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SiPh CPO – A Paradigm Shift

Jean Trewhella, Director of SiPh Packaging Development

IMAPS GBC, March 2026

Agenda

- Why Now ?
- Packaging's Primary Purpose
- Paradigm Shift
- Optical Coupling Features & Assembly
- Driving New Collaborations & Packaging Manufacturing

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Key Themes Defining AI Data Centers



AI Workloads Driving Explosive Growth in Compute Demand

Explosion of Global Data

~24,000 EB of annual global wide area network AI traffic in 2030 (**~100%**↑ vs ’25)

LLM Complexity Growing

>5T parameters now, increasing computational requirements

Power Consumption Skyrocketing

~1,000 TWh of annual data center electricity consumption in 2030 (**~100%**↑ vs ’25)

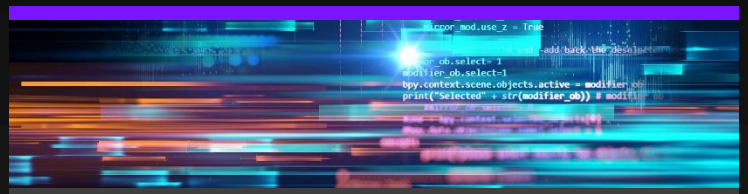


Forcing a Fundamental Shift in Infrastructure Requirements

Transition from Copper to Optical to enable larger scale-up networks

Transition to High Voltage DC to improve power distribution efficiency

Transition from lateral to vertical xPU power delivery to reduce conduction loss



Leading to Critical System-Level Objectives

- Reach
- Bandwidth Density
- Energy Efficiency
- Compute Efficiency

At the right total cost

The Benefits of Optical Networking





Critical Industry Needs	Copper Interconnect	Optical Networking
Reach	<2 m	>>100m
Bandwidth Density	<1 Tb/s/mm	>10 Tb/s/mm
Energy Efficiency	>5 pJ/bit	2-5 pJ/bit
Compute Efficiency	15% GPU Utilization	85% GPU Utilization

At data rates beyond 200G per lane, Optical is the only solution

Illustrative Purposes Only

Copper Has Run Out of Options

Nvidia NVL72 Architecture



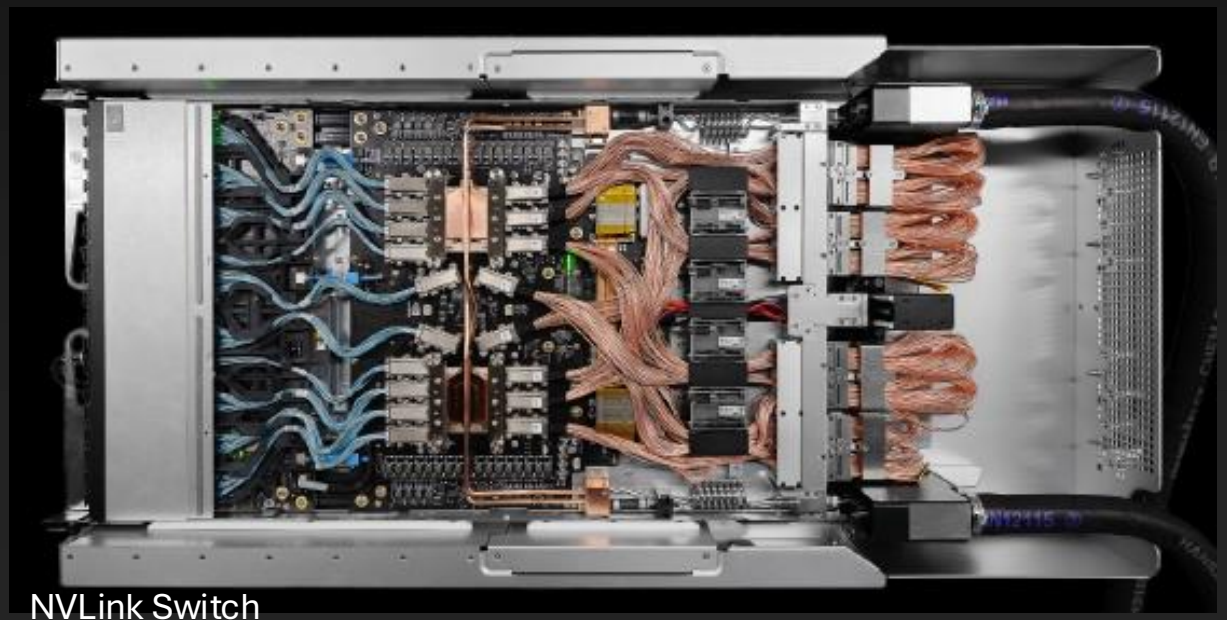
Put all 72 GPU in single 120kW rack

Moved the switches to the middle



GB200 NVL72 Rack

5,184 direct attach copper twisted pair cables



NVLink Switch

Copper wiring harness replaces PCB traces

(Ref: Open-compute Project)

Optical Solutions Embraced by Industry Leaders

MARVELL

"Copper-based interconnects used in today's scale-up systems are approaching their fundamental limits in reach and bandwidth, **creating a compelling need for optical solutions.**"

December 2, 2025

AMD

"You are going to see a transition to optics… from a I/O density point of view, from a bandwidth point of view, from a power point of view, **it just makes all the sense in the world.**"

November 11, 2025

BROADCOM

"**CPO technology is a key enabler for next-generation data center architectures,** offering unprecedented bandwidth density and power efficiency by tightly integrating optical engines with switch silicon."

October 1, 2025

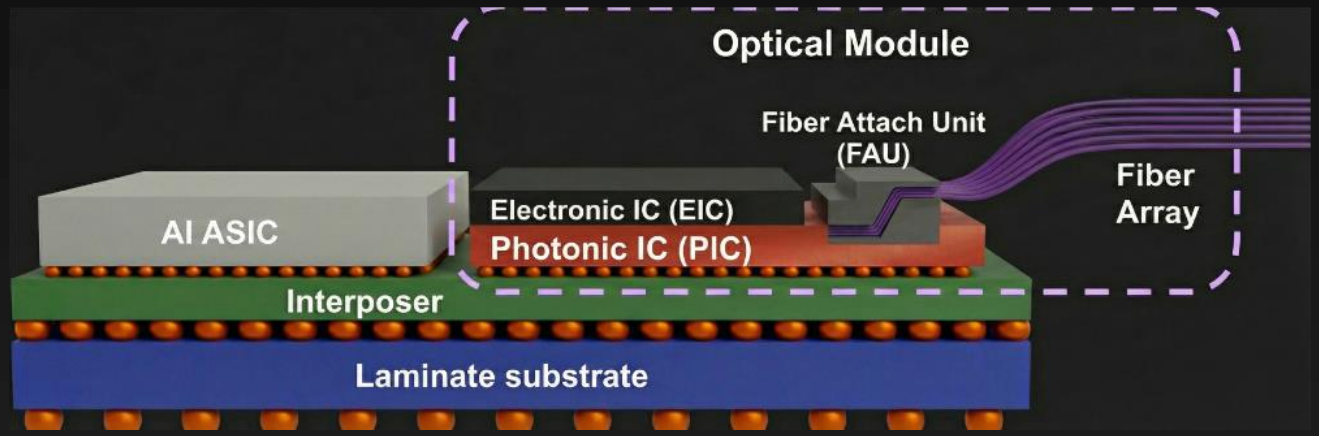
NVIDIA

"The **co-packaged optical design** reduces power consumption, improves reliability, enables rapid deployment, and supports the massive interconnect requirements of agentic AI workloads."

August 18, 2025

00900
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Co-Packaged Optics: A Critical New Innovation



AI Switch ASICs & Co-Packaged Optics

- Massive optical bandwidth & low latency
- Enables terabit-scale optical I/O, reducing power and reach constraints
- GPU utilization goes from 15% to 85% for AI workloads

Performance

Faster data transfer via short, dense interconnects

Power

Reduced signal travel distance & capacitance

Size

Vertical stacking & tight integration for compact devices

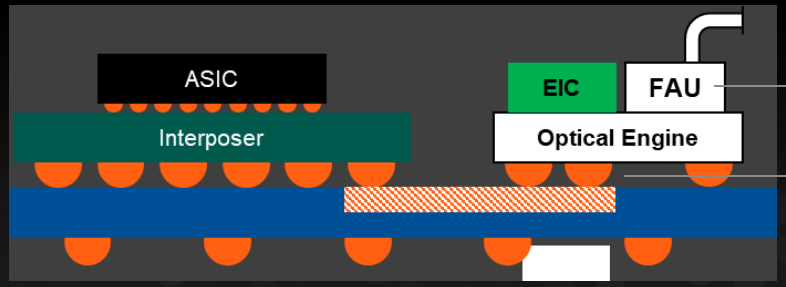
Integration

Combine best-of-breed chiplets from different processes

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Optical Engine Form Factors

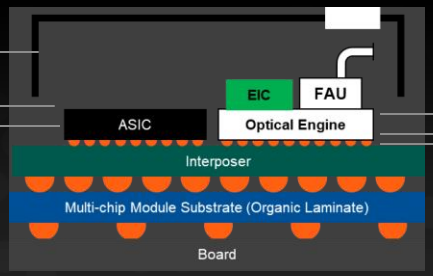
Silicon bridge



- Fiber-Attach Unit
- Mixed-pitch bumps

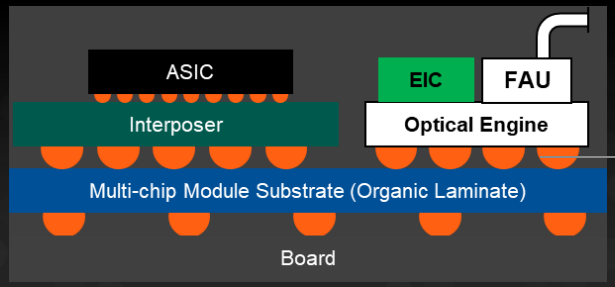
Silicon interposer

- Lidded/unlidded
- Over molding
- Cu pads or Cu2Cu



- TSV
- RDL
- µ bumps

Multi-chip module (organic laminate)



- Bumping

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GF Fotonix™ Technology Solution

Legend:
CMOS
Optical
Packaging

MZI modulators

Micro-ring modulators

dWDM Ring filters

High BW Ge EPI PD

Waveguides, passives

*Passive library: SOI & **SiN Ridge**, rib WGs, bends, tapers, directional couplers, **MMIs**, cross, absorbers, …*

BEOL passives, inductors, VNcap

RF CMOS, standard cell, GPIO, ESD, eFuse, TIA, driver, precision resistor

300mm CMOS-SiPh Monolithic platform

Thermal phase shifters w/ **sealed airgap undercut**

4x MUX/DEMUX Mzi filters

Polarization splitter & polarization rotator

2.5D & 3D integration solutions (Cu Pillar & Cu Rx Pads &TSV)

Top grating couplers

Passive & active fiber attach

Direct laser attach

Spot size converter

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Packaging Primary Purpose – Do No Harm

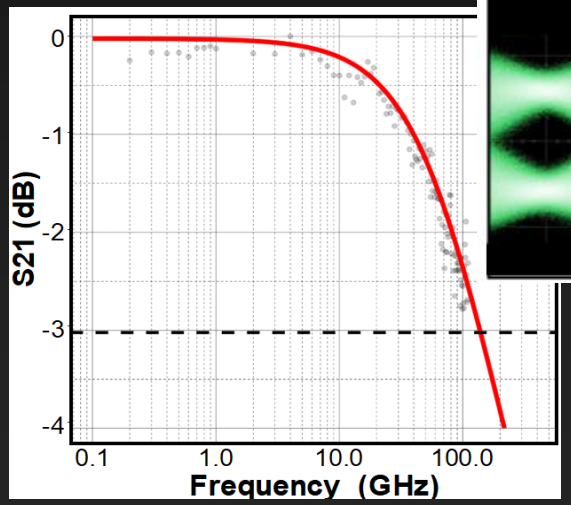
Space Transformation without Degradation of Performance

- Loss
- Power limitations
- Signal Distortions

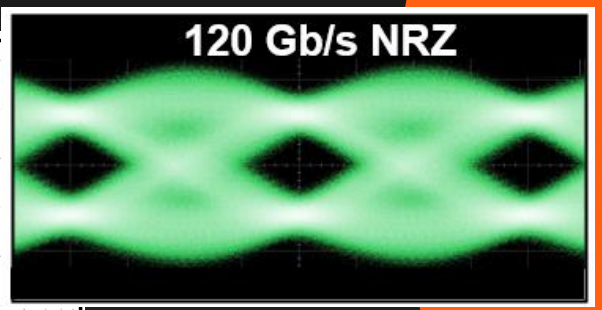
1 µm SiN WG MFD

125 µm Fiber

9.25 µm Fiber MFD

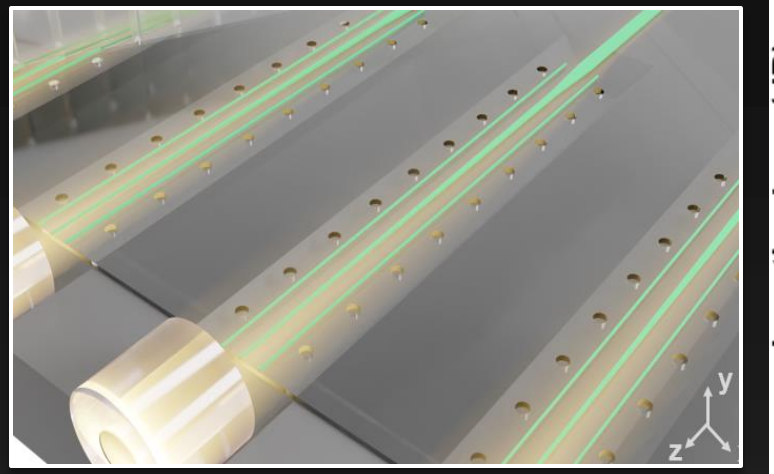


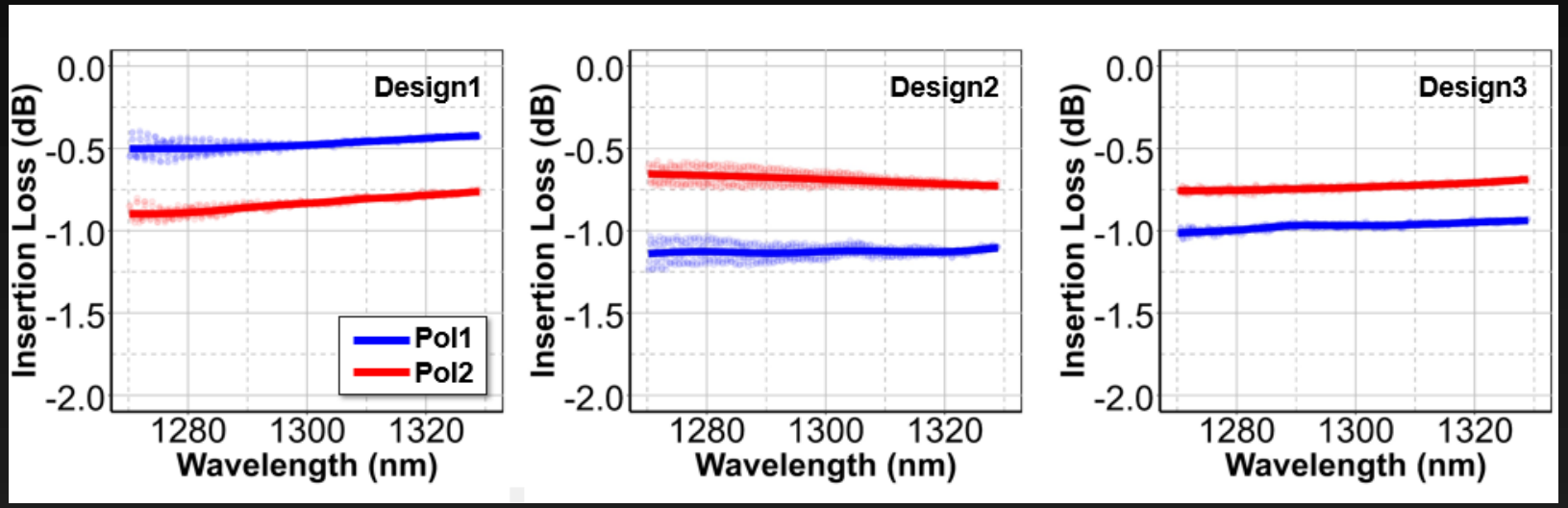
Ultra-high speed Germanium Photodiode w/ 120 GHz Bandwidth



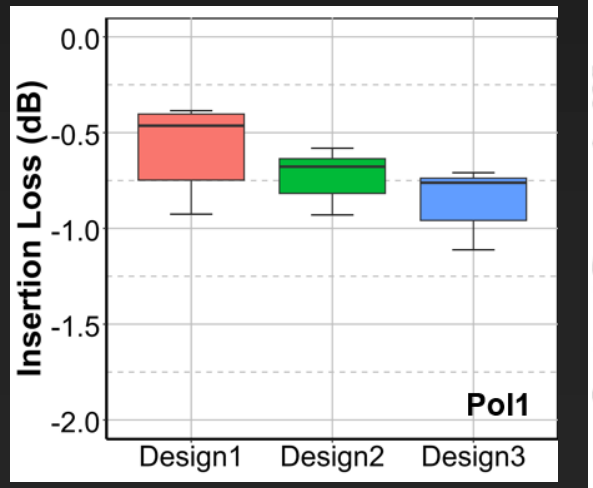


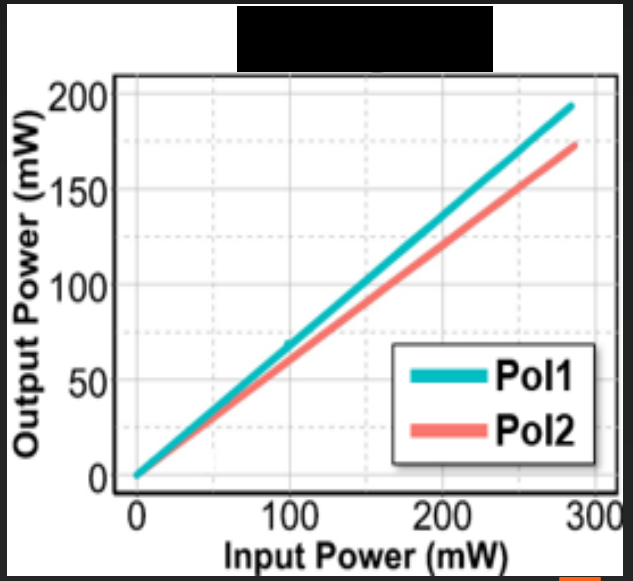
Multi-tip SiN Spot Size Converter for IL reduction





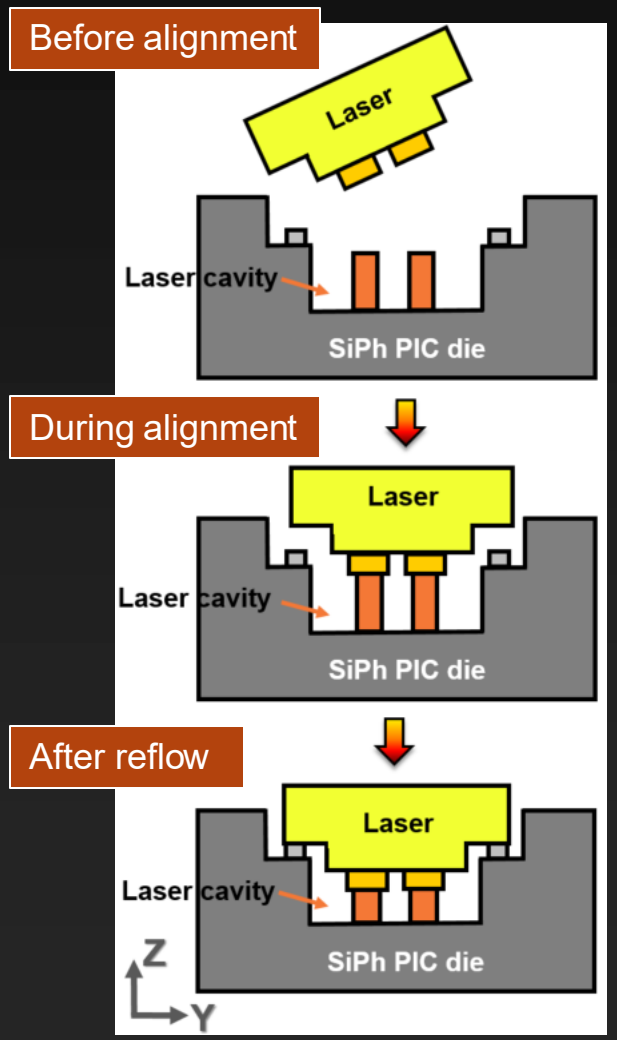
- Broadband high-power V-groove based multi-tip SiN edge coupler
  - **Lowest insertion loss reported: ~0.4 dB**
  - Low polarization dependent loss: **< 0.25 dB**
  - Low wavelength dependence: **< 0.2 dB**
  - Low optical return loss: **< -40 dB**
  - Good high-power handling: **expect > 520 mW**

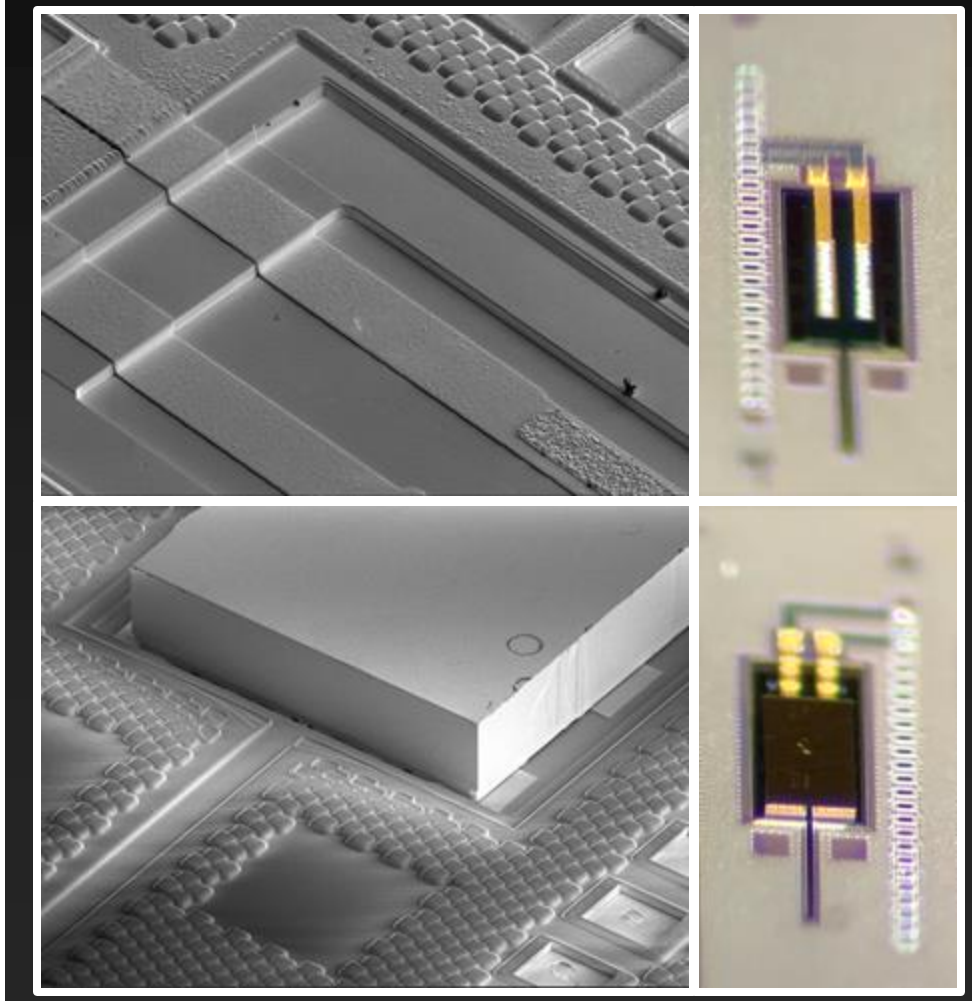




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Flip-chip Hybrid Laser
Higher level of Integration for CPO



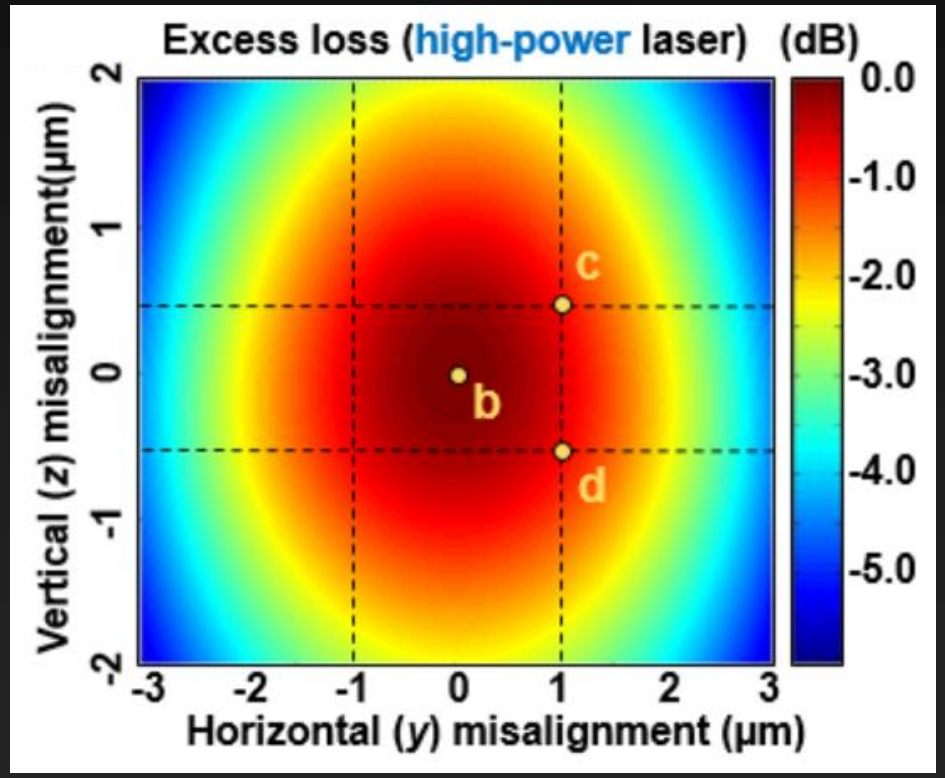


- ❑ High accuracy flip-chip laser attach through precise PIC features
  - ✓ Post fab processing to form wiring layers within the cavity and provide solder connections
  - ✓ Z-alignment and seating of laser using lithographically defined features inside the cavity of the PIC
  - ✓ High precision bonding process for sub-micron alignment in *x* and *y* directions via optical alignment features

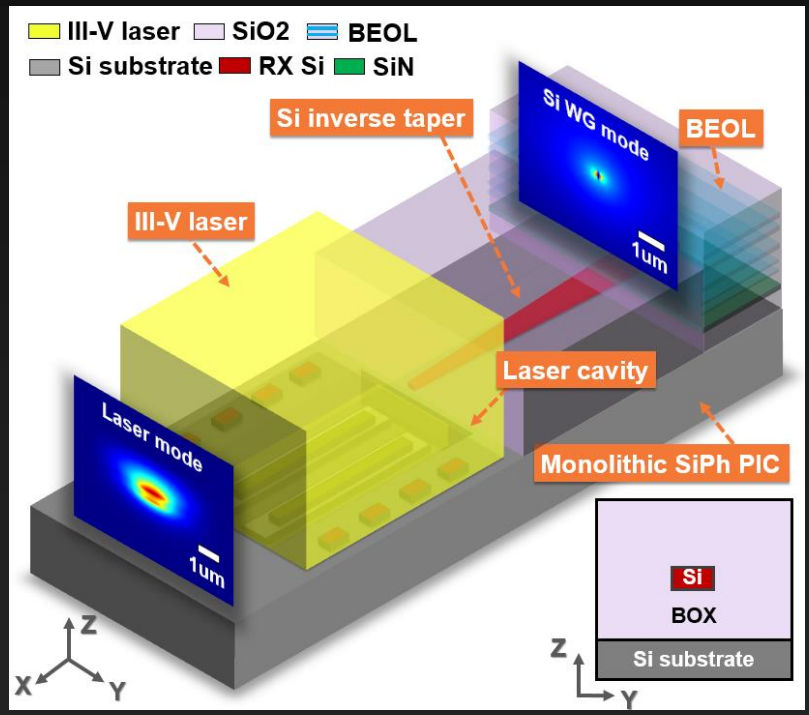
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Optical Interconnect to Laser

- GF Spot Size Converters designed for high coupling efficiency with 1 μm alignment tolerances

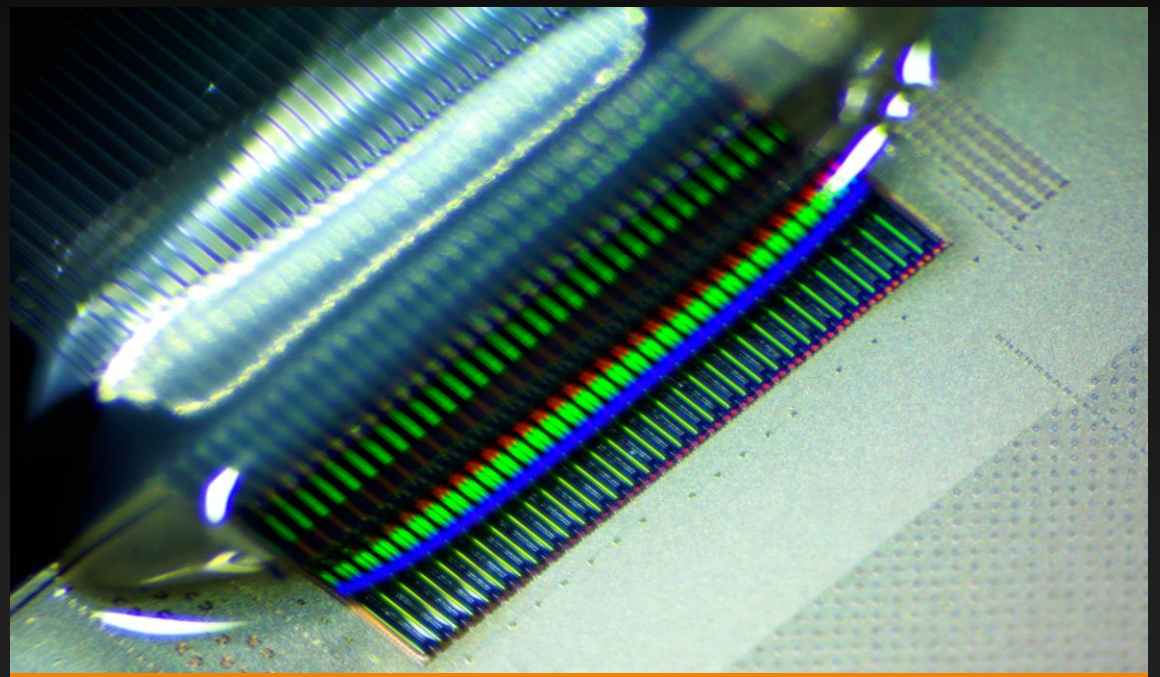


Less than 0.8 dB excess loss if the misalignment can be controlled within ± 1.0 μm

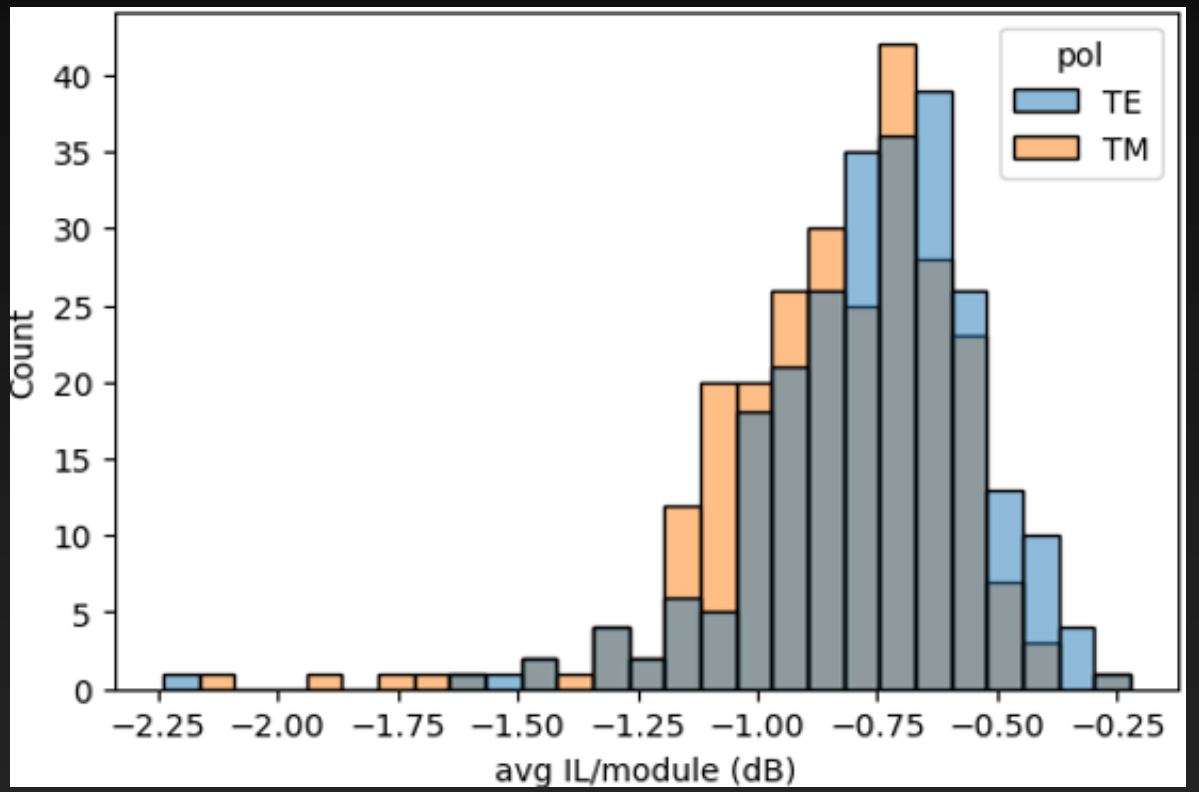


Alignment Tolerances Similar to Advanced Packaging Hybrid Bond

32-channel 127µm-pitch Passive Alignment V-groove



Module with 32-channel fiber ribbon attached



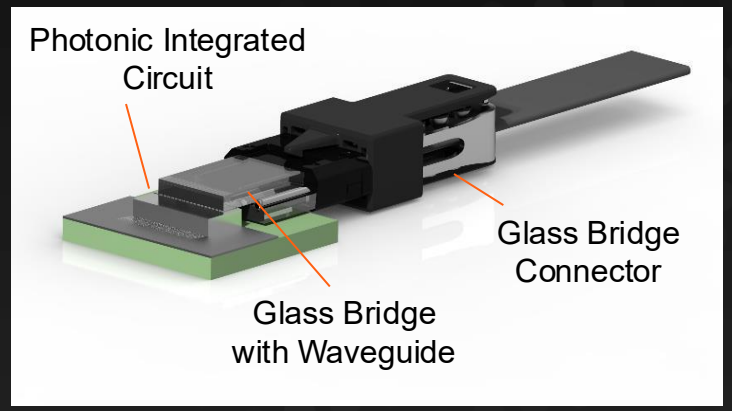
- Sub-1 dB TE and TM IL and < 0.1 dB PDL demonstrated on 32-channel 127µm-pitch Vgroove array, occupying the same footprint as a 16-channel 250µm-pitch array
- 2X Edge bandwidth/beachfront density by doubling the physical port count

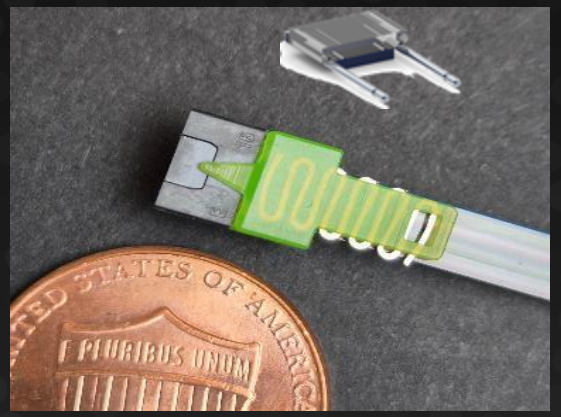
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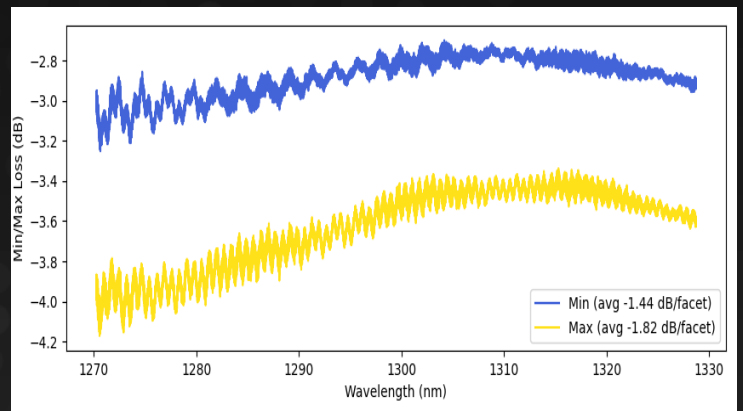
Corning Glass Bridge

Next-generation photonics – Advanced Packaging Glass Bridge Interconnect

Integrated into GF Fotonix™ platform





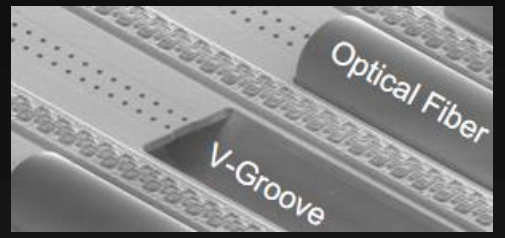


- Glass bridge connector to the PIC
- Waveguides in Glass
- Align to Vgroove array, mechanical and optical
- Ribbon Fixture
- Low thru-band dispersion
- < 1.5 dB/facet TE

Images courtesy CORNING

Relaxed Alignment Thru Mode Expansion and Collimation

Direct Coupling with Passive Fiber Attach
Spot Size Converter in SiN to match fiber mode
V-grooves in the PIC lithographic features
Fibers permanently attached to PIC



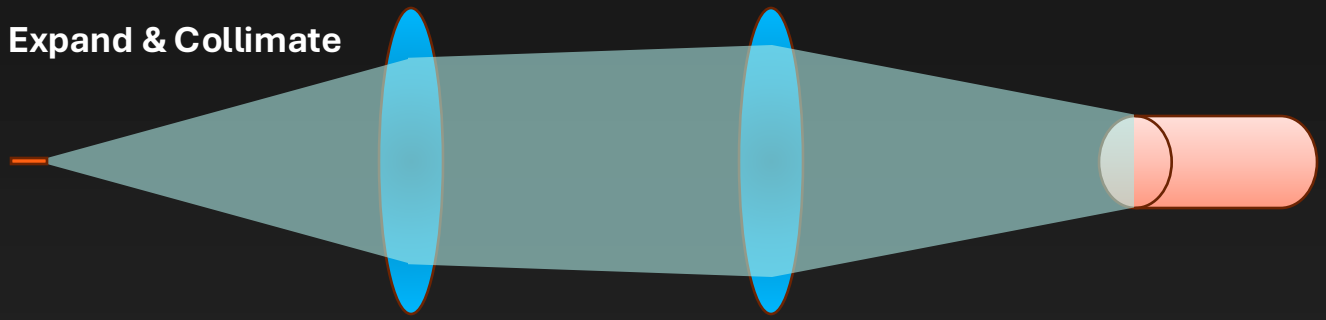
Direct Coupling



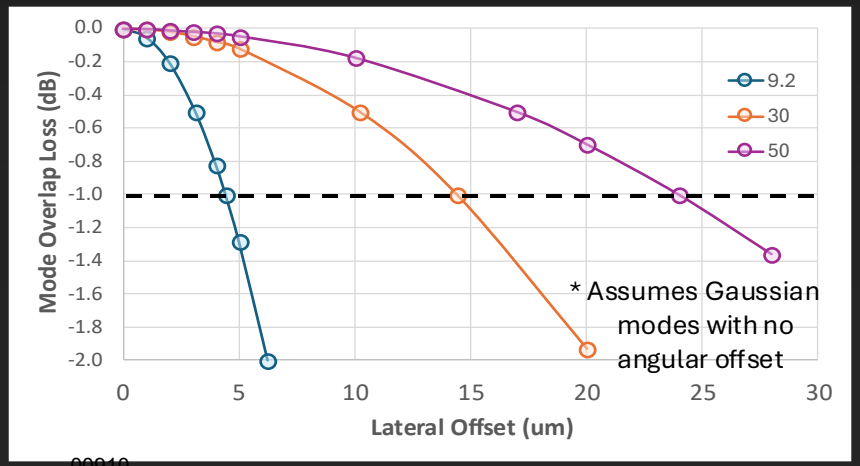
Detachable Coupling with Mode Expansion
Improves tolerance to misalignment between PIC, optic, and fiber

And Collimation
Improves NA of the system. Enables compact optical design that collects all available light.

Expand & Collimate



Reduced Sensitivity to Lateral Offset with Expanded Mode



Mode Field Diameter

1.0 µm	SiN waveguide
3.0 – 6.0 µm	Lensed Fiber
9.2 µm	Single-Mode Fiber

Alignment Tolerance (3σ)

10 – 50 nm	PIC FEOL features
0.3 – 0.5 nm	Attach optic to wafer (permanent)
5 – 20 µm	Fine-align fiber plug (detachable)

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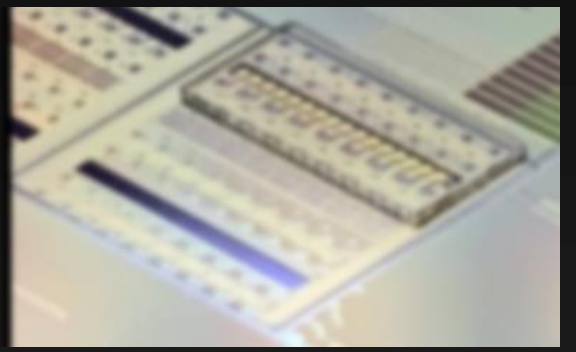
Teramount TeraVERSE® Detachable Fiber Technology

3-Piece Detachable Interconnect System

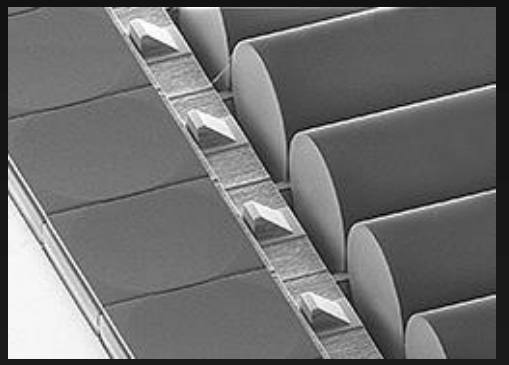
- Photonic Bump – optical elements placed inside PIC cavity
- Mechanical Socket – coarse alignment of Plug to Bump
- Photonic Plug – fiber ribbon aligned to optical elements

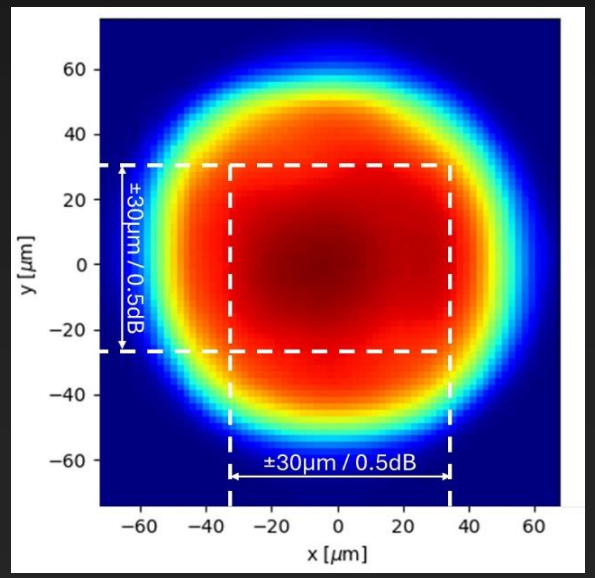
Integrated into GF Fotonix™ platform

Photonic Bump on Wafer

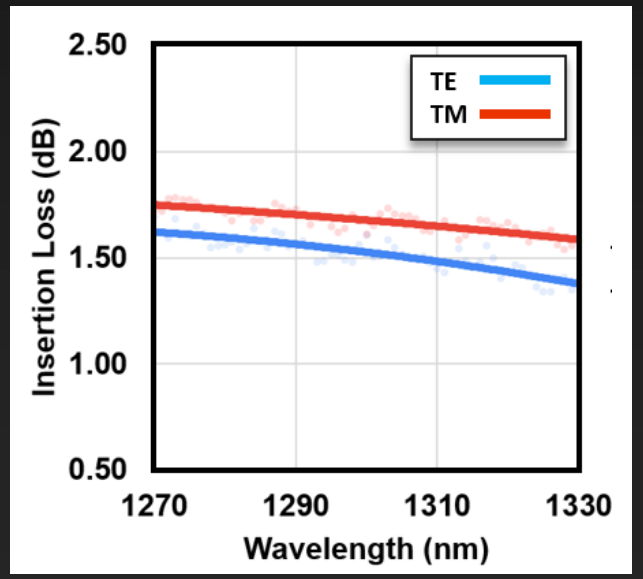


Photonic Plug Detail





Broadband coupling



Broadband coupling

Photonic Plugs in Socket



Images courtesy of

Teramount

A. Israel, *et. al*., "Photonic plug for scalable silicon photonics packaging," Proc. SPIE 11286, Optical Interconnects XX, 1128607 (28 Feb 2020)
A. Israel and T. Hesham, "Fiber to chip optical coupler", U.S. Patent Number 9,804,334 B2 (issued 31 Oct. 2017).

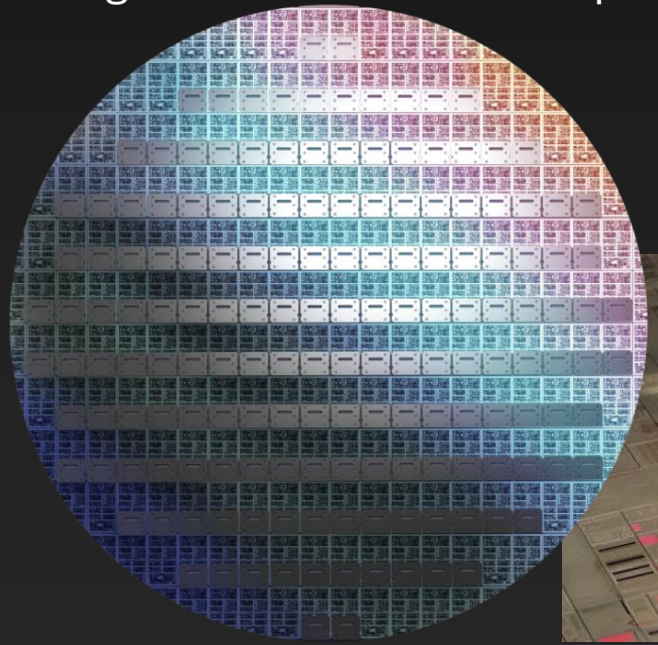
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Senko Detachable Fiber Interface with Wafer-Level optical Testing for Co-Packaged Optics

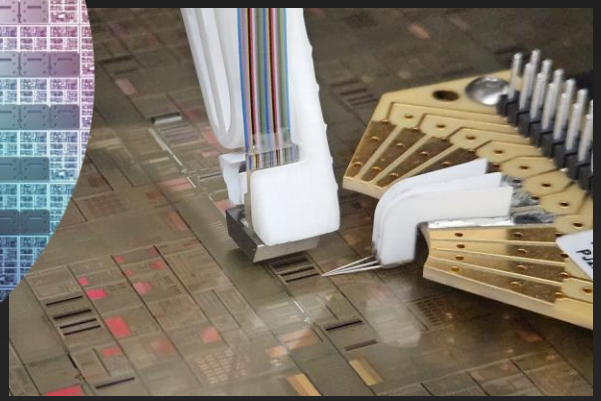
3-Piece Detachable Interconnect System

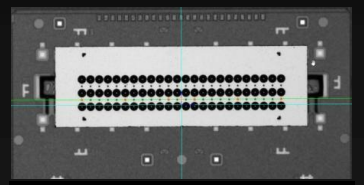
- Micro Prism Array – optical element placed inside PIC cavity
- MPC Receptacle – fine alignment to PIC
- Photonic Plug – aligned to receptacle with MPC Cover Plate

Integrated into GF Fotonix™ platform

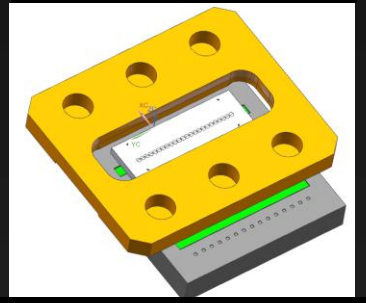


Test connector for wafer level testing

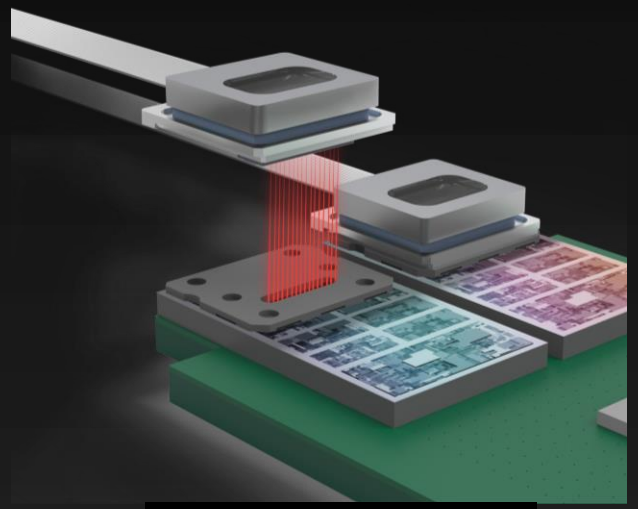




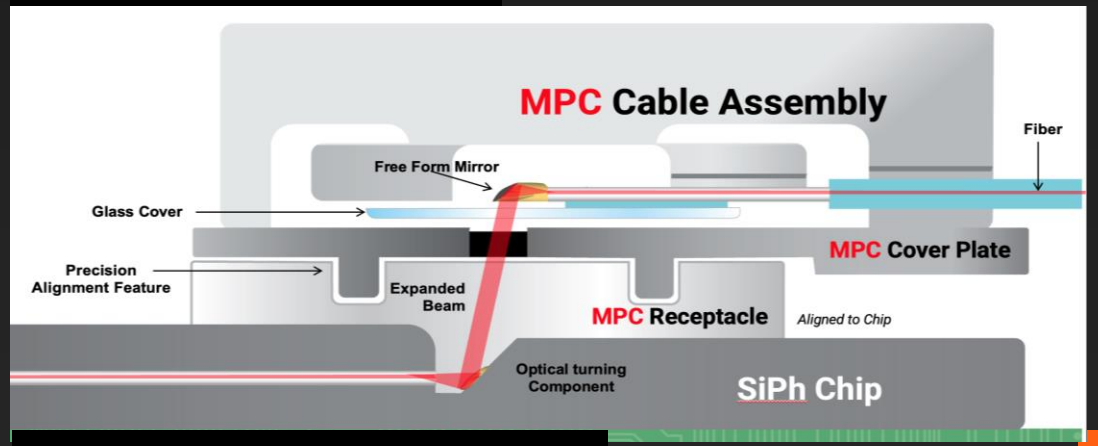
MPA Assembly



Receptacle Assembly



Detachable FAU



Broadband coupling

Meek et al., "Challenges and opportunities of detachable metallic interconnects fiber-to-chip connectors for co-packaged optics in high-volume production", Proc. of the 2026 SPIE Photonics West. San Francisco. Paper 13903-20. January 21, 2026.

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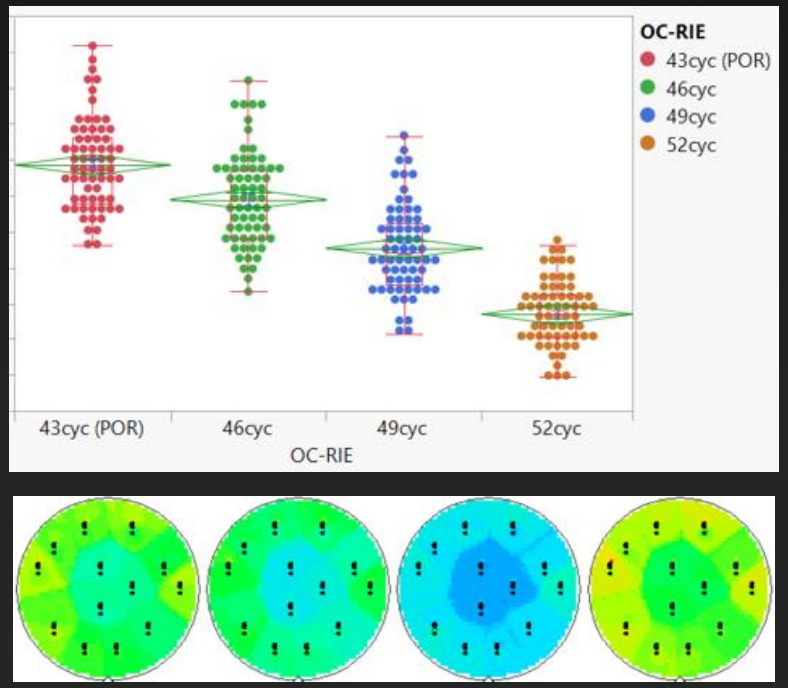
SENKO® Advanced Components

New Features and Components Drive Metrology

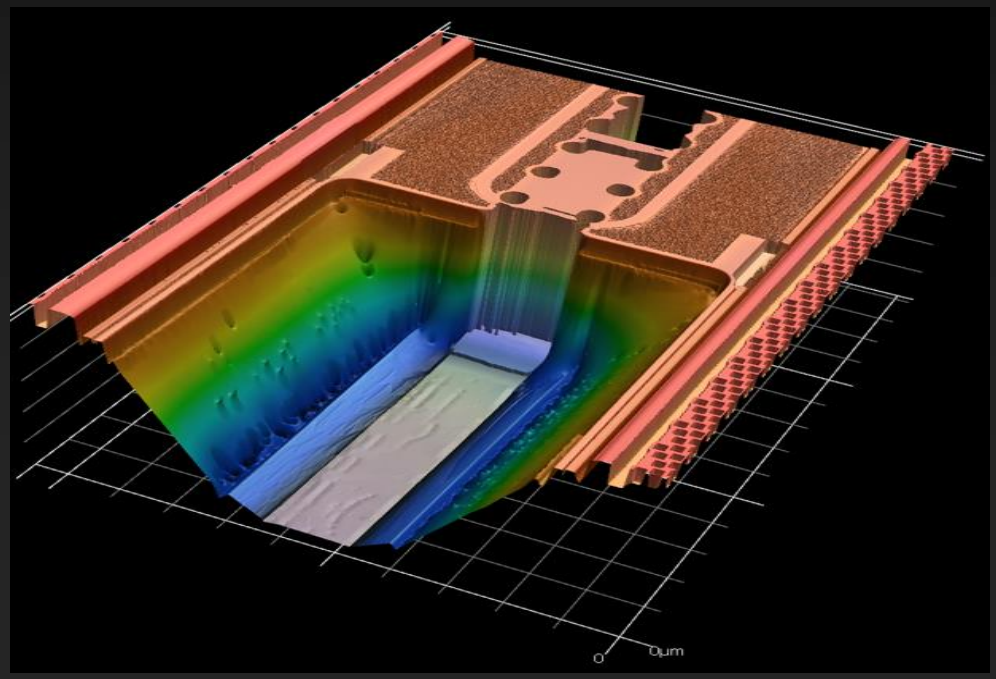
Optical interconnect requires unique inspection tools and methods.

- Laser Confocal Microscopy - detailed 3D visualization.
- 2D/3D inspection system- automated inspection of large CD and defects.

Inline Inspection Results



Laser Confocal Microscope Image of V-groove



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Paradigm Shift Driving New Industry Collaborations

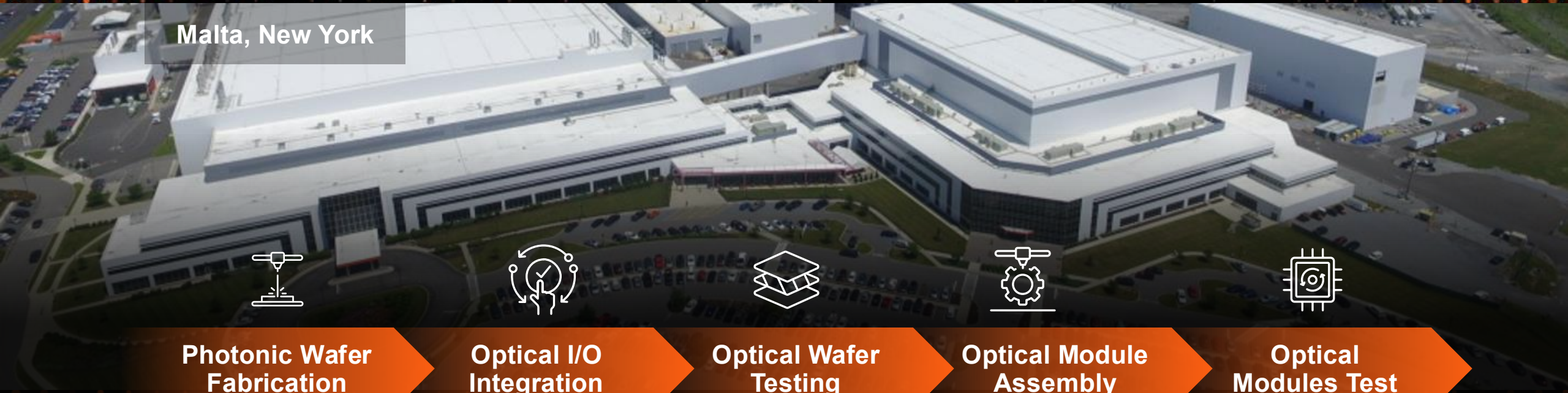
- Scalable active alignment tools delivering speed and accuracy



Bressi et al., "Active alignment for co-packaged optics: an integrated solution to the alignment challenges of multichannel optical devices". Proc. of 2026 SPIE Photonics West. San Francisco. Paper 13903-2. January 20, 2026.

Complete Photonics Development Under One Roof

Fully integrated manufacturing: from Si substrate to known-good optical module

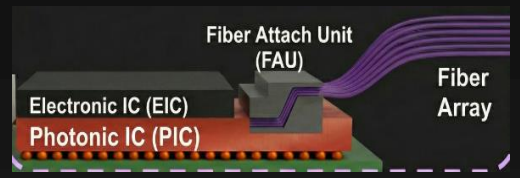


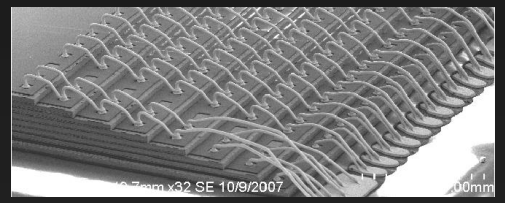
Photonic Wafer Fabrication	Optical I/O Integration	Optical Wafer Testing	Optical Module Assembly	Optical Modules Test
Modulators, Waveguides Photodetectors	Detachable Broadband Optical coupler	Optical Functional Testing	Assembly / packaging of EIC & PIC	EIC / PIC Functional Testing

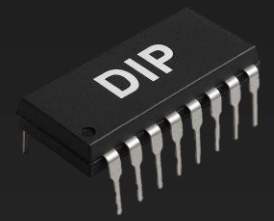
Paradigm Shift Driving New US Manufacturing

What's Old is New Again

50 Years of Innovation – Disrupted by Optical IO









It won't last ! Optical solutions will move to area interconnect

Acknowledgements

Ted Letavic, Kevin Dezfulian, Yusheng Bian, Ken Giewont, Takako Hirokawa, Koushik Ramachandran, Norm Robson, Yarong Lin, Keith Donegan, Zahidur Chowdhury, Arpan Dasgupta, Brian Popielarski, Jae Kyu Cho, Daniel Fisher, Jason Kim, Bob Mulfinger, Ryan Sporer, Vikas Gupta, Rick Carter, Kevin Soukup, Gregg Bartlett, Tom Barber





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