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

<table>
<thead>
<tr>
<th>Lanes</th>
<th>500 m</th>
<th>2 km</th>
<th>10 km</th>
<th>20 km</th>
<th>40 km</th>
<th>Up to 80km</th>
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<tbody>
<tr>
<td>1000BASE-</td>
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<td>LX</td>
<td>LX10 / LH</td>
<td>EX</td>
<td>ZR</td>
<td></td>
</tr>
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<td>ER</td>
<td>ZR</td>
<td></td>
<td></td>
</tr>
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<td>ER</td>
<td></td>
<td></td>
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<td>PSM4</td>
<td>LR4</td>
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<tr>
<td>50GBASE-</td>
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<td>FR</td>
<td>LR</td>
<td>ER</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>10X10</td>
<td></td>
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<tr>
<td>400GBASE-</td>
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<td>FR4</td>
<td>LR4</td>
<td>ER4</td>
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<td>8</td>
<td>FR8</td>
<td>LR8</td>
<td>ER8</td>
<td></td>
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</tbody>
</table>

- **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

2-10km
IEEE defined Ethernet (100 & 400 GbE)
OUR SCOPE

Scenario #2

2-10km
IEEE defined Ethernet (100 & 400 GbE)
OUR SCOPE

> 80 km
DWDM Systems carrying Ethernet traffic

2-10 km
IEEE defined Ethernet (100 & 400 GbE)
OUR SCOPE
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 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

100 GbE Modules by reach

100 GbE & 400 GbE 2 & 10 km SMF Modules

5.6 million modules in 2018

Courtesy Dale Murray, Light Counting
Ethernet’s consistent trend – Narrower/Faster

SERDES speeds

# lanes

* At the right time

10 GbE
40 GbE
200 GbE
100 GbE
400 GbE

1x and 4x bus widths dominate volume adoption

Higher speed
Lower cost*

Fewer lanes

# lanes

Gb/s

1x
2x
4x
8x
10x
16x
10 GbE
25 GbE
50 GbE
100 GbE
200 GbE
400 GbE

* At the right time

Fewer lanes

Higher speed
Lower cost*

1x and 4x bus widths dominate volume adoption
Reduced complexity leads to lower cost – e.g. 100 GbE

- **100GBASE-LR4**
  - 4x 25G
  - 4x CDR + DVR
  - Optical Mux
  - 10 km

- **100G-CWDM4**
  - 4x 25G
  - 4x CDR + DVR
  - Optical Mux
  - 2 km
  - Optical DMux
  - 4x Rx + CDR

- **100GBASE-DR**
  - 4x 25G
  - DSP
  - RX
  - 500 m
  - Optical Mux
  - 2 km
  - Optical DMux
  - 4x Rx + CDR

- **This CFI**
  - 4x optical lane reduction
  - ~2014
  - ~2018

- **4x 25G**
  - 4x CDR + DVR
  - Optical Mux
  - 10 km
  - 4x Rx + CDR
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

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

* 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.

53 GBaud PAM4 (106 Gb/s)  
IEEE Pattern PRBS13Q  
See - mazzini_3cd_01a_0518

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

Optical eye

53 GBaud PAM4 (106 Gb/s)  
IEEE Pattern PRBS13Q  
See - mazzini_3cd_01a_0518

ER=6.9dB, TDECQ= 2.78dB

10 km Penalty = 0.21dB
19 ps/nm

10 km

ER=7.4dB, TDECQ= 4.24dB

21 km Penalty = 1.54 dB
31 ps/nm

21 km

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

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

Electrical eye

Courtesy Broadcom

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Electrical eye

Courtesy Broadcom
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/

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

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

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)
Technical feasibility – Test & Measurement

TDECQ Test methodology is solid and numerous test solutions available

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

- 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

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<table>
<thead>
<tr>
<th>Module IO</th>
<th>25 Gb/s</th>
<th>50 Gb/s</th>
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<td>RT</td>
<td>GB</td>
<td>GB</td>
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<tr>
<td>50 Gb/s</td>
<td>RGB</td>
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<td>RGB</td>
<td>RGB</td>
<td>RT</td>
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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