AARHUS
UNIVERSITET
INSTITUT FOR INGENIØRVIDENSKAB

2018

Optical Networks On Chip: Enabling Future Memory

Martijn Heck

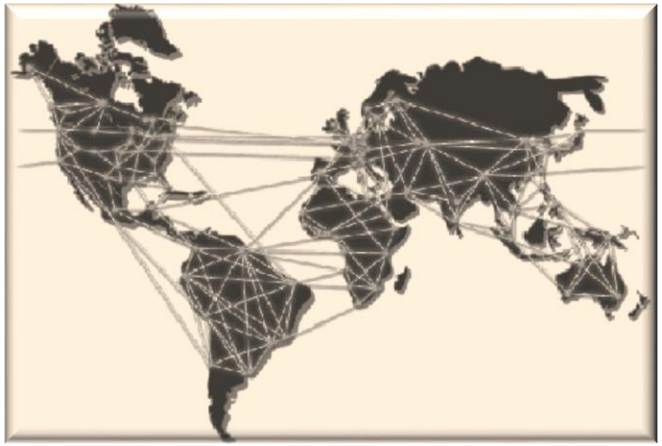
Associate Professor

Department of Engineering

AARHUS
UNIVERSITY
DEPARTMENT OF ENGINEERING

WHY OPTICAL NETWORKS ON CHIP?

Optical networks are already connecting us

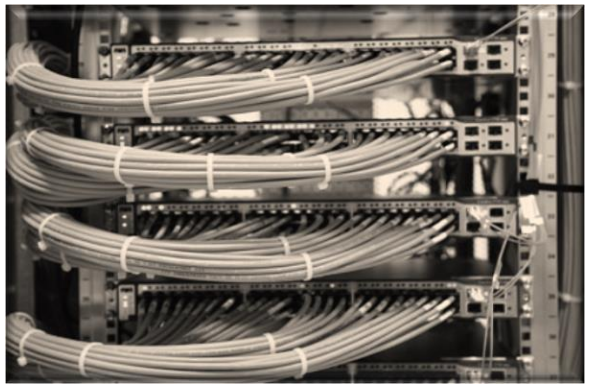


1980s our countries...

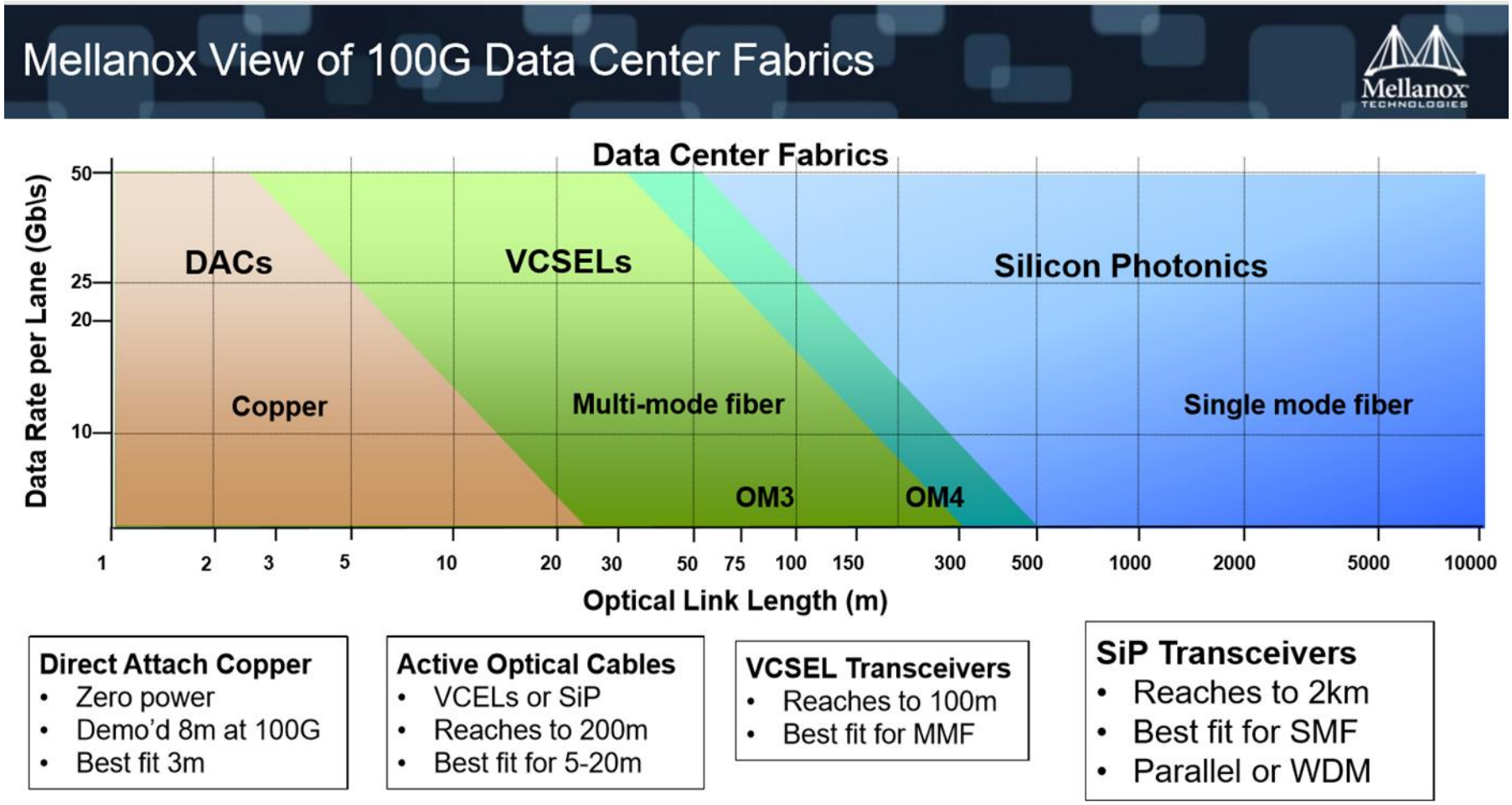
... datacenters and cities

1990s our homes

2000s our computers

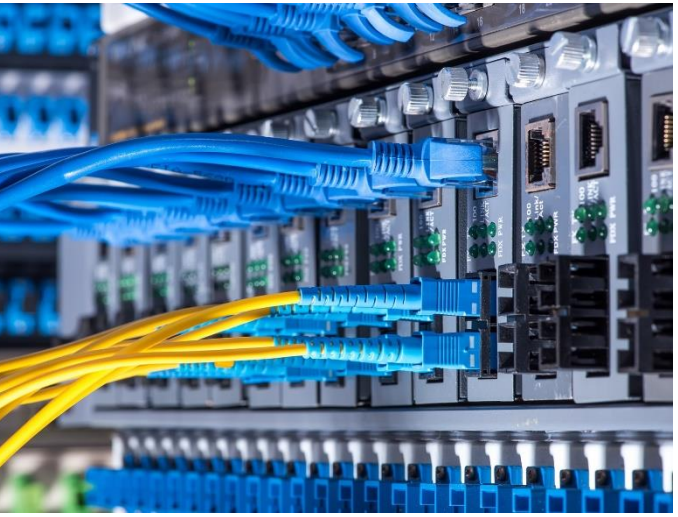


There is a trade-off of length vs. bandwidth

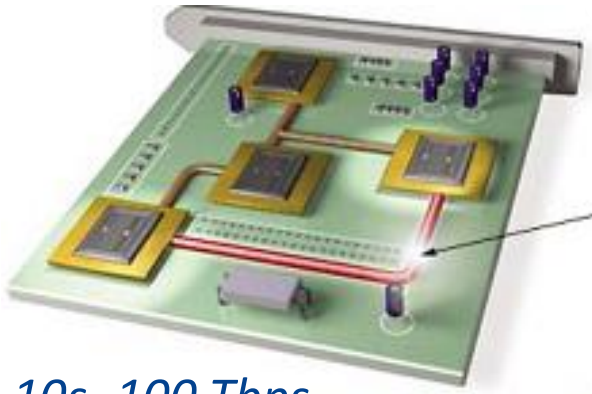


Optical interconnects for increasingly smaller distances, driven by bandwidth requirements

Today – commercial
Optical connections in data centers



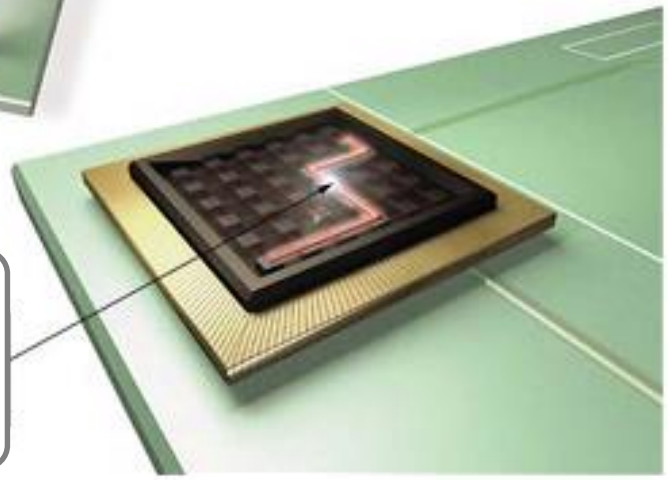
Near future: 1 Tbps...



Today – commercial
Optical connections in/on boards

... 10s -100 Tbps...

Future
Optical interconnects on processor (?)

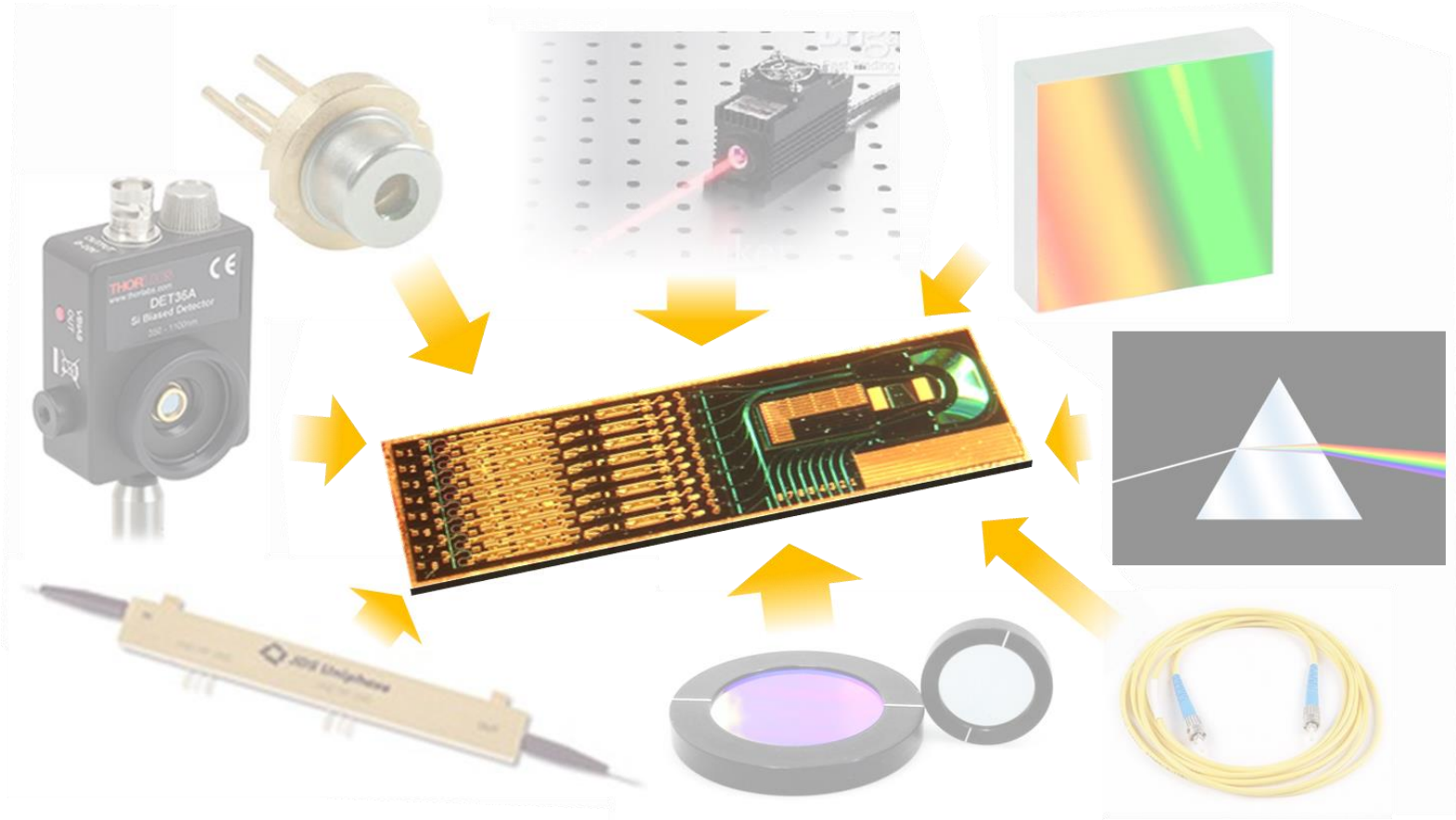


... 500 Tbps

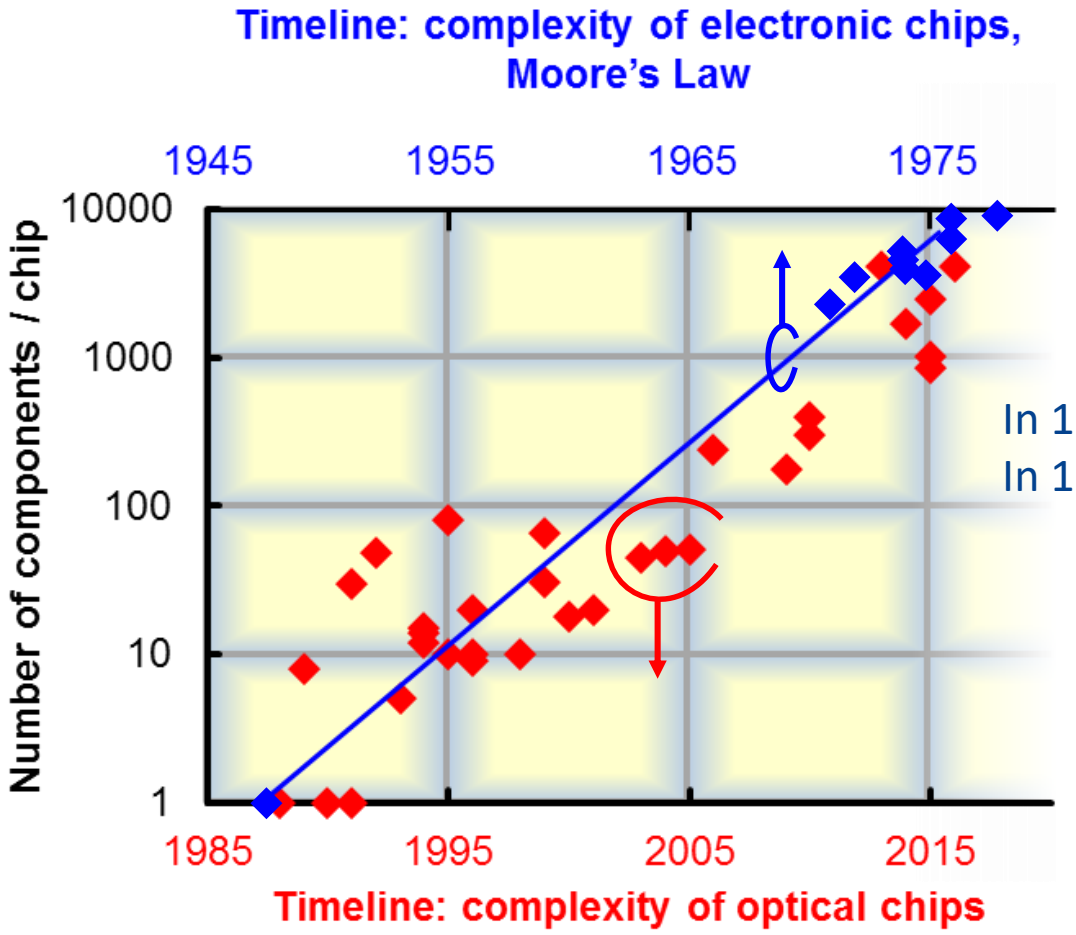
D. A. B. Miller, Proc. IEEE 97, 7 (2009)

HOW OPTICAL NETWORK ON CHIP?

Photonic integration: optical chips



The number of components on an optical chip doubles every two years: Smit's Law

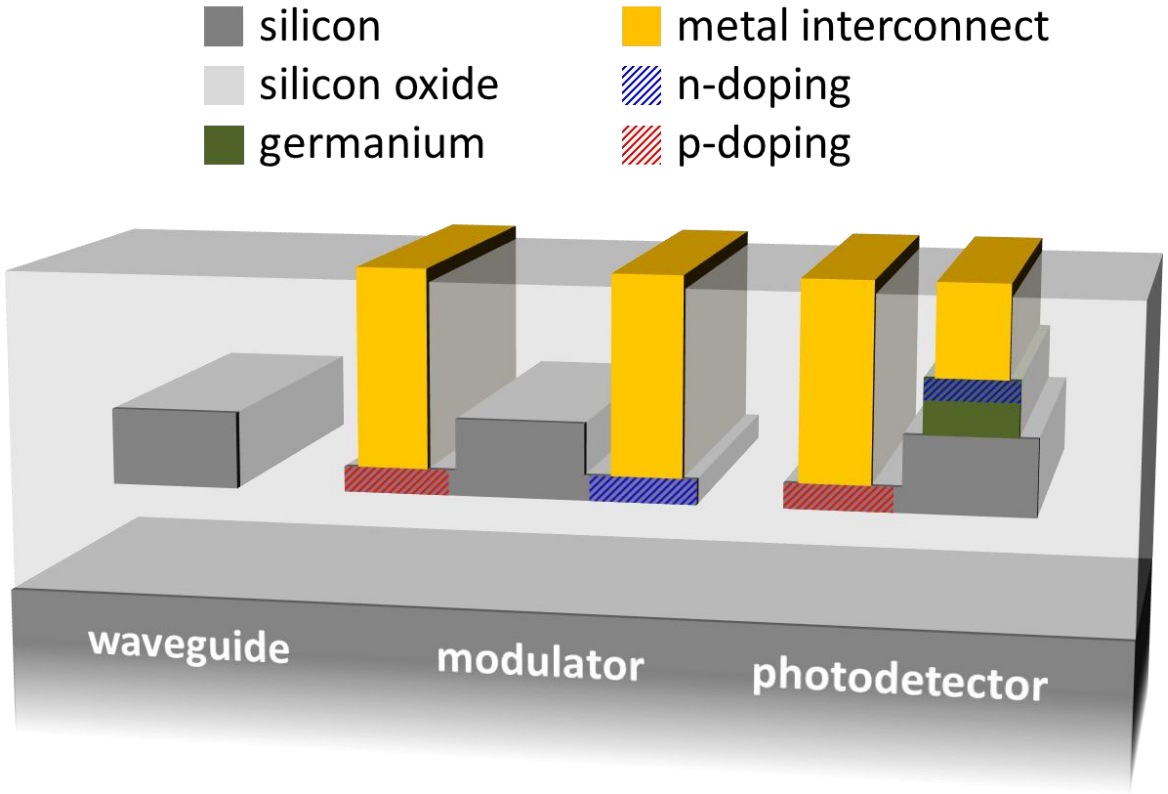


exponential growth of
- *bandwidth;*
- *devices connected to internet;*
- *sensor networks...*

In 1975 Bill Gates founded Microsoft…
In 1976 Steve Jobs founded Apple…

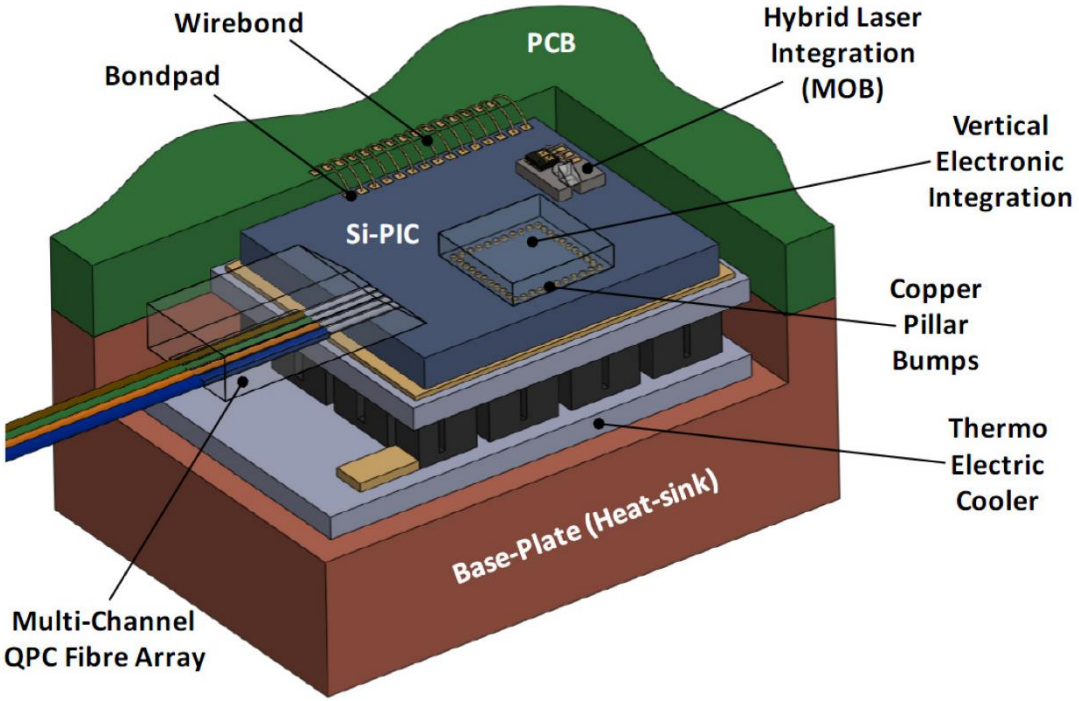
technology drivers
- *CMOS processes;*
- *open foundries;*
- *mature design software...*

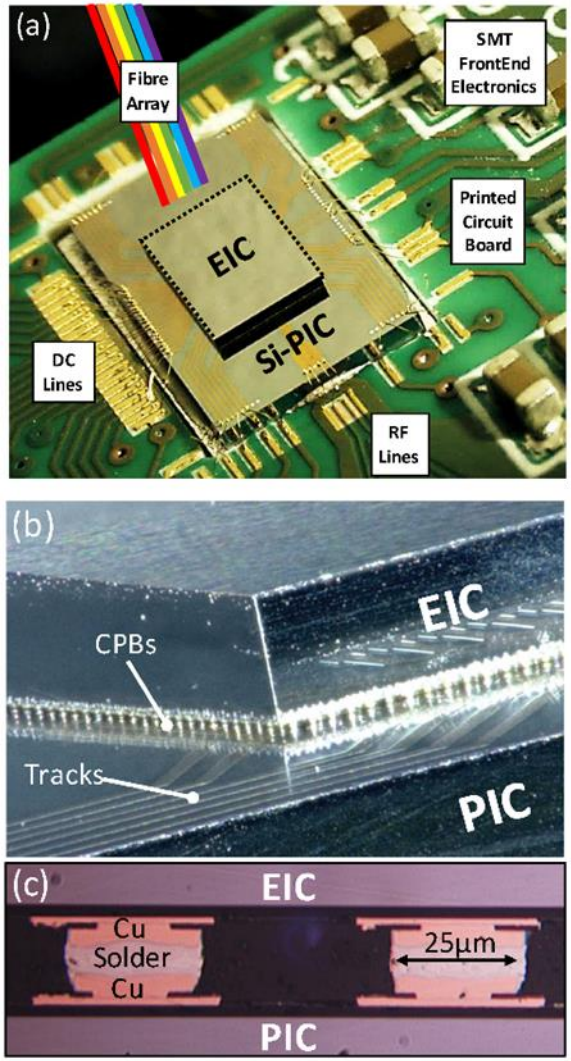
Silicon photonics:
CMOS compatible nanophotonics



External laser typically needed

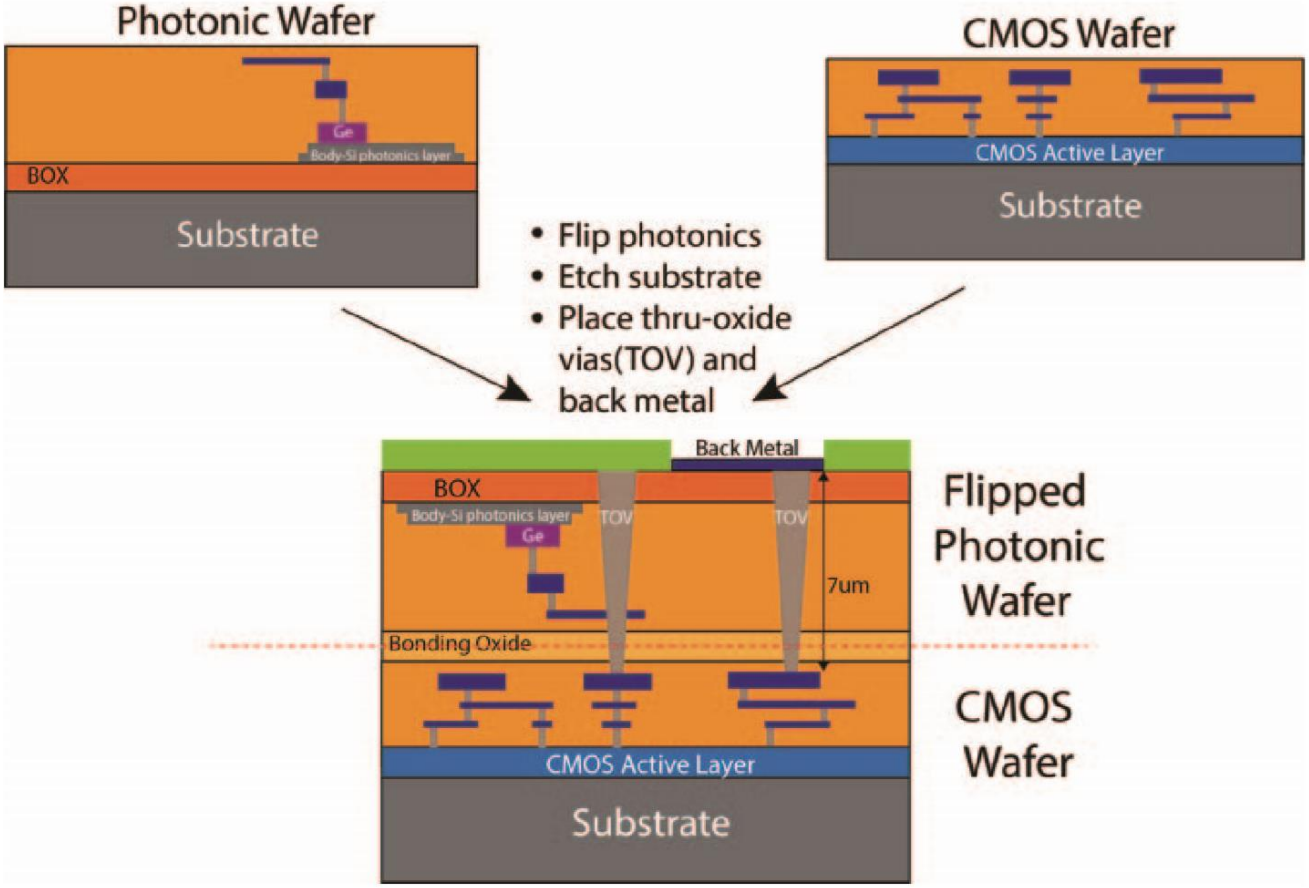
Electronic-photonic integration: copper pillar bump bonding





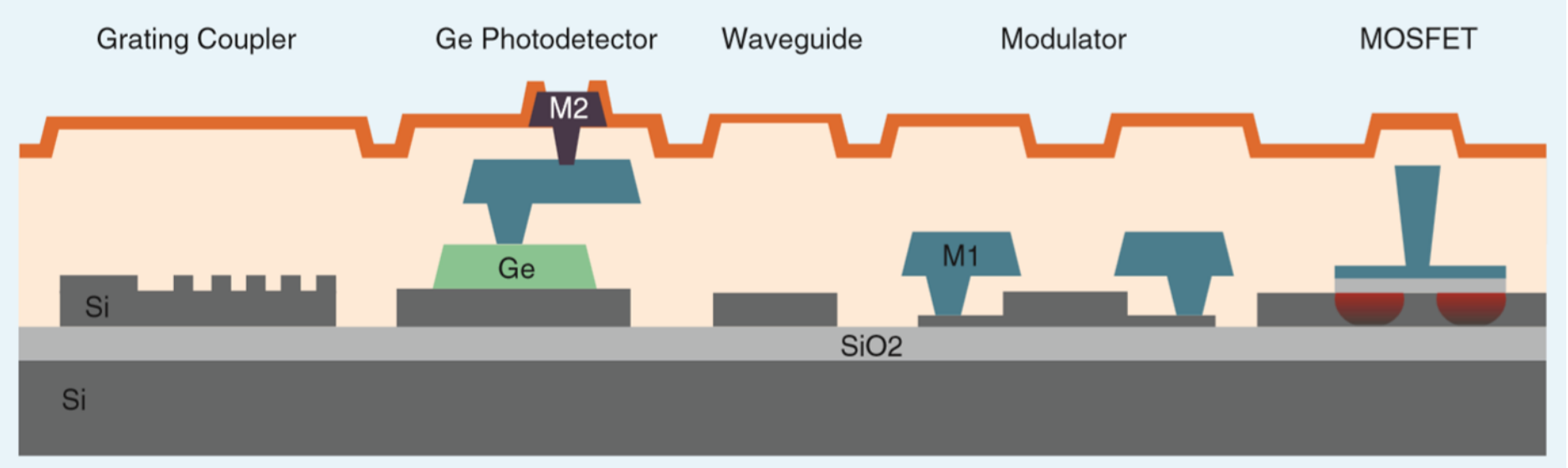
L. Carroll, Appl. Sci. 6, 12 (2016)

Waferscale electronic-photonic integration: through-oxide vias



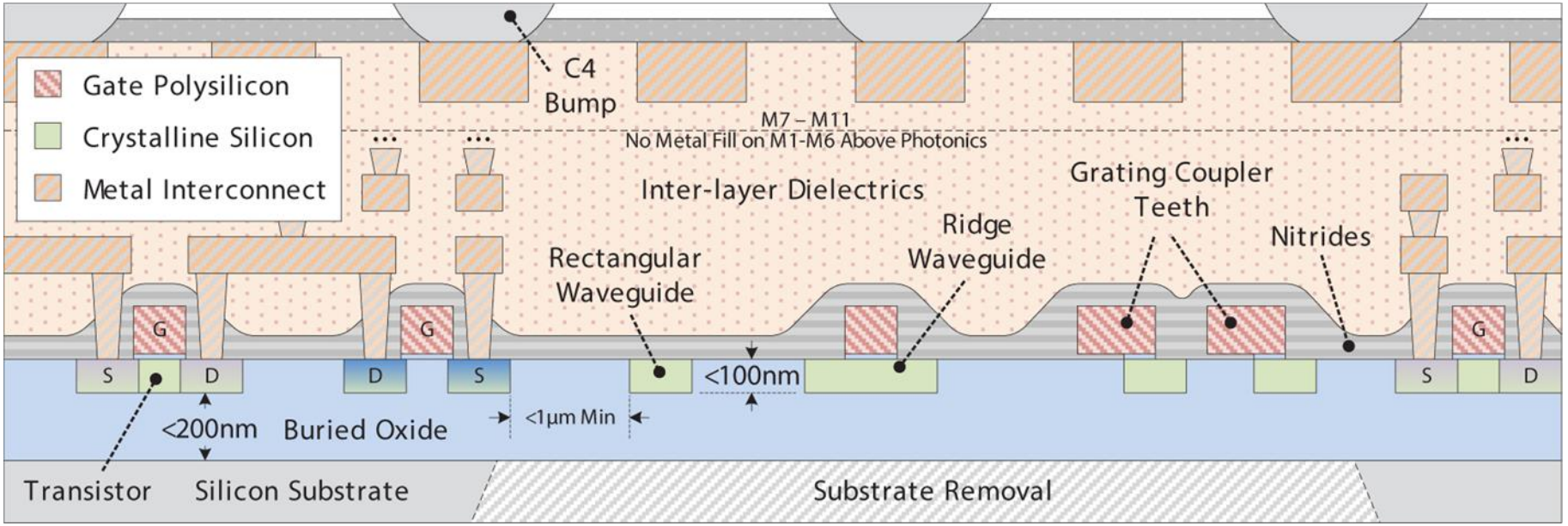
N. DiLello Heidel, IEEE JSTQE, 22, 6 (2016)

Monolithic electronic-photonic integration: 130 nm / 90 nm dedicated CMOS processes



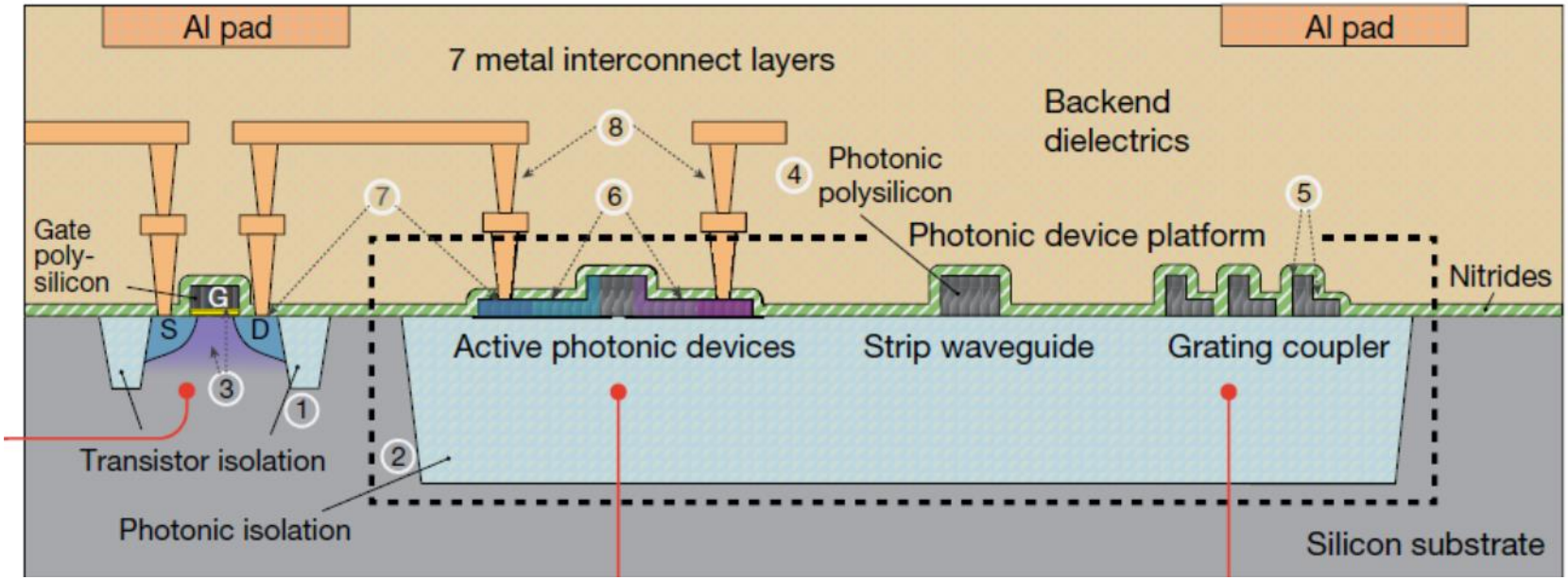
Hochberg, IEEE Solid-State Circuits Magazine, Winter 2013

Zero-change electronic-photonic integration: 45 nm / 32 nm CMOS processes



Sun et al., JSSC. 50, 893 (2016)

Monolithic electronic-photonic integration: bulk CMOS process, 65-nm, 300-mm

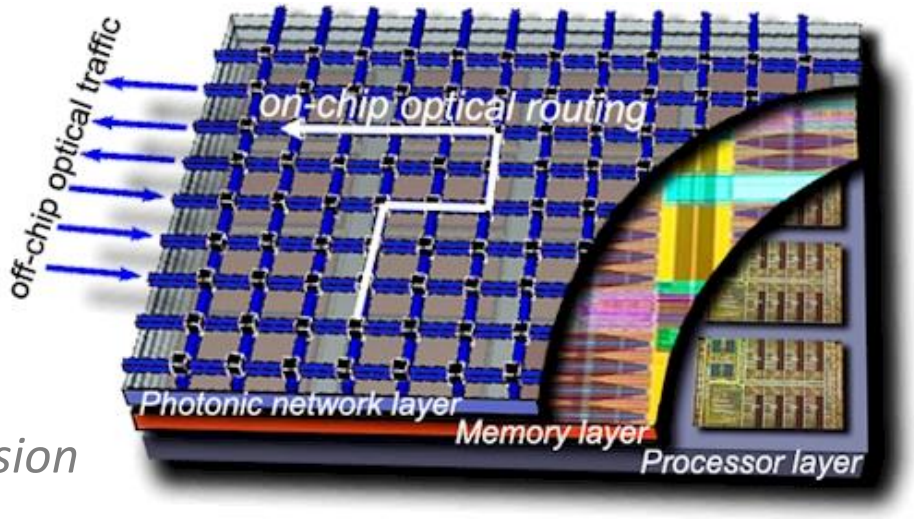


Atabaki et al., Nature 556, 7701 (2018)

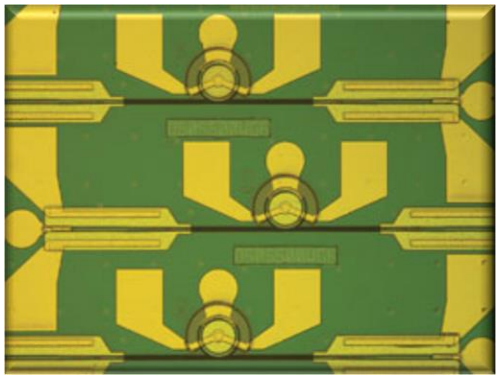
STATUS OPTICAL NETWORKS ON CHIP?

Optical networks on chip: the future (?)

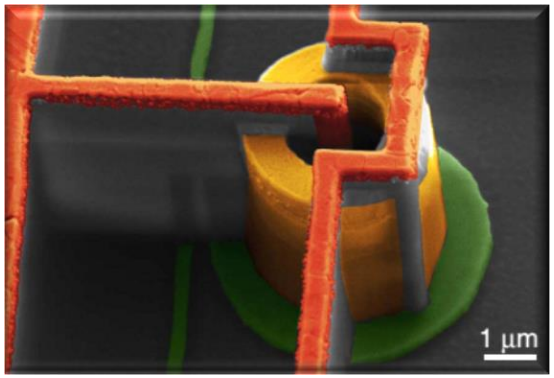
All components for an optical network in silicon have been realized by now



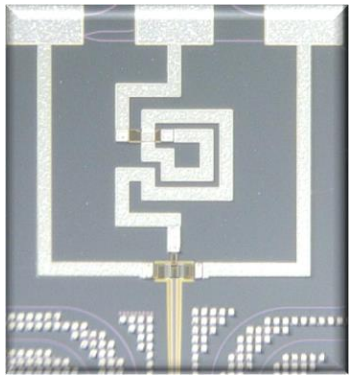
IBM vision



lasers (UCSB)



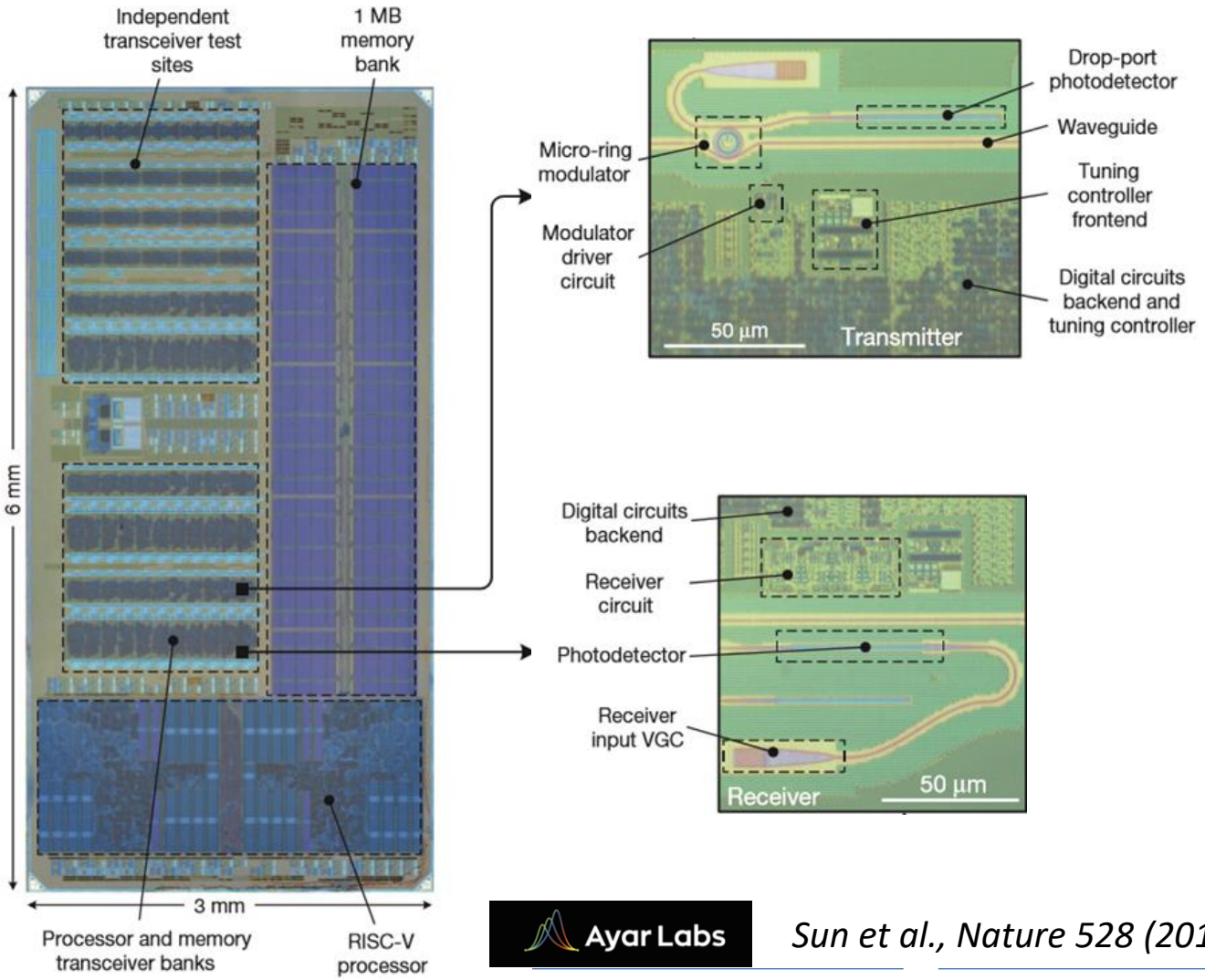
modulator (MIT)



detector (OPSIS)

Zero-change-process microprocessor with optical IO

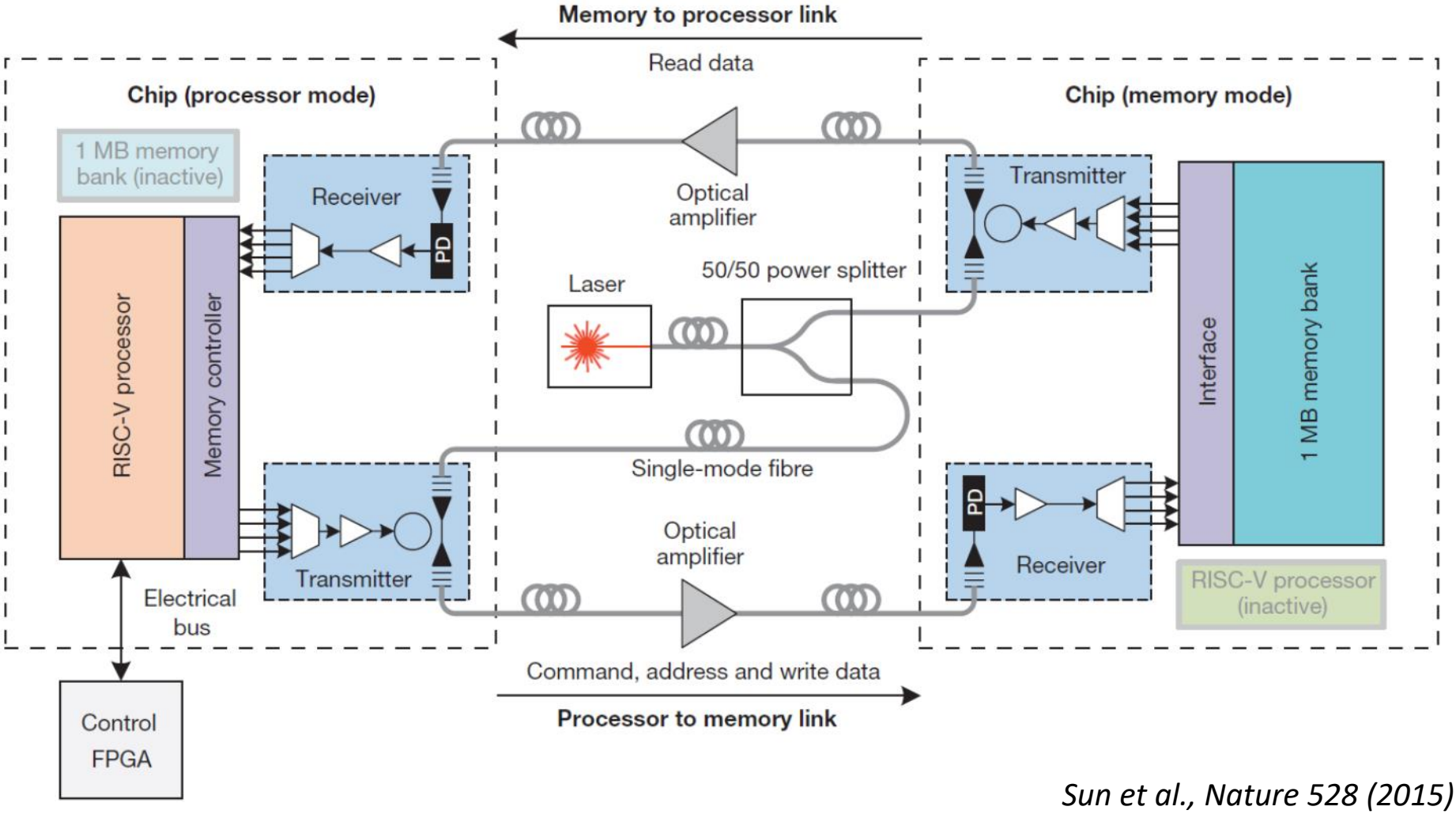
70M transistors
850 photonic components
<200 nm BOX
λ = 1180 nm
5 Gbsp per λ



Ayar Labs

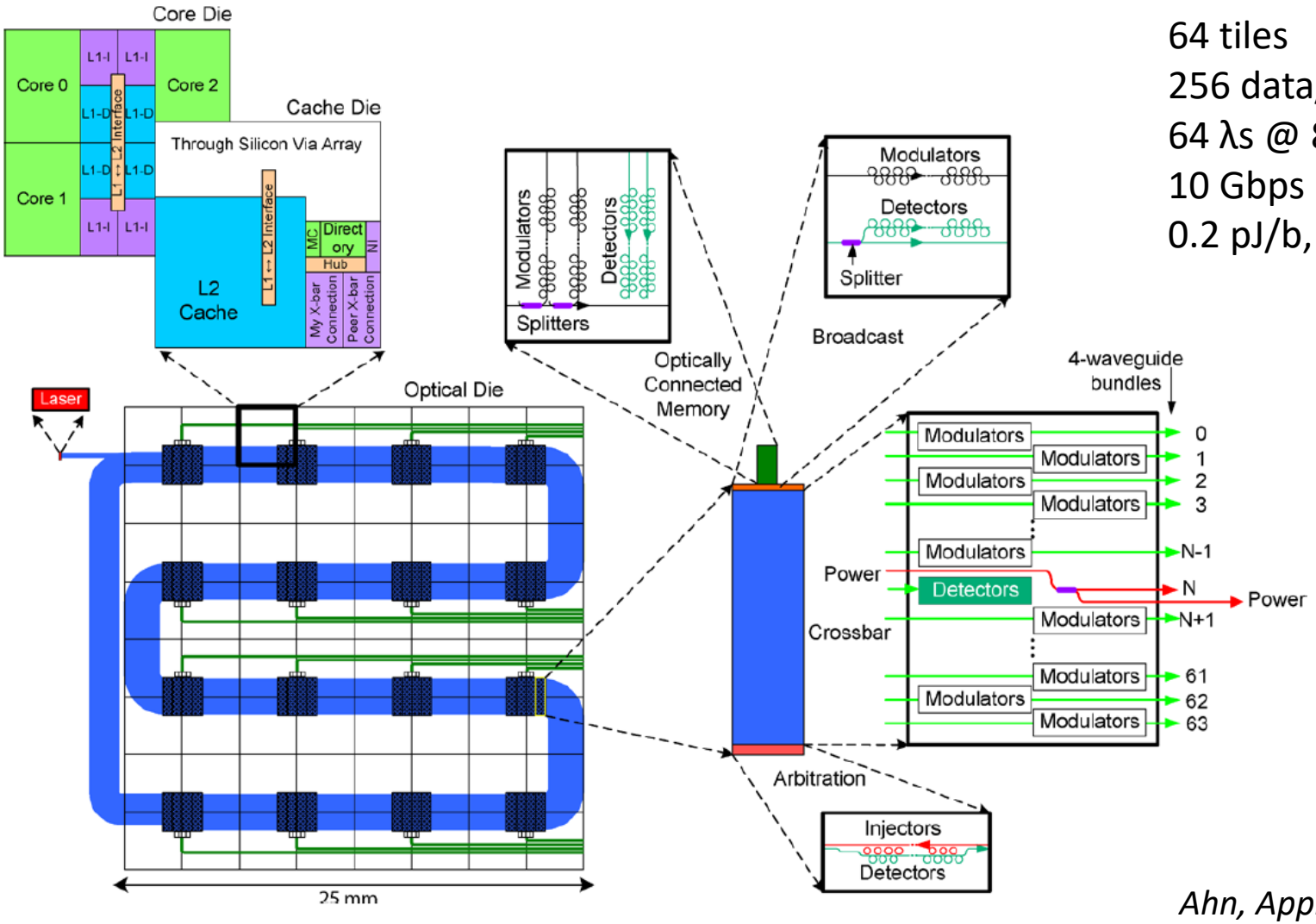
Sun et al., Nature 528 (2015)

Zero-change-process microprocessor with optical IO



Sun et al., Nature 528 (2015)

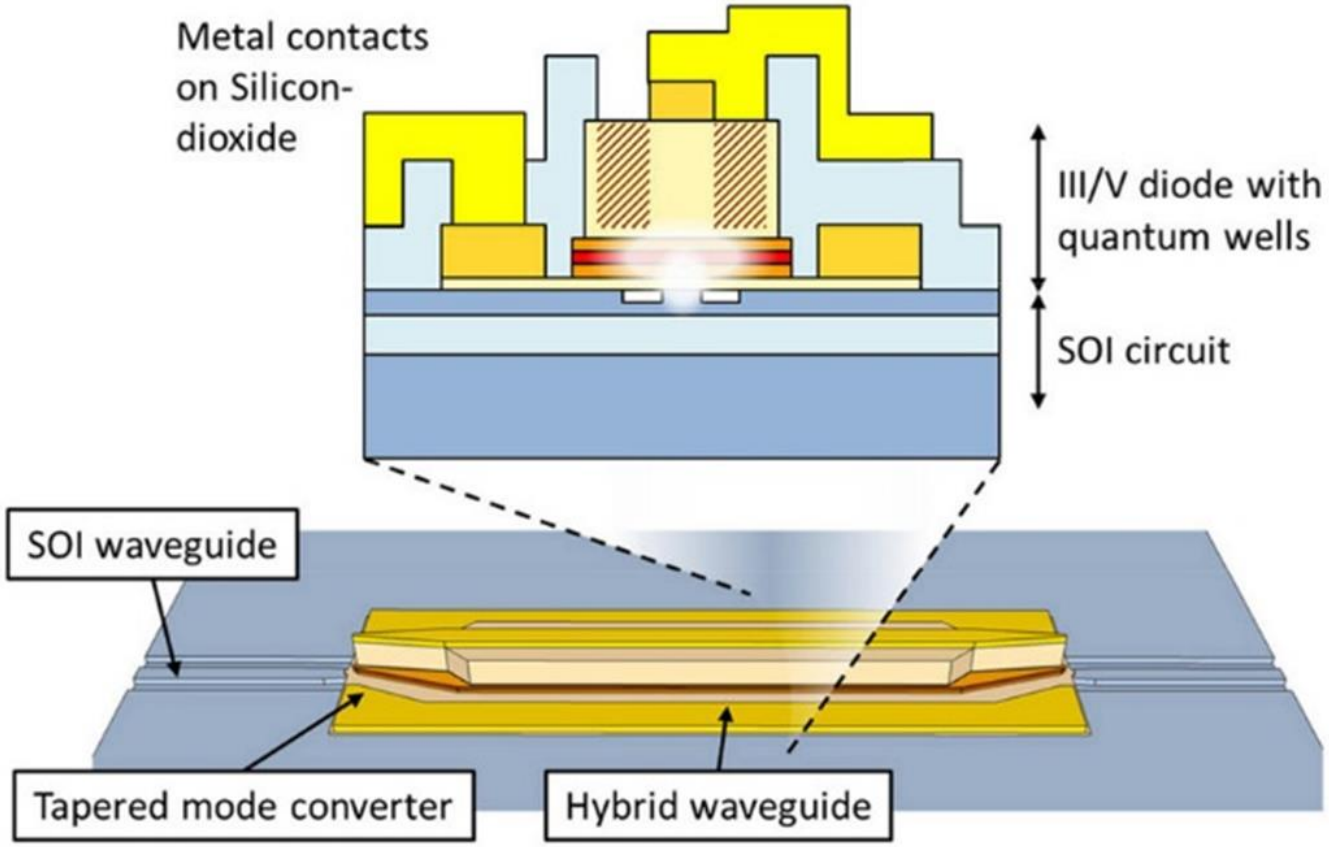
HP's CORONA architecture



64 tiles
256 data/control wgs
64 λs @ 80 GHz
10 Gbps → 20 TBps
0.2 pJ/b, 40 W (17 nm)

Ahn, Appl Phys A (2009) 95

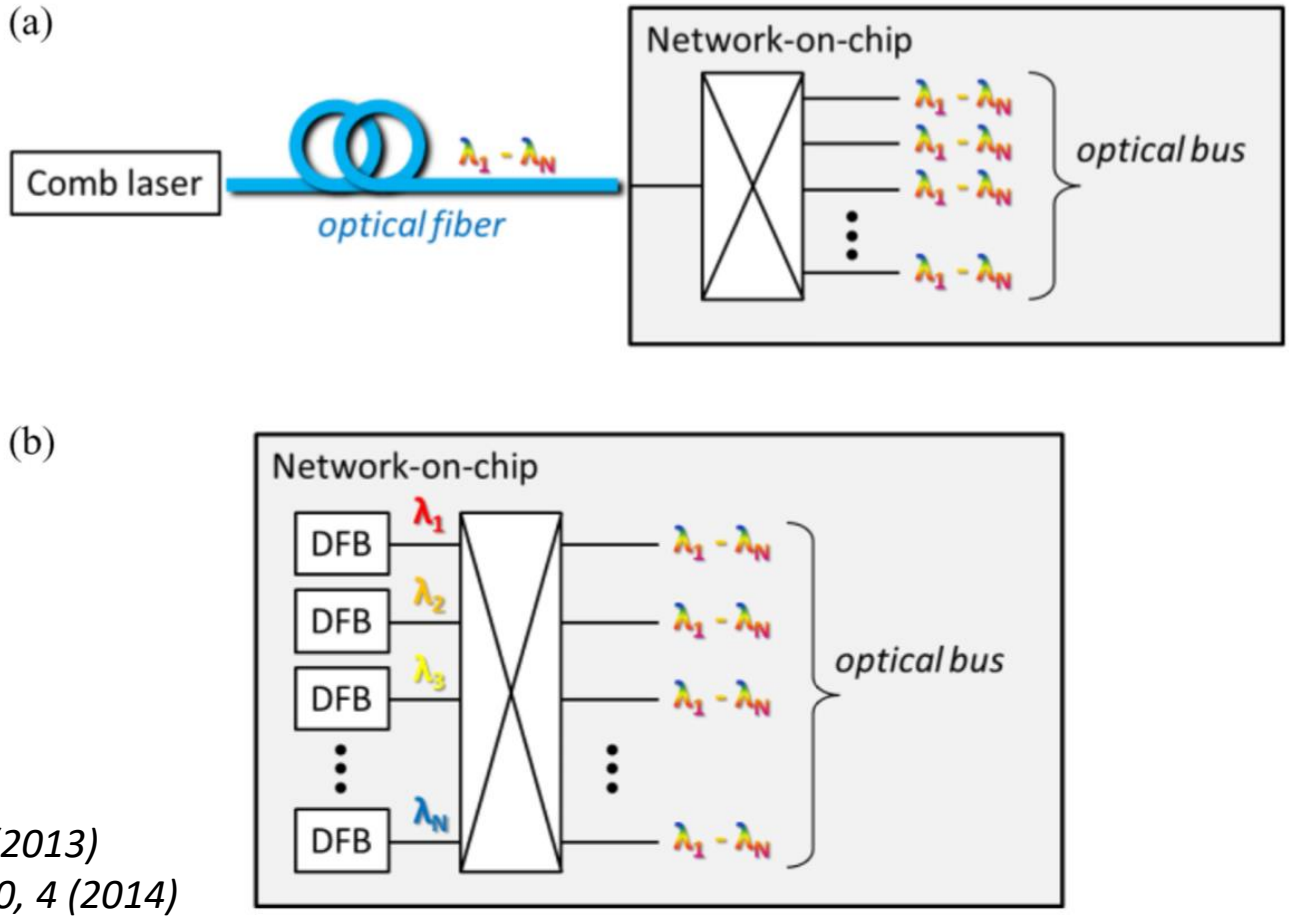
On-chip lasers for energy efficiency and energy proportionality



Heck et al., IEEE JSTQE 19, 4 (2013)
Heck & Bowers, IEEE JSTQE 20, 4 (2014)

UCSB

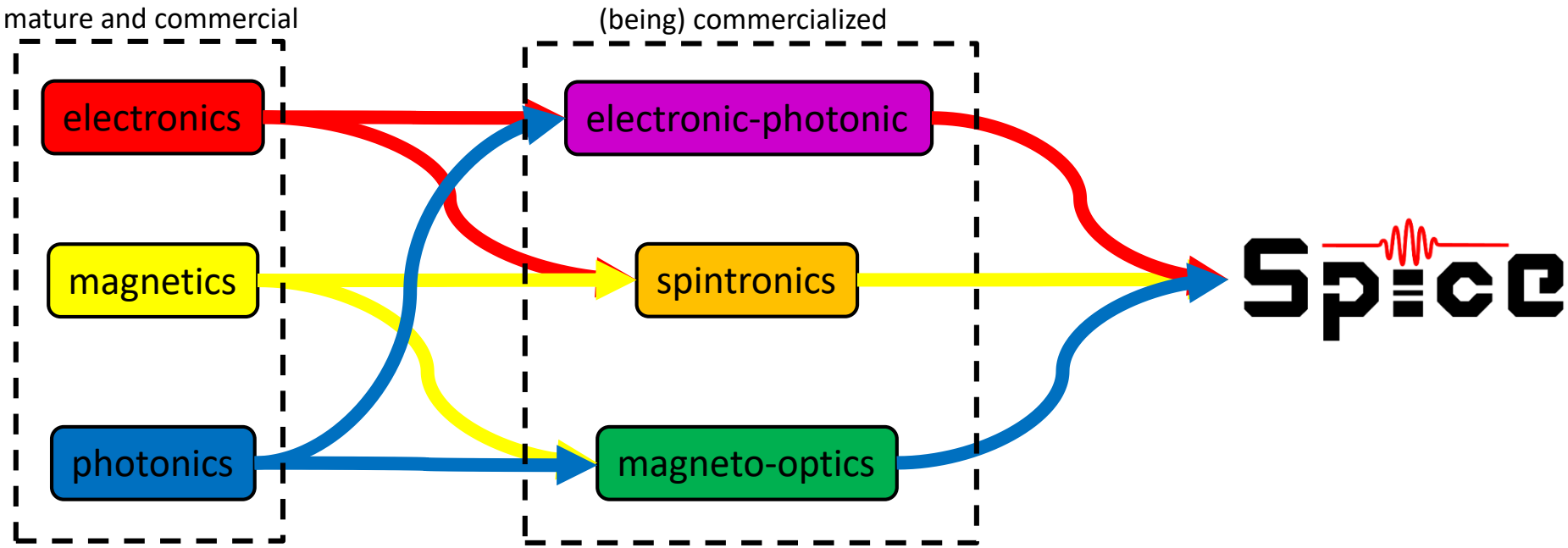
On-chip lasers for energy efficiency and energy proportionality



Up to 20 dB energy saving at lower utilization

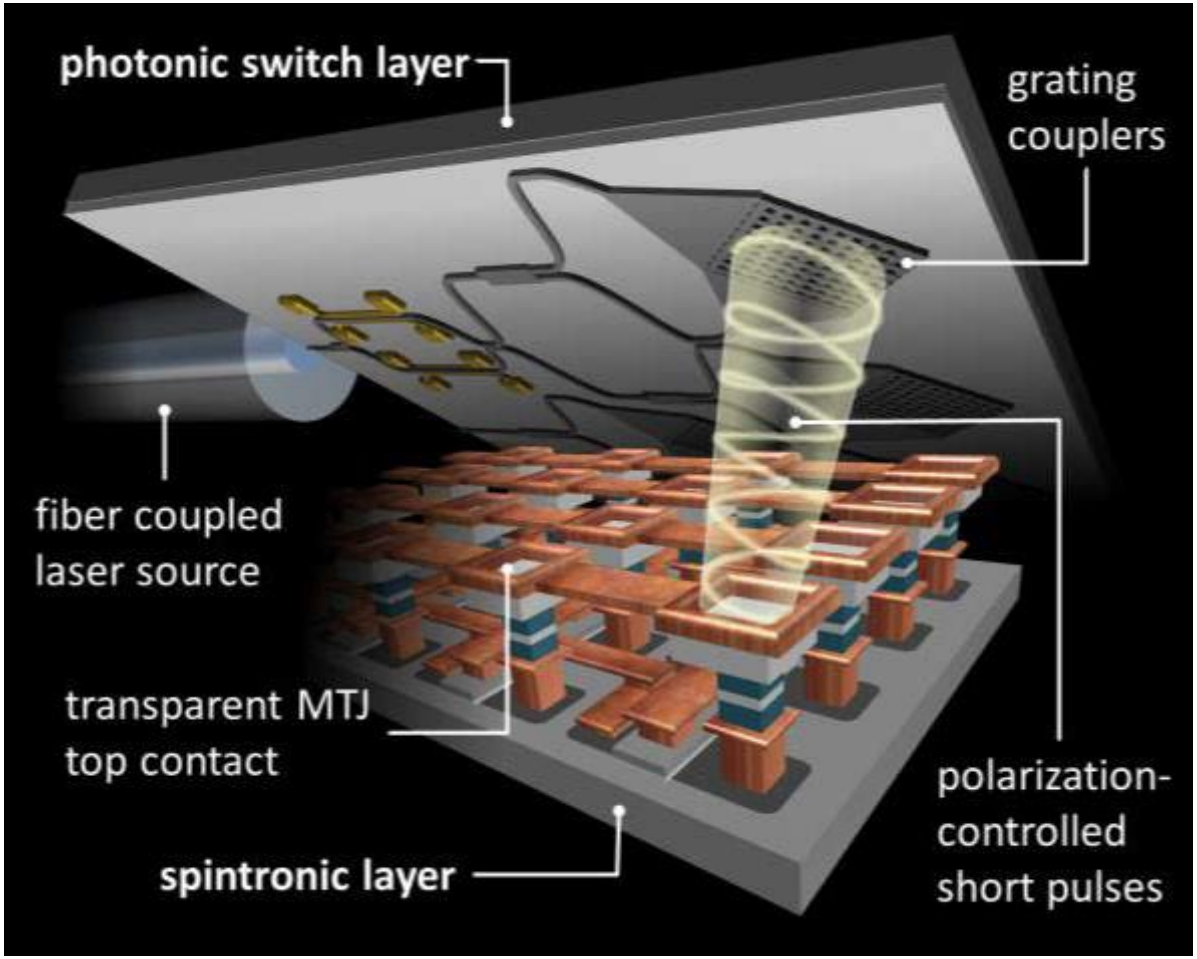
Heck et al., IEEE JSTQE 19, 4 (2013)
Heck & Bowers, IEEE JSTQE 20, 4 (2014)

Exponential technology trends converge



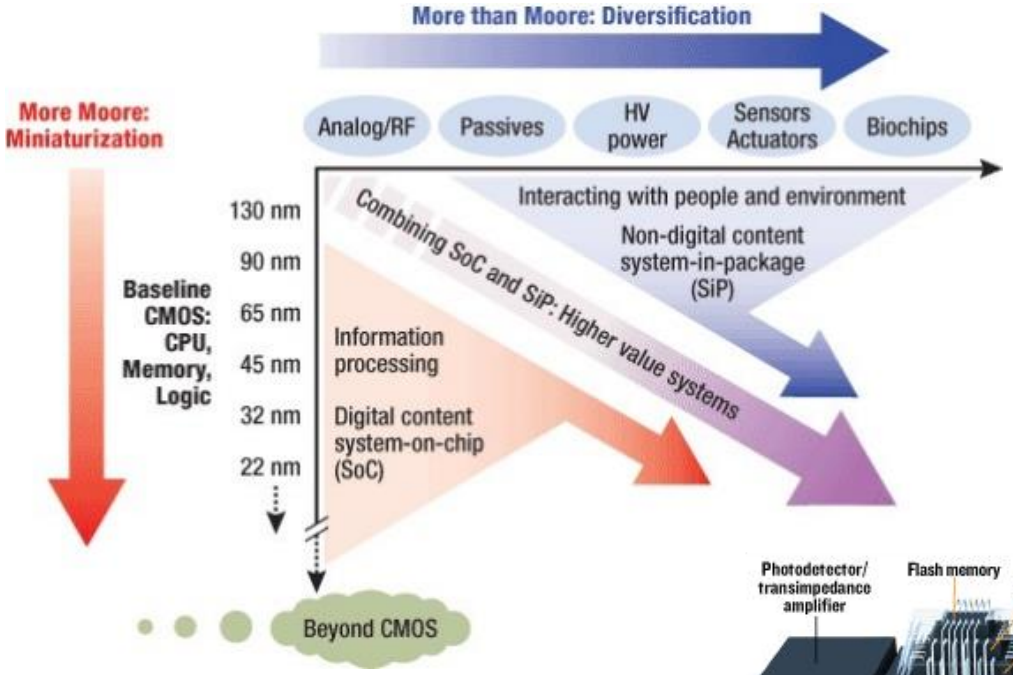
http://spice-fetopen.eu/

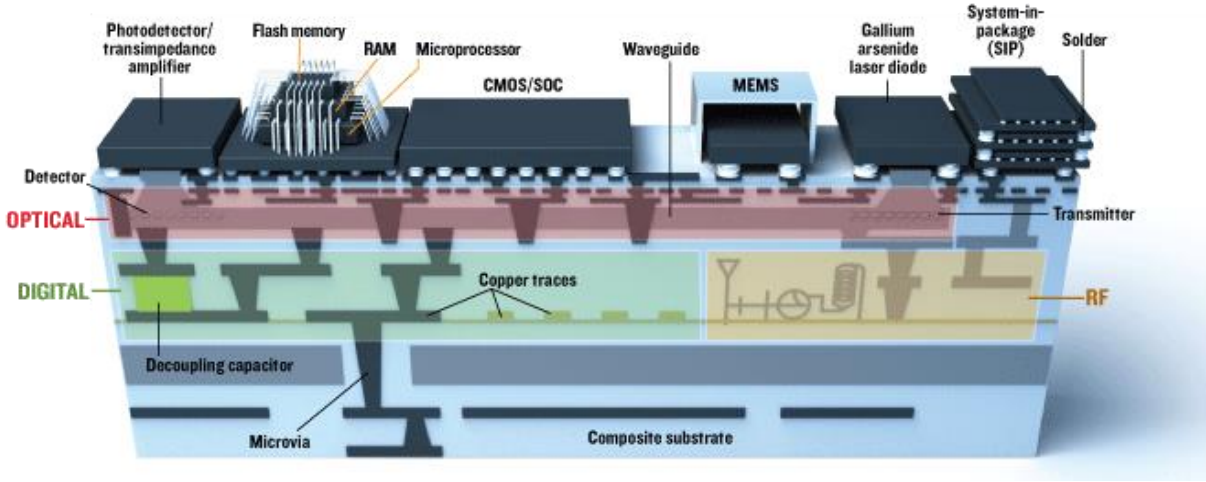
Overall SPICE objective: spintronic-photonic integration platform



http://spice-fetopen.eu/

More than Moore:
SPICE technology for sensors and RF





http://spectrum.ieee.org

dr. Martijn J. R. Heck
Associate Professor
Department of Engineering
Aarhus University

mheck@eng.au.dk

Our research is supported by:

DET FRIE FORSKNINGSRÅD
DANISH COUNCIL FOR
INDEPENDENT RESEARCH

Innovationsfonden

HORIZON 2020