Electrooptic Glass Substrates for Photonic Packaging

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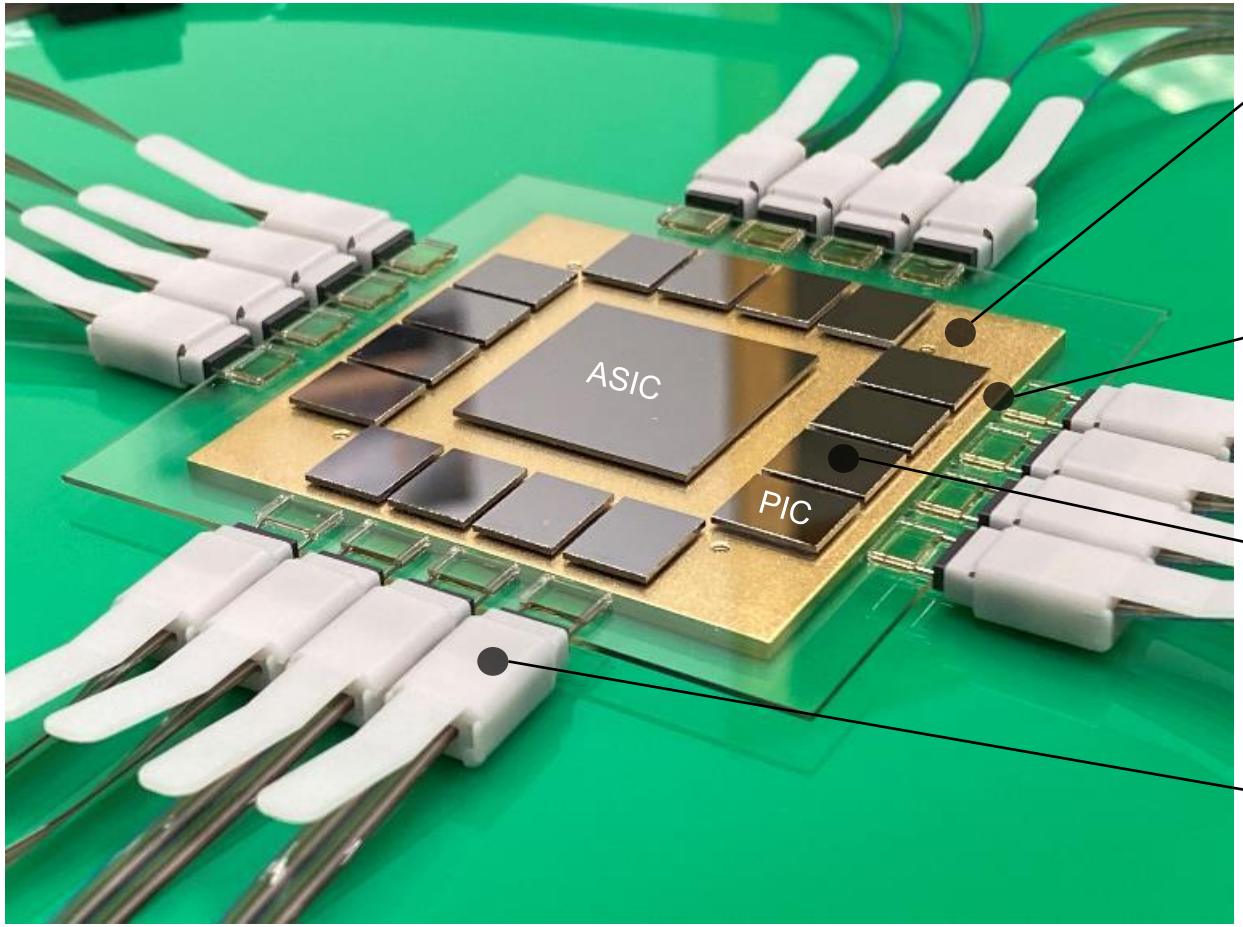
Optoelectronic Glass Substrate for Co-Packaged Optics



Glass Substrate with Through Glass Vias

- Thermal stable → Reduced mechanical stress
- Excellent surface flatness → Low-loss fine-pitch electrical lines and micro-bumps

Glass Waveguides

- Optical fan-out for high density PIC I/O's
- Mechanically de-coupled PIC and fiber interfaces

Flip-chip Attached PICs

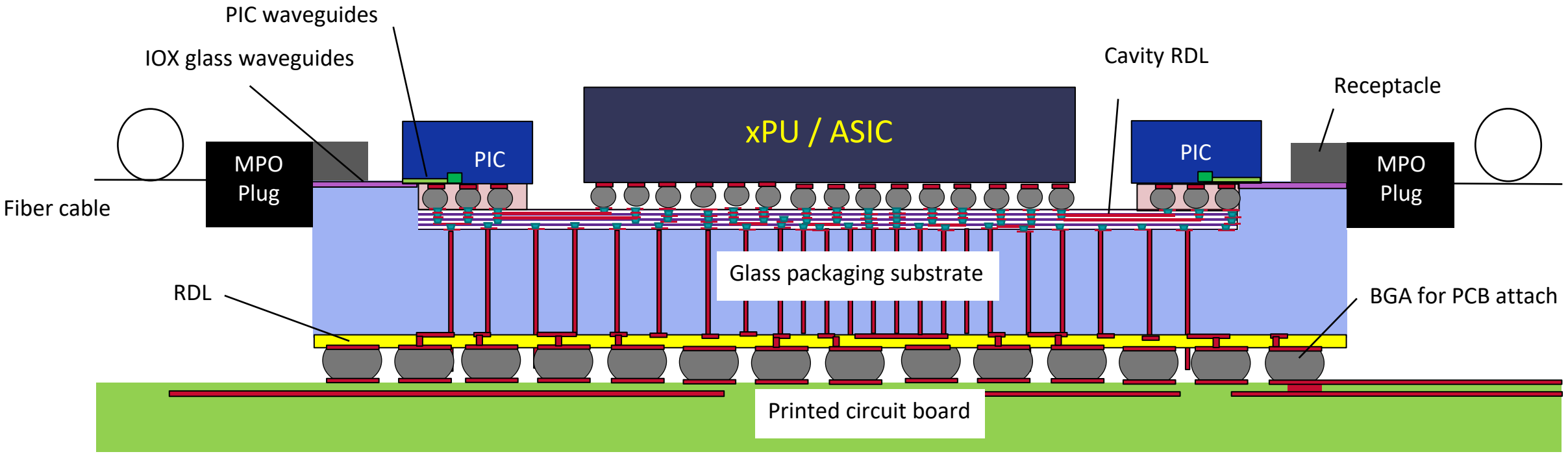
- Low-loss, broadband, high-density optical I/O's by evanescent coupling to glass waveguides

Fiber Connector

- Low-profile 16 fiber connector
- Edge coupled

Value Proposition: Glass Enables Highest Density I/O

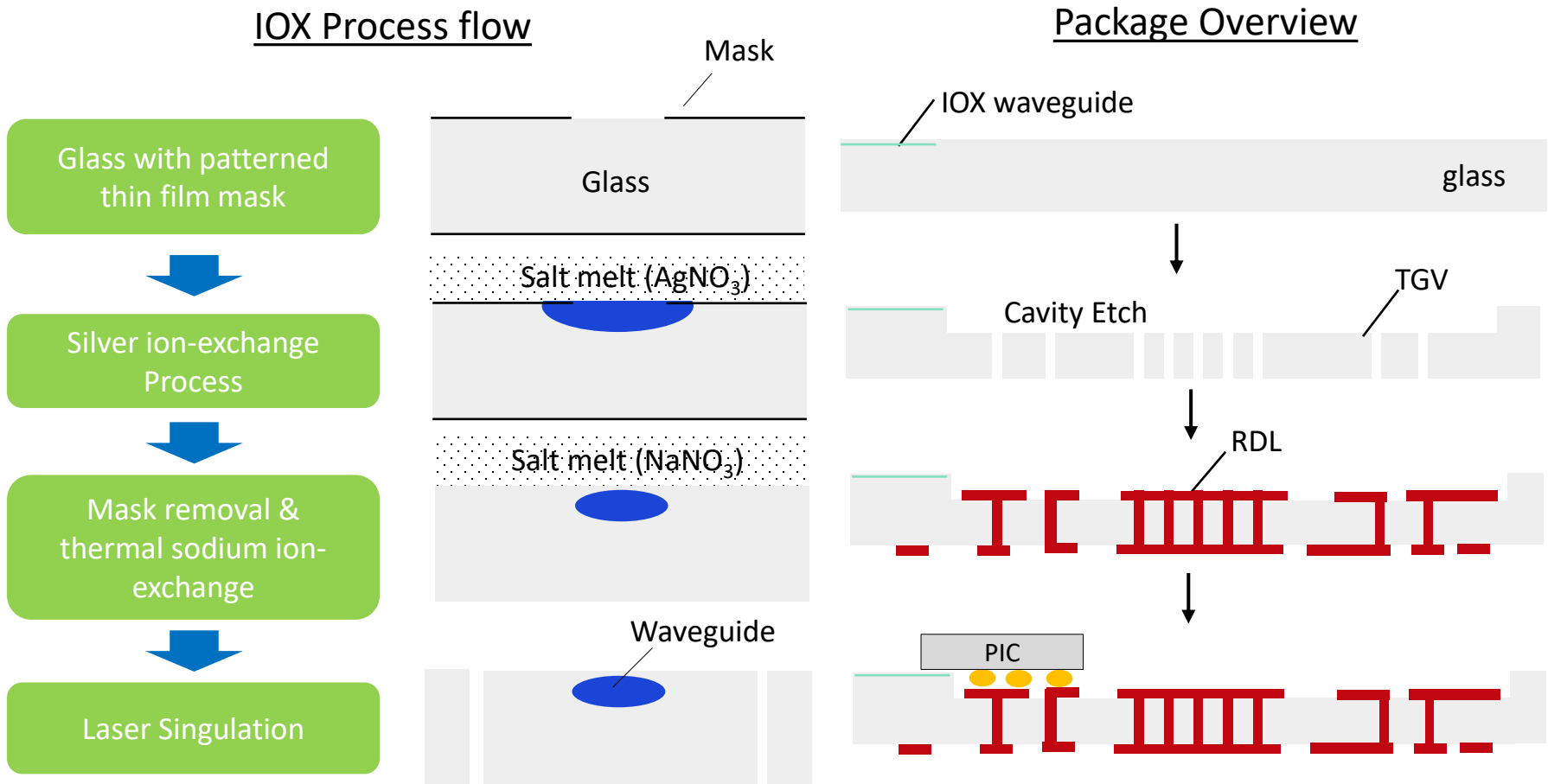
Integrated optical waveguides in glass packaging substrates enable highest density optical I/O's up to multiple 10's Tbps/mm PIC shoreline density



PIC = Photonic Integrated Circuit
RDL = Redistribution Layer

Package Development w/ Ion-Exchange Glass Waveguides

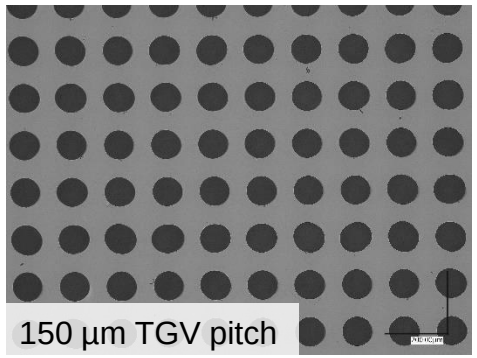
- Thermal ion exchange process between salt melt (ion source) and alkali-containing glass to increase the refractive index in the glass
- Successfully fabricated low-loss (<0.08 dB/cm) single-mode IOX waveguides



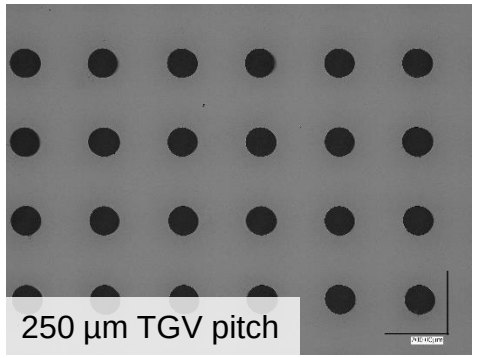
Fine-Pitch RDL on Glass for Routing and Flip-Chip Bonding

10/10µm Cu line/space inside cavity for RDL

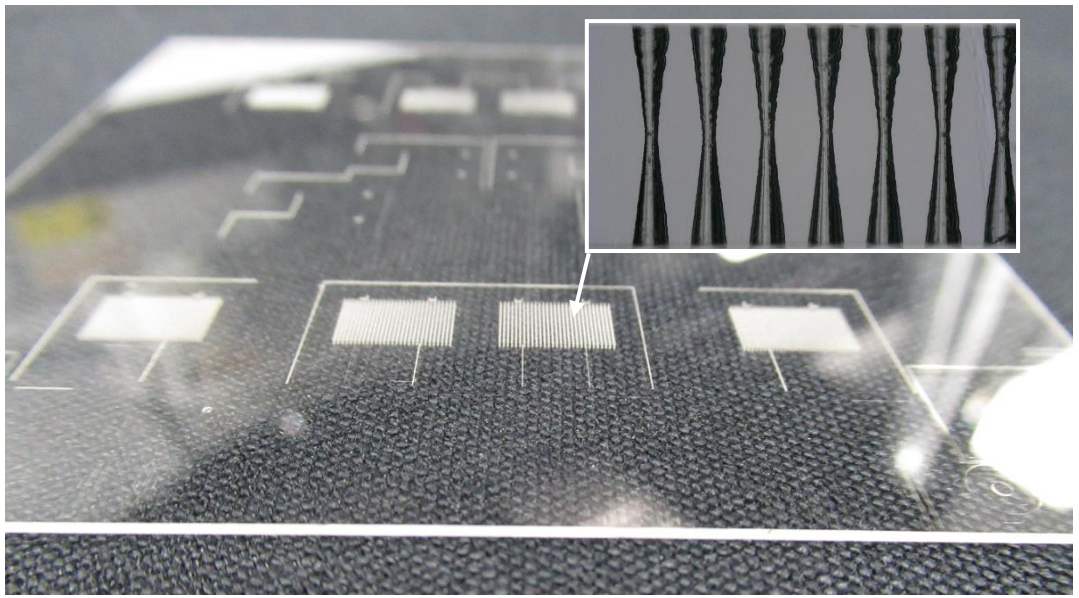
- 1 RDL (developing 3+ for cavity)
- Glass thickness<600µm
- Cavity depth ~30..140µm
- TGV: opening width ~100µm, Waist ~45µm, Min pitch 150µm



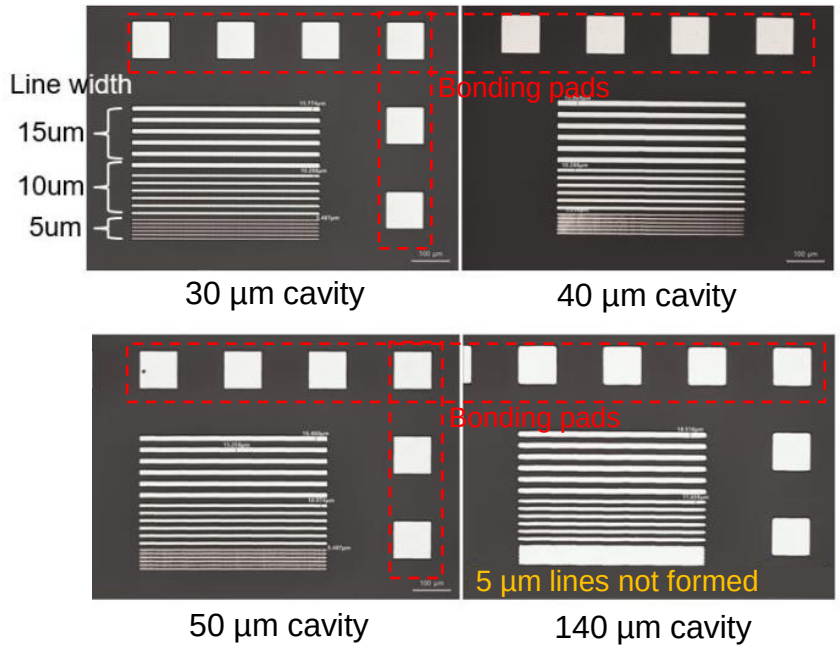
150 µm TGV pitch



250 µm TGV pitch



75mm x 75mm glass substrate with U-shaped cavities, and TGV arrays with 250 µm pitch



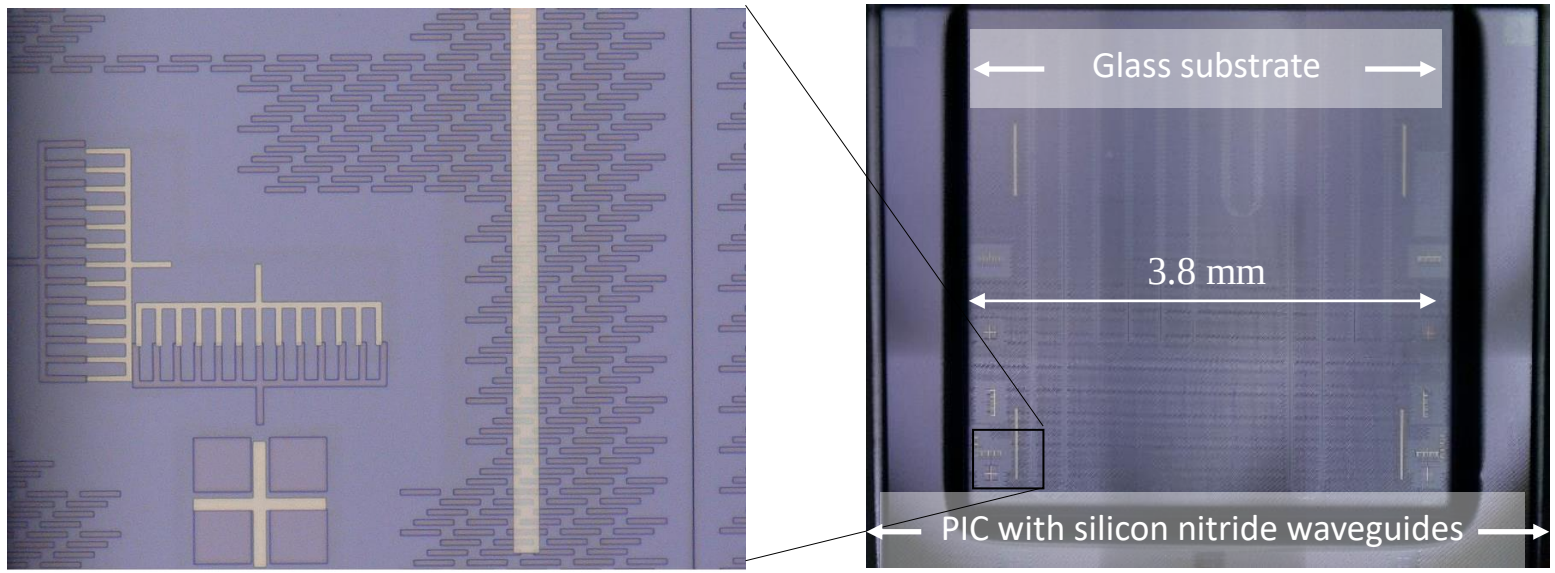
30 µm cavity | 40 µm cavity

50 µm cavity | 140 µm cavity

Cu test pattern inside cavity with bonding pads

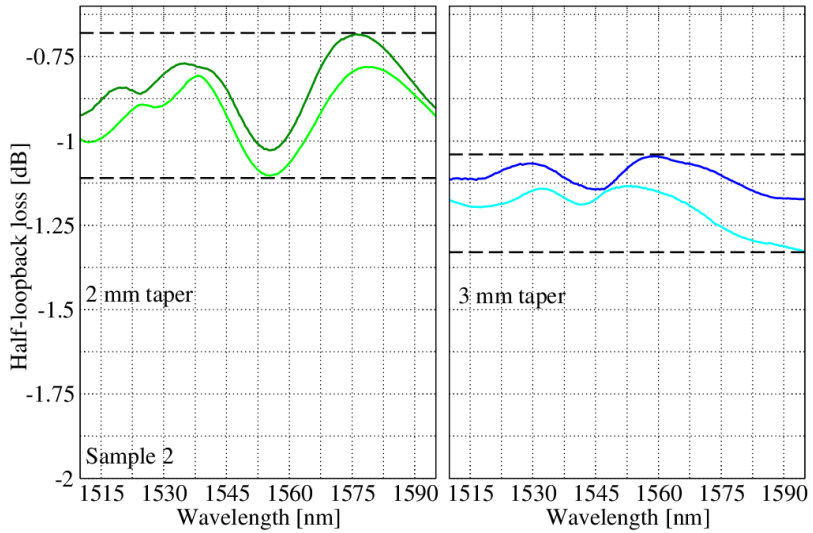
Evanescent Coupling Between IOX and PIC Waveguides

Overcome active alignment and enable pick-and-place assembly of photonic integrated circuit (PIC) on glass



Looking through glass substrate with waveguides at PIC with fiducials

Half-loopback loss

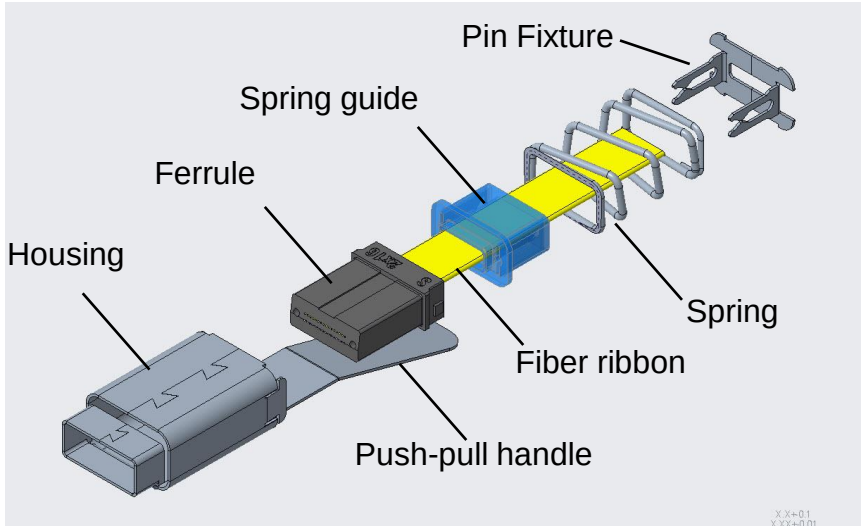


- Measured loss includes SMF to IOX glass edge coupling (0.2 dB) + IOX glass to PIC evanescent coupling
- Lowest and highest loss curves are plotted in dark and light colors for different polarizations
- Measured temperature dependence between 10-60°C → ~0.2 dB increase in polarization dependent loss

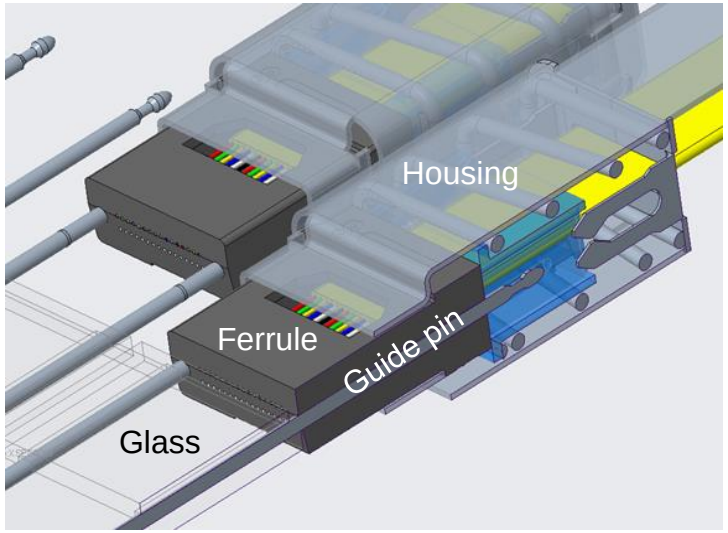
Standard MPO or Low-profile Fiber-to-Glass Waveguide Connector for Solder Reflow

0.42 dB average connector loss with 5N spring force

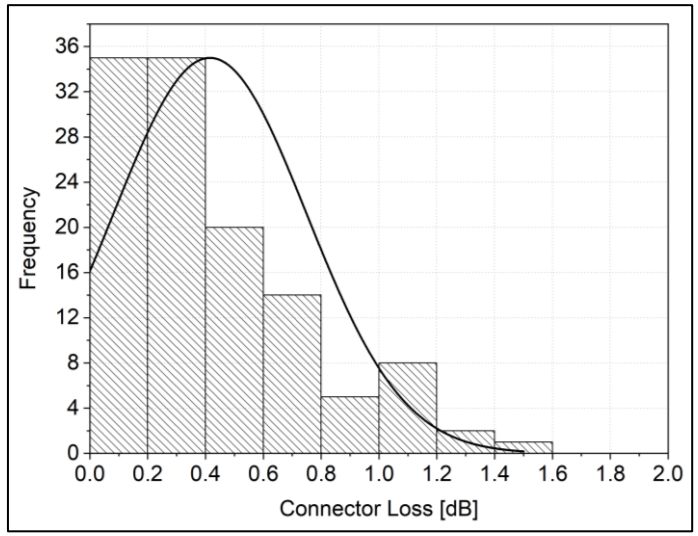
- Passive pin assembly on glass
- Physical contact, MT-ferrule with 16 fibers and 250µm pitch
- 0.3dB additional loss for mode matching
- MPO adapter or low-profile connector (W=7.5mm, H=4.4 mm, L=13 mm)
- No plastic receptacle on the glass for solder reflow



Low-profile Connector Design



Connector Glass Interface



Experimental data for connector with 5N spring

102.4 Tb/s Test Vehicle

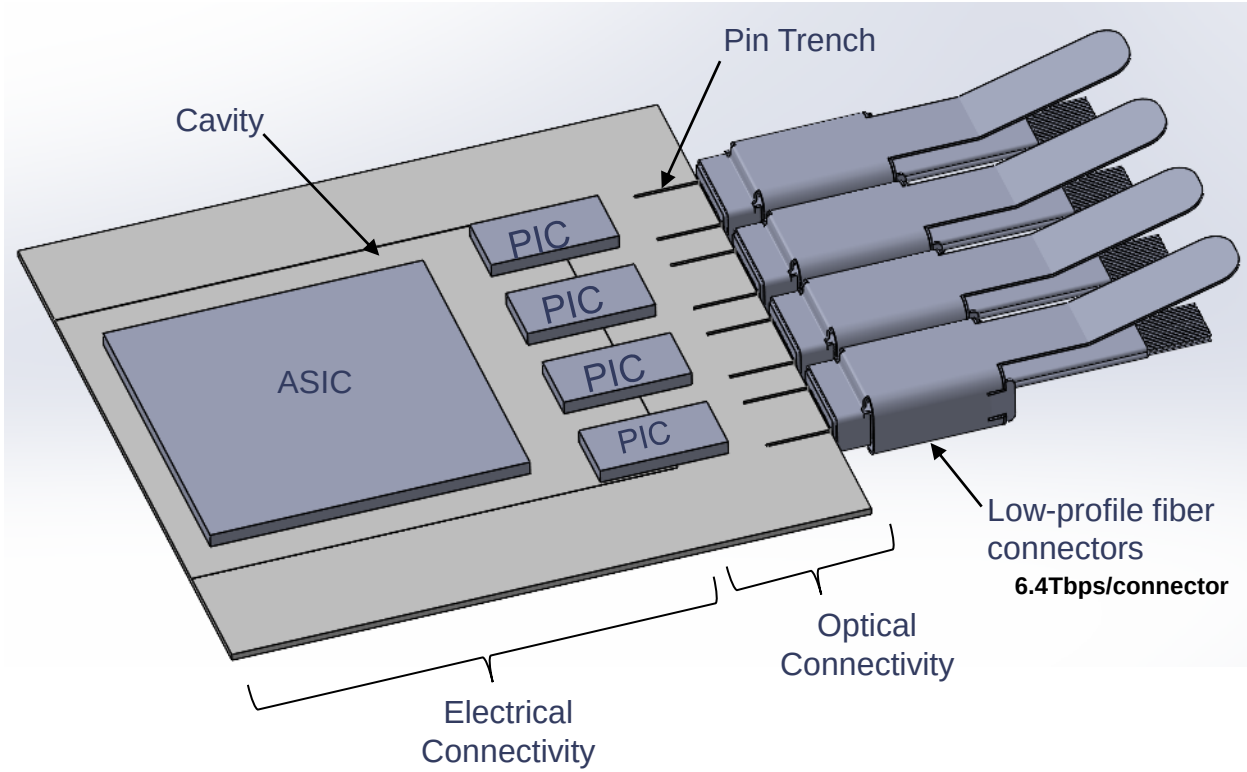
Targeting the major package requirements

- Optical connectivity: end-face fiber coupling, IOX waveguide routing, PIC evanescent coupling
- Electrical connectivity: high speed PIC to ASIC, Power/GND delivery
- Packaging: Cavity RDL fabrication, TGVs, PIC assembly

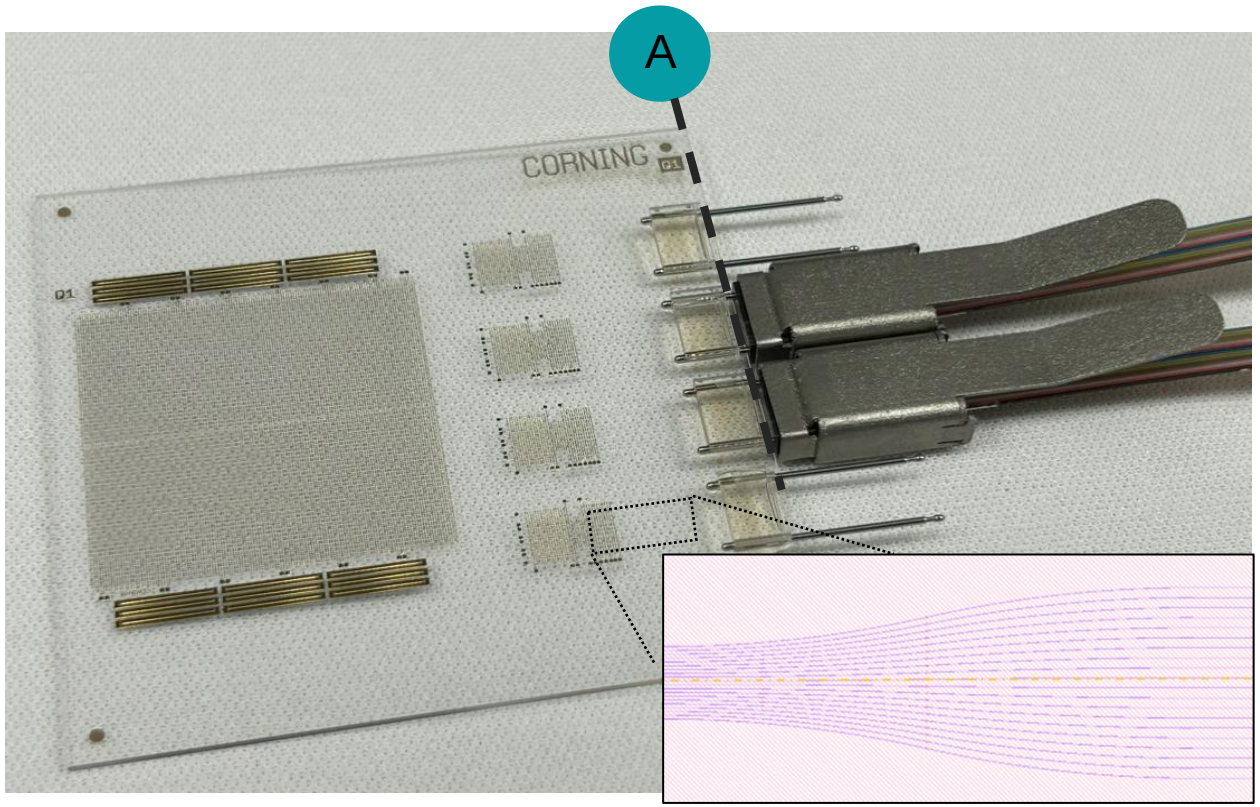
102.4 Tb/s includes 16 optical modules at 6.4 Tb/s - Current focus: one-sided demo

- 4 vs 16 PICs
- Footprint: 50 mm x 50 mm

25.6T demo



Optical Shoreline Density at Glass Edge



- Connector pitch 8mm
- 16 Fibers per connector
- Single core fibers

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Format	Bit Rate (Gbps)	Wavelength	Duplex Capacity (Gbps)	Total Capacity (Gbps)	Shoreline Density (Gbps/mm)
DR	100	1	800	1.600	200
DR	200	1	1.600	3.200	400
FR	100	4	3.200	6.400	800
FR	200	4	6.400	12.800	1.600
DWDM	32	8	2.048	4.096	512
DWDM	64	8	4.096	8.192	1.024
DWDM	128	8	8.192	16.384	2.048

- Optical fan-in / fan-out substrate
- Narrow waveguide pitch below 50um possible
  - Significant increase of PIC shoreline bandwidth density

Summary

- Glass enables integrated electrical and optical connectivity on one packaging platform
- Low loss evanescent coupling demonstrated with potential to go well below 1dB coupling loss from glass waveguide to SiN waveguide
- Detachable optical connector for up to 2Tbps/mm bandwidth density at the edge of the packaging substrate.
- Using glass as optical fan-out element will allow significant increase of shoreline density at PIC edge

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