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# Silicon Photonics Crash Course

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RPI IEEE/EPS | 21 Nov. 2024

# Updates

Last meeting of the semester! ☹

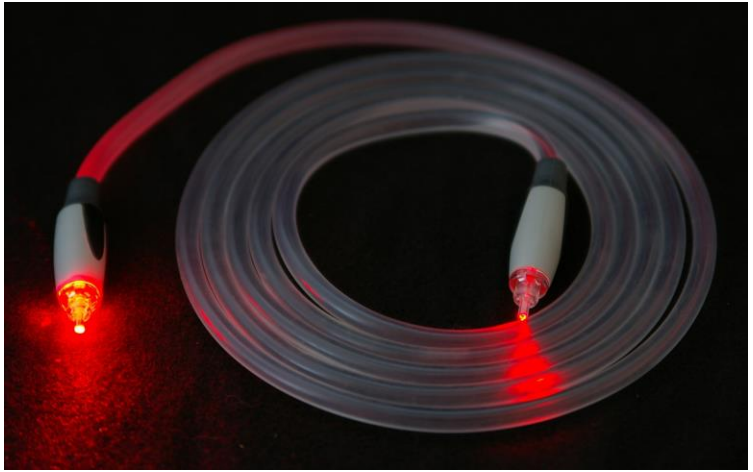
Itherm!?!?!?

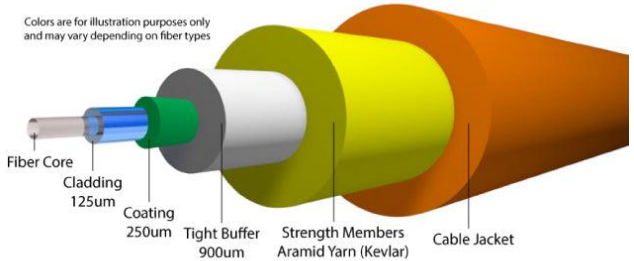
# Overview

Origins (Fiber Optics)
Physics/how it works
Benefits
Systems that use it
Future State

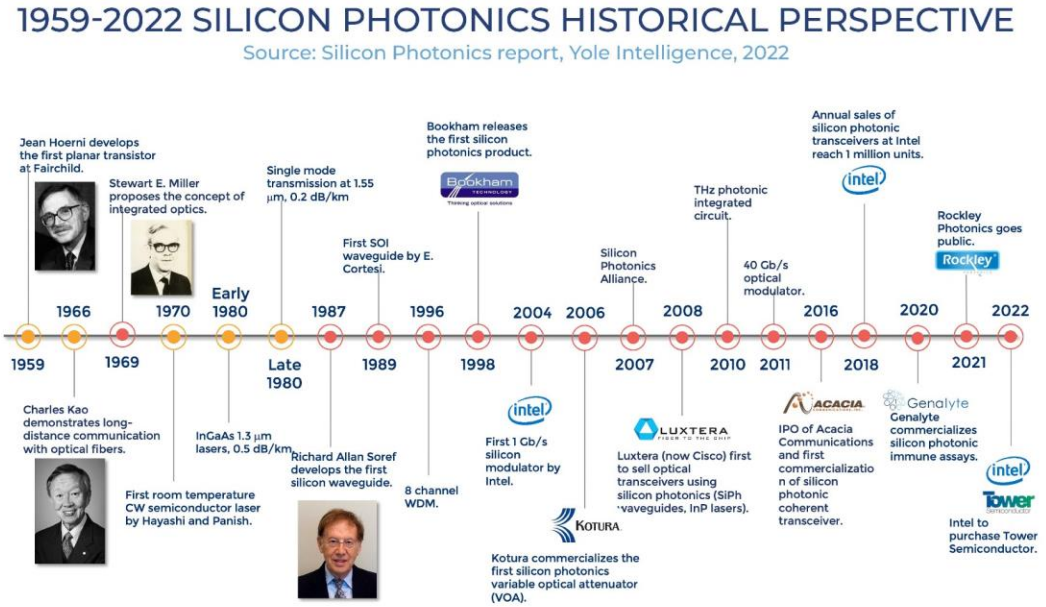
# Origins

1952: First fiber optic cable invented
1970: Corning researchers break attenuation barrier, allowing fiber optics for communication
1986: Sprint becomes first US company with nationwide, 100% digital Fiber Optic Network
1996: All-optic fiber cable laid under pacific ocean





# Origins


1959-2022 SILICON PHOTONICS HISTORICAL PERSPECTIVE
Source: Silicon Photonics report, Yole Intelligence, 2022
1959
Jean Hoerni develops the first planar transistor at Fairchild.
1966
Charles Kao demonstrates long-distance communication with optical fibers.
1969
Stewart E. Miller proposes the concept of integrated optics.
1970
First room temperature CW semiconductor laser by Hayashi and Panish.
Early 1980
InGaAs 1.3 µm lasers, 0.5 dB/km.
Late 1980
Single mode transmission at 1.55 µm, 0.2 dB/km
1987
Richard Allan Soref develops the first silicon waveguide.
1989
First SOI waveguide by E. Cortesi.
1996
8 channel WDM.
1998
Bookham releases the first silicon photonics product.
2004
First 1 Gb/s silicon modulator by Intel.
2006
Kotura commercializes the first silicon photonics variable optical attenuator (VOA).
2007
Silicon Photonics Alliance.
2008
Luxtera (now Cisco) first to sell optical transceivers using silicon photonics (SiPh waveguides, InP lasers).
2010
THz photonic integrated circuit.
2011
40 Gb/s optical modulator.
2016
IPO of Acacia Communications and first commercialization of silicon photonic coherent transceiver.
2018
Annual sales of silicon photonic transceivers at Intel reach 1 million units.
2020
Genalyte commercializes silicon photonic immune assays.
2021
Rockley Photonics goes public.
2022
Intel to purchase Tower Semiconductor.
YOLE Intelligence
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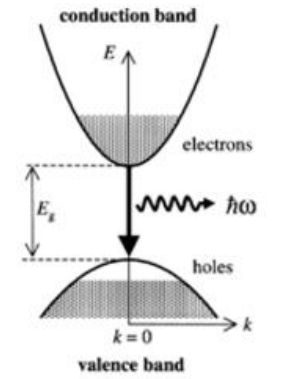
# Physics- Direct Bandgap Challenge

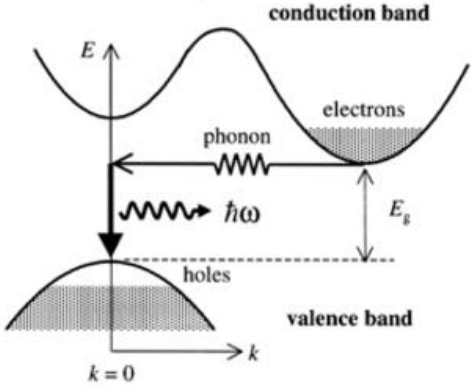
To lase or not to lase…
Band gap: An energy gap that an electron must traverse to change from valence to conduction band…

Direct: Energy release in form of photon
E.g. GaAs, AlGaAs (Typically III-V)

Indirect: Offset between states leads to release of photon (and phonon, to conserve momentum)
-Inefficient
-Most semiconductors do this
E.g. Si* (Typically IV)




(a) direct-band-gap structure



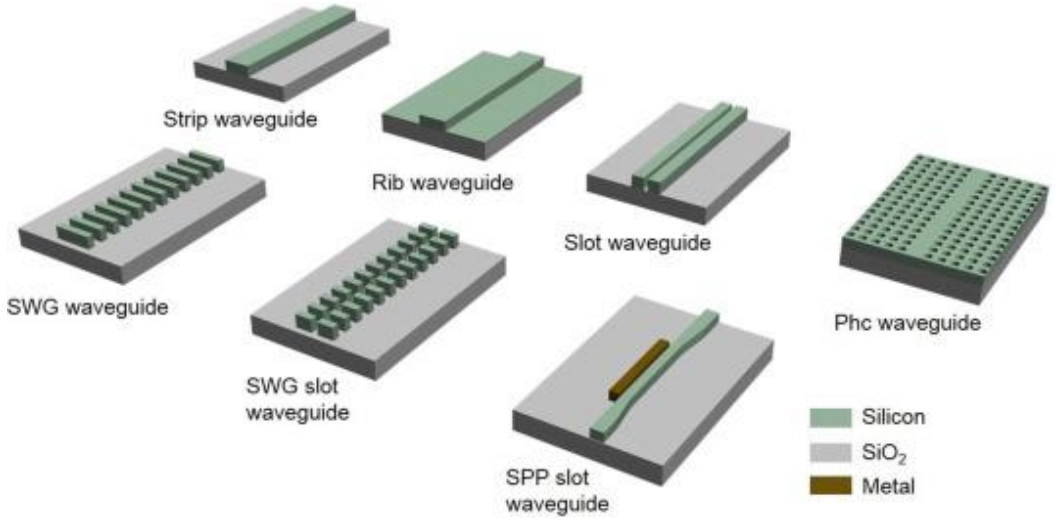

(b) indirect-band-gap structure

# Physics- Transmission mediums

Light transmitted via waveguides

“Light Wires”

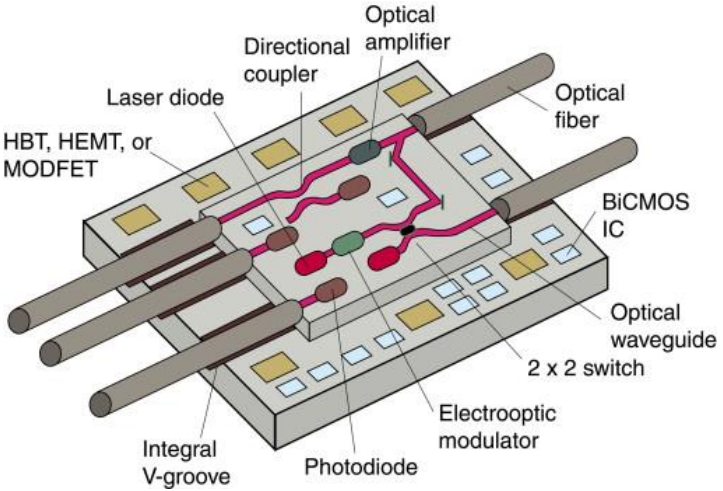
** Wire must be AT LEAST ½ * λ



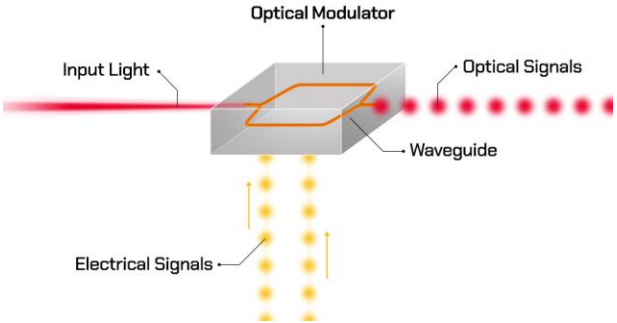
# Physics- Modulators

Photodiodes generate light (As a laser)
Electronic modulators

Physical properties of modulator vary to control light movement




**Conceptual diagram of the process of an optical modulator**

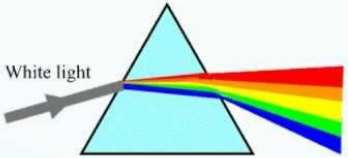


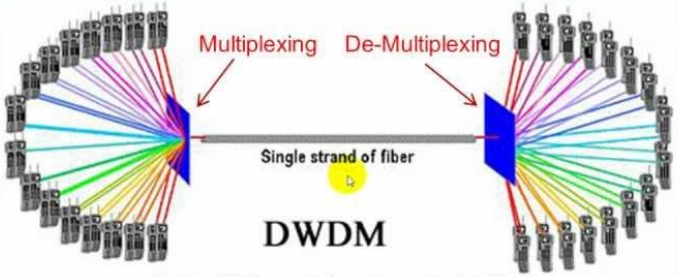
# Physics- Optical Multiplexing

## What is WDM?

WDM = Wavelength Division Multiplexing

Refraction through a prism




40 virtual high-speed channels per physical fiber
Expanding capacity of an OC-48 ring from 2.5 to 100 Gbps

WDM is used on fiber optics to increase the capacity of a single fiber

Fiber Optics For Sale Co.
COMPLETE SUPPLY SOLUTIONS

# Benefits

No electronic power loss in signal transmission

- -Near infinite signal travel length
- -Near infinite signal speed (Speed of light)
- -No heat generation within the wire
- -Signals can be sent via multiplex, increasing signal volume

# Systems using this

Championed by large volume data companies

-Internal servers for companies like google transport more data at any given time than the entirety of the open internet from east to west coast

-Desperate need for reduction in communication cost per bit

Adopted by companies to allow faster overseas data transfer (E.g. cross-Atlantic)

Interest in Silicon Photonics

-Global Foundries industry leader, followed by Intel, Defense companies

# Future State- SoC Integration

Unlikely “Dream”

Challenging to create light-based signals in silicon devices, near impossible at current process nodes

-Wavelength Issue… Find Smaller Wavelengths?

-Silicon has indirect bandgap… New materials?

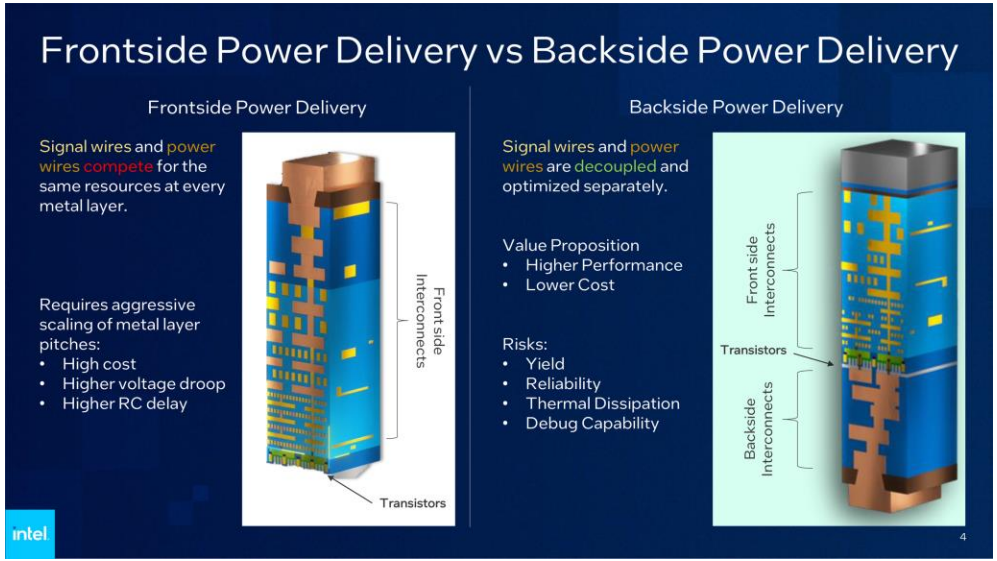
Low power systems, biosensors, long distance signal communication

# Future State- BSPDN 2.0???

Possibility for signal wires do be further decoupled, using waveguides instead of traditional wires

Solves some electrical, power issues

Even faster signals (Near instant transmission)



# Thanks ☺

https://www.youtube.com/watch?v=29aTqLvRia8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