

***On-board photonic integration – closing the gap
between PICs and optical glass fibers***

Dr. Nikolaus Flöry, vario-optics ag

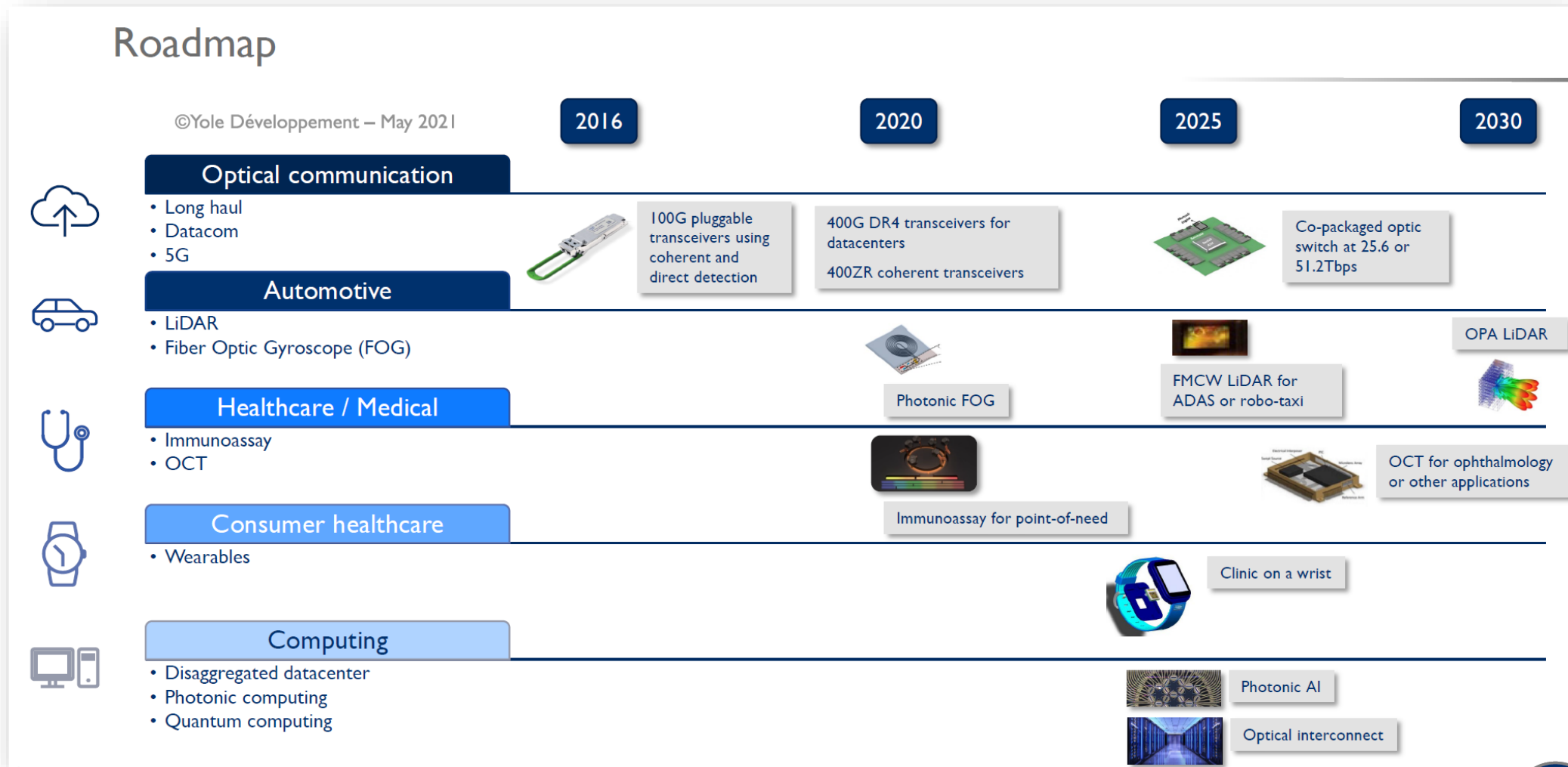


Who we are

- SME based in Heiden, Switzerland
- Spin-off from Varioprint AG (PCB)
- Designer & Manufacturer of photonic boards
- Applications & Markets:
 - Photonic Sensing (Medical, Industrial, Environmental)
 - High-speed on-board communication (Telecom, Aerospace)
 - Photonic chip packaging (Telecom, Sensing,...)



The opportunity: Integrated Photonics is expanding



Source: Silicon Photonics Market & Technology Report, Yole, 2021

The opportunity: Integrated Photonics is expanding

Applications of integrated photonics vary a lot in terms of requirements

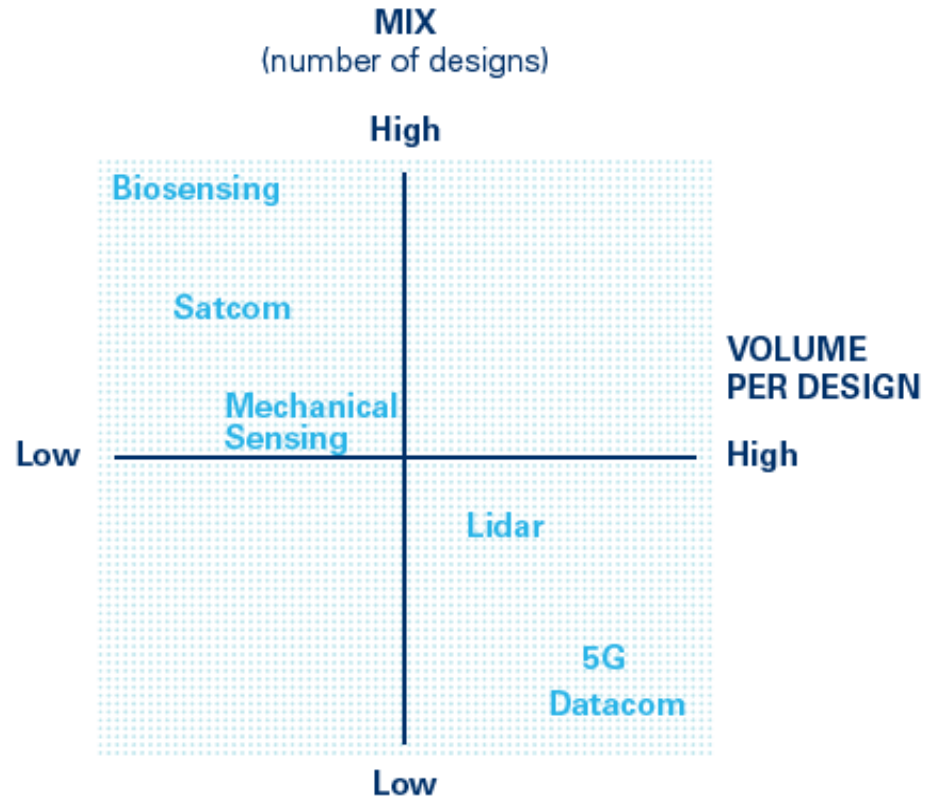
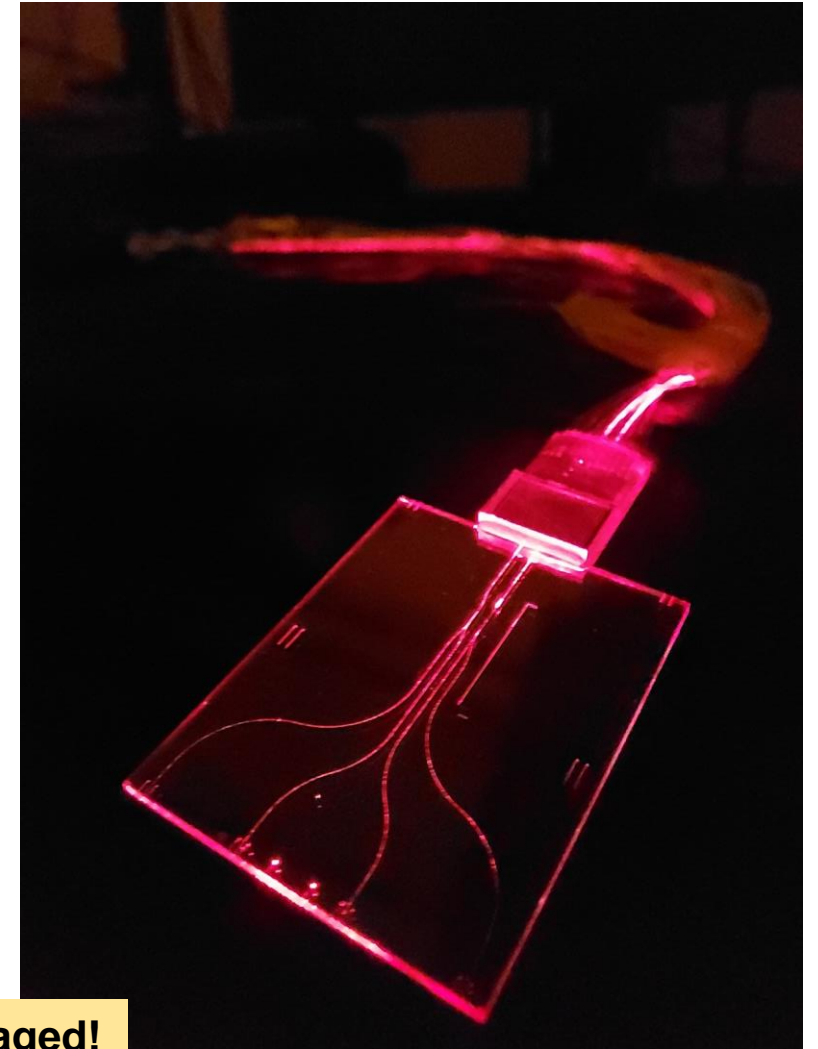


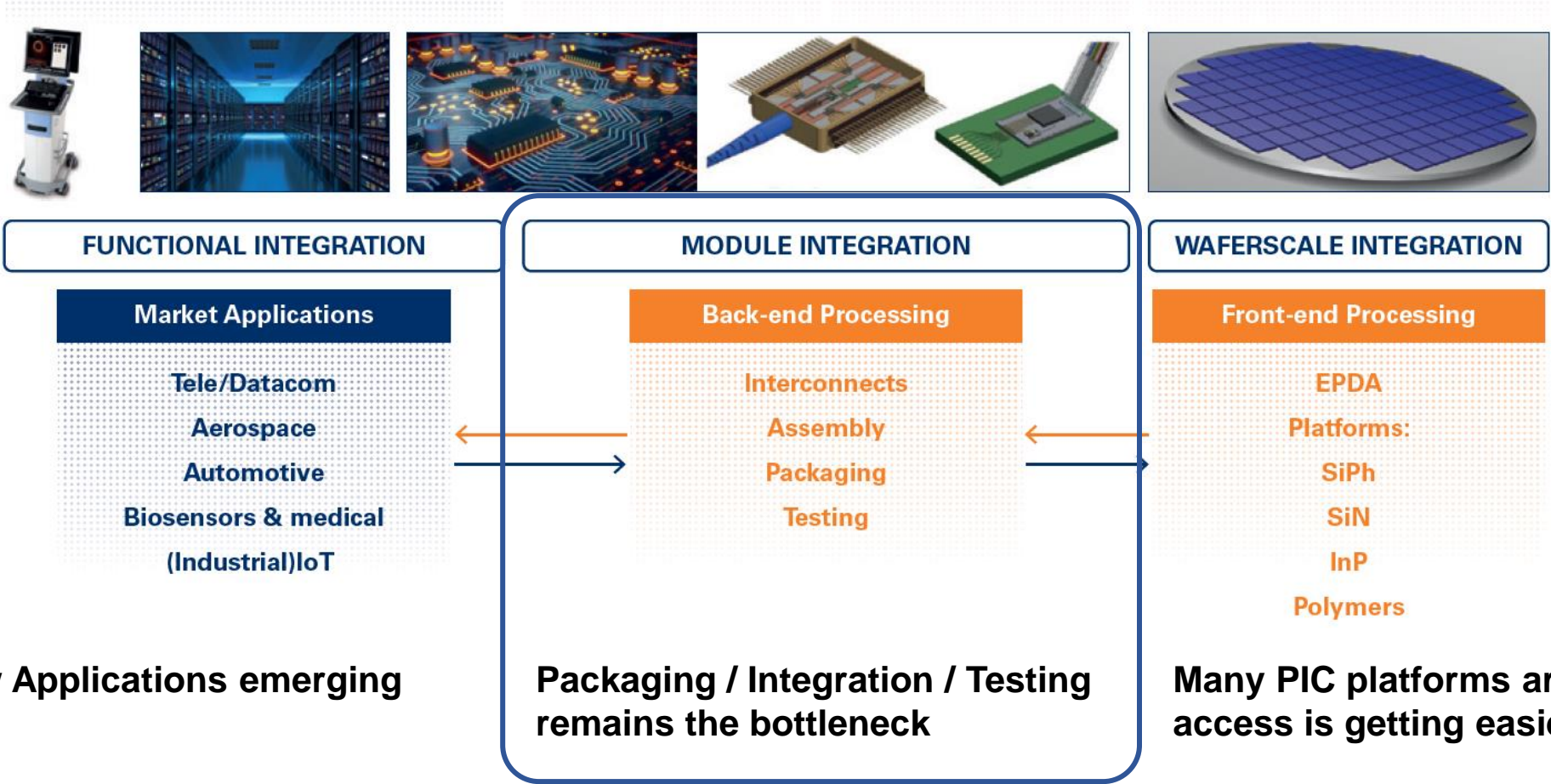
Figure 2 Schematic sketch of applications in the volume VS mix landscape

Source: adapted from IPSR Roadmap 2020

But they all need to be packaged!



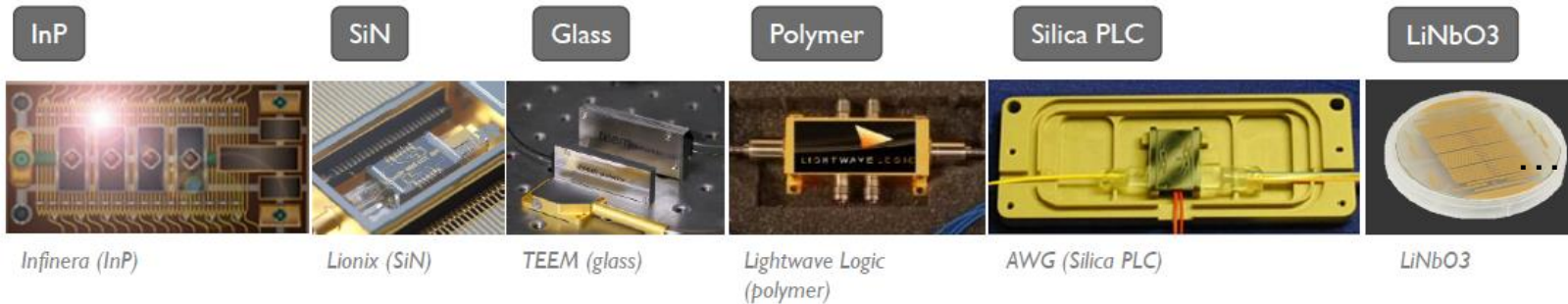
The bottleneck – PIC packaging & integration



Source: adapted from IPSR Roadmap 2020

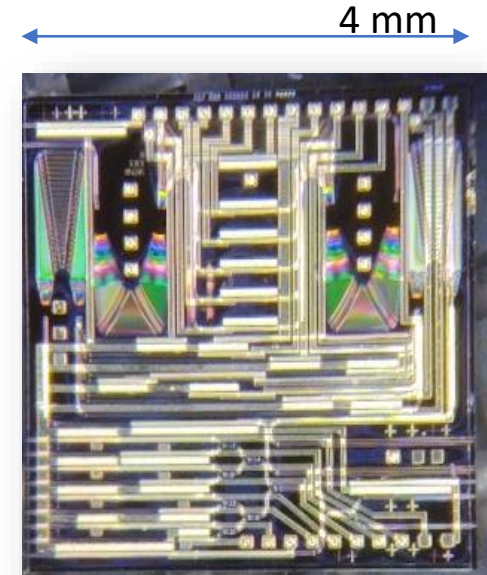
Integrated Photonic Platforms

light-guiding on planar substrates

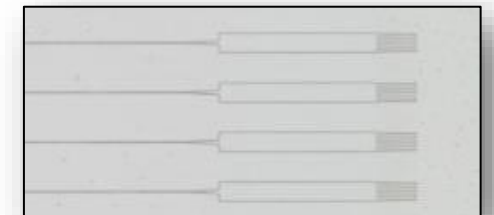


Platforms	InP	SiN	SiPh	GaAs	Polymers
Operating optical window (nm)	1300 - 2000	400 - 2350	1300 - 2000	700 - 1000	400 - 1600
Wafer size	3" - 4" - 5" - (6")	4" - 6" - (8")	4" - 6" - 8" - (12")	3" - 4" - (6")	Spinning on any substrate
Index & (contrast %)	3,4 (10%)	1,8 (25%)	2,5 (>100%)	3,2 (10%)	1,8 (<10%)
Bending radius	100 μm	> 50 μm	> 10 μm	100 μm	> 500 μm
Attenuation (dB/cm)	2,5	< 0,1	3-4	5	< 0,1
Birefringence	< 1 x 10 ⁴	< 1 x 10 ⁴	< 1 x 10 ³	< 1 x 10 ⁴	n.a.
Footprint (typical PIC size)	200 x 300 μm	2.000 x 4.000 μm	200 x 300 μm	-	3.000 x 4.000 μm
CMOS compatibility	No	Yes	Yes	No	Yes
Fiber chip coupling	accurate alignment via edge coupling	Very good edge coupling	accurate alignment via grating coupling	-	Easy
PIC cost	Moderate	Good	Moderate	-	Low
Packaging cost	Challenge	Good	Challenge	-	Low

Source: adapted from IPSR Roadmap 2020



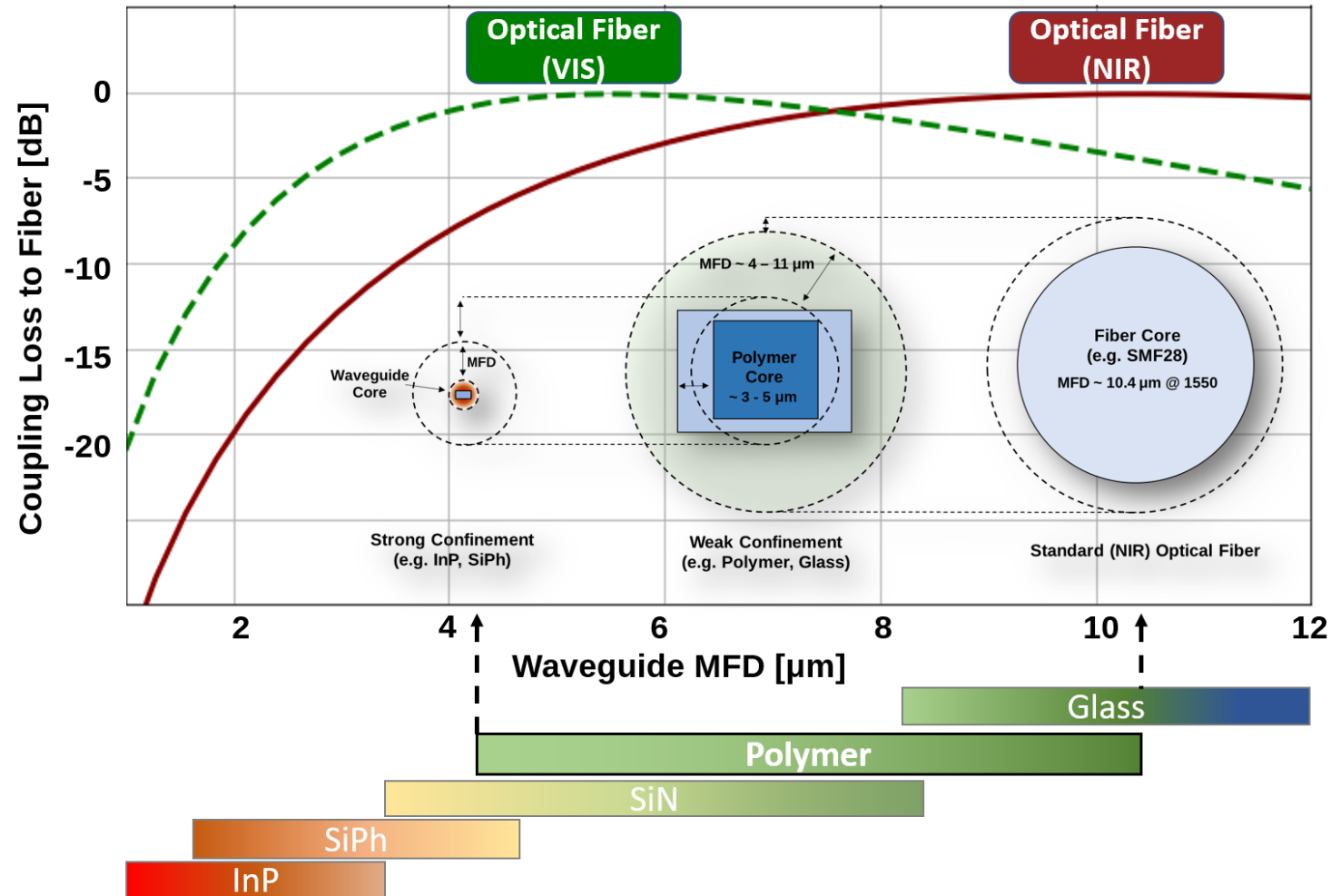
InP Chip



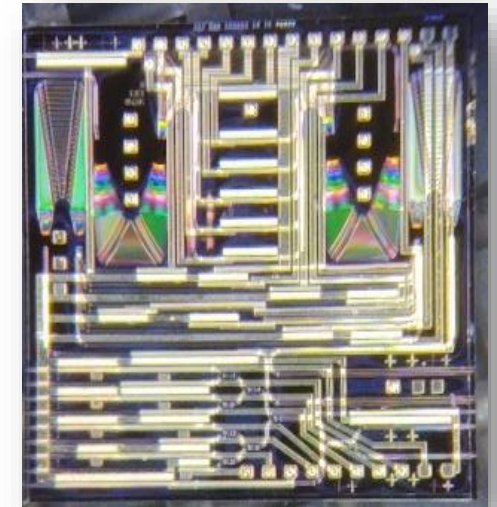
Polymer Waveguide Chip

Closing the gap: Polymer Photonics

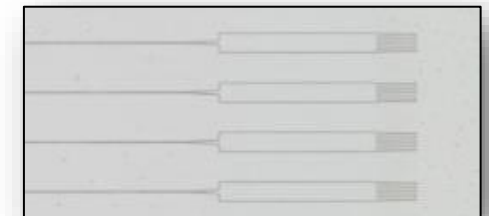
for on-board photonics



4 mm



InP Chip



Polymer Waveguide Chip

vario-optics Polymer Photonics Portfolio

> 15 years of Waveguide R&D Know-How



Process / Technology

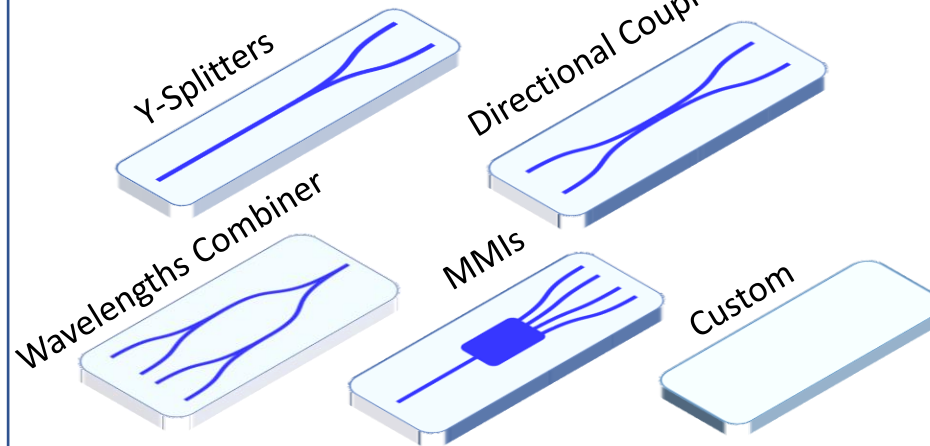
Polymer	Multimode	30 – 500 μm
	<ul style="list-style-type: none"> 500 μm 250 μm 50 μm 	
	Singlemode	2 – 8 μm
Glass	<ul style="list-style-type: none"> 3 μm 5 μm 	
	Singlemode	~ 5 μm
In collaboration with		

Functionality

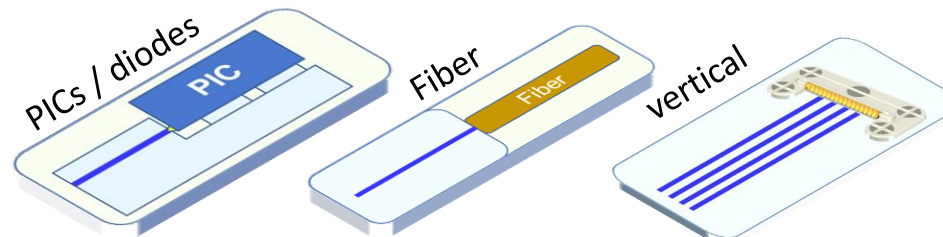
Modefield / NA Adjustment



Splitters & Combiners



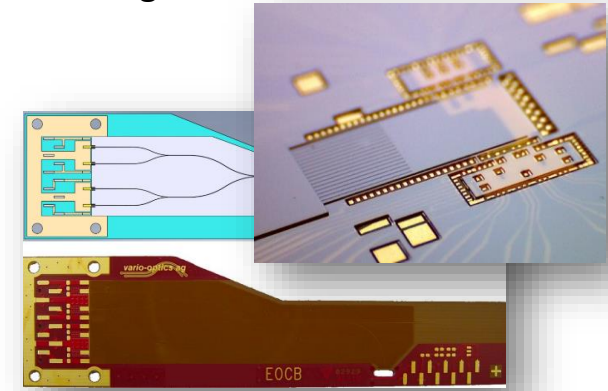
Connectivity



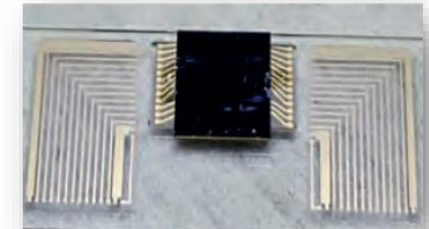
Integration & Assembly

Optical Electrical Mechanical

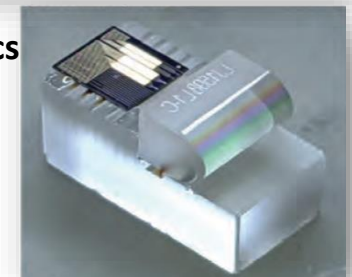
PCB Integration

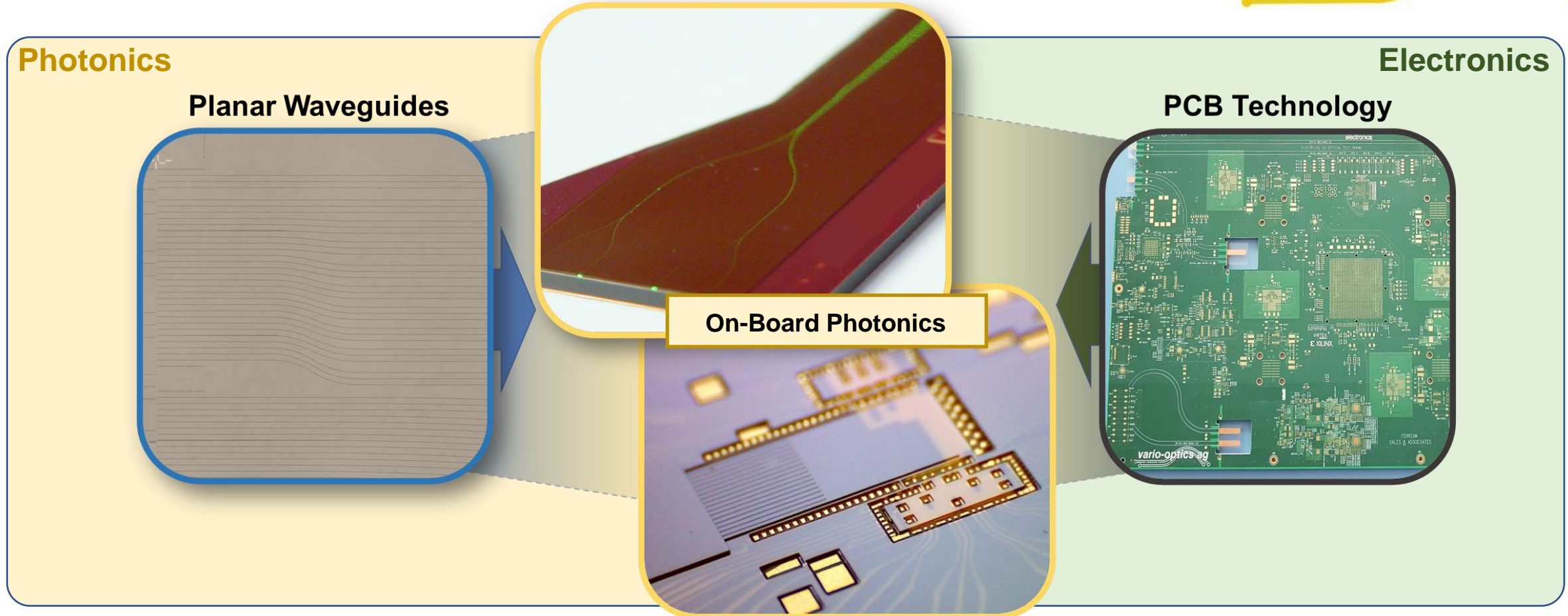


Glass Interposer



Free-Space optics

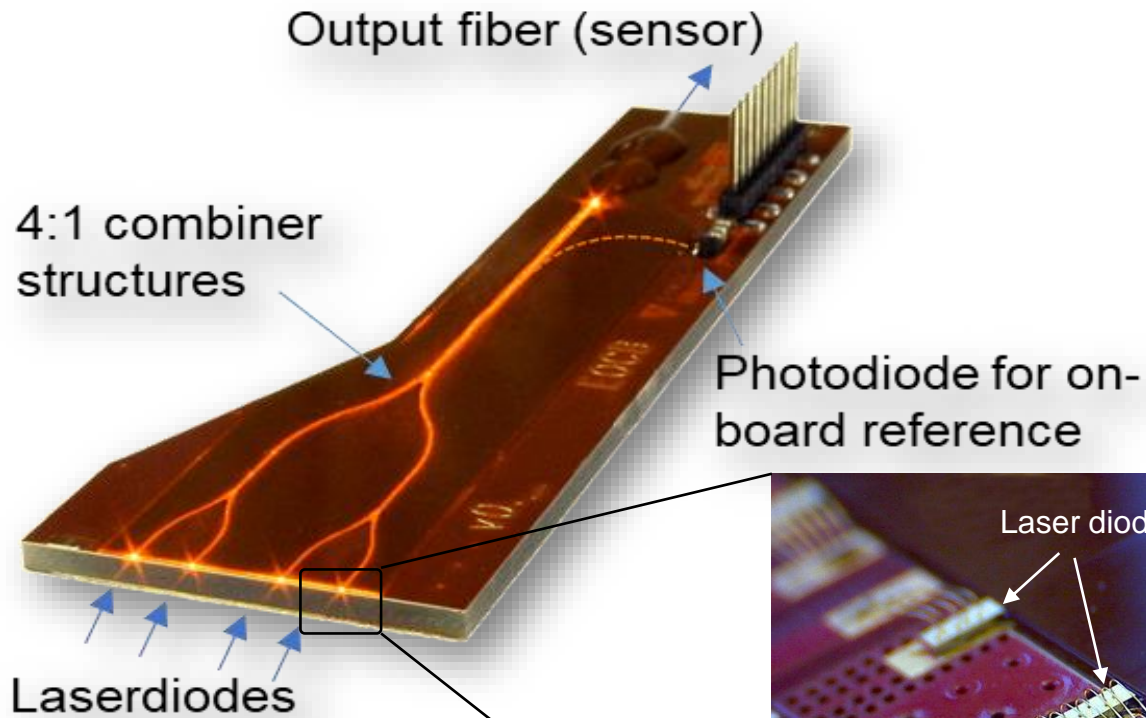




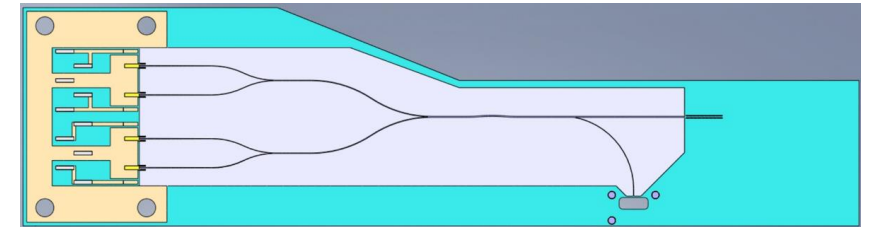
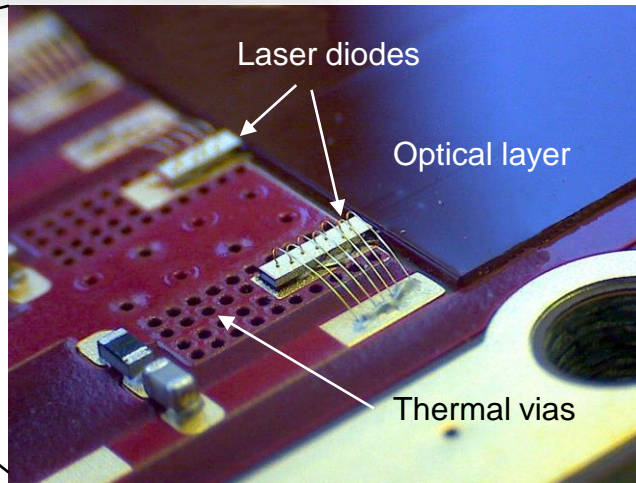
Polymer (integrated) Photonics...

- ... employs planar waveguides & functional (passive) structures
- ... allows efficient coupling to glass fibers
- ... can be integrated with standard PCB Technology

Example: Light-Guiding Multi-Wavelength Laser-Source



- 100 μm Multimode Waveguide Design
- Highly efficient 4:1 coupler & 5% Splitter to photodiode
- Passively aligned to MM glass Fiber
- Highly integrated, fits into a cigarette box
- Outperforms free-space and fiber based optics



Example: On-chip Interferometer

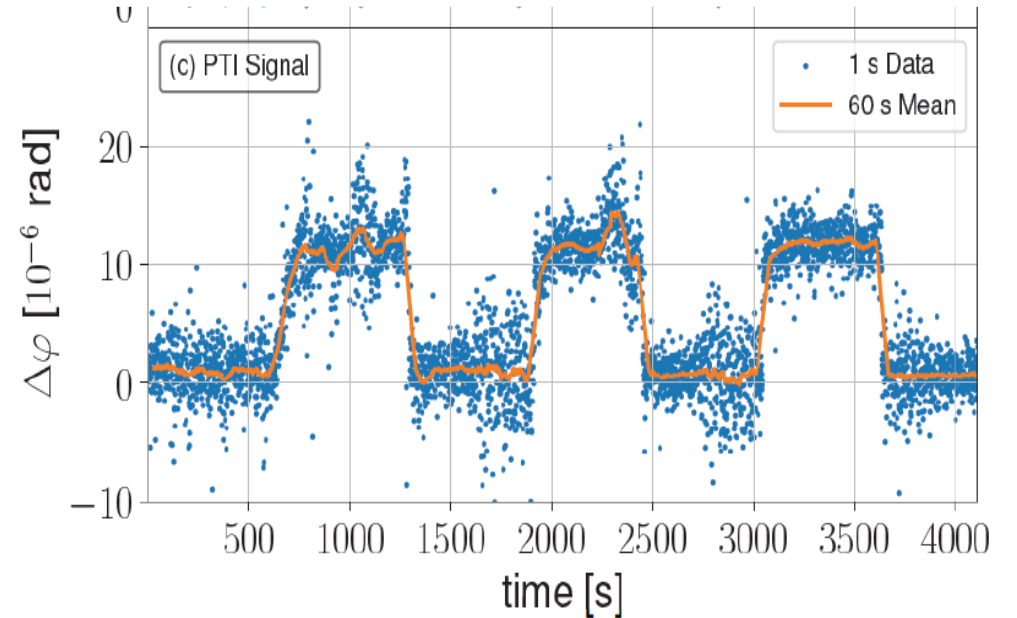
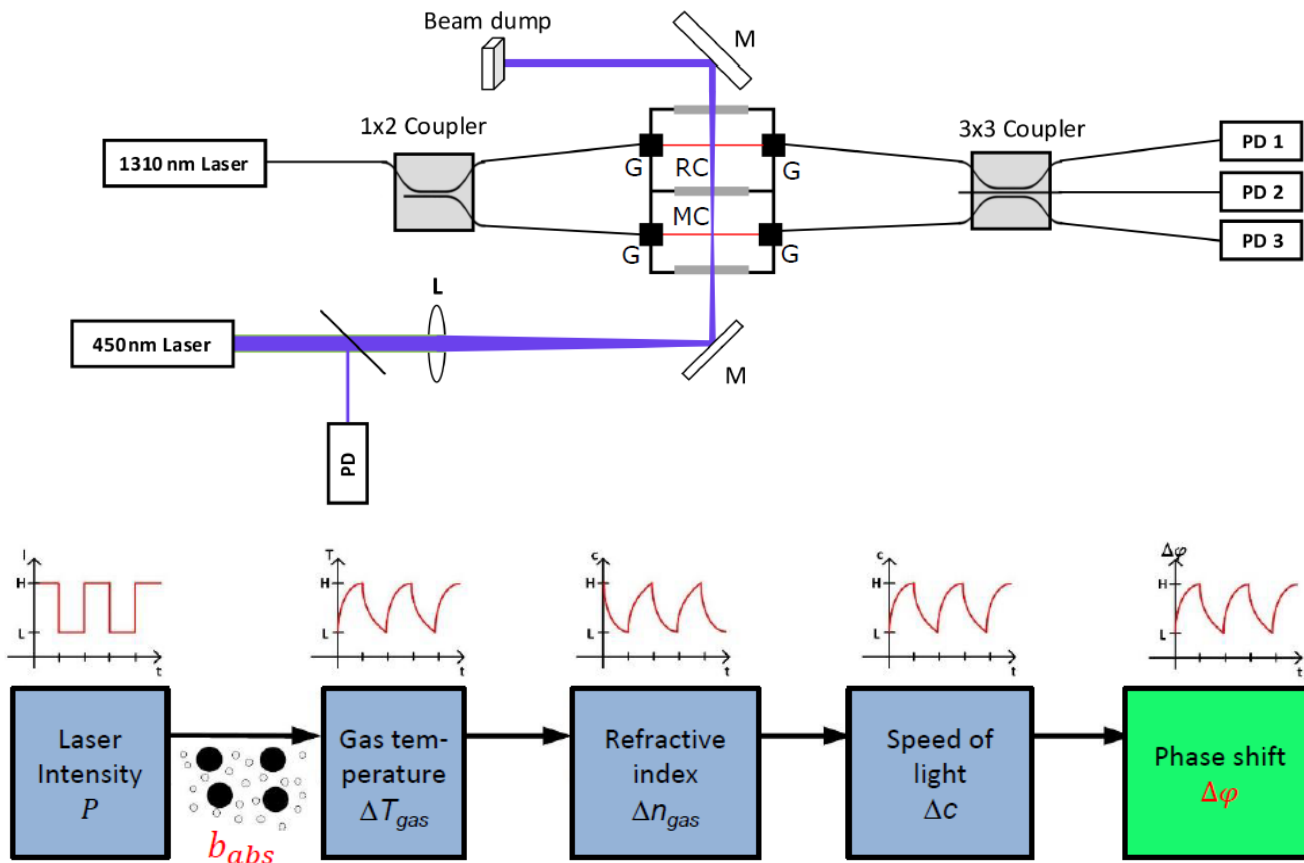
- On-chip – based on integrated photonics (planar waveguides)
- (Mach-Zehnder) Interferometer

Application of on-chip Interferometer

Black Carbon Particle Sensing



Photothermal Interferometry

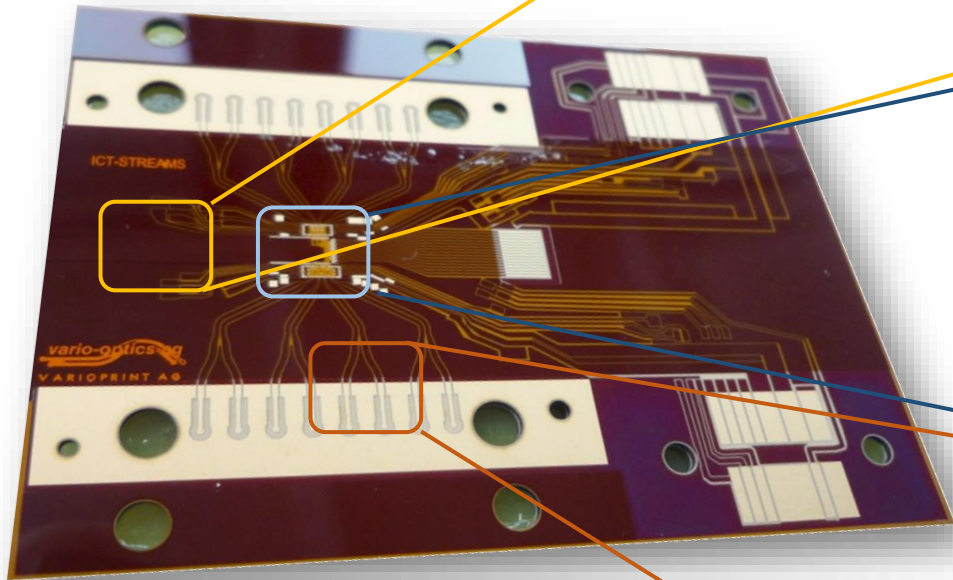


- Phase-shifts of $< 10^{-5}$ can be detected
 - Noise floor $\sim 2 * 10^{-7}$ (1σ , 60s)
- Current detection limit $\sim 10 \mu\text{g}/\text{m}^3$ BC
- Corresponding to optical path length change of $\ll 1$ nm

Waveguide based passively demodulated photothermal interferometer for light absorption measurements, November 2022, [Applied Optics](https://doi.org/10.1364/AO.476868), DOI:10.1364/AO.476868

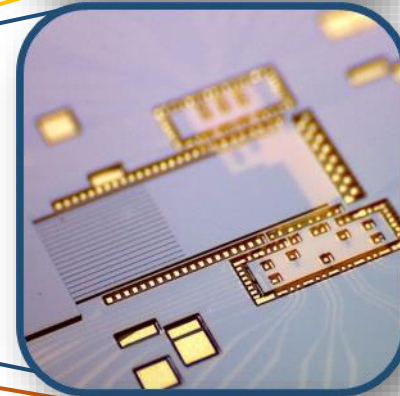
Example: PIC Packaging Platform

based on on-board photonics



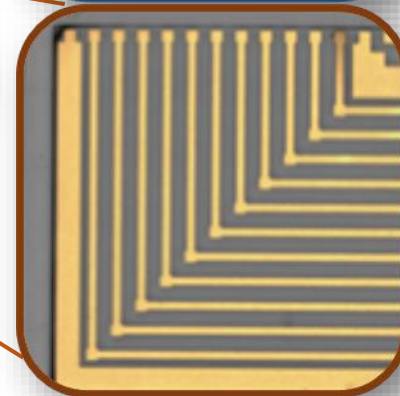
Planar Waveguides

High I/O number optical Fan-outs
On-chip mode conversion (e.g. SiPh to Fiber)
Polarization maintaining Waveguides



Optical Interfaces

Efficient PIC-Waveguide Coupling
(Adiabatic or Butt-Coupling)
Fiber-Interface & Connectors



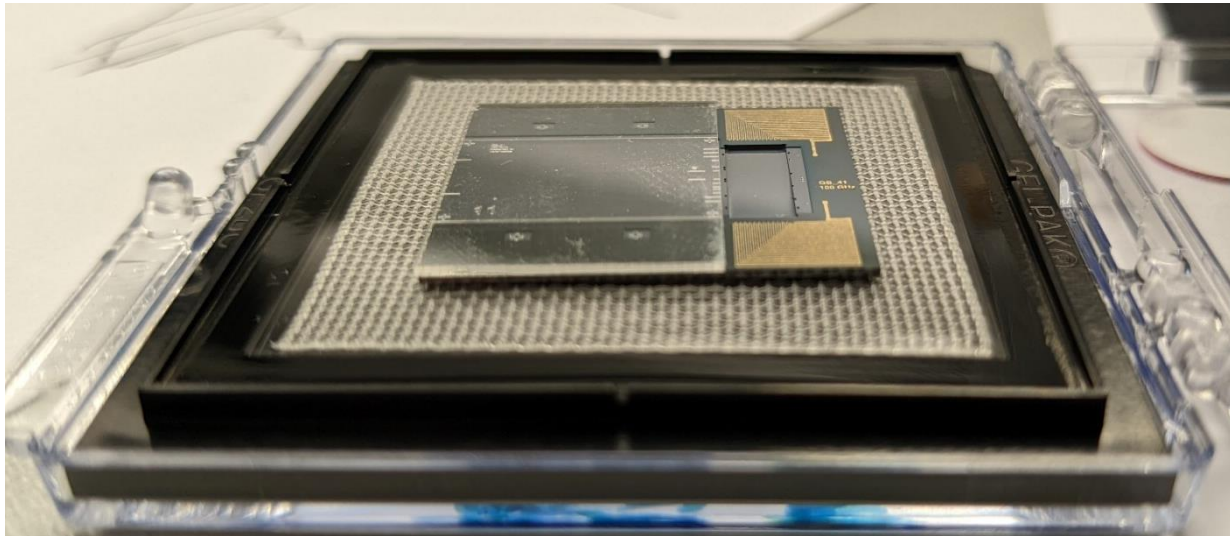
Electrical Interface

Metallization & PCB Integration
Fine-Pitch, Flip-Chip Bonding
RF Interface

Example: PIC Packaging Platform

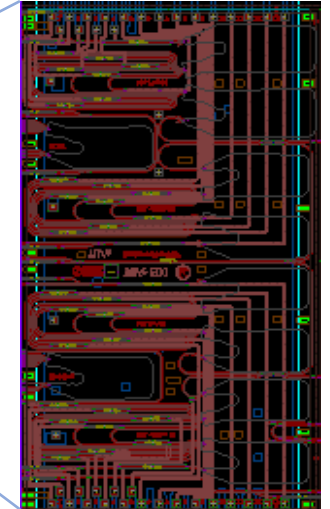
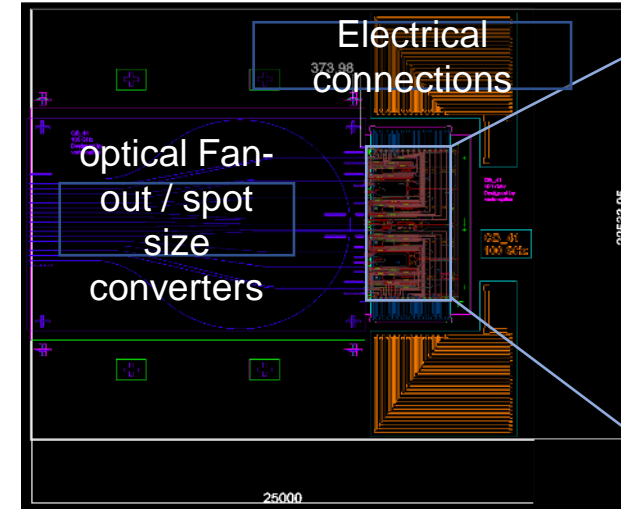
H2020 ICT QAMeleon

Photonic Interposer for multi-channel InP PIC:

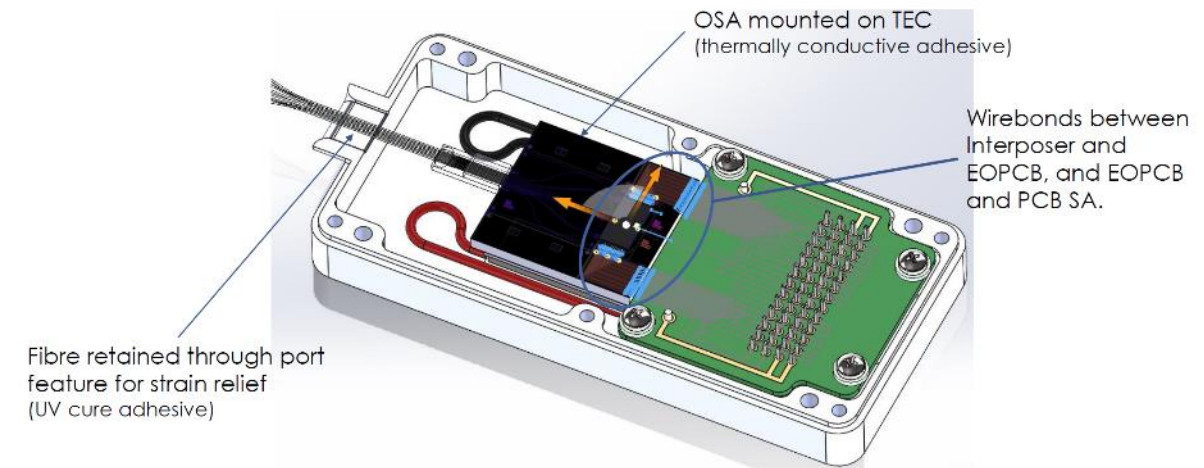
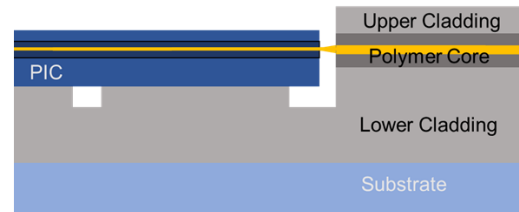


Electro-optical interposer (vario-optics)

InP Chip



- **Butt-coupling interface** with passive Z-Alignment
- **Metallizations for 100GHz**
- **Si substrate with TEC**
Thermal control



Example: ICT-QAMeleon

Reconfigurable Optical Add/Drop Multiplexer (ROADM)

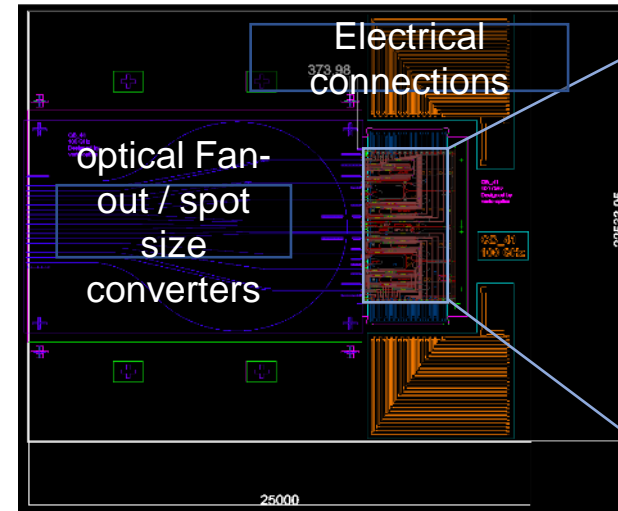
Optical Interface

- 16 optical interfaces I/O
- Fan-Out: 30um to 250um pitch
- Mode conversion: PIC to fiber

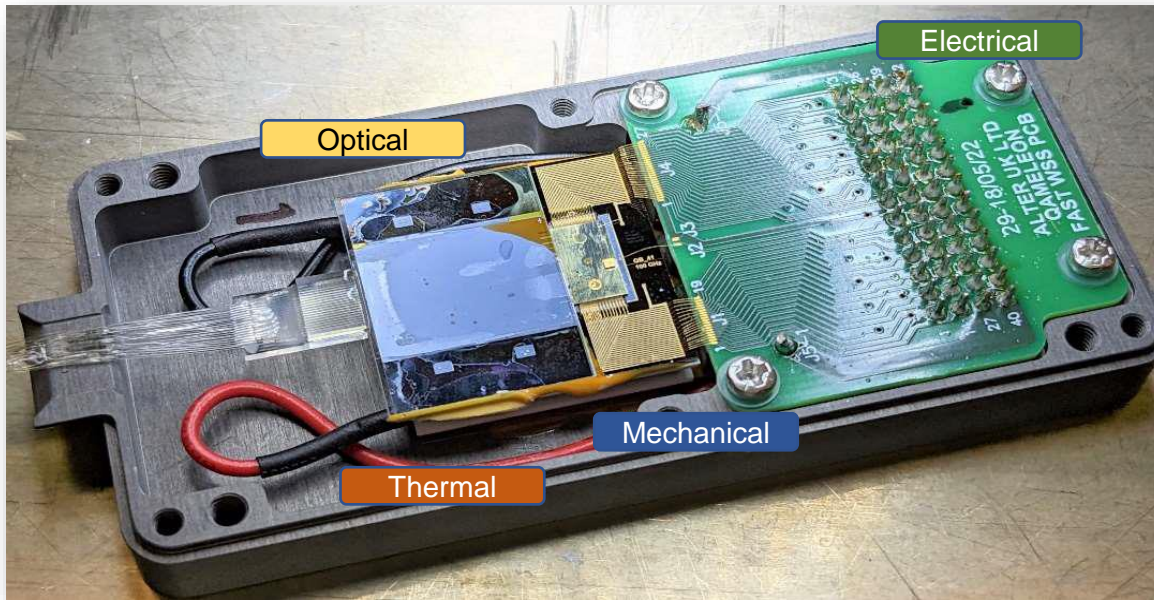
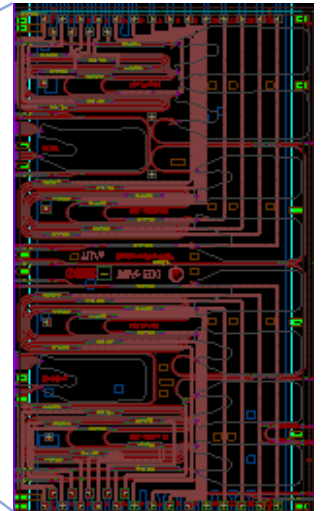
Electrical Interface

- Narrow traces on interposer (5um)
- High-Speed RF interfaces (> 100 GHz)

Electro-optical interposer (vario-optics)



InP Chip

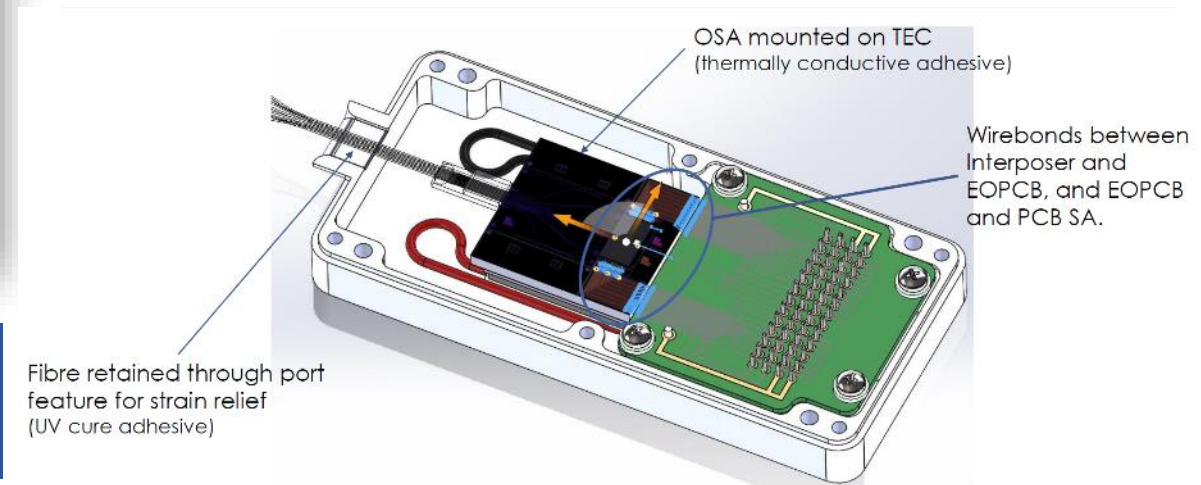


Thermal

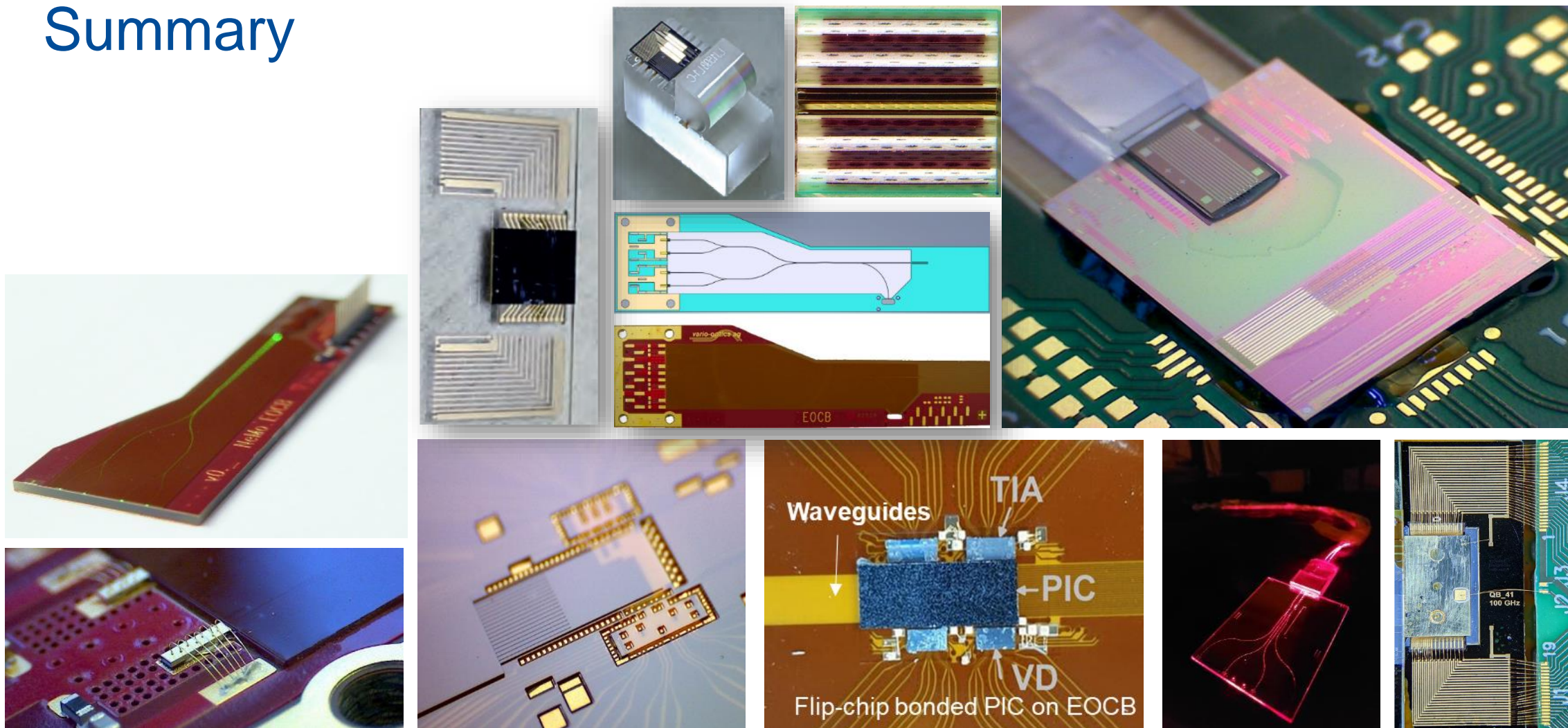
- TEC controller integrated
- Thermal stabilization

Mechanical

- Precise alignment features for PIC
- Semi-passive alignment possible



Summary



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Engineering to Volume Production

Design & Development

- Feasibility Studies
- Simulation & Design
- Electro-optic Co-Design

Prototype/Pilot Production

- Portfolio of building blocks
- Evaluation boards

Manufacturing

- MPW
- Dedicated Custom Runs