Wideband MMF Standardization and S-WDM technology

IEEE 802.3 50G & NGOATH Study Groups

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Paul Kolesar, TIA WBMMF spec editor – CommScope

Supporters

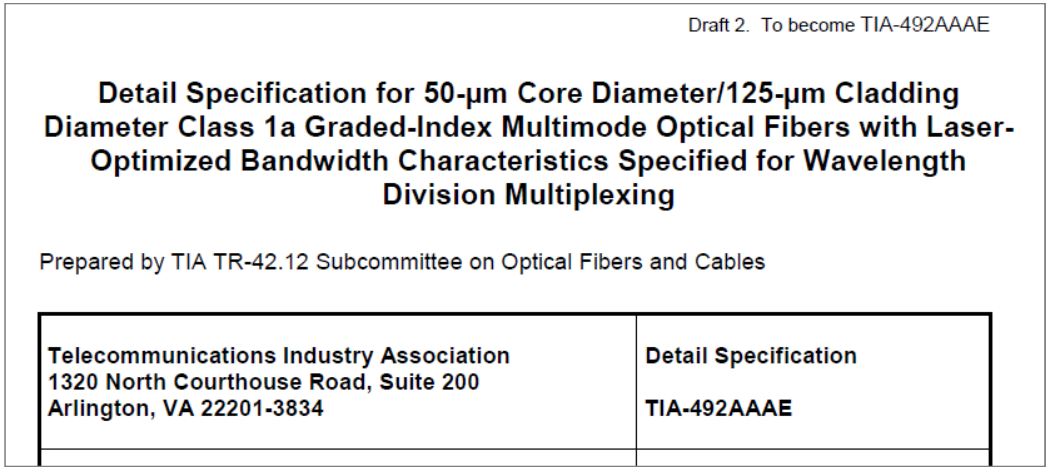
- Adrian Amezcua, Prysmian
- Jonathan King, Finisar
- Brett Lane, Panduit
- Zeng Li, Huawei
- Robert Lingle, OFS
- Jeff Maki, Juniper
- Alan McCurdy, OFS
- David Ofelt, Juniper
- Peter Stassar, Huawei
- Zhuangyan Zhuang, Huawei

Background

- **Lane rates up to 28Gbps standardized over MMF**
  - 32GFC, 100GBASE-SR4, P802.3bs, P802.3by
- **Alternative technologies supplement lane rate increases**
  - Spatial muxing, WDM, higher-order modulation, bi-di transmission
- **WDM technology is gaining momentum**
  - Transceiver manufacturers releasing devices employing short-wave division multiplexing (S-WDM) for 40G and 100G applications
  - SWDM Alliance formed with eleven member companies
  - Fiber manufacturers optimizing properties of MMF to suit
  - New standard for WideBand Multimode Fiber (WBMMF) nearing completion…

WBMMF Standardization

- **Initial presentations to TIA TR-42 October 2014**
  - Coauthored or supported by fiber, transceiver and system companies
- **TIA TR-42 approved project**
  - October 2014, without dissent
  - International participation from IEC 86A members
  - Monthly meetings with several contributors, > 40 contributions
  - TIA-492AAAE anticipated 2016
  - See timeline on later slide
- **For Fibre Channel & Ethernet**
  - 128GFC Gen 2, 256GFC, …
  - 100GE Gen 3, 200GE, 400GE, …



Draft 2. To become TIA-492AAAE

Detail Specification for 50-µm Core Diameter/125-µm Cladding Diameter Class 1a Graded-Index Multimode Optical Fibers with Laser-Optimized Bandwidth Characteristics Specified for Wavelength Division Multiplexing

Prepared by TIA TR-42.12 Subcommittee on Optical Fibers and Cables

Telecommunications Industry Association **1320 North Courthouse Road, Suite 200** **Arlington, VA 22201-3834**	**Detail Specification** **TIA-492AAAE**

Application Evolution Map – Ethernet Examples

Data Rate	10G NRZ Parallel TX RX	25G NRZ Parallel TX RX	50G PAM4 Parallel TX RX	10, 25, 50G WDM & Parallel TX RX
40G		N/A	N/A	
100G				
200G				
400G				

4λ WDM enabling factor of 4 fiber count reduction

Imagine running 10G, 40G, 100G, 200G over the same WBMMF cable plant using duplex LC connections *

Legend

- parallel fiber transmission
- WDM transmission
- WDM + parallel transmission

*Parallel fibers remain essential to support break-out functionality

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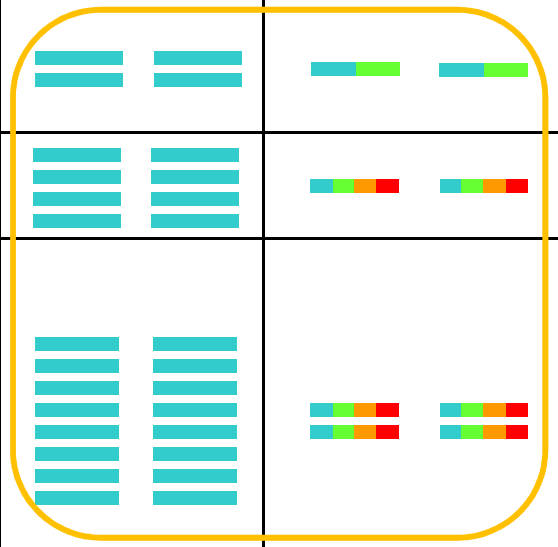
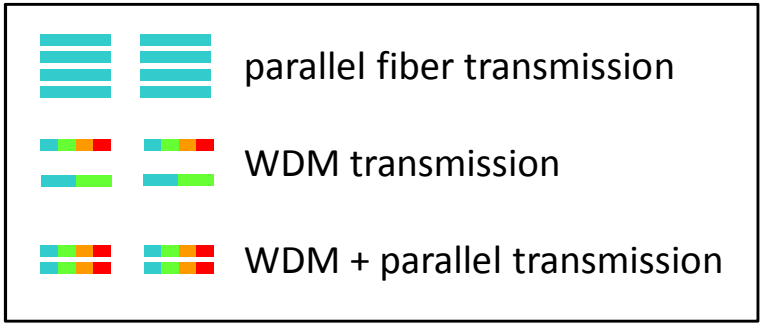


Subset relevant to the scope of this Study Group

Legend



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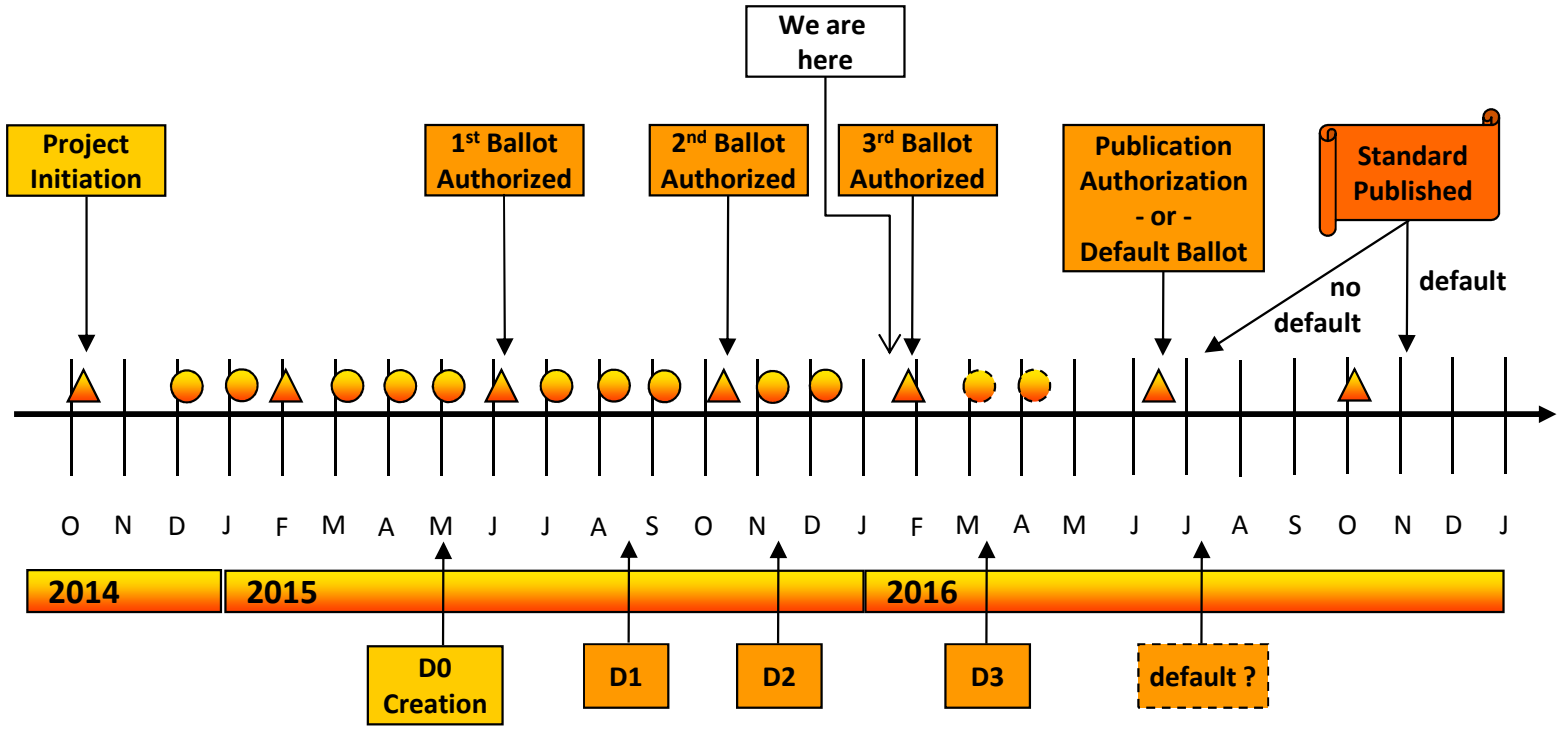
400G				

SG subset with likely best ROI

Legend

- parallel fiber transmission
- WDM transmission
- WDM + parallel transmission

TIA-492AAAE Project Timeline



Objectives and Models

- Objectives (paraphrased)
  1. Support multiple wavelengths including 850 nm
  2. Support at least 28 Gb/s per wavelength (NRZ)*
  3. Deliver at least 100 Gb/s per fiber (NRZ)*
  4. Support transmission to at least 100 m

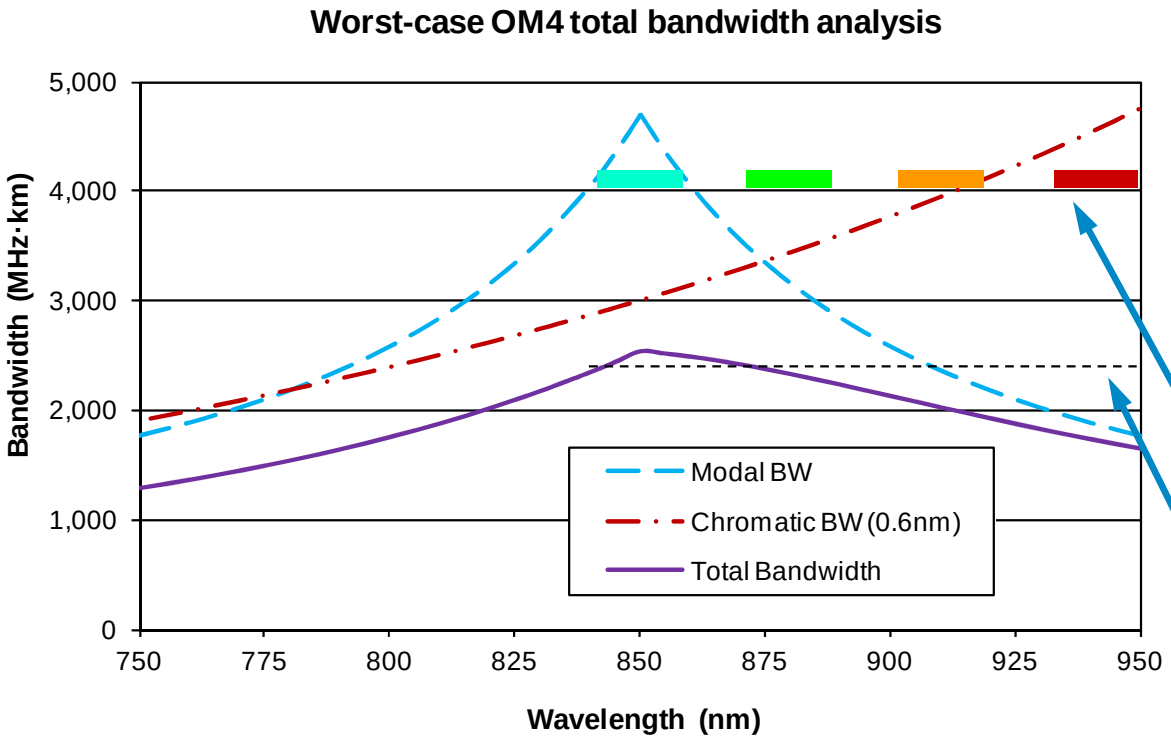
- Models
  - Closure of 32GFC model addresses 1, 2, 4
  - Closure of 100GBASE-SR4 model addresses 1, 3, 4
  - Limiting case imposed by 32GFC model

* PAM4 doubles this data rate without the need for double bandwidth

WBMMF Specification Framework

- **Wavelength range is central to WBMMF specification**
  - although WBMMF standard will not specifically set WDM plan
- **What is clear from the outset:**
  - Legacy application support dictates inclusion of 850 nm wavelength
  - Move towards longer wavelengths to gain improvements from lower chromatic dispersion, lower attenuation, faster VCSELs
  - Four wavelength bands are ideal complement to four-lane parallel
- **Transceiver vendors say low-cost WDM needs ≥ 30 nm pitch**
  - Accommodates low-cost manufacturing tolerances, temperature variation, spectral width, low-complexity filters
- **TR-42 put this all together**
  - to determine shortest wavelength and wavelength range
- **Fiber that closes the models over this wavelength range will provide optimal 4λ S-WDM support**
  - This is the direction of the WBMMF specification

Bandwidth-Wavelength Relationships



Basic Requirements & Indications

Must retain legacy 850 nm application support.

Wavelengths > 850 nm benefit from increasing chromatic bandwidth and improving VCSEL capability.

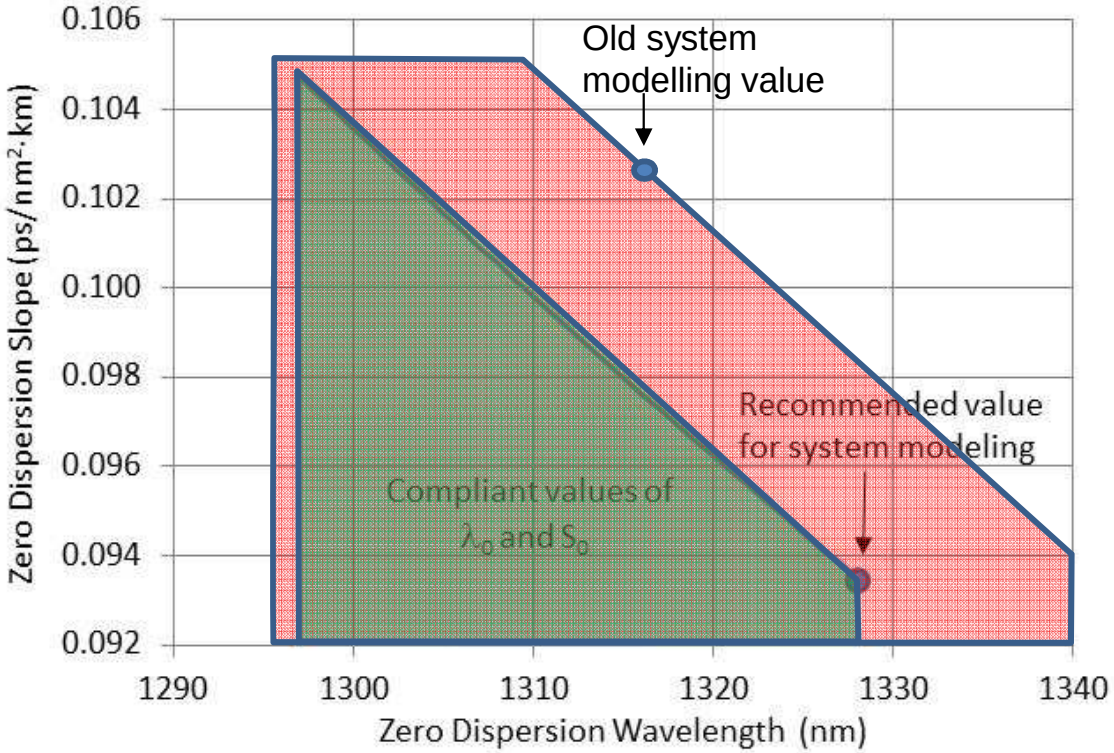
Must support at least 4 wavelengths.

Low-cost WDM needs ~30 nm spacing.

Resulting target wavelength region: ~840 nm to ~950 nm

Bandwidth improvement is needed to raise total bandwidth to that at ~840 nm over target wavelength region.

Improved Chromatic Dispersion Specification for Wideband MMF



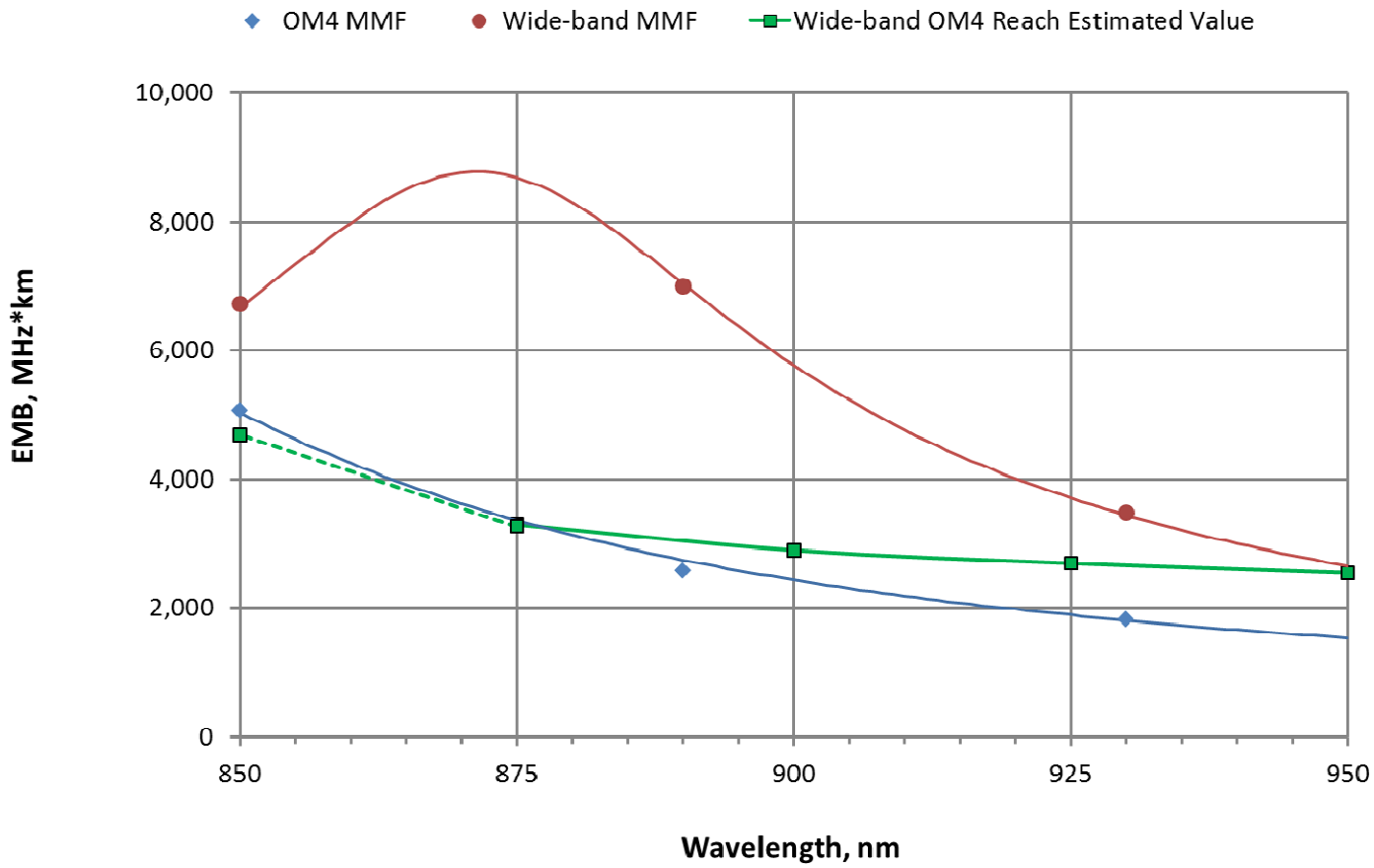
The following values recommended for system modeling:
λ_0 = 1328 nm
S_0 = 0.093477 ps/nm^2 ·km
(worst case for all relevant wavelengths)

Chromatic dispersion specification for wide band fiber tightened from the red region (current OM3 & OM4) to the green region.

Largest dispersion at 840 nm reduced to -103 ps/nm·km from -108.4 ps/nm·km.

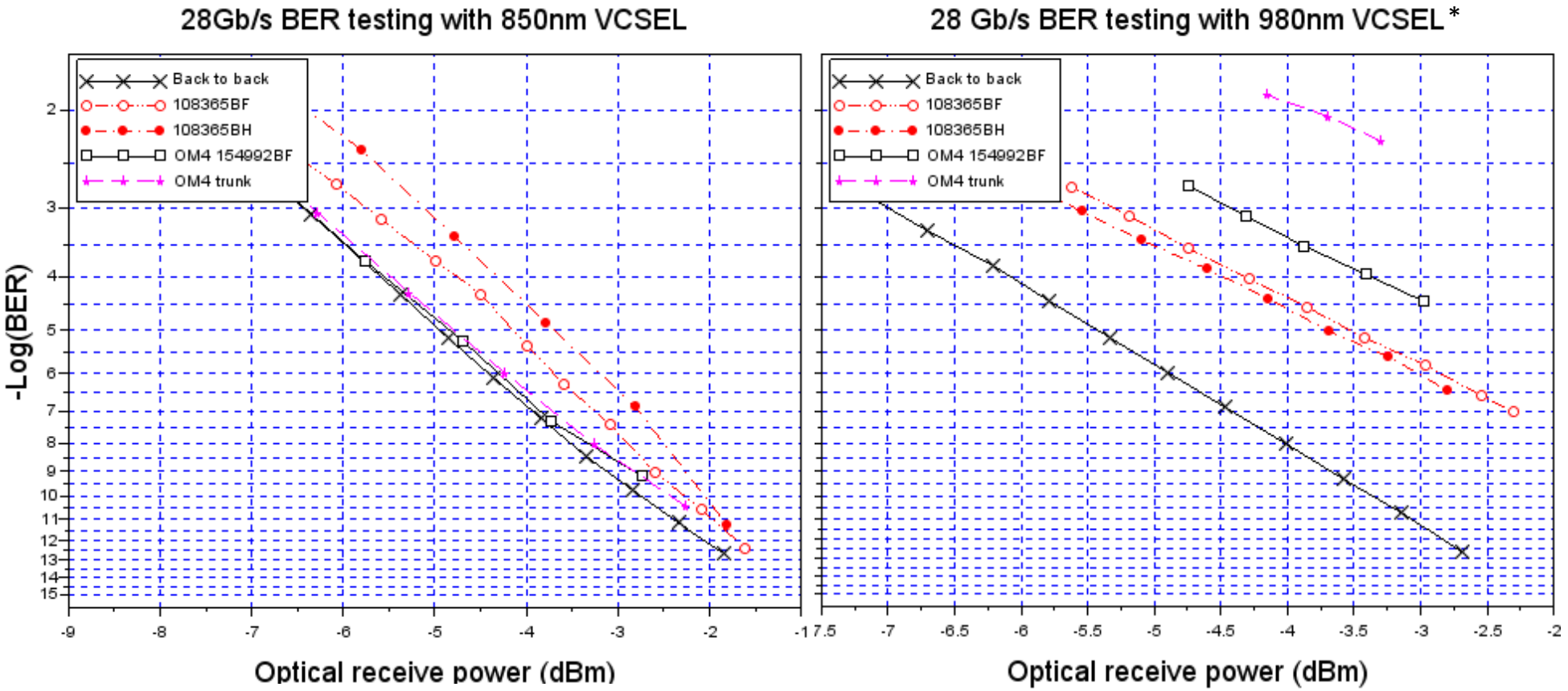
Increases chromatic bandwidth by 5%, reducing ISI, MPN and Pcross penalties.

Samples of Standard OM4 and Wideband MMFs



Fiber and measurements courtesy of OFS

Transmission Performance at 100 m



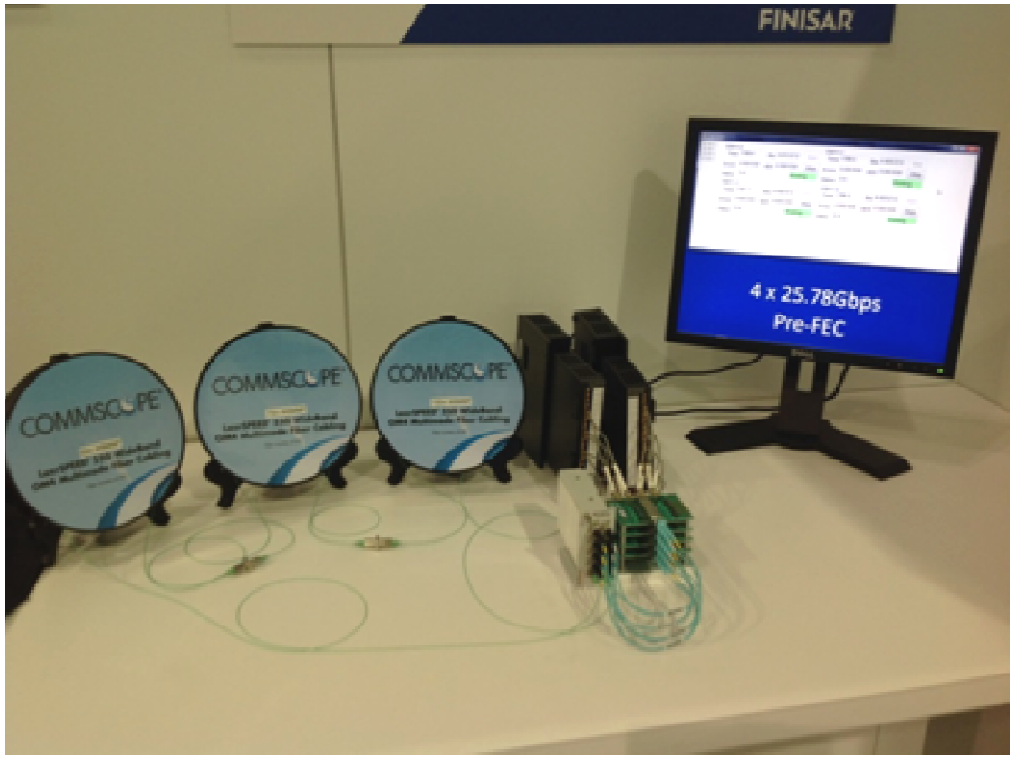
* 980nm VCSELs readily available for transmission tests and extract near-worst-case bandwidth effects.

Compare the left plot at 850 nm to the right plot at 980 nm, noting their different x-axis scales. Notice how the lines for the two OM4 fibers move significantly up and to the right, indicating that transmission impairments have substantially increased at 980 nm for OM4. But the two WBMMFs plotted in red remain comparatively similar at 980 nm to their 850 nm performance showing their ability to well support a very useful range of wavelengths.

Additional references:

- D. Molin, et.al., WideBand OM4 Multi-Mode Fiber for Next-Generation 400Gbps Data Communications, ECOC 2014 p1.6.
- D. Molin, et.al., 850-950nm WideBand OM4 Multimode Fiber for Next-Generation WDM Systems, OFC 2015, M3B.1.

Demo at OFC 2015



- **4λ, each at 25.78 Gb/s**
  - Finisar WDM concept transceiver (4 SFPs mu'xed together)
  - Nominal 850, 880, 910, 940 nm wavelengths
  - WBMMF meeting draft specifications
  - > 100 Gb/s over single-fiber channel
  - 225 m reach (50 m + 75 m + 100 m spools)
  - Error-free without FEC assistance
  - Enabling FEC would have permitted longer reach

Additional WBMMF Demos

Fall BICSI

Las Vegas, USA
September 2015

ECOC

Valencia, Spain
September 2015

GITEX

Dubai, UAE
October 2015

Fully integrated Finisar
WDM transceivers in all demos

Ethernet Project Objective Considerations

- **Experience proves market acceptance of parallel fiber solution**
  - Enables higher density ports via break-out cabling
  - Reduces cost per single-lane channel
- **Experience proves market acceptance of 2-fiber solution**
  - Provides cabling simplicity and continuation of legacy approach
  - WDM enables continuation of 2-fiber solution
  - WBMMF enhances S-WDM capability
- **Both alternatives have broad market potential**
  - The break-out approach will be the first deployed (witness 4×10G)
  - The S-WDM approach will follow as full data rates are required
- **The objectives should be written to permit standardization of both**

Summary

- **The industry is moving to utilize S-WDM**
  - Fibers, cabling, transceivers, switches, servers
- **WBMMF will optimize the reach of S-WDM solutions**
  - While retaining support for 850 nm legacy applications at OM4 reaches
- **S-WDM & WB technologies extend the utility of MMF**
  - Continuing legacy of delivering lowest-cost optical solutions over enterprise' primary transmission medium
- **Ethernet applications can benefit from these technologies**
  - to regain or retain two-fiber paradigm for generations

SWDM.org

Thank You