

# The Road to Single-Mode: Direction for Choosing, Installing and Testing Single-mode Fiber

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# Single-mode Applications/Design

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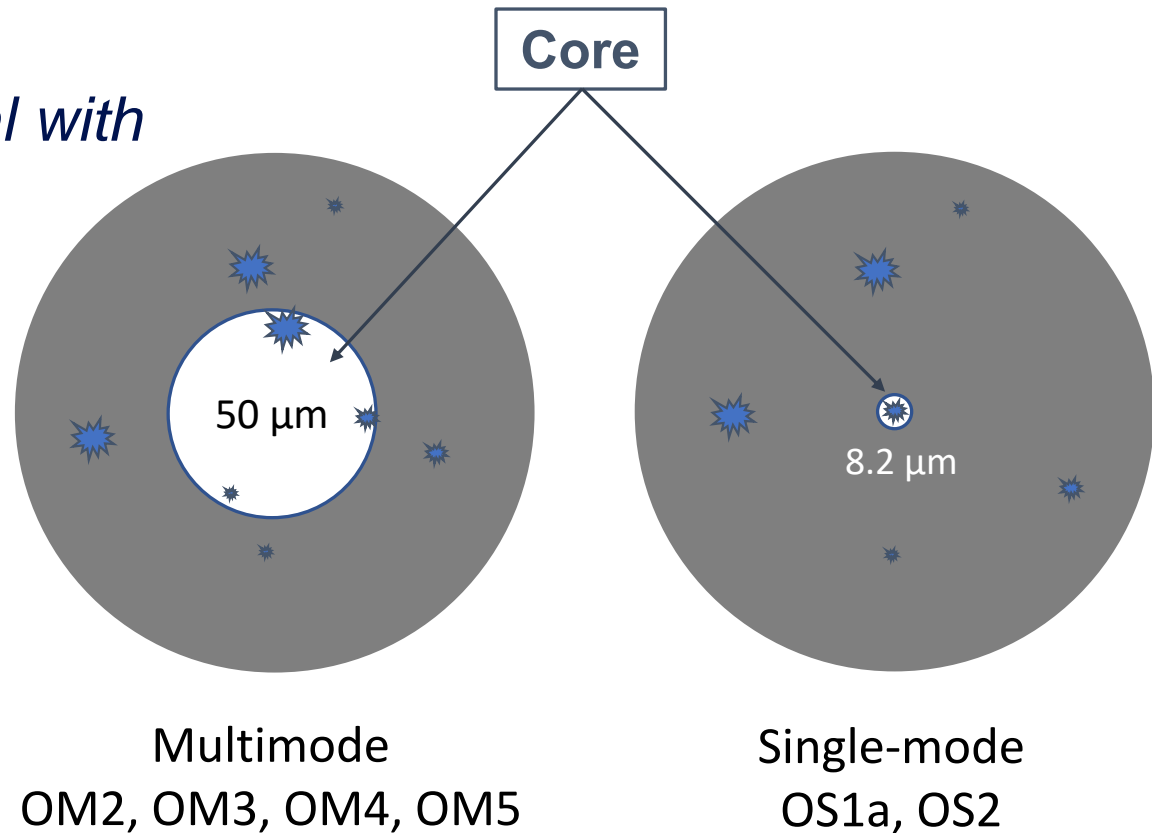


# Traditional Thoughts on Single-mode

- More challenging to keep clean
- Less generations of fiber to deal with
- Transceivers are more expensive
- Applications are duplex, no need for MPOs to achieve higher speeds
- Greater distance with single-mode transceivers
- Greater insertion loss allowed ( $\approx 6.7$  dB) compared to multimode
- Reflectance (return loss/back reflection) concerns
- Uses high power lasers – safety concerns
- May have to use an attenuator on shorter links

# Multimode vs. Single-mode

- *Multimode is easier to deal with*
- Dust in an office
  - 2.5 to 10  $\mu\text{m}$
- Human hair
  - $\approx 100 \mu\text{m}$
- It is a great deal easier to block all the light in a single-mode end face



# Less Generations of Fiber to Deal With

Multimode Cable Type	100GBASE-SR4
OM1	Not supported
OM2	Not supported
OM3	70 m
OM4	100 m
OM5	100 m

Single-Mode Cable Type	100GBASE-DR
OS1a	500 m
—	—
—	—
—	—
OS2	500 m

- If you installed OS1a back in 1999 or OS2 today in 2022, the distance reach is the same for 100GBASE-DR
- The connectors may need replacing, but no pulling new cable
- Decision to install multimode driven by transceiver cost

# Transceivers Are More Expensive

- Single-mode transceivers have certainly come down in cost
- There was a time when you could say 7.5 x cost of multimode
- Large (hyper-scale) data centers driving the demand for low-cost single-mode transceivers have changed the enterprise and data center markets

100GBASE-SR4 (multimode)  $\approx$  100GBASE-PSM4 (single-mode)

# Single-mode Options to 400 Gb/s (Duplex)

1 Gb/s	Distance (m)
1000BASE-LX	5,000
1000BASE-LX10	10,000
1000BASE-EX	40,000
1000BASE-ZX	70,000

10 Gb/s	Distance (m)
10GBASE-LR	10,000
10GBASE-LX4	10,000
10GBASE-ER	40,000
10GBASE-ZR	80,000

40 Gb/s	Distance (m)
40GBASE-LRL4	1,000
40GBASE-FR	2,000
40GBASE-LR4	10,000
40GBASE-ER4	40,000

100 Gb/s	Distance (m)
100GBASE-DR	500
100GBASE-CWDM4	2,000
100GBASE-LR4	10,000
100GBASE-ER4	40,000

200 Gb/s	Distance (m)
200GBASE-FR4	2,000
200GBASE-LR4	10,000

400 Gb/s	Distance (m)
400GBASE-FR8	2,000
400GBASE-LR8	10,000



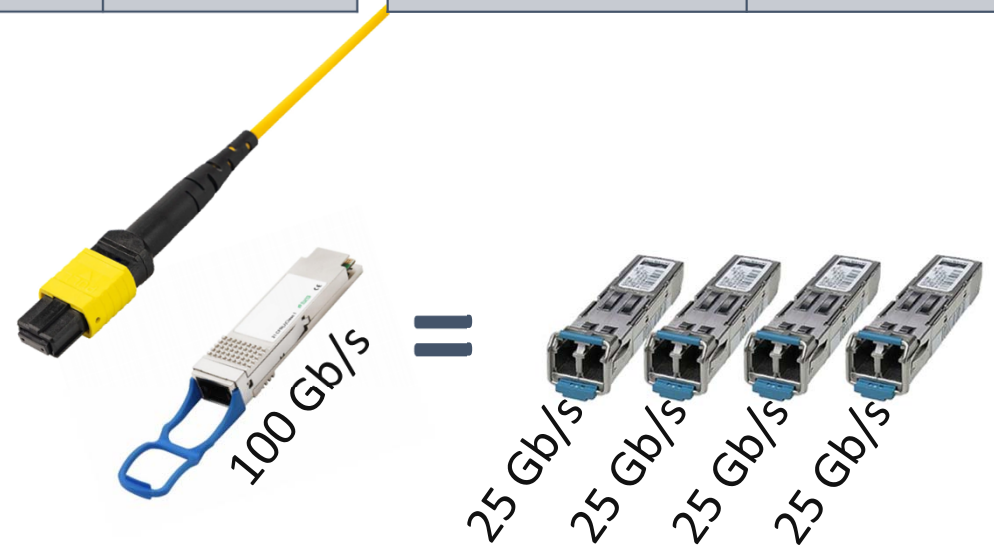
# Single-mode Options to 400 Gb/s (Parallel)

40 Gb/s	Distance (m)	100 Gb/s	Distance (m)	200 Gb/s	Distance (m)
40GBASE-PLR4	1,000	100GBASE-PSM4	500	200GBASE-DR4	500

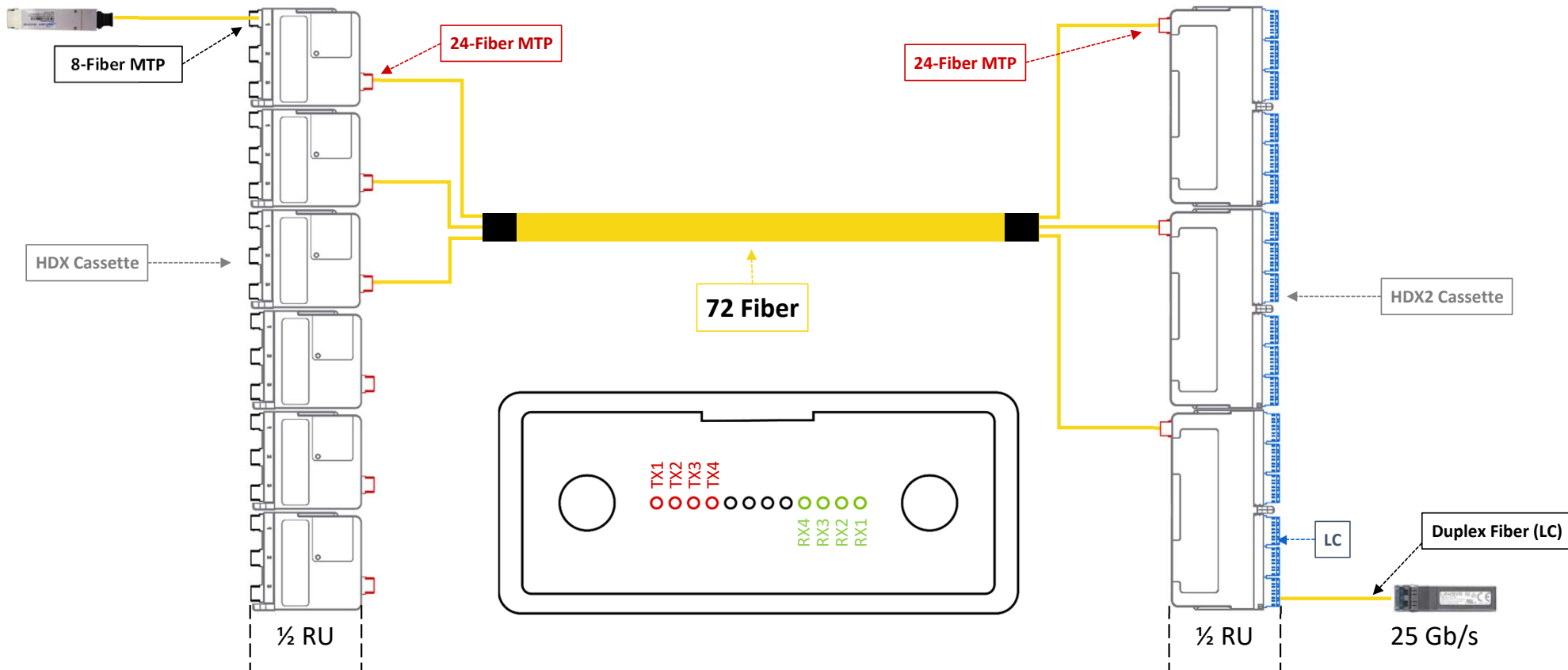
400 Gb/s	Distance (m)
400GBASE-DR4	500

- Transceiver cost reduced
- These options allow breakout
  - Increases port density

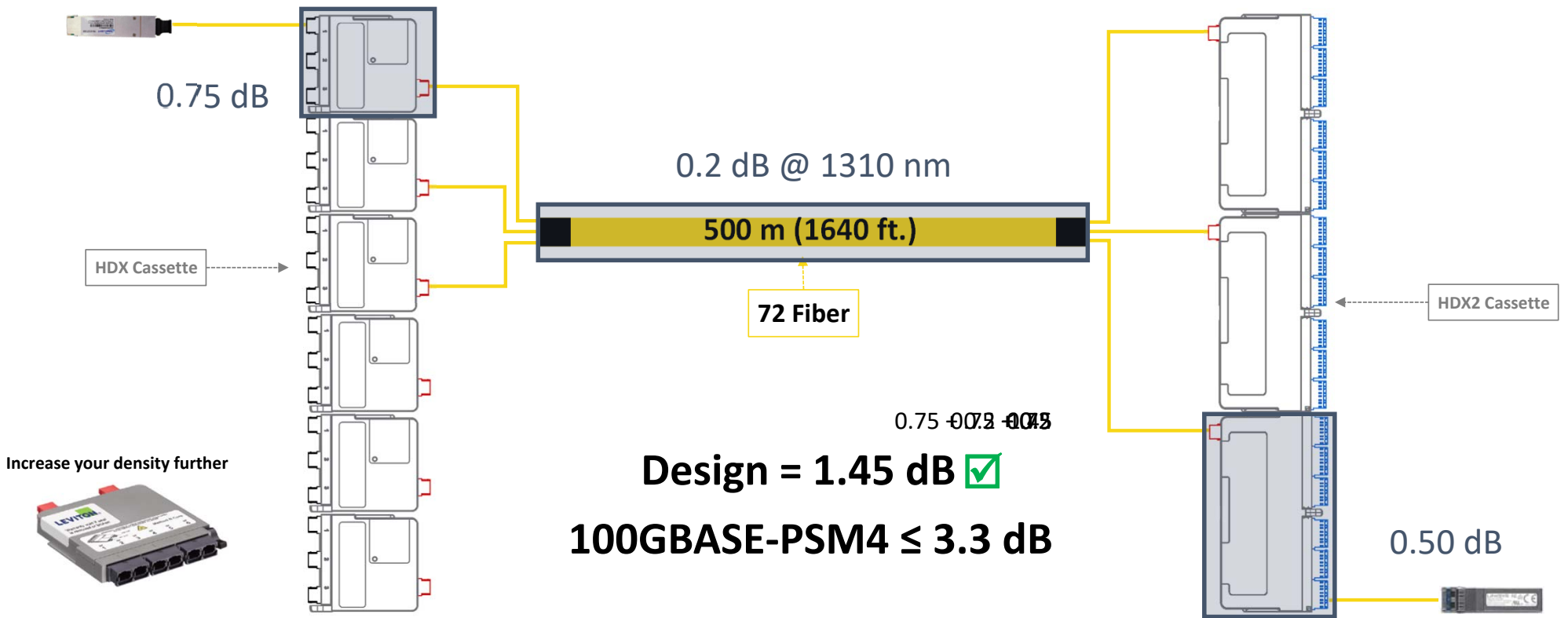




# 100GBASE-PSM4 Breakout



# 100GBASE-PSM4 by the Numbers



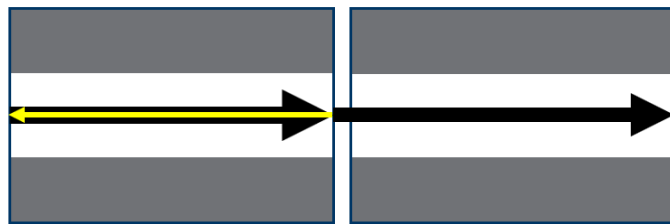
# Greater Insertion Loss Allowed

- No longer a true statement
- With cheaper transceivers comes a reduced allowance for insertion loss
- Designers need to be aware of the reduced loss budget for the newer transceivers targeted at data centers
- If your design has multiple connections, you can run into trouble

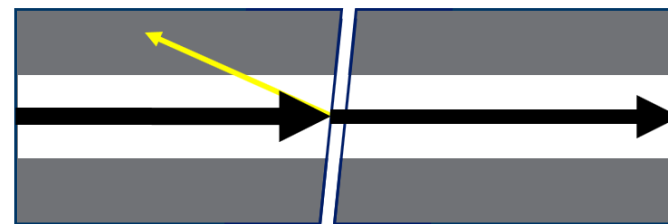
100 Gb/s Ethernet	Channel Loss
100GBASE-ER4	15.0 dB
100GBASE-LR4	6.3 dB
100GBASE-CWDM4	5.0 dB
100GBASE-PSM4	3.3 dB
100GBASE-DR	3.0 dB

# Return Loss (Reflectance)

- What is return loss?
  - It's light reflected back into the transceiver
  - Caused by a change in refractive index (glass – air – glass)
  - At higher data rates, errors are generated if too much light is received back



Physical Contact (PC)



Angled Physical Contact (APC)

- Putting an 8° angle on the end face results in the mode of light being forced back into the cladding rather than the transceiver

# Return Loss (Reflectance) Concerns

- ANSI/TIA-568.3-D calls out connector return loss
- IEEE 802.3 (Ethernet) calls out reflectance for connections
- Measured using Optical Time Domain Reflectometers (OTDRs)
  - Calls out reflective events as reflectance
- Return loss or reflectance?
  - Practically speaking, they're the same thing
  - Return loss is a positive number (e.g. 45 dB)
  - Reflectance is a negative number (e.g. -45 dB)

# Sensitive to Reflectance (Return Loss)

## 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	<b>3.0</b>
	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	—	—	—	—	—	—	—

- Let's take an example link containing four LC/MTP cassettes
- Single-mode MTPs are APC, so there will be four of those (typically > -55 dB)
- The four LCs are factory polished (typically >= -50 dB)
- We have no connections between -35 dB and -45 dB
- Our allowable loss will be 3.0 dB

# Sensitive to Reflectance (Return Loss)

## 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
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	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	<b>2.7</b>	2.7	2.7	—	—
	5	2.8	2.8	2.7	2.7	2.7	2.6	—	—	—
	6	2.6	2.6	—	—	—	—	—	—	—

- Let's take an example link containing four LC/MTP cassettes
- Single-mode MTPs are APC, so there will be four of those (typically > -55 dB)
- The four LCs are factory polished (typically >= -50 dB)
- Future performance could be less than -45 dB
- Our allowable loss will be 2.7 dB

# Uses Higher Powered Lasers

- Long haul versions only
- Class 1M lasers for
  - 100GBASE-DR
  - 100GBASE-PSM4
  - 100GBASE-CWDM4

A Class 1M laser is safe for all conditions of use except when passed through magnifying optics such as microscopes and telescopes.



Video Fiber Scope



Fiber Scope  
(Built in filter)

**LASER RADIATION**  
**DO NOT VIEW DIRECTLY WITH**  
**OPTICAL**  
**INSTRUMENTS CLASS 1M LASER**  
**PRODUCT**



# Attenuators

- If the link is too short, the transmitted light could saturate the receiver
  - This is typically an issue associated with high power lasers only
  - The sort of lasers you find in outside plant such as cable tv
  - If the link is short, the designer will add an attenuator
  - Alternatively, a quick fix is to put a bend in the fiber and tape it in the cabinet/tray
- In the Data Center, low power Fabry–Pérot (FP) lasers are used
  - These lasers have a nominal output of -3 dBm
- Distributed Feedback Lasers can be found in CWDM4 transceivers
  - These laser have a nominal output of 2.5 dBm
- IEEE typically specifies a minimum distance of 2.0 m (6.6 ft.)
  - This avoids any concerns over saturation



# Your Design

100GBASE-PSM4 in a Switch to Switch Environment

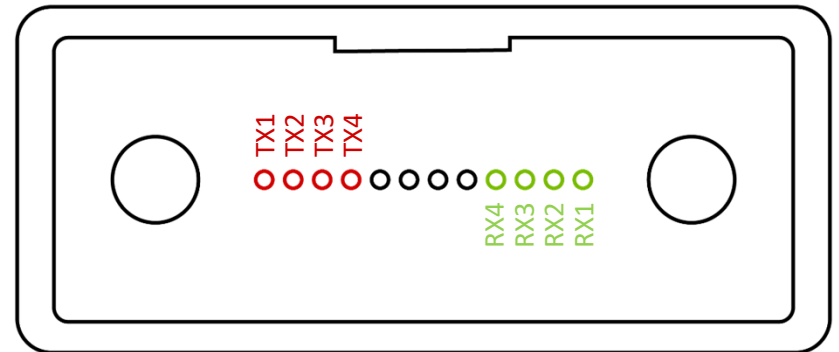
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# 8, 12, or 24 Fiber MPO?

## These applications use 8 fibers:

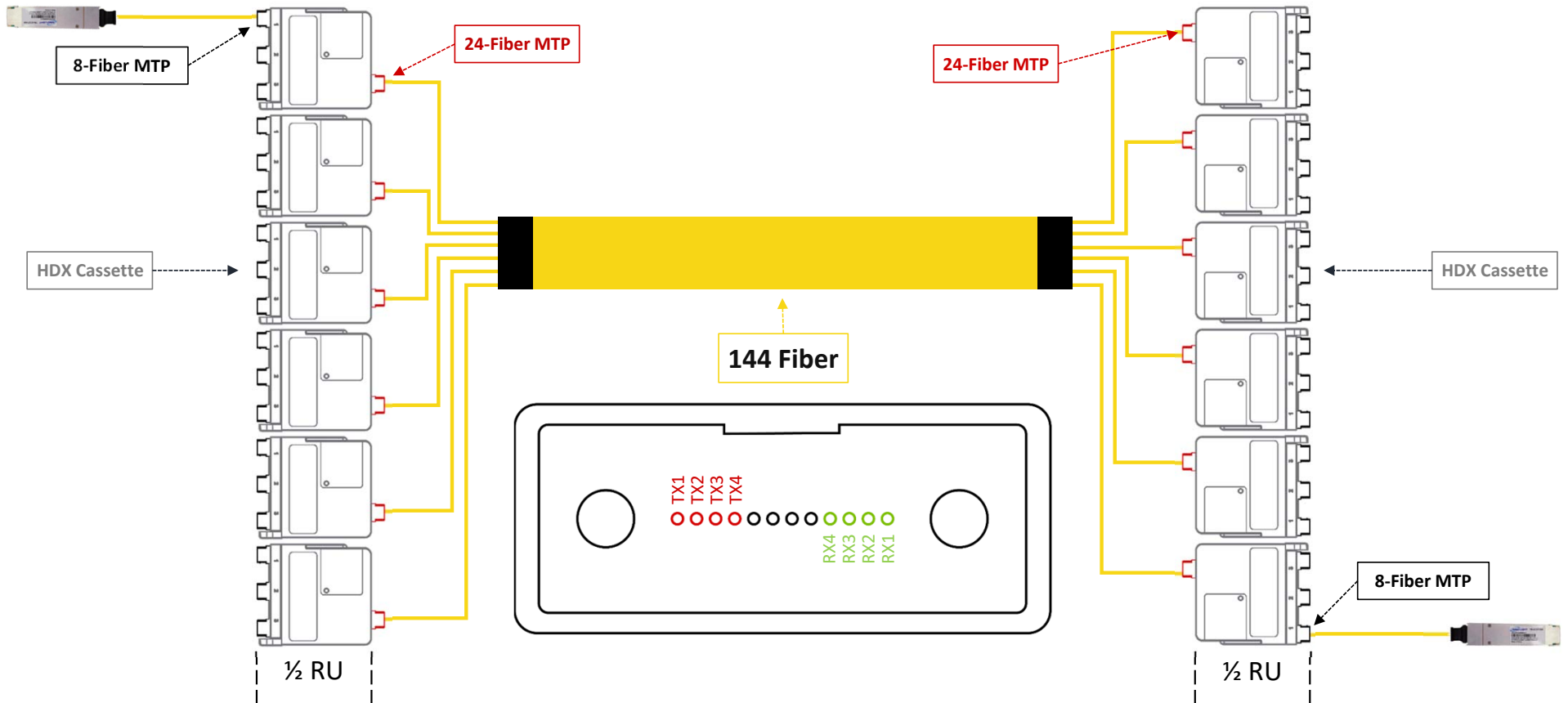
- 40GBASE-PLR4
- 200GBASE-DR4
- 100GBASE-PSM4
- 400GBASE-DR4



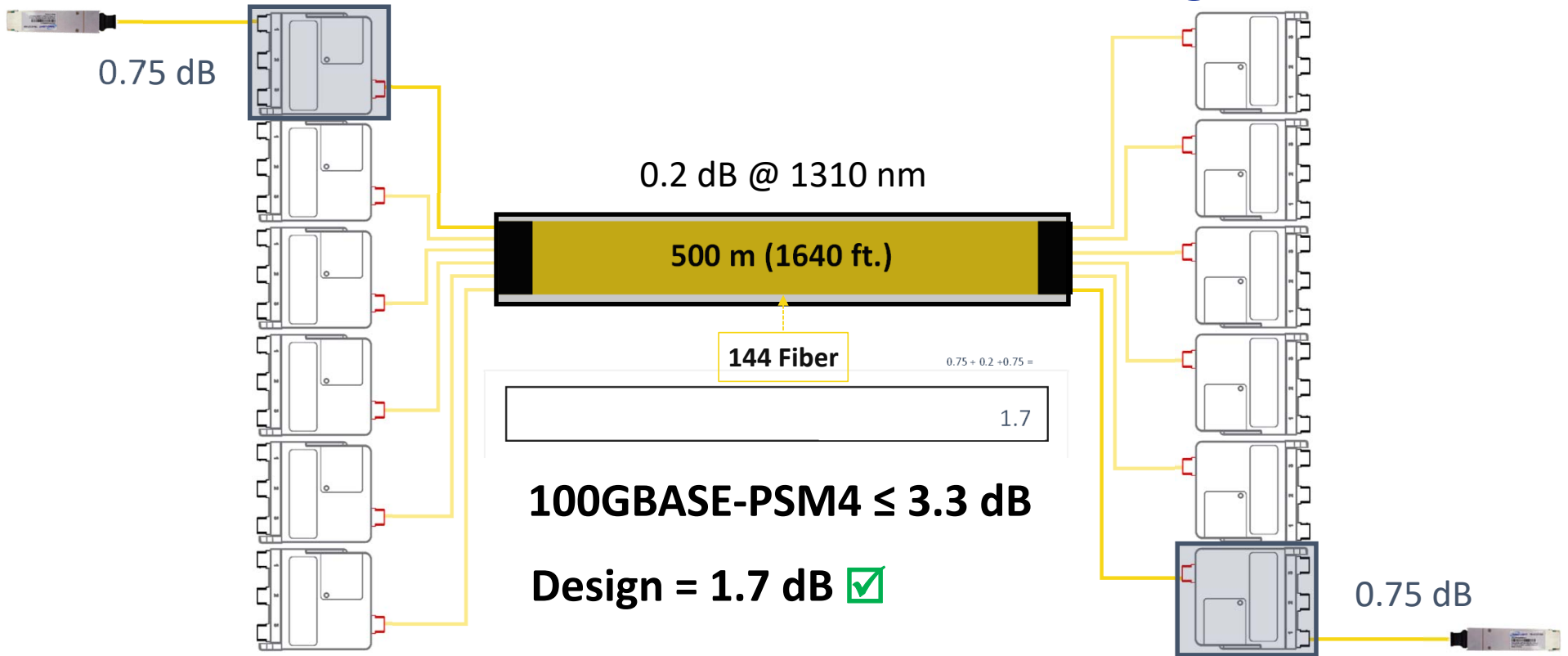
- There is no such thing as an 8 fiber MPO
- The transceiver vendors typically use a 12 fiber MPO
- The 4 fibers in the middle are left unused
- Can lead to an inefficient cabling system



# 100GBASE-PSM4 Efficient Design

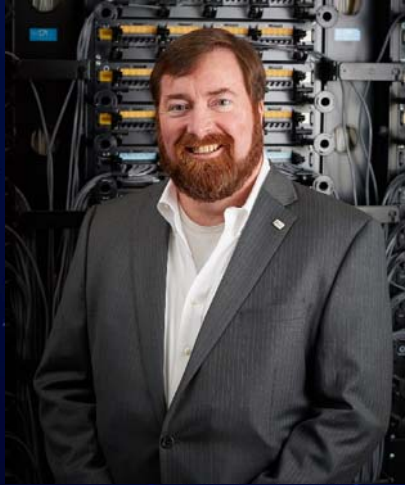


# 100GBASE-PSM4 Efficient Design



# Take-aways

- Cost of data center single-mode transceivers are being driven down
- PSM4 over MPO links allows breakout to LCs for increased density
- Conversion cassettes provide an efficient design
- Single-mode distances low as 500 m, transceiver dependent
- Loss budgets on single-mode have been reduced
- Return loss (reflectance) can impact your loss budget further



# Planning for Single-mode Testing

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Fluke Networks



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# Agenda – Plan Ahead for Greater Efficiency

- Inspection and Cleaning
  - What Camera tips will you need?
- Loss Testing
  - What limit will you use?
  - What are your Cable Identification numbers/sequence
  - Set reference – Process for reliable results
- Troubleshooting with OTDR (briefly!)
- Results Management



# Inspection and Cleaning

Repeat as Needed

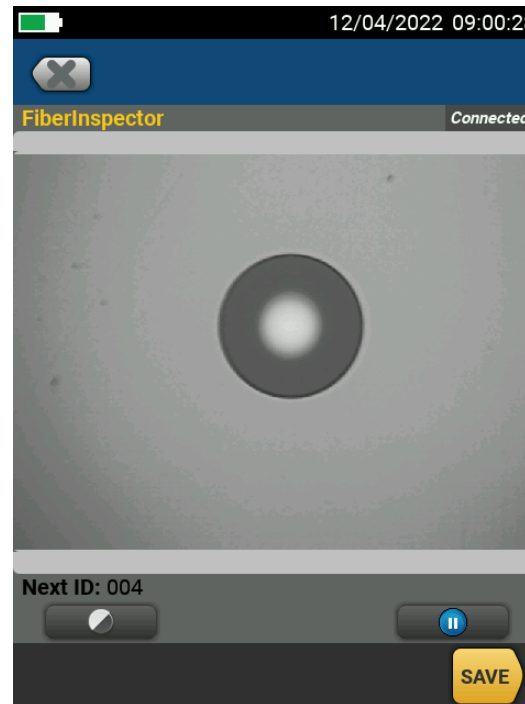
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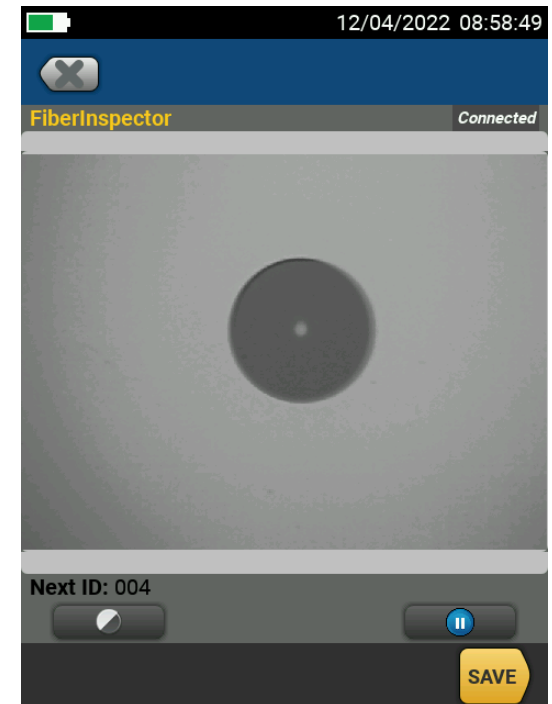
# Inspect, Clean, Repeat



**Video Microscope**



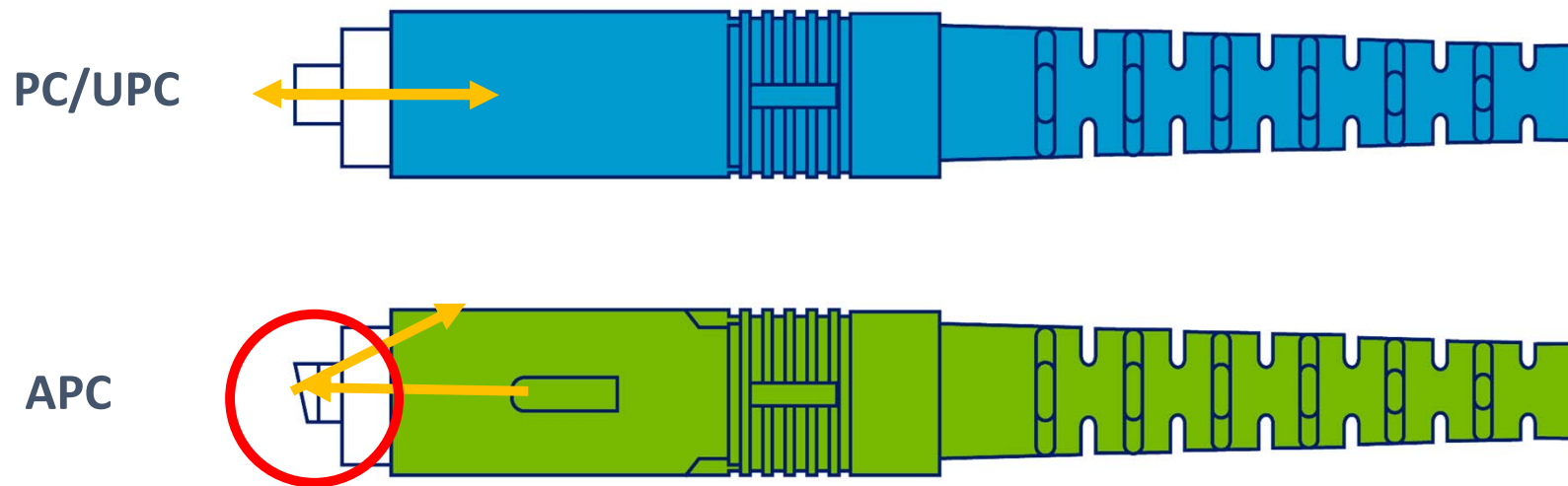
**Multimode has a larger core**



**Single Mode has a smaller Core**

# Inspecting APC Connectors - Compensate for the Angle

- Same cleaning equipment – new camera tips

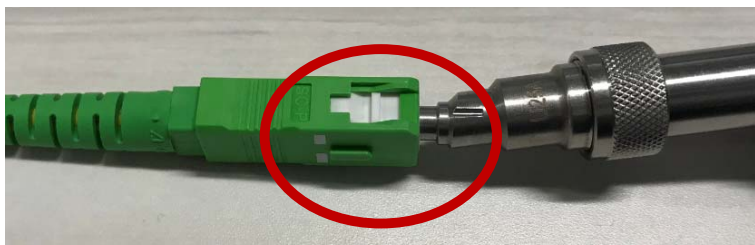


APC – Angled Physical Contact

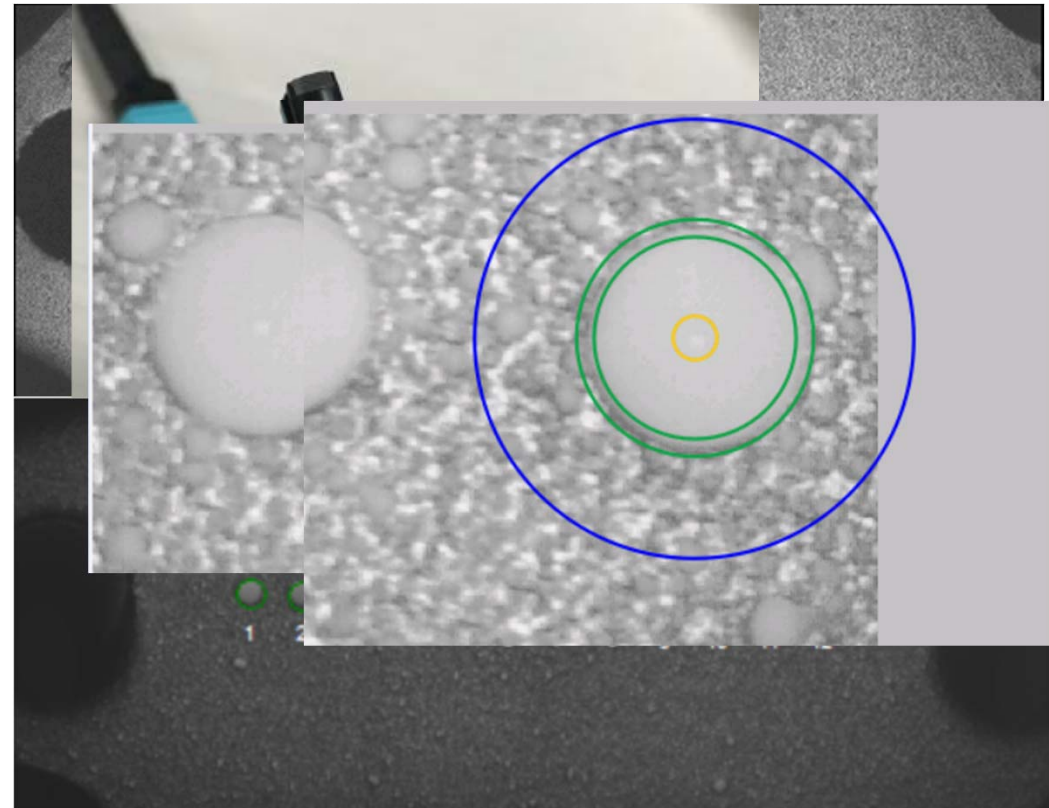
# Tips Have a Slight Angle - These are SC



# APC Connectors May Need a “Twist” to Show Up



## Single-mode MPO Connectors Also Need an Adapter





# Loss Testing

Tier I Testing: Loss, Length and Polarity is Used to Confirm What Applications Will be Supported on a Fiber Link

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# What Limits and Cable IDs Will You Use?

- What does your contract/end-user require?
  - Length based limits (TIA-568.3-D) or Application or a fixed value?
- Preload test limit
  - How many adapters? How many splices? What values?
- Preload cable IDs
  - D3.DK110.43/E5.AM564.20.032 takes time to type into a tester
    - And more time to correct it after words
- Both on tester and remotely
  - Cloud service to update tester in the field?



# Tier 1 (OLTS) Certification

- Test Reference Cords (TRCs) are recommended in ANSI/TIA and ISO/IEC
- Patch cords from a distributor are specified with a loss of up to 0.50 dB



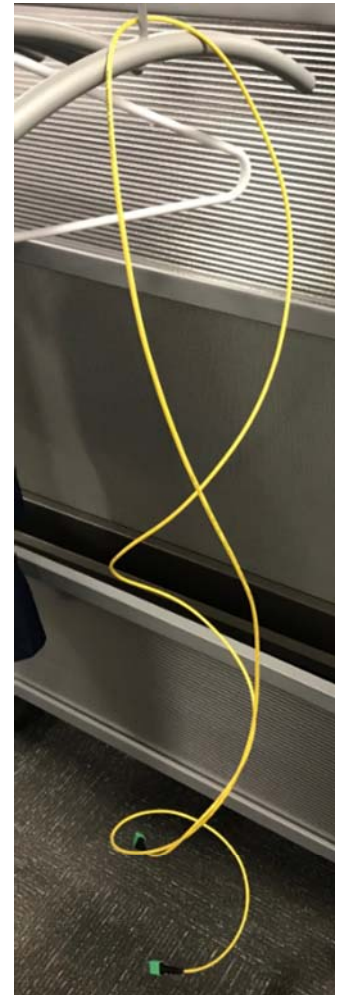
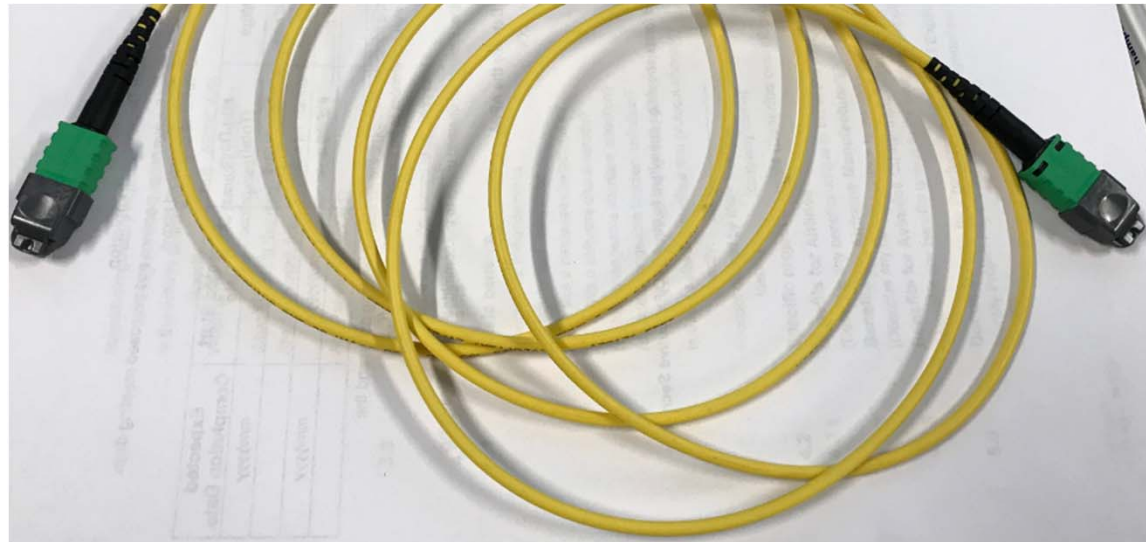
ANSI/TIA-526-14-C & IEC 61280-4-1  
**≤ 0.10 dB**



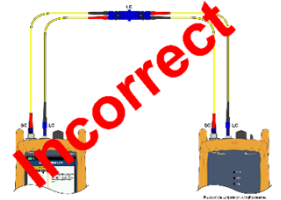
ANSI/TIA-526-7-A & IEC 61280-4-2  
**≤ 0.20 dB**

# Tech Tip

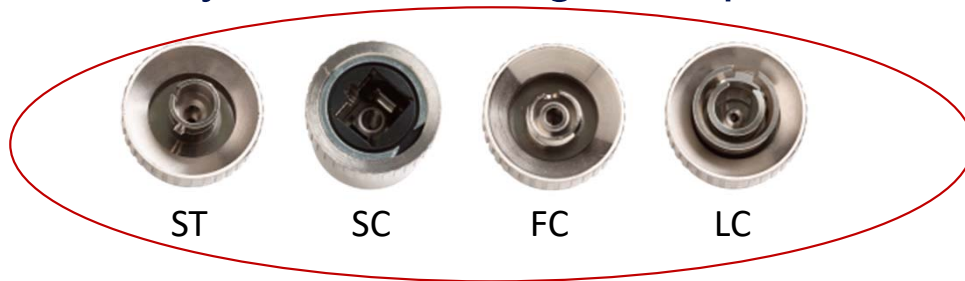
- Before setting a reference, allow cords to relax
- Helps remove the bend from the cords



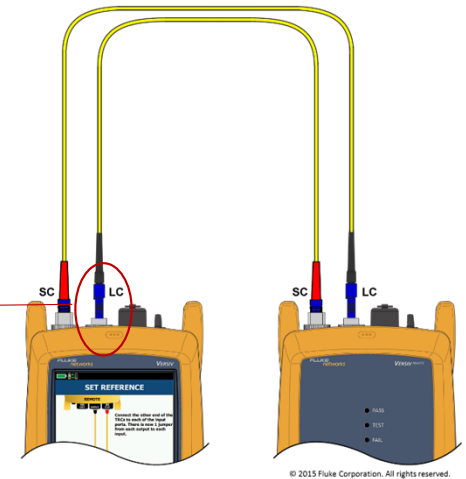
# For the Most Accurate Measurement



- Use a 1 Jumper Reference
  - This provides the least measurement uncertainty
  - Do you have the right adapter for the power port?

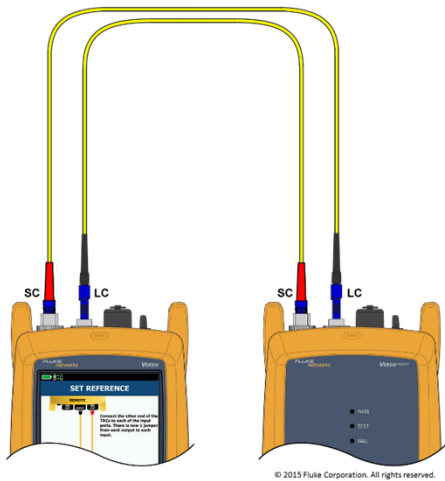


- Do you bring the right cords?
- Are they in good condition?

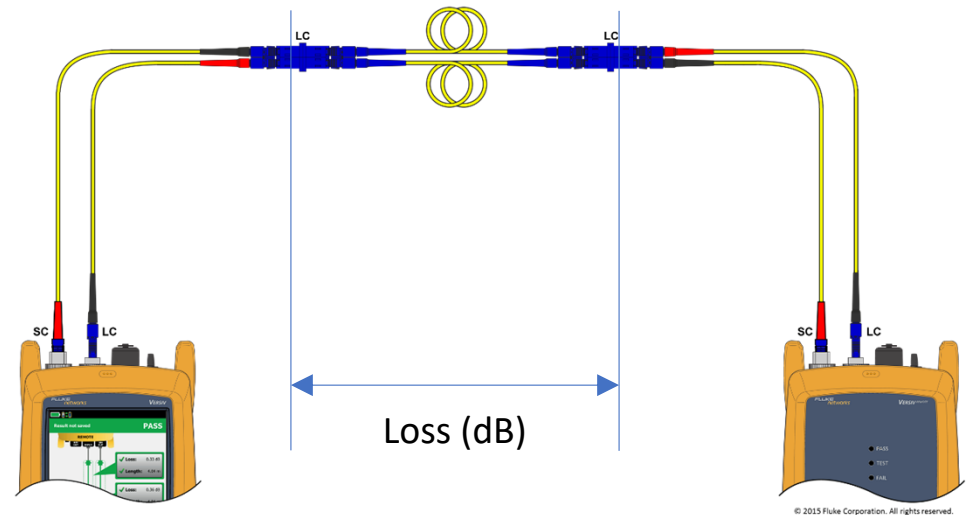


Direct connection  
(No bulkhead adapter!)

# First Set a Reference.. Then Find the Difference



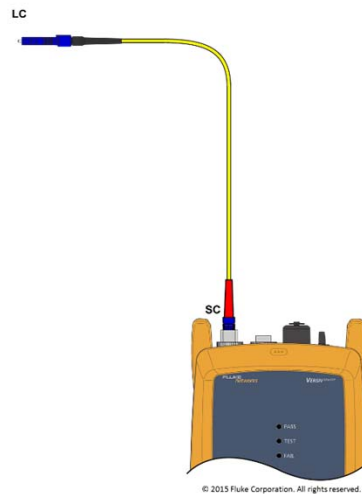
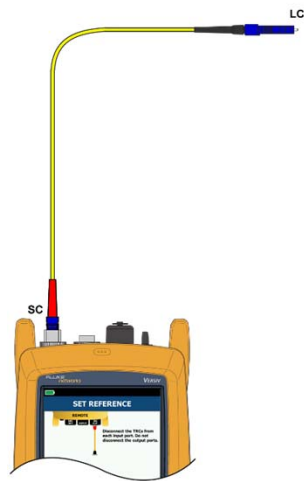
Direct connection  
(No bulkhead adapter!)



The difference is what we want to know

# After Setting the Reference

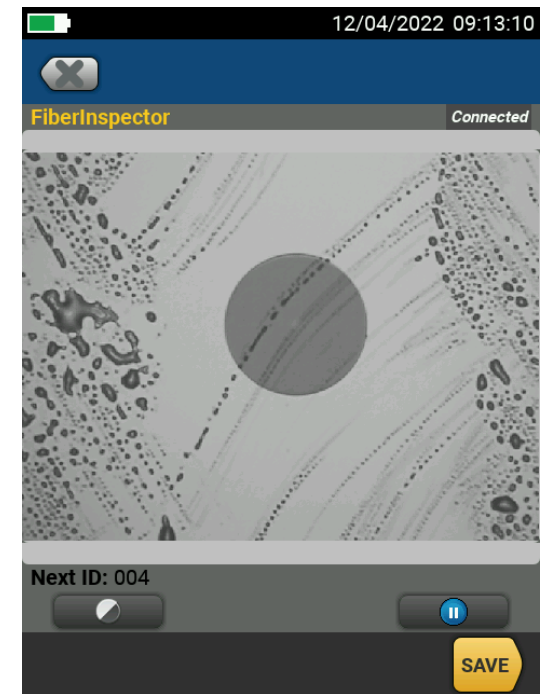
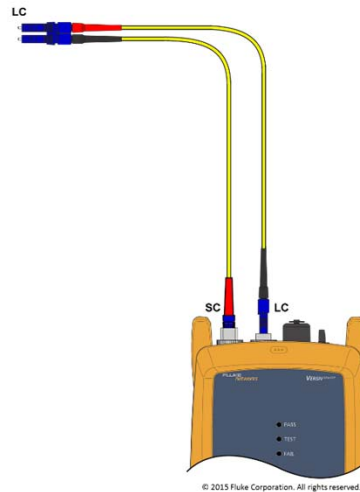
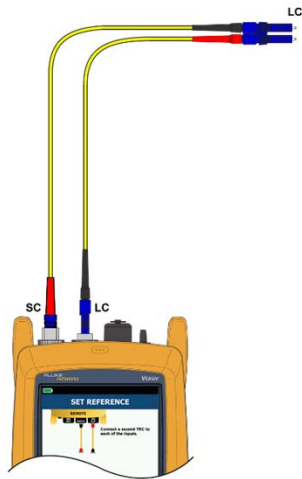
- Remove the cords from the power meter port - this is allowed
- There is no physical contact/alignment at the power meter



APC Connector can also be used

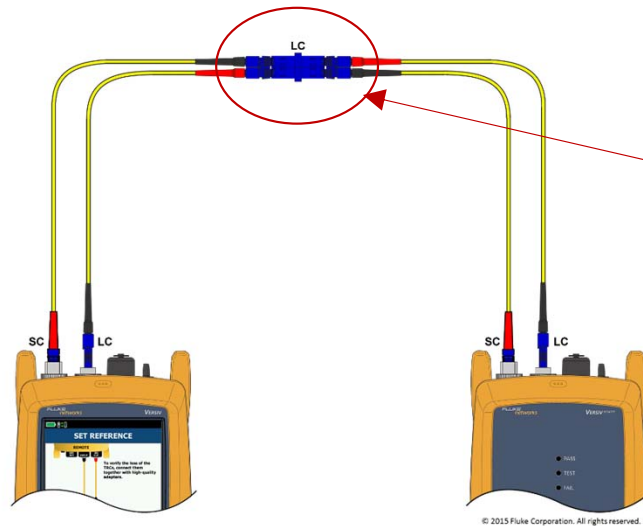
# Insert Known Good Test Reference Cords

- But how do you know they are good?
- You can start by inspecting them.....



# Tester Reference Cord Verification

- Connect the testers together
- Run an optical loss test

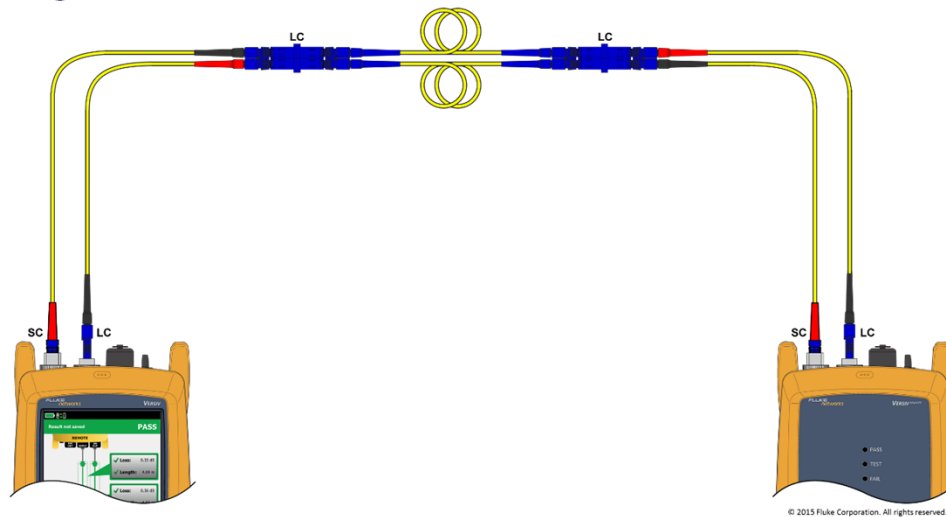


For single-mode  $\leq 0.25$  dB  
For multimode  $\leq 0.15$  dB

**Tip:** Save the result as proof of good test reference cords

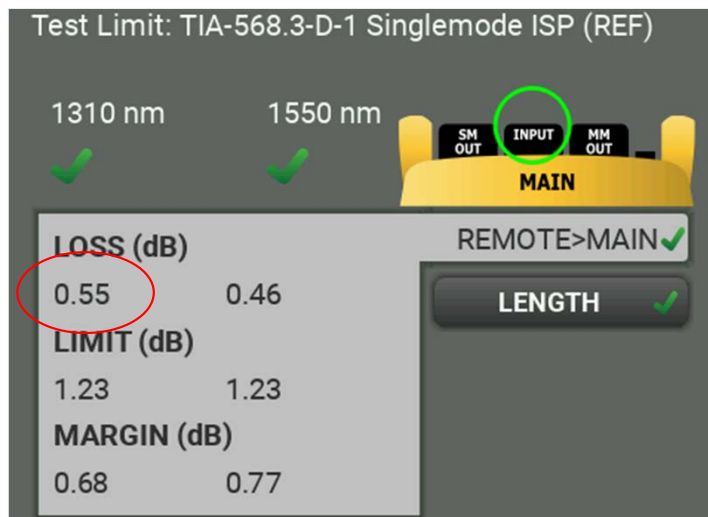
# Connect to Link to be Tested

- Measure at both wavelengths
  - Multimode – 850 nm & 1300 nm
  - Single-mode – 1310 nm and 1550 nm

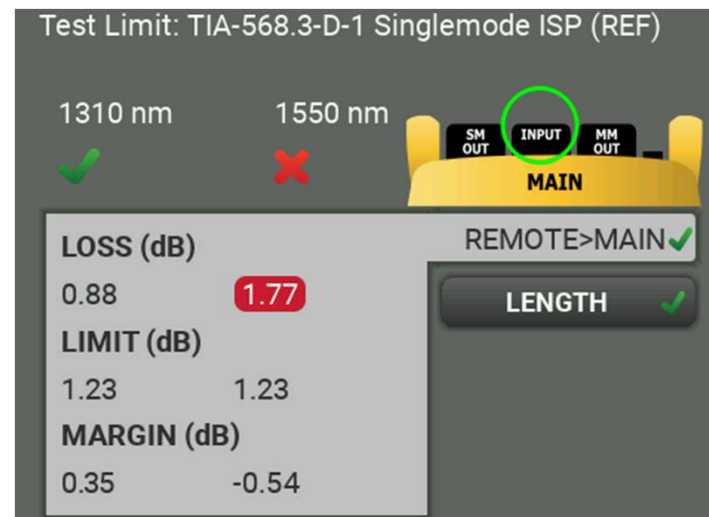




# Testing at Two Wavelengths? Why?



Typically, more loss @ 1310 nm



But can be more at 1550 nm?

When there is a bend or crack in the fiber.....



# Troubleshooting

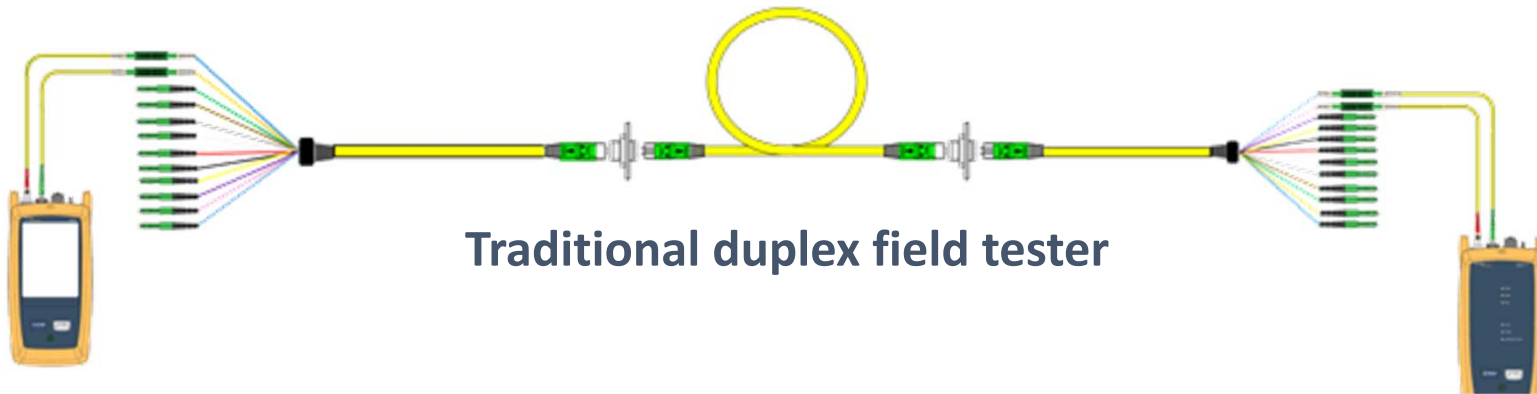
- Optical Time Domain Reflectometer (OTDR)
- Are you an expert with traces?
- Leverage the expert in the tester
  - Here we can see the Bend or Crack in the fiber
  - And here is the distance to the end of the fiber

**Tip:** Make sure you have the correct launch fiber



# Testing MPO Trunk Cables

- Most links will be terminated with a cassette
- But if you have to test MPO trunk cables.....
- Option 1:



# Testing MPO Trunk Cables

- Most links will be terminated with a cassette
- But if you have to test MPO trunk cables.....
- Option 2:



# Results Management

Leverage a Cloud Service

Check the Results Every Day - While Your Team is Still at the Job Site

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# Protect Your Results

- Ways to lose results:
  - Accidental deletion of results
  - Damage to tester
  - Theft of tester
  - Returned to rental company before downloading results
  - .....



# Manage Your Project





# Conclusions for Single-mode Testing

- Testing is time well spent
- Plan ahead, do it correctly the first time
- Inspect and clean if necessary – repeat as needed
- Know the test limit you are required to pass
- Know which connector types you will be working with
- Use a one jumper reference and check the TRCs
- Use an OTDR for troubleshooting
- Leverage Cloud Based Tester Configuration and Results management - check your teams work every day



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# Thank you

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