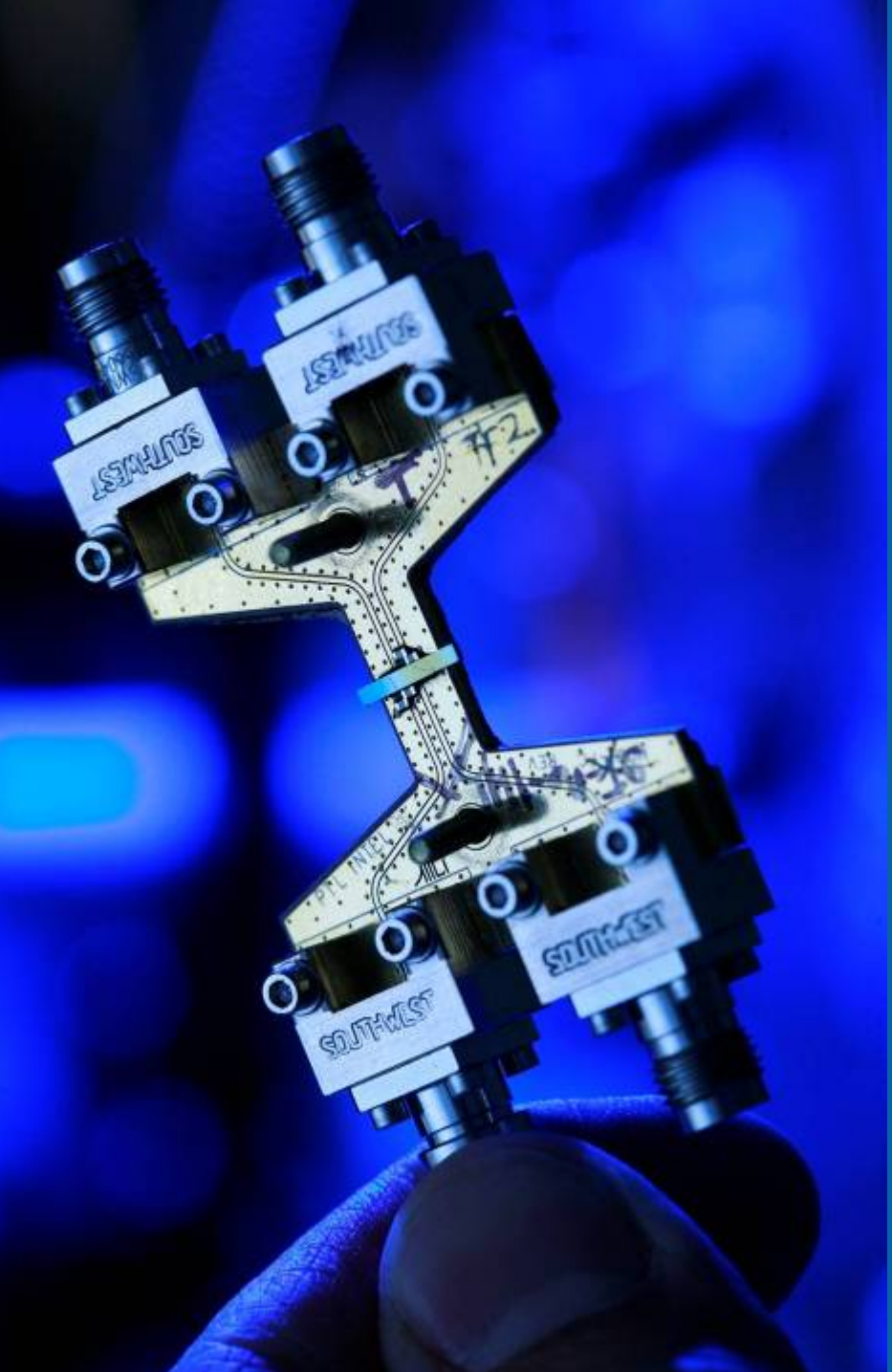


First 40 Giga-bits per second Silicon Laser Modulator

Dr. Mario Paniccia
Intel Fellow
Director, Photonics Technology Lab

Agenda

- What We Are Announcing
- Silicon Photonics Re-cap
- Tera-Scale Computing
- Why is a Silicon Laser Modulator Needed?
- How Does the Silicon Laser Modulator Work
- Results
- Summary

What We are Announcing

- Research Breakthrough: 1st 40 Giga-bits per second Silicon Laser Modulator
  - Fastest Laser Modulator made from silicon
  - Capable of putting one's and zeros on a beam of laser light – 40 Billion time per second
- Intel's Vision
  - Use silicon and CMOS manufacturing techniques to build integrated optical devices
  - Build Tera-Bit per second optical links to enable Tera-scale computing
  - One Tera-bit = 1,000 Billion bits
- Background
  - Intel announced a One Giga-bit per second silicon laser modulator in 2004
  - We have now achieved new milestone of 40 Giga-bits/second (Gb/s)
  - Using 25 Silicon Laser Modulators at 40Gb/s we can build a Tera-bit per second Optical link (25 x 40 Gb/s = 1 Terabit/s)

"Achieving 40Gb/s using a silicon laser modulator is a significant milestone for silicon photonics in that we've matched the data transmission speed records set by fastest III-V optical devices available today," said Justin Rattner, Intel Chief Technology Officer. "We see silicon photonics at the heart of future, low cost optical interconnects for tera-scale computing."

Justin Rattner, Intel Chief Technology Officer

The Photonic Dilemma

Fiber can carry much more bandwidth than copper

However, it is much more expensive.....

Photonics: ***The technology of emission, transmission, control and detection of light (photons) aka fiber-optics & opto-electronics***

Today: ***Most photonic devices made with exotic materials, expensive processing, complex packaging***

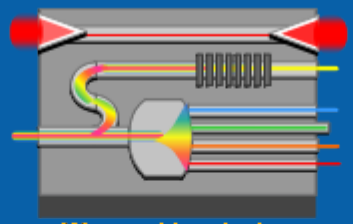
Silicon Photonics Vision: ***Research effort to develop photonic devices using silicon as base material and do this using standard, high volume silicon manufacturing techniques in existing fabs***

Benefit: Bring volume economics to optical communications

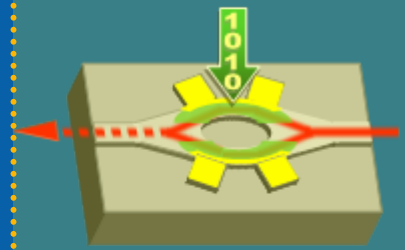
Intel's Silicon Photonics Research

1) Light Source

2) Guide Light

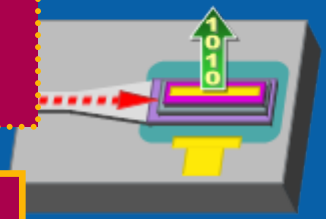


3) Modulation

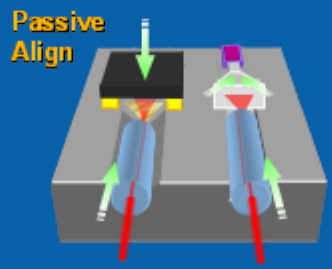


Continuous Wave Silicon Raman Laser *(Feb '05)*

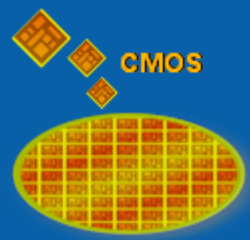
) Photo-detection



5) Low Cost Assembly



6) Intelligence



1GHz *(Feb '04)*
10 Gb/s *(Apr '05)*

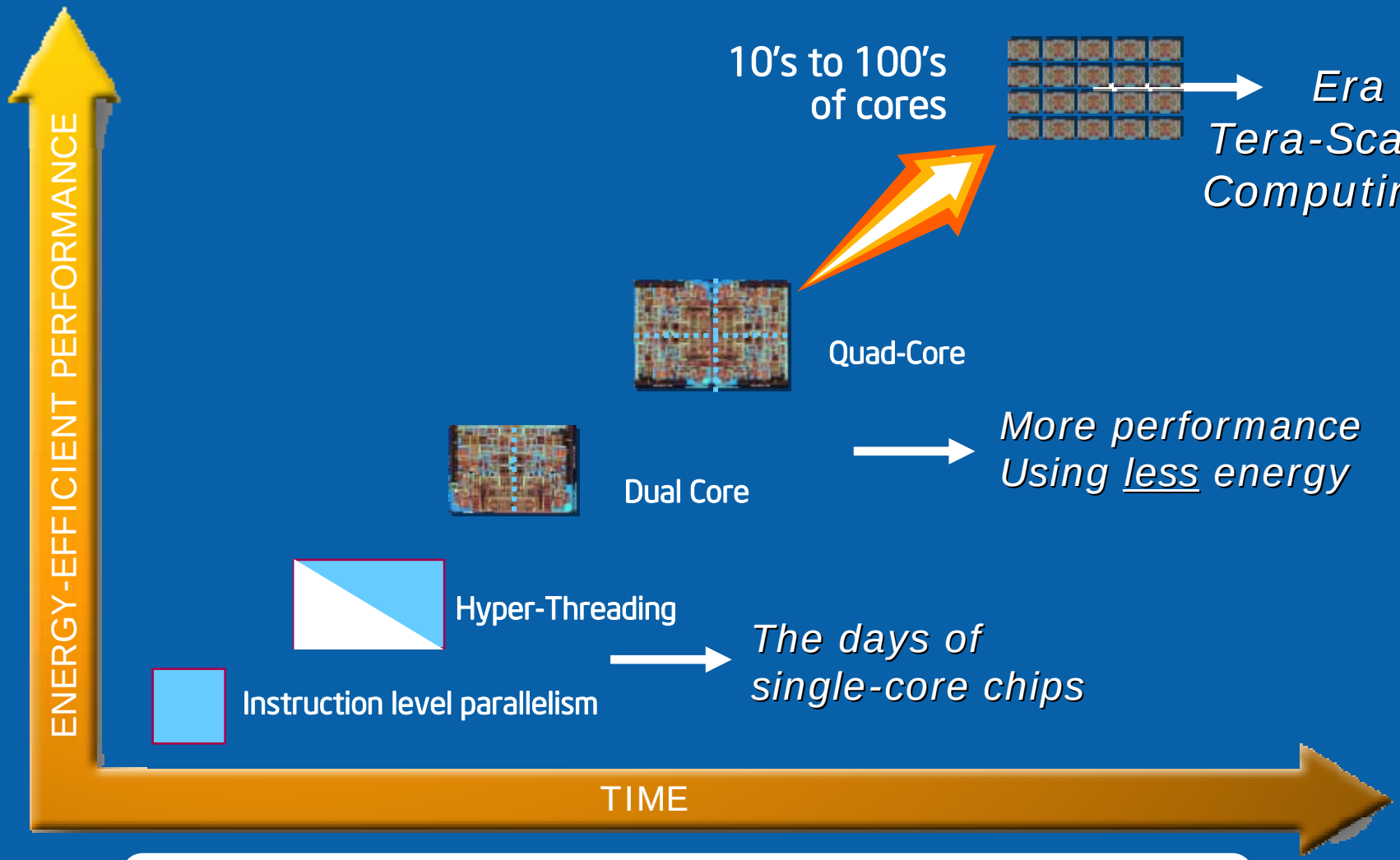
40 Gb/s (Jul '07)

Electrically Pumped Hybrid Silicon laser
(September 2006)

We have achieved 40 Gb/s milestone
Focus is now on integration

intel

Tera-leap to Parallelism:



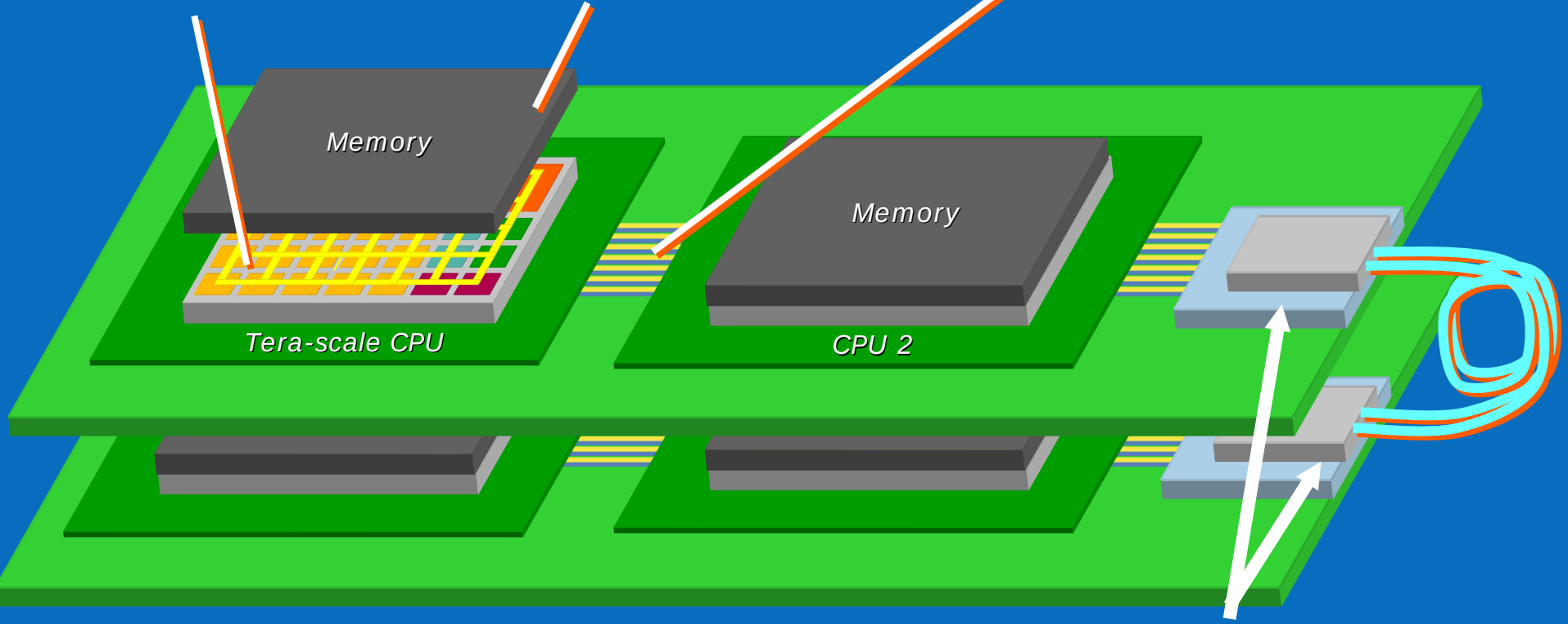
All this compute capability may require high speed optical links

Future Physical I/O for Tera-scale Computing

Core-Core: On Die
Interconnect fabric

Memory: Package
3D Stacking

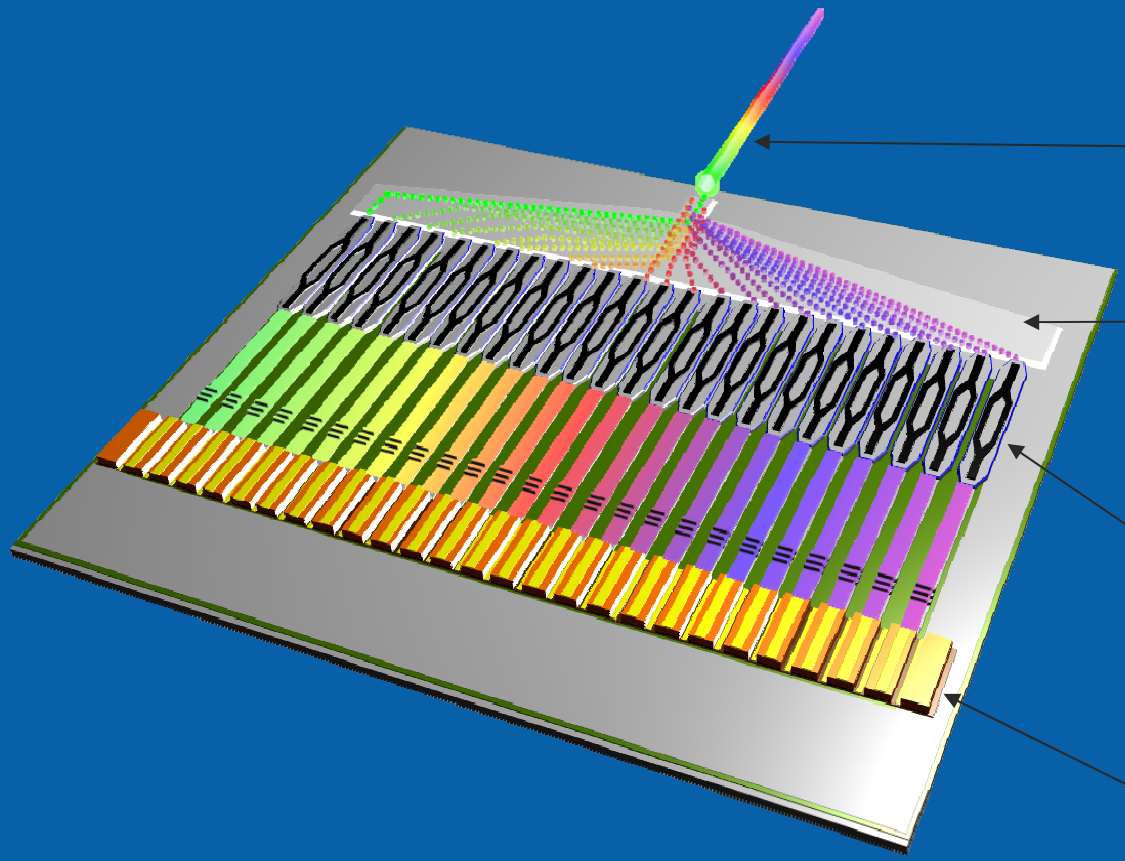
Chip-Chip: Fast Copper
FR4 or Flex cables



Board-board interconnect: electrical or optical?

Integrated Silicon Photonics chips

A Terabit Optical Chip



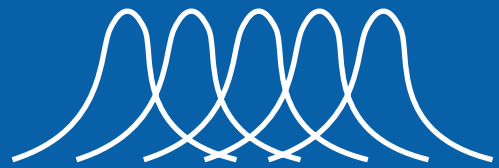
An future integrated terabit per second optical link on a single chip

Why is a Silicon Laser Modulator Needed

On –Off On-Off

1 0 1 0 1 0 1 0 1

As the laser heats and cools the pulses get distorted
This causes errors in the data transmission

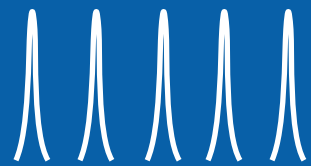


Solution: Externally Modulate the Laser

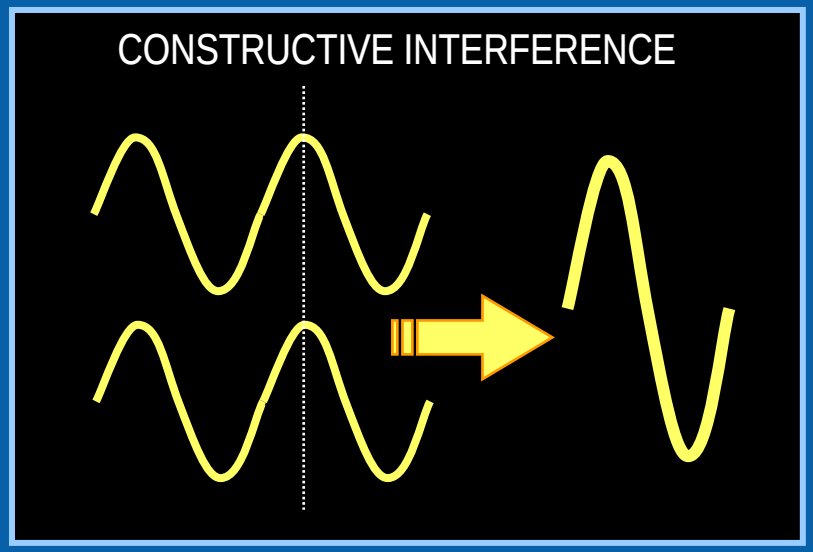
On –Off On-Off

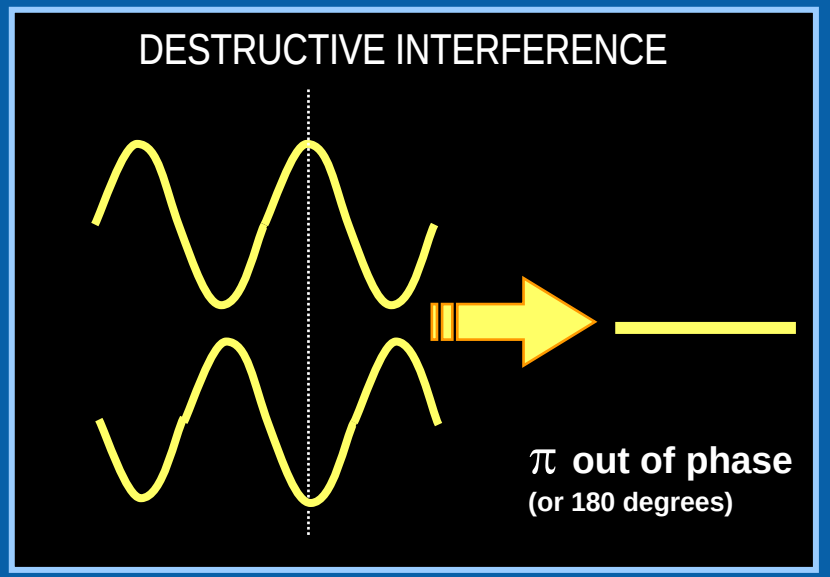
1 0 1 0 1

High fidelity pulses with ext. mod

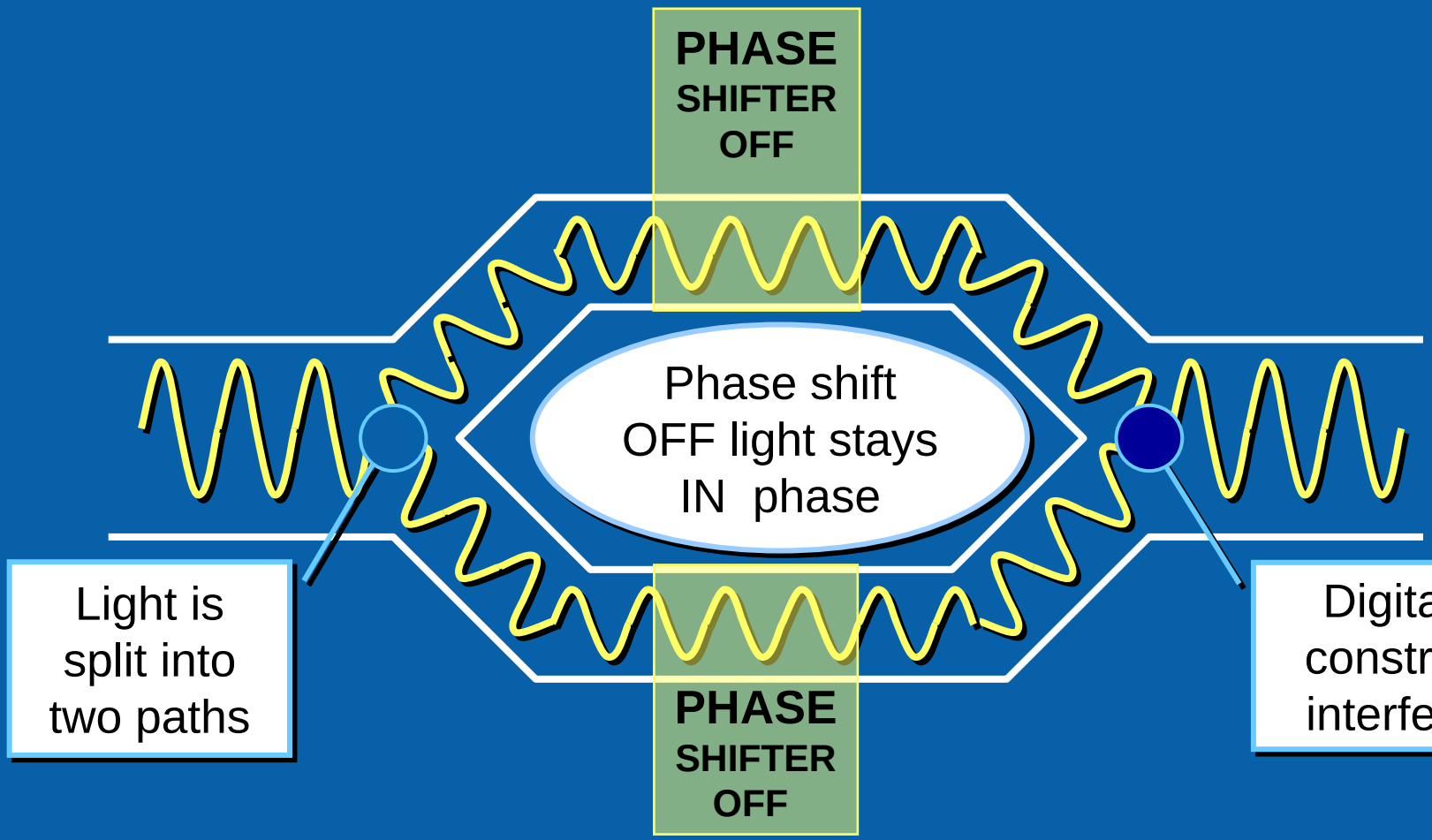


Wave Mechanics of Light



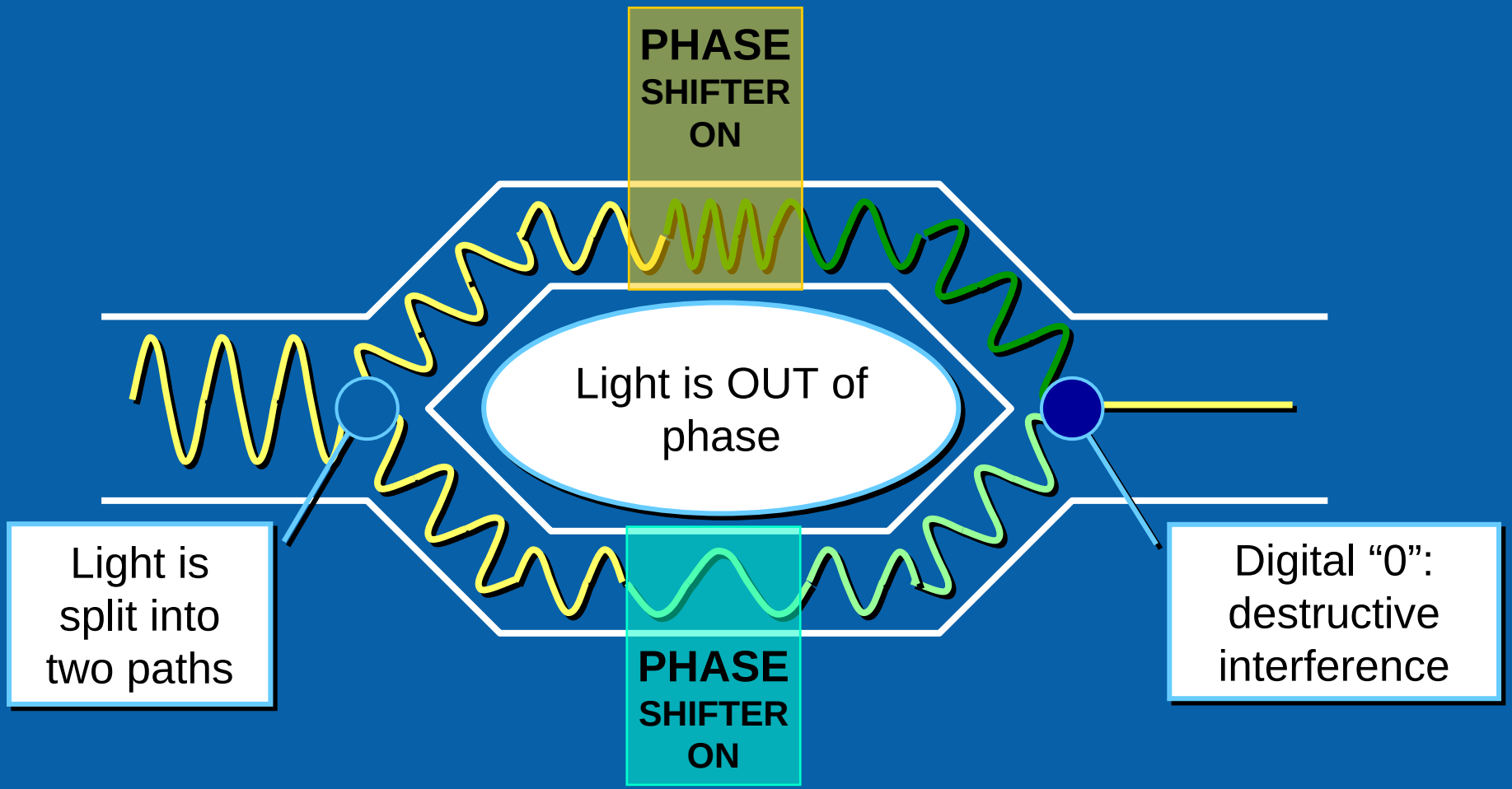


Silicon Laser Optical Modulator



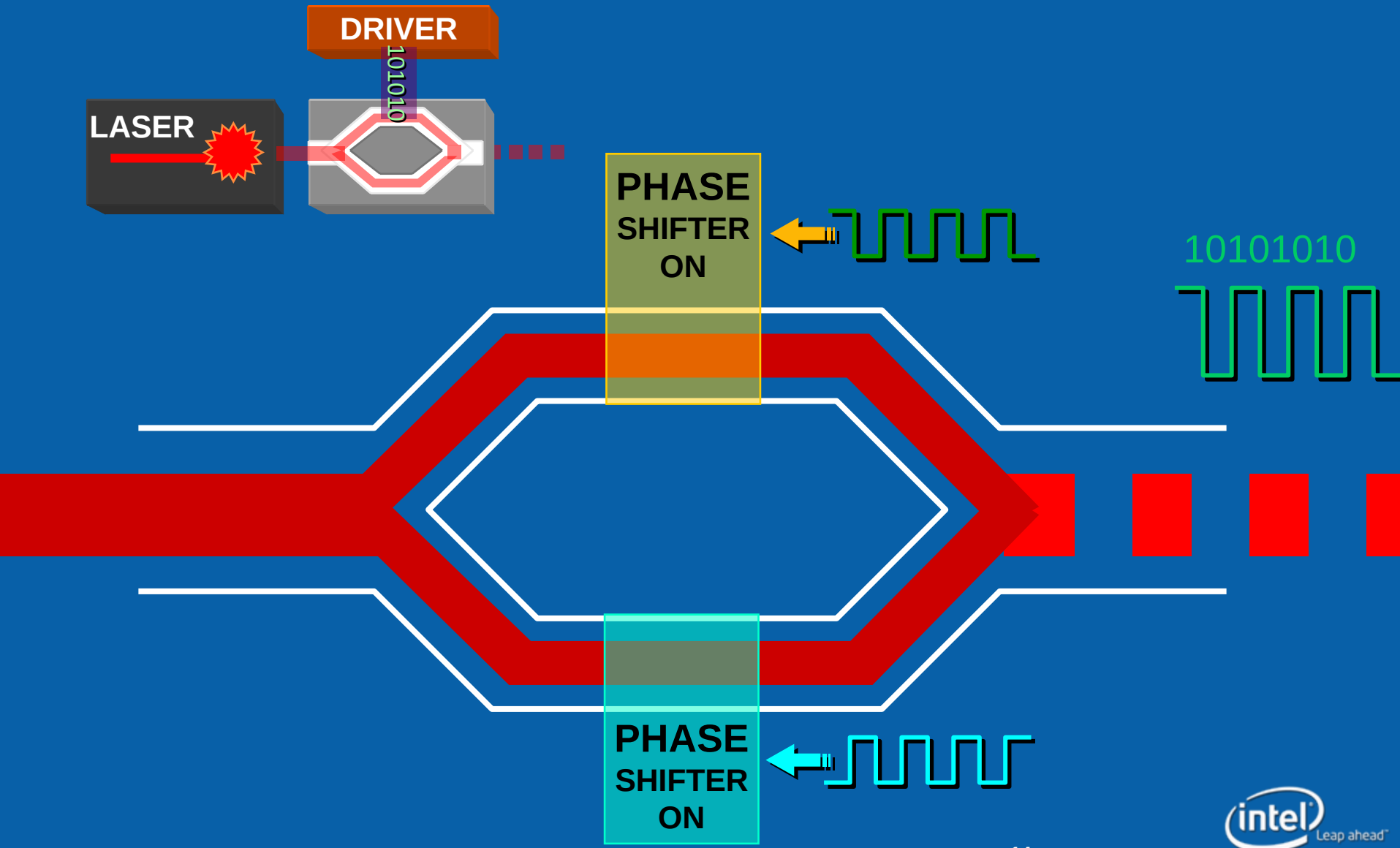
Phase Shifter - A *transistor-like* device

Silicon Laser Optical Modulator



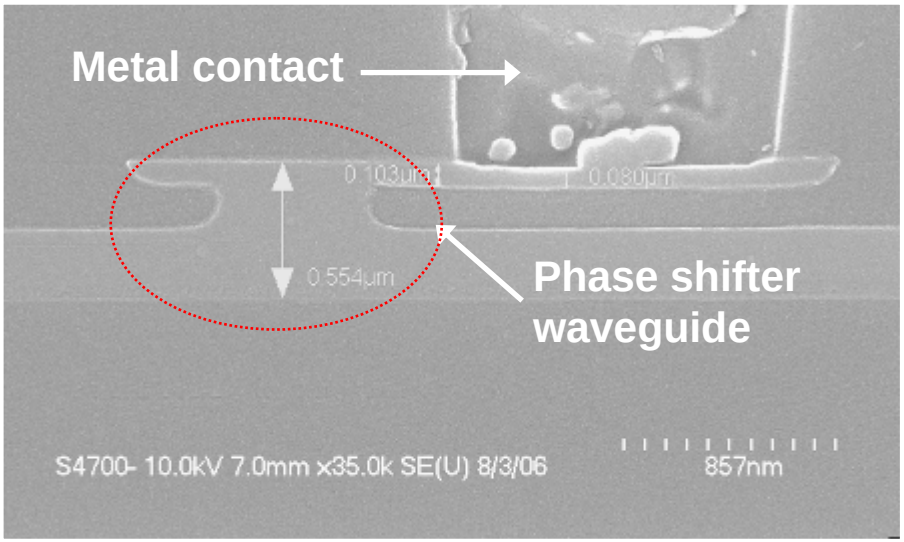
Phase Shifter - A *transistor-like* device

Optically encoding Data



Silicon Laser Modulator

- This new generation modulator is smaller and consumes less power than the first generation modulator that operated at 10 Gb/s
- Based on traveling wave design
- Optimized optical and electrical RF signaling characteristics (high speed transmission traces, termination resistance matching, parasitics reduced)
- Results presented at an invited talk at the IPNRA (Integrated Photonics and Nanophotonics Research and Applications) July 2007 Salt Lake City, Utah USA



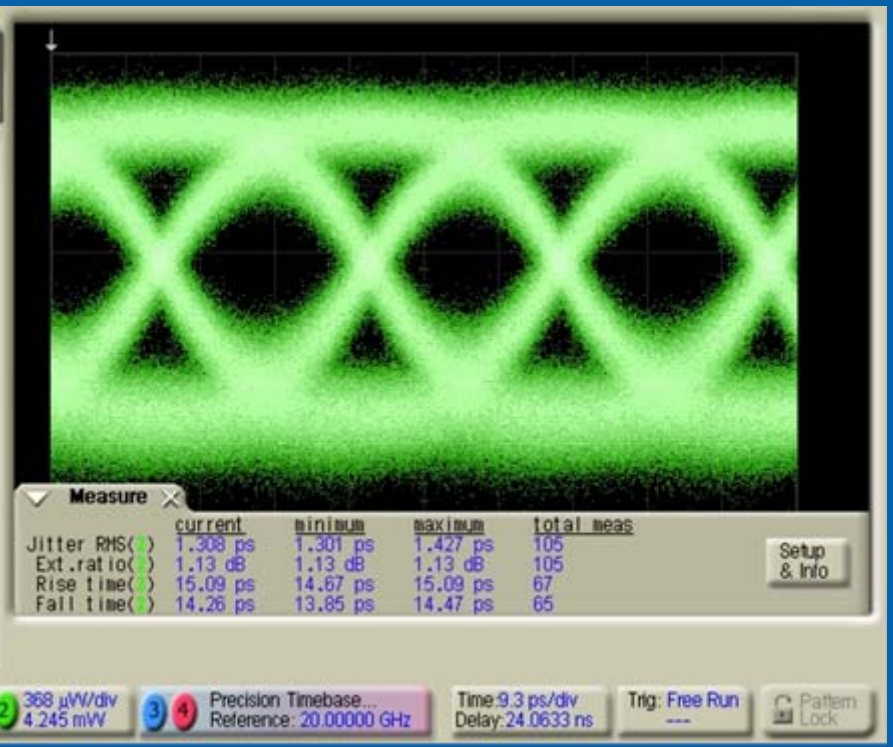
SEM picture of p-n phase shifter

Silicon modulator on PCB

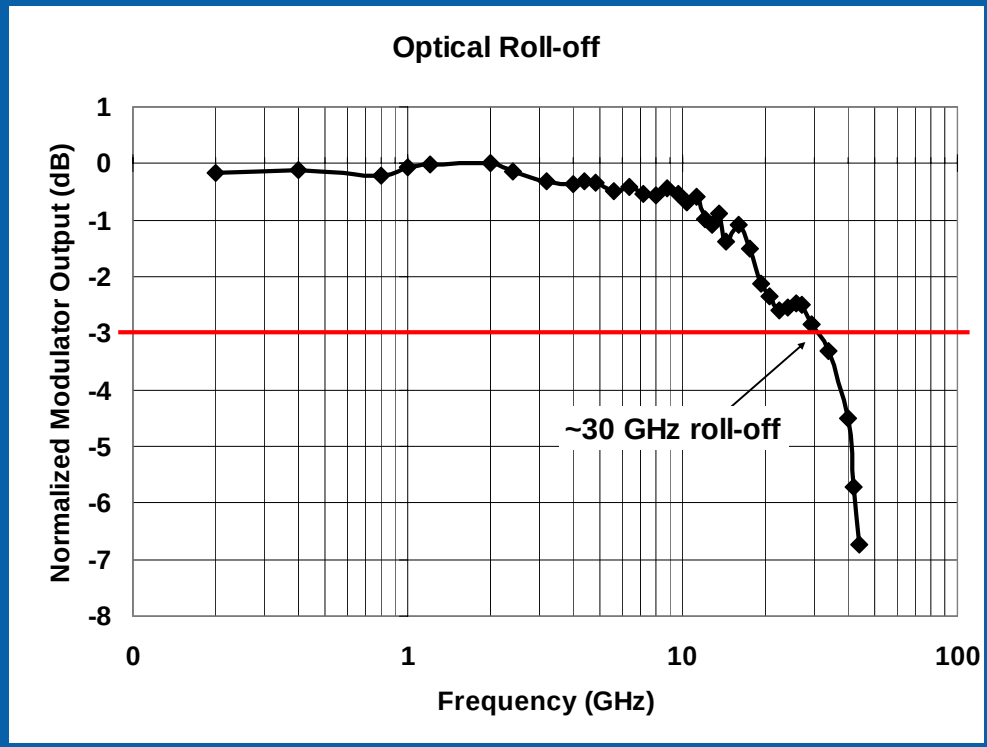
40Gb/s Silicon Laser Modulator

40Gb/s Data Transmission

Results presented at IPNRA



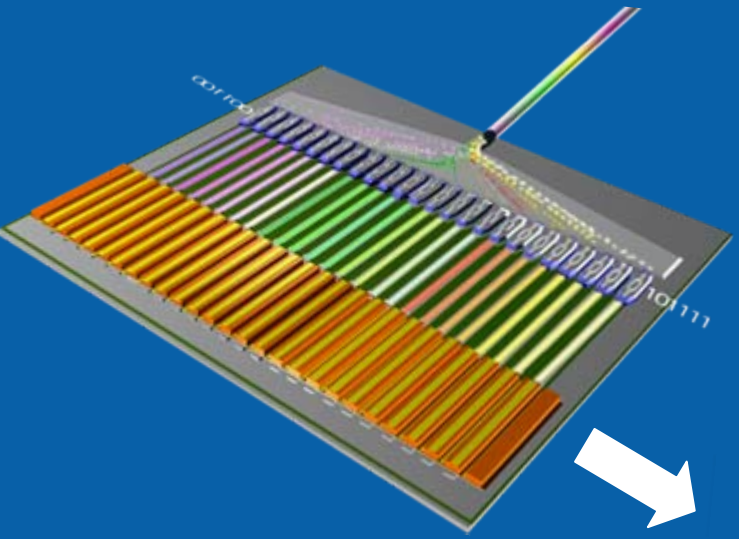
40Gb/s Data Transmission

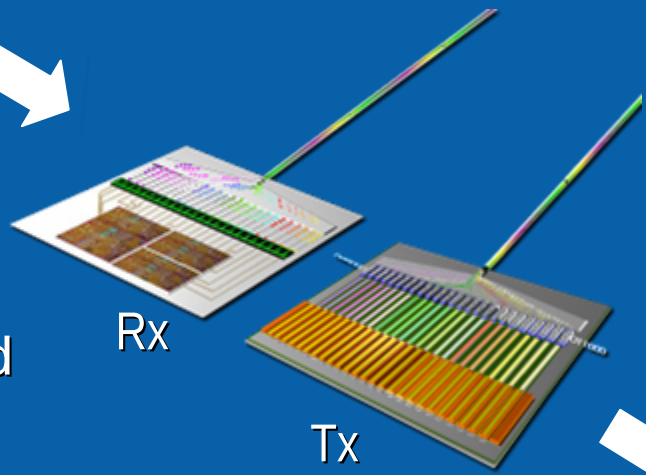


Optical 3 dB roll off ~30 GHz

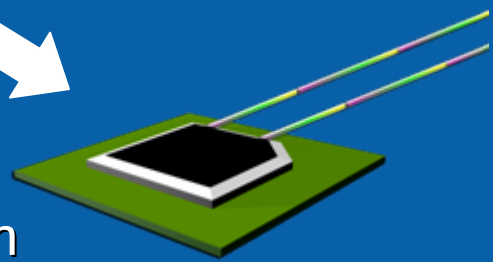
Worlds Fastest Silicon Laser Modulator

Integrating into a Tera-scale System



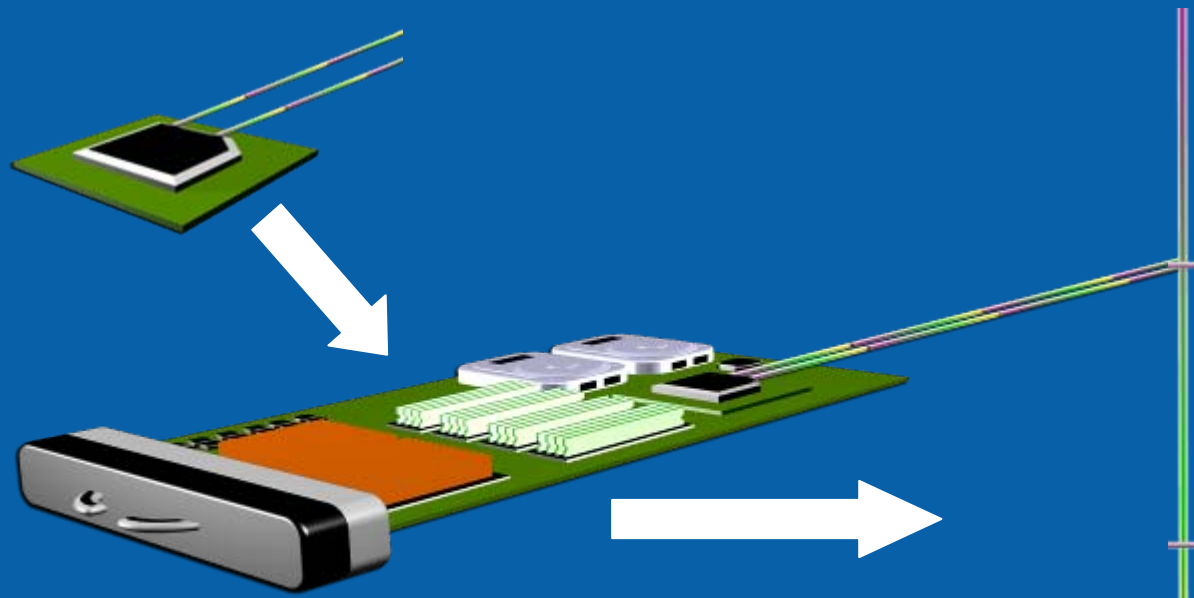


This transmitter would be combined with a receiver



Which could then be built into an integrated, silicon photonic chip!!

Integrating into a Tera-scale System



This integrated silicon photonic chip could then be integrated into computer boards

And this board could be integrated into a Tera-scale system

Summary

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Justin Rattner, Intel Chief Technology Officer

Thank You

More Information is at:

Research blog:
http://blogs.intel.com/research/

High res pictures and press info:
http://www.intel.com/pressroom/kits/research/4Gmodulator.htm

Silicon Photonics Web-site
http://www.intel.com/research/platform/sp/