



# Precision 3D Printing for Photonic Integration and Optical Coupling

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Micro Optics Summit & Expo

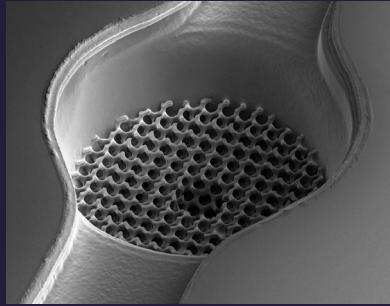
15  
YEARS Think big.  
Print nano.



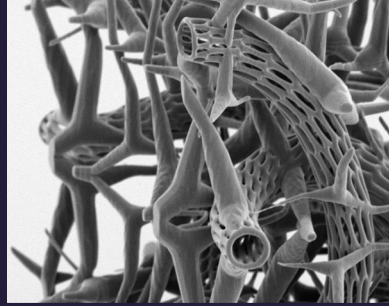
## Company Facts & Figures

- ▶ 100+ employees
- ▶ 35% R&D intensity
- ▶ 4,000+ users
- ▶ 2,000+ publications
- ▶ HQ in Karlsruhe, Germany with >4,200 m<sup>2</sup> space
- ▶ Subsidiary Boston, US
- ▶ Subsidiary Shanghai, CN
- ▶ 17+ years of success

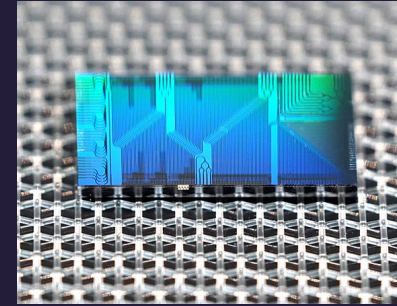
# We empower cutting edge science & industrial innovations



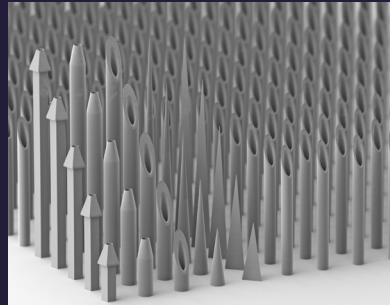
Life Sciences



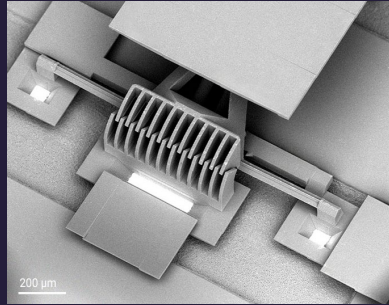
Microfluidics



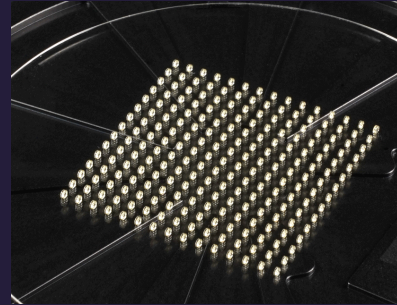
Photonic packaging



Microneedles



MEMS



Microoptics



# The key enabling technology

Read our Whitepapers in our premium section

- 1) Two-Photon Polymerization (2PP)
- 2) Two-Photon Grayscale Lithography (2GL®)
- 3) Industrial Scale-up: Mastering & Replication

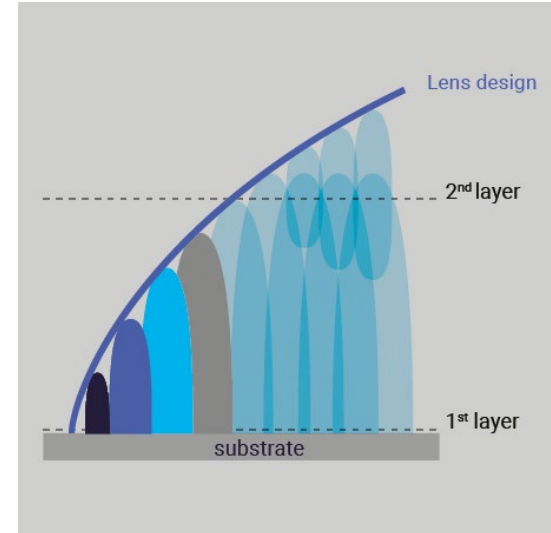
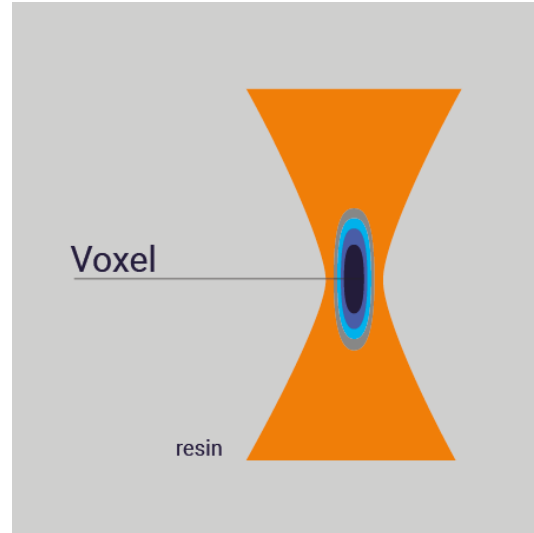
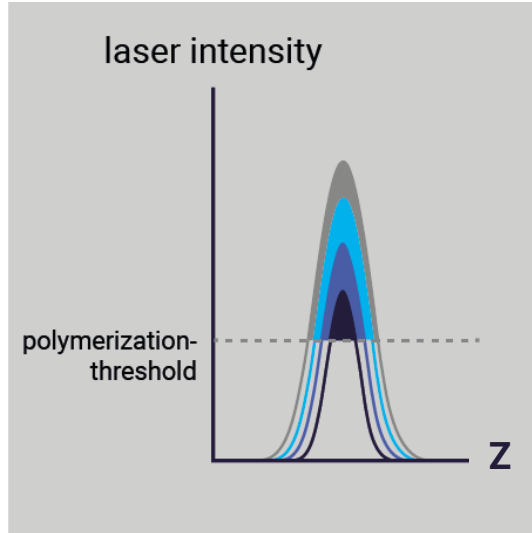




# 2-Photon Grayscale Lithography 2GL<sup>®</sup>

## \*Technology

Dynamic voxel height

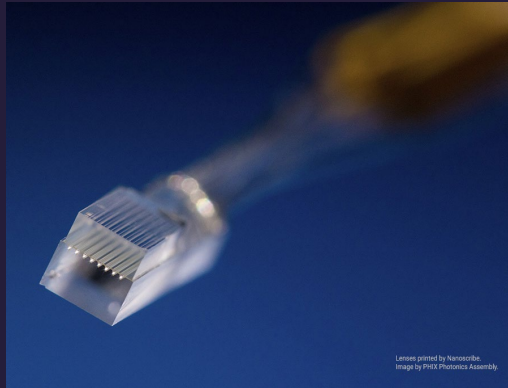


# Free-Space Microoptical Coupling (FSMOC)

## Efficient light coupling solutions

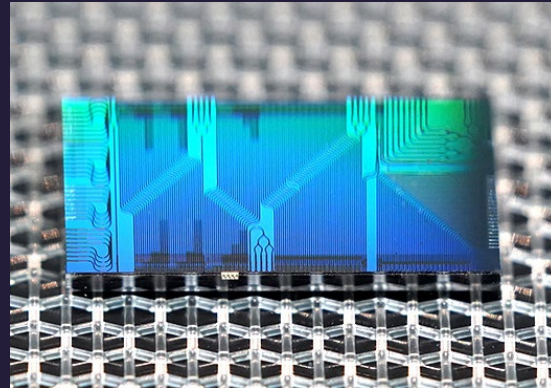


On fiber array



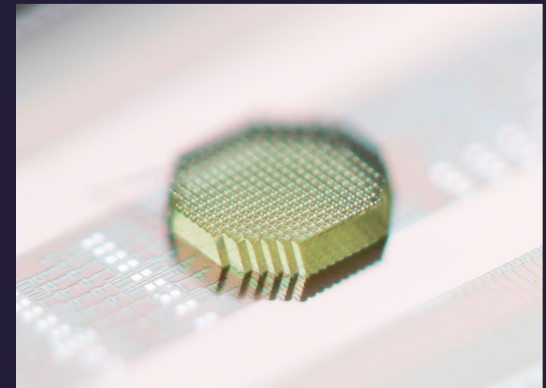
Microoptical elements on optical facet of fibers (fiber array)

On chip edge



Free-space microoptical couplers on chip edge (edge coupler)

On chip surface



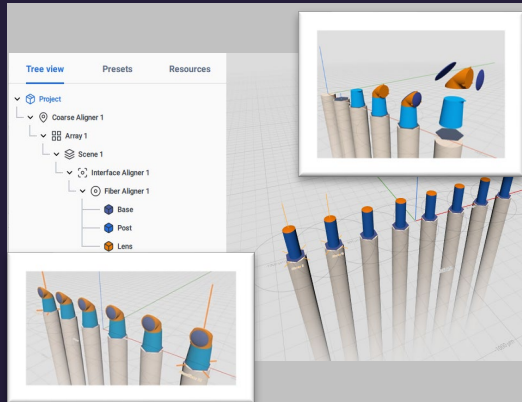
Free-form microlenses for vertical coupling on chip surfaces (grating coupler)

# Fiber Arrays: Adapting the MFD and Numerical Aperture (NA)

## Easy print set up, flexible designs, reliable results

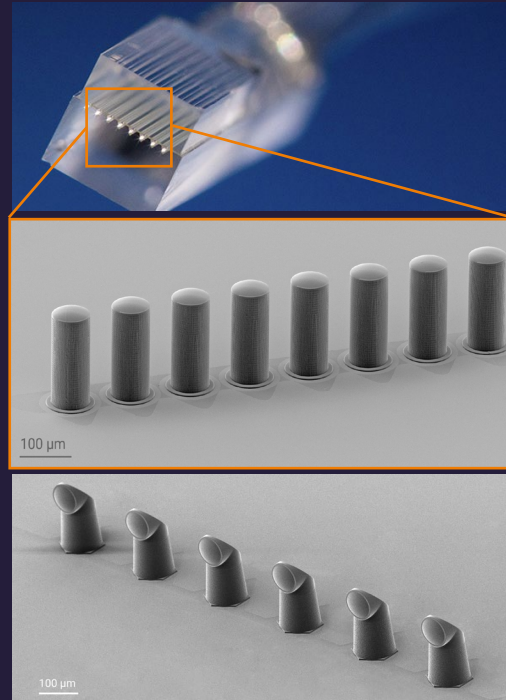


### Workflow

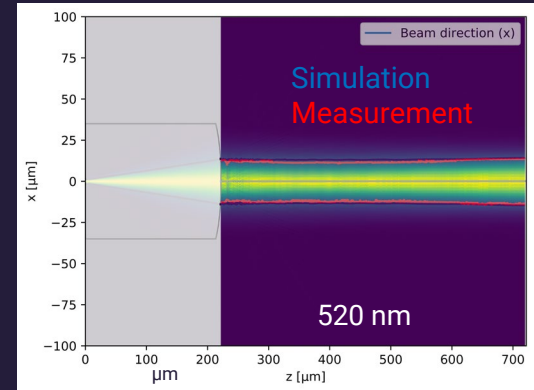


- ▶ Define lenses via formula or STL
- ▶ Align relative to fiber core
- ▶ Select process parameters
- ▶ Print & develop

### Results



### Characterization



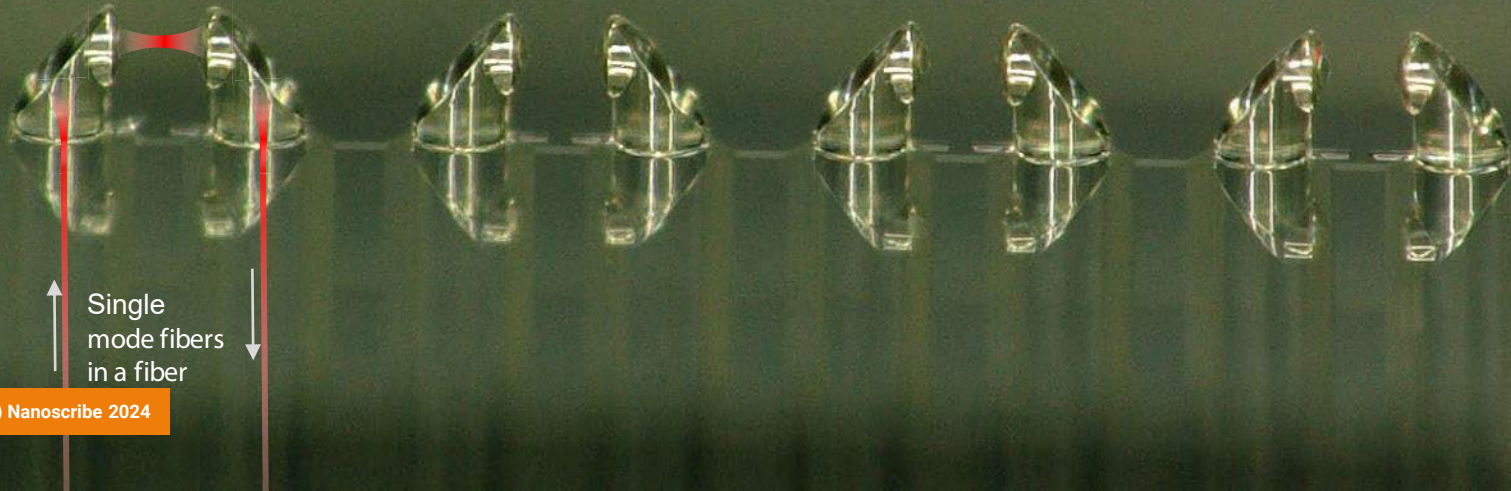
Characteristic	Typ. Value
Shape accuracy	< 50 nm rms
Surface roughness $R_a$	< 5 nm
MFD repeatability	$\sigma$ < 40 nm
Loss	0.5 - 0.8 dB
Print time	10 - 80 sec / lens
Environmental (Resin)	Thermal shock -25°C to 85°C (1,000 cycles); 85° C @ 85 % rh, 1000h

# Microoptical elements on optical facet of fibers



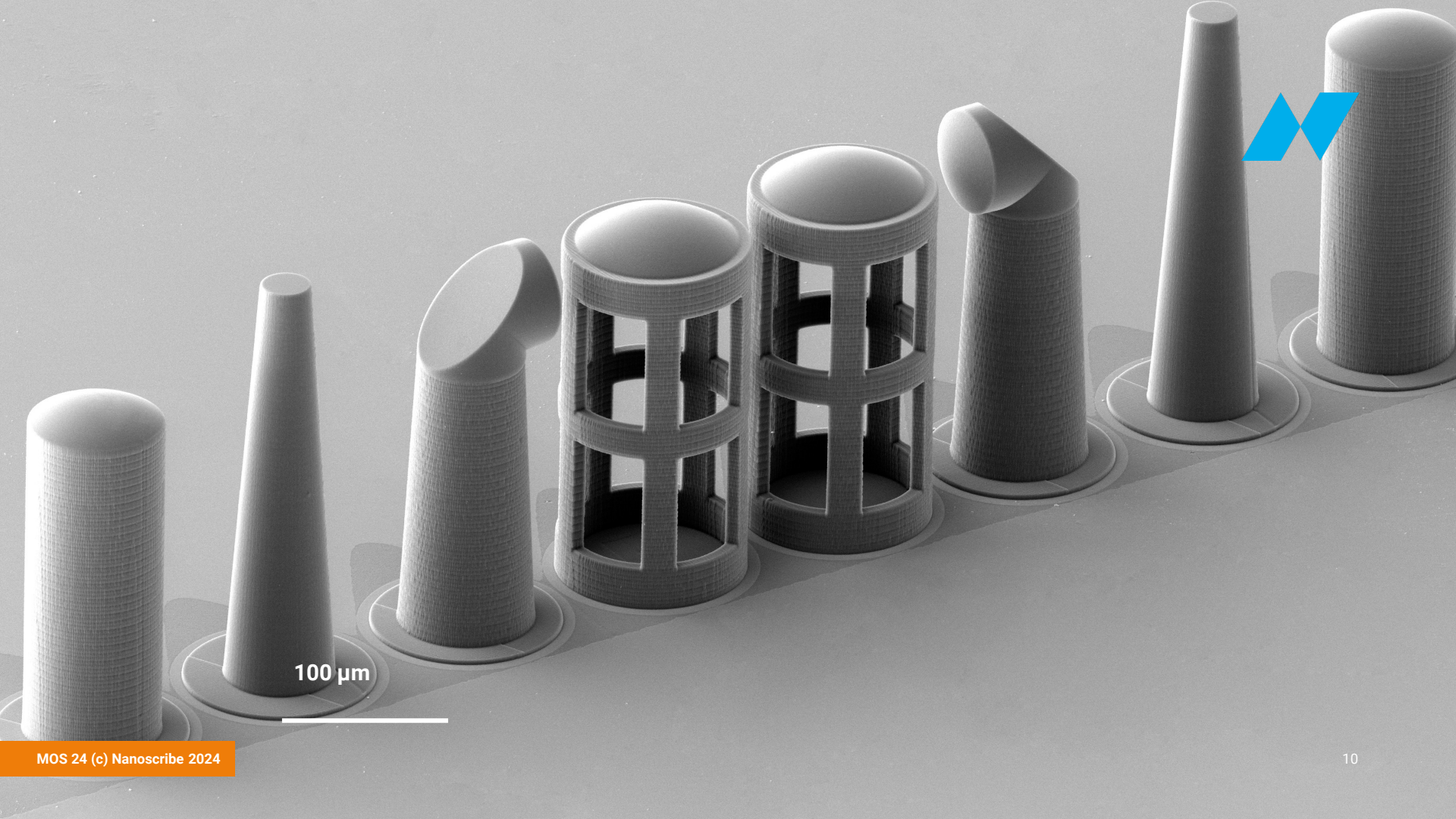
6 $\mu$ m MFD focus periscopic lens for 1550 nm with a polynomial TIR mirror

- down to 0.3dB loss per coupling interface for coupling two channels to each other
- Excess loss < 0.3 dB after 1000 h 85% humidity 85°C



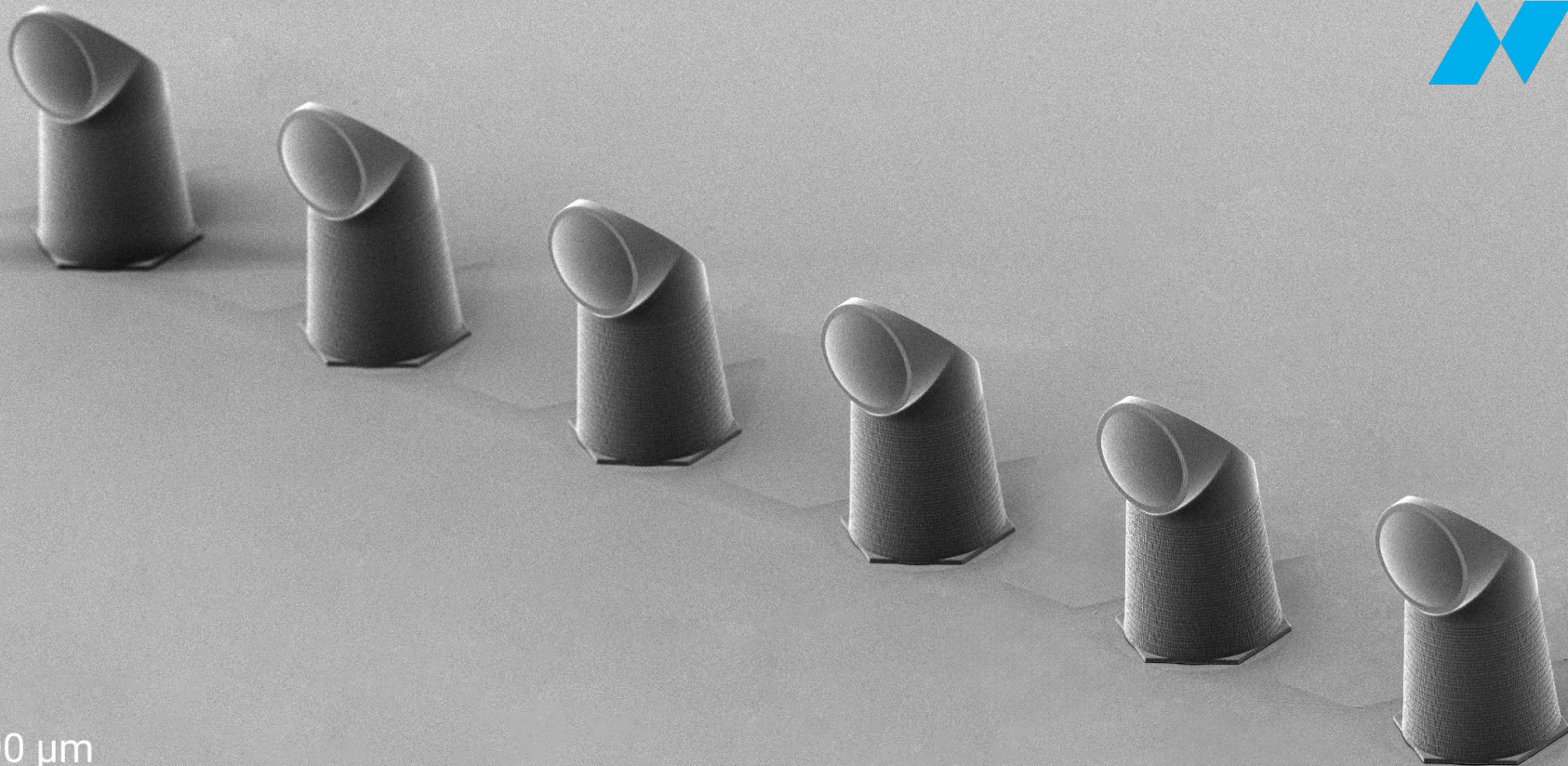
Single  
mode fibers  
in a fiber





100  $\mu\text{m}$





100  $\mu\text{m}$



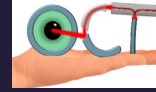
250  $\mu\text{m}$



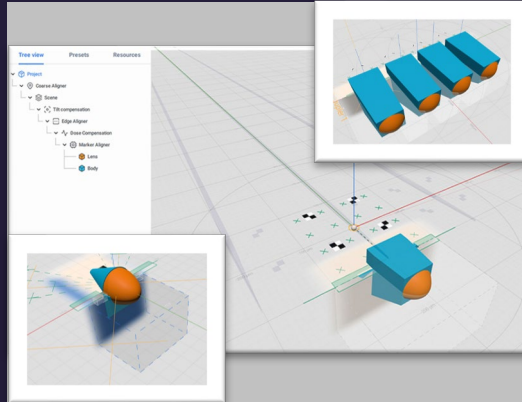


# Microoptics on the Edge of a Chip

## Shaping the beam from elliptical to round with low losses

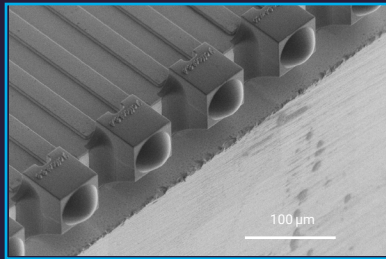
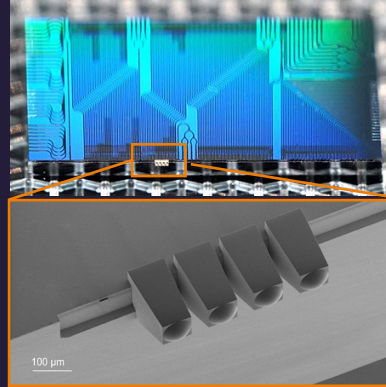


### Workflow

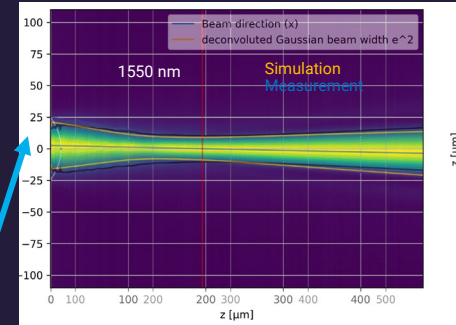


- ▶ Define lenses via formula or STL
- ▶ Align relative to fiducial and edge
- ▶ Select process parameters
- ▶ Print & develop

### Results



### Characterization



Characteristic	Typ. Value
Shape accuracy	+/- 200 nm rms
Surface roughness $R_a$	<5 nm
MFD repeatability	$\sigma < 40$ nm
Loss	0.8 – 1.4 dB
Print time	90 - 280 sec
Environmental (Resin)	Thermal shock -25°C to 85°C (1,000 cycles); 85°C @ 85% rh, 1000h



127  $\mu\text{m}$



Edge coupler microoptics on chip  
EU Project: HandheldOCT  
Horizon 2020: Grant #871312  
Photonic chip: ePIXfab (imec)  
Print: Nanoscribe

127  $\mu\text{m}$

Fiber Array with Collimation lenses (25-39  $\mu\text{m}$  MFD)



<1.35dB coupling loss from the epixfab SOI chip to a fiber(-array) with lens

Lensed Loopbacks

Collimating Lenses, 25-30  $\mu\text{m}$  MFD

1550 nm

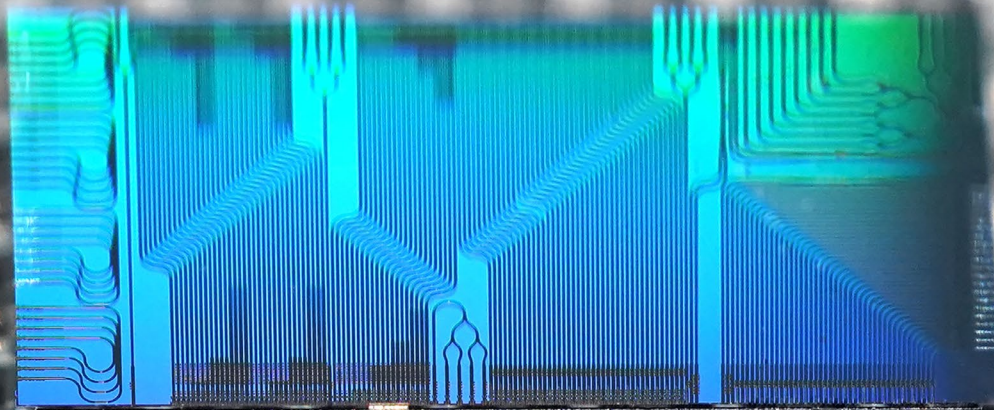
Lensed Loopbacks

Waveguide

Waveguide

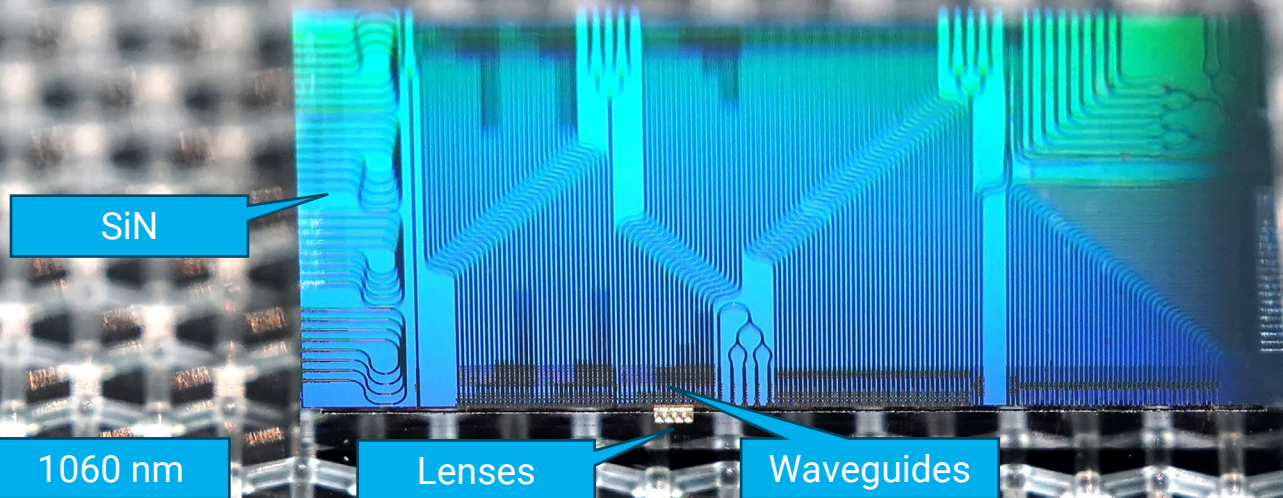
Edge coupler microoptics on chip  
EU Project: HandheldOCT  
Horizon 2020: Grant #871312  
Photonic chip: ePIXfab (imec)  
Print: Nanoscribe





Edge coupler microoptics on chip  
EU Project: HandheldOCT  
Horizon 2020: Grant #871312  
Photonic chip: imec  
Print: Nanoscribe





Edge coupler microoptics on chip  
EU Project: HandheldOCT  
Horizon 2020: Grant #871312  
Photonic chip: imec  
Print: Nanoscribe



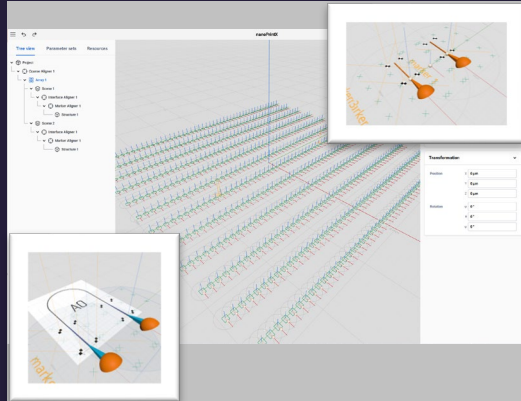
# Vertical Coupling on Chip

## Flexible design enabling low loss (broadband) coupling

Pixel  
Photonics

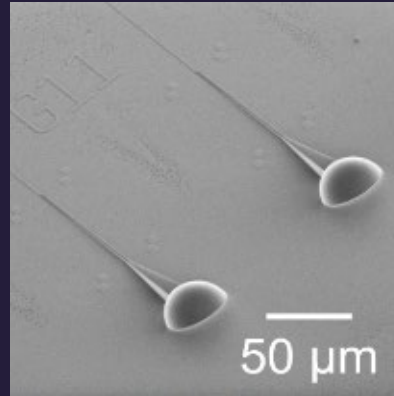


### Workflow

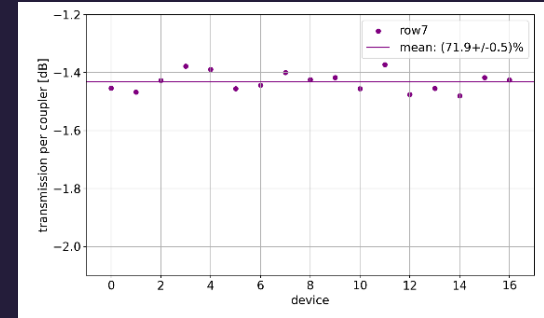


- ▶ Define lenses via STL and create array automatically
- ▶ Align relative to marker (<100 nm)
- ▶ Select process parameters
- ▶ Print & develop

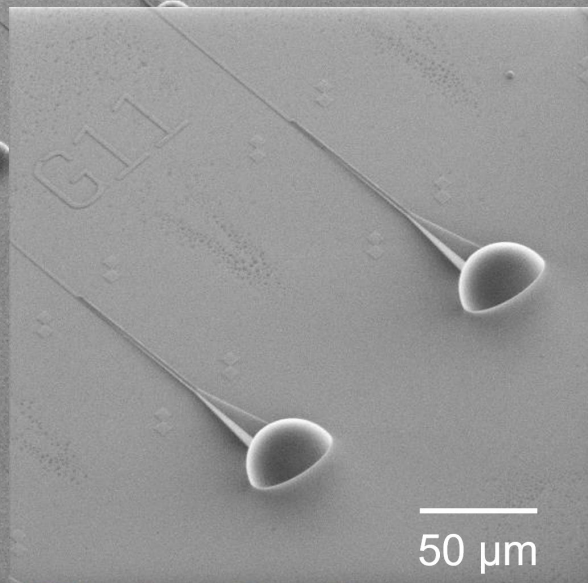
### Results



### Characterization



Characteristic	Typ. Value
Shape accuracy	+200nm rms
Surface roughness $R_a$	< 5 nm
MFD repeatability	$\sigma < 40$ nm
Loss	<1.5 dB
Print time	<60 sec
Environmental	Thermal Shock -25°C to 85°C (1,000 cycles); 85°C @ 85% rh 1000h; cryo at <3 K

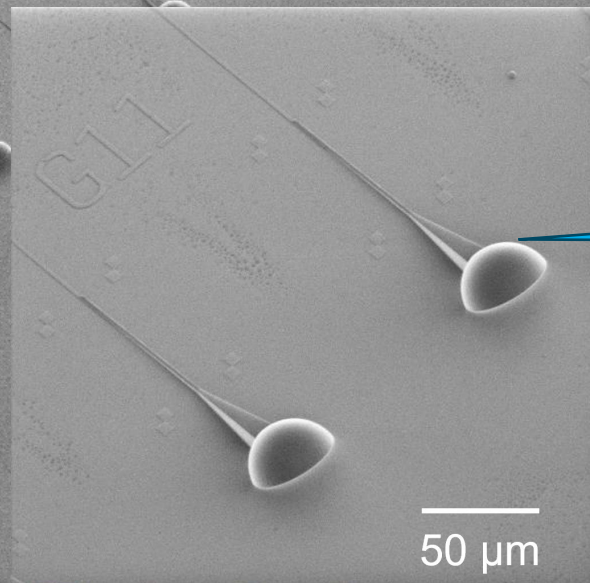


100 μm

50 μm

**Tapered surface couplers**  
EU Project: Phoenix  
Horizon 2020: Grant #101017237  
Design: University of Muenster  
Print: Nanoscribe





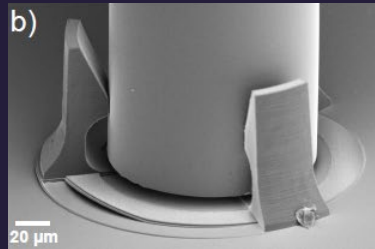
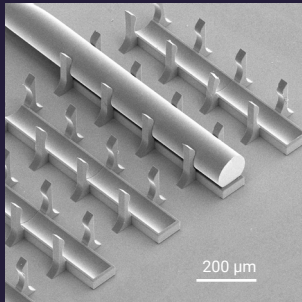
Tapered TIR mirror with lens

SiN Die

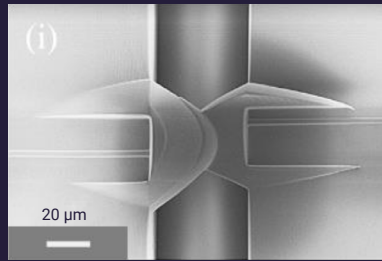
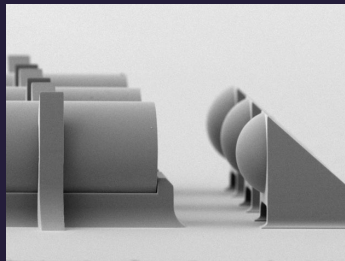
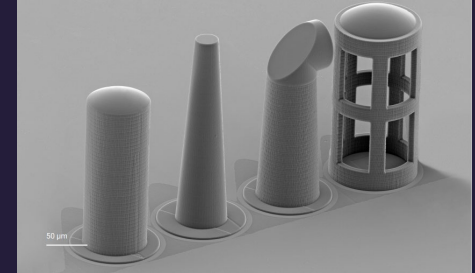
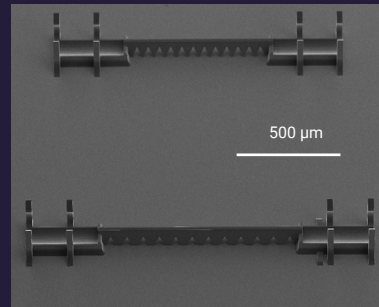
Tapered surface couplers  
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# 3D Printed Optical Interconnects

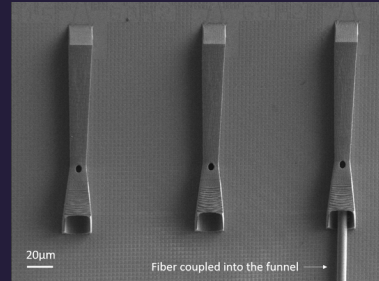
## Mechano-optical fiber coupling schemes



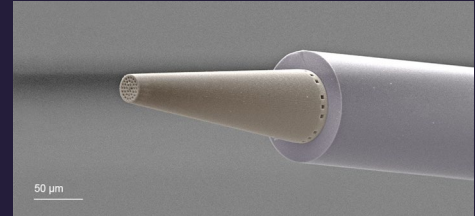
A. Bogucki et al., *Optics Express* 11513 (2018)



H. Huang et al., *Light: Adv. Manuf.* 5, 46 (2024)



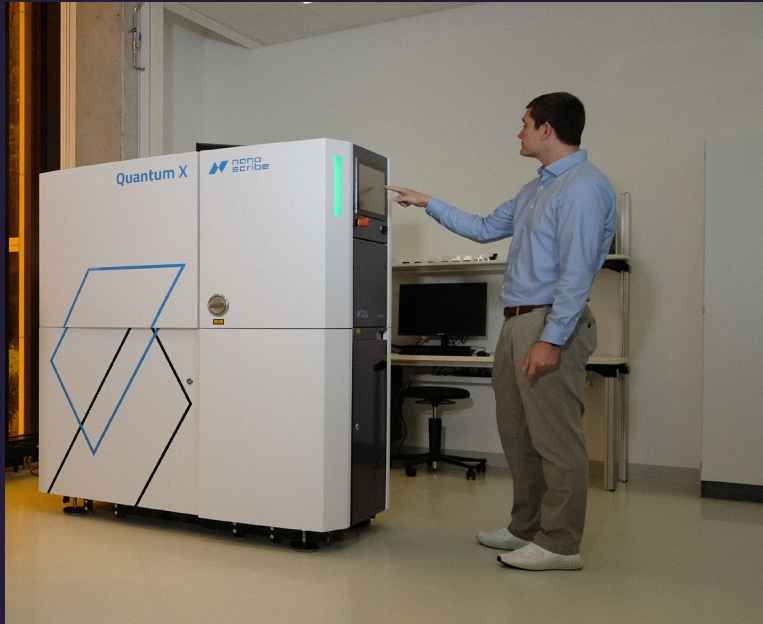
A. Gordillo, et al. *Optics Express* 27.15 (2019)



J. Van Erps et al., *J. Lightwave Technol.* 38 (2020)



# Our offer: Quantum Xalign Connect to the photonic world



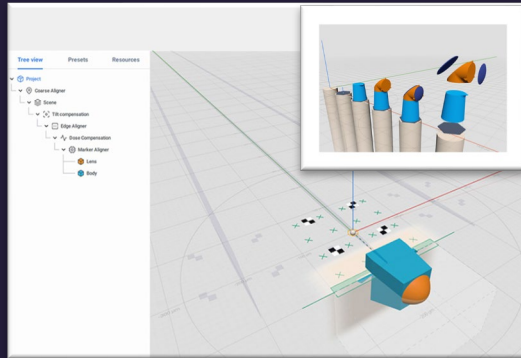
- ▶ 3D printing by 2GL<sup>®</sup> for optical quality at unrivaled speed\*
  - Surface roughness  $R_a$  down to  $\leq 5$  nm
  - Shape accuracy  $S_a$  down to  $\leq 200$  nm
  - Process. time: 6 min / 8x lensed fiber array (typ)
  - 8" wafer processing
- ▶ Automatic alignment to predefined structures
  - On chips\*: down to  $< 100$  nm detection accuracy of fiducials and chip edges
  - On fibers\*: down to  $< 500$  nm detection accuracy of fiber cores
- ▶ Compatible with cleanrooms down to ISO 4

# Our offer: Quantum Xalign

## We cover the whole process chain



### Software



- ▶ Easy definition of print objects (lens formula, STL, OBJ)
- ▶ Align relative to each other or to fiber cores, fiducials, chip edges
- ▶ Remote control of printer

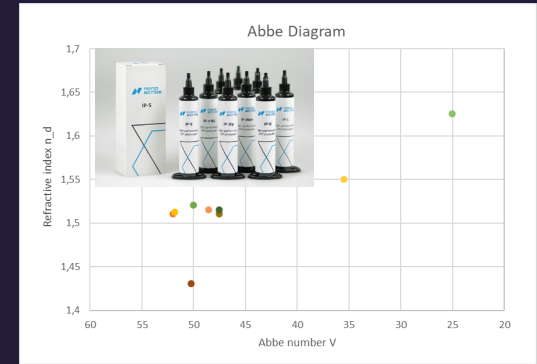
### Hardware



- ▶ Detection modules for fiber cores and fiducials, chip edges
- ▶ Substrate holders for fibers, chips, wafers

Image: courtesy of PHIX

### Printing materials



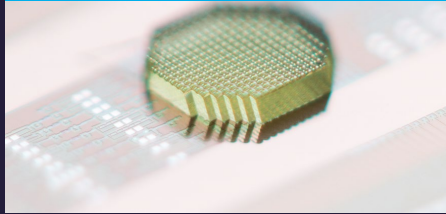
- ▶ High transparency
- ▶ High shape accuracy
- ▶ Smooth surfaces
- ▶ Different refractive indices
- ▶ Reliability data available

# 3D printed free-form microoptics by 2GL® \*

## Prototyping, Mastering & Scale Manufacturing



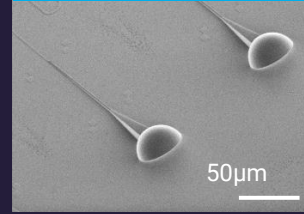
surface coupler  
rapid prototyping



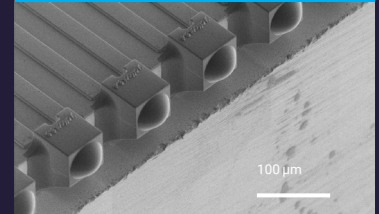
beam shaping optics  
mastering for NIL



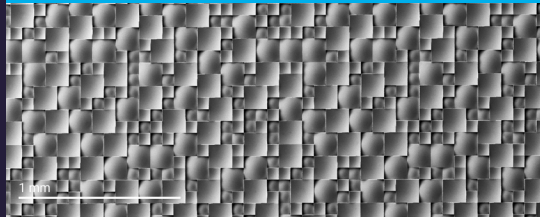
surface coupler  
manufacturing



edge coupler  
manufacturing



Free-form micro lens arrays  
mastering



multilevel microoptics  
manufacturing



lensed fiber arrays  
manufacturing







**Jörg Smolenski**  
**Business Development Manager**

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Web: [nanoscribe.com](https://www.nanoscribe.com)

## Thankyou for your attention !

As the pioneer in 3D printing solutions for optics and photonics, we push the limits of photonics packaging. We deliver smart solutions to optical coupling challenges for best-in-class optical engineering and industrially mature innovations.

**Validate our aligned 3D Microfabrication technology**

**Get to know Quantum X align**

- ▶ Schedule an online / on-site demo
- ▶ Check the feasibility of your project

CERTIFIED  
**ISO 9001**

Quality Management Systems

CERTIFIED  
**ISO 14001**

Environmental Management Systems