REUSE or REPLACE FIBER?
Advice for Addressing Network Demands

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In This Session

- The four fiber options for transmission in the data center and enterprise
  - Duplex
  - BiDi
  - SWDM4/CWDM4
  - Parallel
- The health of your connections
  - Inspecting the end faces of the connectors
  - Cleaning options
  - Field polish vs. factory polish
  - Using an Optical Time Domain Reflectometer (OTDR) to check the health of the link
  - Options for replacing damaged connectors
- Are pre-terminated trunks/cassettes a better option?

DUPLEX

Duplex

- Two fibers can be two multimode or two single-mode fibers
  - Transmit in one direction on a single fiber
  - Receive in the other direction on another single fiber

- As the pulse travels down the multimode cable, the different mode paths cause the pulse to spread

- At a certain distance, the transceiver will not be able to distinguish between a “0” or “1”

Duplex

- There are different multimode fiber types
- Each have a designation based on performance

Designation	Effective Modal Bandwidth @ 850 nm (MHz.km)	1000BASE-SX (Meters)	10GBASE-SR (Meters)	10GBASE-LRM (Meters) 1308 nm	Effective Modal Bandwidth @ 1300 nm (MHz.km)
FDDI	160	225	26	220	500
OM1	200	275	33	220	500
OM2	500	550	82	220	500
OM3	2,000	860	300	220	500
OM4	4,700	860	400	220	500
OM5	4,700	860	400	220	500

- Application standards reference OM1 etc. when stating max. length

Extending the life of your duplex links

BI-DIRECTIONAL (BIDI)

Bi-Di (40 Gb/s and 100 Gb/s)

- Two fibers (at this time) and multimode only
- Designed to extend the life of existing duplex links

- Transmit on Fiber A @ 850 nm (20 Gb/s or 50 Gb/s)
- Receive on the same Fiber A at 900 nm
- Transmit on Fiber B @ 850 nm (20 Gb/s or 50 Gb/s)
- Receive on the same Fiber B at 900 nm

Bi-Di (duplex)

- A faster speed will mean a reduced distance
- Let's take our previous table and apply the new distances

Designation	Effective Modal Bandwidth @ 850 nm (MHz.km)	Effective Modal Bandwidth @ 953 nm (MHz.km)	40GBASE-BD (Meters)	100GBASE-BD (Meters)
FDDI	160	?	-	-
OM1	200	?	-	-
OM2	500	?	30	-
OM3	2,000	?	100	70
OM4	4,700	?	150	100
OM5	4,700	2,470	200	150

- Since it uses 900 nm, there is a distance advantage with OM5 vs. OM4

Distance Limitations of Multimode

- Means more single-mode cabling being installed

Designation	1000BASE-LX (Meters)	10GBASE-LR (Meters)	40GBASE-LRL4 (Meters)	40GBASE-FR (Meters)	40GBASE-LR4 (Meters)
OS1a	5,000	10,000	1,000	2,000	10,000
OS2	5,000	10,000	1,000	2,000	10,000

Designation	100GBASE-DR (Meters)	100GBASE-CWDM4 (Meters)	200GBASE-FR4 (Meters)	400GBASE-FR8 (Meters)
OS1a	500	2,000	2,000	2,000
OS2	500	2,000	2,000	2,000

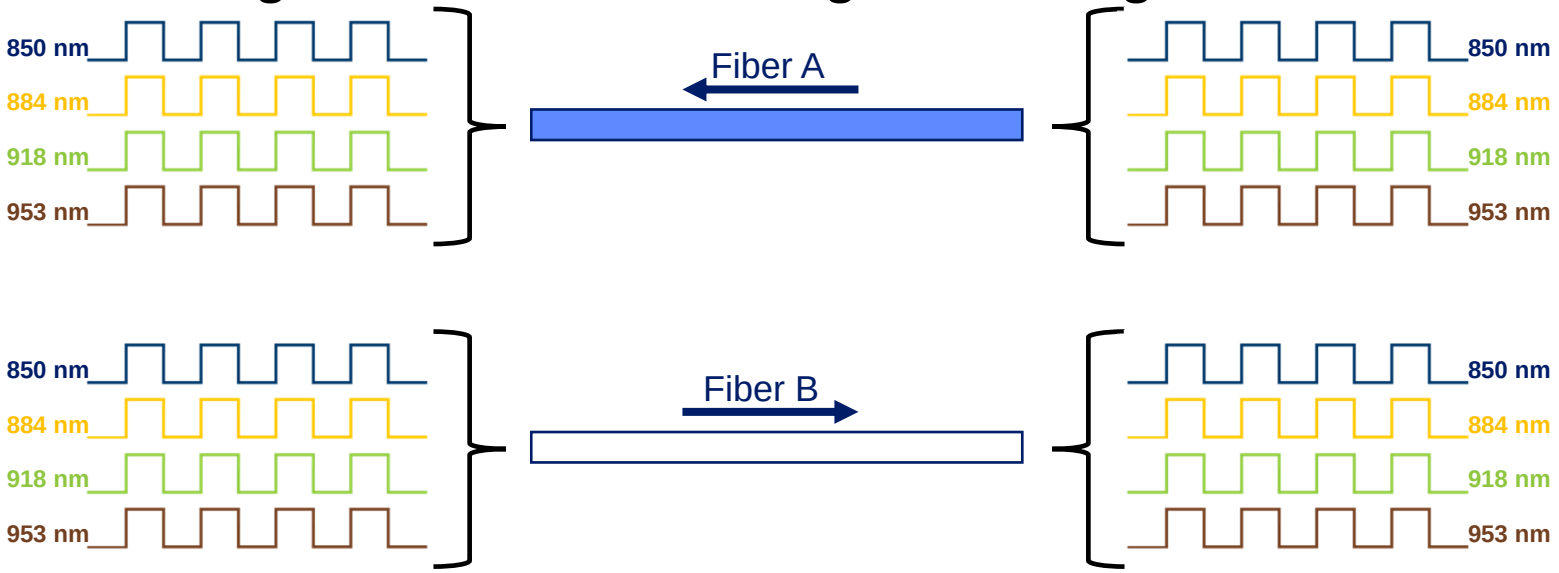
- This is not an exhaustive list of **duplex** single-mode options

Extending the life of your duplex links

SWDM4/CWDM4

Short Wave Division Multiplexing (SWDM4)

- Transmitting four different wavelengths on a single multimode fiber



- Placed onto one fiber and then separated again at the other end

Short Wave Division Multiplexing (SWDM4)

- Let's look at the supported distances again

Designation	Effective Modal Bandwidth @ 850 nm (MHz.km)	Effective Modal Bandwidth @ 953 nm (MHz.km)	40GBASE-SWDM4 (Meters)	100GBASE-SWDM4 (Meters)
FDDI	160	?	-	-
OM1	200	?	-	-
OM2	500	?	-	-
OM3	2,000	?	240	75
OM4	4,700	?	350	100
OM5	4,700	2,470	500	150

- SWDM4 uses up to 953 nm, so OM5 has a clear advantage over OM4
- Is there a path beyond 100 Gb/s for SWDM?

Course Wave Division Multiplexing (CWDM4)

- Transmitting four different wavelengths on a single fiber in one direction, four different wavelengths on the other fiber in the opposite direction (similar to SWDM4 but for single-mode)
- Supports 100 Gb/s transmission to 2 km
- Wavelengths used:
  - 1264.5 nm – 1277.5 nm
  - 1284.5 nm – 1297.5 nm
  - 1304.5 nm – 1317.5 nm
  - 1324.5 nm – 1337.5 nm
- Considered a costly solution compared to parallel optics

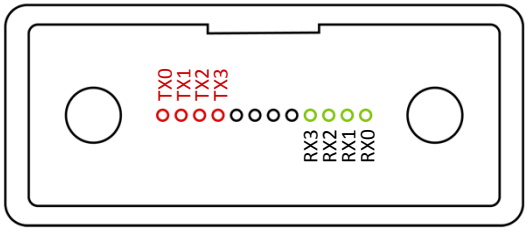
With the option to break out

PARALLEL

Parallel Requires MPO Connectors

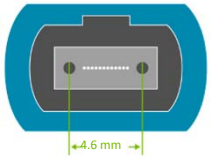
- Parallel optic interfaces differ from traditional duplex two fiber optic communication, in that data is simultaneously transmitted and received over multiple fibers
- The most common format being BASE-**SR4** where four fibers are used to transmit and four fibers for receiving

12 Fiber MPO

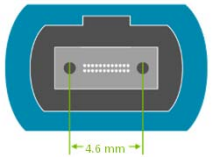


- For enterprise and data center networks, there are currently four different MPO (multi push-on) connectors

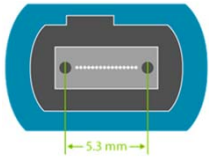
MPO
12 Fiber



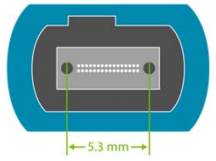
MPO
24 Fiber



MPO
16 Fiber



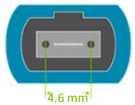
MPO
32 Fiber



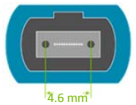
Which MPO Should You Be Installing?

- With a choice of four, let's look to the application requirements

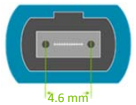
Designation	40GBASE-SR4 (Meters)	100GBASE-SR4 (Meters)	200GBASE-SR4 (Meters)	400GBASE-SR4.2 (Meters)	400GBASE-SR8 (Meters)
FDDI	-	-	-	-	-
OM1	-	-	-	-	-
OM2	-	-	-	-	-
OM3	100	70	70	70	70
OM4	150	100	100	100	100
OM5	150	100	100	150	100



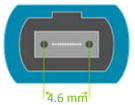
MPO 12 Fiber



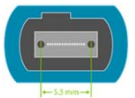
MPO 12 Fiber

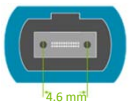


MPO 12 Fiber



MPO 12 Fiber

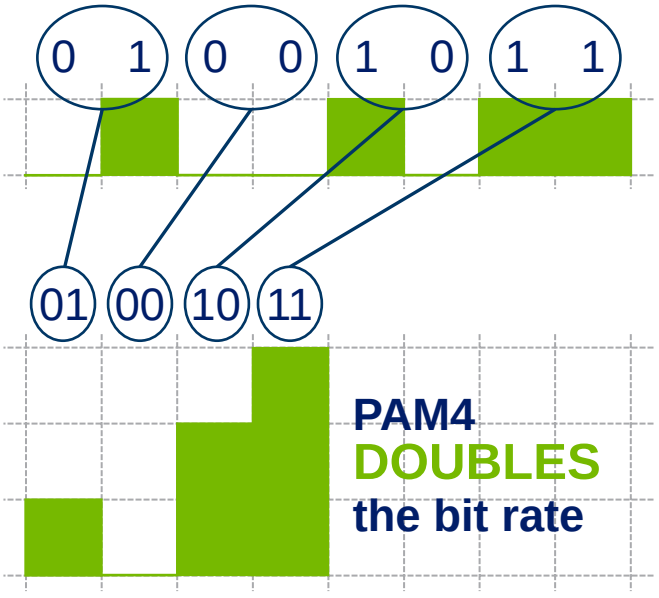

MPO 16 Fiber



MPO 24 Fiber

Keeping the Distance the Same From 100 Gbe to 200 Gbe

- 100GBASE-SR4 uses 4 x 25 Gb/s channels
- With PAM4, we can double that to 4 x 50 Gb/s channels 200GBASE-SR4

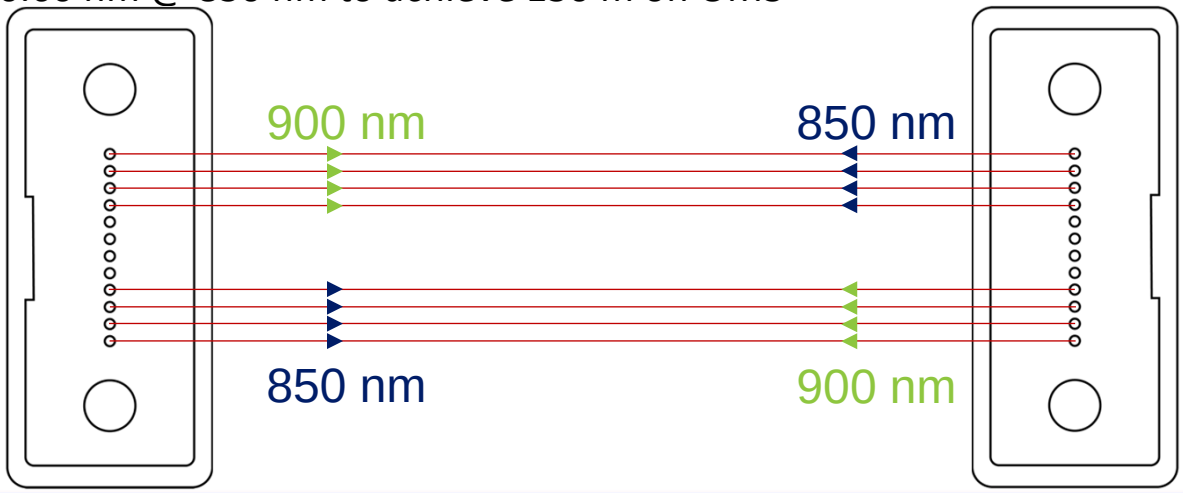


Non Return Zero
(100GBASE-SR4)

Pulse Amplitude Modulation 4 Levels
(200GBASE-SR4)

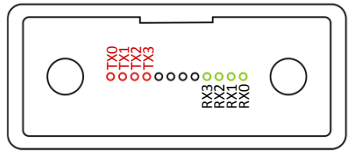
400GBASE-SR4.2 (draft)

- Uses PAM4 and Bi-Di technology – two wavelengths per fiber
  - Takes advantage of the improved EMB @ 900 nm for OM5
  - 400GBASE-SR4.2 requires tightening of the transceiver spectral width from 0.65 nm to 0.60 nm @ 850 nm to achieve 150 m on OM5

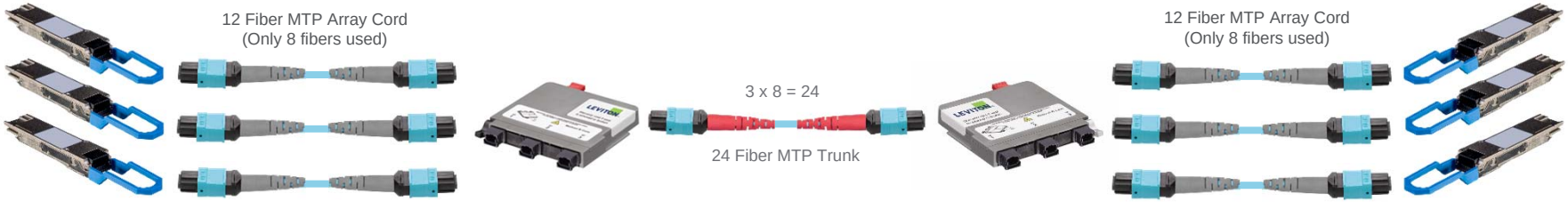


Wavelength 1: 844 nm to 863 nm
Wavelength 2: 900 nm to 918 nm

Optimizing Your Trunk Cables



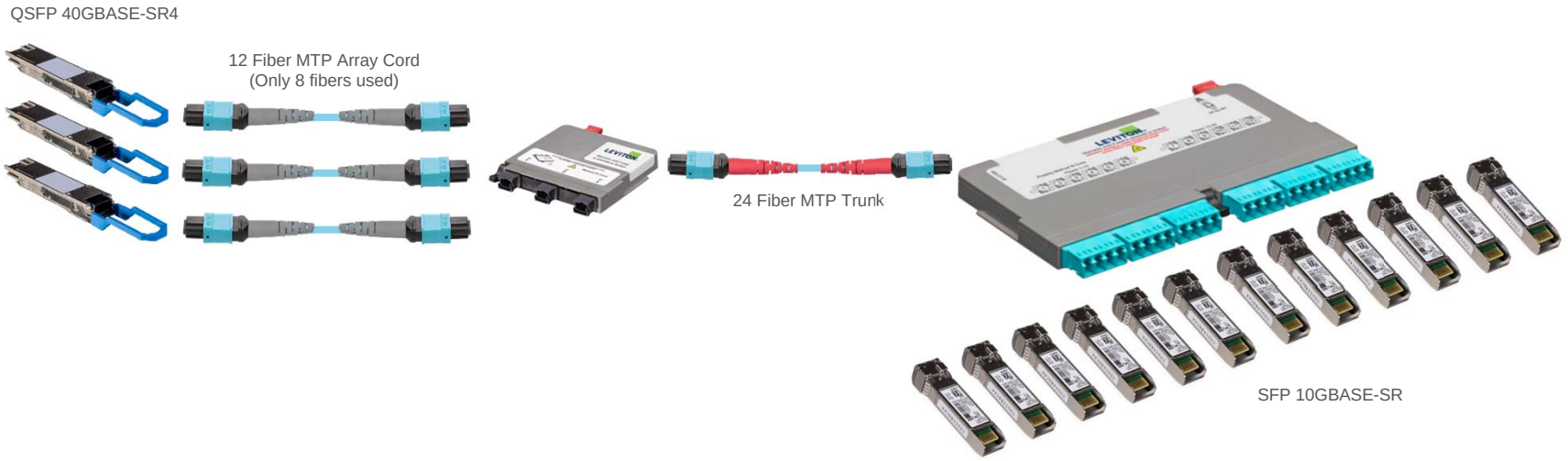
- If the transceiver requires a 12 fiber MPO but only uses 8 fibers, you could have a great deal of many dark fibers
- This is where pre-terminated trunks and cassettes are a benefit



- 40GBASE-SR4
- 100GBASE-SR4
- 200GBASE-SR4
- 400GBASE-SR4.2

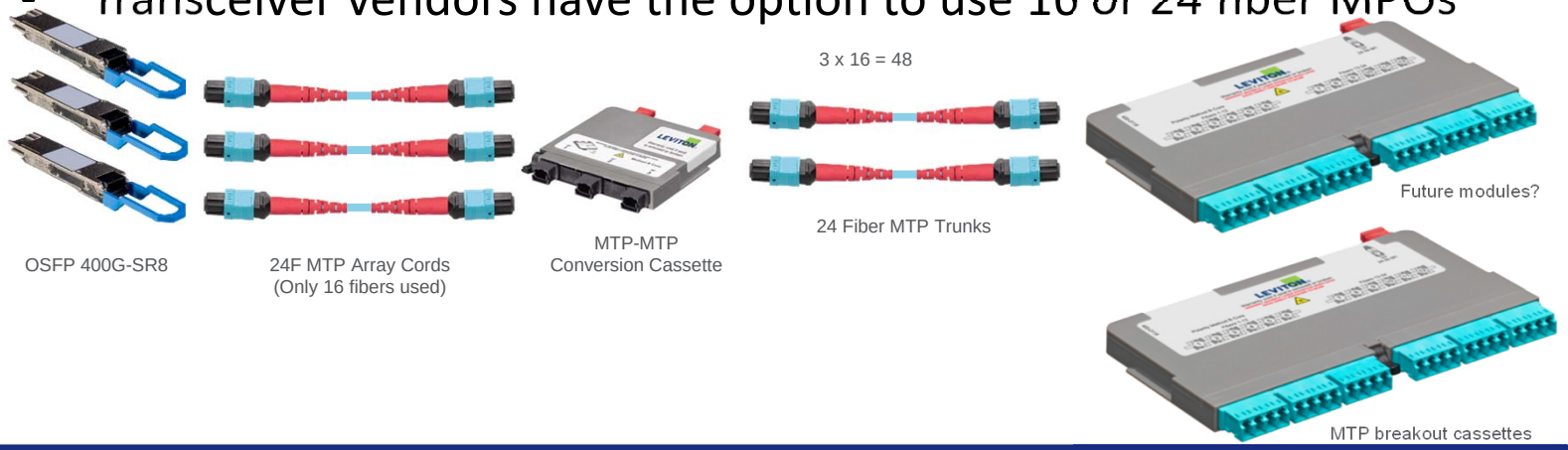
Break Out

- With space a premium at the core, many users breakout the SR4 transceiver into 4 duplex transceivers



400GBASE-SR8

- Targeted for green field (new) installations
- Specifically designed for break-out, provides 8 x 50 Gb/s channels
- New break out cassettes/harnesses required (16 fibers used)
- Transceiver vendors have the option to use 16 *or* 24 fiber MPOs



Parallel Single-mode Options

- Parallel single-mode optics typically cheaper than duplex options

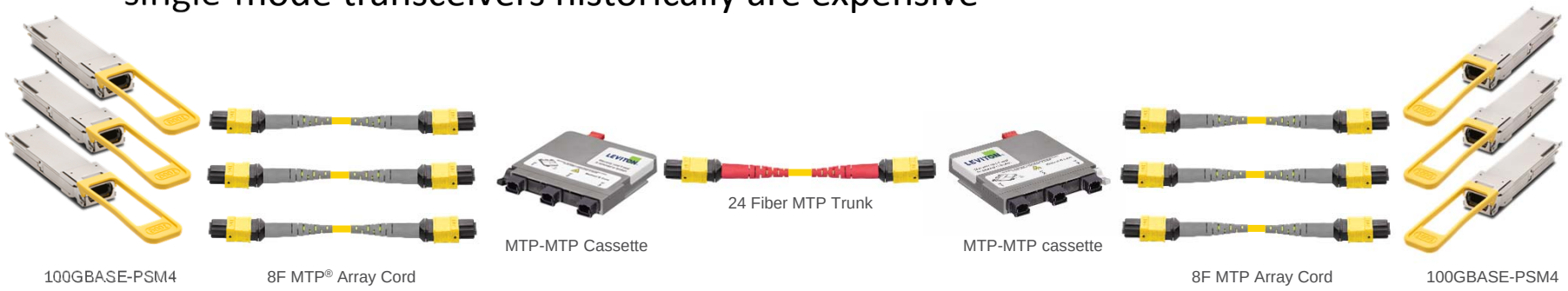
Designation	40GBASE-PLR4 (Meters)	100GBASE-PSM4 (Meters)	200GBASE-DR4 (Meters)	400GBASE-DR4 (Meters)
OS1a	10,000	500	500	500
OS2	10,000	500	500	500

- Targeted for data centers with reduced distances
- Allows break-out, but watch out for Insertion Loss

Designation	40GBASE-PLR4 (dB)	100GBASE-PSM4 (dB)	200GBASE-DR4 (Meters)	400GBASE-DR4 (Meters)
OS1a	6.5	3.3	3.0	3.0
OS2	6.5	3.3	3.0	3.0

100GBASE-PSM4

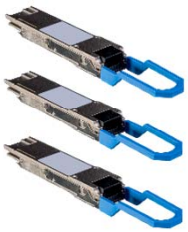
- Not an IEEE 802.3 standard, but an MSA (Multi Source Agreement)
- Extremely popular in hyper scale data centers due to its “reasonable” cost as single-mode transceivers historically are expensive



- Break out is also supported
- Supported to 500 m, Insertion Loss ≤ 3.3 dB

Break Out

- Convert 8-fiber channel into 4 x duplex channels
- No need to replace Base24 backbone cabling



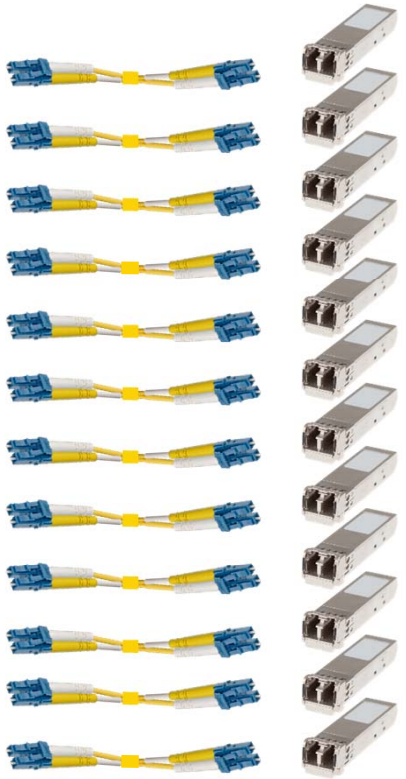
400G-DR4/XDR4

8F MTP Array Cord

MTP-MTP Cassette

Base24 MTP Trunk

MTP-LC Cassette



LC-LC Patch Cords

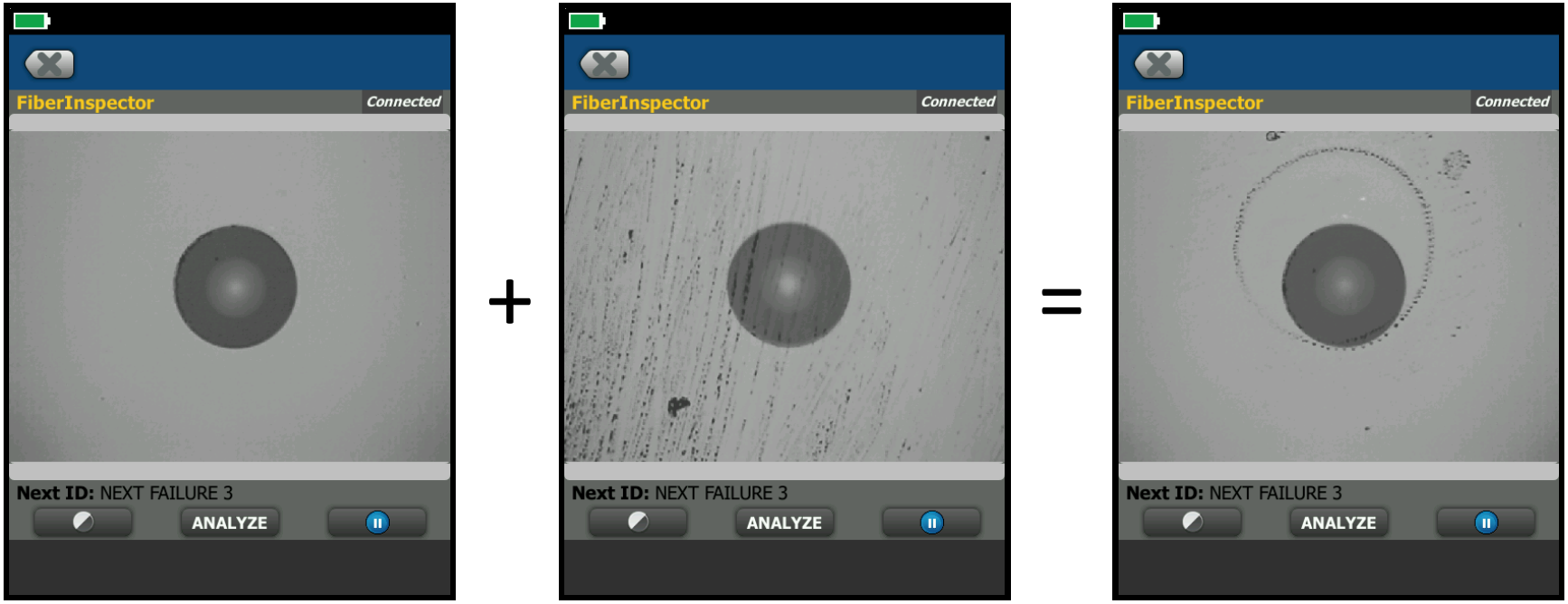
QSFP28 100G-DR

- 4x100G channels/module or 128x100G ports/1U Switch
- 400G-DR4/XR4

"There is no cleaning without inspection"

THE HEALTH OF YOUR CONNECTIONS

Cross Contamination



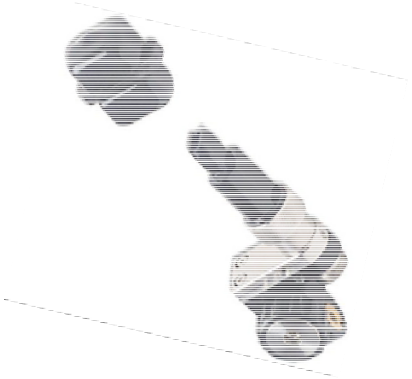
Newly installed connector

Patch cord to be inserted

Your newly installed connector

MPO Inspection

- Multiple options available:

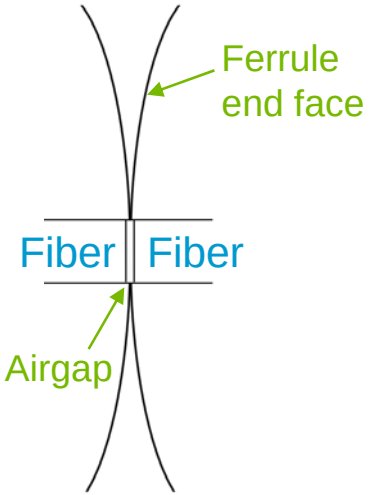


Adapter to fit on your existing probe

Dedicated MPO Inspection

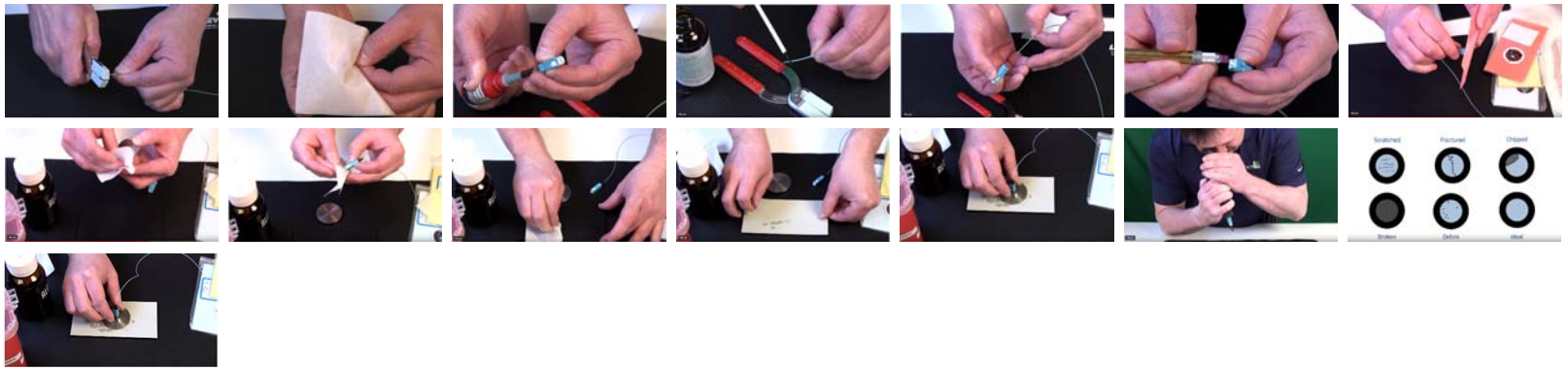
Reflectance (Return Loss)

- This is the reflection of light back into the transceiver
- Most common cause is the airgap between connectors
  - Polishing the ceramic end face can result in an undercut
  - When two connectors are mated, there is small airgap between them
  - Bigger the airgap, worse the return loss (reflectance)
- With higher speeds, now a concern in the enterprise
- ANSI/TIA-568.3-D changed the single-mode requirement from 26 dB to 35 dB
- IEEE 802.3 now designs to 35 dB



How Well Were Your Single-mode Connectors Polished?

- This process can result in a wide range of return loss performance



- We have seen values as poor as 20 dB
- Depending on the final polish, we typically see 30 dB if the link was not subject to an Optical Time Domain Reflectometer, required to measure reflectance (return loss)

IEEE 802.3cd 100GBASE-DR (duplex)

- Variable link loss (budget)

100GBASE-DR Maximum channel insertion loss (dB)		Number of connections where the reflectance is between -45 and -55 dB								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Number of connections where the reflectance is between -35 and -45 dB	**0**	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	2	3.0	3.0	2.9	2.9	2.9	2.9	2.9	2.9	2.9
	3	2.9	2.9	2.9	2.9	2.9	2.8	2.8	2.8	—
	4	2.8	2.8	2.8	2.8	2.7	2.7	2.7	—	—
	5	2.8	2.8	2.7	2.7	2.7	2.6	—	—	—
	6	2.6	2.6	—	—	—	—	—	—	—

- Loss budget is ≤ 3.0 dB @ 1310 nm

IEEE 802.3cd 100GBASE-DR (duplex)

- In a couple years time, will those LC connectors still be > -50 dB?

100GBASE-DR Maximum channel insertion loss (dB)		Number of connections where the reflectance is between -45 and -55 dB								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Number of connections where the reflectance is between -35 and -45 dB	**0**	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	2	3.0	3.0	2.9	2.9	2.9	2.9	2.9	2.9	2.9
	3	2.9	2.9	2.9	2.9	2.9	2.8	2.8	2.8	—
	4	2.8	2.8	2.8	2.8	2.7	2.7	2.7	—	—
	5	2.8	2.8	2.7	2.7	2.7	2.6	—	—	—
	6	2.6	2.6	—	—	—	—	—	—	—

- Loss budget is ≤ now 2.9 dB @ 1310 nm, design to 2.9 dB?

Poor Cleaning Can Increase Return Loss

- Isopropyl Alcohol (IPA) is commonly used – **needs to be 99%**
- Technicians are often forced to deal with what is available

- These pharmacy type IPA often leaves residue behind
- That residue is a change in refractive index resulting in poor return loss

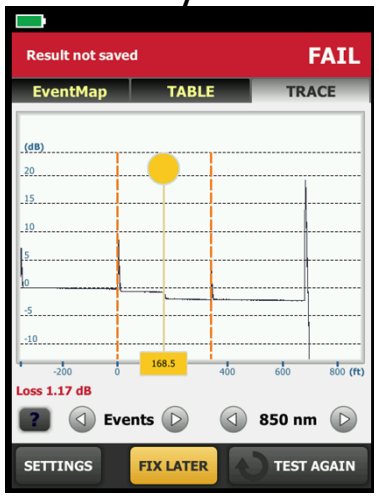
Cleaning Kits

Wet to dry cleaning is ALWAYS better

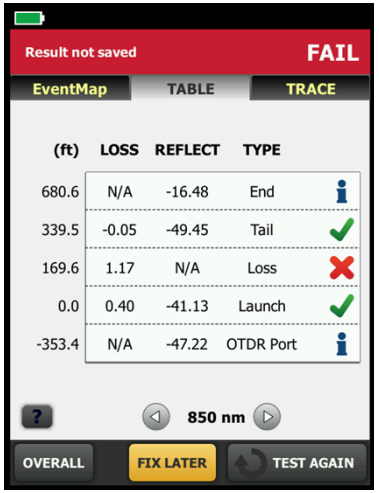
Click pens are ideal for ports, not for cleaning patch cords where end faces are subject to grease from fingers

Did You Inherit the System?

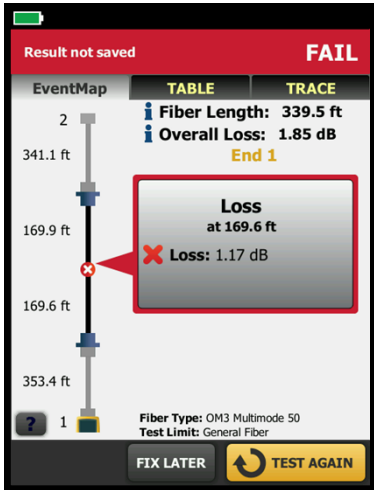
- If you do not know what is in your link, you will either need to walk the link or use an Optical Time Domain Reflectometer (OTDR)
- The OTDR will also let you know the health of the fiber link



OTDR Trace



Event Table



EventMap™

RE-TERMINATION OPTIONS

Field Polish

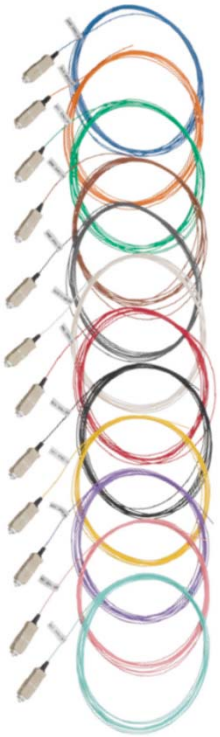
- Declining method – less popular
- Time consuming compared to other options
- Very craft sensitive
- For smaller multimode installations – still viable
- Very difficult to hit the 35 dB Return Loss requirement for single-mode connectors; ANSI/TIA-568.3-D and ISO/IEC 11801:2017
  - An OTDR is required to measure reflectance (return loss)
  - Few do, so the issue of poor reflectance is discovered later when the application is reporting issues

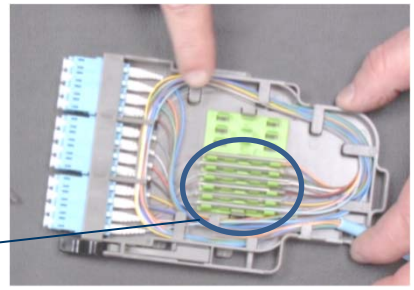
Mechanical Splice

- Increasingly popular method
- Faster termination than field polish
- Less craft sensitive
- Factory polished end faces
  - Better insertion loss
  - Better return loss (reflectance)
- Less consumables
  - No polishing papers
- A precision cleaver is required

Pigtail Fusion Splice

- Factory polished connector terminated with a length of fiber
  - Low insertion loss
  - Low return loss (reflectance)
- The pigtail is fused to the trunk cable
- Fusion splicer can estimate loss of fusion
  - Reduced uncertainty compared to a mechanical splice/field polish
- Fusion splicers have come down in price
- Skill in dressing splice trays





Fused fiber

Fusion Splice Connector

- Factory polished connector terminated with a length of fiber
  - Low insertion loss
  - Low return loss (reflectance)
- No polishing / gel / splice trays

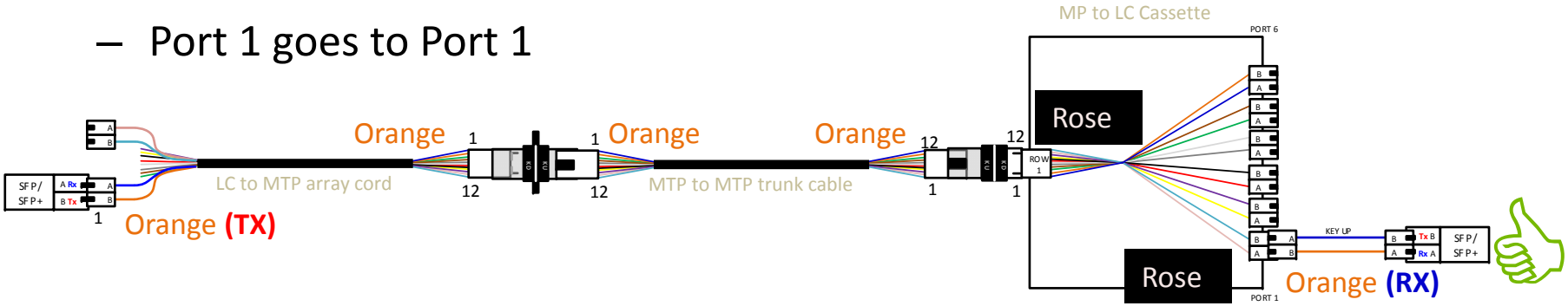
THE CASE FOR PRE-TERMINATED FIBER

Is Pre-terminated Fiber Right For Me?

- Yes, if:
  - Your application is Parallel (MPO), you are either looking at pre-terminated or splice on – there is no field polishing of MPOs
  - Your project involves hundreds of fibers, either duplex or parallel – the reduced time to project completion is very attractive
    - However, ensure that cables can be delivered to your location within two weeks
  - You are operating to tight loss budgets – far more predictable
  - You are confident in the length required for a trunk cable
  - You are unsure about polarity – technician simply connects the components together ……

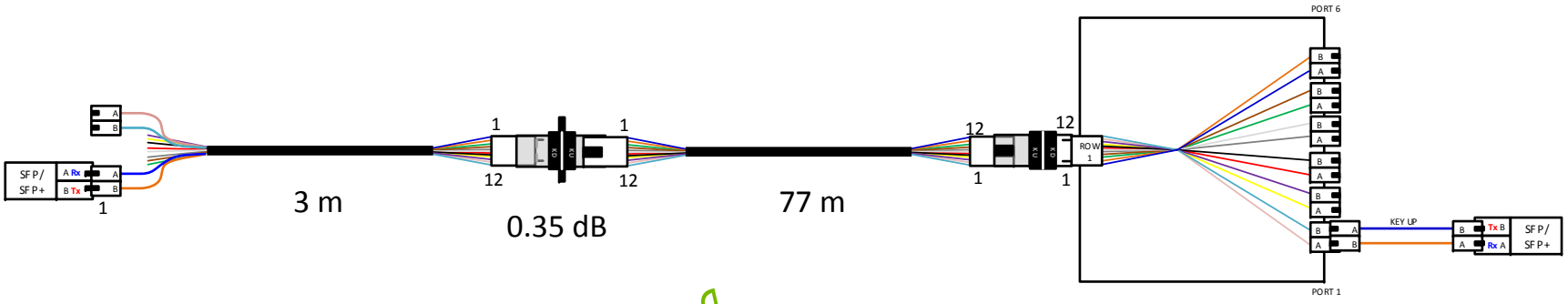
Verifying Polarity

- The goal is simple
  - Transmit goes to receive and vice versa
  - Port 1 goes to Port 1



Verifying Loss Budget; 10GBASE-SR

- Cable choice is OM3
  - Loss budget is 2.6 dB @ 850 nm – max length 300 m



- Length = 3 m + 77 m = 80 m
- Loss @ 850 nm = Cable (3 dB/km) + Connections
  = (0.003 dB x 80 m) + 0.35 dB + 0.50 dB = 1.09 dB

Summary

- Know the length limitations for your application on a given fiber
- A BiDi or SWDM4 can extend the life of your duplex cabling plant
- Single-mode is length limited if choosing a data center transceiver
  - Distance options are 500 m, 2 km, 10 km……
  - Reduced allowance for insertion loss on the 500 m options
  - Watch out for return loss – design to a worse case scenario
- Invest in inspection and cleaning equipment
  - Look at the label of the IPA if you are using it – 99% is required
- Evaluate the best termination method that works for you
- Pre-terminated takes a great deal of uncertainty out of the equations

Thank You