High-Throughput Photonics Packaging for Cost-Efficiency and Scalability.

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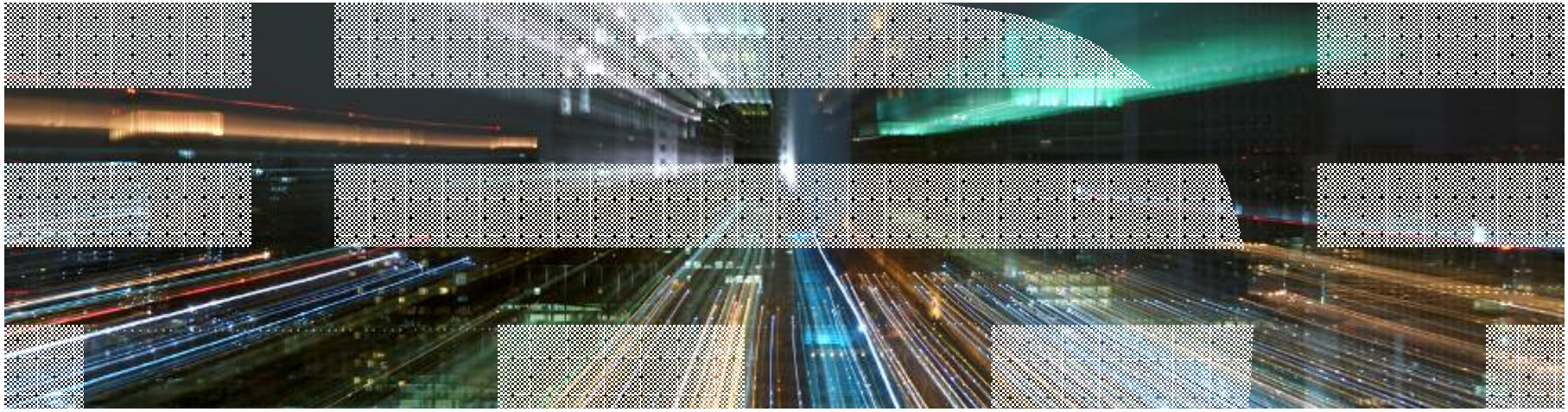
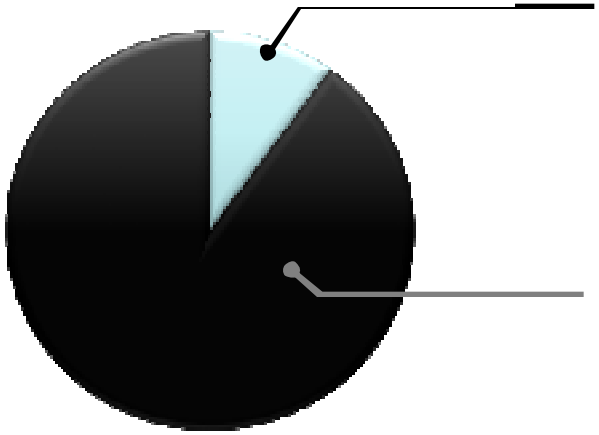


Silicon Photonics May be Hampered by Everything But the Silicon



Component cost

Silicon chip(s)

Everything else
- assembly
- testing
- fiber connector(s)
- laser(s)
- etc.

Need to reduce the cost of "everything else" for large scale deployment

Leverage cost-efficiency of microelectronics in package not just wafer

Manual

Custom Tools

Standard IC Tools

Leverage high-throughput microelectronic assembly lines for photonics packaging

Comparing approaches to photonic packaging

Relative cost structure

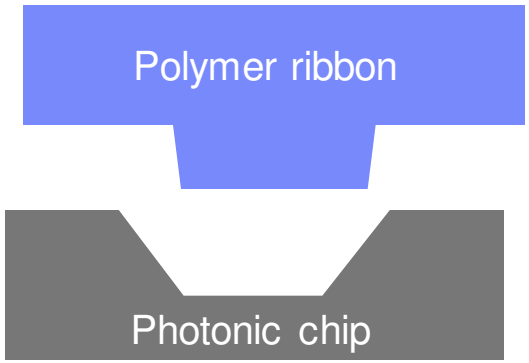
	Bill of materials	Tools amortization	Labor	R&D cost
Manual assembly	$$	$	$$$	$
Automated - custom tools	$	$$$	$	$$$
Automated - conv. pick & place tools	$$	$	$	$$$

- High-throughput automation appears as logical trend with volume/complexity
- Share pick & place tools with IC assembly gives high tool amortization
- Relegating packaging IP to SiPh chip minimizes reconfiguration cost of assembly tools and jigs

Challenges to leveraging high-throughput tools for photonics

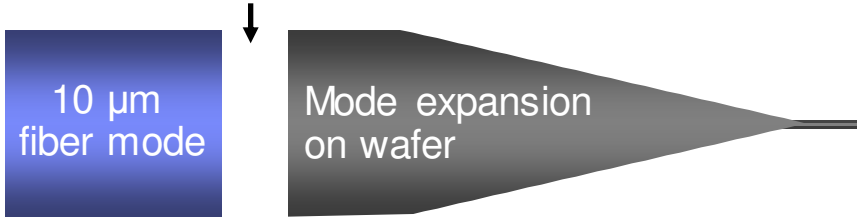
1. Limited placement accuracy of ± 10 µm

Self-alignment for 1-2 µm accuracy



Mode engineering for max tolerances

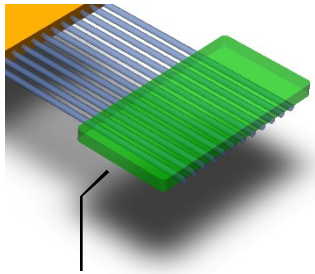
Connect at largest mode for tolerances



Avoid small-mode fibers for cost and tolerances

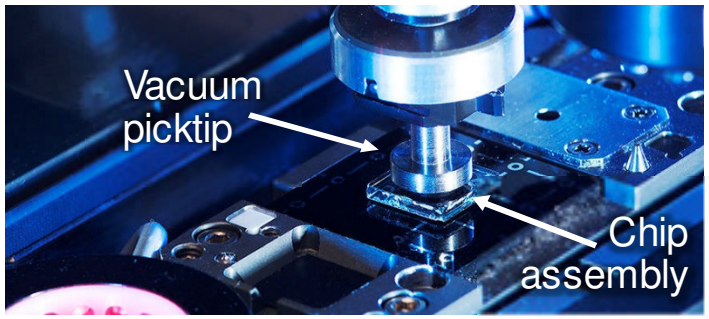
2. Inflexible pick-and-place handling

Vacuum pick-tip handling



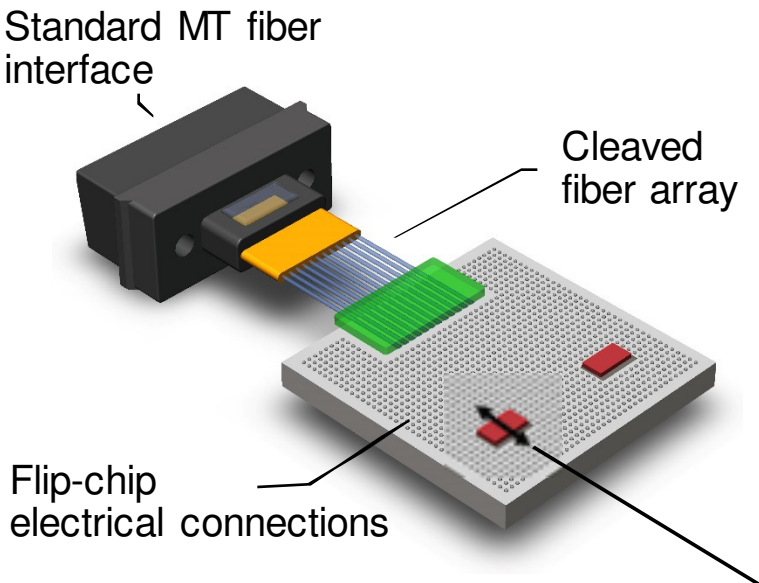
Integrate polymer lid for fiber handling

Pressure-sensing movement only vertical

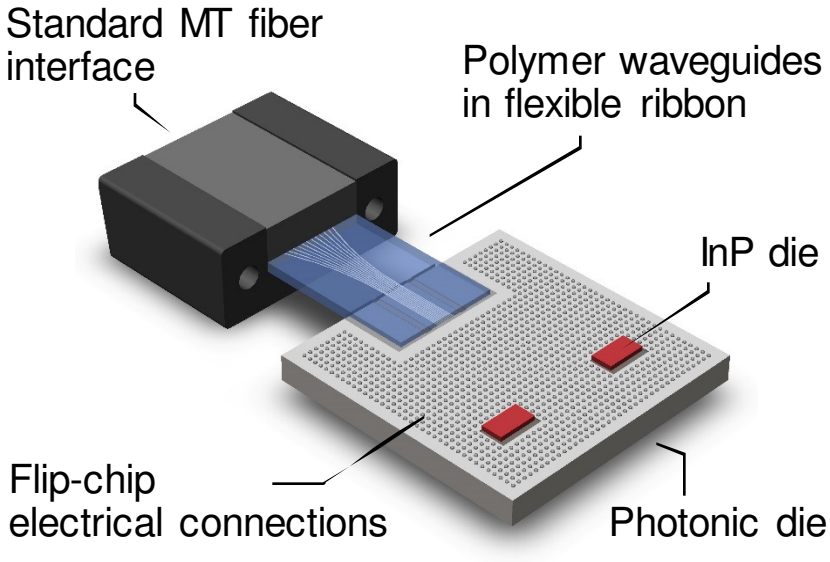


Our solutions to low-cost and scalable photonic packaging

Parallelized fiber assembly



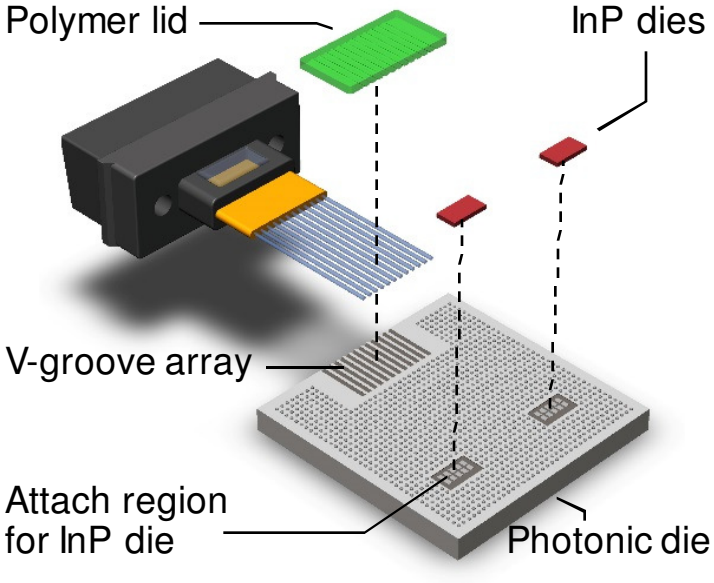
Compliant polymer interface



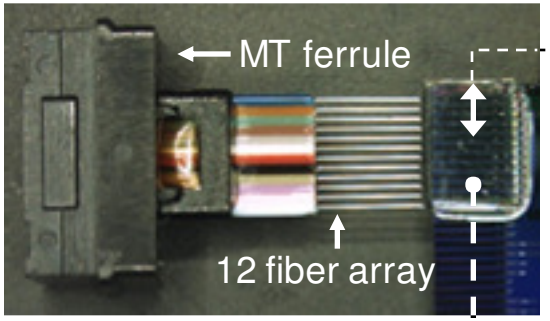
Direct flip-chip assembly of InP die

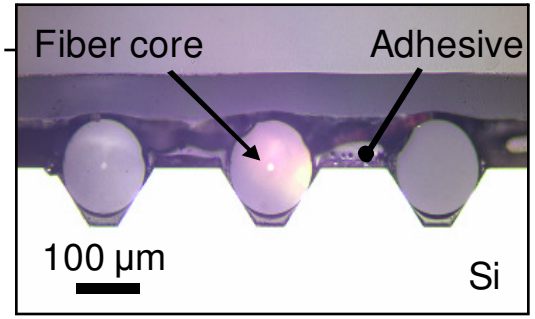
- All approaches fully compatible with existing high-throughput assembly tools.
- Minimum number of parts and assembly steps for cost efficiency and scalability

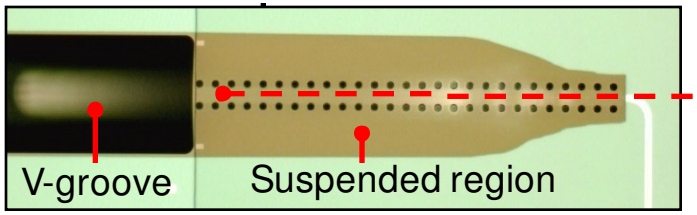
Parallelized fiber assembly



Mechanical design

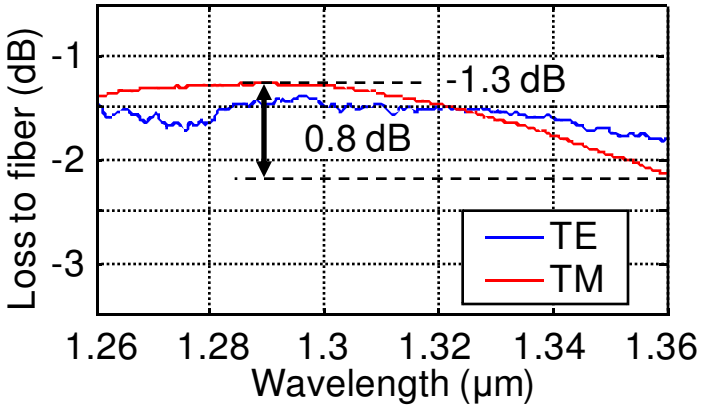




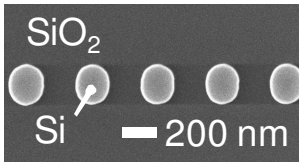


- Low cost pick & place assembly in high-throughput tools.
- Any number of fibers in 1D array.
- In-plane coupling for CWDM bandwidth with full fiber mode

O-band converter response



Metamaterial fiber coupler



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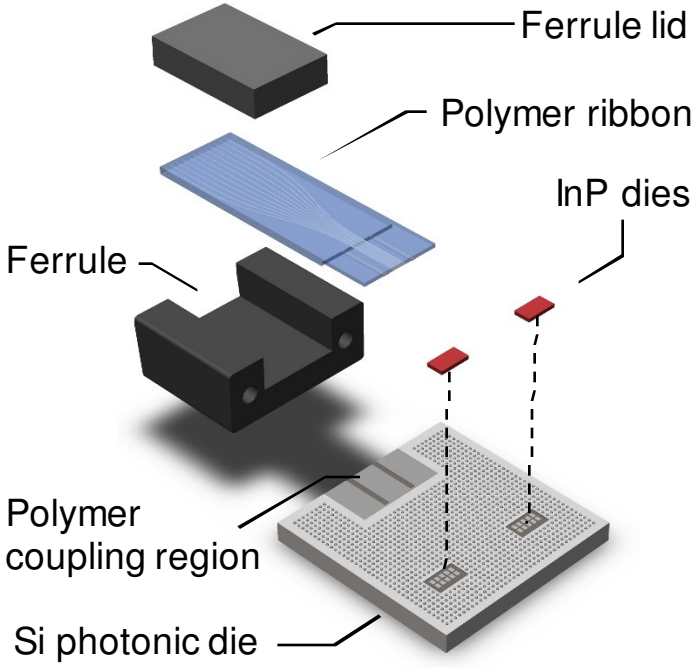
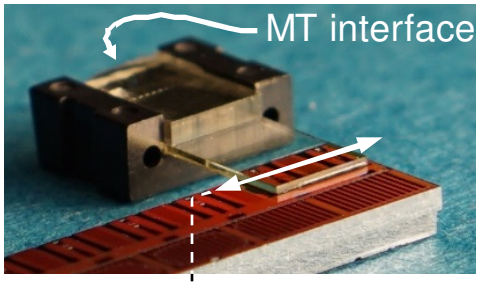
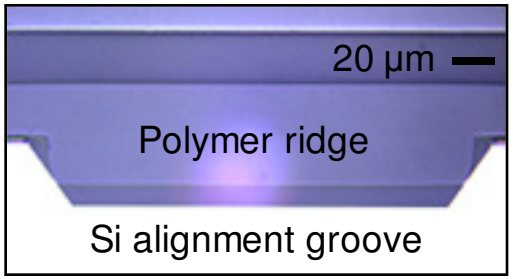
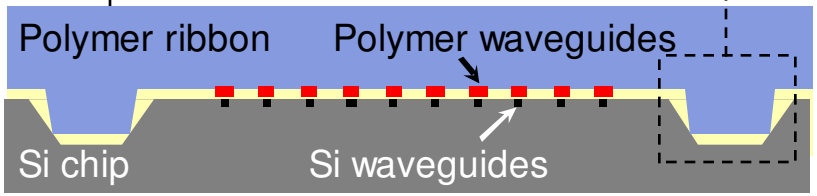


A few design details

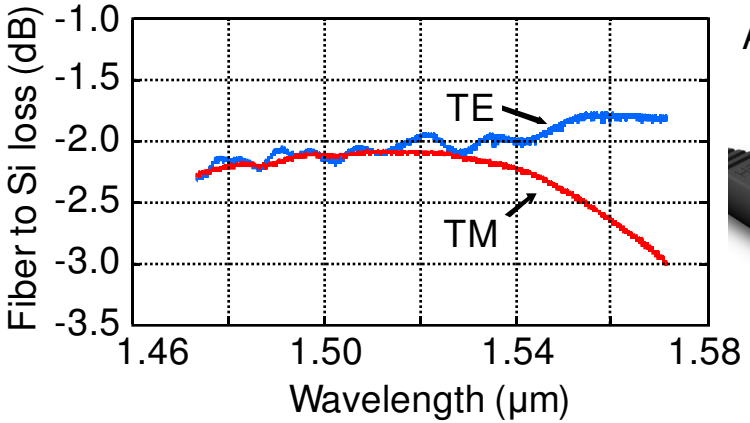


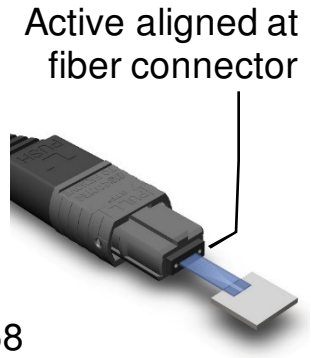




- Large number of optical ports
- Flexible for mechanical reliability
- Self-aligned assembly (±1-2 µm) in high-throughput tools (±10 µm)

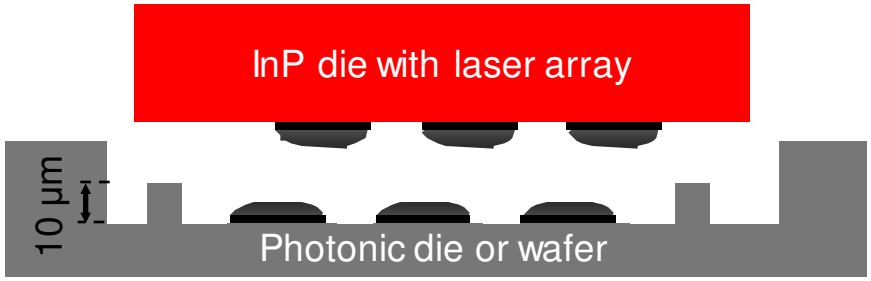
Optical performance → 1.8 dB peak



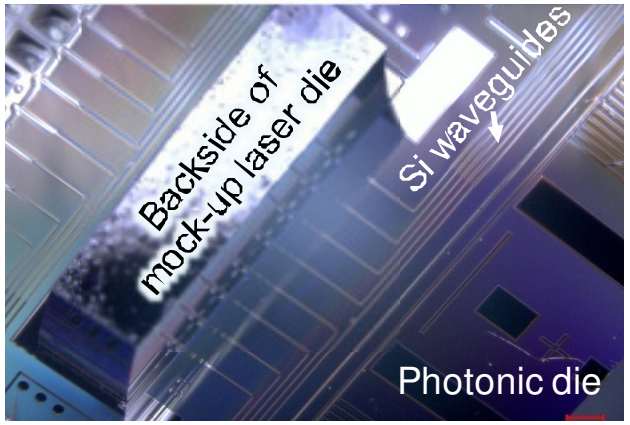


Self-aligned photonic flip-chip assembly for InP integration

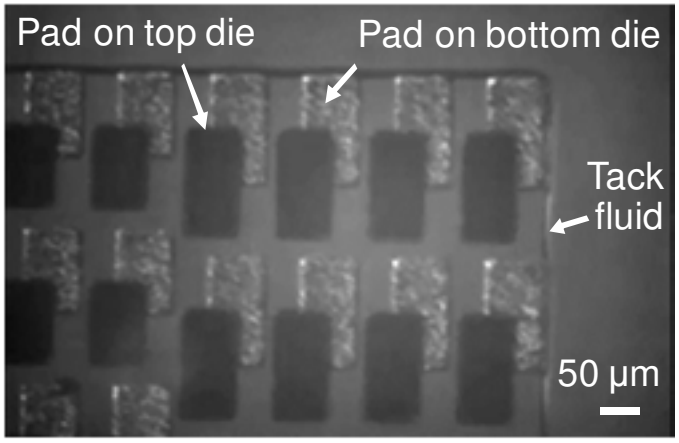
Solder induced self-alignment



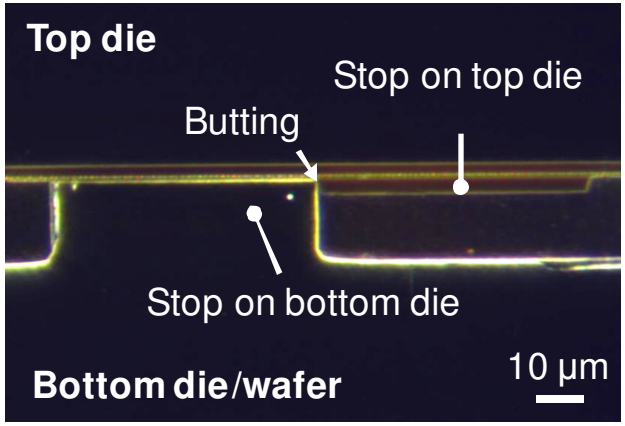
Pick and place (±10 µm), then anneal (< ±1 µm)



Infrared view through assembly



Cross-section after assembly

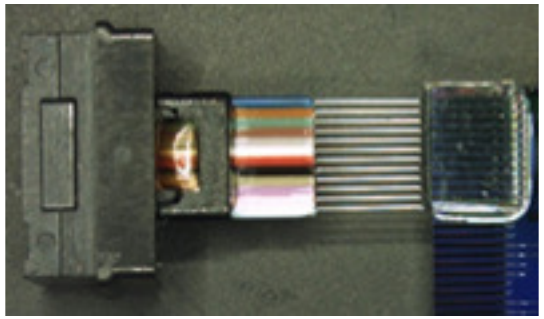


- Tighter alignment than in fibers as universally achievable mode size is smaller
- Self-alignment with lithographic stops in standard high-throughput tools
- Optical demo with 1.1 dB chip-to-chip transmission submitted for publication

Conclusion

Our vision is the integration of photonic packaging within microelectronic packaging facilities.

→ *Same facility, different "node"*
→ *Same tools, different processes/jigs*



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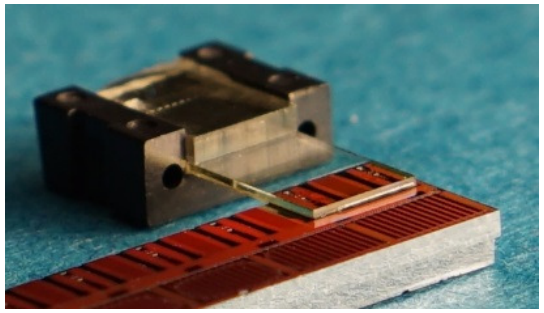

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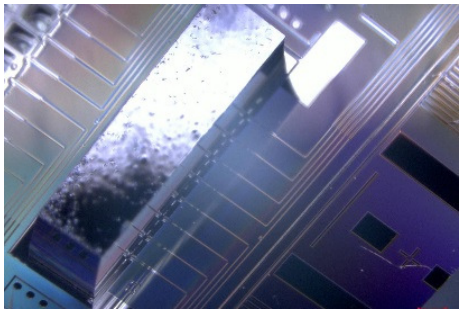

Self-aligned photonic flip-chip

Demonstrated photonic packaging compatible with high-throughput microelectronic facilities

Working on bringing 3 solutions to the photonics community
Requirement → MEMS-like process for self-alignment structures on wafer.

Team and Acknowledgment

IBM T.J. Watson, NY USA
Design, fabrication, analysis

IBM Research - Tokyo
Ribbon-ferrule assembly

Former 'IBM – Burlington'
Chip manufacturing

IBM Bromont – C2MI
Assembly, measurement

Outside partners

AFL

Ted Lichoulas
Eddie Kimbrell
Fiber stub fabrication

AGC ASAHI GLASS

Shotaro Takenobu
Polymer ribbon fabrication

FURUKAWA ELECTRIC

Masato Shiino
Custom ferrule fabrication

Follow our progress

Through our IBM project website → Google "Silicon nanophotonic packaging."