LUXTERA
NANOPHOTONIC INTEGRATED CIRCUITS

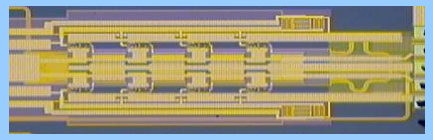
CMOS Photonics™ Technology

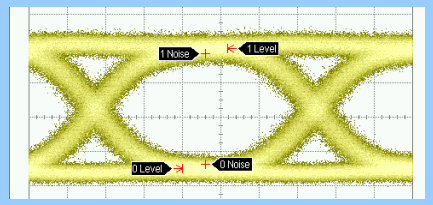
Enabling Optical Interconnects

Cary Gunn
VP Technology

Luxtera CMOS Photonics Technology

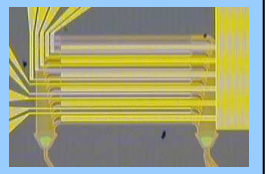
Silicon 10G Modulators
- driven with on-chip circuitry
- highest quality signal
- low loss, low power consumption

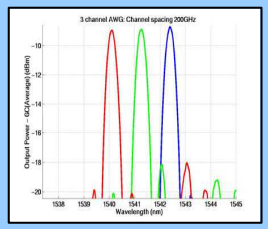




Flip-chip bonded lasers
- wavelength 1550nm
- passive alignment
- non-modulated = low cost/reliable

Silicon Optical Filters - DWDM
- electrically tunable
- integrated w/ control circuitry
- enables >100Gb in single mode fiber





Complete 10G Receive Path
- photodetectors
- trans-impedance amplifiers
- output driver circuitry

Fiber cable plugs here

Ceramic Package

The Toolkit is Complete
- ✓10Gb modulators and receivers
- ✓Integration with CMOS electronics
- ✓Cost effective, reliable light source
- ✓Standard packaging technology

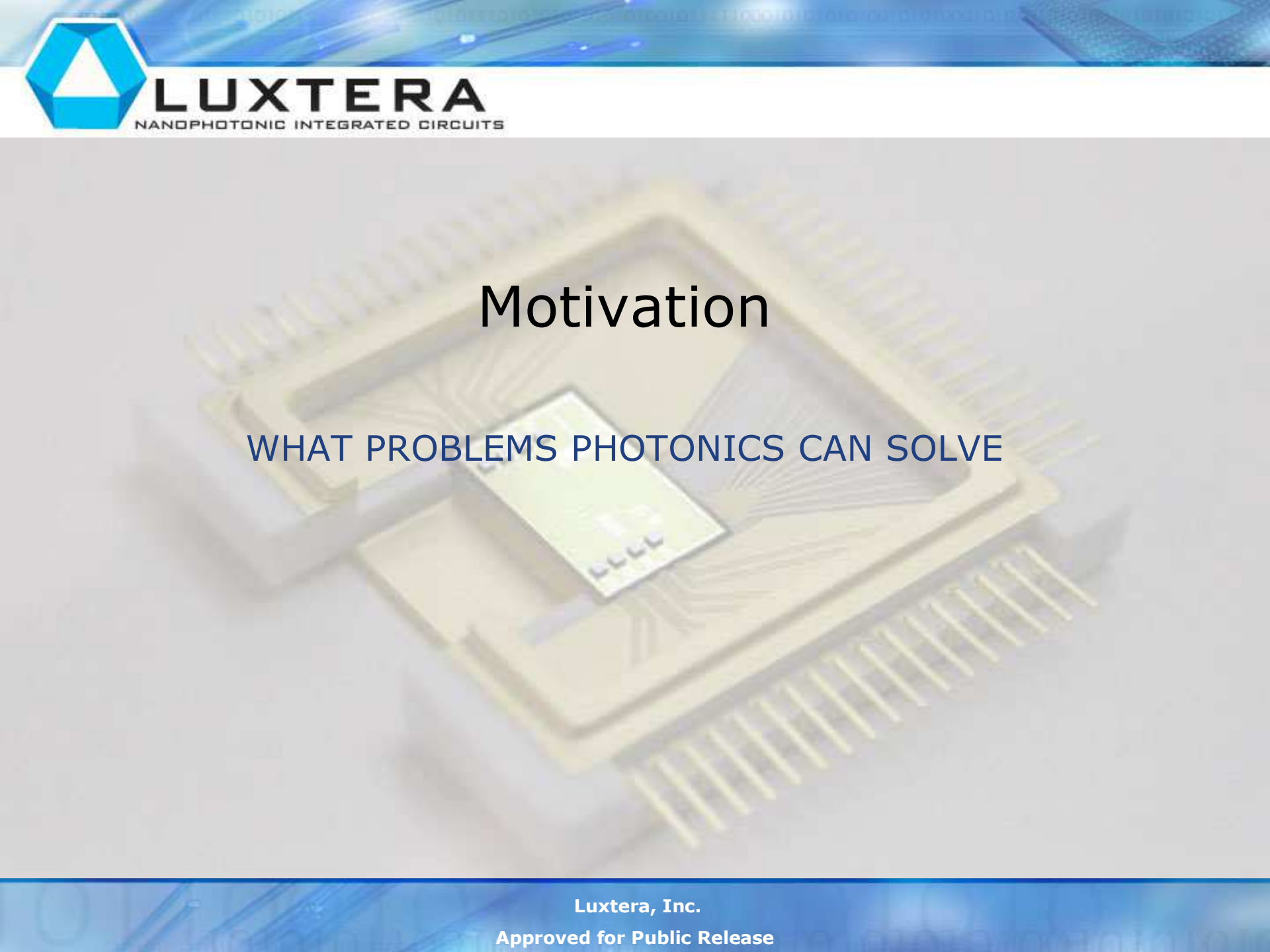
Agenda

- Motivation
  - The problems w/ electrical interconnect
- Introduction to CMOS Photonics
  - Today's Technology

  (And why it's better than 10GBASE-T)
  - How it scales and how it will do >100G

Motivation

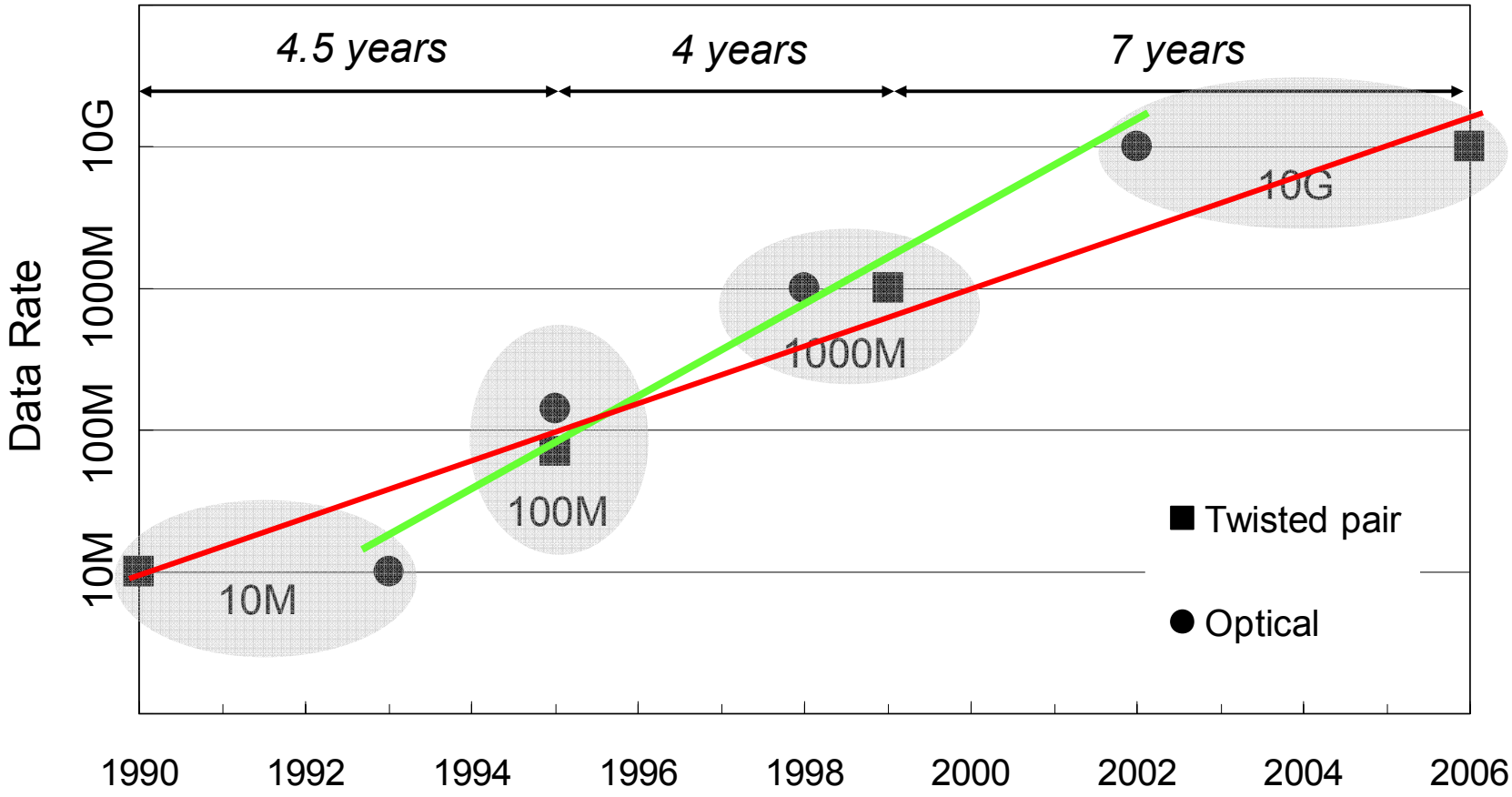
WHAT PROBLEMS PHOTONICS CAN SOLVE



Motivation

- The demand for 10G LAN interconnect is strong, but…
  - Copper is pushing the laws of physics at 10G
  - Legacy optical systems perform well at 10G, but are very expensive to manufacture
- Integration of optical components into a CMOS platform allows:
  - high performance of optical links
  - a price that's compelling for the traditional LAN customer

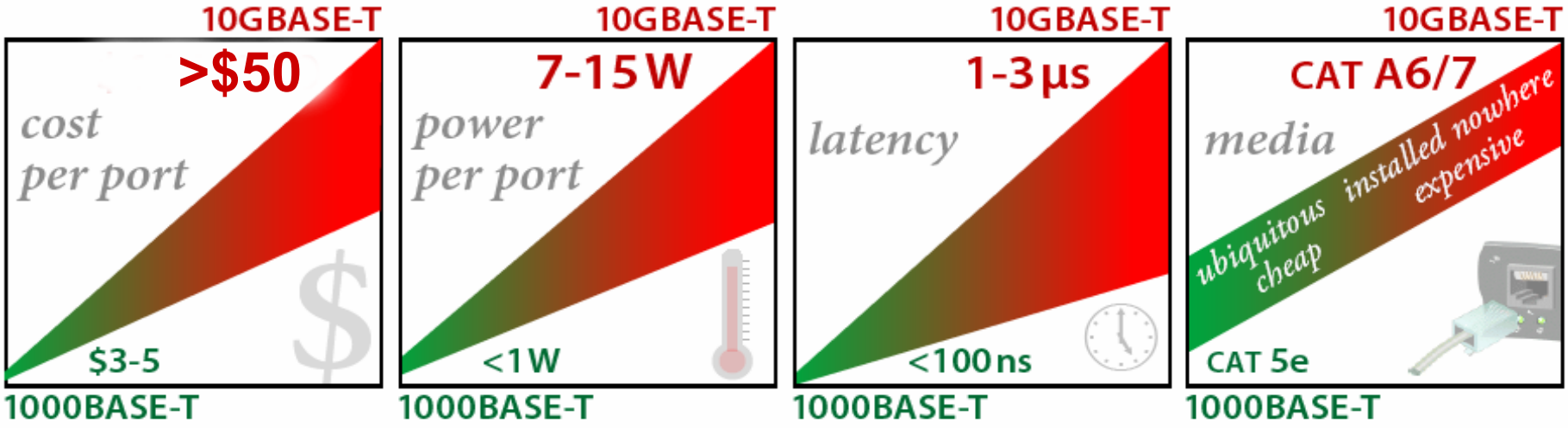
Ethernet Adoption



Optical bandwidth has been growing faster than electrical

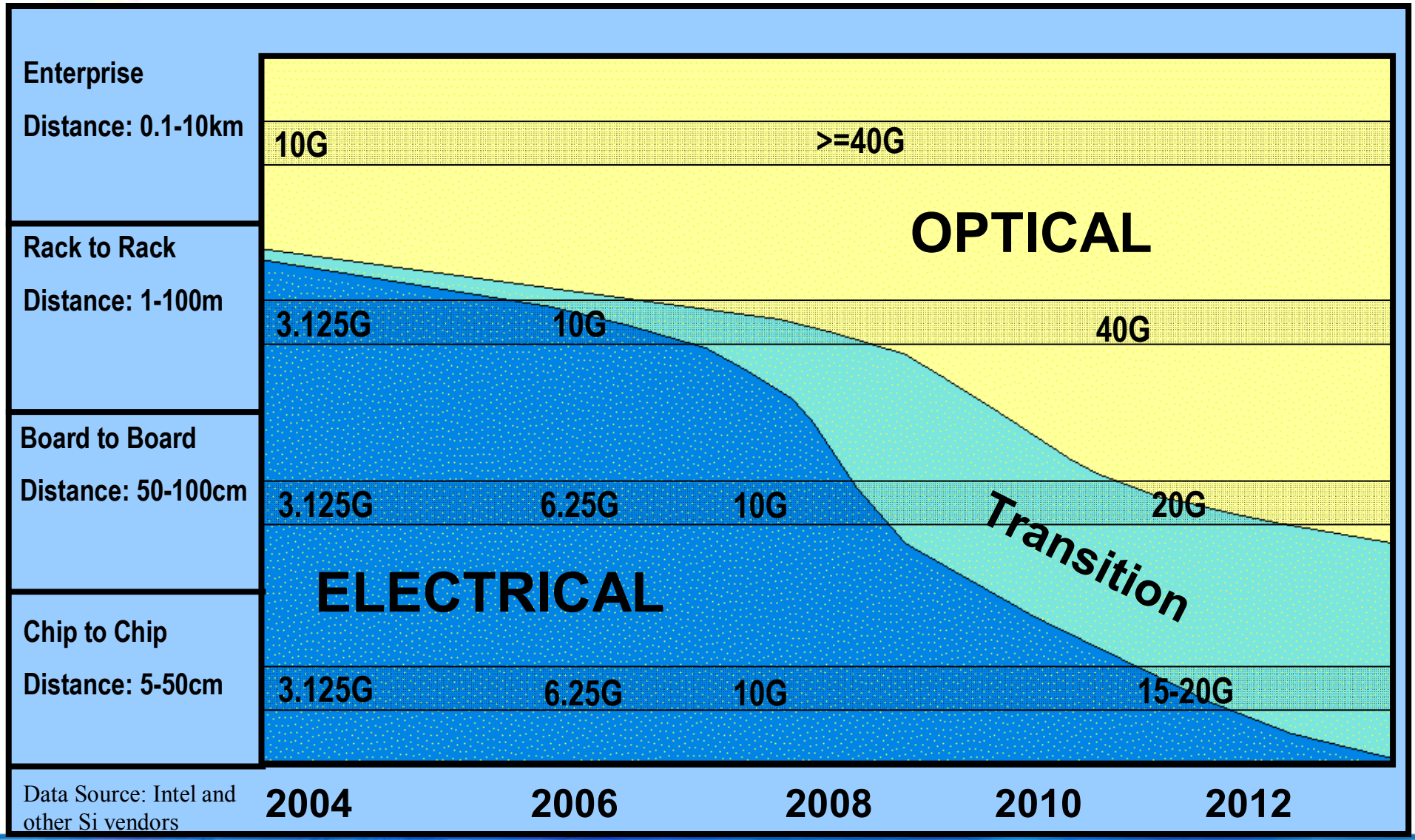
10G Ethernet vs. 1G Ethernet

10GBASE-T will be far less appealing...



...than familiar 1000BASE-T Ethernet.

What Major Silicon Vendors are saying:



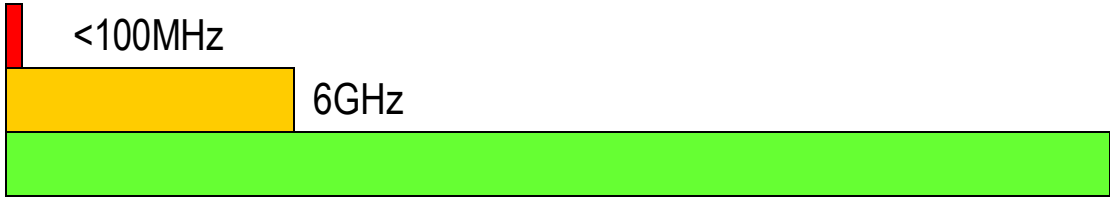
Data Source: Intel and other Si vendors

Fiber vs. Twisted Pair

Considering a 300m cable at 10G

Bandwidth

- Twisted Pair
- Multi-Mode Fiber
- Single Mode Fiber



Power Transmission

80THz →

- Twisted Pair
- Multi-Mode Fiber
- Single Mode Fiber

Dispersion

- Twisted Pair
- Multi-Mode Fiber
- Single Mode Fiber

SMF has endless capacity, negligible loss, and negligible dispersion

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Today's Technology Status

HOW WE'RE DOING 10G

CMOS Photonics: Ready Now

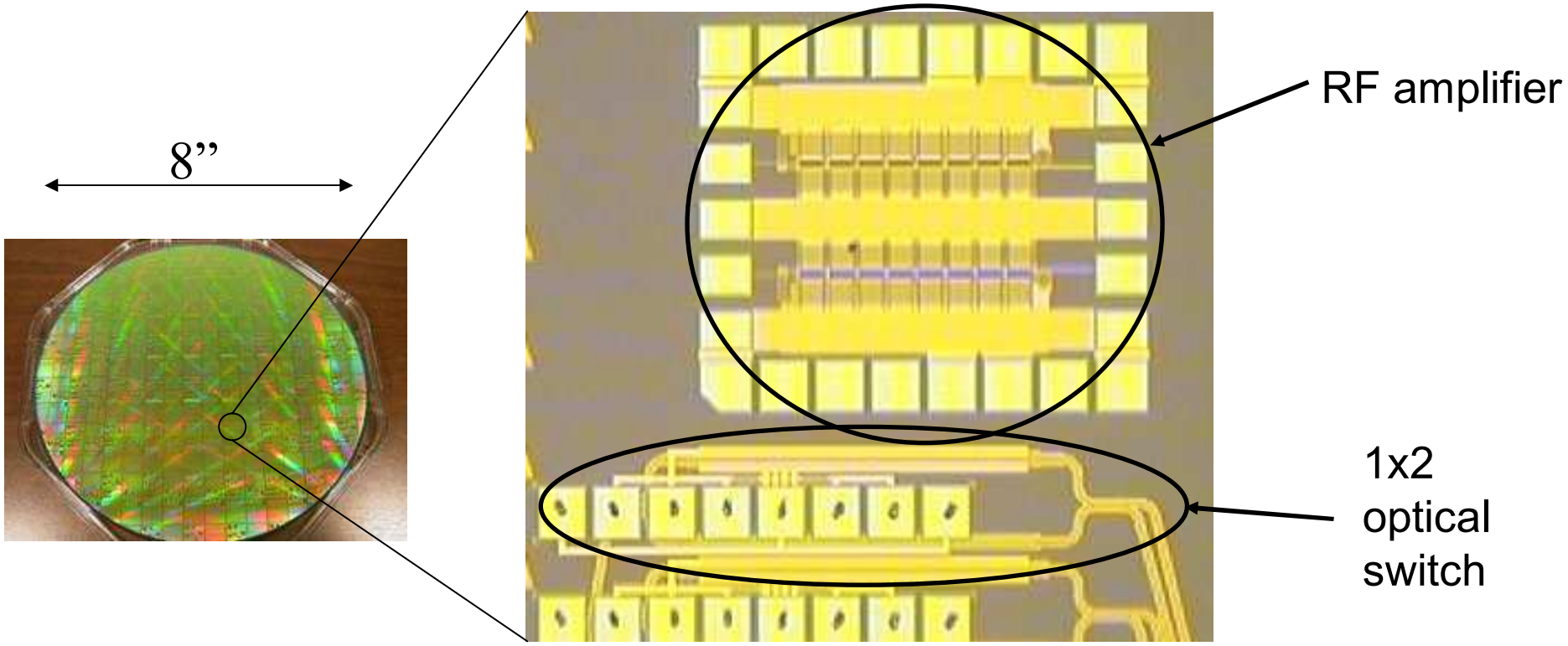
- CMOS Photonics technology for 10G LAN/SAN has been demonstrated
  - Integration with CMOS electronics
  - Optical modulator and receiver optics
  - Transmitter and receiver PMD circuits
- Superior performance to 10GBASE-T:
  - Price
  - Reach
  - Power consumption
  - Latency
  - Scalability

10G LAN Technology Comparison

	Electrical 10GBASE-T	Short Range Optical 10GBASE-SR 10GBASE-LX4 10GBASE-LRM	Long Range Optical 10GBASE-LR 10GBASE-ER	Luxtera CMOS Photonics
Reach	55m	28m – 300m	10km-40km	2000m
Power	>7W	2-4W	>2W	1.7W
Transceiver Latency	1-3 µsec	<10 ns	<10 ns	<<10 ns
Cabling Costs	$$-Cat6/7	$$-MMF	$-SMF	$-SMF
Cost per port (in volume)	<$50	$350-$800	$500	<$50
Samples Availability	2006 Q2	Now	Now	2006 Q2
Technology scales to 100Gb	No known path	No	Yes, for $$$	Integrated DWDM
Media scales to 100Gb	No	No	Yes	Yes

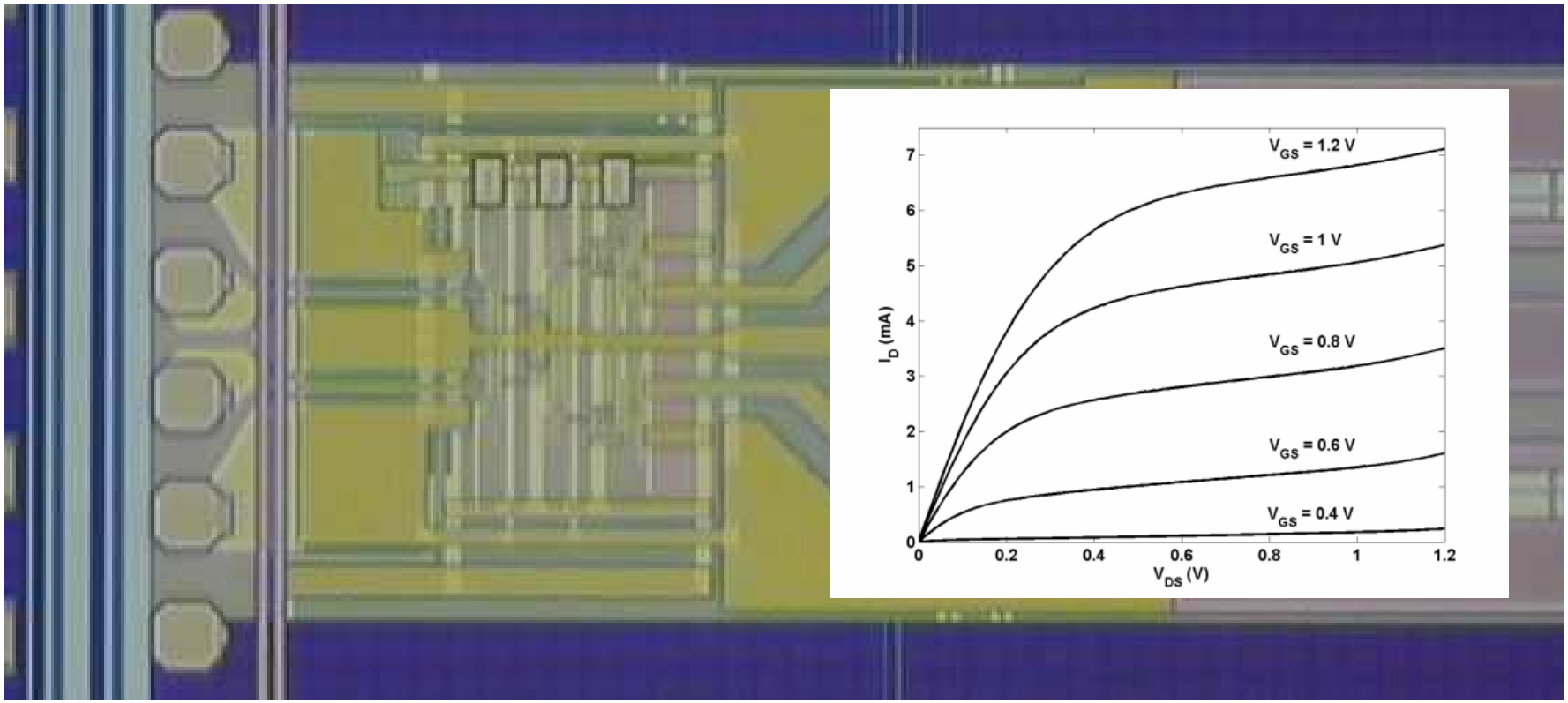
- The performance of optics for the price of electronics
- For LAN/SAN, 10G is tipping point for transition to optical links

Monolithic Integration of Optics and Electronics



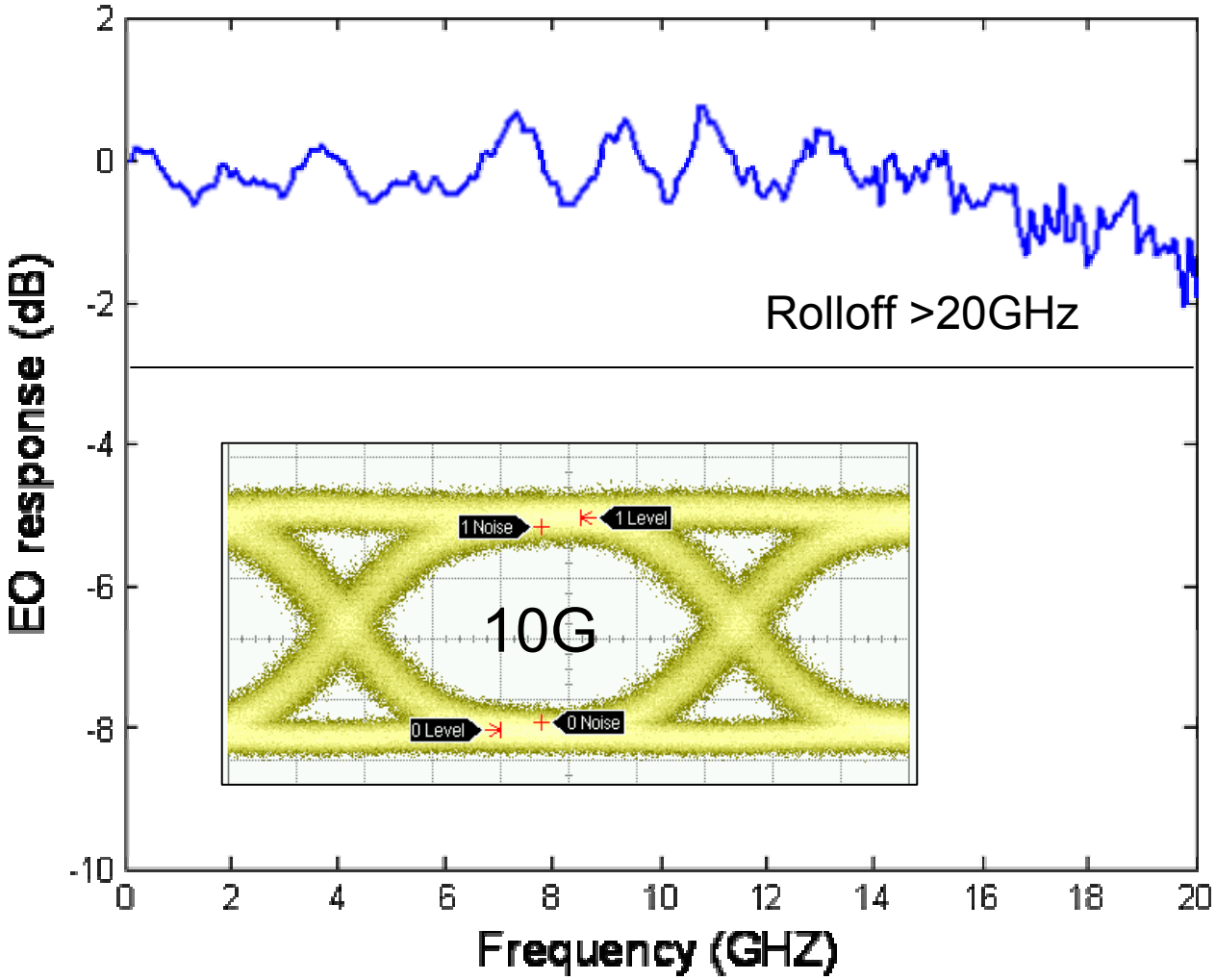
Optical devices and transistors are constructed side-by-side monolithically in the silicon

Integration w/ Transistors is here now!



CMOS Optical Modulator with Differential Driver

CMOS Optical Modulator Performance



Benefits of CMOS Photonics

- CMOS is the lowest cost platform for optical devices
  - Substantial power and size reduction
  - Reduced use of expensive III-V compound semiconductors
  - Integration of ~25 individual optical parts per 10G channel (lower cost of manufacture, higher reliability)
- Leverages mature CMOS infrastructure
  - Freescale 0.13µm SOI embedded CPU process
  - Designers access digital library and photonics library
  - Cadence design environment for electronics and optics
  - VLSI circuitry can be integrated with optical transceivers (PHY, MAC, SERDES, etc.)
- Performance scales better than CMOS
  - Moore's Law for electronics density and speed
  - Optical DWDM for bandwidth

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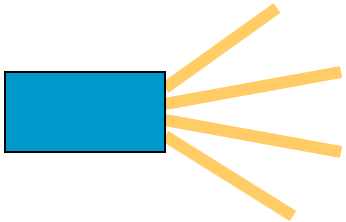
Tomorrow's Technology

HOW WE WILL DO 100Gbit -> 1Tbit -> 10Tbit

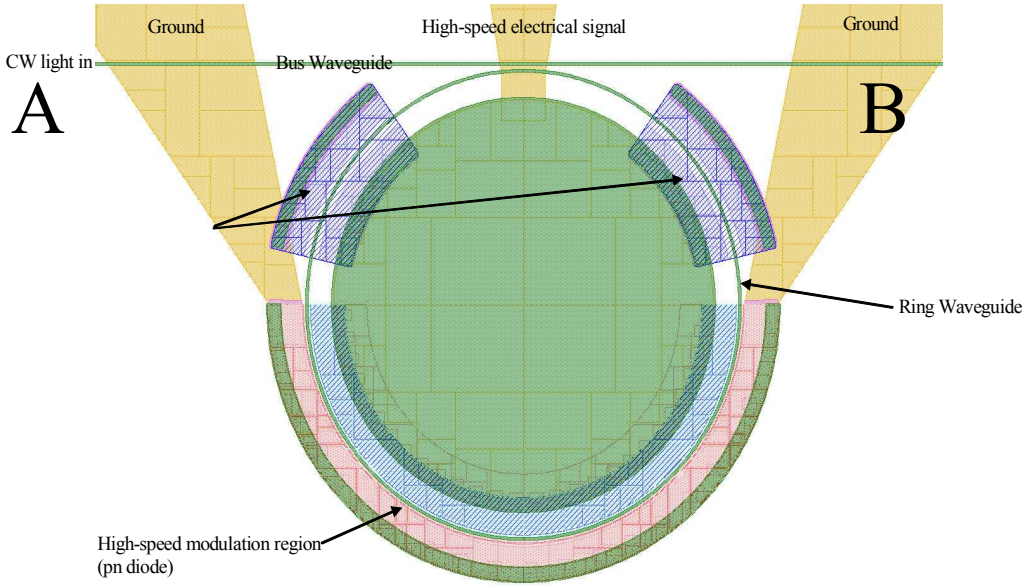
CMOS Photonics Scaling

- Optical components allow unprecedented data density
  - Small optical components allow many channels to be integrated on a single die
  - Wavelength Division Multiplexing integrates many 10G channels into a single fiber
- WDM for scaling of point-to-point links (single fiber):
  - 10G -> 100G -> 1T -> 10T
  - 10G -> 40G -> 80G -> 160G -> 320G -> 640G -> 1.2T, etc.

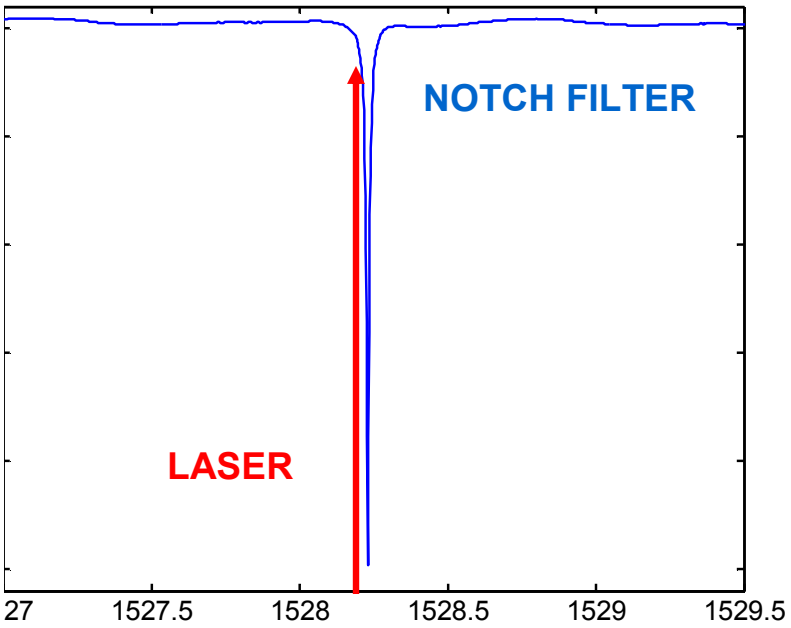
- Many parallel 10G channels in a single die:
  - Dual, Quad, Octal, etc.



Ring modulators = high density/bandwidth

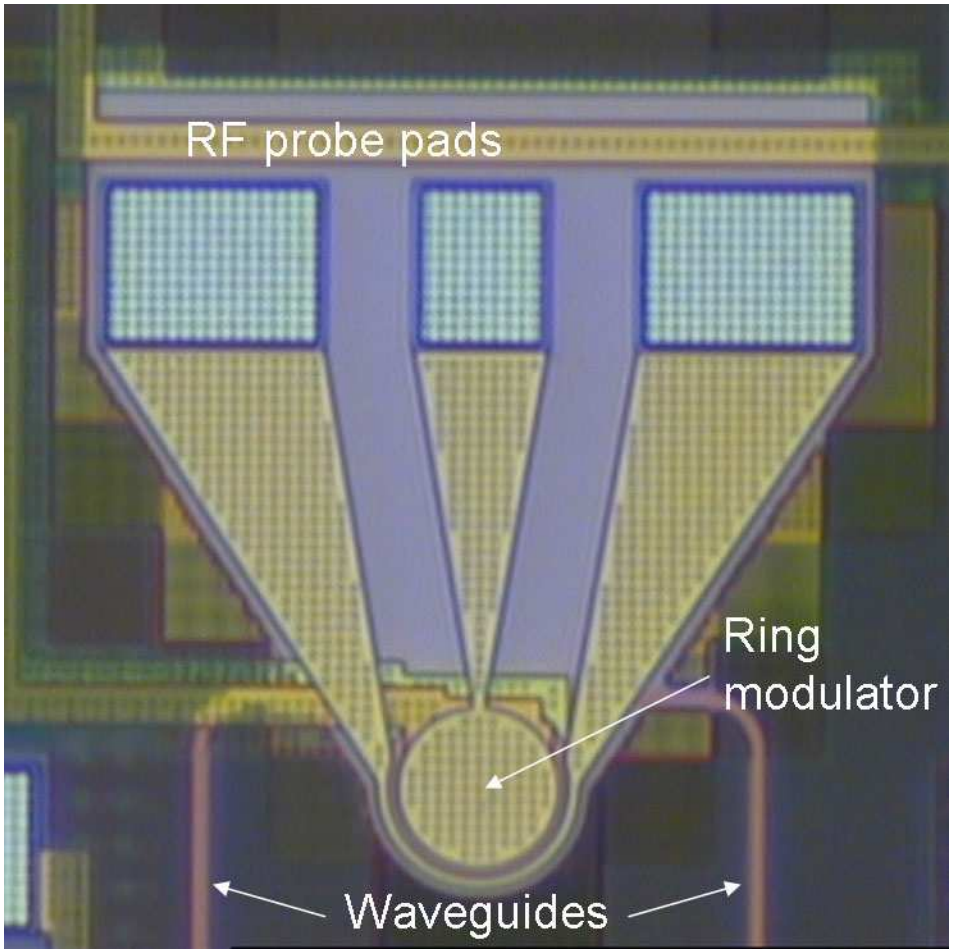


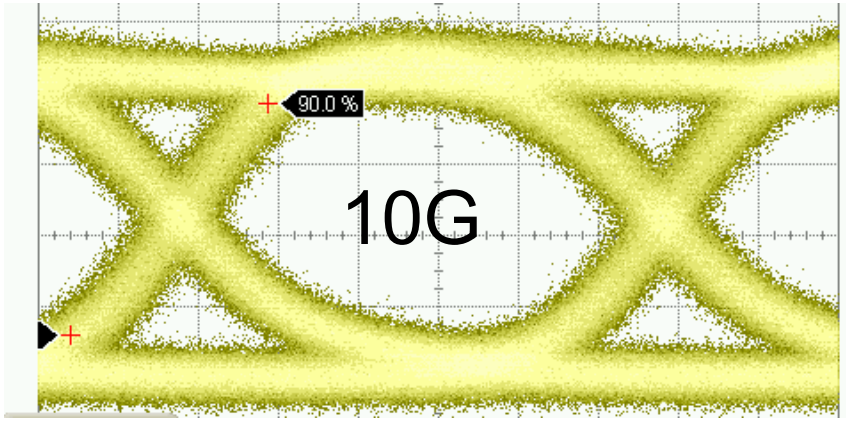
Transmission A-> B

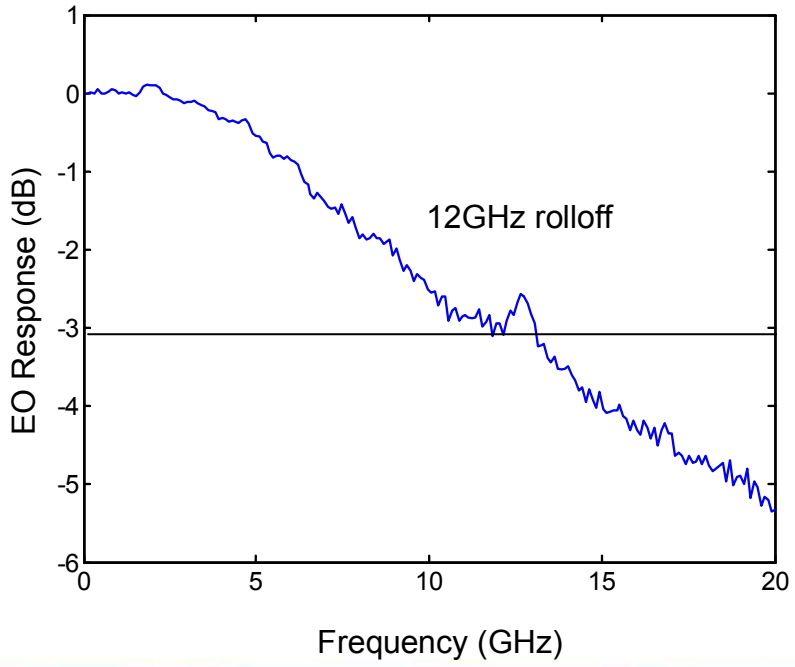


- 30 μm radius ring
- 3Tb per mm²
- 2000x smaller than electronic PHY

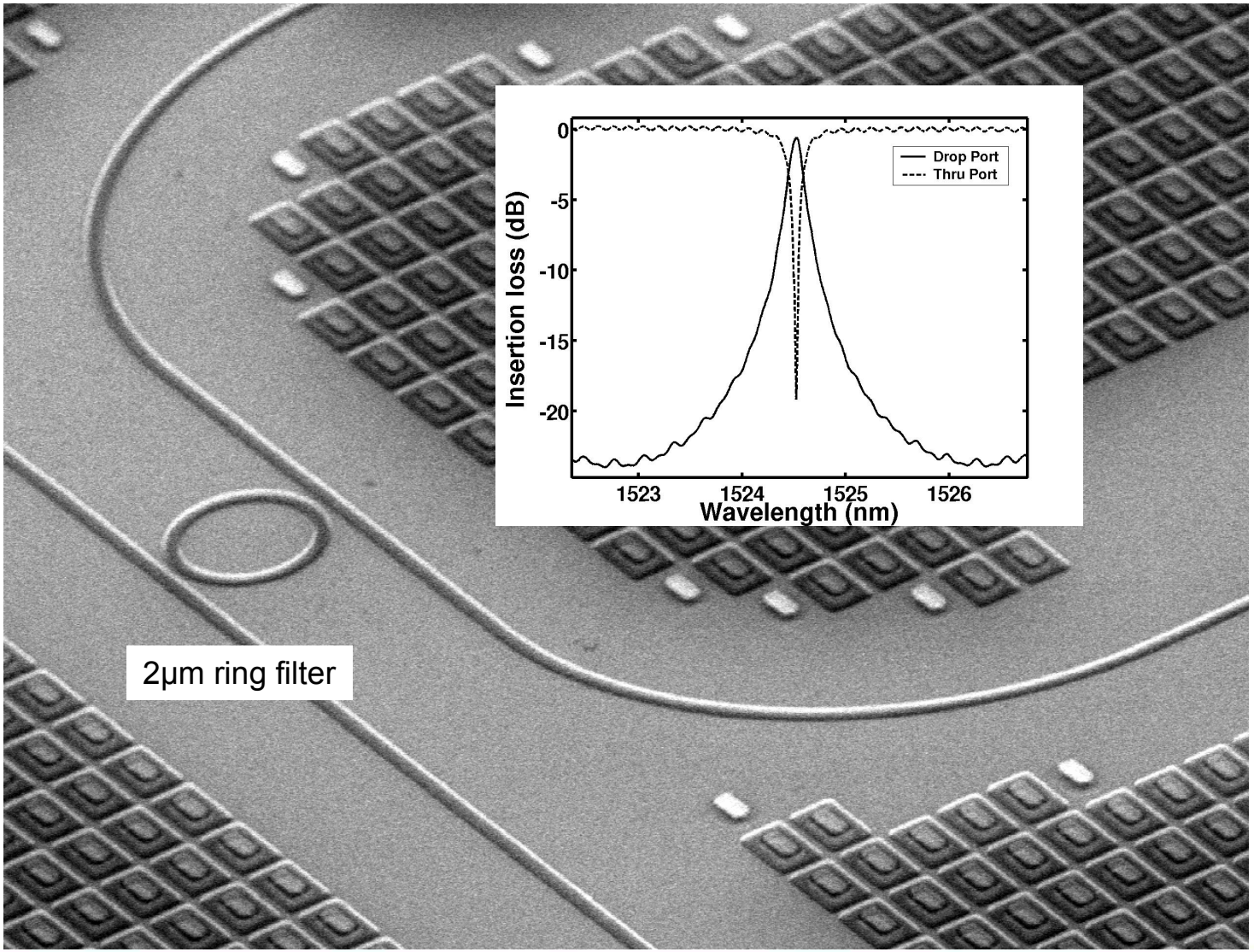
Ring Modulators Work at 10G



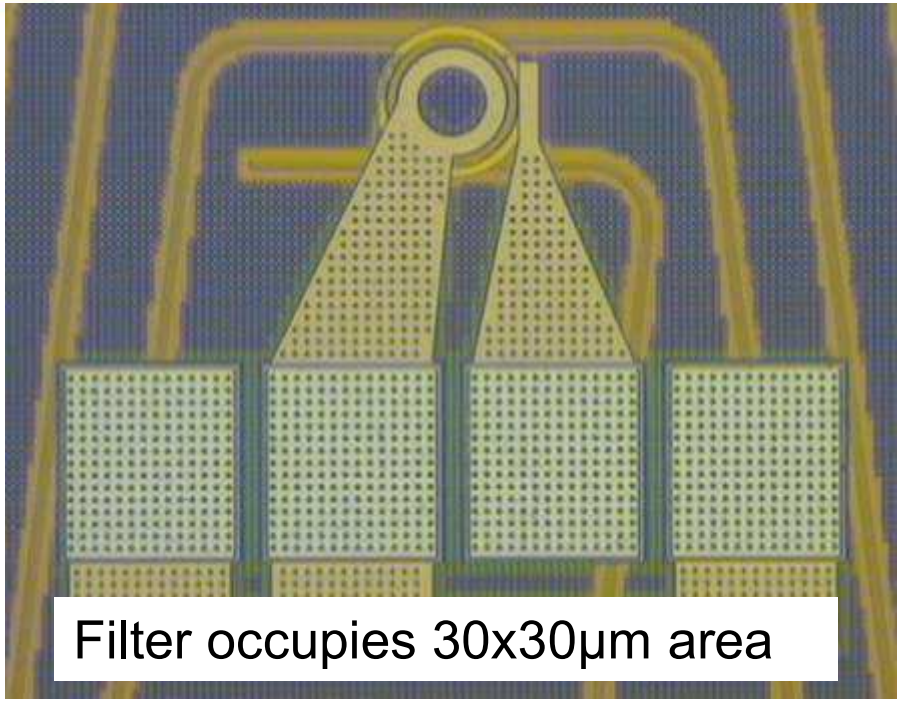


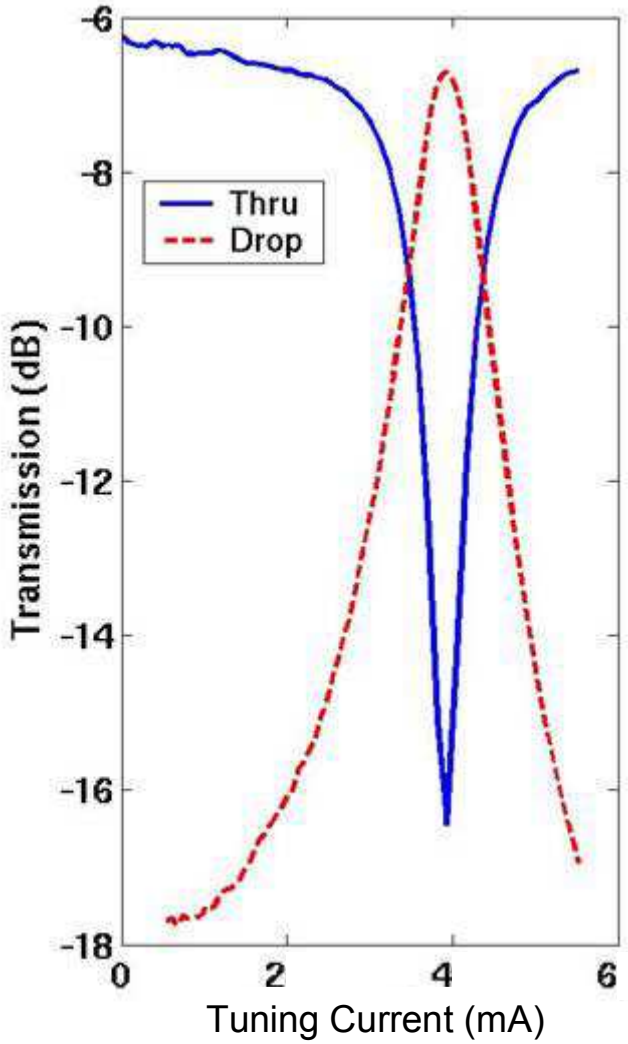


Optical Multiplexing



Small Tunable Optical Filter for WDM



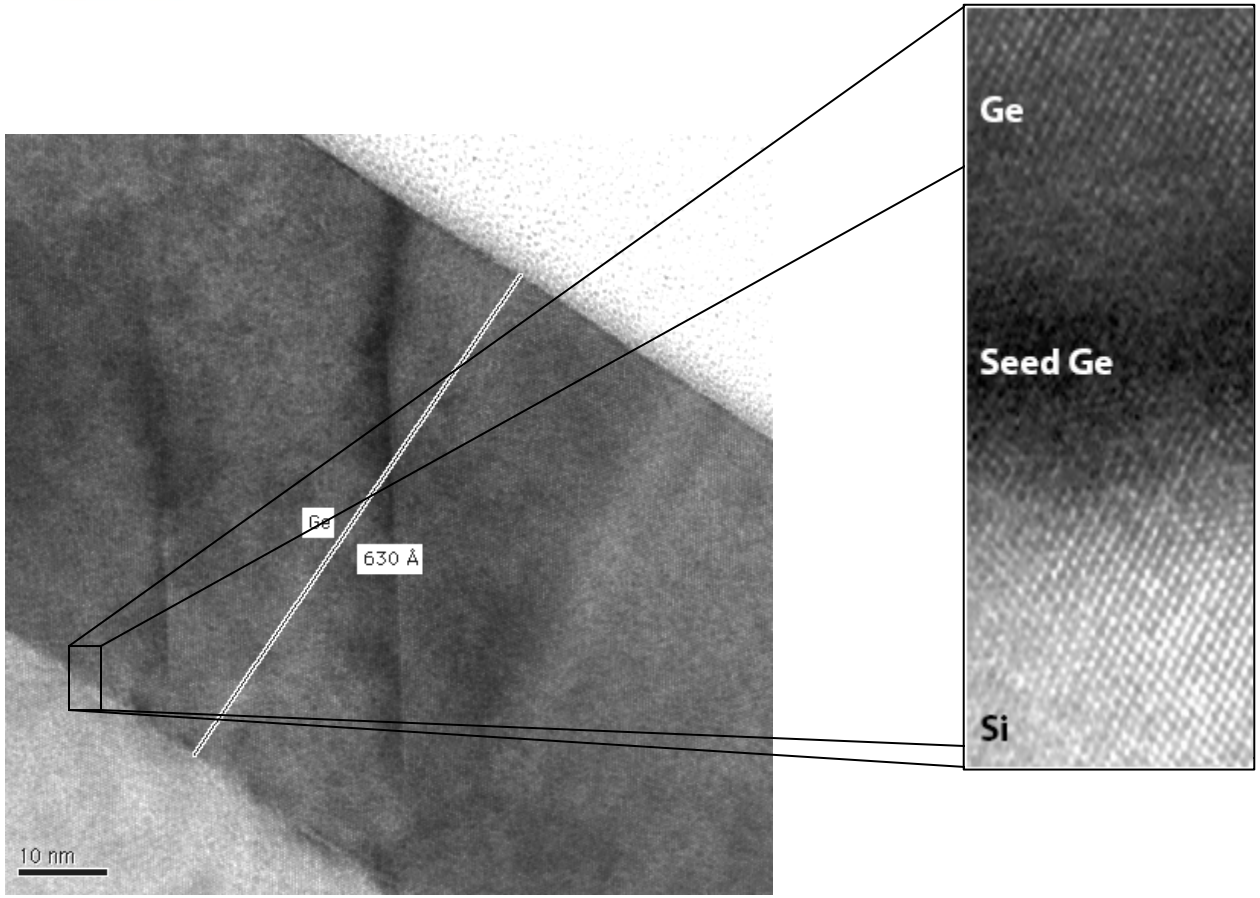


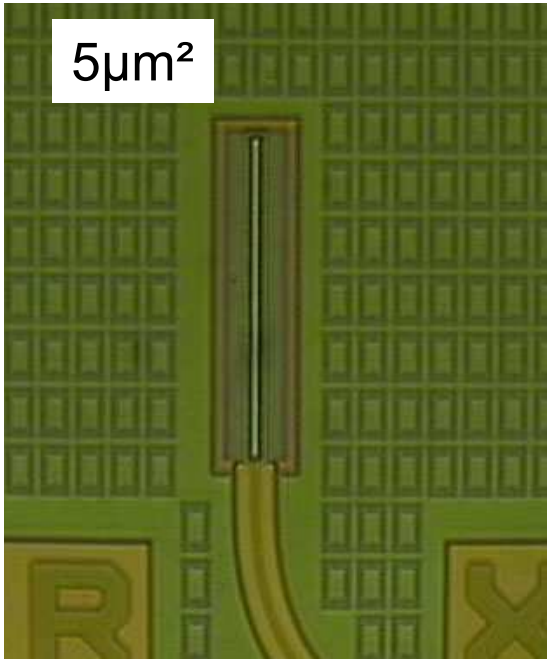
Tunable filters allow:

Dynamic reconfiguration

Operation over wide temperature range

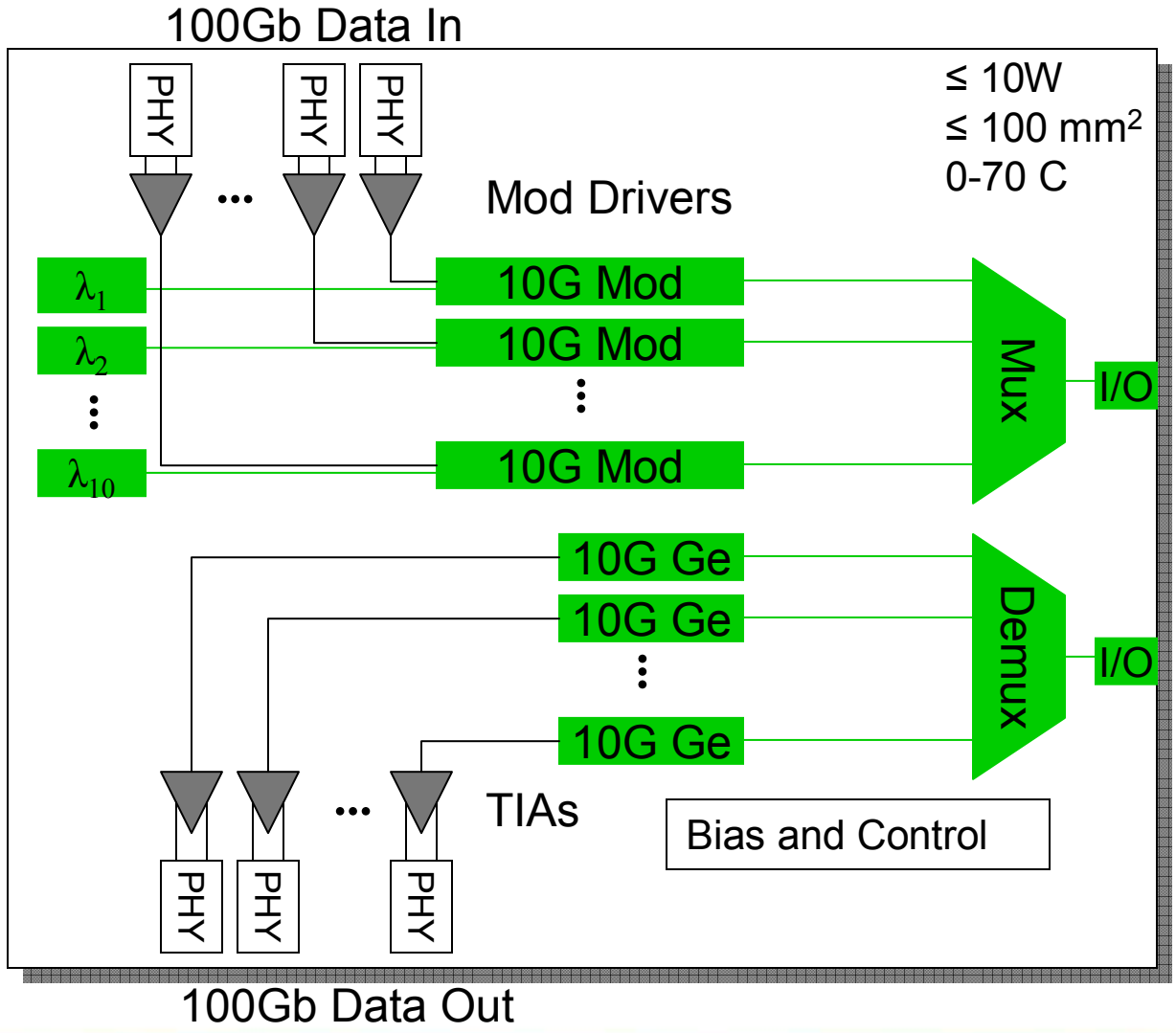
Process module for CMOS photodetectors





High quality single-crystal Ge grown on silicon using CMOS process module.

100Gb Transceiver Block Diagram



TX Fiber – 100Gb

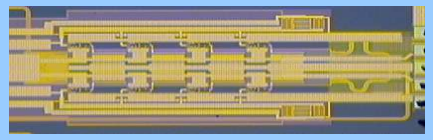
RX Fiber – 100Gb

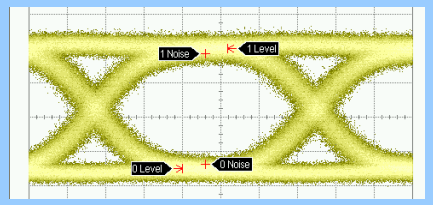
Summary

- CMOS Photonics allows construction of high bandwidth transceivers with the traditional cost structure of silicon
- The technology is ready!
- 10G is the tipping point between fiber and copper in LAN/SAN
- First CMOS Photonics product: 10G sampling Q2 2006
- Single Mode Fiber is the ONLY future-proof media
- CMOS Photonics will scale: 10G ->100G -> 1T -> 10T

Luxtera CMOS Photonics Technology

Silicon 10G Modulators
- driven with on-chip circuitry
- highest quality signal
- low loss, low power consumption





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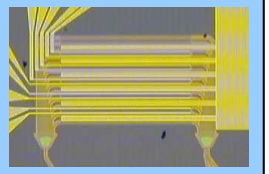

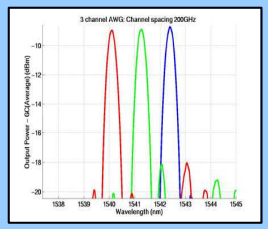

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