Silicon Photonics: Fueling the Next Information Revolution

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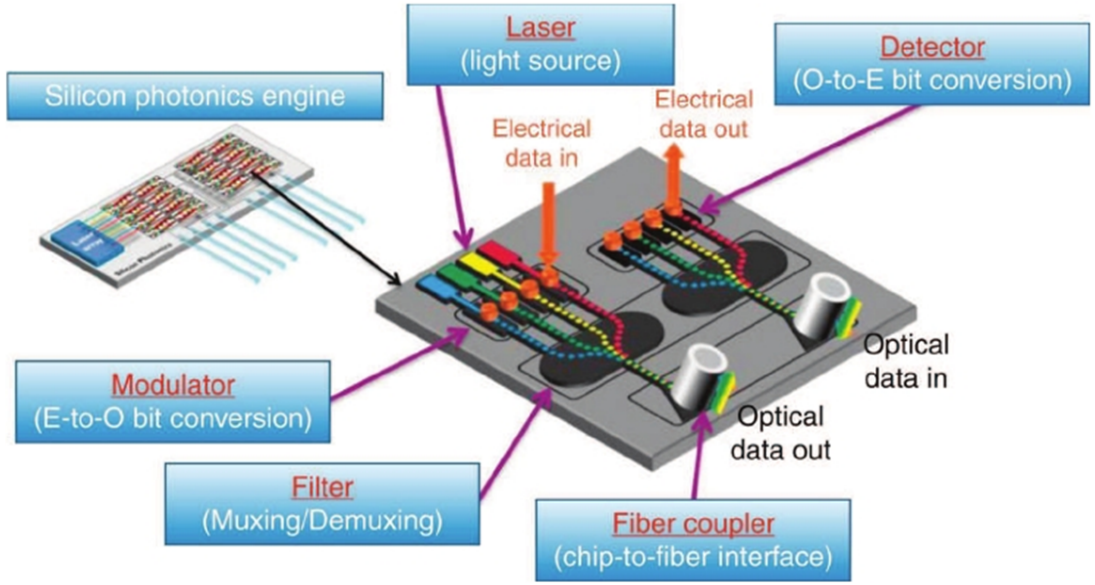
Outline

- Silicon photonics defined
- Its promise
- The reality
- Case studies: success requires market-leading performance
  - Mellanox (Kotura)
  - Luxtera
  - Cisco
  - Acacia Communications

- Numerous opportunities
  1. Moore's law coming to an end
  2. Telecom approaching C-band's data-carrying capacity
  3. Datacenter—central cog in the digital economy
  4. System performance improvements
- Reaching the tipping point for silicon photonics
- Silicon photonics as a disruptive force

Silicon photonics defined

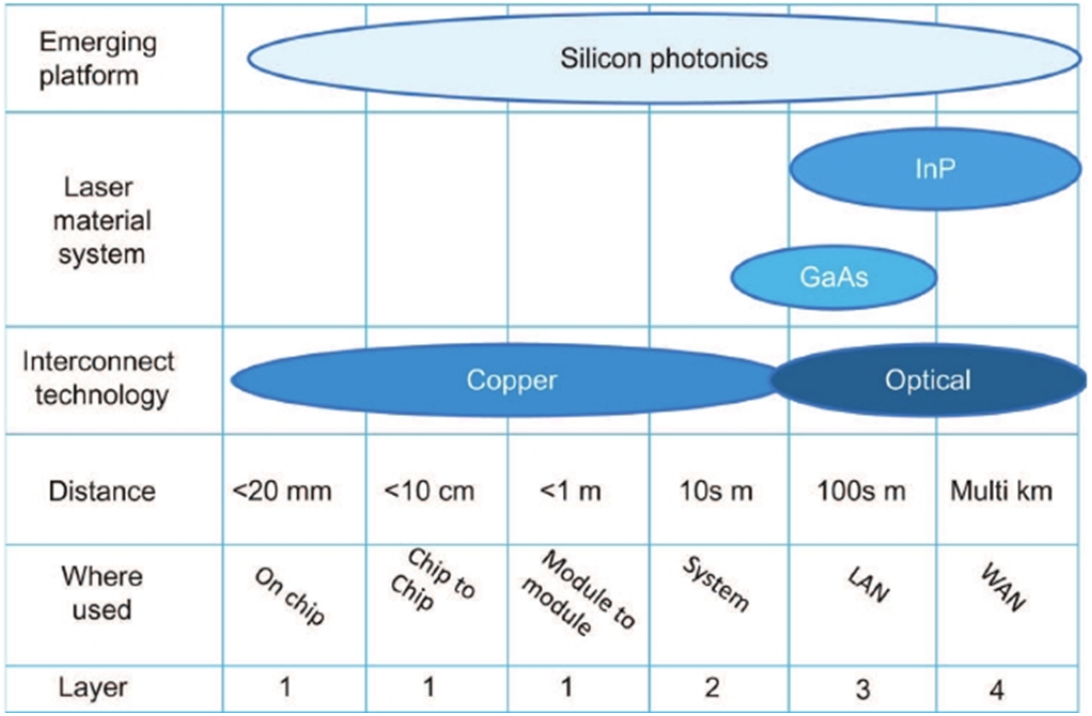
- Making photonic devices on a silicon substrate
- Devices fabricated in a CMOS chip facility



Courtesy of EETimes

Silicon photonics is mainly used to connect

- Telecom and datacom networks are the main uses today
- Silicon photonics can be used across a vast range of distances
  - Consequently the opportunity is huge
  - The opportunity is also challenging as silicon photonics must displace incumbent technologies

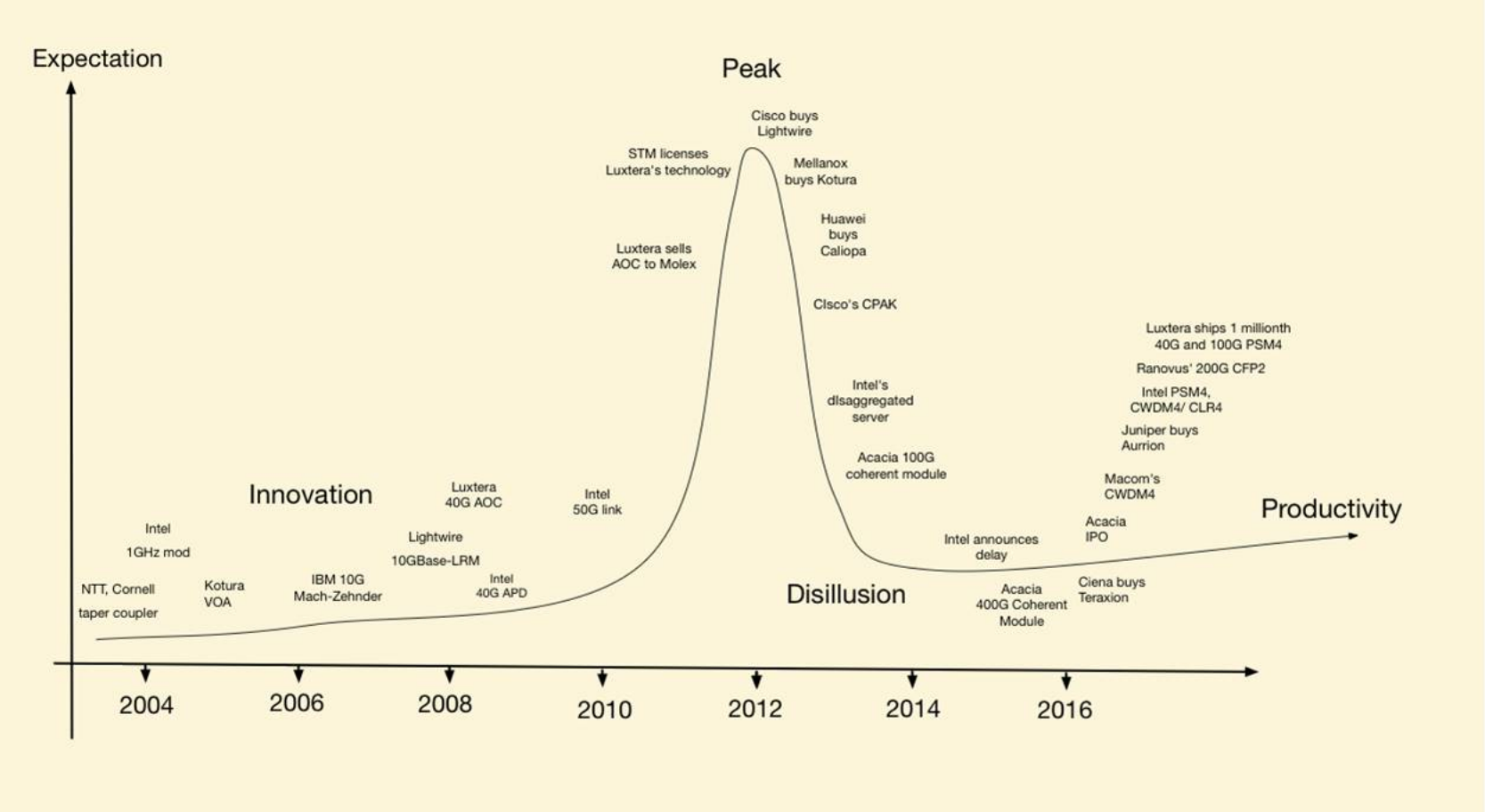


Source: Based on On-board Optical Interconnect, CTR III TWG report **#3**, MIT Microphotonics Center

Silicon photonics promises

- To support a large range of distances
  - Centimeters to thousands of kilometers
- To deliver low cost, high volume solutions
  - as it piggybacks on the semiconductor infrastructure
- To support many markets and applications
  - Telecom, datacom, Sensors, LIDAR, medical devices, etc.
- To disrupt the optical communications market
  - Its advent impacts the traditional optical component market, optical communications equipment market, and the traditional semiconductor market

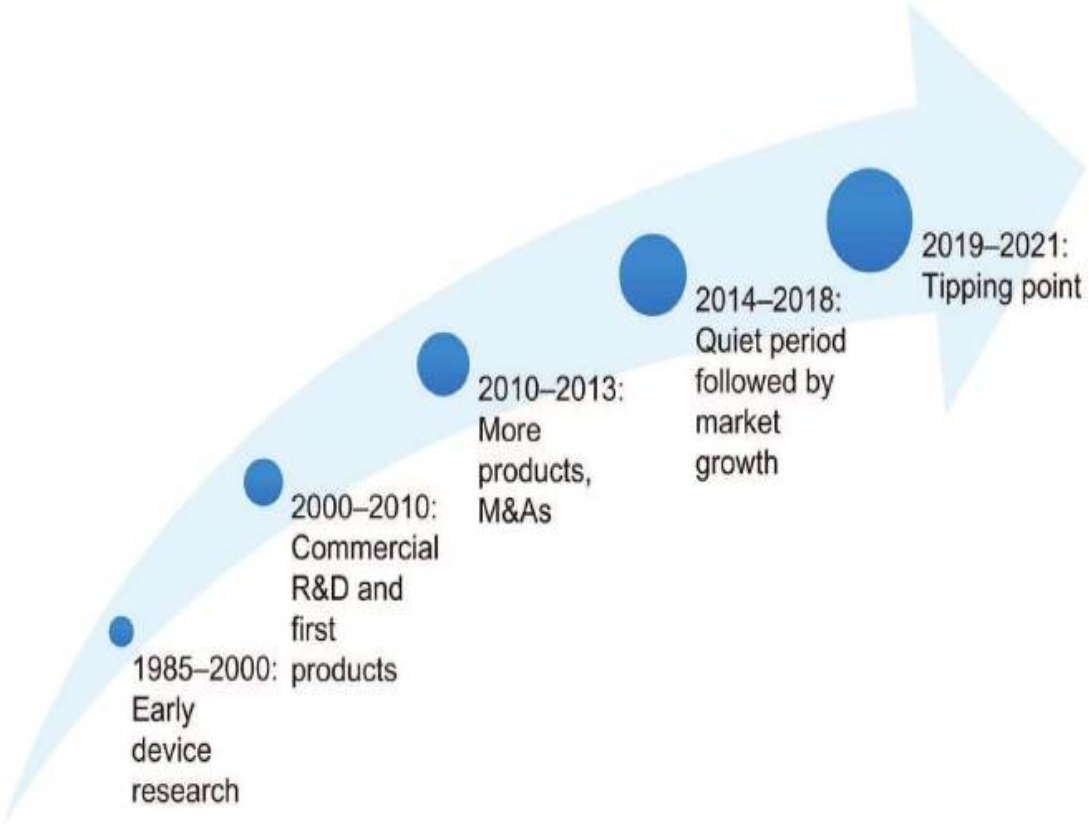
But, silicon photonics adoption has been slow



- Early hype, followed by disillusion
  - Recently entered the productivity phase!
- Market driven by optical component vendors
  - Low volumes
  - Don't have the full support of foundries and electronics industry
- System vendors are acquiring silicon photonics specialists
  - Demonstrating the importance of the technology
    - But fragmenting technology standardization and broad market development

Source: Authors

And, silicon photonics has not reached its tipping point



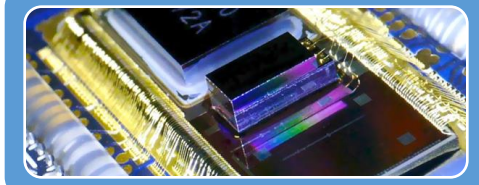
Source: Authors

- Technical challenges
  - Ostensibly “me too” when compared to incumbent technologies
  - Silicon does not lase
- Market
  - Most solutions not differentiated from competitive approaches
- Cost
  - Low volumes
  - Many different technologies—no economies of scale
  - Faces with the same challenges as competing technologies: packaging and fiber attach

Case studies show forward path: Success requires performance differentiation

Mellanox (Kotura): variable optical attenuator

- Performance differentiator—fastest response time
- Gained and secured a market lead



Luxtera: A PSM4 transceiver at 40 and 100 Gb

- Performance differentiator—low cost, low power
- Only one laser, an expensive part of the bill of materials, is used rather than four

Cisco: 100GBase-LR4 CPAK transceiver in a small form factor

- Performance differentiator—first to market with the highest density front plate switch
- The use of silicon photonics advanced system performance

Acacia: 100-Gb transceiver chip for long-distance transmission

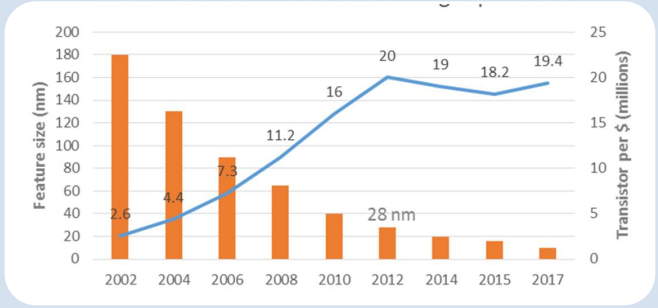
- Performance differentiator—first to market with single-chip coherent CFP transceiver (now same with CFP2-DCO)
- Compact, low-power consumption design lowers the cost of coherent modules

Source: Authors and companies listed

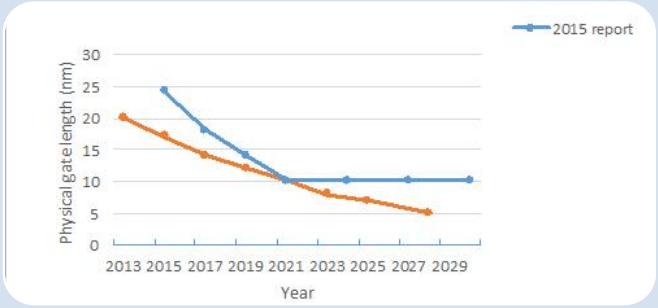
Bright silicon photonics future as there are numerous opportunities

1. Moore’s law is coming to an end
2. Telecom approaching fiber’s bandwidth-carrying capacity
3. Internet content providers, and their data centers becoming a central cog in the digital economy
4. New class of equipment emerging (data center interconnect)
5. Connectivity of equipment inside data centers
6. Close proximity of electronics and optics to improve system performance

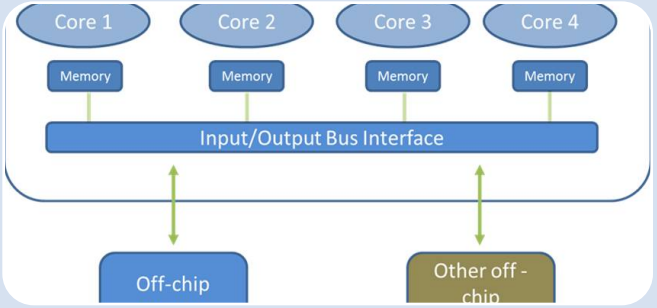
#1—Silicon photonics needed as Moore's law is coming to an end



Source: The Linley Group



Source: ITRS

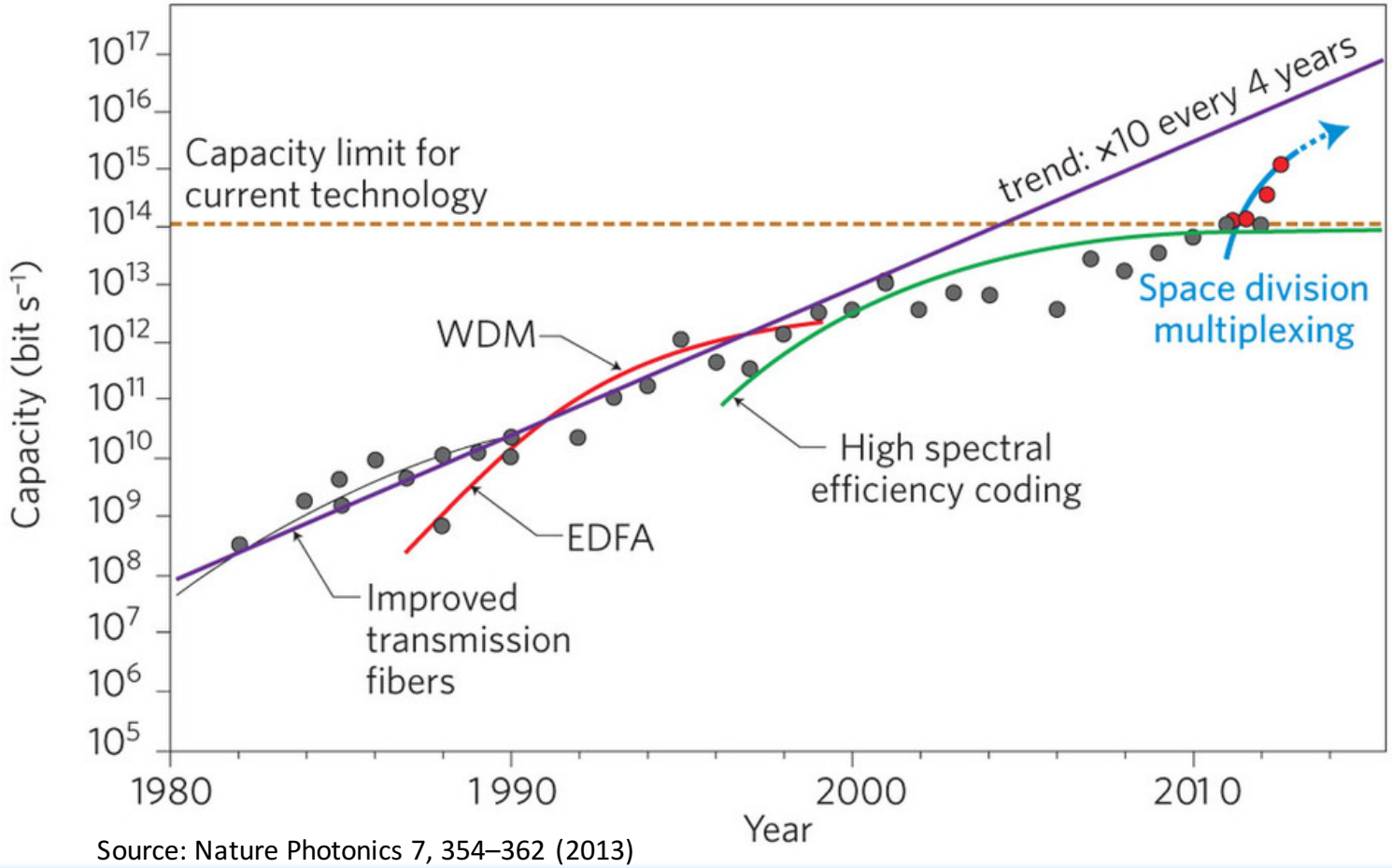


Increasing transistor cost after 28 nm

Transistor gate length estimated to stop decreasing after 2021

Multi-core chip architecture used to scale, interconnect to become limiting

#2—Silicon photonics needed for Telecom as fiber approaches its bandwidth-carrying capacity



Source: Nature Photonics 7, 354–362 (2013)

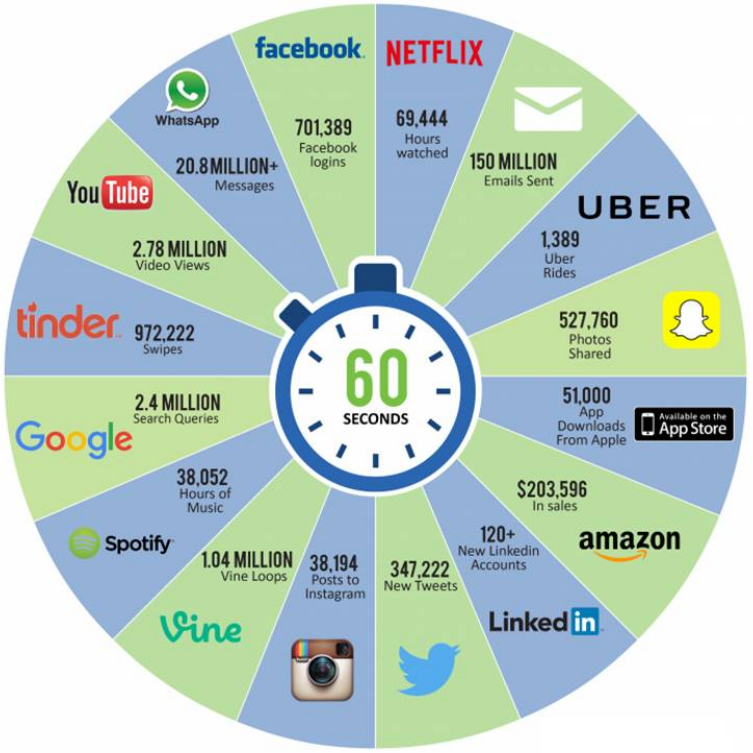
Photonic integration needed and hence silicon photonics

#3—Silicon photonics needed for data center, the central cog in digital economy

Web 2.0 are building data centers

Source: Facebook (Prineville, Oregon data centers)

To support the growing internet reliance



What happens in an internet minute?

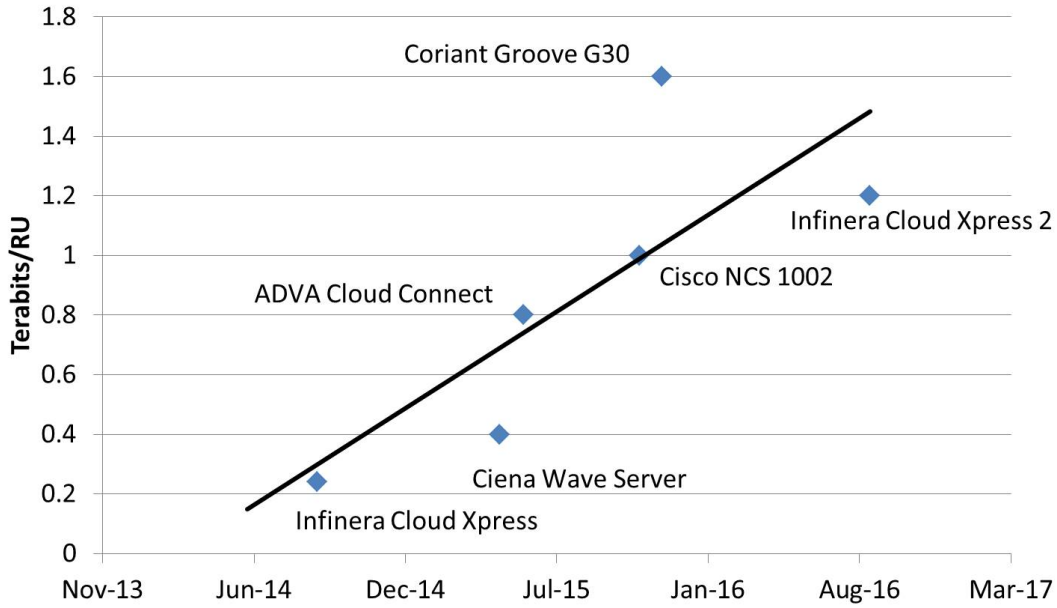
Source: Excelacom

Prof. Lionel Kimerling, MIT

"Everything that has happened in the telecom network is now being replicated in the data center. And then everything that is happening in the data center is going to be on the board, and then everything on the board is going to be in a package, and then everything in a package is going to be on the chip."

#4—Silicon photonics needed to support the data center interconnect network equipment

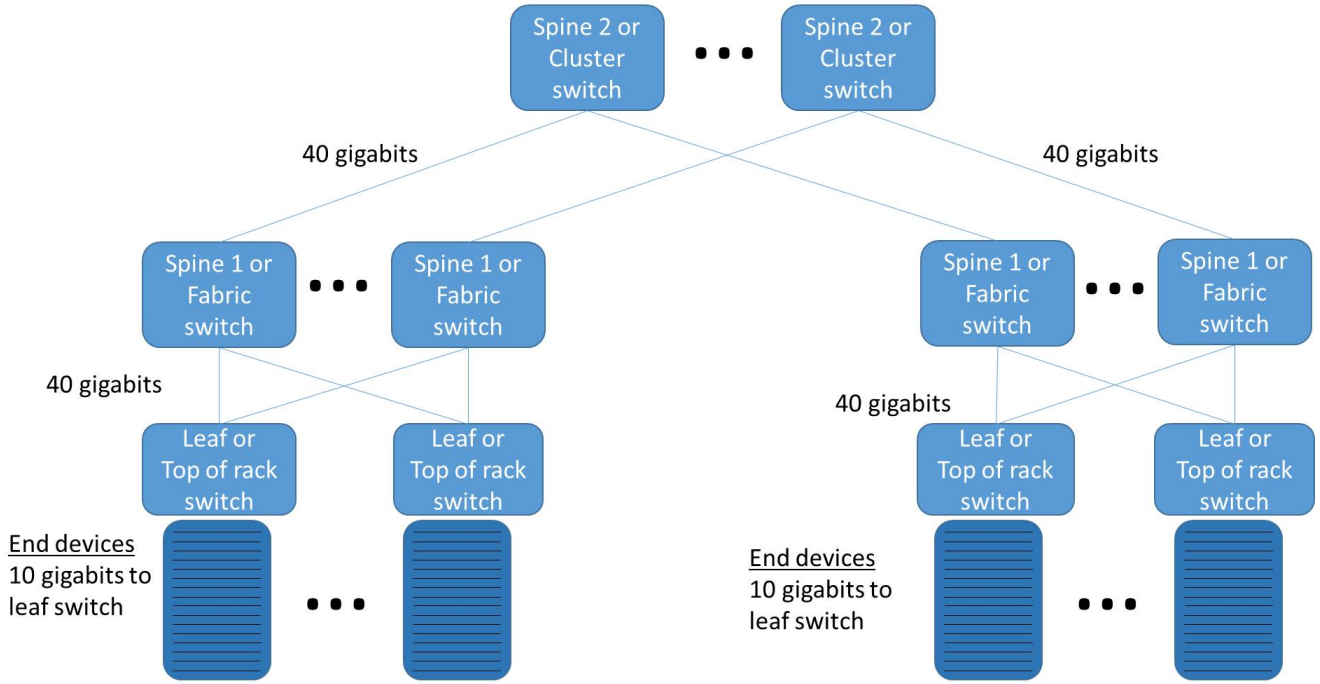
- New class of optical networking gear defined by high density
- Driven by the internet content providers
- Photonic integration needed for this new class of equipment



Source: Authors

#5—Silicon photonics needed to support data center equipment connectivity

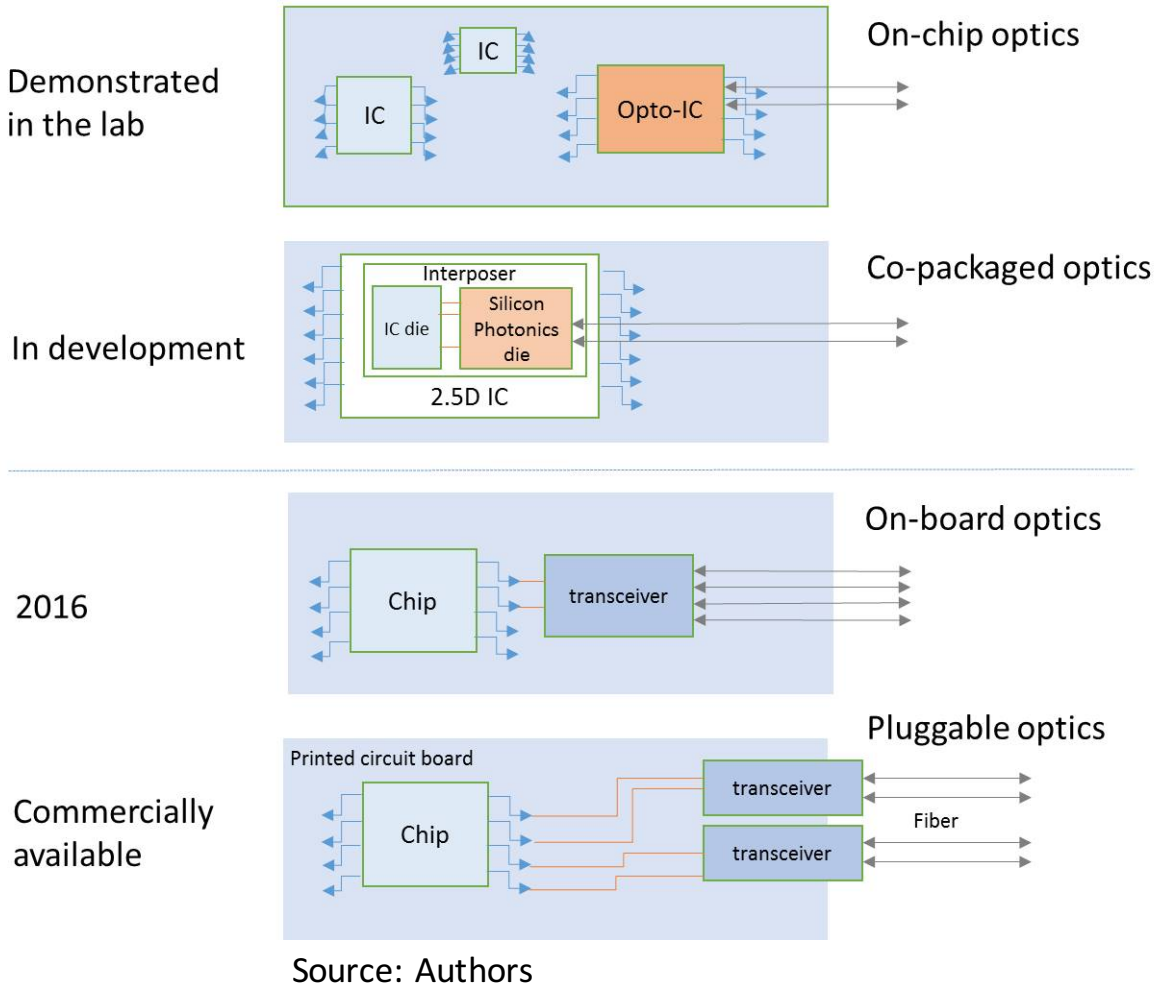
- Throughput limited by equipment connections
  - Server to switches
- Low power consumption required
- Interconnects at 100G, moving to 400G
  - Photonic integration needed



Source: Modified from Facebook

#6—Silicon photonics needed to improve system performance

- Evolution from pluggable optics to on-chip optics
- To deliver low power, higher system performance
- Silicon photonics technology is in pole position to support on-chip optics, the ultimate endgame

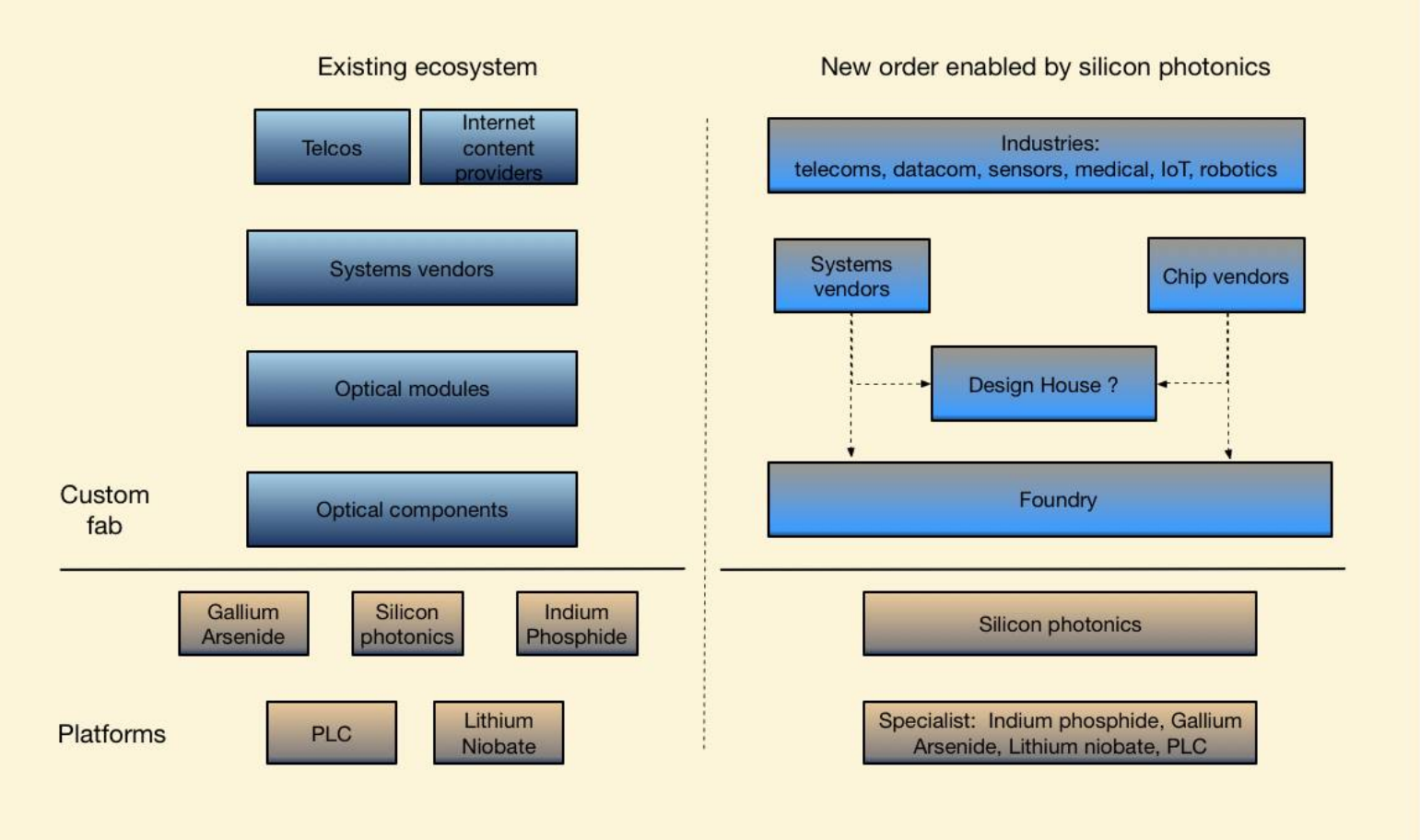


Source: Authors

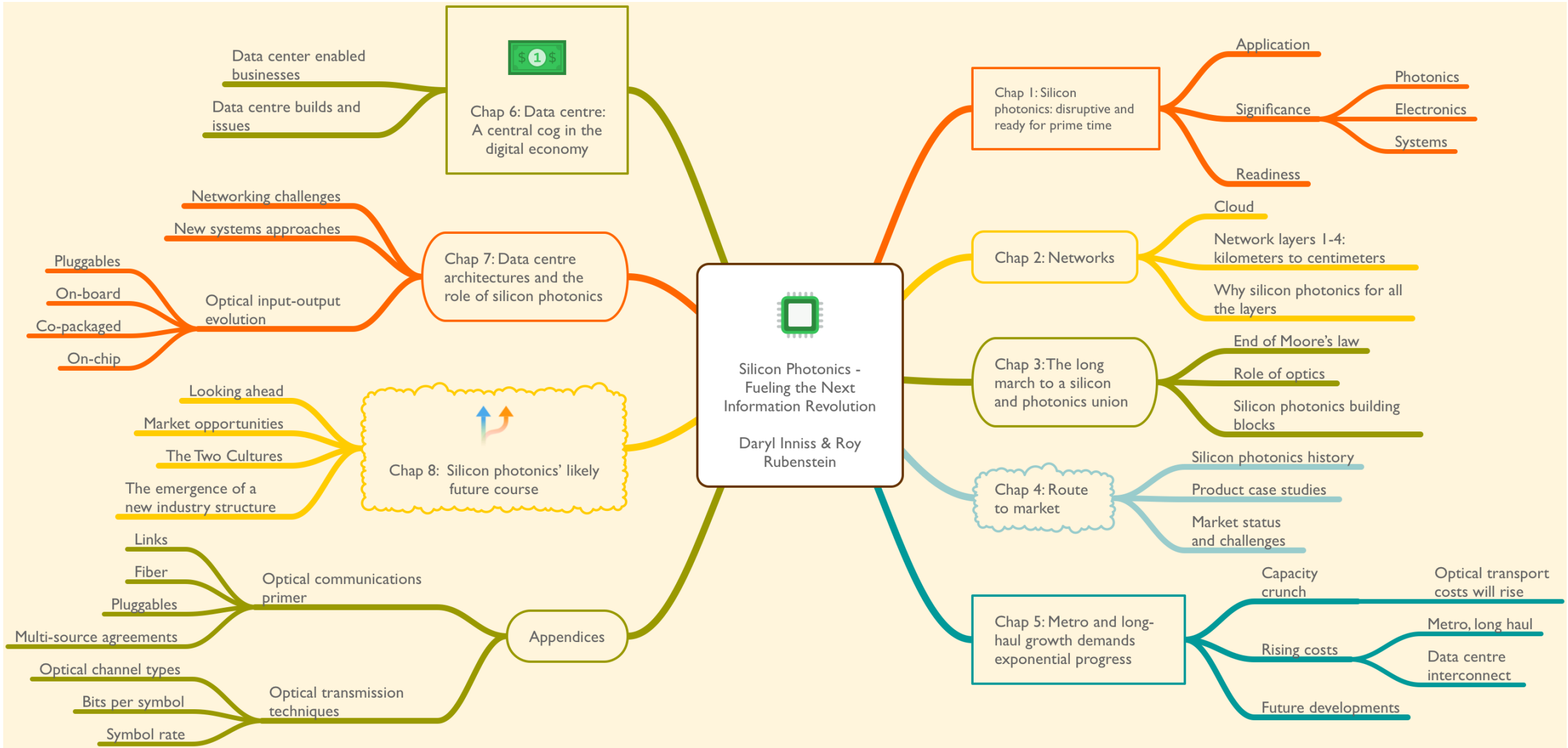
Silicon photonics' tipping point reached when electronics adds optics to standard tool-kit

- Electronics focused on multi-core today, scaling technology that has a lifetime of multiple years
- But interconnect will become a limiting factor
- High bandwidth and low power consumption will be needed to evolve these architecture
- Silicon photonics hits its tipping point when the electronics industry use optics as part of its standard tool-kit

Silicon photonics' disruptive force drives a new market structure



Source: Authors



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