Field Testing and Troubleshooting of PON LAN Networks per IEC 61280-4

Jim Davis
Regional Marketing Engineer
Fluke Networks

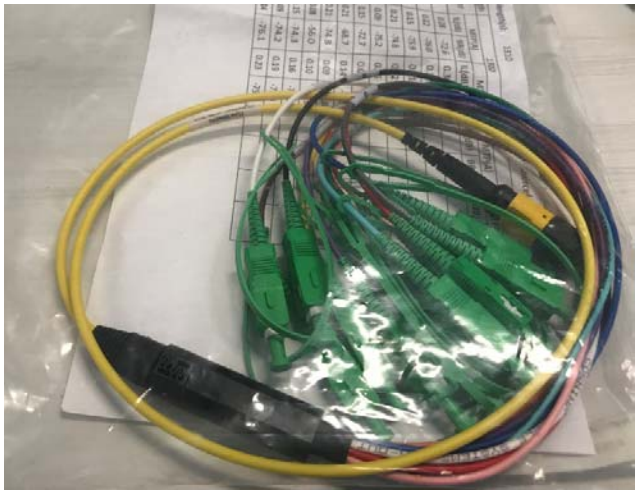
Agenda

- Inspection and Cleaning
  - APC vs UPC
- PON basics
  - Wavelengths
  - Architecture
    - Splitters
- Loss Budget – How Many Connectors/Splitters
  - Setting a reference
- Troubleshooting
  - OTDR
  - Power Meter
- Document Results

Inspection, and, If Necessary, Cleaning
(repeat as needed)

Please be sure to Inspect ALL Connectors before installing, clean them if necessary, inspect again!!

Video Microscope



Brand new out of bag

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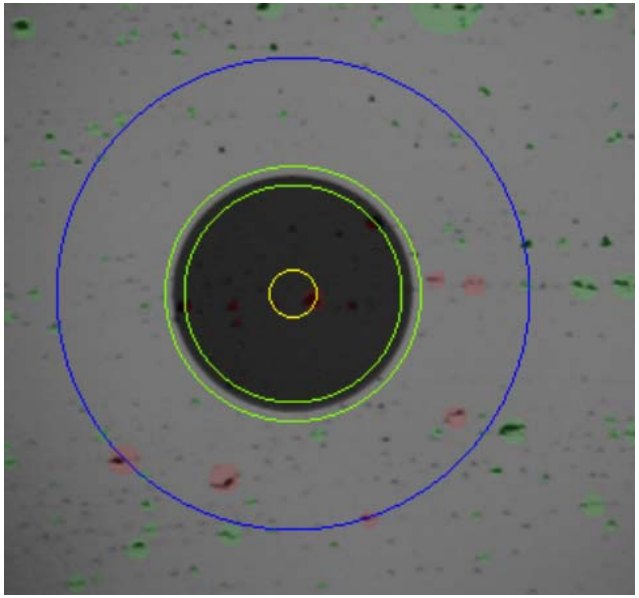
Video Microscope



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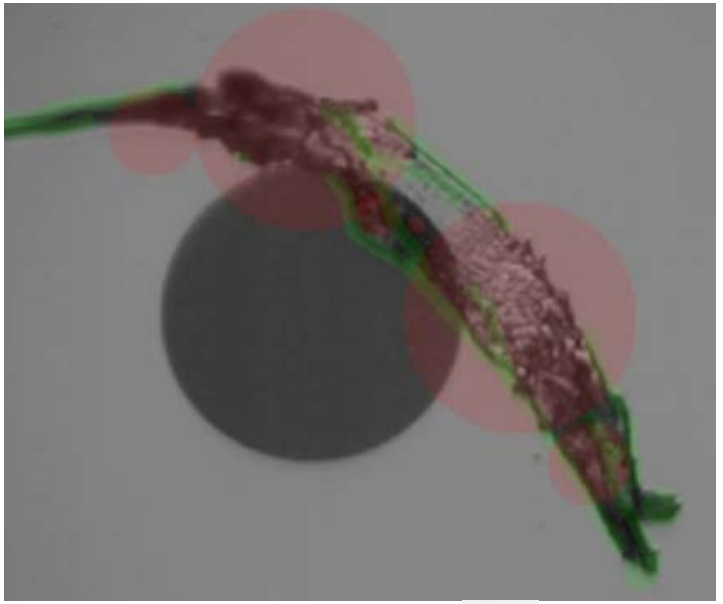
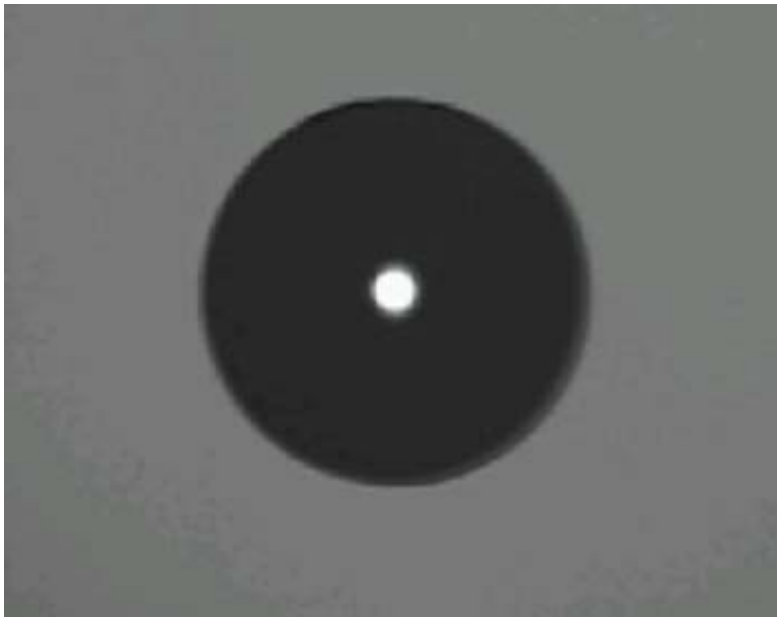


After Cleaning 🙄

Automated Analysis – Single Mode APC Limits

IEC 61300-3-35 ED.2 SM APC

Zone Name	Scratches	Defects
A: Core (0-25µm)	4 ≤ 3 µm None > 3 µm	None
B: Cladding (25-115µm)	No Limit	No Limit < 2 µm 5 from 2 - 5 µm None > 5 µm
C: Adhesive	No Limit	No Limit
D: Contact (135-250 µm)	No Limit	No Limit < 10 µm None > 10 µm



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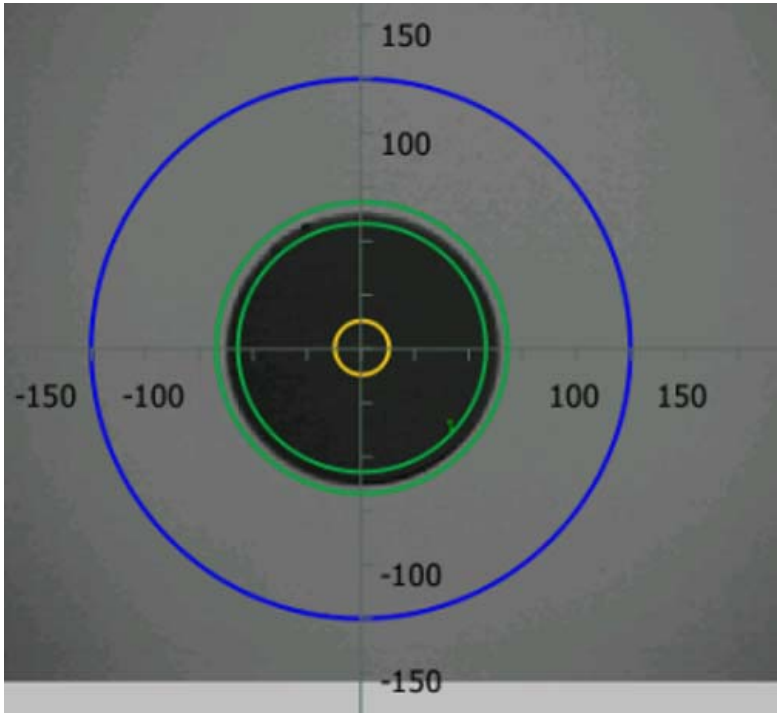


That Little Angle on the APC Minimizes Back Reflection

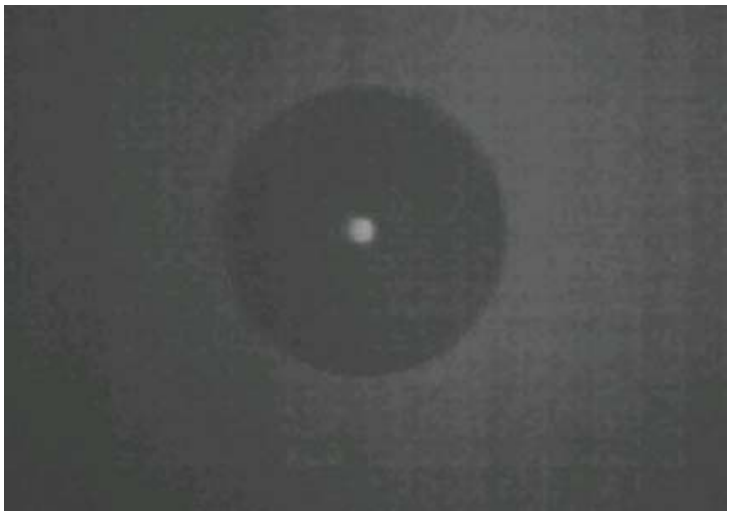
Especially important with high-power transmissions to avoid damage to equipment

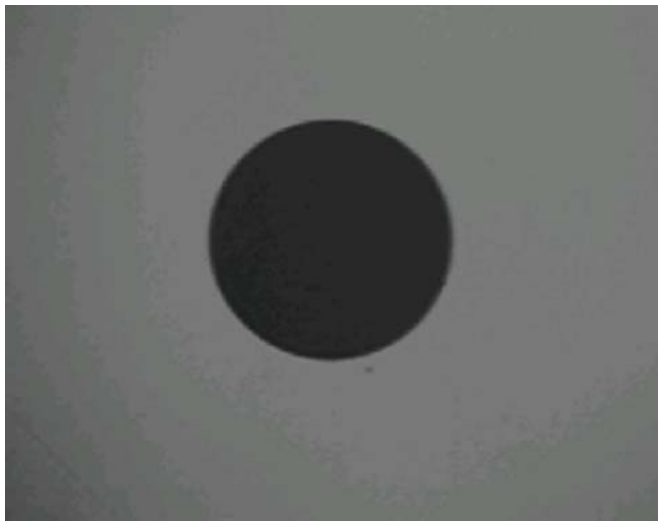
PC/UPC

APC

APC Tips Have a Slight Bend – These are SC

APC connectors may need a “Twist” to show up





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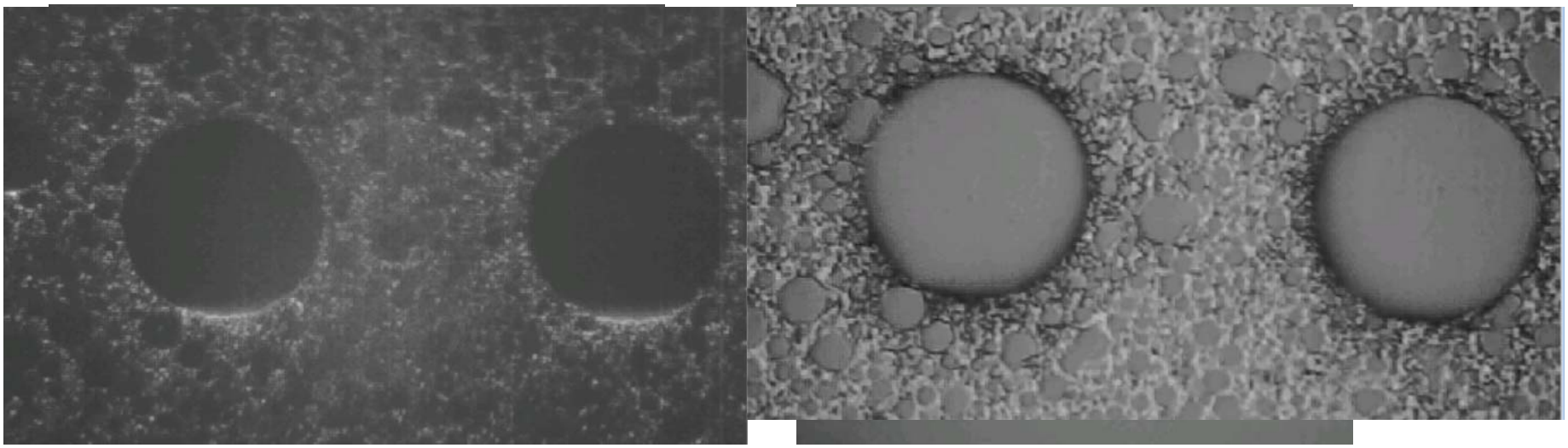
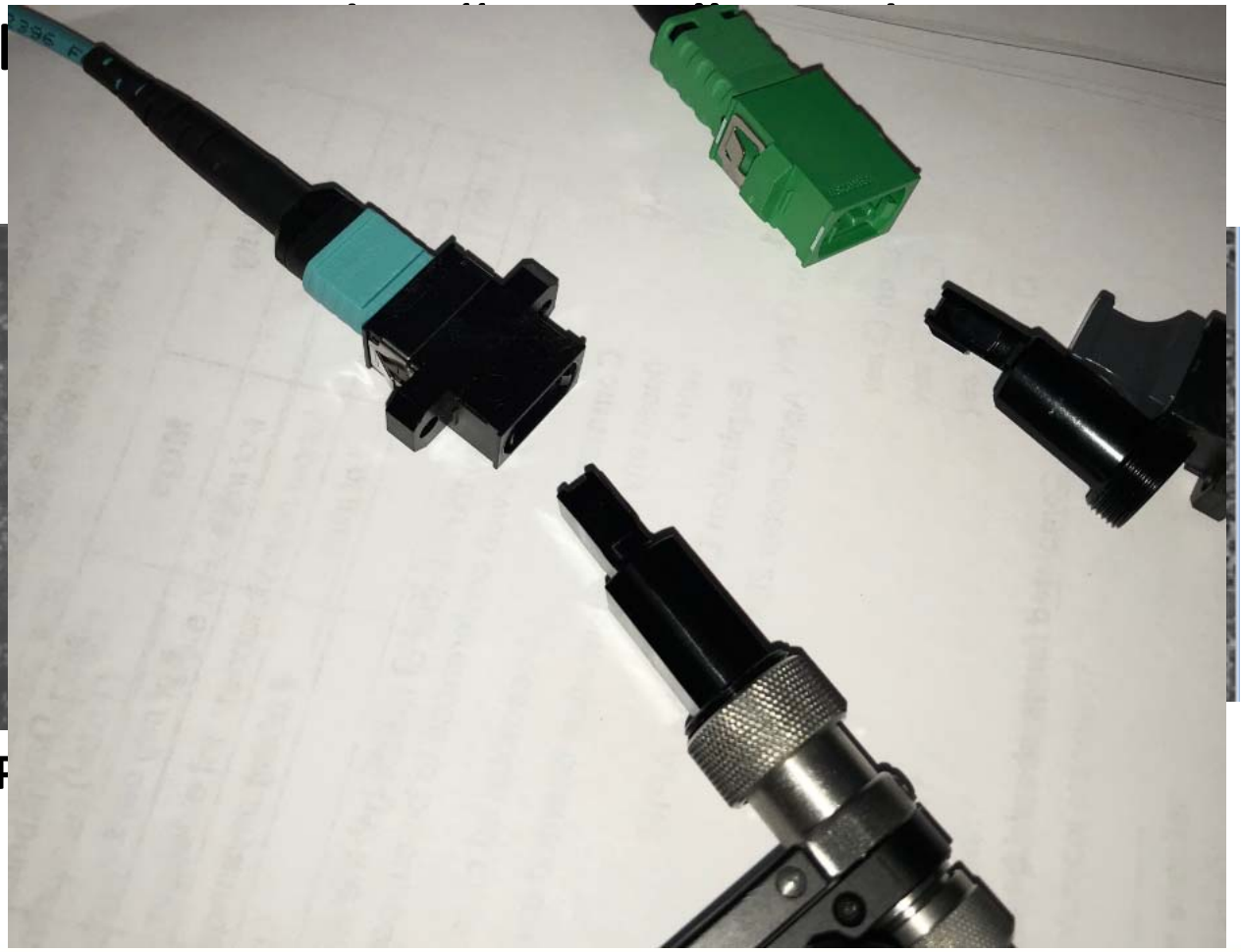


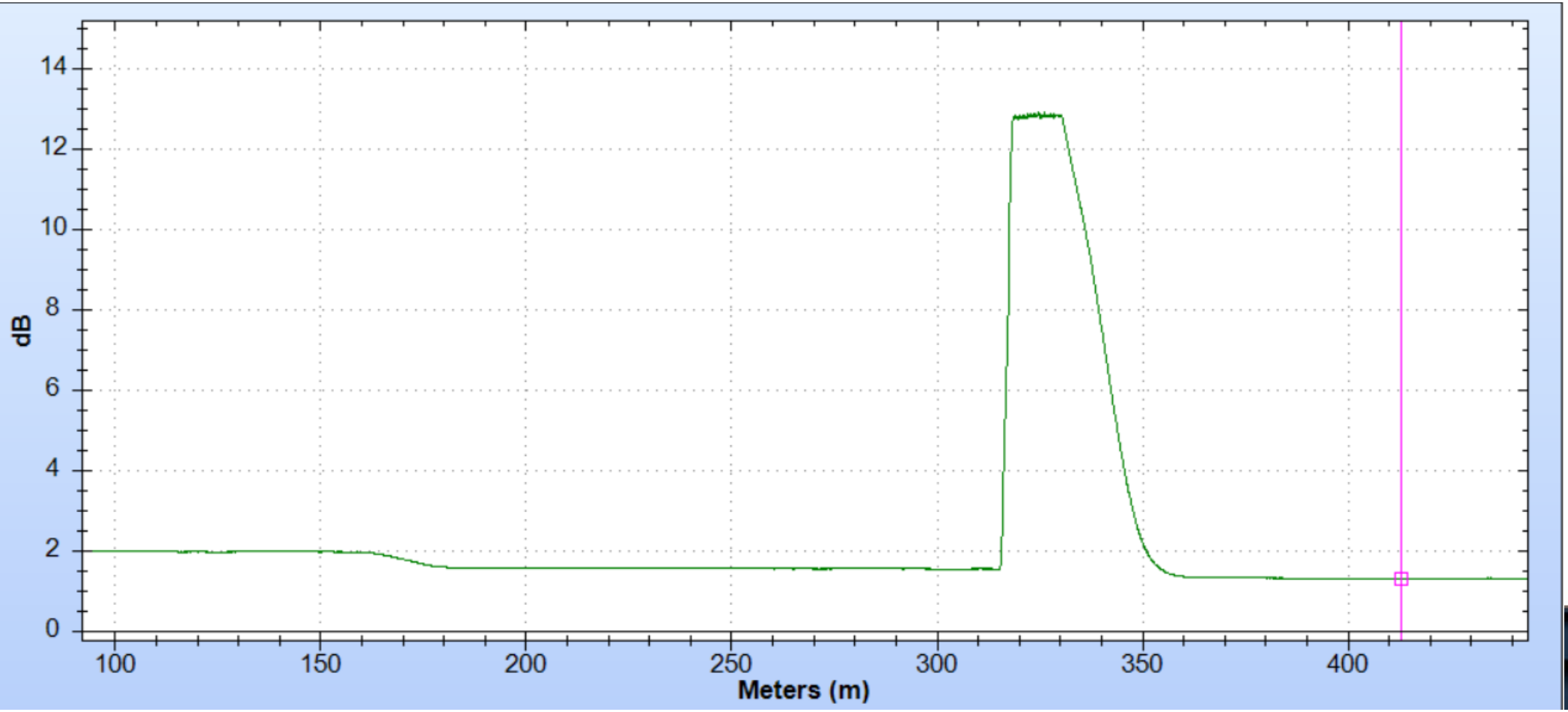
Single Mode MPO connectors will also require a special adapter

S

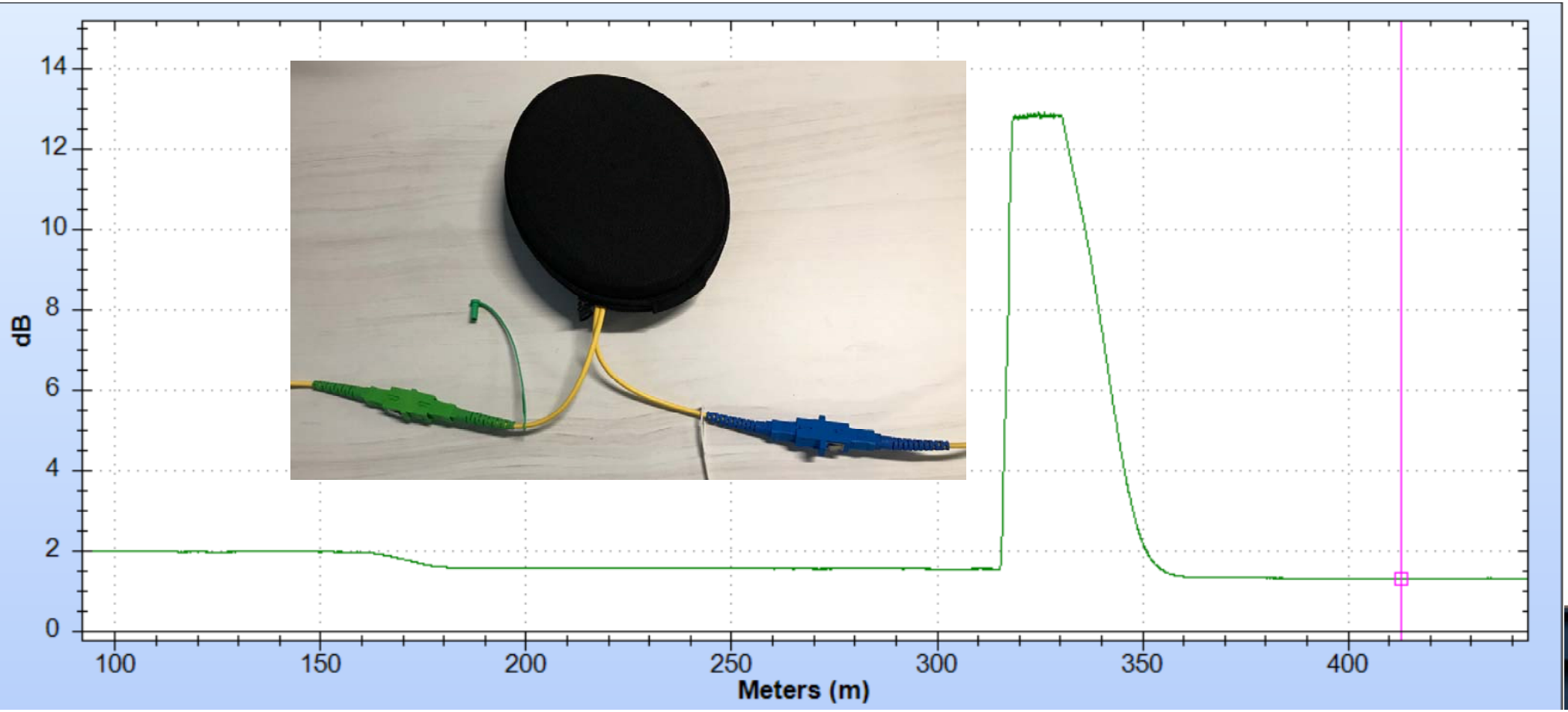


MP

APC Connector vs. UPC Connector



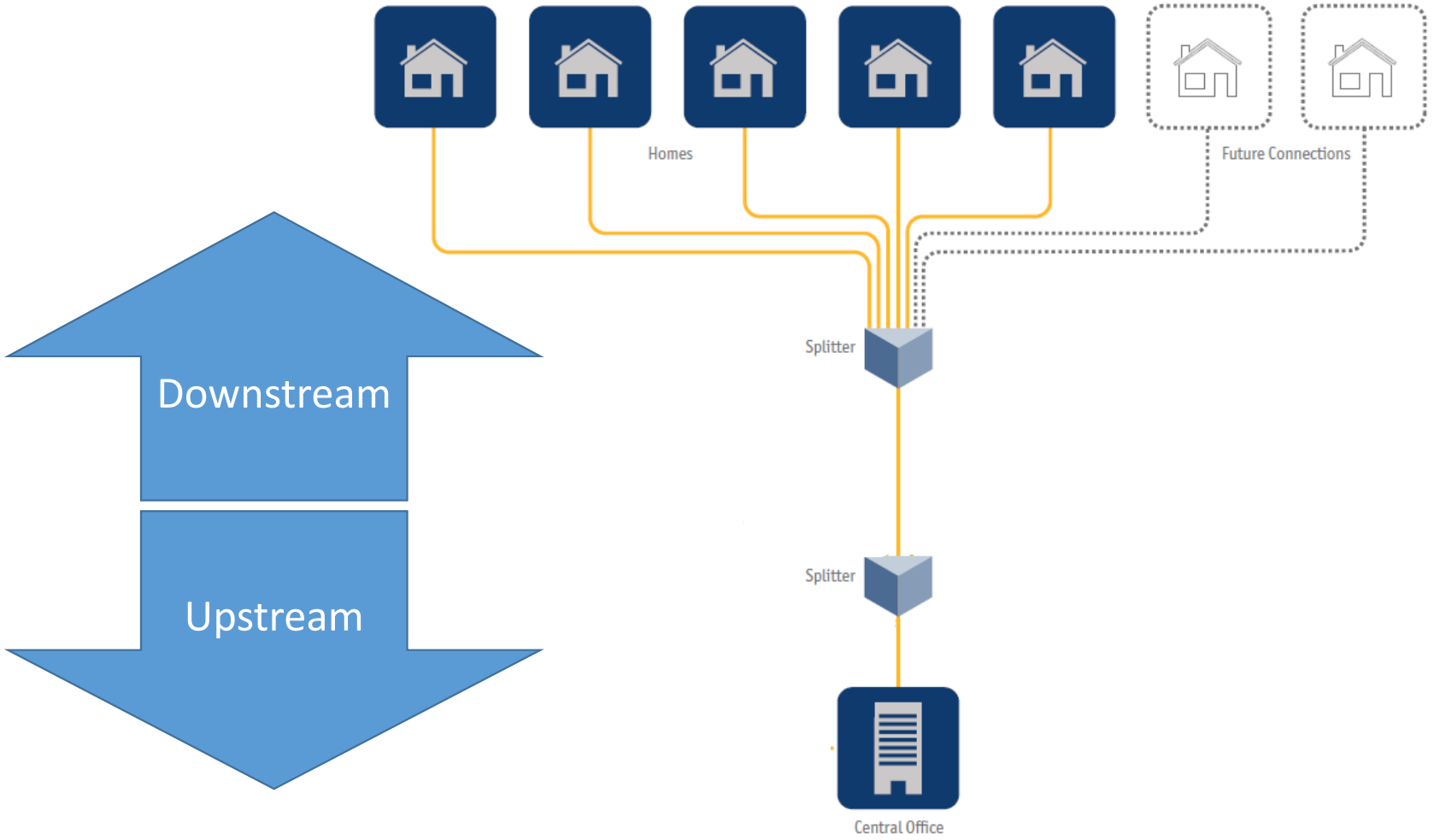
APC Connector vs. UPC Connector



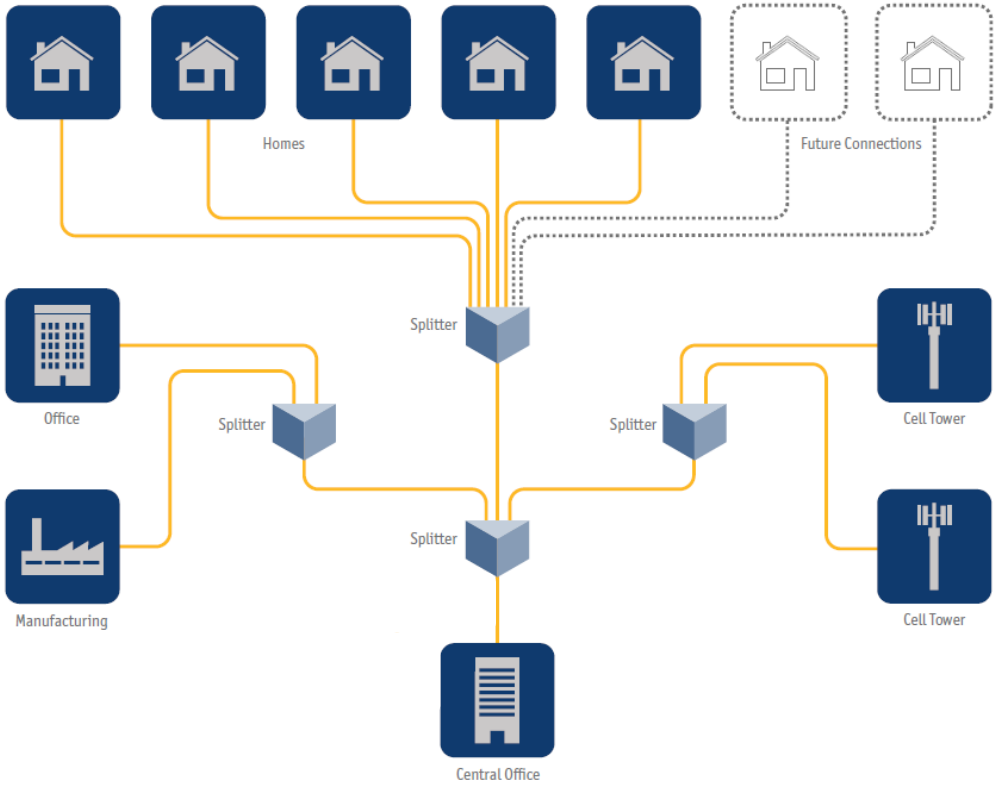
“Flavors” of Passive Optical Networks

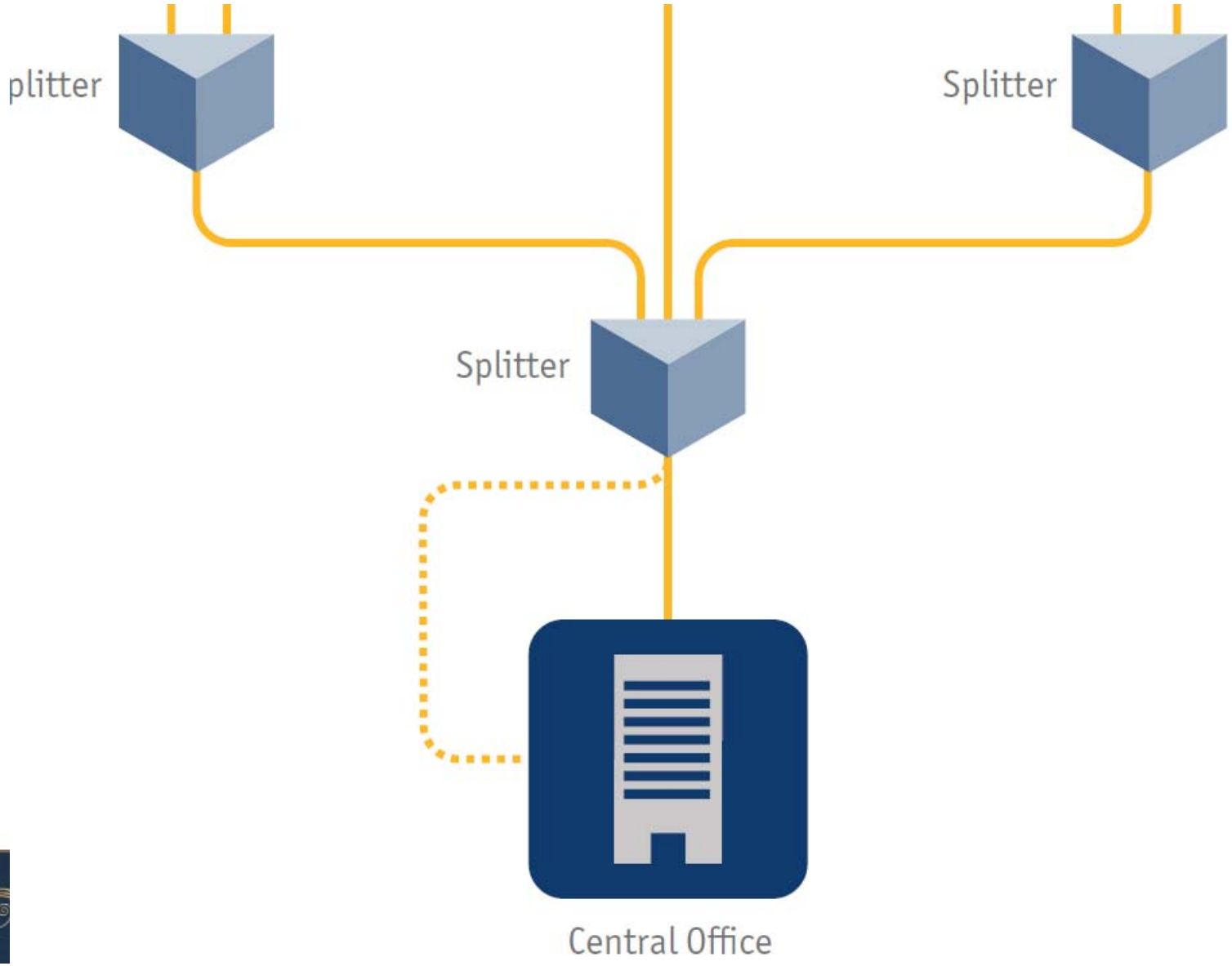
- E-PON and G-PON – most common today
- 10G or XG-PON, NG-PON, NG-PON2
- TBD-PON
- FTTx
- PON-LAN
- We don’t care what you put on the road – we want to make sure the road is in good shape to support today’s applications
  - Loss Budgets, Distances, Reflectance limits may be tighter with future versions

‘Basic’ PON Architecture



‘basic’ PON architecture - redundancy




plitter
Splitter
Splitter
Central Office

Basic PON LAN Layout

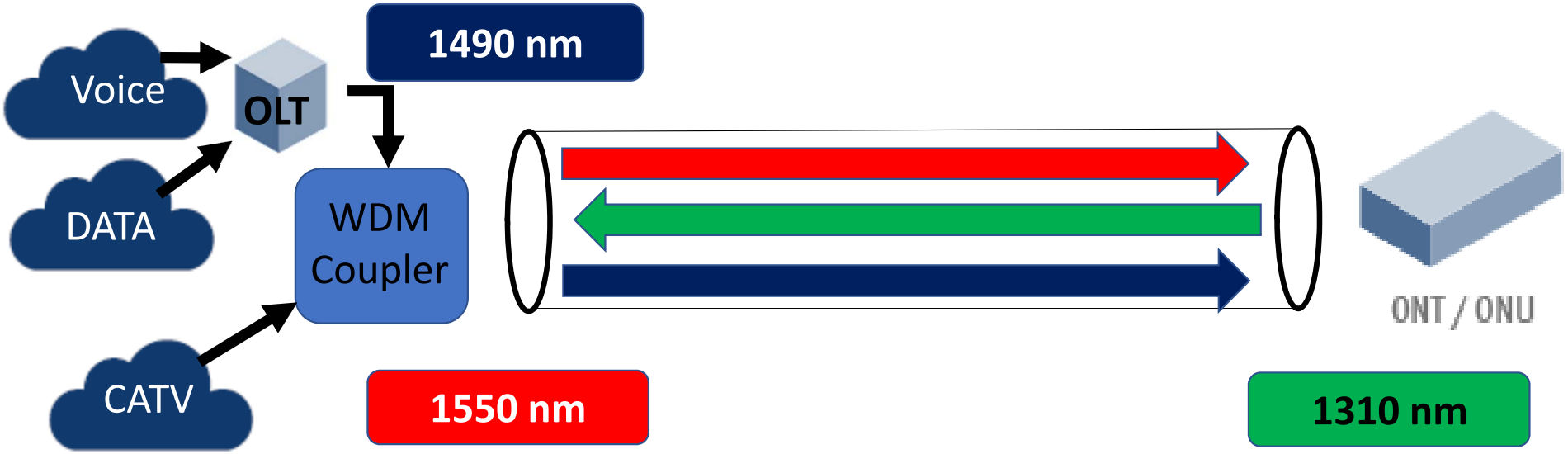
Fiber Concentration Point (FC/FCP)

Fiber Distribution Terminal (FDT)

Fiber Distribution Hub (FDH)
Data Center/MDF Single Administration Point


HG-P8-RA-B-24
HG-P8-RA-B-24

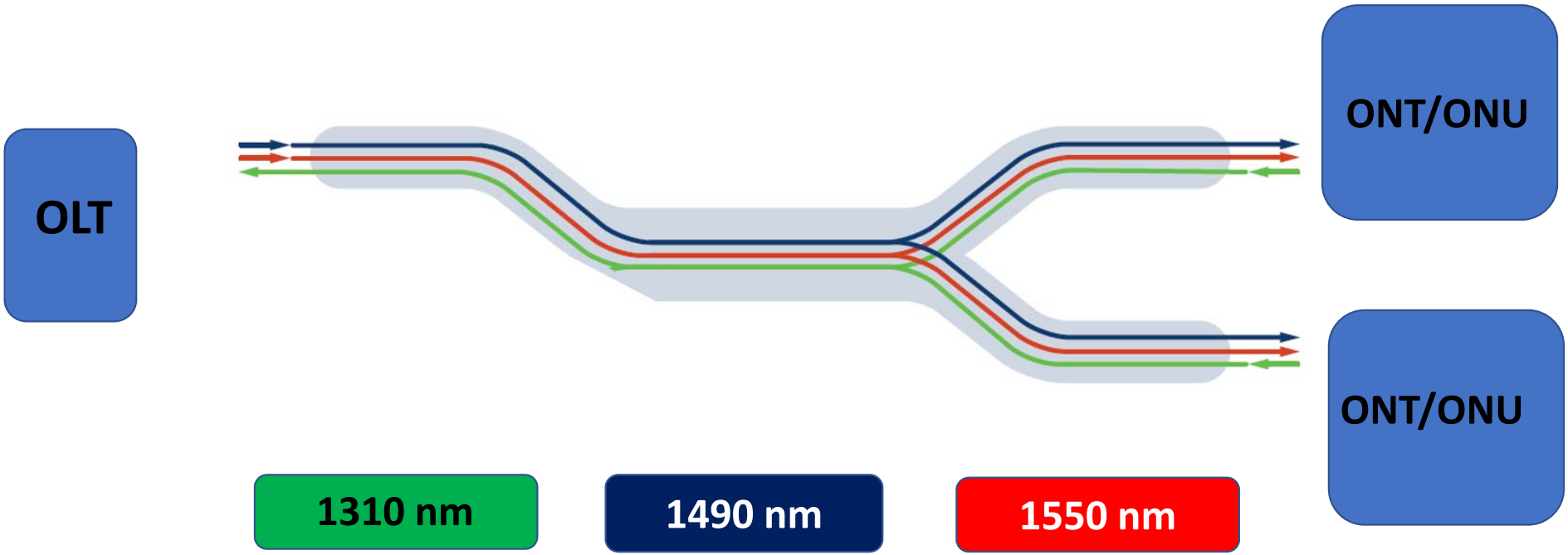
Multiple Wavelengths λ One Fiber



OLT – Optical Line Terminal
ONU – Optical Network Unit (ONT – Optical Network Terminal)

Splitters – Putting the *P*assive in *P*ON

Multiple Wavelengths λ One Fiber - Split



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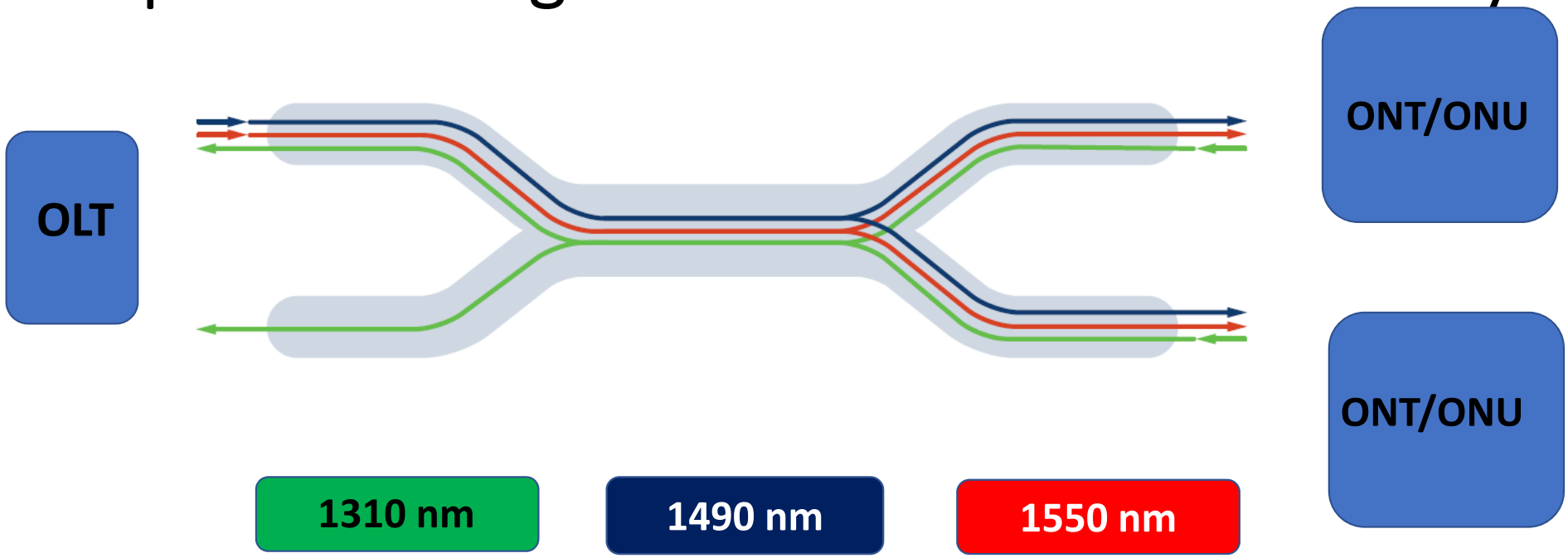
Multiple Wavelengths λ One Fiber – Redundancy



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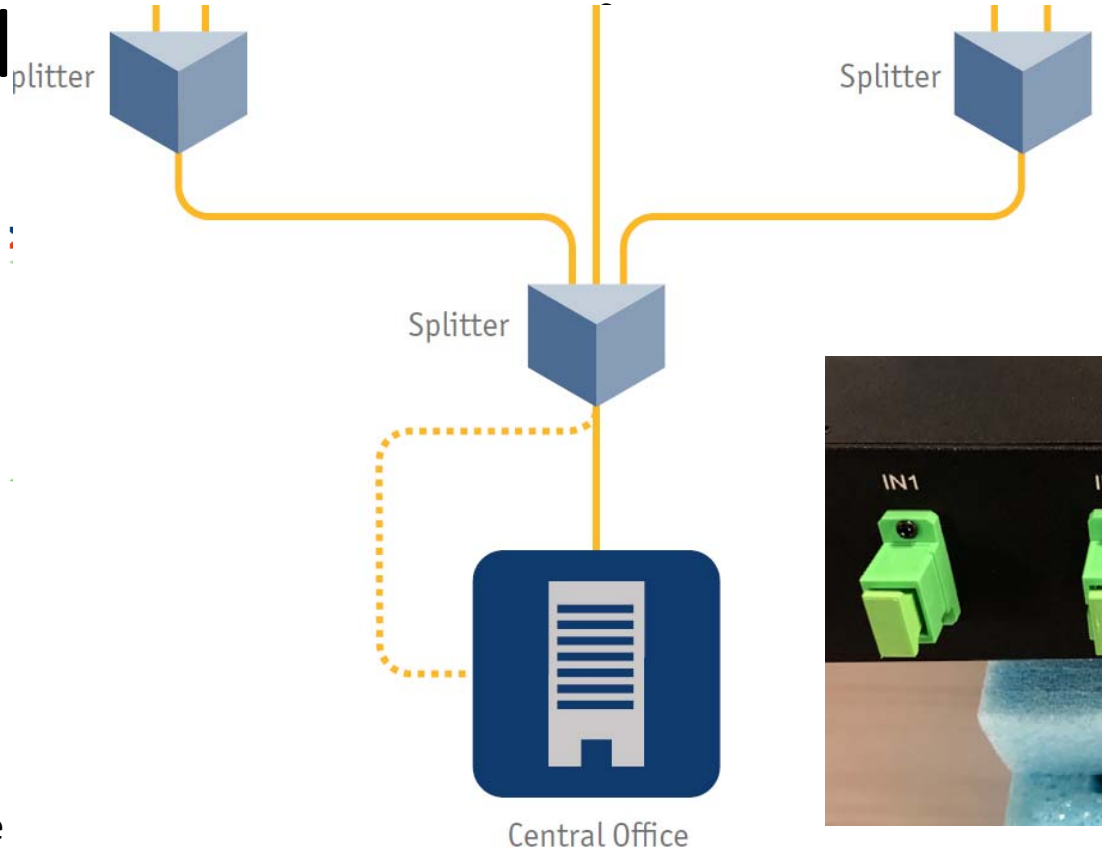
Multipl Redundancy



OLT – Optical Line
ONU – Optical Network Unit (ONT – Optical Network Terminal)

Splitters as the Name Suggests Divide the Light

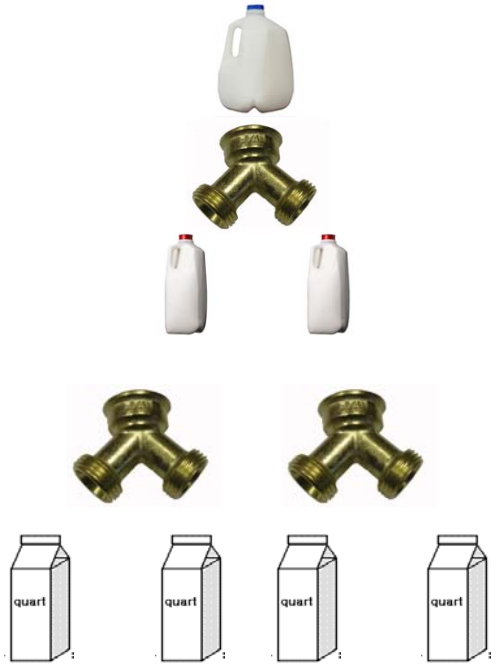
- Think of a splitter like a “Y” on a garden hose
  - If you put a gallon of water into the hose, you will get ½ gallon on each port
  - In optical power, that “loss” would be expressed as 3 dB
    - And a little bit for the connectors more for SC or LC connectors than a fusion splice
    - A 1 x 2 splitter should have about 3.5 dB of loss

Splitters and Bandwidth

- There is ***not*** a relationship between loss value and available bandwidth
- There ***is*** a relationship between number of users and available bandwidth
- GPON offers 2.54 Gig/sec downstream and 1.25 upstream
  - The number of splits will not affect downstream speeds, it is broadcast
  - Upstream speeds will be affected by the number of users and the applications they are using.
  - Through DBA (Dynamic Bandwidth Allocation), the available bandwidth can be changed or assigned.
    - Bandwidth can be allocated as needed to maintain a good customer experience

As you increase the split, you attenuate the light that is coming out of a splitter

- A 1 x 2 = 3.5 dB of loss
- 1 x 4 = 7 dB of loss



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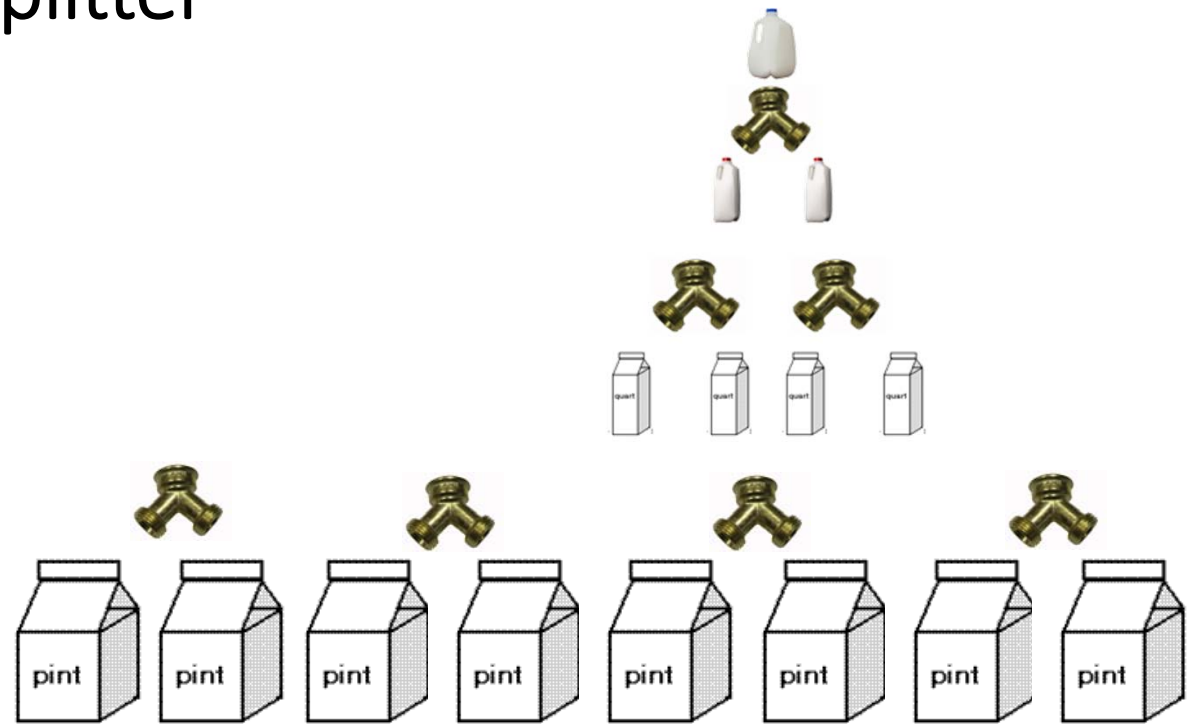
- 1 X 4 = 7 dB of loss
- 1 X 8 = 10.5 dB of loss



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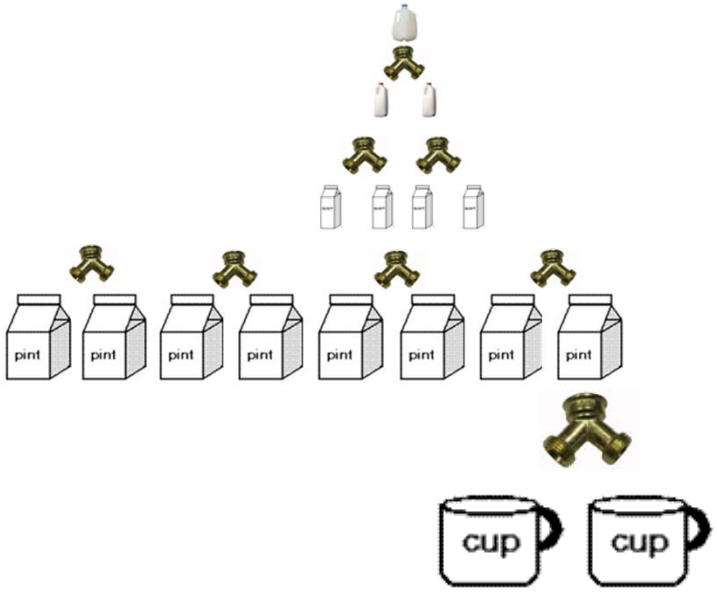
- A 1 X 2 = 3.5 dB of loss
- 1 X 4 = 7 dB of loss
- 1 X 8 = 10.5 dB of loss
- 1 x 16 = 14 dB

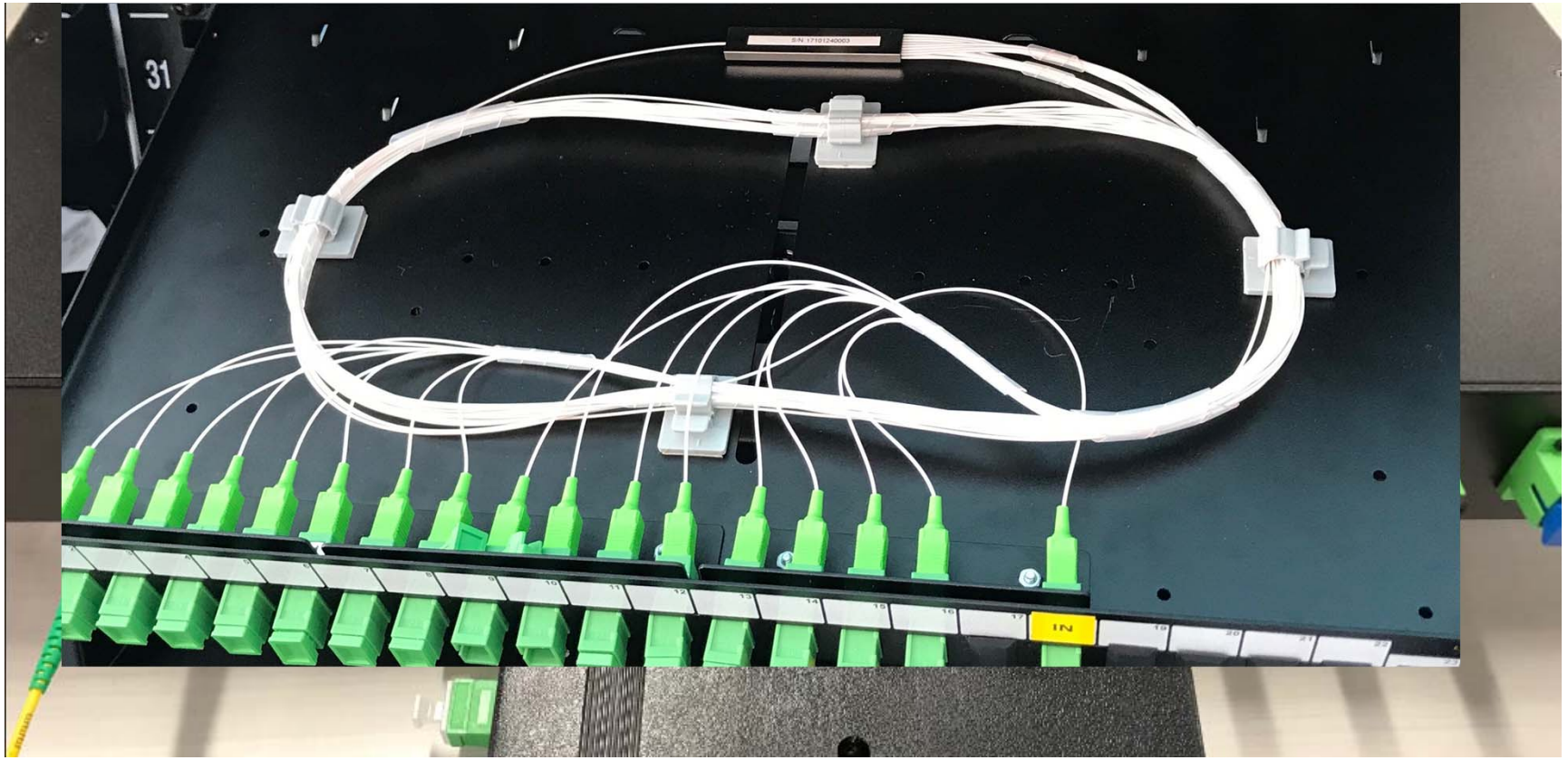


Loss Budget per Split per TIA-568 Annex D

Maximum permitted loss 3.9 dB

Under the Hood

Under the Hood



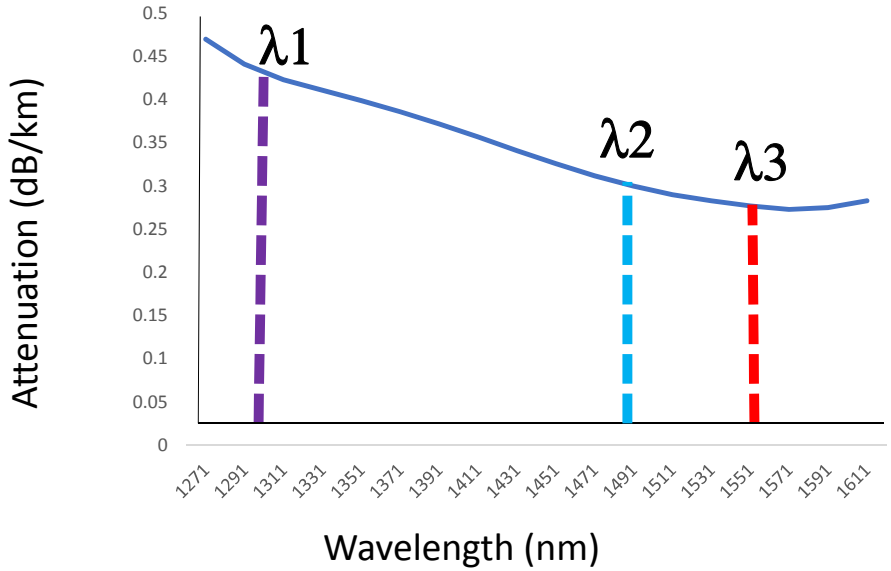
Under the Hood

Test of PON Networks

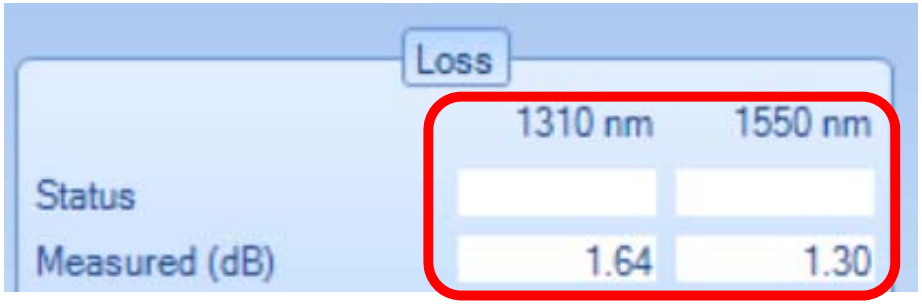
What To Test – Per IEC 61280-4-3

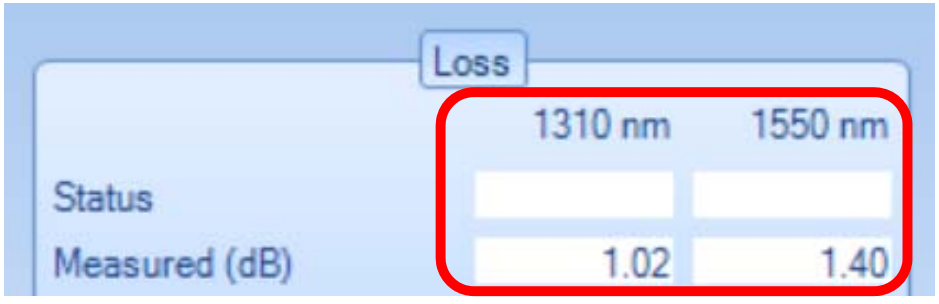
- Single Stage Optical Distribution Network (ODN)
- Multiple Stage ODN
- Attenuation
  - Light Source and Power Meter
  - 1310 and 1550 nm
  - OTDR (only in the upstream direction)

We don’t need to test every wavelength to identify problems – they are bound
If one of two wavelengths is off – there is a problem



A Quick Study of Testing at Two Wavelengths

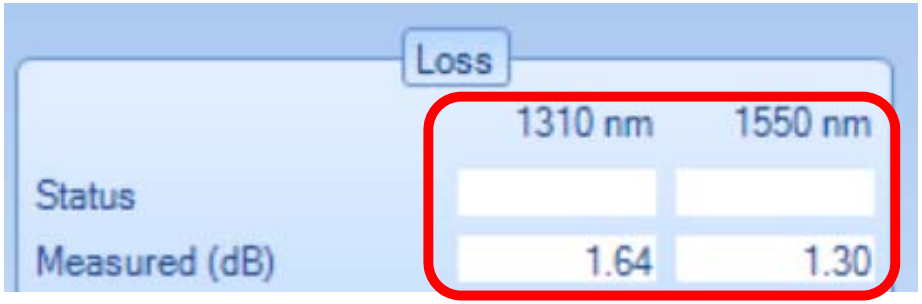




A Single Fiber Link
More Loss at 1310 than 1550

A Single Fiber Link with a Bend
More Loss at 1550 than 1310

A Quick Study of Testing a



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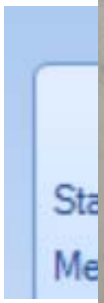

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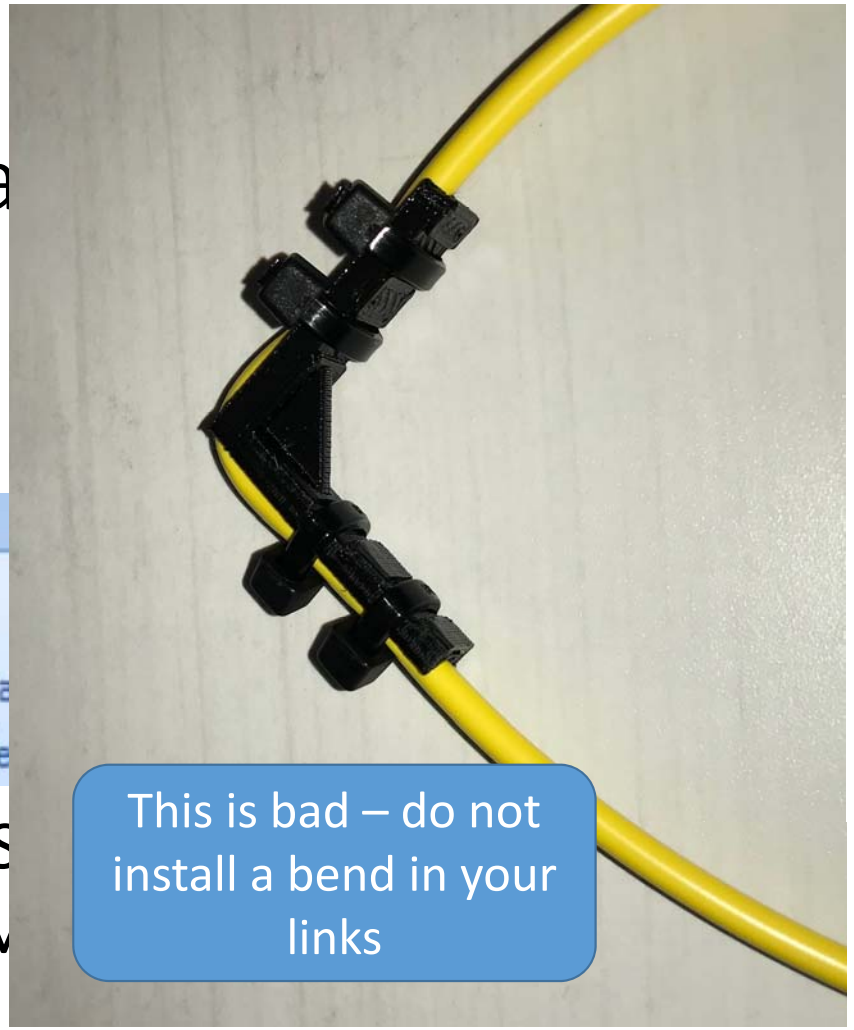
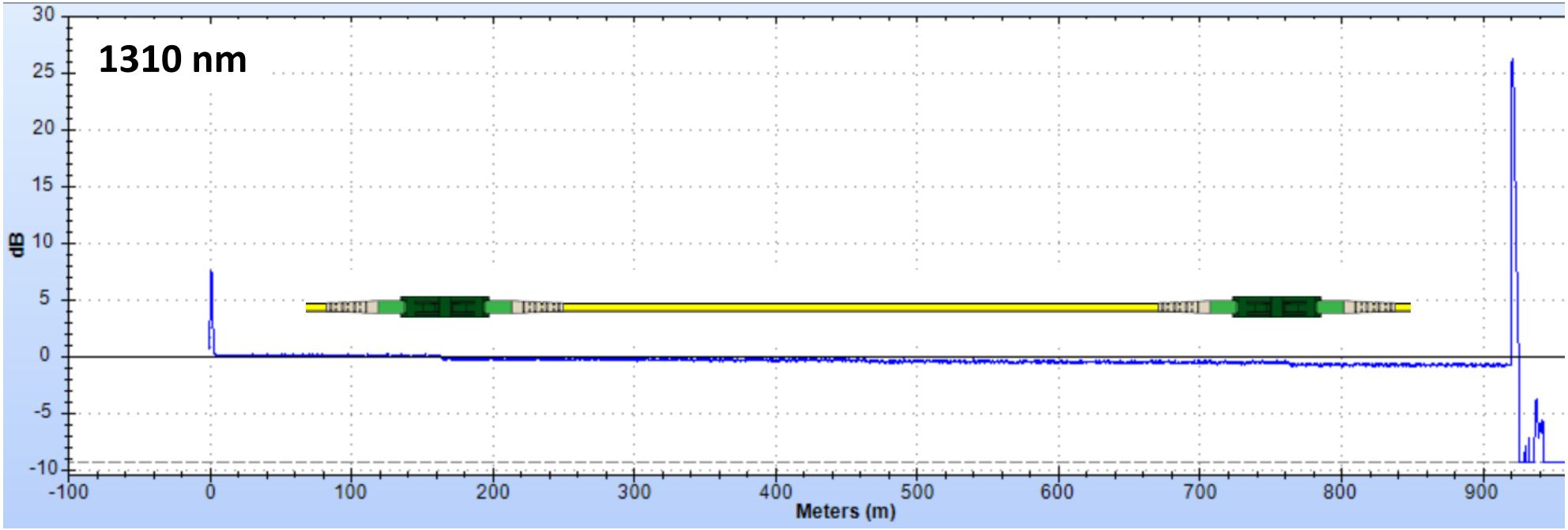


OTDR Trace Shows Location of Bend

But not at 1310 nm



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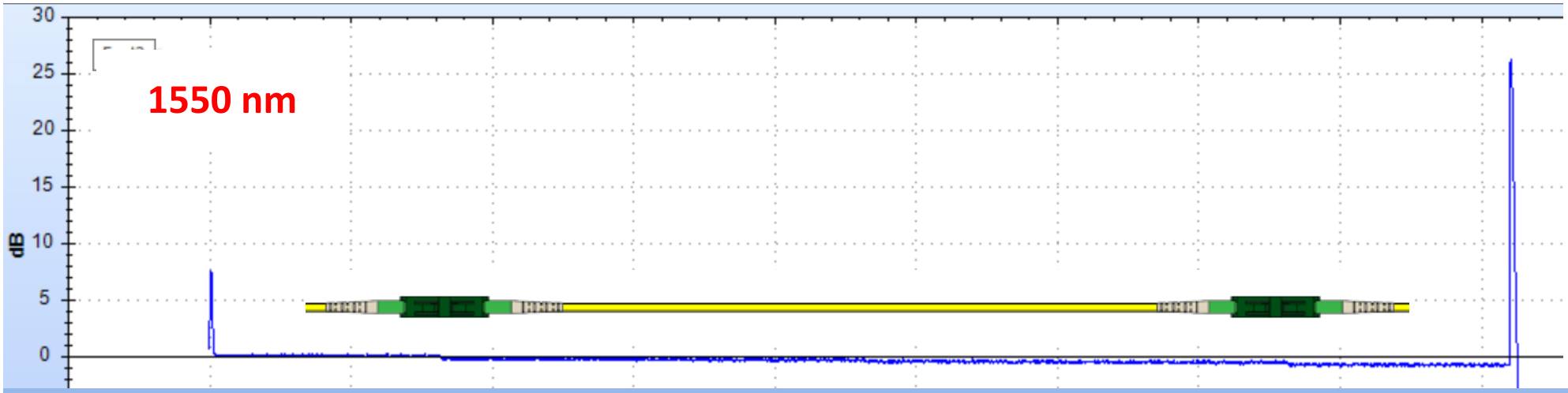
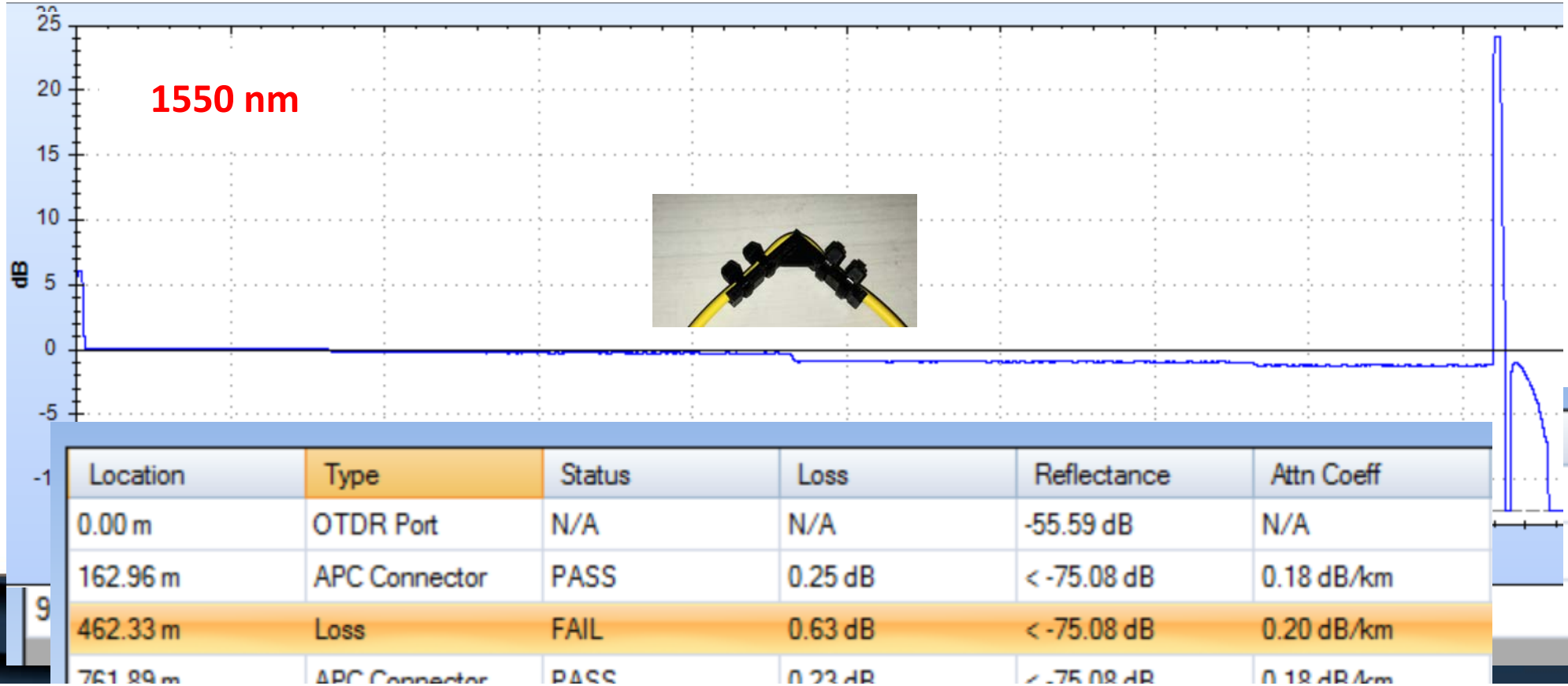


Location	Type	Status	Loss	Reflectance	Attn Coeff
0.00 m	OTDR Port	N/A	N/A	-54.88 dB	N/A
162.62 m	Loss	PASS	0.19 dB	< -77.06 dB	0.27 dB/km
920.15 m	End	N/A	N/A	-14.87 dB	0.79 dB/km

OTDR Trace Shows Location of Bend

But not at 1310 nm

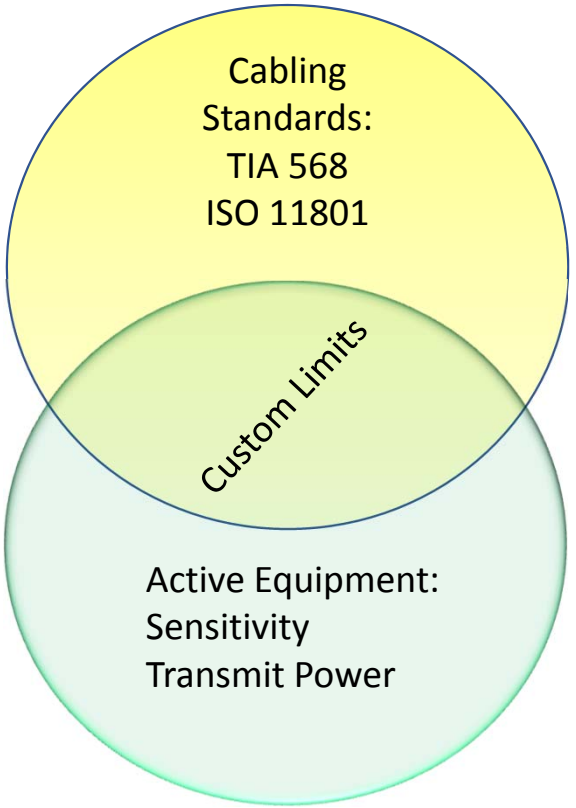


Location	Type	Status	Loss	Reflectance	Attn Coeff
0.00 m	OTDR Port	N/A	N/A	-55.59 dB	N/A
162.96 m	APC Connector	PASS	0.25 dB	< -75.08 dB	0.18 dB/km
462.33 m	Loss	FAIL	0.63 dB	< -75.08 dB	0.20 dB/km
761.89 m	APC Connector	PASS	0.23 dB	< -75.08 dB	0.18 dB/km

Loss Budget Calculation

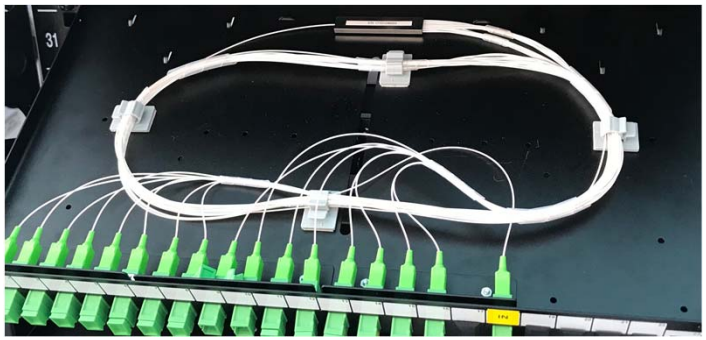
What Loss Budget to Use When Testing

- There can be different loss budgets that can be used
  - A Cabling limit, like the one called out in the IEC standard
    - Cable + Connectors + Splitters
  - An active equipment limit – depends on equipment
    - Fixed value 27 dB



Loss Budget Calculation and Splitters

- We have seen the loss budget for the splitters



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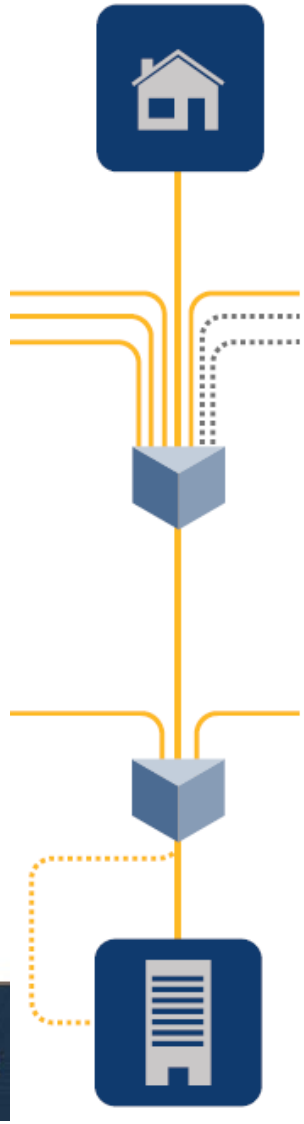

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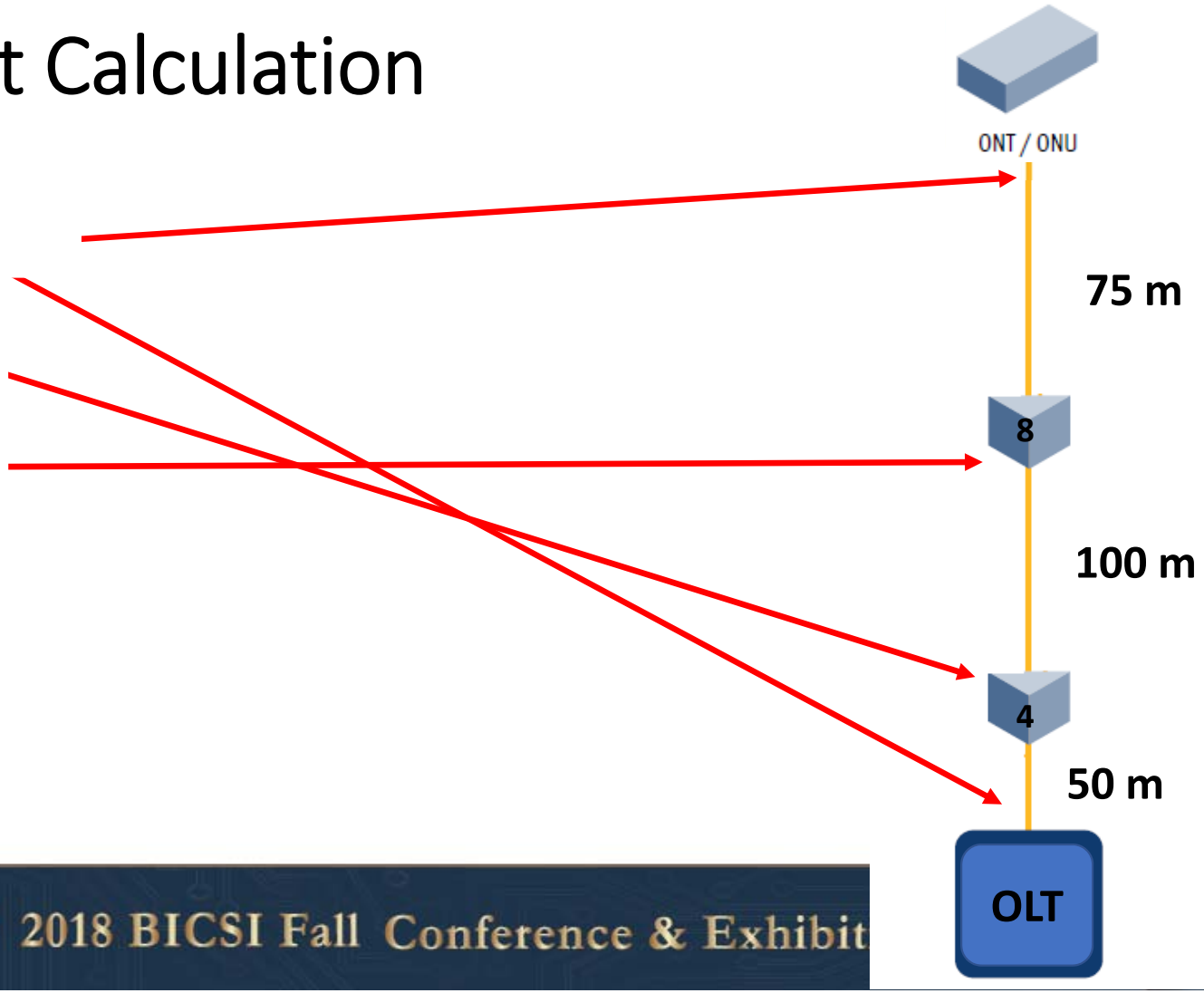
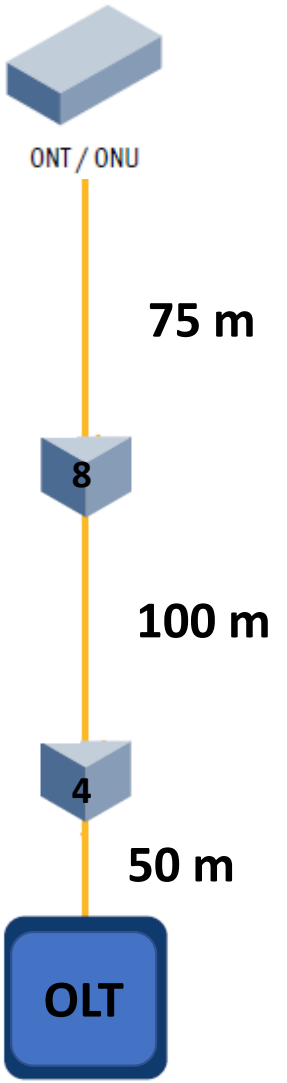


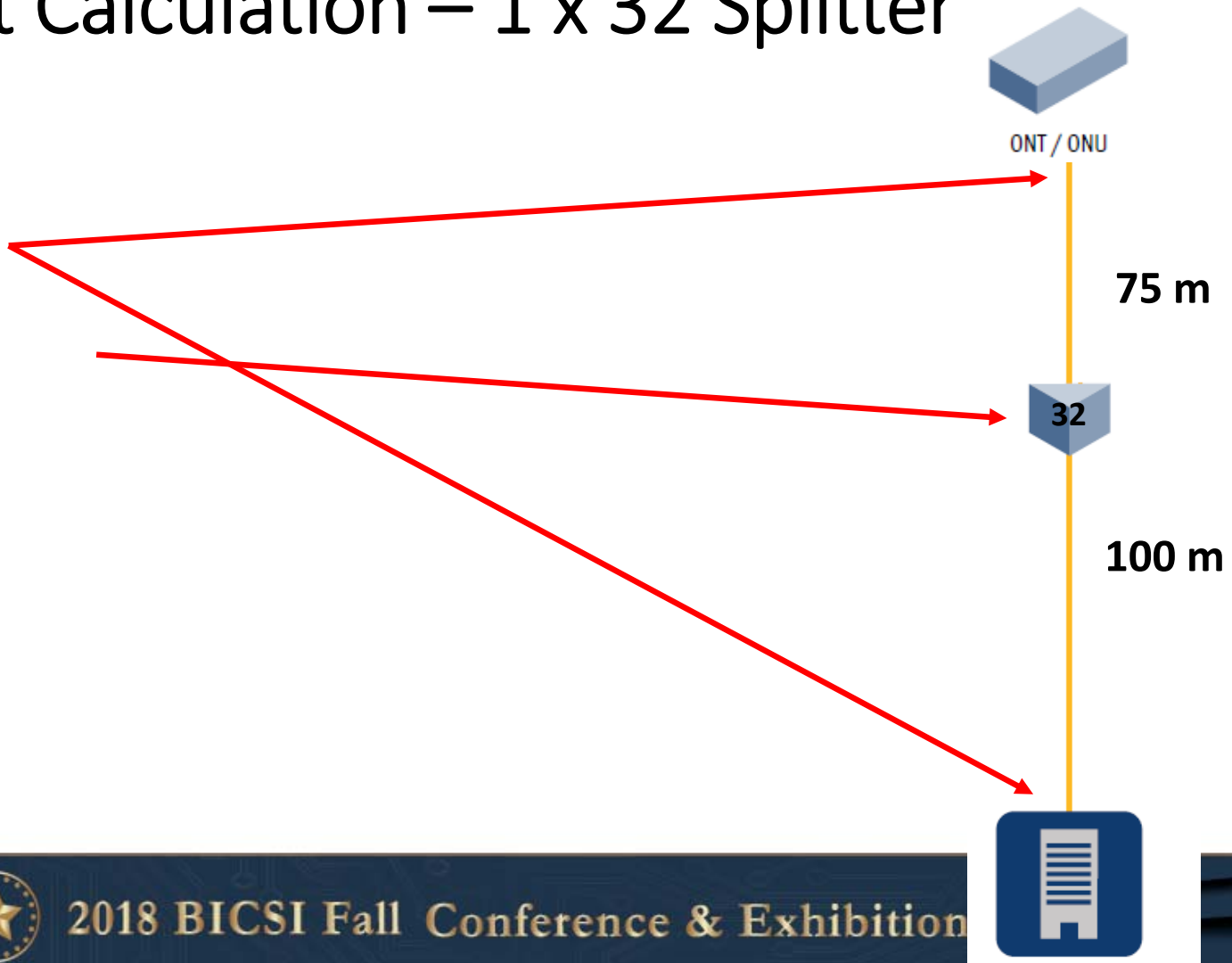
Loss Budget Calculation

Connectors * 0.75 dB
2 * 0.75 = **1.5 dB**
Splitters * budget
1 X 4 Port = **7.3 dB**
+ 2 * 0.75 for SC = **1.5 dB**
1 X 8 Port = **10.7 dB**
+ 2 * 0.3 for splices = **0.6 dB**
KM of Fiber * 1 dB/Km (Tight buffered indoor)
50 m + 100 m + 75 m = **.225 dB**
Total Loss Budget = 21.83 dB

Check with your supplier for their specific performance

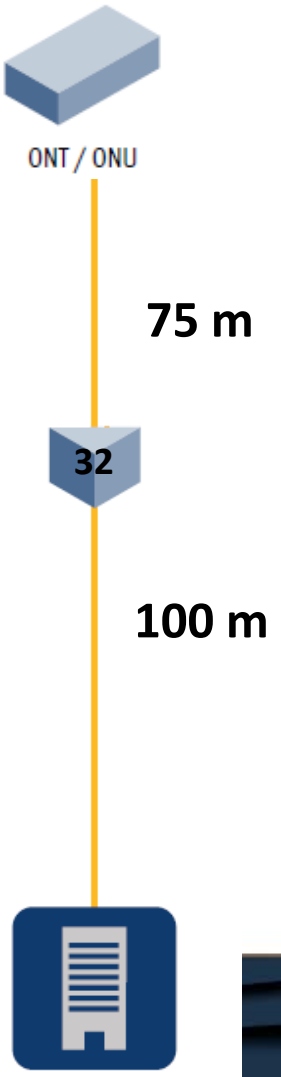


Loss Budget Calculation – 1 x 32 Splitter



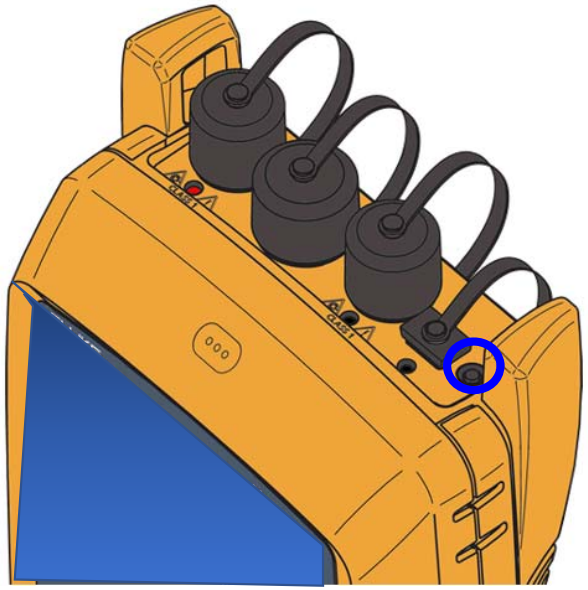
Loss Budget Calculation – 1 x 32 Splitter

Connectors * 0.75 dB
2 * 0.75 = **1.5 dB**
Splitters * budget
1 X 32 Port = **17.5 dB**
Splice in/Connect out = **1.05 dB**
KM of Fiber * 1 dB/Km (Tight buffered indoor)
100 m + 75 m = **0.175 dB**
Total Loss Budget = **19.18 dB**



Loss Testing with Minimal Uncertainty and Maximum Repeatability

Accurate Loss Testing Will Assure Support for Today's and Future Network Applications

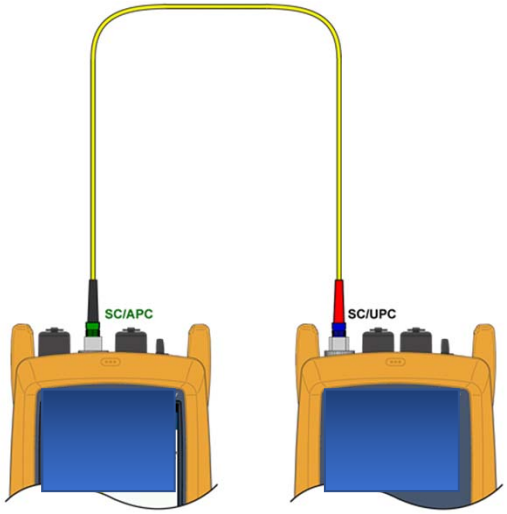


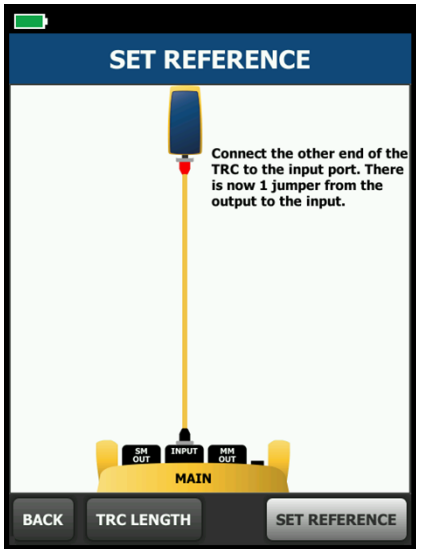
- A One Jumper reference is called out in the standard
- A Simple Light Source and Power Meter can be used, or you can use common **OLTS** units, provided they can be put into a "**Far End Source Mode**"

Pressing this button again sets the singlemode port to 1310/1550 nm

Single Fiber Testing – Setting a Reference

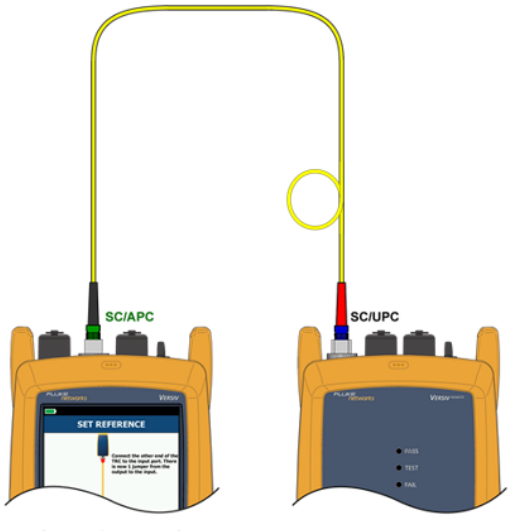
- Connect the MAIN and SOURCE units together
  - **One Jumper Reference**
  - **Must have input port that is the same as the connector to be tested**





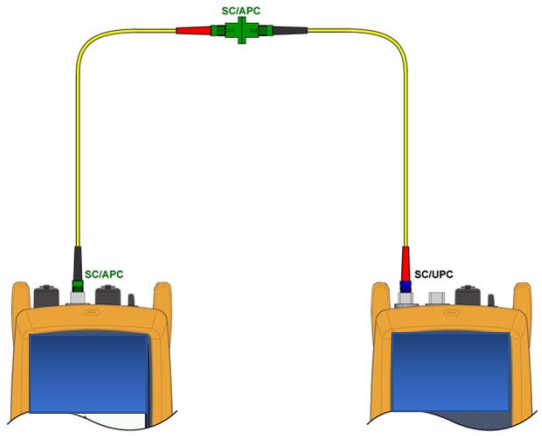
1 Jumper Reference and the 30 mm Loop

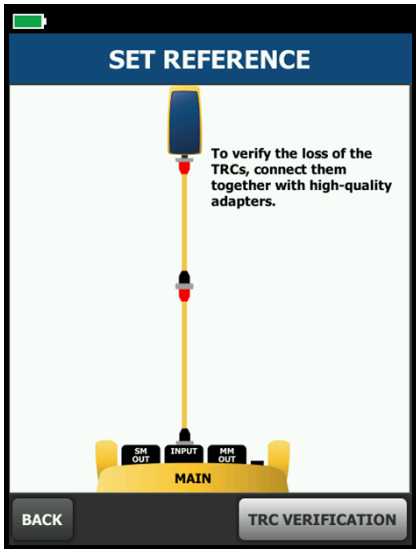
- The exact wording of the ANSI/TIA-568.3-D standard calls for a 30mm loop to be applied to the launch cord
- This is to work as a higher order mode filter
- These higher order modes have a very short propagation distance, perhaps less than 1 meter



Single Fiber Testing – TRC Verification

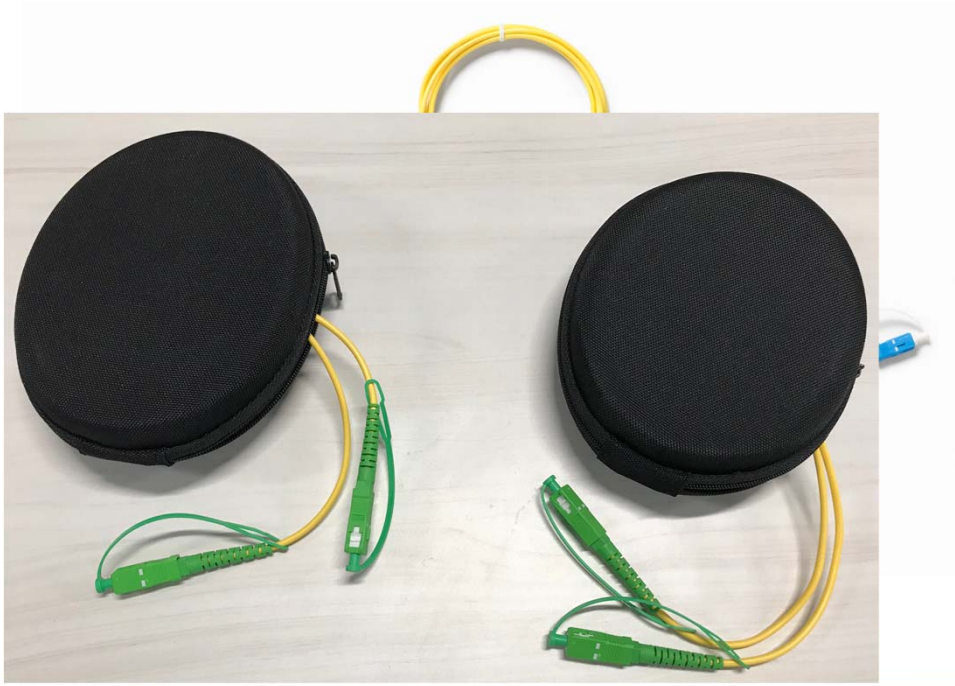
- After the reference is set, verify the condition of the other Test Reference Cord
- Loss for this test, with reference grade connectors should be **>0.25 dB**
- **Save this in your test results!**





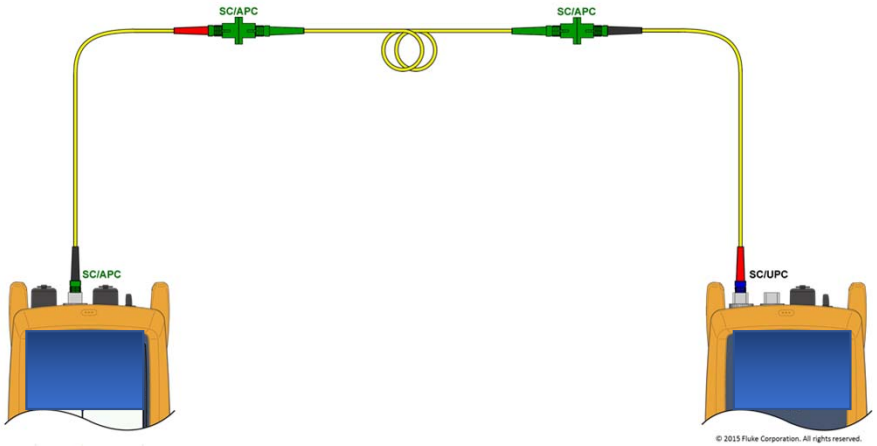
Test Reference Cord or Launch Fiber?

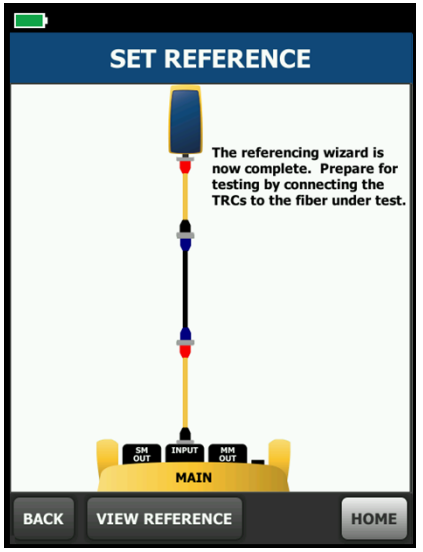
- A Test Reference Cord is used for Loss Testing (OLTS) and is usually from 1 to 5 meters long



Single Fiber Testing – Setting a Reference

- Connect to the link you wish to test





Sample Test Results

Cable ID: HGI ROOM 204
Date / Time: 12/29/2017 09:28:09 AM
Cable Type: OS2 Singlemode

n = 1.4670 (1310 nm)
n = 1.4680 (1550 nm)

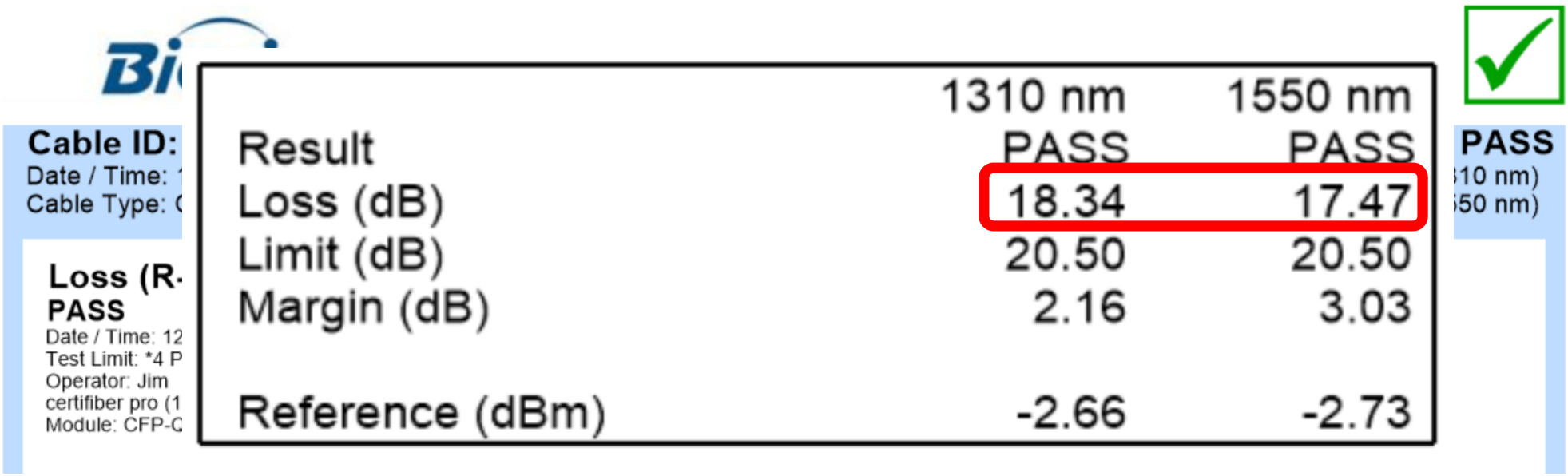
Test Summary: PASS
Backscatter Coefficient: -79.5dB (1310 nm)
Backscatter Coefficient: -82.0dB (1550 nm)

Loss (R->M)
PASS
Date / Time: 12/29/2017 09:28:09 AM
Test Limit: *4 PORT & 8 PORT*
Operator: Jim
certifiber pro (17455007 v5.3 build 20171229
Module: CFP-QUAD(2427616)

	1310 nm	1550 nm
Result	PASS	PASS
Loss (dB)	18.34	17.47
Limit (dB)	20.50	20.50
Margin (dB)	2.16	3.03
Reference (dBm)	-2.66	-2.73

Connector Type: LC
Patch Length1 (m): 2.0
Reference Date: 12/29/2017 09:08:10 AM
1 Jumper

Sample Test Results - Detail



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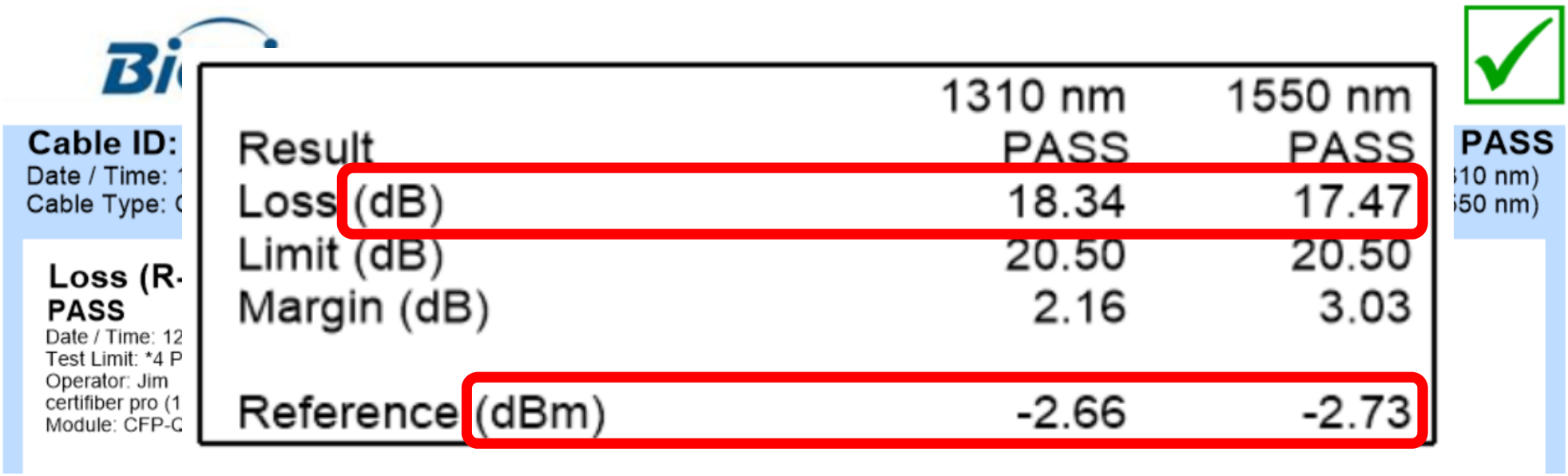

Cable ID:
Date / Time:
Cable Type:

Loss (R-
PASS
Date / Time: 12
Test Limit: *4 P
Operator: Jim
certifiber pro (1
Module: CFP-C

	1310 nm	1550 nm
Result	PASS	PASS
Loss (dB)	18.34	17.47
Limit (dB)	20.50	20.50
Margin (dB)	2.16	3.03
Reference (dBm)	-2.66	-2.73

PASS
310 nm)
550 nm)

Alternate Loss Budget Calculation

- Single Mode light sources are very powerful
- Often, they can accept any amount of light down to a given level
  - Usually -27 dBm

Alternate Loss Budget Calculation

- Single Mode light
- Often, they can a
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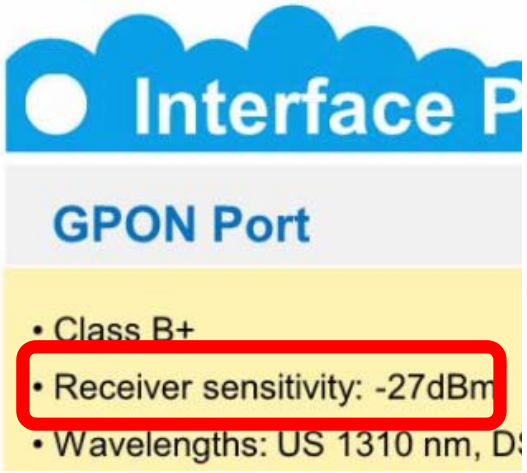

Cisco
Table

Table

Typ

PON

GPON

- De acordo com o padrão GPON ITU-T G.984.x;
- Transmissor de 1.244Gbps sentido upstream em mo
- Receptor de 2.488Gbps sentido downstream;
- Comprimento de onda de transmissão: 1310nm;
- Comprimento de onda de recepção: 1490nm;
- Framing totalmente compatível com ITU-T G.984;
- Múltiplos T-CONTs por dispositivo;
- Múltiplos GEM Ports por dispositivo;
- Suporta modo Single T-CONT ou modo Multiple T-C
- Mapeamento flexível entre GEM Ports e T-CONTs;
- Forward Error Correction (FEC);
- Suporte para Multicast GEM Port;
- Mapeamento de GEM Ports em um T-CONT com filas de prioridade;
- Potência Óptica de Transmissão: 0,5dBm ~ +5dBm
- Potência Óptica de Recepção: -8dBm ~ -27dBm

- BBF TR.156 - Using GPON in the context of TR
- Advanced Encryption Standard (AES)
- Forward Error Correction (FEC)
- Class B+ optics (28dB)

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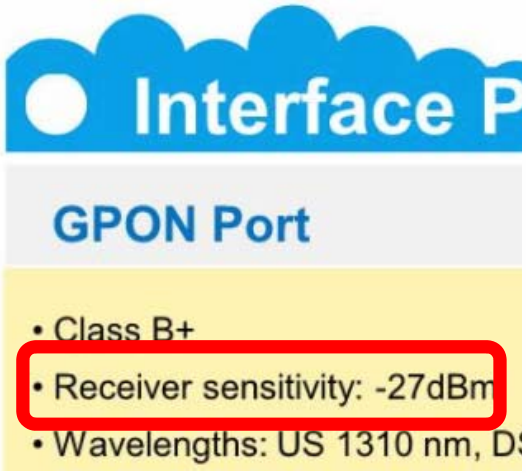


Cisco ME 4600 Series ONT Standards, Protocols, and Compliance

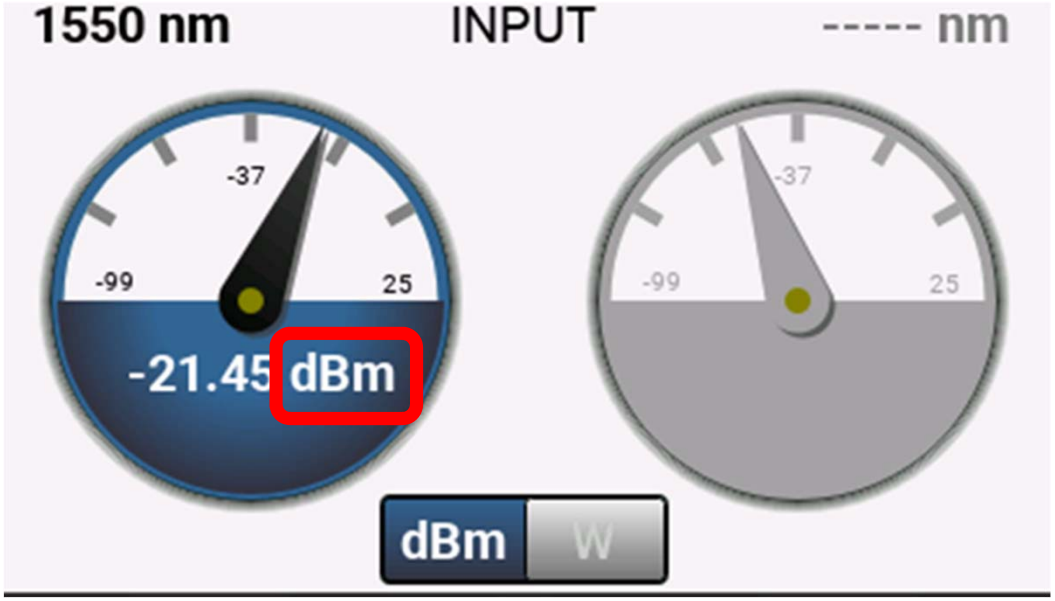
Table 5 lists the standards and protocols that apply to the Cisco ME 4600

Table 5. Standards and Protocols

Type	Standards
PON layer	• ITU-T Recommendation G.984.x (GPON) • ITU-T Recommendation G.988 (OMCI) • BBF.247 - GPON certification program OLT inte • BBF TR.156 - Using GPON in the context of TR • Advanced Encryption Standard (AES) • Forward Error Correction (FEC) • Class B+ optics (28dB)

Alternate Loss Budget Calculation

- Single Mode light sources are very powerful
- Often, they can accept any amount of light down to a given level
  - Usually -27 dBm
  - Rule of thumb – give yourself some margin 3 dB?
- When troubleshooting or testing with the OLT installed check for greater than -27 dBm in the POWER mode, not LOSS mode
  - - 26 dBm is greater than -27 dBm
  - -28 dBm is less than -27 dBm



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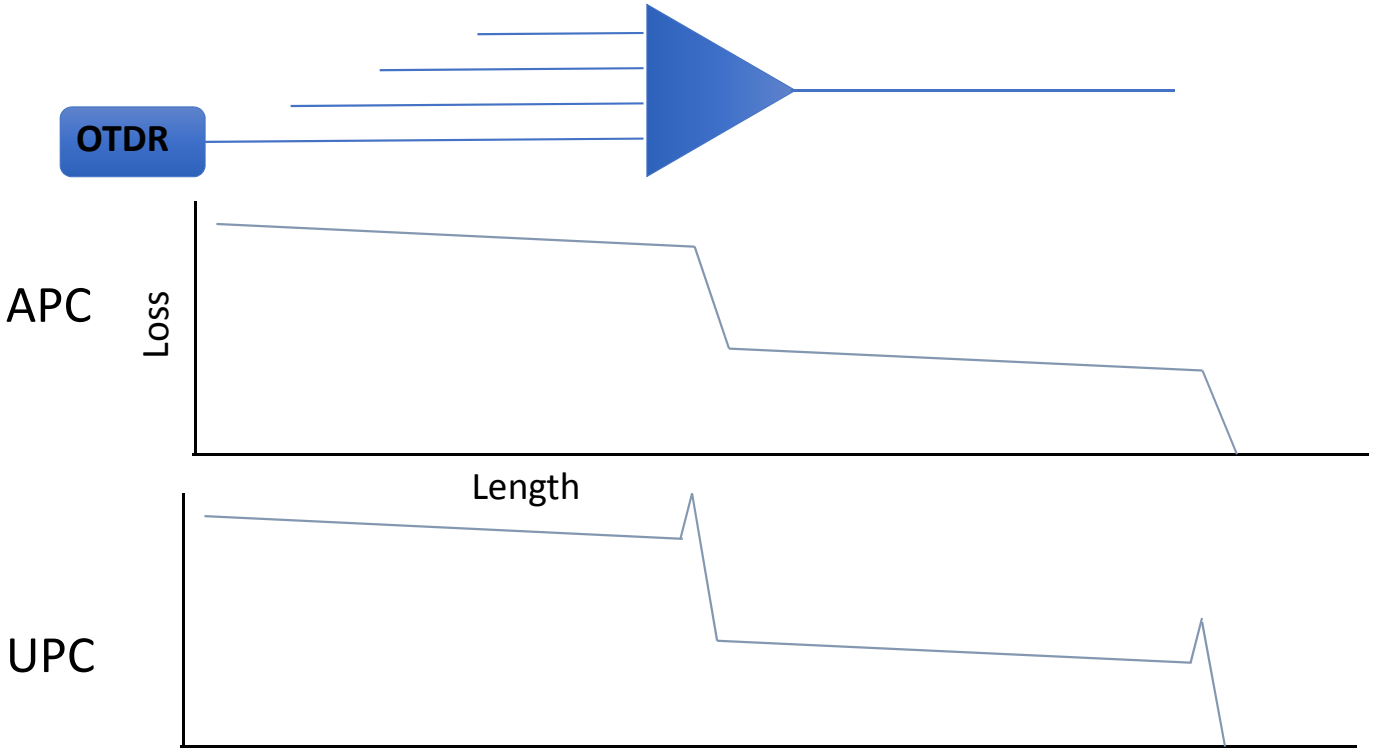
  - -28 dBm is less than -27 dBm
- Loss is measured in dB
  - And should be a positive number

OTDR Testing

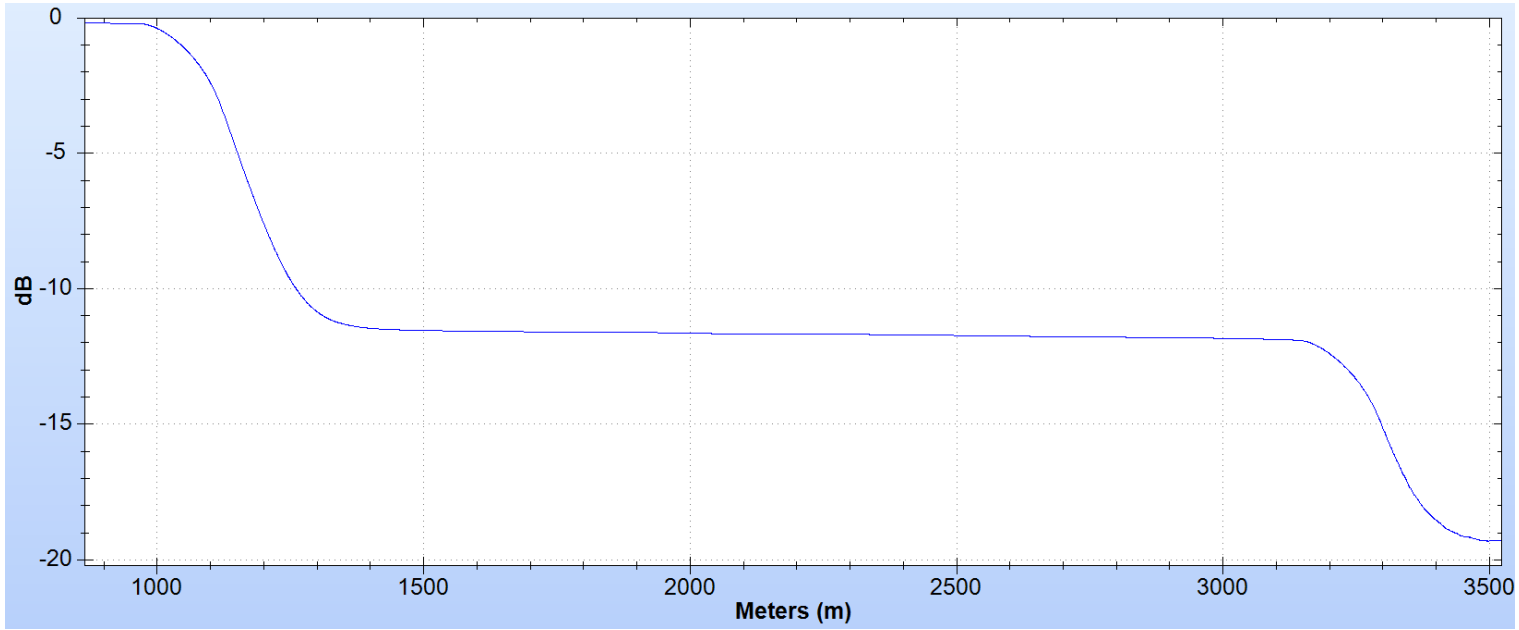
- Used to measure loss and reflectance of events
- Upstream only
- Requires a launch and tail cord
  - Cords should have close backscatter coefficient to link under test
- Shall be capable of using a short pulse ≤ 20ns
  - A larger pulse and larger dynamic range are required for larger “splits”
  - A larger pulse leads to a larger dead zone
- Check the launch a receive cords prior to testing (B.6.2)

Upstream OTDR Testing



Upstream OTDR Testing

APC

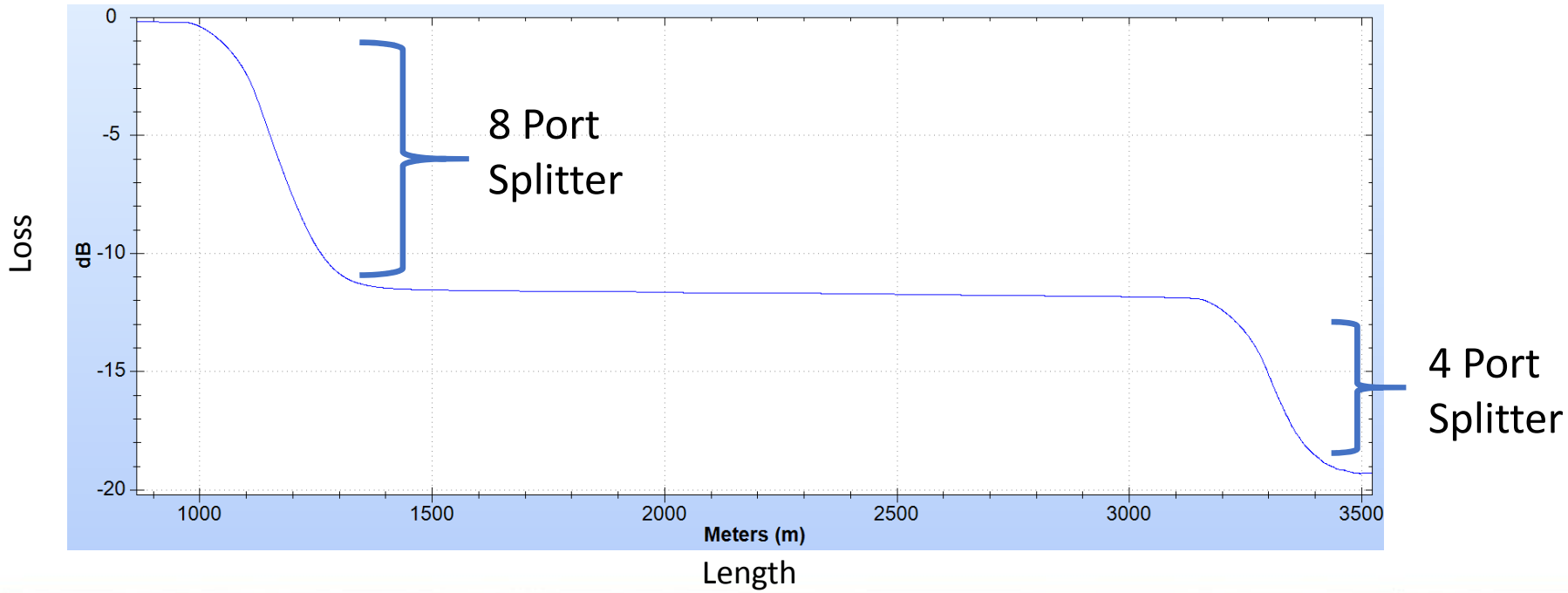


Loss

Length

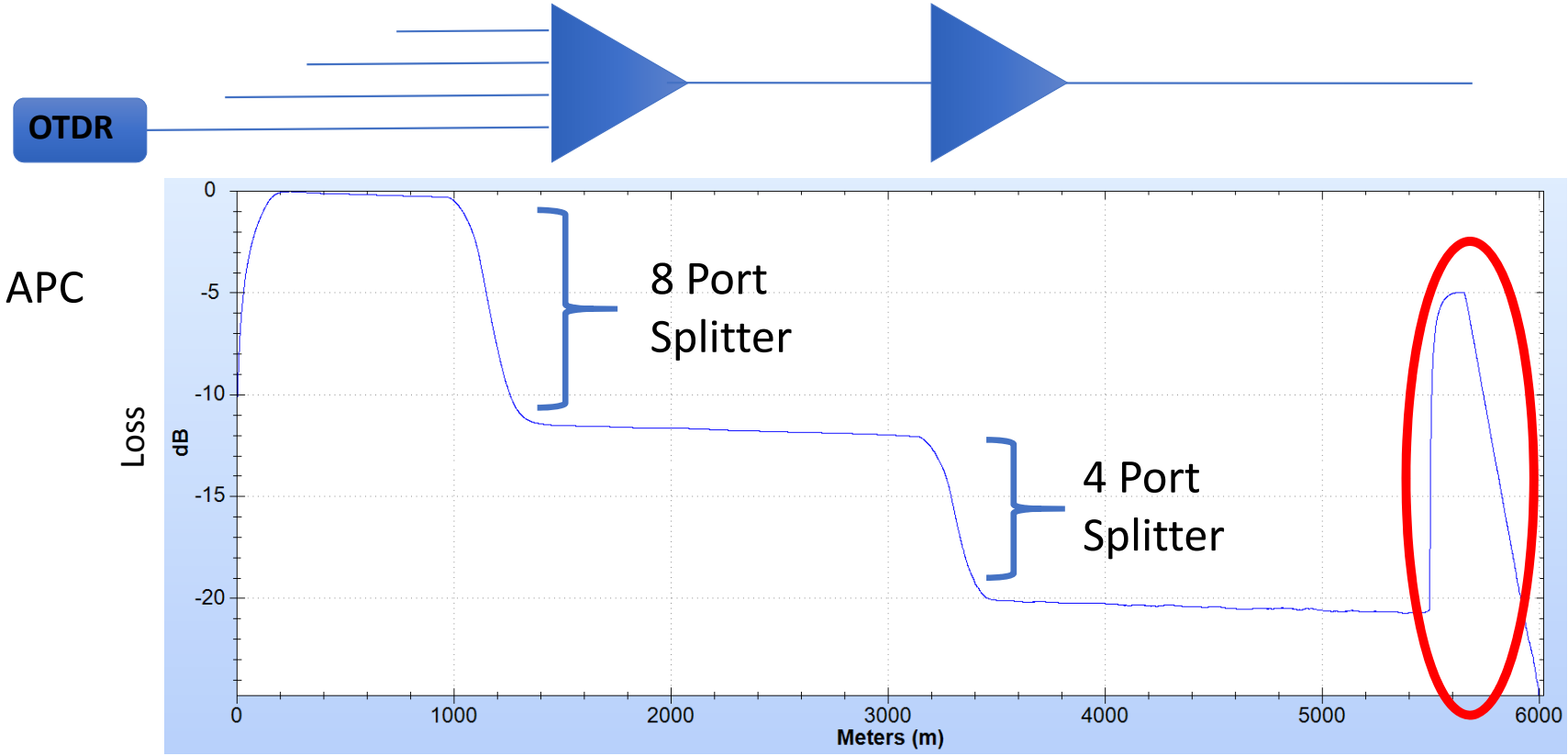
Upstream OTDR Testing

APC

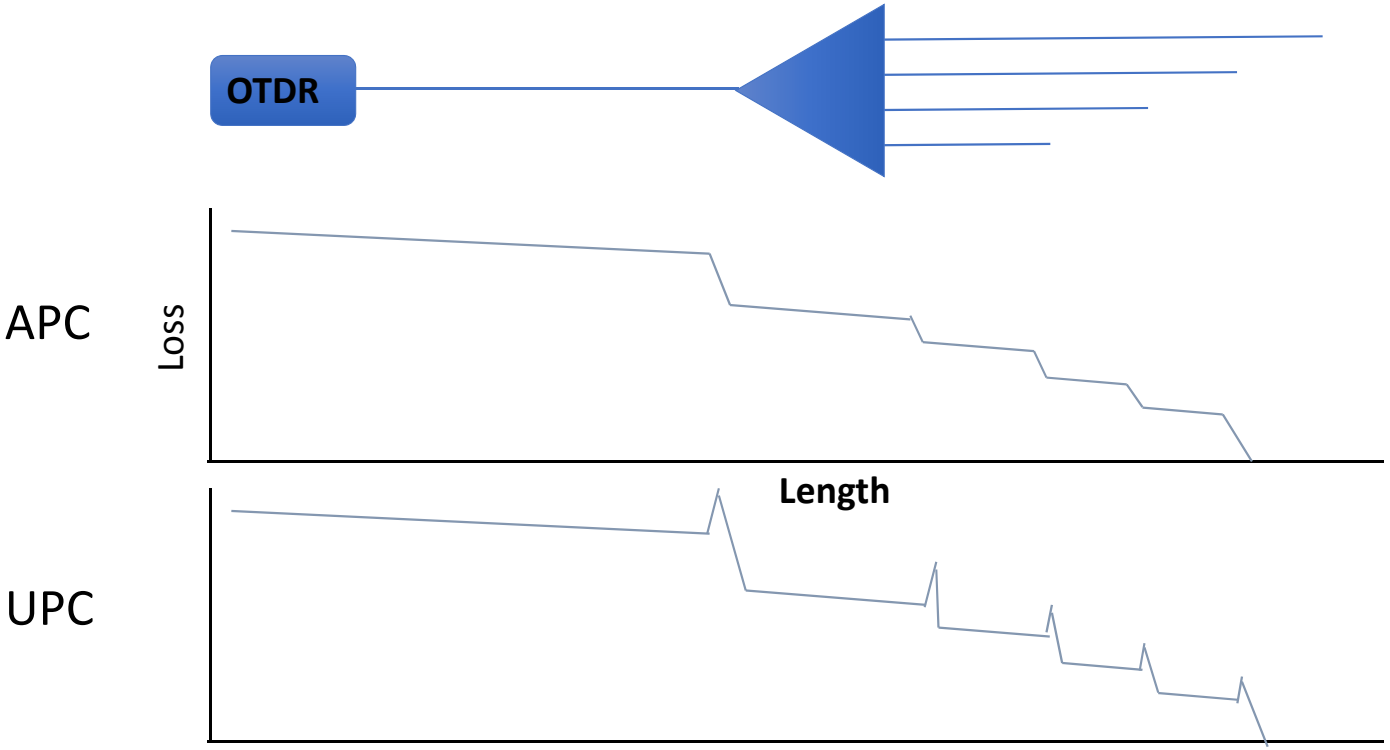


Length

Upstream OTDR Testing – OTDR Like Reflective Terminations



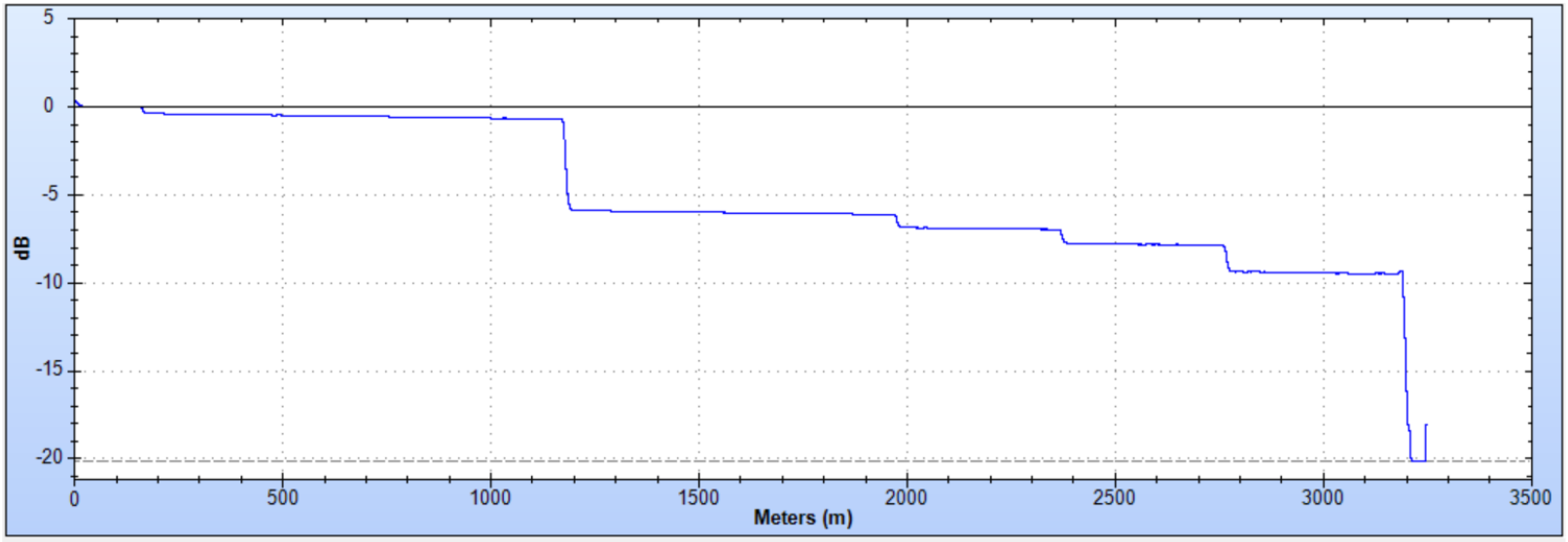
Downstream Testing



Downstream Testing

APC

Loss



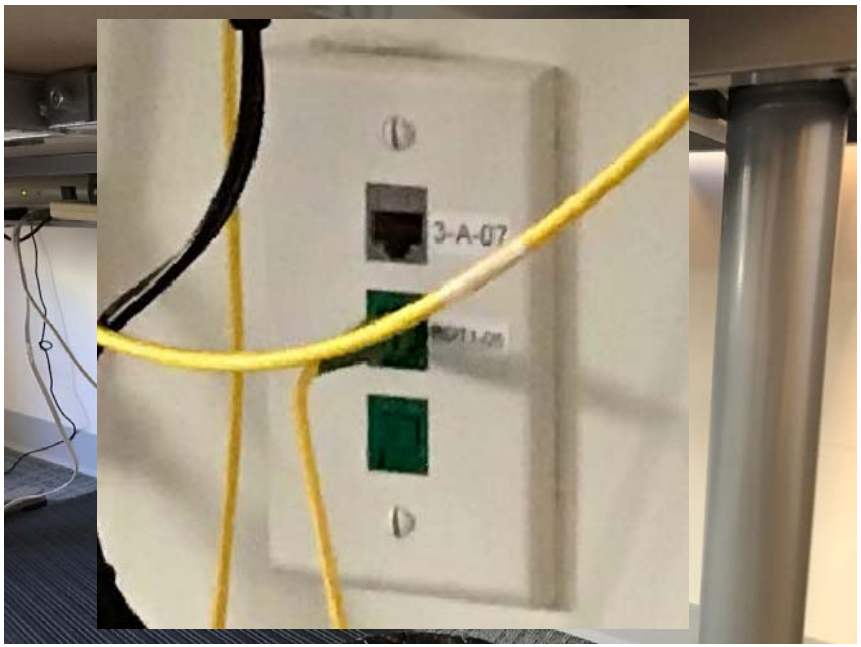
Length

Troubleshooting Links

Did you try rebooting?

Example of PON to the desk

Example of PON to the desk

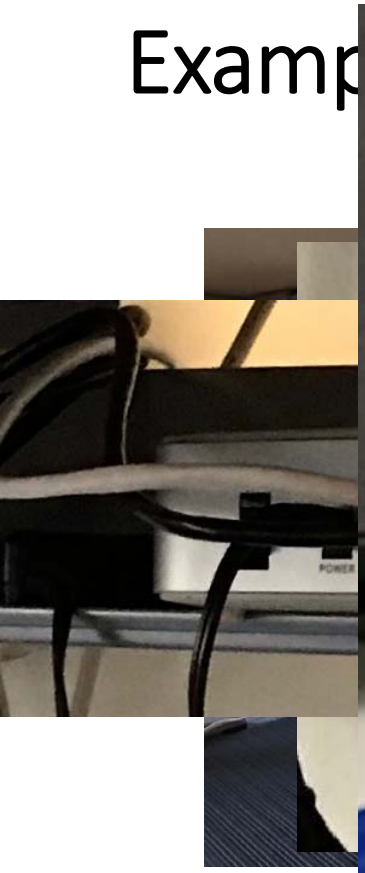


- Just a single fiber

Example of PON to the desk

- Just a single fiber
- Four port switch – in this example – to provide copper connectivity to phone, PC, laptop, local WAP, etc.

Examp



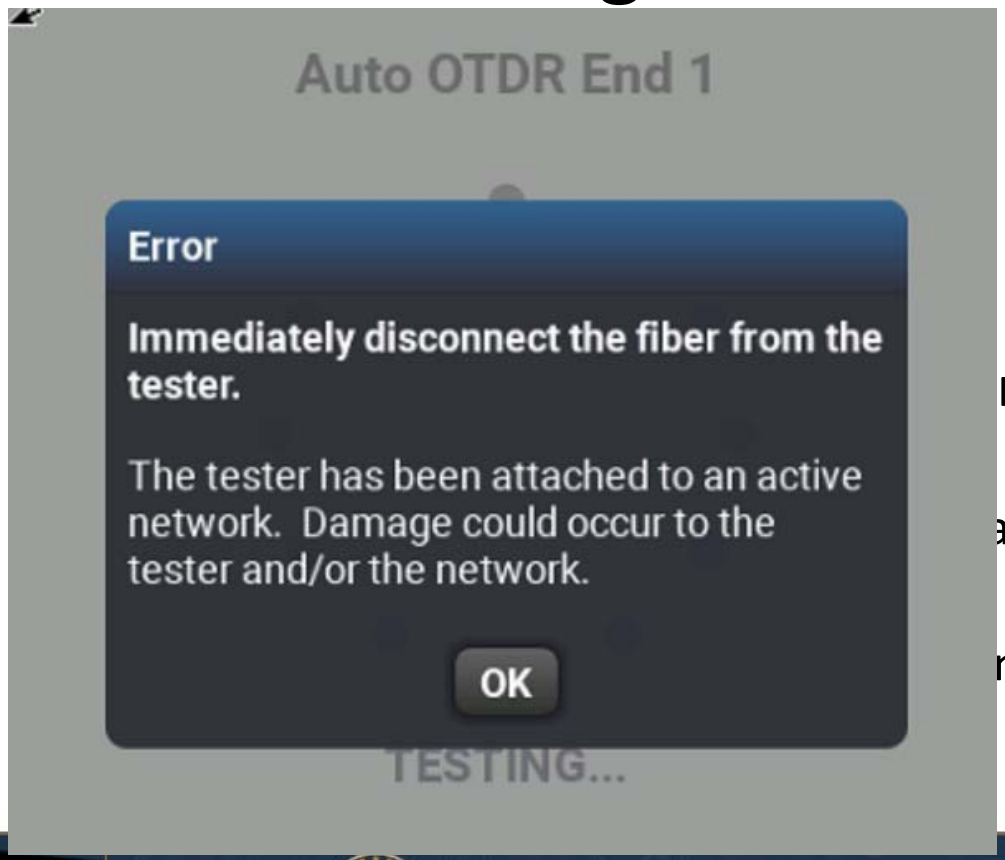
iber

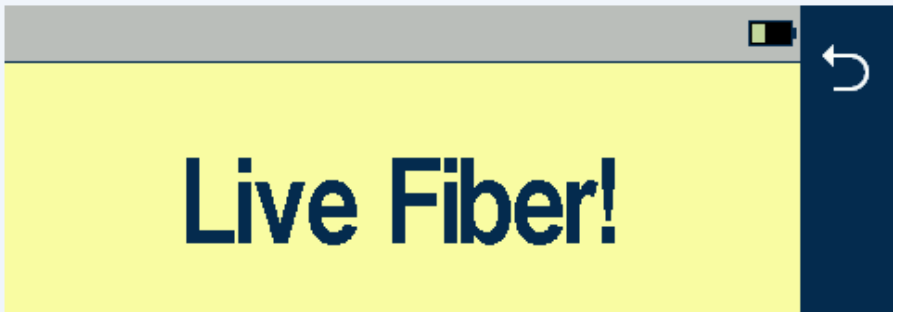
tch – in this
provide copper
o phone, PC,
WAP, etc.

Troubleshooting a Live Network With an OTDR

- OTDR shoots a pulse of light
- Measures time for light to return
  - Closer events come back sooner
  - Farther events take longer to return
- What if there is an OLT transmitting on the fiber?
  - Light is always arriving
  - How to tell the difference from OTDR transmitted pulse and OLT pulse
  - Unplug from OLT (and run)
  - Unused wavelength – 1625 nm or 1650 nm

Troubleshooting a Live Network With an OTDR



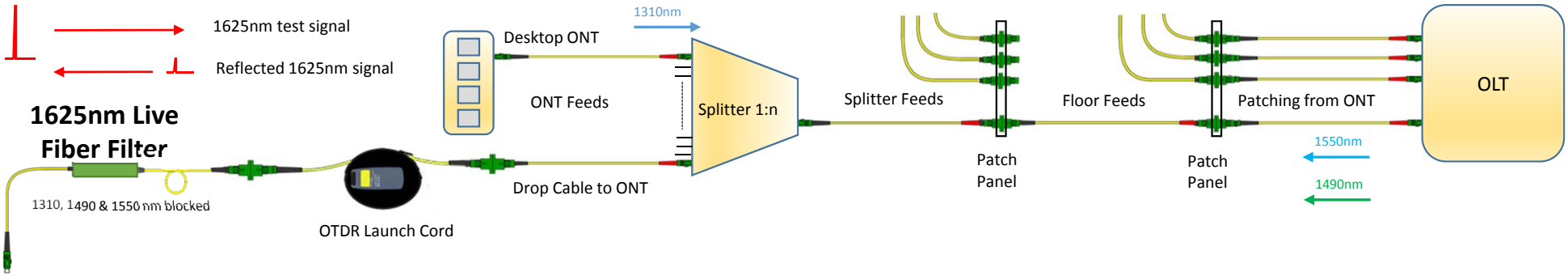


n t

ansmitted pulse and OLT pulse

nm

Filtered Test Configuration for POLAN

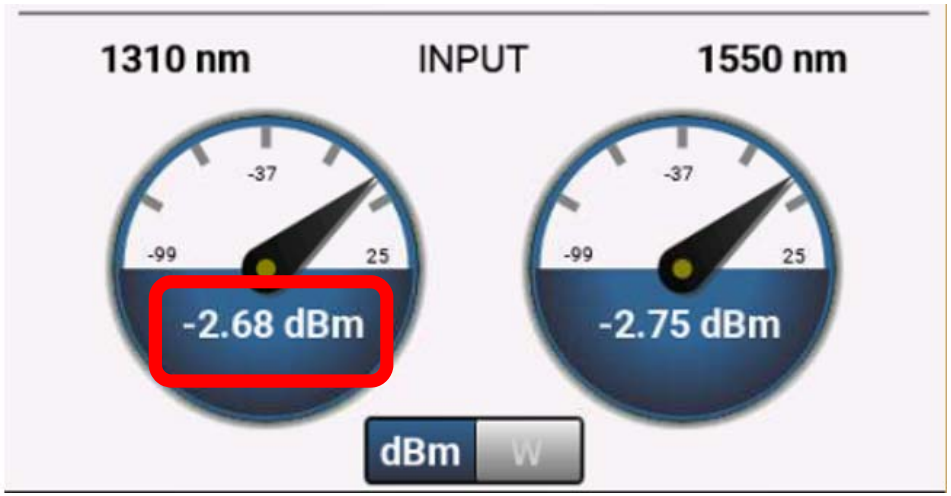


OTDR

- When troubleshooting a connectivity issue you need to be able to connect into a live system with an OTDR to troubleshoot without disturbing the system and without the POLAN signals interfering with the OTDRs measurements.
  - A 1625nm **Live Fiber Filter** allows the OTDR to use an out of band 1625nm test wavelength to meet this purpose.
    - 1625nm will not interfere with the active POLAN signals
    - The filter blocks the 1310nm, 1490nm and 1550nm wavelengths from entering the OTDR port, preventing them from interfering with the measurement

Gotcha – Don’t plug ONT to OLT with 2 meter patch cord to check if it works ☺

- Potência Óptica de Transmissão: 0,5dBm ~ +5dBm
- Potência Óptica de Recepção: -8dBm ~ -27dBm



Documenting Results

- Request your test results in Native Format, not .pdf
  - Your tester only delivers results in Paper format?
- Consider using a cloud based results management service
- Check that the reference value is correct and recent
- Did they verify the known good leg?
- Deliver the results today, not in a month
  - While your team still has access to the site

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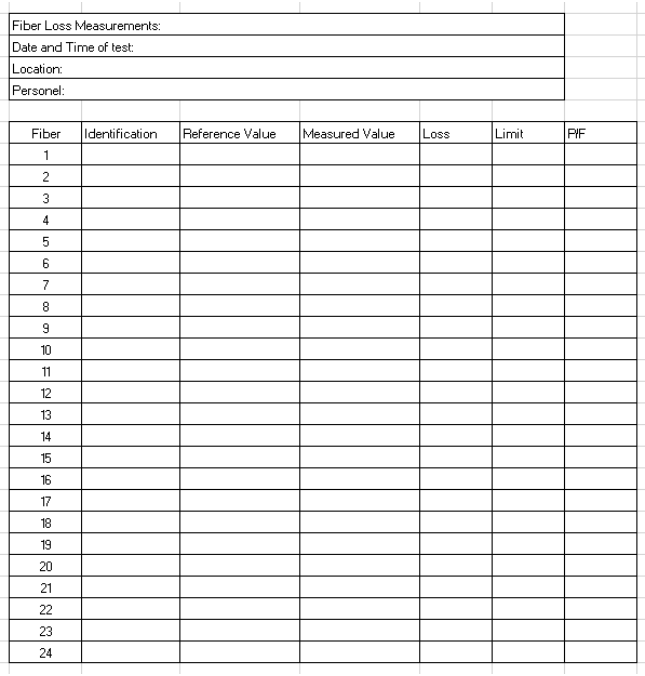
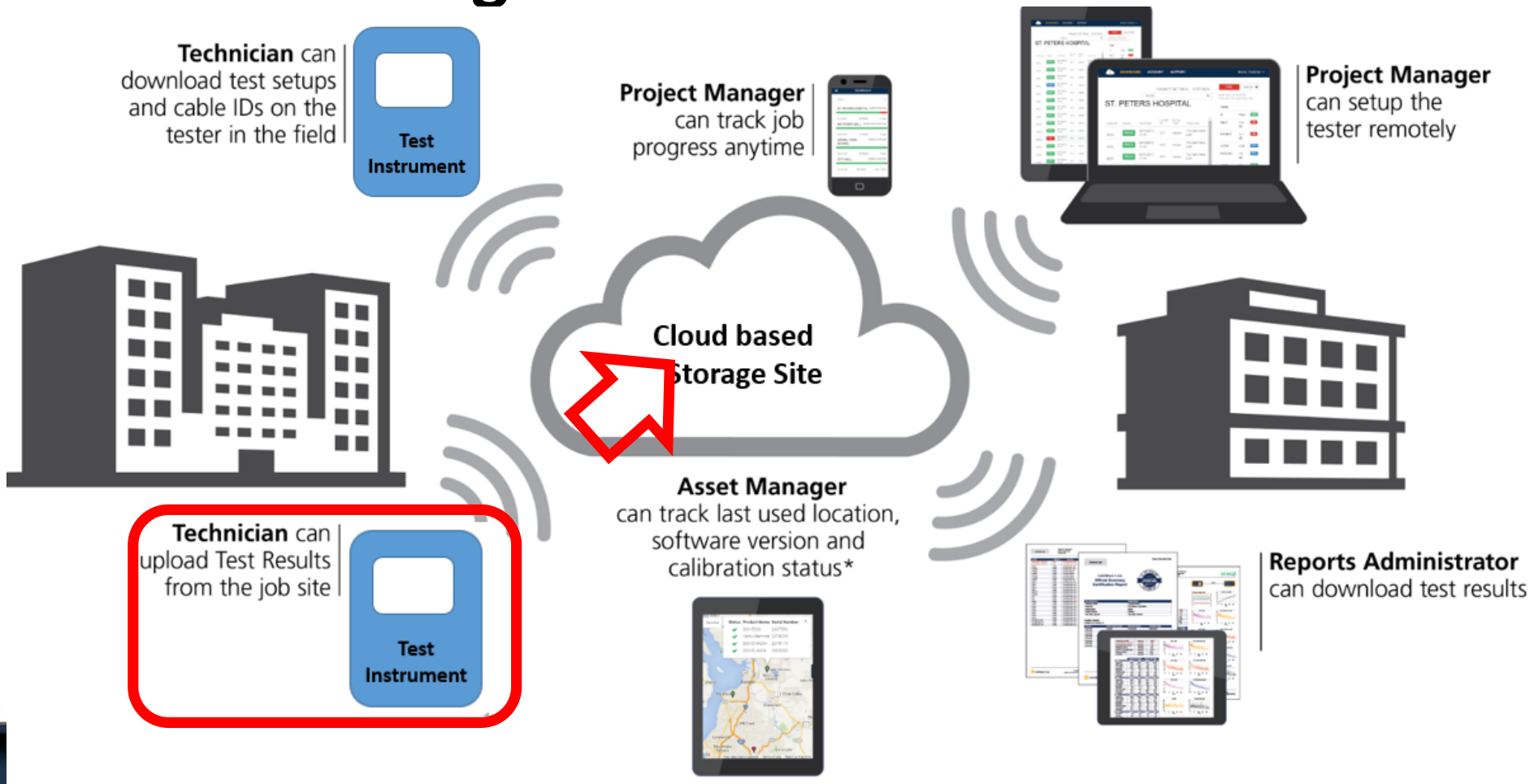


Fiber Loss Measurements:						
Date and Time of test:						
Location:						
Personel:						

Fiber	Identification	Reference Value	Measured Value	Loss	Limit	P/F
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						

Documenting Results



In Conclusion

- PON or POL is a valid alternative to pure copper networks
- Many niche markets are appearing
  - Hospitals
  - Hotels
  - Government
- Follow best practices for loss testing
  - One Jumper reference, accurate loss budget
- OTDRs can be used for Troubleshooting
  - Clean the fibers before you connect them!

Thank you, Gracias, Obrigado

Jim Davis

Fluke Networks

Jim.Davis@flukenetworks.com

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