Additive Manufacturing and Nanoimprint Lithography of optics

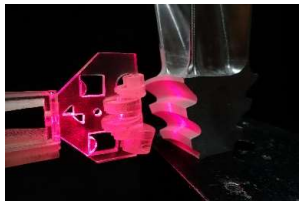
Zentrum für Optische Technologien, HS Aalen

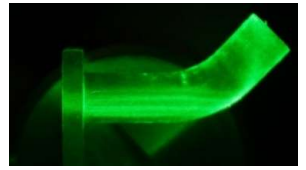
Andreas Heinrich

Outlook

- Optical Technologies @ HS Aalen
- Commercial Printing Technologies @ ZOT
- Examples 3D printed optics
- Analysis of 3D printed optics
- Own developed Printing Technologies
- Refractive index
- Replication of 3D printed parts using NIL

APH+OE ZOT





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Optical Technologies @ HS Aalen

- Education in Applied Photonics

Angewandte Photonik

Bachelor Optical Engineering konventionell	Bachelor Optical Engineering Dual
Master Applied Photonics konventionell	Master Applied Photonics Dual

Promotion Photonik

ZEISS Dual: Udo Schlickenrieder (Corporate Human Resources)

- Research in Applied Photonics
  - Laser Application Center
  - Center for Optical Technologies

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Work presented done by PhD-students of the group

Selina Burkert

Annika Dehm

Arielle Koffi

Sangeetha Suresh-Nair

Yannick Bauckhage

Mike Dohmen

Christian Eder

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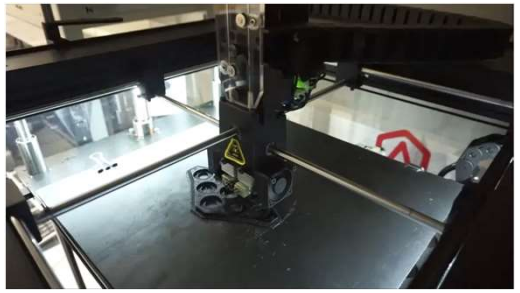
- Commercial Printing Technologies @ ZOT

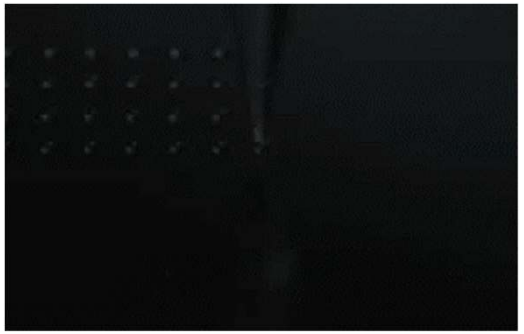
FDM Printing



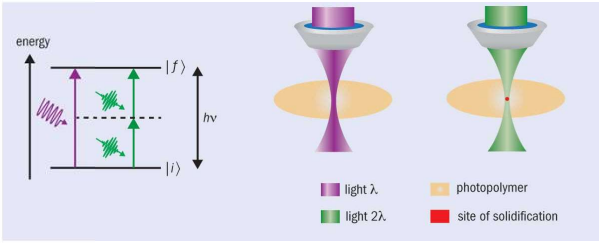
STL Printing

Ink-Jet Printing

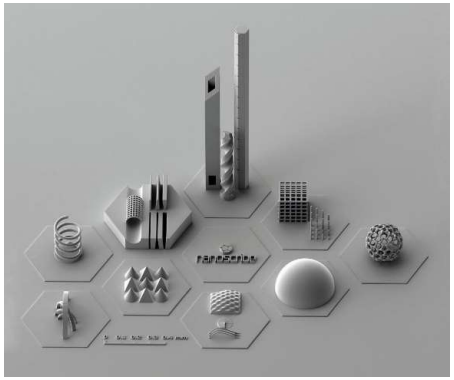
Dispenser Printing



2PP (Nanoscribe Quantum X)



Ref.: S. Steenhusen, Fraunhofer ISC



Ref.: Nanoscribe

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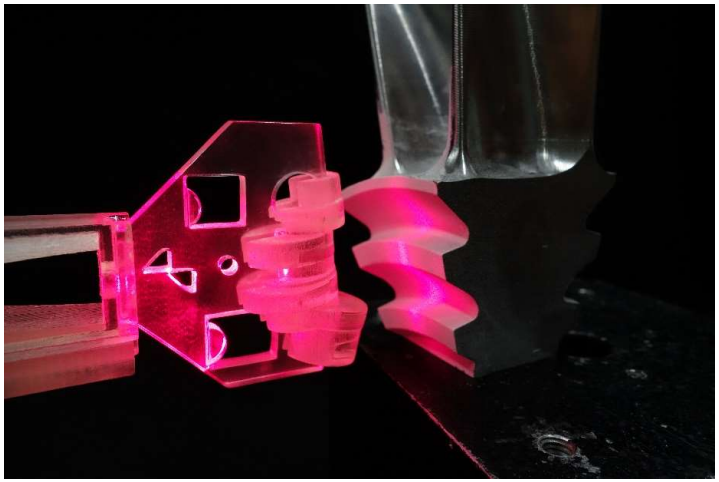
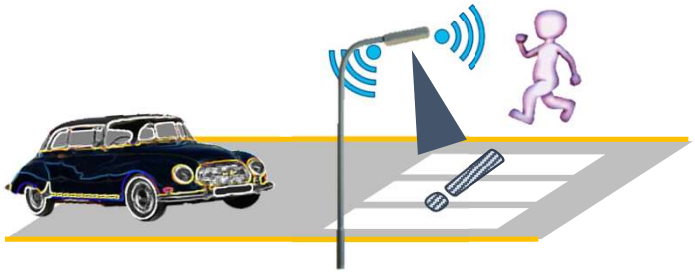


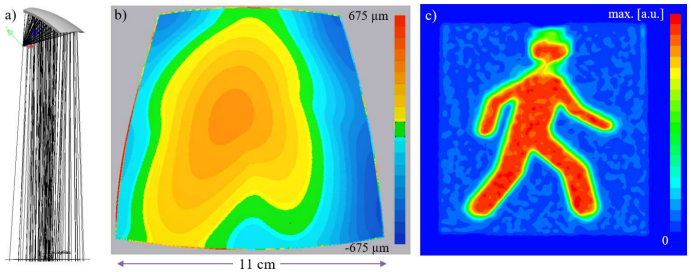
Examples 3D printed optics

- 3D printed reflector – Task



- Realization

- Design

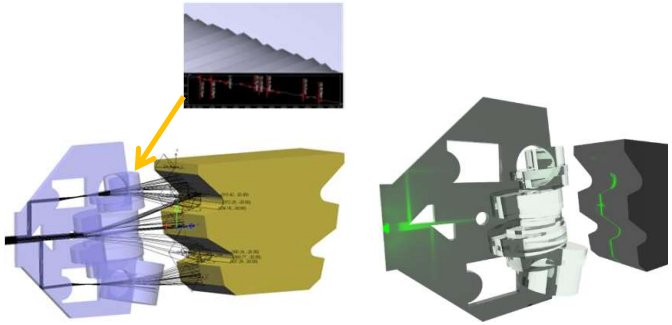


- Result

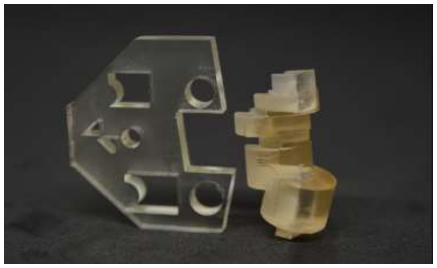
Examples 3D printed optics

- Shape metrology – Task

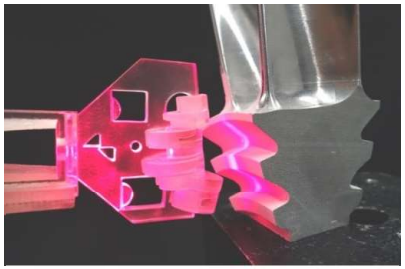
- Design

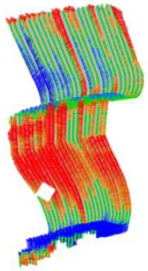


- Realization



- Result

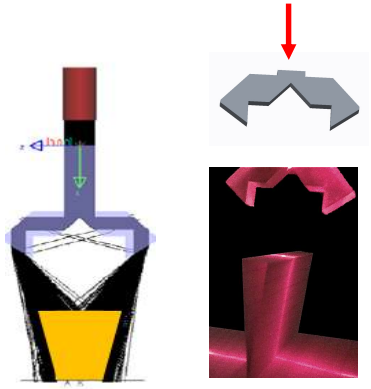




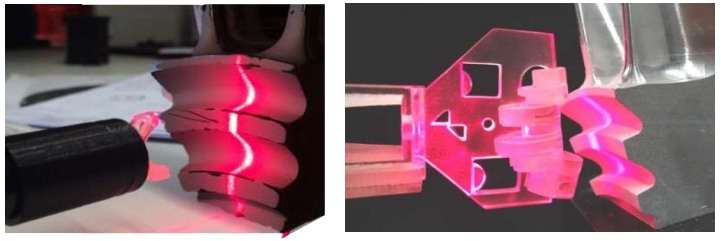
Examples 3D printed optics

- Shape metrology / improvement – Task

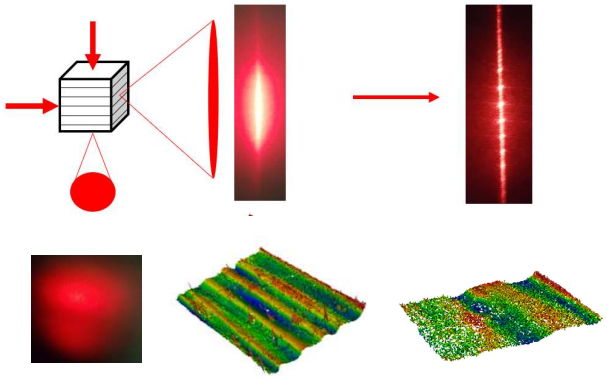
- Realization



- Result



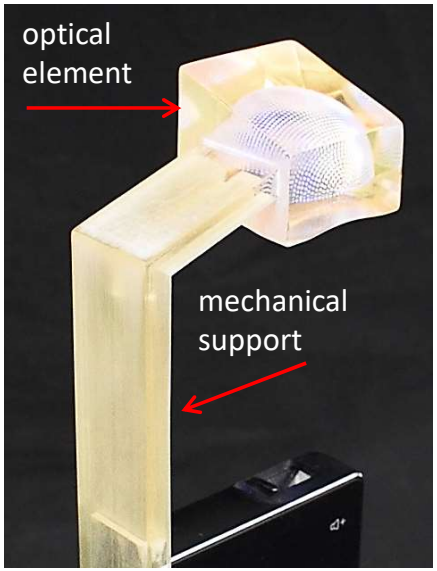
- Design based of diffractive effect



not polished polished

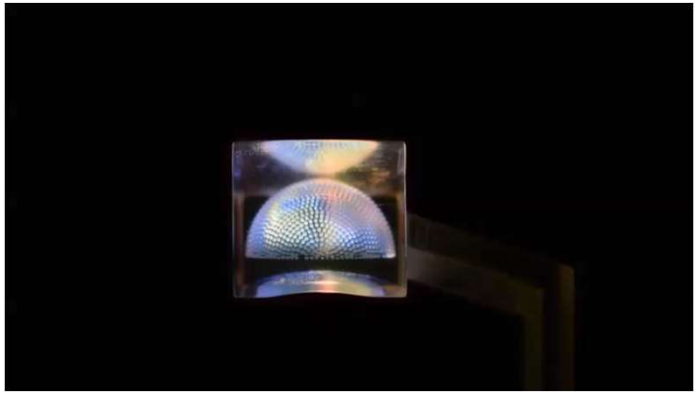
Examples 3D printed optics

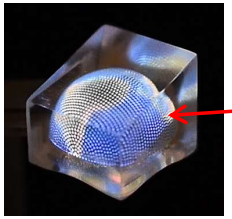
- Volume Display



pico projector

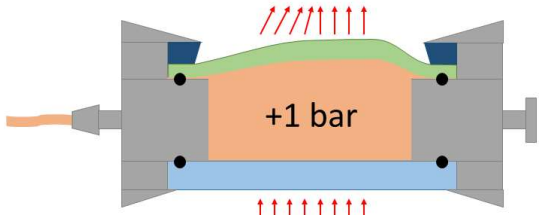
- realization

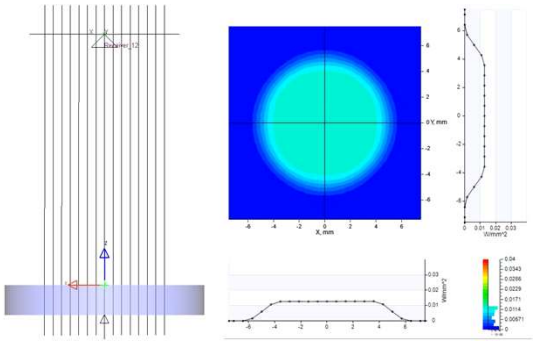


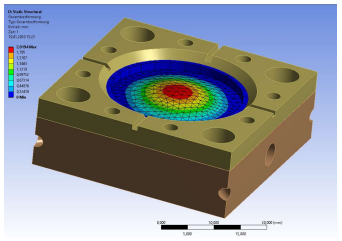


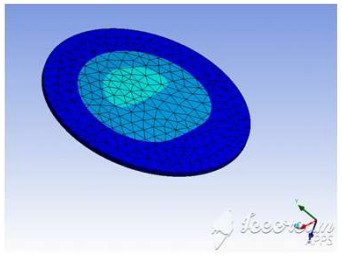
Examples 3D printed optics

- Liquid lens - idea

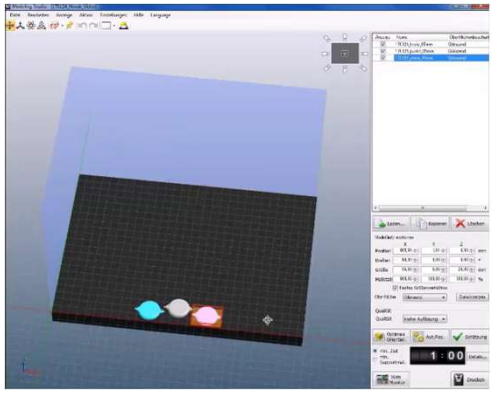


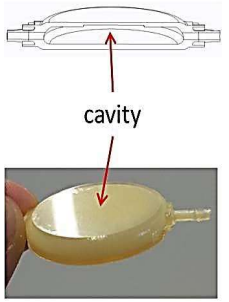


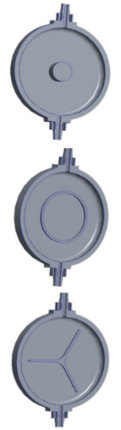




- Realization

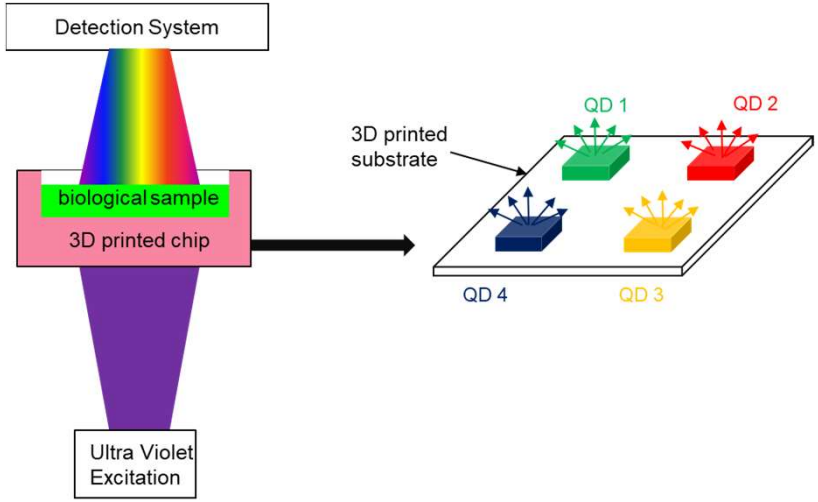




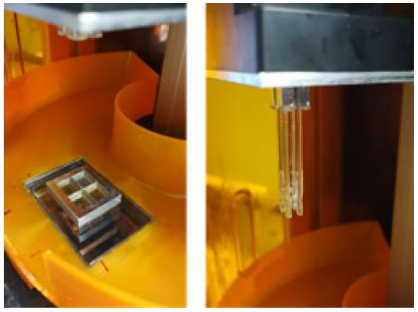


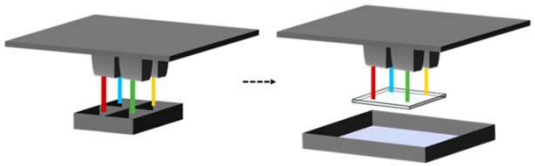
Examples 3D printed optics

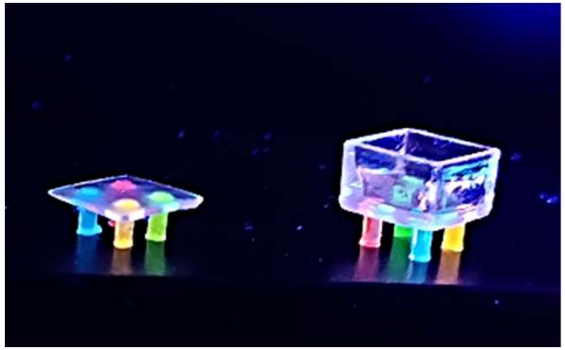
- Luminescent Optics - idea



- Realization







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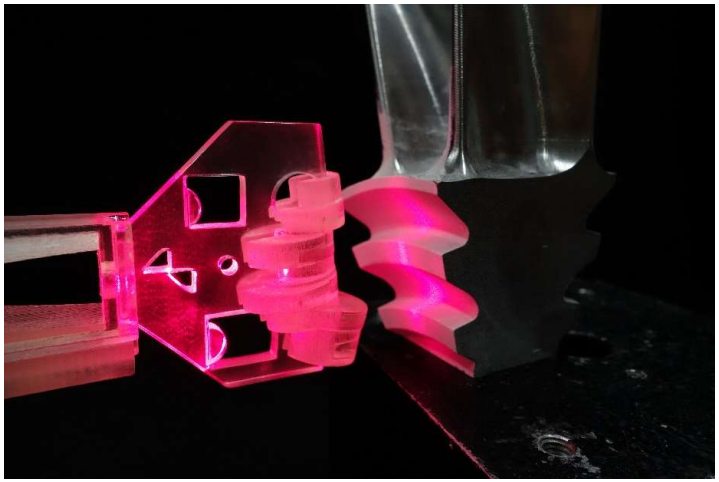

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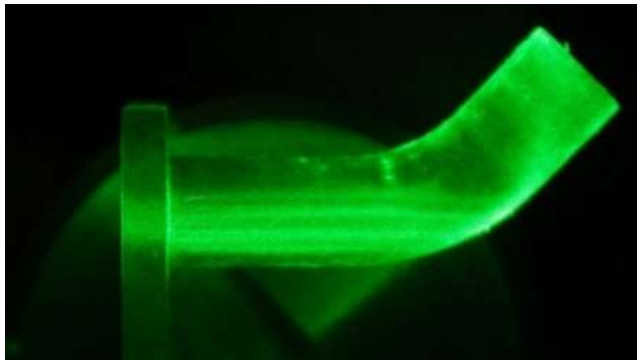
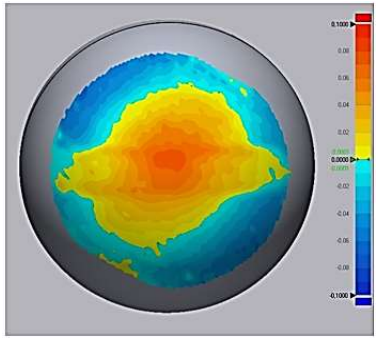


Analysis of 3D printed optics

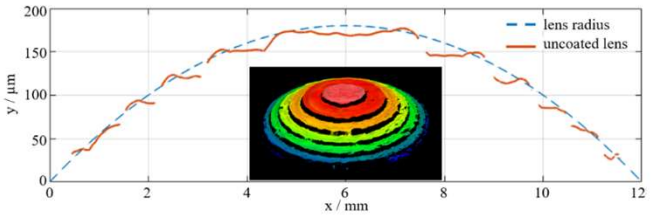
- Shape deviation



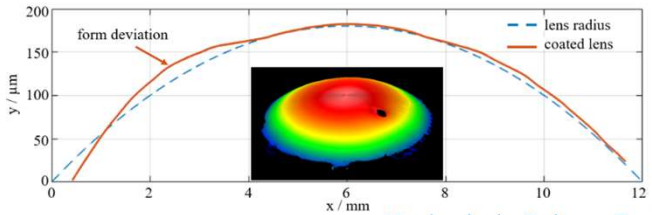
comparison: best-fit sphere

need to be reflected in design

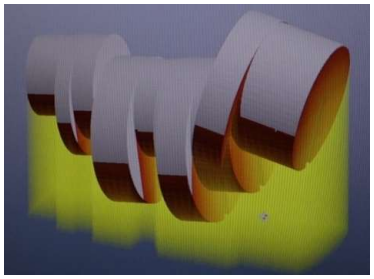
- Steps



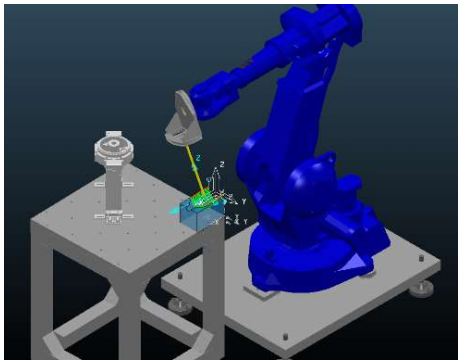
coated:

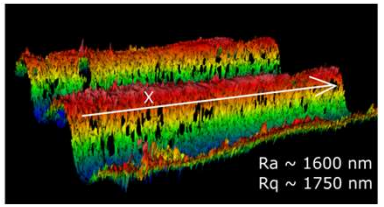


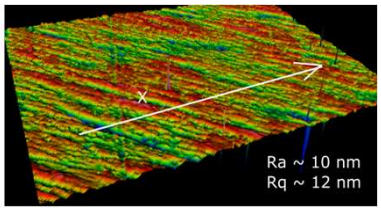
- Support structure / surface roughness



- Rework: e.g. coating or polishing (R. Börret)

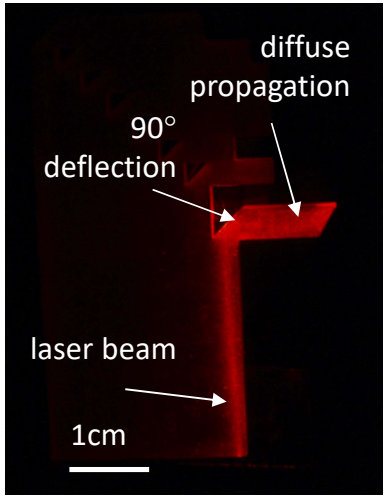


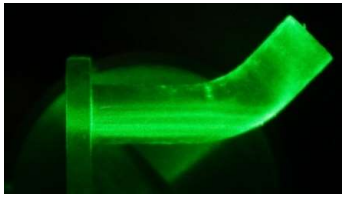


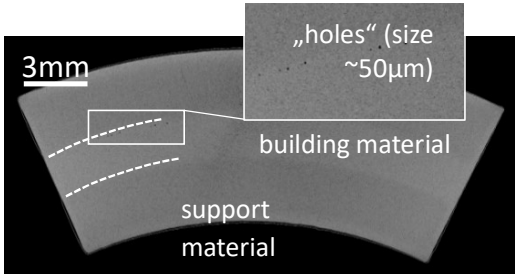


Analysis of 3D printed optics

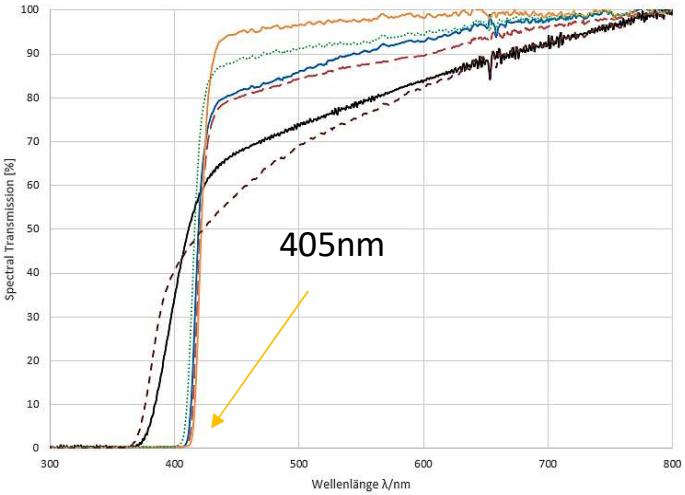
- scattering







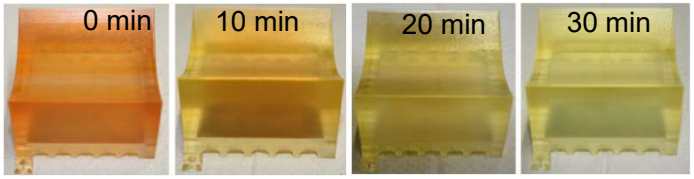
- transmission



  - Example damping: MJM/AR-M2: 0.078 dB/mm (@ 532nm)
    SLA / Detax luxaprint: 0.083 dB/mm

- Thermal / UV treatment & material

Example
Keyence AR-M” @ 100°C



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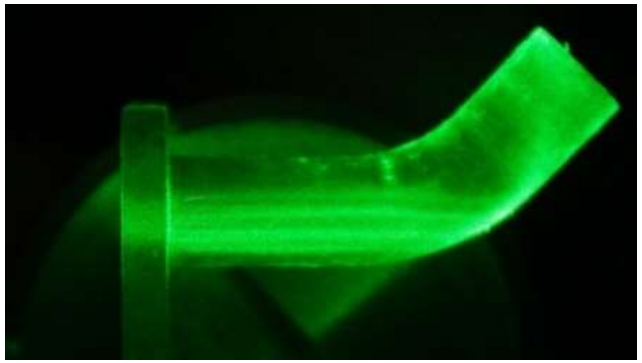

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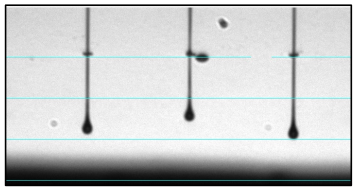
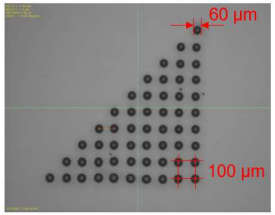
Development of printing Technologies

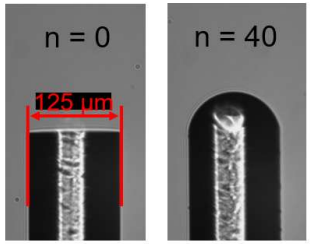
- Issues with printed macrooptics
  - Volume scattering
  - Rough surface needs to be polished
  - Non homogeneous refractive index distribution
- Can we overcome this issues?
- Solution: ink-jet printing of micro optics: accumulation of droplets (~10pL/drop)

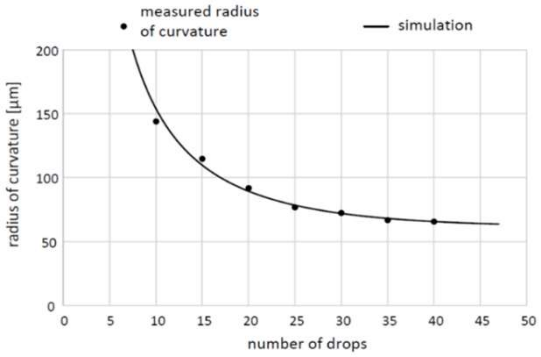


- Result
  - Lenses printed on a plane substrate



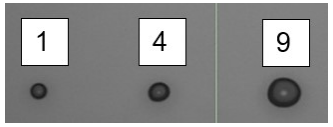
  - Lens printed on a glass fiber

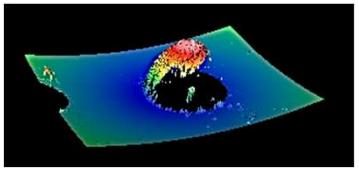




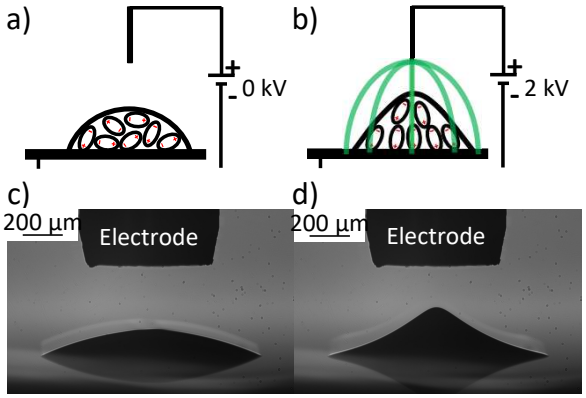
Development of printing Technologies

- But: spherical drops only!

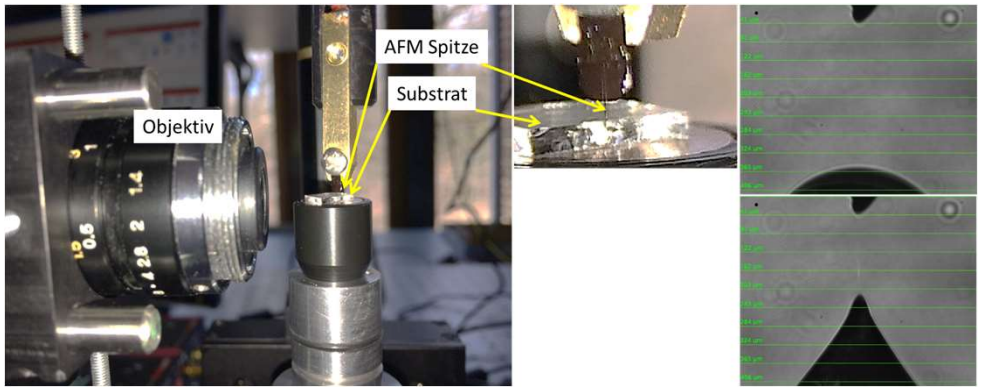




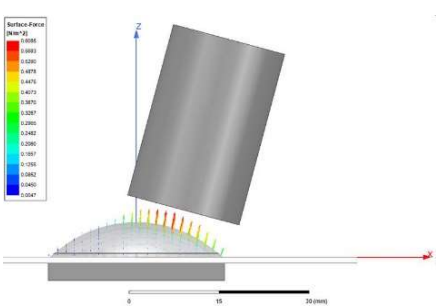
- How to generate an asphere?
  - Dielectrophoresis

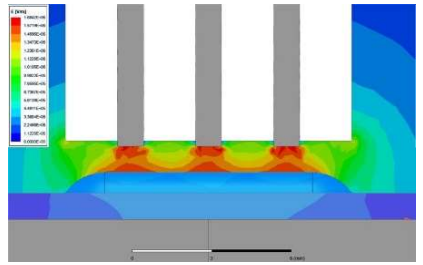


- Experimental Set-up



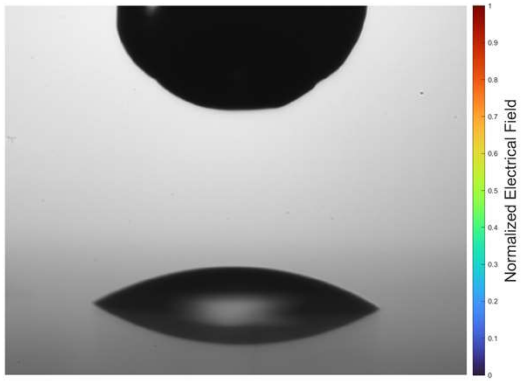
- Shape and position of tip matters!

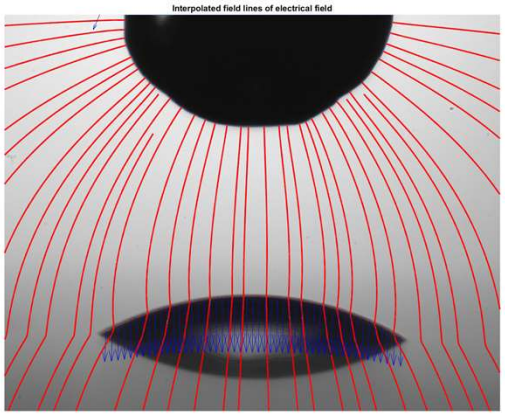


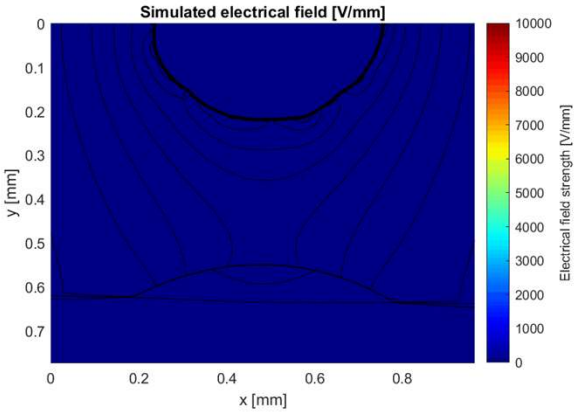


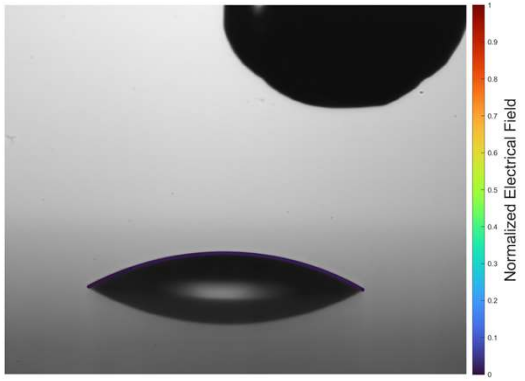
Development of printing Technologies

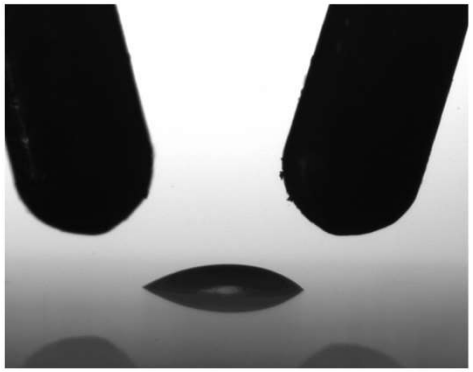
- Example Micro lens





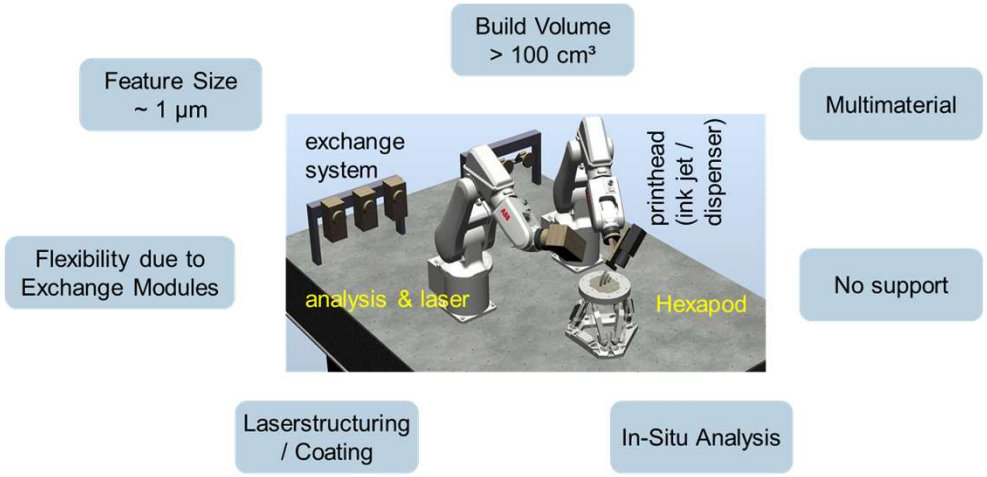




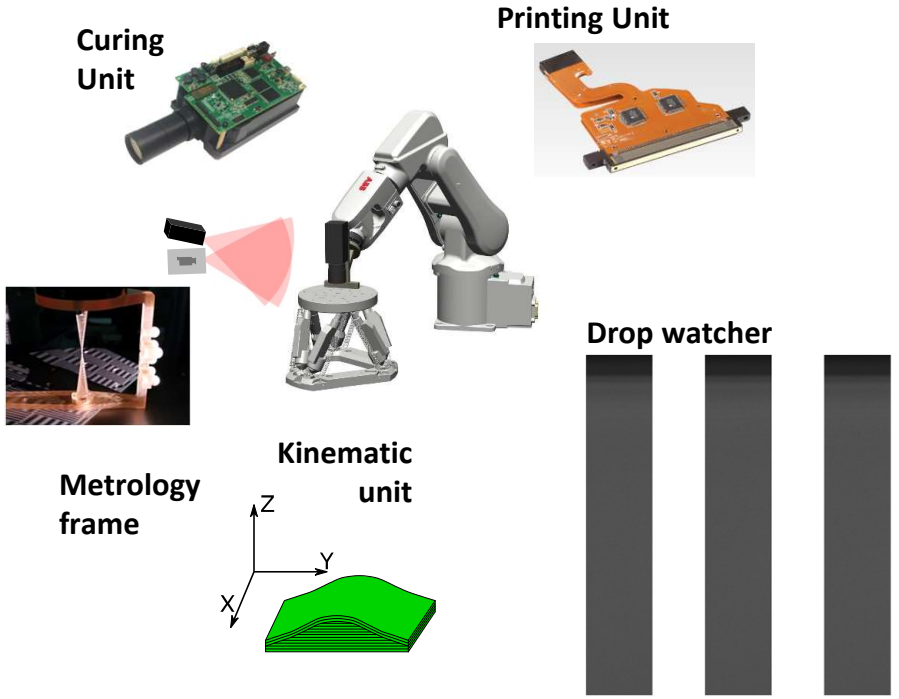


Development of printing Technologies

- 6DOF printing platform - idea

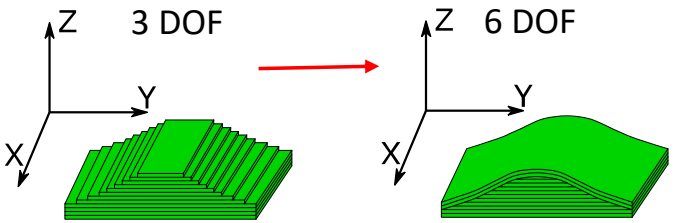


- System overview

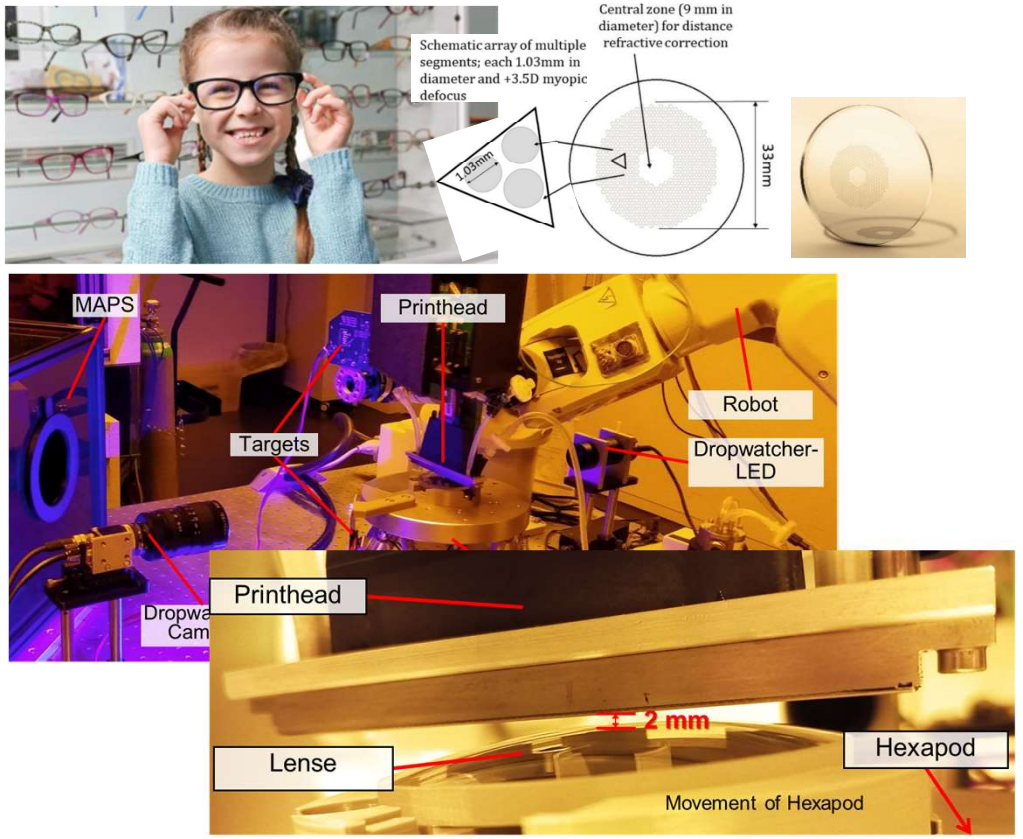


Development of printing Technologies

- 6DOF printing platform - kinematic

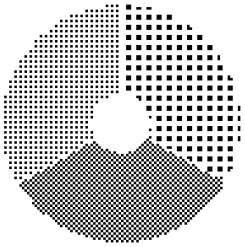


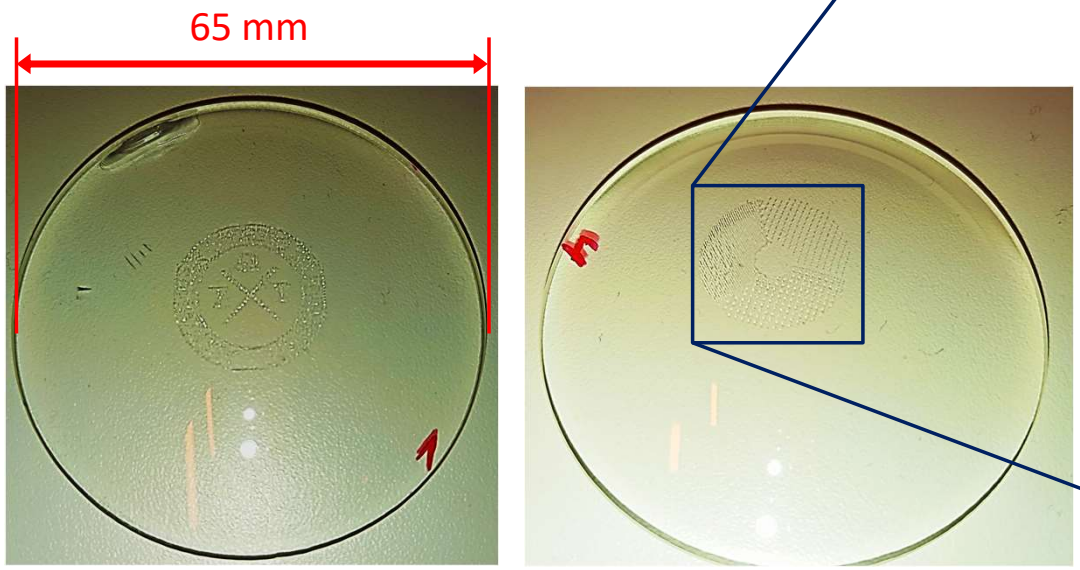
- Example: Ink-Jet print on spectacle lenses

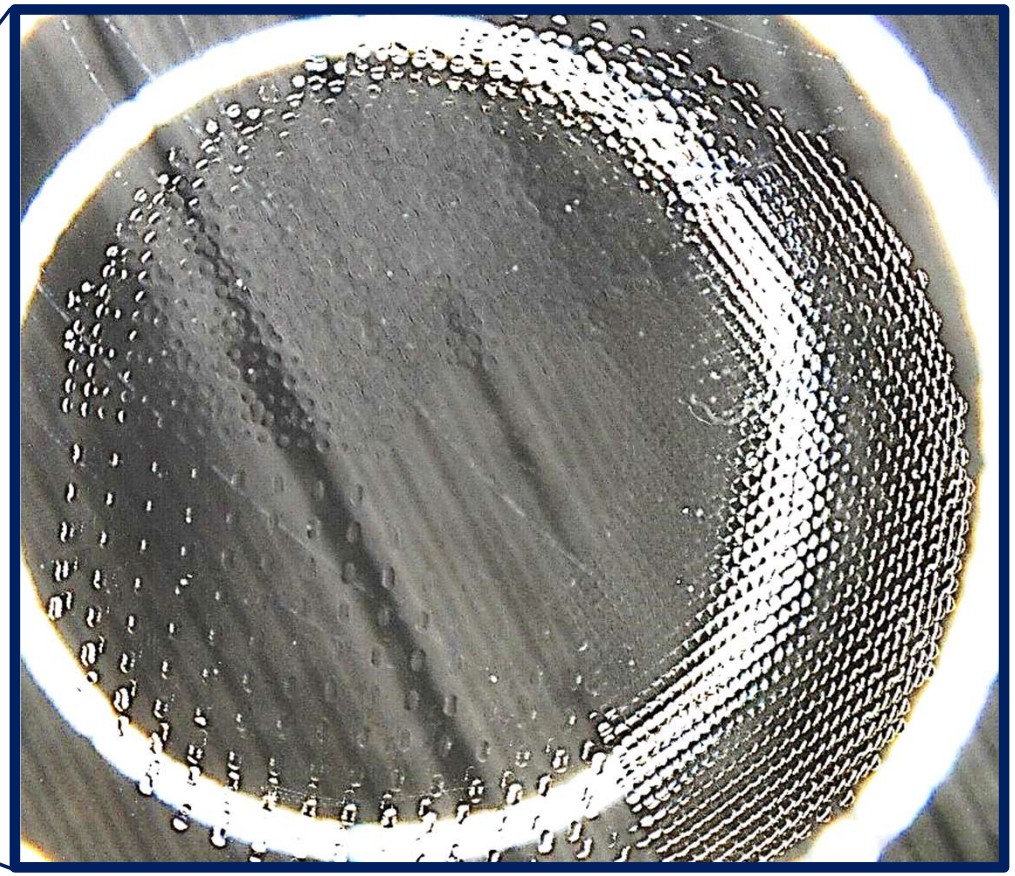


Development of printing Technologies

- Example: Ink-Jet print on spectacle lenses

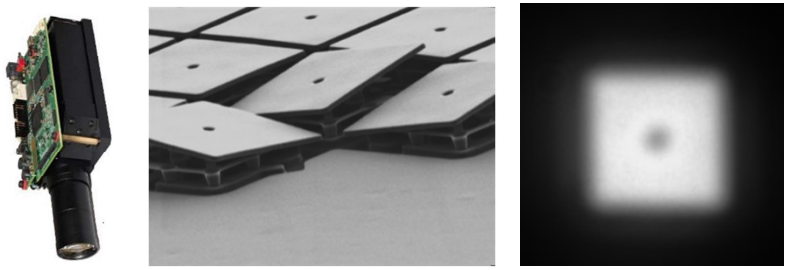




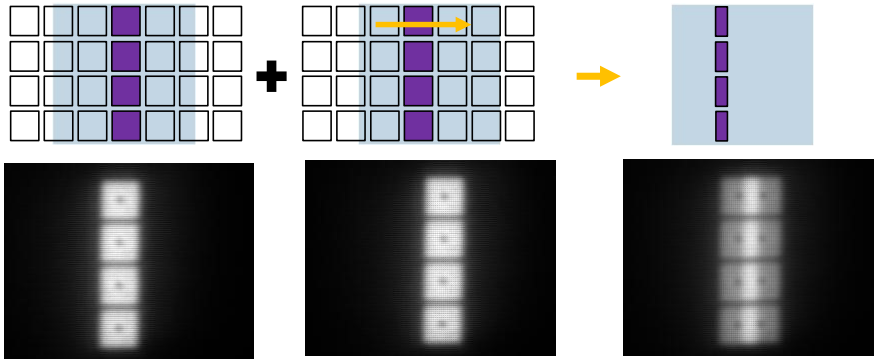


Development of printing Technologies

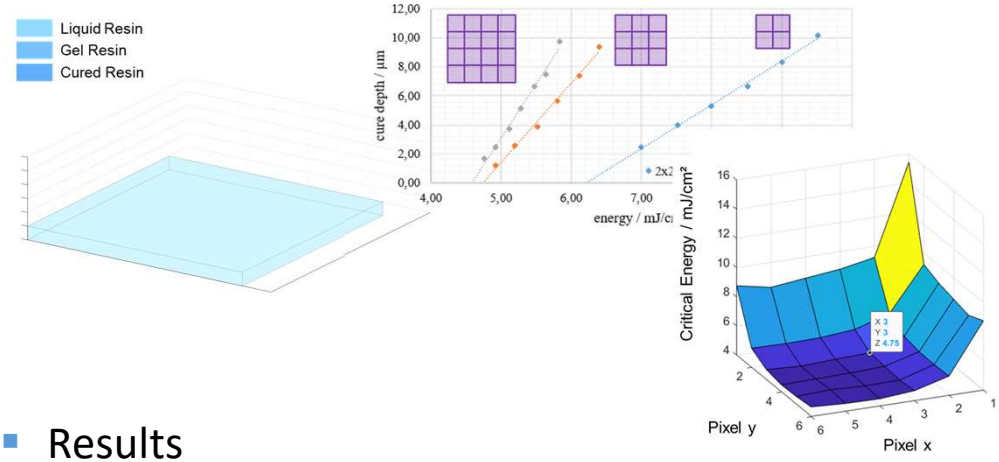
- 6DOF printing platform – curing
  - Curing unit / projector illumination



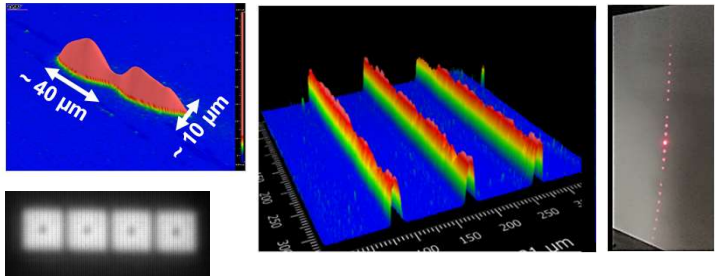
  - Concept of double patterning



- 6DOF printing platform – curing
  - Concept of double patterning



  - Results



Outlook

- Optical Technologies @ HS Aalen
- Commercial Printing Technologies @ ZOT
- Examples 3D printed optics
- Analysis of 3D printed optics
- Own developed Printing Technologies
- Refractive index
- Replication of 3D printed parts using NIL

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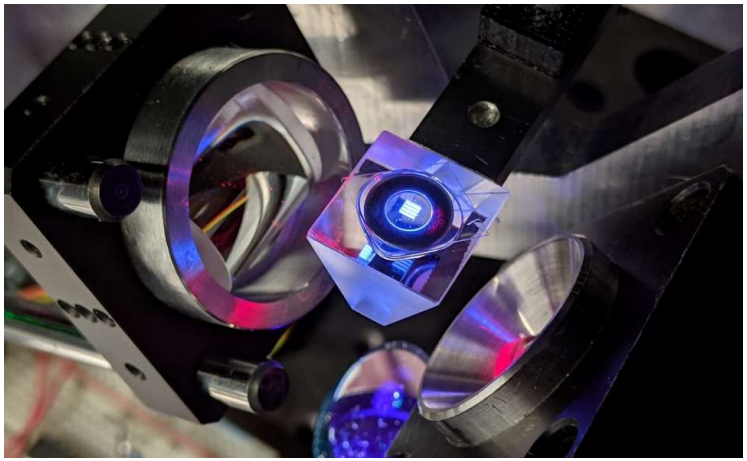
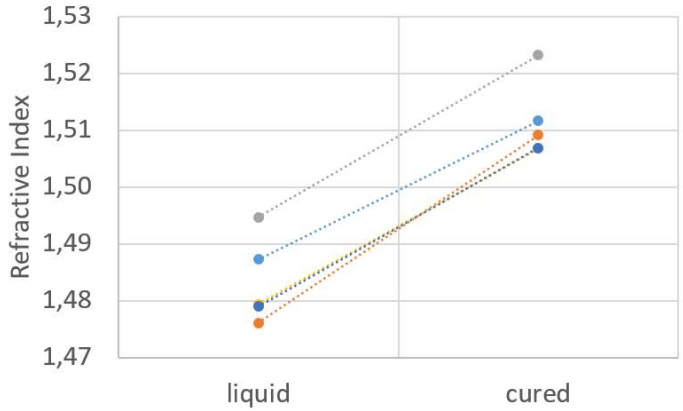
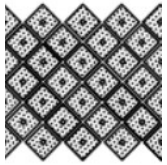


Refractive index of 3D printed optics

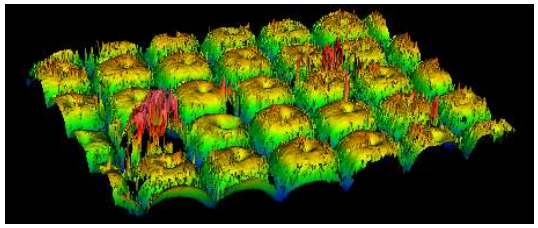
- Refractive Index changes during curing



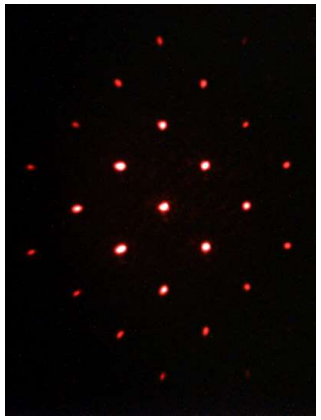
  - DLP projector is used for curing

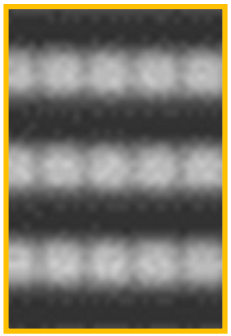


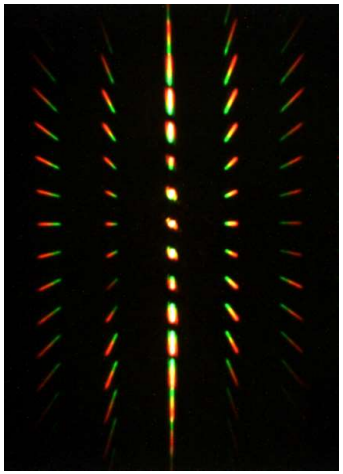
- Surface of DLP cured samples



- Diffraction pattern due to inhomogeneous (but periodic) illumination

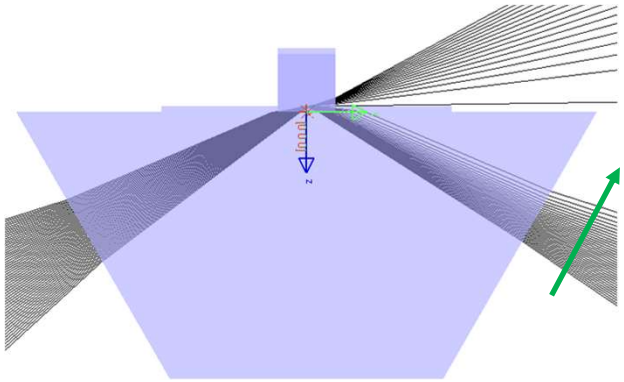


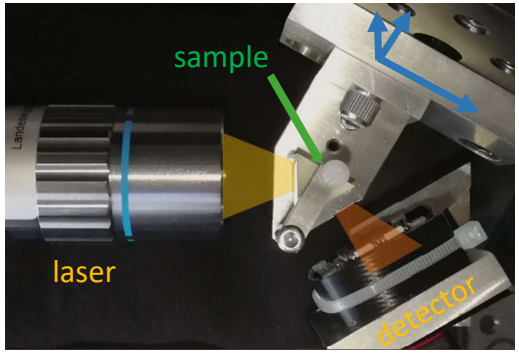


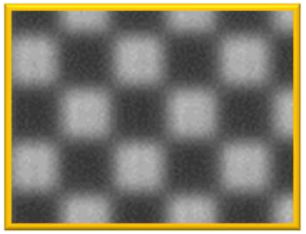


Refractive index of 3D printed optics

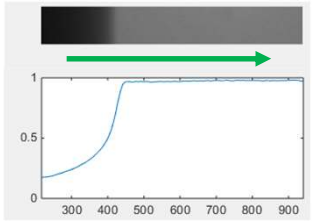
- Metrology:
  scanning focused refractive index microscopy

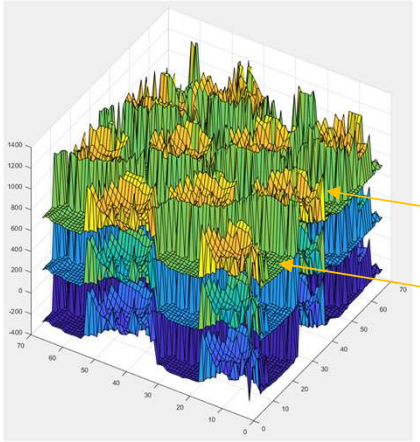






Total internal reflection
creates dark-bright edge



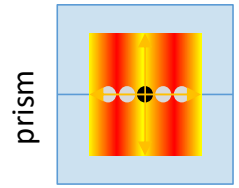


n ≈ 1,503

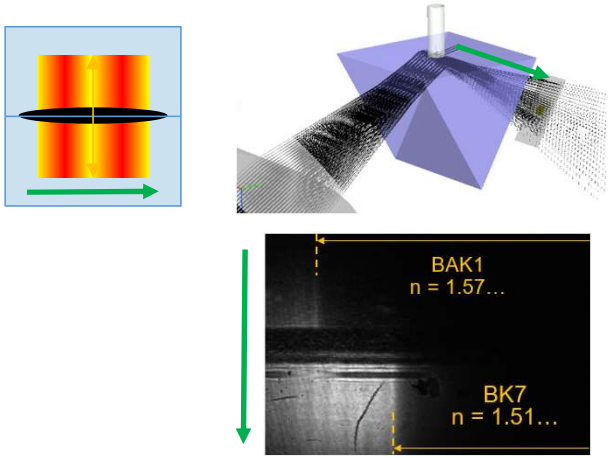
n ≈ 1,489

Refractive index of 3D printed optics

- SFRIM: point based measurement
  - Scanning in both (or all) axis necessary
  - High lateral resolution not always necessary
  - Single Y-Scan takes 20 – 60 sec
  - Too slow to capture time dependent processes

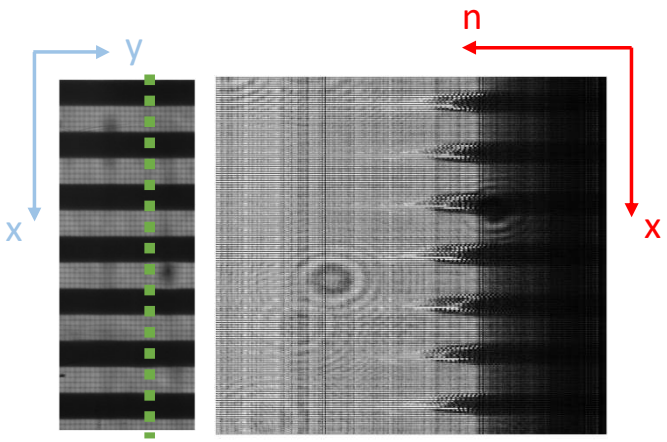


- LineSFRIM
  - Cylinder lens for line shaped measurement profile
  - Camera exposure time defines time resolution

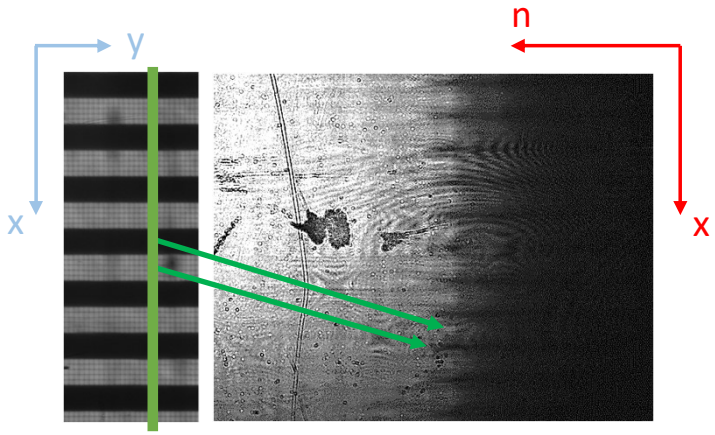


Refractive index of 3D printed optics

- SFRIM: point based measurement
  - DMD pattern (35 µm pixel size, 5 pixel on (high n), 5 pixel off
  - Higher resolution, 20x slower

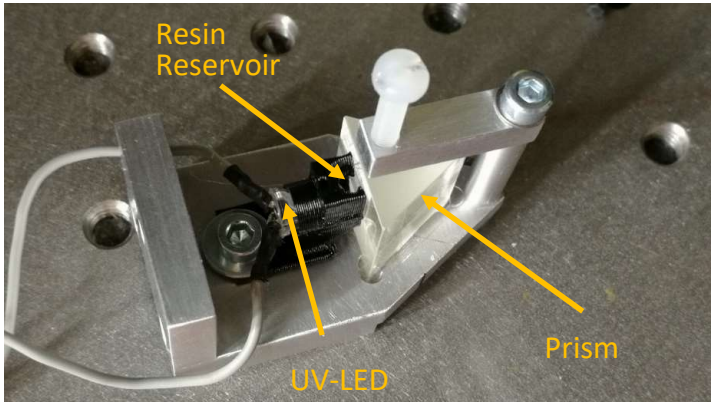


- LineSFRIM
  - DMD pattern (35 µm pixel size, 5 pixel on (high n), 5 pixel off
  - field of view > 5mm
  - camera exposure: 1ms

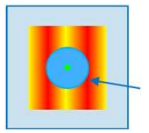


Refractive index of 3D printed optics

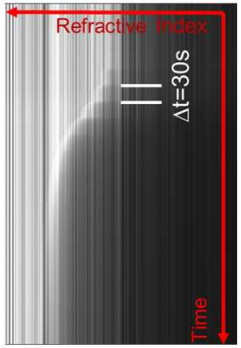
- SFRIM: point based measurement – live curing
  - integration of a resin reservoir onto the prism
  - resin cured by UV LED
  - SFRIM and LineSFRIM used to observer change in refractive index



- SFRIM live curing
  - Interval based illumination
    - 0.2 sec UV exposure
    - 30 sec waiting time
    - 1 image / sec
  - SFRIM offers single point measurement
    - Whole edge moves in video (left)
    - Evaluation only along center line (orange)
    - Summary (right) shows transition over time

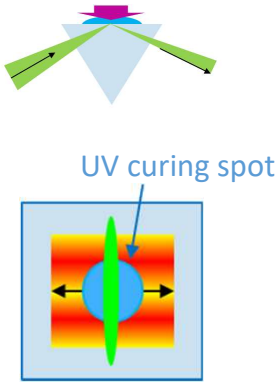


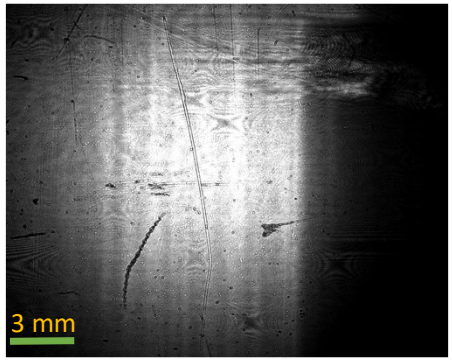
UV curing spot



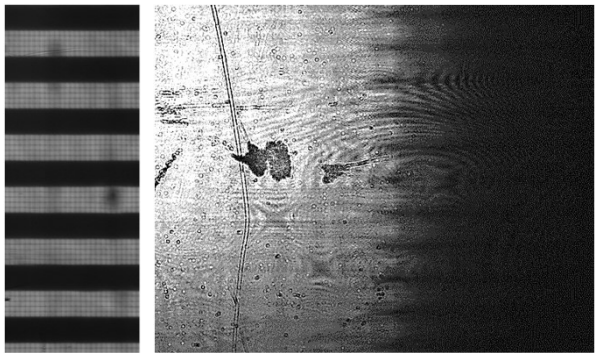
Refractive index of 3D printed optics

- LineSFRIM: live curing
  - Interval based illumination
    - 0.2 sec UV exposure
    - 30 sec waiting time
    - 1 image / sec
  - LineSFRIM enables spacially resolved live analysis of refractive index transition
    - Starts at position and spreads out



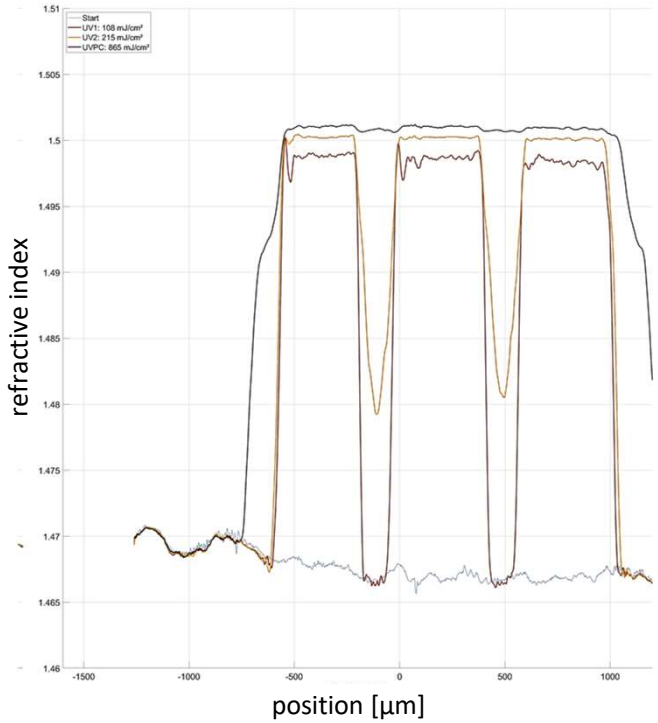


- LineSFRIM before and after curing

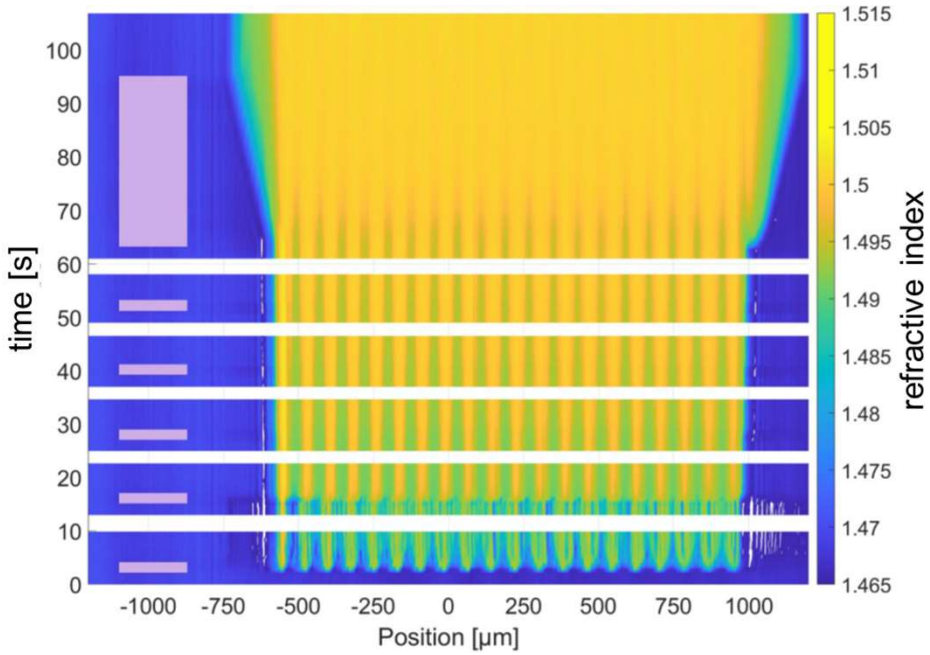


Refractive index of 3D printed optics

- Evaluation
  - By Fresnel fit (t=4s) or using a neural net (t=0.09s)



- Evaluation over time



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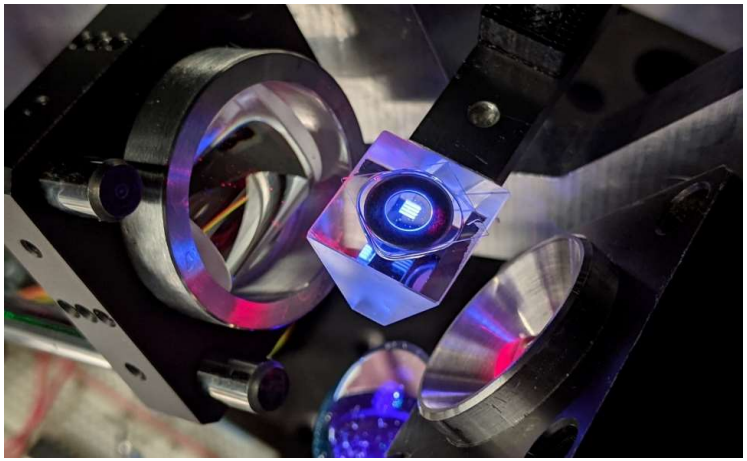

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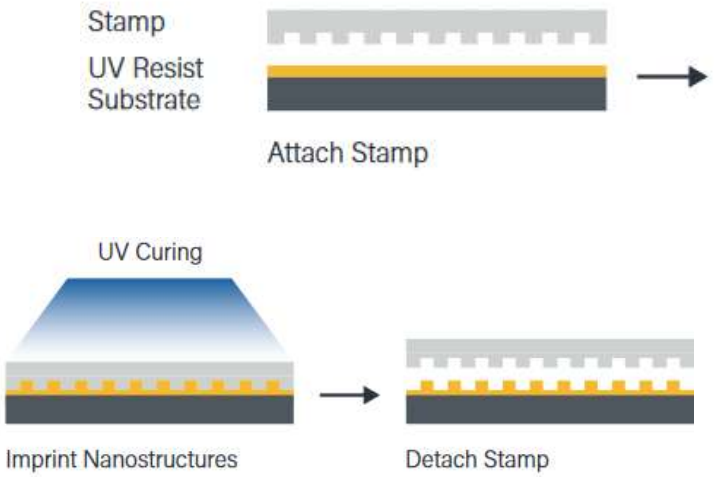
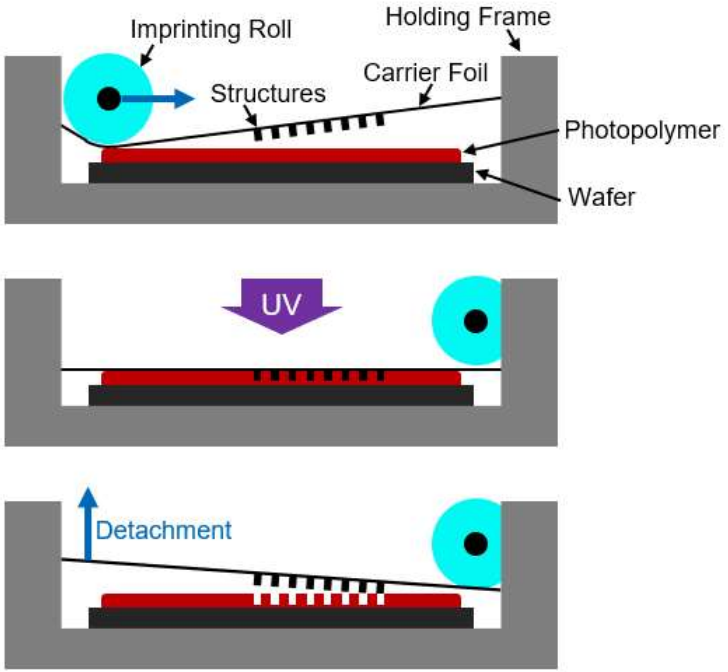
Nanoimprint Lithography

- Principle
  - Soft NIL



- Principle
  - Smart NIL

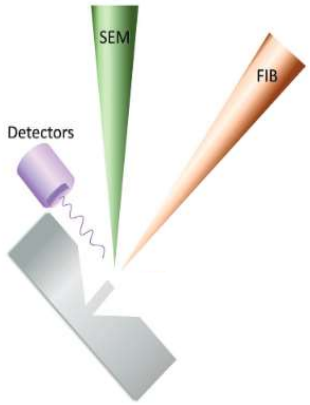


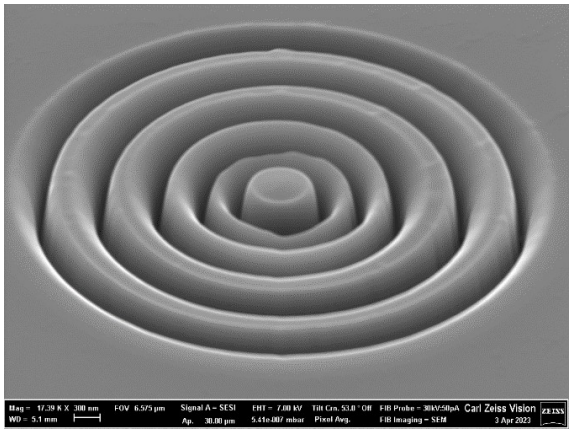
Nanoimprint Lithography

- System: EVG 620
  - Spincoating and (pre)bake for
    - Anti Sticking layer, Replication polymers etc.

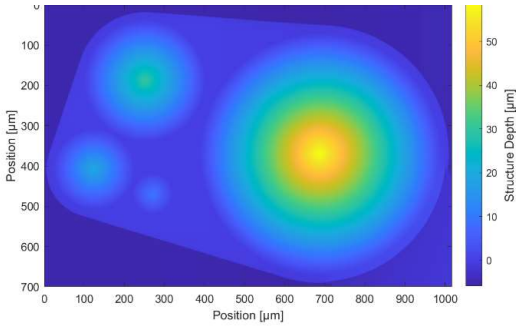

    - Replication:

- How to create the master?
  - FIB (collaboration with Carl Zeiss Vision)



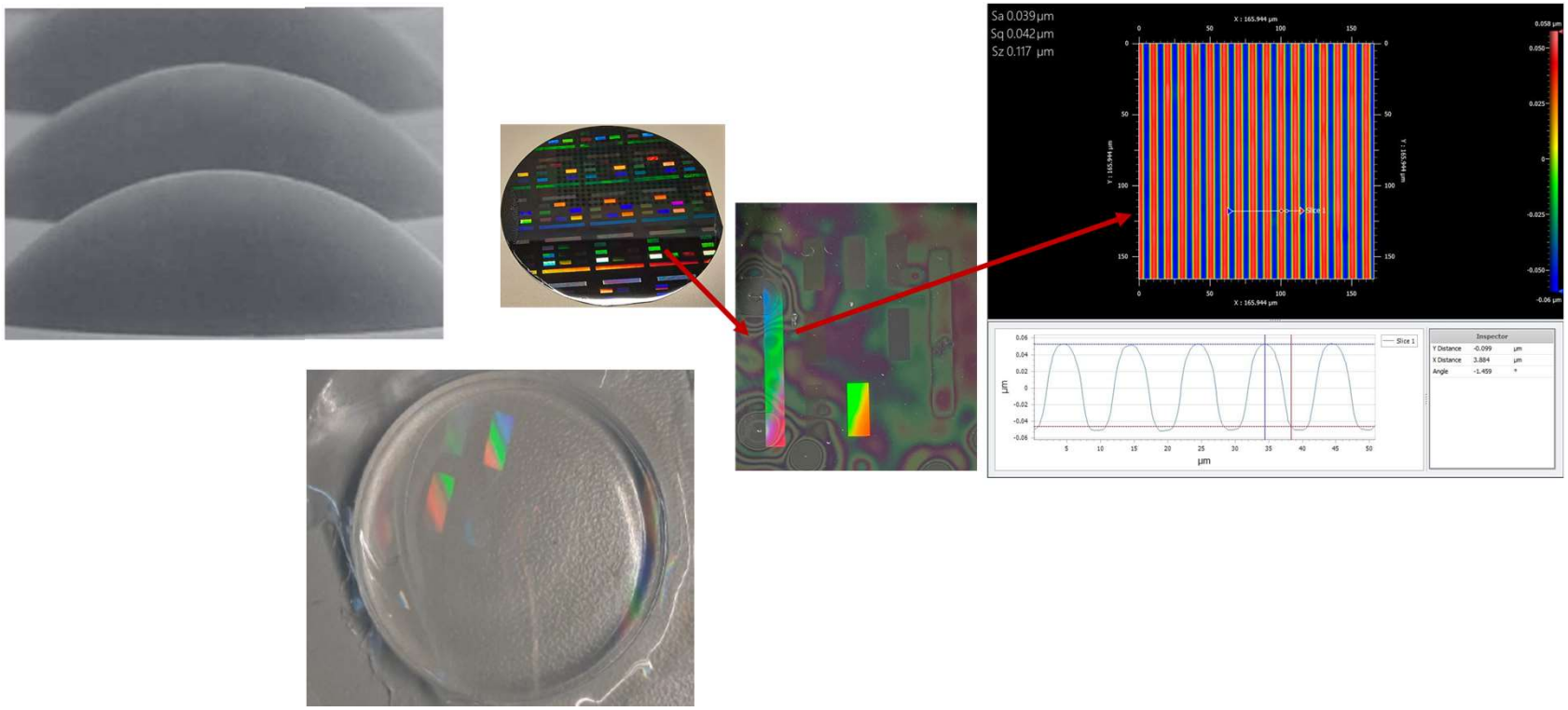


  - 2PP System



Nanoimprint Lithography

- Examples
  - Replication of Microlenses and gratings



Summary

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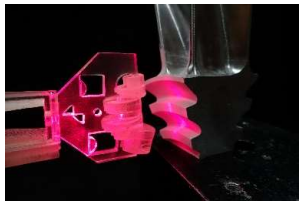

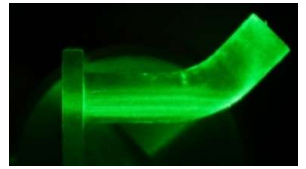

Hochschule Aalen

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Andreas.Heinrich@hs-Aalen.de

Thank you for your attention!

APH+OE ZOT

DFG Deutsche Forschungsgemeinschaft
Baden-Württemberg Stiftung
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ZEISS
Bundesministerium für Bildung und Forschung

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