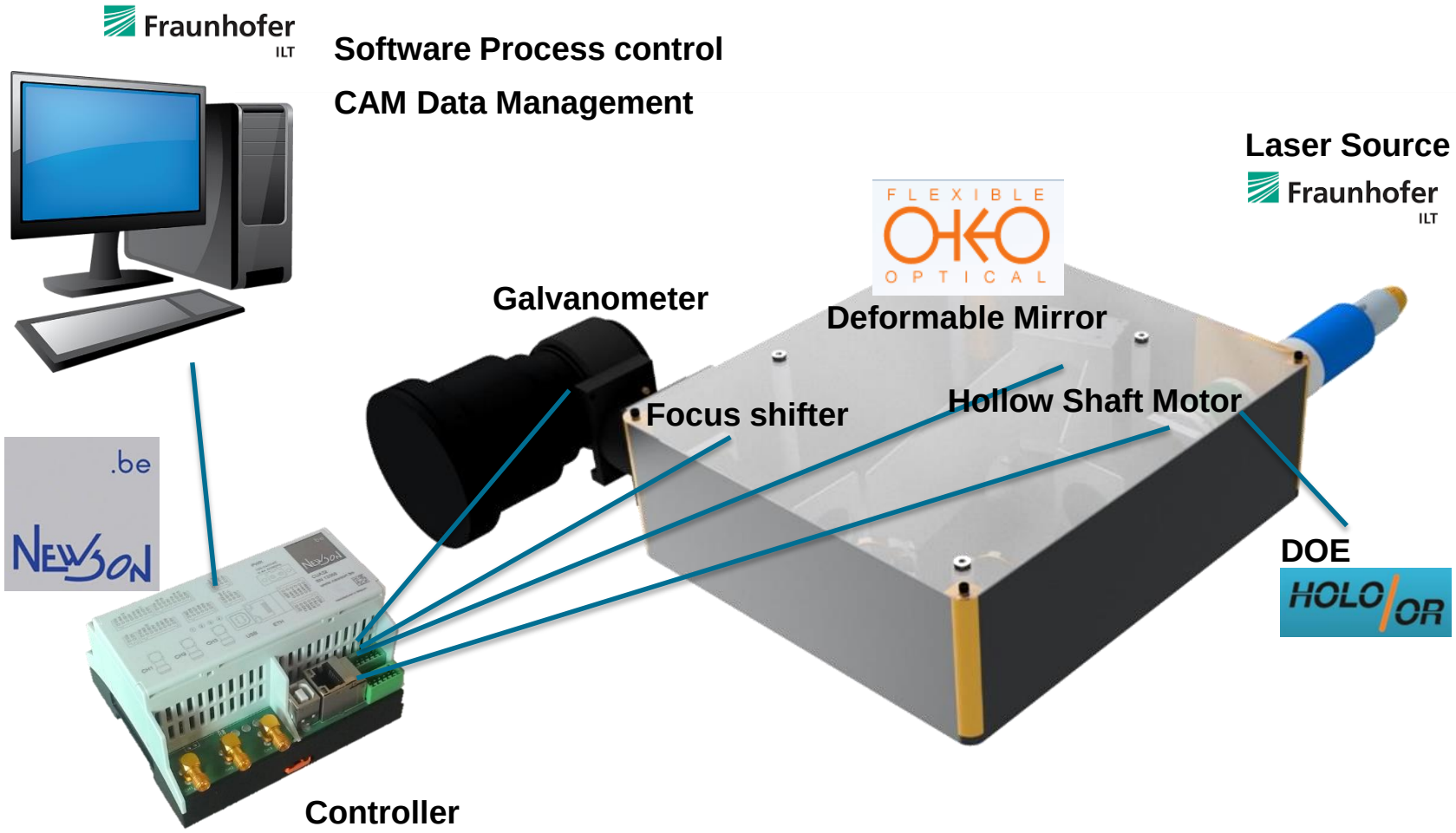
  - ➢ additional (static) beam-shaping element required

Beam-Shaping Optics (SO1) - Concept

- **Adapted concept:**
  - beam is pre-shaped with a rotatable diffractive optical element (DOE)
  - PDM compensates for scanner and 3D-surface related distortions



Beam-Shaping Optics (SO1) - Realization



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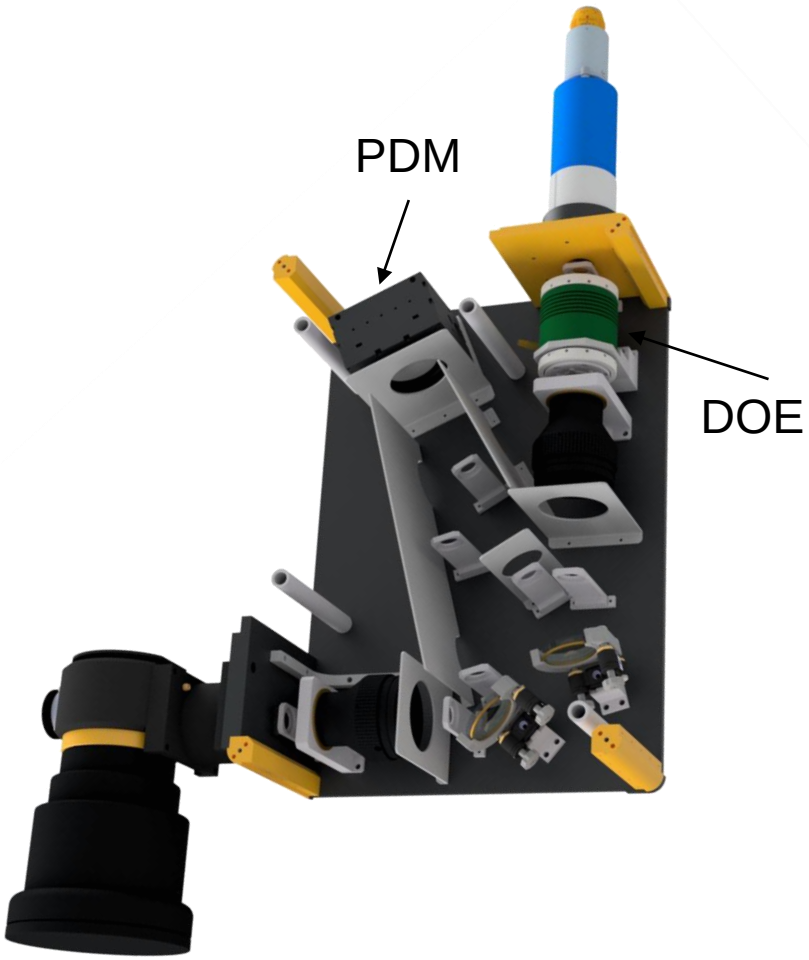
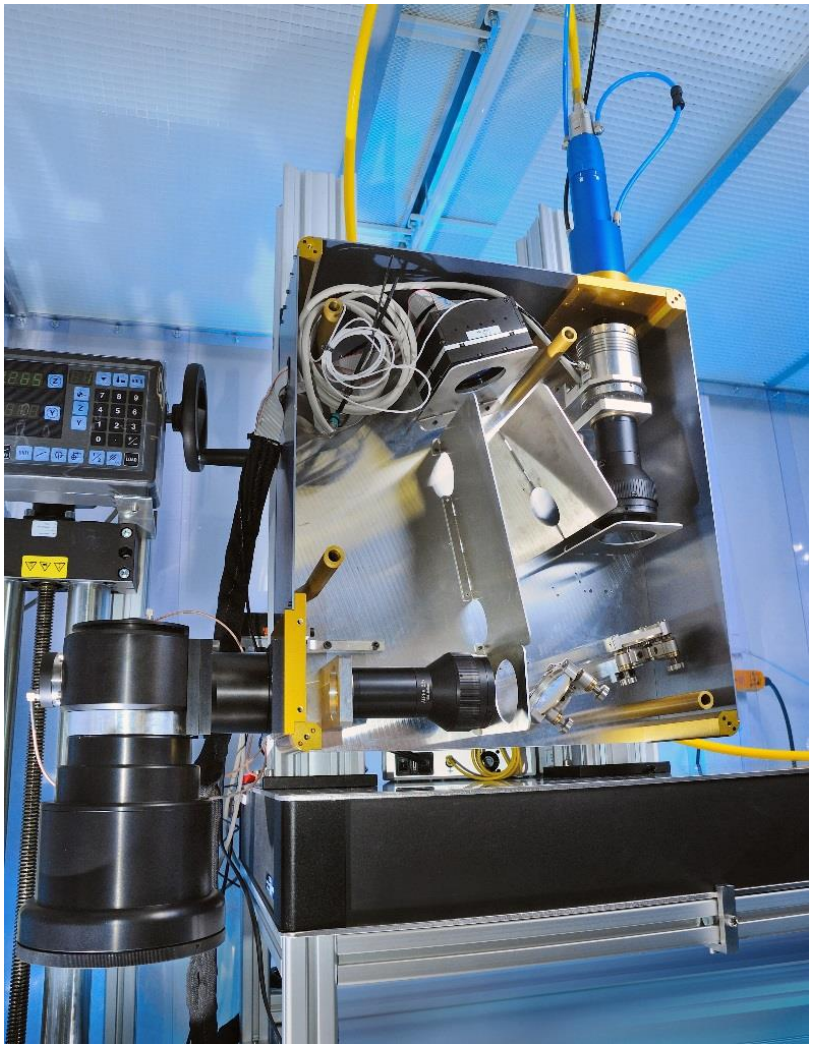
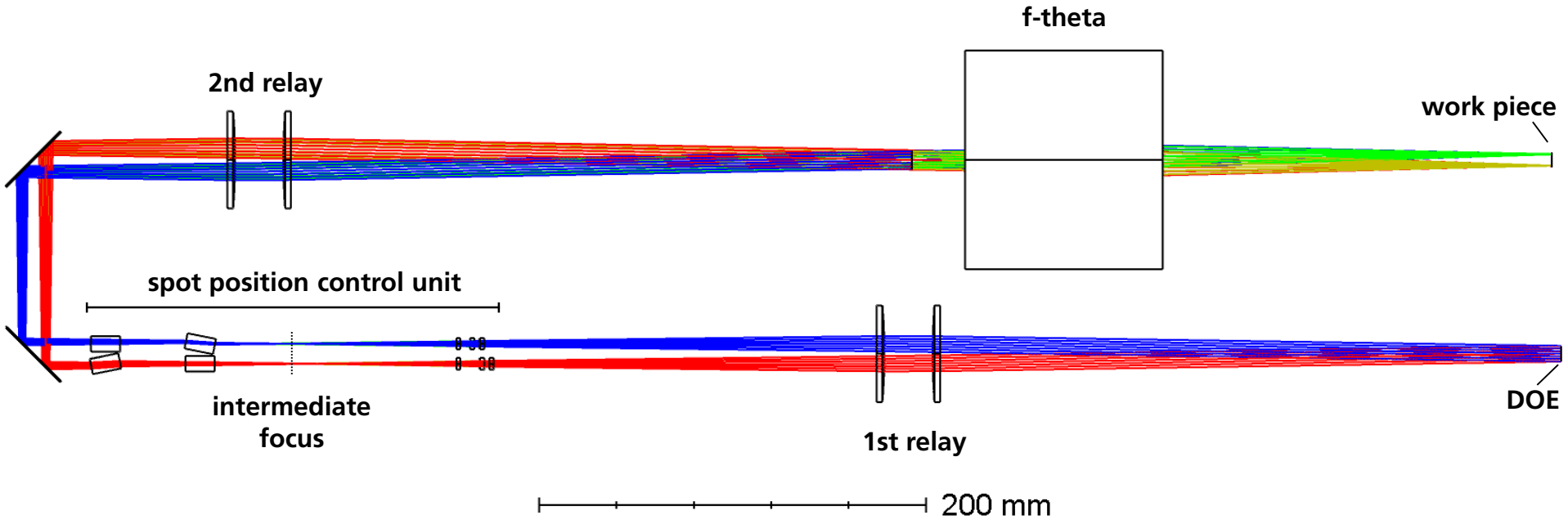


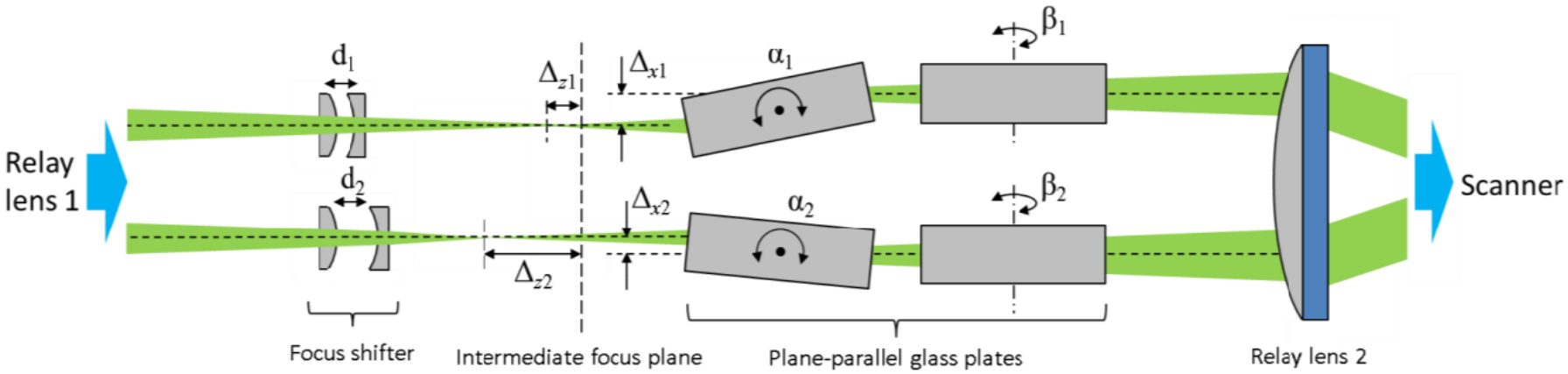


Multi-Beam Optics (SO2) - Concept

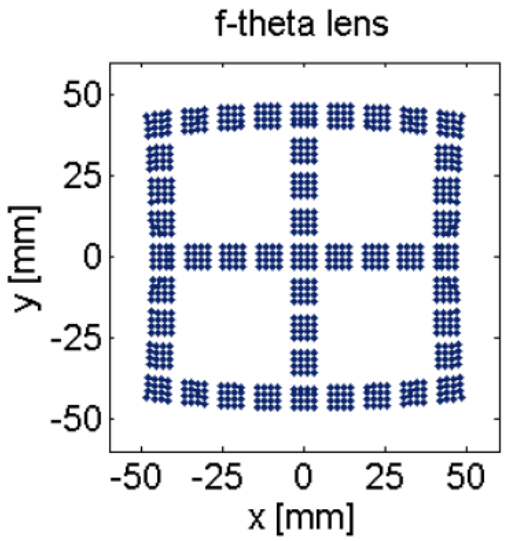


- DOE (diffractive optical element) splits initial beam into separate beams
- 1st relay lens focuses light into intermediate focus
- 2nd relay lens images DOE into scanner
- Spot position control unit for individual beam positioning

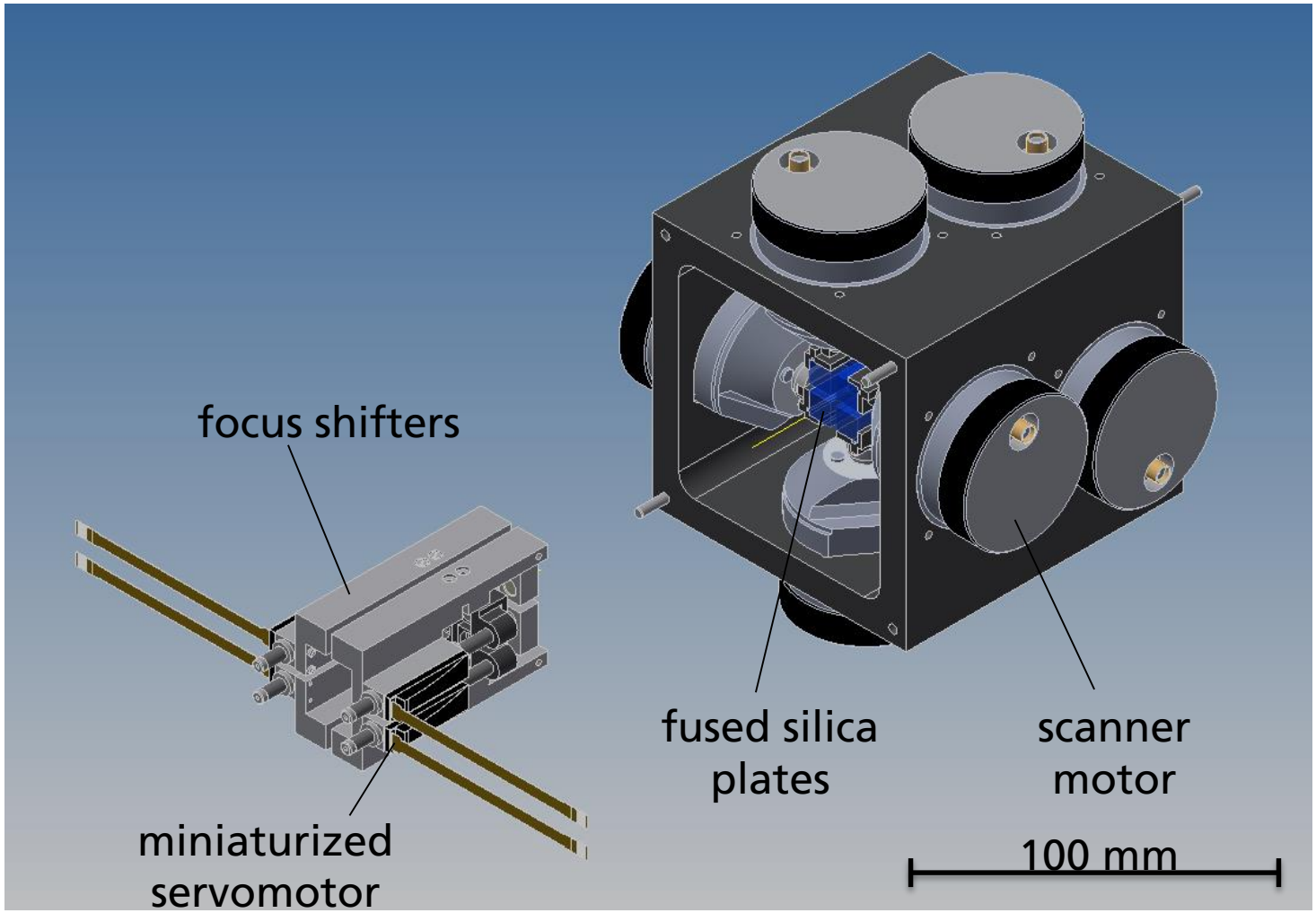
Multi-Beam Optics (SO2) - Spot Position Control Unit



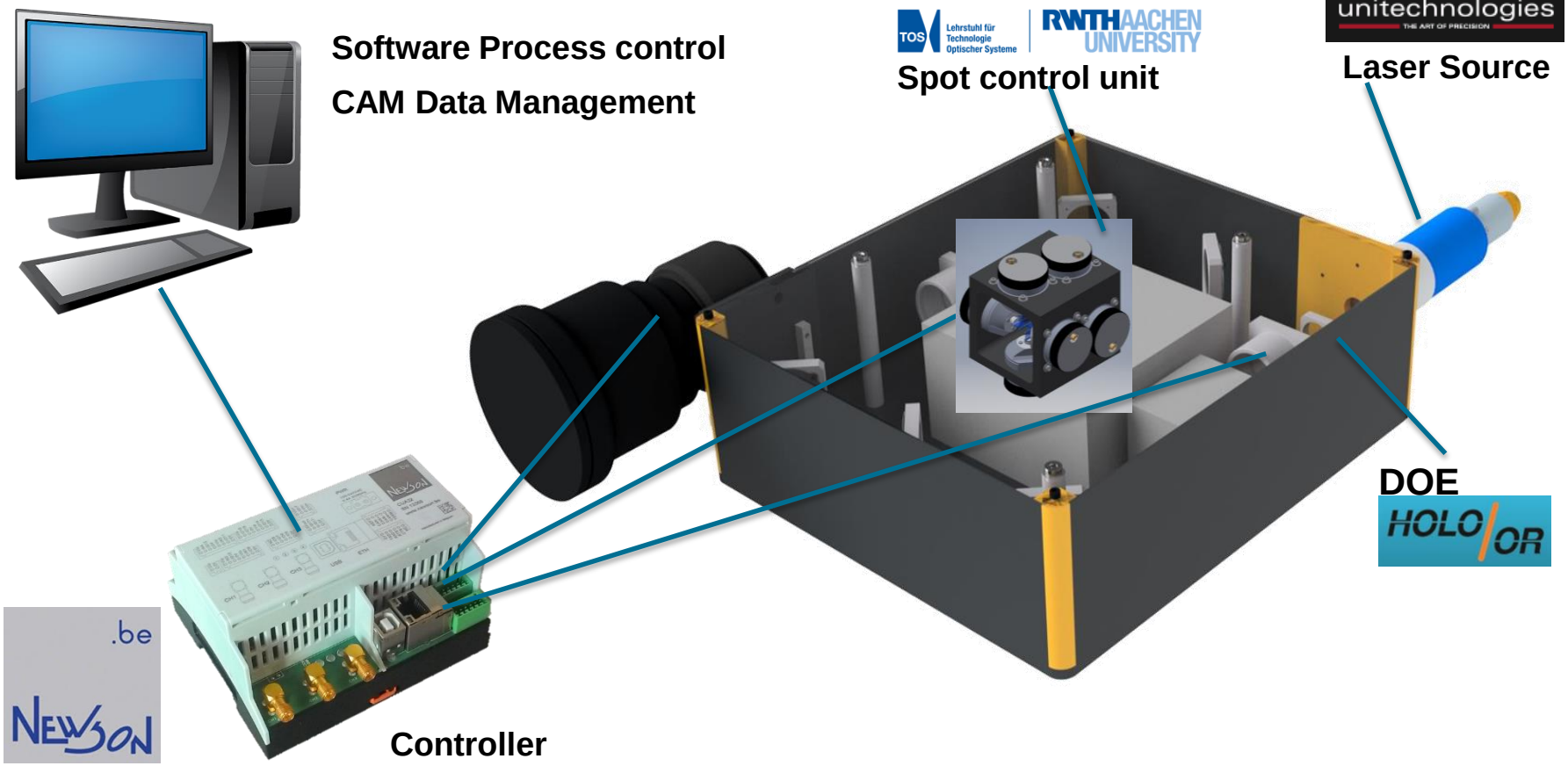
- Independent x-, y- and z-positioning of each beam
  - z: miniaturized focus shifter for each beam (+/- 3.5 mm)
  - x + y: 2 rotatable plane-parallel glass plates per beam (+/- 400 µm)
- Compensation of:
  - Local surface tilt (>10°)
  - Distortion of spot array for large scan angles



Multi-Beam Optics (SO2) - Spot Position Control Unit

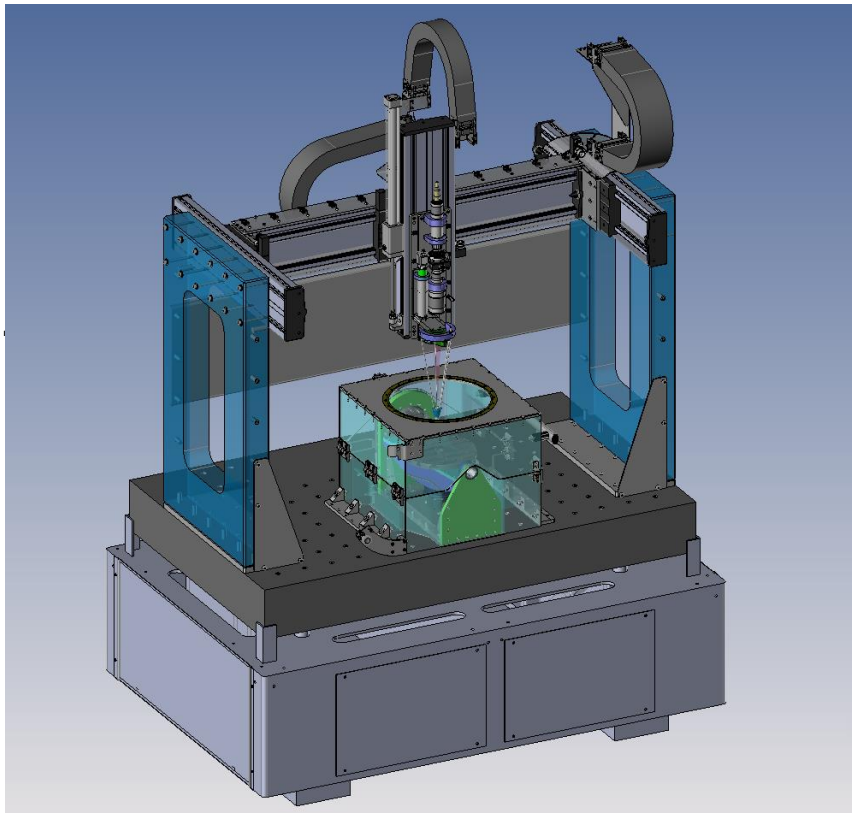


Multi-Beam Optics (SO2) - Realization

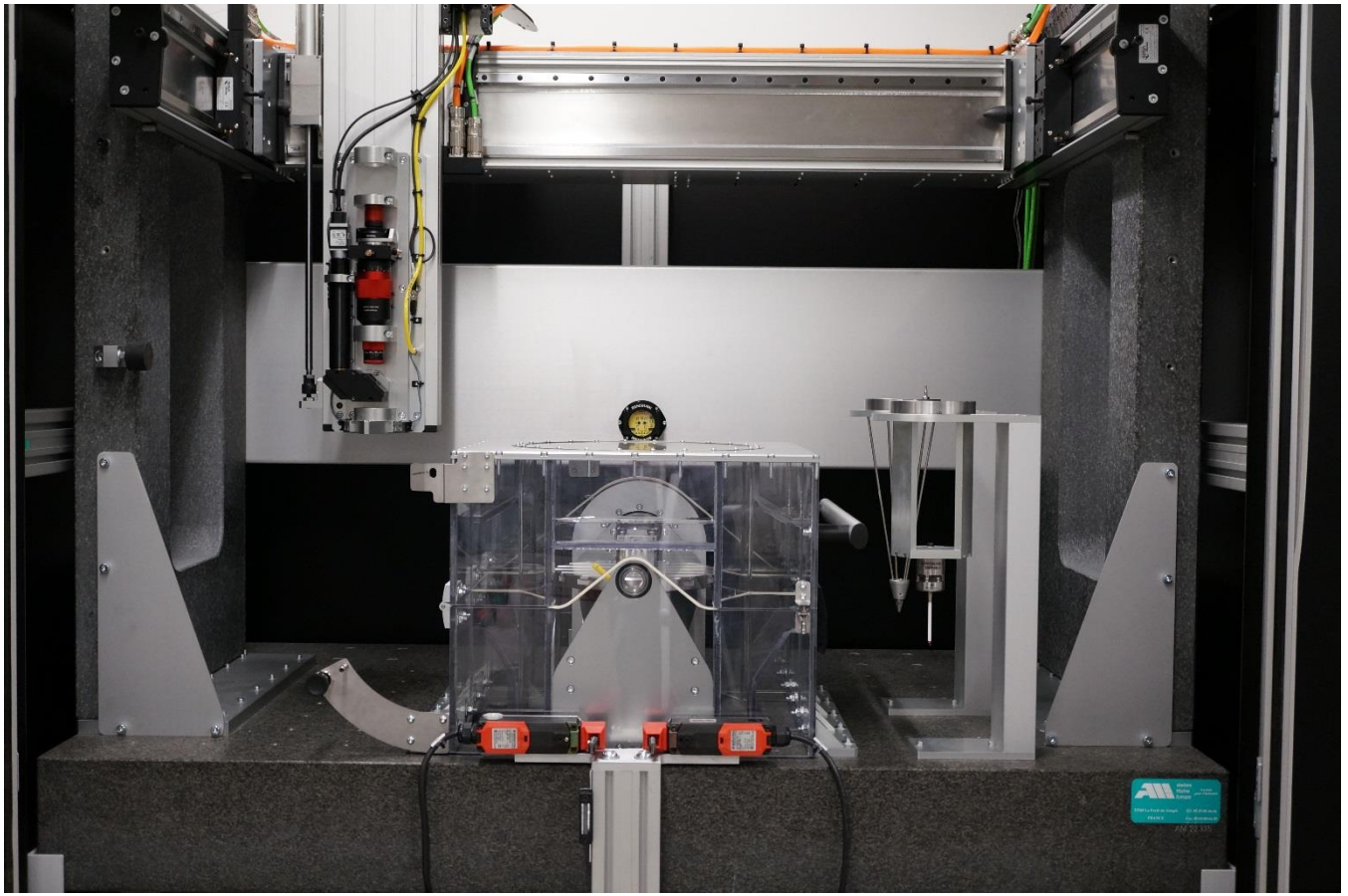


Machine Tool (SO3) - Concept

- Mechanical engineering
  - 5 numerical axis
  - granite base
  - measurement probe integrated
- Utilities (electrical, pneumatics, safety, ...
  - protective atmosphere
  - suitable laser safety housing



Machine Tool (SO3) - Realization



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Consortium


FLEXIBLE OPTICAL
NEWSON
Fraunhofer ILT
TOS Lehrstuhl für Technologie Optischer Systeme
PULSAR PHOTONICS
P&G
SCHAEFFLER
GEMÜ
unitechnologies
THE ART OF PRECISION
HOLO/OR

Contacts & role in the project

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