Evgenii Glushkov, Roger Krähenbühl, Mohamed Asbahi, Ton Offermans, Guillaume Basset

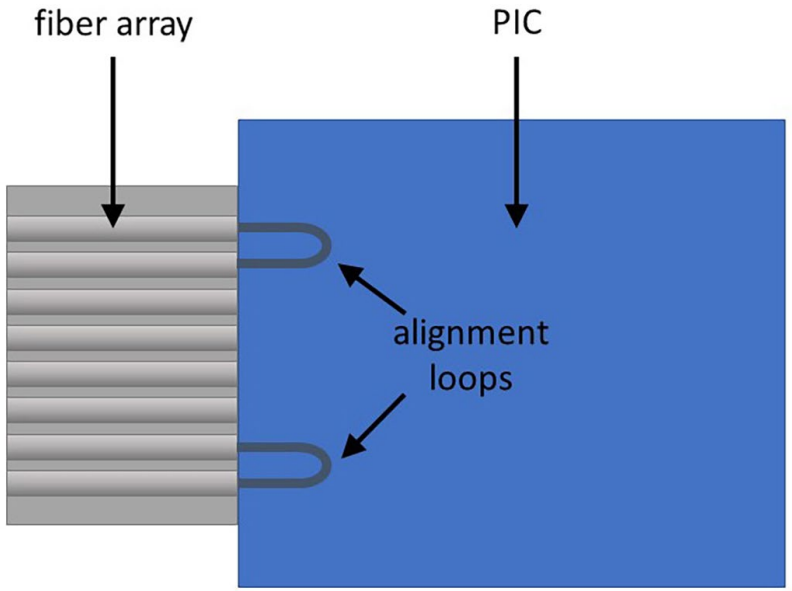
08.05.2025

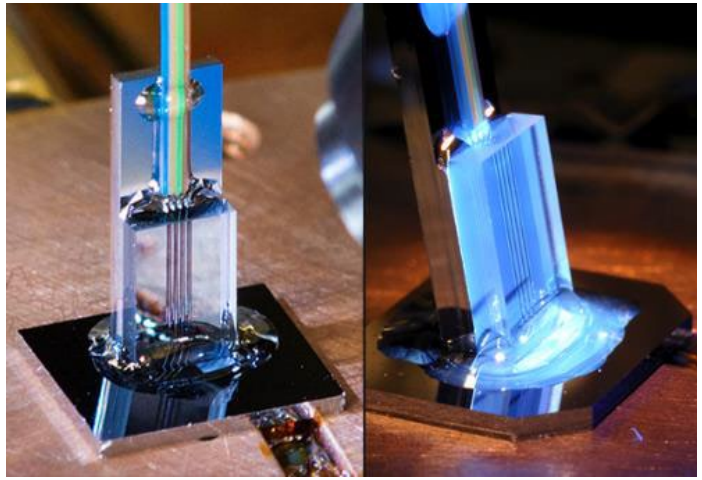
NEW CAPABILITIES FOR THE COST-EFFECTIVE FABRICATION OF FIBER-TO-PIC INTERCONNECTS

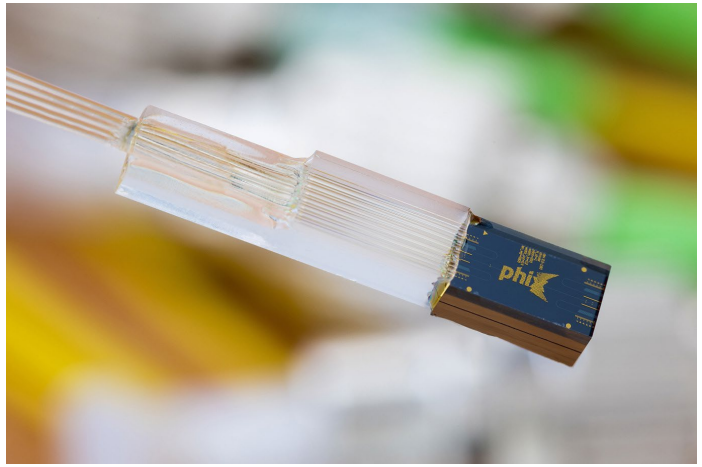
PICs = HIGH PACKAGING COSTS

PIC packaging remains one the most challenging and costly steps in the optoelectronic system industry, especially for multiple channels.

Current method of active alignment to couple light between the optical PICs and optical fibers largely contributes to that.







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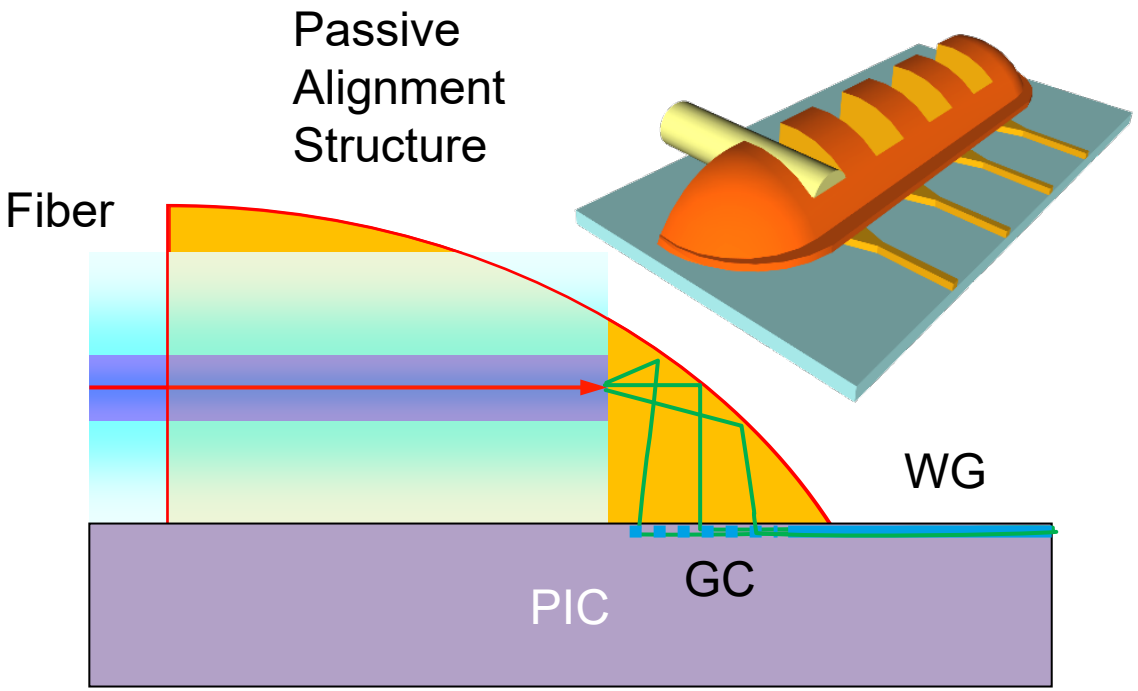
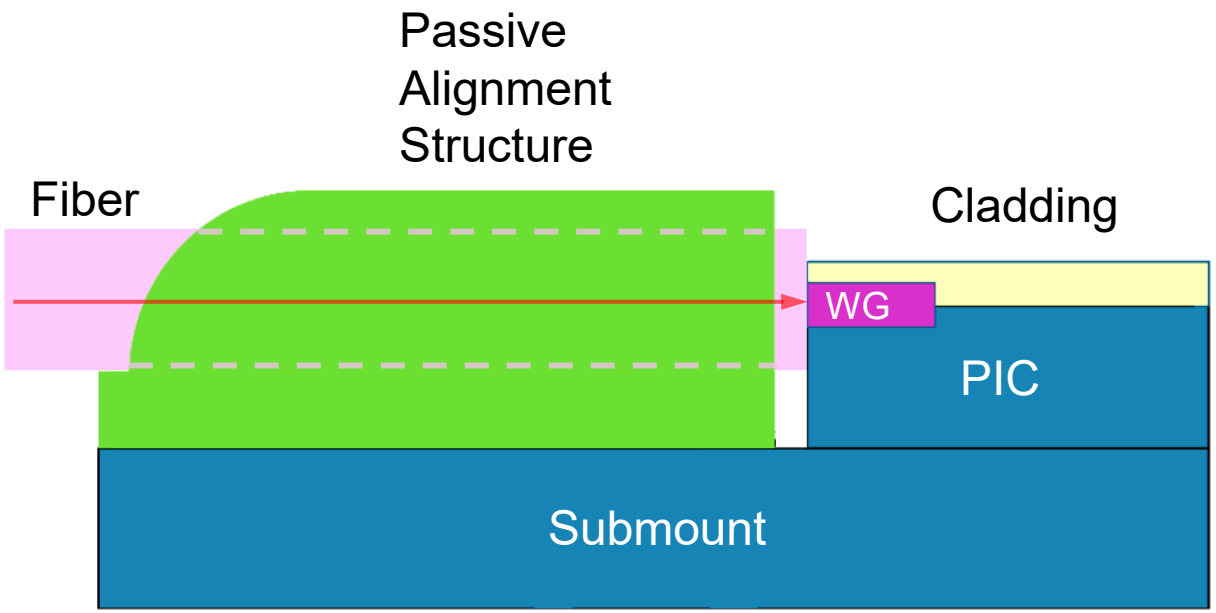
SOLUTION: PASSIVE ALIGNMENT STRUCTURES

For grating couplers



For edge couplers



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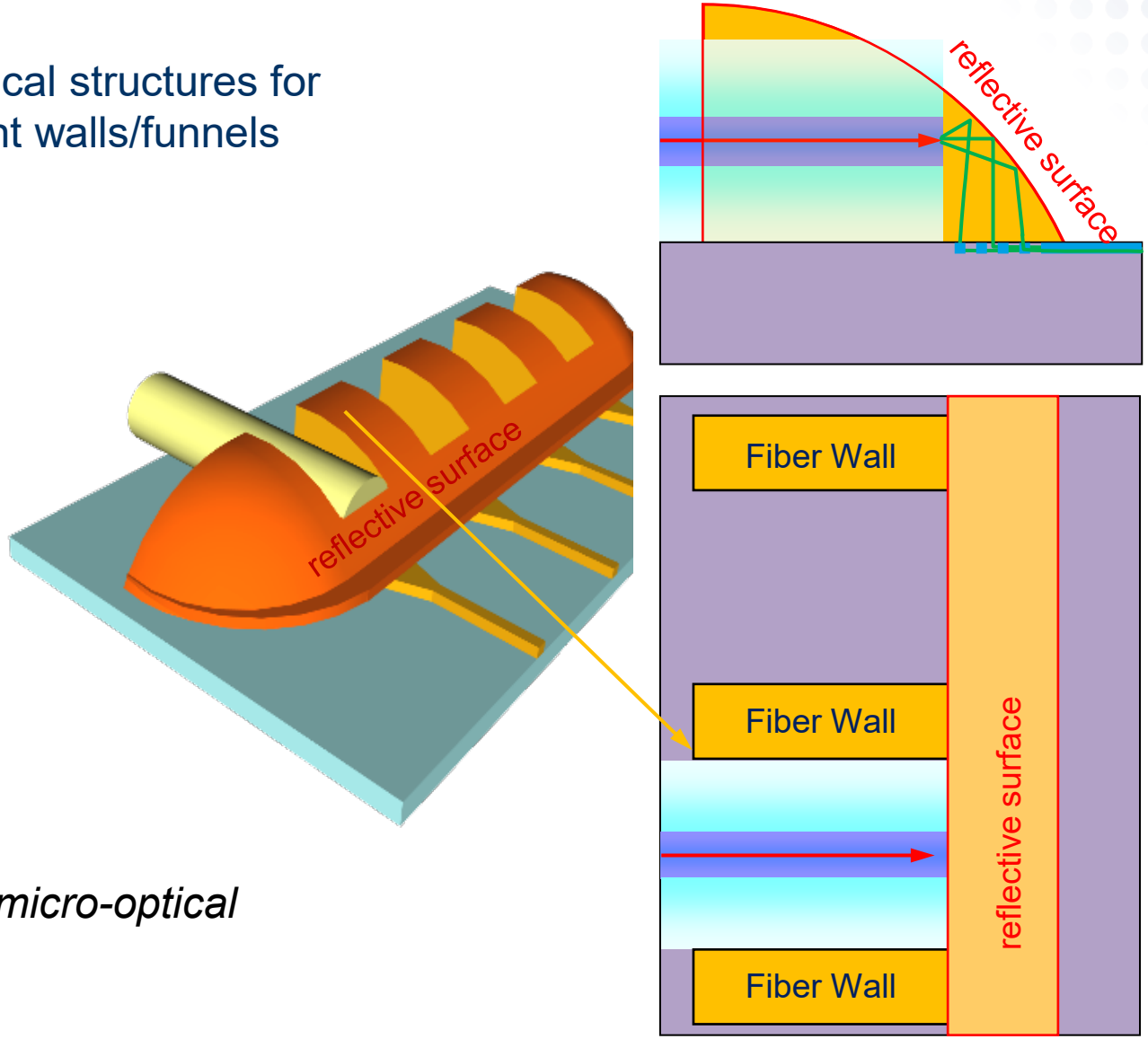
MICRO-OPTICAL INTERCONNECT FOR GCs

Wafer-scale micro-imprinted optical & mechanical structures for beam refocusing/redirecting and fiber alignment walls/funnels

- Ultra-smooth reflecting surfaces using total internal reflection (TIR) and based on a photoresist reflow process
- Passive fiber array coupling using integrated self-alignment structures
- Operational for all standard telecommunication optical fibers (SM and MM)



R. Krähenbühl, et al., "Wafer-scale in-plane micro-optical interconnects for fiber arrays" (2022)

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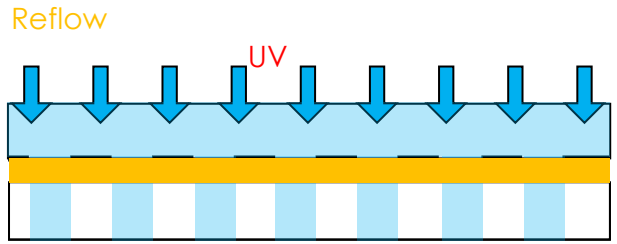
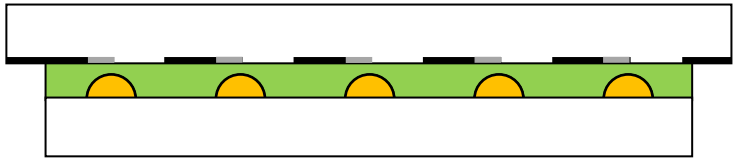
FABRICATION PROCESS

Wafer scale photoresist reflow and UV-replication process for high throughput and smooth surfaces

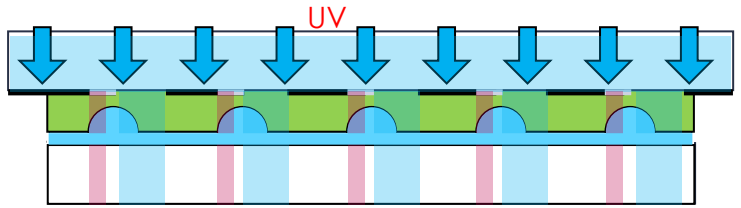
- Master origination: wafer-scale reflow



- Mould/stamp tool realization on structured photomask



- On the active wafer, a single process step !
  UV-Replication process in a mask aligner for the reflective surface and alignment structures formation:
  - Wafer scale process compatible for 6”, 8”, 12” wafers
  - Material compatible to the soldering reflow process



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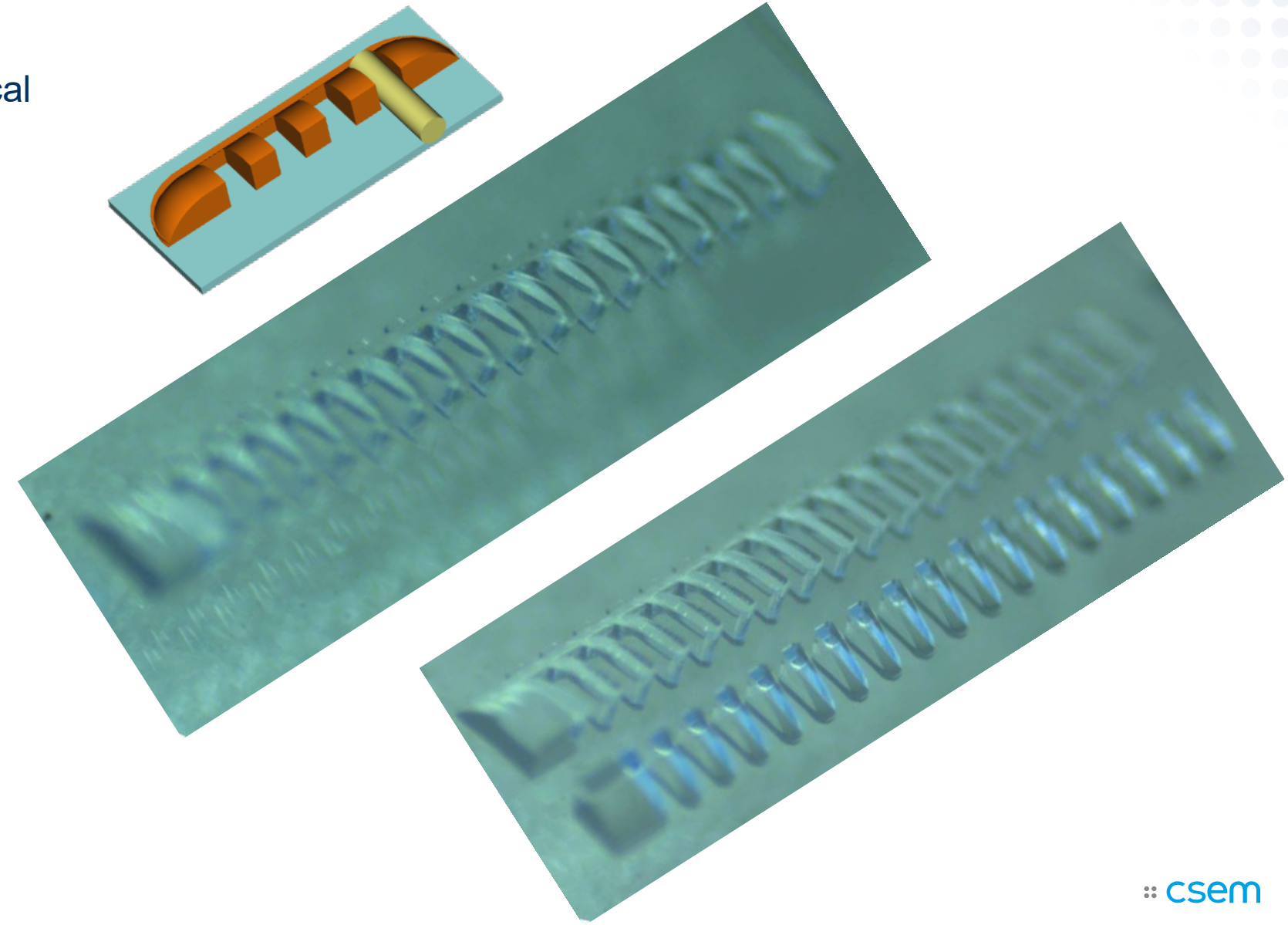
REALIZATION: REPLICATED STRUCTURES ON GLASS

Replication of in-plane micro-optical interconnects on a glass wafer.

Different alignment structures are possible: funnels, stress releases



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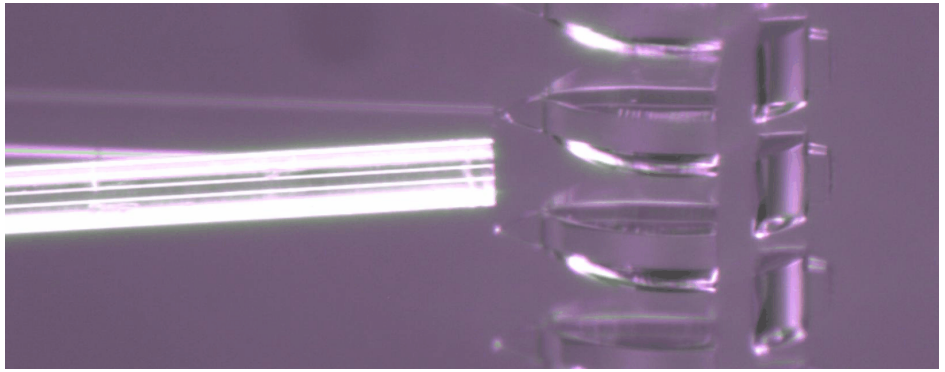
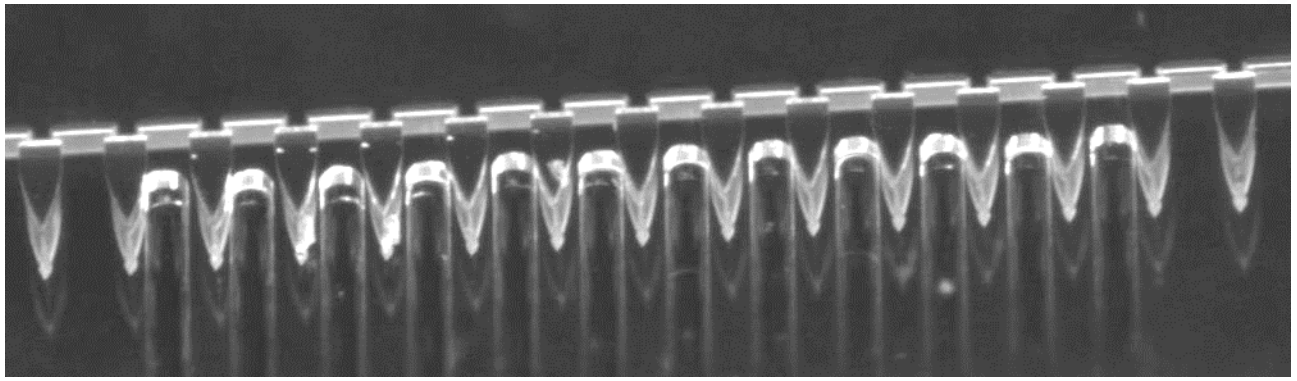
PLUG AND PLAY FIBER ASSEMBLING

Plug & Play assembling using fiber self-alignment structures

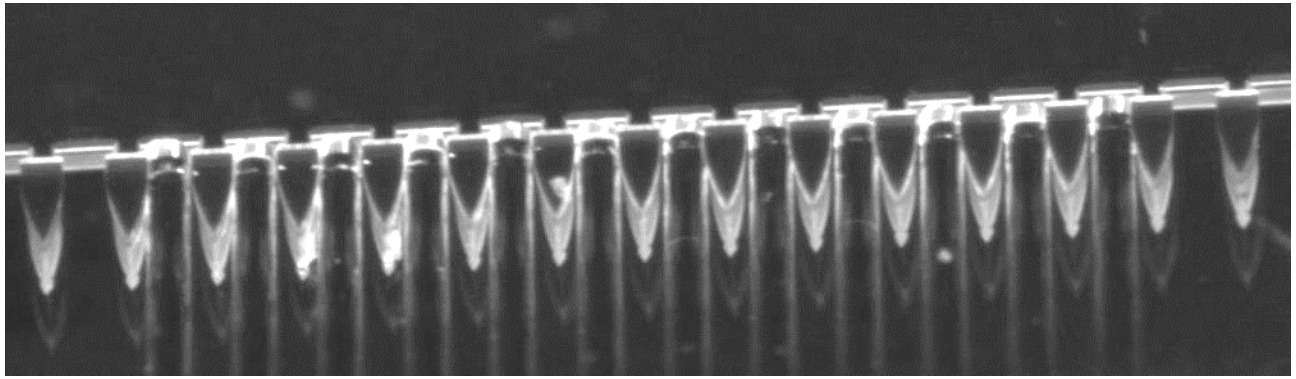


- Single fiber
- Multi-fiber
- Fiber arrays

Partially-inserted fiber array (12 fibers)



Fiber array fully pushed against the reflecting element



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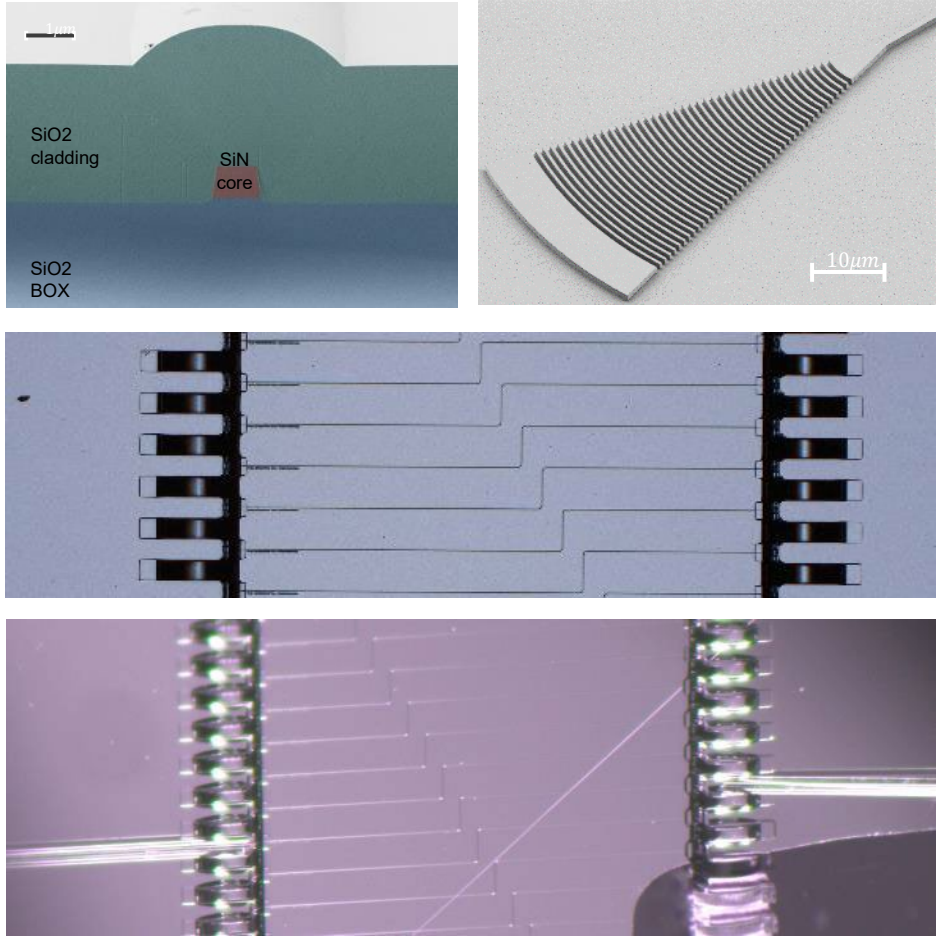
RESULTS: COUPLING INTO SiN WAVEGUIDE THROUGH GRATING COUPLERS

Test of in-plane micro-optical interconnects on Si substrates with waveguide gratings through GCs



Fiber-to-PIC-to-fiber transmission measurements (additional losses):

- 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

Losses mainly caused by positional offset due to material shrinkage which can be optimized

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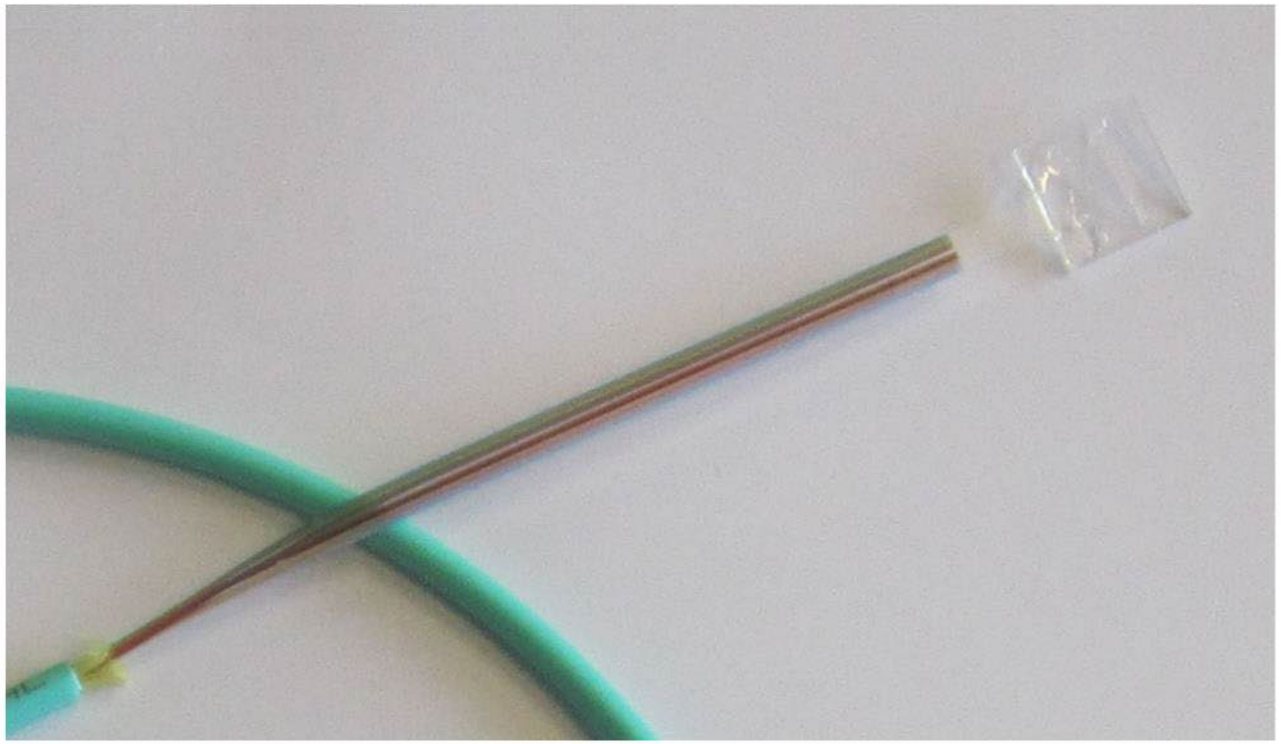
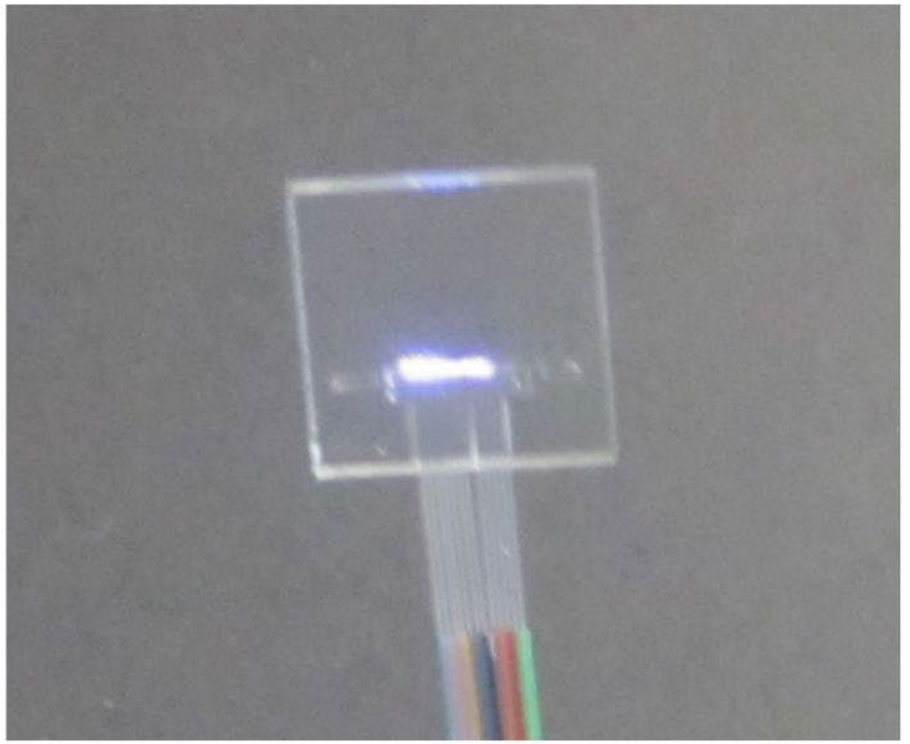
BROADBAND FIBER ASSEMBLY DEMONSTRATOR

Demonstrator with in-plane micro-optical interconnects to a fiber array (12x) on a glass substate





White light from a torch is clearly visible at the back side of the glass substrate

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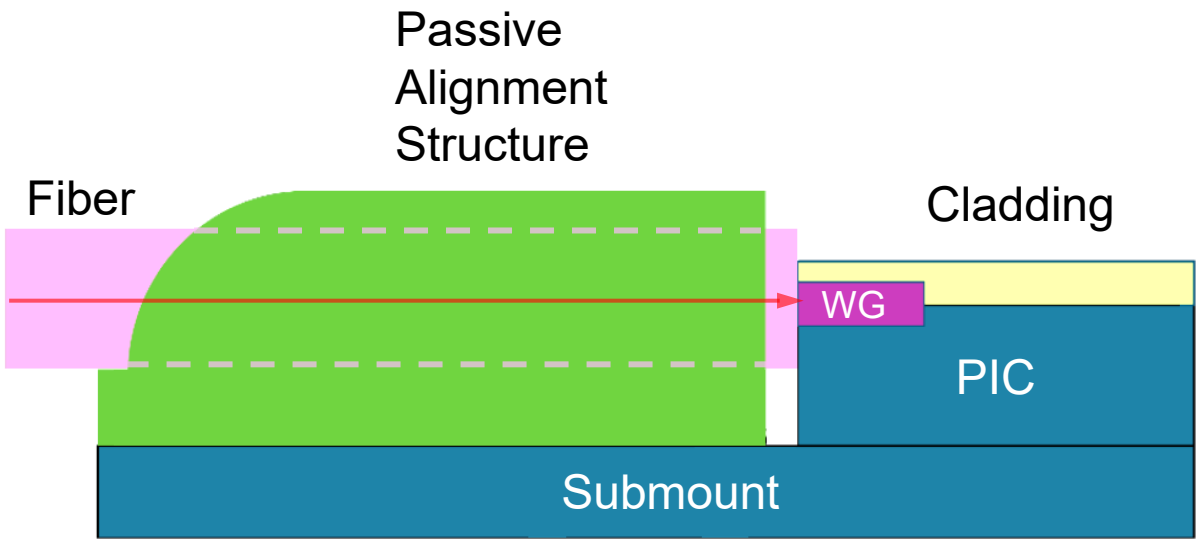
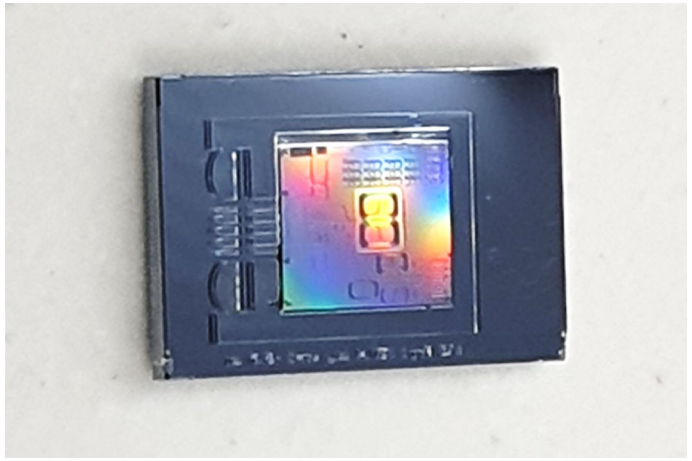
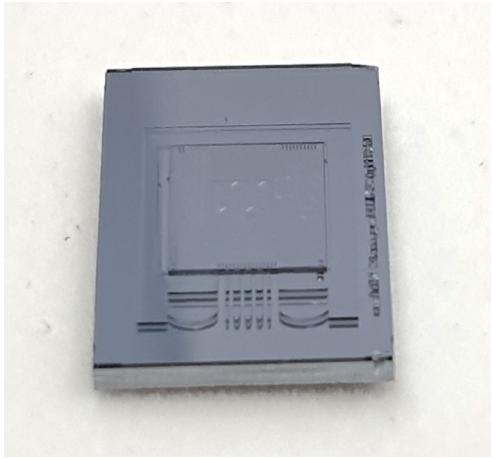
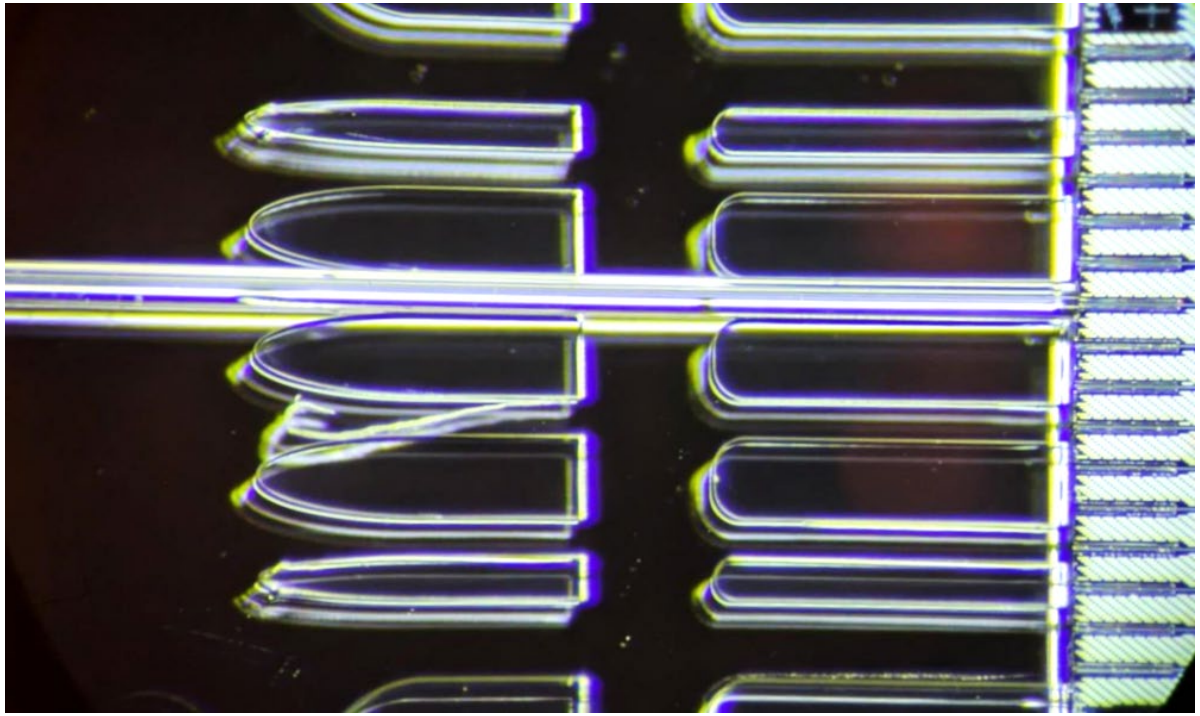
PASs FOR EDGE COUPLERS









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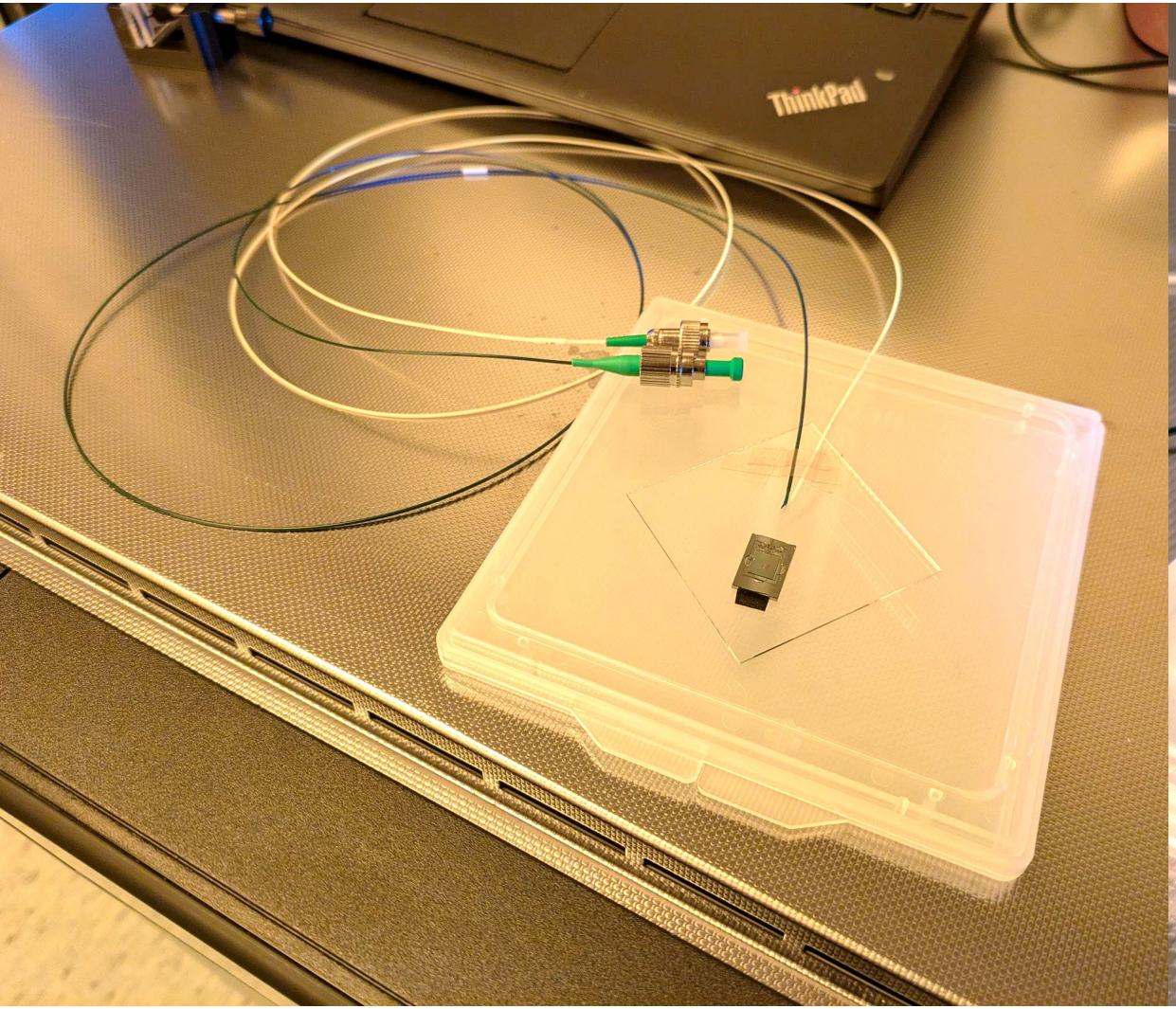
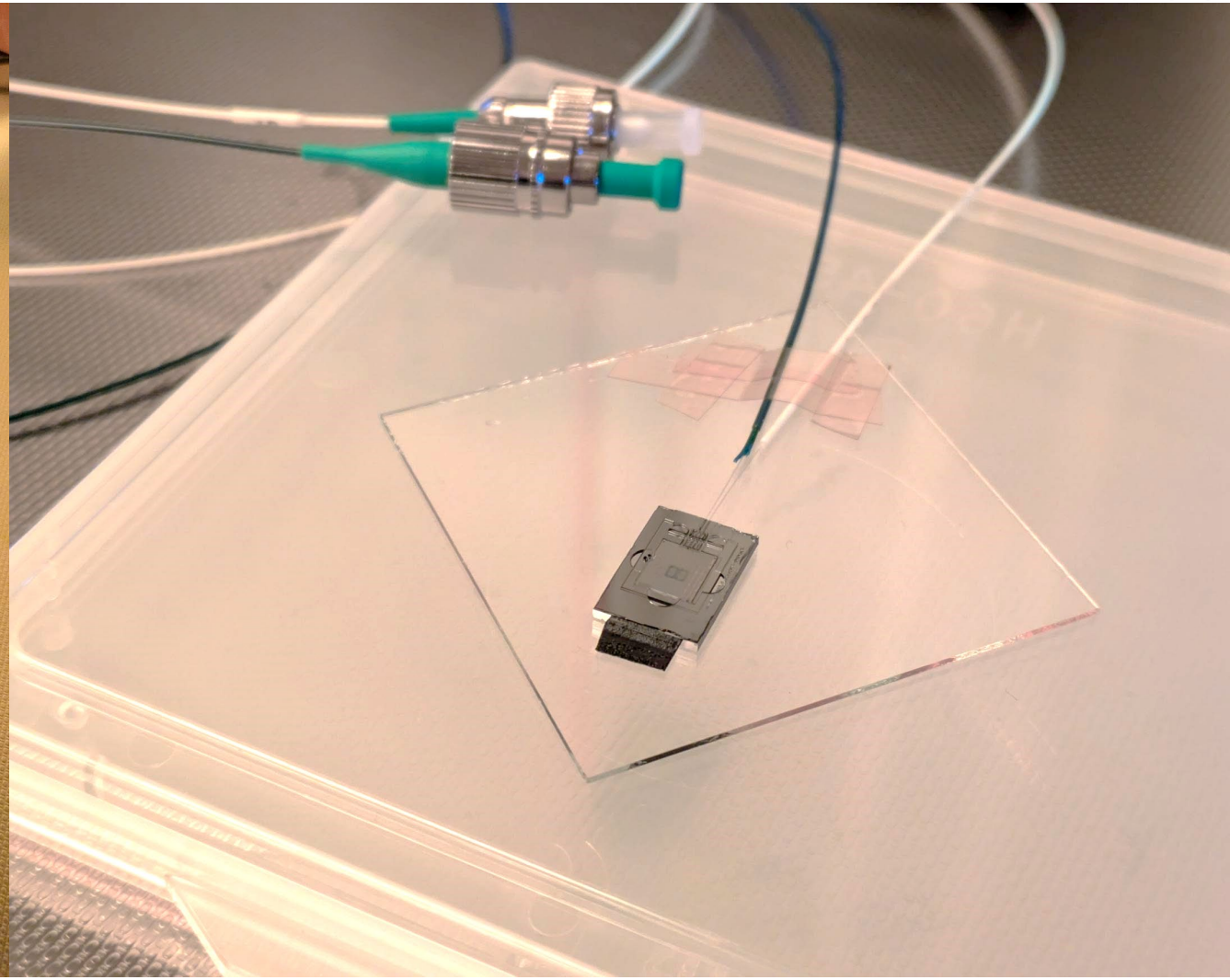
PASs ASSEMBLY WITH OPTICAL FIBERS





(coupling efficiency measurements ongoing)

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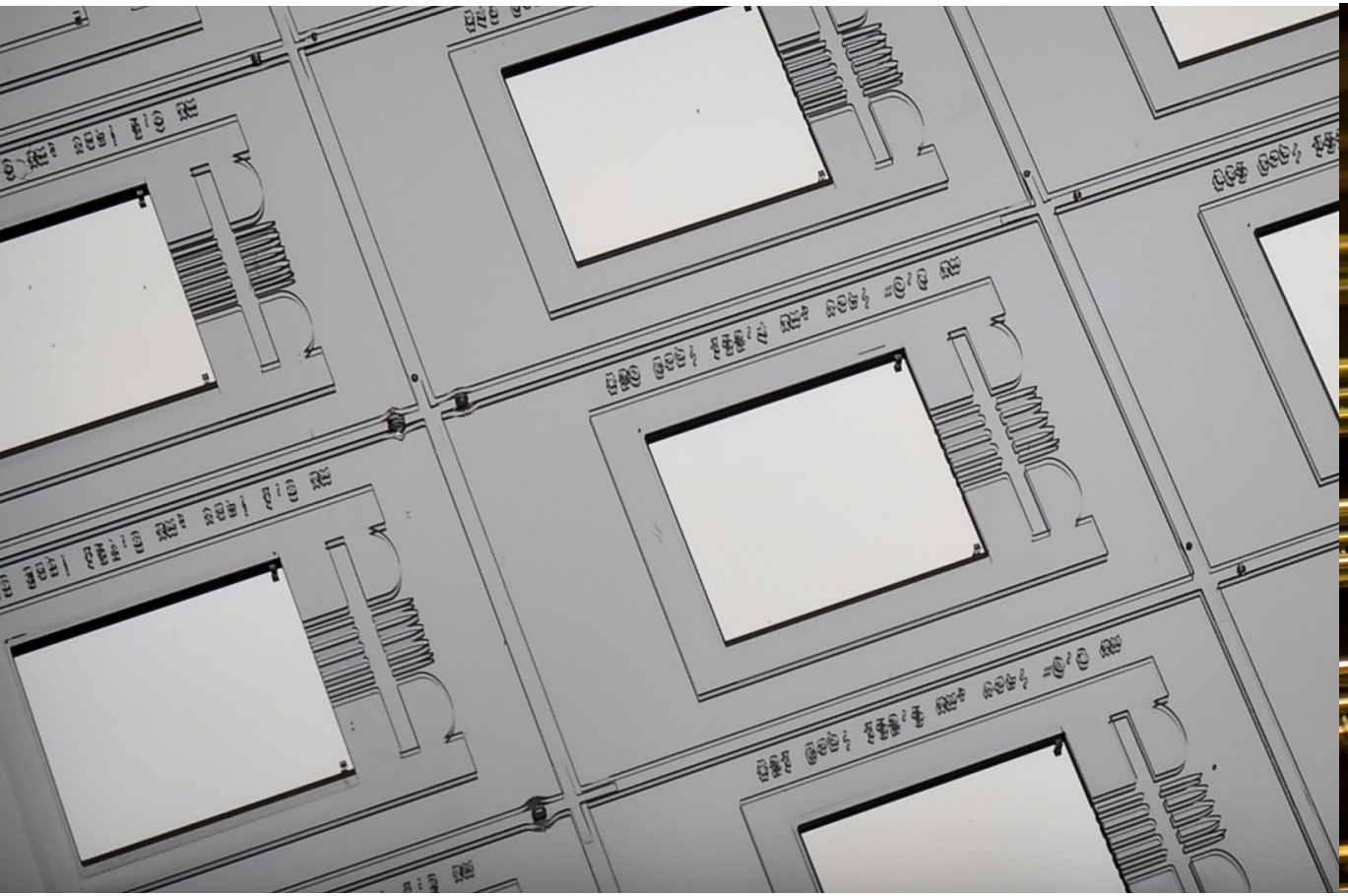
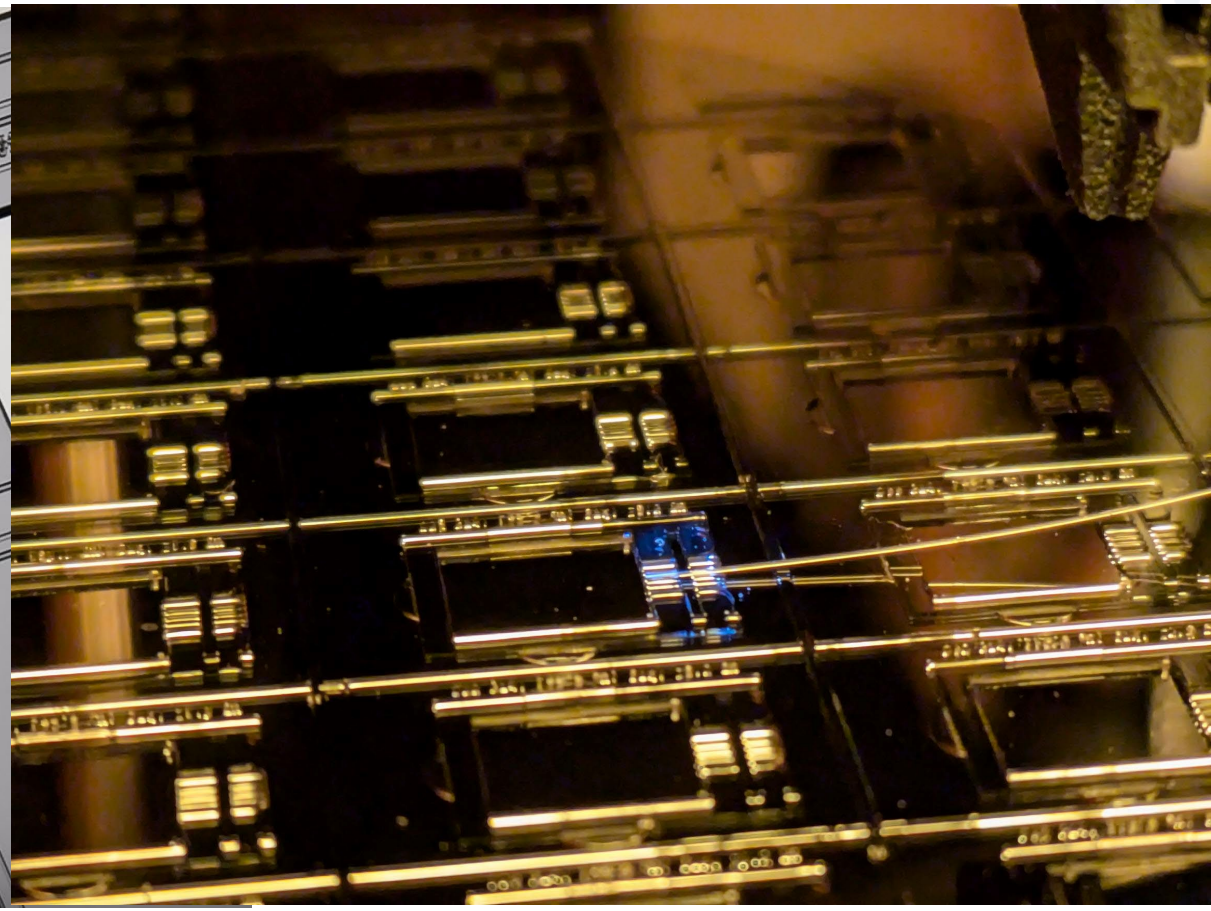
PROSPECTS OF WAFER-SCALE FABRICATION





(scaling up to chip stripes is straightforward)

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OUTLOOK AND APPLICATIONS

This family of interconnects can be used for a wide variety of applications to ease optical communication and chip integration by preparing packaging at the wafer scale for fiber/fiber arrays

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

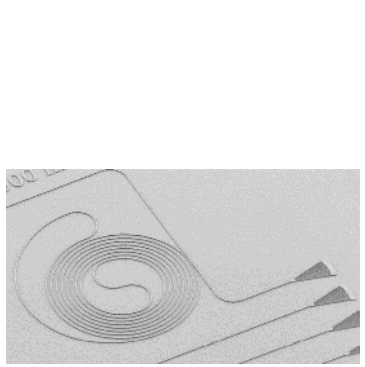
Interconnect to photonic integrated circuits
Self aligned fiber to chip (PIC's)

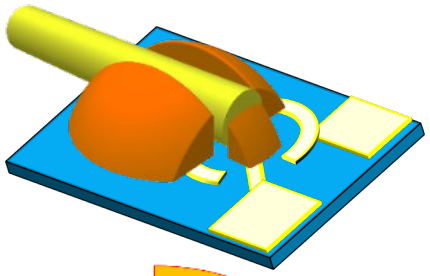
Angled fiber to fiber interconnect
Backplane connector with enlarged alignment tolerances

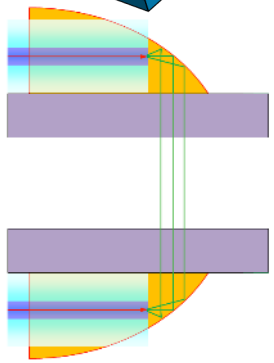
Chiplet to chiplet interconnect in a single package
Enhance the data transmission with an easy packaging

Chip to chip interconnect
Compact on board solution

Connectivity to waveguide in electro-optical boards
Electro-optical board connectivity to fiber arrays







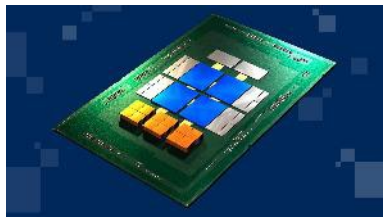


Image from Intel

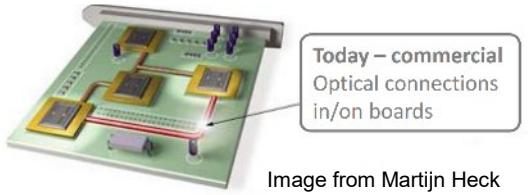
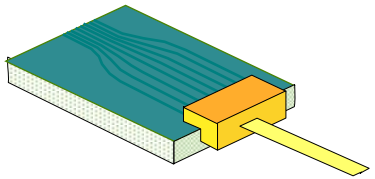


Image from Martijn Heck



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COME TO OUR BOOTH!

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Facing a challenge? Let's tackle it together!

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Acknowledgements
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FACING THE CHALLENGES OF OUR TIME

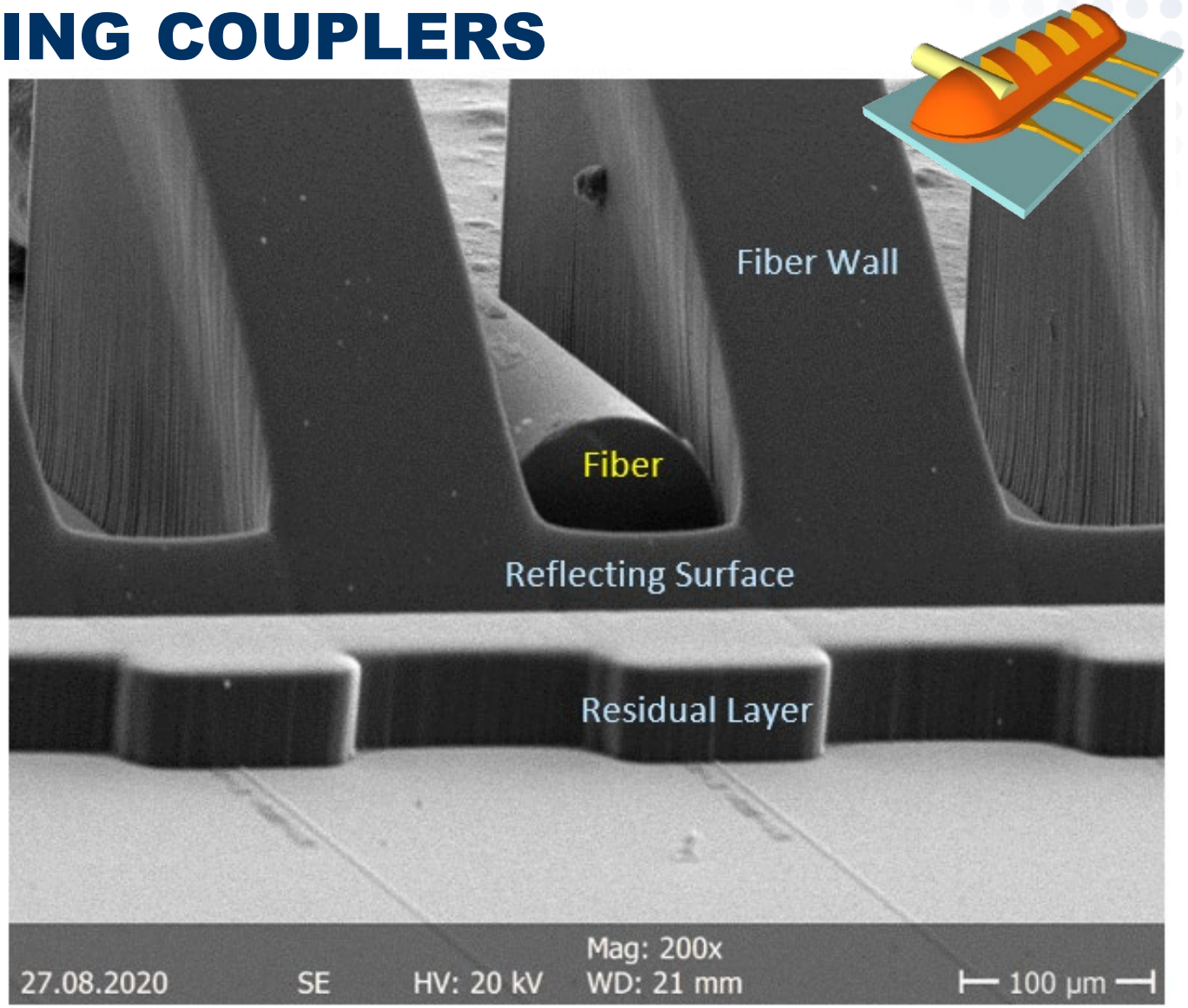
REALIZATION: REPLICATED STRUCTURES ON SiN WAVEGUIDES WITH GRATING COUPLERS

Replication of in-plane micro-optical interconnects on SiN waveguides:

Smooth reflecting surface (TIR) as well as fiber alignment walls

Radius of curvature = 1100µm

Wall height = 400µm. Tunable to adapt to the fiber assembly process



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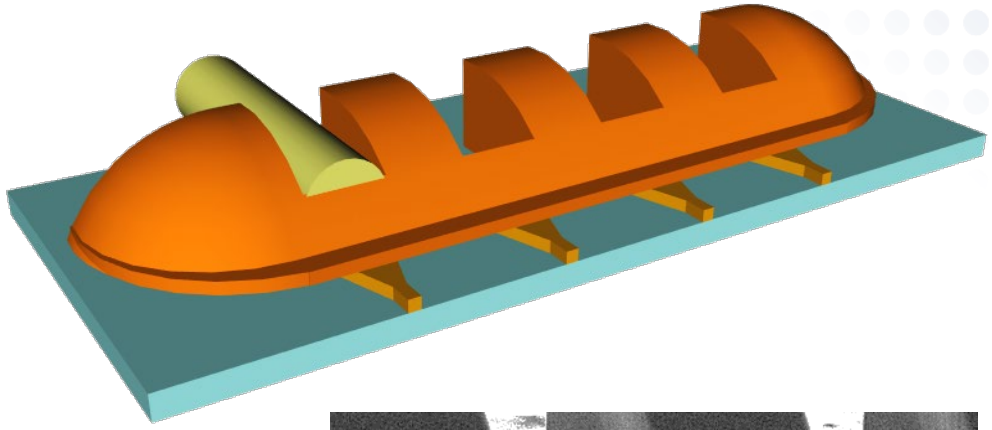
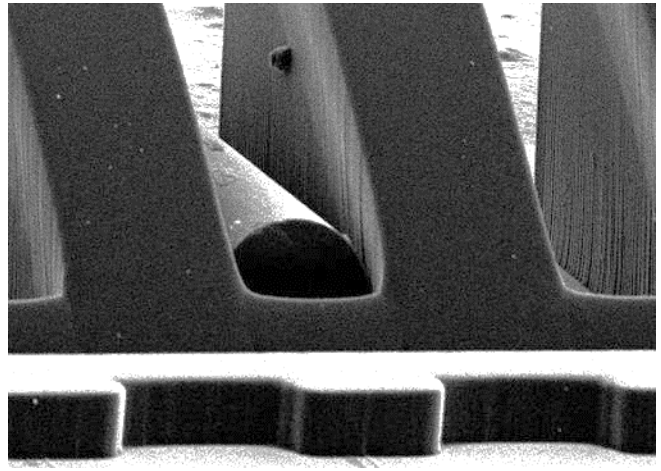
SUMMARY

- Innovative compact in-plane optical interconnect
- Broadband light refocusing and redirection
- Integrated alignment structures for passive fiber array plug and play assembly
- Excess losses as low as 0.34 dB were reached while maintaining the optical profile
- Fabrication by wafer-scale UV-imprinting
- Integration onto SiN waveguide grating demonstrated the performance and manufacturing on active wafer

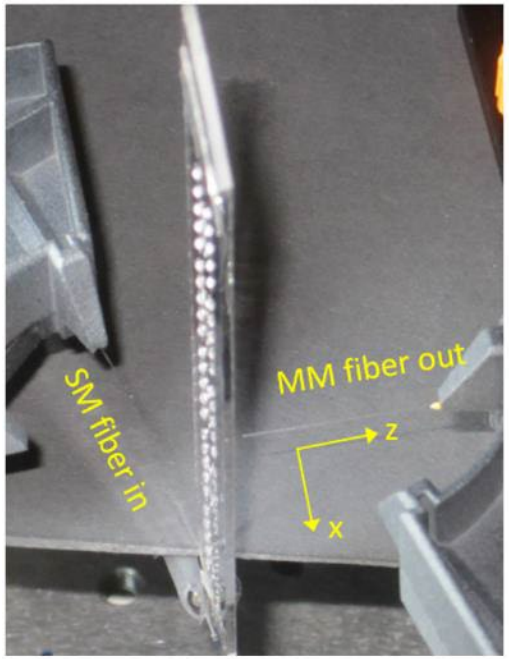


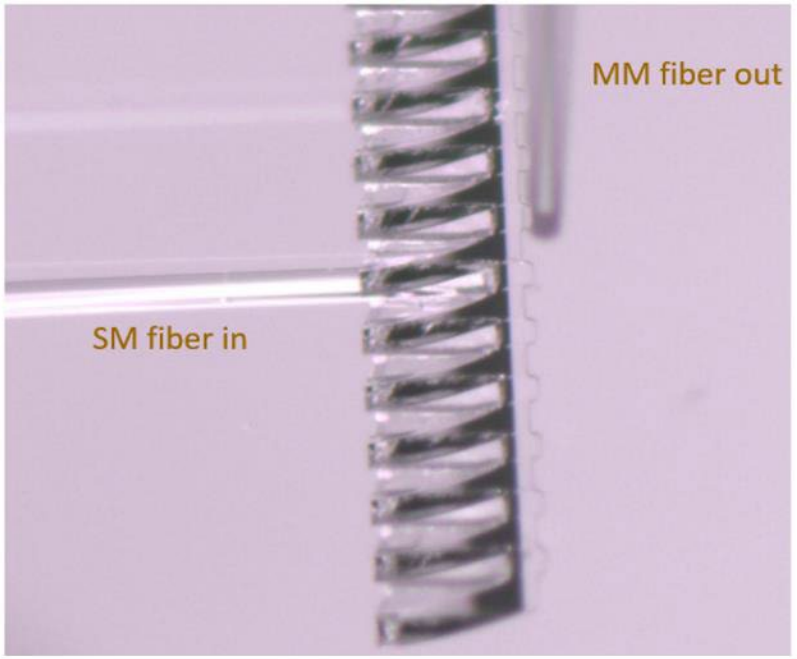


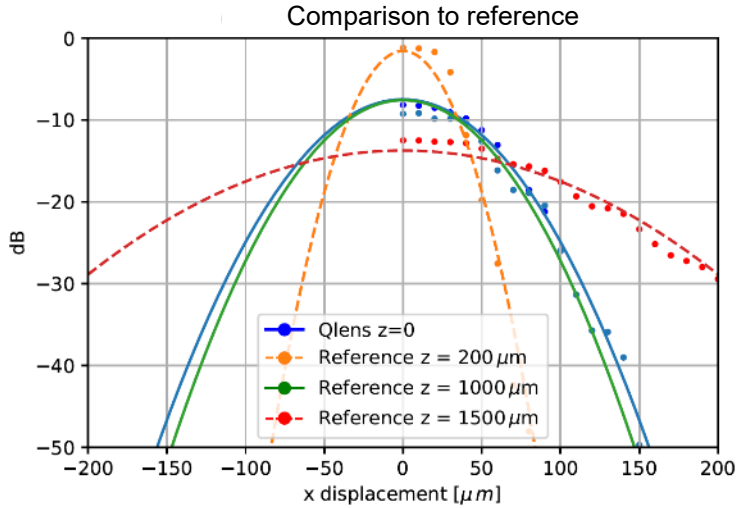
This micro-optical interconnect can be implemented for industrial volume production and will facilitate integration and packaging of electro-optical components

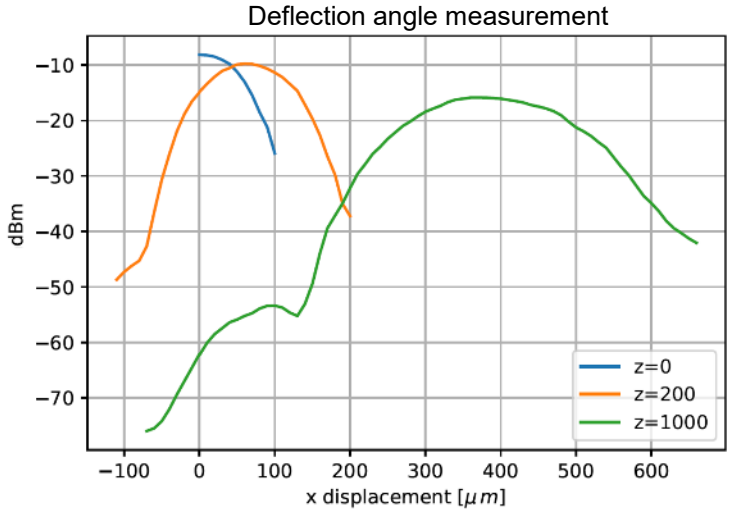
CHARACTERIZATION: REFLECTING SURFACE

Replications on glass wafer: measurements on an optical setup with input and output fibers (SM or MM) on adjustable micro stages (x, y, z, α)









=> measurements of fiber-to-fiber transmission showed losses as low as 0.35dB

=> beam quality and deflection angle were as expected (following reference)

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