Universität Bremen

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Bremer Institut für angewandte Strahltechnik GmbH

Nanophotonics in Three Dimensions: Heading from Microelectronics towards Optical Computing

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Germany

SysInt, Bremen, 2nd - 4th July, 2014

Content

- “More than Moore”
  From Micro-Electronics to Nano-Photonics

- Design, Simulation and Fabrication of
  3D-Nanophotonic Structures

- From Si-Microelectronics to Nano-Photonic
  Information Processing (Saphir)

- Conclusion

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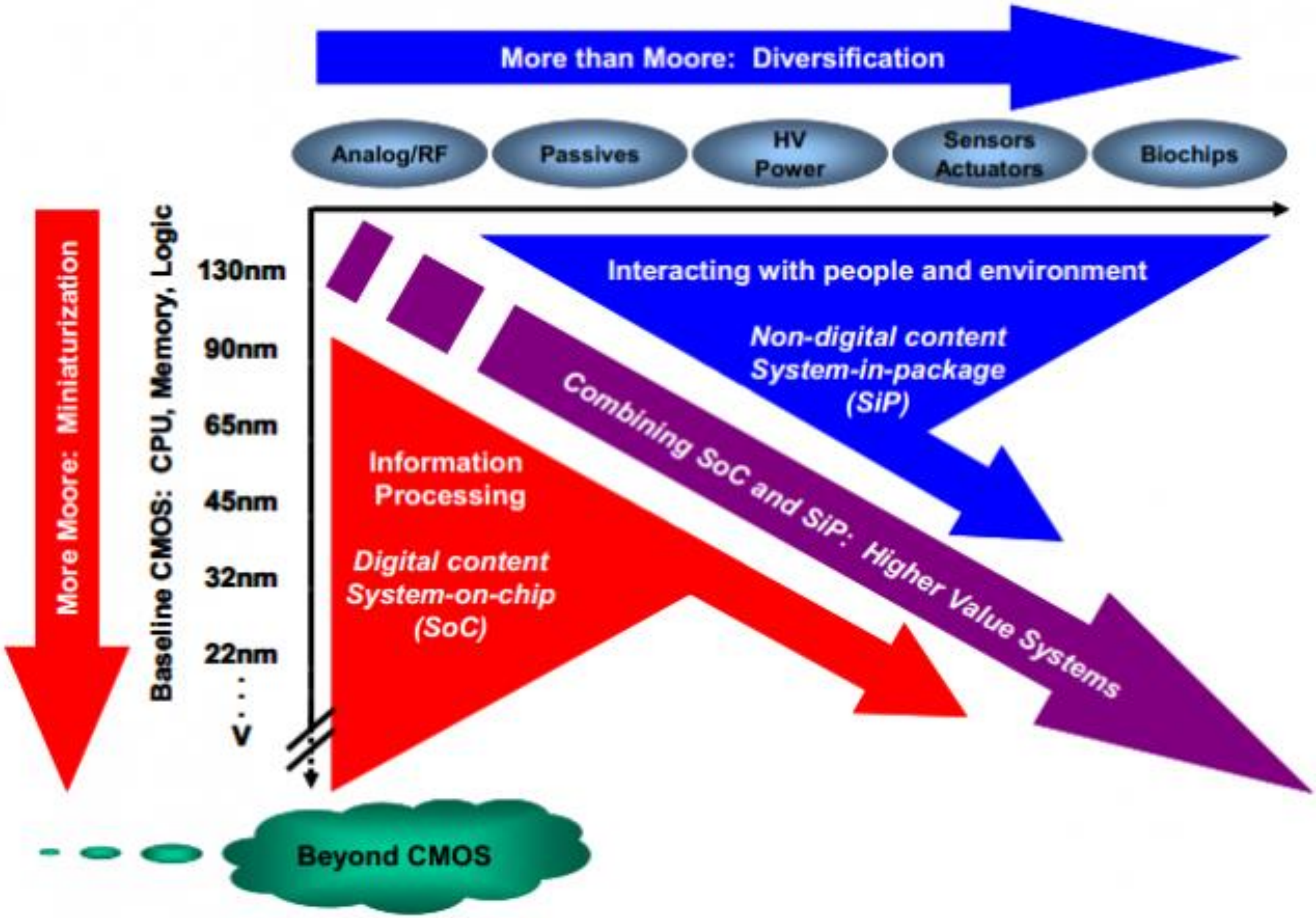
“More than Moore”



Source: International Technology Roadmap for Semiconductors ITRS 2012

How to proceed with Photonic Interconnect?

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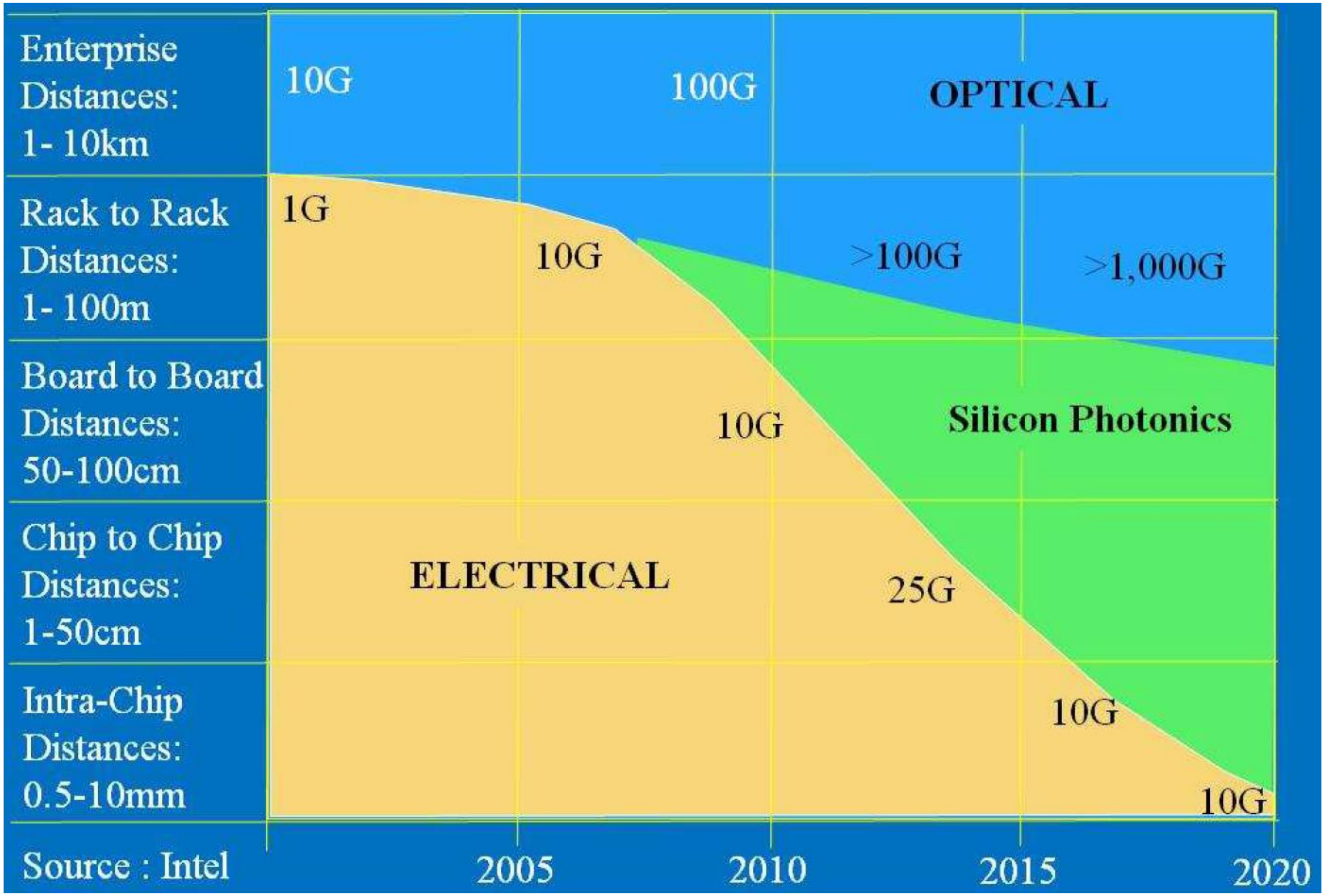

Source: Marizio Zuffada, STMicroelectronics, 2013 (taken from Intel) at: ESSDERC 42th Europ. Solid State Device Research Conference

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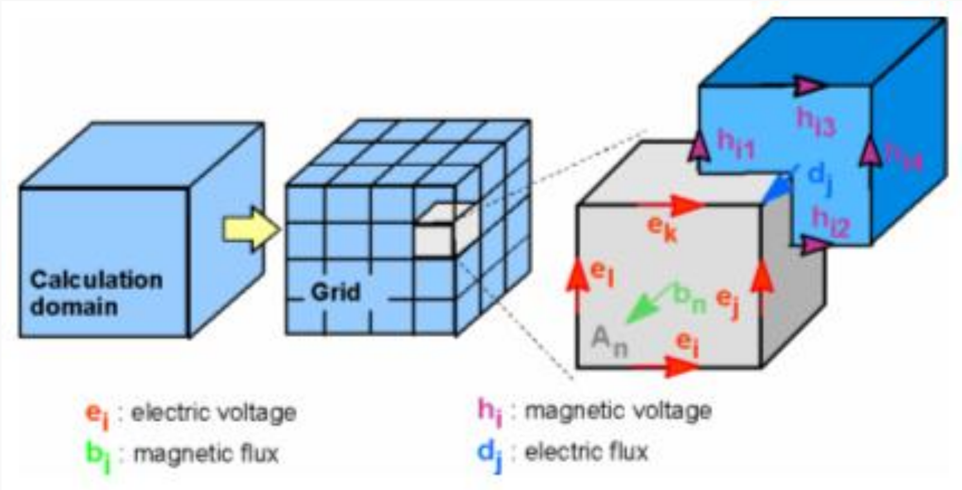
Modeling: Finite Integration Technique (FIT)

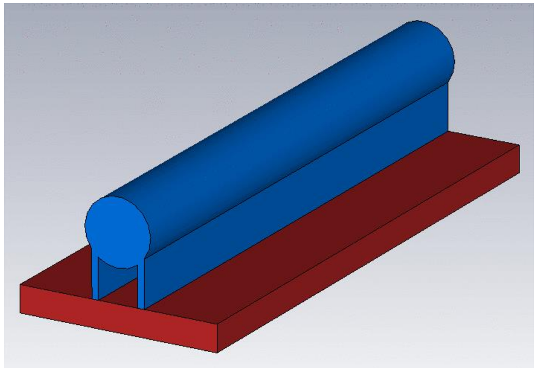
- Segmentation in meshcells with known material properties ε_r , μ_r , κ
- Solving of Maxwell‘s equations in integral form for every cell
  - Analyze E- and H-Field distribution
  - Determine transmission and losses
  - Optimize design by parameter studies

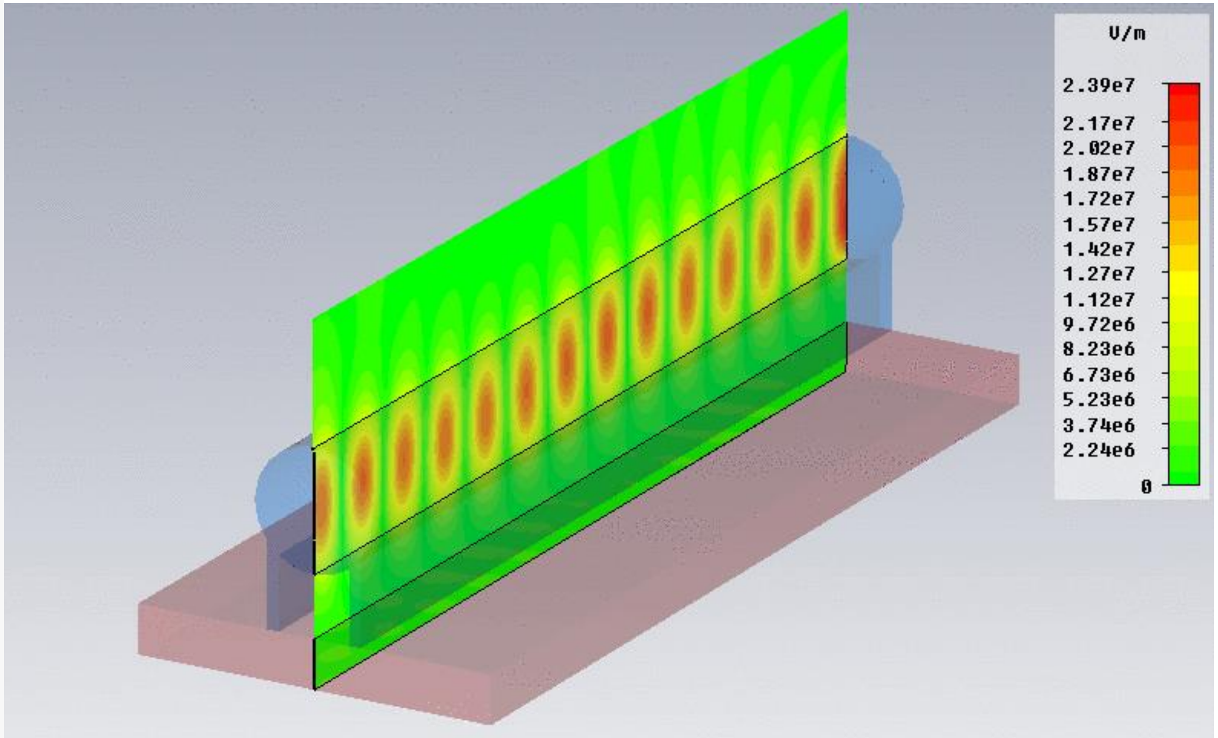


Source: cst.com

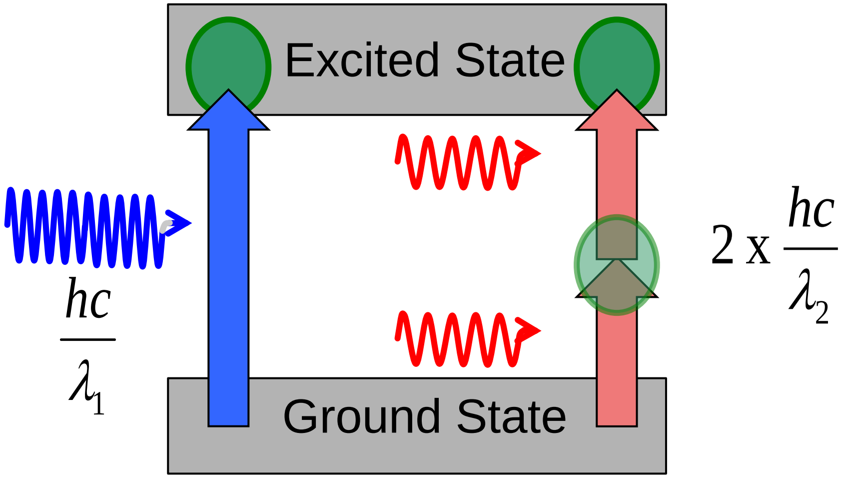
Design of POWs on Stilts

- Wavelength = 1.55 µm
- Diameter = 1 µm
- n(SU8) = 1.57 < n(Si) = 3.48
- ➢ Wave guiding!



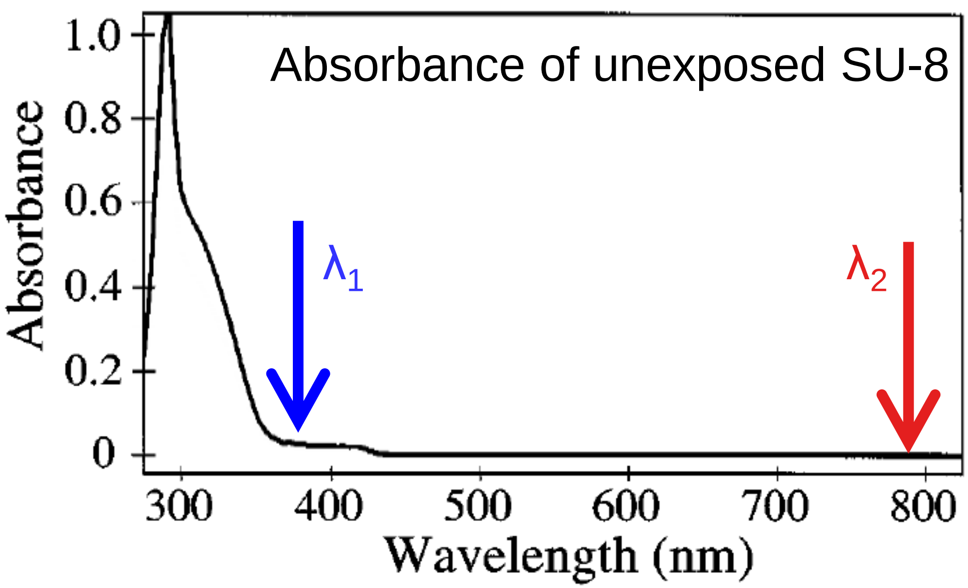


Fabrication: Two-Photon Lithography



Parameters:

Pulse width	70 fs
Repetition	100 MHz
Voxel size	120 x 300 nm



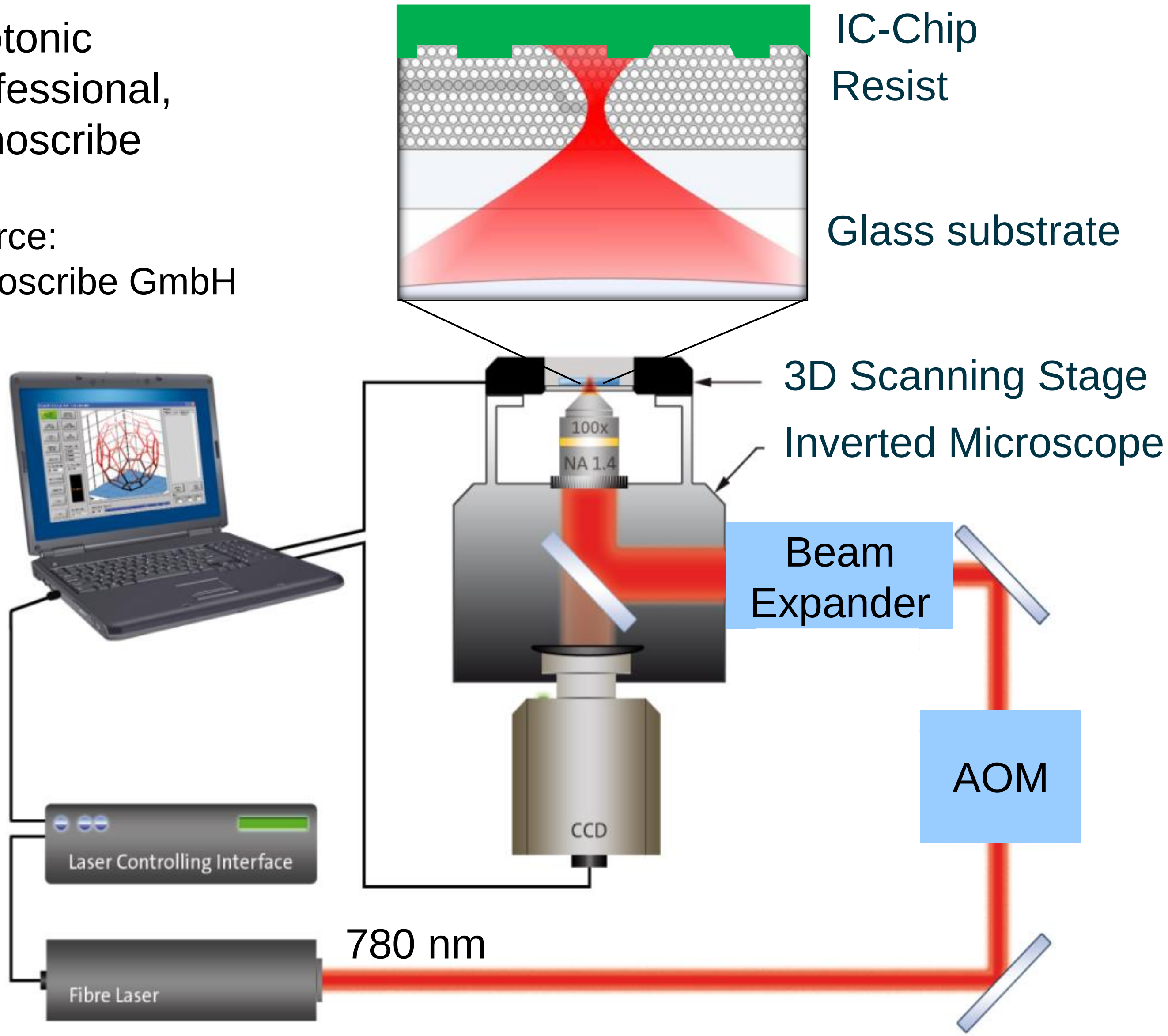
UV sensitive and NIR (780 nm) transparent

G. Witzgall et al., Opt. Lett. 23, 1745 (1998)

Two-Photon 3D Laser Lithography

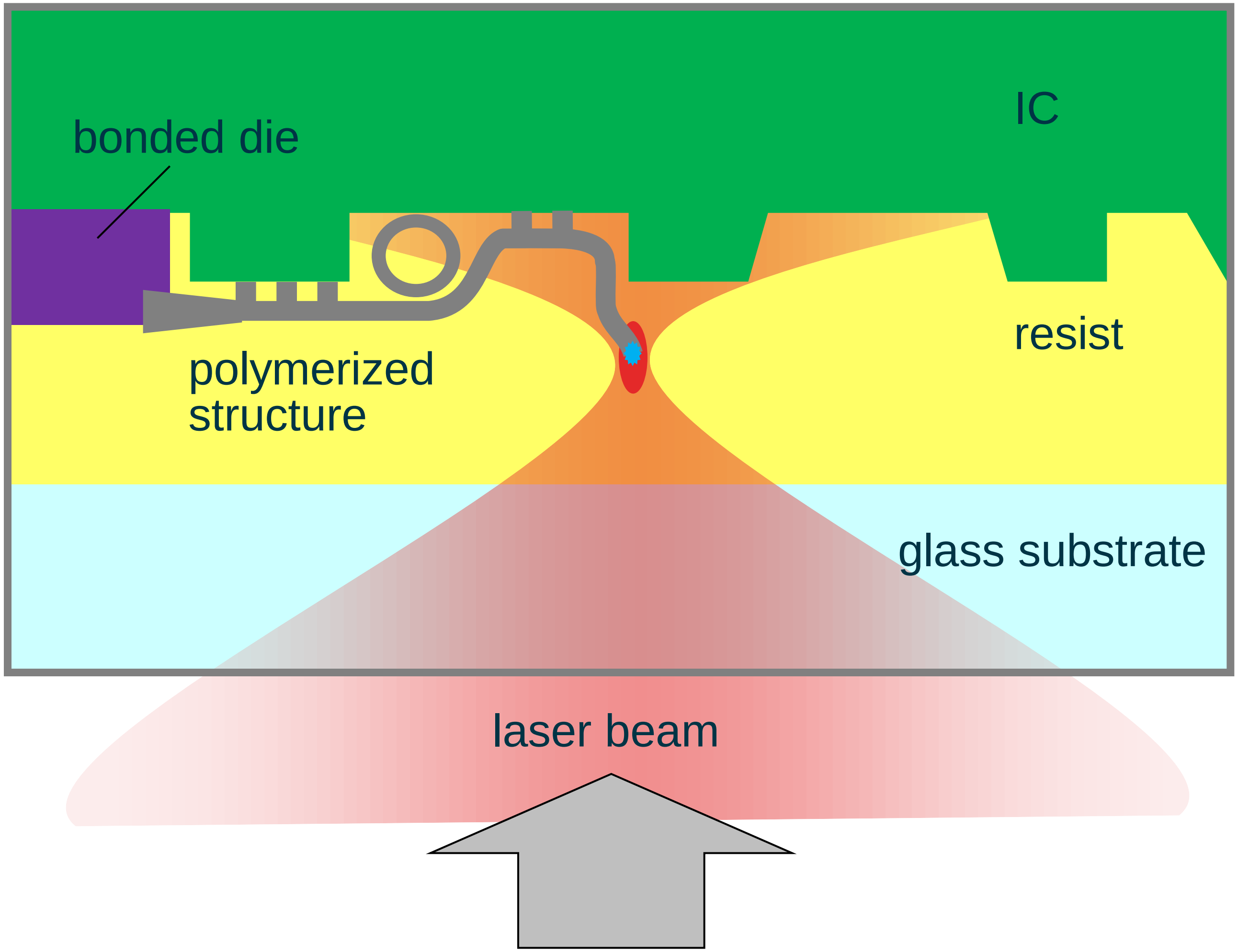
Photonic Professional, Nanoscribe

Source: Nanoscribe GmbH



Two Photon Laser Lithography System Photonics Professional (Nanoscribe Corp.)

Direct Integration on IC Surface



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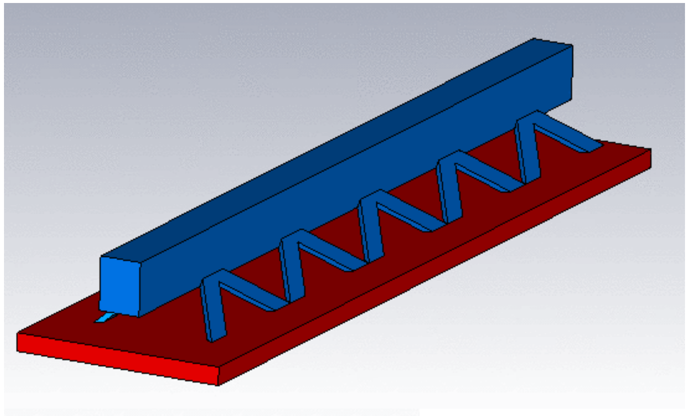
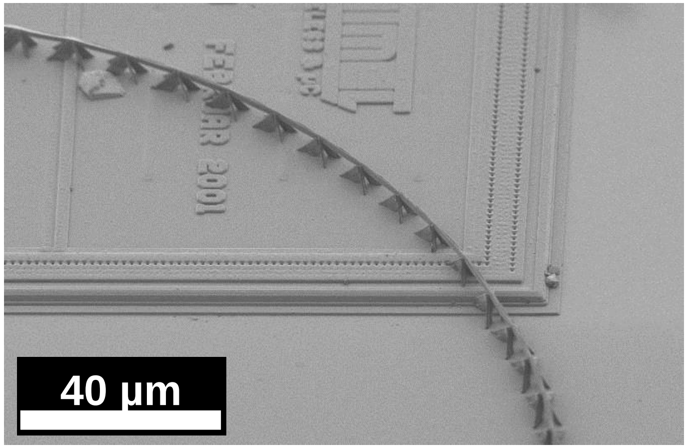
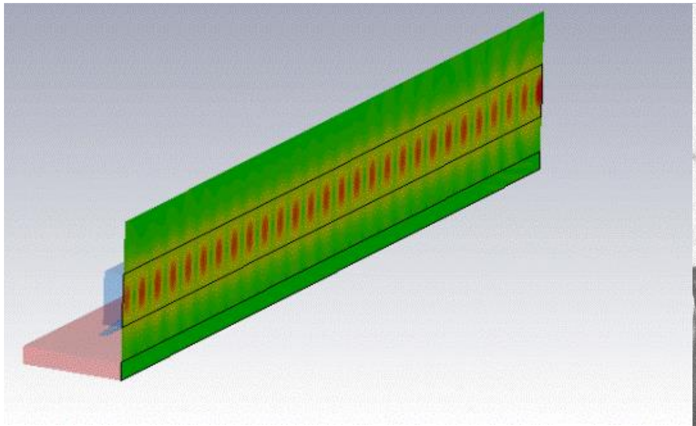
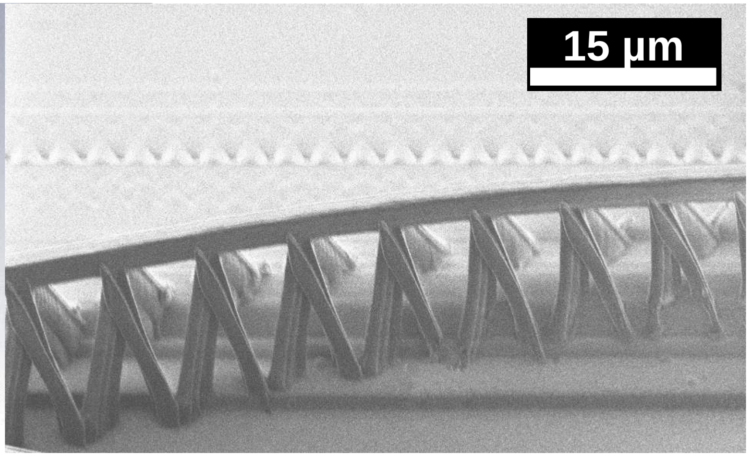
Waveguides: Design, Simulation and Fabrication



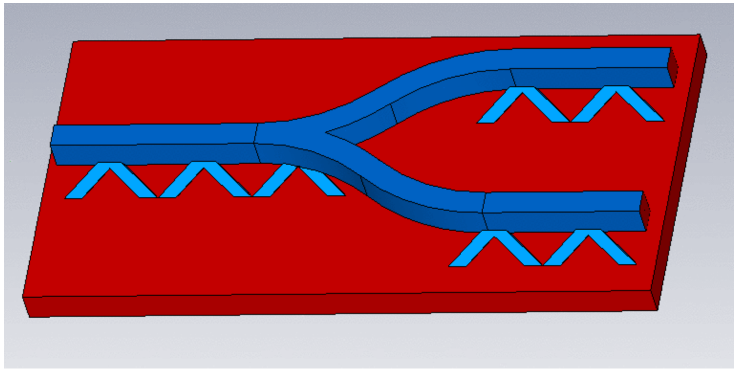


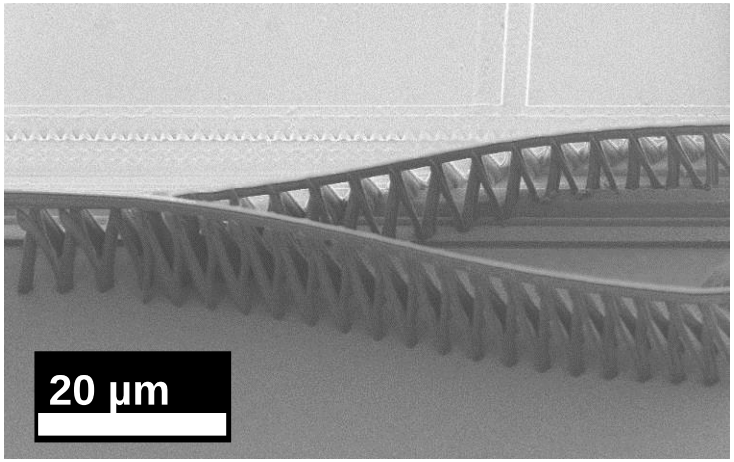


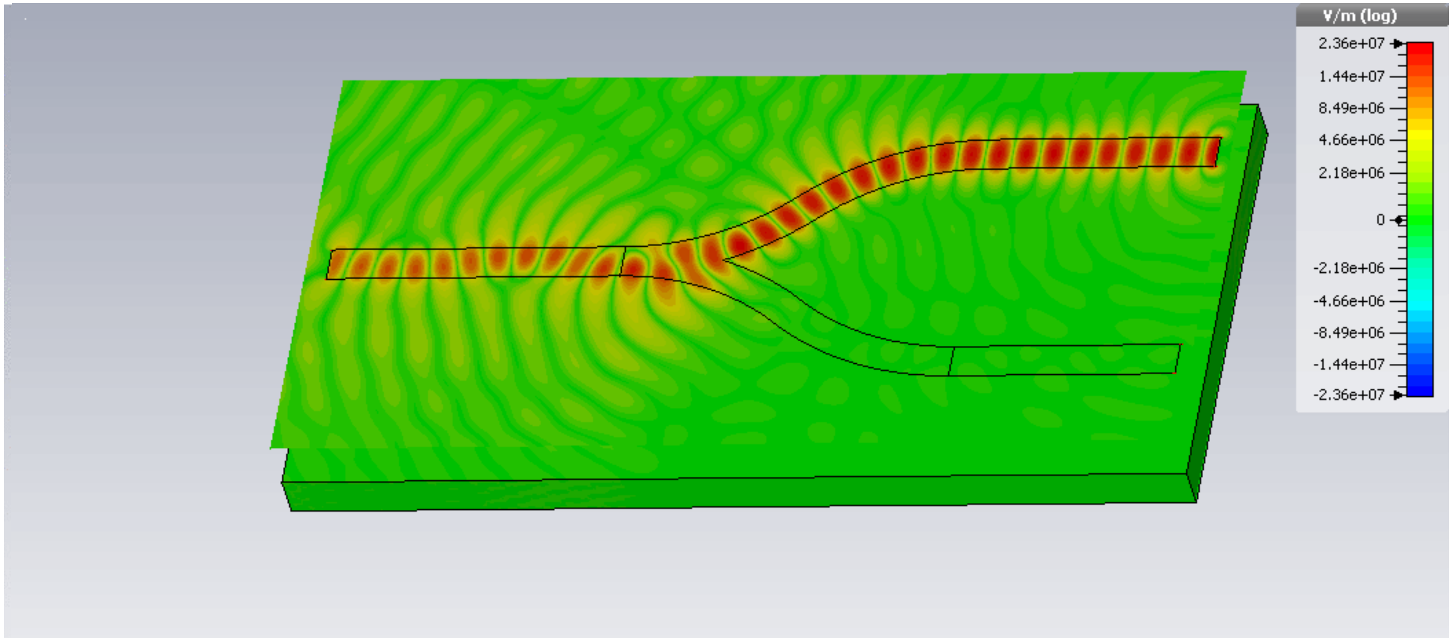


See also: M. Schröder et al., Europ. Opt. Soc. Rap. Public. 7, 12027 (2012)

Splitters and Combiners







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Saphir

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R. Bergmann
BIAS: Optical Metrology and Opto-electronic Systems
University of Bremen: Photonic Microsystems; Applied Optics

ITEM.IDS

A. Garcia-Ortiz
Institute for Electrodynamics and Microelectronics, Group of Integrated Digital Systems

Saphir: From ***S***i-Microelectronics to n***a***no-***ph***otonc ***I***nformation P***r***ocessing

J. Gutowski
Institute of Solid State Physics, Semiconductor Optics Group

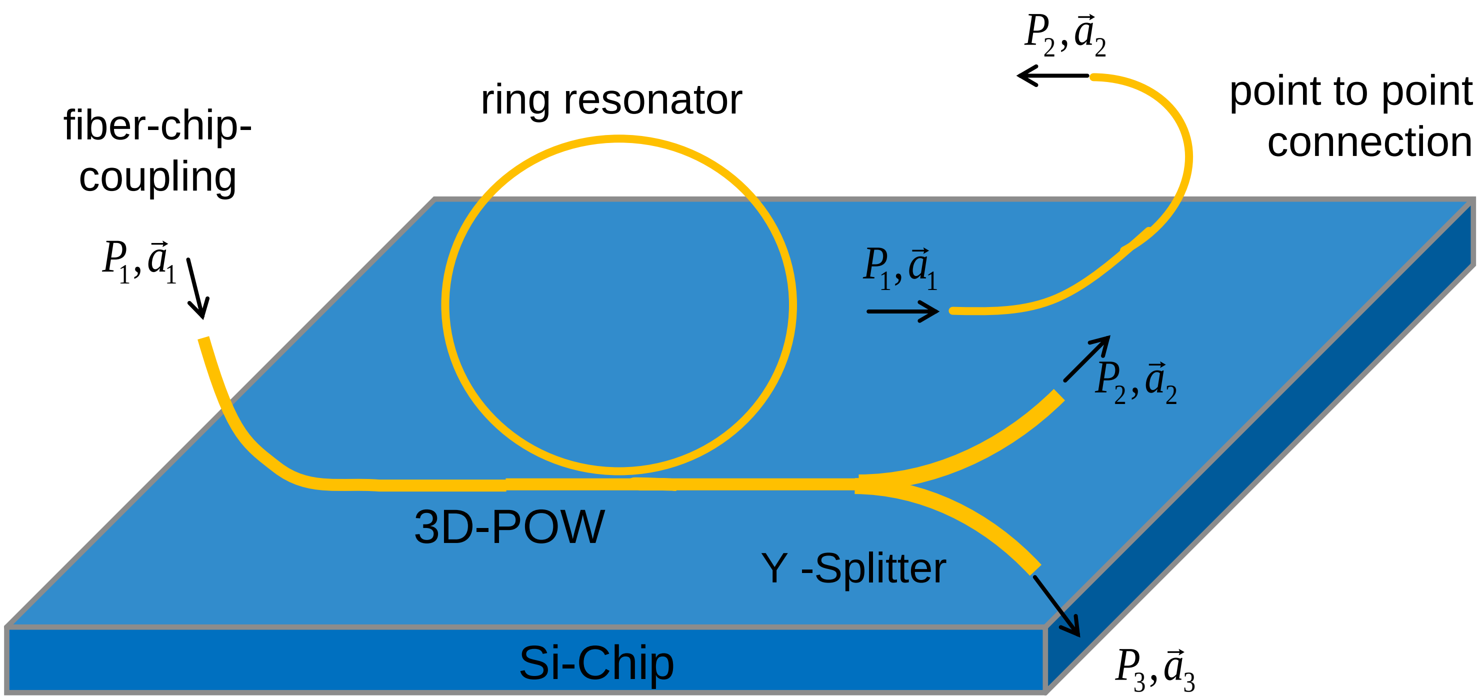
IMSAS

W. Lang
Institute for Microsensors, -Actuators and –Systems

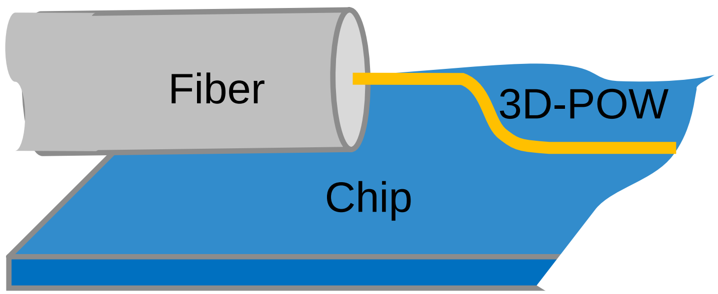
in cooperation with MCB (Microsystems Center Bremen)

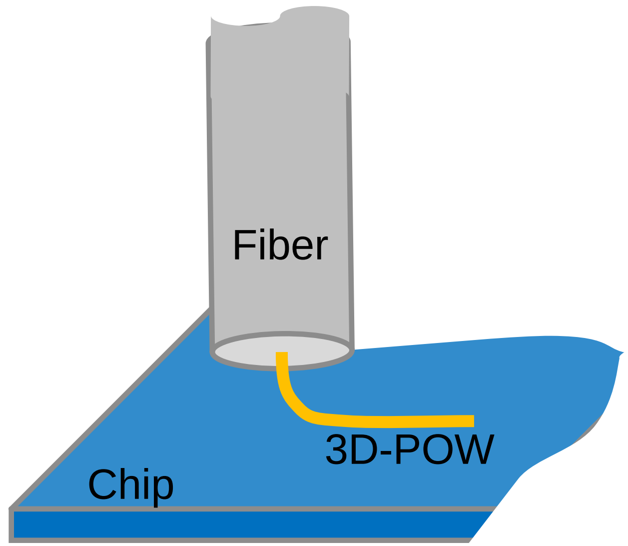
Goal: Setting up a 3D-POW Construction Kit

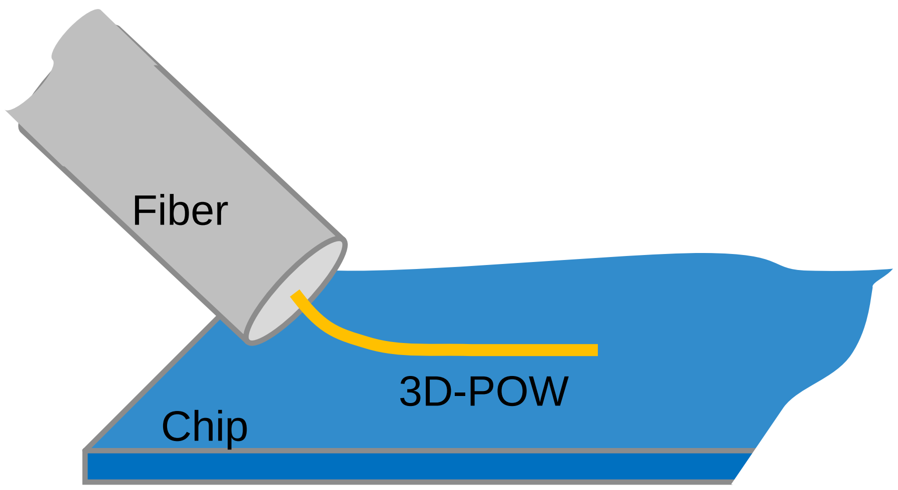
- Modular system by combining various 3D-POW building blocks
- Parameters: Positions, Vectors
- Following design principles such as Electronic Design Automation (EDA)



Setting up a 3D-POW-Fiber-Coupling



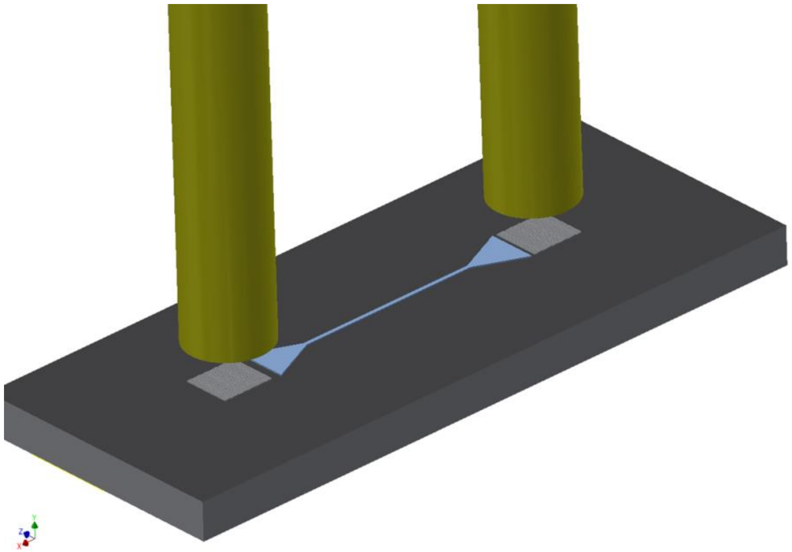


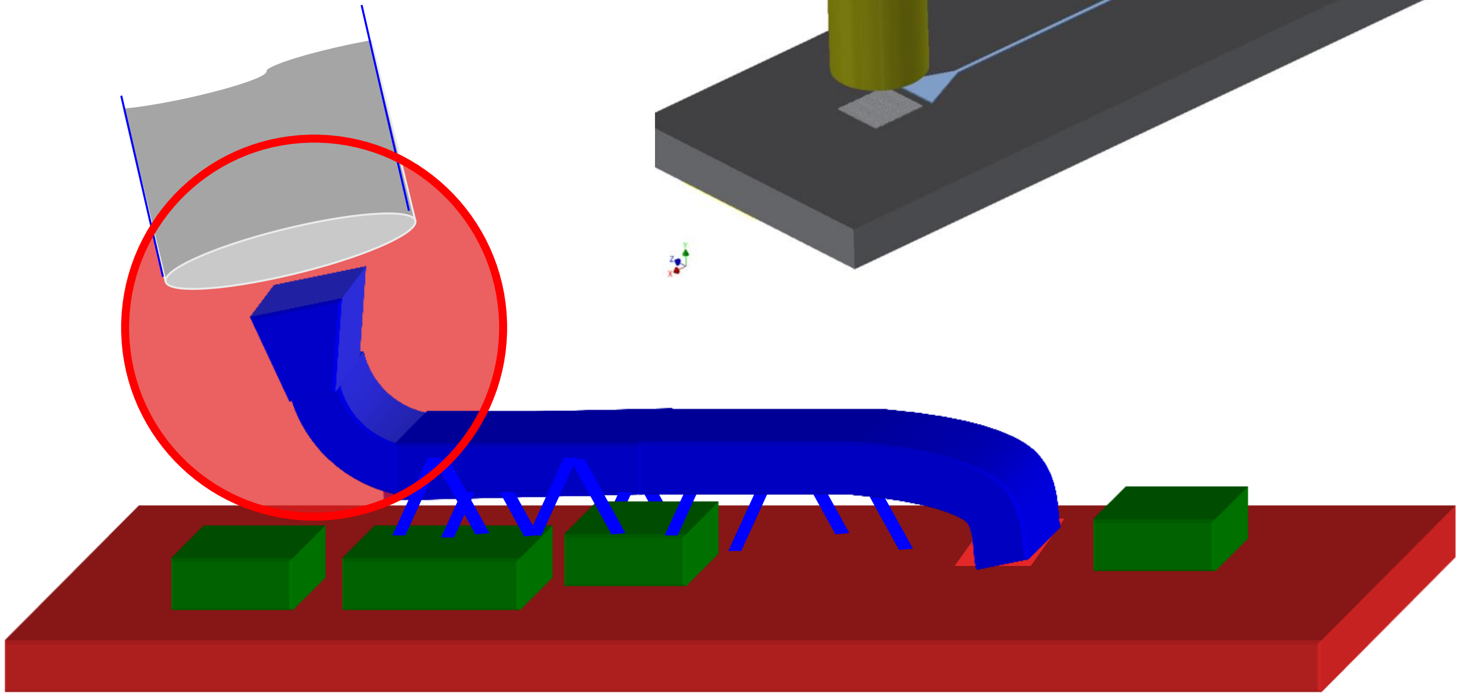


3D-Coupling of POWs

2,5 D design (conventional)

- coupling of fiber to waveguide using surface grating and taper

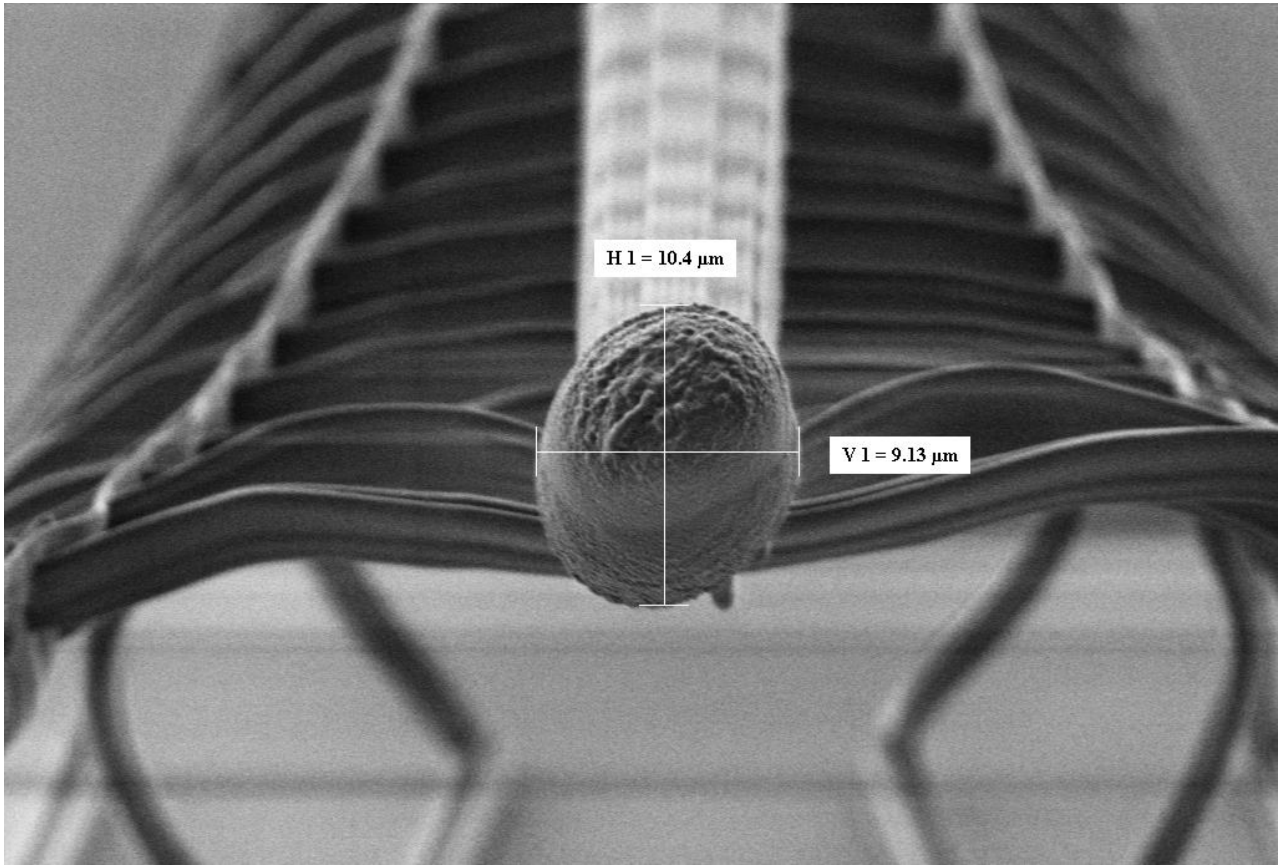




3D design

- Integration independent of technology platform
- Freedom of design via 3D

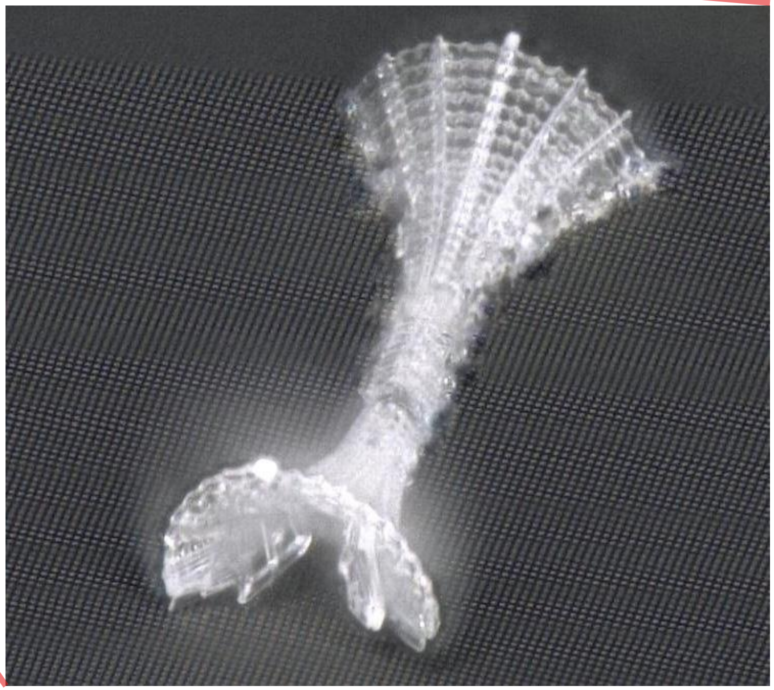
First 3D POWs: Optical interconnect



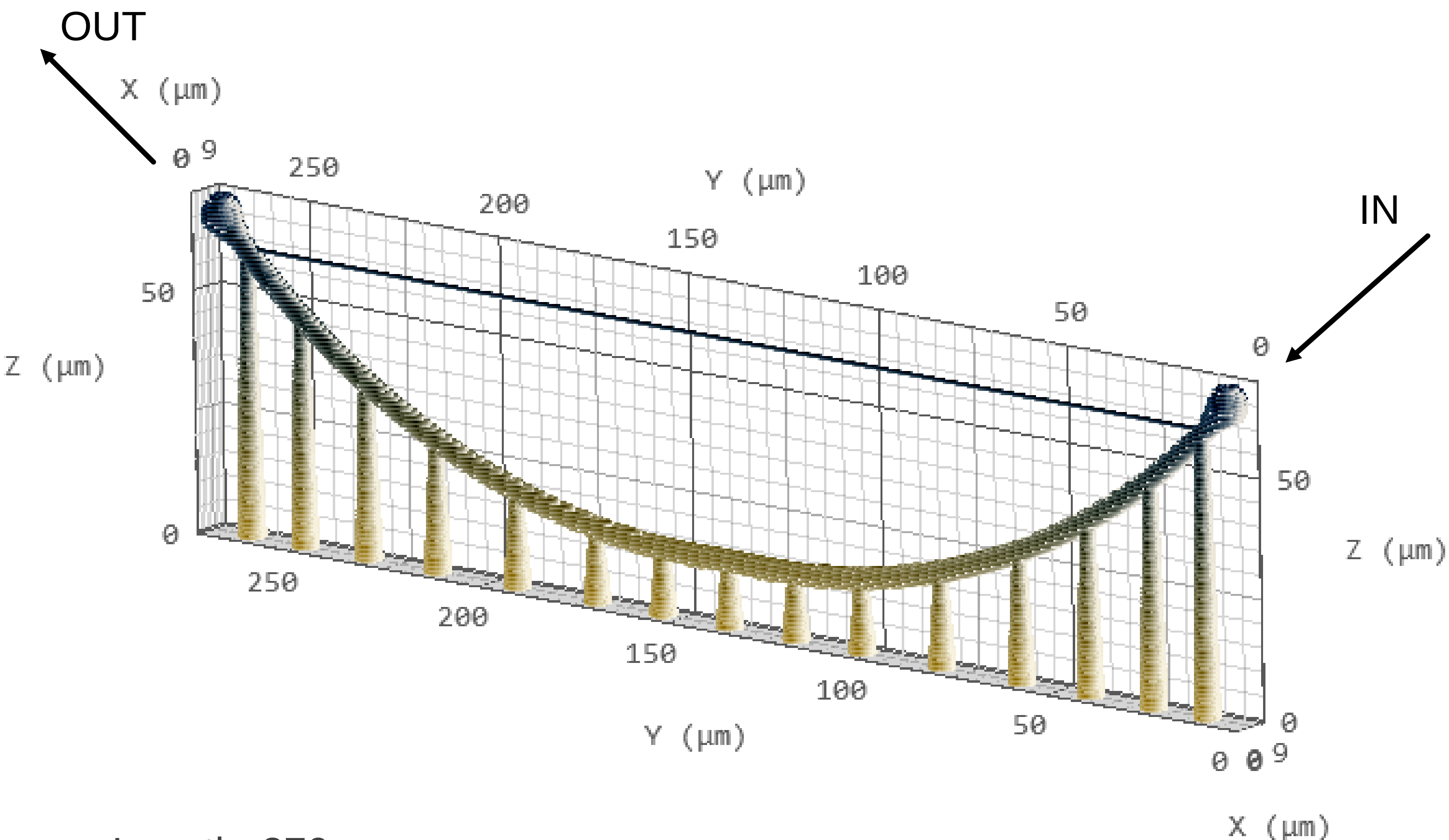
- Magnified view of the lens at the end of the waveguide
- Lens is designed to produce critical angle = 41° for waveguide with NA of 1.14

Integration of POW on a CCD-Chip

first experiment:
POW on pixel array

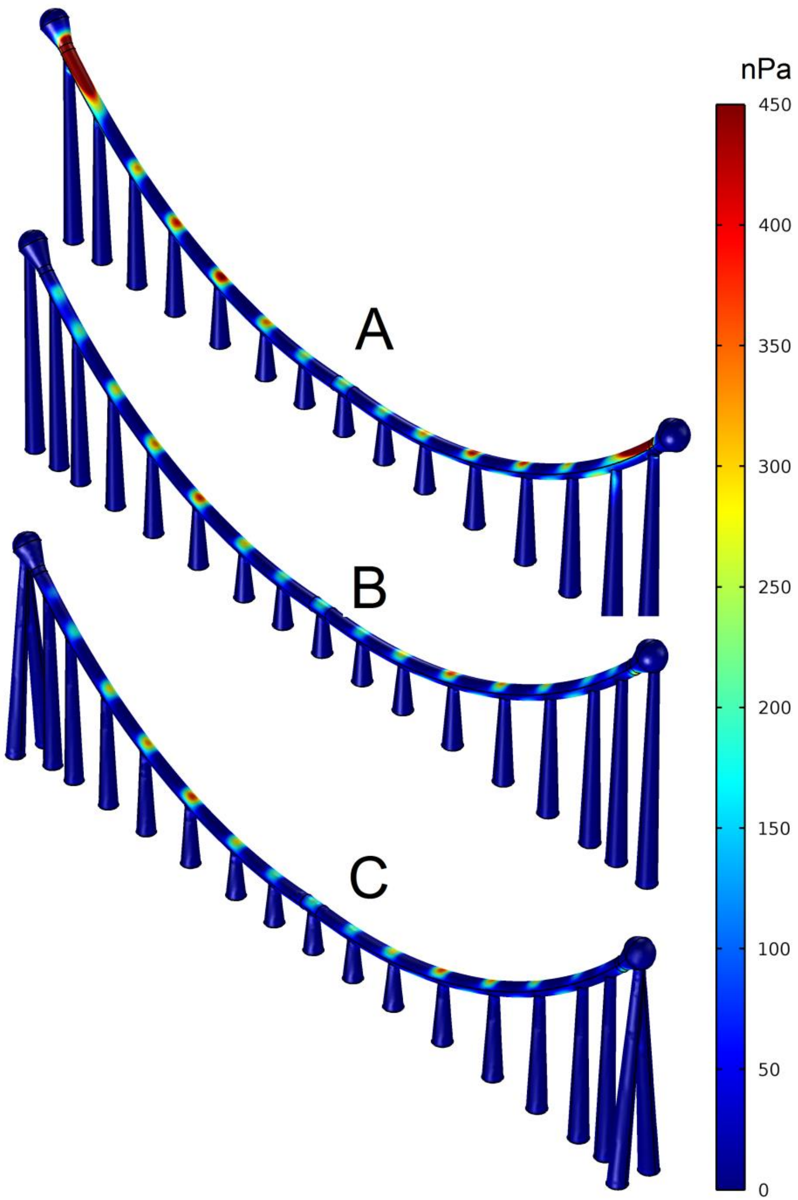


Design of ‚slim' 3D-POWs



Length: 270 µm
Core diameter: 6 µm

Stress Distribution in 3D-POWs

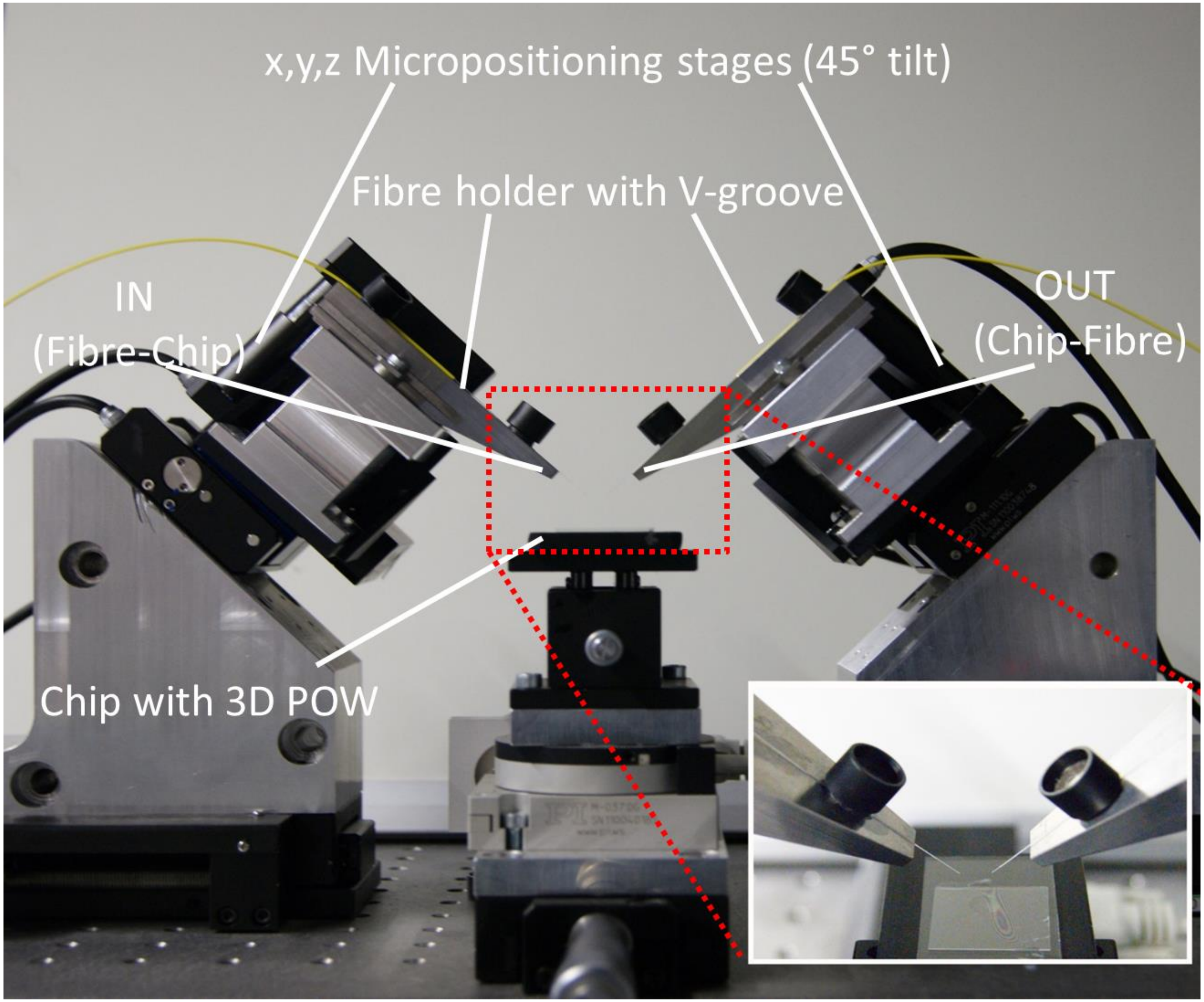


✗ 2000 nPa

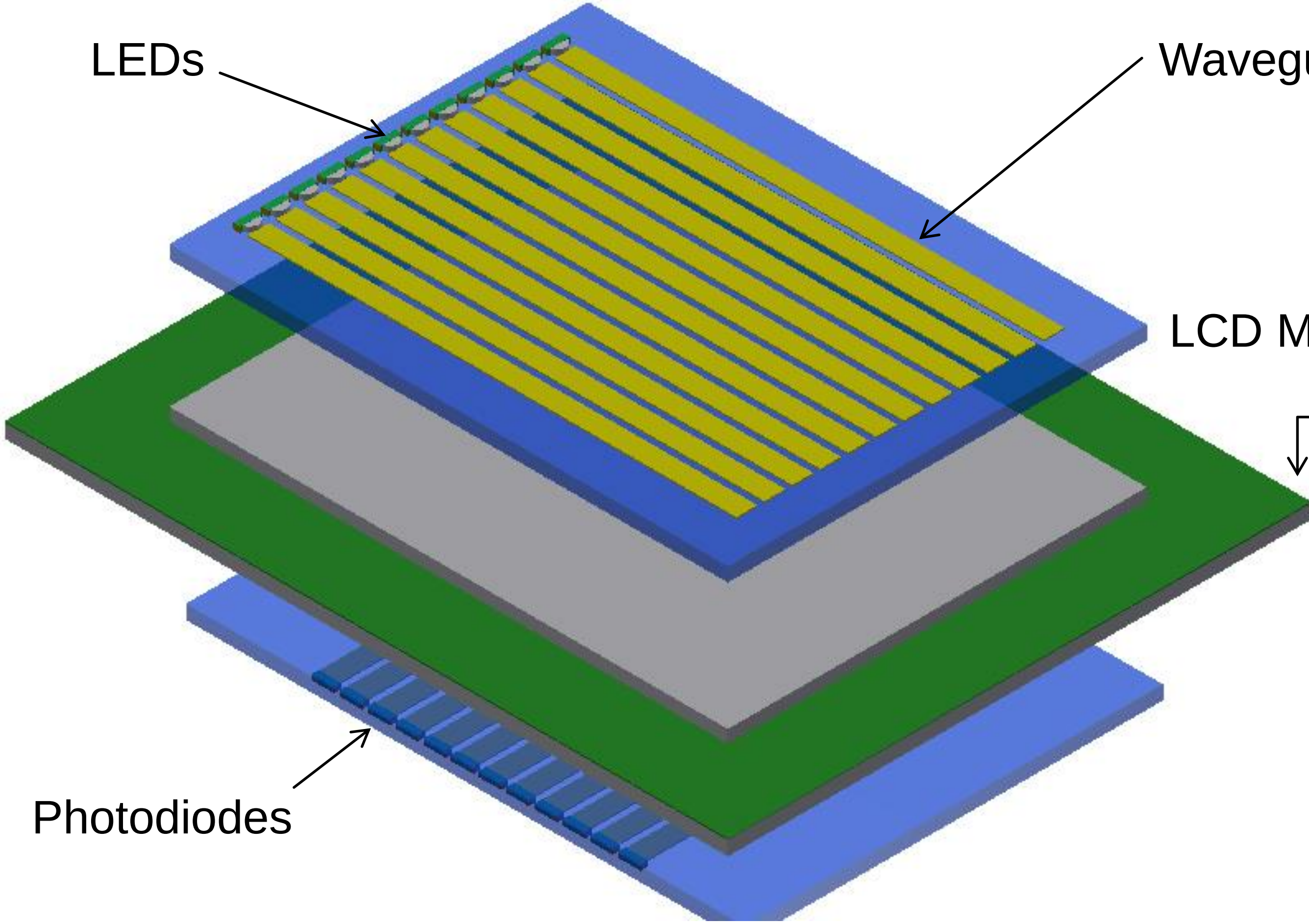
✓ 250 nPa

✓ 250 nPa

Modular Optical Nano Analyzer (MONA)



VMM – Demonstrator design



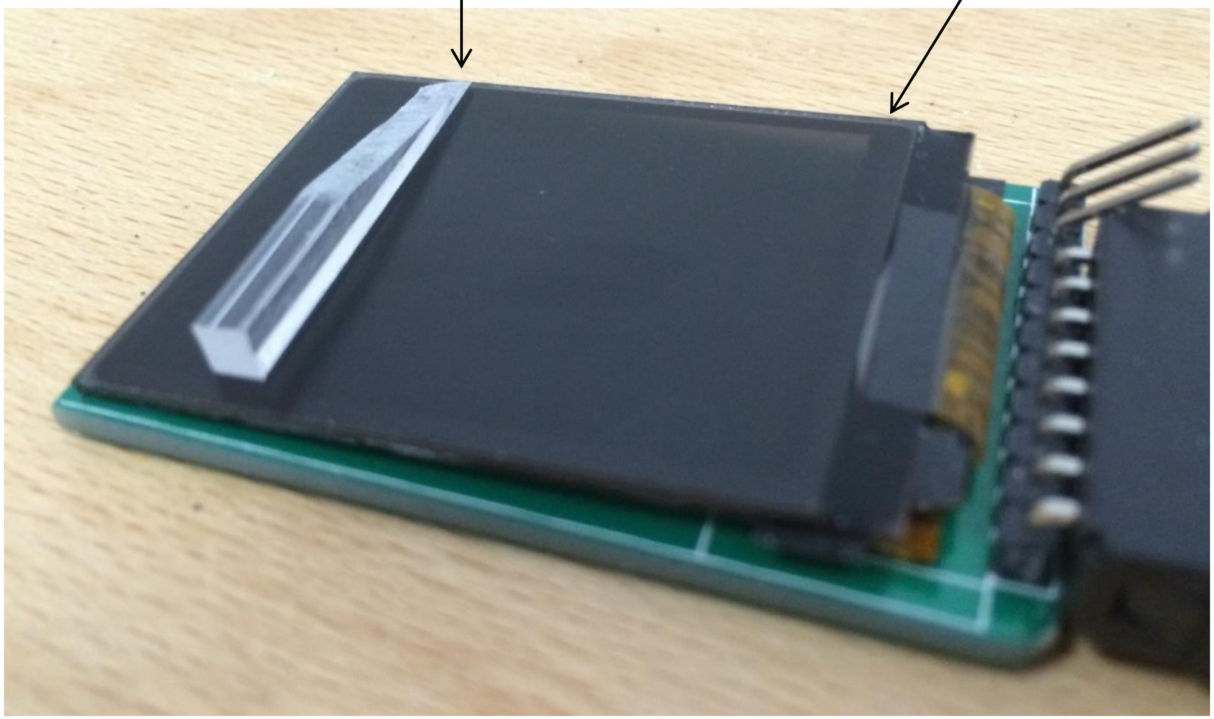
G. Dumstorff, W. Lang, IMSAS

1.5 x 2.5 cm^2
polarizers not shown

VMM – Demonstrator: Initial steps

Angled polycarbonate waveguide

Matrix display



V. V. Parsi Sreenivas et al., EOSAM 2014, Sept 2014, Berlin, to be published

Conclusions and Outlook

- Photonic 3D structures
  - Design and simulation of device performance
  - Fabrication and initial optical characterization
  - Direct integration onto electronics

- Further work
  - Further optical characterization and optimization
  - Demonstration of high fill factor using 3D design
  - Structures for coupling of fibers, diodes and dies
  - Setting up of optical tool kit
  - Demonstration of combined electronic / photonic devices

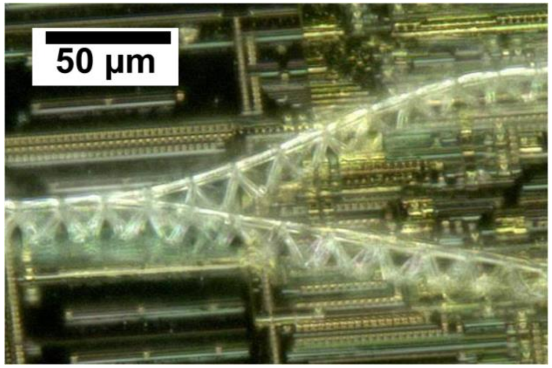
Thank You for Your Attention!

For further information see:

- M. Schröder, M. Bülters, C. von Kopylow, R. B. Bergmann
  J. Europ. Opt. Soc. Rap. Public. 7, 12027 (2012)
- V. V. Parsi Sreenivas, M. Bülters, R. B. Bergmann
  J. Europ. Opt. Soc. Rap. Public. 7, 12035 (2012)
- V. V. Parsi Sreenivas, M. Bülters, M. Schröder, R. B. Bergmann
  Proc. SPIE 9130, Micro-Optics 2014, 91300M (May 2, 2014)
- V. V. Parsi Sreenivas, M. Bülters, K. Morosov, R. B. Bergmann
  Proc. 4th Internat. Conf. on Nanomanufacturing (nanoMan2014) Bremen, 8 – 10 July, 2014

- European Optical Society Annual Meeting (EOSAM) 2014
  www.myeos.org/events/eosam2014

Berlin (Adlershof), 15.-18. 9. 2014 Si-Photonics (TOM2)



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