Lect. 1: Introduction

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● Goals

- Introduction to Si photonics
- Basics of key devices in Si photonics
- Simulation skills for Si photonic devices

● Prerequisite

- Introductory courses in EM waves and optoelectronics/optical communications

Lect. 1: Introduction

- Topics to be covered
  - Introduction to Si Photonics
  - Basics of Si processing technology
  - Basics of PN junction
  - Basics of Waveguides
  - Waveguide Devices (Directional coupler, WDM filter, ...)
  - Grating coupler
  - Phase Modulators
  - Mach-Zehnder Interferometer Modulators
  - Ring Modulators
  - Photodetectors
- Simulation tools will be extensively used for deeper understanding of above topics
  - Synapsis T-CAD for process simulation (Demo only)
  - Lumerical Device for PN junction characteristics
  - Lumerical Mode for waveguide devices
  - Lumerical FDTD for waveguide devices/grating coupler
  - Lumerical Device for photodetectors

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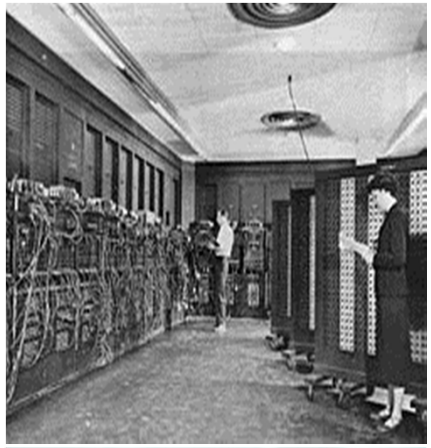
- Grades
  - Quiz for each topic (30%)
  - Design exercises for each topic (30%)
  - Design project at the end of the semester (30%)
  - Attendance and class participation

Lect. 1: Introduction

- Why Si Photonics? (From Si perspective)



	ENIAC (1946)	A4(2010)
Performance (Clock Speed)	**10KHz**	**1 GHz**
Power	**170 KWatts**	**20 Watts**
Weight	**28 tons**	**Negligible**
Size	0.9 m (w) x 2.6 m (h) x 26 m (l) ~ 약 **63 m²**	**53.3 mm²**
Technology	**17468 vacuum tubes**	**200 million 45nm CMOS TR**
Cost	**$ 487,000**	**$ 637**

Secret of success?

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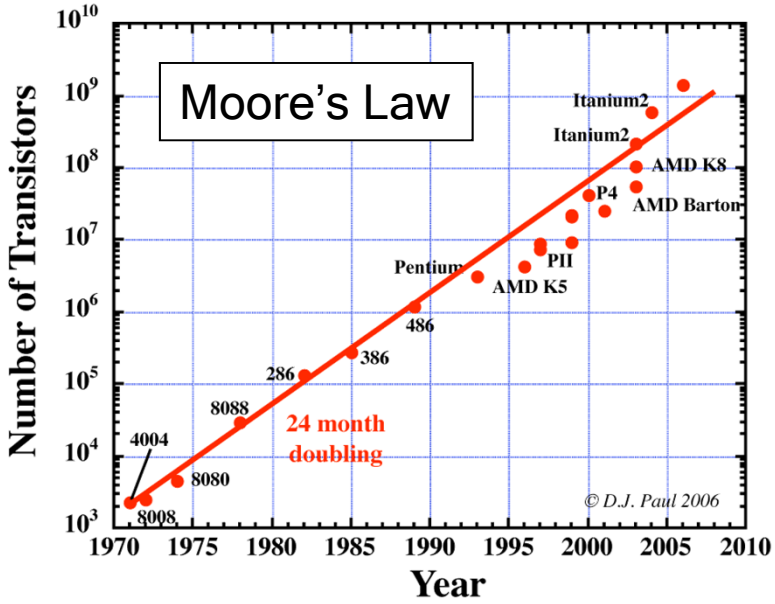
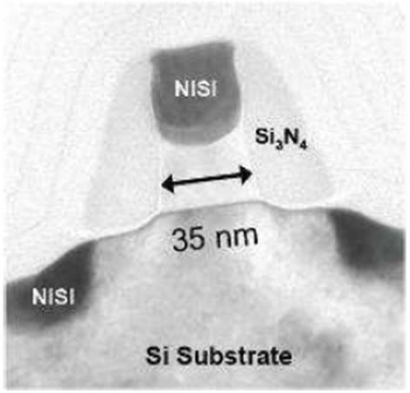
- Why Si Photonics?

  - Scaling and Integration



65 nm Generation Transistors ...
but already moving to 22nm!!



From Intel Corp.

  - Can this continue?

More Moore: Continuation of CMOS scaling

More than Moore: New materials, New technology (***Photonics***)

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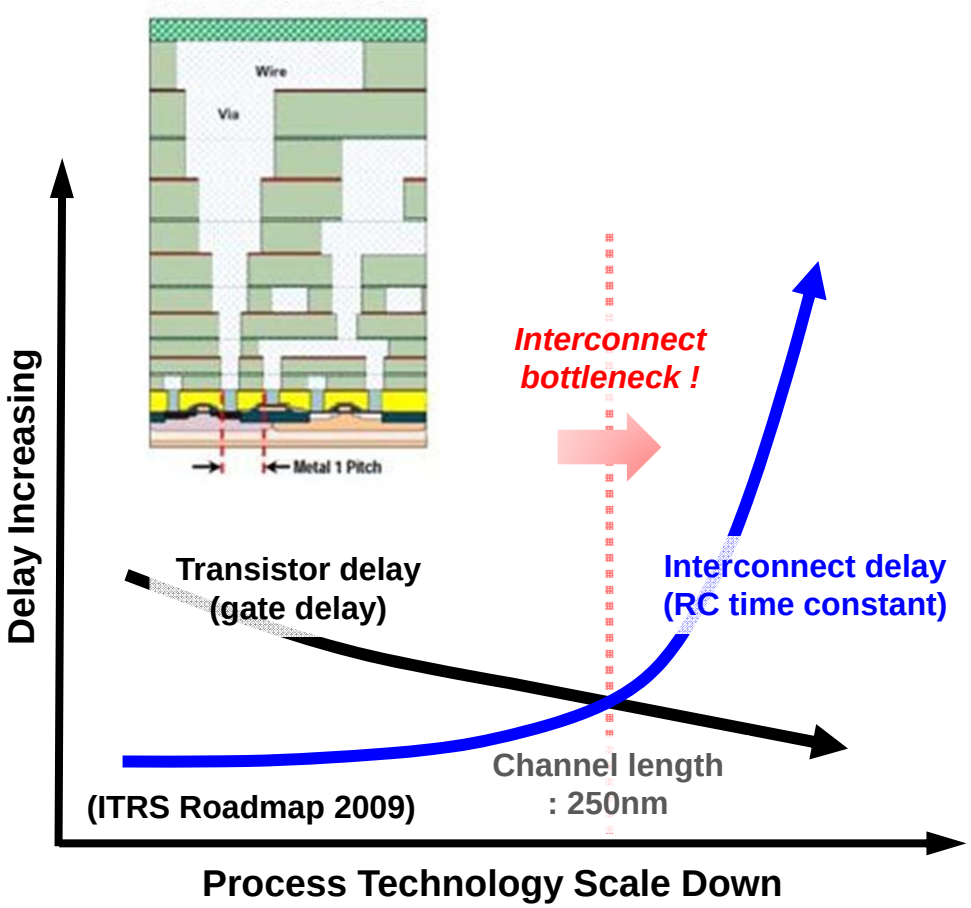
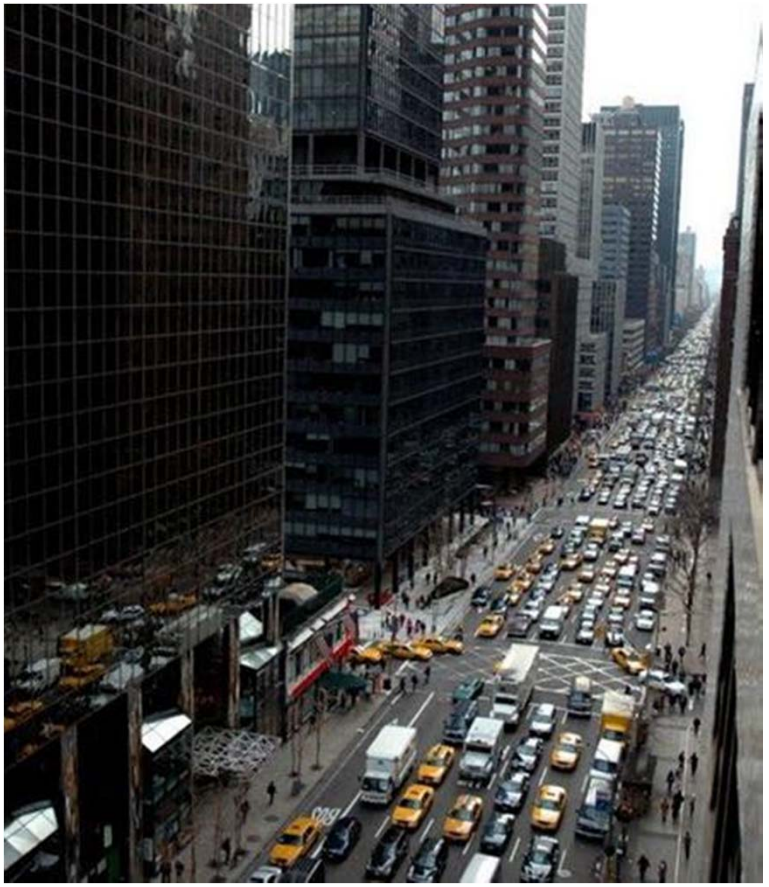
- Why Si Photonics?

-Interconnect Bottleneck: On-Chip Interconnect





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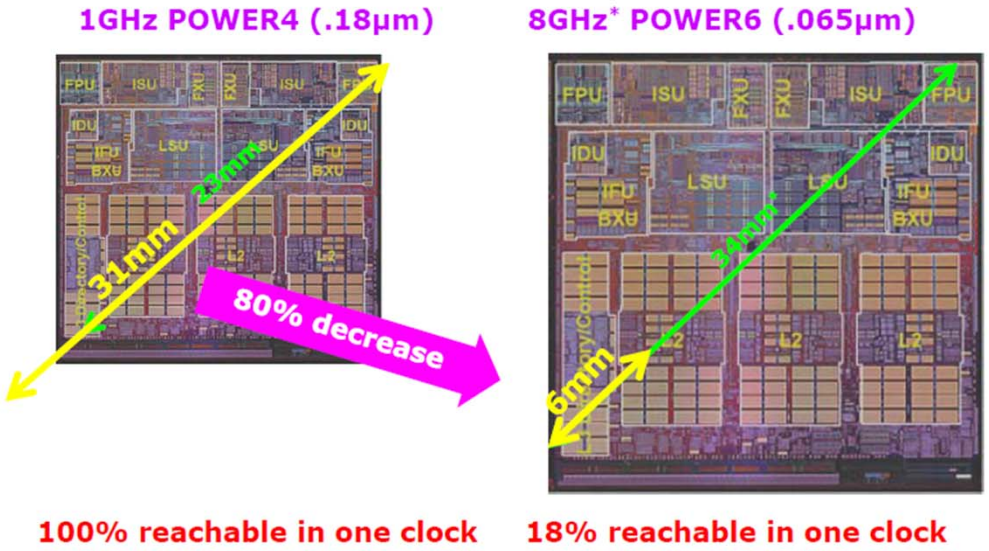
- Why Si Photonics?

-Interconnect Bottleneck: On-Chip Interconnect



- Chips are getting larger but clocks are getting faster
- Difficult to cover the entire chip within one clock cycle
- Interconnection within chip becomes very important for performance

"The development of CMOS-compatible optical components is of paramount importance"

(ITRS Road 2009 – Interconnect, p.56)

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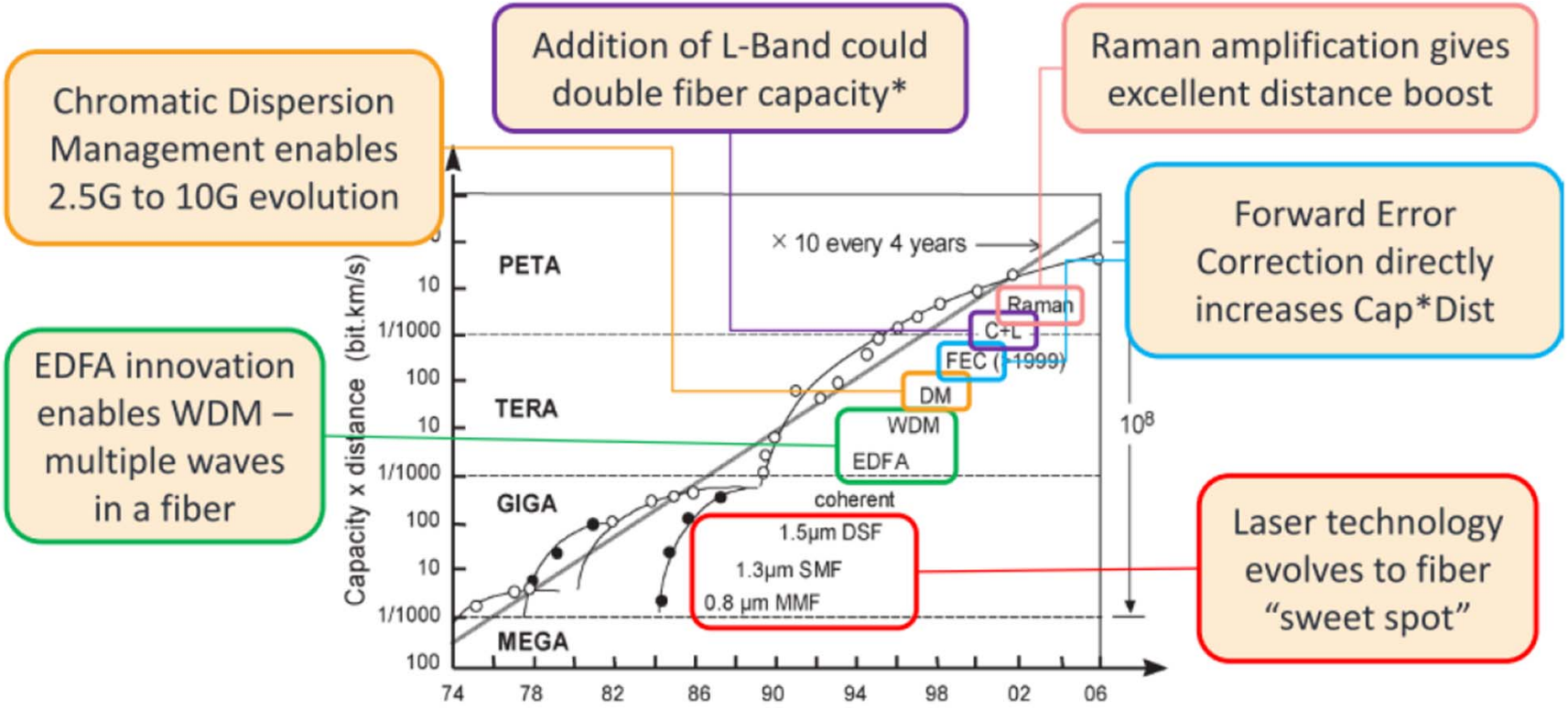
● Why Si Photonics? (From photonics perspective)



Emmanuel B. Desurvire. "Capacity Demand and Technology Challenges for Lightwave Systems in the Next Two Decades" JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL. 24, NO. 12, DECEMBER 2006

- Can this continue?

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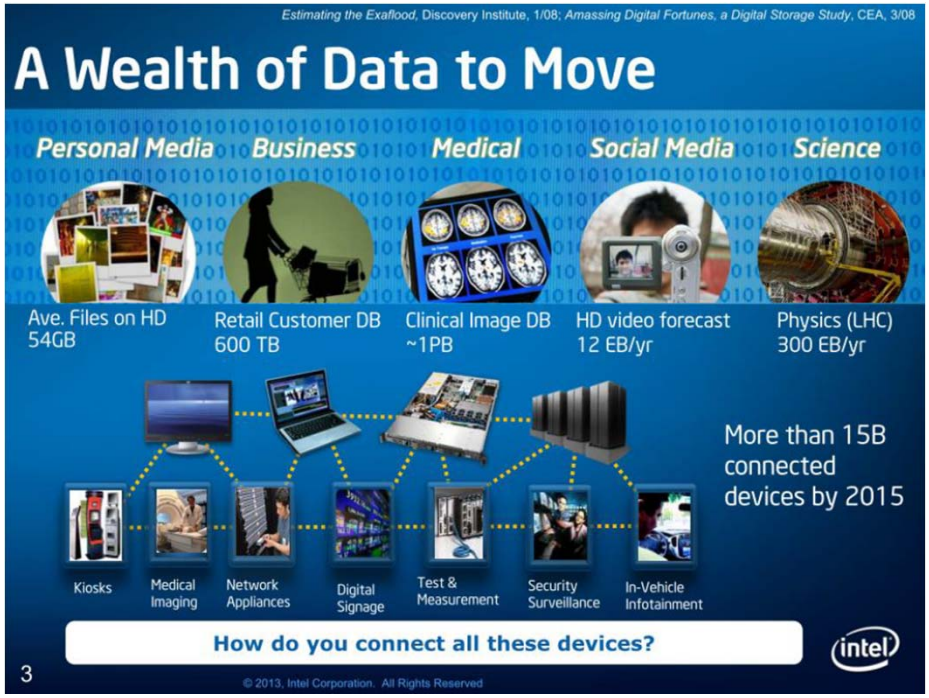
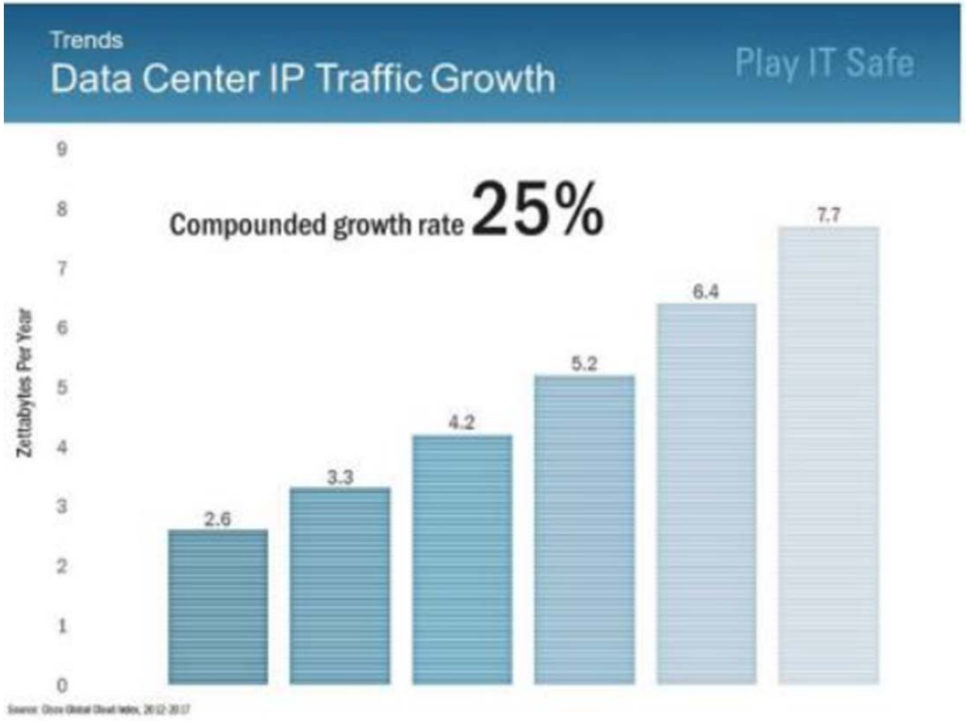
- Why Si Photonics?





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- Data Centers
  - Power consumption
    - Data center use 1.5% of total electricity in USA
  - Size/Weight & Connections

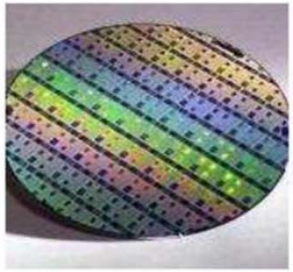



- Cost requirement for data centers are very tight

Lect. 1: Introduction

- Integration is the only way to cut the cost of optical links
- Silicon photonics combines the advantage of photonics with CMOS manufacturing

CMOS

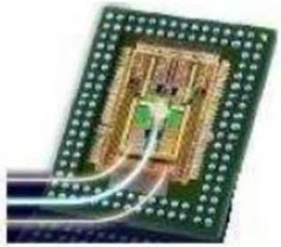


- Volume production
- Low cost
- High integration
- Miniaturization

Photonics

- High performance communication
- Low power
- Small size and weight
- Reduce heat dissipation

Si Photonics



Picture: Courtesy of Luxtera

- High integration
- Miniaturization
- Higher bandwidth
- Lower cost
- Lower power
- Further reduce heat dissipation

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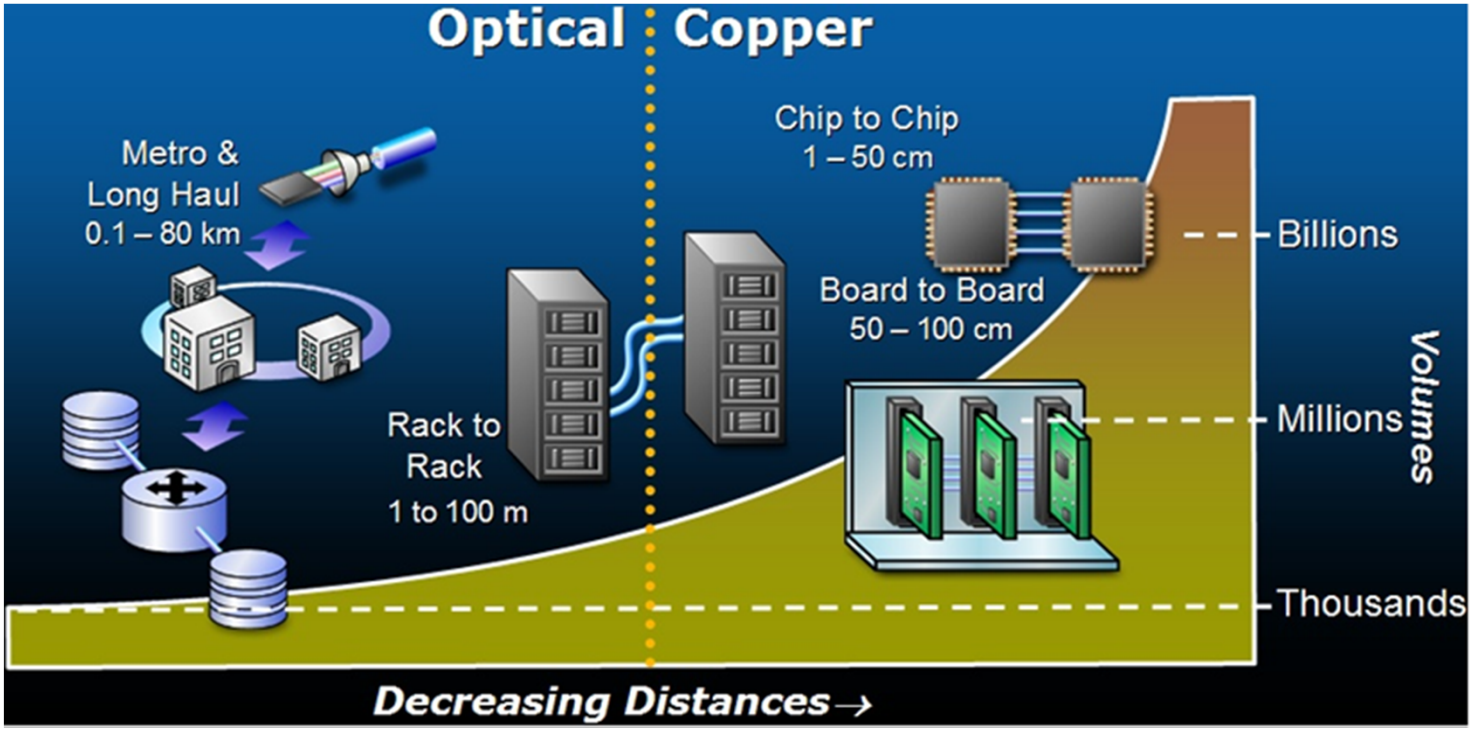

- Optical communication: transmitting lots of serialized data for long distance!
- Strong driving force for evolution from ***left*** to ***right***
- But barriers on the right: Cost
- Can *Si* help?

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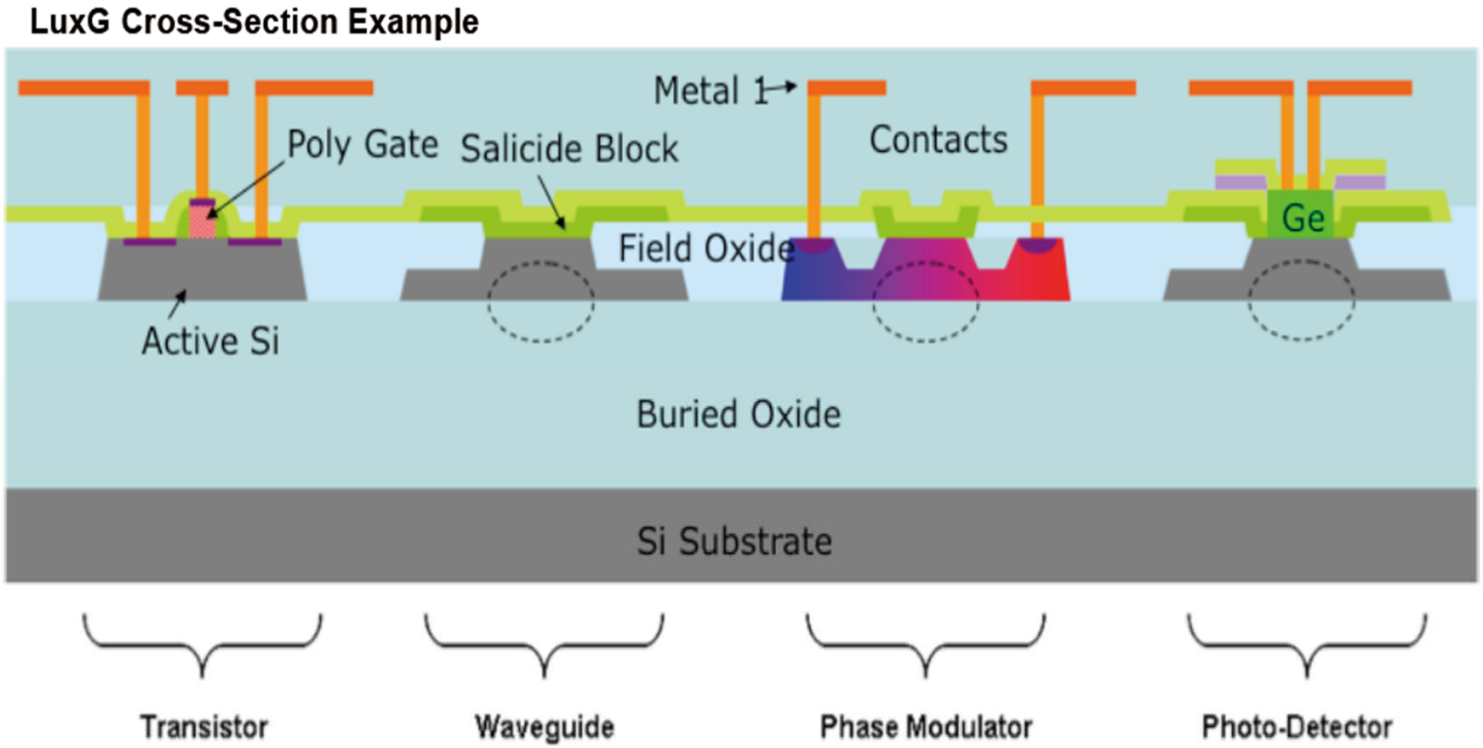

- 0.13-μm SOI CMOS Technology on Si wafer (Luxtera / Freescale Semiconcutor)
- On-going research activities in realizing optimal individual devices and integrated circuits
- 1.5μm lasers are not available

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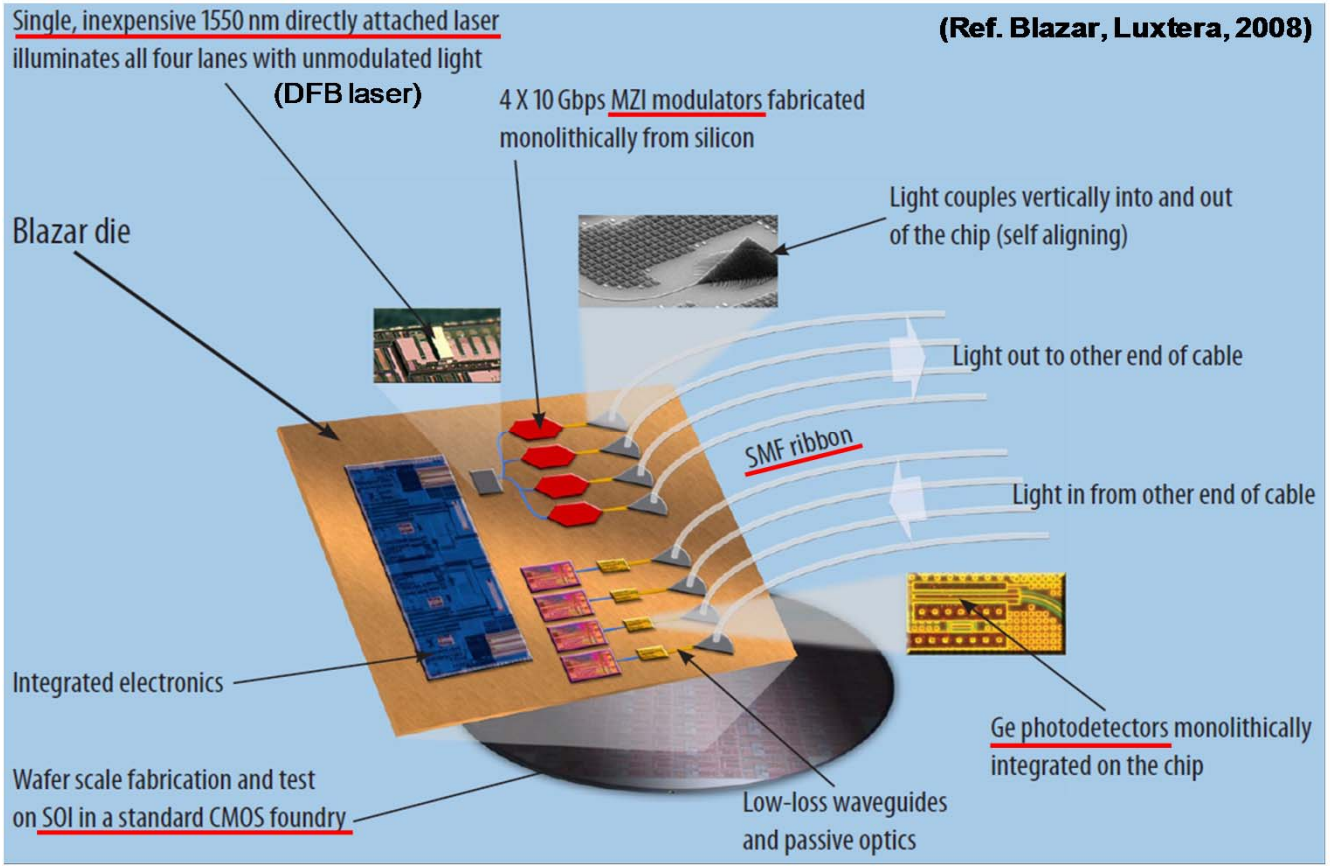

- **Monolithic integration** of optical components and electronics
  : Modulators, waveguides, PDs, Couplers

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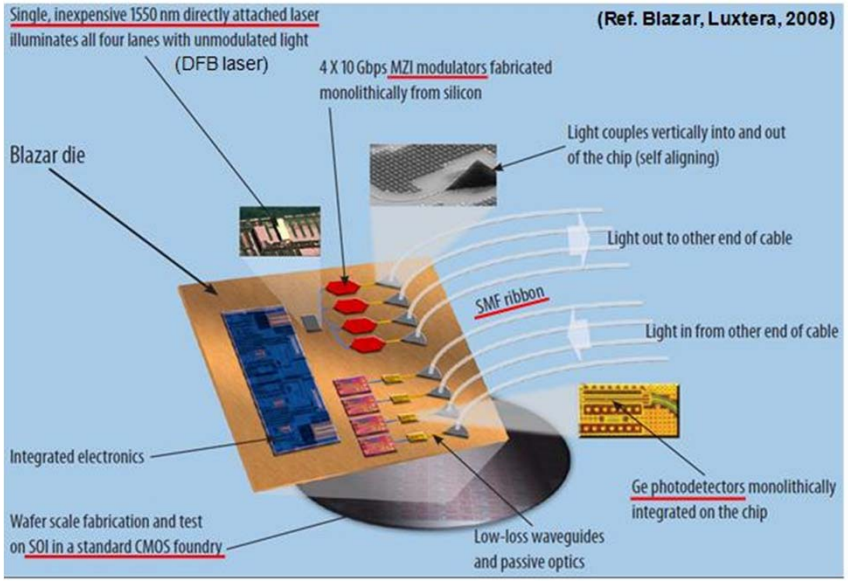

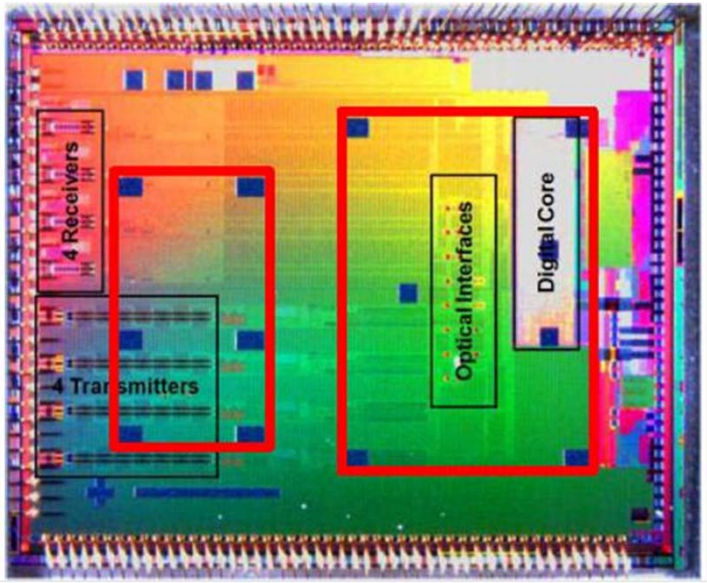

LUXTERA

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● Summary

- Si technology is very much interested in photonics for solving its interconnect bottleneck problem if and only if photonic solutions are provided on Si platform
➔ Si Photonics

- Photonics technology needs integration for continuing its growth. Si is the most mature technology for integration
➔ Si Photonics

- Si Photonics is something required from the application perspective. Not the other way around.