

Forschungsfabrik Mikroelektronik Deutschland

Fraunhofer Group for Microelectronics in Cooperation with Leibniz
Institutes FBH and IHP



Photonics for the Internet and Datacenter

Martin Schell, Fraunhofer HHI

HHI's origin: Long Reach (~100s-1000s km) Telecom



Traffic growth 40% to 60% p.a.
since a couple of decades

Small market sizes of 100.000s pcs
p.a. worldwide

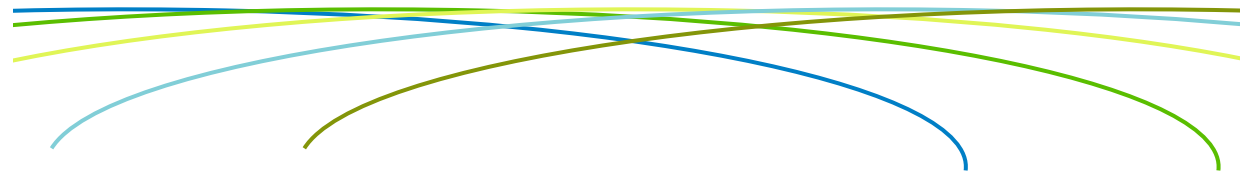
Optochip performance is
paramount

Long Reach: Dispersion is our Challenge ... and problems grow quadratically with speed

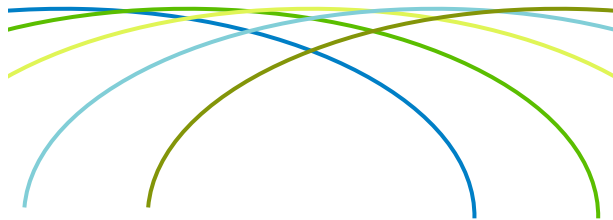
At fiber input, 1 bit is
~ 1 cm long ...



... at output, it has
smeared out to ~ 1 m
and overlaps with 100
others



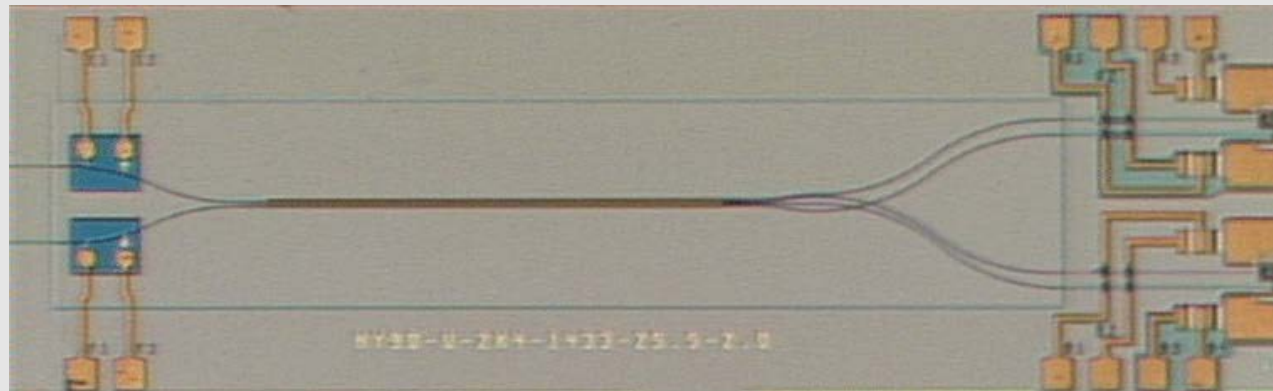
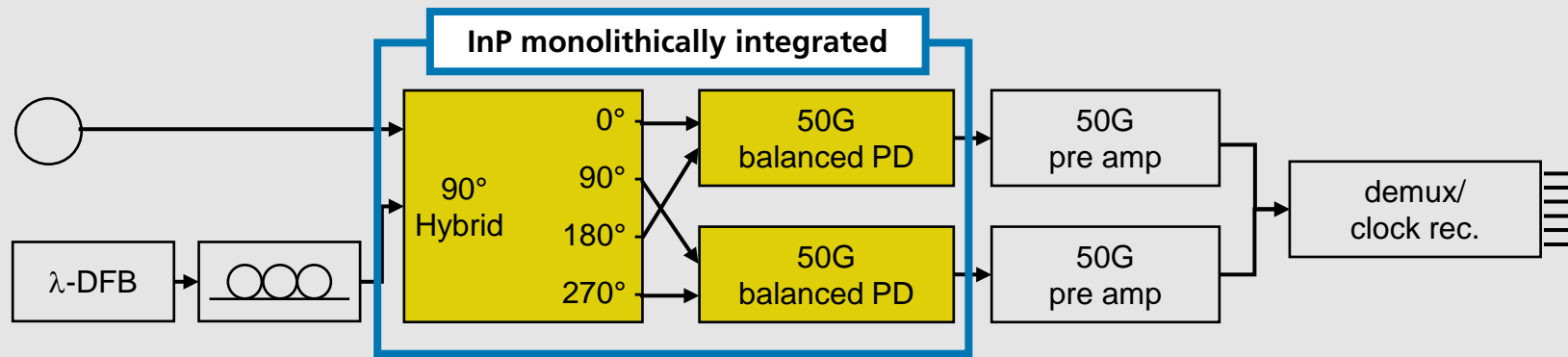
Fourier transforming allows for Compensation but Requires Detecting Phase and Amplitude



$$\text{FFT} \Rightarrow e^{iD\omega^2} \Rightarrow \text{IFFT}$$

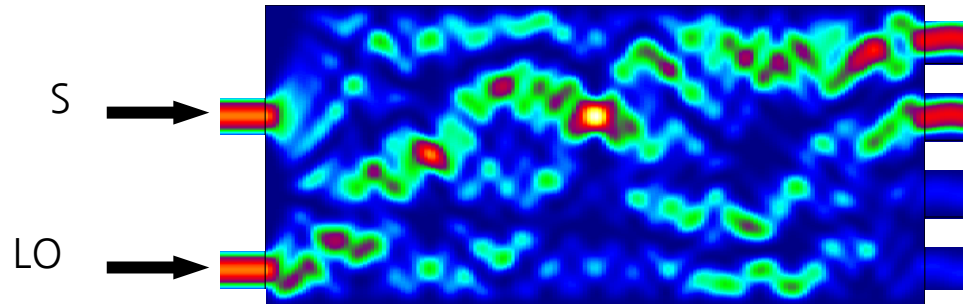


InP monolithic QPSK receiver

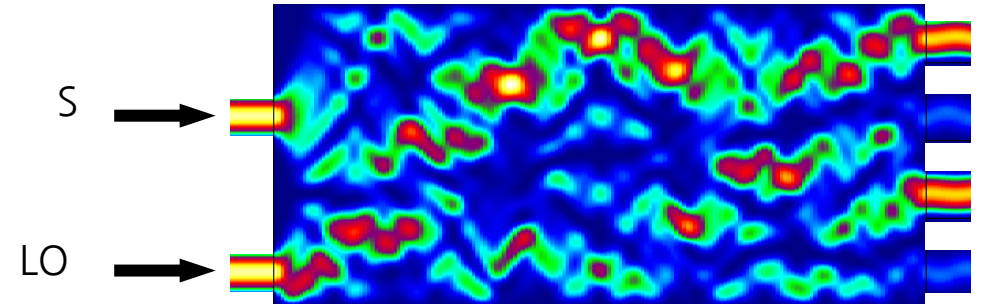


InP monolithic QPSK receiver - Phase difference of input signals determines output ports

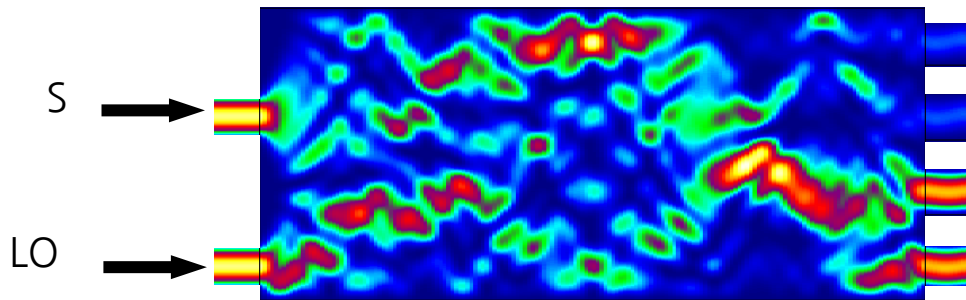
$\Delta\varphi = 0\text{deg}$



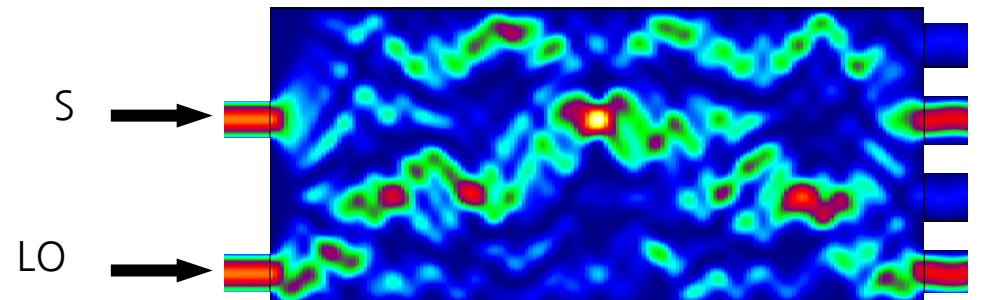
$\Delta\varphi = 90\text{deg}$



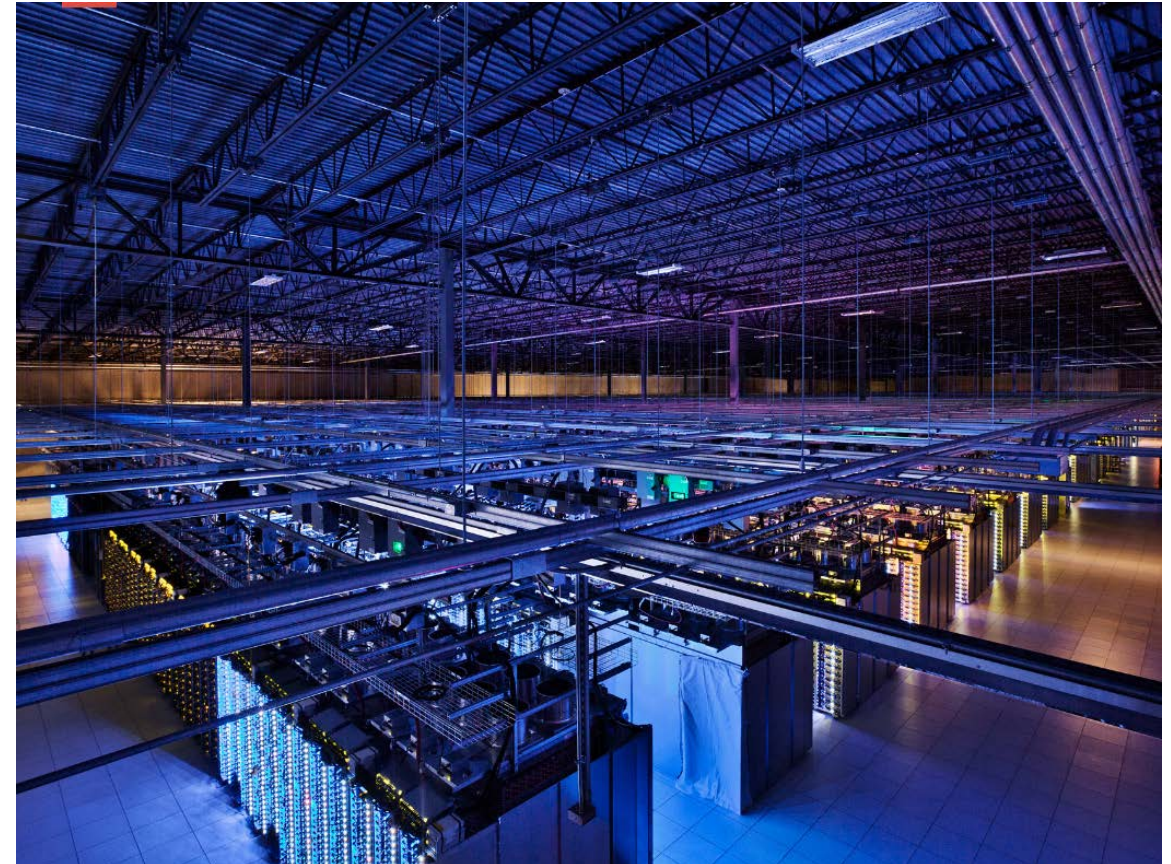
$\Delta\varphi = 180\text{deg}$



$\Delta\varphi = 270\text{deg}$



HHI's target: Intra Datacenter



In Datacenters, 'normal' Lasers Compete Well: One single 3" InP Laser wafer can transport the internet

White paper
Cisco public

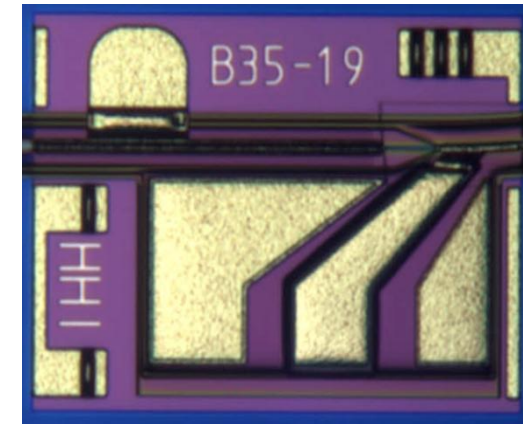


The Zettabyte Era: Trends and Analysis

June 2017

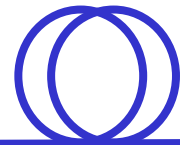
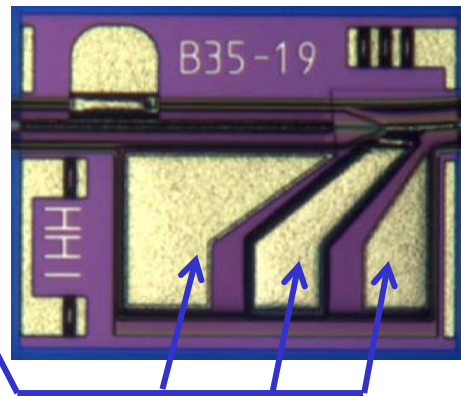
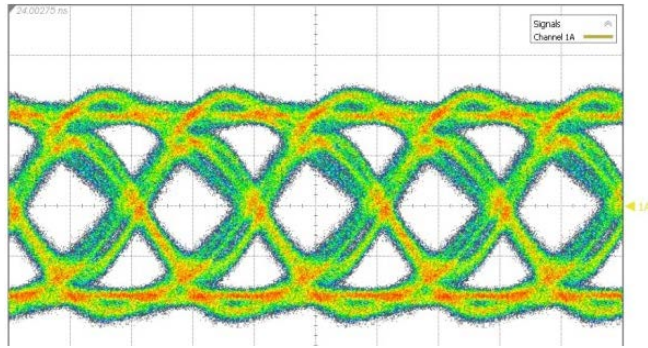
„Annual global IP traffic will reach
3.3 ZB per year by 2021, In
2016, the **annual runrate ... was
1.2 ZB per year**“

500µm x
400µm



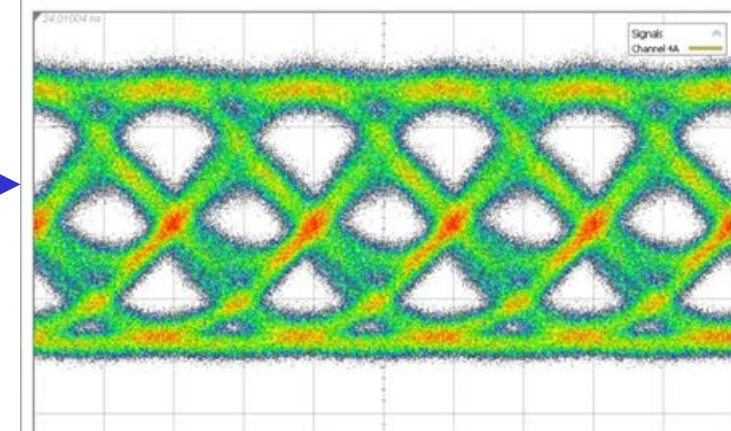
About 20.000 chips per 3" wafer,
56 GBit/chip
**A single InP 3" Wafer can
support 3 ZB/year**

Single Laser supports 100 Gb/s on/off



10km

100Gb/s Optical Signal

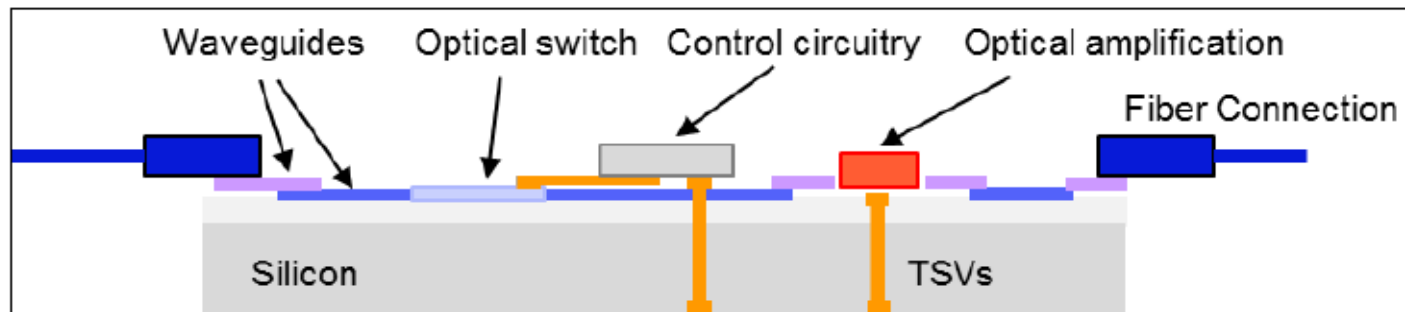


Farer future: Optical Switch Matrices

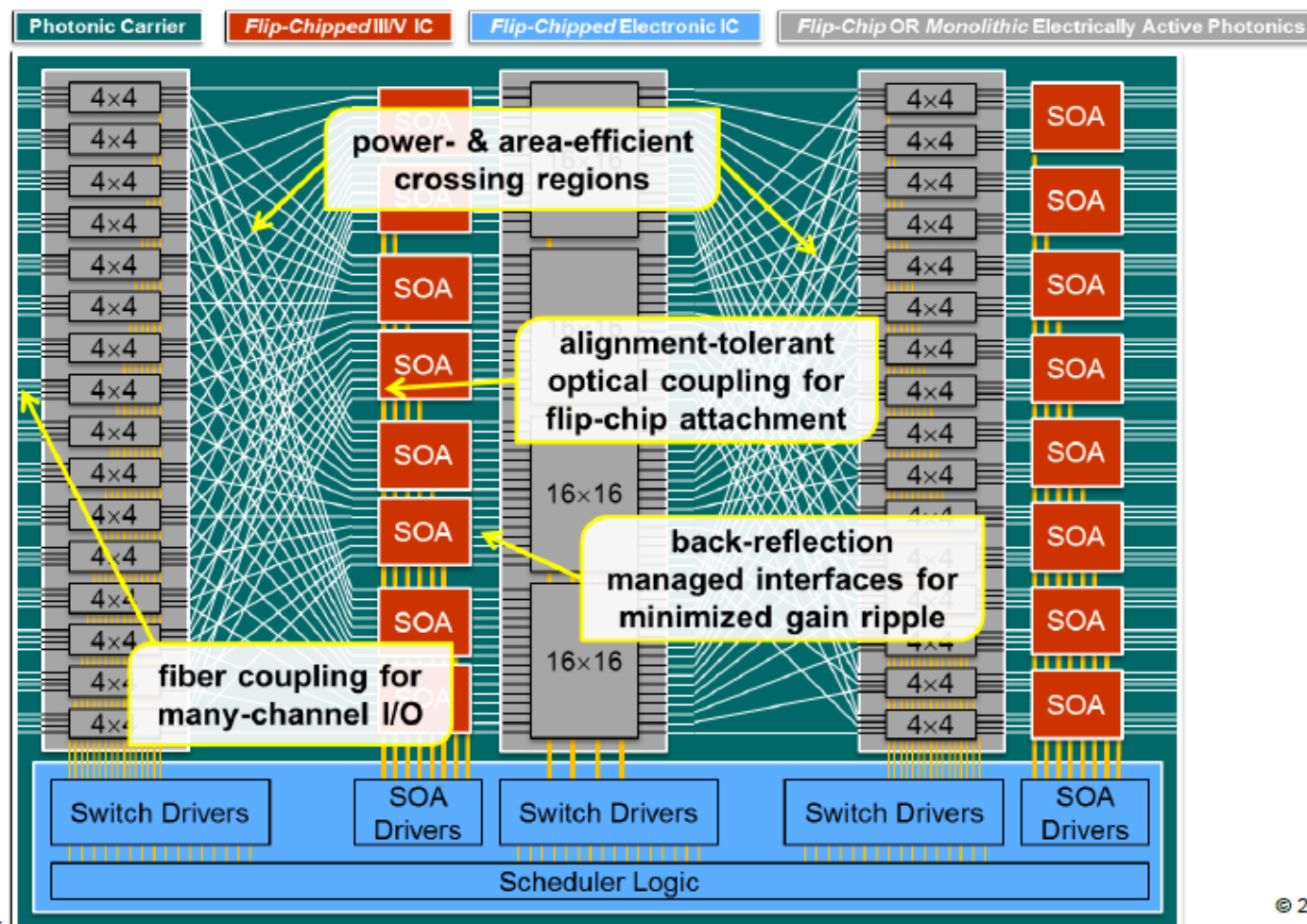
1.6 Mio Cores to be Connected



Conceptual cross-section:



Topological view:



A Gain-Integrated Silicon Photonic Carrier with SOA-Array for Scalable Optical Switch Fabrics

L. Schares⁽¹⁾, T. N. Huynh⁽¹⁾, M. G. Wood^(1,2), R. Budd⁽¹⁾, F. Doany⁽¹⁾, D. Kuchta⁽¹⁾, N. Dupuis⁽¹⁾, B. G. Lee⁽¹⁾,
C. L. Schow⁽³⁾, M. Moehrle⁽⁴⁾, A. Sigmund⁽⁴⁾, W. Rehbein⁽⁴⁾, T. Y. Liow⁽⁵⁾, L. W. Luo⁽⁵⁾, G. Q. Lo⁽⁵⁾

(1) IBM – Watson Research Center, Yorktown Heights NY, USA. Email: schares@us.ibm.com. (2) The Ohio State Univ., Columbus, OH, USA.
(3) Univ. of California, Santa Barbara, CA, USA. (4) Fraunhofer HHI, Berlin, Germany. (5) A*STAR – Institute of Microelectronics, Singapore.

Abstract: We built a 4-channel photonic carrier with input/output SiN waveguides and a flip-chip-attached SOA array, incorporating end-to-end reflection-management and mode-matching. All channels demonstrate fiber-to-fiber gain of >10dB and support error-free 4- λ x 25-Gb/s WDM links.

OCIS codes: (200.0200) Optics in computing; (230.4480) Optical Amplifiers; (200.4650) Optical interconnects

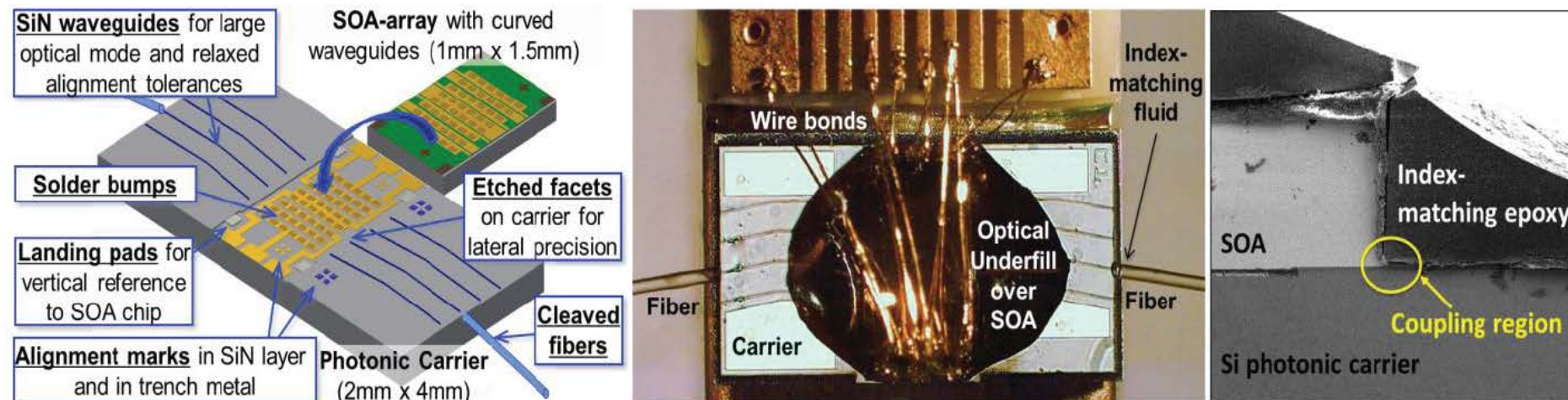
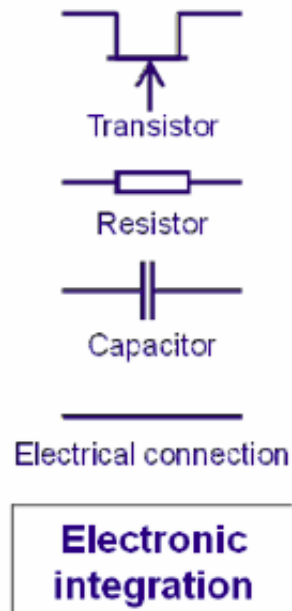
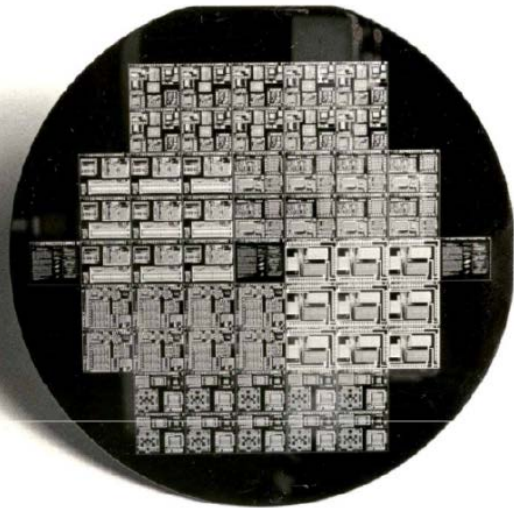


Fig.1. Left: SOA / photonic substrate integration test vehicle. Center: Assembled carrier with SOA embedded in optical underfill. Right: SEM image of cross-sectioned assembly showing the index matching epoxy between SOA and SiN waveguides.

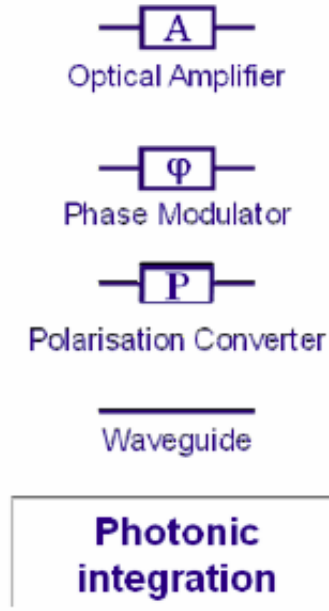
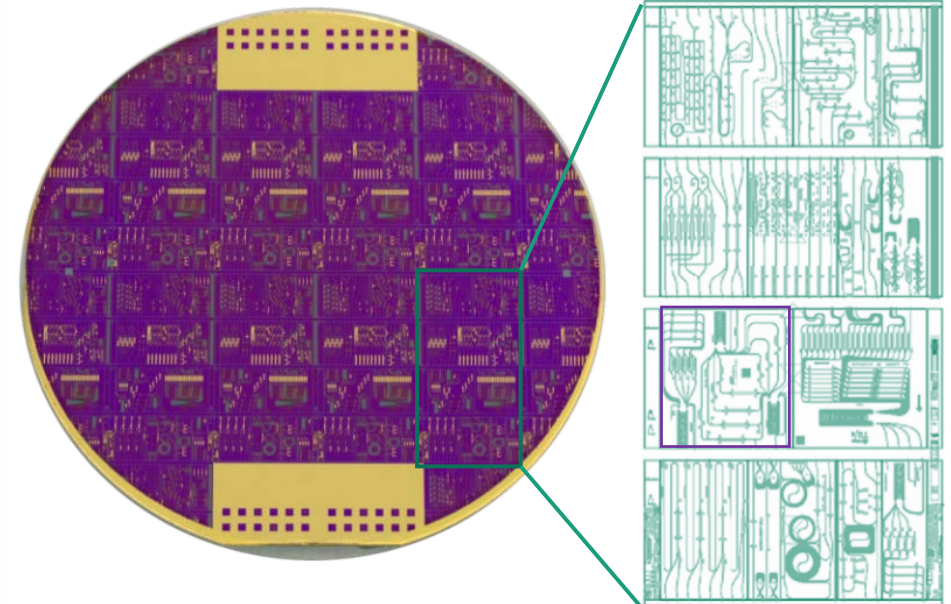
Adopt foundry model widely used with Silicon ICs to InP PICs

Like Electronics: Make Building Blocks, Separate Design from Process

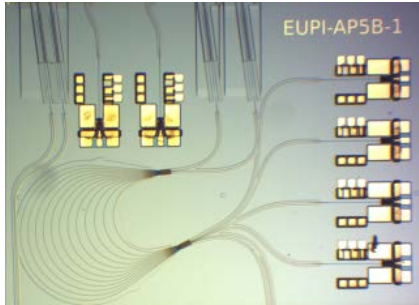
Silicon ICs ~1979



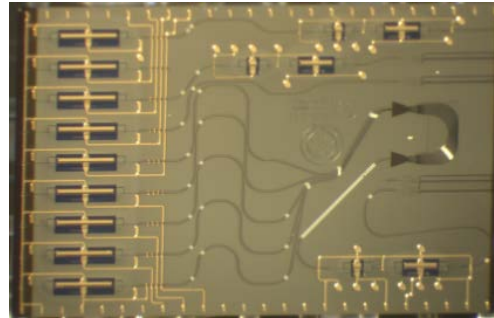
InP Photonic ICs ~2014



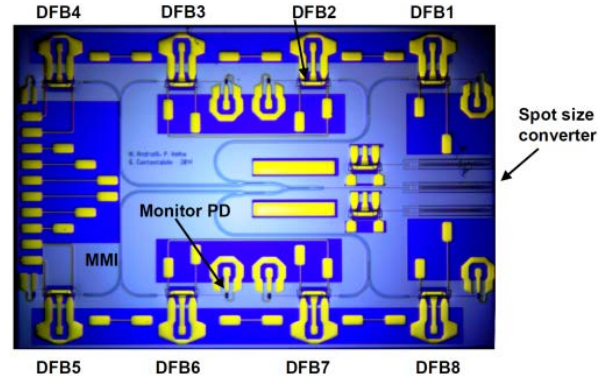
PIC Examples From Fraunhofer HHI Fab



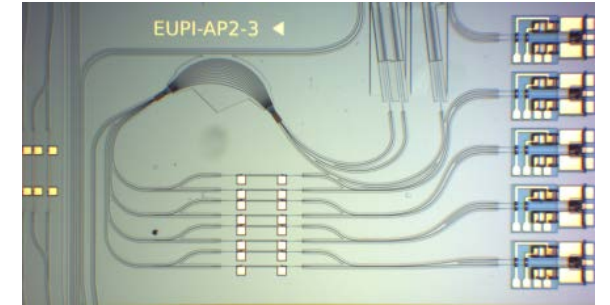
WDM receiver for FTTH
(Genesis)



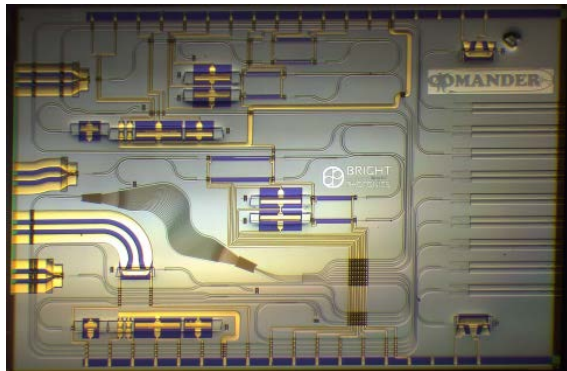
AWG-based harmonic mode-locked laser
(Chinese Acad. of Sciences)



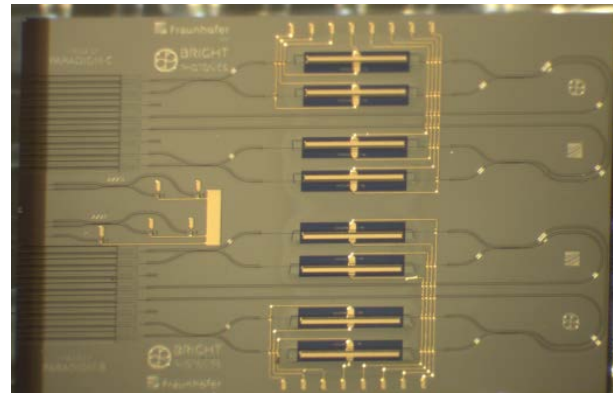
Multi-Wavelength transmitter
(Scuola Superiore Sant'Anna)



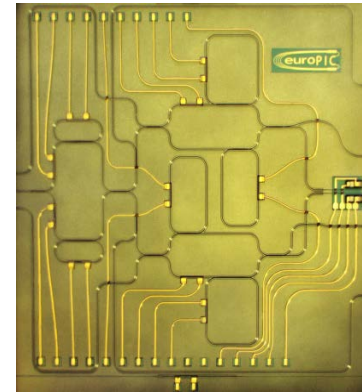
FBG-readout
(Fibresensing)



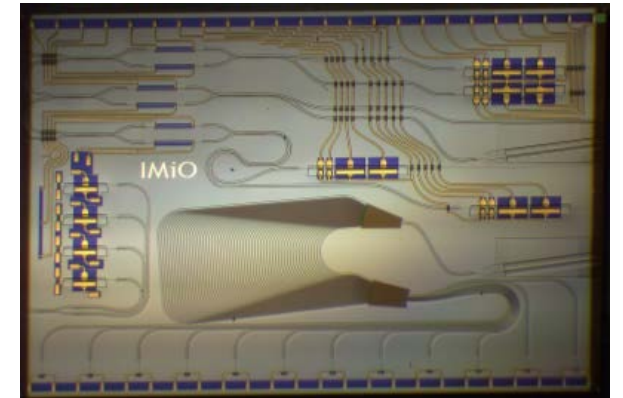
Integrated Tunable Filter
(EU Commander)



5Gb/s Optical Flip-Flop Chip
(Uni Thessaloniki)



Optical frequency discriminator
(U Valencia/VLC)



Photonic integrated interrogator
for fiber-optic sensor networks
(Uni Warsaw)



Summary

InP Optochips for all communication needs – long reach to intra-datacenter

Current focus on TOR connections 500 m – 2 km

Small chip size gives volume capability even to 3" fab

Eye-safe 1.3 μ m..1.5 μ m LIDAR

Proven history in transferring ideas from TRL1 to TRL9

One of the three worldwide accessible InP Photonic Integrated Circuits foundries

Your Contact



Martin Schell

Executive Director Fraunhofer HHI

martin.schell@hhi.fraunhofer.de