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

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Single-mode Applications/Design

Adrian Young, Product Manager
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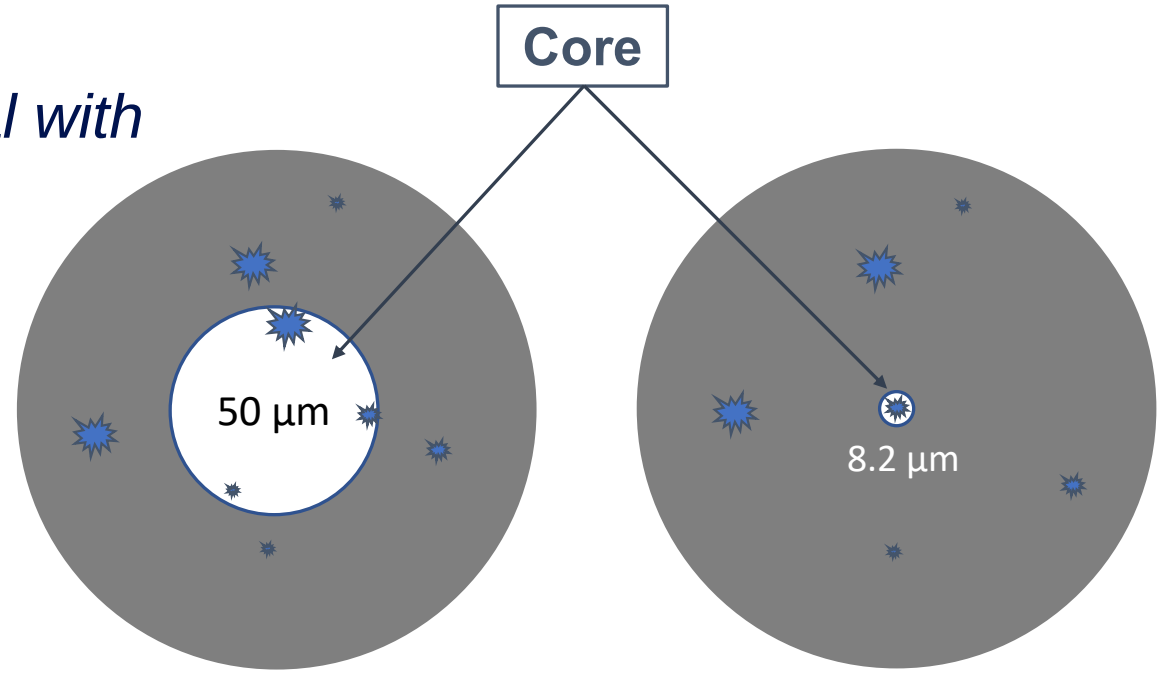
Traditional Thoughts on Single-mode

- 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 (≈ 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 µm
- Human hair
  - ≈ 100 µm
- It is a great deal easier to block all the light in a single-mode end face



Multimode
OM2, OM3, OM4, OM5

Single-mode
OS1a, OS2

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) ≈ 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)

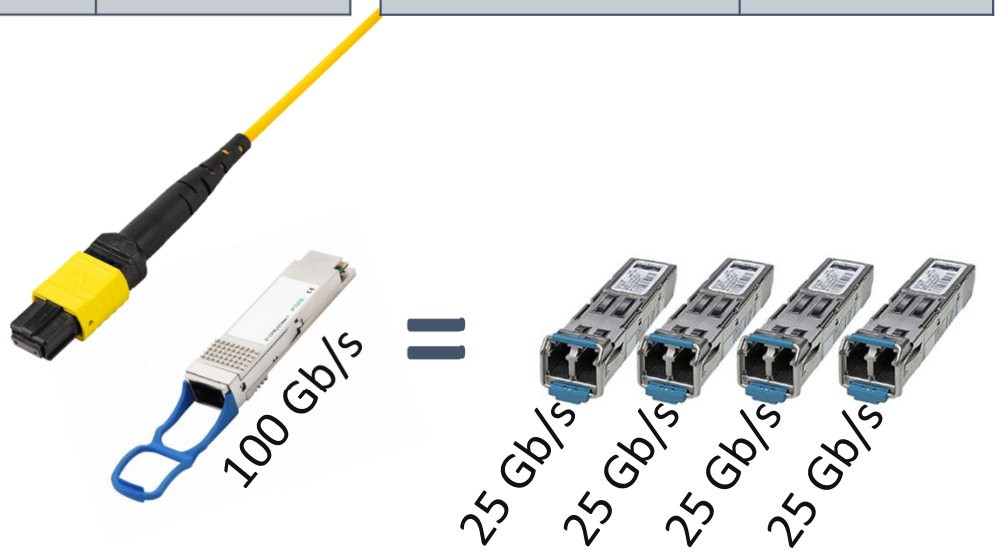
40 Gb/s	Distance (m)
40GBASE-PLR4	1,000

100 Gb/s	Distance (m)
100GBASE-PSM4	500

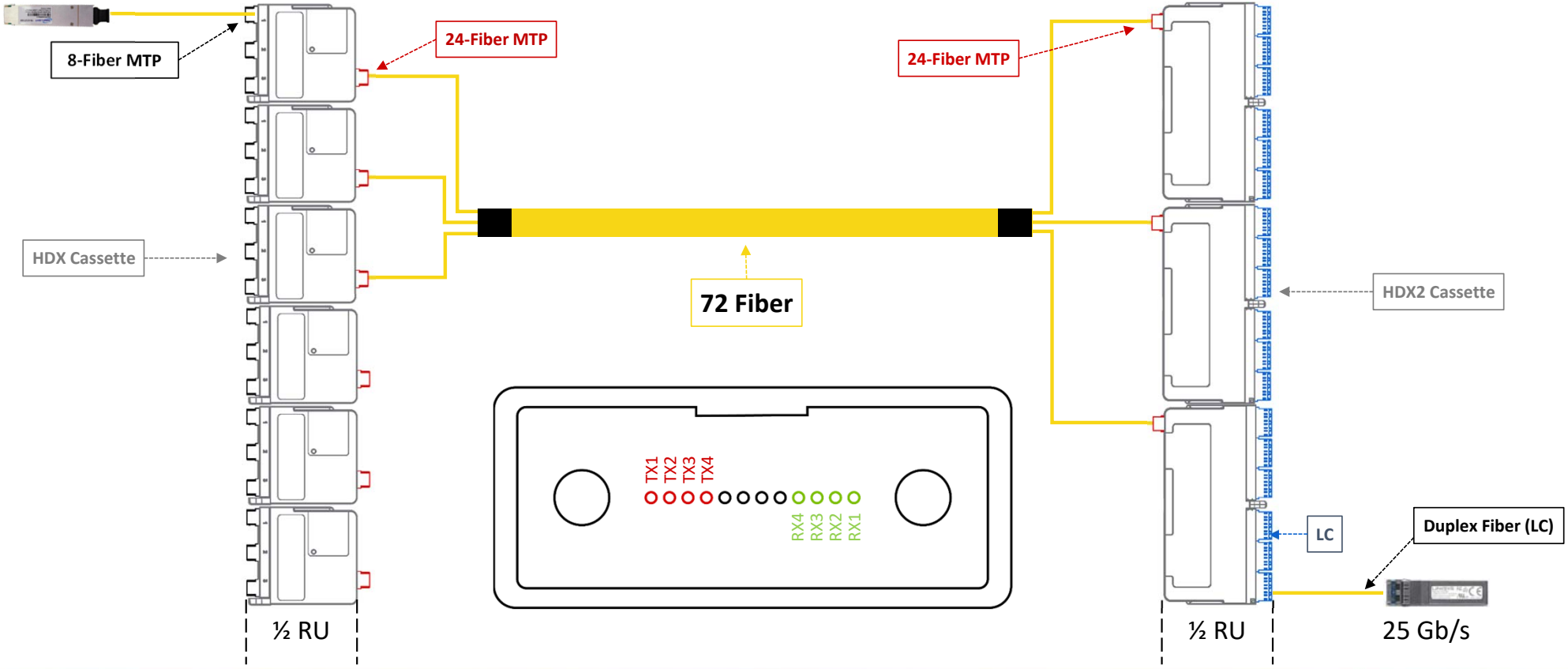
200 Gb/s	Distance (m)
200GBASE-DR4	500

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

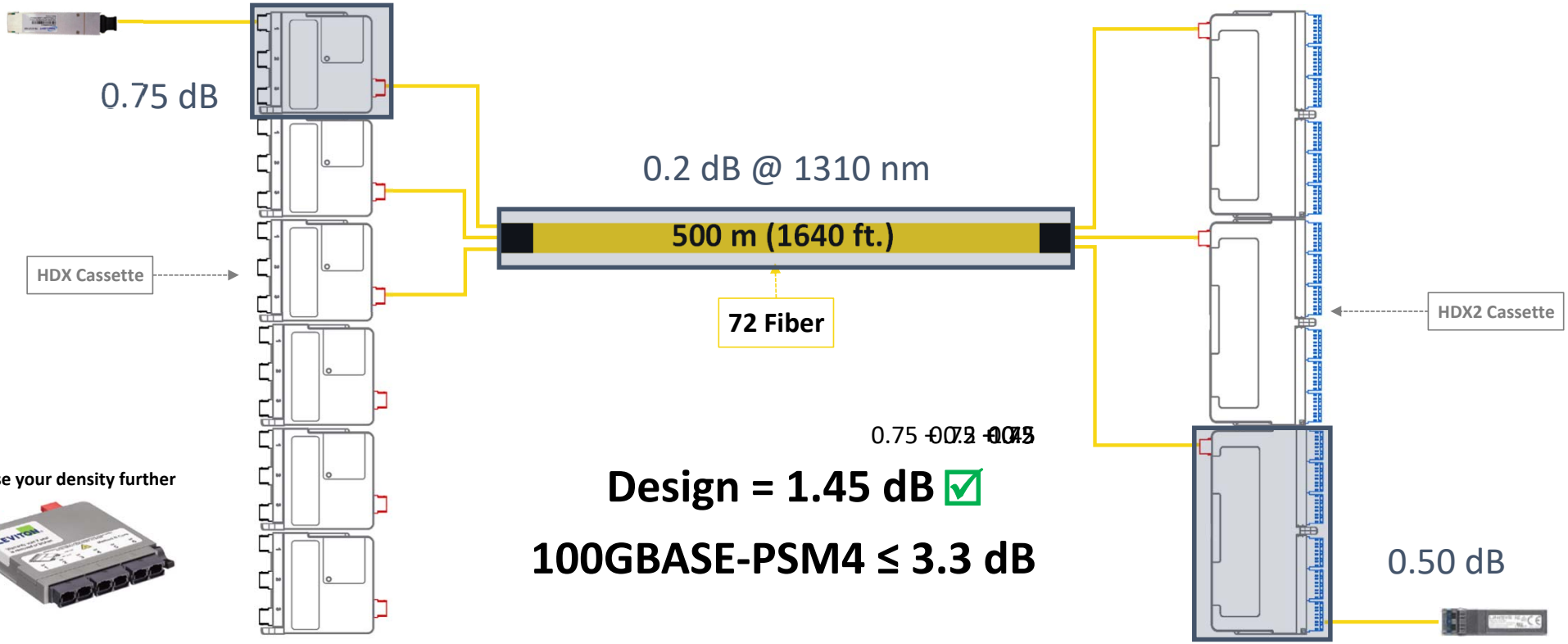
- Transceiver cost reduced
- These options allow breakout
  - Increases port density



100GBASE-PSM4 Breakout



100GBASE-PSM4 by the Numbers



0.75 ~~0.2~~ ~~0.45~~

Design = 1.45 dB ☑

100GBASE-PSM4 ≤ 3.3 dB

Increase your density further

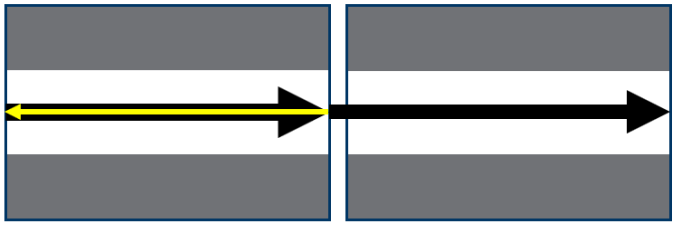
Greater Insertion Loss Allowed

- 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

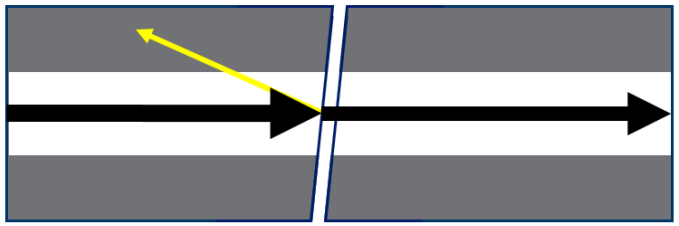
100 Gb/s Ethernet	Channel Loss
100GBASE-ER4	15.0 dB
100GBASE-LR4	6.3 dB
100GBASE-CWDM4	5.0 dB
100GBASE-PSM4	3.3 dB
100GBASE-DR	3.0 dB

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 -35 and -45 dB	Number of connections where the reflectance is between -45 and -55 dB								
	0	1	2	3	4	5	6	7	8
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	—	—	—	—	—	—	—

- 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 -35 and -45 dB	Number of connections where the reflectance is between -45 and -55 dB								
	0	1	2	3	4	5	6	7	8
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	—	—	—	—	—	—	—

- 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

Video Fiber Scope

Fiber Scope
(Built in filter)

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

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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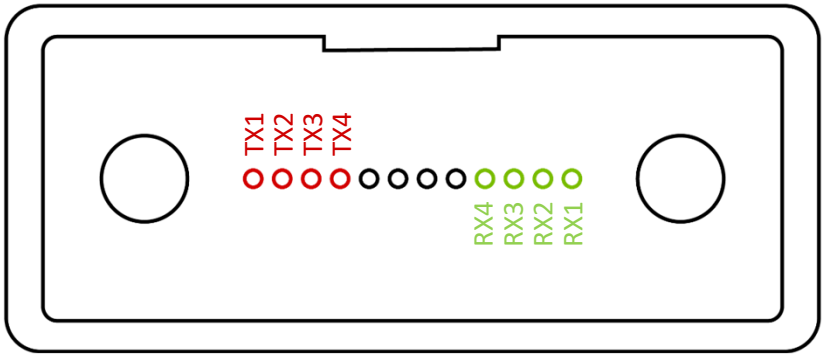
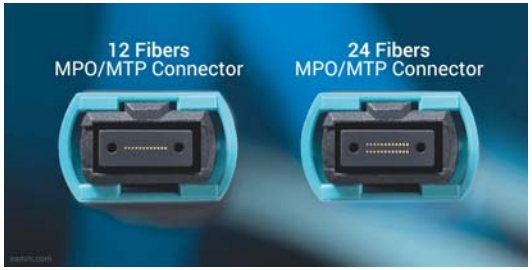
8, 12, or 24 Fiber MPO?

These applications use 8 fibers:

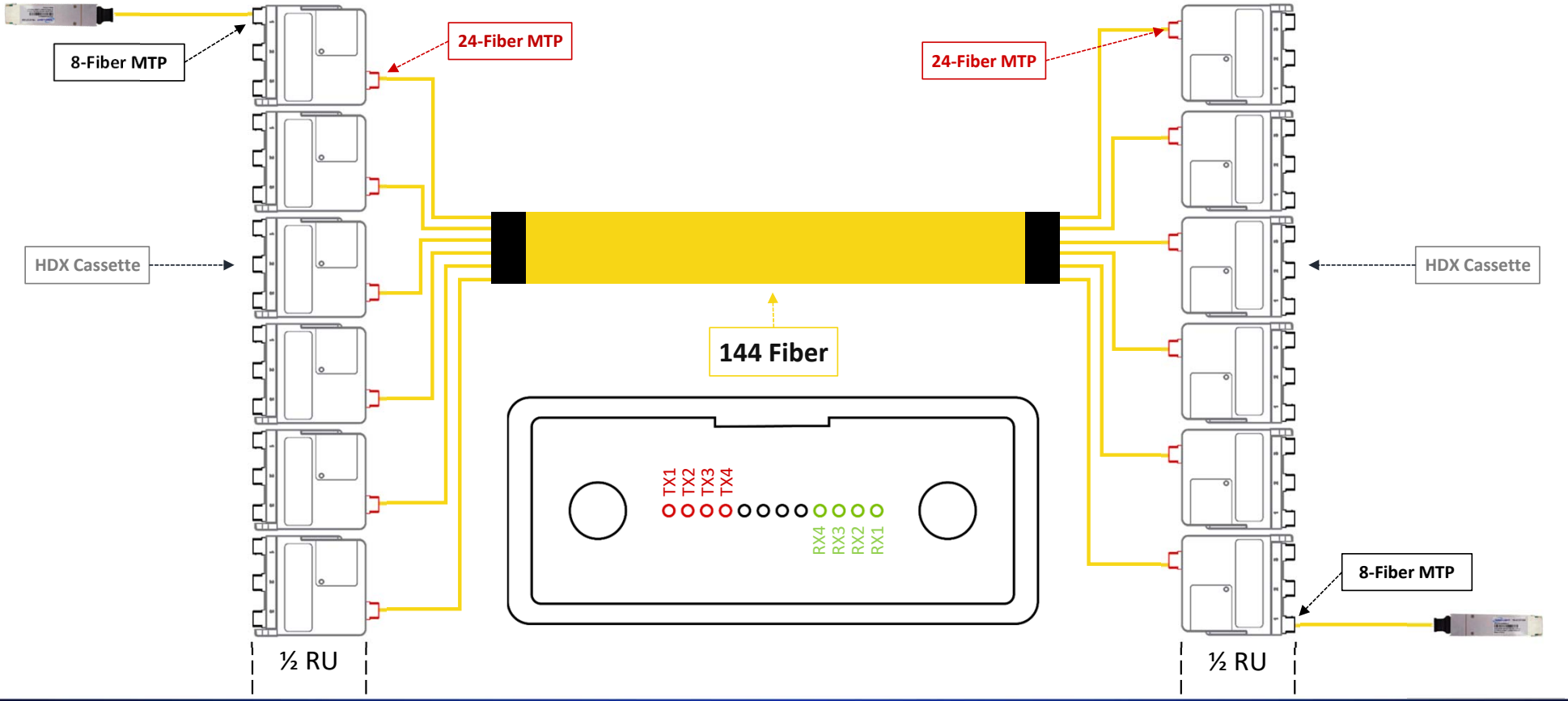
- 40GBASE-PLR4
- 100GBASE-PSM4
- 200GBASE-DR4
- 400GBASE-DR4



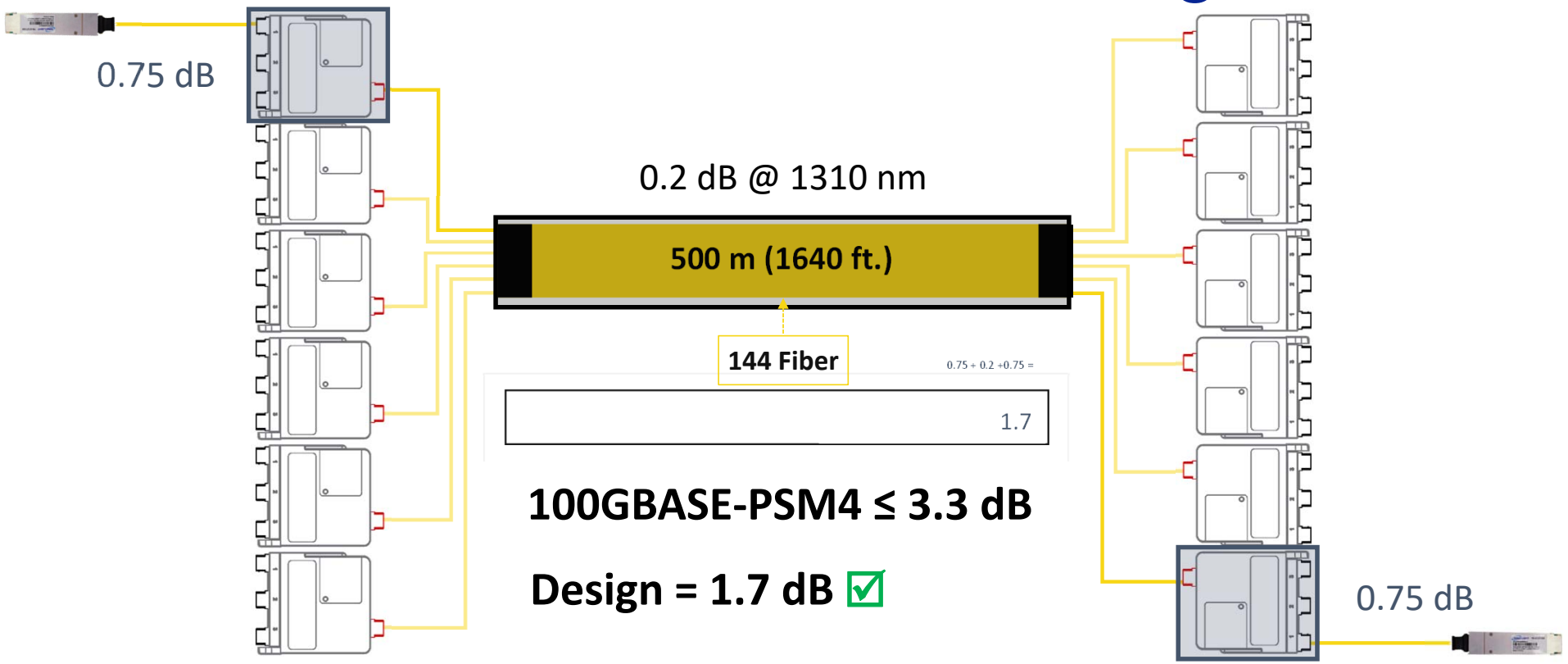
- There is no such thing as an 8 fiber MPO
- The transceiver vendors typically use a 12 fiber MPO
- The 4 fibers in the middle are left unused
- Can lead to an inefficient cabling system



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

Jim Davis, Regional Marketing Engineer
Fluke Networks

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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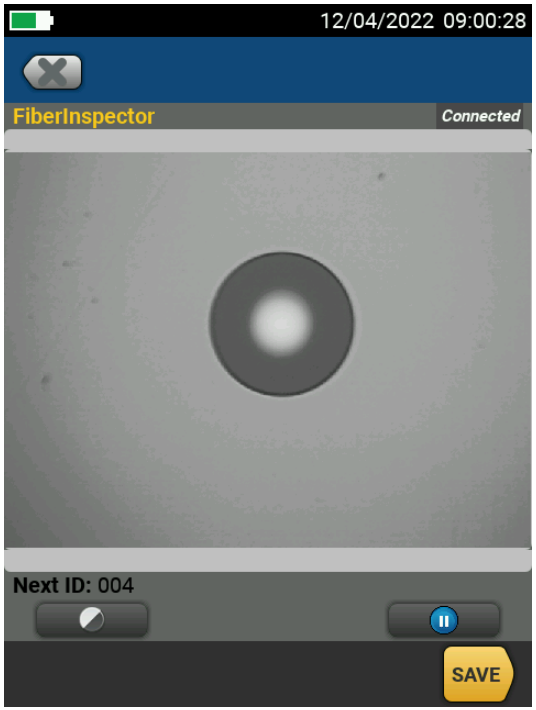
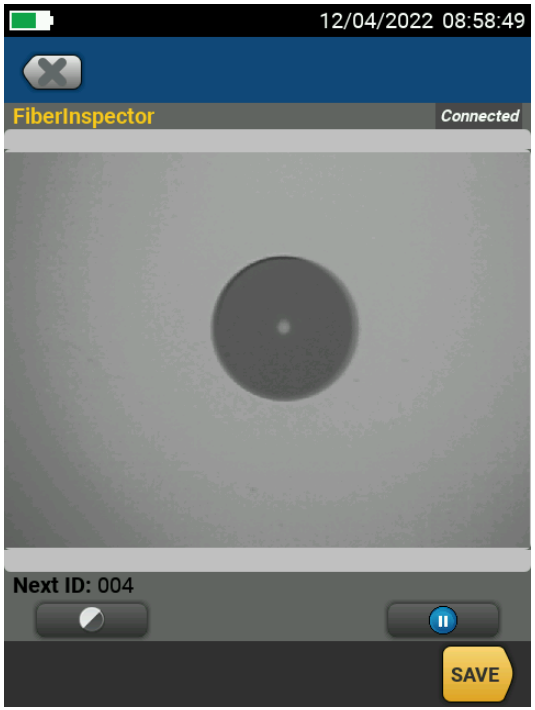
Inspect, Clean, Repeat

Video Microscope



Multimode has a larger core

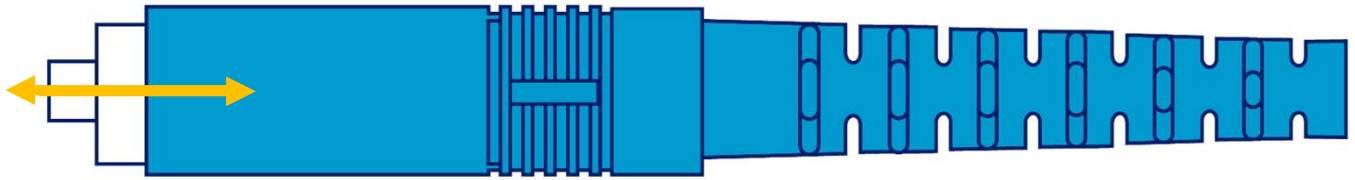


Single Mode has a smaller Core

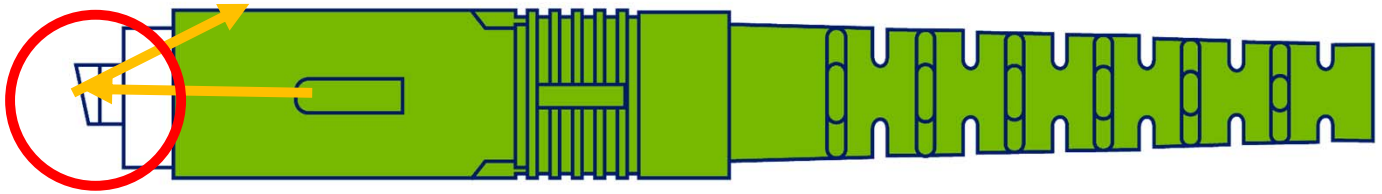
Inspecting APC Connectors - Compensate for the Angle

- Same cleaning equipment – new camera tips

PC/UPC

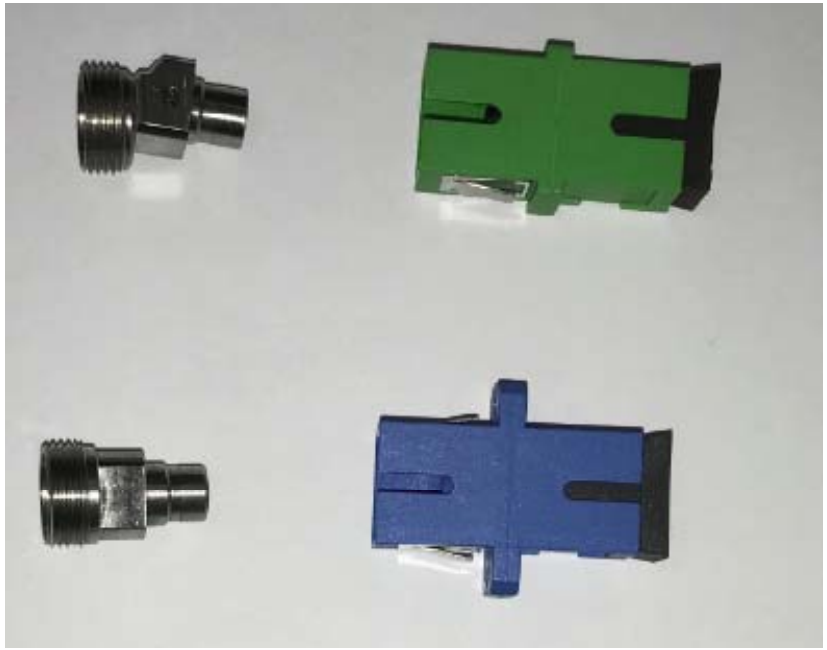


APC

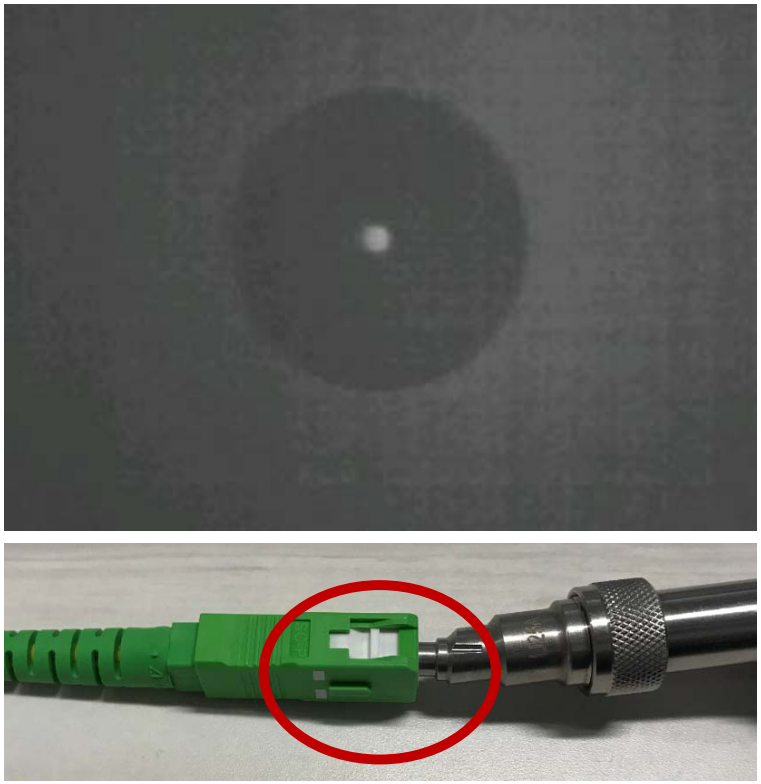


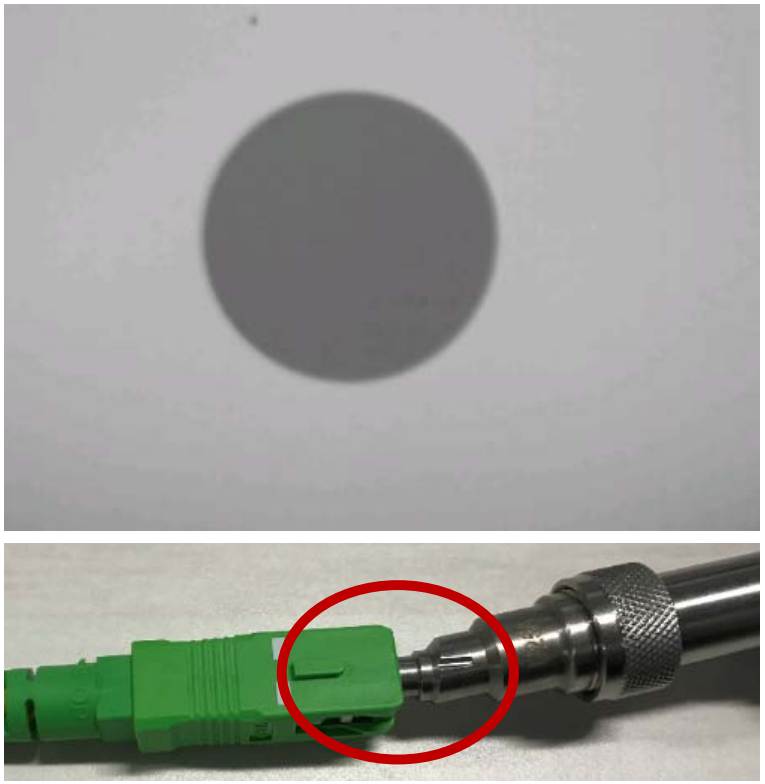
APC – Angled Physical Contact

Tips Have a Slight Angle - These are SC

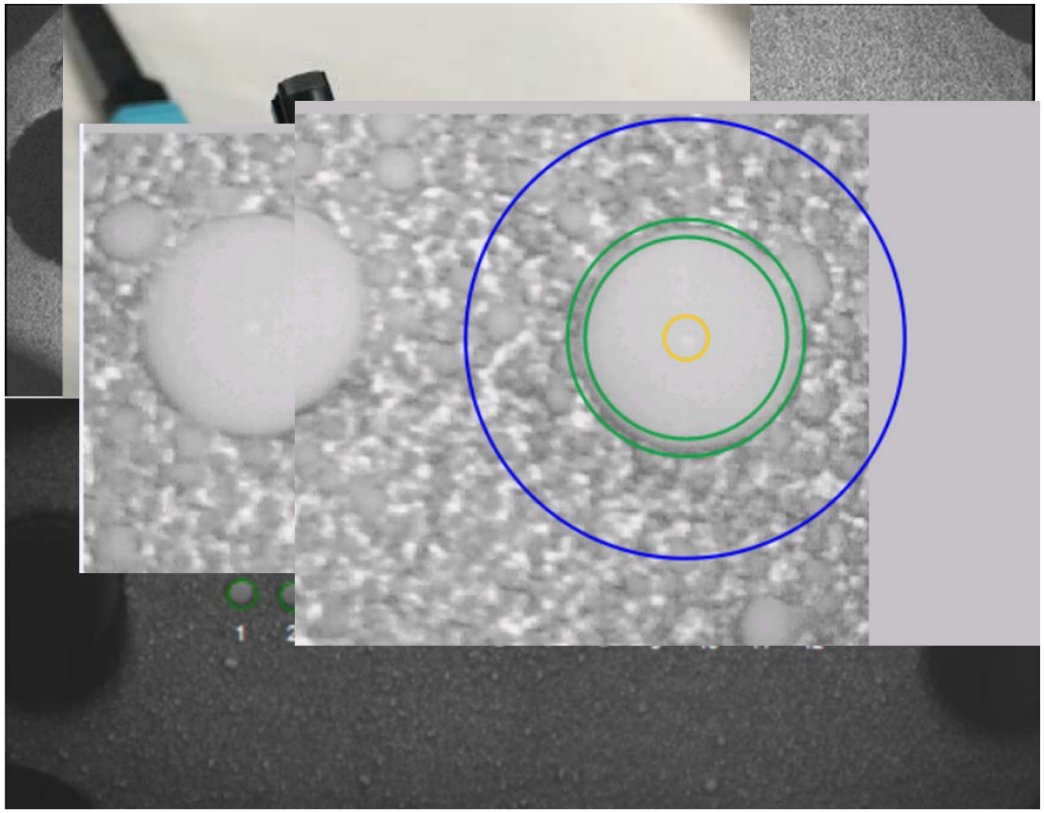


APC Connectors May Need a “Twist” to Show Up





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

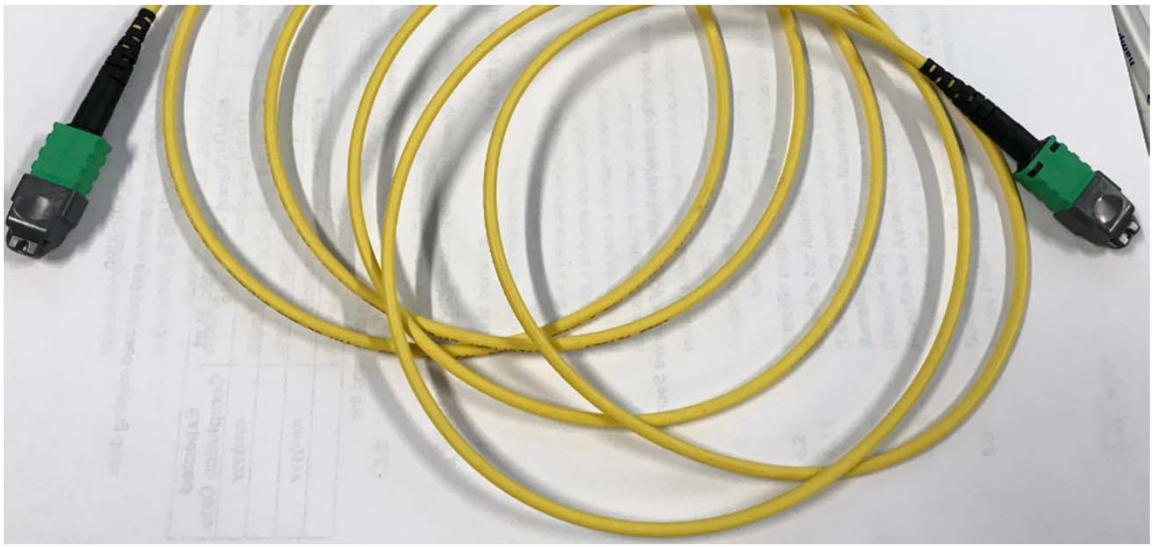
- Test Reference Cords (TRCs) are recommended in ANSI/TIA and ISO/IEC
- Patch cords from a distributor are specified with a loss of up to 0.50 dB

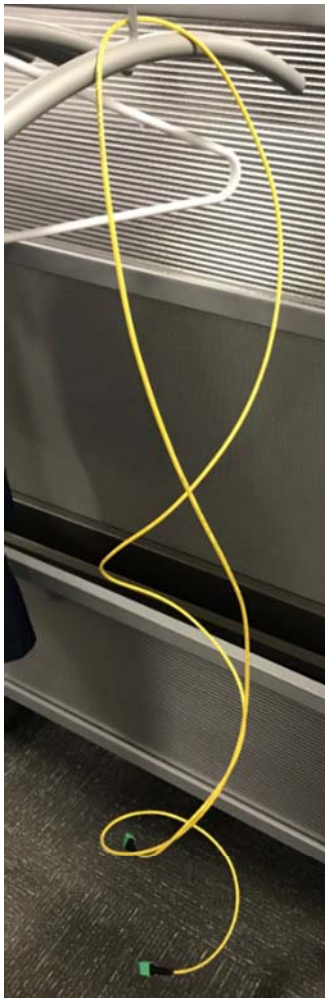
ANSI/TIA-526-14-C & IEC 61280-4-1
≤ 0.10 dB

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

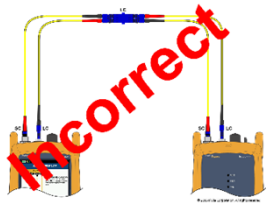
Tech Tip

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

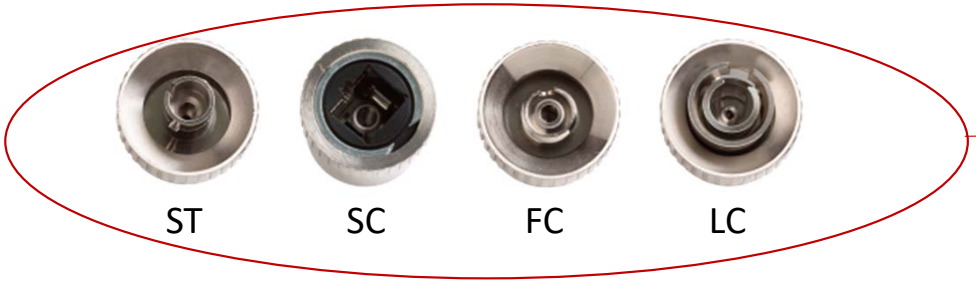




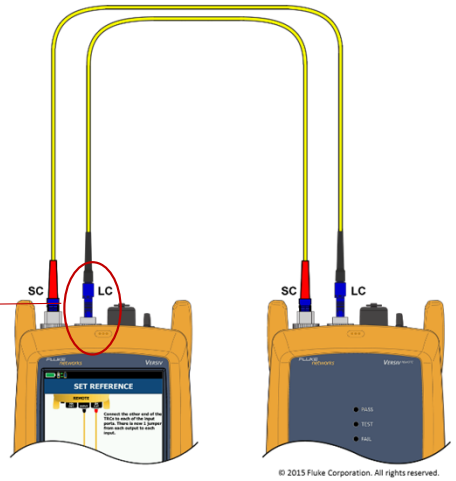
For the Most Accurate Measurement



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

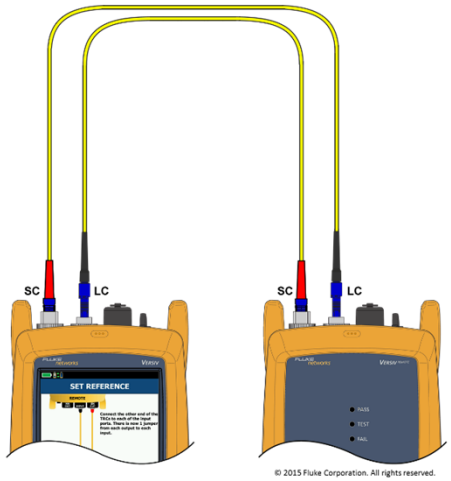


  - Do you bring the right cords?
  - Are they in good condition?

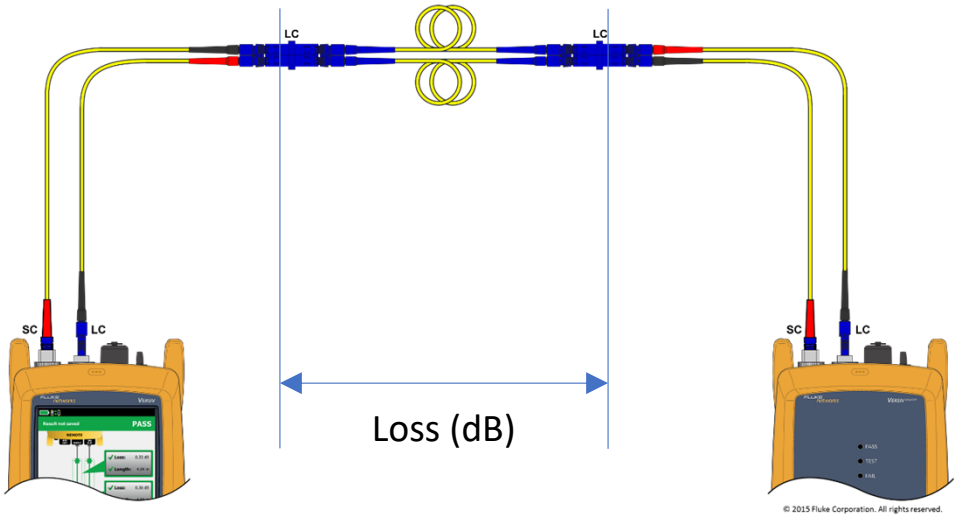


Direct connection
(No bulkhead adapter!)

First Set a Reference.. Then Find the Difference



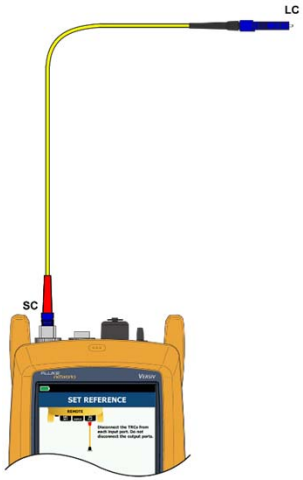
Direct connection
(No bulkhead adapter!)

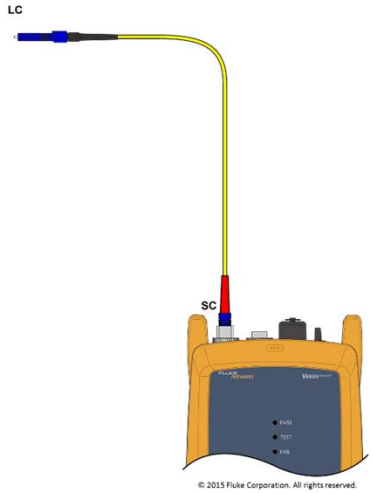


The difference is what we want to know

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

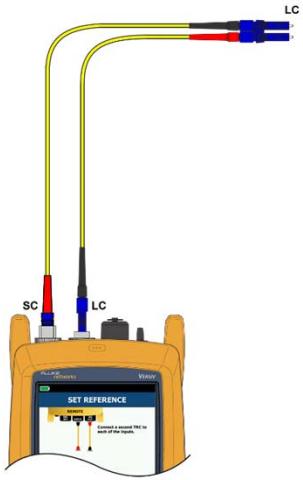


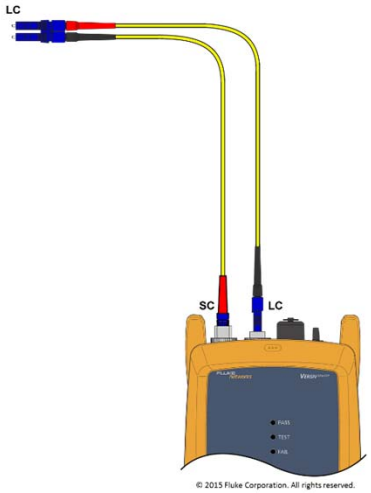


APC Connector can also be used

Insert Known Good Test Reference Cords

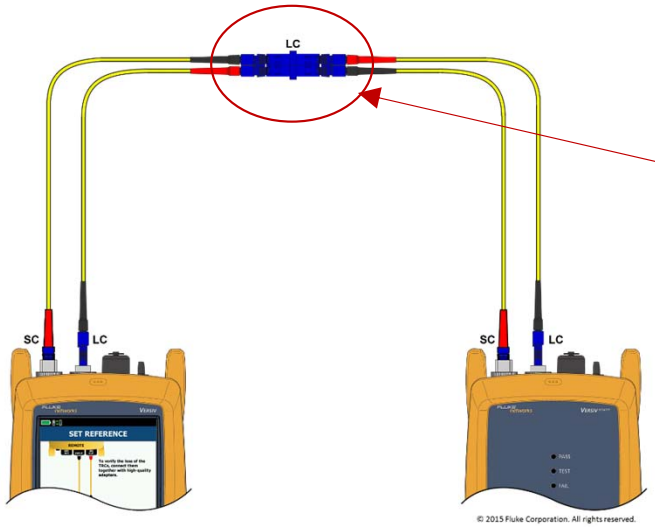
- But how do you know they are good?
- You can start by inspecting them……..





Tester Reference Cord Verification

- Connect the testers together
- Run an optical loss test



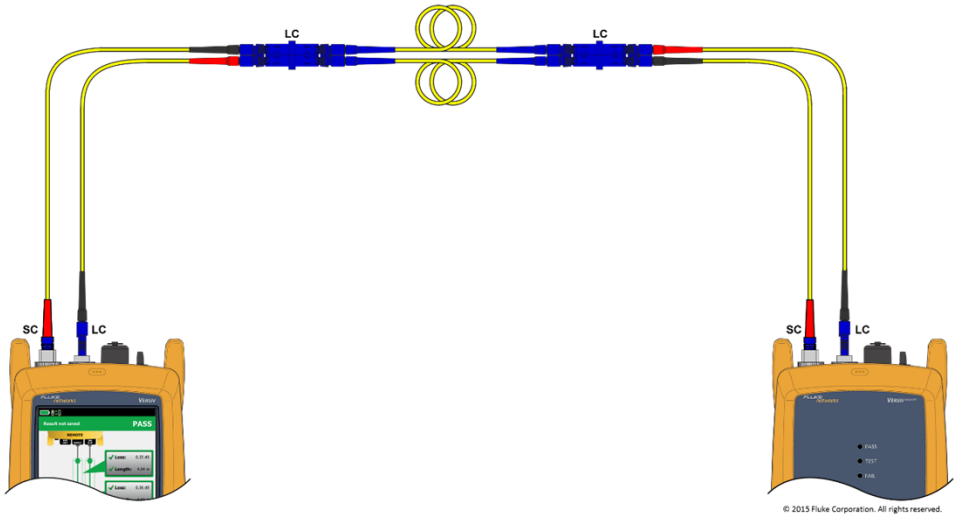
For single-mode **≤ 0.25 dB**

For multimode **≤ 0.15 dB**

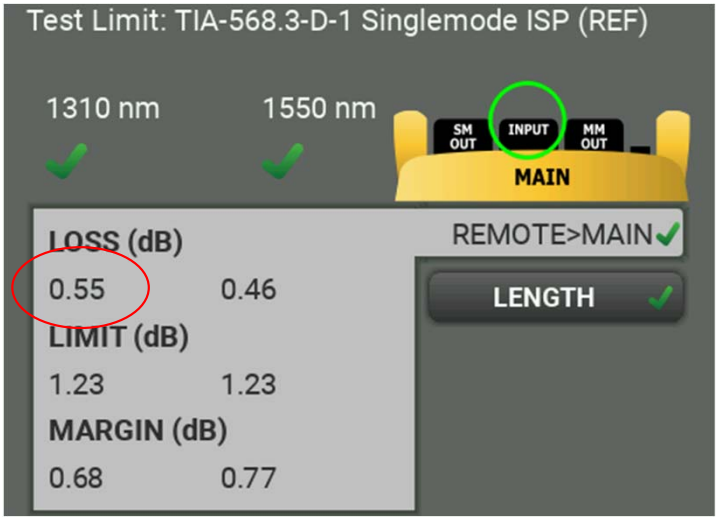
Tip: Save the result as proof of good test reference cords

Connect to Link to be Tested

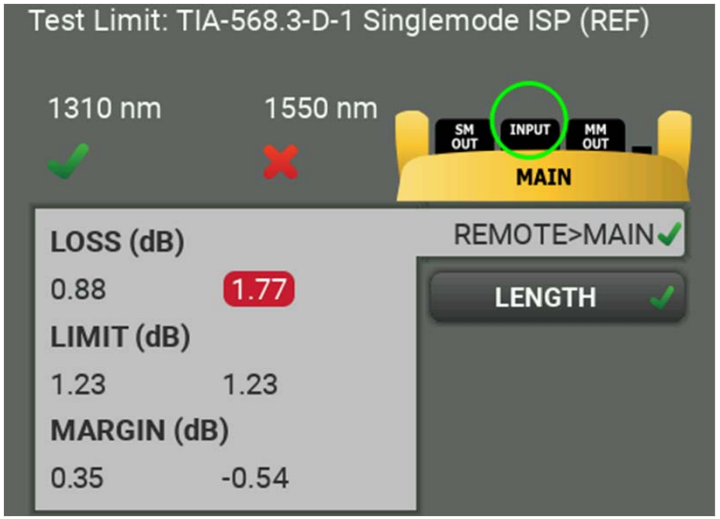
- Measure at both wavelengths
  - Multimode – 850 nm & 1300 nm
  - Single-mode – 1310 nm and 1550 nm



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……

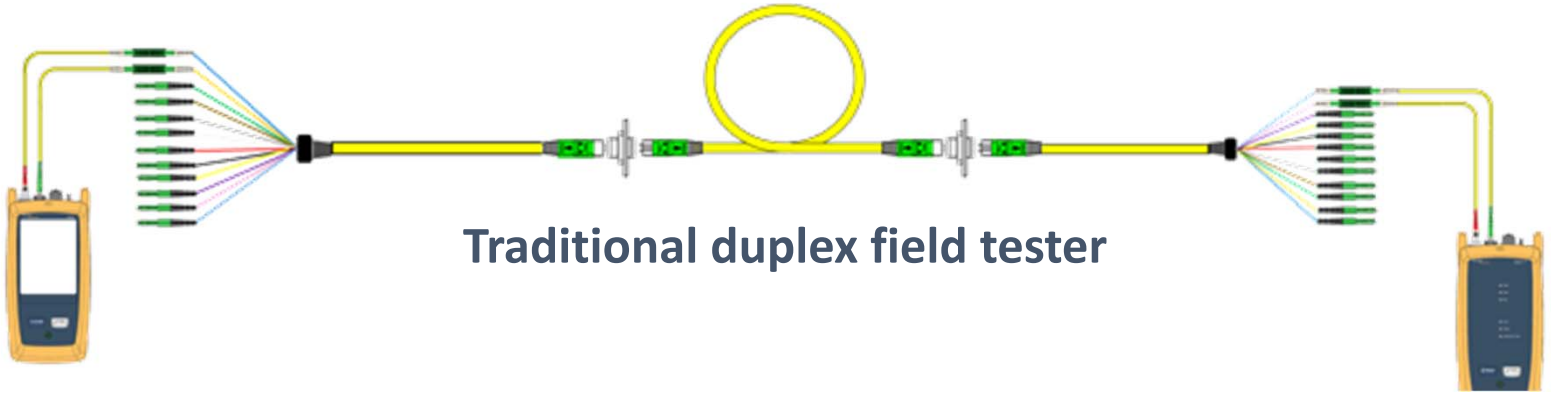
Troubleshooting

- 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

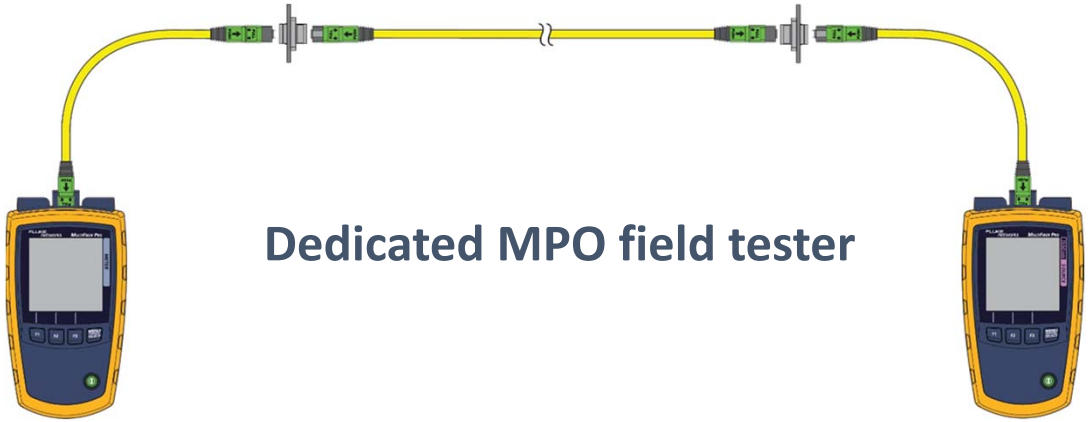
- Most links will be terminated with a cassette
- But if you have to test MPO trunk cables……
- Option 1:



Traditional duplex field tester

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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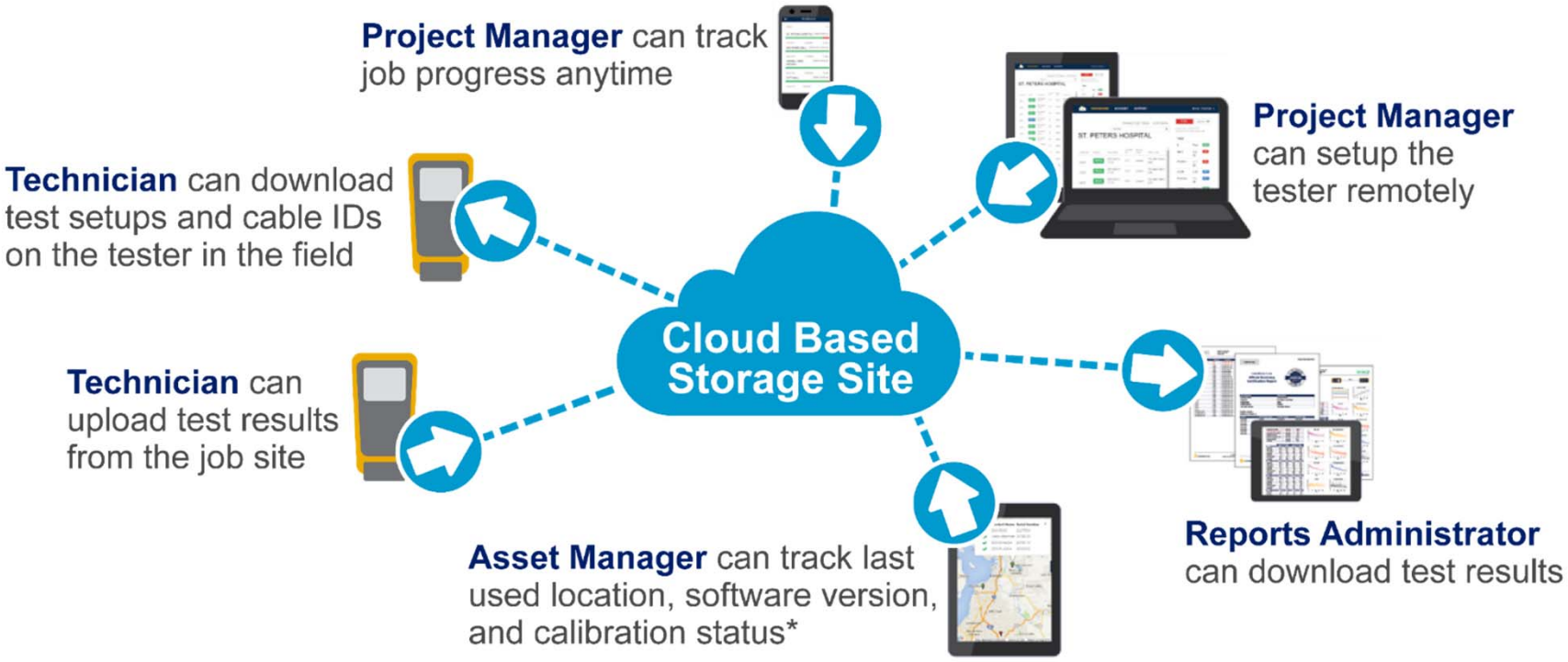
Protect Your Results

- 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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