Next-gen 200 and 400 Gb/s PHYs over Fewer MMF Fiber Pairs than Existing Ethernet Projects

Call For Interest Consensus Presentation

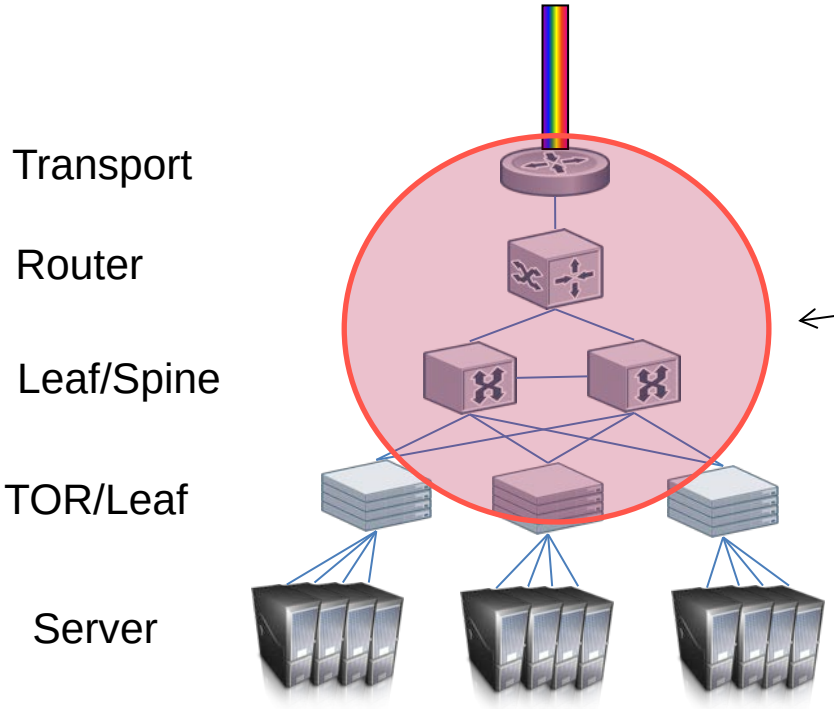
October 13, 2017

Draft 1.5 for NEA Ad Hoc Review

CFI objectives

- To measure the interest in next-gen 200 and 400Gb/s PHYs over fewer MMF pairs
- We do not need to:
  - Fully explore the problem
  - Debate strengths and weaknesses of solutions
  - Choose a solution
  - Create a PAR or 5 Criteria
  - Create a standard
- Anyone in the room may vote or speak
- RESPECT … give it, get it

What are we talking about?



Applications for early adoption of next-generation MMF PMDs include connectivity in web2.0 and *largest* enterprise data centers for

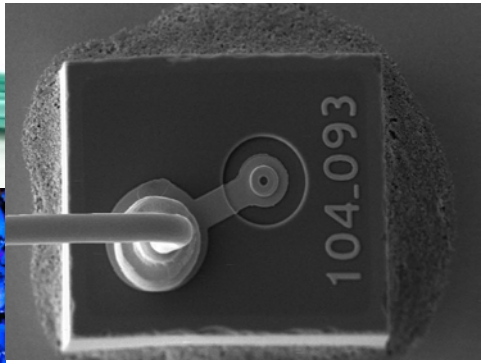
- switch-to-switch
- switch-to-router
- router-to-transport

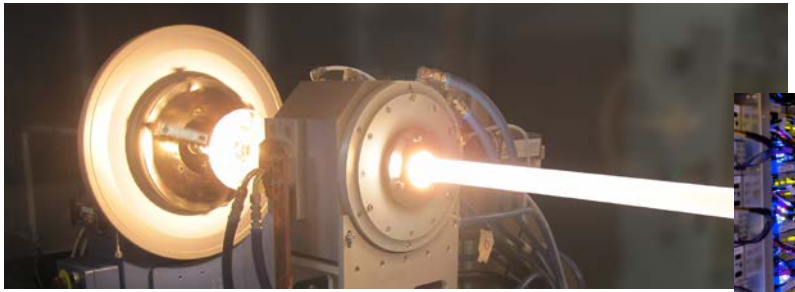
Other applications may arise later when the broad enterprise market needs higher speeds

Agenda

- **Presentations**
  - **Market Drivers**
    - Robert Lingle, Jr. (OFS)
    - Dale Murray (LightCounting)
    - David Piehler (Dell EMC)
  - **Technical Feasibility**
    - Jonathan Ingham (FIT)
    - Jonathan King (Finisar)
  - **Why Now?**
    - Robert Lingle, Jr. (OFS)
- **Straw Polls**

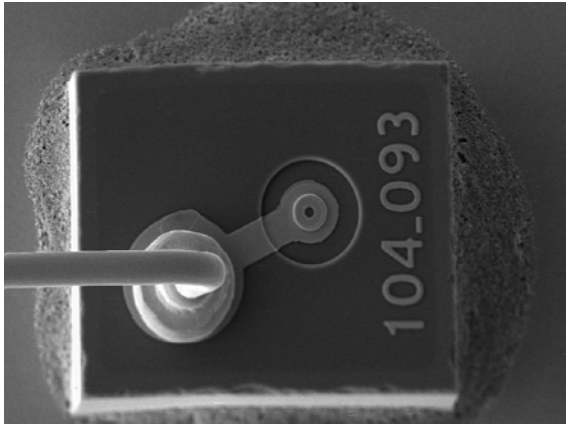
Market drivers

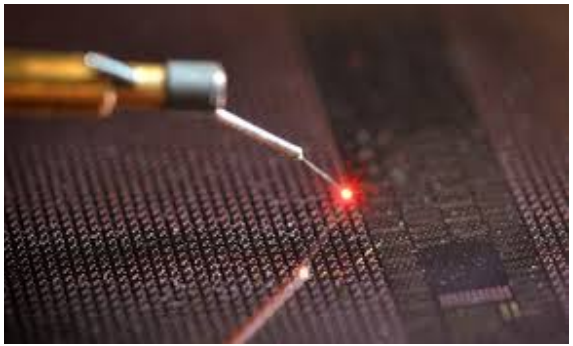




Historically VCSEL-MMF links have been seen by many as the lowest cost and power short-reach interconnect

- Relaxed alignment tolerances
  - Several microns vs. sub-micron
  - Allows passive alignment in module
  - Better cost/loss trade-off for connectors
- Connectors more resilient to dirt
  - Cleaning SMF connectors is common issue
- Lower drive currents
  - 5-10mA vs. 50-60mA
- On-wafer testing

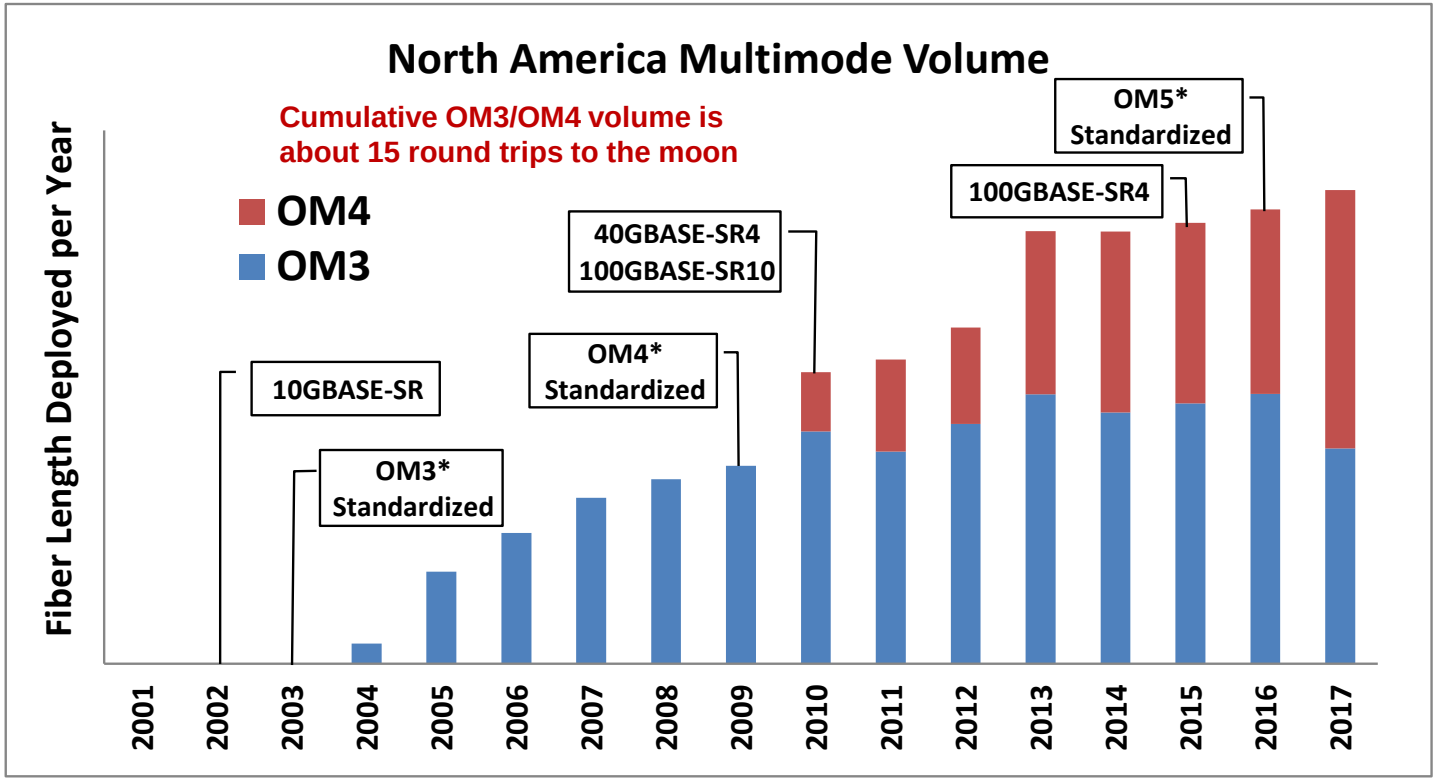




10/40/100G have been widely deployed over MMF

- Large installed base of duplex OM3/OM4 MMF deployed for 10GBASE-SR
- Large installed base of parallel OM3/OM4 MMF deployed for 40GBASE-SR4 and 100GBASE-SR4
- Industry investment in MMF cabling continues

Deployment of OM3 MMF ramped up after standards were complete, with OM4 ramping up next after standards issued

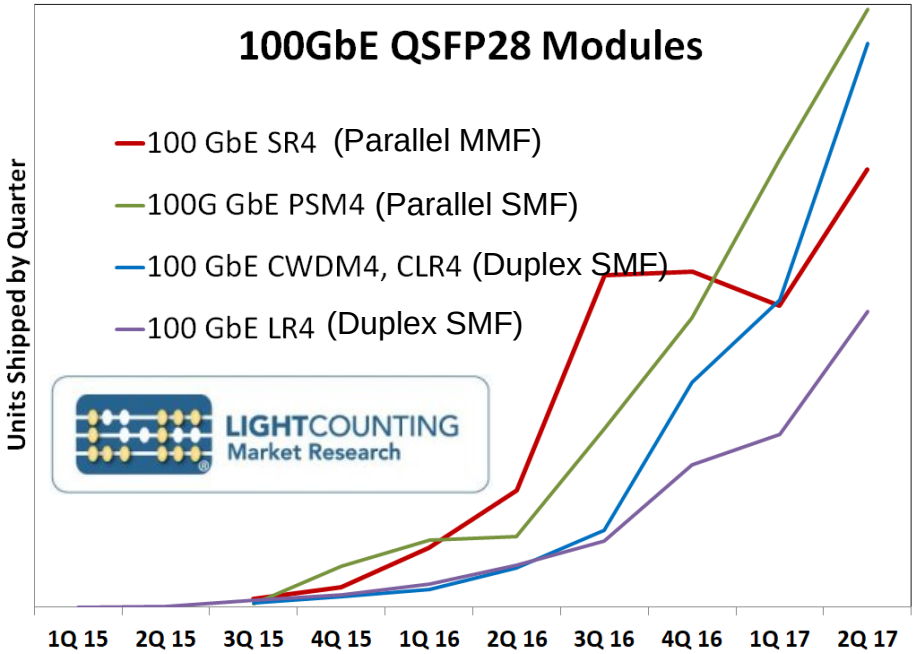


* Dates are ANSI/TIA standardization dates, not ISO/IEC

2017 estimated by annualizing 1H17 volume

Used with permission: Matthew Burroughs North America Multimode Reports

100GBASE-SR4 in QSFP28 was required by web2.0 and largest enterprise data centers as soon as 100G switches entered the market



100GbE QSFP28 Consumption

Chart courtesy of Dale Murray, LightCounting

- Modules for MMF cabling had largest share of units shipped in 2016
- LightCounting predicts strong growth for all four module types.
- MMF is not dead!
- Deployment of 4-pair 100G links today suggests need for an upgrade path to 400G

Market applications of 400G short reach

- Initial volume applications in switch-router & switch-switch connections
  - in the cloud
  - *largest* enterprise DCs

- Smaller volumes used for low-cost router-transport in telecom & the cloud, CO transformation at service providers, and laboratory development applications in telecom and the cloud

Comments on prospects for 400GBASE-SR4, by Chongjin Xie, Sr. Director of Infrastructure Service at Alibaba

- Alibaba uses 100GBASE-SR4 heavily for 100m switch-switch connections now
- 100GBASE-SR4 links over MMF cabling are lower cost for Alibaba today than PSM4 or CWDM4 links over SMF cabling
- Alibaba expects to deploy 100G switching for approximately three years, perhaps moving to 400G in 2019
- He hopes to have 400GBASE-SR4 available in 2019 and strongly supports its standardization in IEEE

Comments on a switch vendor's experience of demand for 100Gb/s MMF optics, from David Piehler (Dell EMC)

- Sold 100GBASE-SR4 into large enterprise DC space in 2016
  - Could also have sold 100G duplex MMF transceivers in 2016 had they been commercially available
- There is demand for MMF solutions with the highest speeds, and the lowest fiber counts
- He expects this trend to play out again for >100 Gb/s speeds

The introduction of data center functionality into Service Provider central offices for NFV/SDN has created a new space for short reach interconnects in the ≤100m range

Central Office Floor

Datacom Gear Room

- Datacom gear requires that room be upgraded for fire safety & cooling load
- Smaller size is friendly to <100m reach for standardized MMF links
- Deploying 40 & 100Gb/s MMF links now

- SMF often preferred in CO's in spite of higher link cost, since connections may be required between floors
- Telecom grade equipment allowed relaxed fire code rating and lower cooling load in traditional central offices

400GBASE-SR4.2 (as an example) is a better fit to the data center market than existing 400GBASE-SR16

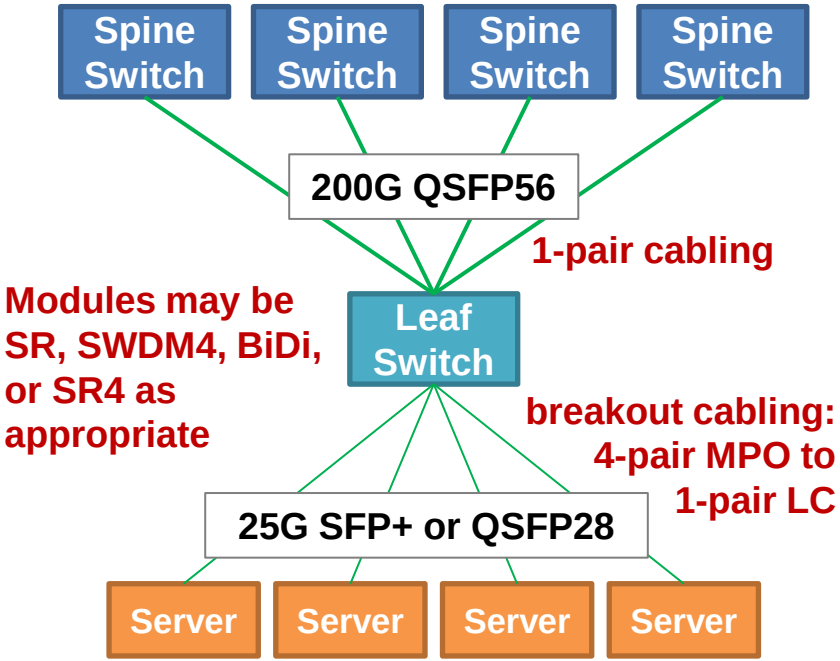
	400GBASE-SR16	400GBASE-SR4.2
Design Intent	400G with 25G SerDes; originally aimed at CDFP form factor, now CFP8	400G based on 50 Gb/s SerDes; fits into OSFP and QSFP-DD
Electrical Interface	Requires gearbox to operate with 400GAUI-8	Native to 400GAUI-8
Cabling Medium	Requires 16f pair cabling, not commonly available	Operates on commonly available array cabling
Optical Connector	Atypical 32f MPO	Typical MPO
Transceiver Form Factor	Incompatible with likely target form	Compatible with target forms
Cost Implications	Higher – more fibers, more ICs, low port availability	Lower – fewer fibers, fewer ICs, existing cabling

Note: using the SRm.n nomenclature, m = # of fiber pairs, n = number of wavelengths

Market need for a 200G module for duplex MMF

- 200G switching is expected to find acceptance in parts of the cloud and enterprise DC networking space on same time frame as 400G
- 200GBASE-SR4 is already being standardized in 802.3cd to support parallel MMF cabling
- The early demand for 100G duplex MMF optics suggests that large enterprise data centers may need 200G duplex optics as well
  - Believe there is value for the industry in a *standardized* solution for 200G over single pair of MMF

Server-uplink evolution in large enterprise datacenters requires higher speed, duplex MMF connections



Generation 3 Example

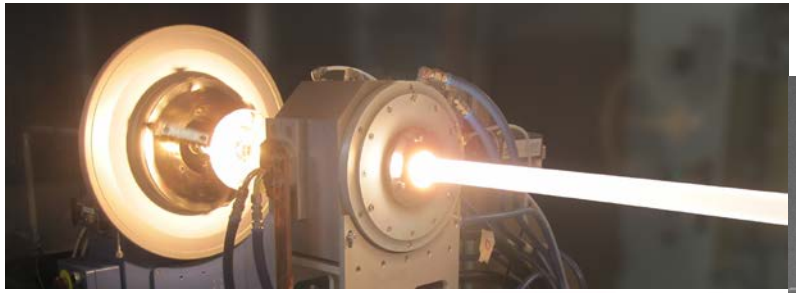
Generation	Server Rate	Up-link Rate
1 → 2	10G	40G → 100G
3	25G	200G
4	50G	400G

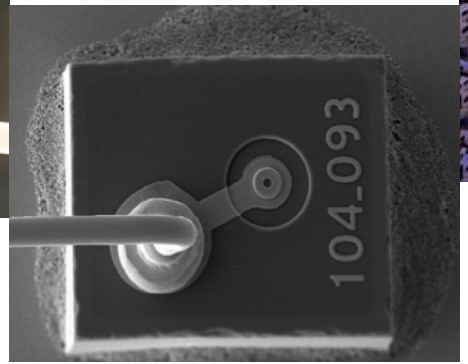
The same MMF cabling infrastructure can serve multiple generations using primarily duplex connectivity

"The ability to support 100, 200 and 400G over a duplex multi-mode optical fiber path at data center useful distances would be of considerable value."

Large Enterprise DC Architect

Technical feasibility





Technologies for next-gen MMF PMDs

- PMDs for 400G over 4 MMF pairs and 200G over < 4 MMF pairs will require three technologies

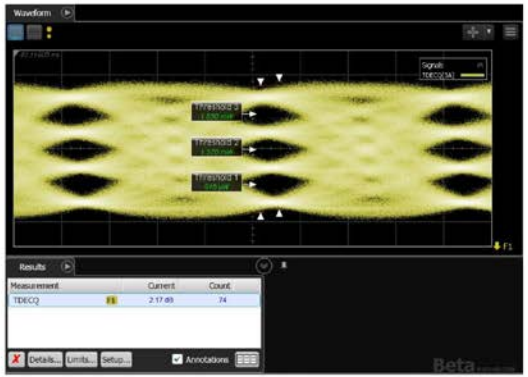
1. Multiple wavelengths on MMF – introduced in 2013
2. VCSELs supporting 50Gb/s PAM4 signaling – sampling now
3. Parallel cabling with MPO termination – in production for years

50Gb/s PAM4 over MMF in IEEE 802.3cd

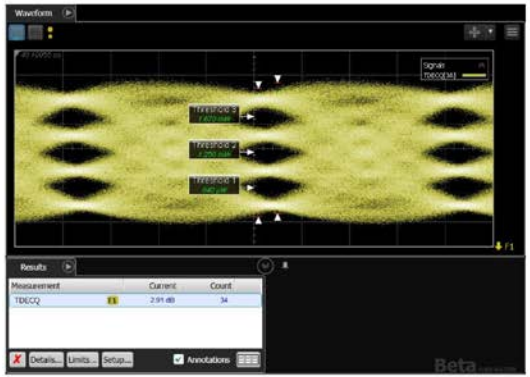
- 802.3cd has an objective to “Define single-lane 50 Gb/s PHY for operation over MMF with lengths up to at least 100m”
- 26.5625 GBd signaling with PAM4 modulation was selected to implement 50 Gb/s
- Could re-use RS(544,514,10) FEC from clauses 134 (50G), 91 (100G), and 119 (200G and 400G) if appropriate in this project

Feasibility of two-wavelength PAM4 over MMF

- Transmission of 26.5625 GBd PAM4 over 70 m worst-case OM3 MMF
- TDECQ measured for 855 nm and 908 nm VCSEL-based transmitters



855 nm Tx
TDECQ: 2.2 dB



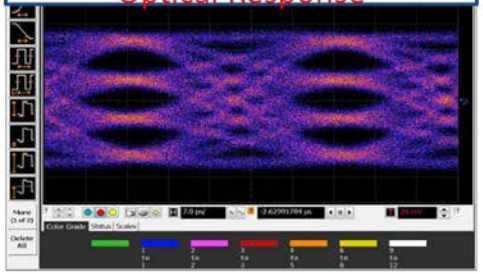
908 nm Tx
TDECQ: 2.9 dB

- For both wavelengths, transmission over worst-case MMF results in TDECQ values within the 4 dB requirement for MMF PMDs in P802.3cd

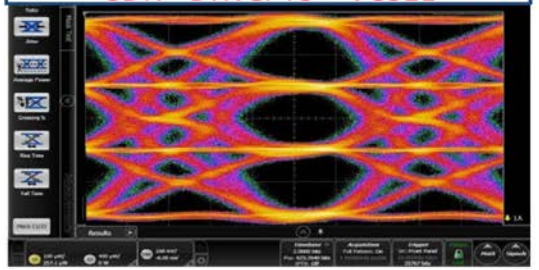
Finisar demonstration of 50G PAM4 over MMF from king_GE_NGOATH_01_0116

Bench top PAM4 experiments using 25Gb/s VCSELs

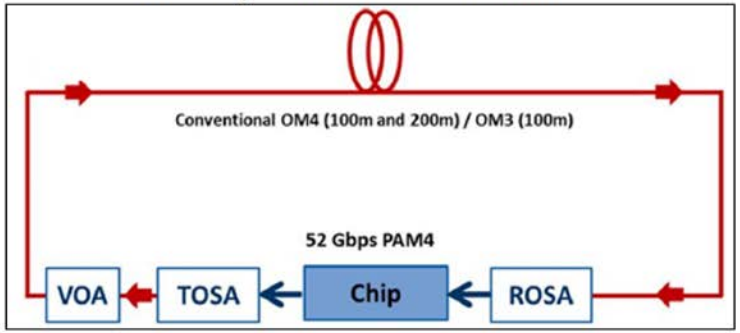
50Gb/s AWG + VCSEL Optical Response

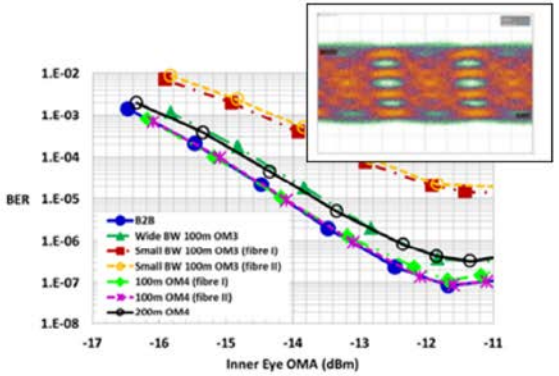


50Gb/s PAM4 Optical Response CDR+ Driver IC + VCSEL



and early PAM4 PHY evaluation….





SWDM Alliance promotes multiple wavelength VCSEL modules technology. SWDM MSA has published specs for 40 &100Gb/s VCSEL modules using four wavelengths

http://www.swdm.org/

SWDM Alliance

Anritsu COMMSCOPE

CORNING DELL EMC

FINISAR H3C

Hisense HUAWEI

HUBER+SUHNER Excellence in Connectivity Solutions inneos

JUNIPER NETWORKS LUMENTUM ofs A Furukawa Company

PANDUIT Prysmian Group SURUGA SEIKI

YOFC 长飞

SWDM MSA Technical Specifications Rev 2

100G SWDM4 MSA Technical Specifications

Optical Specifications

Table 2-1: Wavelength-division-multiplexed lane assignments

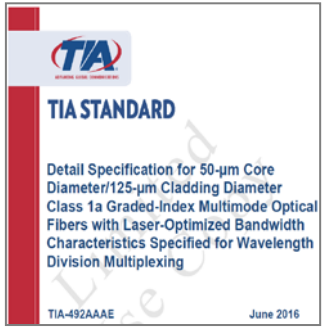
Lane	Center wavelength	Wavelength range	Module electrical lane
L_0	850 nm	844 to 858 nm	Tx0, Rx0
L_1	880 nm	874 to 888 nm	Tx1, Rx1
L_2	910 nm	904 to 918 nm	Tx2, Rx2
L_3	940 nm	934 to 948 nm	Tx3, Rx3

Adding wavelengths & PAM4 to MMF modules preserves the historical cost & power advantage over SMF modules

- Tolerances for mux/demux are significantly more relaxed in the case of MMF than SMF
- More costly circuits are needed to implement PAM4 for both fiber types
- Reduction of laser RIN for PAM4 is not more difficult for VCSELs than for DFBs
- Packaging for VCSEL sources at 50Gb/s PAM4 is based on known technology, whereas packaging for 1310nm sources at 100 Gb/s per lane PAM4 has required significant development

Standardized Wideband MMF/OM5 improves performance with multiple wavelengths

- OM5 MMF extends the 850nm performance of OM4 out to 953nm
- Drop-in replacement for OM4 at 850nm. Fully backward-compatible with previous IEEE standards
- Accommodates at least four wavelengths on economical grid spacing
- Standards:
  - Fiber: TIA-492AAAE (2016), IEC 60793-2-10 ed. 6 (1Q17)
  - Cabling: ANSI/TIA-568.3-D (2016), ISO/IEC 11801 ed. 3 (4Q17)
  - Application (WBMMF/OM5 operating at 850nm only): IEEE 802.3bs draft (2016), IEEE 802.3cd draft (2016), Fibre Channel FC-PI-7/64GFC & 256GFC (2Q17)



Fiber Standards

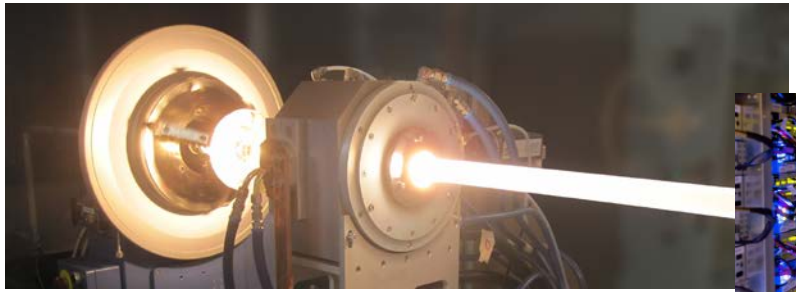
Structured Cabling Standards

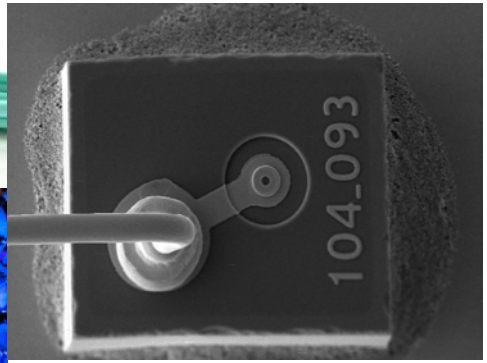
The VCSEL optical lane rate roadmap will support PMDs beyond those contemplated here

		Examples of PMDs possible at bit rate		
Bit rate per optical lane (Gb/s)	**Year for bit rate**	**Speed for SR1.4 module**	**Speed for SR4 module**	**Speed for SR4.2 module**
25	2015	100G	100G	
50	2018	200G	200G	400G
100	proofs-of-concept exist*	400G	400G	800G

* Several technical presentations at OFC & ECOC 2017 showed research feasibility of 100G / lane; modules at that lane rate have not yet been demonstrated.

Why now?





Why Now?

The use of VCSELs & MMF thrives at shorter reach, even though SMF modules are now defined for 500m reach

- Cloud DCs in North America & China and *largest* enterprise DCs were early adopters of 100G-SR4
- The low relative cost and high technical feasibility of SR4.n for short reach should be valuable to early adopters at 400G as well
- Duplex MMF transceivers with speeds > 100G have a place in large enterprise DC switching as server I/O migrates from 10 to 25 to 50 Gb/s

The enabling technologies exist to support next-gen MMF PMDs over fewer fiber pairs

- 50Gb/s PAM4 in development for 802.3cd; already used in proprietary modules
- Two and four wavelengths already used in proprietary duplex MMF transceivers
- Two and four wavelength operation over the installed base is supported

Data shows that the market continues to deploy MMF cabling

- Standardizing lower cost applications for MMF facilitates upgrades and enlarges Ethernet market

Contributors

Dale Murray, LightCounting
Chongjin Xie, Alibaba
David Piehler, Dell EMC
Jonathan Ingham, FIT
Jonathan King, Finisar
Steve Swanson, Corning
John Kamino, OFS
Mabud Choudhury, OFS
Paul Kolesar, CommScope
James Young, CommScope
Carl Rumbolo, Wells Fargo
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Supporters (38 Individuals from 28 companies)

Scott Kipp, Broadcom
Jeffery Maki, Juniper
David Piehler, Dell EMC
Ted Sprague, Infinera

Rob Stone, Broadcom
John Johnson, Broadcom
Frank Chang, Inphi
Mike Dudek, Cavium

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Rich Mellitz, Santec
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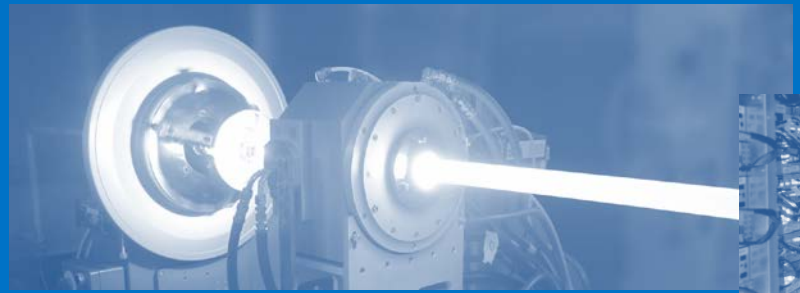
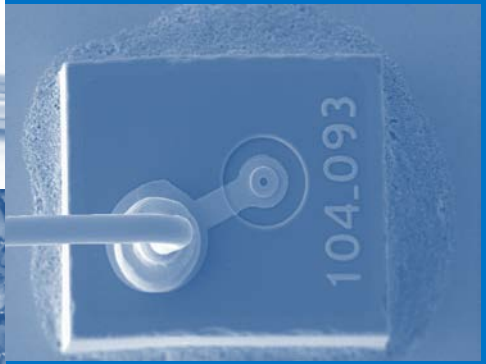
Greg Schneider, UT-Services

Carl Rumbolo, Wells Fargo
James Deese, Wells Fargo
Dale Murray, LightCounting
Chongjin Xie, Alibaba

Alan Flatman, LAN Technologies
Ali Ghiasi, Ghiasi Quantum

Straw Polls





Call-for-Interest Consensus

- Should a study group be formed for “Next-gen 200 and 400 Gb/s PHYs over Fewer MMF Pairs than Existing Ethernet Projects”?
- Y: N: A:
- Room count:

Participation

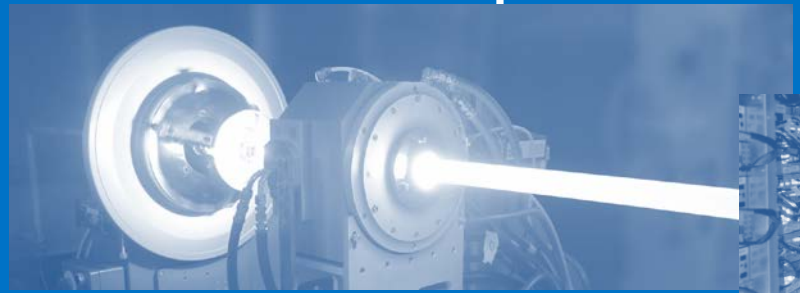
- I would participate in a “Next-gen 200 and 400 Gb/s PHYs over Fewer MMF Pairs than Existing Ethernet Projects” study group in IEEE 802.3
  - Tally:

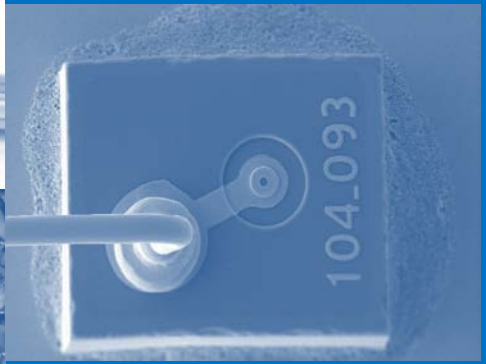
- My company would support participation in a “Next-gen 200 and 400 Gb/s PHYs over Fewer MMF Pairs than Existing Ethernet Projects” study group
  - Tally:

Future Work

- Ask 802.3 at Thursday's closing meeting to form study group
- If approved:
  - Request 802 EC to approve creation of the study group on Friday
  - First study group meeting would be during January 2018 IEEE 802.3 interim meeting

Back Up





40 & 100Gb/s MMF optics have been used in volume for switch-to-switch connections in data centers

- 40G SR4 for 4 pairs MMF
  - ~ 50% used in switch-to-switch links
- 40G BiDi & SWDM4 for 1 pair MMF
  - Proprietary solutions used in switch-to-switch connections
- 100G SR4 for 4 pairs MMF
  - The 100GBASE-SR4 links deployed in 2016 comprise switch-to-switch and switch-to-router connections in cloud and largest enterprise DCs
- 100G BiDi & SWDM4 for 1 pair MMF
  - Proprietary solutions; expected in 2017; market demand existed in 2016

Chart shows some of the options for 200/400G over fewer MMF pairs; but we are not choosing the solution here!

Technology (per fiber)	1 fiber pair	2 fiber pairs	4 fiber pairs	8 fiber pairs	16 fiber pairs
25G-λ NRZ	25G-SR		100G-SR4		400G-SR16
50G-λ PAM4	50G-SR	100G-SR2	200G-SR4	**400G-SR8**	
2x50G-λ PAM4	100G-SR1.2	**200G-SR2.2**	**400G-SR4.2**	**Examples of technologies for 200 & 400 Gb/s links over fewer MMF fiber pairs**	
4x25G-λ NRZ	100G-SR1.4	**200G-SR2.4**	**400G-SR4.4**		
4x50G-λ PAM4	**200G-SR1.4**	**400G-SR2.4**	800G-SR4.4		

Existing IEEE standard

In progress in 802.3bs, cd

Multi-Wavelength Nomenclature

SRm.n m = # fiber pairs

n = # wavelengths