IEEE 802.3
Call For Interest
100 Gb/s Per Lane Optical PHYs for 2 km and 10 km for 100 GbE and 400 GbE

Consensus Presentation

Objective for this Meeting

- To *measure the interest* in starting a study group to address:
  - 100 Gb/s Per Lane Optical PHYs for 2 km and 10 km for 100 GbE and 400 GbE
- We don't need to
  - Fully explore the problem
  - Debate strengths and weaknesses of solutions
  - Choose any one solution
  - Create PAR or five criteria
  - Create a standard or specification
- Anyone in the room may speak / vote
- RESPECT… give it, get it

Agenda

- Market Drivers
- Technical Feasibility
- Why Now?
- Q&A Panel
- Straw Polls

Presenters and Panelists

- David Lewis, Lumentum
- Mark Nowell, Cisco
- Jeffery Maki, Juniper
- Kohichi Tamura, Oclaro

Overview: Motivation

Significant industry interest and progress has been made towards extending the existing IEEE 802.3 Optical PHYs using 100 Gb/s per lane optical technology to longer reaches.

This proposed study group would look to develop 2 km and 10 km SMF PHYs for both 100 GbE and 400 GbE

The motivation is to leverage technology to address the ongoing cost pressures on optical interconnects for a set of known and identified markets including:

- Web-scale data centers
- Service Provider
- Enterprise data centers

Lower cost solutions occur due to reduced lane/component count or through enabling higher density solutions.

Today's Point-to-Point SMF Ethernet

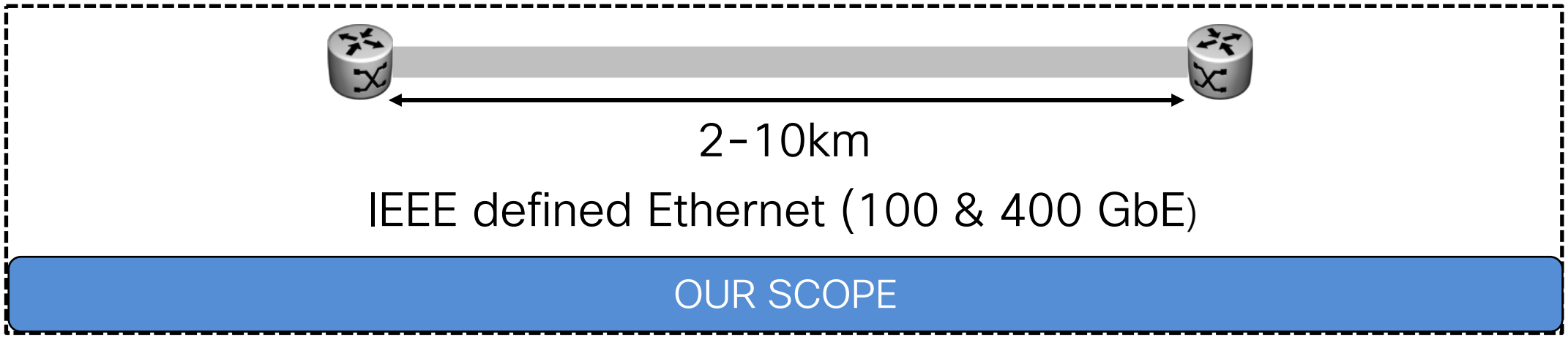
	Lanes	500 m	2 km	10 km	20 km	40 km	Up to 80km
1000BASE-	1		LX	LX10 / LH		EX	ZX
10GBASE-	1			LR		ER	ZR
25GBASE-	1			LR		ER	
40GBASE-	4	PSM4		LR4		ER4	
	1		FR				
50GBASE-	1		FR	LR		ER	
100GBASE-	10		10X10				
	4	PSM4	CWDM4 / CLR4	LR4 / 4WDM-10	4WDM-20	ER4 / 4WDM-40	
	1	DR					"ZR"
200GBASE-	4		FR4	LR4		ER4	
400GBASE-	8		FR8	LR8		ER8	
	4	DR4					
	1						"ZR"

Black Text IEEE Standard
Red Text In Standardization
Blue Text Non-IEEE standard but complies to IEEE electrical interfaces

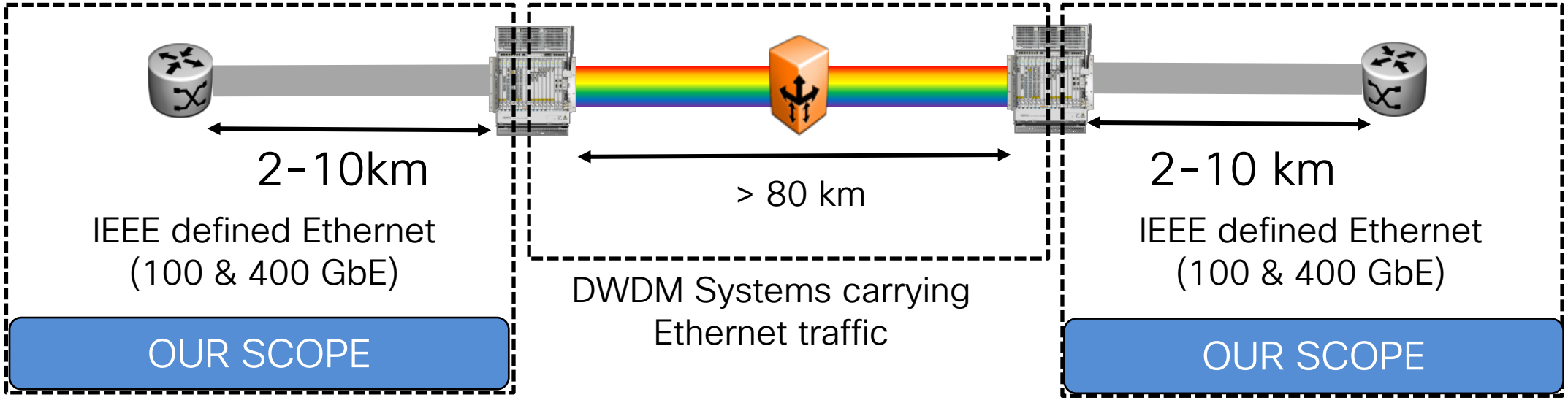
Focus of this CFI

What Are We Talking About?

Scenario #1



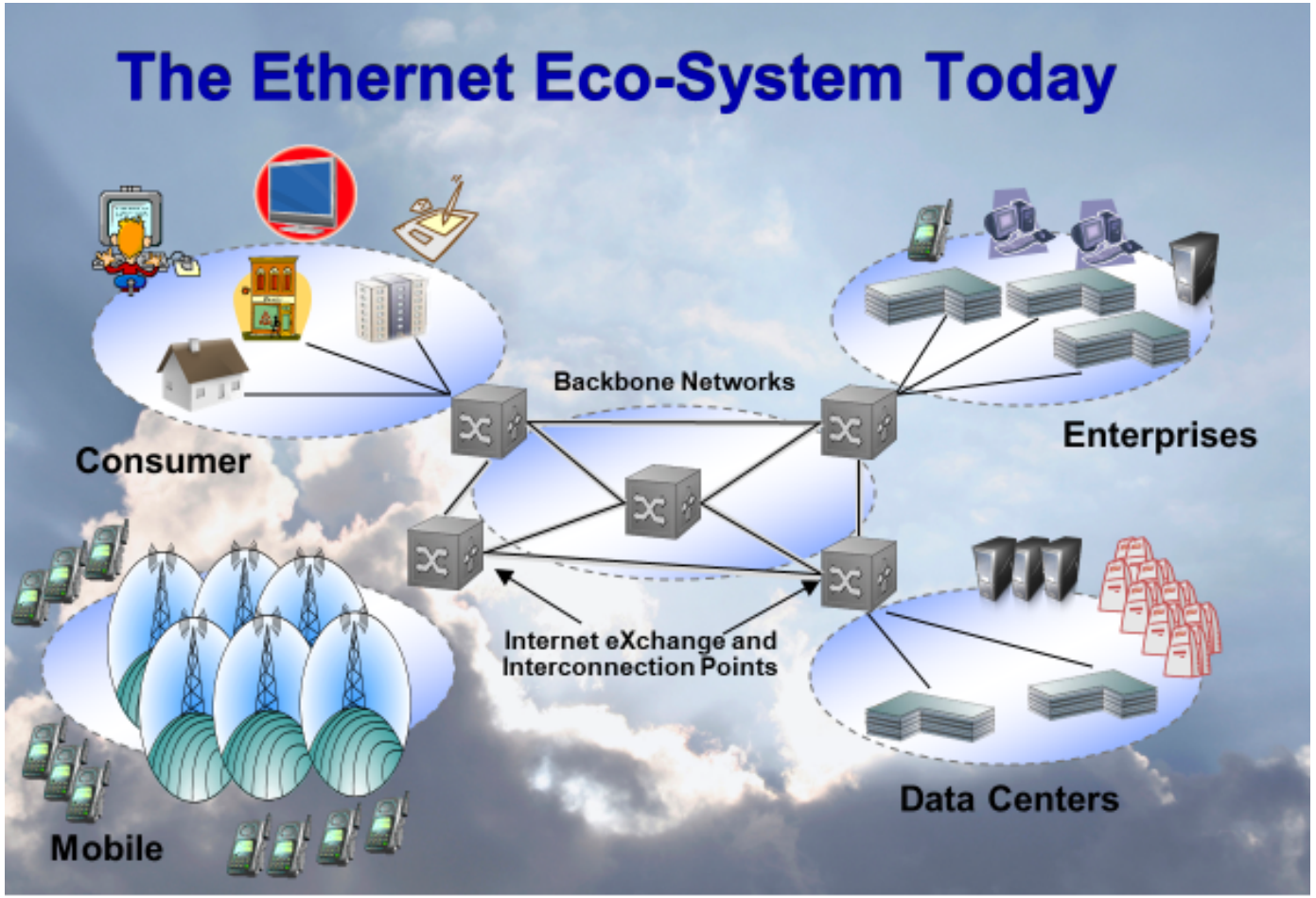
Scenario #2



Market Drivers:

longer reach (up to 10 km) 100 Gb/s per lane optical technology

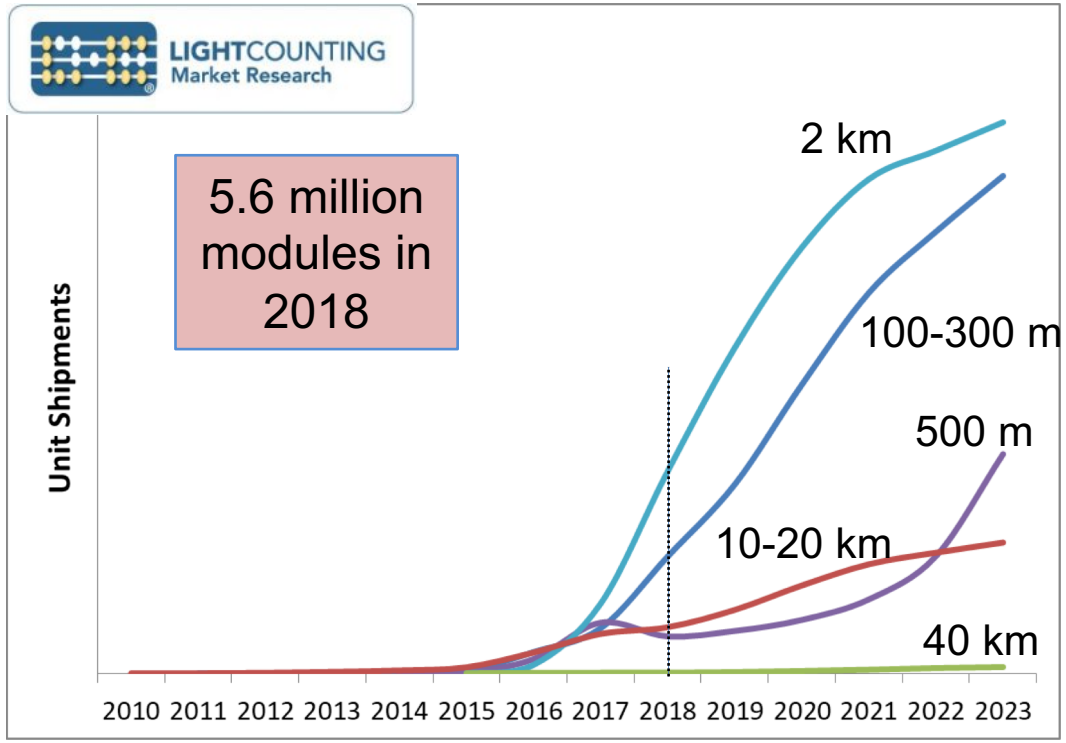
2 km & 10 km optics dominate throughout SMF ecosystem



- Equipment interconnect within buildings
  - Web-scale Data Center
  - Service Provider Data Center and Point-of-presence
  - Enterprise Data Center
- Inter-building interconnects in campus environment (up to 10 km)
- Forecast SMF market size (100 GbE and 400 GbE) of 12 Million modules per year in 2023
- This CFI's goal is to add next generation optical technology into that ecosystem

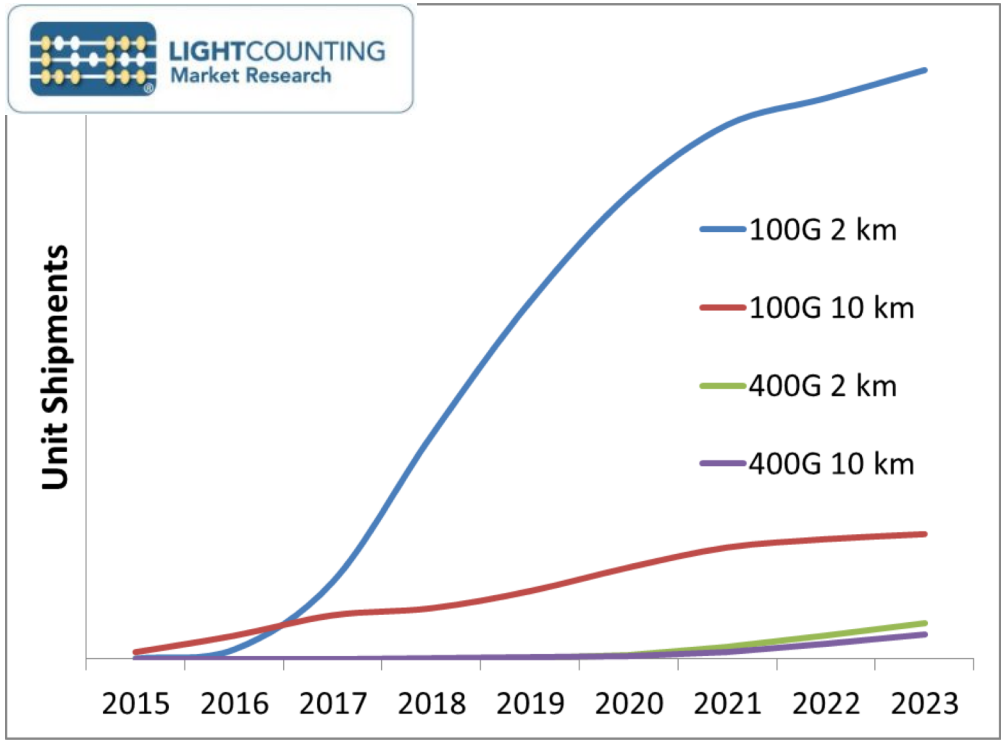
Market Forecast slides

100 GbE Modules by reach



Courtesy Dale Murray, Light Counting

100 GbE & 400 GbE 2 & 10 km SMF Modules



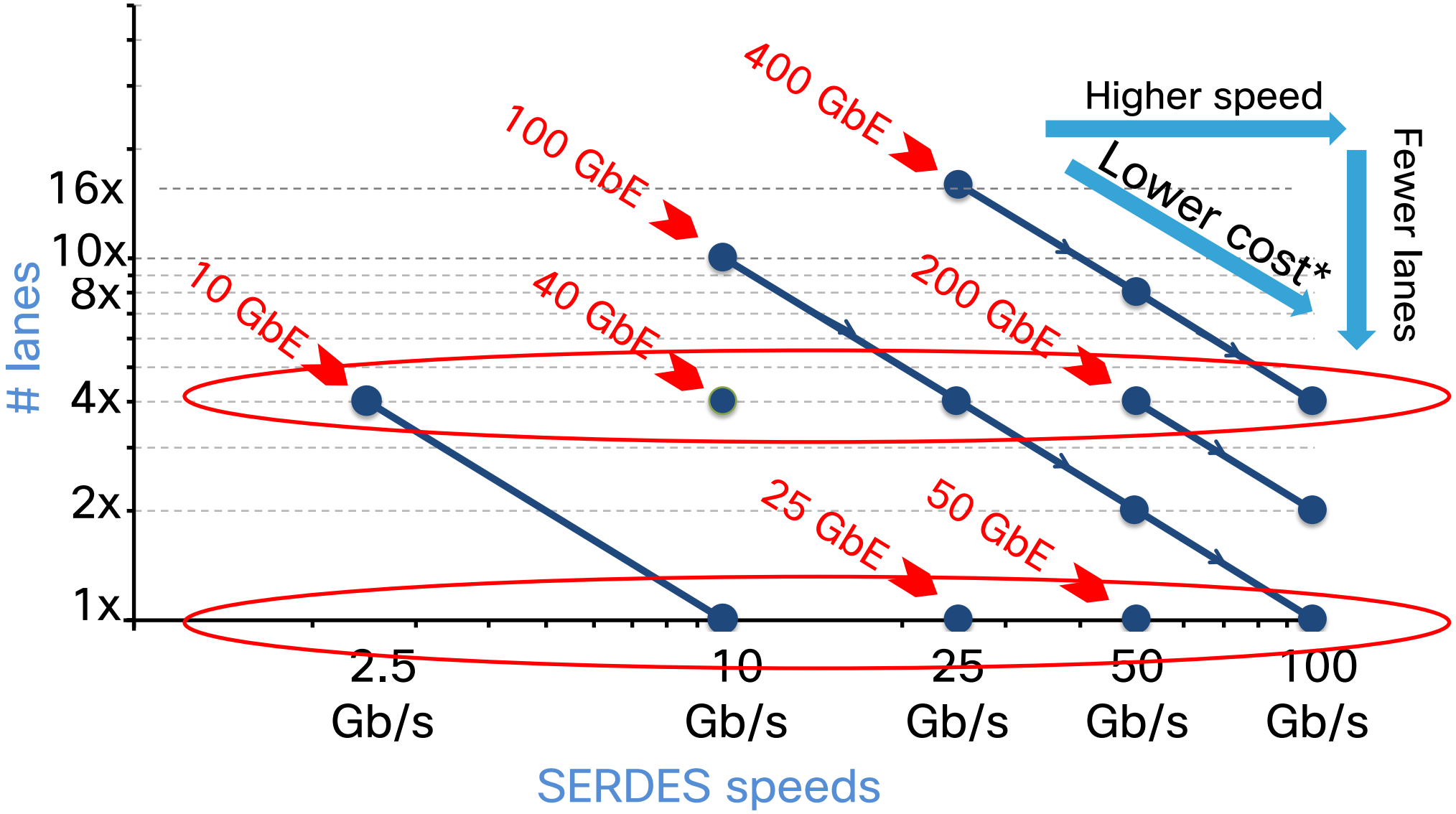
Courtesy Dale Murray, Light Counting

- 100 GbE optics market still in strong growth phase
- 400 GbE at start of its ramp but expected to be fast

} Both market conditions benefit from cost reductions

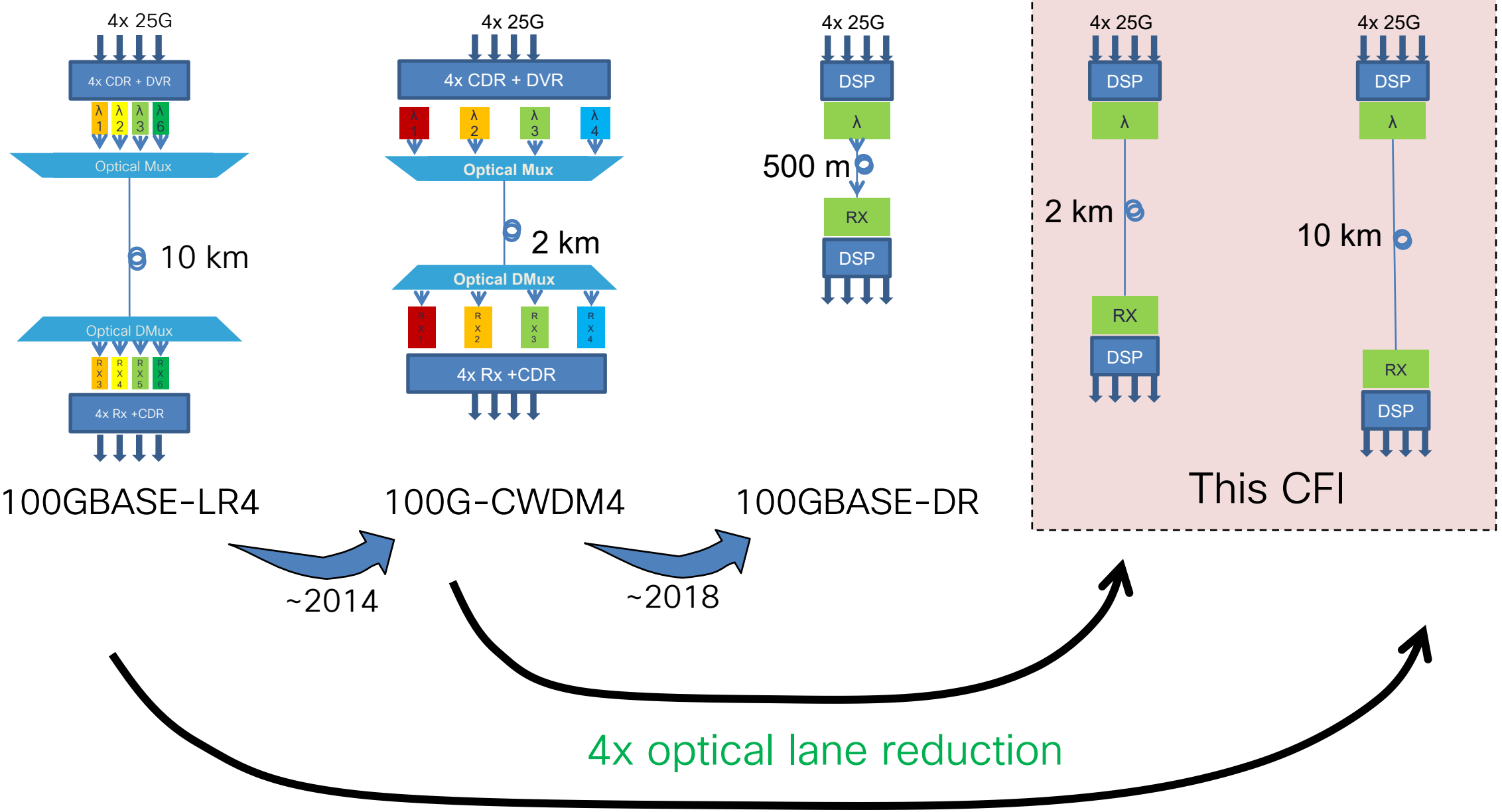
* At the right time

Ethernet's consistent trend – Narrower/Faster

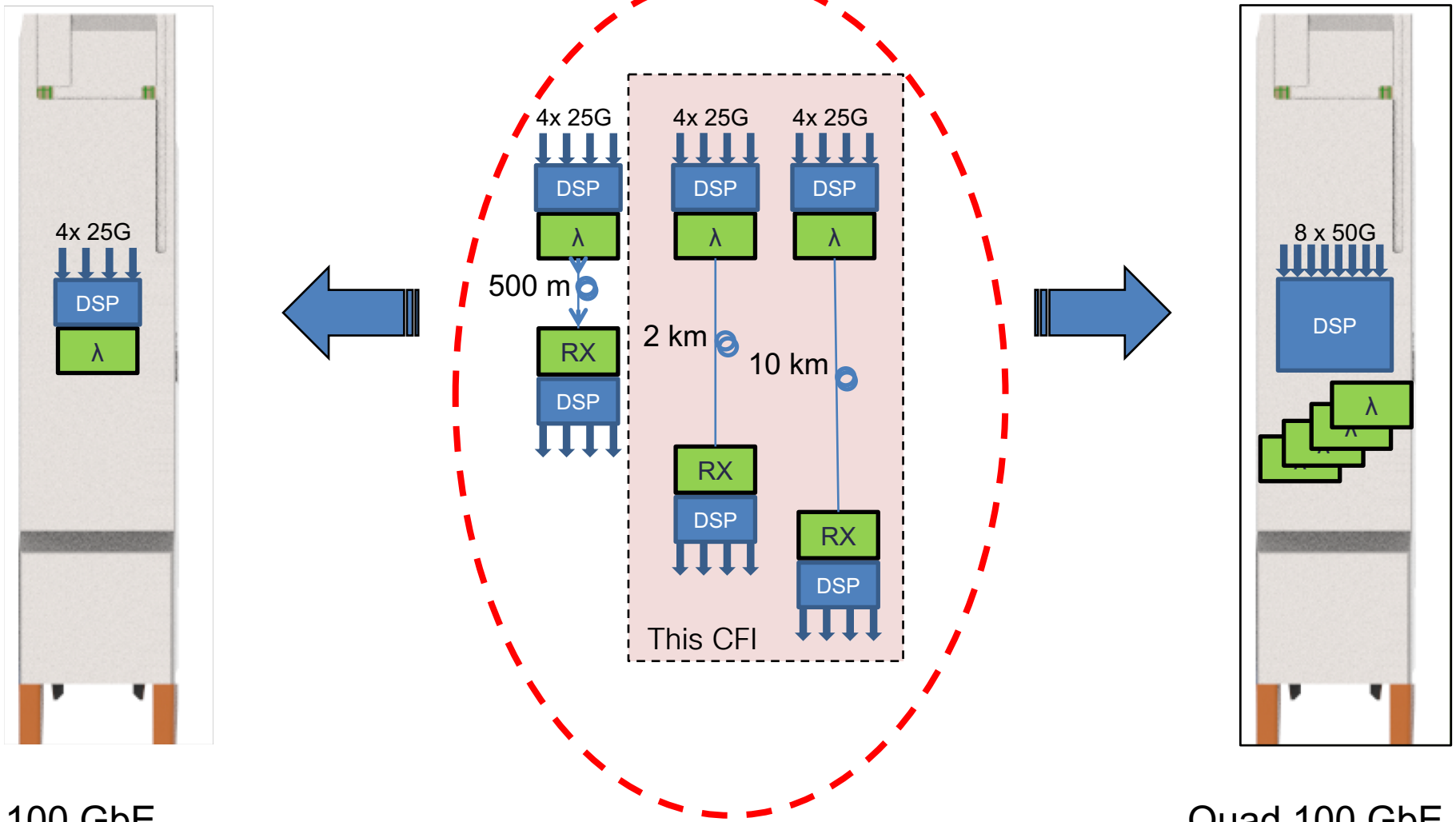


1x and 4x bus widths dominate volume adoption

Reduced complexity leads to lower cost – e.g. 100 GbE



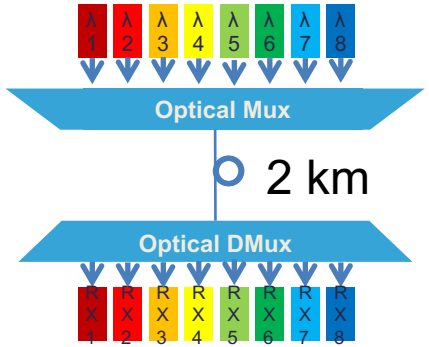
Reduced component count enables denser solutions e.g. 100 GbE



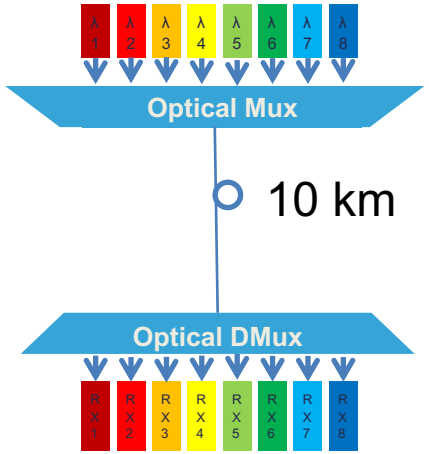
100 GbE
in QSFP28

Quad 100 GbE
in QSFP-DD

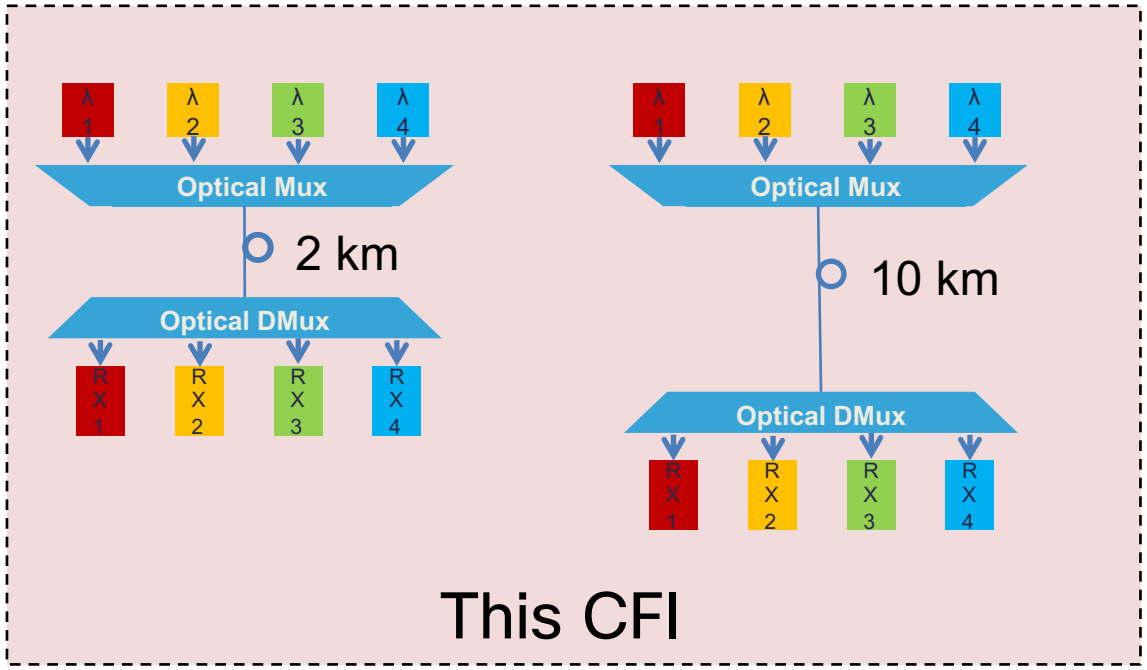
400 GbE Duplex SMF Optics – potential complexity reduction



400GBASE-FR8



400GBASE-LR8



This CFI

2x optical lane reduction

Moving from 8 lanes to 4 lanes further enables relaxation on wavelength grid to be considered

Market Drivers: Summary

Ethernet has a strong legacy of market success by leveraging newer technology to cost reduce solutions

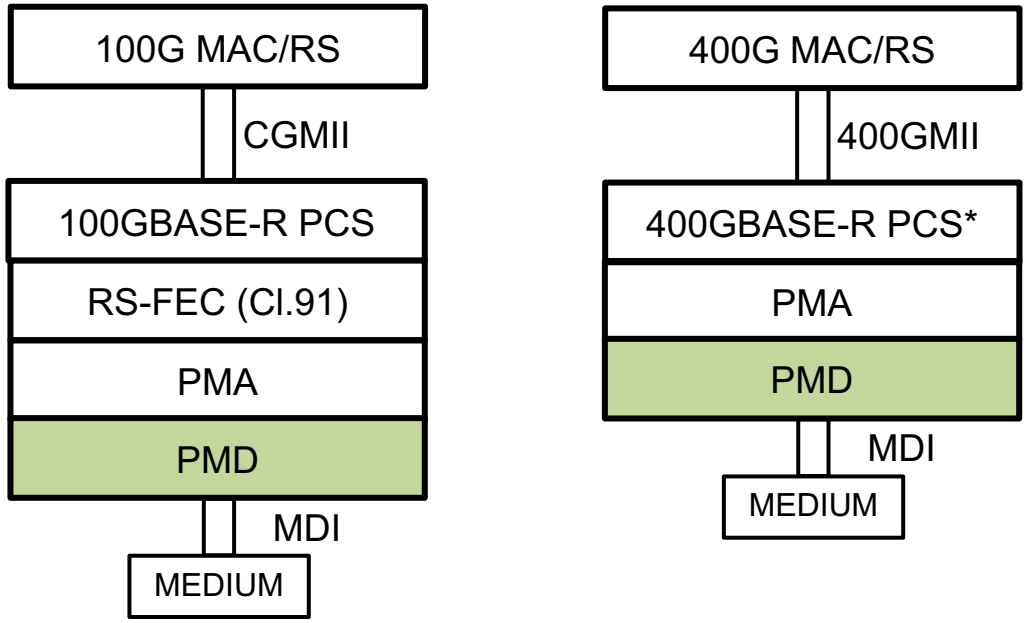
100 GbE SM optics market forecast growth is very strong – lower cost or higher density solutions under demand

400 GbE market adoption about to start in earnest. Significant technology maturity in last few years has led to lower cost solutions than the current Ethernet standardized interfaces being feasible and in demand.

Web-scale, Service Provider and Enterprise Data Centers all identified as potential adopters

Technical Feasibility

IEEE 802.3 Architectural view



- No architectural changes based on anticipated work and scope of project if approved
- New PMDs to be defined
- No compatibility issues with existing host designs

new

* FEC is part of the 400G PCS sublayer

Industry Progress on 100 Gb/s per lane technology

- 400GBASE-DR4 Completed Dec 2017
- 100GBASE-DR Submitted to RevCom – Oct 2018
- Multiple public demonstrations of 100 Gb/s per lane technology
  - 100 GbE – 500m, 2km, 10km
  - 400 GbE – 500m, 2km
- Ethernet Alliance awards “Holy Cup” to 5 companies who were the first to do a public demonstration of 2km SMF 100 Gb/s per lambda in QSFP28 @ ECOC 2018
  - https://twitter.com/EthernetAllianc/status/1044678676799905793

Extending the reach beyond 100GBASE-DR & 400BASE-DR4

Link budgets that would extend beyond the current 500m specifications need to deal with:

- Extra fiber loss
- Extra wavelength mux/demux loss (400 GbE 2 km & 10 km only)
- Extra dispersion penalty

Options to address include:

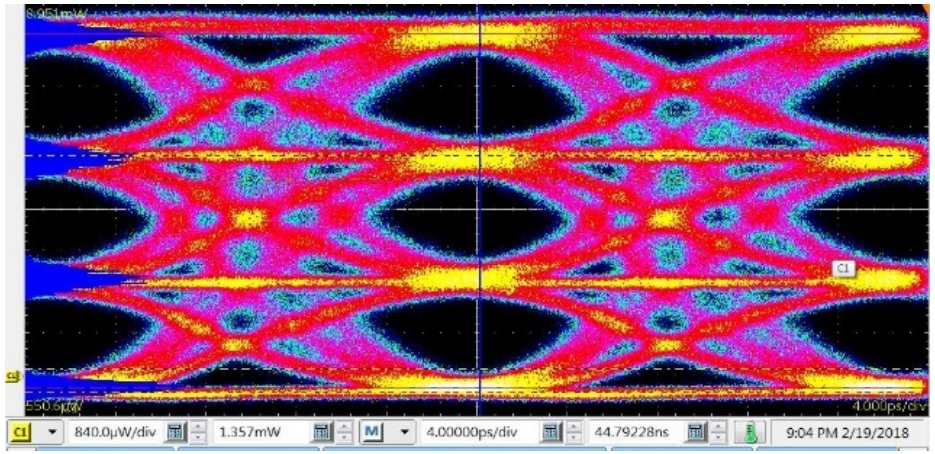
- Increased launch power
- Improved receiver sensitivity (including PIN or APD)
- Wavelength grid – Coarse WDM (20nm) vs. LAN WDM (4nm)

Technical feasibility – Transmitters

Various transmitters capable of 100 Gb/s PAM4 have been demonstrated or presented

Optical eye

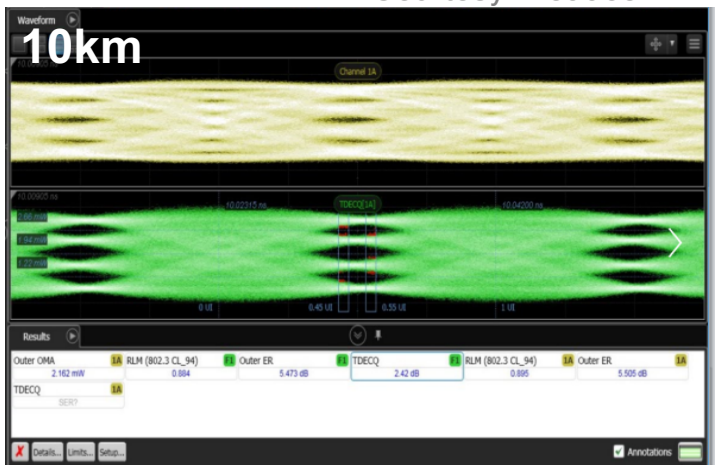
TDECQ = 1.26 dB (2 km @ 5.2 ps/nm)



53 GBaud PAM4 (106 Gb/s)

IEEE Pattern PRBS13Q See – mazzini_3cd_01a_0518

Courtesy Broadcom



10 km Penalty = 0.21dB

19 ps/nm

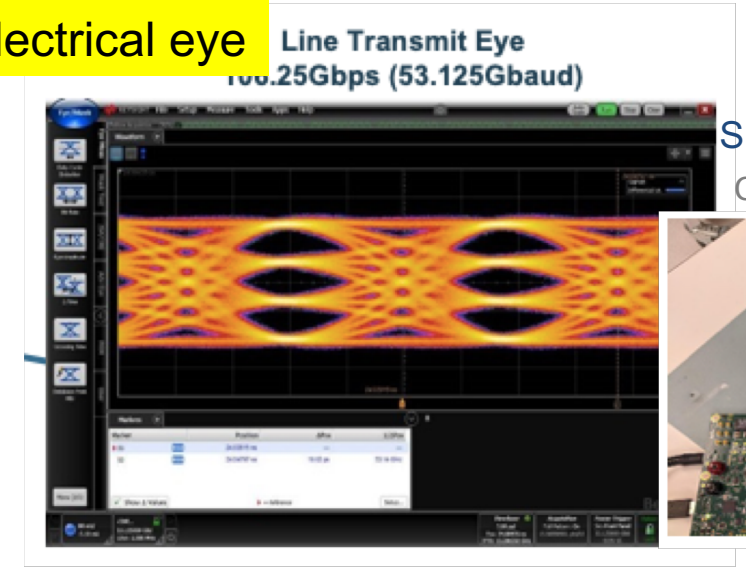
ER=6.9dB, TDECQ= 2.78dB

21 km Penalty = 1.54 dB

31 ps/nm

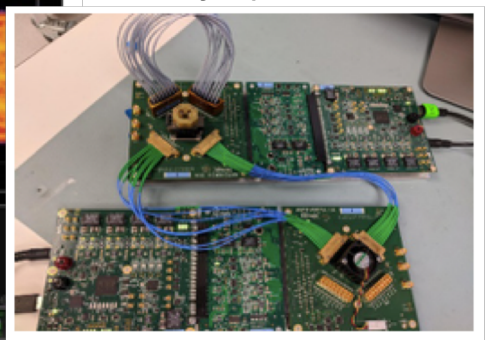
ER=7.4dB, TDECQ= 4.24dB

Electrical eye



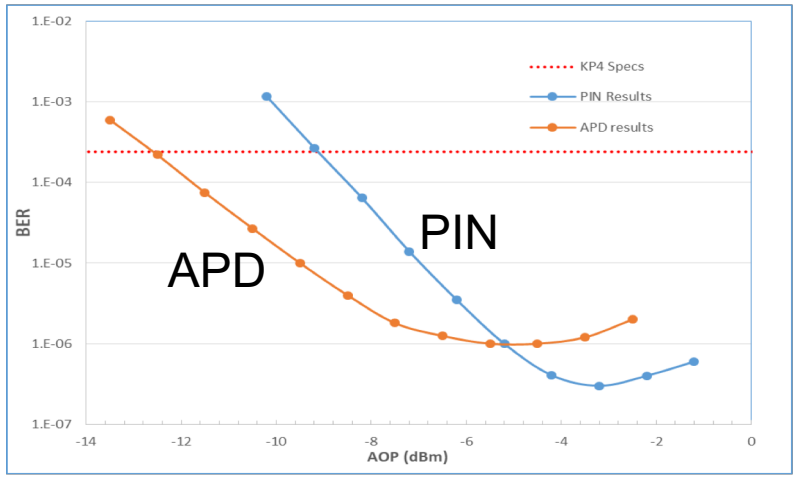
Electrical Loopback
SNR >24dB, BER < 1e-12

Courtesy Inphi



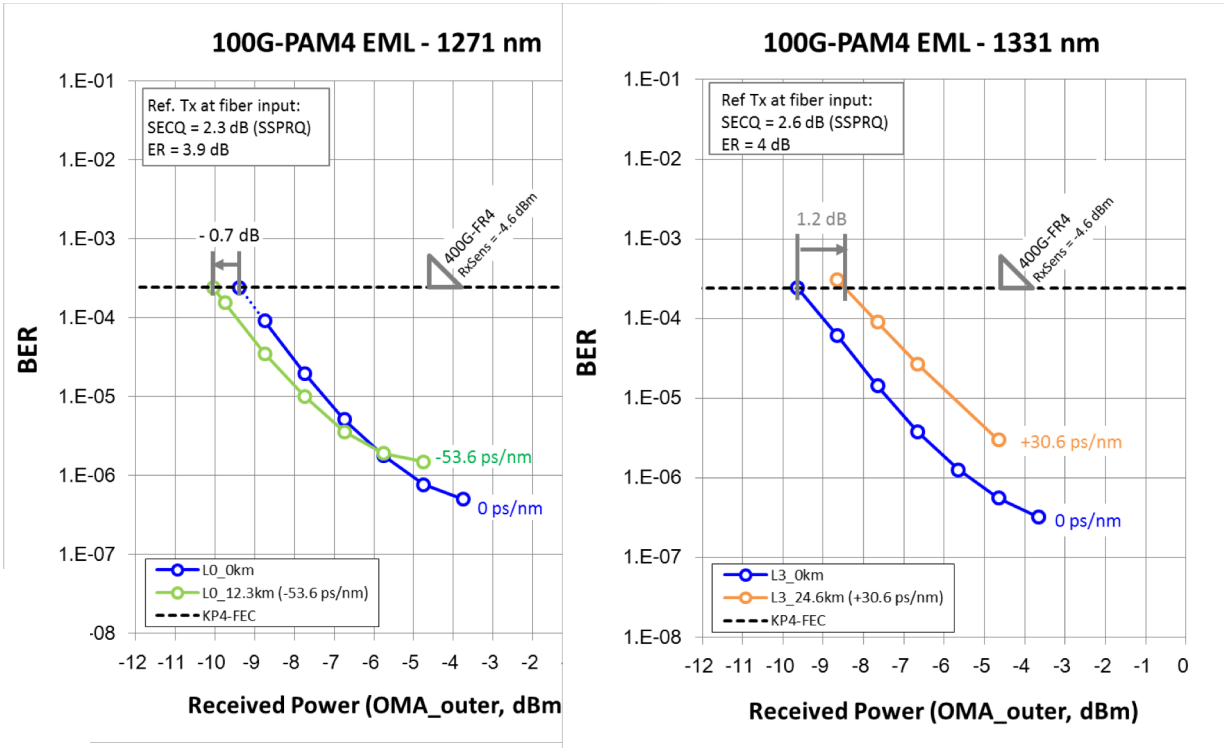
Transmitter: AWG + linear amplifier, Vpp = 1.2V
No emphasis applied at the AWG
SSPRQ pattern at 53 GBd
56GBd EML CoC, **λ = 1330nm**

Technical feasibility – Receivers

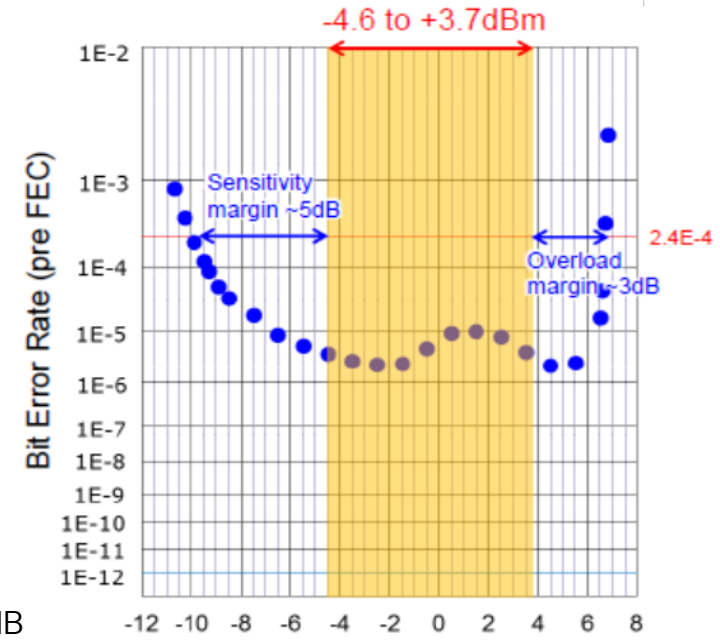


- 53.125GBaud, PAM4 PRBS31Q EML CoC (1304nm), ER ~ 5.1dB, SECQ ~ 1.8dB
- Same TIA, Same DSP

Source: IEEE OI'2018, Santa Fe, 4-6 June 2018 (Inphi/Source)
https://ieee-oi.org/program/



400G - 2km CWDM



53.125Gbd
PRBS15Q
ER=5.5dB
TDECQ1.6dB

	CD (ps/nm)
IEEE MIN Spec for L0, 10km	-59.4
Measured (1271 nm, 12.3 km)	-53.6

	CD (ps/nm)
IEEE MAX Spec for L3, 10km	33.4
Measured (1331 nm, 24.6 km)	30.6

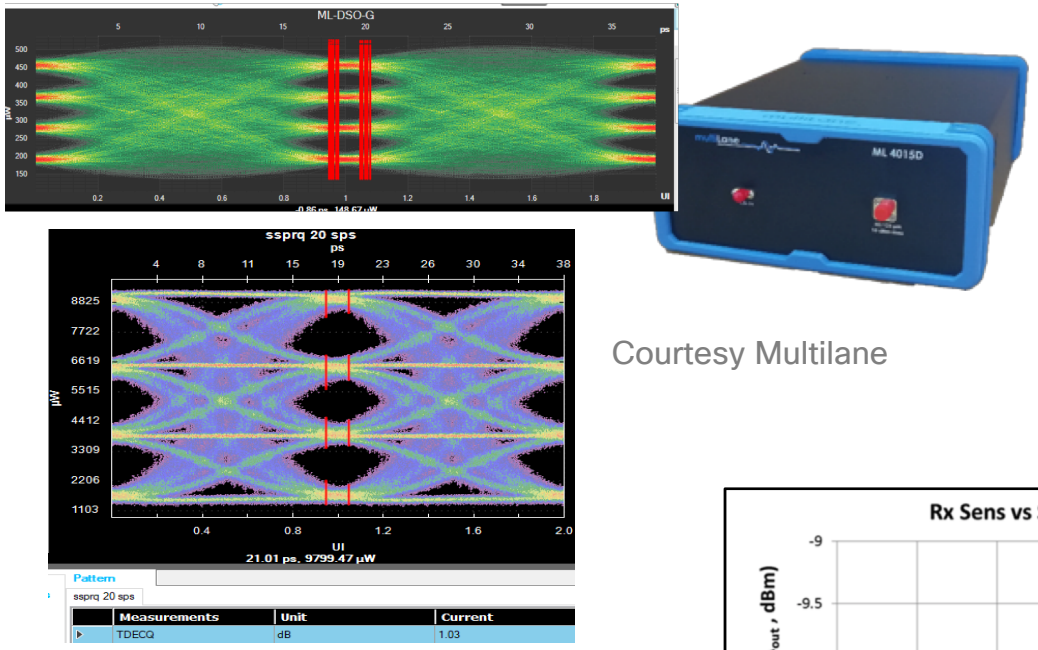
Courtesy: Oclaro

Experimental Configuration:
PRBS15 53.125 Gbaud PAM4
CWDM EML CWDM PIN-PD
DSP (FFE>5 taps)
SM fiber: L0 (12.3 km) & L3 (24.6 km)

Courtesy: Sumitomo Electric

Technical feasibility – Test & Measurement

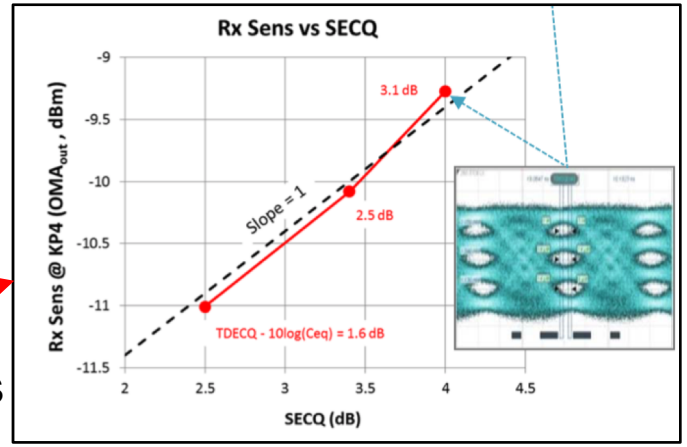
TDECQ Test methodology is solid and numerous test solutions available



Courtesy Multilane

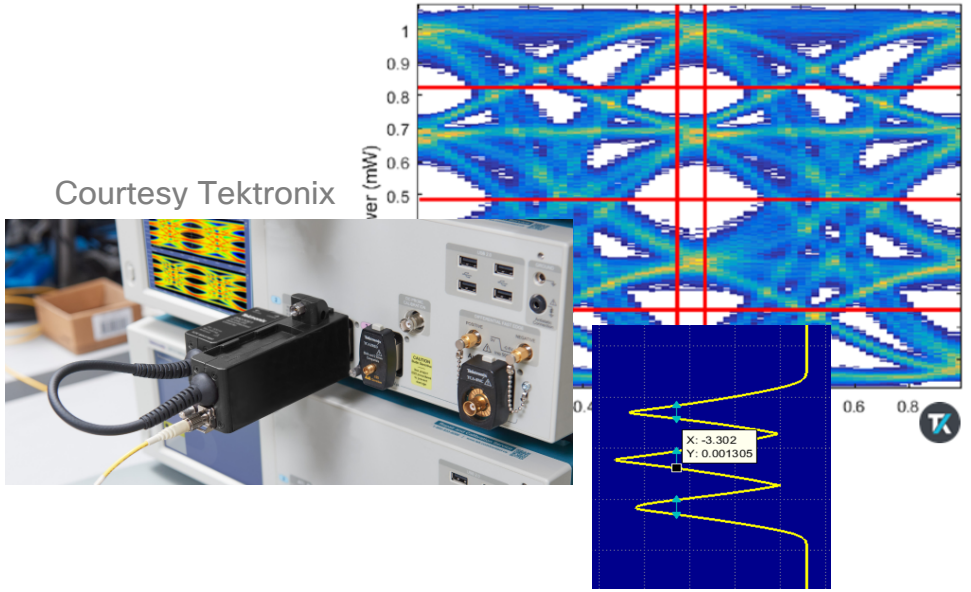
Courtesy Keysight

Excellent SECQ vs. Rx Sensitivity correlation demonstrated (50 Gb/s in this published example)



tamura_3cd_01c_0718.pdf

Courtesy Tektronix

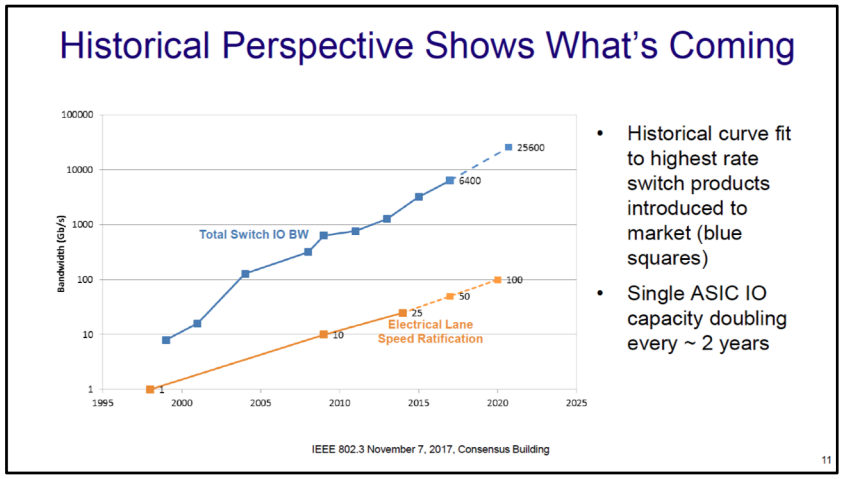


Technical Feasibility: Summary

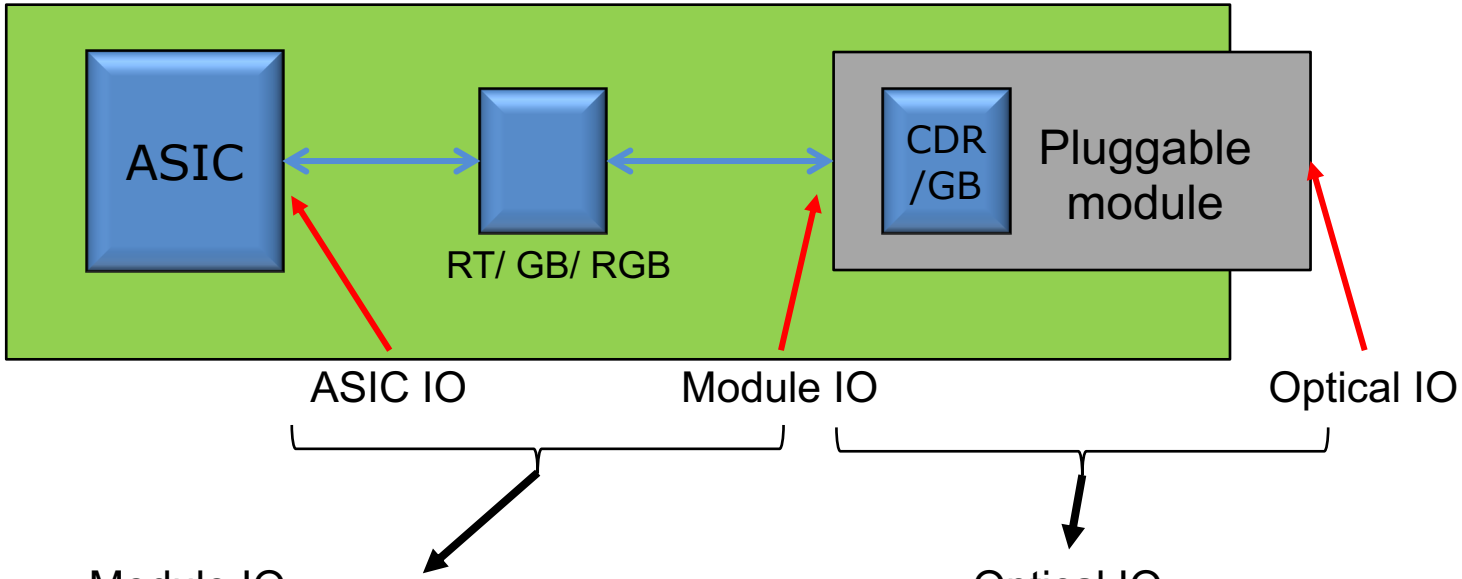
- Multiple public demonstrations of 100 Gb/s per wavelength technology over 2 km and 10 km
- Variety of technology choices for key components
- Test solutions from multiple suppliers available
- Demonstrating technical feasibility not expected to be an issue for the proposed Study Group

Why Now?

Matching ASIC IO to Module IO



IEEE P802.3ck's CFI:
http://www.ieee802.org/3/cfi/1117_3/CFI_03_1117.pdf



- ASIC IO "needs" to increase
- Module IO "advantage" to match ASIC IO (no mandatory extra host device)
- Optical module simplified when Optical IO matches Module IO

Module IO

ASIC IO	25 Gb/s	50 Gb/s	100 Gb/s
25 Gb/s	RT	GB	GB
50 Gb/s	RGB	RT	GB
100 Gb/s	RGB	RGB	RT

Optional
(vs. Mandatory)

Optical IO

Module IO	25 Gb/s	50 Gb/s	100 Gb/s
25 Gb/s	RT	GB	GB
50 Gb/s	RGB	RT	GB
100 Gb/s	RGB	RGB	RT

Simplest

RT: Retimer/CDR GB: Gearbox RGB: Reverse Gearbox

Why Now?

- Technical developments underway already to extend 100 Gb/s per lane technology to longer reaches
- Current IEEE Ethernet solutions not fully aligned with end user demand,
  - especially Web-scale Data Centers looking for solutions based on 100 Gb/s per lane technology
- Technical feasibility demonstrations happening
- Standardization in IEEE 802.3 brings industry convergence and extends Ethernet's solution breadth
- Target markets are:
  - Moving into high volume and therefore cost sensitive (e.g. 100 GbE)
  - Initiating early adoption that cost reduction will accelerate (e.g. 400 GbE)

Supporters

Justin Abbott, Lumentum
Anand Anandakumar, Maxlinear
Pete Anslow, Ciena
Rich Baca, Microsoft
Vittal Balasubramanian, Innovium
Thananya Baldwin, Keysight
Vipul Bhatt, Finisar
Brad Booth, Microsoft
Matt Brown, MACOM
Jose Castro, Panduit
Frank Chang, Source Photonics
David Chen, Applied Optoelectronics
Chris Cole, Finisar
Piers Dawe, Mellanox
Chris Diminico, PHY-SI
Mike Dudek, Cavium
David Estes, Spirent
Arash Farhoodfar, Inphi
Jan Filip, Maxim Integrated
Paul Goldgeier, ColorChip
Mark Gustlin, Cisco
Rita Horner, Synopsis
Jonathan Ingham, Foxconn Interconnect Technology
Hideki Isono, Fujitsu
Kenneth Jackson, Sumitomo Electric
John Johnson, Broadcom
Mark Kimber, Semtech
Jonathan King, Finisar
Paul Kolesar, Commscope
Greg Lecheminant, Keysight
Jon Lewis, Dell
David Lewis, Lumentum
Mike Li, Intel
Robert Lingle, OFS
Hai-Feng Liu, Intel
Karen Liu, Lightwave Logic
Kent Lusted, Intel
Mabud Mabud Choudhury, OFS
Khushrow Machhi , Broadcom
Jeffery Maki, Juniper
David Malicoat, Senko
Flavio Marques, Furakawa Electric
Marco Mazzini, Cisco
Rich Mellitz, Samtec
Shirao Mizuki, Mitsubishi Electric
Ray Nering, Cisco
Gary Nicholl, Cisco
Shawn Nicholl, Xilinx
David Ofelt, Juniper
Tom Palkert, MACOM
Rajiv Pancholy, Broadcom
Earl Parsons, Commscope
Jerry Pepper, Keysight
Rick Pimpinella, Panduit
Kees Propstra, Multilane
Rick Rabinovich, Keysight
Rajesh Radhamohan, Maxlinear
Salvatore Rotolo, ST Microelectronics
Sam Sambasivan, AT&T
Scott Schube, Intel
Shikui Shen, China Unicom
Kapil Shrikhande, Innovium
Scott Sommers, Molex
Ted Sprauge, Infinera
Phil Sun, Credo
Takanori Suzuki, Oclaro
Steve Swanson, Corning
Tomoo Takahara, Fujitsu Laboratories
Mike Takefman, Inphi
Kohichi Tamura, Oclaro
Pirooz Tooyserkani, Cisco
Nathan Tracy, TE
Matt Traverso, Cisco
Eddie Tsumura, Sumitomo Electric
Jeff Twombly, Credo
Ed Ulrichs, Source Photonics
Mike Wang, HiSense
Brian Welch, Luxtera
Chongjin Xie, Alibaba
Simon Ximen, ColorChip
James Young, Commscope
Ryan Yu, Molex
Hua Zhang, HiSense
Kevin Zhang, IDT
Pavel Zivny, Tektronix

Questions?

Straw Polls

Straw Poll 1: Call-For-Interest

Should a Study Group be formed to consider 100 Gb/s Per Lane Optical PHYs for 2 km and 10 km for 100 GbE and 400 GbE?

Y: 80 N: 0 A: 3

Room Count: 90

Participation

I would participate in the “100G Lambda”* Study Group in IEEE 802.3.

Tally:55

My company would support participation in the “100G Lambda”* Study Group in IEEE 802.3.

Tally: 43

* *100 Gb/s per Lane Optical PHYs for 2 km and 10 km for 100 GbE and 400 GbE*