The Fiber Formula – Fact, Fiction & Fantasy

Rodney Casteel, RCDD, DCDC, NTS, OSP - CommScope, Chair TIA FOTC
Cindy Montstream, RCDD, NTS, EE, CPLP - Legrand, Standards Chair TIA FOTC
Paul Neveux, Jr., Ph.D. - Superior Essex International, LP
John Kamino, RCDD - OFS
David Asta, RCDD - Panduit
Tyler Vander Ploeg, RCDD - VIAVI Solutions
Jim Davis - Fluke Networks
Rob Gilberti - AFL
Romain Tursi - EXFO

Agenda

First Half – 80 minutes

- FOTC Introduction – Rodney Casteel
- IEEE Standards Update – Paul Neveux
- TIA Standards Update – Cindy Montstream
- Fiber Trends Update – John Kamino
- MPO Technology – Robert Reid
- MPO Connectivity – Rodney Casteel
- Fiber Testing & Inspection – Test Manufacturers

Break – 15 minutes

Second Half – 80 minutes

- Hands-on stations

Fiber Optics Tech Consortium

www.tiafotc.org

- Part of the Telecommunications Industry Association (www.tiaonline.org)
- Formed 24 years ago as the Fiber Optics LAN Section.
- Mission: To provide current, reliable, and vendor neutral information about fiber optics and related technologies for advancing new and better communications solutions.
- Webinars posted on website www.tiafotc.org or FOTC channel on Bright Talk
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Current Members

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- Superior Essex
- The Siemon Company
- Viavi

Fiber Optics Technology Consortium

- Recent Webinars Available on Demand
  - **LAN Standards, News & Trends: 2018 Update**
  - **Field Testing Single Mode Fiber to support 100G and Beyond for Campus and Data Centers – Available on Demand**
  - **Key Considerations for Choosing a Fiber Termination Method – Available on Demand**

- Visit www.tiafotc.org or our channel on BrightTalk
  - **TIA's BrightTalk Channel: www.brighttalk.com/channel/727**

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Optical Fiber Ethernet Update

IEEE Standards

Paul Neveux, Jr., Ph.D.

Superior Essex International, LP

IEEE Optical Fiber Standards in Development

- P802.3ca – 25G/50G EPON
- P802.3cd – 50/100/200 Gb/s Ethernet
- P802.3cm – 400 Gb/s over MMF

Review: 10, 40 and 100 Gb Ethernet on MMF

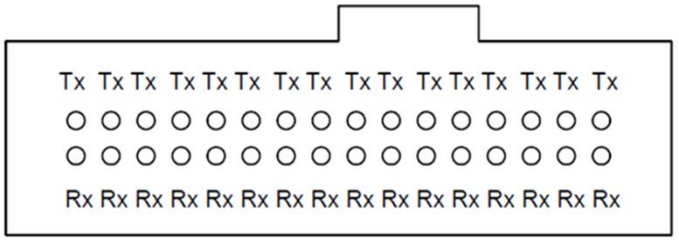
Ethernet Speed	IEEE Task Force	Designation	Fiber Type	Number of Fibers	Maximum Link Length (m)	Maximum Channel Insertion Loss (dB)
10 Gb	802.3ae	10GBASE-SR	OM3	2	300	2.6
40 Gb	802.3ba	40GBASE-SR4	OM3	8	100	1.9
40 Gb	802.3ba	40GBASE-SR4	OM4	8	150	1.5
100 Gb	802.3ba	100GBASE-SR10	OM3	20	100	1.9
100 Gb	802.3ba	100GBASE-SR10	OM4	20	150	1.5
100 Gb	802.3bm	100GBASE-SR4	OM4	8	100	1.9
400 Gb	802.3bs	400GBASE-SR16	OM3/4/5	32	80/100/100	1.9

Review: 40/100/200/400 Gb Ethernet on SMF

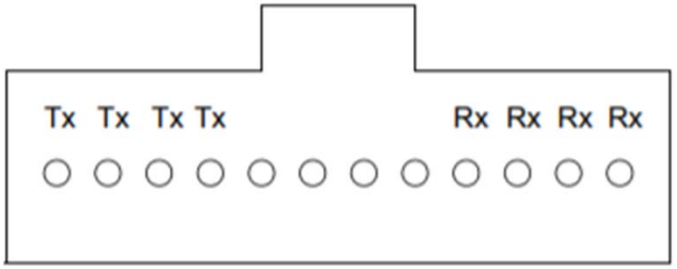
Ethernet Speed	IEEE	Designation	Wave-lengths	Number of Fibers	Max. Link Length	Max. Channel Insertion Loss (dB)
40 Gb	802.3ba	40GBASE-IR4 40GBASE-LR4	4 λ	2	2 km 10 km	4.0 6.7
100 Gb	802.3ba	100GBASE-LR4	4 λ	2	10 km	6.3
200 Gb	802.3bs	200GBASE-DR4 200GBASE-FR4 200GBASE-LR4	4 λ	4 2 2	500 m 2 km 10 km	3.0 4.0 6.3
400 Gb	802.3bs	400GBASE-DR4 400GBASE-FR8 400GBASE-LR8	4 λ 8 λ 8 λ	4 2 2	500 m 2 km 10 km	3.0 4.0 6.3

IEEE 802.3bs – 200/400 Gb/s Ethernet

MMF MPO:



SMF MPO:



IEEE Standards in Development

IEEE 802.3cd 50/100/200 Gb/s Ethernet

- 50 Gb/s Ethernet PHYs
  - MMF with lengths up to at least 100 m (OM4/5; 50GBASE-SR)
  - SMF with lengths up to at least 2 km and lengths up to at least 10 km
- 100 Gb/s Ethernet PHYs
  - MMF with lengths up to at least 100 m (OM4/5; 100GBASE-SR2)
  - Duplex SMF with lengths up to at least 500 m
- 200 Gb/s Ethernet PHYs
  - MMF with lengths up to at least 100 m (OM4/5; 200GBASE-SR4)

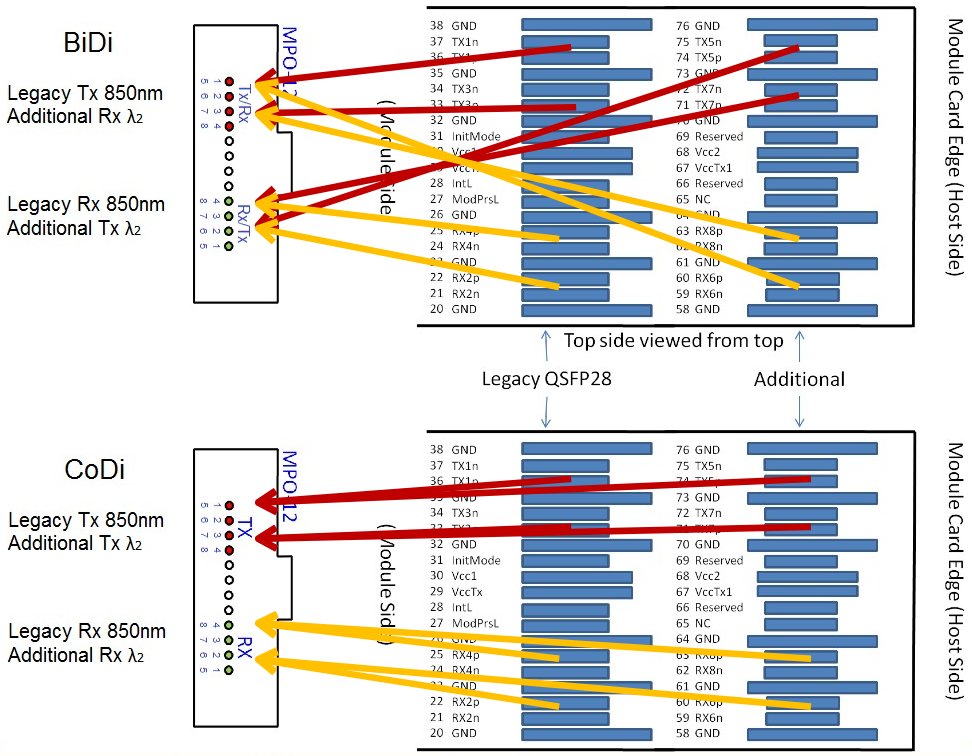
P802.3cm 400 Gb Ethernet over MMF

- Fiber types: OM3/4/5 Fiber
- Two implementations
  - 400GBASE-SR8 using a 16 or 24 fiber MPO
  - 400GBASE-SR4.2 using 12 fiber MPO
- Wavelengths resolved: Nominal 850 nm and 910 nm
- MPO lane assignment not yet decided

400GBASE-SR4.2 Implementation Approved

- FEC supported 26.5625 GBd using PAM4 modulation
- OM3 and OM4 lengths at least 100 meters
- OM5 length at least 150 meters
- Bi-directional Transmission
  - Allows easier VCSEL launch design
  - Larger eye safety margin, relative to a co-directional approach
  - 100G Bi-Di provides a path to support breakout applications

Co-di vs. Bi-di: Board Routing



– or a bidi compatible PHY with crossovers inside the IC

400GBASE-SR4.2 Link Power Budget

Parameter	OM3	OM4	OM5	Unit
Effective modal bandwidth at 850 nm[a]	2000	4700	4700	MHz-km
Effective modal bandwidth at 918 nm	1210[b]	1850[b]	2890[a]	MHz-km
Power budget (for max TDECQ)	6.6			dB
Operating distance	70	100	150	m
Channel insertion loss[c]	1.8	1.9	2	dB
Allocation for penalties[d] (for max TDECQ)	4.6			dB
Additional insertion loss allowed	0.2	0.1	0	dB

TIA Standards Update

Cindy Montstream, RCDD, NTS, EE, CPLP

Director of Technology Support & Training
Data Communications Division, Legrand

Chair, TIA TR-42.3

FOTC Standards Chair

TIA Standards Update

TR-42 | TELECOMMUNICATIONS CABLING SYSTEMS

- Develops standards for telecommunications cabling infrastructure
- Standards are grouped into 3 categories: Common, Premises and Cabling & Components
- Standards cover many different premises, i.e. data center, commercial building, residential, healthcare facility, education facility, etc.

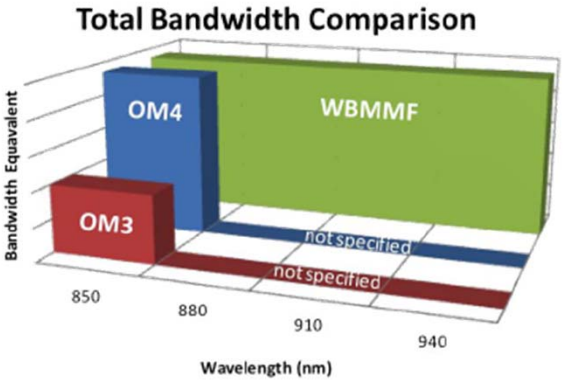
New Media Types & Connector

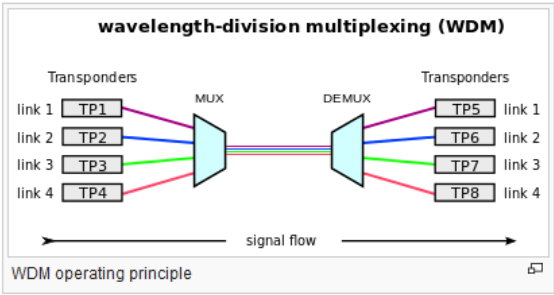
OM5: Wide Band Multimode Fiber

New fiber type

ANSI/TIA-492AAAE
Wide Band Multimode (WBMMF)

- 50µ Laser Optimized Multimode Fiber
  - Use cost effective MM VCSEL technology
- Optimized to support at least 4 wavelengths
- OM5 designation
- Backwards compatible
  - Continue to support legacy 850nm OM4 applications
- No additional field testing required
- Field polished the same way as any other MMF
- Published 06/2016

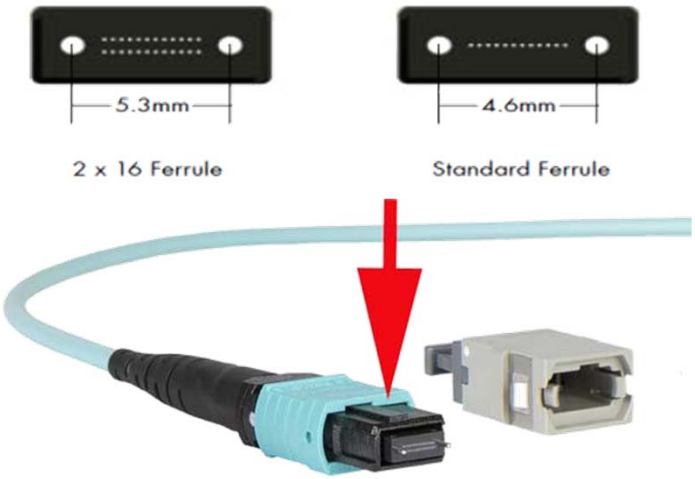




WDM operating principle

ANSI/TIA-604-18 (FOCIS 18)

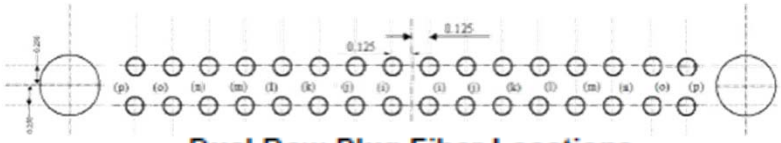
- 1x16 and 2x16 Multifiber Push-On connector
  - Has offset key
- 1x16 is similar to 12-fiber MPO & 2x16 similar to 24-fiber MPO (FOCIS 5)
    - Requires new FOCIS document because connector requires different distance between guide holes
- Supports 1st generation of 400 GbE over MMF



16 Fibers

Single Row Plug Fiber Locations

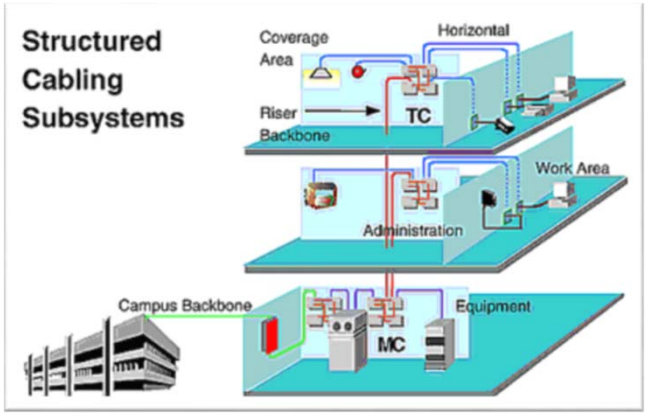
32 Fibers



Dual Row Plug Fiber Locations

Standards Integrating New Media Types

- ANSI/TIA-568.0-D Addendum 1
  (Generic Telecommunication Cabling)
  - Recognized fiber now stated as --multimode optical fiber cabling (ANSI/TIA-568.3-D) 2-fiber (or higher fiber count); (updated reference & recommendation of OM3 or higher
  - OM5 added to application MM fiber table
- ANSI/TIA-568.1-D Addendum 1
  (Commercial Building Telecommunication Cabling)
- ANSI/TIA-1179-A (Healthcare)
  - OM4 is minimum MMF recommended
  - Min 2 fiber backbones
  - Array connectors



Standards Integrating New Media Types

- ANSI/TIA-942-B (Datacenter)
  - Cabinets should be at least 48” deep & wider than 24”
  - Max length for direct attach cables in EDA – 7m (were 10m)
    - Direct attach cabling between rows is not recommended
  - Added MPO-16 / 32 & MPO-24
  - Recommends pre-terminated cabling

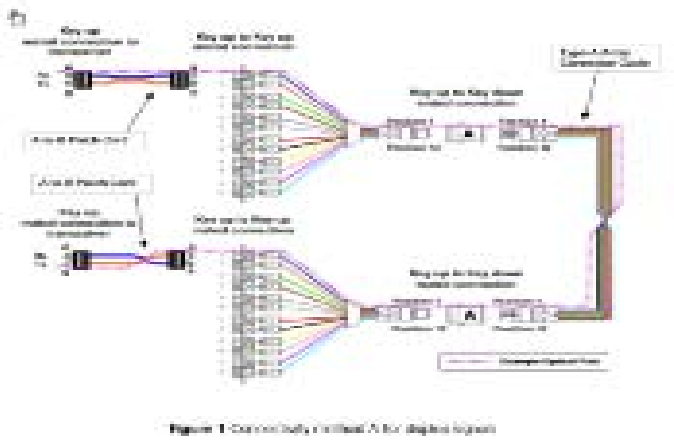
- ANSI/TIA-862-B Addendum 1 (Intelligent Building)
  - 2 fiber minimum

- ANSI/TIA-4966 Addendum 1 (Education)
  - OM4 or OM5

Optical Fiber Cabling Components

ANSI/TIA-568.3-D

- Now components & cabling (testing, polarity, etc.)
  - Polarity from TIA-568.0
  - Testing from TIA-568.0
  - Passive optical network component specs
- Splitters are part of budget
  - Specifies encircle flux launch conditions for testing MMF @ 850 nm
    - Eliminates testing @ 1300 nm
  - Raises min. return loss of SM connections & splices from 26 dB to 35 dB



Optical Fiber Cabling Components

ANSI/TIA-568.3-D continued….

- Lowers OM3 & OM4 attenuation @ 850nm to 3.0 dB/km
- Accounts for insertion loss of reference-grade test conditions
- Demotes OM1, OM2 & OS1 to not-recommended
- Adds specification for wideband multimode fiber
- Adds specification for OSP microduct cable
- Published 09/2016

In Process & New Work

Optical Fibers and Cables

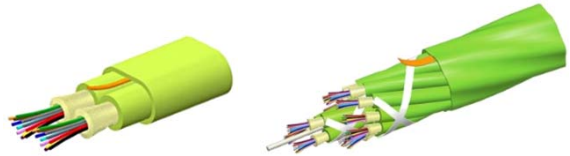
Ongoing work:

Revising TIA-598D

- Addendum 1: Specs for colors 13-16
  - TG formed for round robin on color measurement for colors 13-16;
  - 2nd industry ballot
- Addendum 2: Jacket color for WBMMF
  - Approval of Lime for jacket color for OM5 fiber applications.

Table 1 - Individual fiber, unit, and group identification

Position #	Base color/tracer per TIA	Abbreviation/print legend
1	Blue	1 or BL or 1-BL
2	Orange	2 or OR or 2-OR
3	Green	3 or GR or 3-GR
4	Brown	4 or BR or 4-BR
5	Slate	5 or SL or 5-SL
6	White	6 or WH or 6-WH
7	Red	7 or RD or 7-RD
8	Black	8 or BK or 8-BK
9	Yellow	9 or YL or 9-YL
10	Violet	10 or VI or 10-VI
11	Rose	11 or RS or 11-RS
12	Aqua	12 or AQ or 12-AQ
13	Lime	13 or LM or 13-LM
14	Tan	14 or TN or 14-TN
15	Olive	15 or OL or 15-OL
16	Magenta	16 or MG or 16-MG
17	Blue with Black Tracer	17 or D/BL or 17-D/BL[a)]
18	Orange with Black Tracer	18 or D/OR or 18-D/OR
19	Green with Black Tracer	19 or D/GR or 19-D/GR
20	Brown with Black Tracer	20 or D/BR or 20-D/BR
21	Slate with Black Tracer	21 or D/SL or 21-D/SL



Optical Fiber Systems

Ongoing work:

TIA-568.3-D Addendum 1

Scope:

- Use of OM5 name
- Use of OS1a name
- Color for OM5 connecting hardware
- Connecting hardware color definitions
- Reference-grade to standard-grade loss allocation
- MPO testing

Table 11 - Test cord loss allowance

Mated termination combination	Multimode (dB/connection)	Single-mode (dB/connection)
Reference-grade to standard-grade	0.5[1]	0.5[2]
Standard-grade to standard-grade	0.75	0.75

Note 1 – This value is taken from ANSI/TIA-526-14, Table F.1.
Note 2 – This value is taken from ANSI/TIA-526-7, Table G.1.

New Work

- ANSI/TIA-570-C (Residential)
  - Submitted for 2nd industry ballot

- ANSI/TIA-758-B (OSP)
  - Project request to start C revision approved
  - 1st industry ballot based on editors schedule

- Places of Assembly Task Group
  - Working on potential standard for Airports, Stadiums, Theaters, etc.

Additional Information Available

FOTC Website

Summary of current TIA standards

ANSI/TIA-568.0-D	GENERIC TELECOMMUNICATIONS CABLING FOR CUSTOMER PREMISES	09/14/15
ANSI/TIA-568.1-D	COMMERCIAL BUILDING TELECOMMUNICATIONS INFRASTRUCTURE STANDARD	09/09/15
*ANSI/TIA-568-C.2	BALANCED TWISTED-PAIR TELECOMMUNICATIONS CABLING AND COMPONENTS STANDARDS	04/2010
ANSI/TIA-568-C.2-1 (category 8 Addendum)	BALANCED TWISTED-PAIR TELECOMMUNICATIONS CABLING AND COMPONENTS STANDARD, ADDENDUM 1: SPECIFICATIONS FOR 100Ω CATEGORY 8 CABLING	06/30/16
ANSI/TIA-568.3-D	OPTICAL FIBER CABLING COMPONENTS STANDARD	09/16
ANSI/TIA-568-C.4	BROADBAND COAXIAL CABLING AND COMPONENTS STANDARD	7/11/11
ANSI/TIA-569-D	TELECOMMUNICATIONS PATHWAYS AND SPACES	11/19/15
ANSI/TIA-569-D-1	TELECOMMUNICATIONS PATHWAYS AND SPACES-ADDENDUM 1, REVISED TEMPERATURE AND HUMIDITY REQUIREMENTS FOR TELECOMMUNICATIONS SPACES	10/21/16
*ANSI/TIA-570-C	RESIDENTIAL TELECOMMUNICATIONS INFRASTRUCTURE STANDARD	08/16/12
ANSI/TIA-604-18	FOCIS 18 Fiber Optic Connector Intermateability Standard- Type MPO- 16	11/23/2015
*ANSI/TIA-606-B	ADMINISTRATION STANDARD FOR TELECOMMUNICATIONS INFRASTRUCTURE	6/22/12
TIA-606-B-1 (Addendum to TIA-606-B)	ADMINISTRATION STANDARD FOR TELECOMMUNICATIONS INFRASTRUCTURE ADDENDUM 1- AUTOMATED INFRASTRUCTURE	12/23/2015

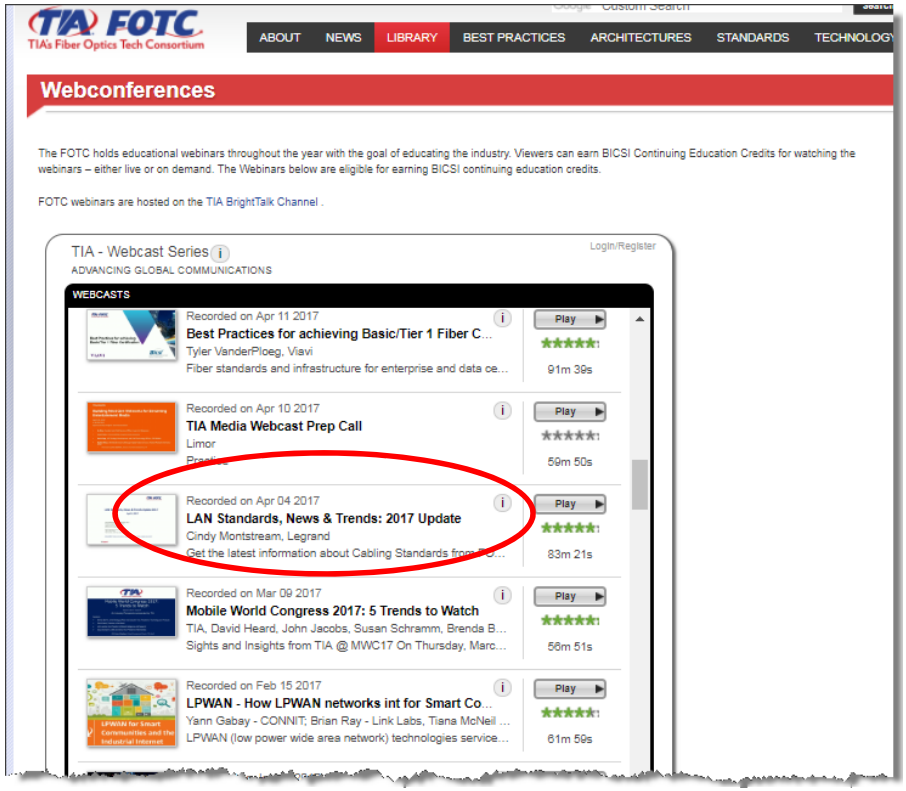
http://www.tiafotc.org

FOTC Website

LAN Standards, News & Trends 2017

http://www.tiafotc.org

Library >Webconferences



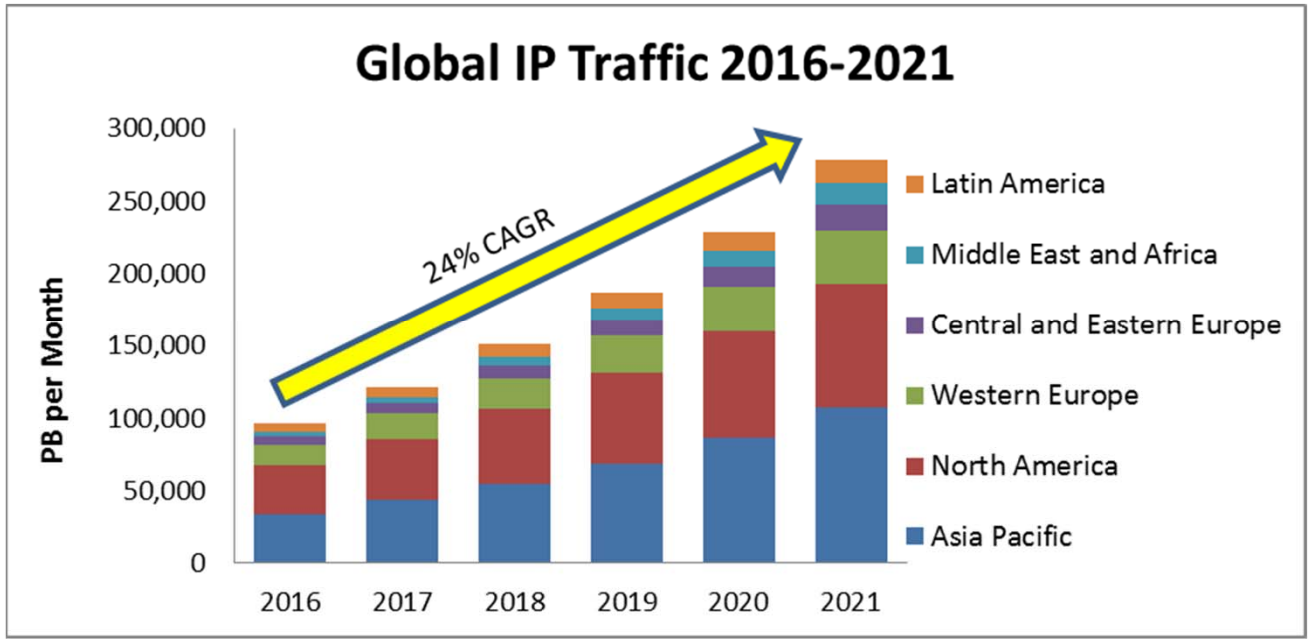
Fiber Industry Trends

John Kamino, RCDD

OFS

jkamino@ofsoptics.com

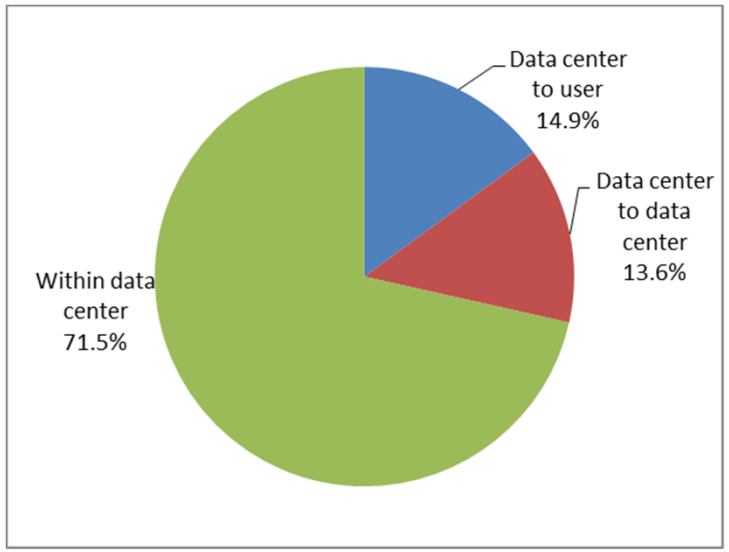
Network IP Traffic Growth

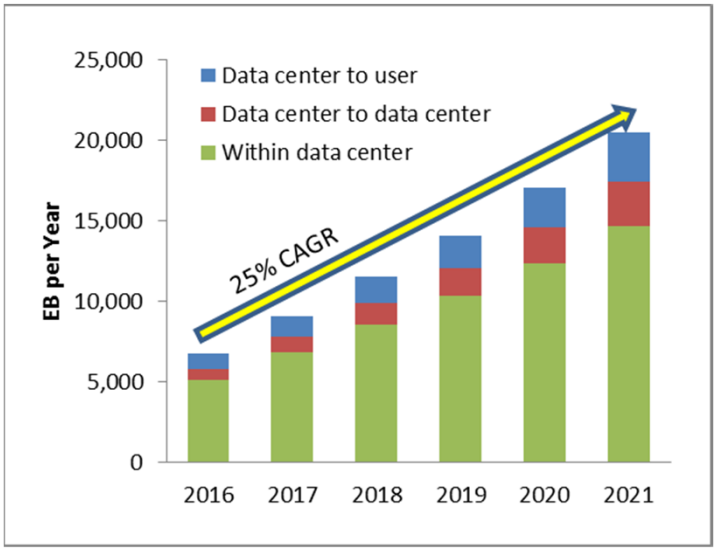


- Global IP traffic will reach 3.3 zettabytes (10^{21}) per year in 2021. By 2020, global IP traffic will reach 2.3 ZB per year
- Global IP traffic will have increased by 127X from 2005 to 2021
- By 2021, PCs will only account for 25% of traffic, while smartphones will account for 33% of traffic.
- Wireless and mobile devices will account for 63% of traffic in 2021, up from 51% in 2016.

"Cisco Visual Networking Index :
Forecast and Methodology, 2016-2021"
6/6/2017

Data Center Traffic

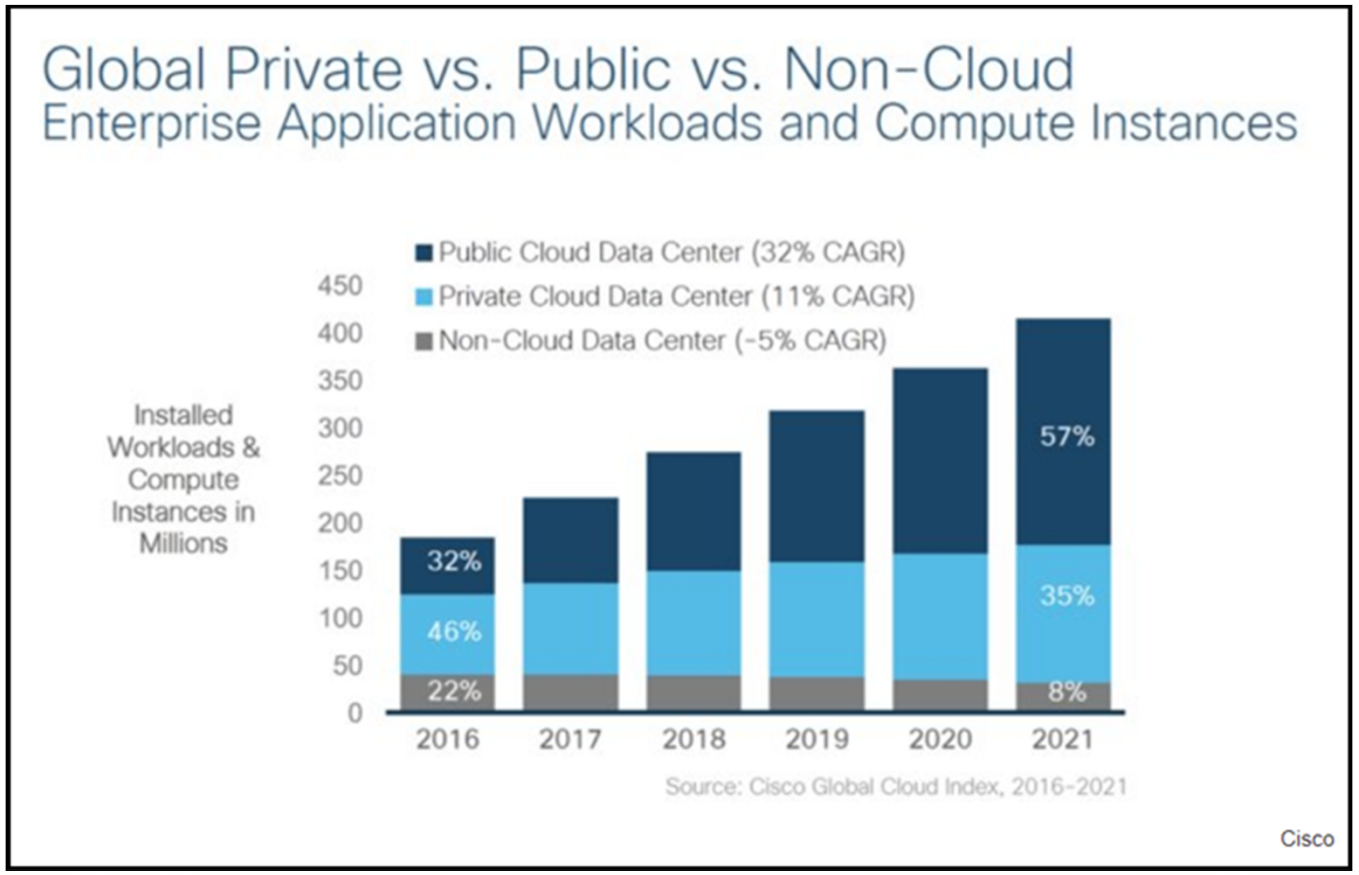




- Global data center traffic will reach 20.6 Zettabytes in 2021, from 6.8 Zettabytes in 2016
- Total East-West traffic will be 85%
- Traffic is growing at a 25% CAGR

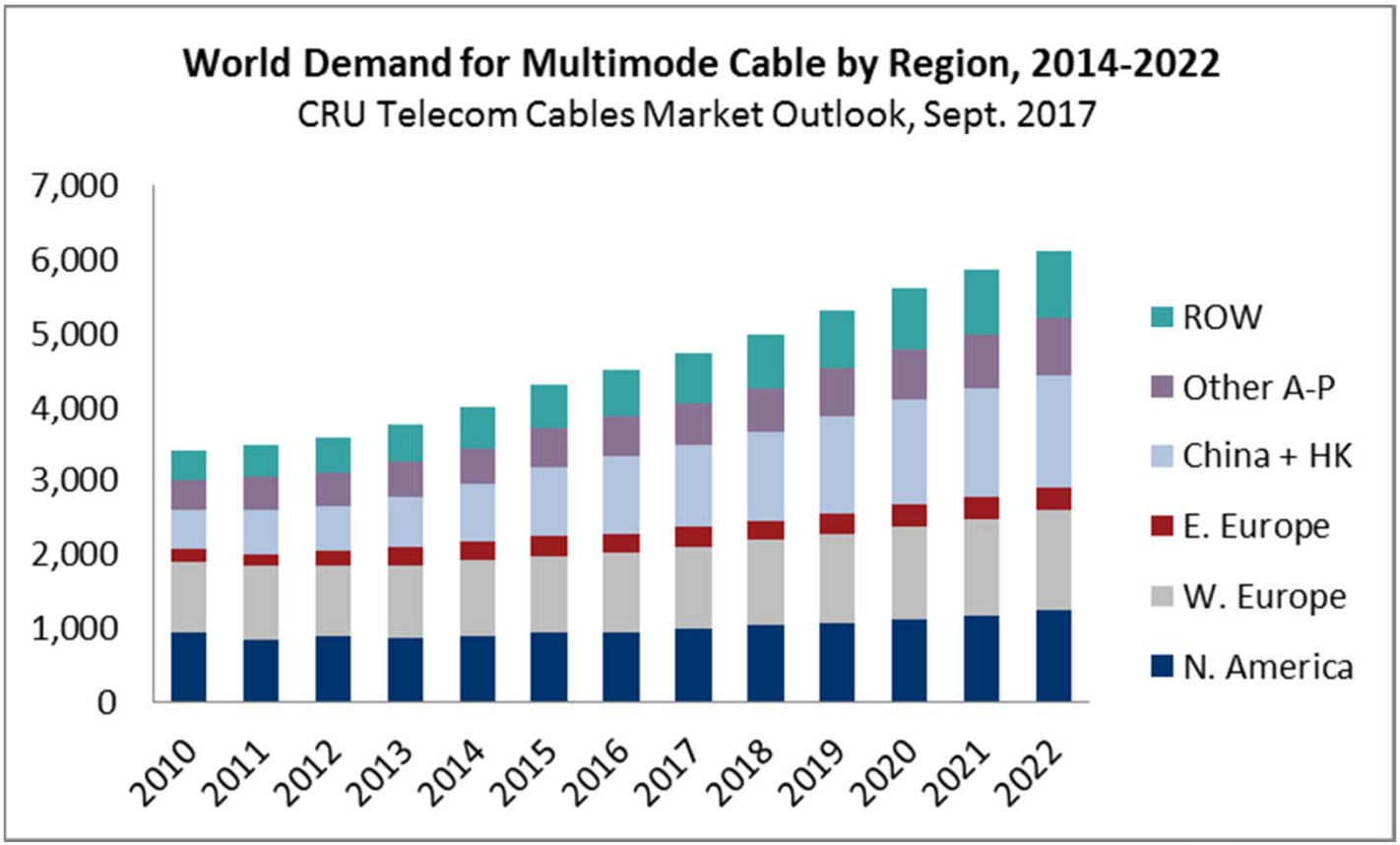
Source: Cisco Global Cloud Index: Forecast and Methodology, 2016-2021 January 2018

Global Data Center Traffic Growth

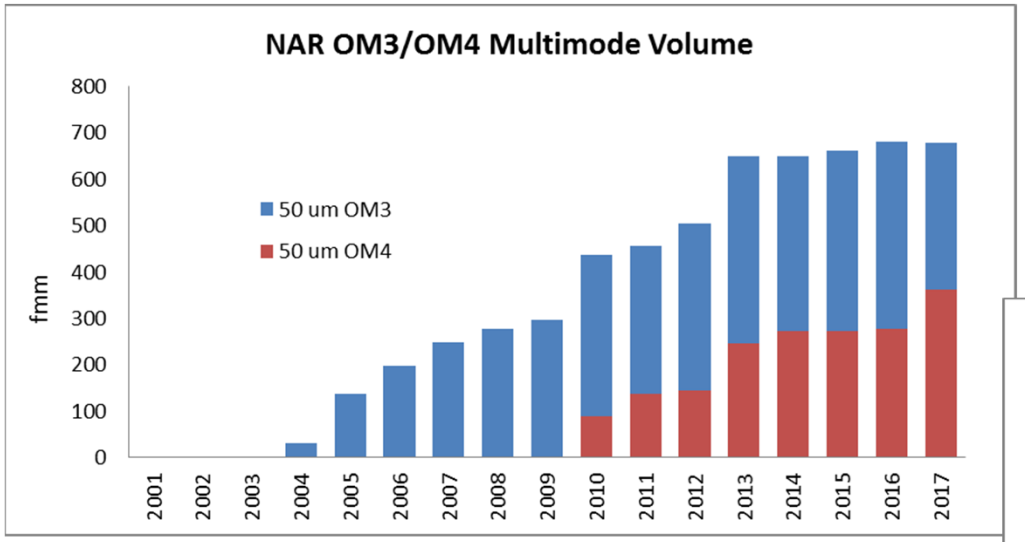


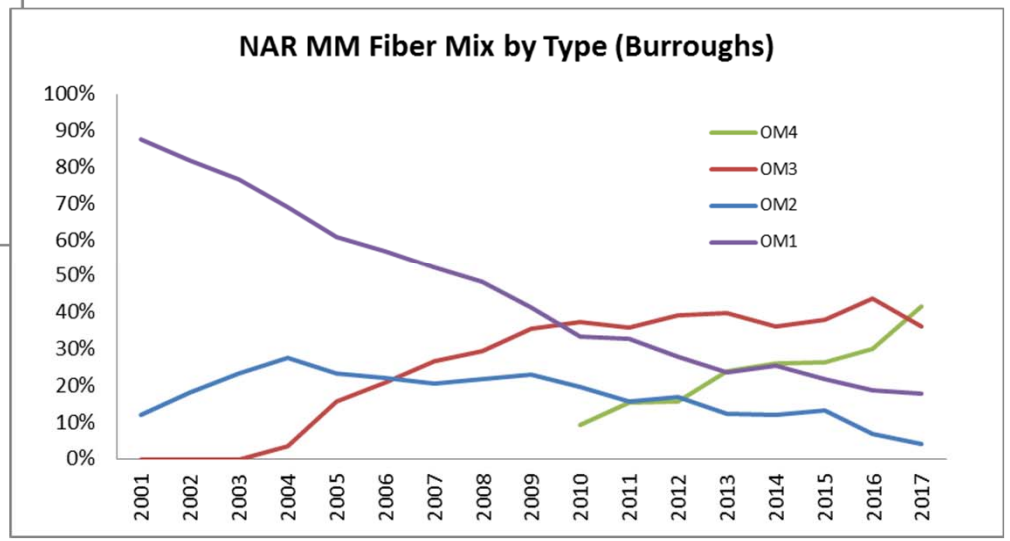
Worldwide Multimode Cable Demand by Region

All this demand combines to create multimode volume growth!



Burroughs North America Multimode Fiber Shipments

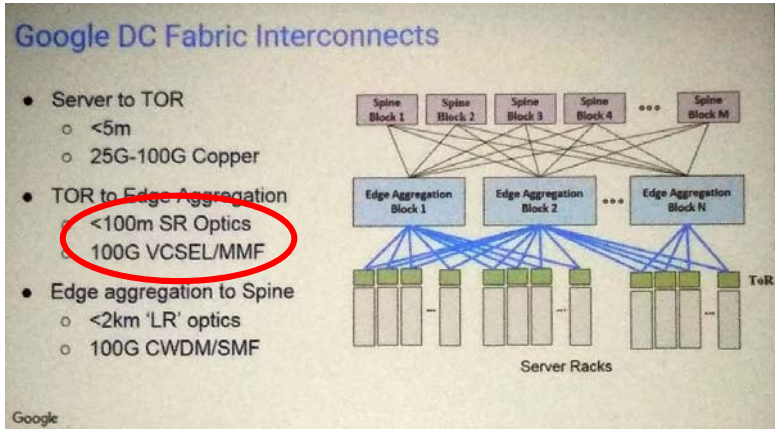


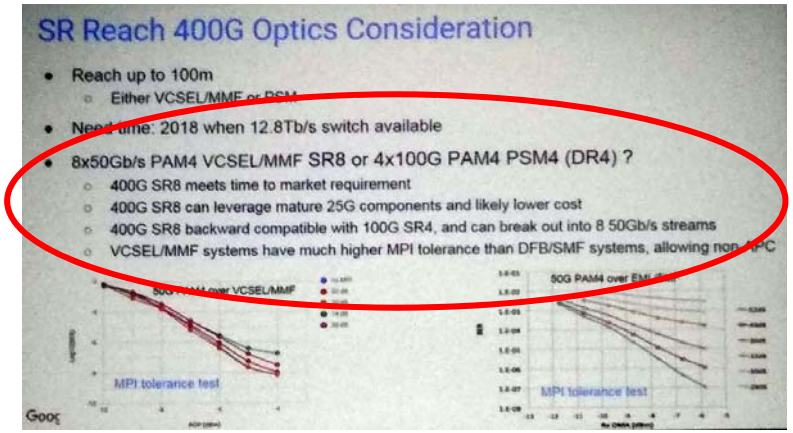


Source: Burroughs Multimode Fiber Reports

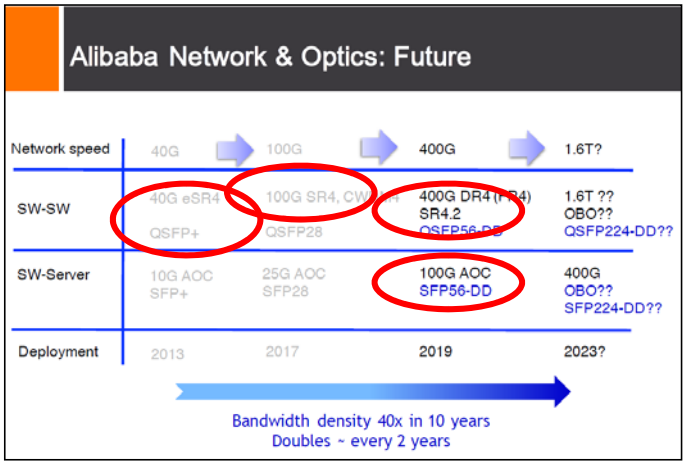
The hyperscale cloud market will continue to deploy multimode fiber!

- Google
  - Deploying 100GBASE-SR4
  - Roadmap to 400GBASE-SR8
  - Z. Shen of Google proposed 400GBASE-SR8 for 802.3cm
- Alibaba
  - Deploying 100GBASE-SR4
  - Roadmap to 400GBASE-SR4.2
- Baidu
  - Deploying 100GBASE-SR4
  - Roadmap to 400GBASE-SR4.2
- Other Big Cloud in US
  - Growing interest for 400G-SR4.2, including breakout





X. Zhou, Google, OFC 2018, San Diego



C. Xie, Alibaba OIF Q4 2018 Shanghai

C. Gang, Baidu, 2018 Optinet, Shanghai

Conclusions

- Bandwidth demand continues to grow
- Multimode demand is growing
- Multimode fiber demand is moving to higher grade fiber types
  - OM4 fiber has the largest share (by type) in North America
- Hyperscale data centers are looking to deploy multimode fiber in next generation data centers

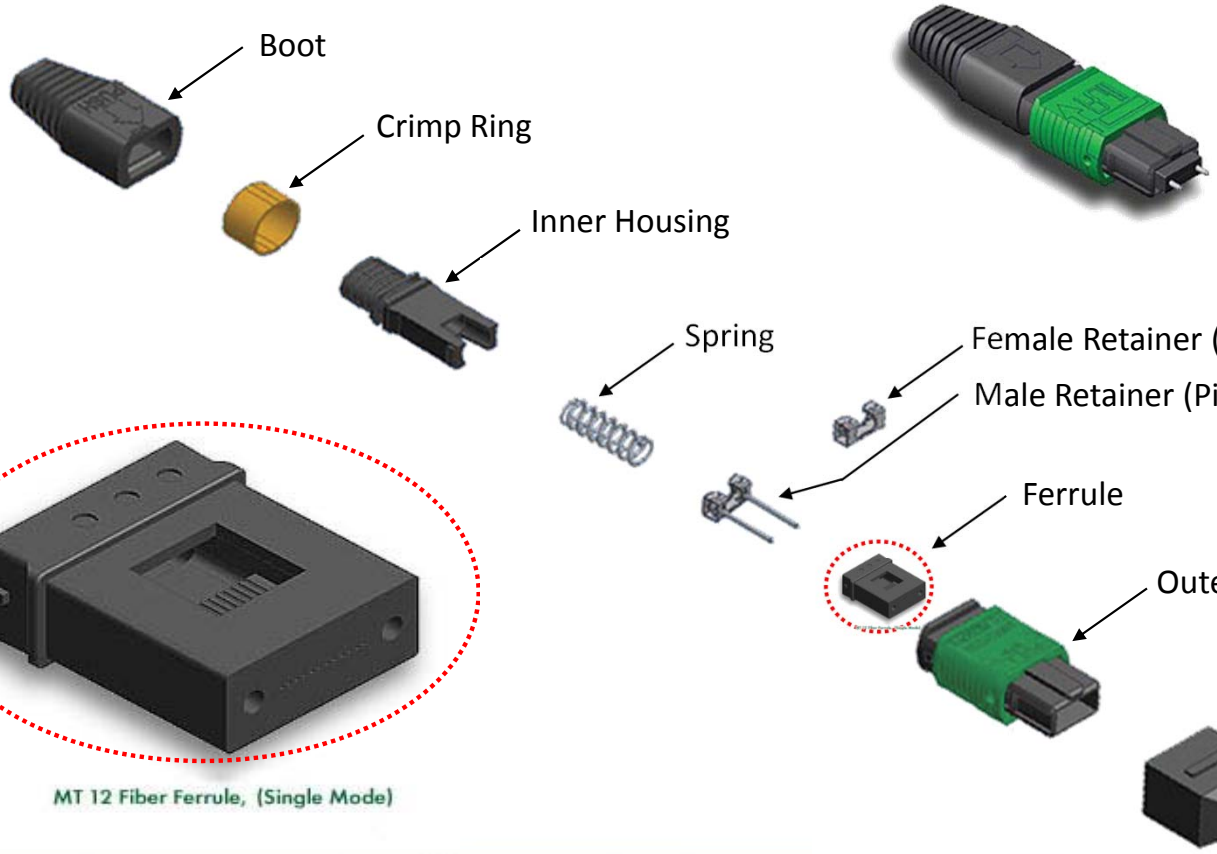
MPO Technology

David Asta, RCDD

Panduit

PANDUIT

Anatomy of an MPO



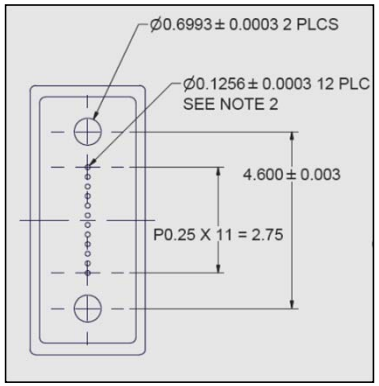
MPO 'Ferrule'

MT Ferrule Technology

Optical performance is based on:

- Fiber Alignment (axial & angular based on ferrule & guide pin)
  - True Position of fiber-holes in the ferrule relative to alignment pin holes
  - Tolerance of the alignment pins
  - Diameter tolerance of fiber holes and alignment pin holes
- Fiber Tip Contact (endface geometry + connector spring force)
- Fiber Tip Cleanliness & Quality

The fiber alignment is <u>independent</u> of the adapter!



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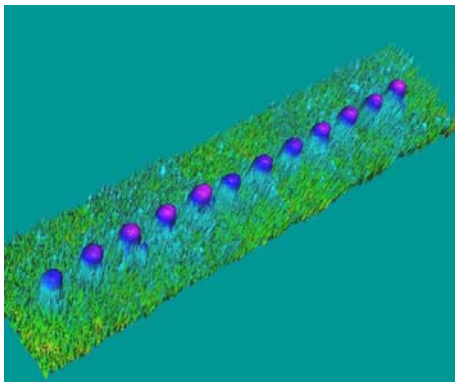

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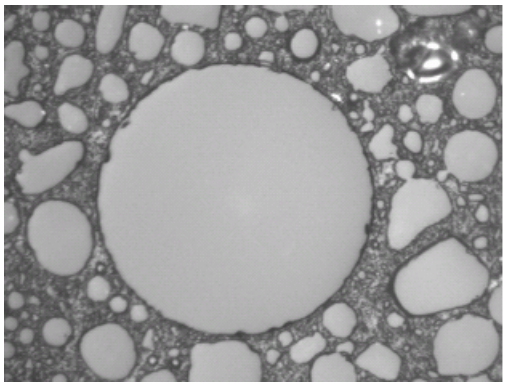


Connector Component Quality | **Endface Quality** | **Fiber Tip Quality**

TIA Connectivity Definition for MPOs

The MPO connector family is defined by two existing standards. Internationally the MPO is defined by IEC-61754-7. In North America the MPO is defined by TIA-604-5 (also called FOCIS 5).

FOCIS 18 presents the intermateability standard for connectors with the commercial designation of MPO-16 that support 16 fibers per row of fibers, and is used as an addendum to TIA/EIA-604, *(*2015 Edition, November 23, 2015)

4f Through 72f Fiber MPO Standard

TIA STANDARD

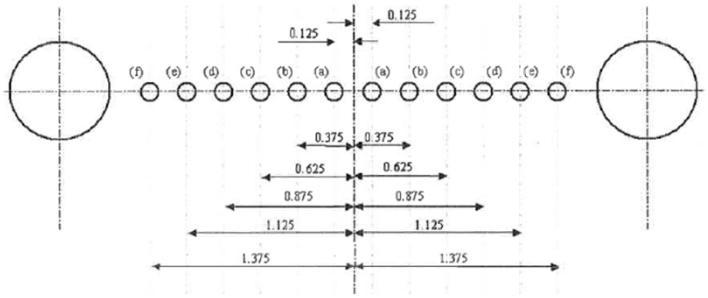
Fiber Optic Connector Intermateability Standard, Type MPO

TIA-604-5-D

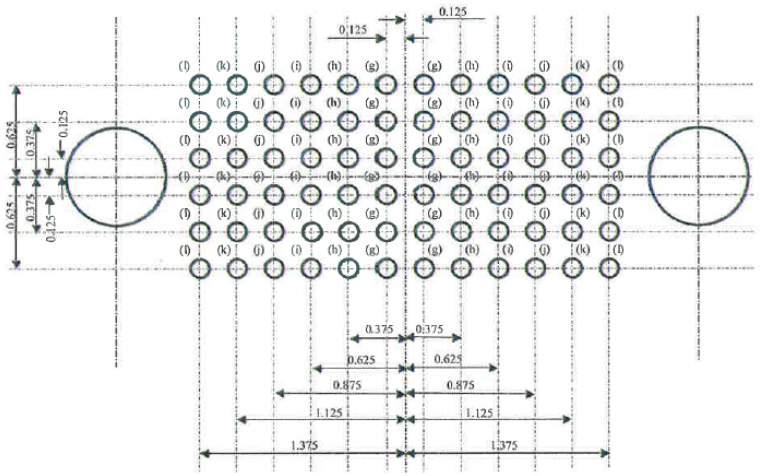
April 2007

TELECOMMUNICATIONS INDUSTRY ASSOCIATION

Single Row Plug
Option m = 1



Six Row Plug
Option m=6



What Does the Standard Say About MPO?

Plug designation

The complete designation for a FOCIS 5 connector plug is:

FOCIS 5P-n-k-a-c-t

where:

P designates that it is the plug

n is the number of fibers

k defines the keying configuration

a is the angle of contact

c designates alignment pins or holes

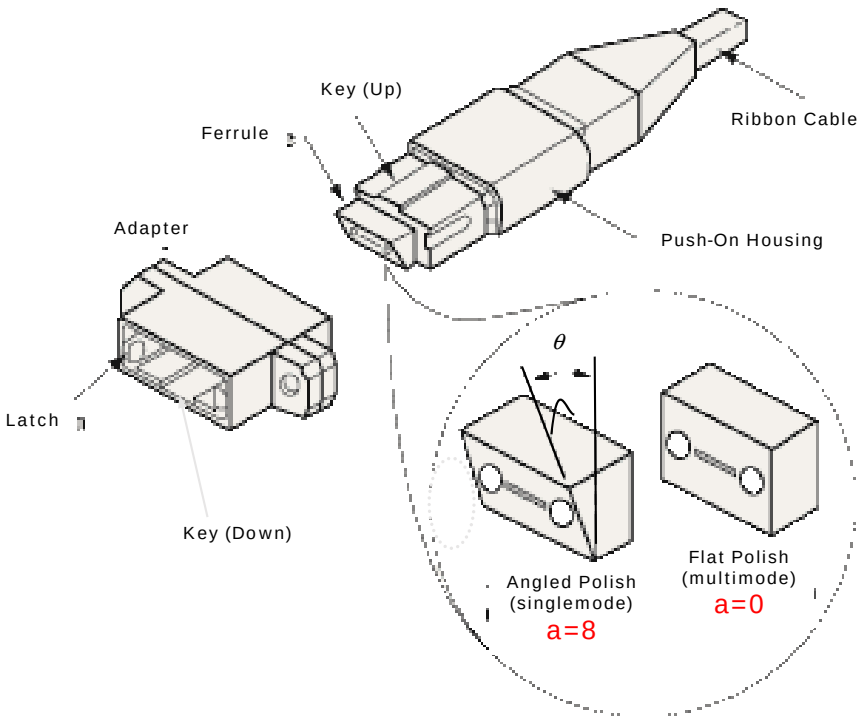
t alignment pin/hole diameter

Number of Fibers

Values have defined for the number of fibers

4, 6, 8, 10, 12, 16, 20, 24….

Singlemode Variant



- Singlemode MTP connectors are polished at a nominal eight (8) degrees with respect to the connector key
- Return Loss from the angled interface is maximized (>55dB)
- Assures that the normal Key Up/Key-Down adapter sleeve aligns the angled surfaces to compliment each other
- Precludes the use of Key Up/Key Up adapters for the single application (unless two different connector polishing orientations are made – not in the FOCIS document for SM)

Two Different MPO/MTP Adapters

Adapter designation

Designation for a FOCIS 5 connector adapter is:

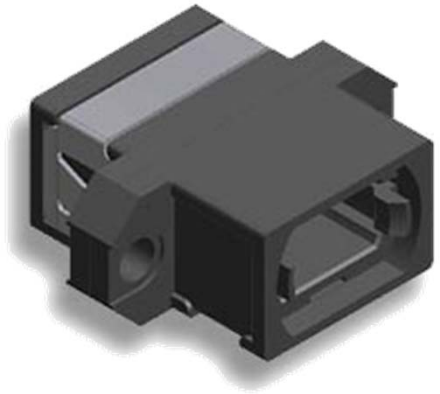
FOCIS 5A-k-m

where:

A designates that it is the adapter

k defines the keying configuration

m defines the mounting configuration



Adapter Keying Options

Two options are defined for the adapter keying configuration:

k = 1 - standard keying configuration for FOCIS 5 adapters

k = 2 - alternative keying configuration

TIA Connectivity Definition for MPOs

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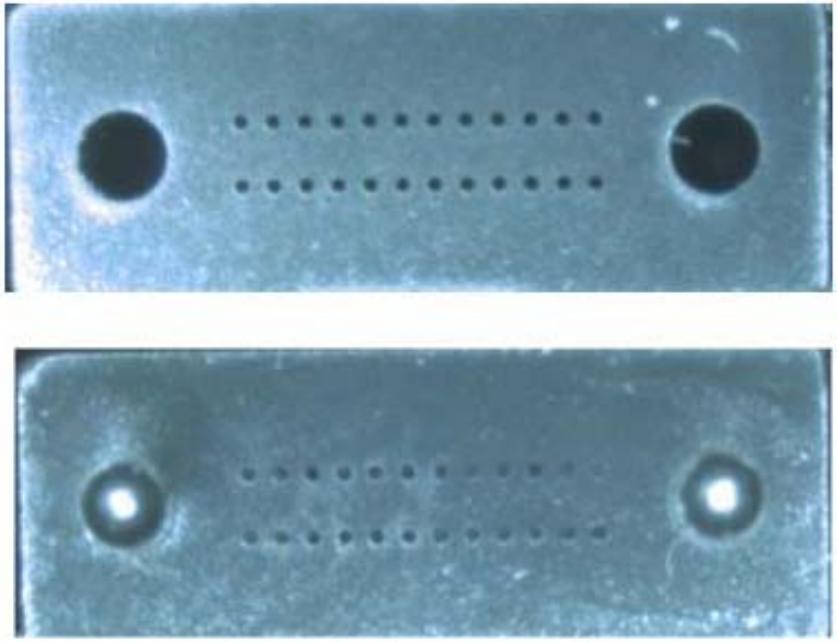
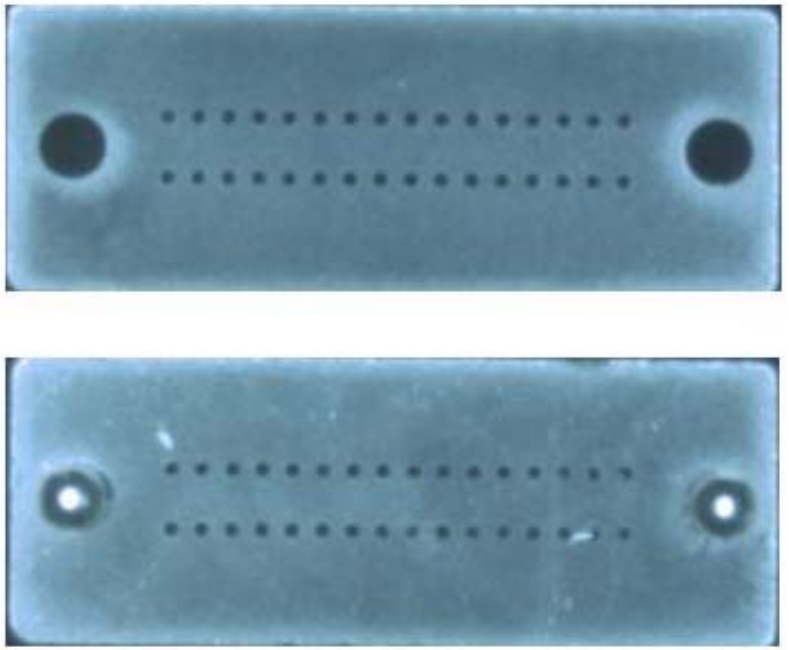
FOCIS-5 & FOCIS-18 MPOs



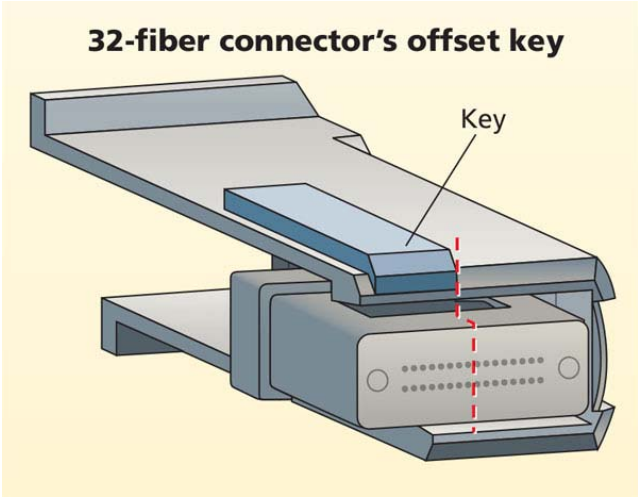
FOCIS-5, 24 fiber position connector



FOCIS-18, 32 fiber position connector

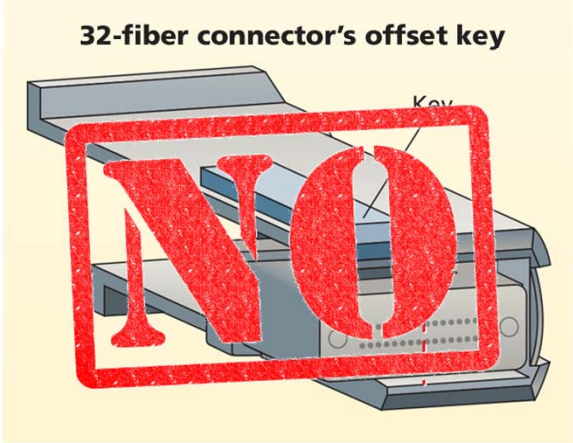
TIA Connectivity Definition for FOCIS-18 MPOs

- Published in Q4 2015
- Same MT ferrule footprint & fiber pitch in X & Y axes
- Different pin/hole diameter & pin pitch
- Limited to two rows maximum
- FOCIS 18 defines a flat polish only
- Flat is the norm for all MPO MM
- APC is the norm for all MPO SM
- Offset key to prevent mating with FOCIS 5 connectors
- FOCIS 18 MM connectors available in 1x16 (SR8) and 2x16 formats (SR16)



“Brute Force” - Multiple Lanes MPO

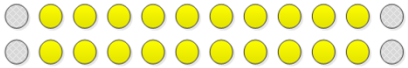
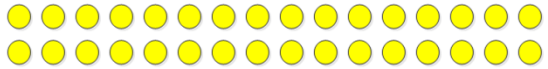
- Move toward 16 fiber units? 400GBASE-SR16
- 32/16-pin MPO connectors (TR 42.13)
  - Polarity descriptions that cover n-number of fiber units (TR 42.11)
  - 4 new fiber colors to support 16-fiber ribbons bundles (TR 42.12)
- Likely upgrade paths (MM) results in units of 4 fibers:
  - 40G ÷ 10G per fiber = 8 (2x4F) fibers (40GBASE-SR4)
  - 100G ÷ 25G per fiber = 8 (2x4F) fibers (100GBASE-SR4)
  - 400G ÷ 25G per fiber = 32 (2x16F) fibers (400GBASE-SR16)
  - 400G ÷ 50G per fiber = 16 (2x8F) fibers (400GBASE-SR8)
  - 400G ÷ 50G per fiber = 8 (2x4F) fibers (2 lambda = 400GBASE-SR4,2)
  - 400G ÷ 25G per fiber = 8 (2x4F) fibers (4 lambda = 400GBASE-SR4,4)



8 FIBER
(BASE8)

SFP/QSFP Fiber 'Migration'

SWDM or CWDM

	10G/Fiber	25G/Fiber	25G/λ - 4λ/Fiber
10G		N/A	N/A
25G	N/A		N/A
40G		N/A	N/A
100G			
400G	N/A		

MPO Configurations

Rodney Casteel, RCDD, DCDC, NTS, OSP

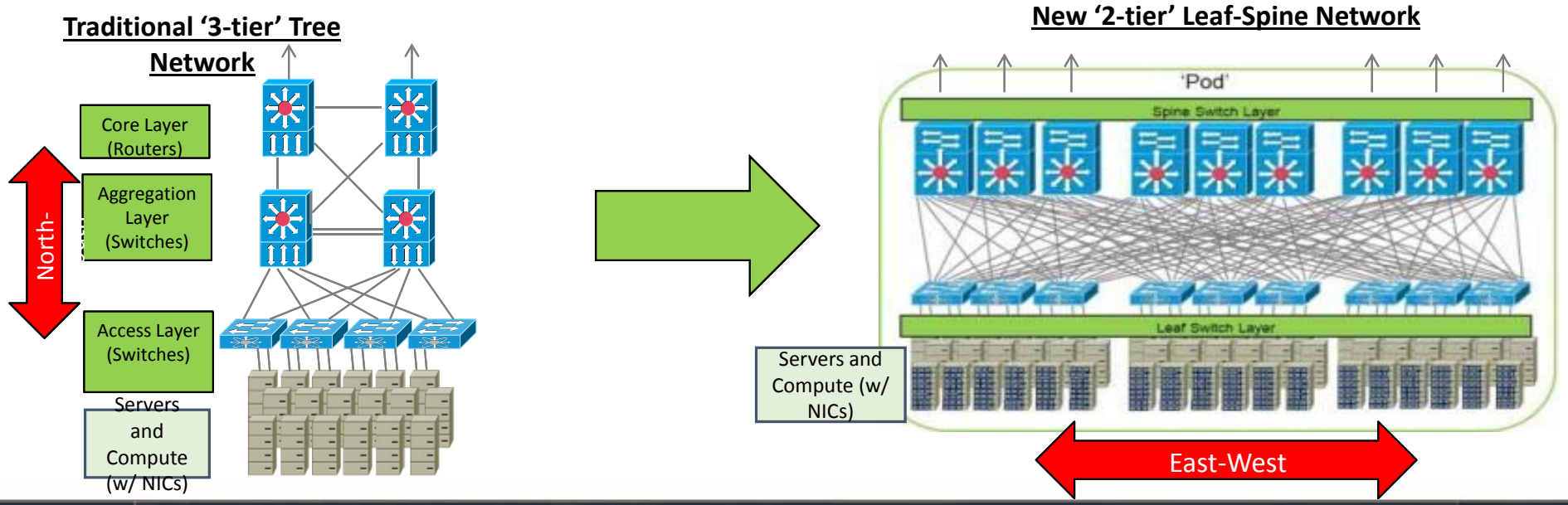
CommScope - Sr. Field Application Engineer

Chair TIA Fiber Optic Technology Consortium

COMMSCOPE®

Hyperscale Architectures Adapted for Enterprise Data Centers

- Historically Enterprise has been a 3-tier topology – aggregation and blocking architecture
- Cloud data center networks are 2-tier topology
  - Optimized for East-West traffic
  - Workloads spread across 10s, 100s, sometimes 1000s of VMs and hosts
  - Higher degree (10-20X) of east-west traffic across network (server to server)



High Speed Migration Challenges

Application speeds are increasing

Channel lengths are shortening

Optical loss budgets are decreasing

More choices for media and connectivity

Growing infrastructure complexity

Standards provide limited guidance

What should your physical infrastructure do…?

Support current and future applications

Optimize channel distances

Allow for additional connections

Simplify optical media selection

Provide for automated management

Enable flexible topologies

Data Center Multimode Speed Roadmap

# lanes				
16		**400GBASE-SR16**		
10	**100GBASE-SR10**			1 Tb/s?
8				800 Gb/s?
4	**40GBASE-SR4**	**400G-SWDM4?**	**400G-4.2?**	400 Gb/s?
2			**400G-SWDM4?**	200 Gb/s?
1	**40GBASE-SWDM4**	**100G-SWDM4**	**200G-SWDM4?**	100 Gb/s?
Lane rate >	10 Gb/s	25 Gb/s	50 Gb/s	100 Gb/s
Encoding >	NRZ		PAM-4	

Multimode 40G/100G Applications

Maximum reach based on Standards, MSAs and/or vendor specifications

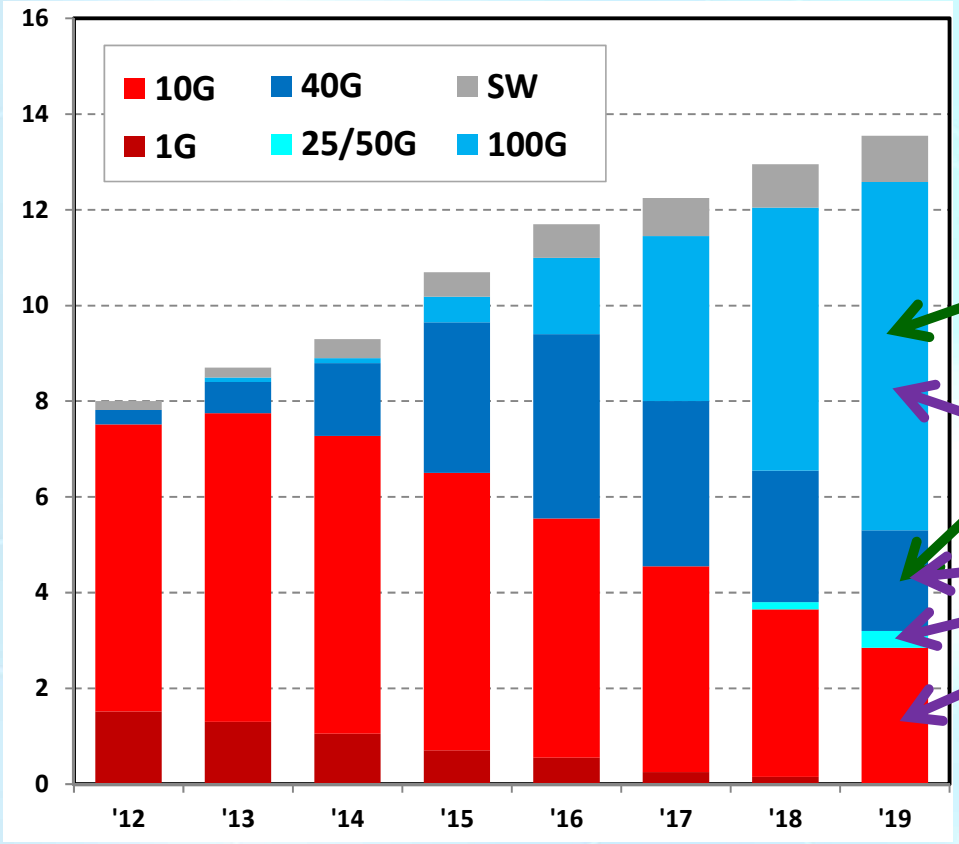
	Standard/Spec/MSA	# fibers	maximum distance
40G	40GBASE-SR4	(8)	OM3 100 m; OM4/OM5 150 m
	40G-BiDi	(2)	OM3 100 m*; OM4 150 m*; OM5 200 m
	40G-eSR4	(8)	OM3 300 m; OM4/OM5 400 m
	40G-SWDM4	(2)	OM3 240 m*; OM4 350 m*; OM5 440 m
100G	100GBASE-SR4	(8)	OM3 70 m; OM4/OM5 100 m
	100GBASE-SR10	(20)	OM3 100 m; OM4/OM5 150 m
	100GBASE-SR2	(4)	OM3 70 m; OM4/OM5 100 m
	100G-eSR4	(8)	OM3 200 m; OM4/OM5 300 m
	100G-BiDi	(2)	OM3 70 m*; OM4 100 m*; OM5 150 m
	100G-SWDM4	(2)	OM3 75 m*; OM4 100 m*; OM5 150 m
	100G-eSWDM4	(2)	OM3 200 m*; OM4 300 m*; OM5 400 m

*NOTE: OM3/OM4 effective modal bandwidth only specified at 850 nm

"In addition to supporting the same 850nm and 1300nm applications as OM4, ***OM5 provides advantage in the support of future applications using WDM in the wavelength range 850nm to 953nm***" ***(ISO/IEC 11801-1)***

Data Center Market: Ethernet Switch Rev. ($B)

Revenue By Port Speed



Source: Dell'Oro – Oct 2015 (public webinar)

Parallel

Duplex

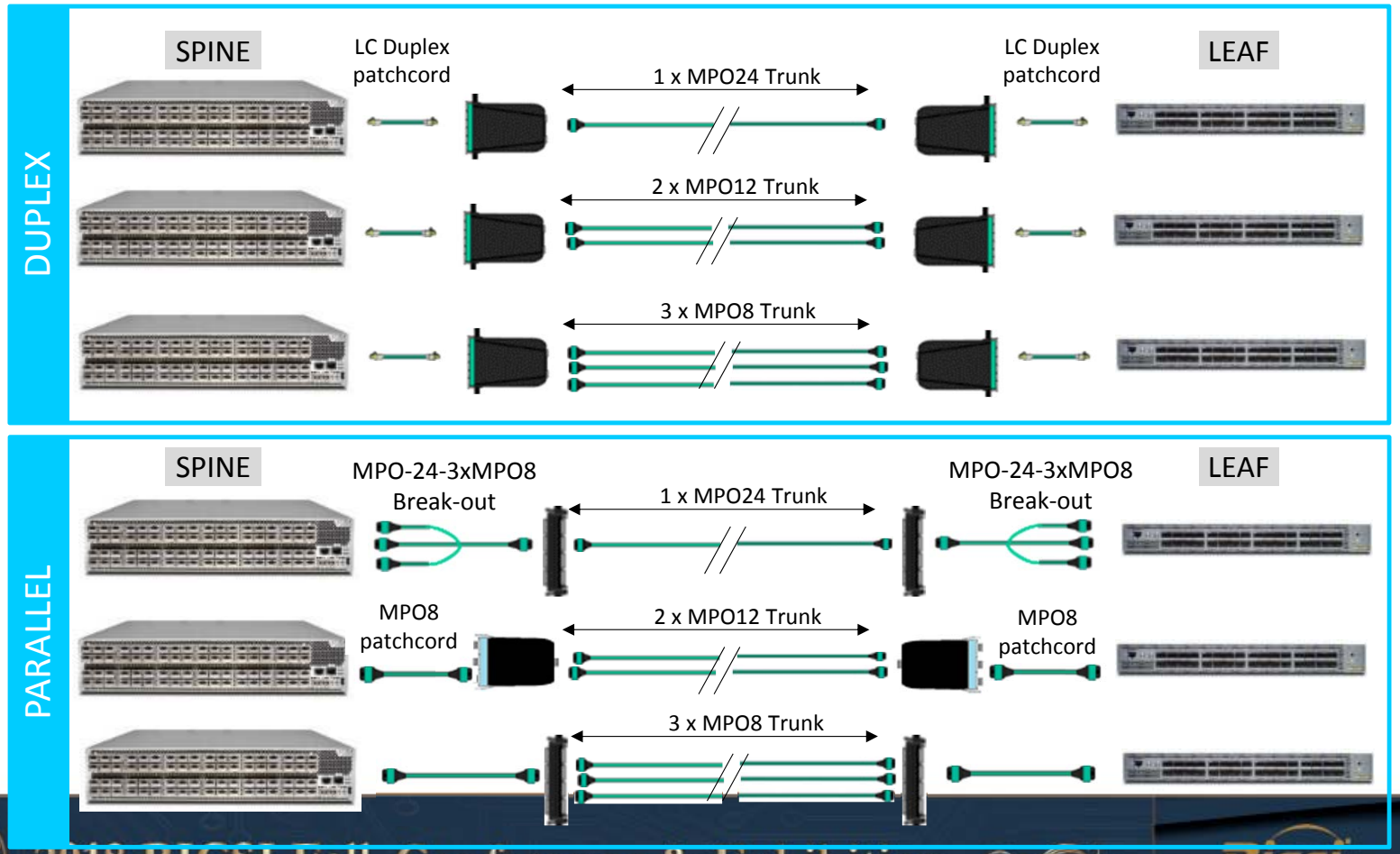
Data Center connectivity through 2020+ likely to be mix of duplex and parallel

Which MPO for High Speed Migration?

MPO-24	MPO-12	MPO-8
		
Future ready Lowest cost duplex support for multimode applications Highest panel density	**Large installed base** Existing multimode and singlemode preterm deployments Familiar interface and trunks	**Supports QSFPs** For multimode and singlemode transceivers and breakouts Lowest panel density

MPO24 vs. MPO12 vs. MPO8 for Multimode Trunks

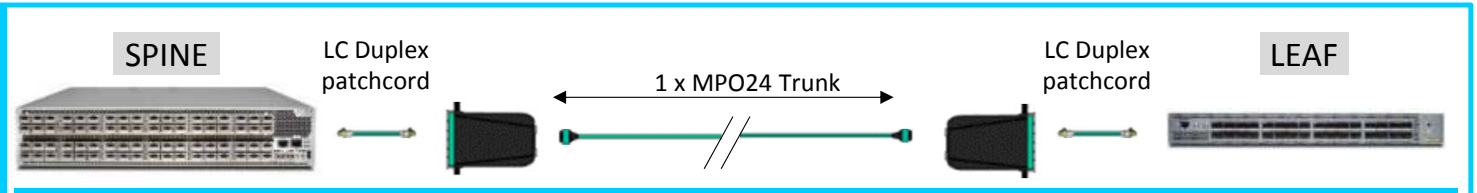
Leaf-Spine Applications on multimode fiber	
Application	**#Fibers**
10GBASE-SR	**2**
40G-SR4	**8**
40G-BiDi	2
40G-SWDM4	2
100G-SR4	**8**
100G-SR2	***4***
100G-SWDM4	2
100G-BiDi (?)	2
200G-SR4	***8***
200G-SR1.2 (?)	2
400G-SR4.2/4.4 (?)	8
400G-SR2.4 (?)	4
400G-SR1.4 (?)	2



Advantages of MPO24 for Multimode Trunks

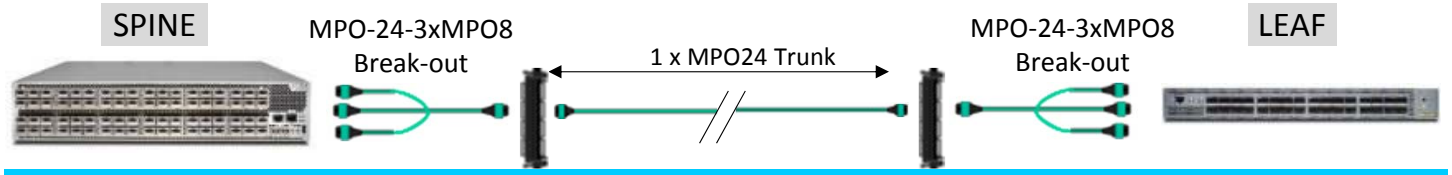
Leaf-Spine Applications on multimode fiber	
Application	**#Fibers**
10GBASE-SR	**2**
40G-SR4	**8**
40G-BiDi	2
40G-SWDM4	2
100G-SR4	**8**
100G-SR2	***4***
100G-SWDM4	2
100G-BiDi (?)	2
200G-SR4	***8***
200G-SR1.2 (?)	2
400G-SR4.2/4.4 (?)	8
400G-SR2.4 (?)	4
400G-SR1.4 (?)	2

DUPLEX



Fastest Installation
Best pathway efficiency
Lowest cost

PARALLEL



Fastest Installation
Best pathway efficiency
Highest panel density
Lowest cost

High Speed Configurations

8f Duplex

High Speed Configurations

8f QSFP

High Speed Configurations

12 f Duplex

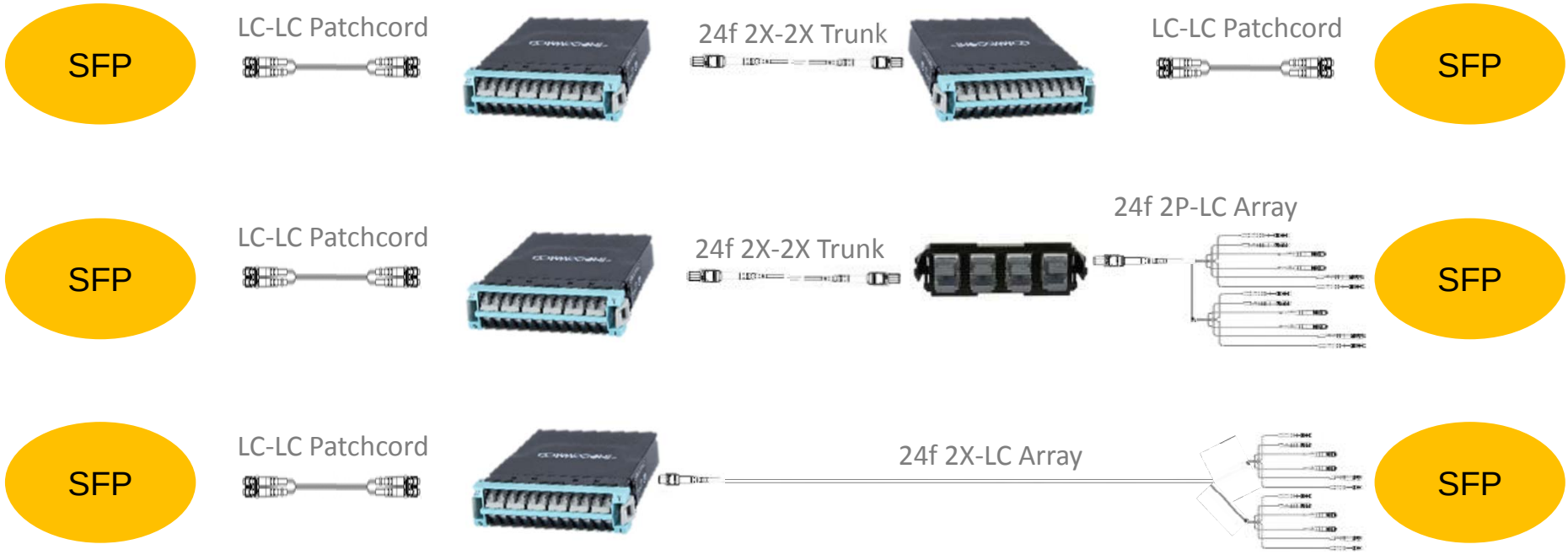
High Speed Configurations

12f QSFP

QSFP	8f QP-QP Patchcord		12f MX-MX Trunk	 8f QP-QP Patchcord	QSFP
QSFP	8f QP-QP Patchcord		12f MX-QP 2X3 Array		QSFP
QSFP	8f QP-QP Patchcord		12f MX-MX Trunk	 12f MP-QP 2X3 Array	QSFP
QSFP	12f MP-QP 2X3 Array		12f MX-MX Trunk	 12f MP-QP 2X3 Array	QSFP
QSFP	12f MP-QP 2X3 Array		12f MX-QP 2X3 Array		QSFP

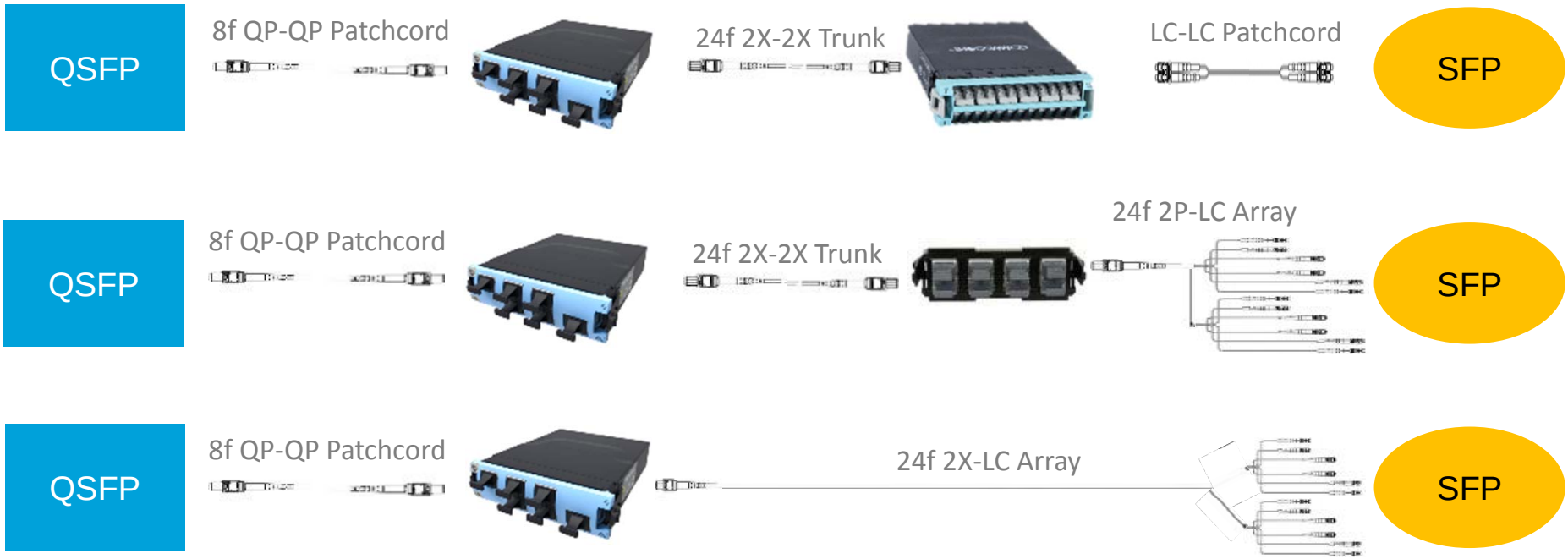
High Speed Configurations

24f Duplex



High Speed Configurations

24f to QSFP Duplex



High Speed Configurations

24f QSFP

QSFP	8f QP-QP Patchcord		24f 2X-2X Trunk		8f QP-QP Patchcord	QSFP
QSFP	8f QP-QP Patchcord		24f 2X-2X Trunk		24f 2P-QP Array	QSFP
QSFP	8f QP-QP Patchcord		24f 2X-QP Array			QSFP
QSFP	24f 2P-QP Array		24f 2X-2X Trunk		24f 2P-QP Array	QSFP
QSFP	24f 2P-QP Array		24f 2X-QP Array			QSFP

Bottom Line

- There are a multitude of options for migrating to higher speeds
  - OM3, OM4, OM5, SM
  - MPO 8, MPO 12, MPO 24, MPO 16, MPO 32
  - Parallel & Duplex
  - SWDM, CWDM
  - Proprietary Options
- Need to ensure the strategy includes
  - Long term planning
  - Most efficient, cost effective and sustainable option
  - A solution that can be tested and validated

Fiber Testing & Inspection

Tyler Vander Ploeg, RCDD - VIAVI Solutions
Jim Davis - Fluke Networks
Romain Tursi - EXFO
Rob Gilberti - AFL

Agenda

- Connector Inspection & Cleaning (Guillaume Lavallee – EXFO)
- Tier 1 Testing (Jim Davis – Fluke Networks)
- Tier 2 Testing (Rob Gilberti – AFL)
- Testing MPO Connectivity (Tyler Vander Ploeg – VIAVI Solutions)
- Break (15 minutes)
- Hands On Training

Fiber Optic Connectors Inspection and cleaning

Romain Tursi
Product Specialist
EXFO

Connectors Come in Multiple Flavors

- Single fiber connectors

- Multifiber connectors

⇒ And both can co-exist in same architecture

No. 1 cause of network failures is BAD connectors

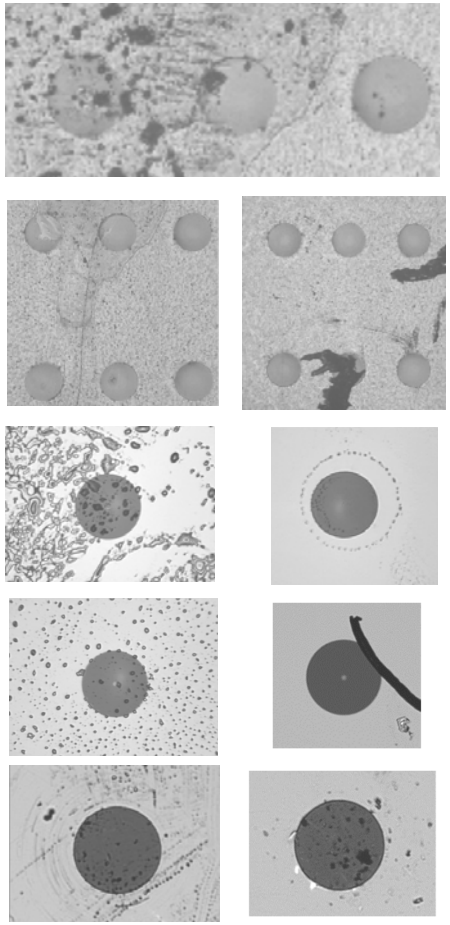
- NTT-Advanced Technology Research

80% Network owners report having connector issues

Why inspecting is important?

Not because it's nice to have clean connectors!

- Direct impact on IL & ORL => BER => System performance and Network reliability
- Bad connectors may work at low data rate and cause failure at higher data rate
- Some soils can change over time (freezing, drying, etc.)

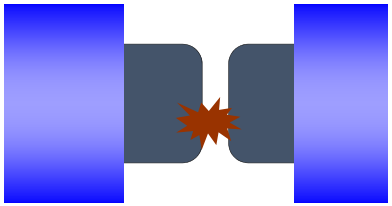


Why are connectors dirty or damaged ?

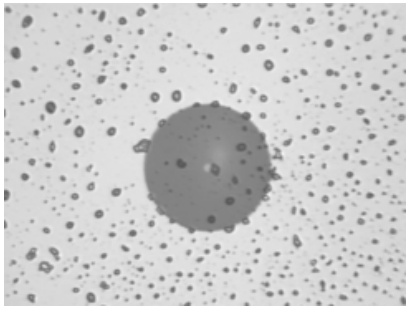
- Skin oil and particles, sticky fingers, hairs, drywall, dusty dust caps, etc…

Dust/Dirt/Debris Residues Transfer

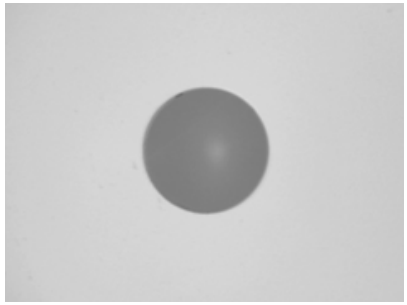
- A connection is made of 2 connectors….
- They should both be inspected and cleaned if needs be.



Before mating:

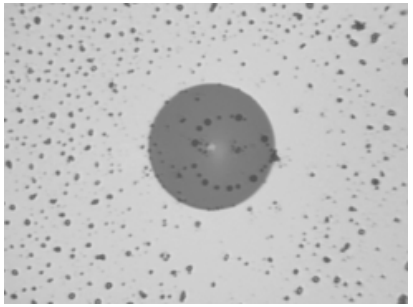


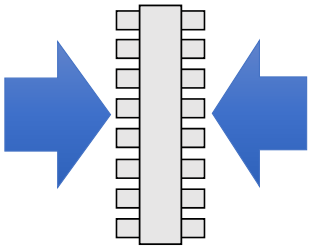
Connector A



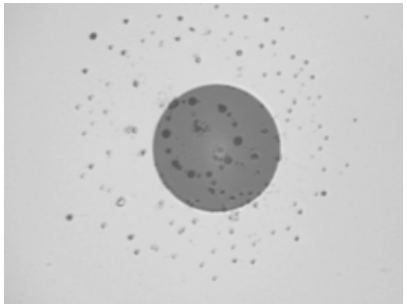
Connector B

After mating:





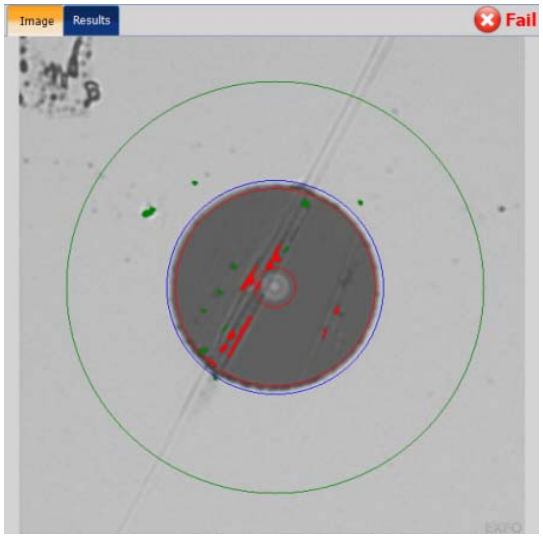
Patch Panel



Cleaning Alone is Not Enough…or too much!

DAMAGED = REPLACE

You CANNOT clean a damaged connector

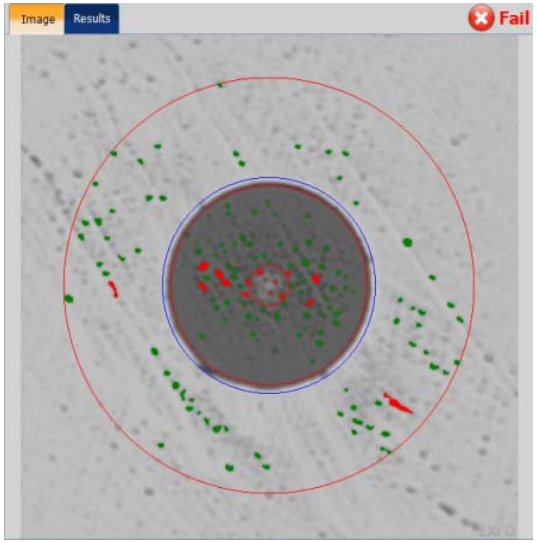


CLEAN = CONNECT

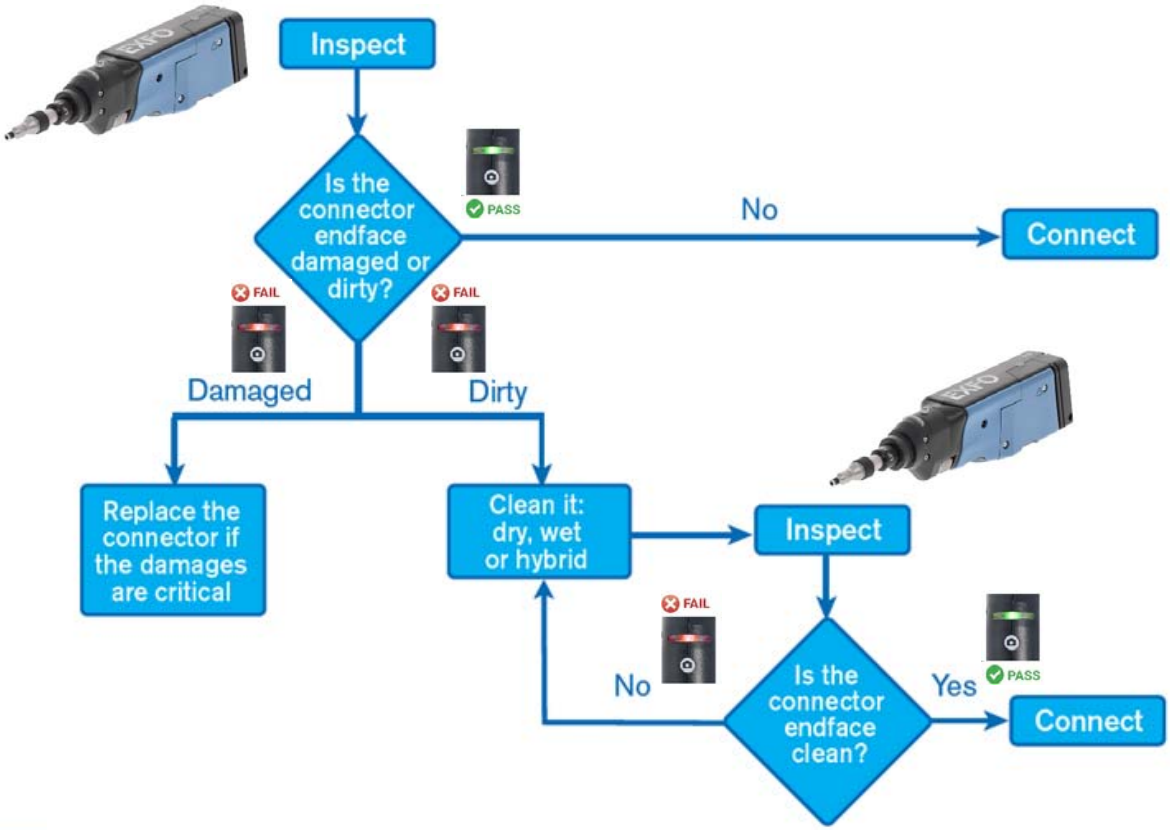
NO cleaning required

DIRTY = CLEAN

Clean ONLY if needed



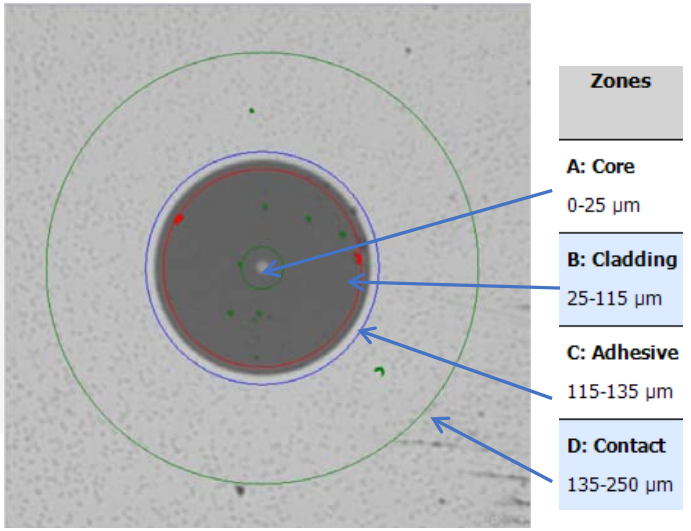
Inspection / Cleaning Flow



Connector Inspection Standards

Standards-based criteria

- IEC 61300-3-35
  Fiber-optic interconnecting devices and passive components—basic test and measurement procedures
  http://webstore.iec.ch/
- IPC 8497-1
  Cleaning methods and contamination assessment for optical assembly
  http://www.ipc.org/



- Connectors are divided in **zones with specific tolerances**
- Zones & criteria **varies depending connector type:**
  - Singlemode vs Multimode,
  - UPC vs APC,
  - Single fiber vs Multifiber

Zones	Scratches	Defects
A: Core	None	None
B: Cladding	No limit ≤3 µm None >3 µm	No limit <2 µm 5 from 2 – 5 µm None >5 µm
C: Adhesive	No limit	No limit
D: Contact	No limit	None ≥10 µm

Example : Singlemode single fiber UPC connector zones and criteria as per IEC 61300-3-35 Ed.2

Pass/Fail Automated Assessment

Using an analytical software guarantees a uniform level of acceptance according to industry standards:

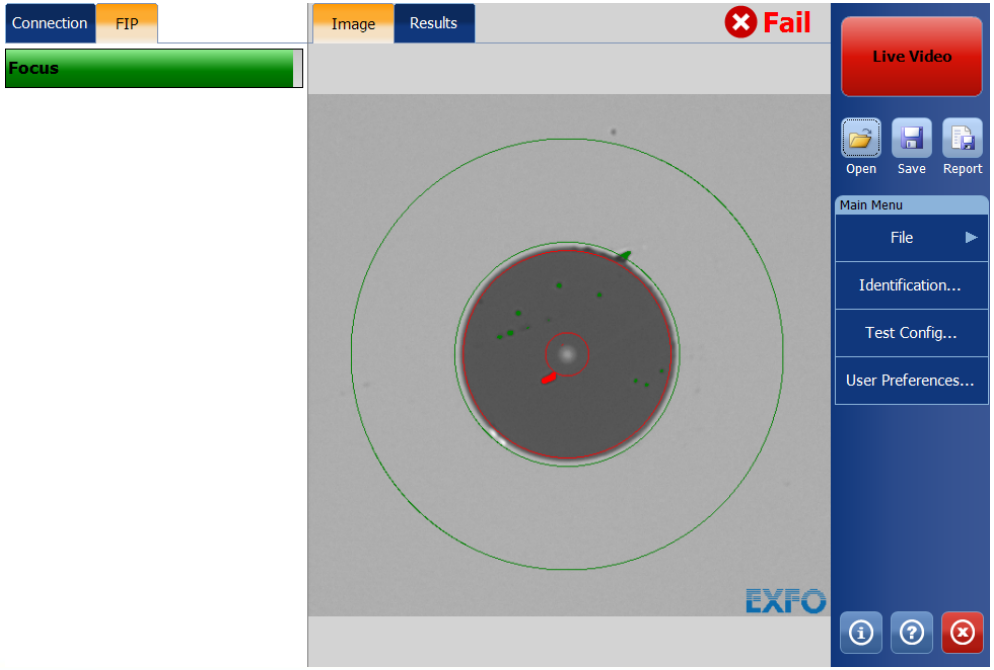


Image | Results — Fail

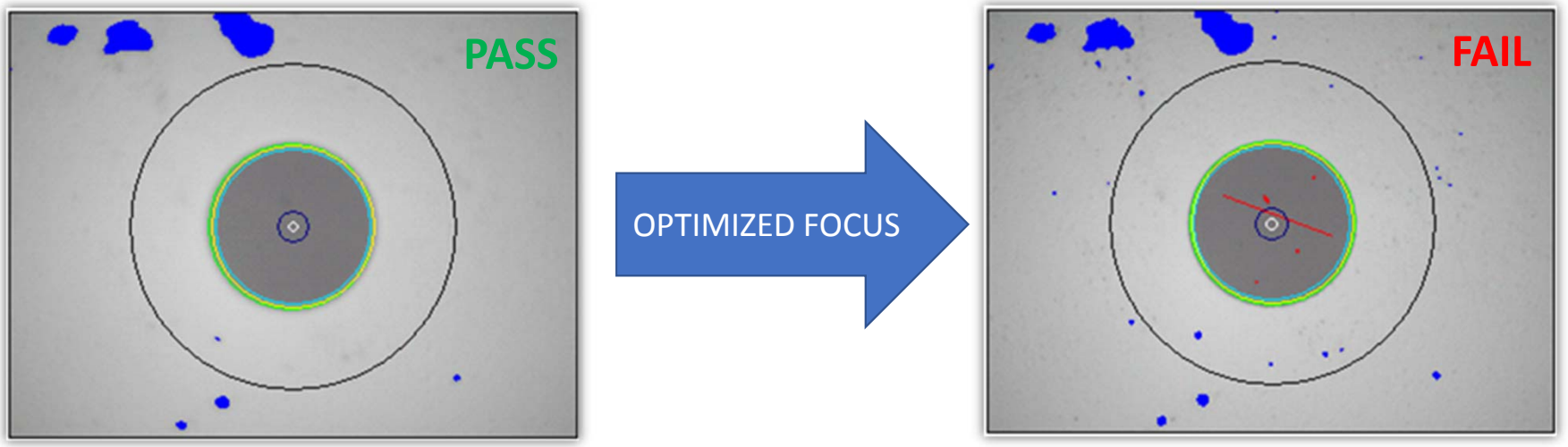
Inspection Results

Zones	Scratches			Defects		
	Criteria (µm)	Thld	Cnt	Criteria (µm)	Thld	Cnt
A: Core 0-25 µm	0 ≤ size < ∞	0	0	0 ≤ size < ∞	0	1
B: Cladding 25-120 µm	0 ≤ size < 3 3 ≤ size < ∞	Any 0	0 0	0 ≤ size < 2 2 ≤ size < 5 5 ≤ size < ∞	Any 5 0	6 4 1
C: Adhesive 120-130 µm	---	---	---	---	---	---
D: Contact 130-250 µm	0 ≤ size < ∞	Any	0	0 ≤ size < 10 10 ≤ size < ∞	Any 0	1 0

Test Configuration	Connector	Cladding
IEC SM SF UPC ORL ≥ 45 dB (61300-3-35, 1.0)	SF	125 µm

Beware of False Positives

- **Focus adjustment and assessment might be user subjective**
  => PASS/FAIL results are impacted by a poor focus.



Out-of-focus image can hide critical defects delivering a « Pass » verdict

Optimized focus will ensure seeing all defects affecting performances

How to clean a connector?

Dry cleaning	
Convenience of readily available tools	Can possibly create electrostatic charges
Fast and easy	Not effective in removing all contaminant types

Wet cleaning	
Can dissolve complex soils and contaminants	Can leave residue on the ferrule when too much solvent is used and not properly dried
Eliminates the accumulation of electrostatic discharge on the ferrule	Solvent choice can be confusing with issues of performance and EH&S

Hybrid cleaning	
Cleans all soil types	Requires multiple products
Reduces potential static field soil accumulation	
Automatically dries moisture and solvent used in the cleaning process	
Captures soil in wiping material as an integrated aspect of cleaning procedure	

Connectors Inspection and Cleaning Conclusion

Leave nothing to chance:

- Inspect against appropriate standard, and clean only as needed
- Use reliable and repeatable processes, with controlled focus and pass/fail
- Be equipped for dry & wet cleaning
- Be ready to toggle between single and multifiber inspection and cleaning

=> Don’t plug & pray!

Tier I Testing of Fiber Optic Links

How much light is coming out of the end of the fiber?
How much should be coming out?

Jim Davis
Regional Marketing Engineer
Fluke Networks

How Fiber Loss is Measured

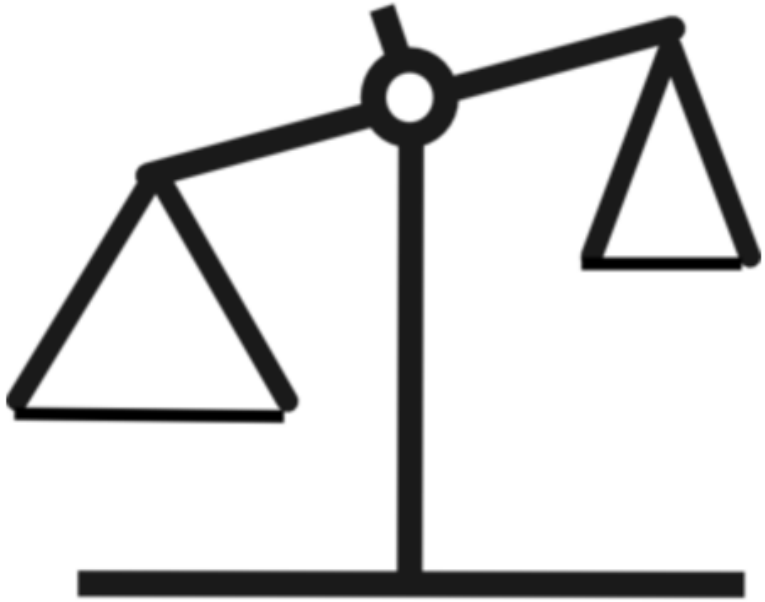
Set a reference

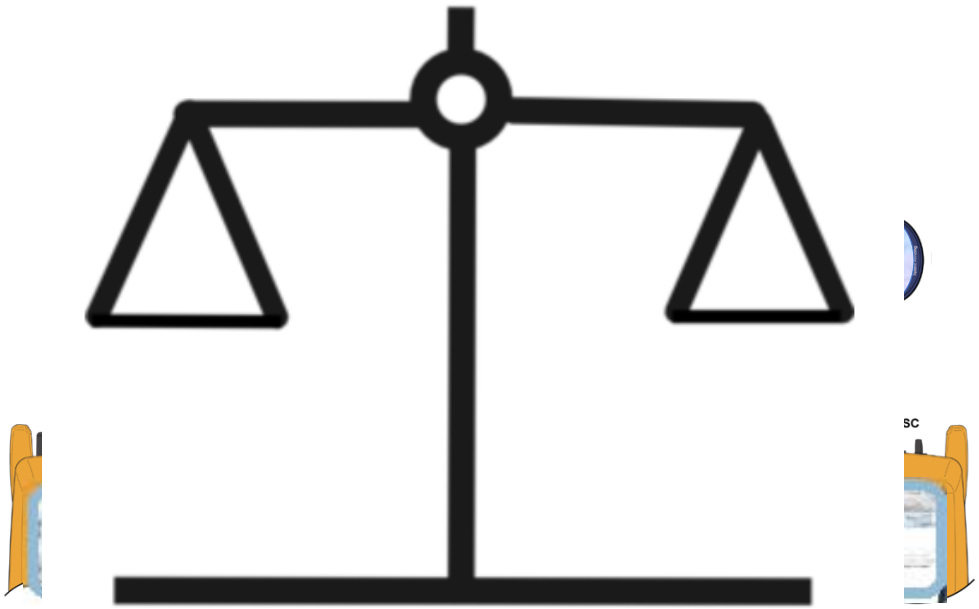
Run a test

Find the difference

First set a reference

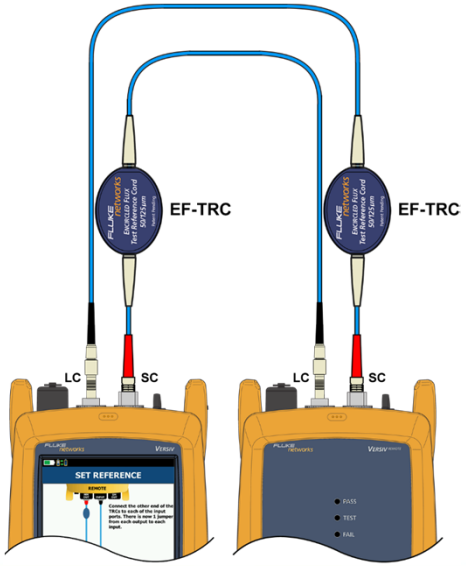
Then find the Difference





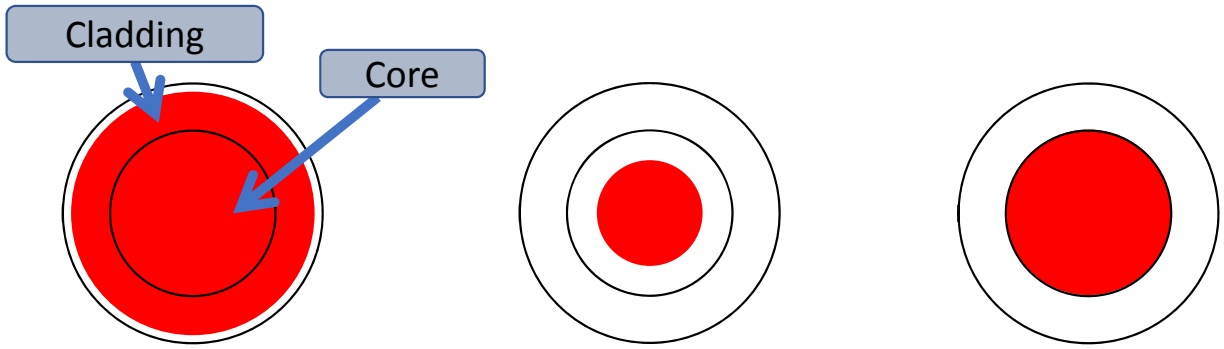
Accurate Test Process and Values Will Reduce Uncertainty

- For less uncertainty in our fiber testing, especially of ***multimode*** fiber, there are 4 key ingredients to loss testing
  - A one jumper reference
  - An LED source
  - Reference Grade Connectors
  - Encircled Flux compliance



Encircled Flux Compliance

- The light source's launch condition determines how and where the light is distributed within the fiber



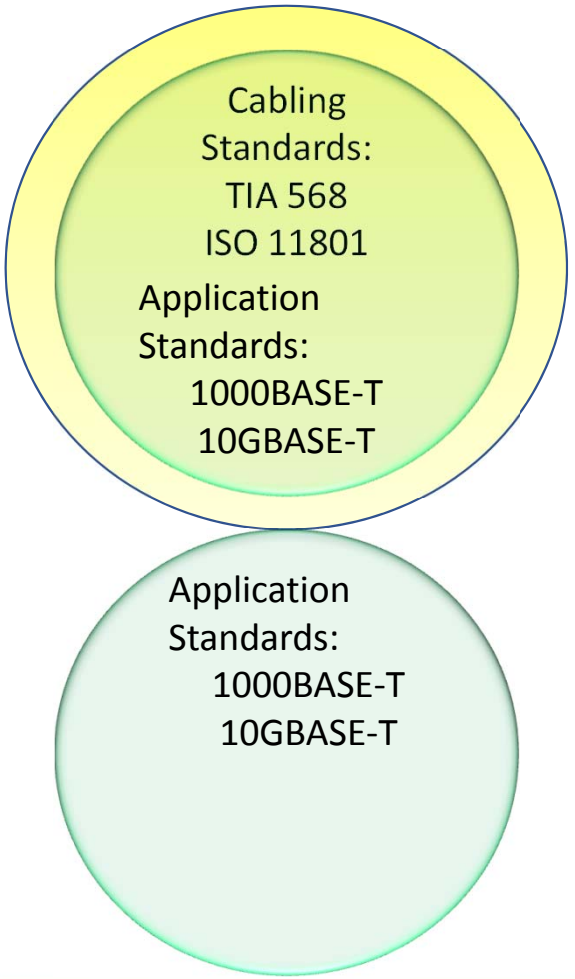
Calculating a Loss Budget

Difference between a TIA limit and an application limit

The Loss Budget determines what "Passes" and "Fails"

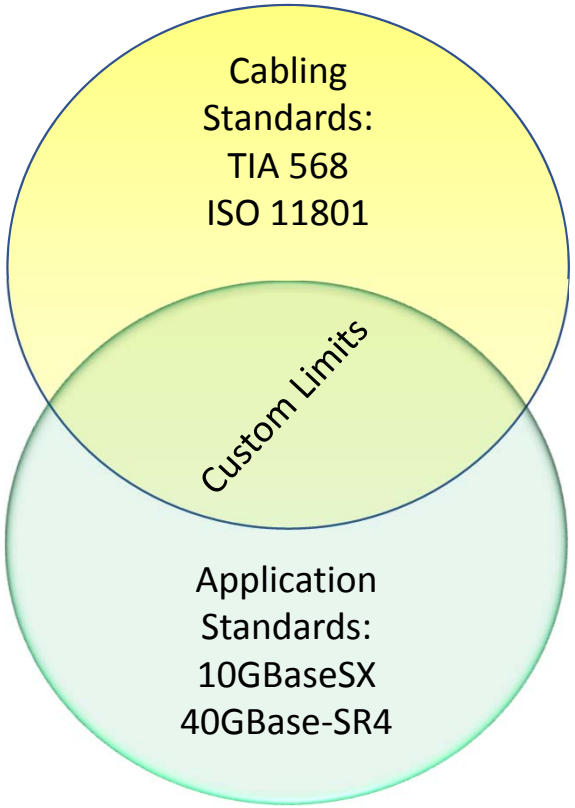
Which Limits to use?
Does this link really pass?

- There is no “Cat 6A” for fiber
- There is conflict between what the standard will support and what the application requires
- Installers should use Custom Limits to certify links



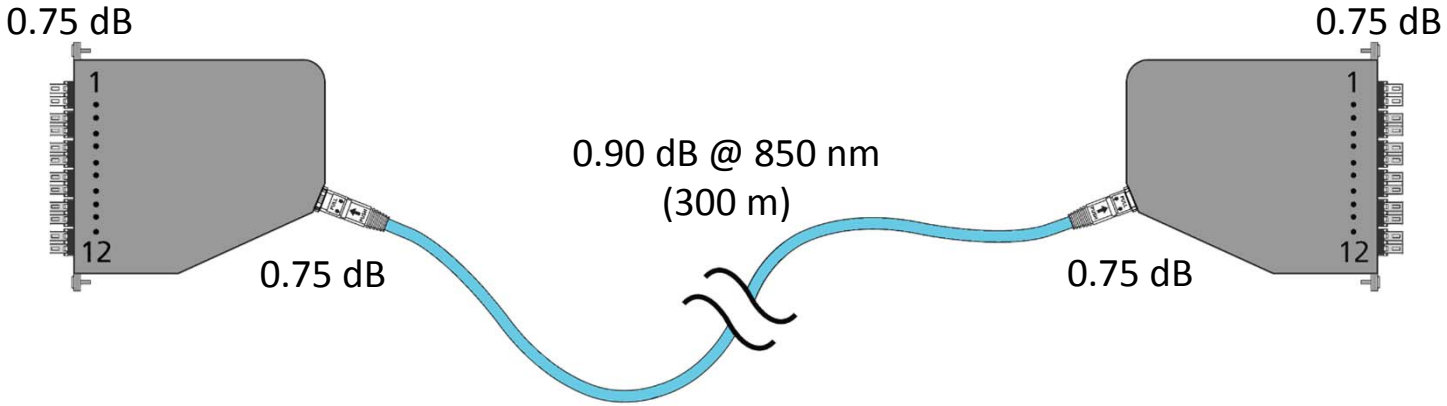
Which Limits to use?
Does this link really pass?

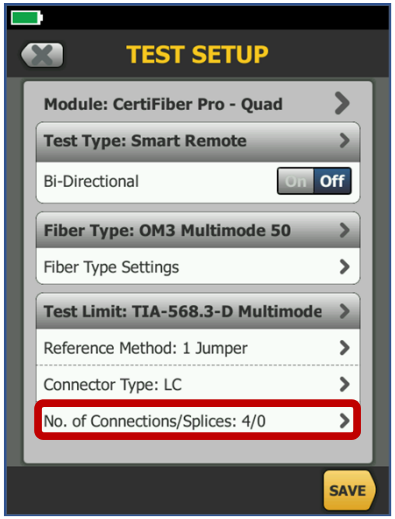
- There is no “Cat 6A” for fiber
- There is conflict between what the standard will support and what the application requires
- Installers could use Custom Limits to certify links
  - Manufacturers may offer a custom link loss calculator for their components



Using a TIA Limit Without Understanding the Application

- Customer wants to run 10GBASE-SR on this multimode link



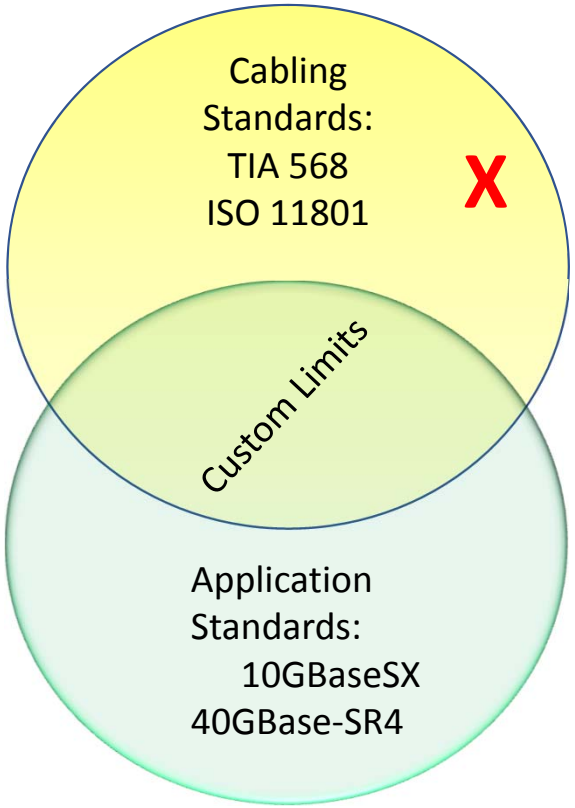


TIA (tester) Limit = 0.75 dB + 0.75 dB + 0.90 dB + 0.75 dB + 0.75 dB
= **3.90 dB @ 850 nm**

10GBASE-SR Limit = **2.55 dB @ 850 nm** **This design will not support 10GBASE-SR**

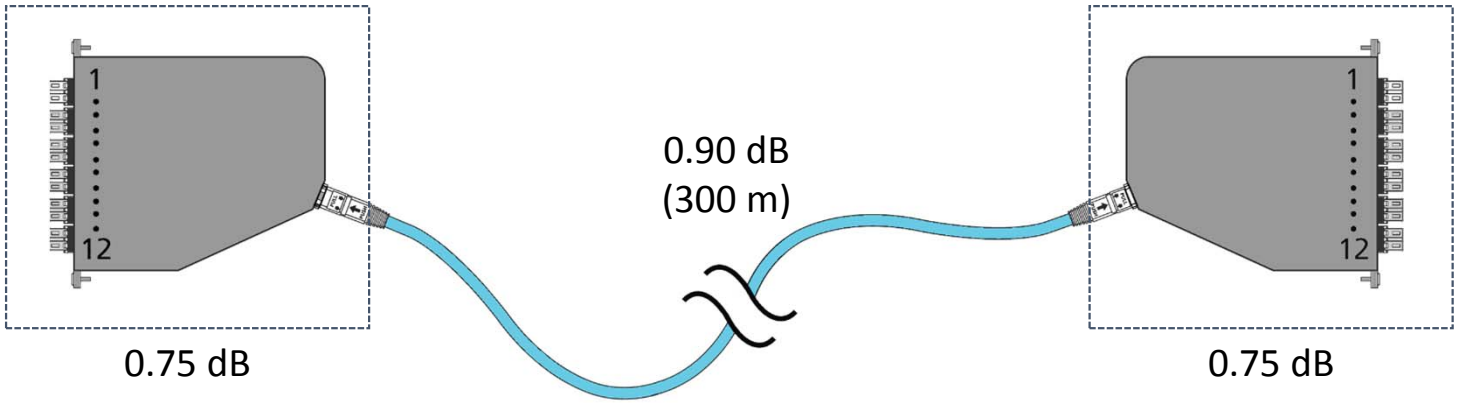
Which Limits to use?
Does this link really pass?

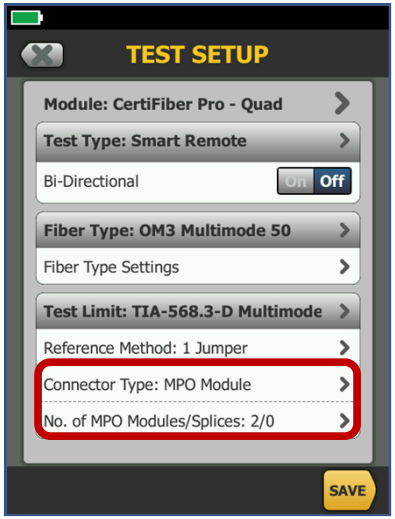
- That 3.90 loss budget falls within the acceptable values for the cabling standard, but outside of the acceptable values for the application



Using a TIA Limit Without Understanding the Application

- Customer wants to run 10GBASE-SR on this multimode link



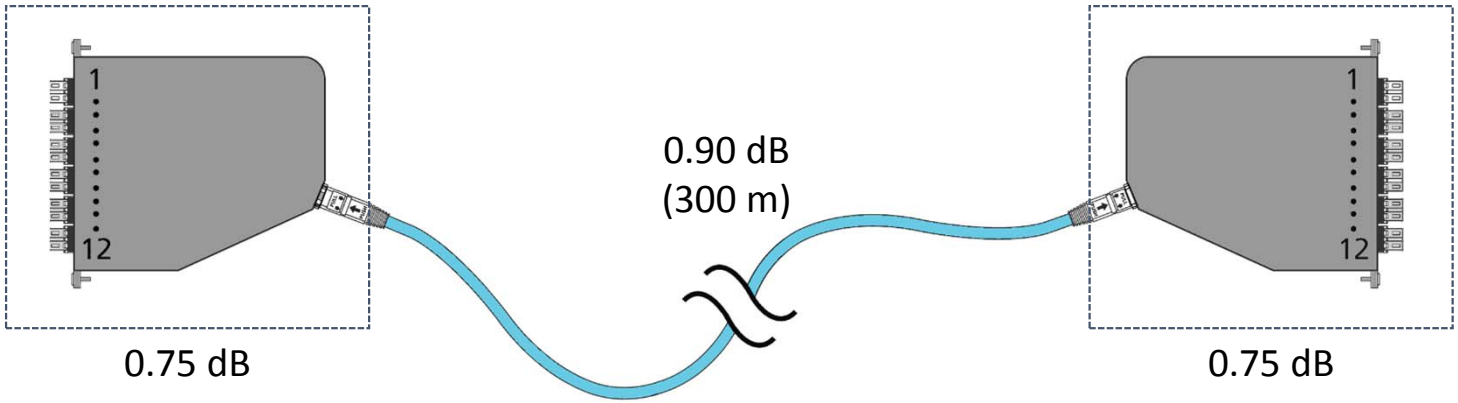


TIA (tester) Limit = 0.75 dB + 0.90 dB + + 0.75 dB
= **2.40 dB @ 850 nm**

10GBASE-SR Limit = **2.55 dB @ 850 nm** **This design will support 10GBASE-SR**

Using a TIA Limit Without Understanding the Application

- Customer wants to run 10GBASE-SR on this multimode link



Confirm the performance of your MPO cassettes
Many manufacturers have “regular” and “High Performance” or “Low Loss” cassettes. Regular may have > 1 dB of loss for the two connections

Tier I Conclusions

- Try to use a One Jumper Reference
  - If testing a connector that you do not have a port for on your power meter, you may have to set a three jumper reference
    - MPO, MTRJ, ‘keyed’ connectors
- Use the right loss budget
  - TIA/ISO variable ‘length’ based limit
  - IEEE fixed loss, fixed length application limit
  - Custom limit that mixes both

OTDR/Tier2 Testing of Fiber Optic Links

Rob Gilberti
Sr Product Line Manager
AFL

OTDR Functions

An OTDR uses Reflected Light to measure and characterize an Optical Fiber

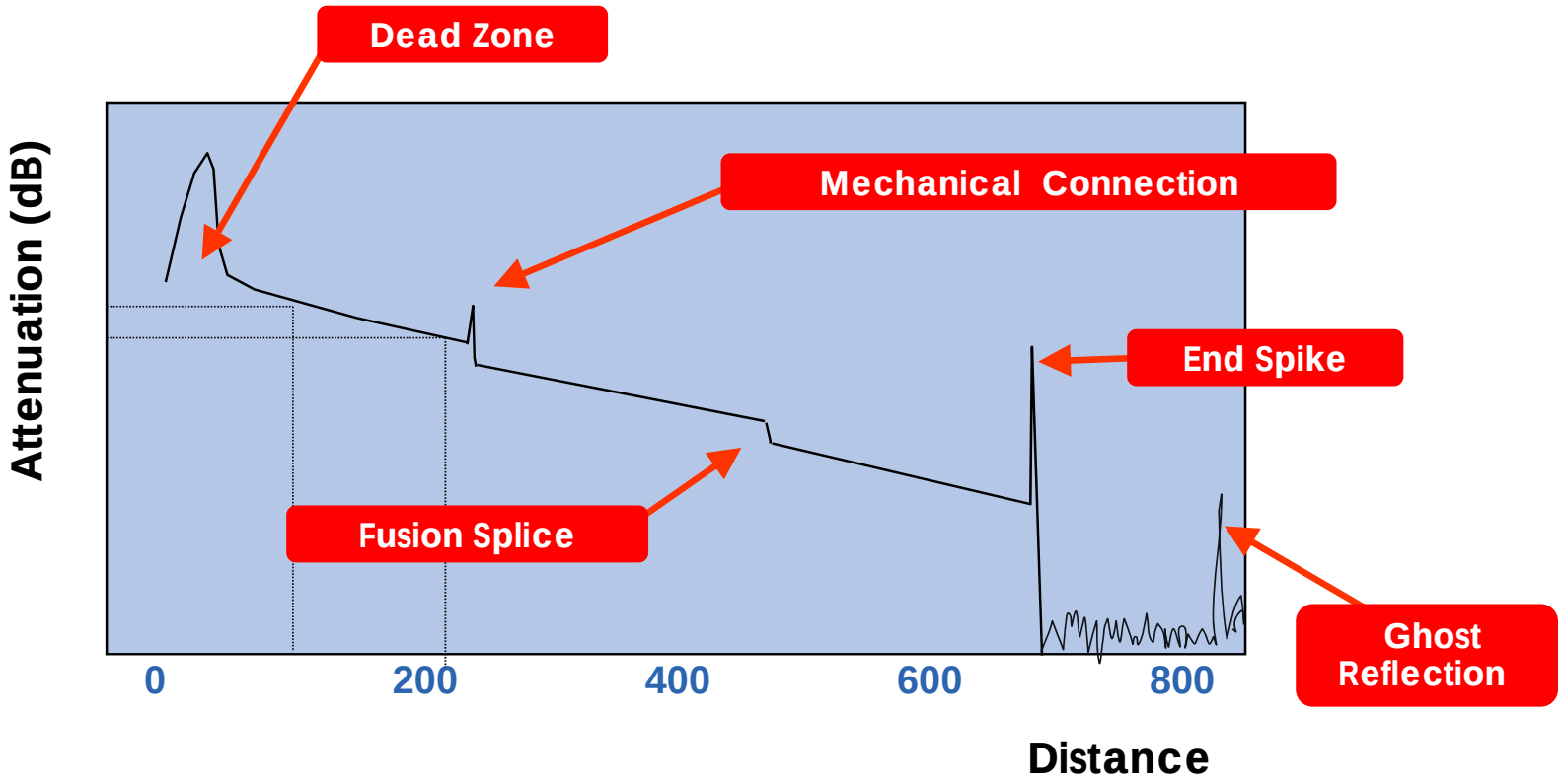
Functions

- Measure Loss and Distance
- Locate and Measure Connectors and Splices
- Locate and Characterize Faults – Macrobends, Breaks
- Measure Link Optical Return Loss (ORL)
- Evaluate Connector Reflections

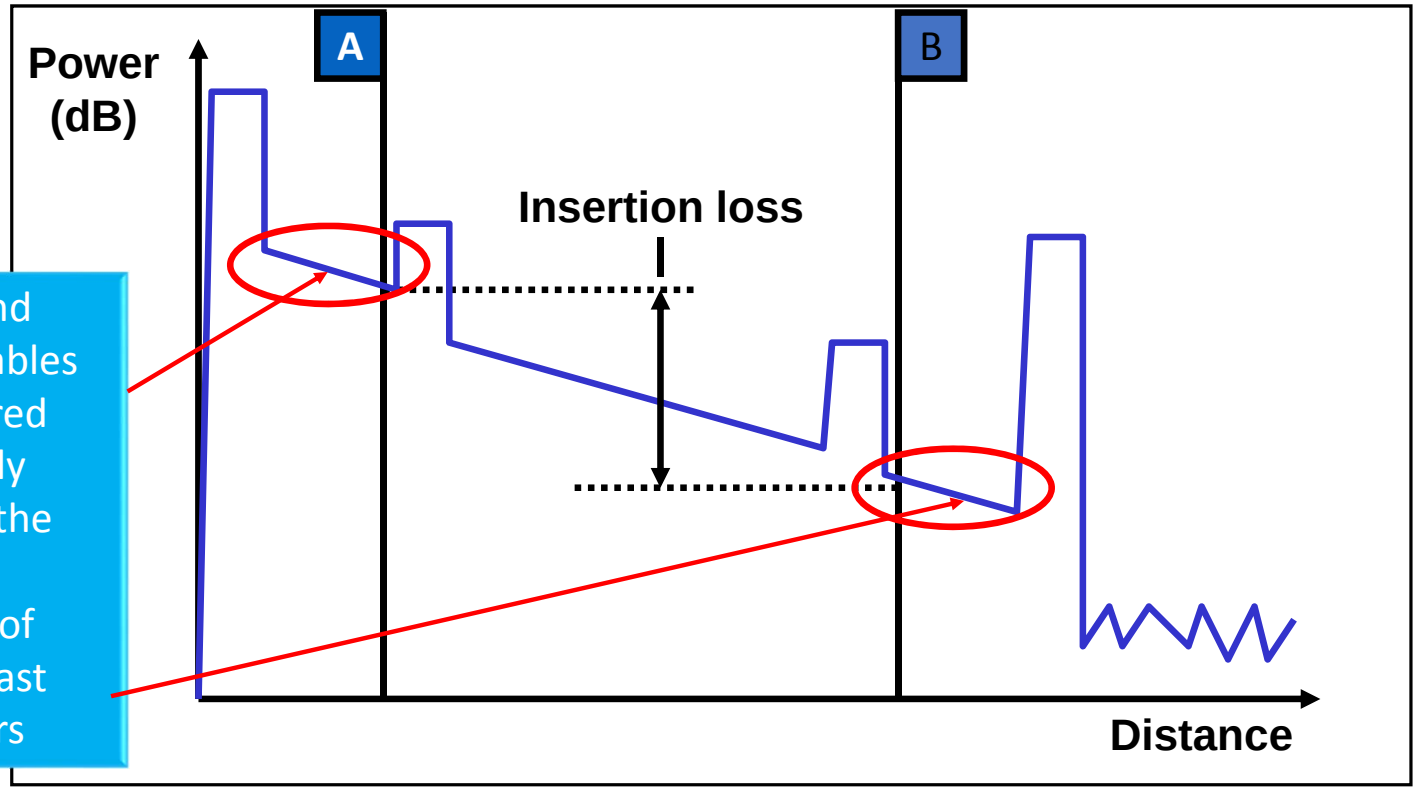
Applications/Uses

- Installation/Commissioning Troubleshooting
- Emergency Restoration
- Fiber/Link Characterization
- Maintenance
- Link/Network Quality Assurance

The OTDR Trace

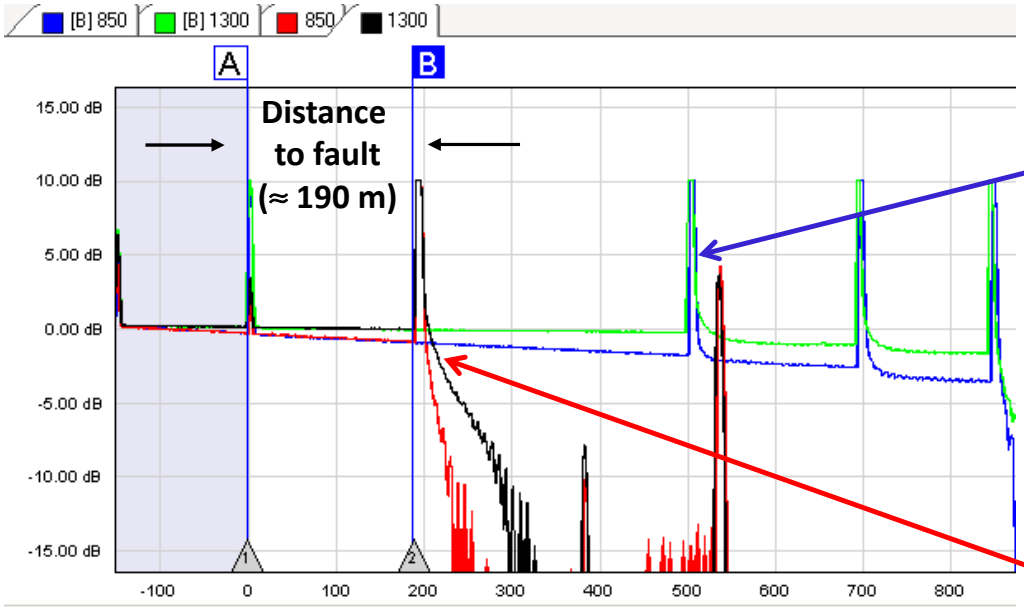


OTDR Two-point Insertion Loss Including End Connections



Launch and receive cables are required to properly measure the loss and refection of first and last connectors

Using an OTDR to Fault Locate



Relative Power (dB)

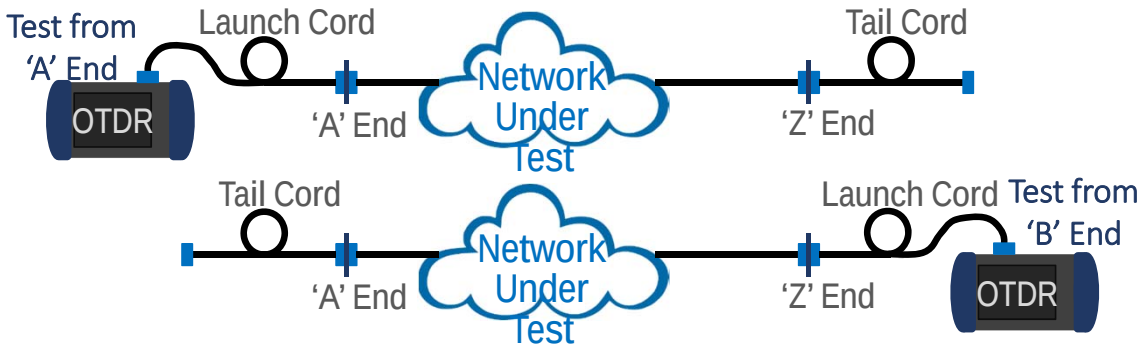
Expected Trace from install

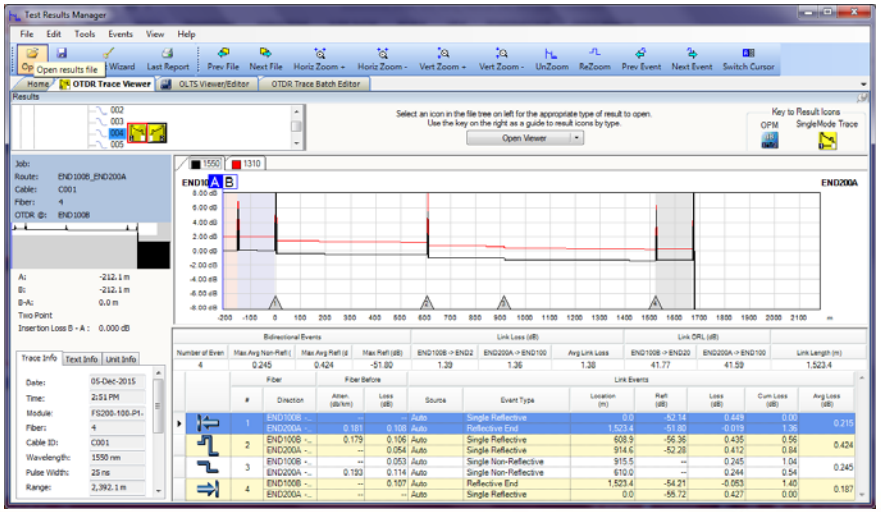
Captured Trace shows fault location

Distance (m)

OTDR Bi-Directional Testing

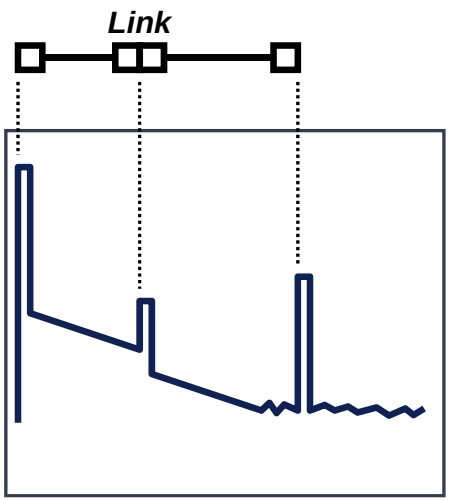
- If backscatter characteristics are different from each fiber, measured loss across the event will be exaggerated in one direction and reduced in the other direction
  - Different fiber types (e.g. G.652.D vs. G.657.B2) have different backscatter
  - Older fiber typically has higher backscatter then newer fiber
- A more accurate measure of an event's loss is obtained by testing the network from each end and averaging the measured event loss in both directions at each event





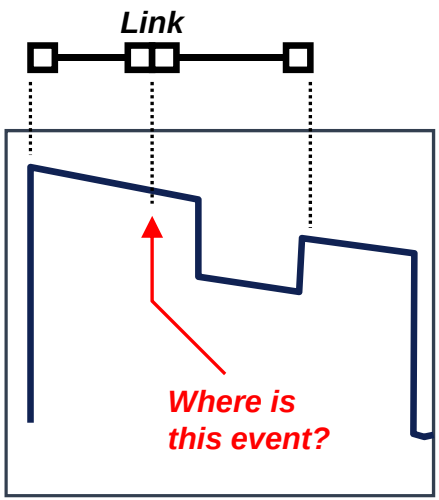
How to Determine OTDR Pulse Width

Too Narrow



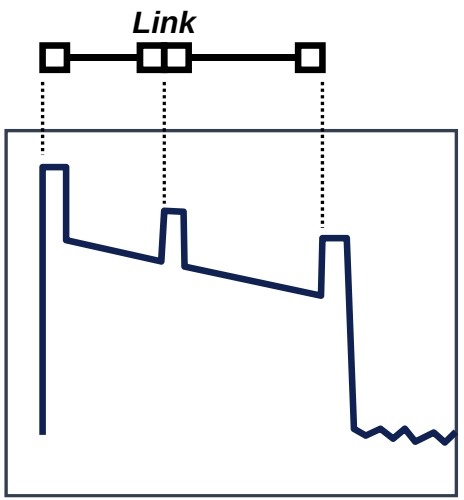
Trace “disappears” into noise floor

Too Wide



Can’t resolve events

About Right



Events can be seen and trace is smooth

Multi-pulse Acquisition

- Combines results of multiple acquisitions using different settings & wavelengths
- Narrow pulses for short range event-finding...
  - Detects and measures closely spaced connectors within CO or datacenter
  - Provides high-resolution before splitter in PONs
- Plus wider pulses for medium and long range event analysis…
  - Overcomes noise as network loss increases (after splitter or near end of long fibers)
- With consolidated 1310, 1550 and/or 1650 nm test results
  - Distinguishes between macro-bends and poor splices
  - 1650 nm supports live fiber testing (in-service PONs)

Reflectance – It's important!

Standards

	10Gbase	TIA-568.3-D	Industry
SMF	-26dB	-35dB	-35 to -50dB (UPC)
MMF	-20dB	-20dB	

High Reflectance can indicate poor quality connections or UPC/APC mismatches

Multi-fiber OTDR Testing with MPO Switch

Connect to MPO Network or use Hydra/Breakout to connect to individual fibers/connectors

OTDR controls switch via USB and Software cycles through 12 fibers automatically testing each fiber

OTDR captures .SOR files for 12 individual fibers for dual wavelength and consolidates data for single report

Testing MPO Connectors

OLTS for Tier I
OTDR for Tier II

Tyler Vander Ploeg, RCDD
Fiber Solutions Marketing Manager
VIAVI Solutions

Which MPO connections will you likely test?

12 Fiber

- Large installed base
- Existing MM & SM deployments
- Familiar interface and trunks
- For plug and play cassettes in datacom environment
- 40 Gig applications

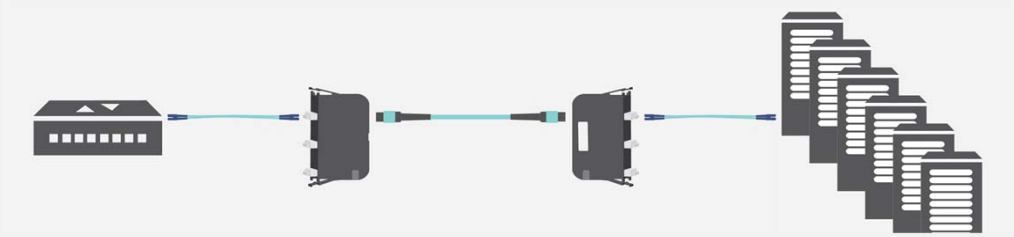
8 Fiber

- Supports QSFPs
- For MM & SM transceivers and breakouts
- Lowest panel density
- Removes 4 fibers in middle
- 40 & 100 Gig applications

24 Fiber

- Future ready
- Lowest cost duplex support for multimode applications
- Highest panel density
- For data center & server side
- 100 Gig applications

MPO Testing Scenarios



6 x 1/10Gbps Ethernet Channels (MMF)
6 x 1/10Gbps Ethernet Channels (SMF)

Tests to perform:
- Inspect all connections
- Test duplex (LC) drops w/duplex OLTS

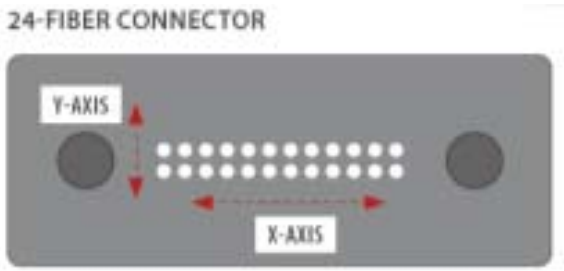
4 x 10Gbps Ethernet Channels (MMF)

Tests to perform:
- Inspect all connections
- Test from MPO to simplex
- OR use fan-out cable and test MPO-MPO

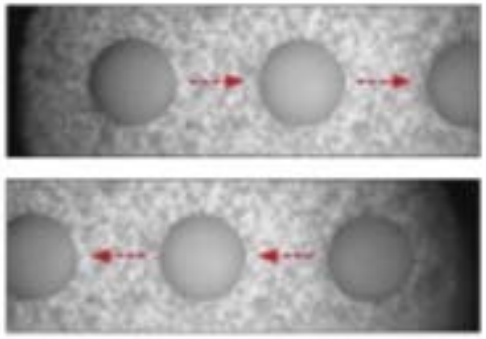
40/100Gbps Ethernet Channels (MMF)
40/100Gbps Ethernet Channels (SMF – PSM4)

Tests to perform:
- Inspect all connections
- Test MPO Links/Channels

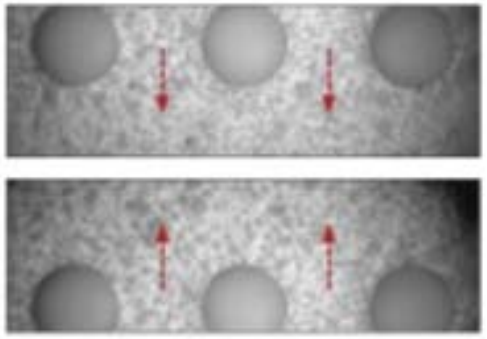
Inspect ALL Fibers in a Multi-Fiber Connector



X-AXIS



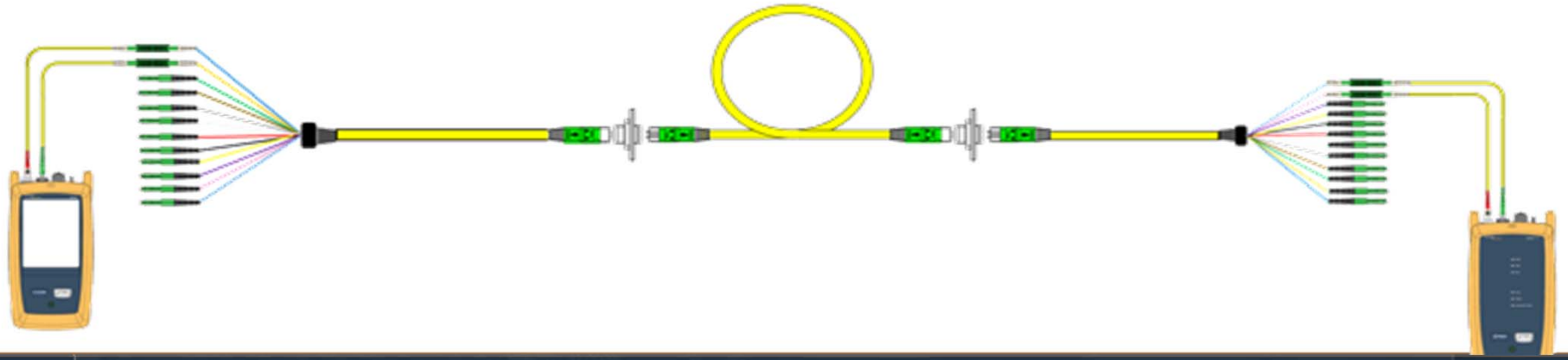
Y-AXIS



MPO Tier 1 Certification

Duplex Optical Loss Test Set

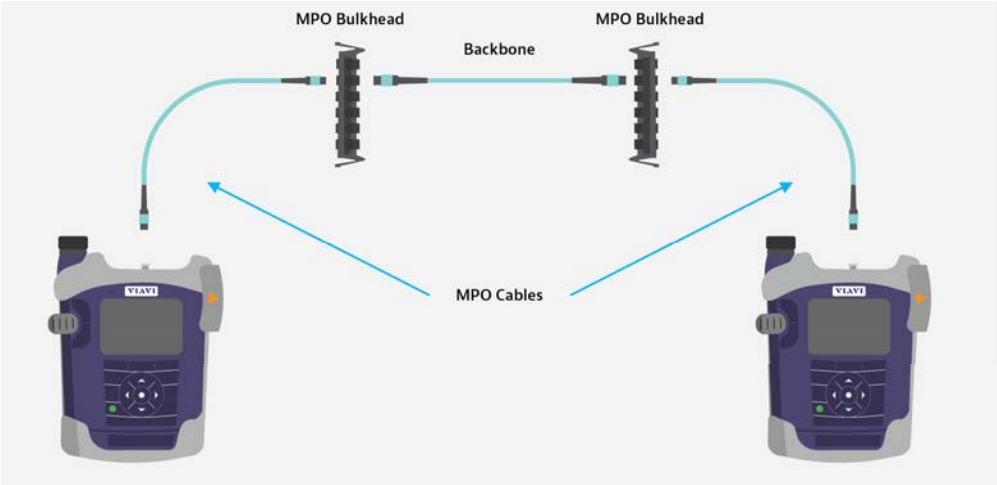
- Test MPO Links and Channels
- Loss, length and polarity
- Uses a cable or cassette to breakout MPO into simplex fibers
- Test results for each duplex fiber pair one set at a time



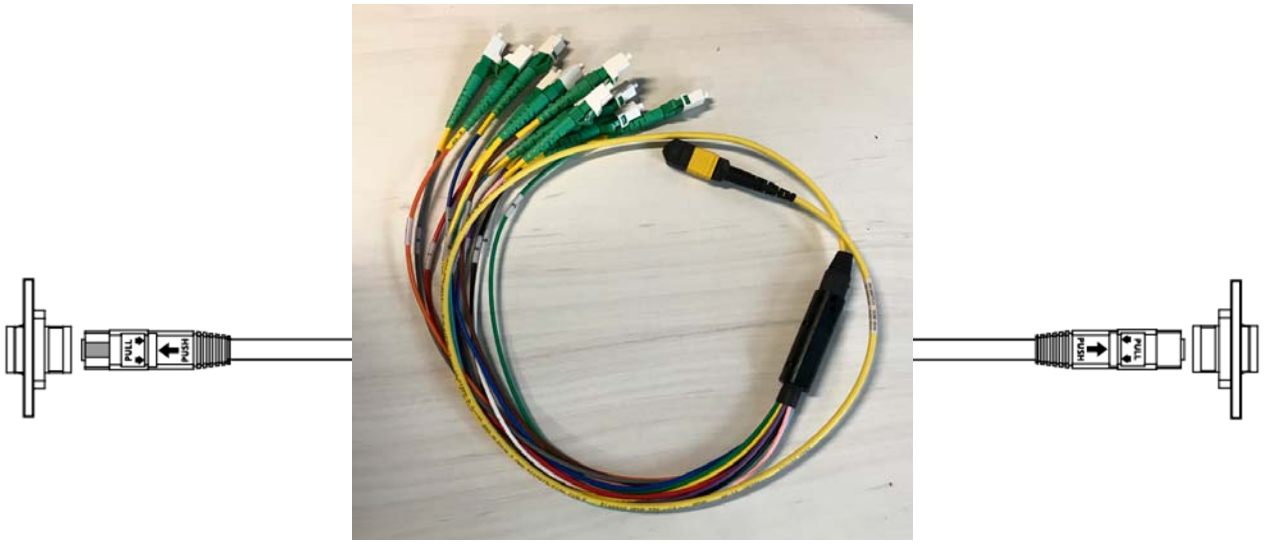
MPO Tier 1 Certification

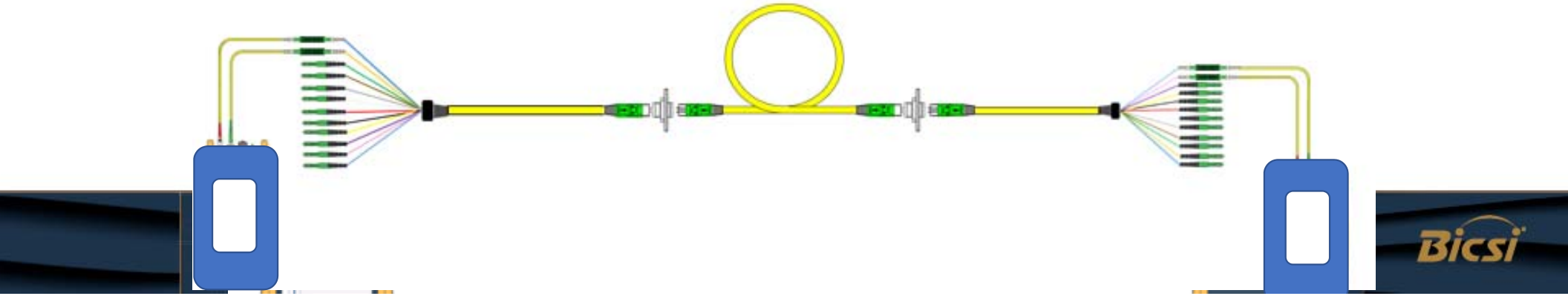
Dedicated MPO Optical Loss Test Set

- Test MPO Links and Channels
- Loss, length and polarity
- Plug MPO connectors directly into field test device
- Test results for all fibers in the MPO connector together



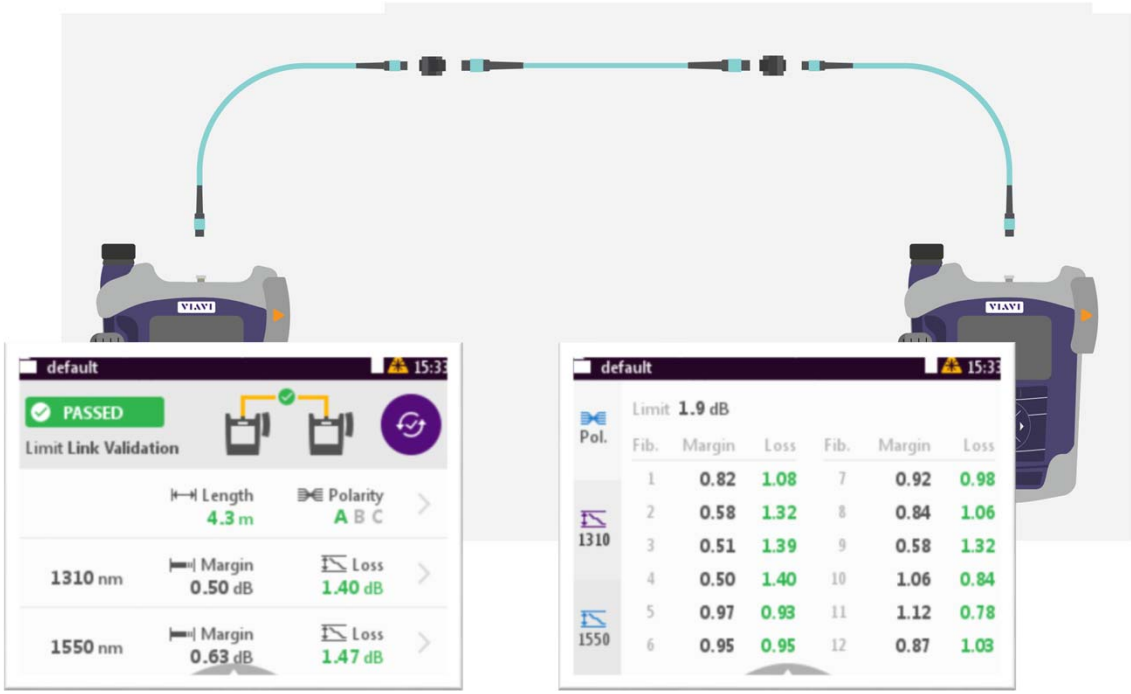
MPO/MTP Testing with Duplex OLTS – 3 Jumper Reference





Testing with Dedicated MPO OLTS

1. Set Reference with MPO test leads on each end
2. Add “Device Under Test” in middle
3. View & document results

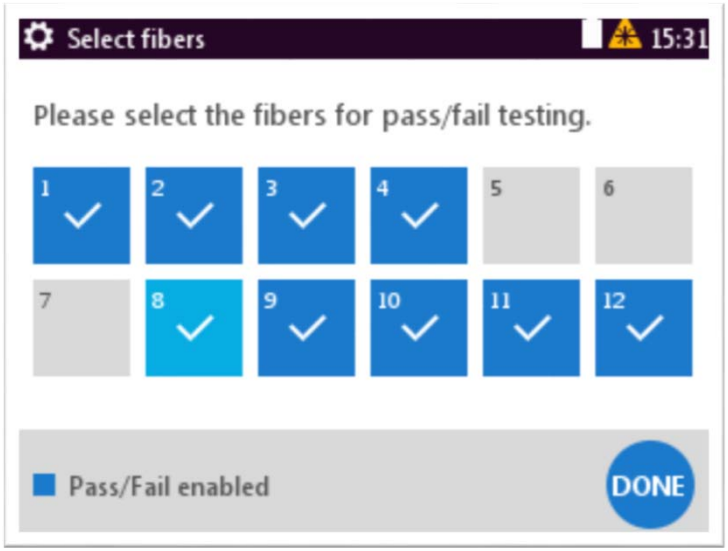


Main Challenge for Tier 1 Testing of MPO

- One-cord reference
  - If test set has pinned ports then unpinned to unpinned test cord must be used to perform reference
  - Receive cord is then added (unpinned to unpinned)
  - Can then test a pinned system
  - Cannot verify reference without adding a third cord
- There are MPO connectors available that allow pins to be retracted or removed
  - Helps solve pinned/unpinned challenges

Selecting Channels

- Can apply to any of the above scenarios
- Allows selection of which of the 12 channels are part of pass/fail analysis
- Eliminates false fails in cases when 8 or fewer fibers are present in MPO links (e.g. 40GBASE-SR4)
- Results reflect topology



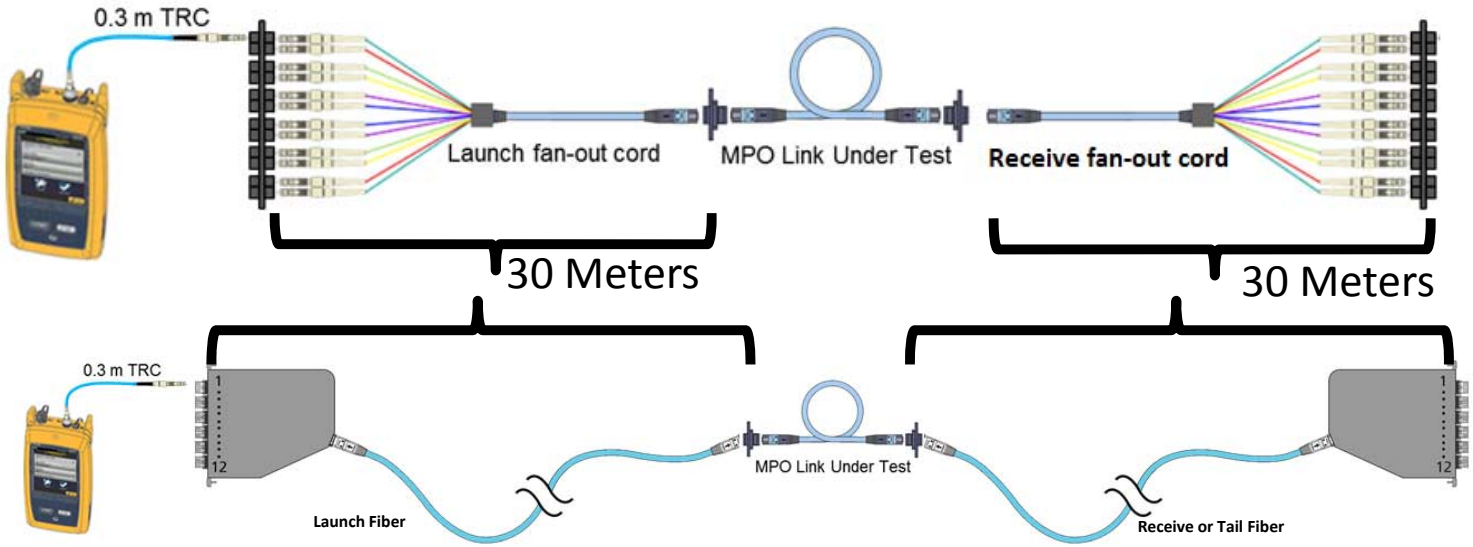
Tier 2 Testing of MPO

- Tier 1 testing cannot ensure individual event (splices and connection) losses are within spec OR the cable attenuation is uniform
- Tier 2 (OTDR) testing adds the characterization of these events to the certification test
- Tier 2 testing is also the ideal fiber trouble shooting tool to find the cause AND location of excess loss (incl. breaks) and reflectance
- Requires MPO switch or breakout cables
- Pinned/unpinned systems require different launch and receive cords

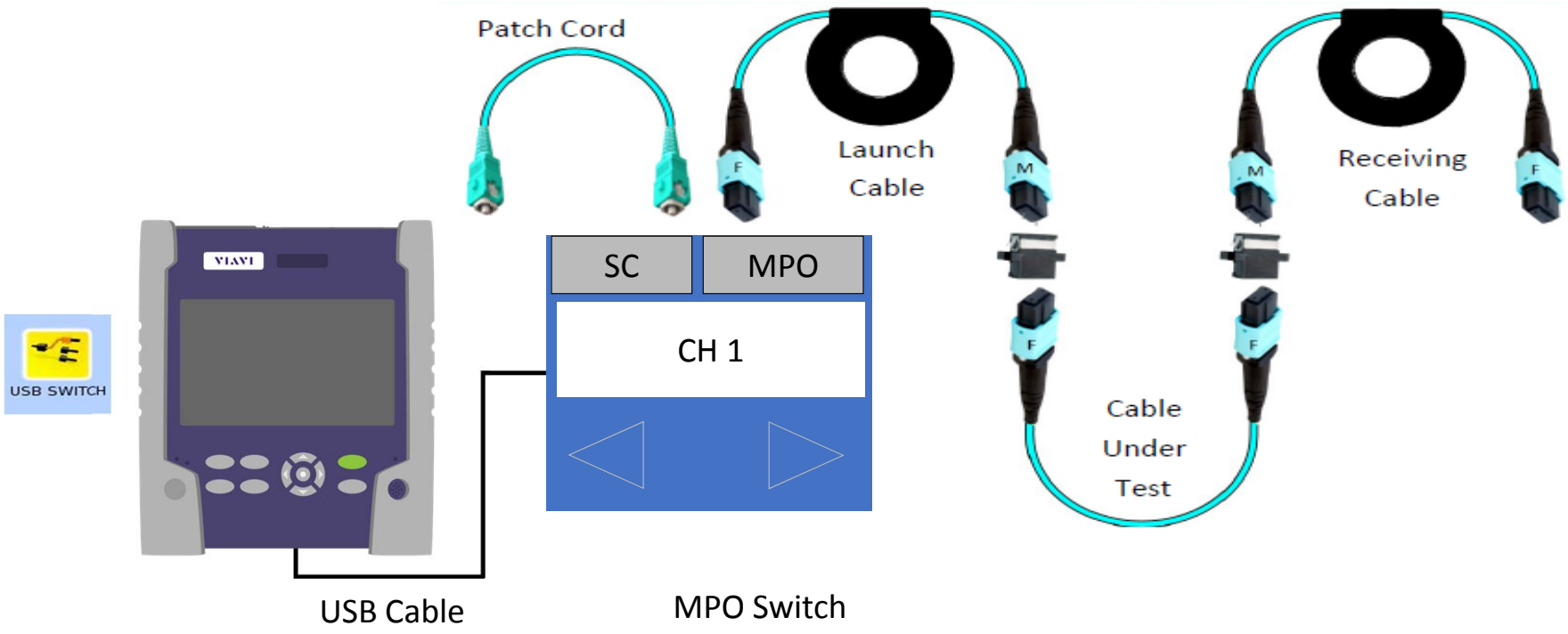
OTDR Testing of MPO Connectors

Don't forget your Pinned/Unpinned connections! ☺

- Ideally you will have **at least** 30 Meters of Launch and Receive fibers
  - Provided that the link under test is short: standards call out 100M and 150M
- Use a fan out cord or cassette to convert from Single fiber Port on OTDR



MPO OTDR Testing (External Switch)



Automatic switching driven by the OTDR via USB

Thank You For Your Time

COMMSCOPE®
Rodney Casteel, RCDD, DCDC, NTS, OSP
rcasteel@commscope.com

ofs
John Kamino
jkamino@ofsoptics.com

PANDUIT
David J Asta, RCDD
David.Asta@Panduit.com

legrand®
Cindy Montstream, RCDD, NTS, EE, CPLP
Cindy.Montstream@legrand.us

AFL
Rob Gilberti
Rob.Gilberti@aflglobal.com

FLUKE networks
Jim Davis
jim.davis2@flukenetworks.com

SUPERIOR ESSEX
Paul Neveux, Jr., Ph.D.
Paul.Neveux@spsx.com

EXFO
Romain Tursi
romain.tursi@exfo.com

VIAVI
Tyler Vander Ploeg, RCDD
Tyler.VanderPloeg@viavisolutions.com