CONNECTING AT THE SPEED OF LIGHT

ECOC 2017 - Market Focus
State of the Optical Transport Market

SEPTEMBER 19, 2017

ACACIA® COMMUNICATIONS, INC.

Demand Surging for Bandwidth and Network Capacity

Traffic demand is growing for traditional carriers and Web 2.0 content providers

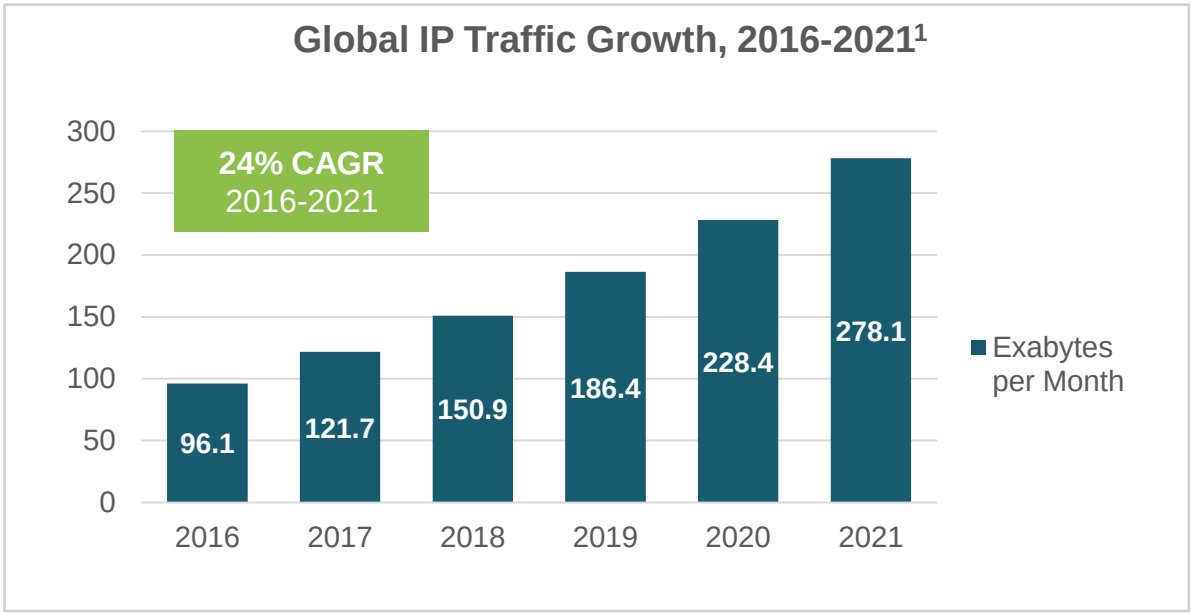
Data and video
Video will represent 82% of all IP traffic in 2021[1]

Mobile and 4GLTE/5G
Wireless and mobile device traffic more than 63% of total IP traffic by 2021[1]

Cloud Services
By 2020, 92% of all data center traffic will come from the cloud[2]

Changing Traffic Patterns
Smartphone traffic will exceed PC traffic by 2021[1]

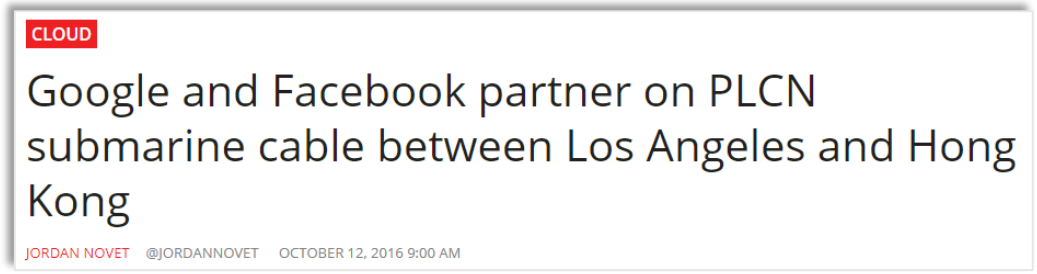
"Internet of Things"
The number of devices connected to IP networks will be 3x as high as the global population in 2021[1]



Global IP traffic expected to increase ~3x from 2016 to 2021

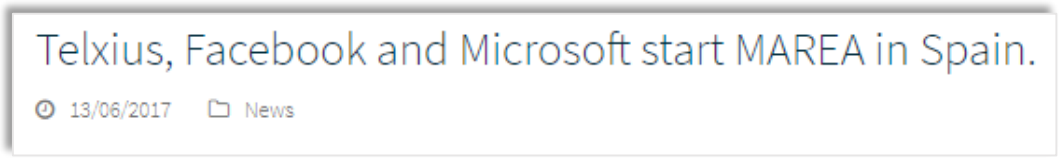
1. Source: Cisco VNI Global IP Traffic Forecast 2016-2021 2. Source: Cisco Global Cloud Index 2016-2020, June 2017

Expanding Global Network Capacity

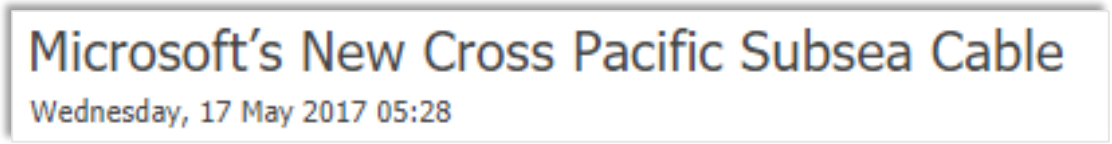

CLOUD

Google and Facebook partner on PLCN submarine cable between Los Angeles and Hong Kong

JORDAN NOVET @JORDANNOVET OCTOBER 12, 2016 9:00 AM


Telxius, Facebook and Microsoft start MAREA in Spain.

13/06/2017 News


Microsoft's New Cross Pacific Subsea Cable

Wednesday, 17 May 2017 05:28


Amazon's Cloud Arm Makes Its First Big Submarine Cable Investment

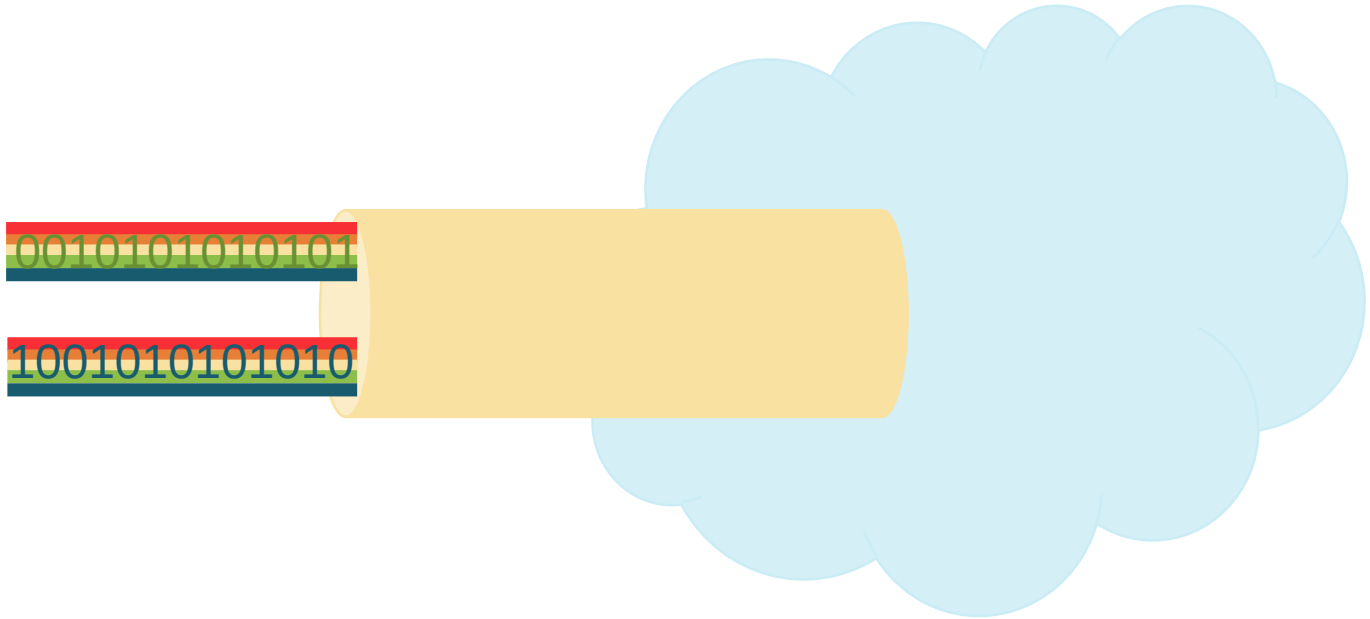
Transpacific Hawaiki cable expected to improve AWS latency for users in Australia and New Zealand

Yevgeniy Sverdlik | May 13, 2016

Despite dramatic improvements in spectral efficiency enabled by coherent technology, network operators are making investments to deploy more fiber in costly submarine networks

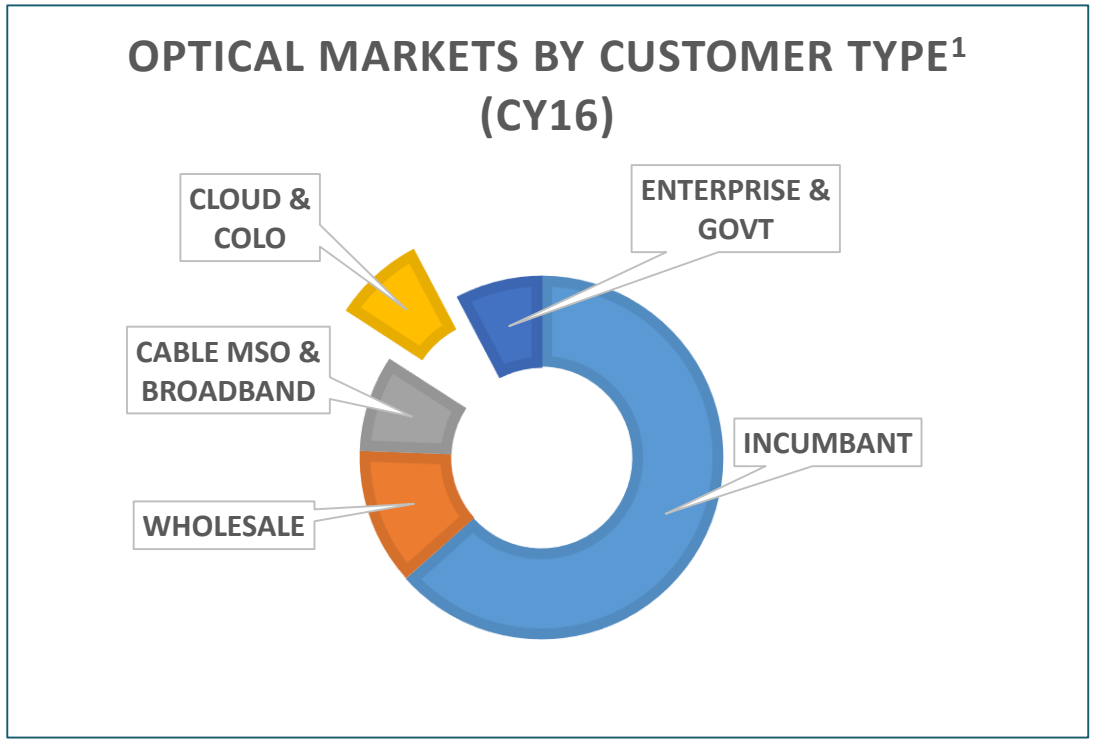
Doubling Fiber Capacity (C+L)

- Increasing interest in C+L band networks
  - Fiber exhaust in both submarine and terrestrial networks
  - Cost to deploy new fiber (if possible) is often high compared to the cost of to expand to L-band
- Leverage existing component technology with design modifications



Changing Market Dynamics

- Cloud and Colo
  - Currently ~10% of the optical networking market
  - Shorter lifecycles than carrier networks
- Innovation cycles are shortened
  - Network disaggregation allows greater flexibility to adopt new technology
  - Network build-outs driven by new switch technology that follows CMOS innovation cycle
    - Optical networks must scale with Moore's Law



How do optical interfaces keep pace?

1Source: Cignal AI, April 2017

Why so much focus on 10% of the market?

- Cloud & Colo
  - Fastest growing market segment
  - Volume consolidated among fewer companies
    - 5 companies dominate the capex spend
  - Early adopters of new technology
  - Adoption of datacenter architectures and commercial models by traditional carriers and MSO's

Google

amazon

Microsoft

Open ROADM

OPEN NETWORKING FOUNDATION

CORD™
Central Office Re-architected as a Datacenter

ACACIA COMMUNICATIONS, INC.

Disaggregation and Integration Trends

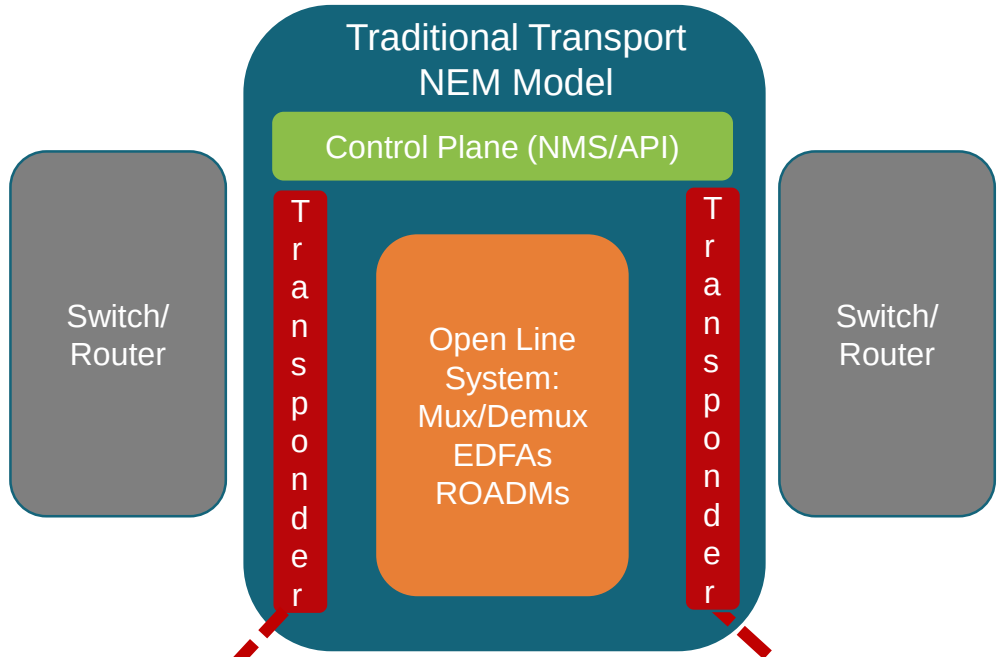
Network elements are being disaggregated

Allow key elements to be specified and sourced individually

- **Control Plane**
- **Open Line System**
- **Transponder**

Transponders are being integrated

Component integration within transponders enables smaller footprints with lower power and cost



Linecard / Discrete

Integrated Module

Discrete

Integrated Component

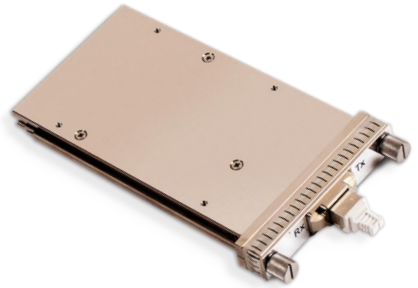
"Disaggregation at the data center level. Integration on the component level."

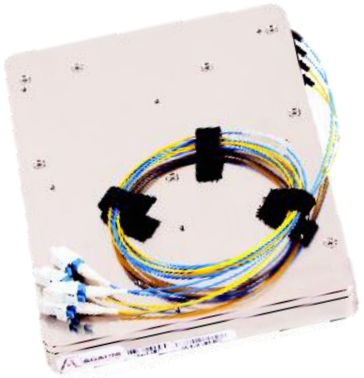
- Brad Booth, Microsoft [1]

[1] Source: NGON, Knect365, May 2017

Fast Ramps and Shorter Life-Cycles

- Early adoption of new technology
  - Increased focus on first mover status
- Time to market is critical
  - ROI is difficult if you miss the front end of the life-cycle
  - Execution early in the life-cycle has increasing impact on share
- Modular designs with proven host interfaces can accelerate product availability and ramp
- Increasing focus on SDK to reduce development time





Scaling Optical Interfaces

Optical Integration

- Necessary to scale with switch port density
- Reduces optical packaging cost
- Enables greater automation and faster product ramps

Electronic Processing

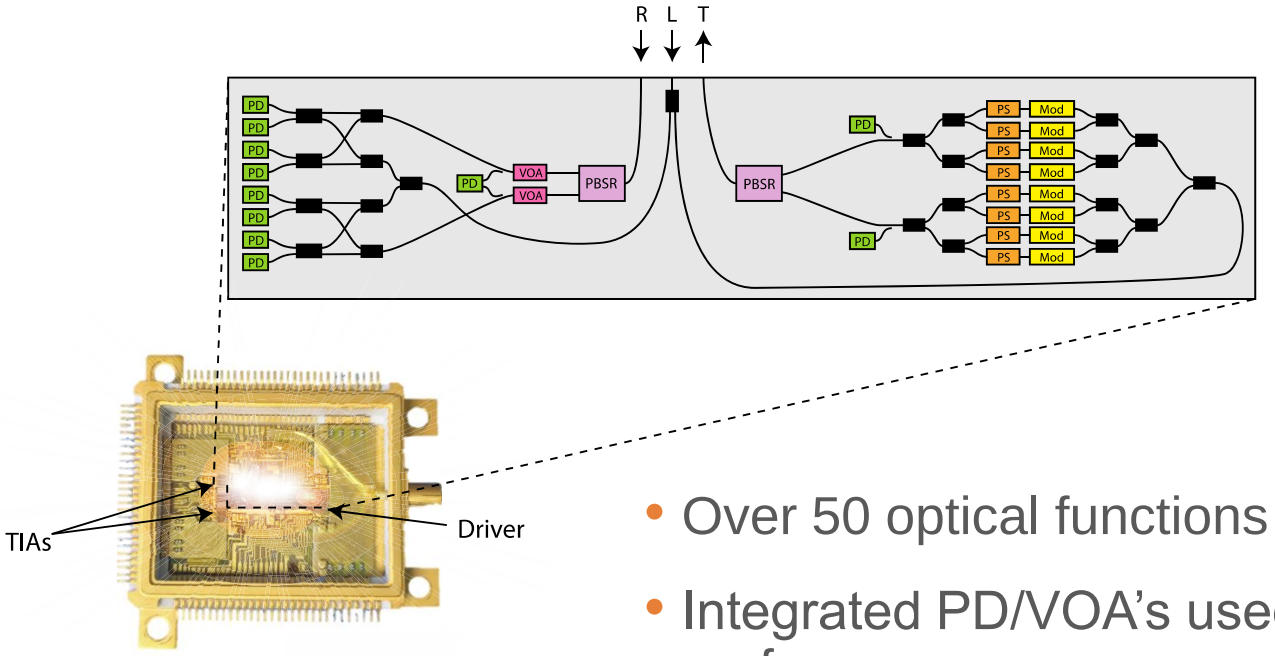
- Necessary at higher data rates to overcome bandwidth limitations and fiber impairments
- Scales at CMOS pace
- Can reduce cost/complexity of optics

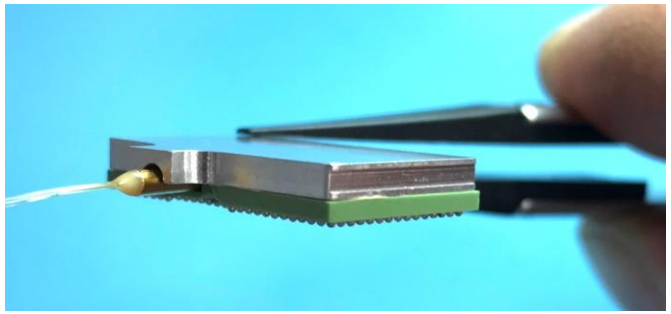
Changing Architectures

- Simplified transport networks
  - Disaggregation
- Partition components differently
  - On board optics or pluggable?
  - Integrated laser or separate?

Leverage all three to maintain scale

Photonic Integration in Silicon



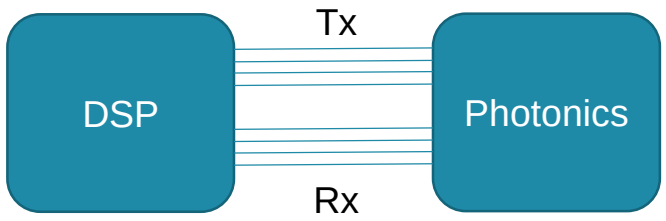


BGA Packaging

- Over 50 optical functions per carrier
- Integrated PD/VOA's used to optimize performance
  - Power balance between I/Q and X/Y

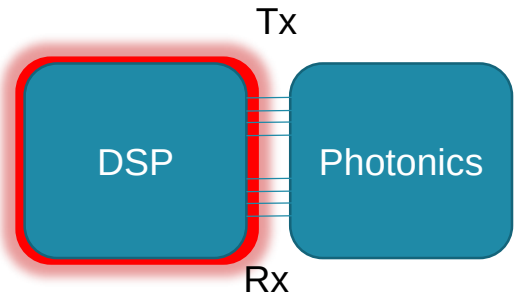
Silicon Photonic PIC used in all applications from DCI to Submarine

Challenges at High Data Rates



At higher data rates, the interface between the DSP and photonics can dominate performance

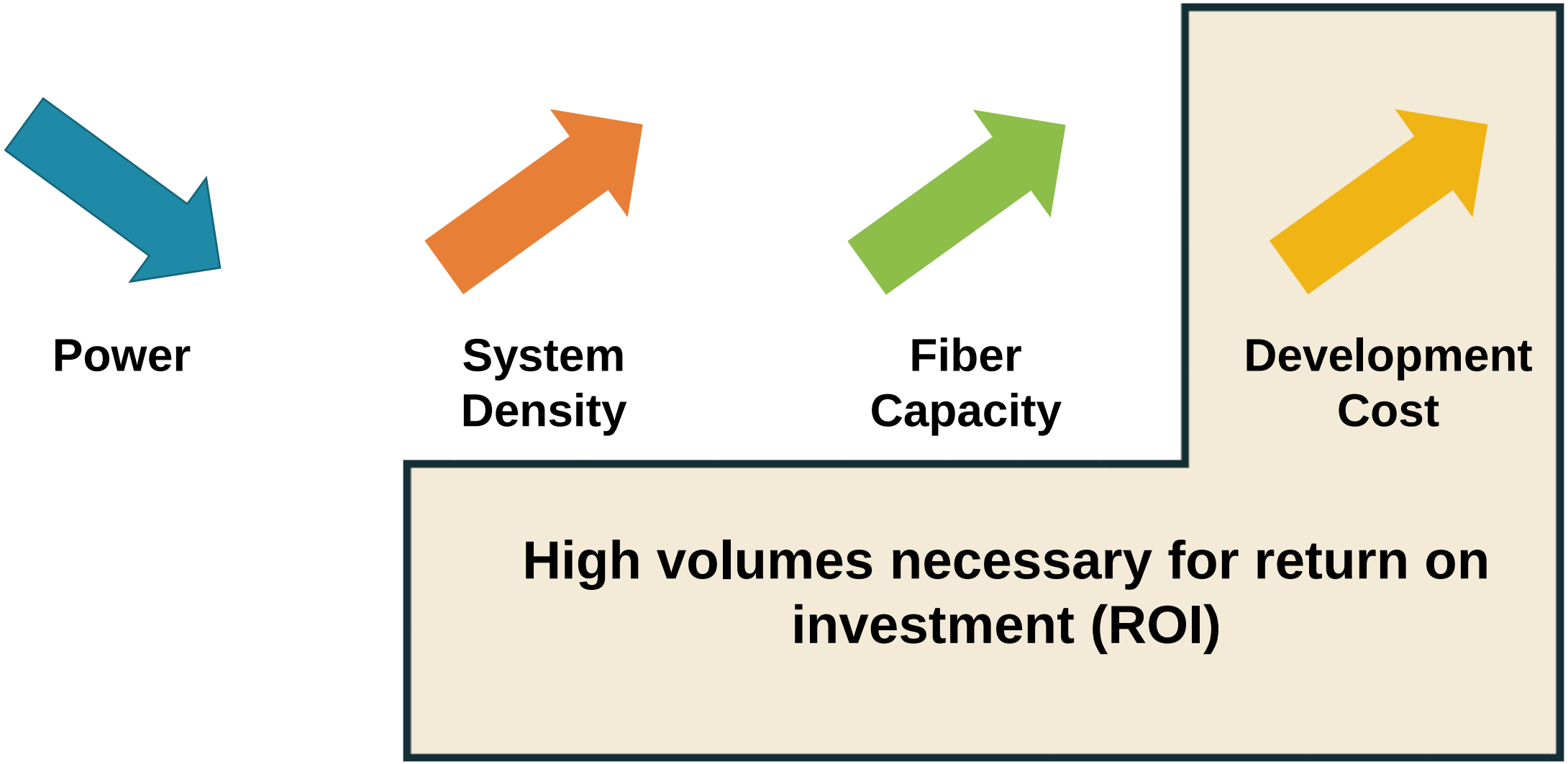
Signal integrity is critical when increasing both modulation order and baud rate



Temperature insensitive silicon photonics can be placed close to DSP

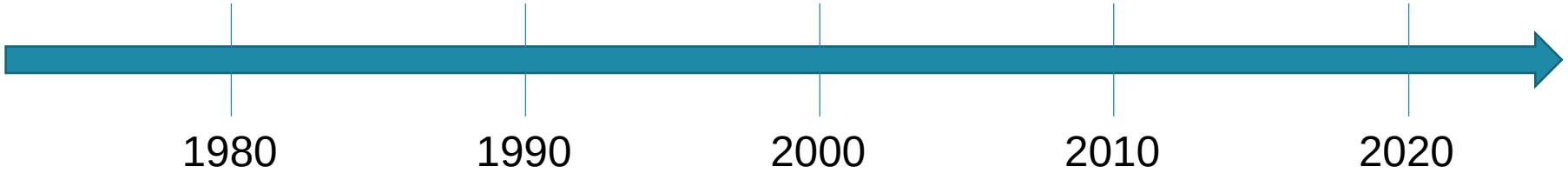
DSP interface can be customized for photonics to achieve best power and performance

Leveraging New CMOS Process Nodes



Coherent Migration to Shorter Interconnects

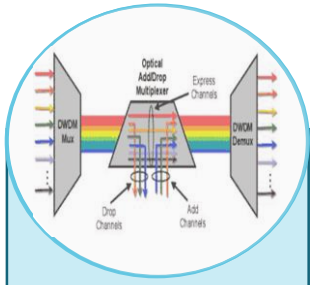
New technologies that are introduced in long haul are later adopted for shorter reaches as data rates increase



Fiber Optics

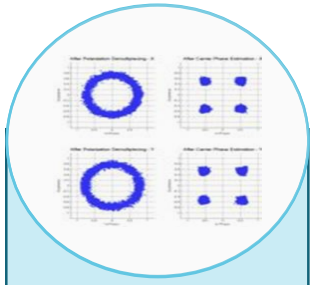
<10m today

WDM



<2km today

Coherent



OIF project will define ~80km @ 400Gbps

Coherent Interoperability Standardization

OIF	IEEE	CableLabs	ITU
• Data Center Interconnect	• Beyond 10km Study Group	• Access Networks	• Carrier Metro

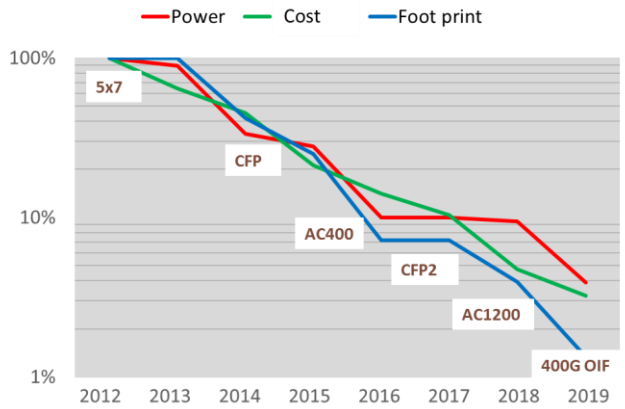
Similar link requirements (<120km)

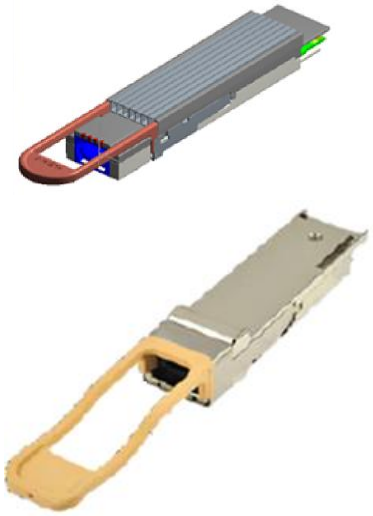
Common component technology

Pluggable Coherent 400G

- Targeting “client” form factors
- Coherent power/bit has reduced at ~40%/year
  - Smaller CMOS technology nodes
  - Increased bits/symbol
  - Optimization for shorter reach interfaces
    - LH → Metro → DCI
- <15W module power target based on 7nm process
  - OSFP, QSFP-DD, or COBO form factors
  - Single λ application may be lower
    - Fixed Laser
    - Reduce CD compensation

Evolution in Power, Cost and Density per 100G





Conclusions

- Demand for optical bandwidth continues to grow
  - Driven by end user demand for mobile, video, and cloud services
  - Sustained by healthy business models at end customers
- Cloud and content provider demand growing faster than the rest of the market
  - Driving network disaggregation and shorter life-cycles
  - Traditional service providers adapting to new models
- Need to leverage both optical and electrical integration to maintain pace
- Coherent technology expanding toward shorter reach applications and standardization