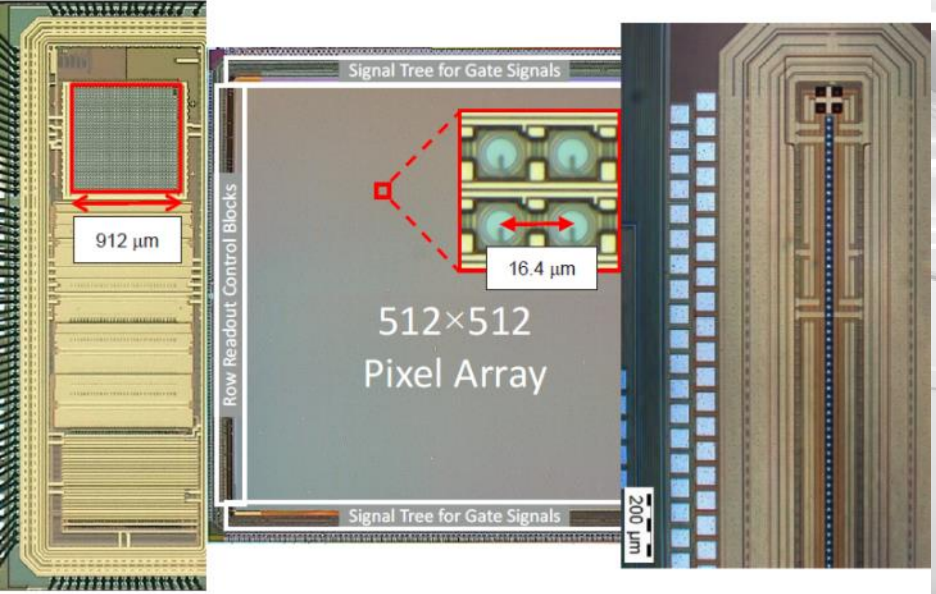
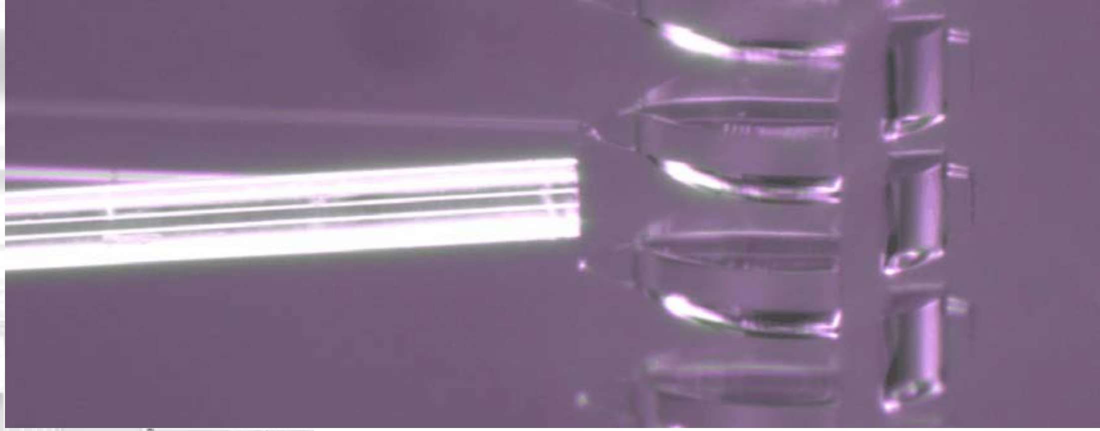


Fig. 1. Micrographs of Piccolo, a 32 × 32 SPAD array with photosensitive area on the top section, highlighted in red (left) [41,42] – see also Fig. 8 (center); SwissSPAD2 512 × 512, a gated SPAD imager with 4 pixels shown in the inset (center, featuring round SPAD active areas in this case) [45]; Detail of LinoSPAD2, a 512 × 1 linear SPAD array with top alignment cross integrated in the metal stack (right).

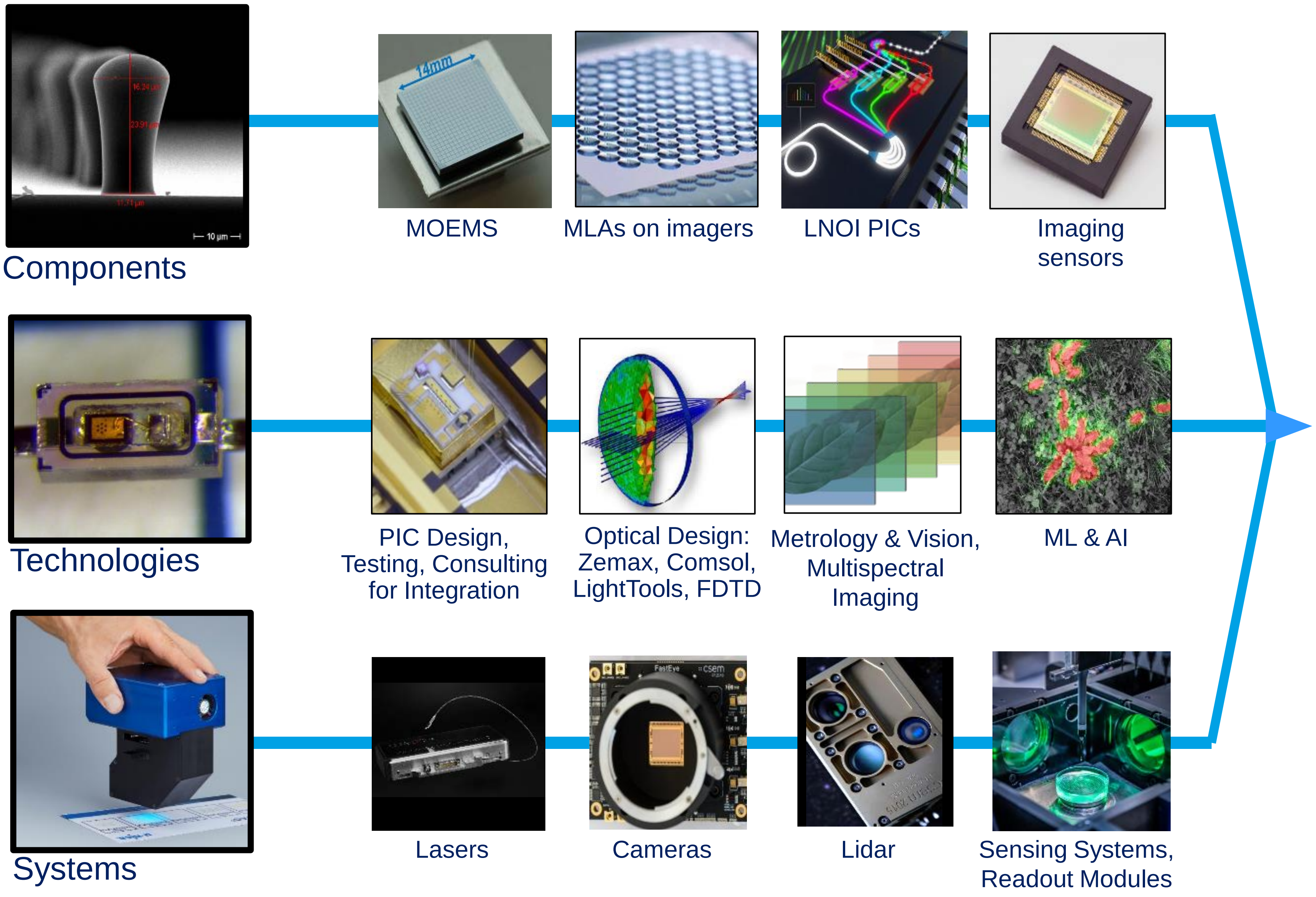


Guillaume Basset
Focus Area Manager Photonics
Group Leader Micro Nano Optics

SwissPhotonics Workshop
March 21st 2024

PHOTONICS INTEGRATION AT CSEM

PHOTONICS AT CSEM



Many industrial partners & EU/global Partnerships:

phabulous

MedPhab
Photonic Medical Devices

PhotonHub Europe

OPTICA

EPIC
European Photonics Industry Consortium

PHOTONICS21
PHOTONICS PUBLIC PRIVATE PARTNERSHIP

2 INTEGRATION HIGHLIGHTS

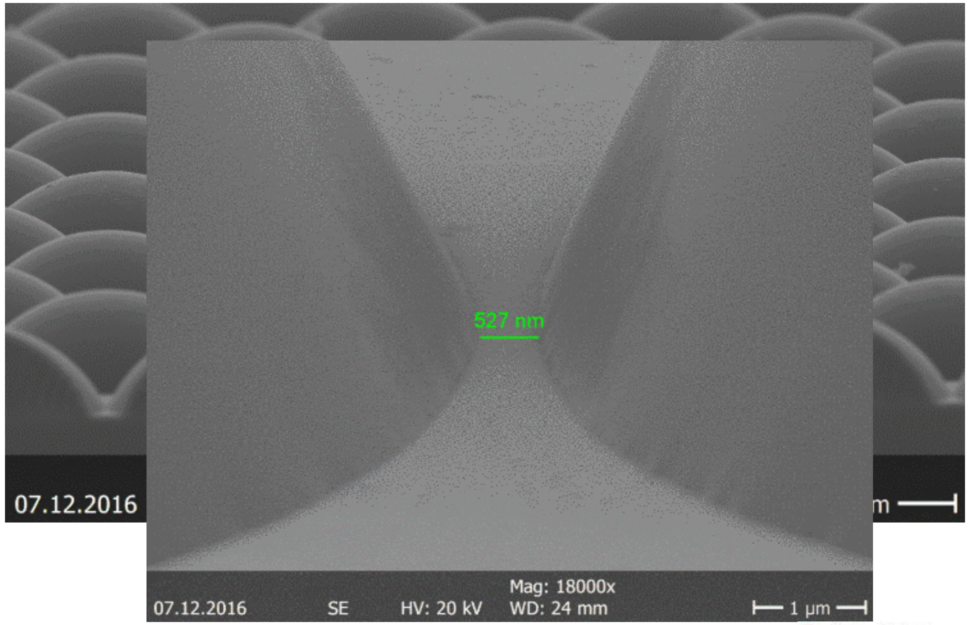
1. MICRO-OPTICS INTEGRATION ON-CHIPS: MICROLENS ARRAYS (MLA)

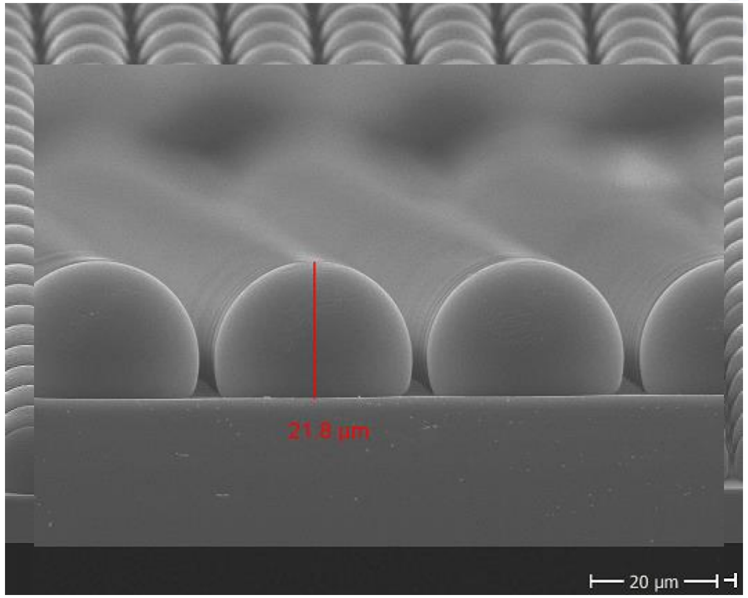
2. MICRO-OPTICS INTEGRATION ON-CHIPS: PHOTONICS INTEGRATED CIRCUITS

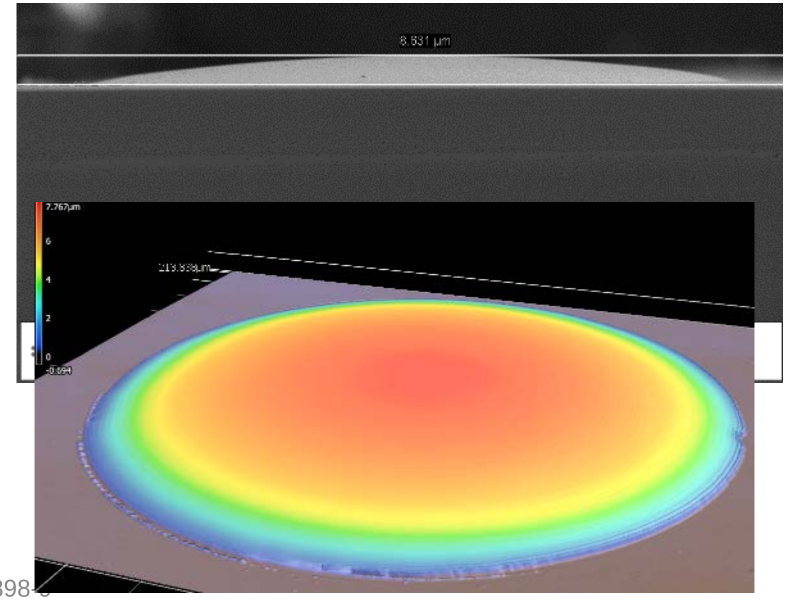
FABRICATING ADVANCED MICROLENS ARRAYS

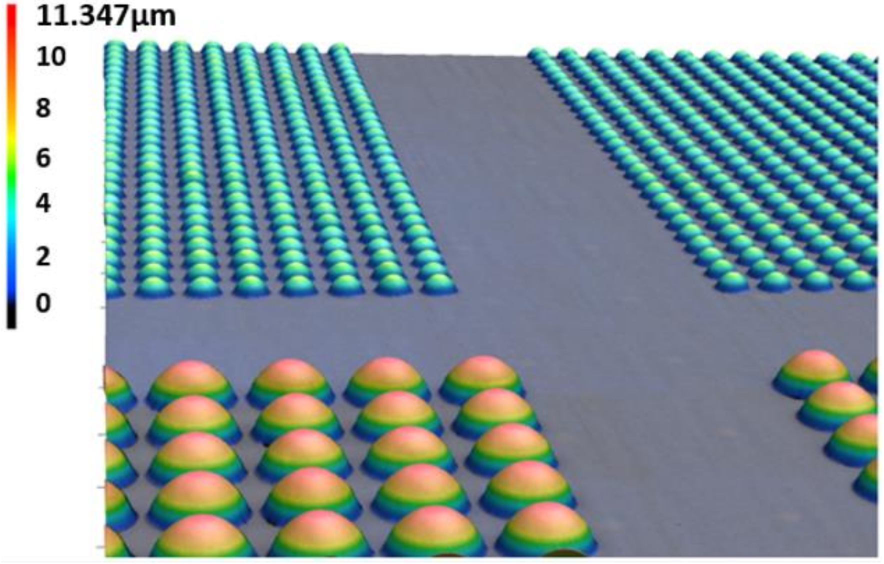
Microlenses from 2 microns to 2 mm
- ✓ Nearly gapless MLA
- ✓ High aspect ratio MLA
- ✓ Ultra flat MLA
- ✓ Multi height/Sag MLA

If not good enough, we make the micro-optics freeform



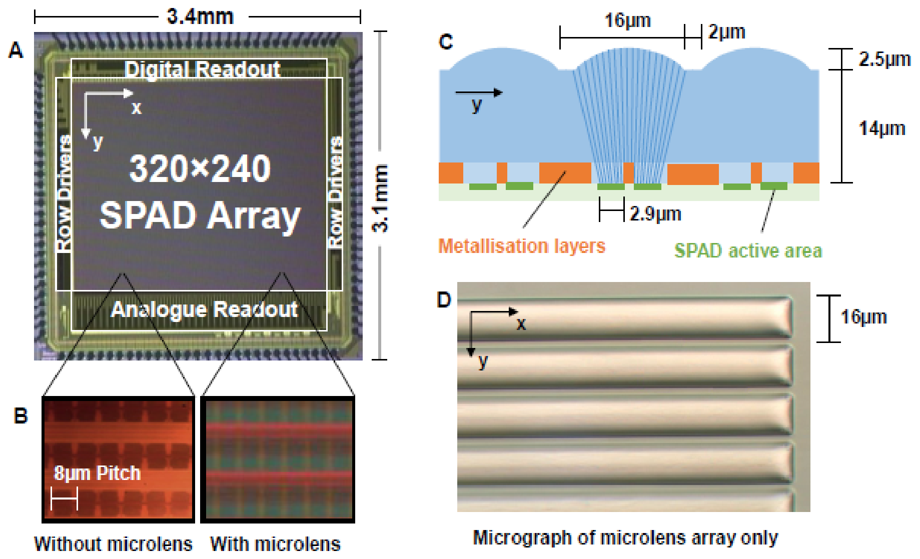




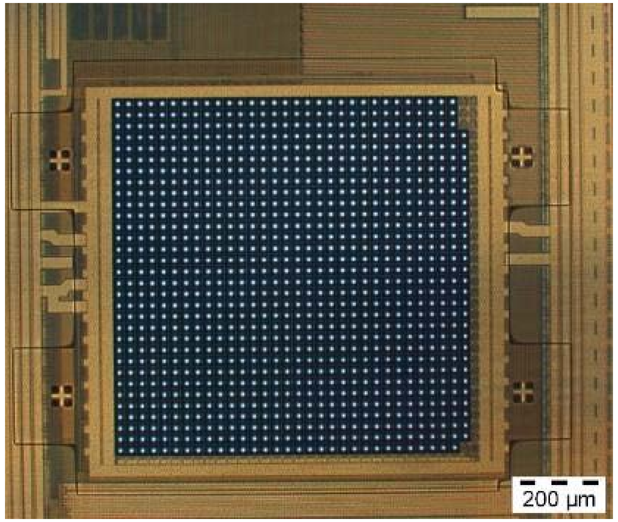


csem

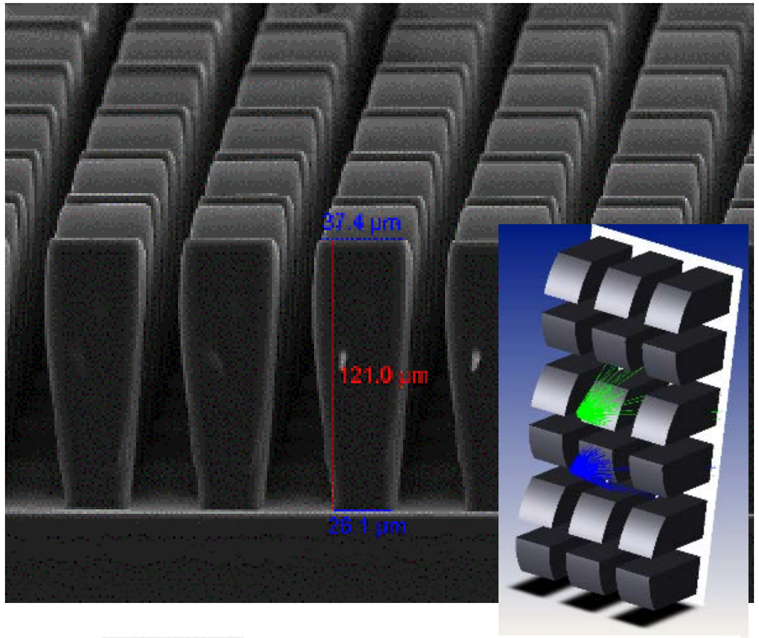
MICRO-OPTICS INTEGRATED ON IMAGERS

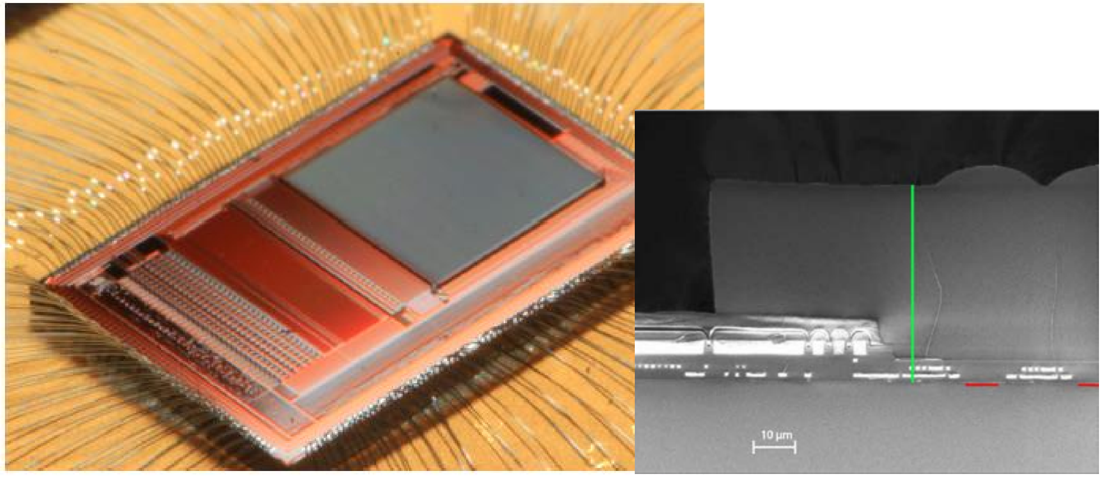


I. Gyongy et al., Optics Express, **26**, 2280-2291 (2018)

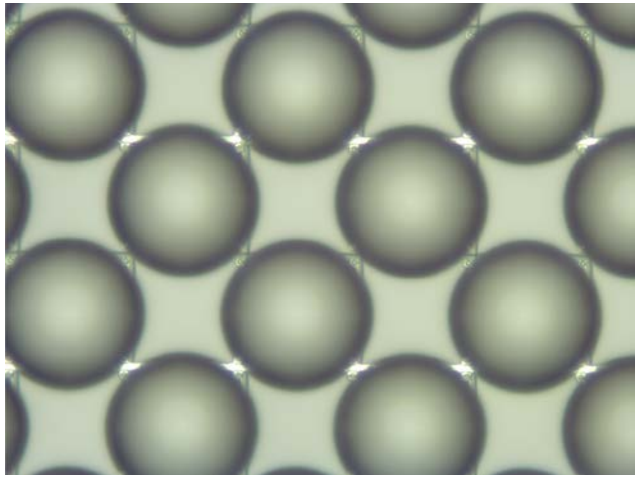


I. M. Antolovic et al., Quantum Sensing and Nano Electronics and Photonics XVI, **10926**, 359–365 (2019)

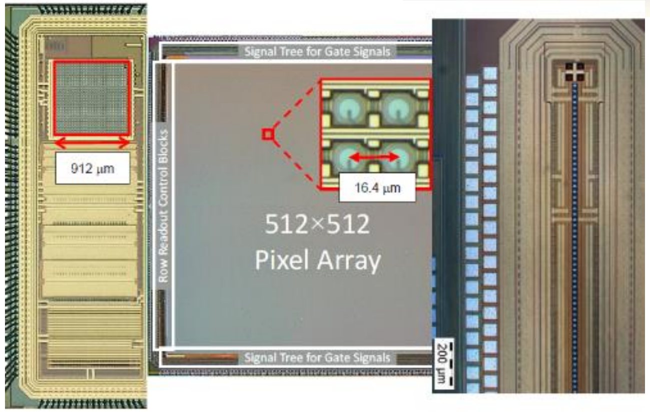




J. Mata Pavia et al., Opt. Express **22**, 4202-4213 (2014)



C. Trippl et al., Nucl. Instrum. Methods Phys. Res., A **1040**, 167216, (2022)



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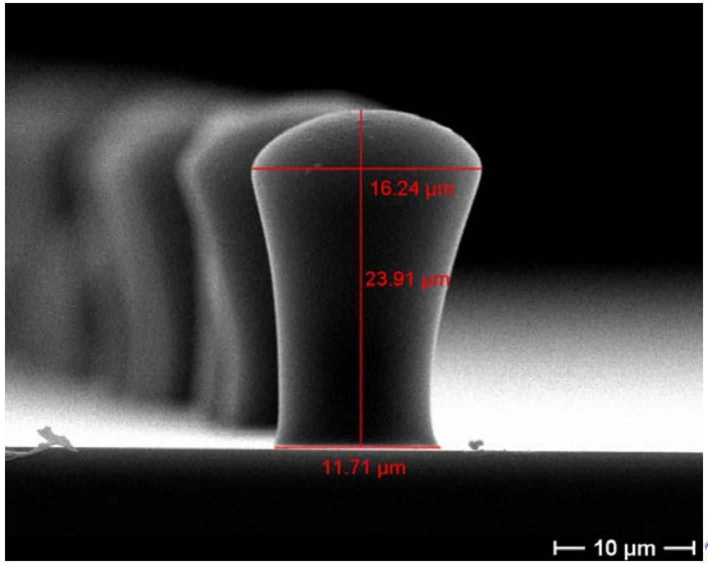
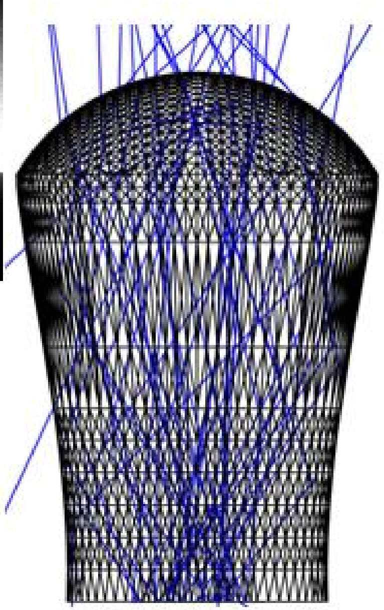
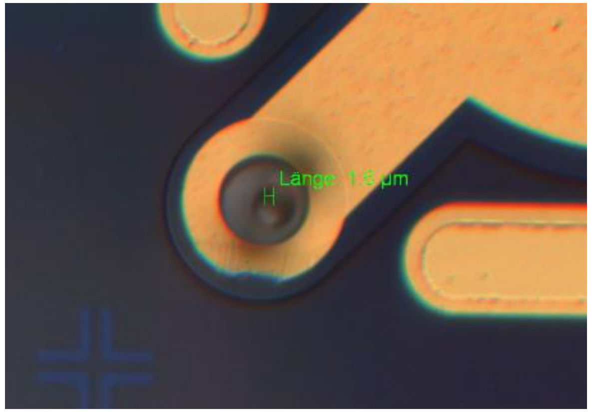
C. Bruschini et al., Optics Express, **31** (13), 21935-21953 (2023)

MICRO-OPTICS INTEGRATED ON LIGHT EMITTERS

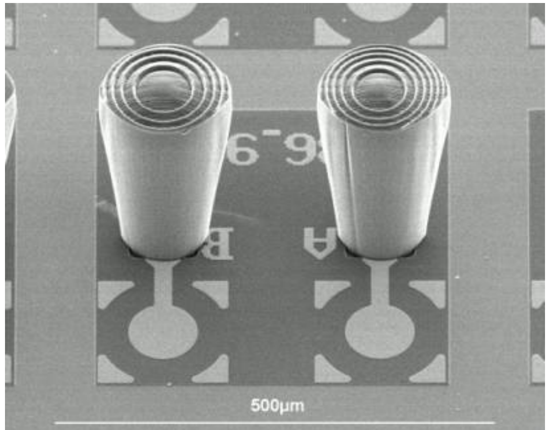
Micro-LEDs beam-shaping

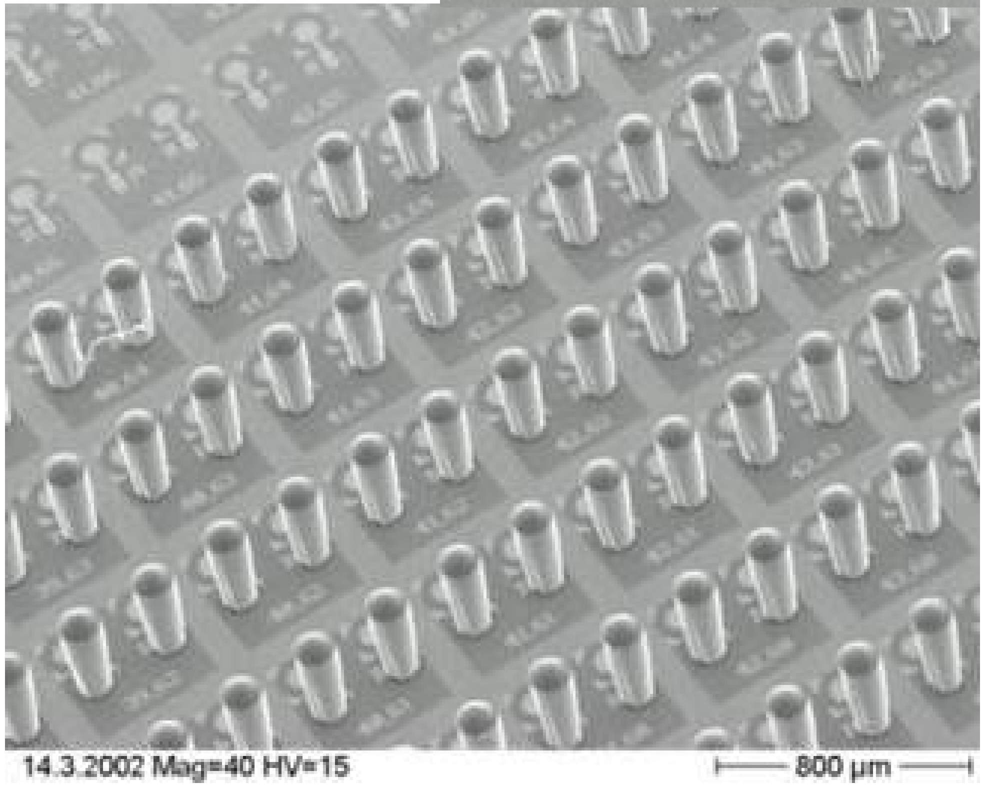






VECSEL beam-shaping





2 INTEGRATION HIGHLIGHTS

1. MICRO-OPTICS INTEGRATION ON-CHIPS: MICROLENS ARRAYS (MLA)

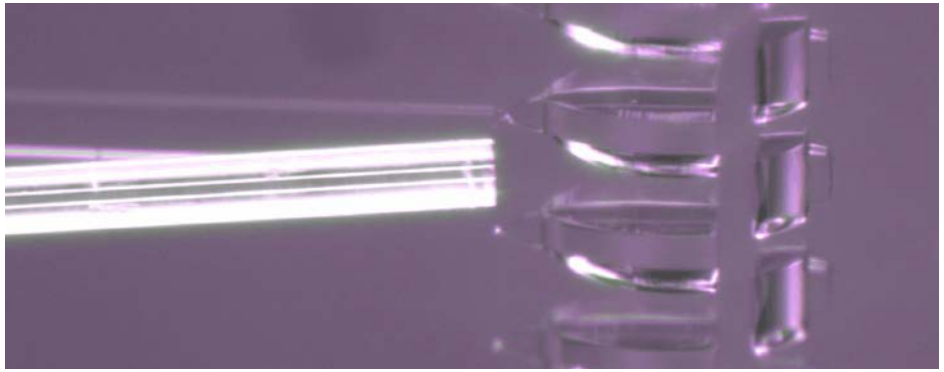
2. MICRO-OPTICS INTEGRATION ON PHOTONICS INTEGRATED CIRCUITS

FIBER ARRAY HOLDER FOR PASSIVE ALIGNMENT MICRO-OPTICAL INTERCONNECT

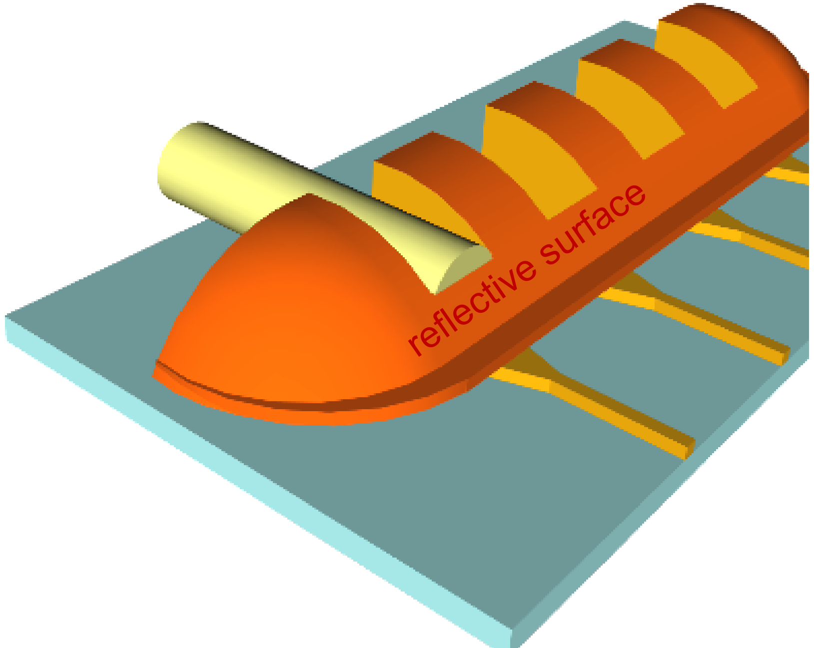
Wafer-scale micro-imprinted micro-structures for fiber passive alignment walls/funnels and beam redirecting

- Passive fiber array coupling using integrated self-alignment structures
- Ultra-smooth reflecting surfaces using total internal reflection (TIR) and based on a photoresist reflow process
- Operational for visible and all standard telecommunication optical fibers (SM and MM, 850-1650nm)
- Redirection angle adjustable:
  $\alpha = 70 – 110$ degree

Plug & Play passive fiber assembly using the wafers-scale-alignment structures

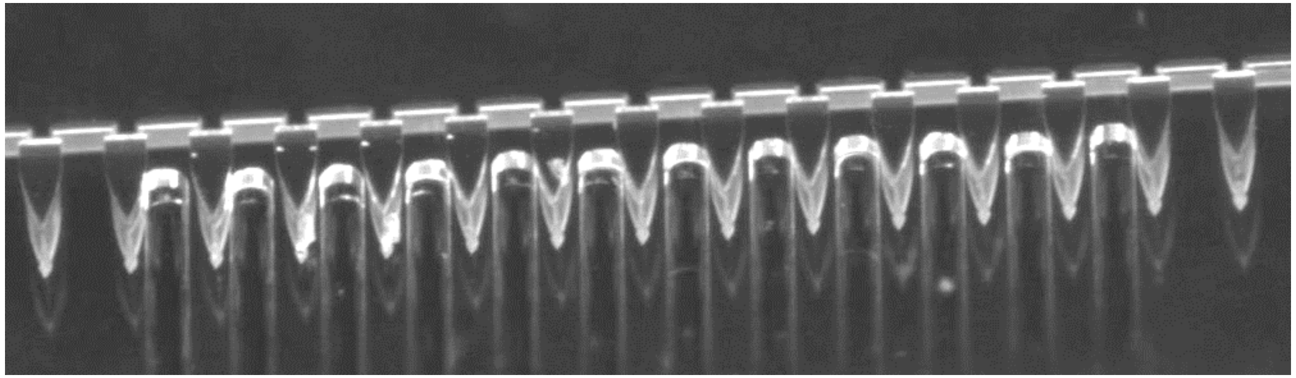


For single fiber, multi-fiber, fiber ribbons

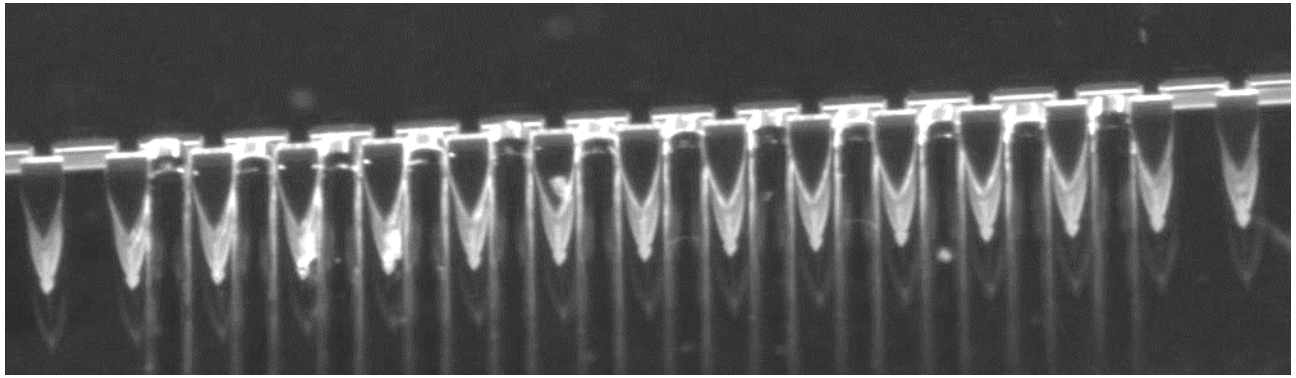


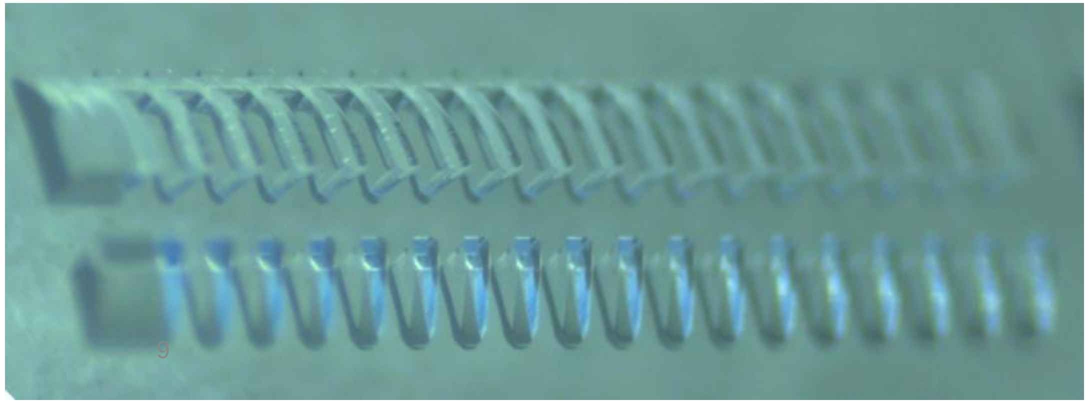
PLUG AND PLAY FIBER ASSEMBLING

Partly inserted fiber array

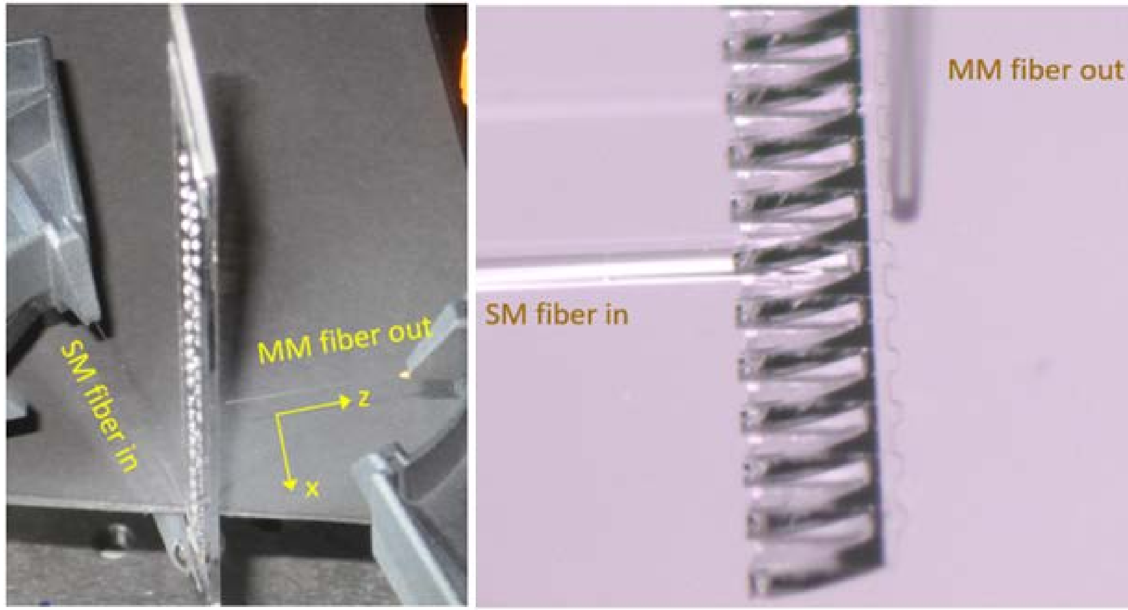


12er fiber ribbon fully inserted against the reflecting element

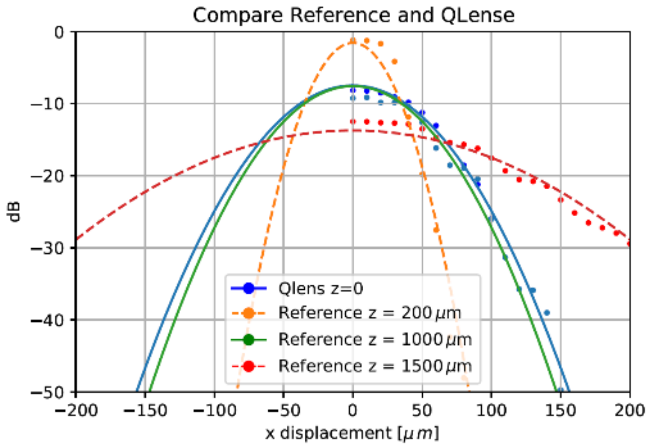




Test on glass wafer: measurements with input and output fibers (SM or MM) on adjustable micro stages



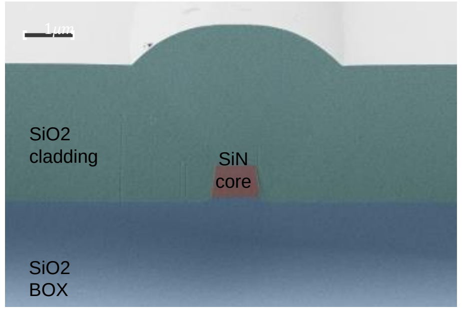
Different functions are possible: funnels, stress releases, waveguide protection / extra cladding…

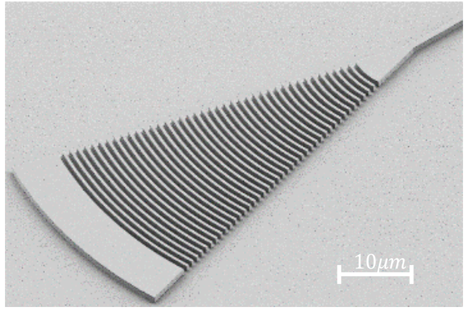


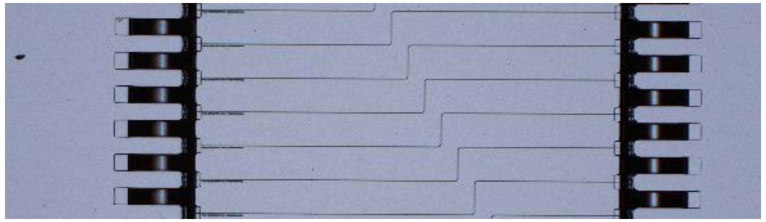
Fiber-to-fiber transmission losses measured at 0.35dB

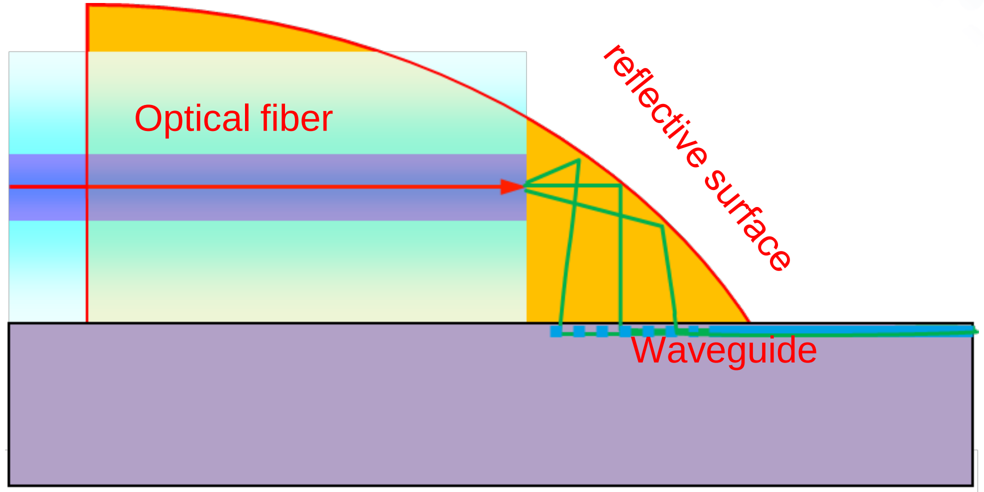
MEASURED EFFICIENCY OF THE INTERCONNECTS

Test on Si substrates with SiN waveguide with non-optimized grating couplers









Fiber-to-PIC-to-fiber measured transmission:

- 8-10 dB for the optical coupling from the SMF-28 into the input grating
- 3-5 dB per coupling into the MM G50 fibers

Intrinsic fiber-to-fiber transmission losses measured at 0.35dB
Beam quality and deflection angle as expected
Low-efficiency grating couplers to be replaced

OUTLOOK AND APPLICATIONS

Wafer-scale fiber alignment structure for fully passive PIC packaging are intrinsically very efficient.

Demonstration with (inefficient) grating couplers and SiN waveguide.

Packaging of electro optical devices
Self aligned fiber to device (VCSEL, photodiodes arrays)

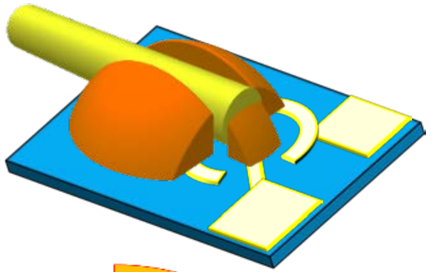
Interconnect to photonic integrated circuits
Self aligned fiber to chip (PIC's)

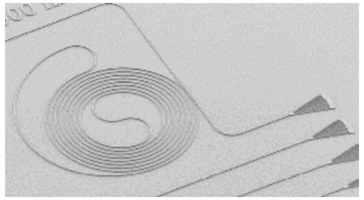
Angled fiber to fiber interconnect
Backplane connector with enlarged alignment tolerances

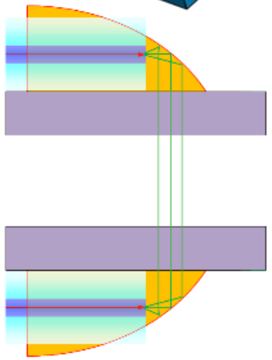
Chiplet to chiplet interconnect in a single package

Enhance the data transmission with an easy packaging

Chip to chip interconnect
Compact on board solution







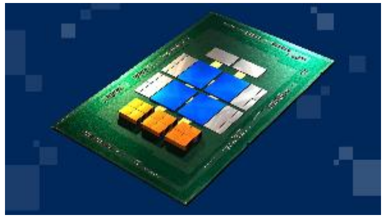


Image from Intel

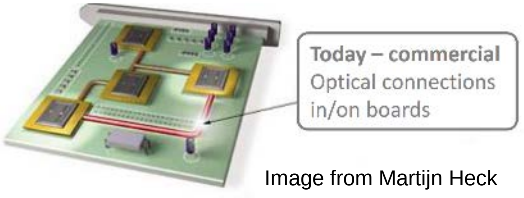


Image from Martijn Heck

Coming in 2024: Wafer-scale micro-optics for passive assembly with (efficient) edge couplers

SUMMARY

- Broad set of photonic expertise, technologies & their integration
- From components to systems
- Design, prototype up to small production
- Key and unique platforms:
  - MPWs for LNOI
  - MLAs on imagers and emitters
  - Fs-laser
  - Edge & AI imagers

Even highly advanced cameras will be boosted with integrated micro-optics

Innosuisse

Enjoy the SwissPhotonics Workshop !

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