HEIDELBERG INSTRUMENTS

Maskless Lithography for Photonics Integration and Packaging

EPIC Technology Meeting on Photonic Integration and Packaging at Fraunhofer IZM
Berlin, June 4-5, 2024

Steffen Diez, Heidelberg Instruments Mikrotechnik GmbH

heidelberg-instruments.com

Heidelberg Instruments in a Nutshell

- Inhouse mechanical, electronical, and optical design
- Extensive application knowledge
- Lithography know-how since 1984

- Part of LAB14 group: Full range of technologies for microfabrication
- Close collaboration with key customers and suppliers
- Customized solutions

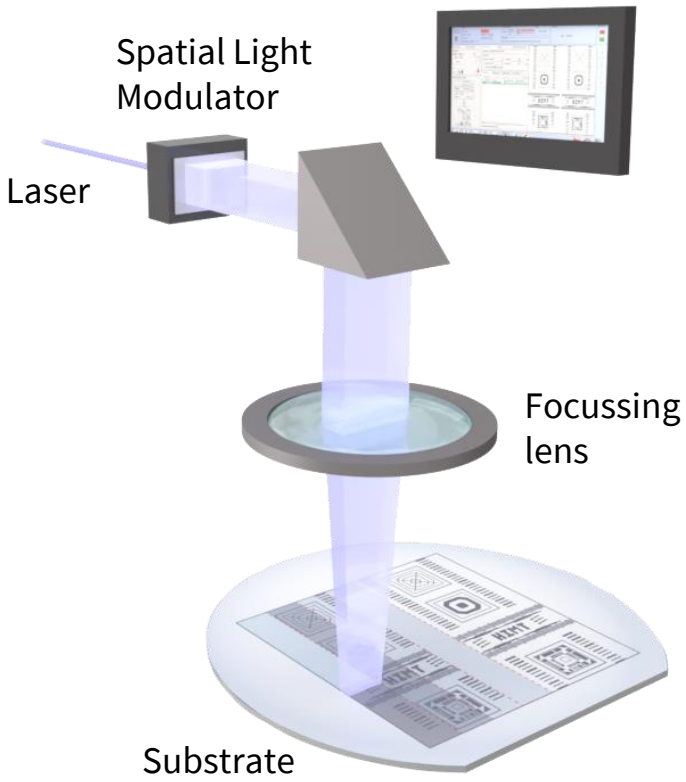
- Worldwide installation base of more than 1400 systems
- Global Sales and Service network
- More than 380 employees worldwide

- ISO 9001 certification
- Expert support for systems and applications
- Worldwide process and application labs

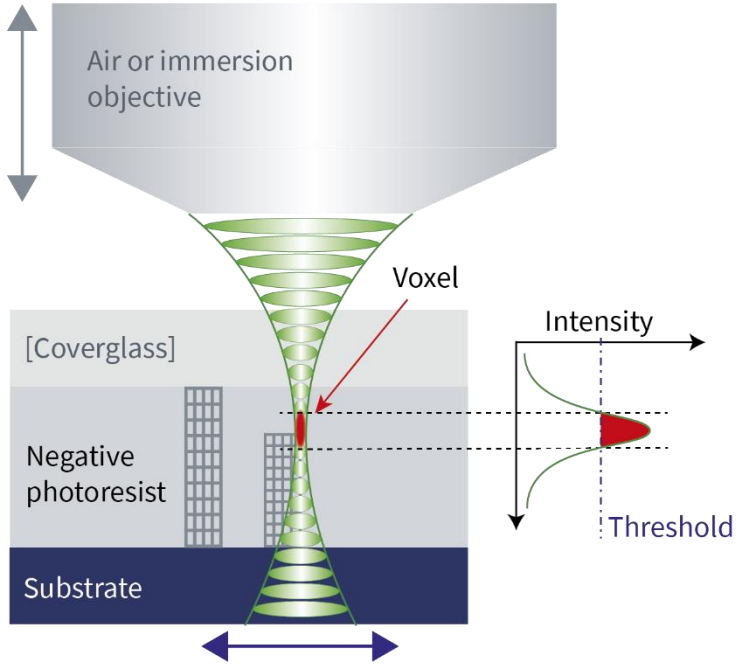
Product Portfolio

Our Three Core Technologies

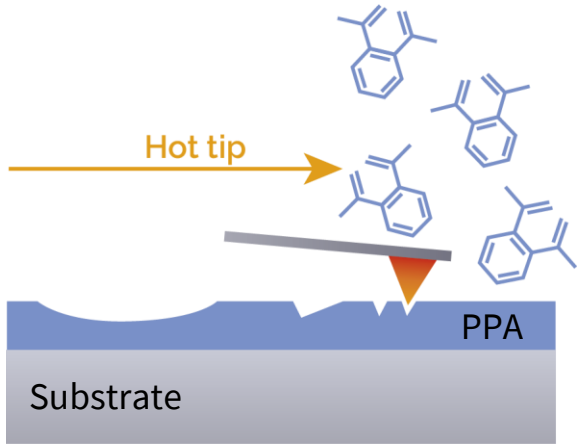
Maskless Laser Lithography



3D Laser Lithography Two-Photon Polymerization (TPP)



Thermal Scanning Probe Lithography (t-SPL)

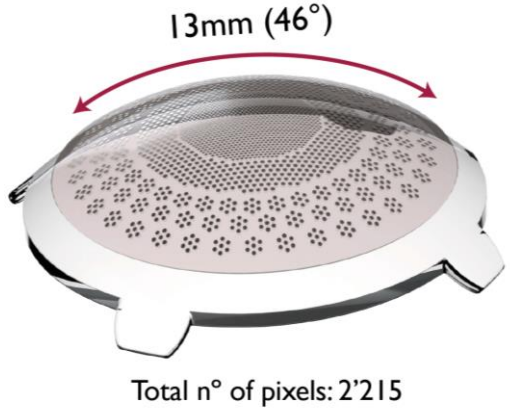


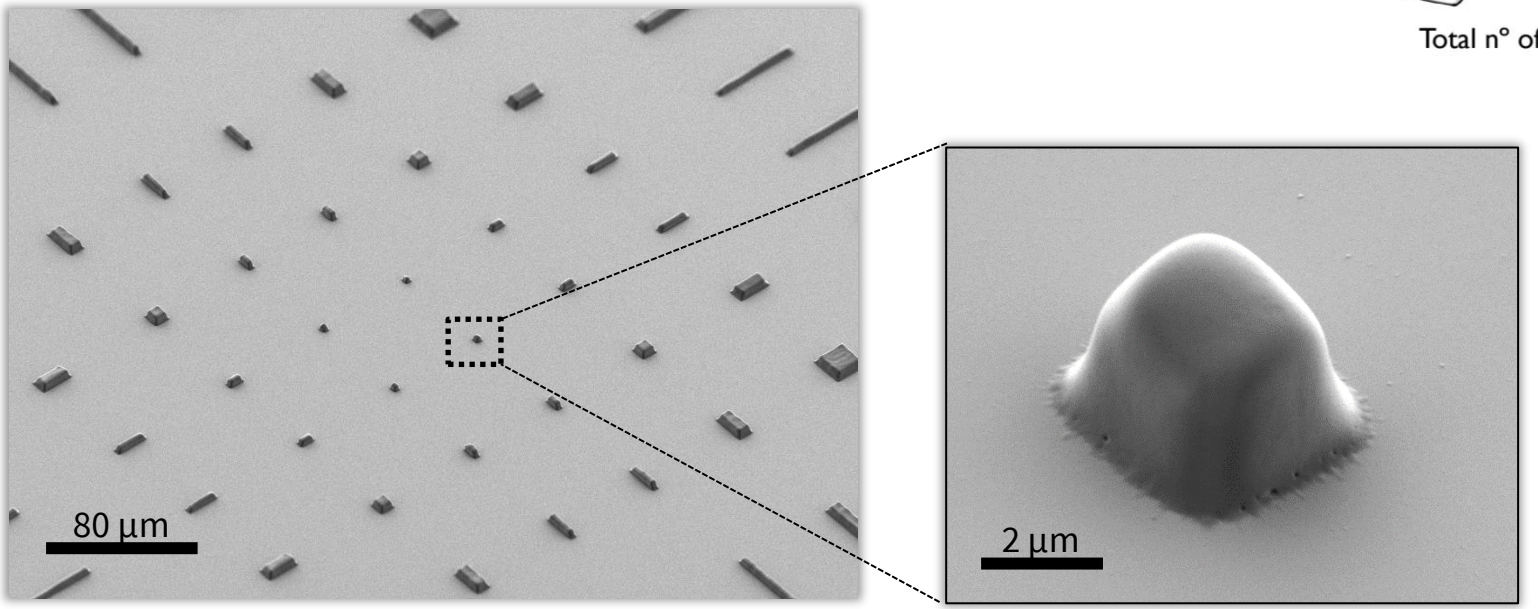
Maskless Aligner MLA 150 – A Game Changer for Lithography in R&D

Key Features	
Fast exposure time	100 mm wafer in less than 10 min
Usability	Software Wizards with step-by-step tutorial, teaching time for new users in less than one hour
Compatibility	Compatible to all standard Mask Aligner Processes
Performance	500 nm feature size with 250 nm layer to layer overlay
Flexibility	Valuable Options: High-Aspect Ratio Mode, BSA, Draw Mode, Grayscale

Medical Implants

- New materials with specific properties are required for medical implants
- Ostemers are bio-compatible, impermeable and UV curable
- Ideal material for implants such as artificial retina
- **Challenge**: Ostemers are viscous liquid
- **Solution**: Contactless exposure with MLA 150

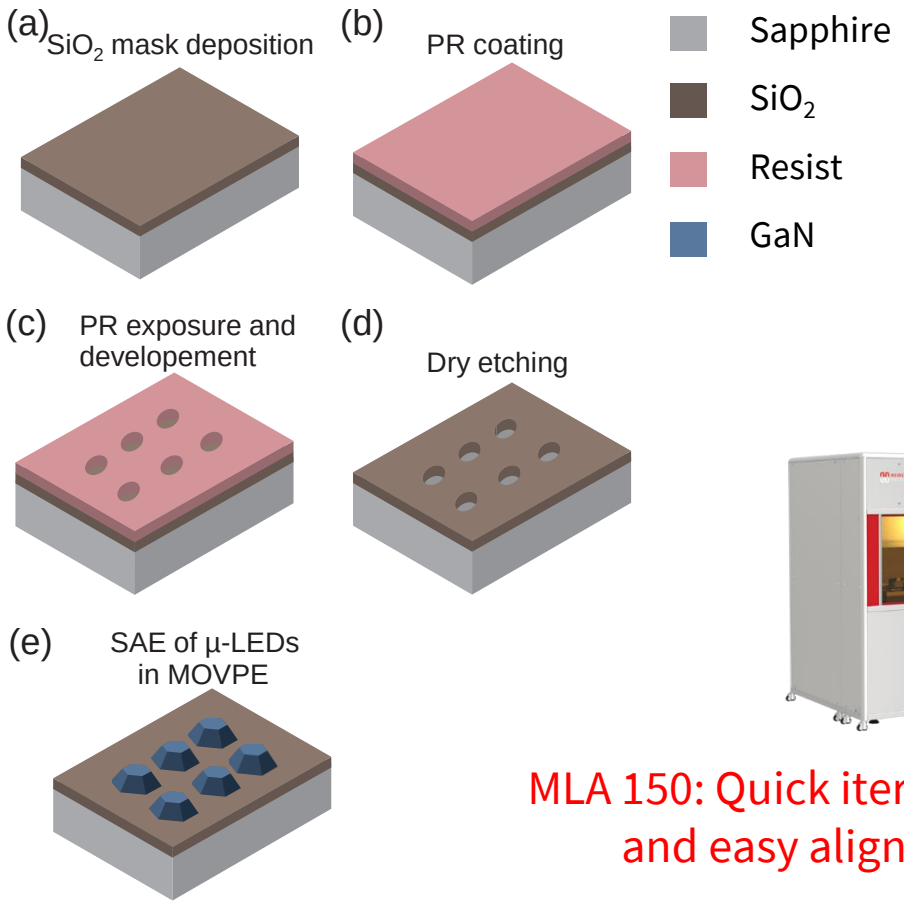




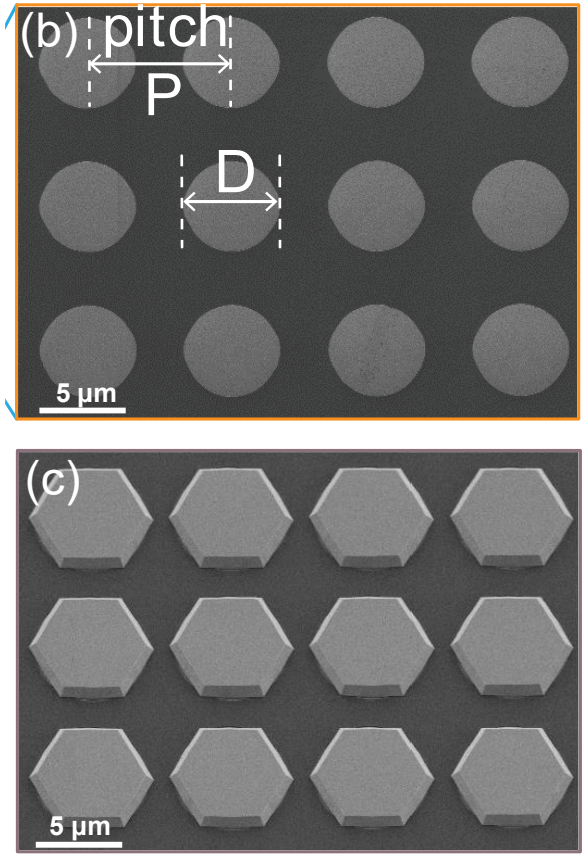
Marta Airaghi Leccardi, EPFL, Laboratory of NeuroEngineering

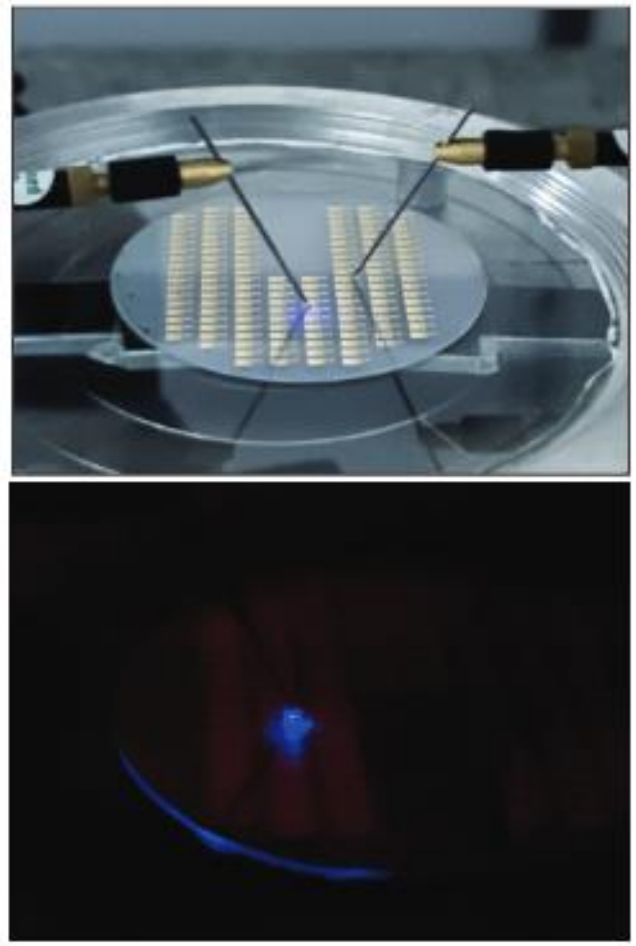
Micro LED from Selective Area Epitaxy (SAE)

EPFL



MLA 150: Quick iteration and easy alignment





Courtesy of Y. Chen, "Study of growth-induced point defects and their impact on InGaN-based optoelectronic devices" EPFL_TH10259, Laboratory of Advanced Semiconductors for Photonics and Electronics, EPFL

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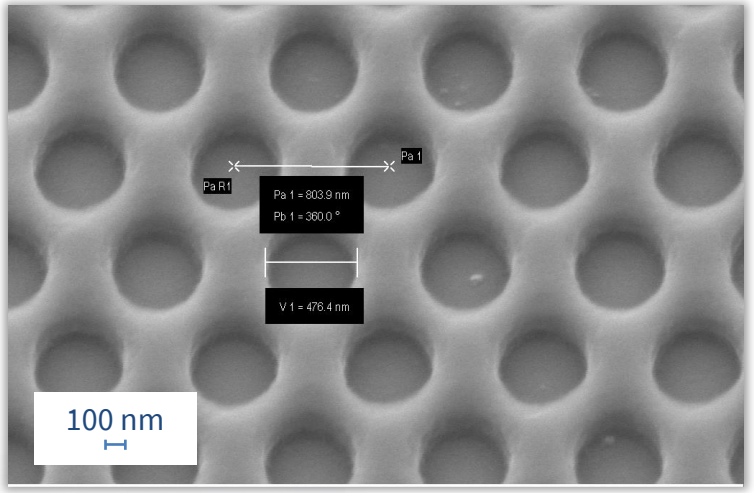
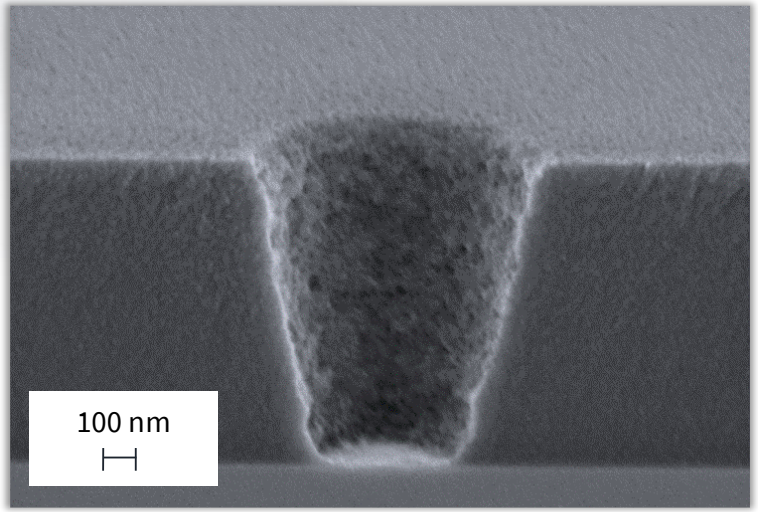
The Maskless Direct Imager VPG 300 DI

Laser Direct Writer for high accuracy and high resolution exposures

- Performance comparable to i-line stepper
- **Without die size limitation**
- No photomask required
- Industry ready
- Resolution – **500 nm Minimum Feature Size**
- Speed – up to 2000 mm^2/min @ 800nm MFS
- Exposure Time 300 mm Wafer – **45 min @ 800nm MFS**
- Precision – 2nd layer alignement of < 100 nm





Images courtesy of IMS Chips

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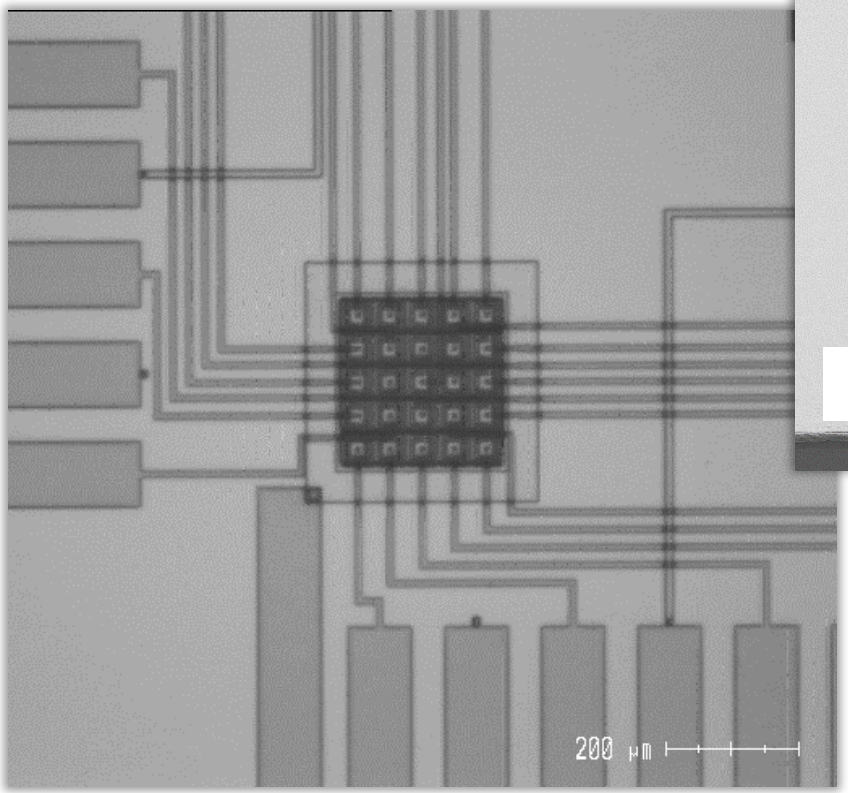
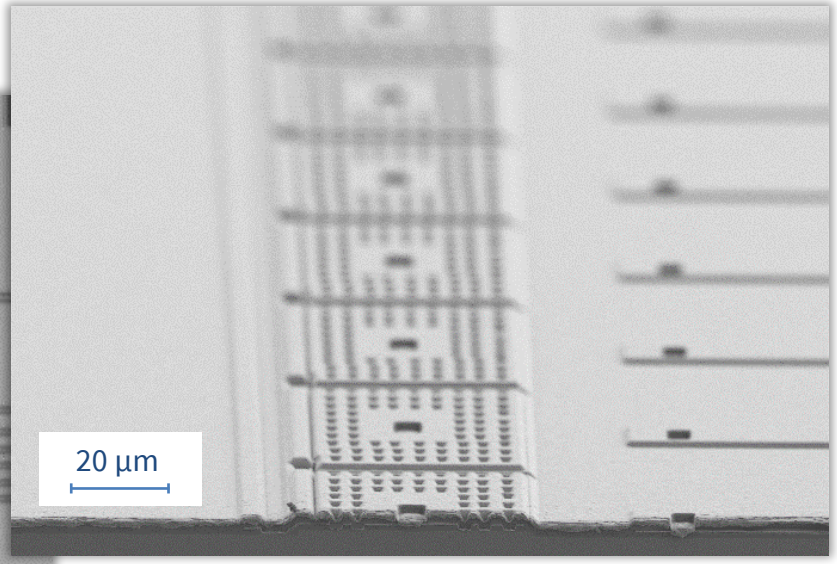
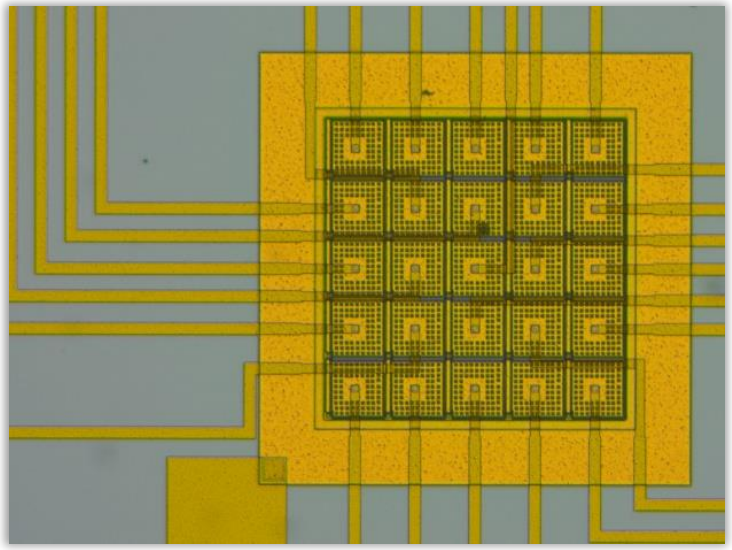
Silicon Photonics



Structured resist of the metal2 conductor paths for SiGe-SPADs (Single Photon Avalanche Diodes from Silicon-Germanium)



Line detector from SiGe-SPADs (REM transverse fracture)

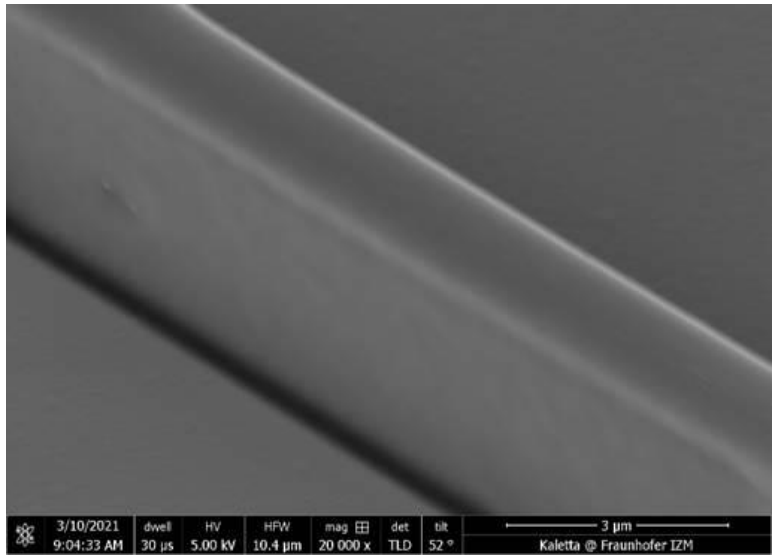


5x5 matrix of an image sensor from SiGe-SPADs (optical microscope)

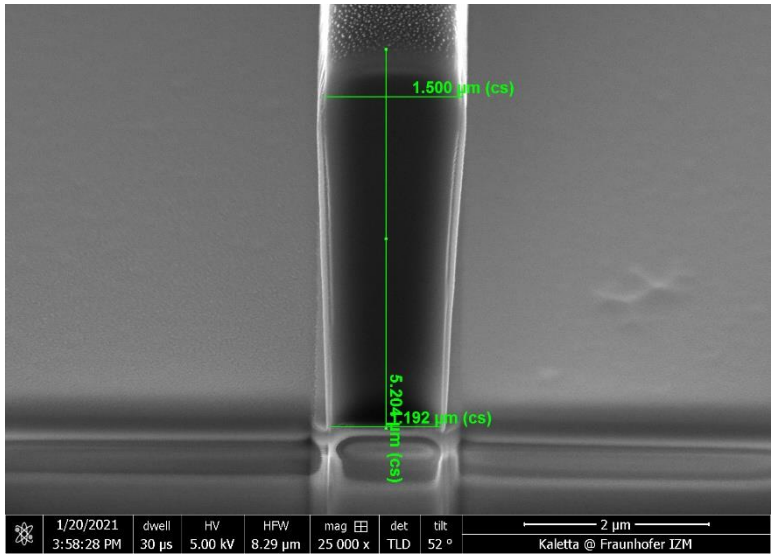
Images courtesy of IMS Chips

Waveguides Made in Resist for Dry Etching

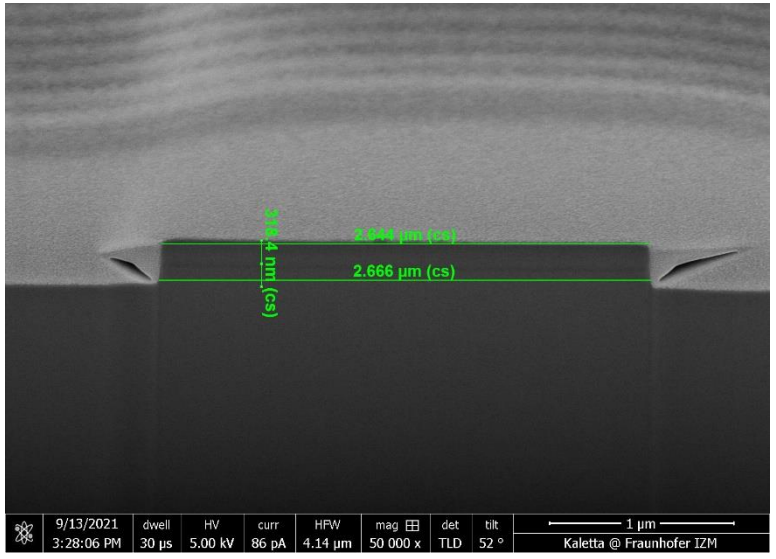
Fraunhofer IZM



Smooth side wall of the resist.



FIB cross section of a resist structure for waveguide etching.
Width: 1.2 µm. Height: 5.2 µm



FIB of silicon nitride waveguide after resist removal

Courtesy of M. Wöhrmann, Fraunhofer IZM

VPG+ :
High precision and edge roughness

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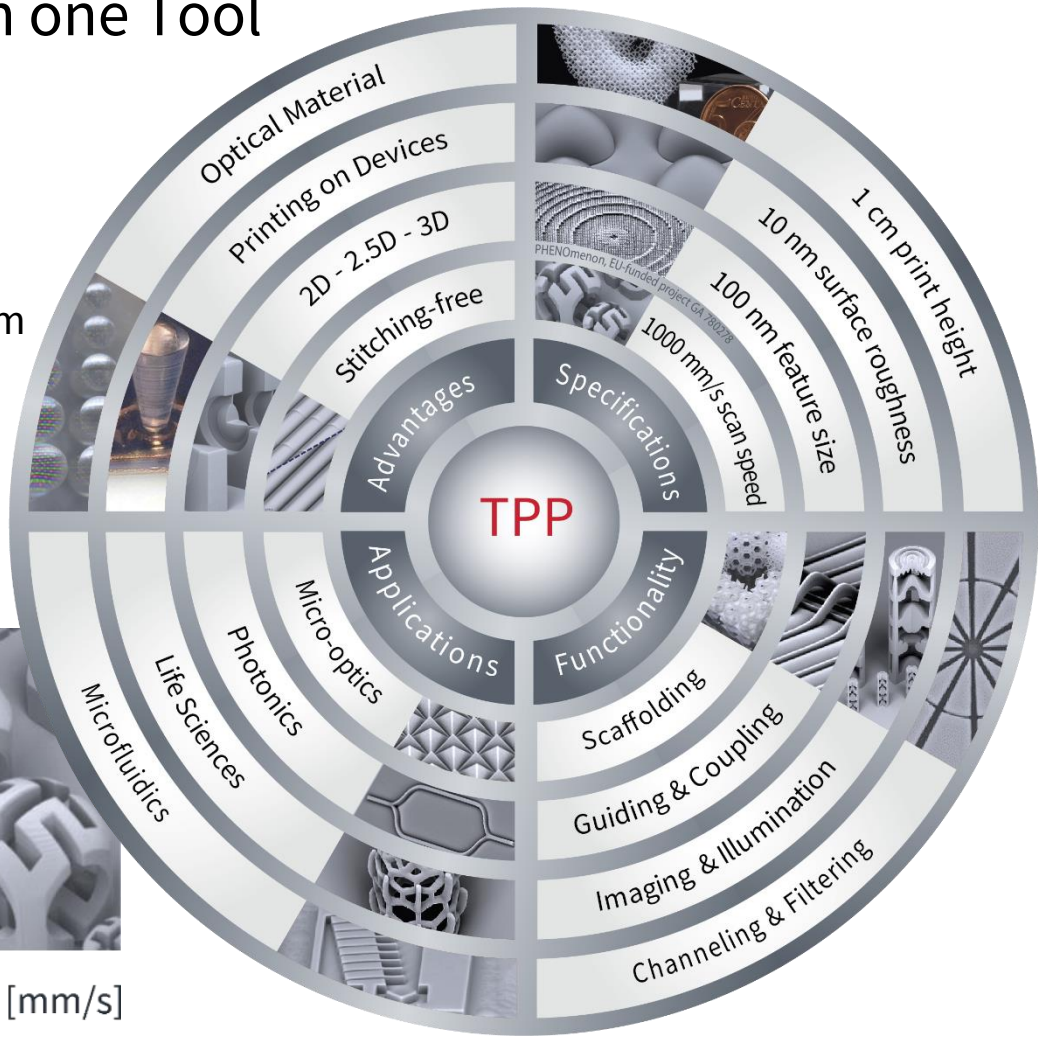
MPO 100 – 3D Lithography and 3D Microprinting in one Tool

Key characteristics:

- Two-Photon-Polymerization (TPP) Technology
- Printing height of over 1 cm
- Superior surface quality: Roughness down to 10 nm
- Resolution down to 100 nm
- Scan speeds over 1000 mm/s
- Stitching-free fabrication capability

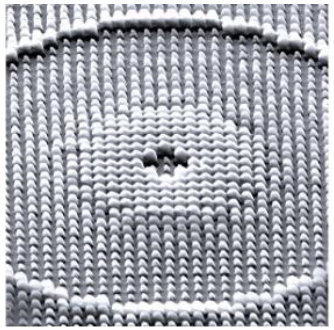


Print height [cm]

1

Roughness [nm]

10



Resolution [nm]

100

Scan Speed [mm/s]

1000

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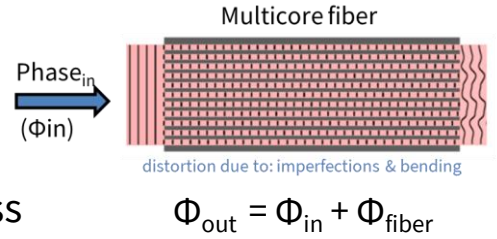
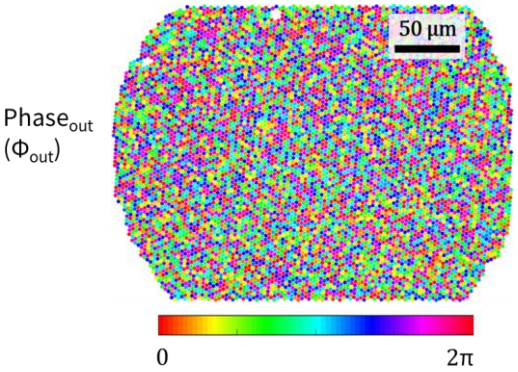
3D Endoscopy

Challenge:

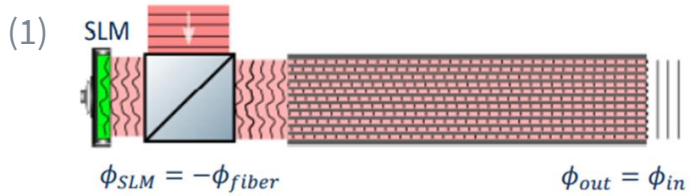
- Fiber endoscopy provides non-invasive imaging of tissue
- Need for small diameter < 0.5 mm => standard optics limit compactness
- Imperfections of multicore fibers leads to phase delays => no 3D imaging



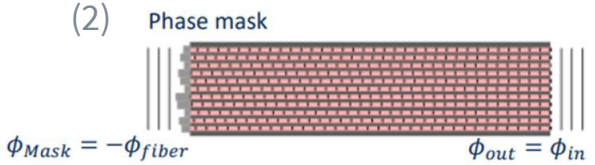


Solution:

- Calibration and compensation of Φ_{fiber}
- Possibilities:
  - (1) Spatial Light Modulator
  - (2) Phase Mask, e.g. DOE



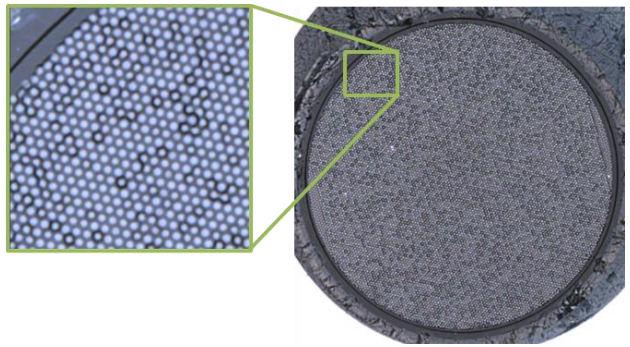
Flexible application
Expensive SLM and constant alignment



No misalignment & cost efficient
& small footprint
Individual DOE for each fiber

MPO 100 Contribution:

- Phase corrected lensless endoscope with on-fiber printed DOE via 3D lithography



Freeform Optics for Beam Shaping in 3D Sensing

Challenge:

- 3D Sensing is increasingly implemented for depth-sensing in
- Consumer Electronics (face recognition, gesture control, …)
- Automotive (driver attention, …)
- Industrial (gesture control, collision warning, …)

→ Requirements on 3D sensing cameras: small size, high image quality, …

Face Recognition

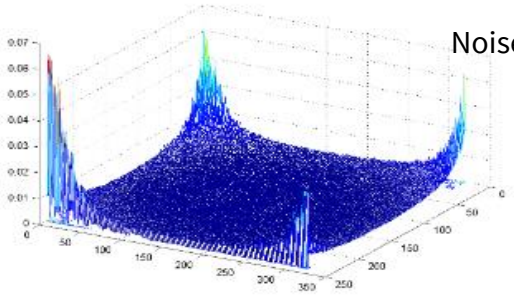
ams.com

Solutions:

Stereovision **Structured light** **Time-of-Flight (TOF)**

TOF cameras are compact and are based on LED, EEL, VCSEL as light sources

→ Image quality can be affected by beam divergence

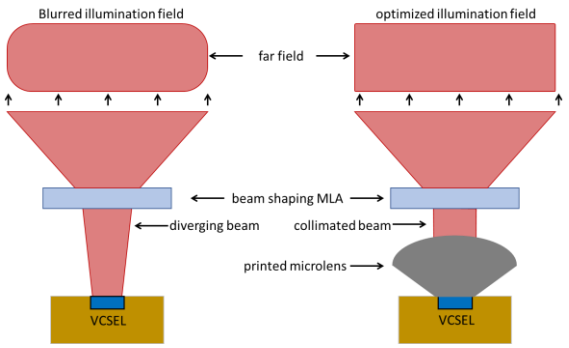


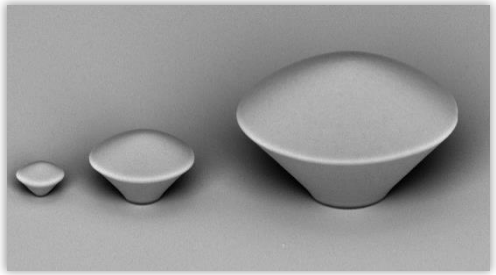
Noise near corners [1]

[1] 2008 IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops, Anchorage, AK, 2008, pp. 1-7

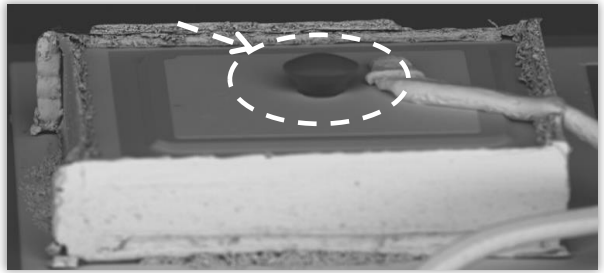
MPO 100 Contribution:

- Collimation for uniform image
- Beam shaping for larger FoV





Microlenses with conic base



Microlens on VCSEL

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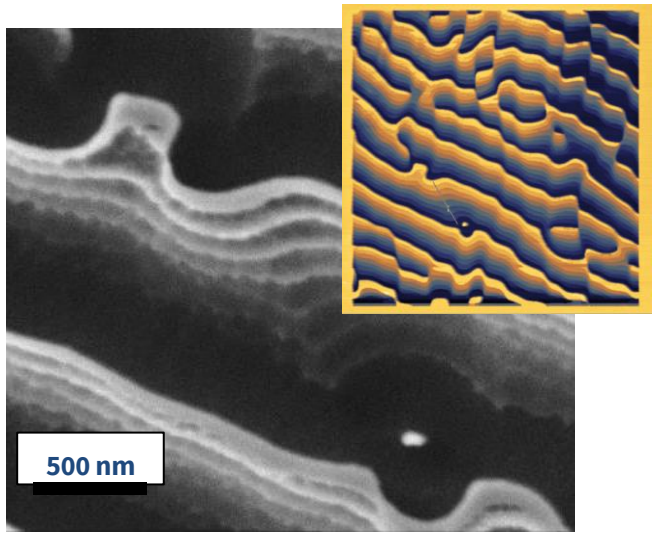
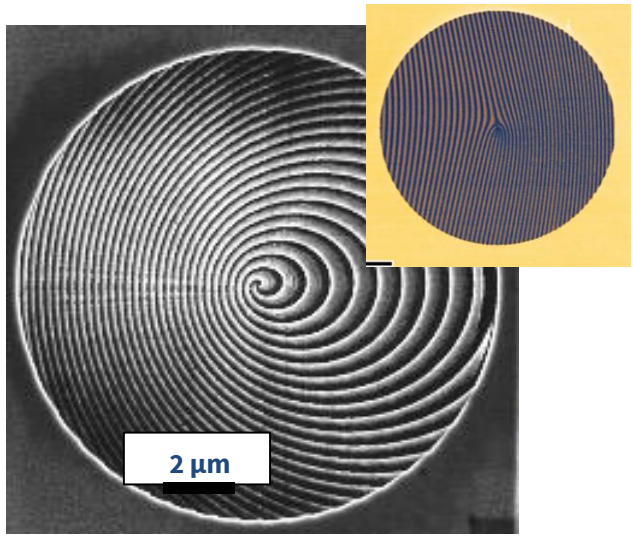
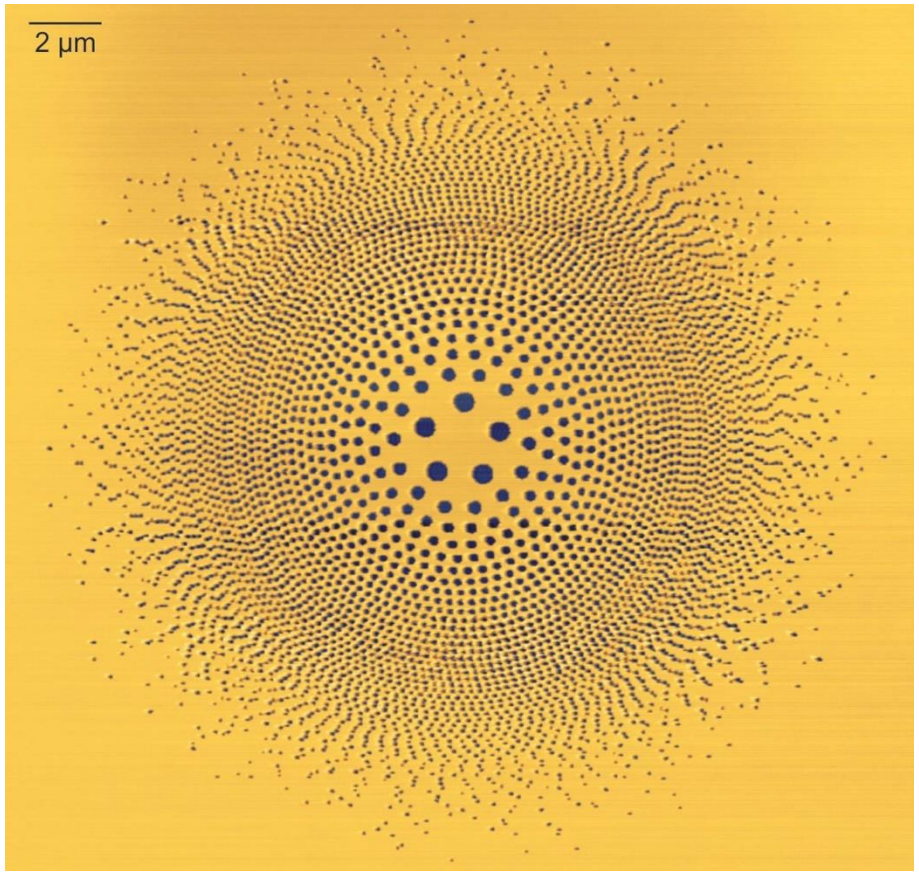
Thermal Scanning Probe Lithography for 2D and 2.5D Photonics



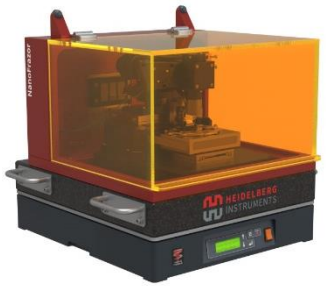
Hologram in Si (700 nm deep)
Kulmala *et al.*, SPIE, 2018



Phase plates in SiN membranes
Hettler *et al.*, Micron, 2019



A photonic sieve can be used for focusing light beyond the diffraction limit. Design: Adam Jeff, CERN



NanoFrazor :
Nanometric resolution
15 nm lateral & 2 nm in Z

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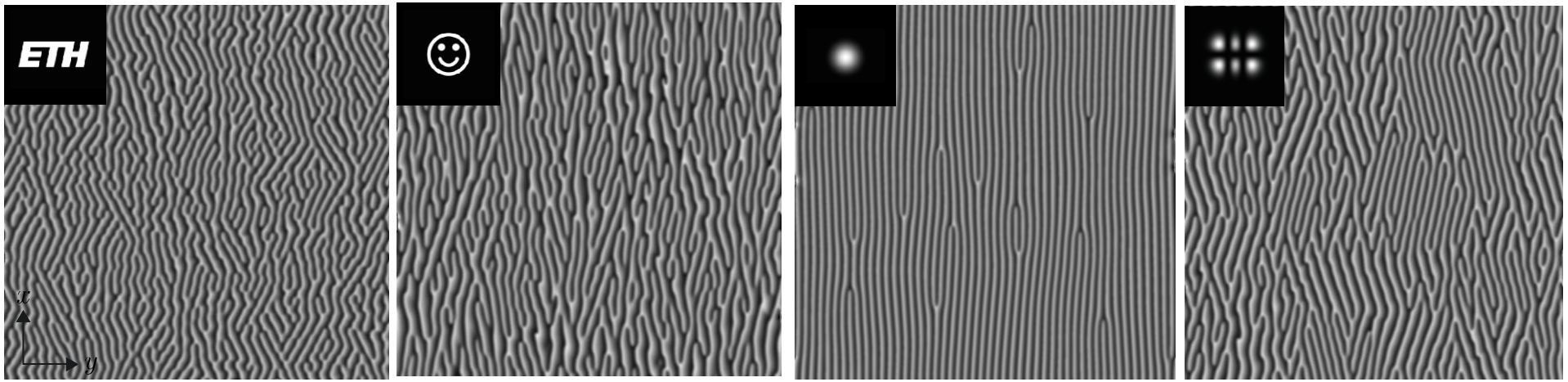
Sub-nm Grayscale Precision Enables new Possibilities in Photonics

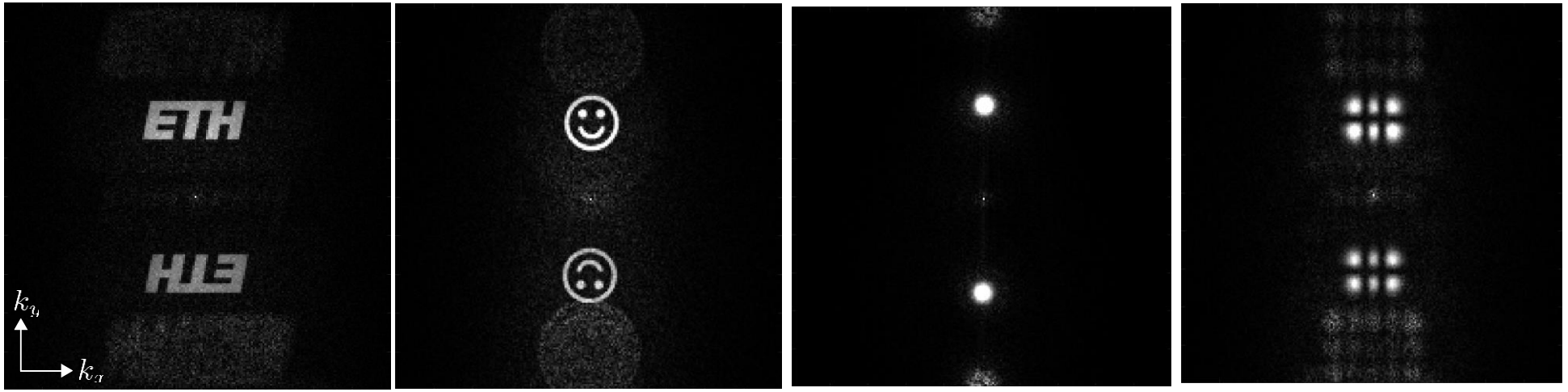
ETH zürich

OMEL Optical Materials Engineering Laboratory

Generated Bitmaps



Fourier Domain Images



PhD work of Yannick Glauser

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THANK YOU!

HEIDELBERG INSTRUMENTS
MIKROTECHNIK GMBH
MITTELGEWANNWEG 27
69123 HEIDELBERG
GERMANY
PHONE +49 6221 728899-0

heidelberg-instruments.com