

Silicon Photonics

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What is Photonics?

- Silicon Integration Initiative
- The science of photonics includes the generation, emission, transmission, modulation, signal processing, switching, amplification, and detection/sensing of light.

http://www.np.edu.sg/~sat/Schprj/Photonics/photonics.html





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Current Applications of Silicon in Photonics

- Planar Waves
 Directional Couplers
 Y-Junctions ilicon Integration AWG (Arrayed Wave Guides)
 - Add-Drop MUX/DEMUX and other multiplexers
 - **Light Source/Detection**
 - Semiconductor Lasers



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Problems with Silicon in Photonics

- Indirect Nature of Si Bandgap
- Absence of linear optoelectric effect
 - Electric fields change the index of refraction in Si
 - The bandgap of Si does not match the wavelengths the optical communications industry has adopted (1.3um or 1.55um)

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Photo courtesy of http://www.herrera.unt.edu.ar/nano/research.html



Why Silicon Photonics?

- "Silicon is the material par excellence. It is the Silicon Integration Initiativ most widely studied material in the history of civilization." [1]
 - ...However, the semiconductor industry indicates a decline in Moore's law
 - The interconnect problem
 - The speed and performance problem
 - **Optoelectronic Integrated Circuits (OIEC)** provide increased communication bandwidth, reduced power consumption, reduced thermal radiance, and increased interconnect density.



The Interconnect Problem



Figure 1.2 Schematic view of electrical interconnect in very large-scale integrated (VLSI) circuit.

- Metallization, interlevel dielectric deposition and etching techniques create a structure as shown above.
- The first problem with this approach is density; electrical connections cannot go through one another without insulation (Si02)

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The Interconnect Problem

- The second problem is power consumption. The interconnects draw far more power than the transistors themselves, and produce more heat.
- The third problem is speed and performance. The RC time delay (specifically, the capacitive rise time of the copper or aluminum interconnects) is a fundamental source of lag.



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The Interconnect Problem



Figure 1.3 Variation of interconnects propagation delay with year and feature size for Al–SiO₂, Cu–low-k dielectric, and projected optical interconnects technology.



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The Interconnect Problem Summary

"The optical interconnect using silicon microphotonics technology offers a potential solution to the RC time delay associated with traditional metal interconnects.

Using Photons as bits of information, instead of electrons, a speedier performance of the devices is expected.

Use of photons also solves the power dissipation problem. Photons propagate in transparent media with less heat dissipation and almost no cross-talk.

Unlike electrical current beams, light beams can cross one another without using any insulator.

The multilevel interconnection scheme shown in figure 1.2 is not needed when light beams are used for interconnects within the chips." [1]

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Dense Wavelength Division Multiplexing

 Today's fiber-optic links employ dense wavelength division multiplexing (DWDM), using hundreds of carrier wavelengths, each modulated at 10 Gb/s or more, transmitted by a single fiber.



Figure 1.4 Schematic diagram of a WDM point-to-point communication link.

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Level of Device Integration in Commercially Available Products

Discrete Componente in	Package		
Driver Monitor Laser	rackage		
Criver Montor Laser			
Driver Monitor Laser	Modulator VOA		
Hybrid Integration on C	hip		
Laser	lodulator		
	VOA	Monitor PD	
Monolithic Integration on Chip			PD TIA
Laser	Modulator		
	VO	Monitor PD	Mux
SOA	Modulator		
Laser SOA	Modulator		
Driver Monitor Laser SOA	Modulator VOA	Monitor PD	Mux Demux PD TIA

Figure 1.5 Level of device integration in commercially available products. Reproduced with permission from [2] Copyright (2004) Springer Science + Business Media



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[1] M. Jamal Deen and P. K. Basu, *Silicon Photonics*. West Sussex, UK: Wiley, 2012



THANK YOU!

QUESTIONS?

