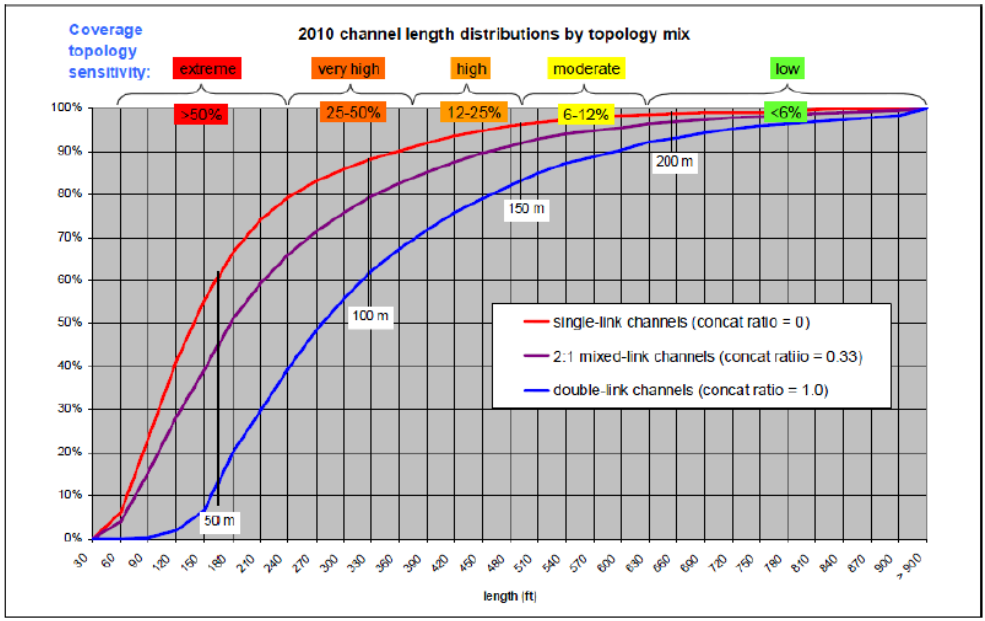
LUXTERA

Next Gen 100G Interconnect

Technical Feasibility Using Silicon Photonics

Data Center Needs at 100Gbps

- Low cost transceivers
  - Very low cost at ~150m
  - Low cost at ~2,000m
- Low power consumption
- Small form-factors
  - High front panel density
- Multi-sourcing
  - Multi-vendor interoperable



Coverage topology sensitivity = (single-link coverage - double-link coverage) / single-link coverage

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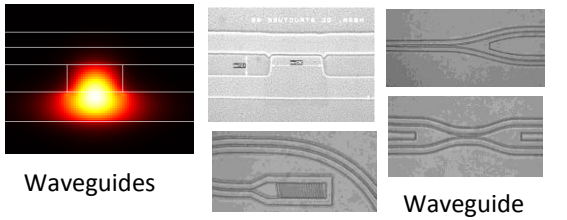
- IEEE needs to respond with standardization activities that enable:
  - Application of new technologies that can meet cost-performance objectives
  - Existing and new technologies interoperable solutions
  - Support for distances needed in emerging large data centers

What are the Potential New Technologies

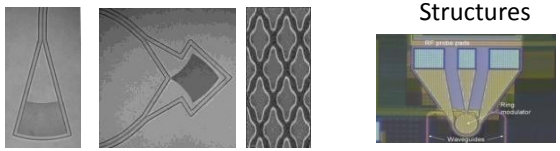
Silicon Photonics – Electro Photonic Integrated Circuit

CMOS Photonic Circuits



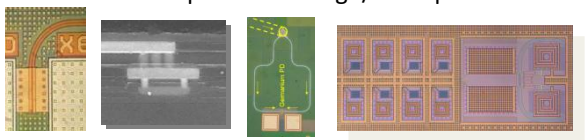
Waveguides

Waveguide Structures



Vertical Couplers

High/Low Speed Modulators



Waveguide Photo-detectors

Integrated PD & TIA/LA

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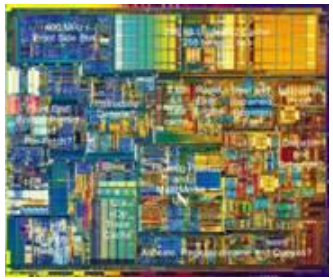
CMOS Analog & Digital Circuits



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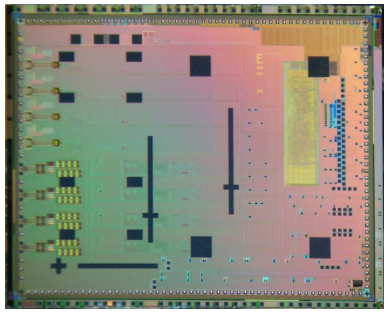
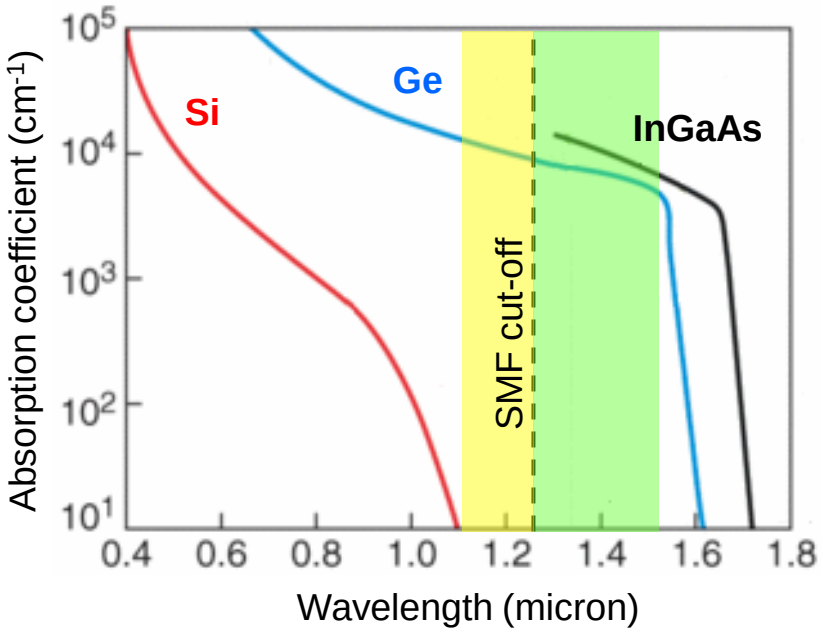
Integrated CMOS Photonic, Analog & Digital Circuits



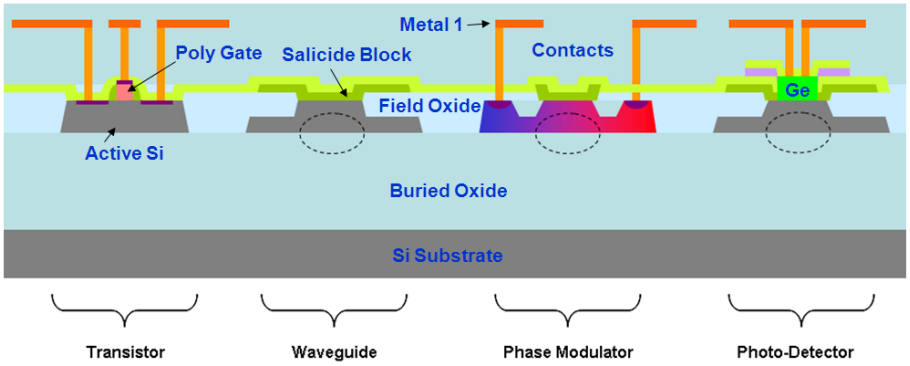
- A number of companies are working on this technology, including:
  - Luxtera, Intel, IBM, Lightwire, Kotura, and other new startups

Key Technical Characteristics of Silicon Photonics

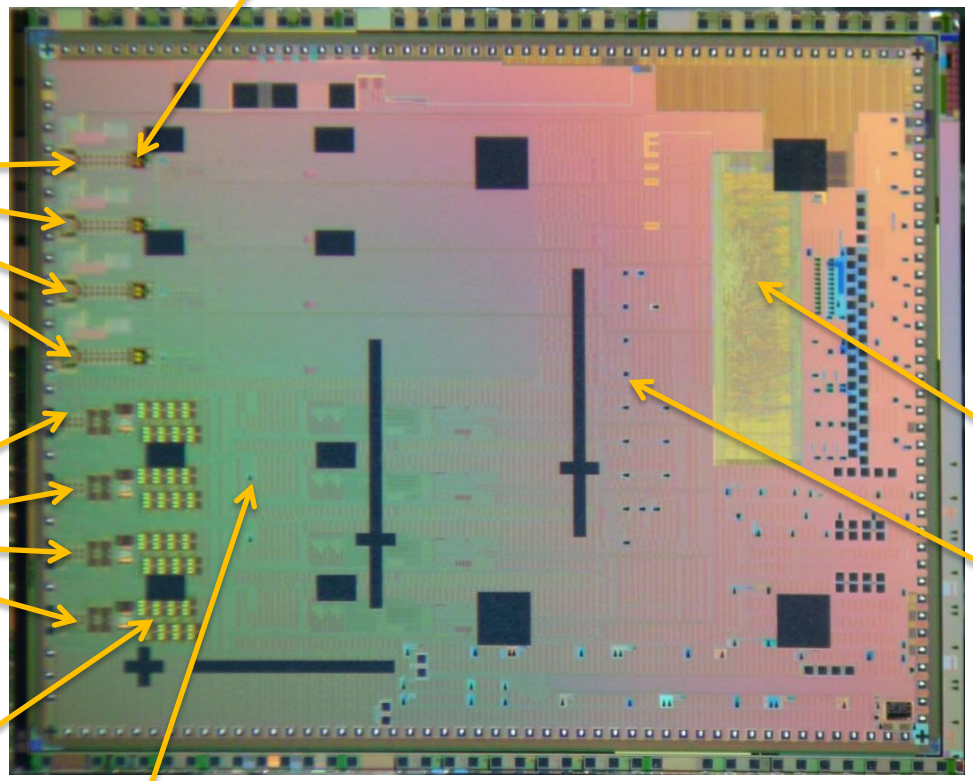
- Silicon is transparent to light at wavelengths longer than 1100nm
  - Need transparency to build a waveguide
- Germanium efficiently absorbs light up to 1560nm
  - Need absorption to build an efficient photo-detector
  - Germanium enables monolithic Photo-detector
- Light from a waveguide couples most efficiently to a single mode fiber
  - Low loss due to small diameter of SMF core



- RESULT: to enable a low-cost, low-power and small form factors of silicon photonics the following are needed:
  - Wavelength between 1100nm and 1560nm
  - Single Mode Fiber transmission media



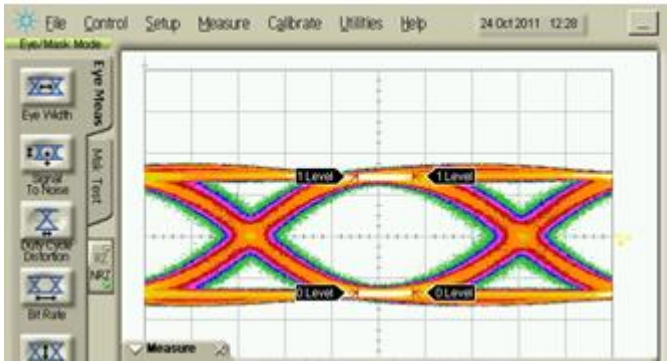
Example of a 4x28Gbps SP Optical Transceiver



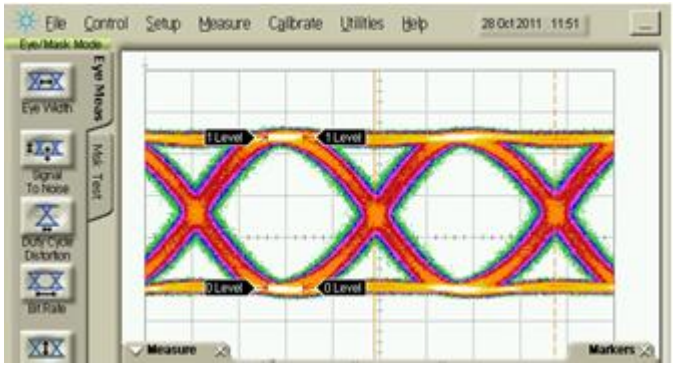
Enables Performance Needed at 26G and 28Gbps

Applications: 100GE Ethernet and EDR InfiniBand

26 Gbps Electrical Output Eye with PRBS 31

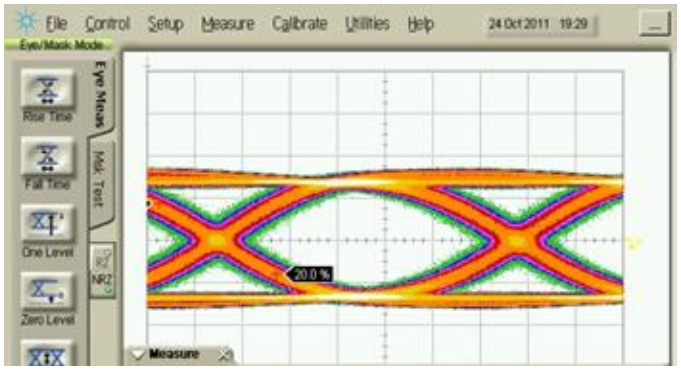


26 Gbps Optical Output Eye with PRBS 31

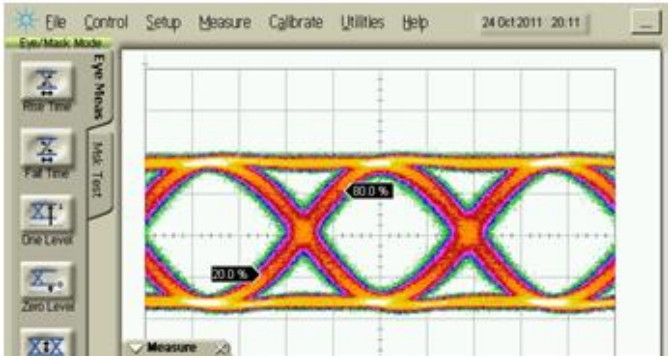


Applications: 28G VSR and 28G Fibre Channel

28 Gbps Electrical Output Eye with PRBS 31

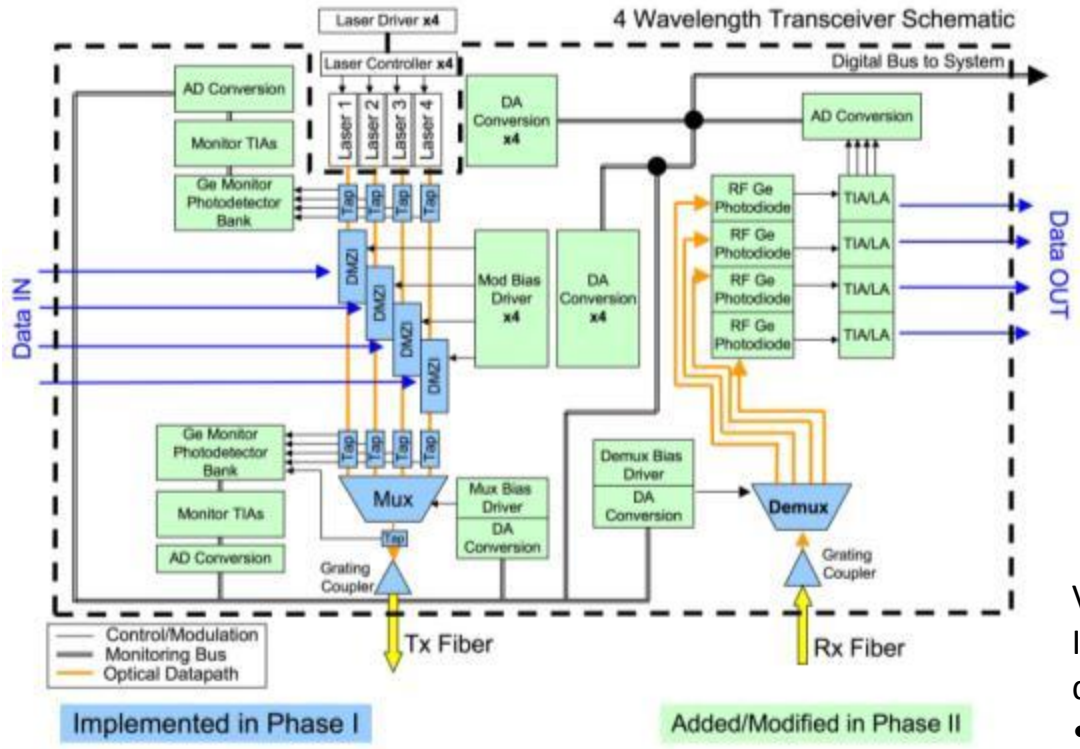


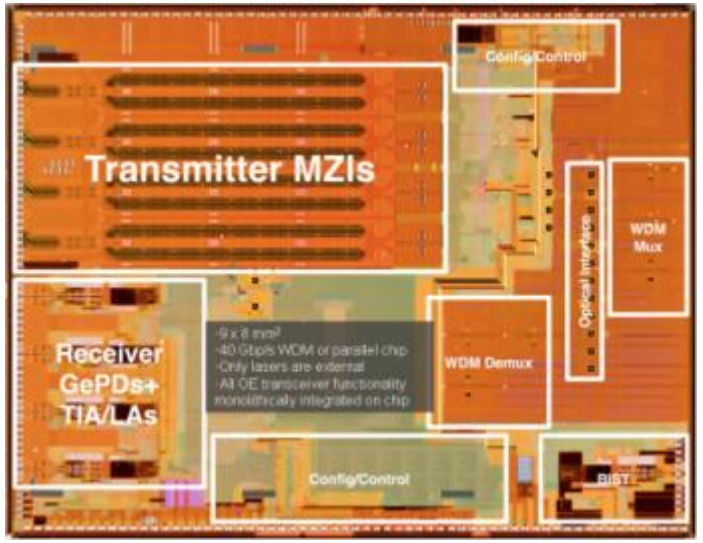
28 Gbps Optical Output Eye with PRBS 31



4 λ WDM SP Demonstrator For DARPA

Within DARPA-EPIC program developed and demonstrated a fully integrated WDM transceiver IC operating error free at 4x10 Gb/s bi-directional traffic (module-to-module).





Various WDM MUX/DEMUX structures (AWG, Interleaver, Ring) have been tested and demonstrated on system die:

- Channel spacing = 1.6 nm = 200 GHz
- Combined with control circuitry: phase tuners shift spectral response for:
  - Temperature compensation
  - Process compensation
  - Agile wavelength plan

100G Form-Factor Options

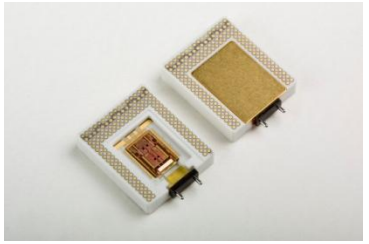
100G QSFP Module with Silicon Photonics

- Dual Retimed Interface
  - One CMOS Chip
- Power per 100G
  - Parallel: < 20 pJ/bit
  - WDM: < 30pJ/bit
- Cost for 100G Transceiver
  - ~25% lower than conventional
- Mechanically backward-compatible

100G Embedded Optics with Silicon Photonics

- Non-retimed interface
  - <2 inch electrical traces
- Power per 100G
  - Parallel: < 7.5 pJ/bit
  - WDM: < 17 pJ/bit
- Cost for 100G Transceiver
  - ~60% lower than conventional
- Optically compatible to modules

100G Silicon Photonics Integration with ASICs

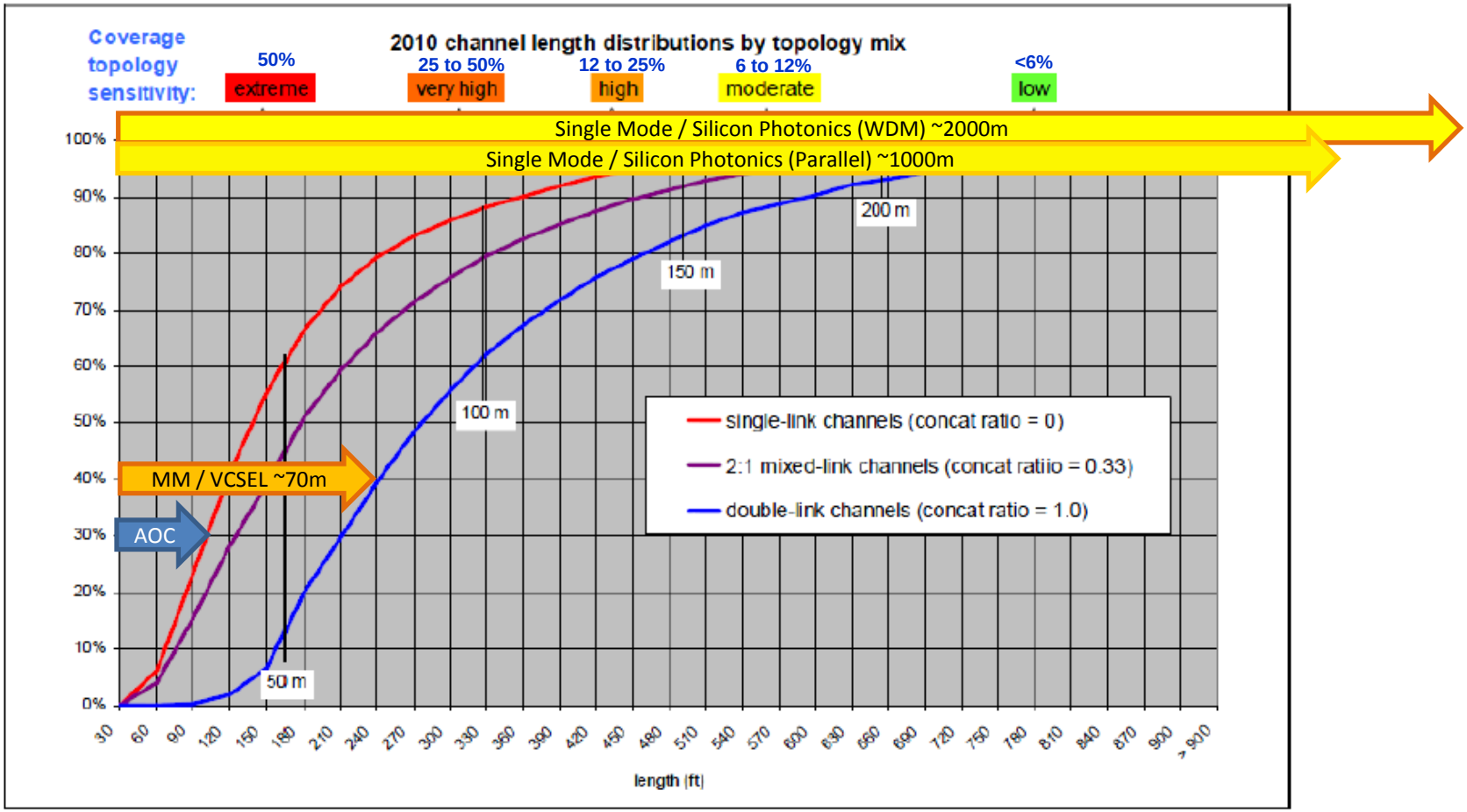


- No chip-to-chip I/O
  - No electrical traces
- Power per 100G
  - Parallel: < 3pJ/bit
  - WDM: < 10pJ/bit
- Cost for 100G Transceiver
  - ~90% lower than conventional
- Optically compatible to modules and embedded optics

All form-factors interoperable at 1310nm over single mode fiber and reaches from 0 to 10KM

Data Center Needs Low Cost, >100m Interconnect

Multi-Mode VCSEL Serves ~ 50% of Links, Single Mode Silicon Photonics Serves 100% of Links
Two Solutions Provide 100% Data Center Coverage with Low Cost Parallel Transceivers



Coverage topology sensitivity = (single-link coverage - double-link coverage) / single-link coverage

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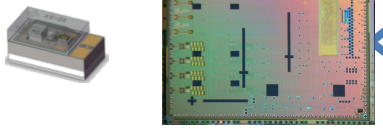
Proposed Solutions for All Reaches

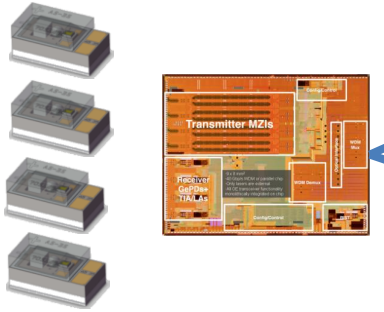
1310nm Parallel Solution

- 1 Laser
- 1 Chip
- Lowest cost at short reach
- Lowest power
- Ideal for short reach



1310 nm WDM Solution

- 4 Lasers
- 1 Chip
- Lowest cost at long reach
- Reuse fiber plant
- Ideal for long reach



0 to 30m: Active Optical Cable – Wavelength Agnostic

4x25G QSFP

Reach limited by deployment practicality of AOC, not by the optical transceiver

0 to 70m: Parallel Multi-Mode Fiber – 850nm to 1060nm

4x25G QSFP with MPO

0 to 1000m: Parallel Single Mode Fiber – 1310nm

4x25G QSFP with MPO

Longer Reach Possible

Embedded Optics with MPO

0 to 2000m: WDM Single Mode Fiber – 1310nm

4x25G QSFP with LC

Longer Reach Possible

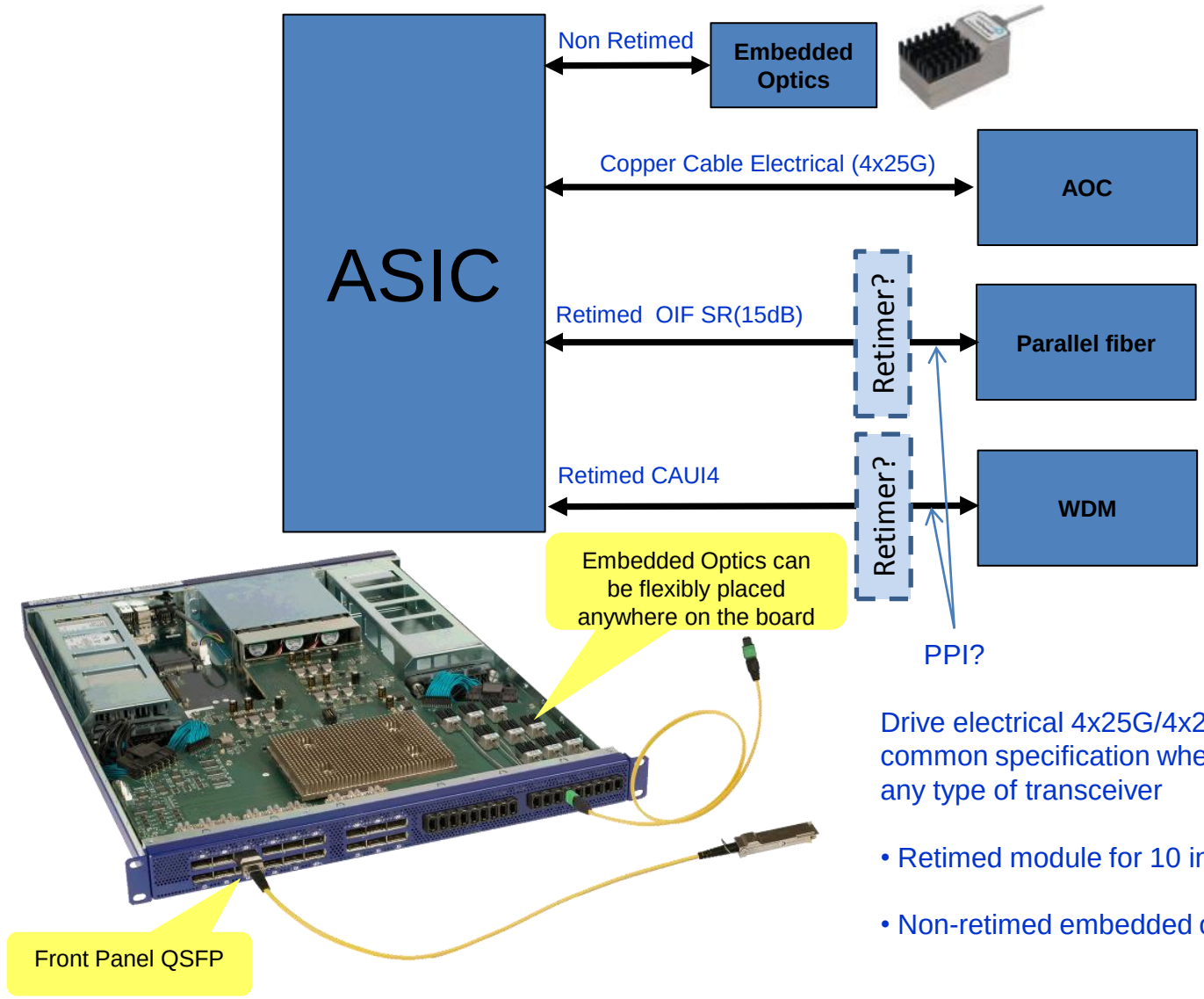
Embedded Optics with LC

0 to 10,000m: WDM Single Mode Fiber – 1310nm

4x25G QSFP with LC

Embedded Optics with LC

Electrical Interfaces

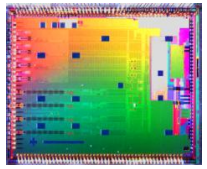


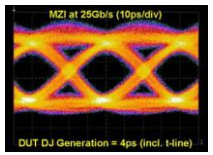
Drive electrical 4x25G/4x28G ASIC to Module interface to a common specification where a single ASIC can be serviced by any type of transceiver

- Retimed module for 10 inch electrical traces
- Non-retimed embedded optics for 4 inch or shorter traces

Summary

- Silicon Photonics provides technical feasibility for Next Gen 100G interconnects:
  - Low cost/power
  - Small form-factor
  - Meets possible reach objective of 300m for data center
  - Meets possible reach objective of 1-2km (10KM possible)
  - Demonstrated 25Gbps data rates and WDM
    - Interoperable with traditional EML, hybrid solutions at 1310nm
  - Parallel fiber solutions are viable and are in production at 4x10G.





- Multiple Form-Factors supported
  - Parallel and WDM QSFP modules or Embedded Optics
    - ***End users will have flexibility to select the most optimal solution for their application***
    - ***Cost / power consumption / ease of deployment trade-offs***
    - ***common electrical interface to ASICs and a common mechanical form-factor (QSFP)***