



LUXTERA
FIBER TO THE CHIP

The Luxtera EPIC Program

“Electronic and Photonic Integrated Circuits”

March 5, 2007

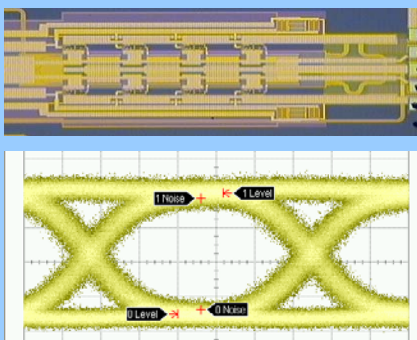
Cary Gunn
CTO, Co-founder

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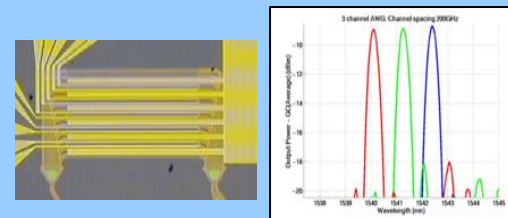
Luxtera CMOS Photonics Technology

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
Ge 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



Trailblazer in Silicon Photonics

▶ **Mission:**

- Deliver photonic solutions manufactured in a mainstream CMOS fabrication, test and assembly processes to provide customers with high performance optical solutions at price points traditionally associated with copper

▶ **Funded:** November 2001

▶ **Location:** Carlsbad, CA

▶ **Staff:** 57

▶ **Top Tier Investors:**

- August Capital
- New Enterprise associates
- Sevin Rosen Funds
- Three Corporate Investors

▶ **Intellectual Property:**

- >100 Patents Filed For
- 40 Issued

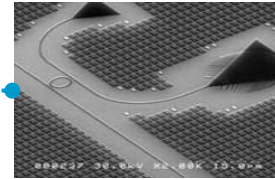


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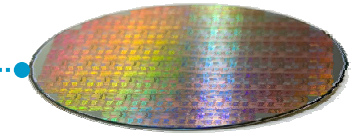


Unbroken String of Industry's Firsts

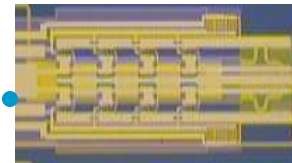
- ▶ **2001** – The first CMOS waveguide and Fiber-to-the-Chip Coupler



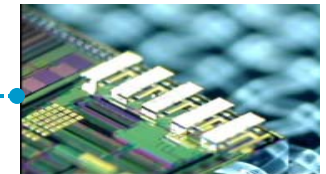
- ▶ **2002** – The first CMOS photonics in standard 130 nm SOI-CMOS process



- ▶ **2003** – The first CMOS 10G Modulator



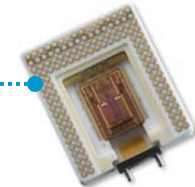
- ▶ **2004** – First Laser bonded to a CMOS die



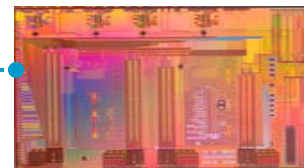
- ▶ **2005** – First wafer scale optical probing



- ▶ **2005** – First single chip dual XFP transceiver



- ▶ **2006** – First monolithic CMOS 4x10G WDM



- ▶ **2007** – ***Major announcements coming...***

?



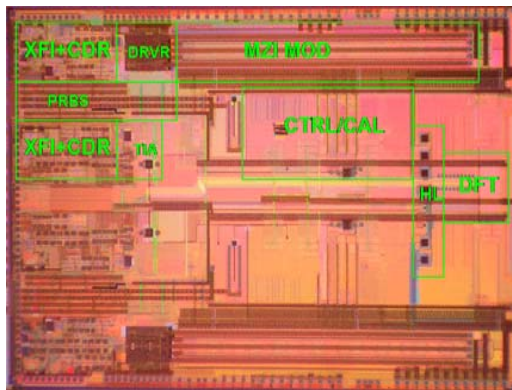
CMOS Photonics Foundry

- ▶ Luxtera uses FSL's 0.13 μ m SOI process
 - Same process used to construct their PowerPC™ embedded microprocessors
 - Very high yield, high volume, mature process
- ▶ Design environment is Cadence at the system/subsystem level
 - Device design done on 200 node cluster running 3D FDTD
 - Can perform LVS, DRC on optical circuits
- ▶ Philosophy: Started with existing electronics design manual, and make the optics fit – requires extensive characterization, simulation, compromise
 - ~80 films in a CMOS process, need to understand optical properties of ALL of them



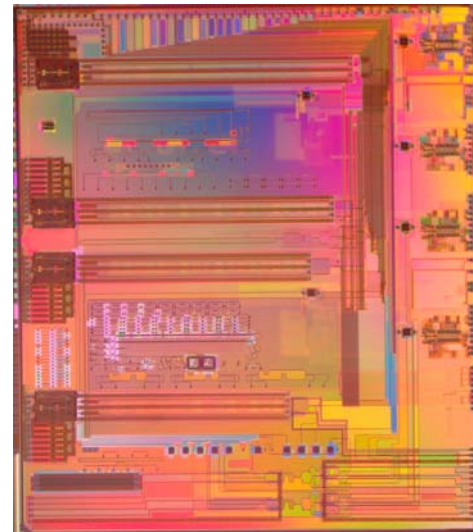
Example CMOS Photonics Chips:

Aurora



Two independent
10Gb transceivers
on a single die
(contains
complete PHY
circuitry)

Pulsar



A single 40Gb WDM
transceiver
 $4\lambda \times 10\text{Gb}$
(PMD circuits only)

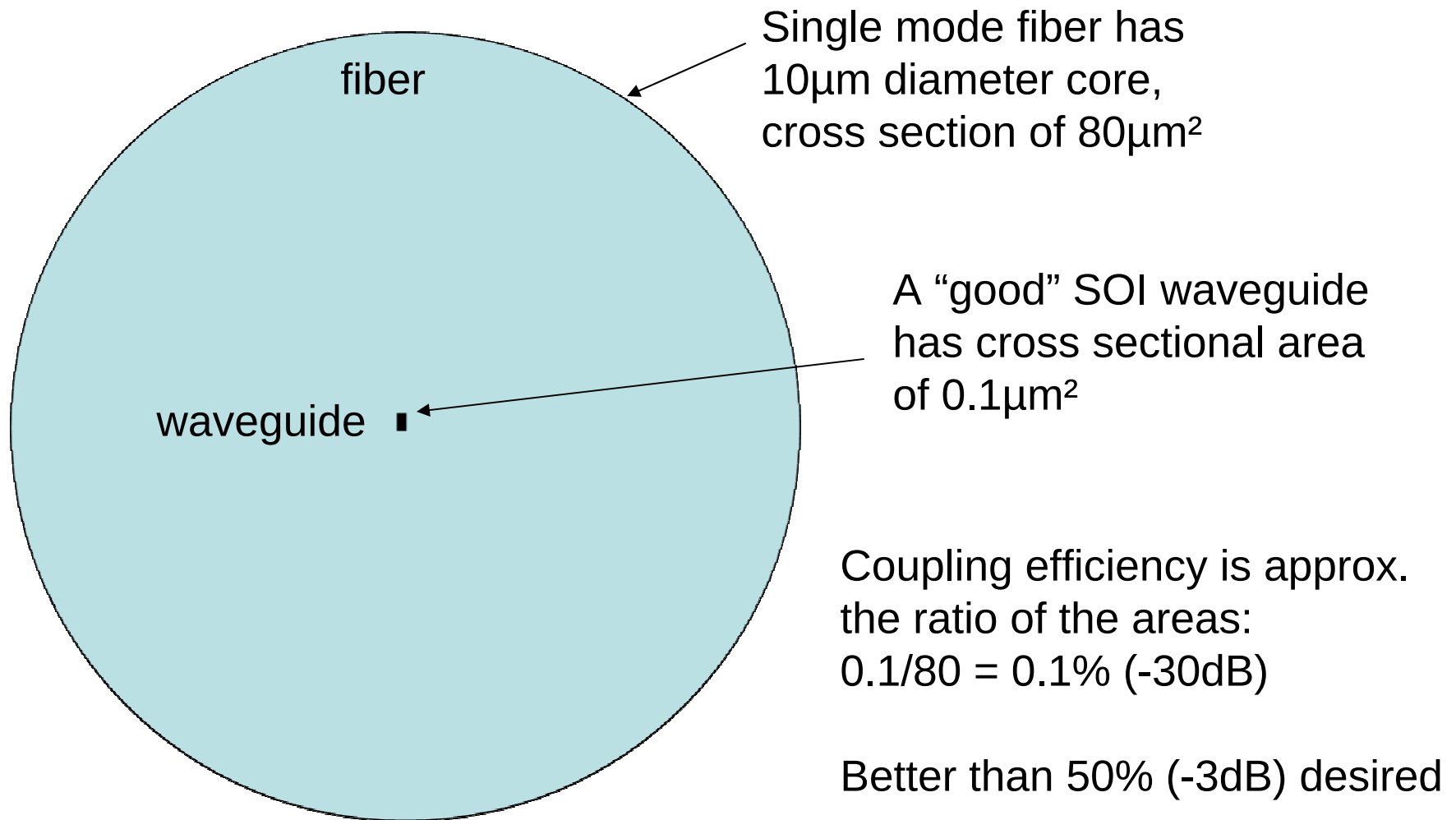


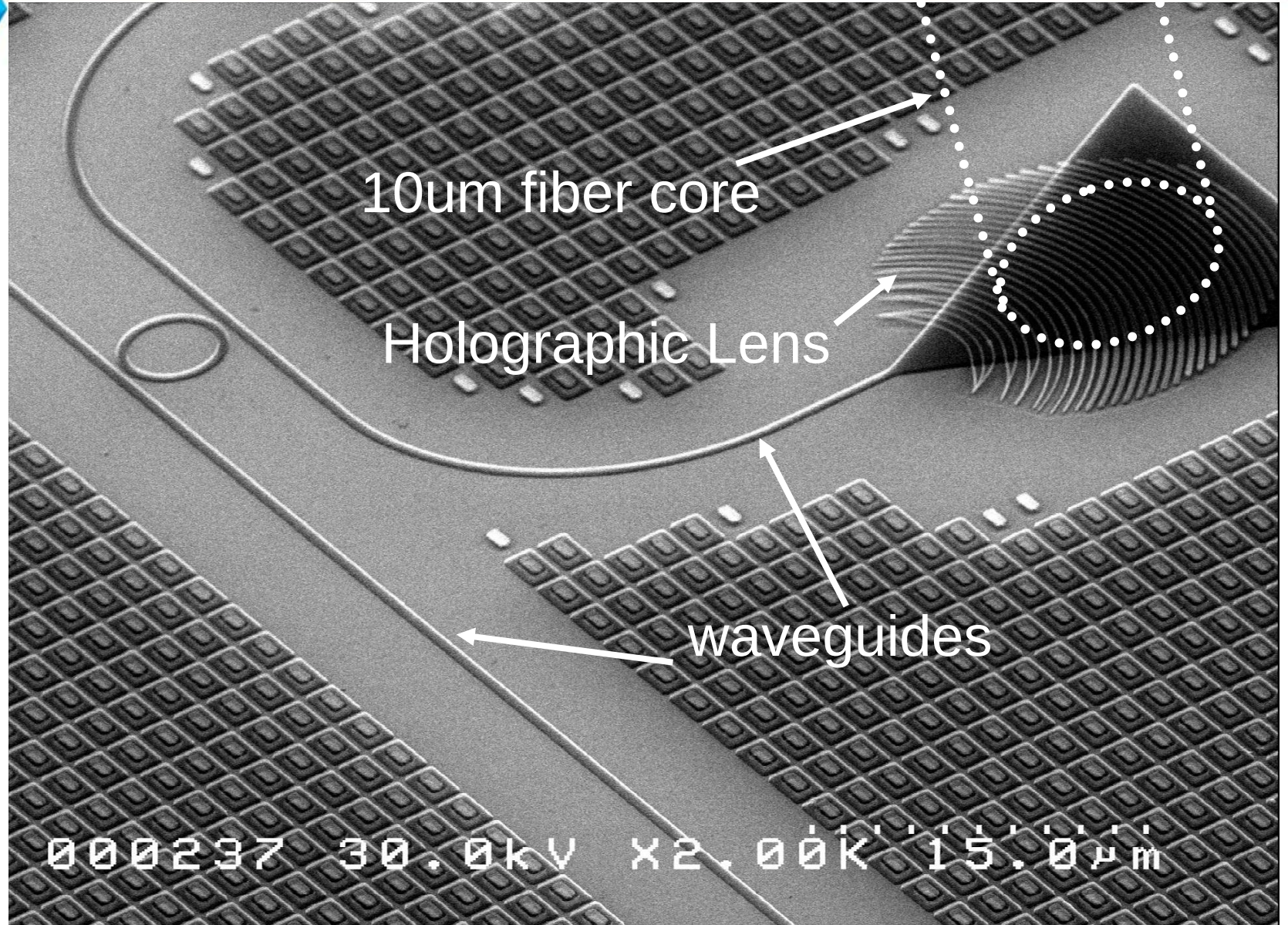
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Component Level Technology



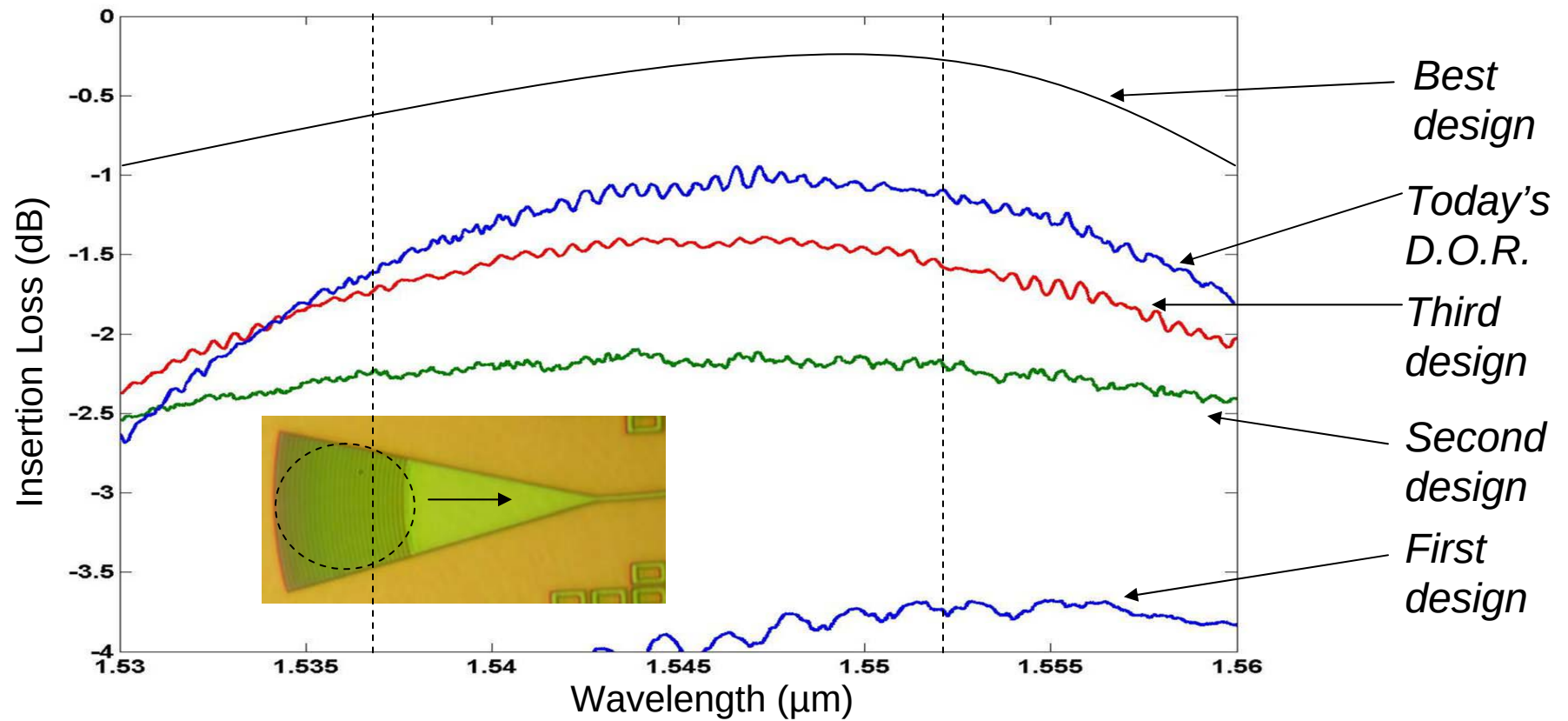
The fiber coupling problem





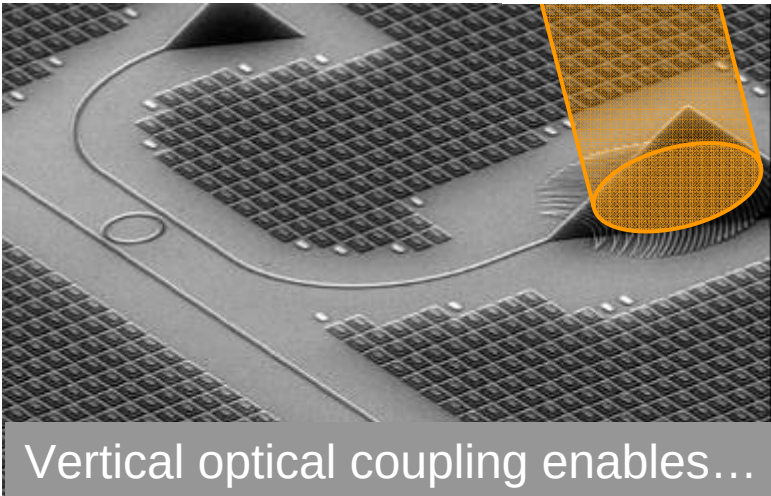


Holographic Lens Evolution

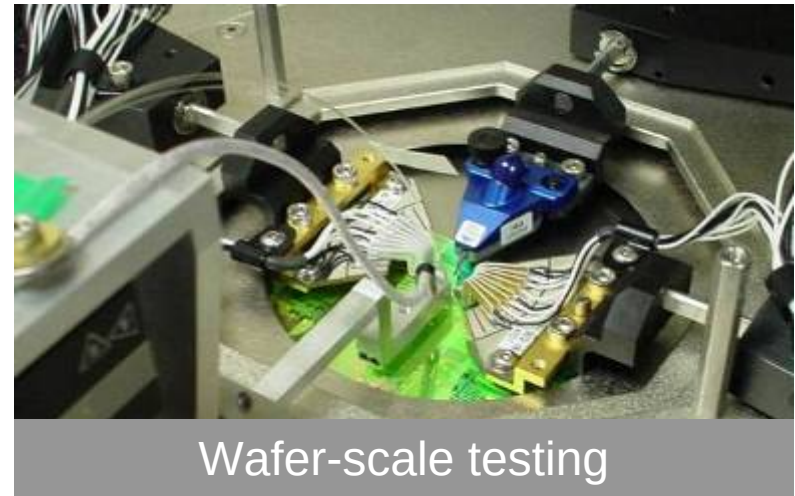




Luxtera's key to Fiber-to-the-chip: connecting the micro and nano scales

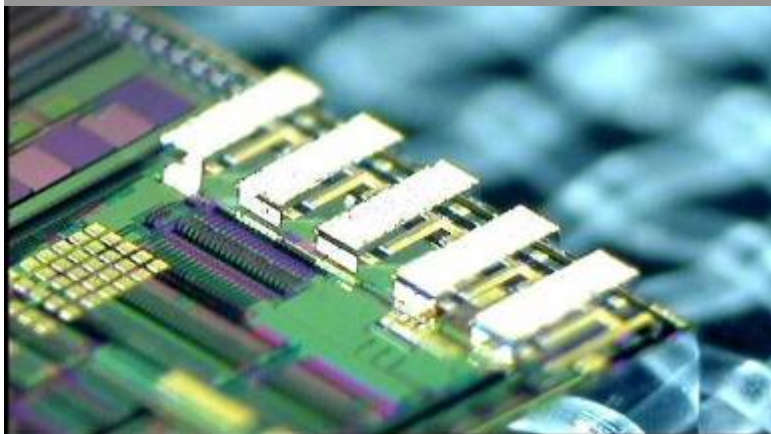


Vertical optical coupling enables...

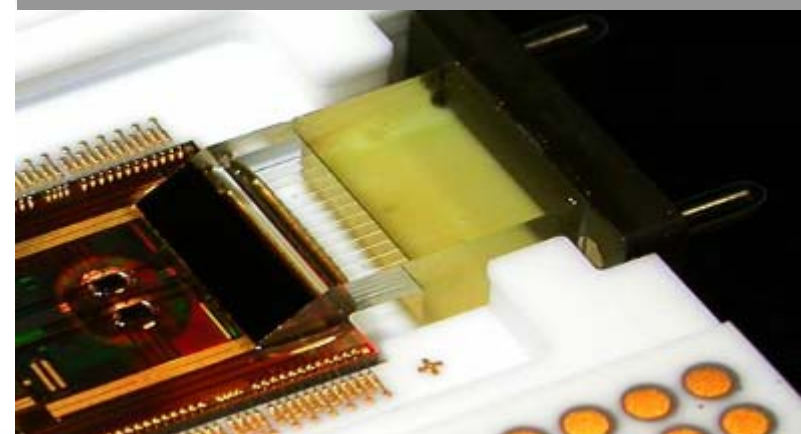


Wafer-scale testing

Flip-chip mounted lasers

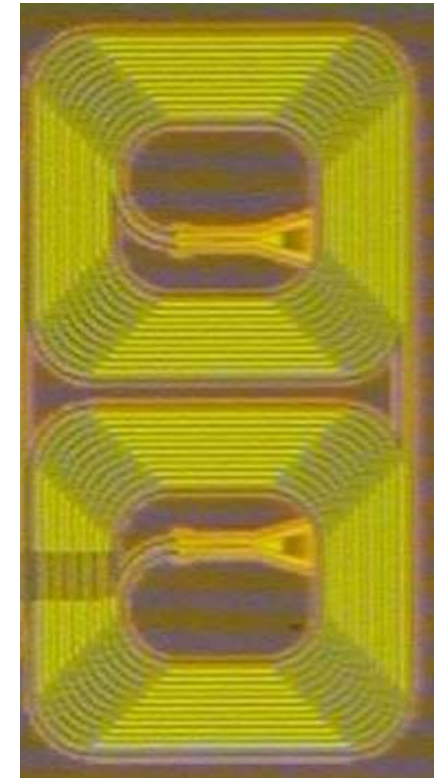
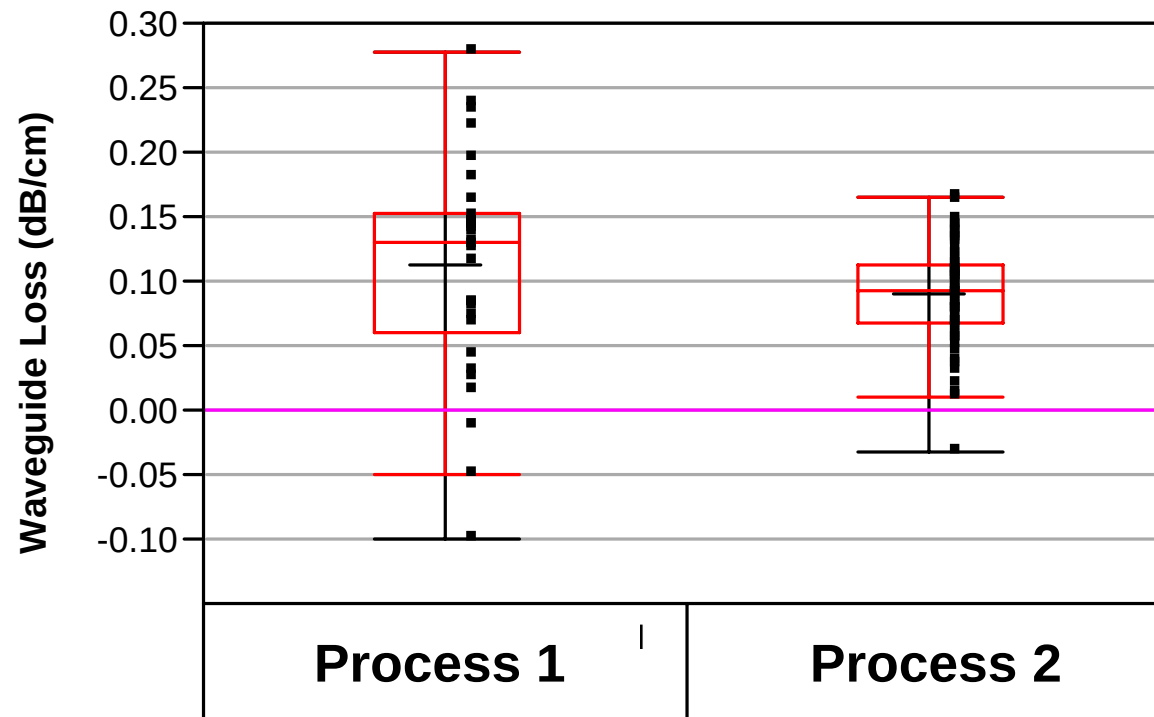


Low cost Fiber to the Chip attach





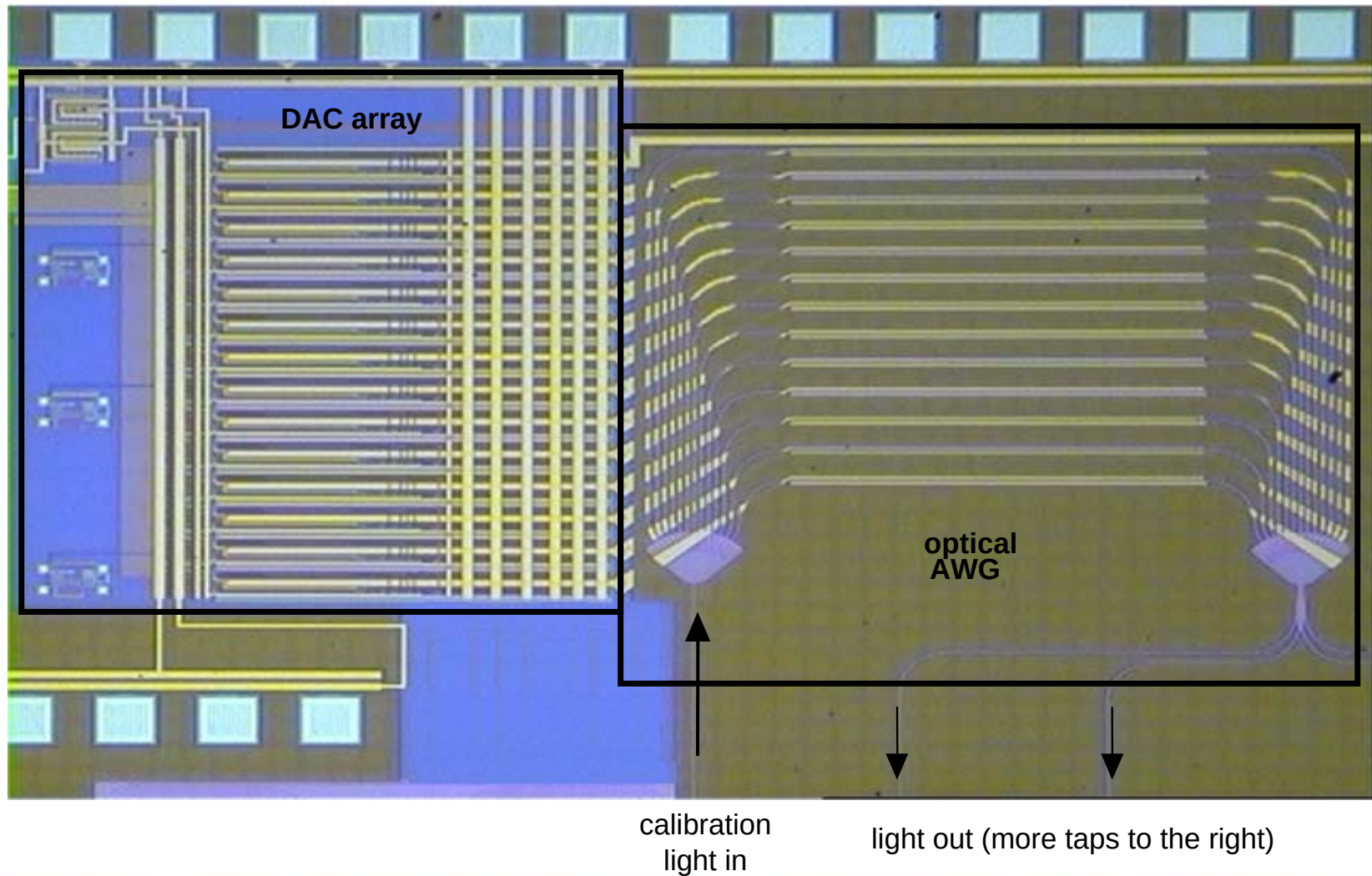
Routing - Waveguide Loss



Waveguide Loss no longer a major issue

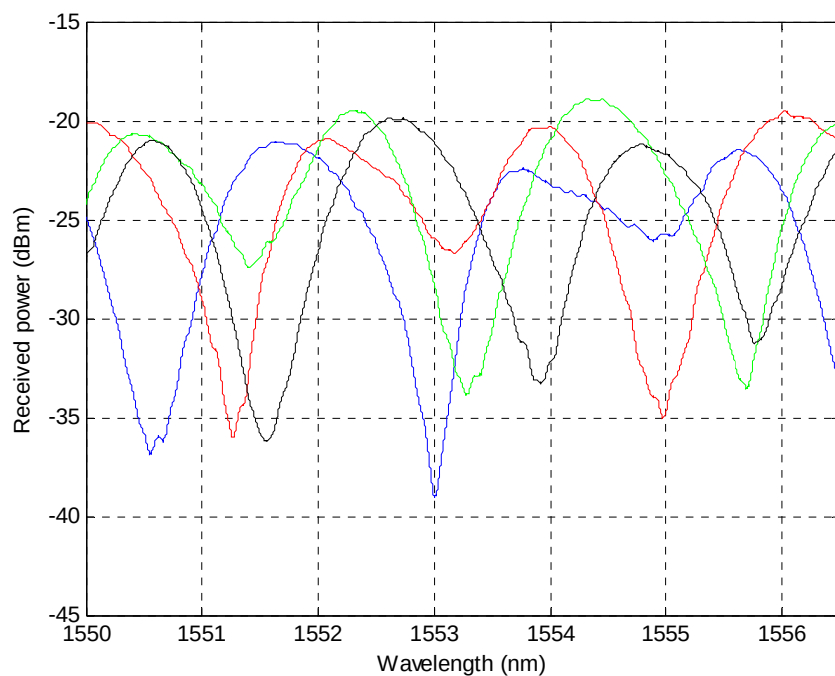


Electrically Tunable Arrayed Waveguide Grating (AWG)

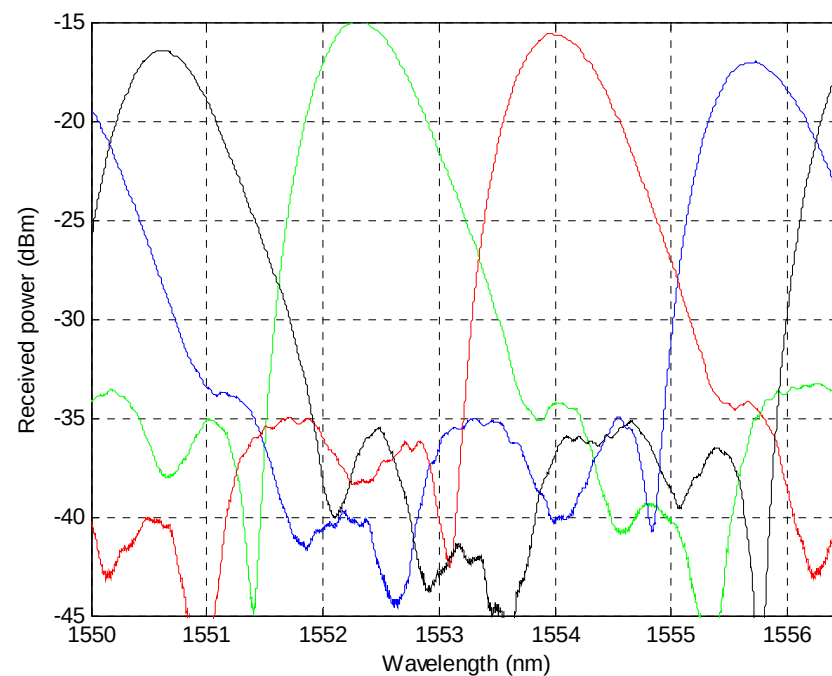




Electrically tunable AWG results



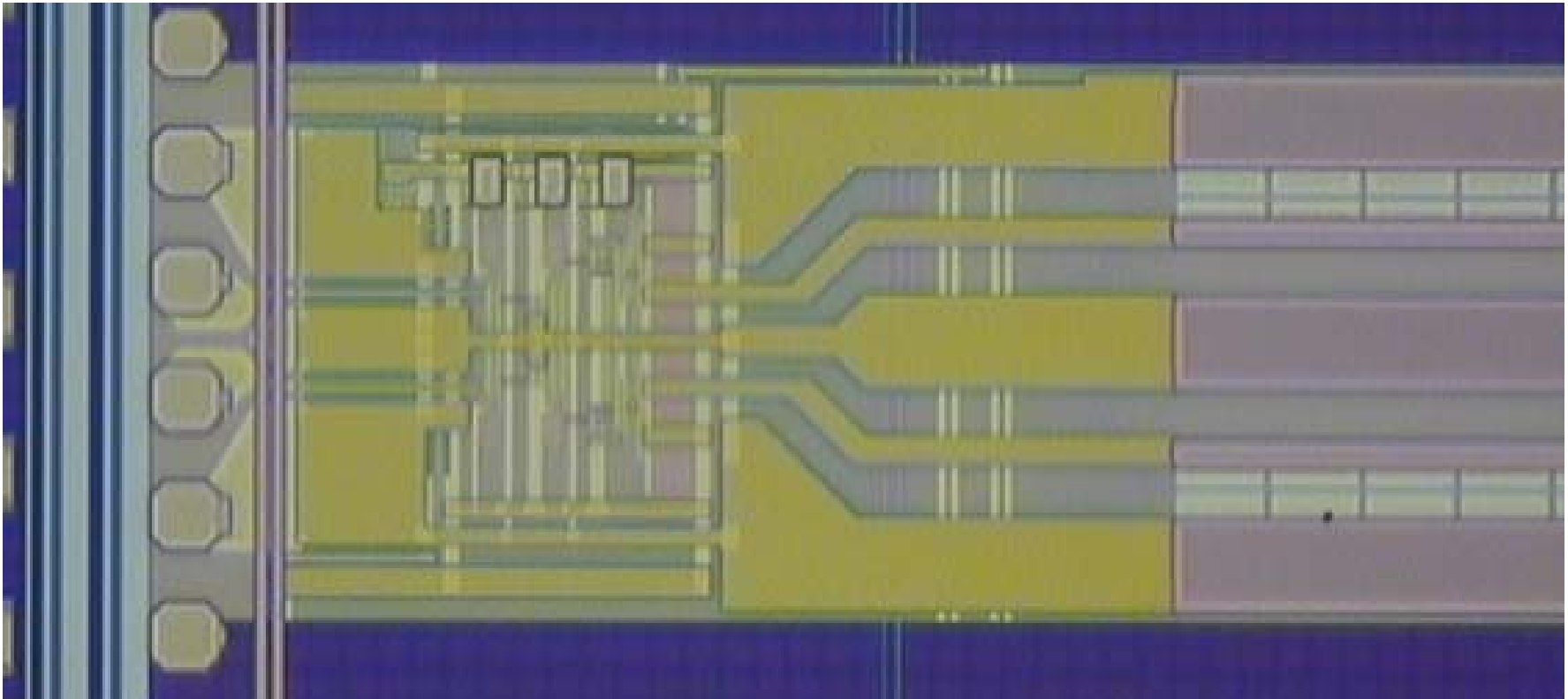
BEFORE TUNING



AFTER TUNING



Modulator with integrated driver

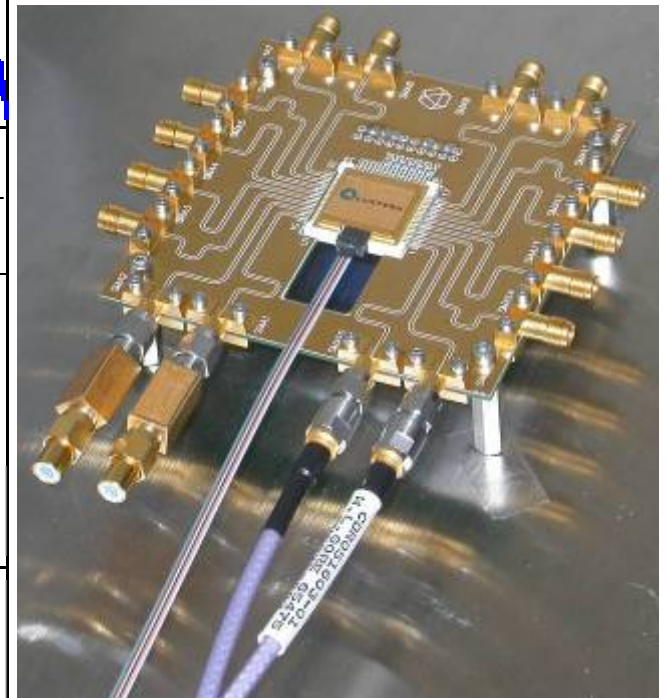
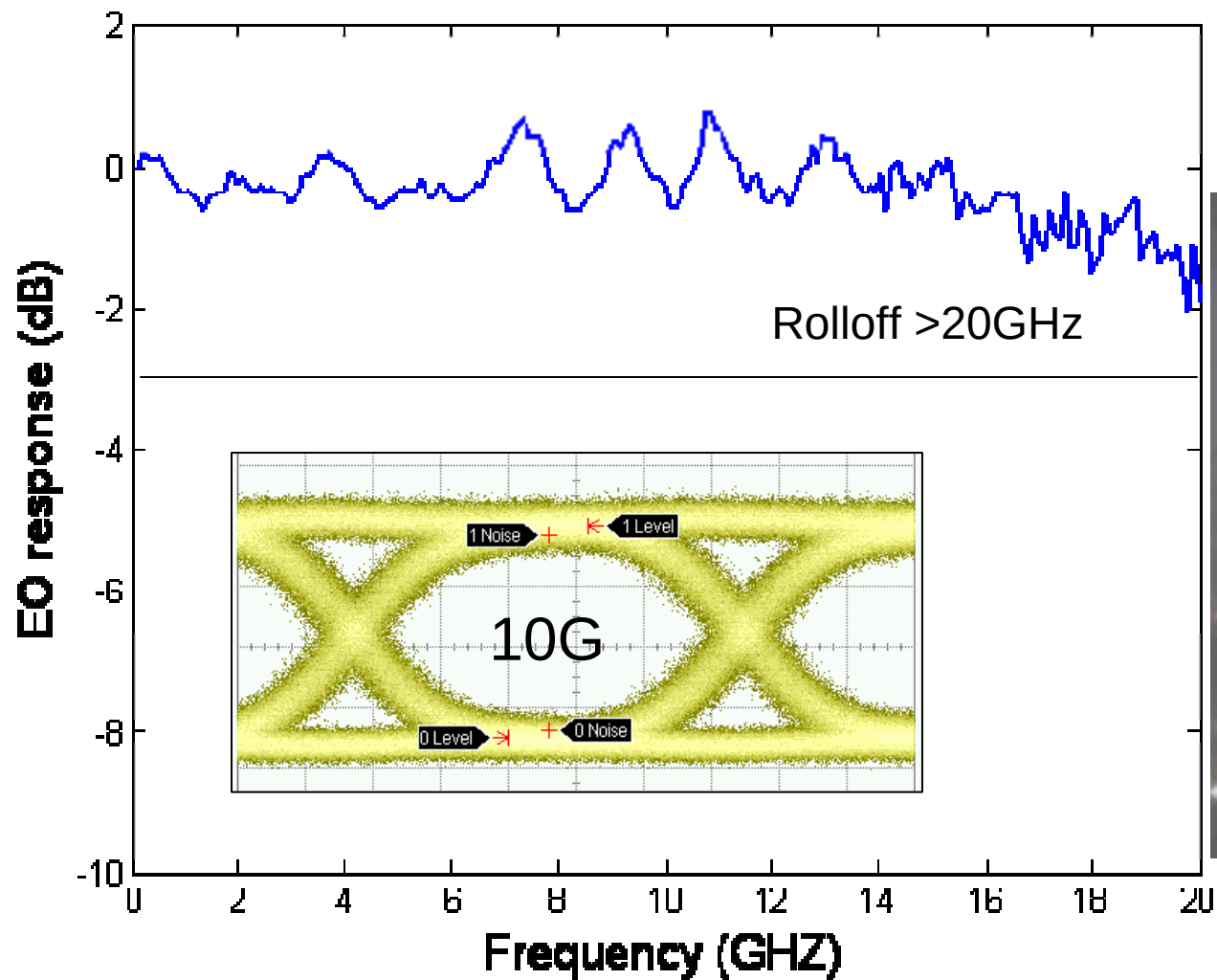


CMOS Optical Modulator with Differential Driver

ISSCC 2006, A Huang, et al.

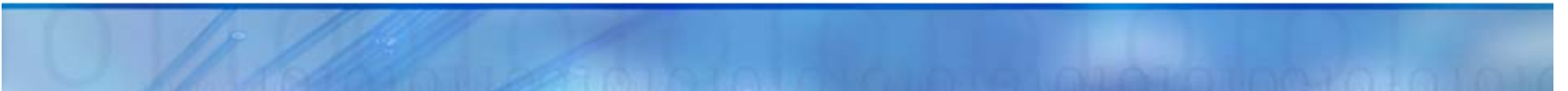


CMOS Optical Modulator Performance



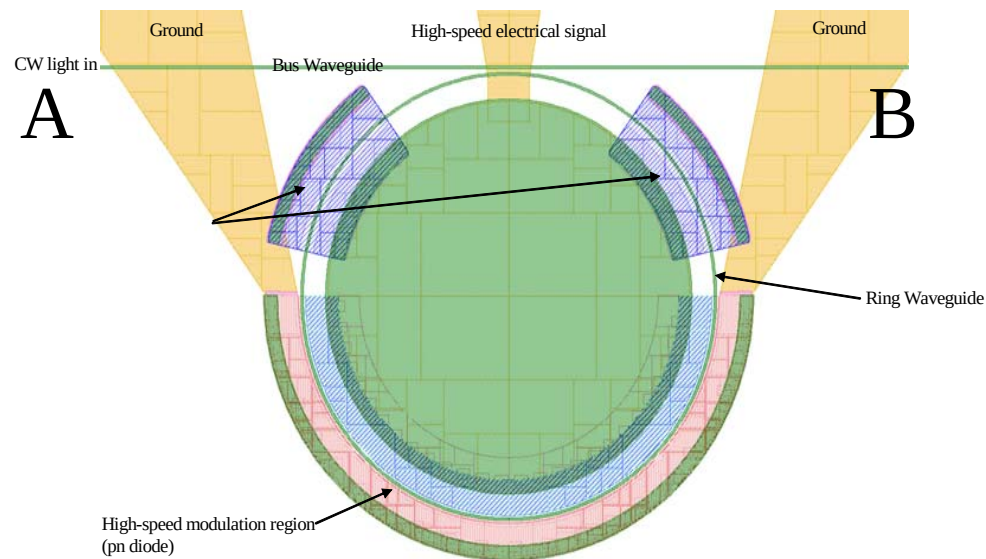


Second Generation Technology



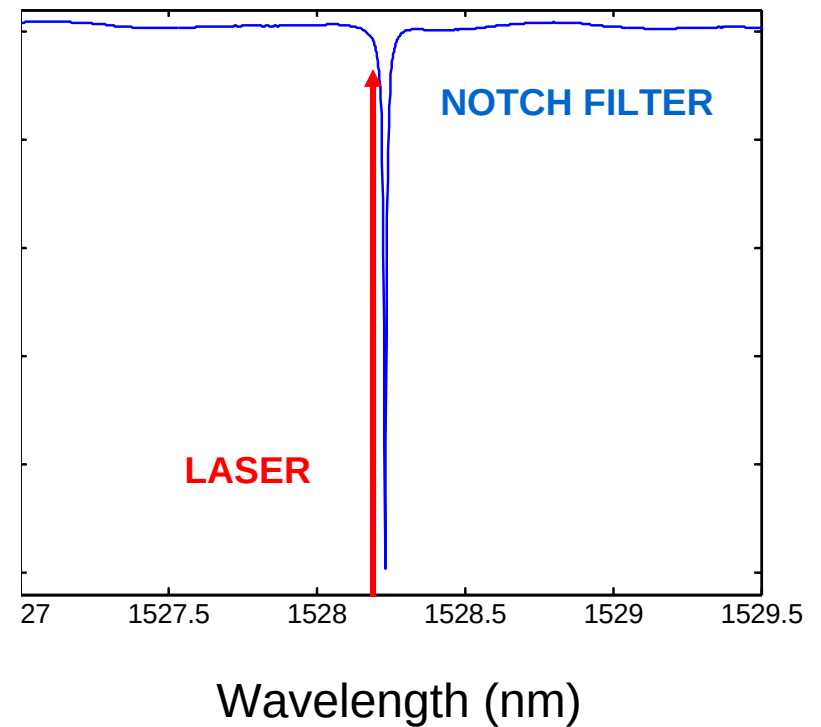


Ring modulators = high density / bandwidth



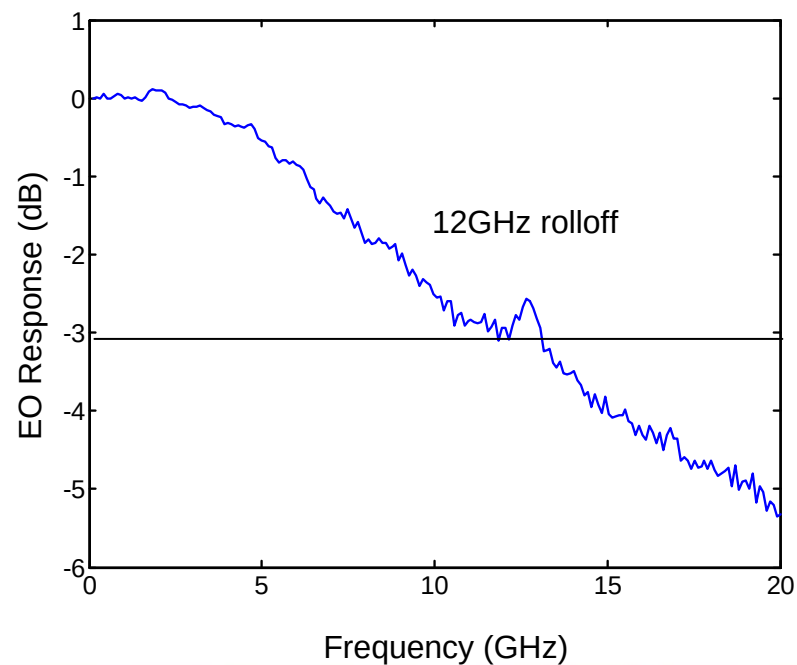
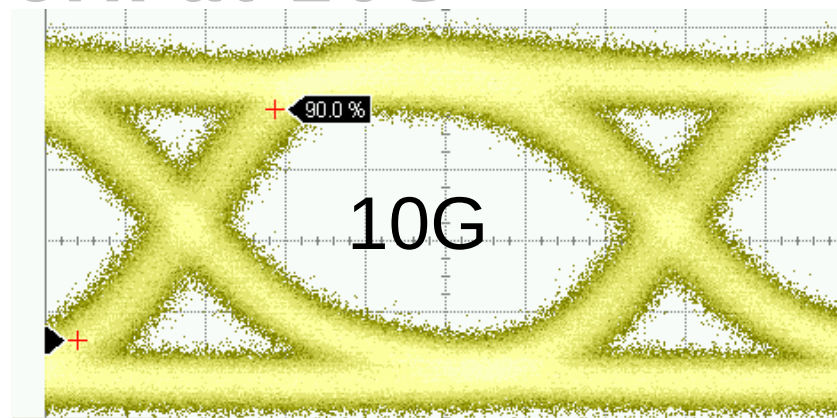
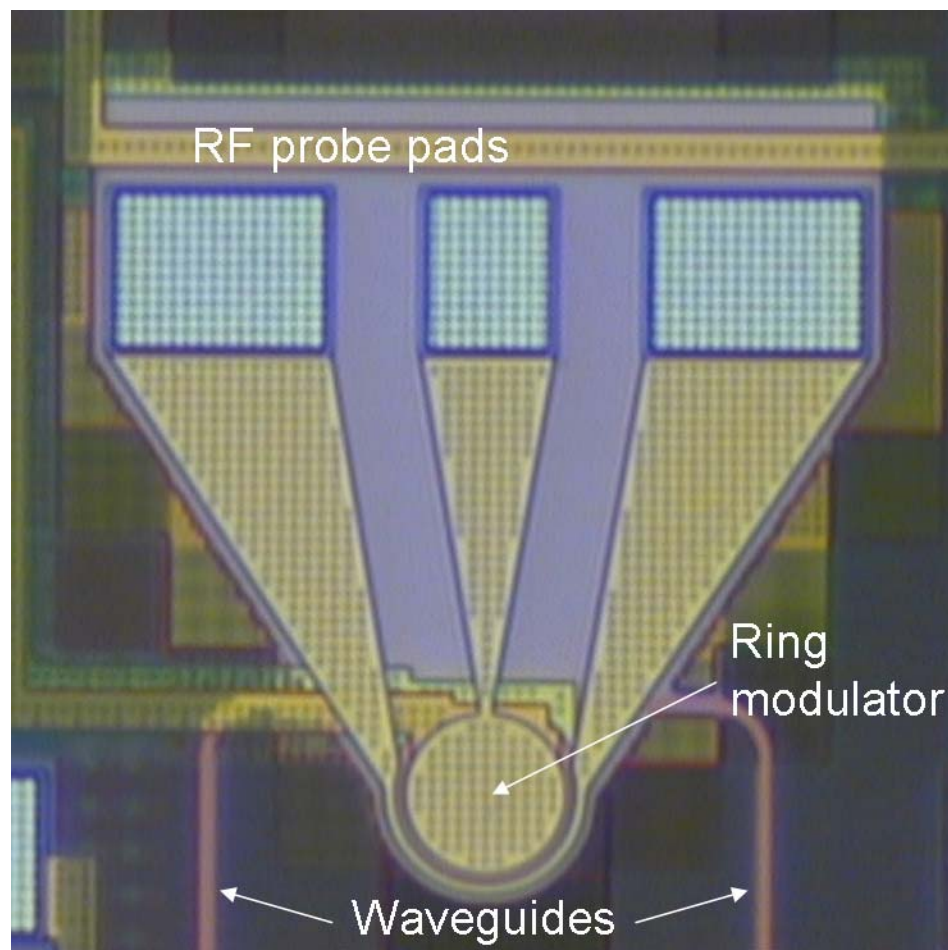
- ▶ 30 μm radius ring
- ▶ Many Tb per mm^2
- ▶ 2000x smaller than electronic PHY

Transmission A $\rightarrow$ B



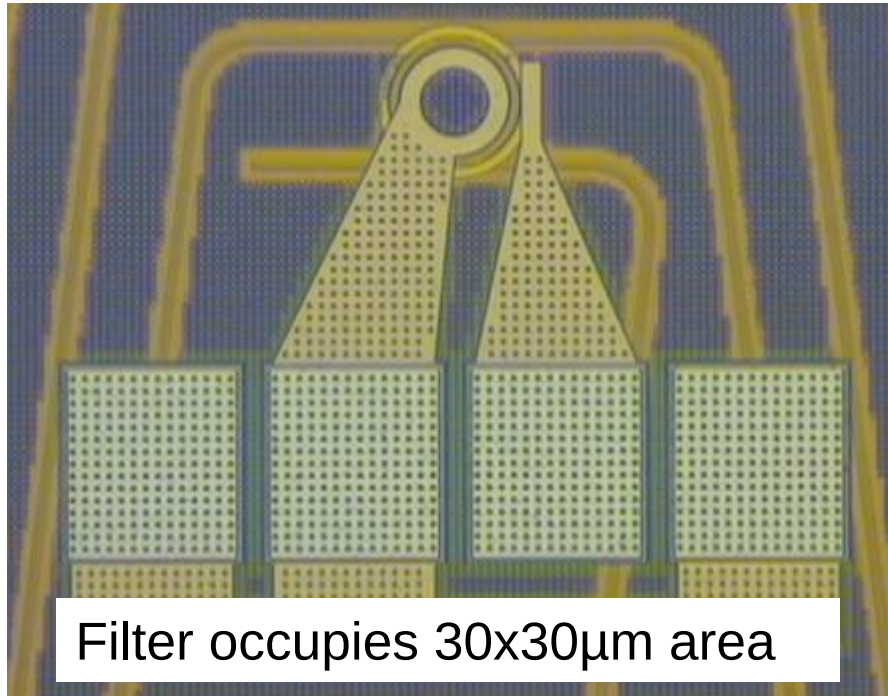


Ring Modulators Work at 10G



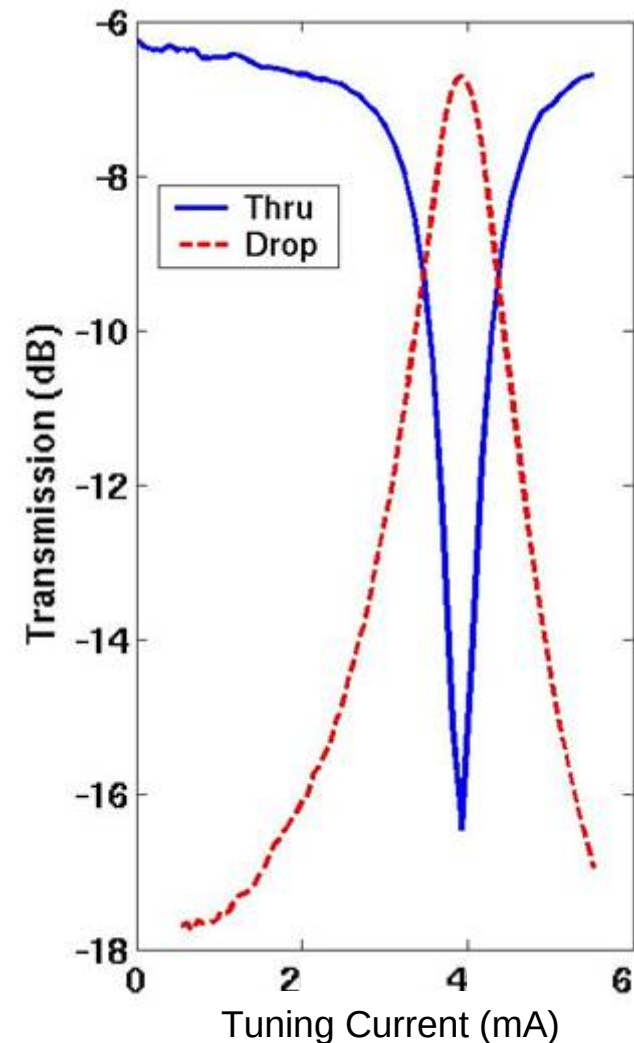


Small Tunable Optical Filter for WDM



↓ ↓ ↑
Thru Drop Input

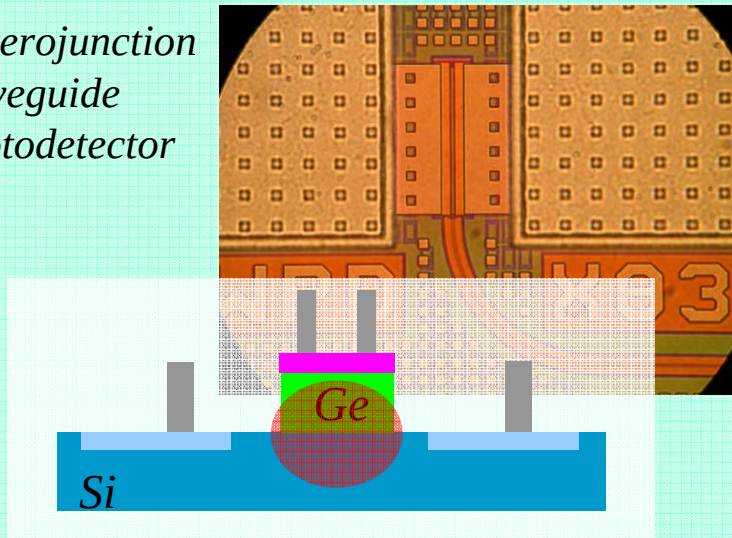
Tunable filters allow:
Dynamic reconfiguration
Operation over wide temperature range





Ge detectors at 10Gbps

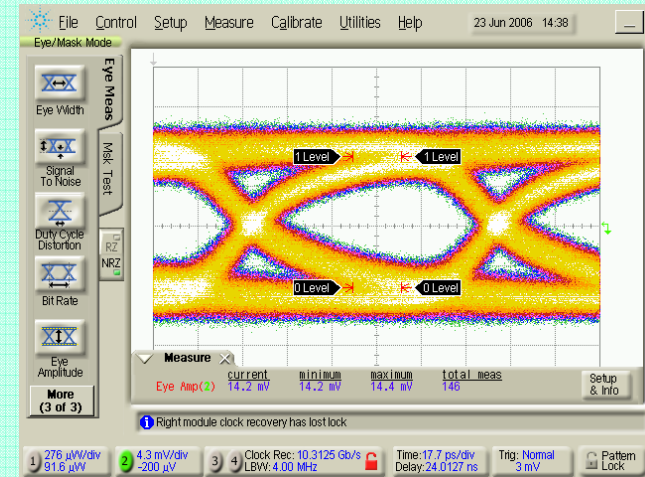
*Heterojunction
waveguide
photodetector*



Low speed device

**Typical performance @ 50C,
1550nm, 3V reverse bias**

Responsivity	0.4A/W
Dark current	3nA
Bandwidth	5 GHz

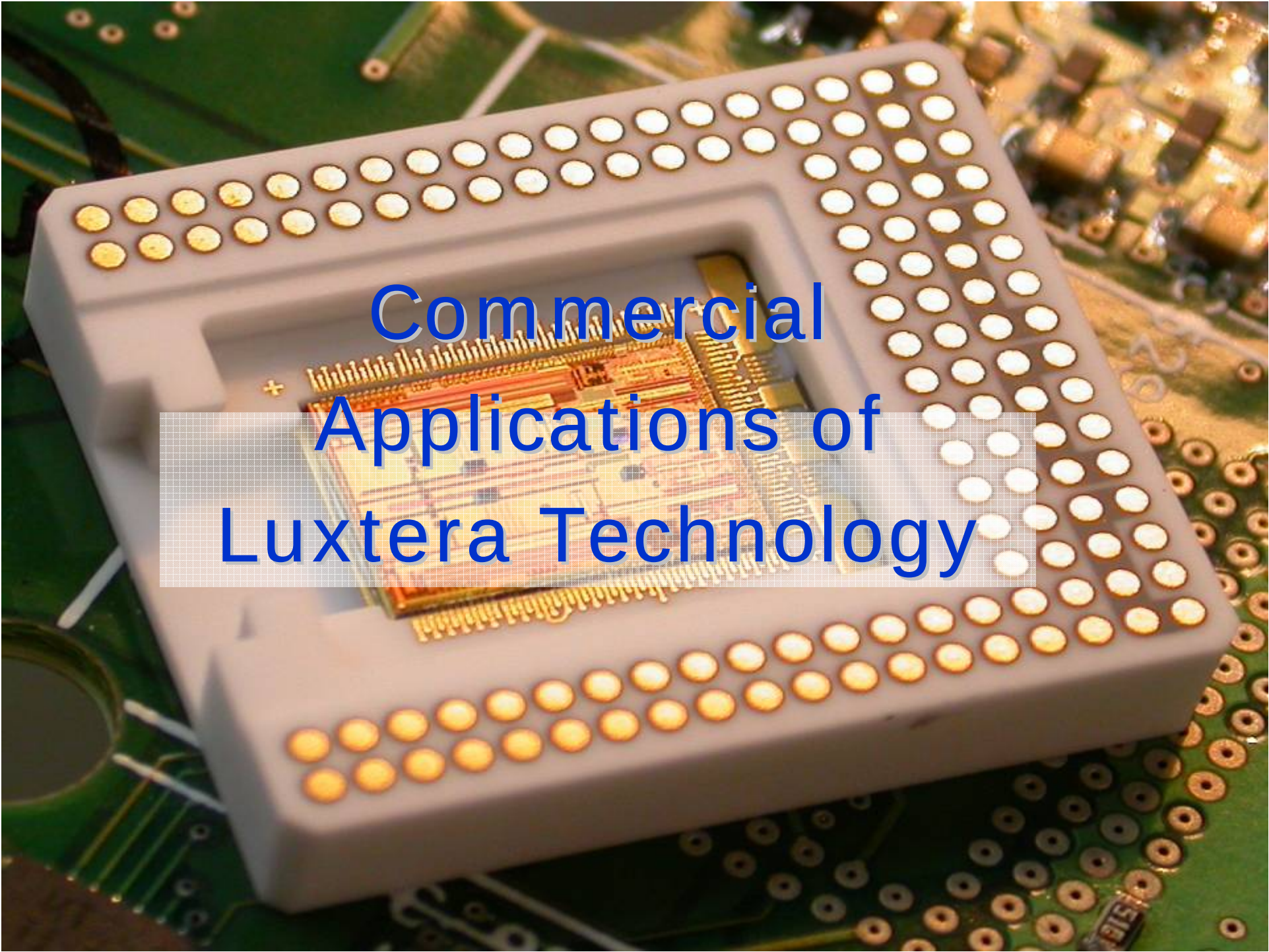


*Eye diagram at 10Gb/s, 1550nm,
3V reverse bias, no TIA*

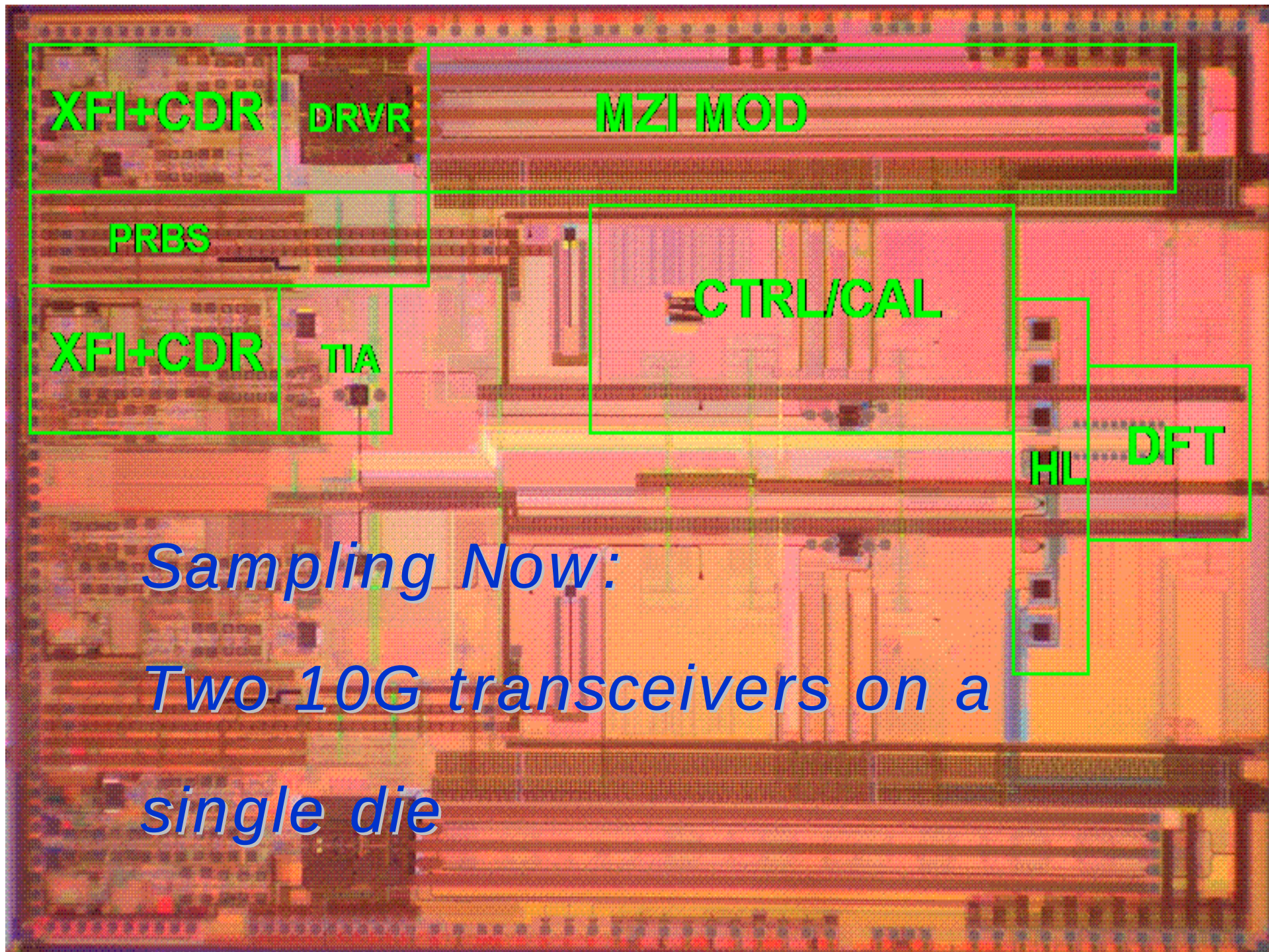
High speed device

**Typical performance @ 50C,
1550nm, 3V reverse bias**

Responsivity	0.5A/W
Dark current	30uA
Capacitance	30fF
Bandwidth	14 GHz



Commercial Applications of Luxtera Technology



Sampling Now:

*Two 10G transceivers on a
single die*



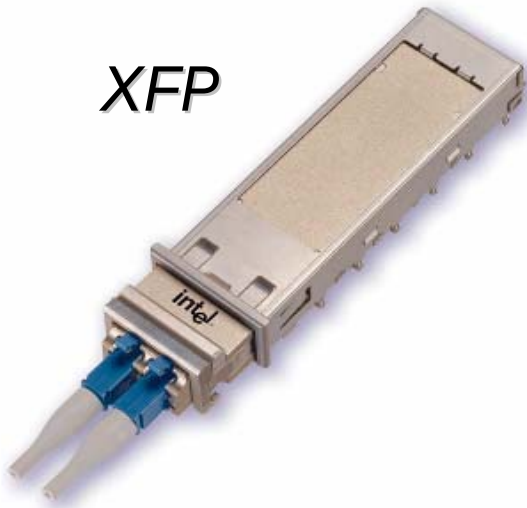
Aurora – the First Product

2 XFP Modules in a single Chip

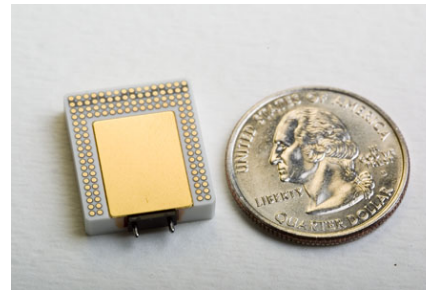
XFP



XFP



Aurora

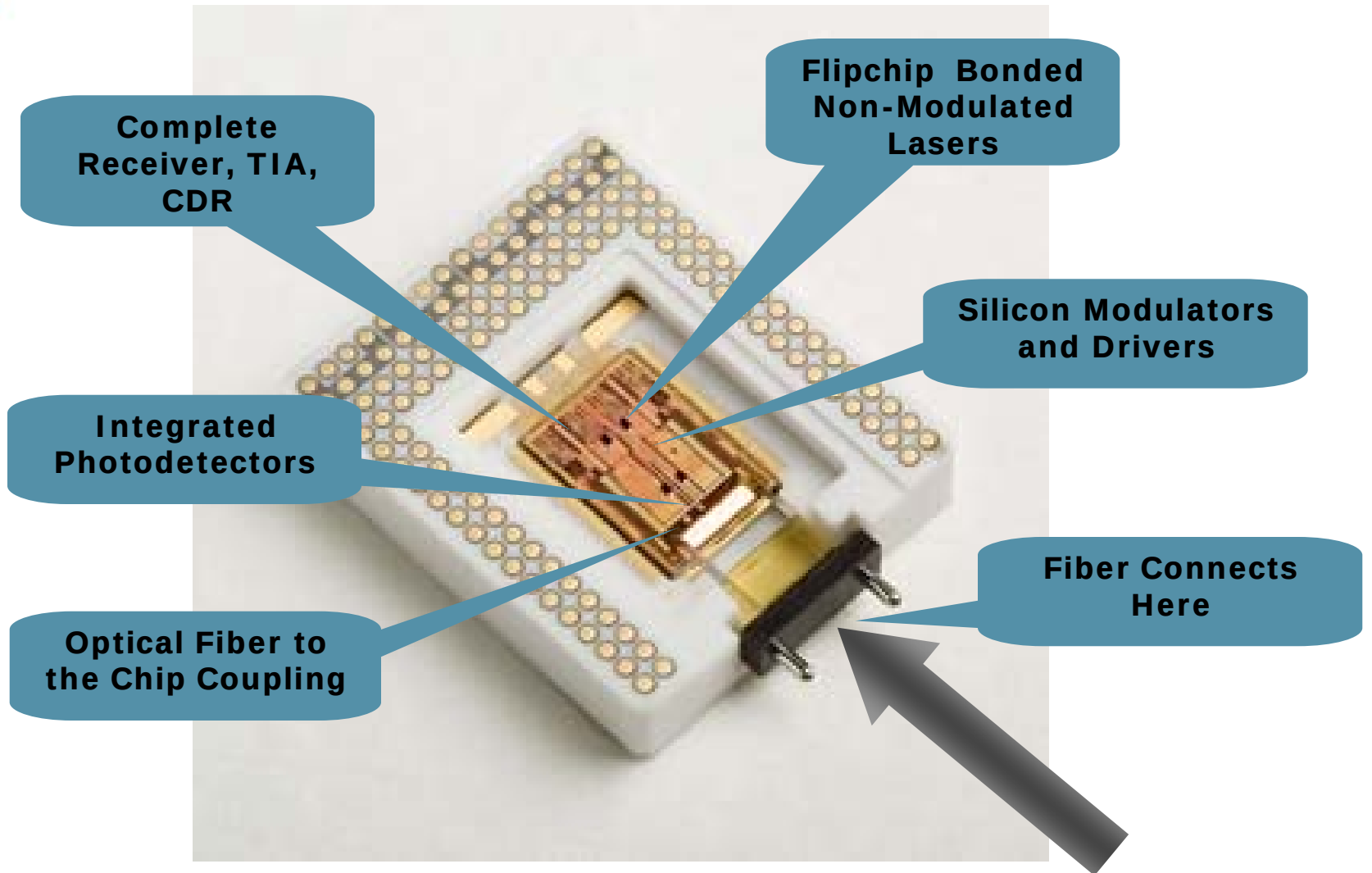


¼ size of XFP

Over 50 % lower cost

Up to 2,000m reach

***XFP compliant
management***



**Complete
Receiver, TIA,
CDR**

**Flipchip Bonded
Non-Modulated
Lasers**

**Silicon Modulators
and Drivers**

**Integrated
Photodetectors**

**Optical Fiber to
the Chip Coupling**

**Fiber Connects
Here**

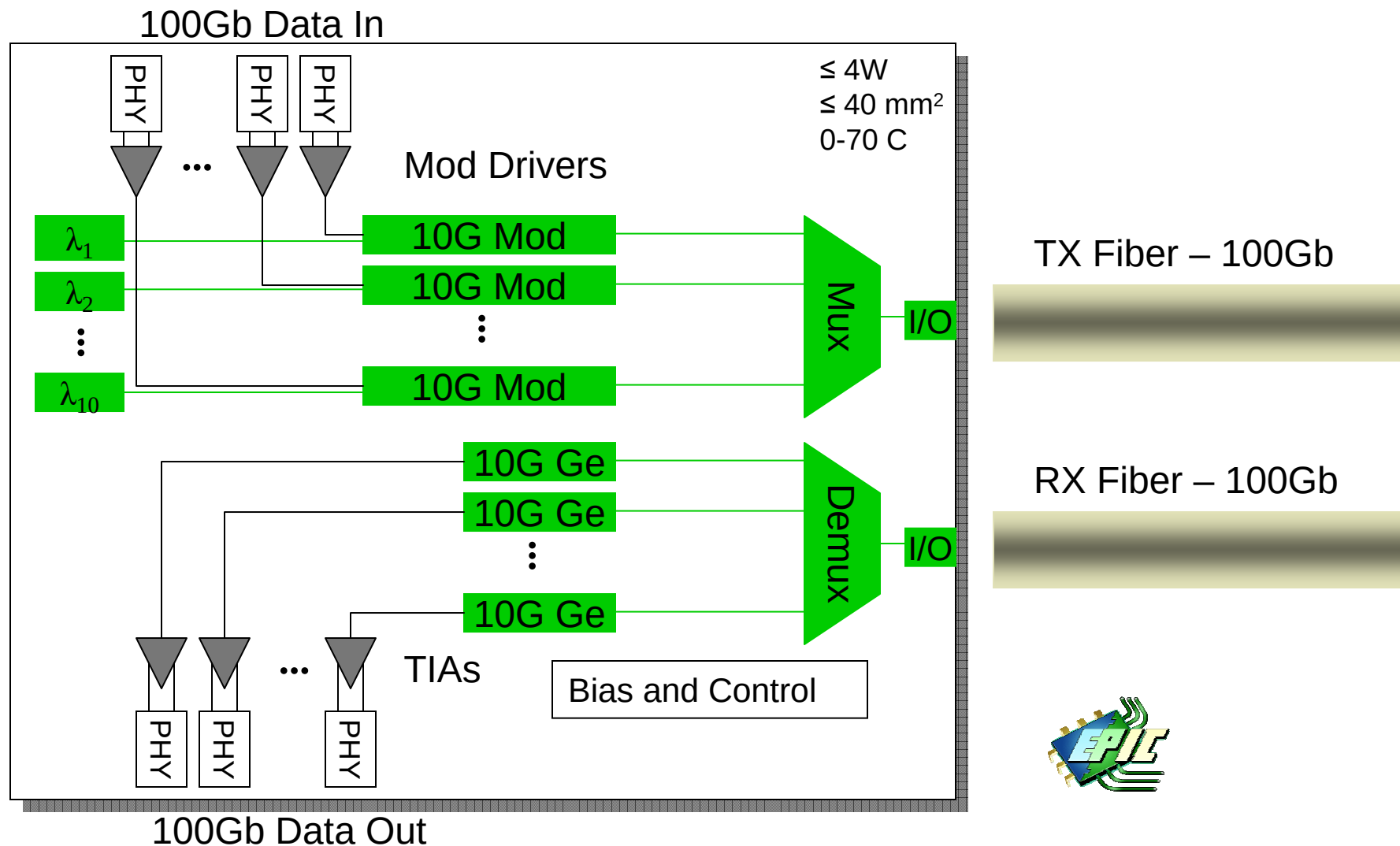


EPIC Program Progress – Multiwavelength Transceivers





100Gb Transceiver – Prototypes Oct 2008





Snapshot of fabricated Pulsar die

Low speed PDs
For control system

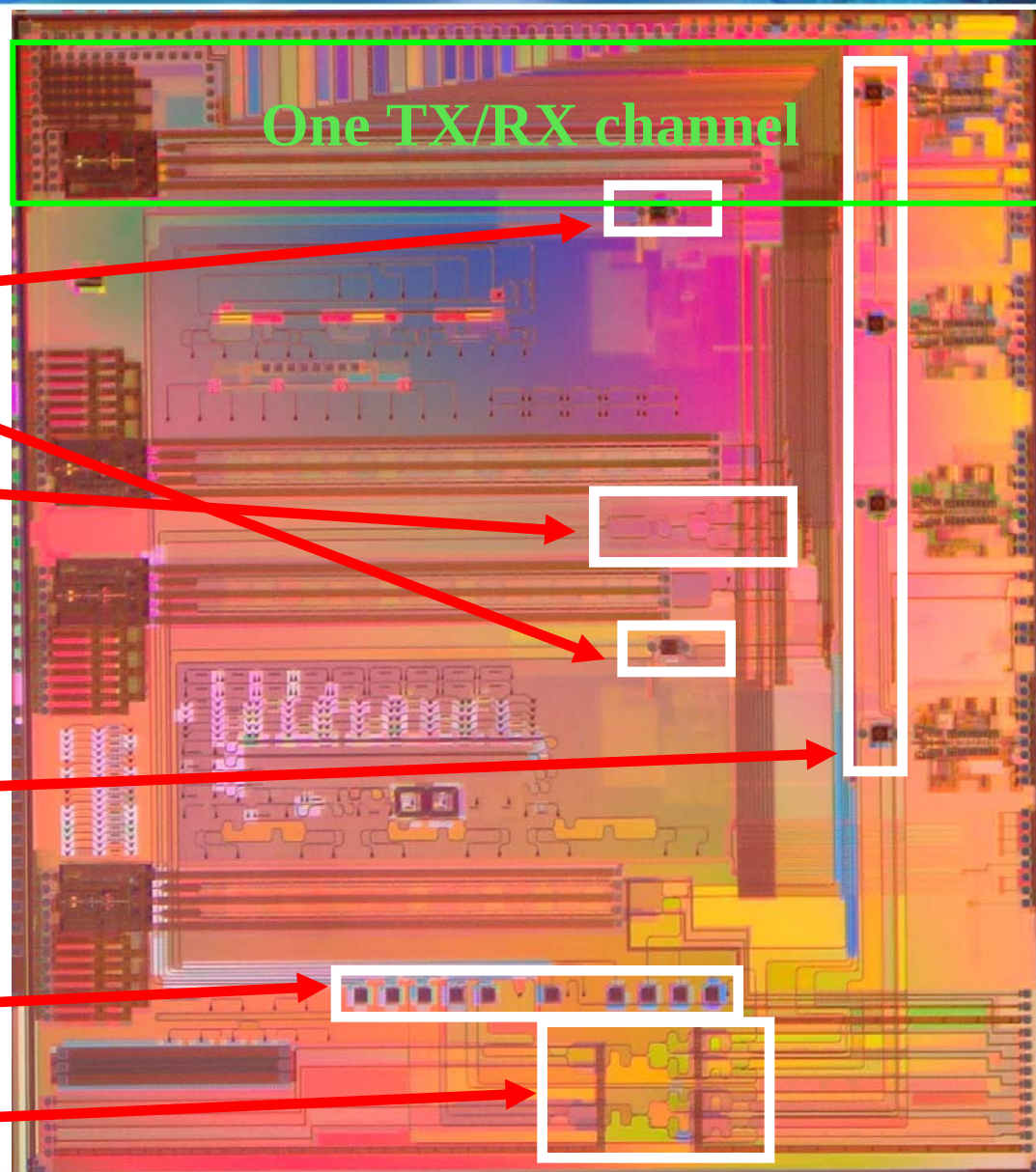
4-ch Optical mux

**Single-chip 40 Gb/s
transceiver**

High speed PDs

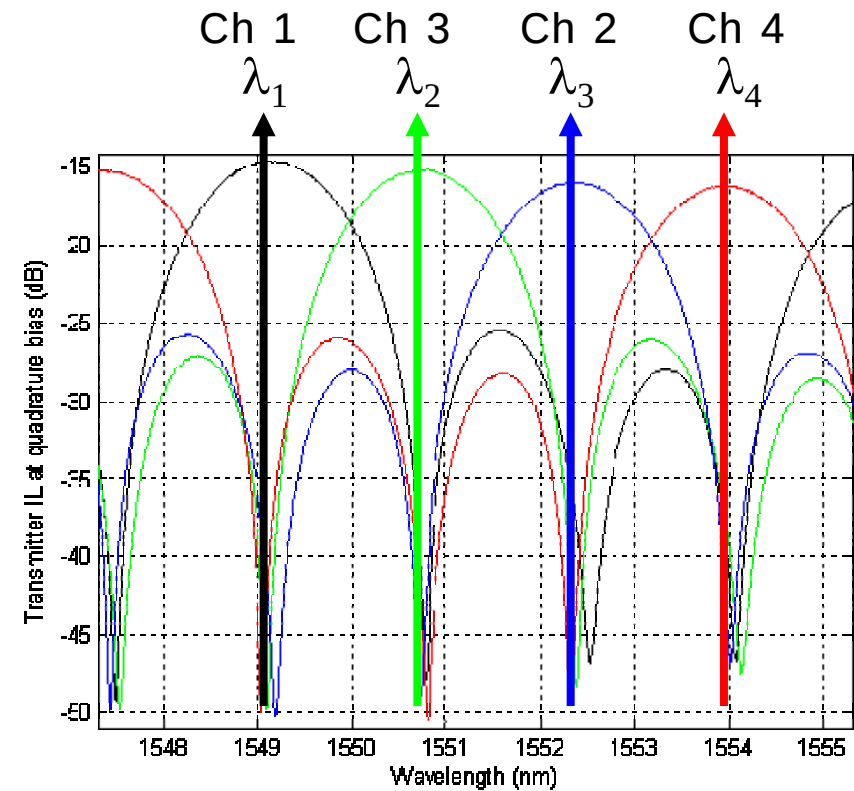
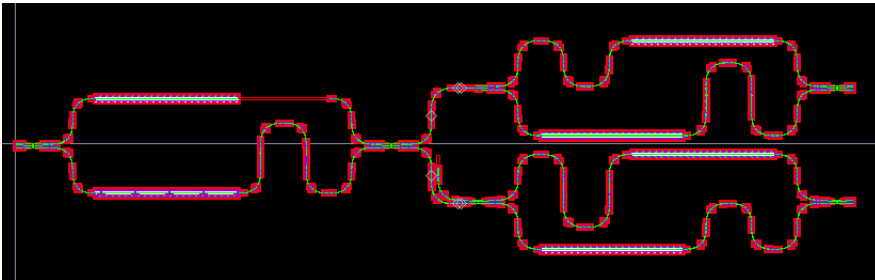
Holographic lenses

Optical demuxes





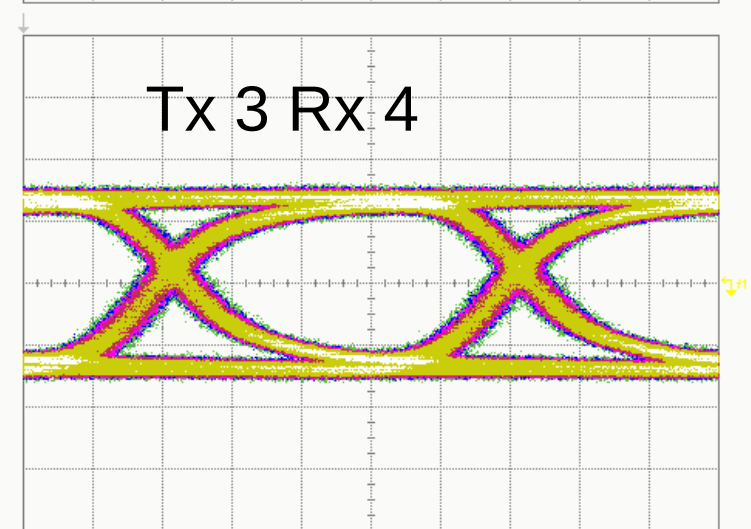
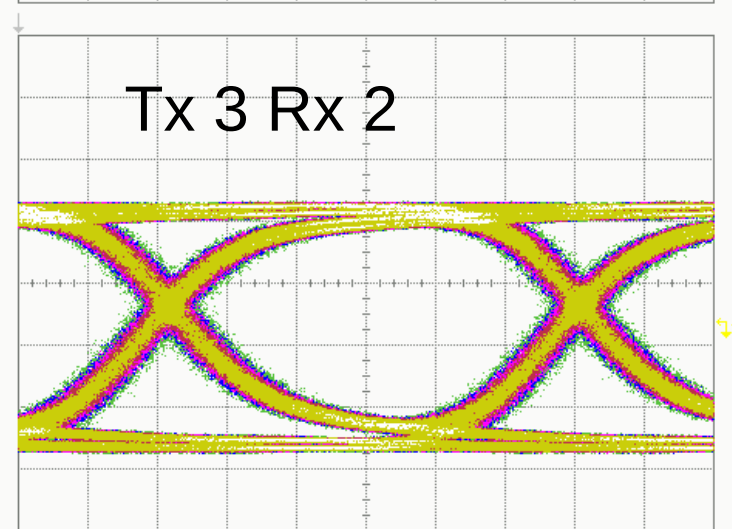
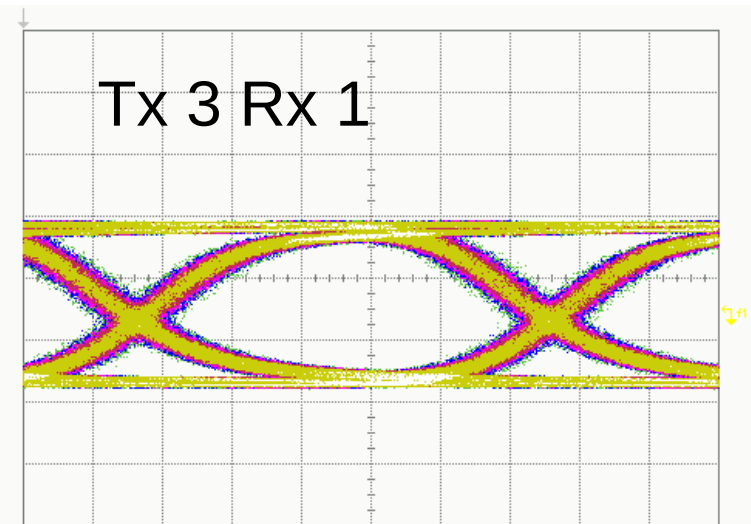
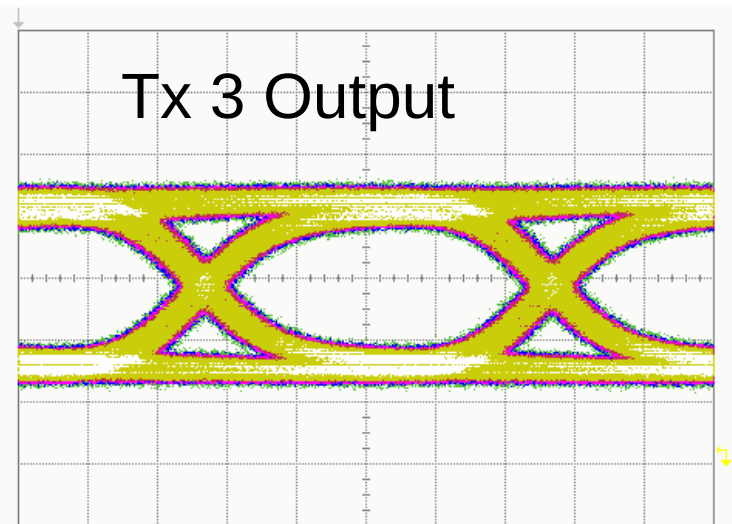
WDM mux/demux



- ▶ IL = 1.5dB
- ▶ Crosstalk ~20dB
- ▶ Bias and Control algorithm implemented off-chip



Results





Can we do a 10Tb transceiver in a 1cm die? (That's 1000 10Gb TRXs, each 316x316 μ m!)

Total Area (mm ²):	0.1000
Modulator	0.0036 (3.6%)
Demux:	0.0009 (1%)
Mux:	0.0009 (1%)
Detector:	0.0001 (.1%)
Optical Routing:	0.0050 (5%)

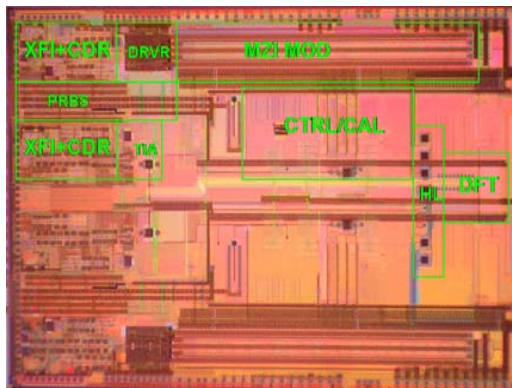
Area remaining for transceiver electronics	0.0886 (89%)

Luxtera has demonstrated the optics for a 10Tb transceiver in a 1cm² die



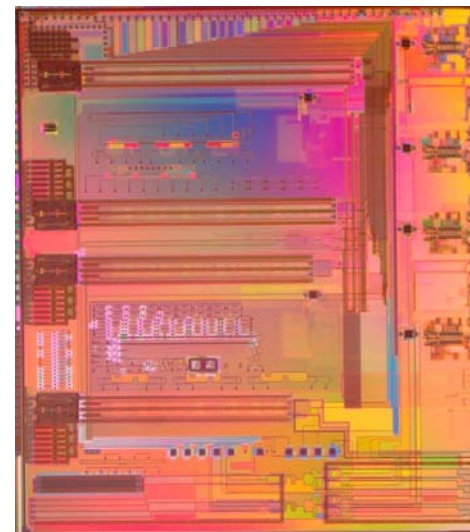
Conclusion: CMOS Photonics Chips Are Working

Aurora



Two independent
10Gb transceivers
on a single die
(contains
complete PHY
circuitry)

Pulsar



A single 40Gb WDM
transceiver
 $4\lambda \times 10\text{Gb}$
(PMD circuits only)



Conclusions

- ▶ DARPA EPIC Program has already been a success -- Silicon Photonics Technology is working – currently sampling to customers
- ▶ Technology offers the performance of optics, at the price of copper
- ▶ There are many technical advantages for silicon photonics to achieve low cost
 - CMOS Manufacturing
 - Wafer scale testability of optics and electronics
 - Built-In Self Test
 - Simplified packaging approach
 - Many channels can be put in a single package
- ▶ Longwave (1300-1600nm), single-mode fiber will become the lowest cost alternative