Field Testing and Troubleshooting of PON LAN Networks per IEC 61280-4-3

Jim Davis
Regional Marketing Engineer
Fluke Networks

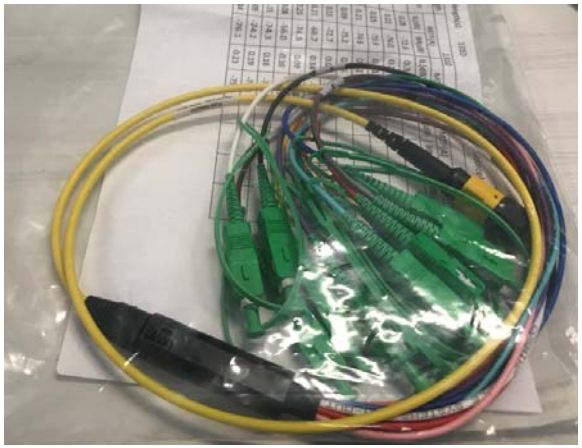
Agenda

- 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)

Inspect, Clean, Repeat

Video Microscope



Brand new out of bag

🙄

Inspect, Clean, Repeat

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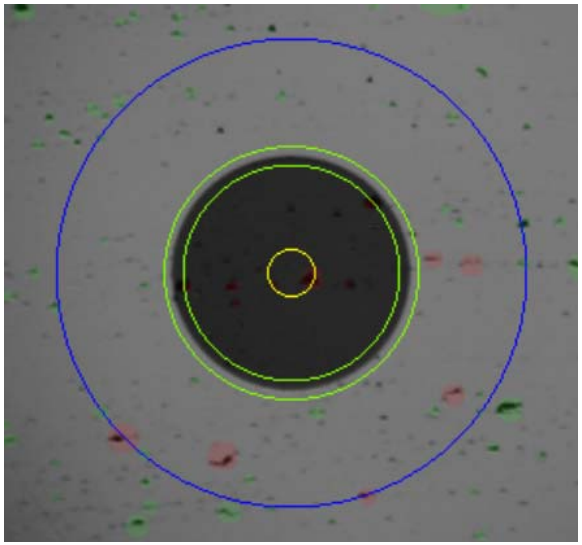

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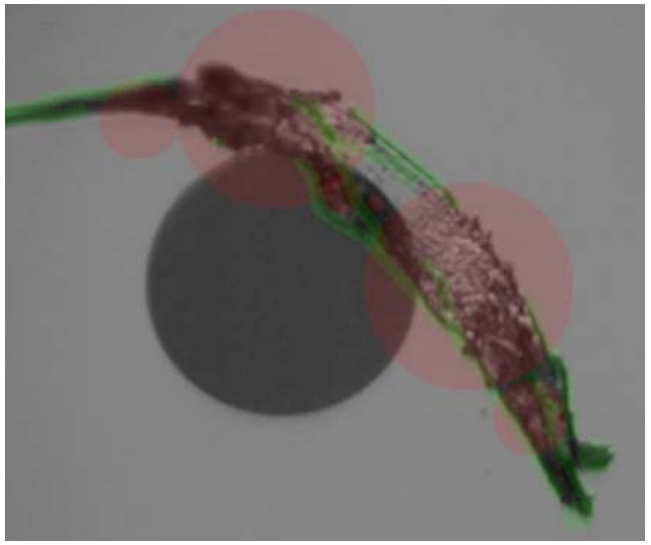
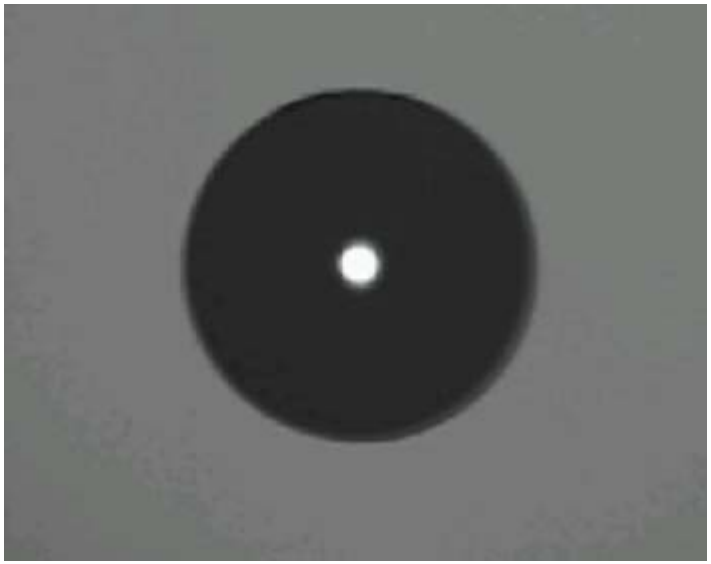


After Cleaning 🙄

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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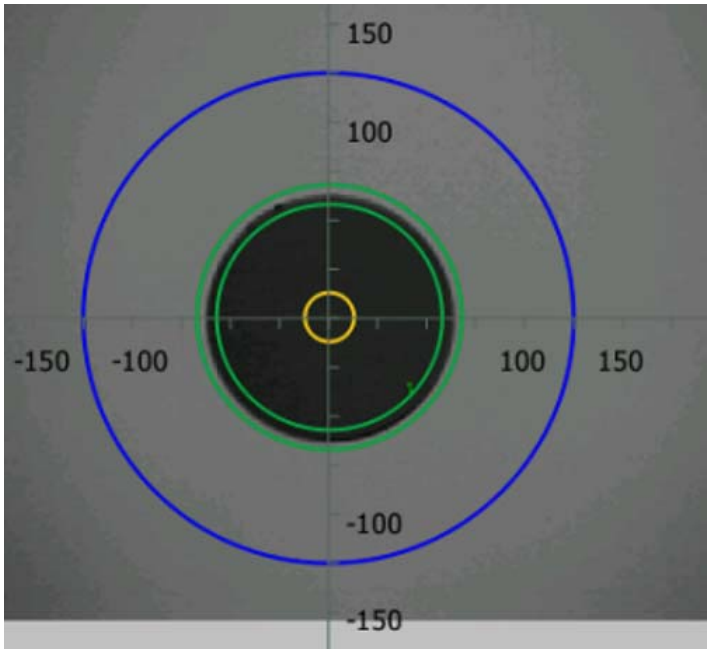


That little angle on the APC minimizes back reflection

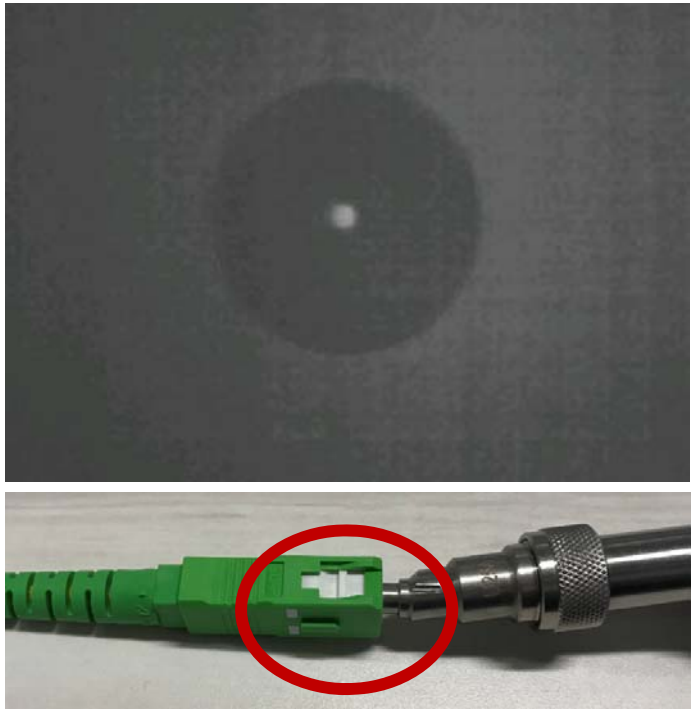
Especially important with high-power transmissions to avoid damage to equipment

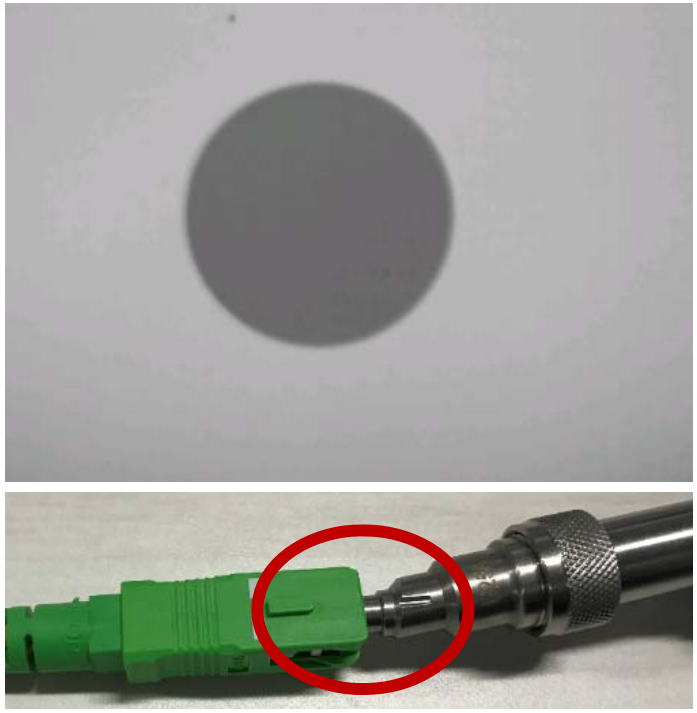
PC/UPC

APC

APC Tips have a slight bend – these are SC

APC Connectors May Need a “Twist” to Show Up





Single-mode MPO connectors also need an adapter

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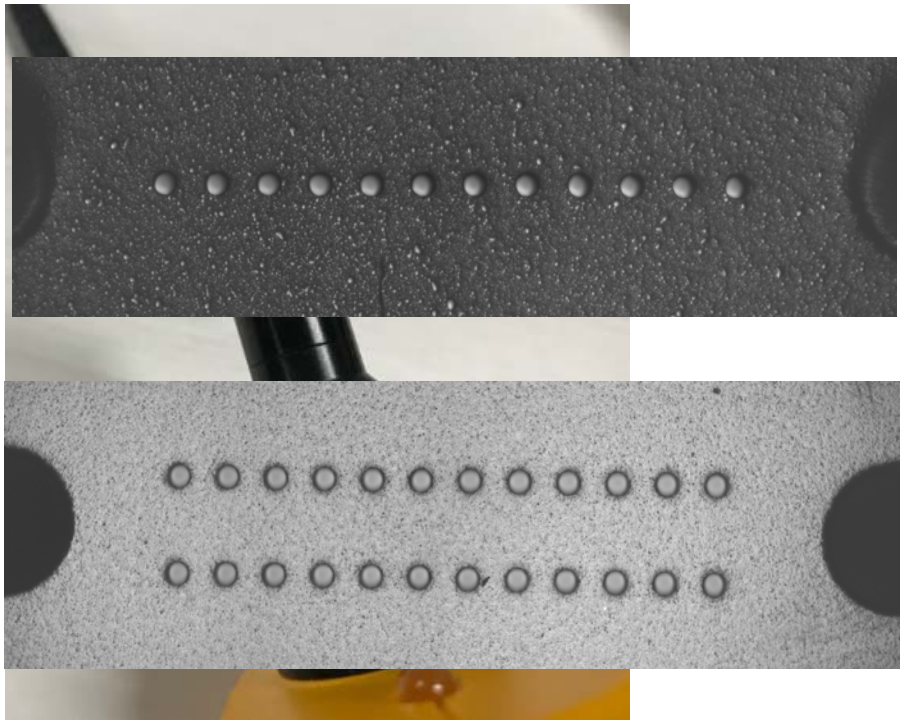

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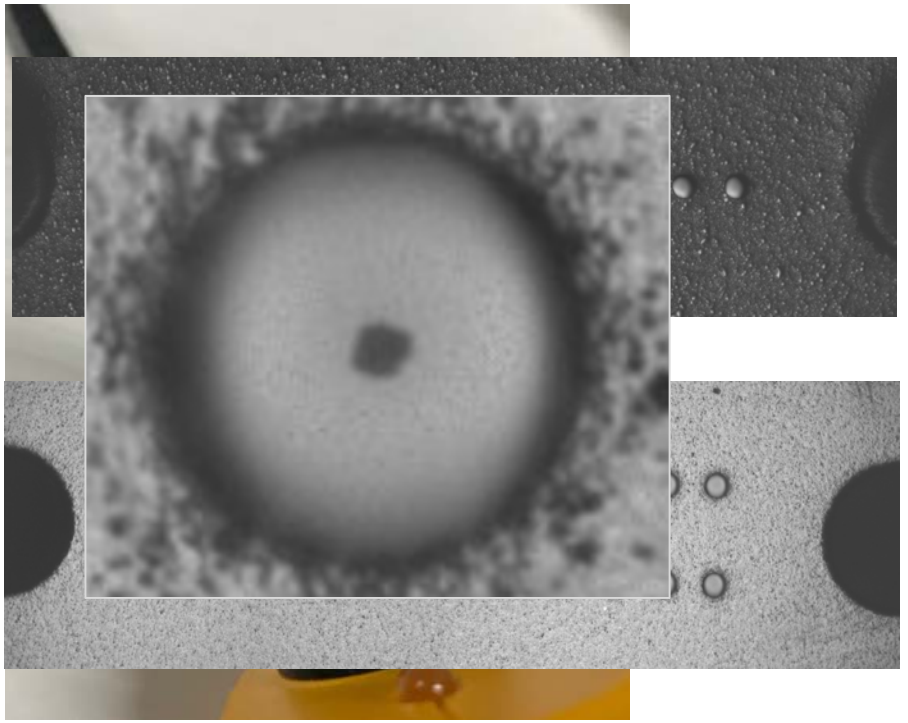
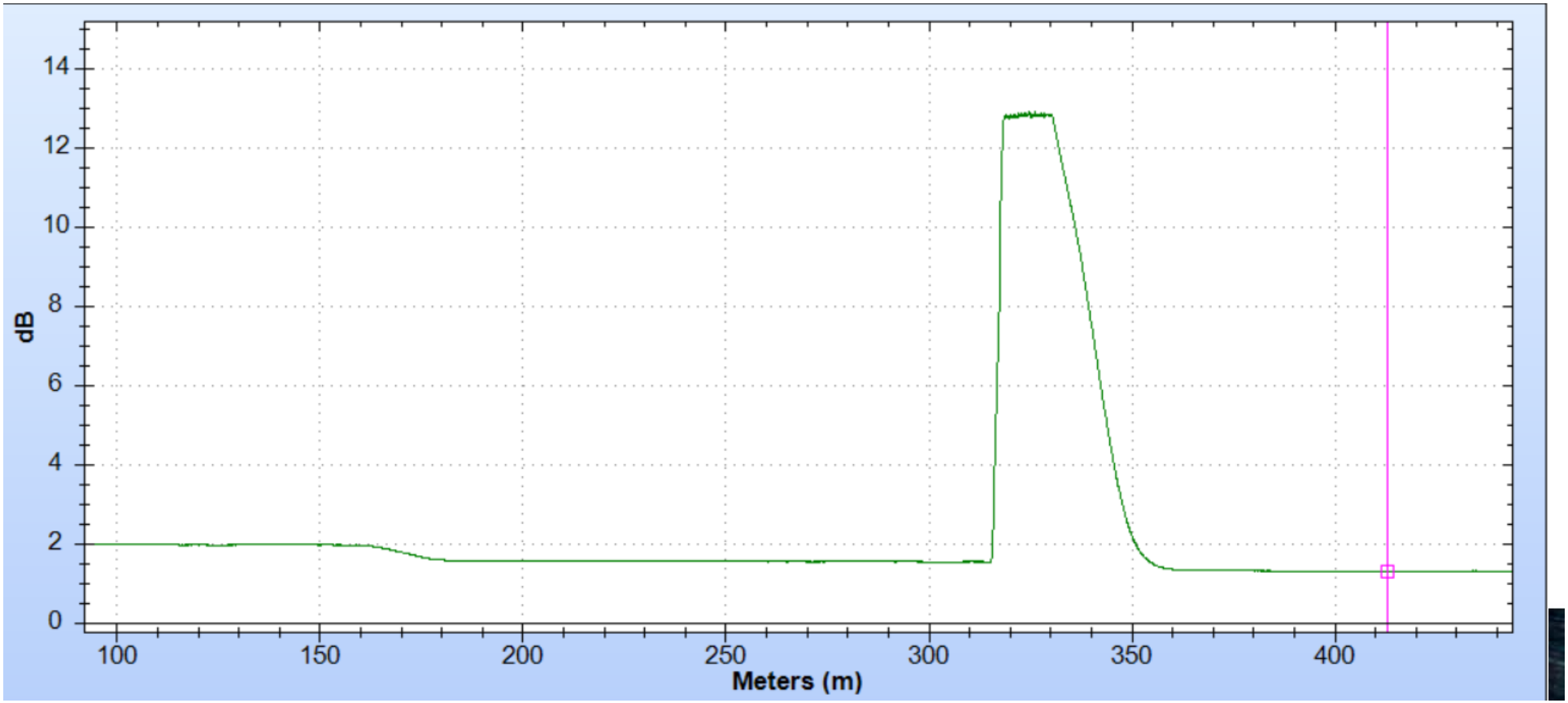
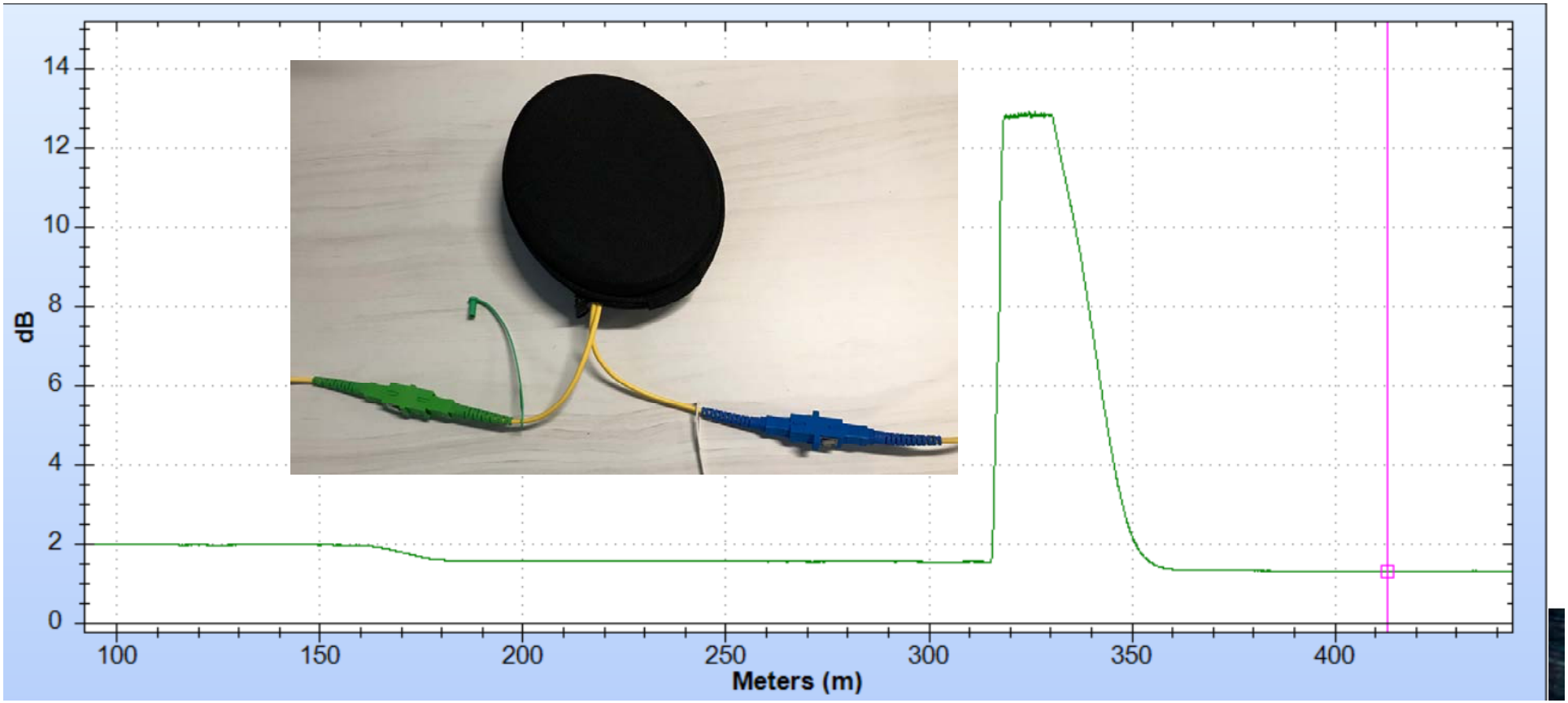


APC Connector vs. UPC Connector



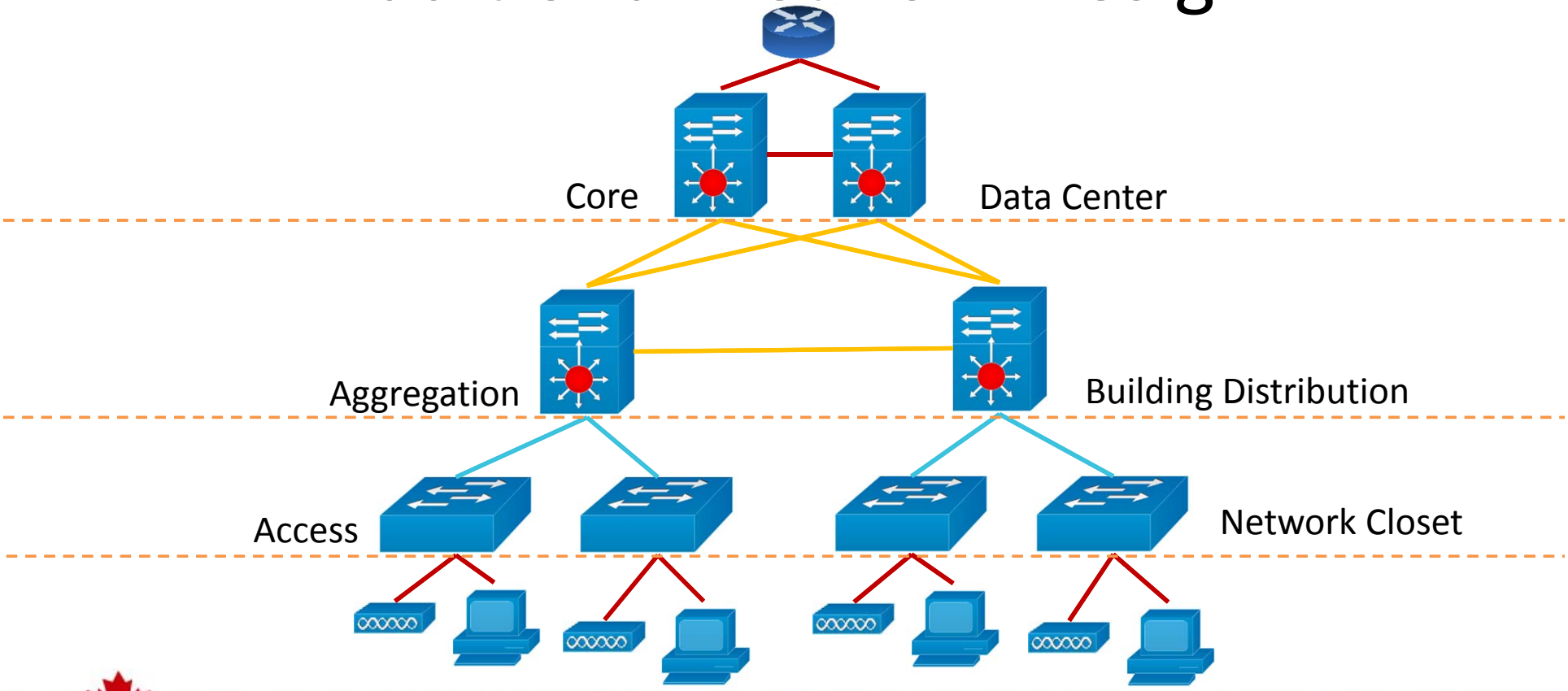
APC Connector vs. UPC Connector



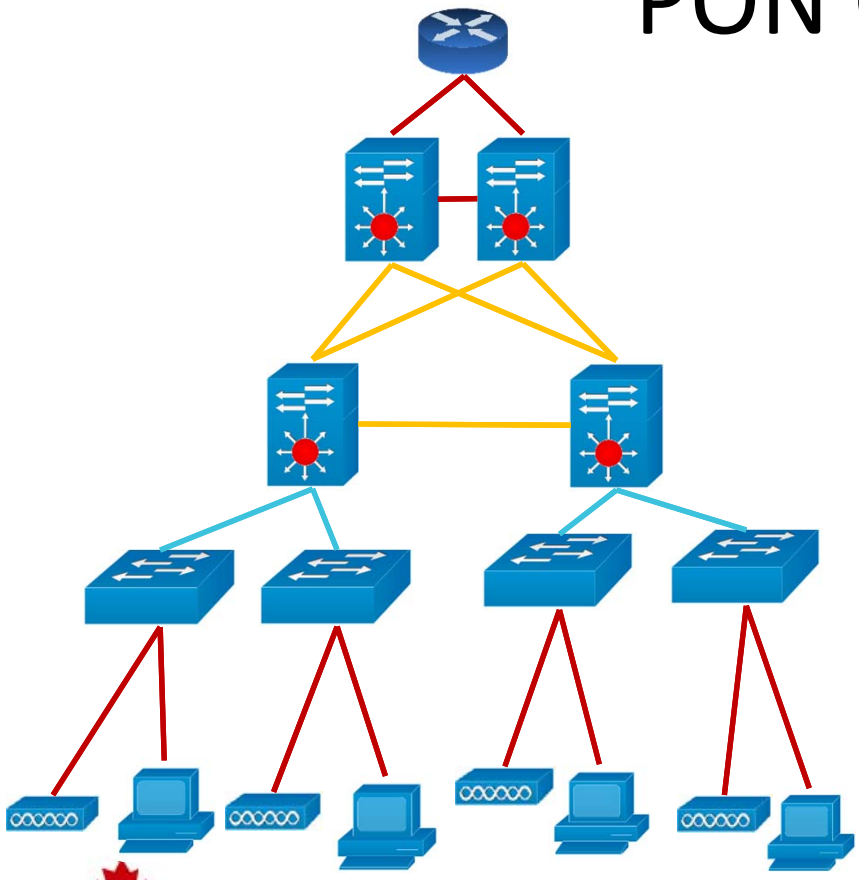
G-PON

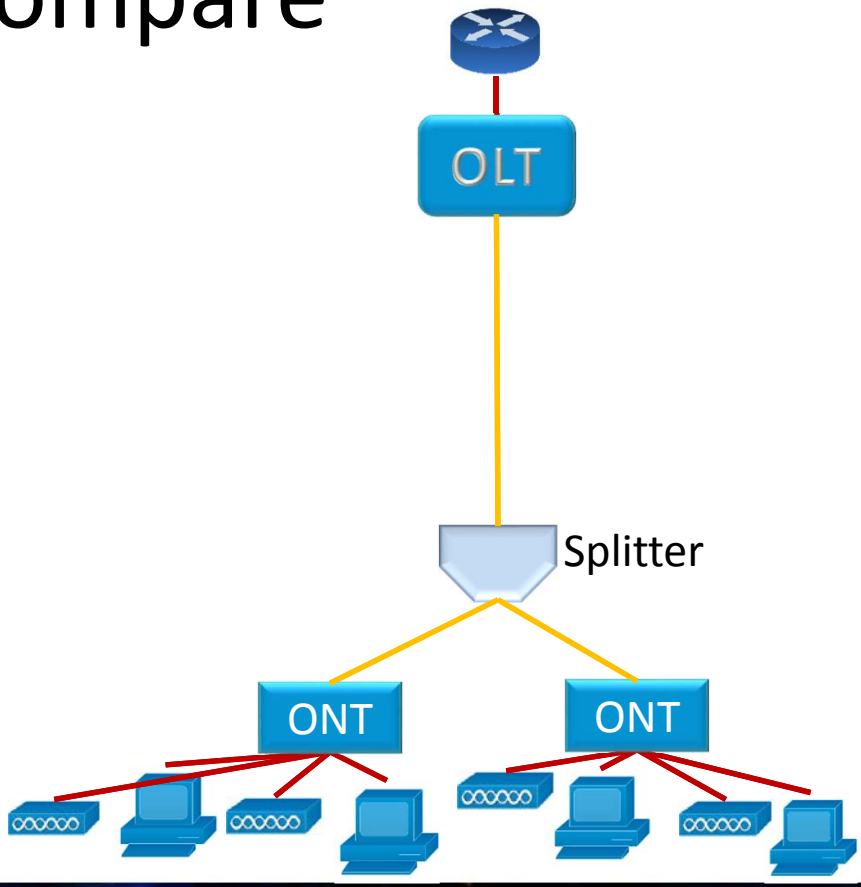
- E-PON and G-PON – most common today with GPON standardized through ITU-recommendation series G.984.1 through G.984.4
- 10G or XG-PON, NG-PON, NG-PON2
- TBD-PON [Super-PON]
- FTTx
- PON-LAN
- We don't care what you put on the road – we want to make sure the road is in good shape to support today's applications
  - Loss Budgets, Distances, Reflectance limits may be tighter with future versions

Traditional Network Design



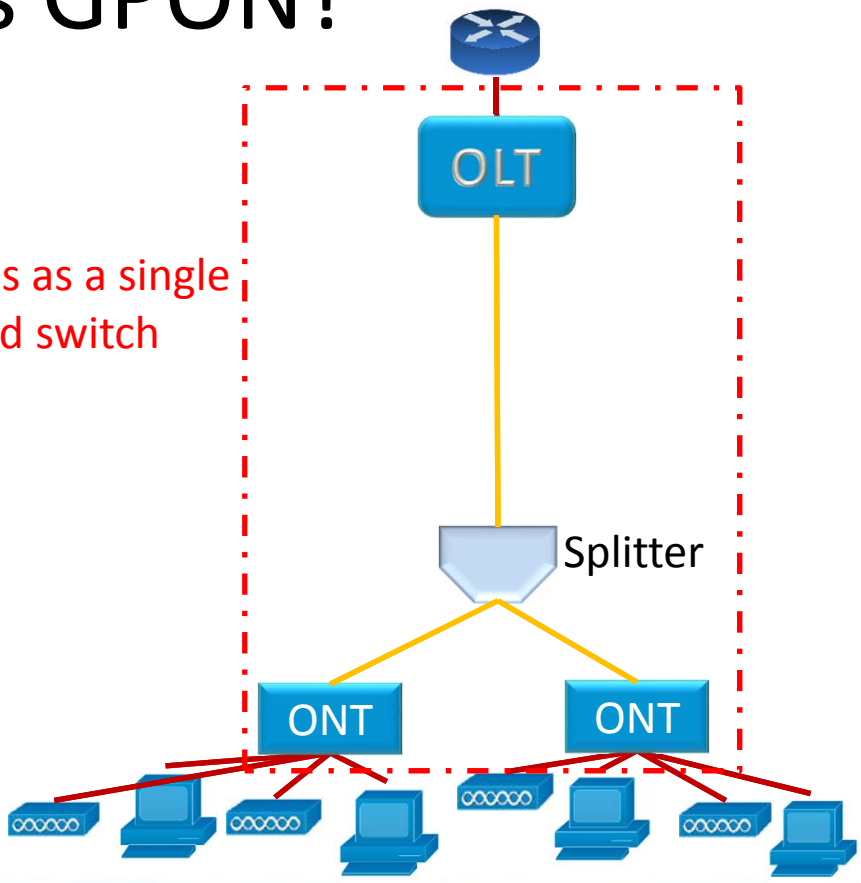
PON Compare



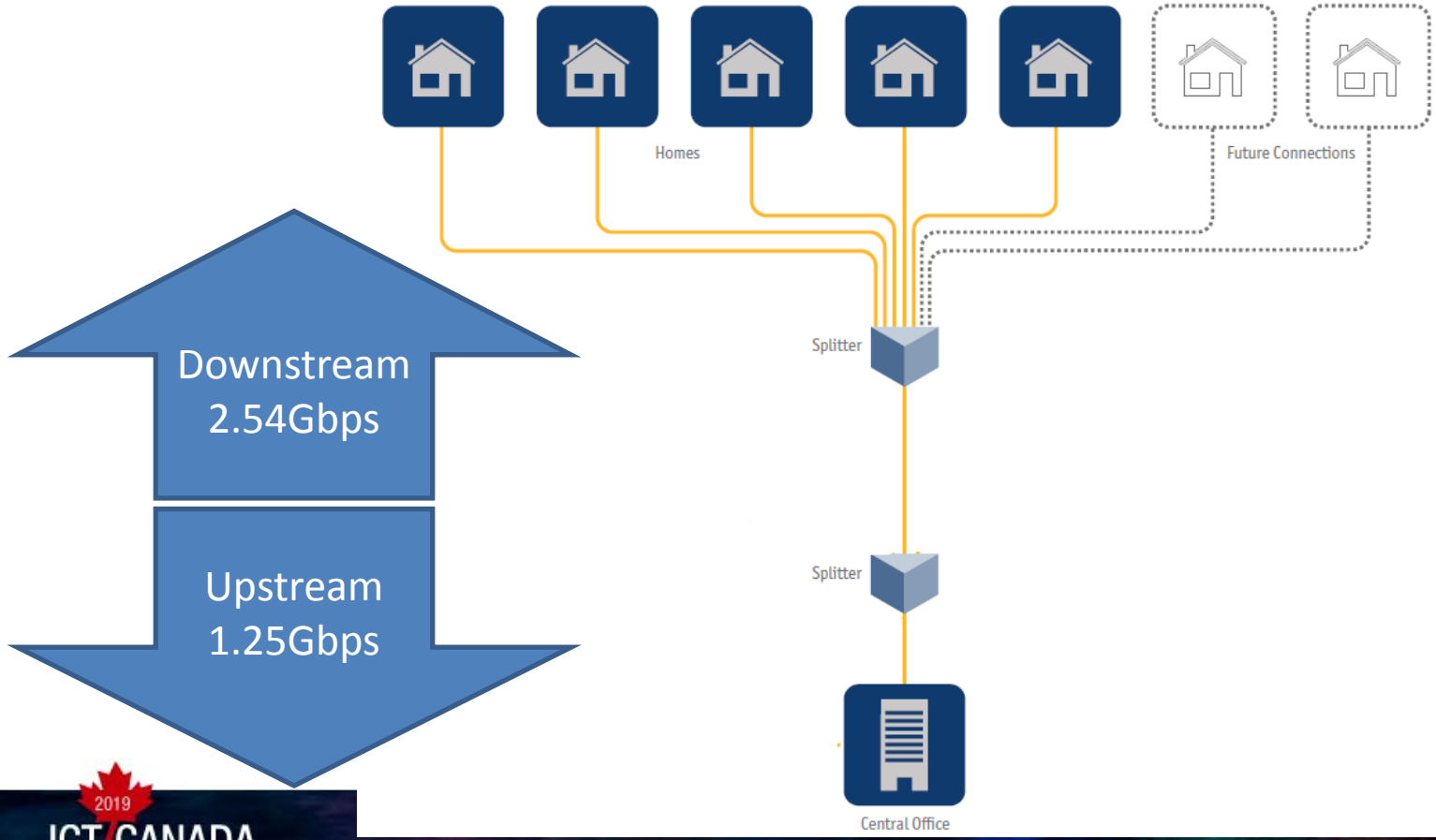


What is GPON?

Operates as a single managed switch



‘basic’ PON architecture



PON LAN Layout

Fiber Concentration Point
(FC/FCP)

Fiber Distribution Terminal (FDT)

Fiber Distribution Hub (FDH)
DataCenter/MDF Single Administration Point

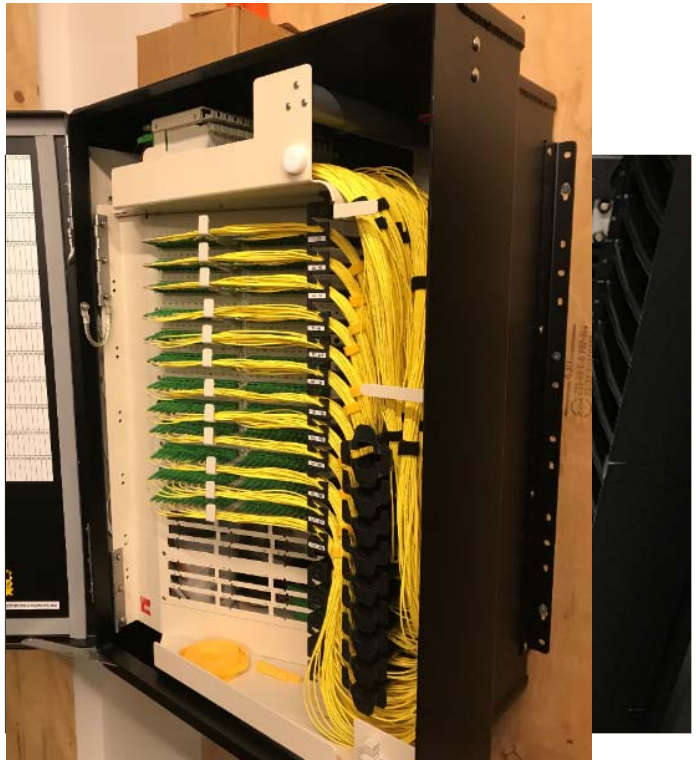
Basic PON LAN Layout

OLT goes here

Basic PON LAN Layout

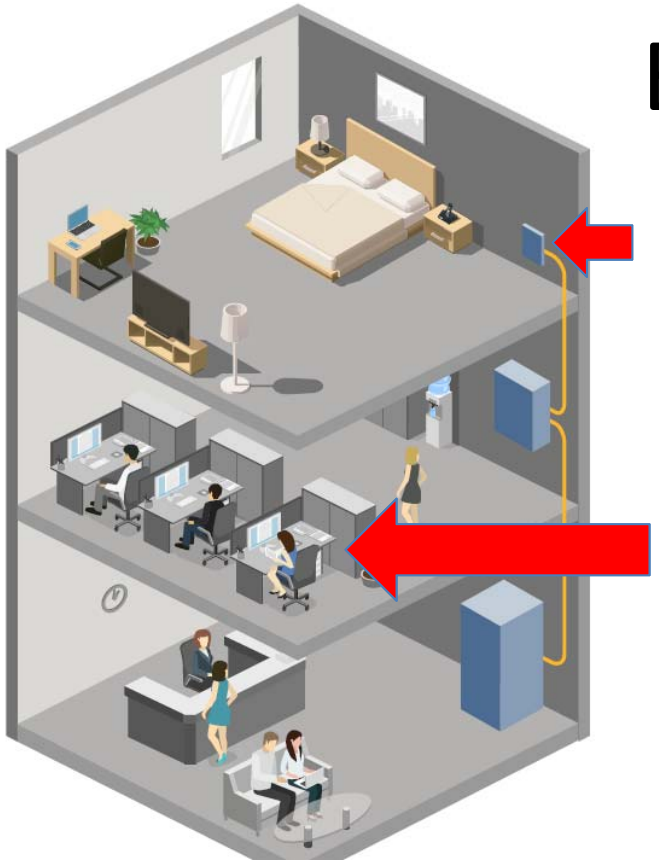
Fiber Distribution Hub

OLT goes here



Basic PON LAN Layout

ONT/ONU goes here



Basic PON LAN Layout

Fiber Concentration Point
(FC/FCP)

Fiber Distribution Terminal (FDT)

Fiber Distribution Hub (FDH)
DataCenter/MDF Single Administration Point

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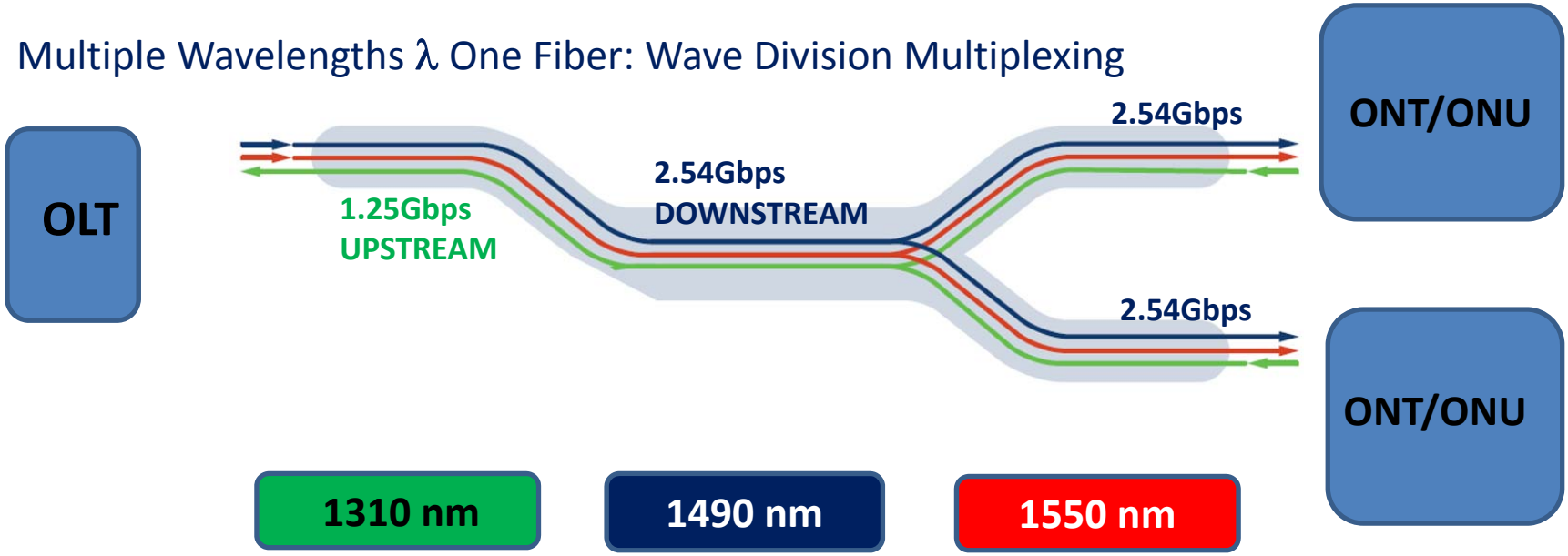
SPLITTERS – PUTTING THE *P*ASSIVE IN *P*ON

VFL Goes in – Light comes out on all ports

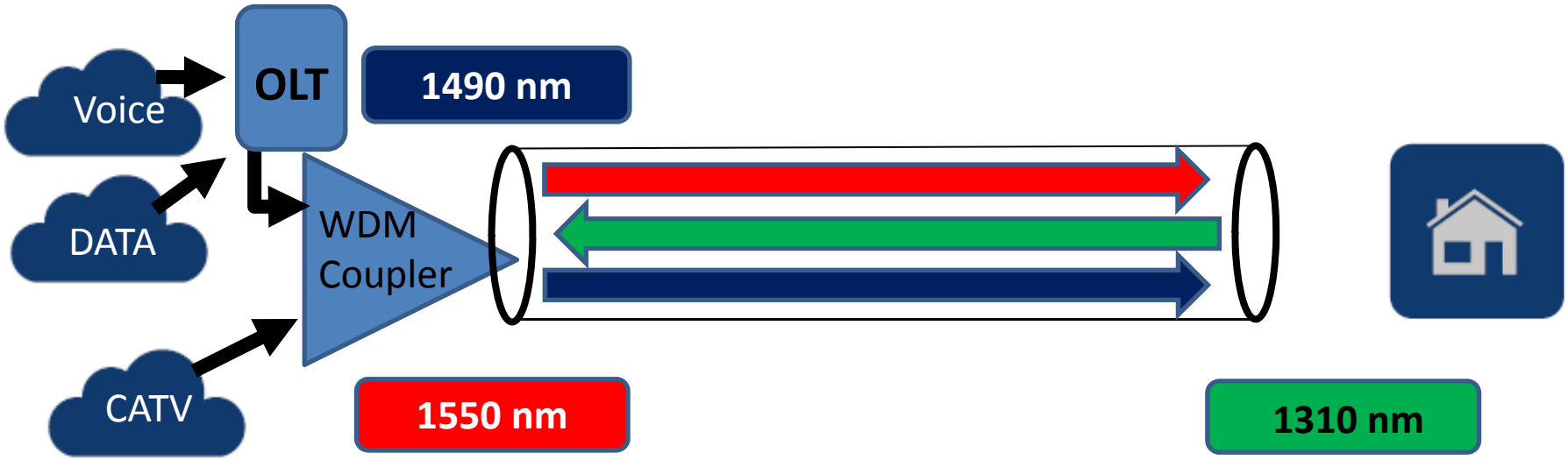
How does the data move?

Multiple Wavelengths λ One Fiber: Wave Division Multiplexing



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

Multiple Wavelengths λ One Fiber



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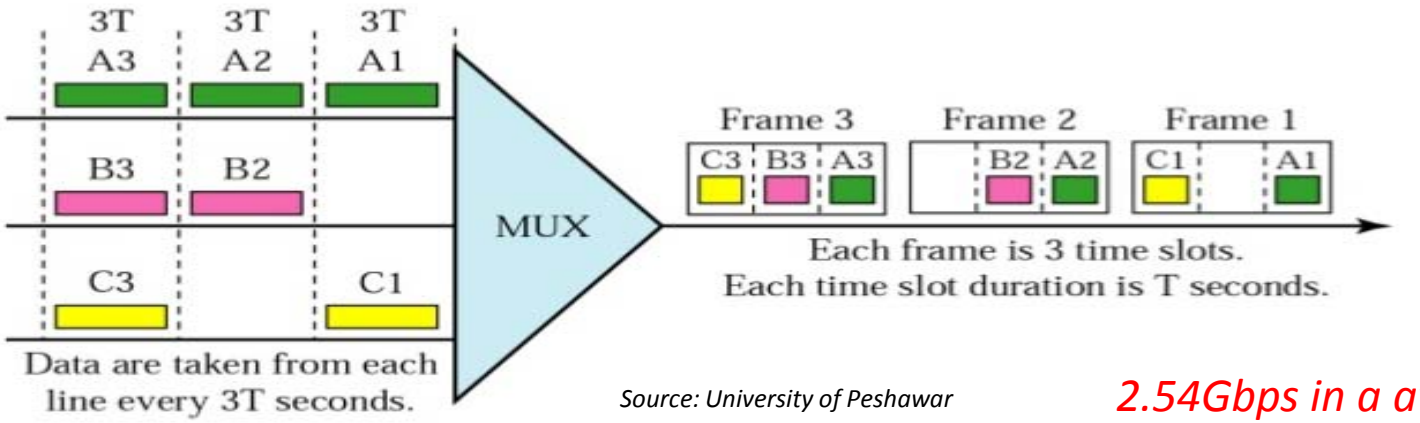
How does the data move upstream?

Time Division Multiplexing: TDM



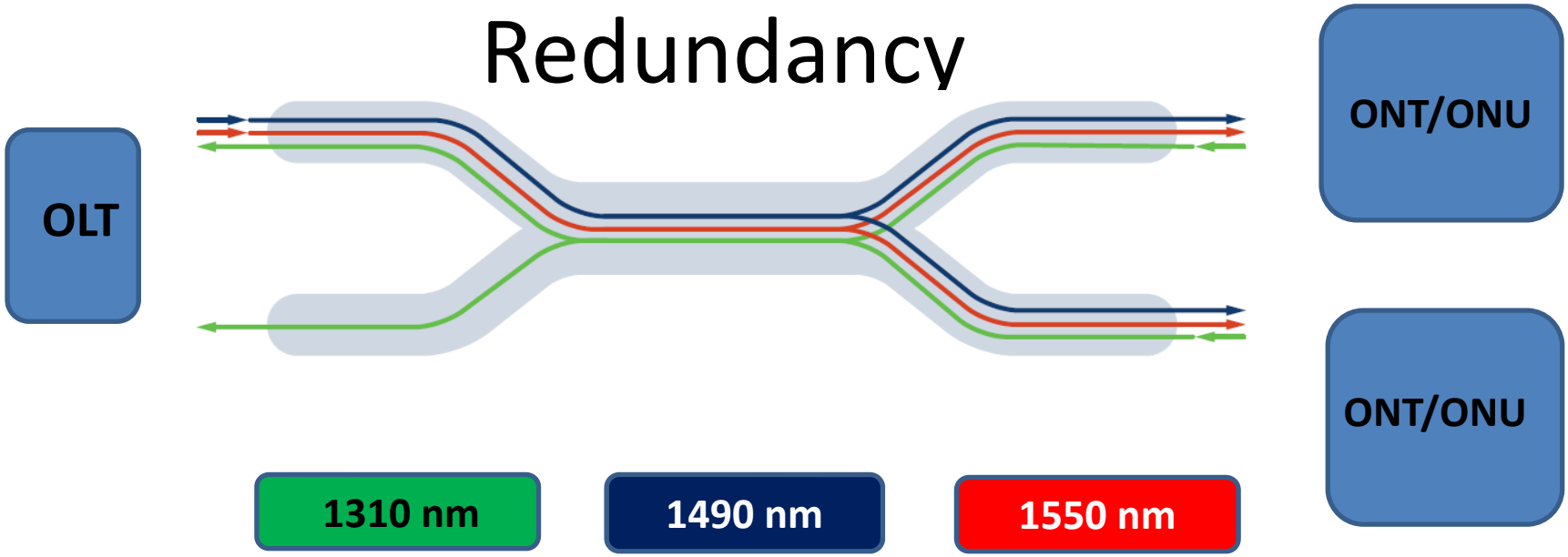
Source: University of Peshawar

2.54Gbps in a available to all ONTs downstream 1.25Gbps upstream, however TDM is employed to deal with traffic

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

Multiple Wavelengths λ One Fiber – Redundancy



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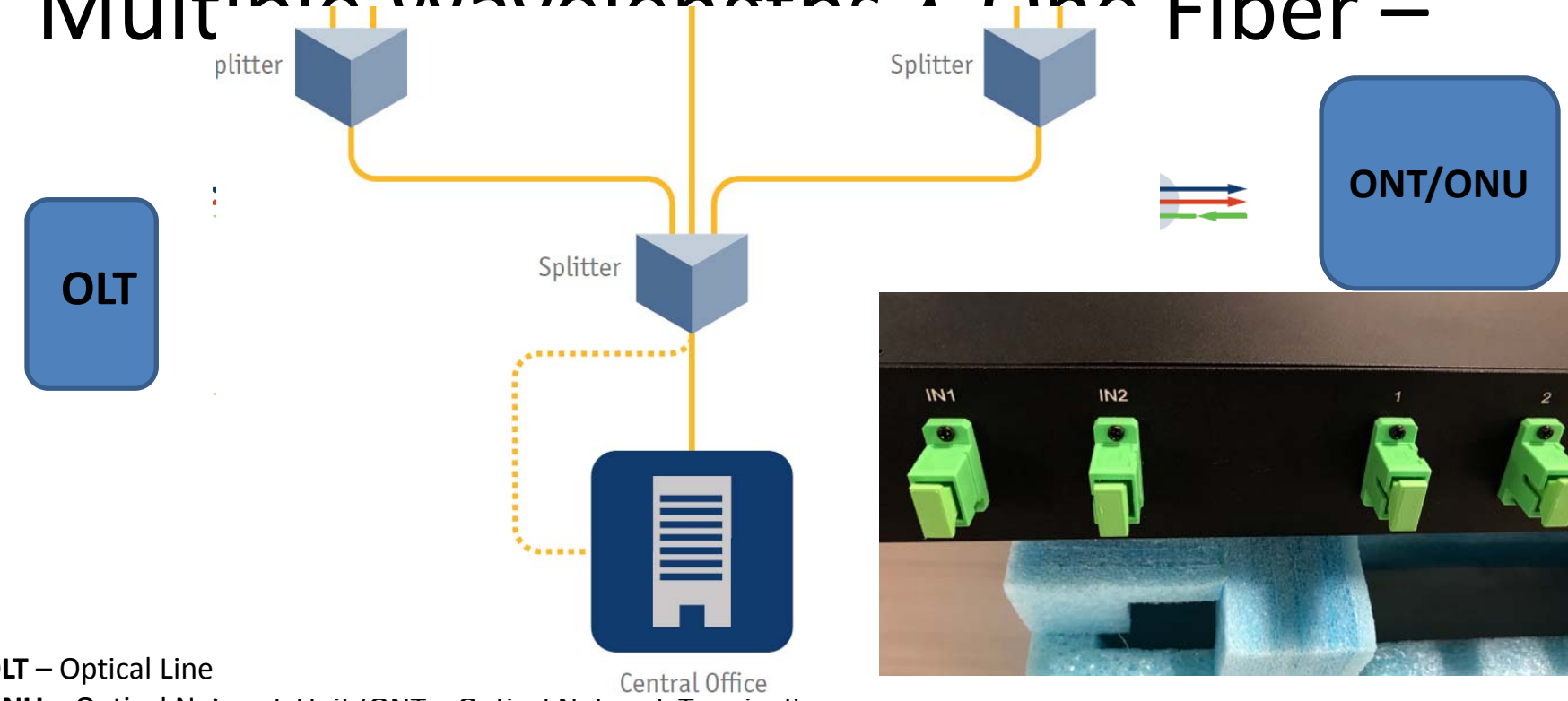
Multiple Wavelengths λ, One Fiber –



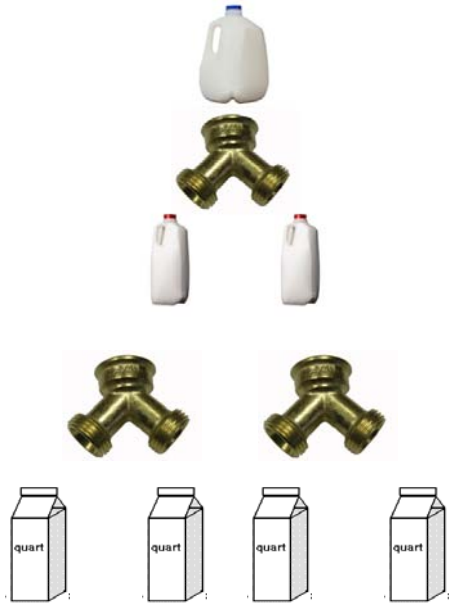
OLT – Optical Line
ONU – Optical Network Unit (ONT – Optical Network Terminal)

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

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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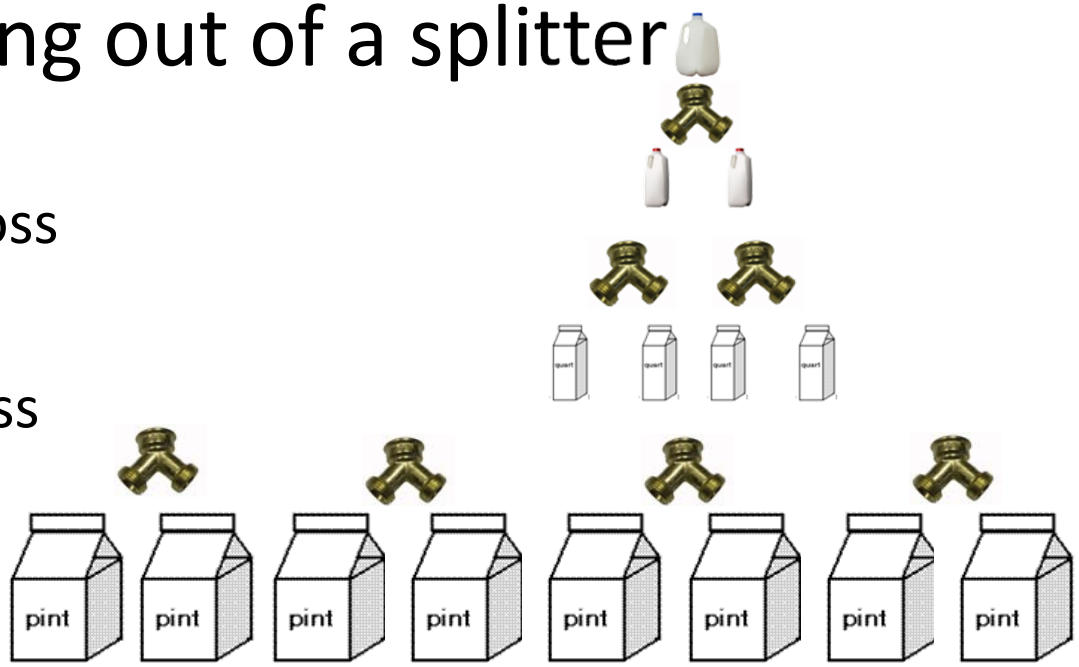
- 1 X 8 = 10.5 dB of loss



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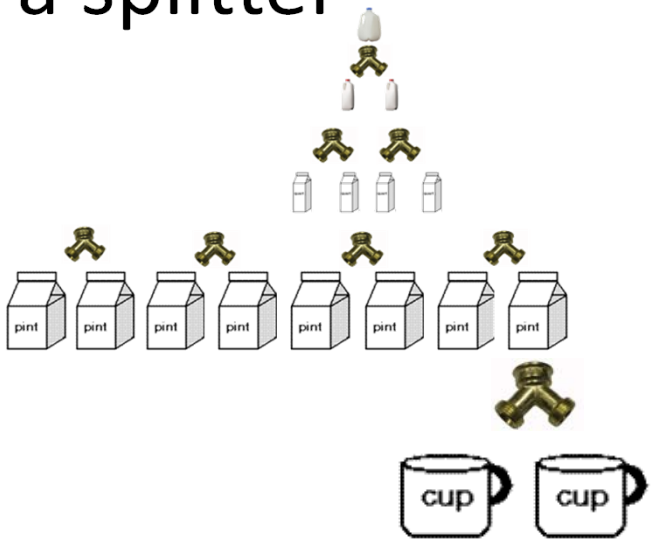
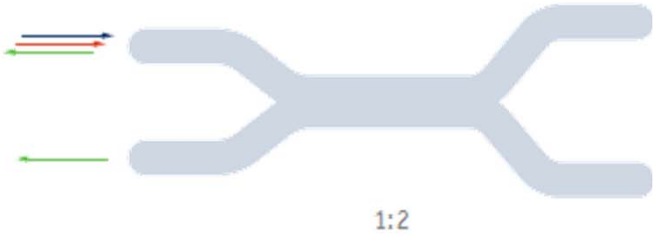
- 1 X 4 = 7 dB of loss
- 1 X 8 = 10.5 dB of loss
- 1 x 16 = 14 dB

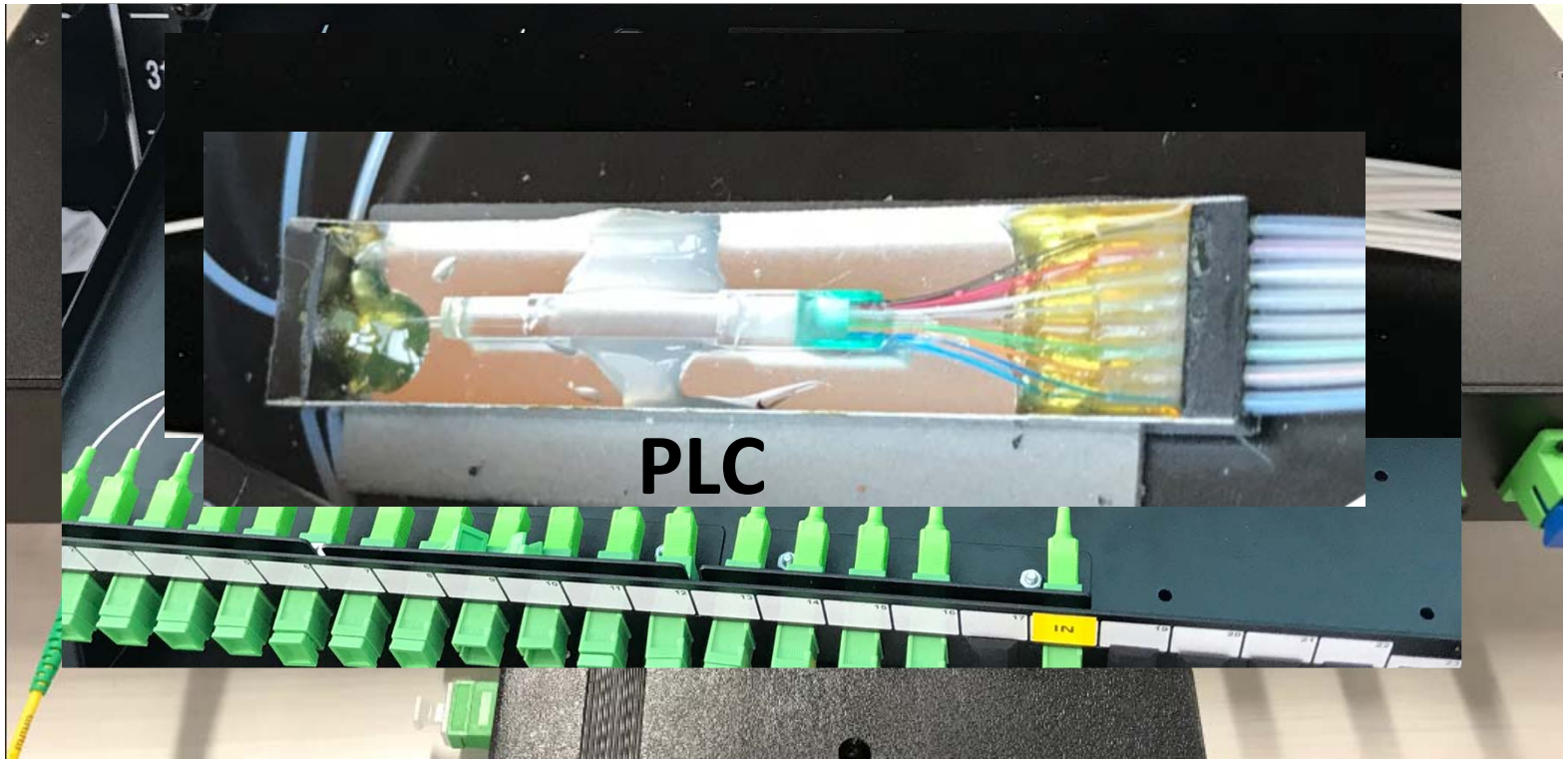


Loss Budget per Split per TIA-568 Annex D



Maximum permitted loss 3.9 dB

Under the Hood



TESTING OF PON NETWORKS

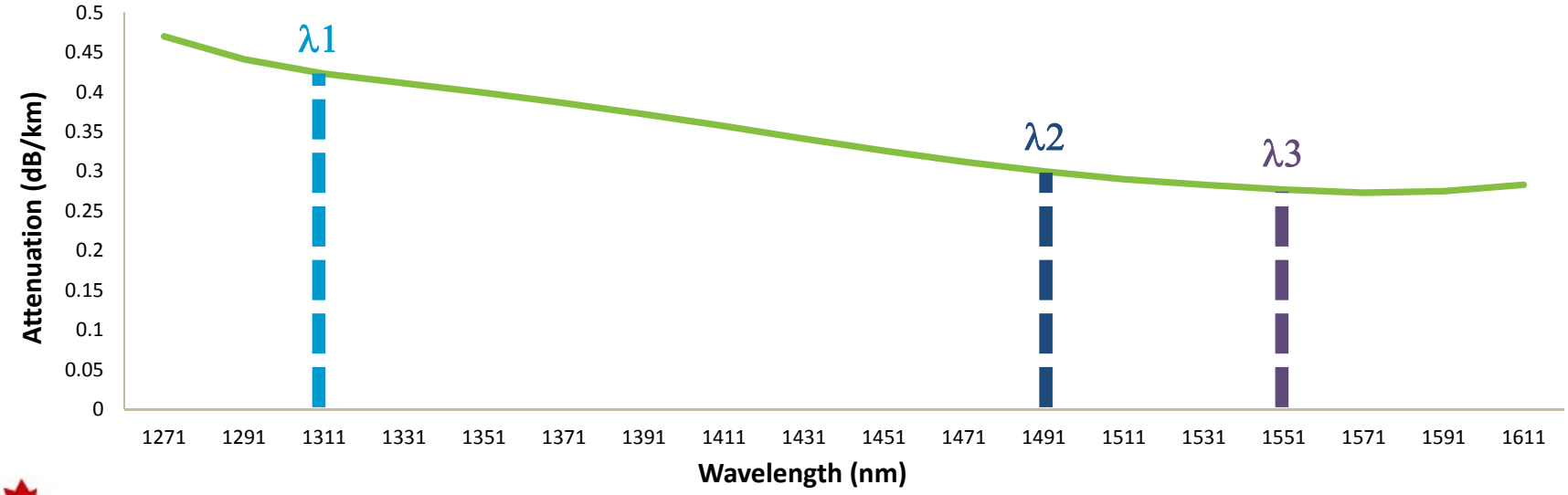
What To Test – Per IEC 61280-4-3

- 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)

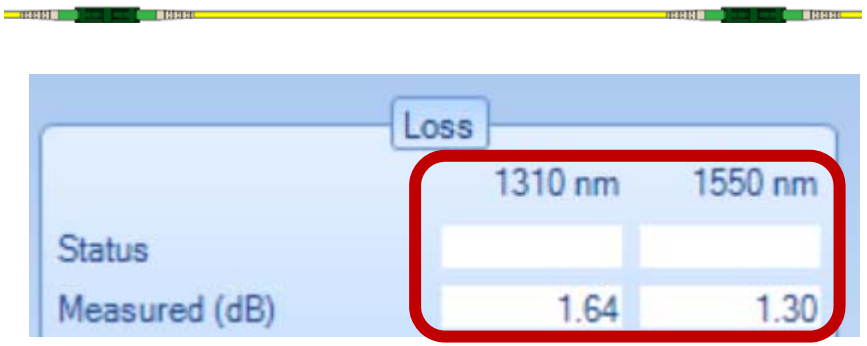
Bend Detection and Future Proofing

Wavelengths are “bound”

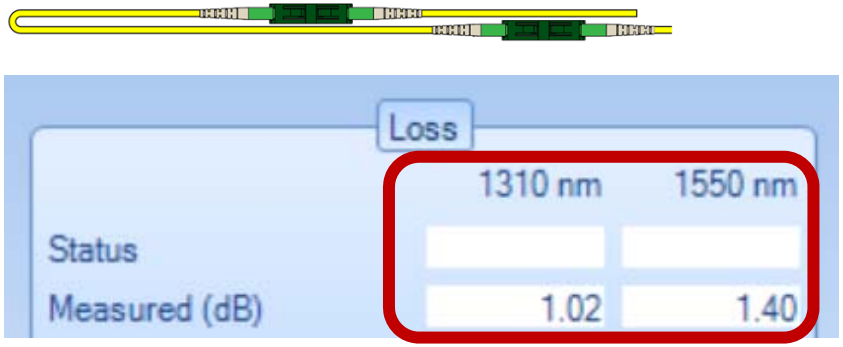
- If 1310 nm and 1550 nm pass, the others wavelengths will pass



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 at Two Wavelengths

Loss	1310 nm	1550 nm
Status		
Measured (dB)	1.64	1.30

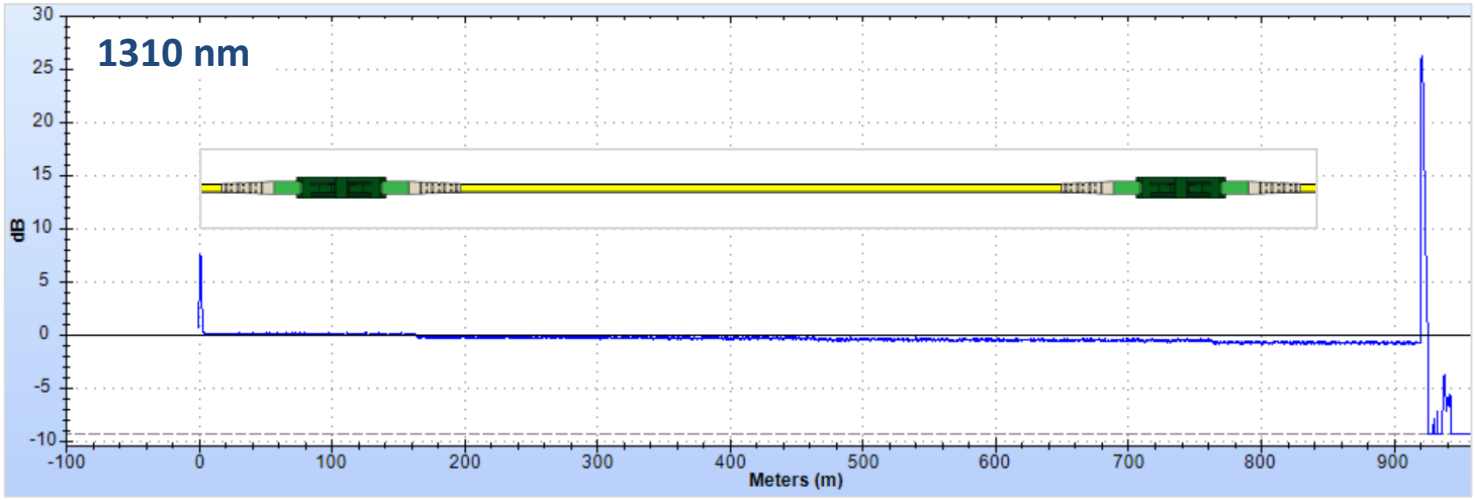
A Single Fiber Link
More Loss at 1310 than 1550

	1550 nm
Status	
Measure	1.40

A Single
More Lo

OTDR Trace Shows Location of Bend

- But not at 1310 nm



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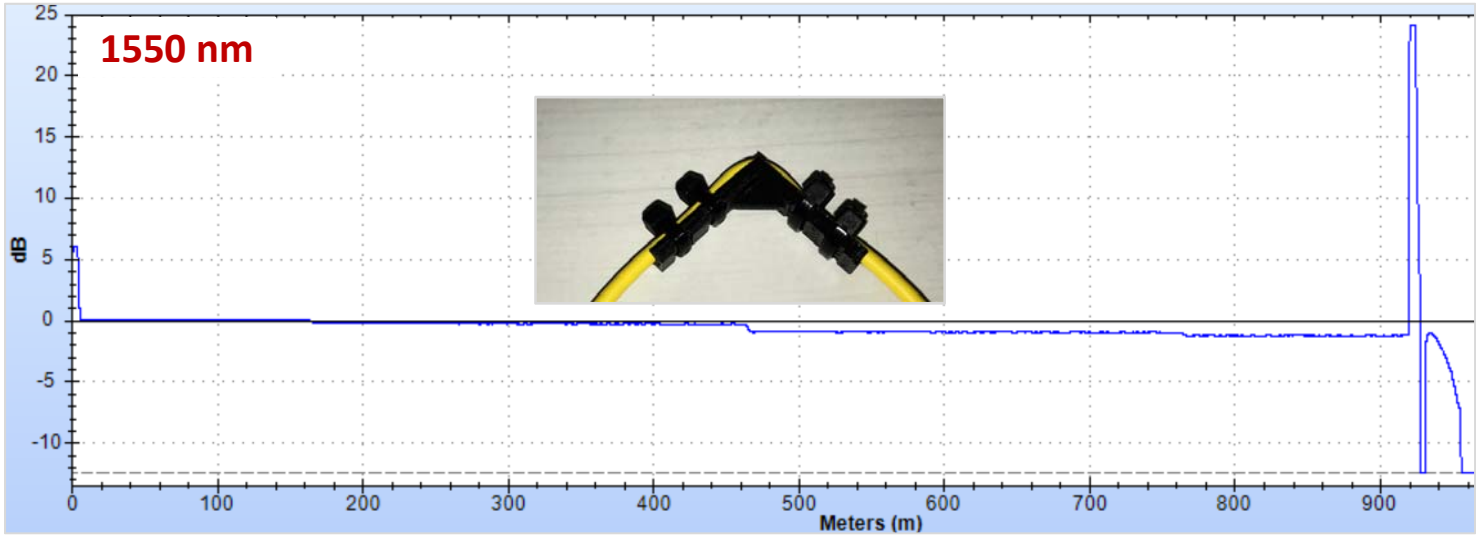
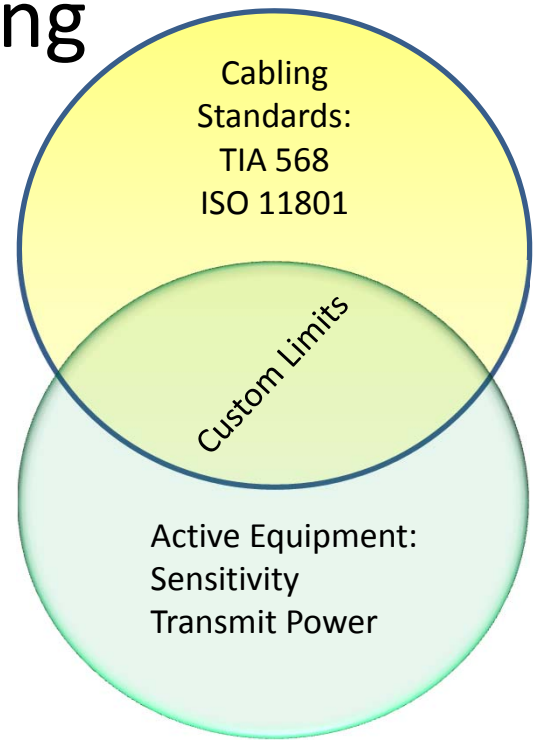


LOSS BUDGET CALCULATION

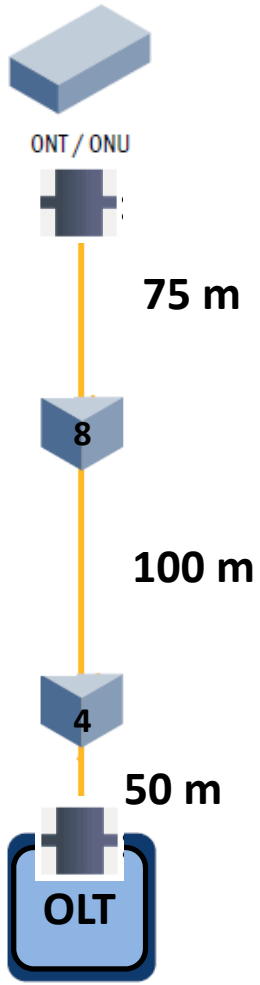
What loss budget to use when testing

- 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



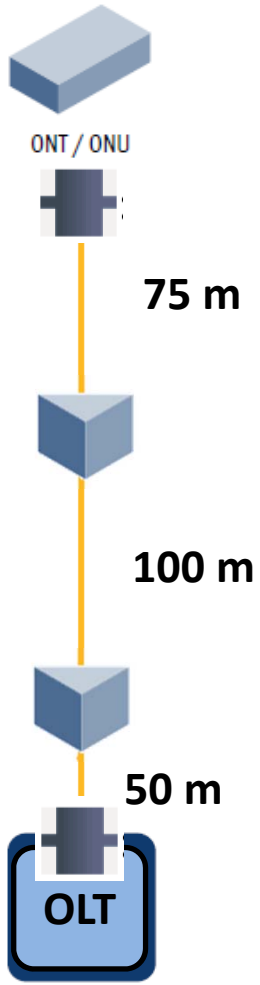
Loss Budget Calculation

Connectors * 0.5 dB



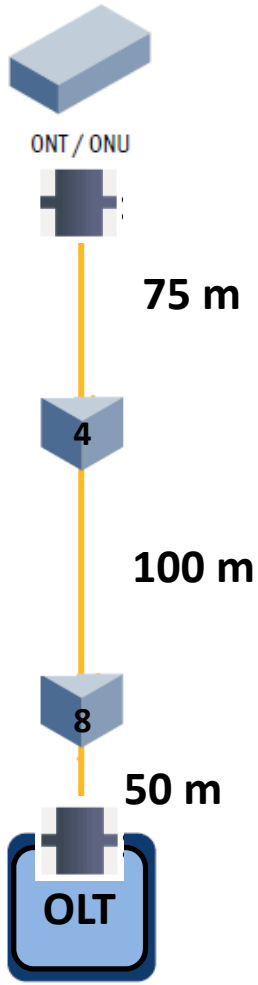
Loss Budget Calculati

Connectors * 0.5 dB
2 * 0.5 = **1.0 dB**
Splitters * budget



Loss Budget Calculati

Connectors * 0.5 dB
2 * 0.5 = **1.0 dB**
Splitters * budget
1 X 4 Port = **7.3 dB**
1 X 8 Port = **10.7 dB**
KM of Fiber * 1 dB/Km (Tight buffered indoor)
50 m + 100 m + 75 m = **.225 dB**



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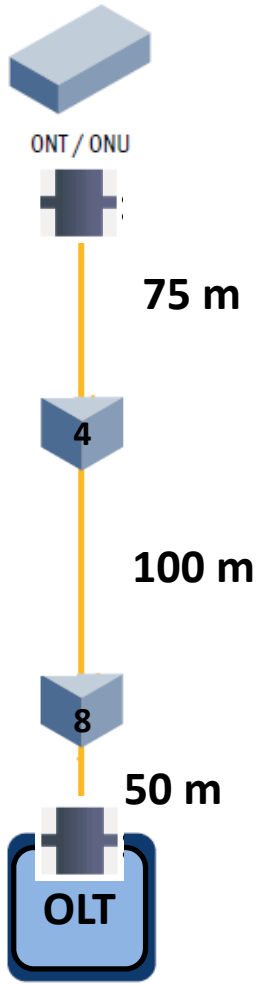
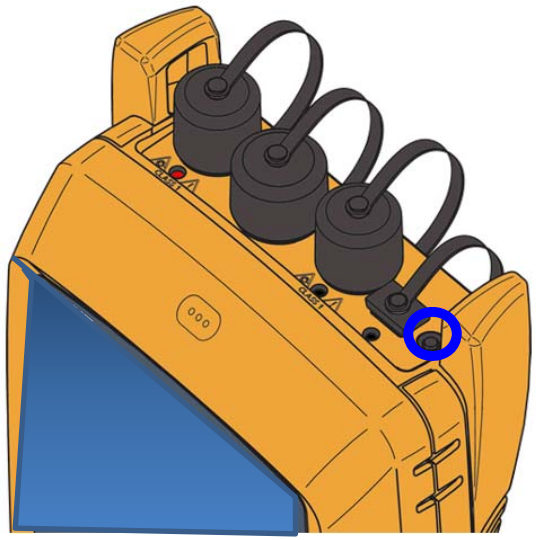
KM of Fiber * 1 dB/Km (Tight buffered indoor)
50 m + 100 m + 75 m = **.225 dB**
Total Loss Budget = 19.2 dB

Check with your supplier for their specific performance



Loss testing with minimal uncertainty and maximum repeatability

Accurate Loss Testing will assure support for today's and future network applications

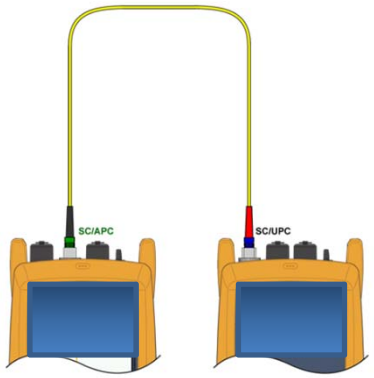


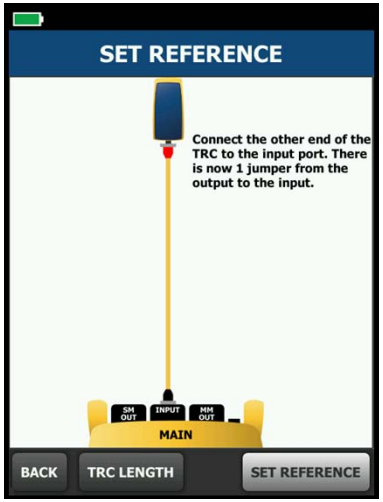
- A One Jumper reference is called out in the standard
- A Simple Light Source and Power Meter can be used, or you can use common **OLTS** units, provided they can be put into a "**Far End Source Mode**"

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

Single fiber testing – setting a reference

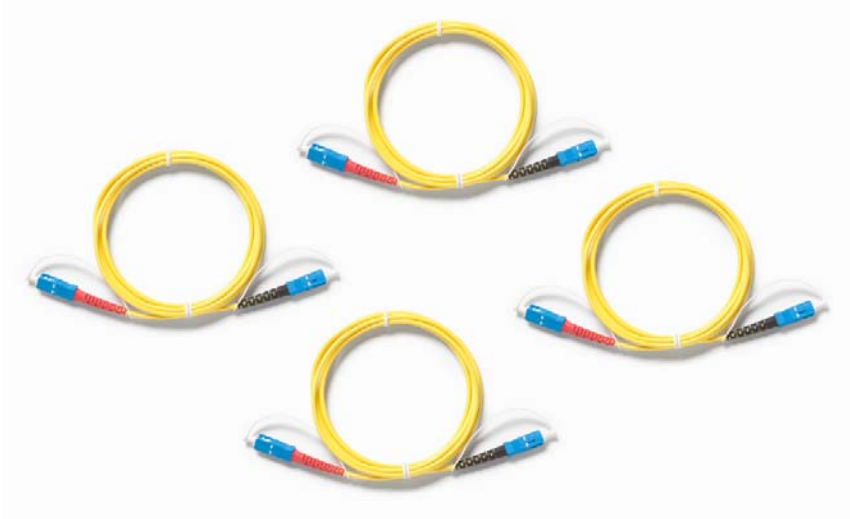
- Connect the Power Meter (main) and Light Source (remote) units together
  - **One Jumper Reference**
  - **Must have input port that is the same as the connector to be tested**





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



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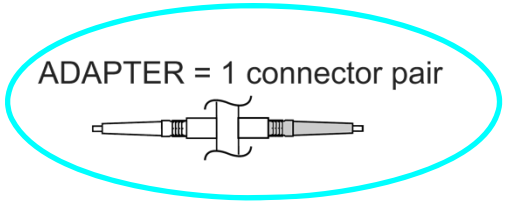
Reference Grade Connectors

- In ISO/IEC 14763-3 (2006), cords were recognized as a **source of great uncertainty**
- This standard reduced uncertainty by defining the performance of the test cord connector
- Reference grade connectors were required
  - Multimode ≤ 0.10 dB
  - Singlemode ≤ 0.20 dB
- ISO/IEC 14763-3 (current) was updated to use new mated loss values for reference grade connectors

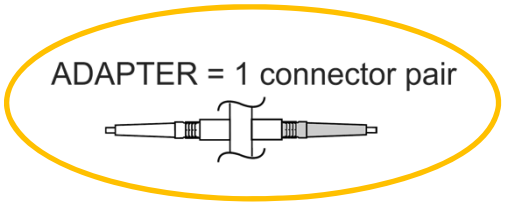
Multimode



0.10 dB **0.75 dB**

≤ 0.30 dB

Single-Mode

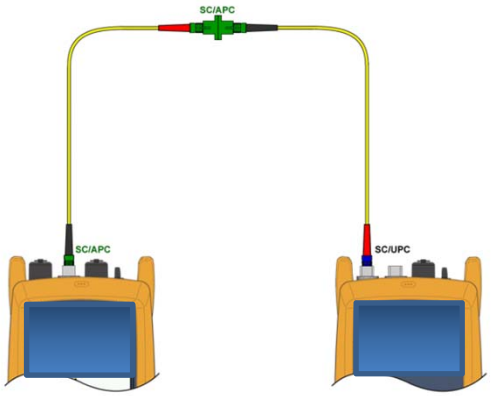


0.20 dB **0.75 dB**

≤ 0.50 dB

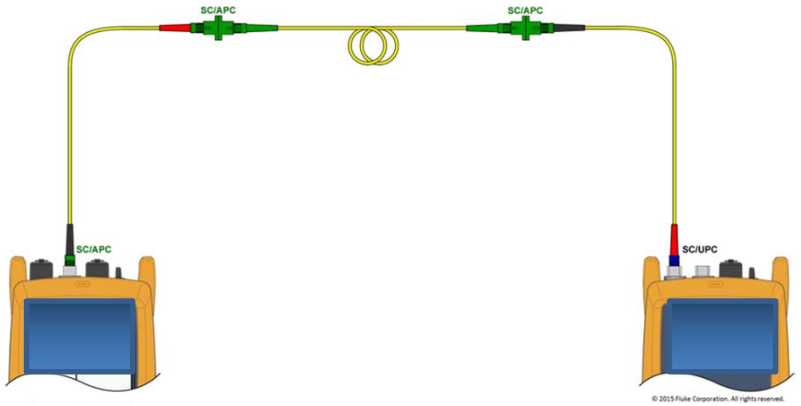
Single fiber testing – setting a reference

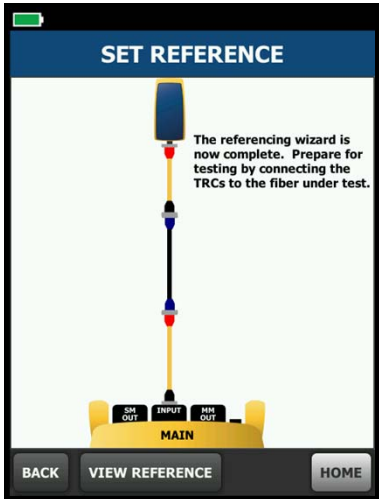
- After the reference is set, verify the condition of the other Test Reference cord
- Loss for this test, with reference grade connectors should be **>0.25 dB**
- Save this in your test results!



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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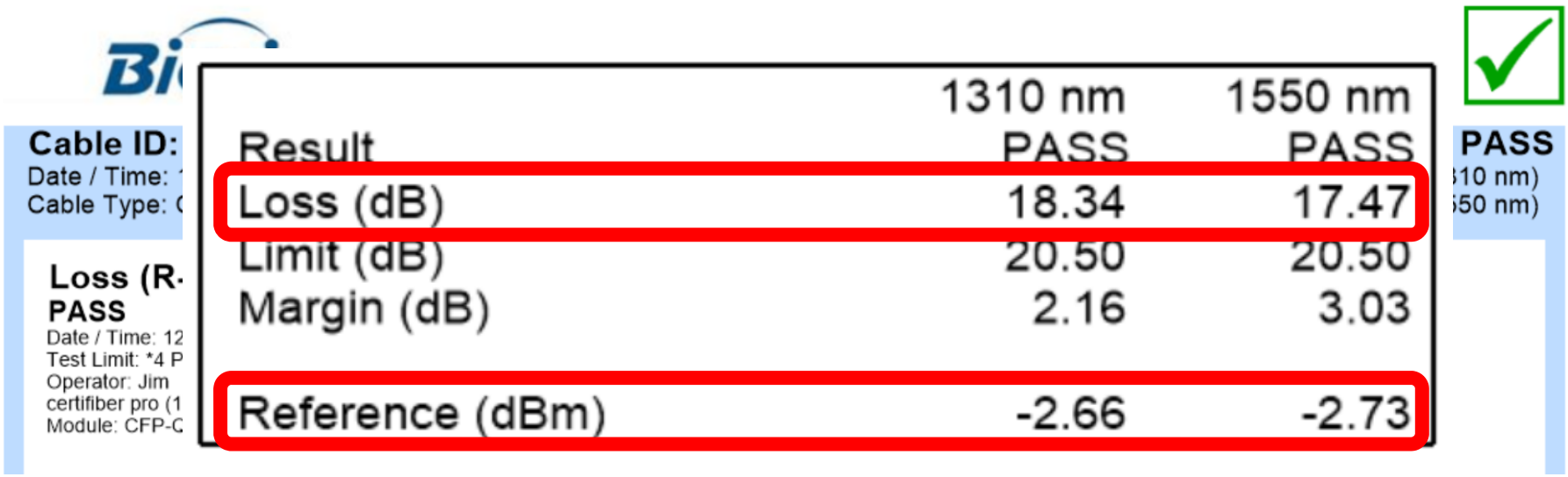

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Alternate Loss Budget Calculation

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

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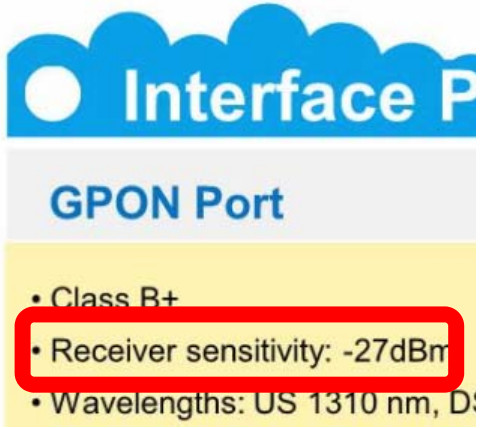


Cisco ME 4600 Series ONT Standards, Protocols, and Compliance

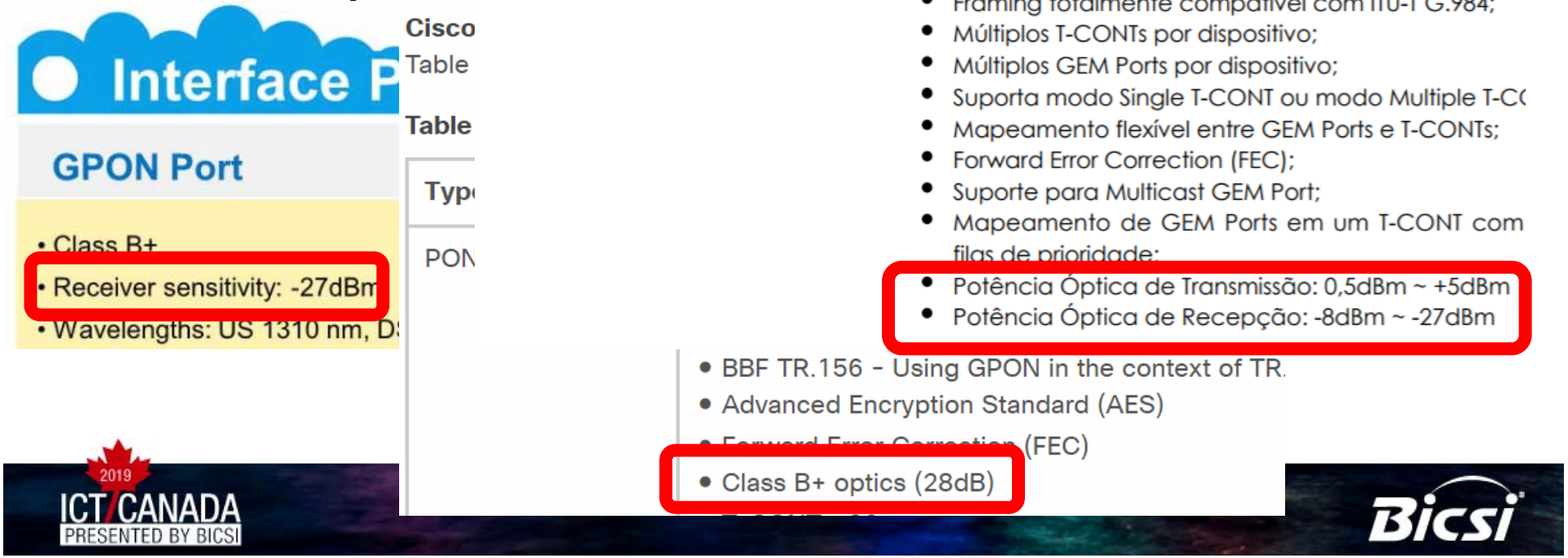
Table 5 lists the standards and protocols that apply to the Cisco ME 4600

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 Mo
- Often, the



Alternate Loss Budget Calculation

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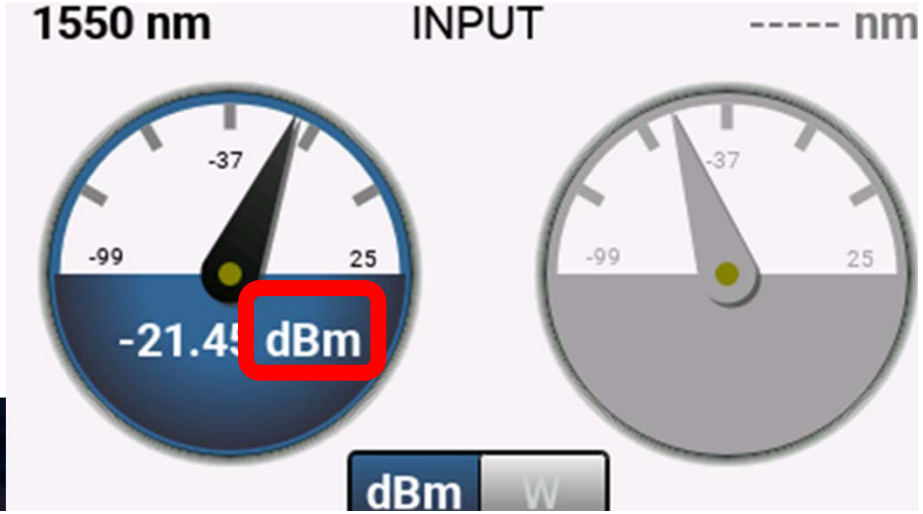

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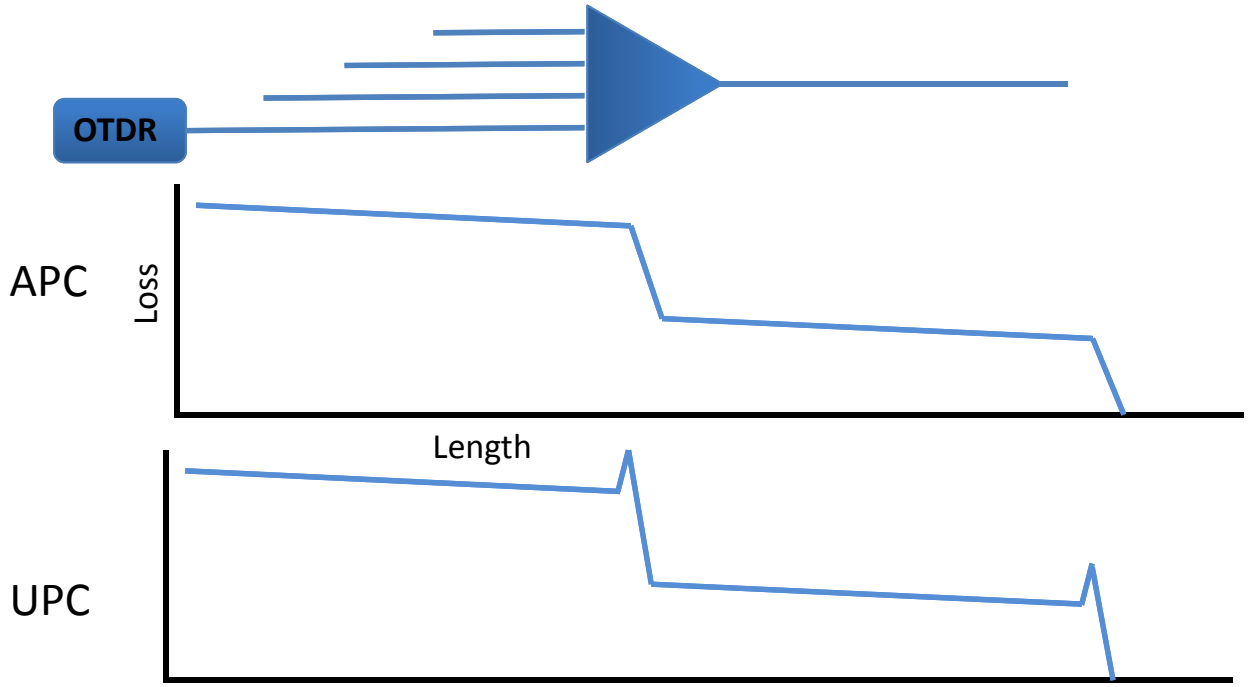
  - - 27 dBm is greater than -28 dBm
  - -29 dBm is less than -28 dBm
- Loss is measured in dB
  - And should be a positive number

OTDR testing

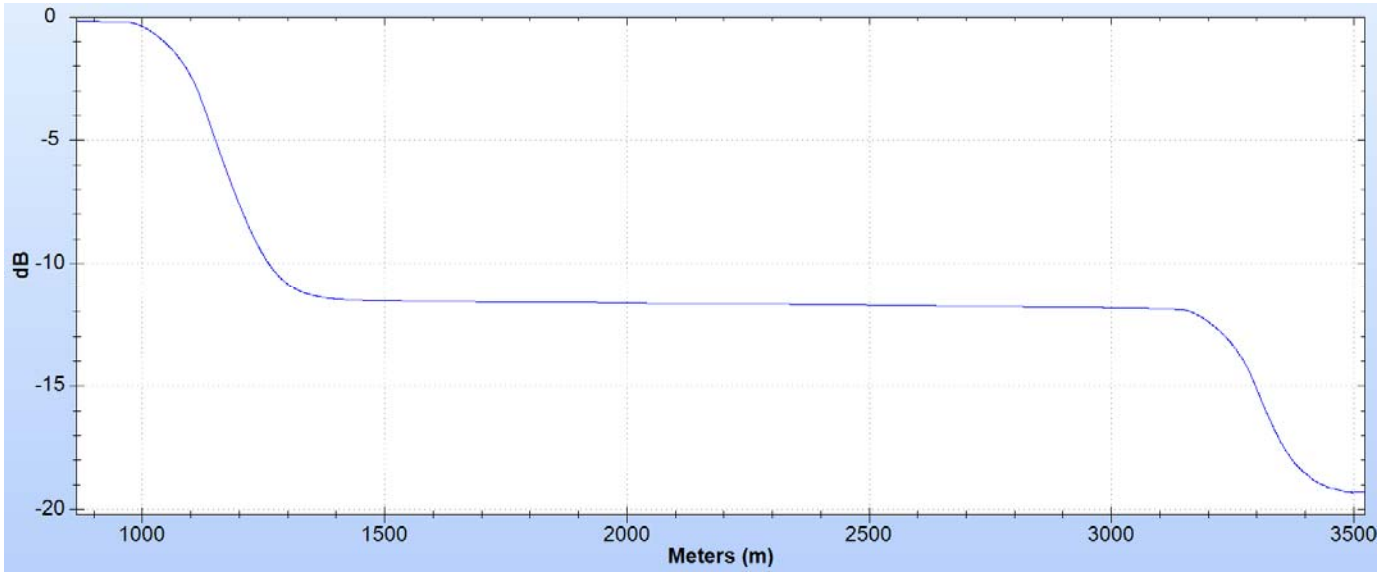
- Used to measure loss and reflectance of events
- Upstream only
- Requires a launch and tail cord
  - Cords should have close backscatter coefficient to link under test
- Shall be capable of using a short pulse ≤ 20ns
- Check the launch a receive cords prior to testing (B.6.2)

Upstream OTDR Testing



Upstream OTDR Testing

APC

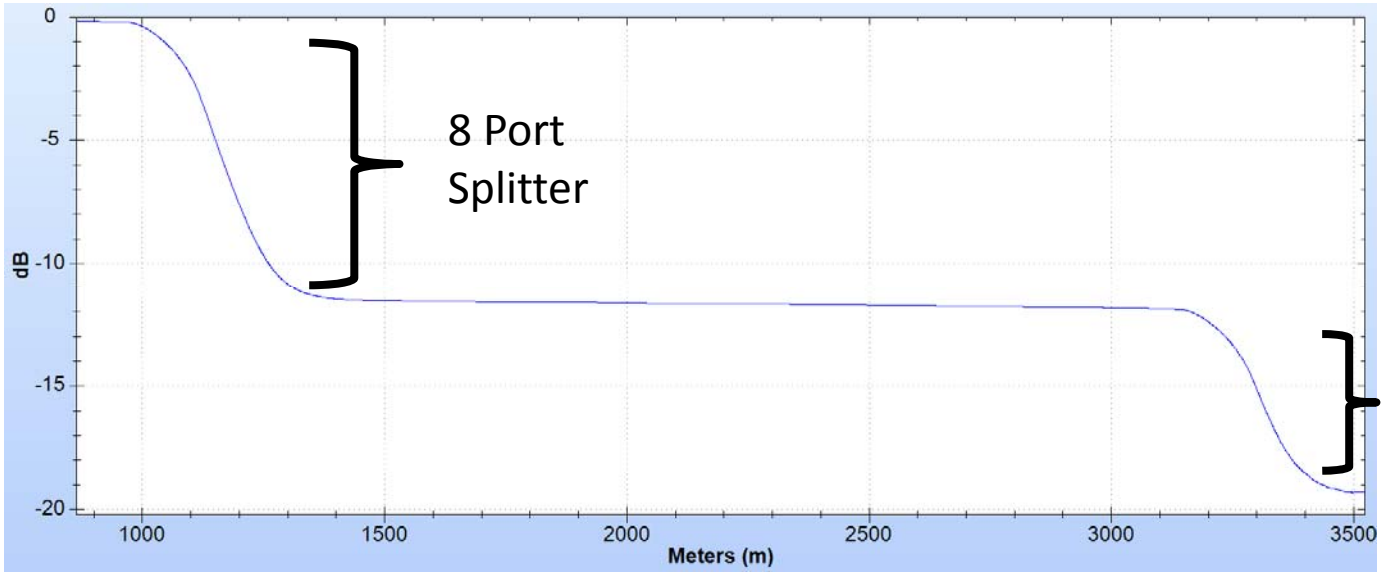


Loss

Length

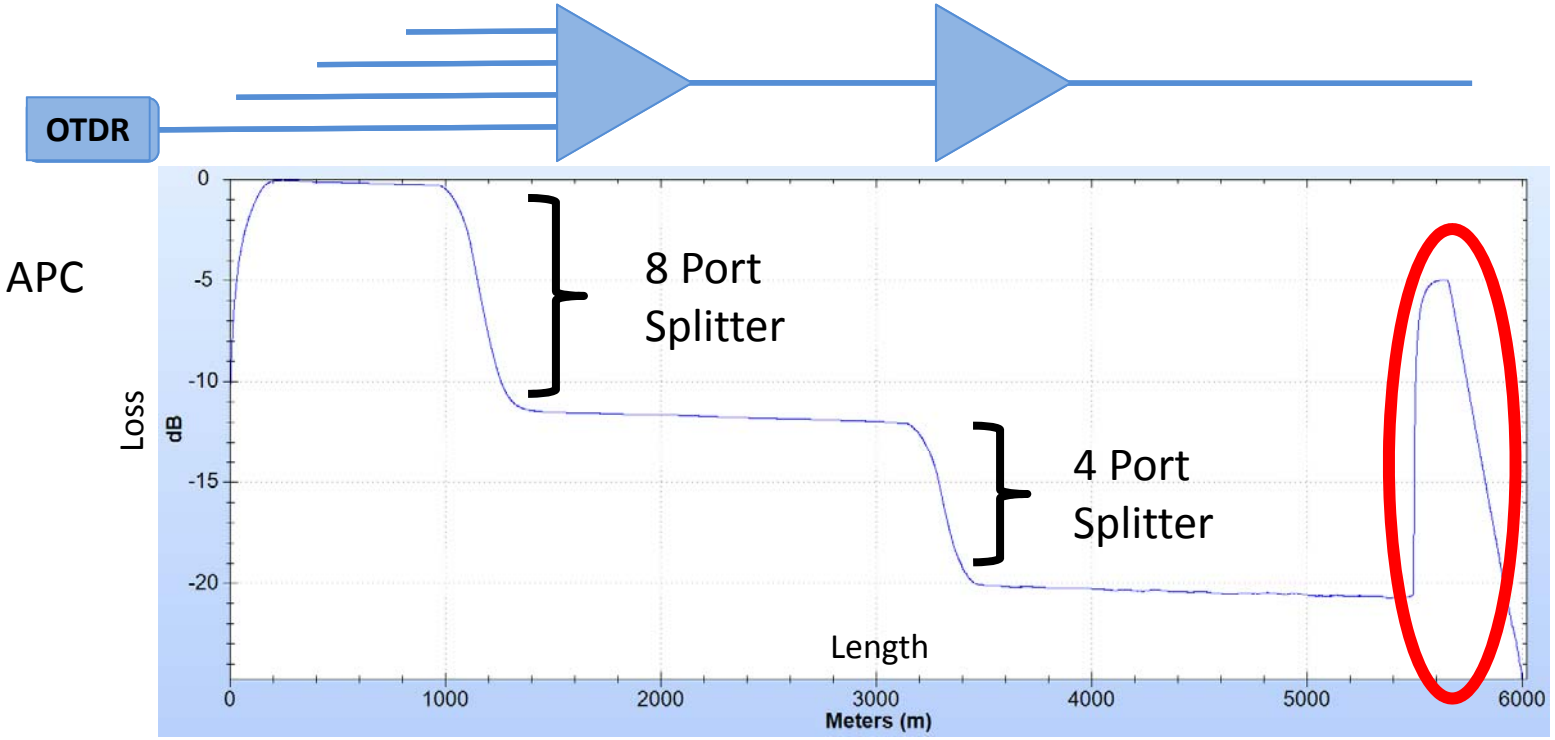
Upstream OTDR Testing

APC

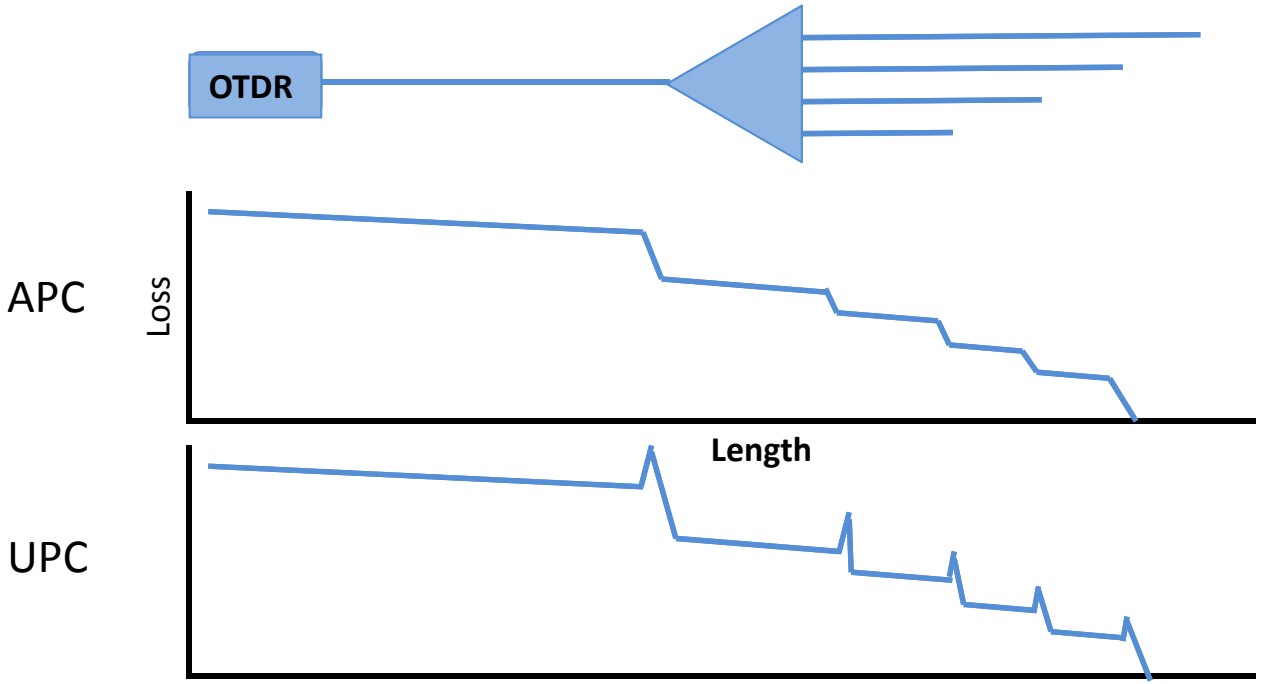


Length

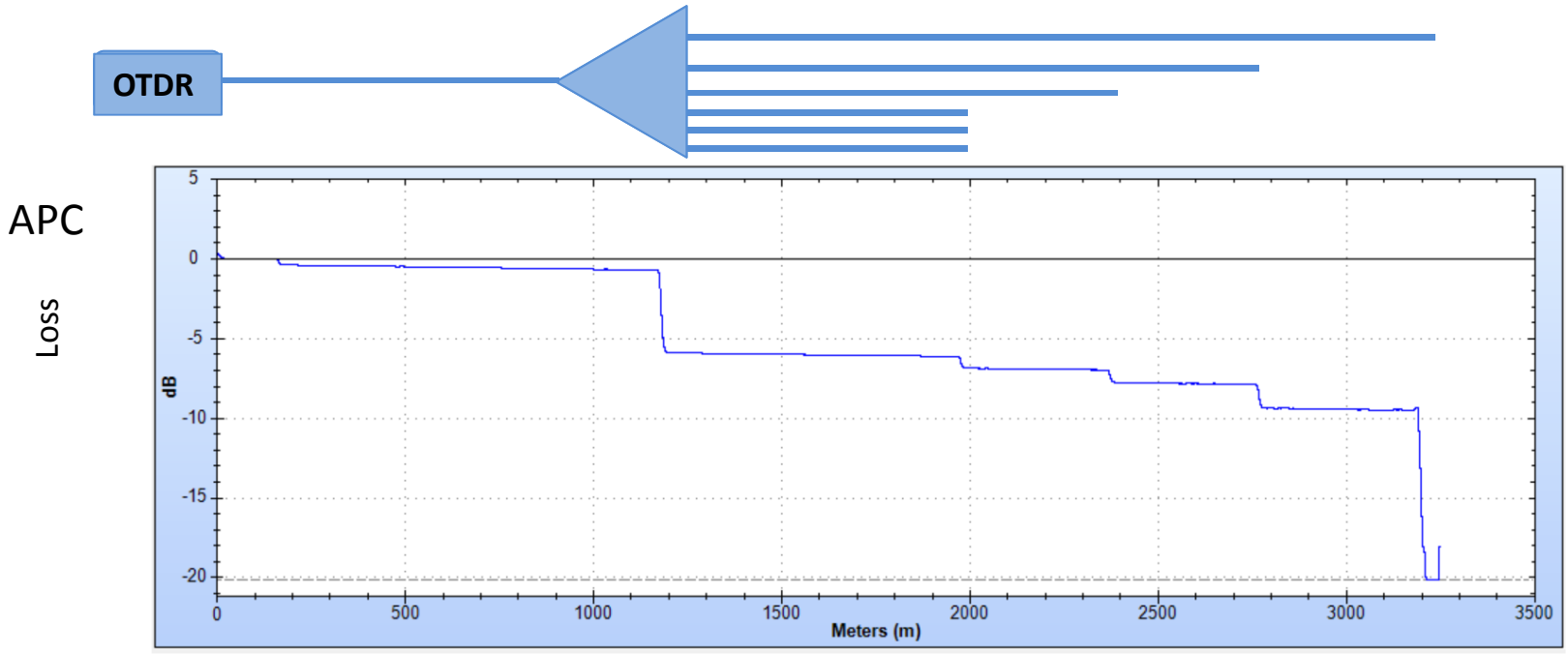
Upstream OTDR Testing – If you are connected to an OLT there may be a reflective event at the end



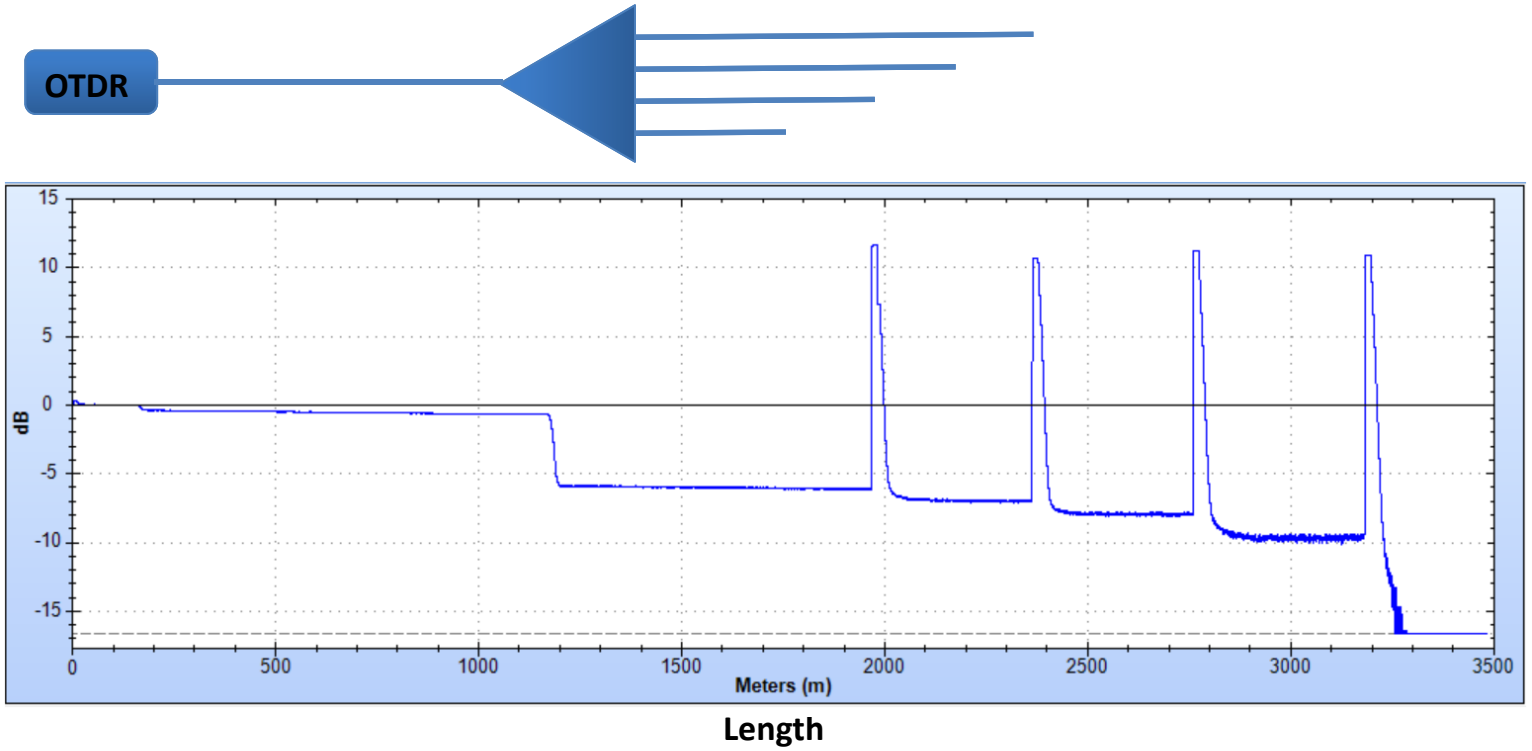
Downstream Testing



Downstream Testing



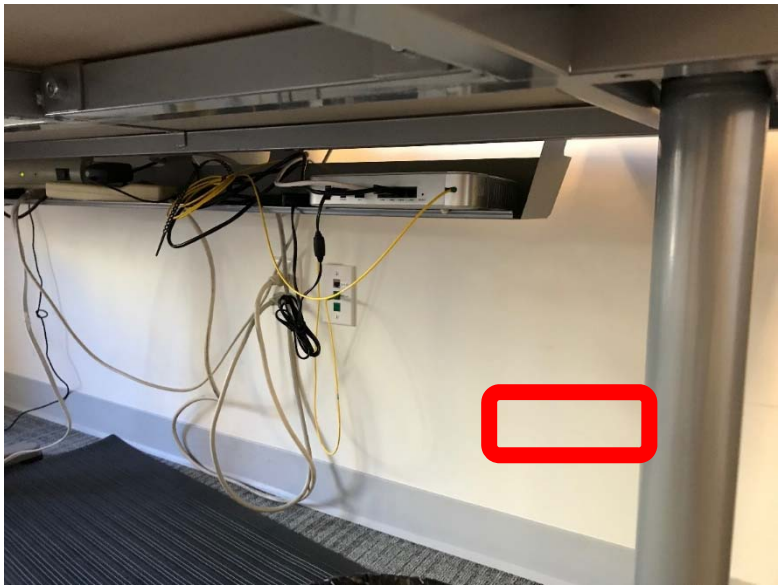
Downstream Testing ONT w/ONT



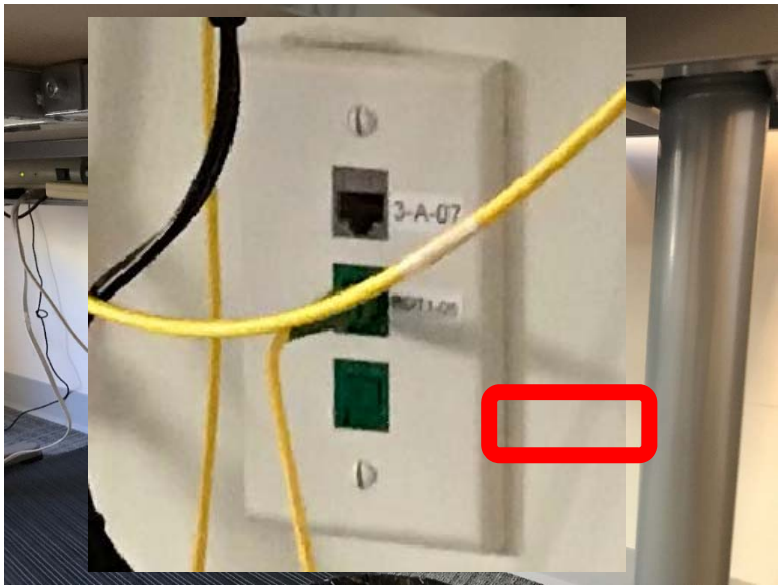
TROUBLESHOOTING LINKS

Did you try rebooting?

Example of PON to the desk

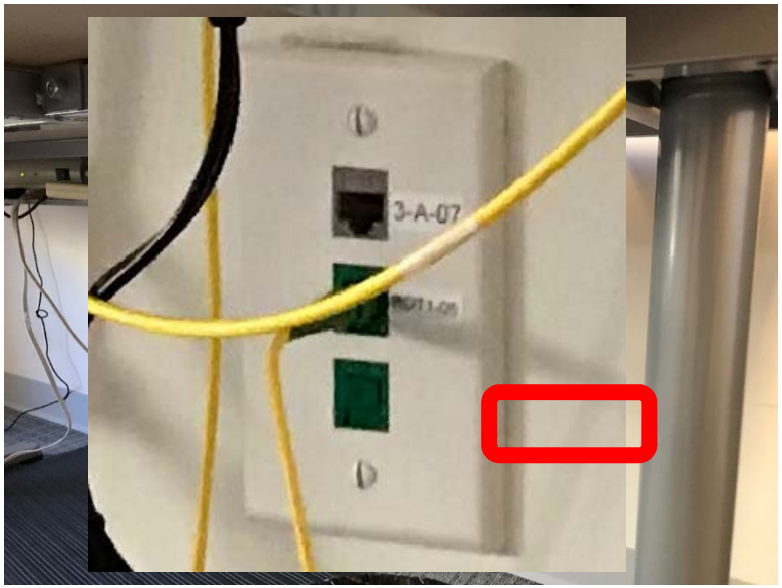


Example of PON to the desk



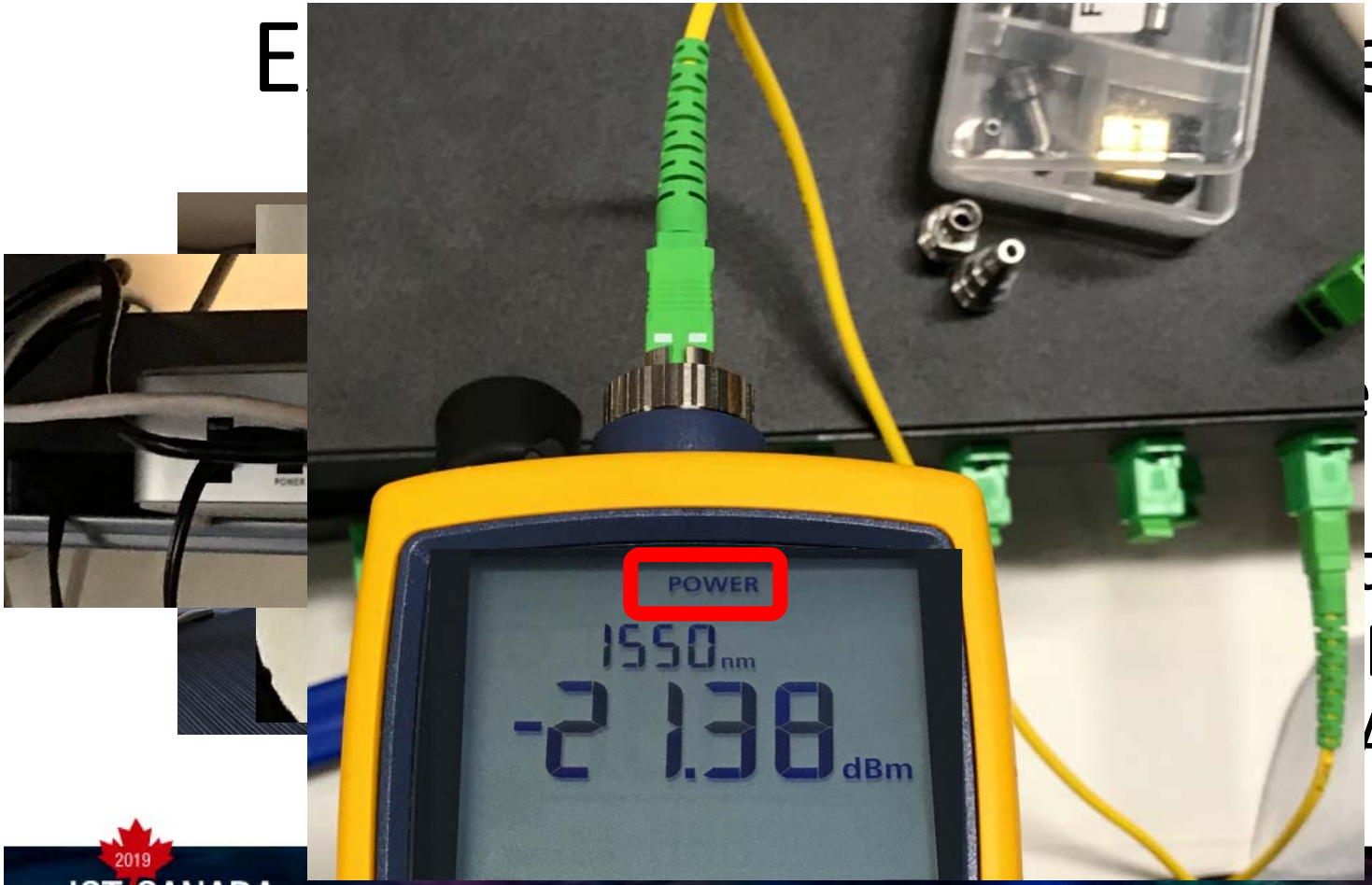
- Just a single fiber

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.

E esk



ngle fiber

rt switch –
xample – to
copper
tivity to
PC, laptop,
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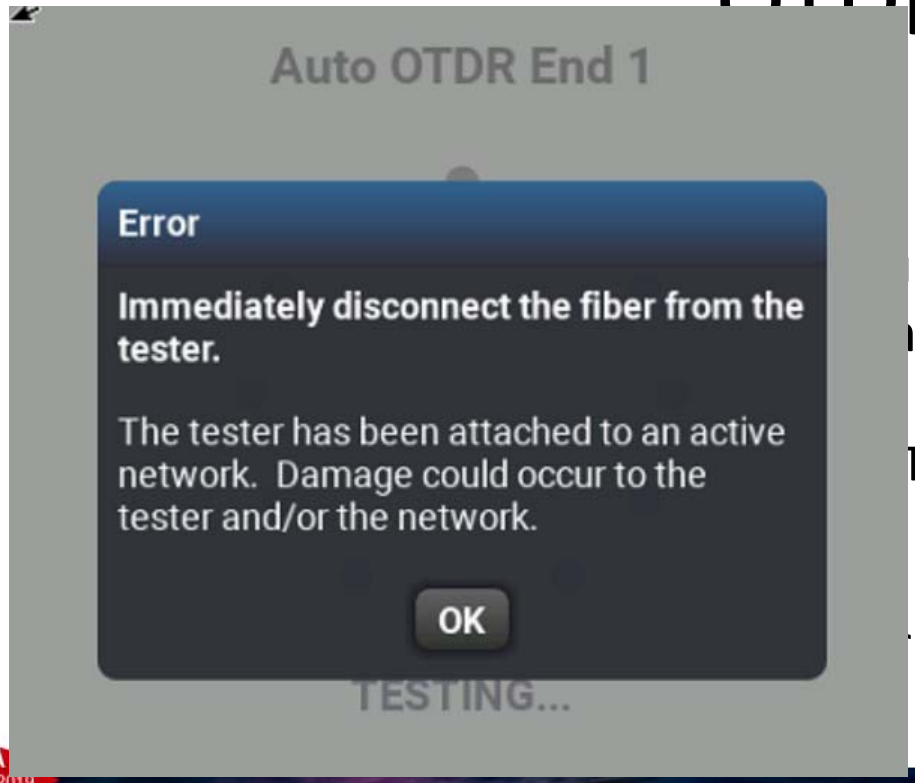
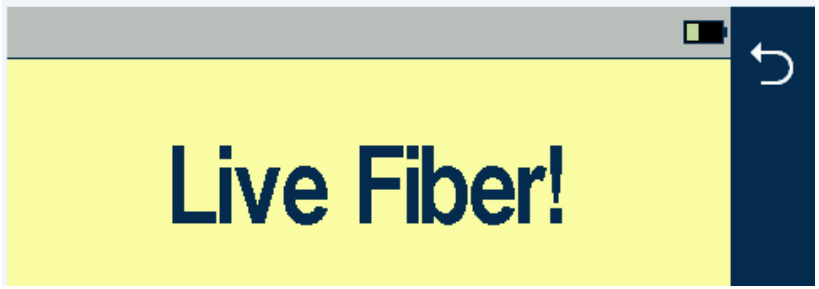
Troubleshooting a live network with an OTDR

- 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



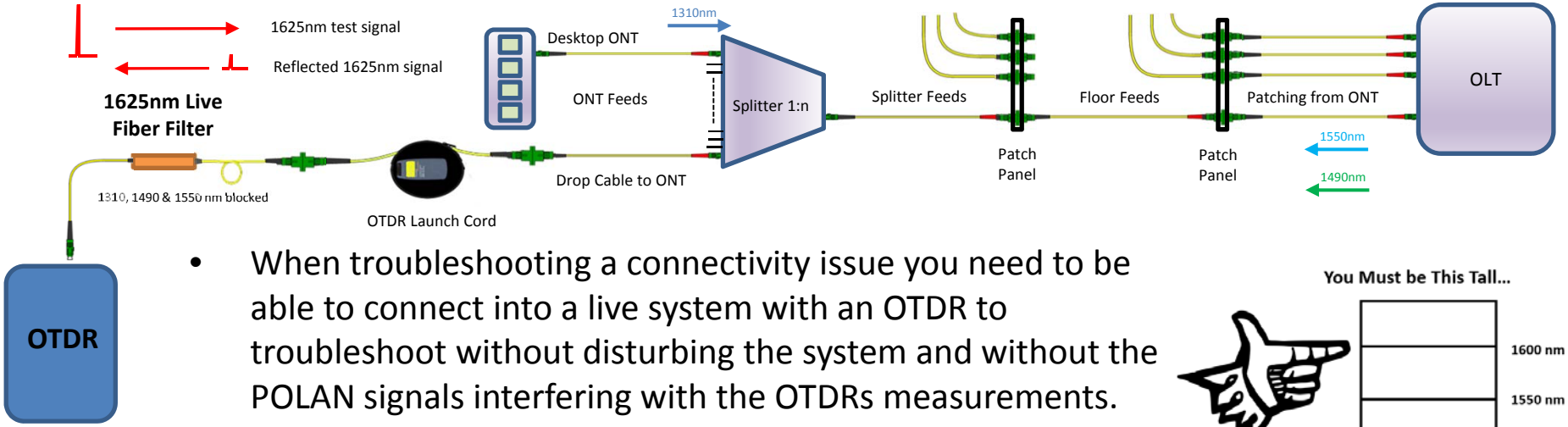


rn
ng

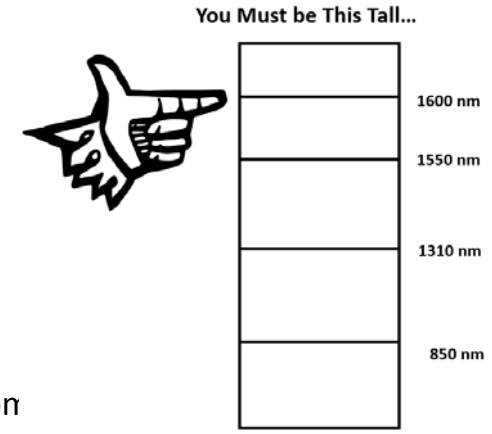
TDR transmitted pulse and OLT

1650 nm

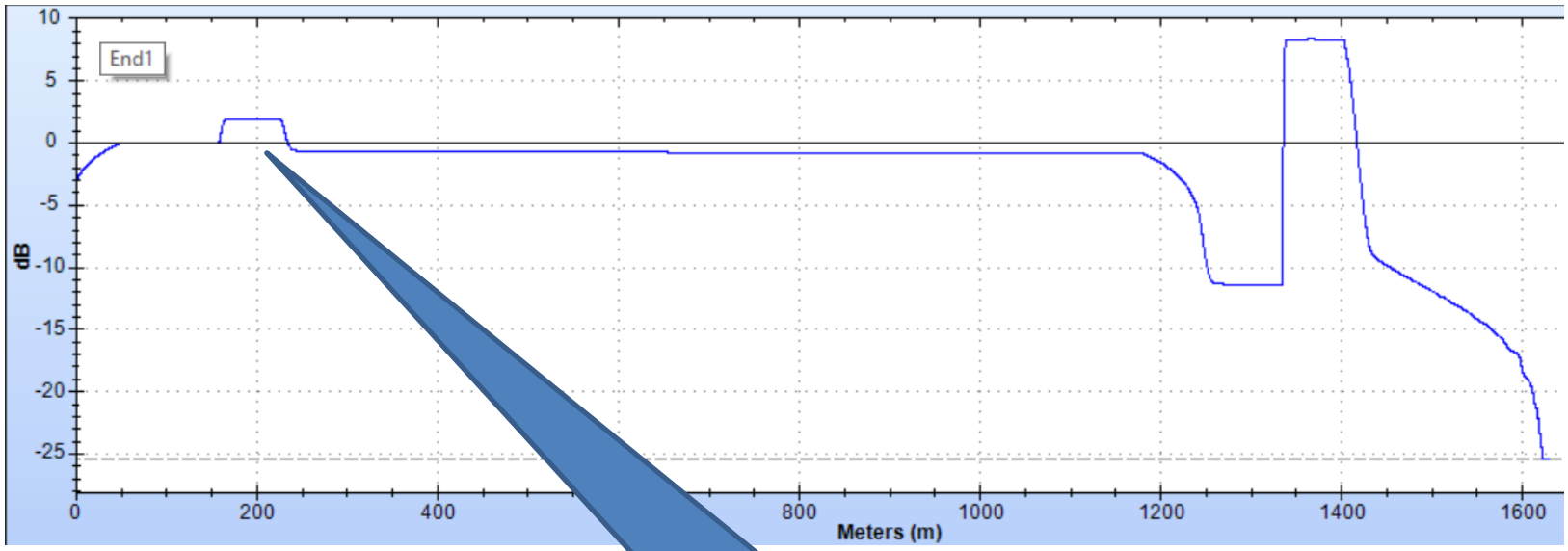
Filtered test configuration for POLAN



- 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

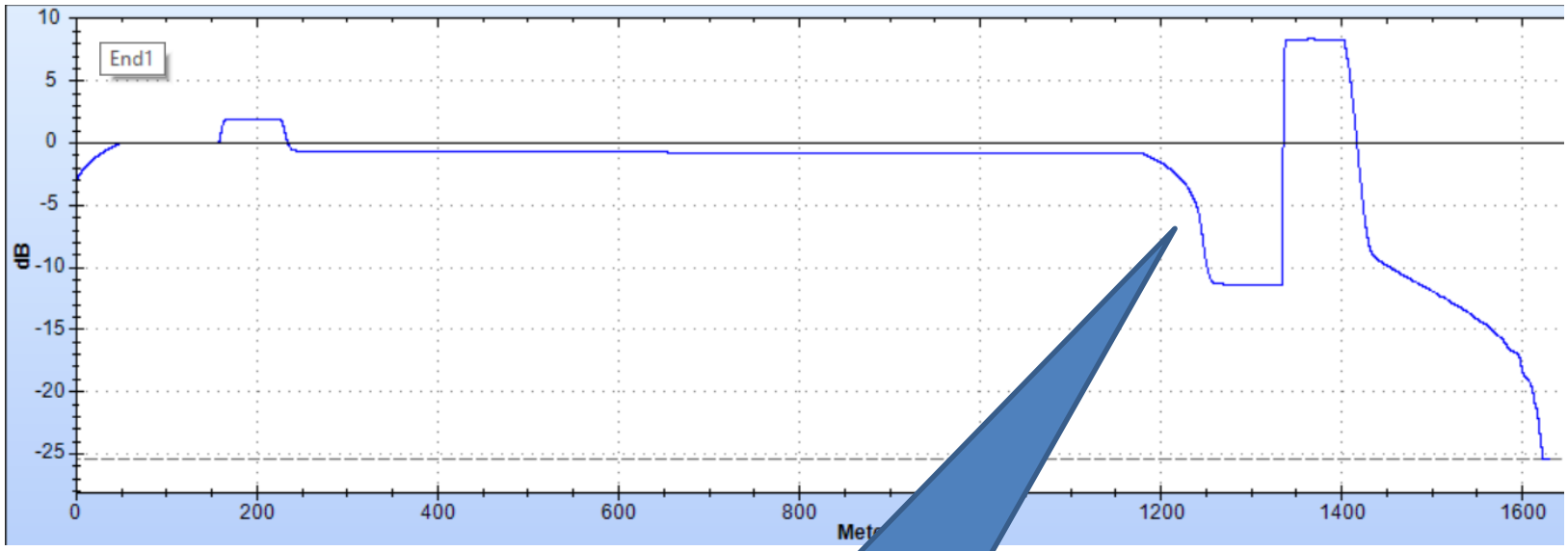


Here is a sample trace at 1625

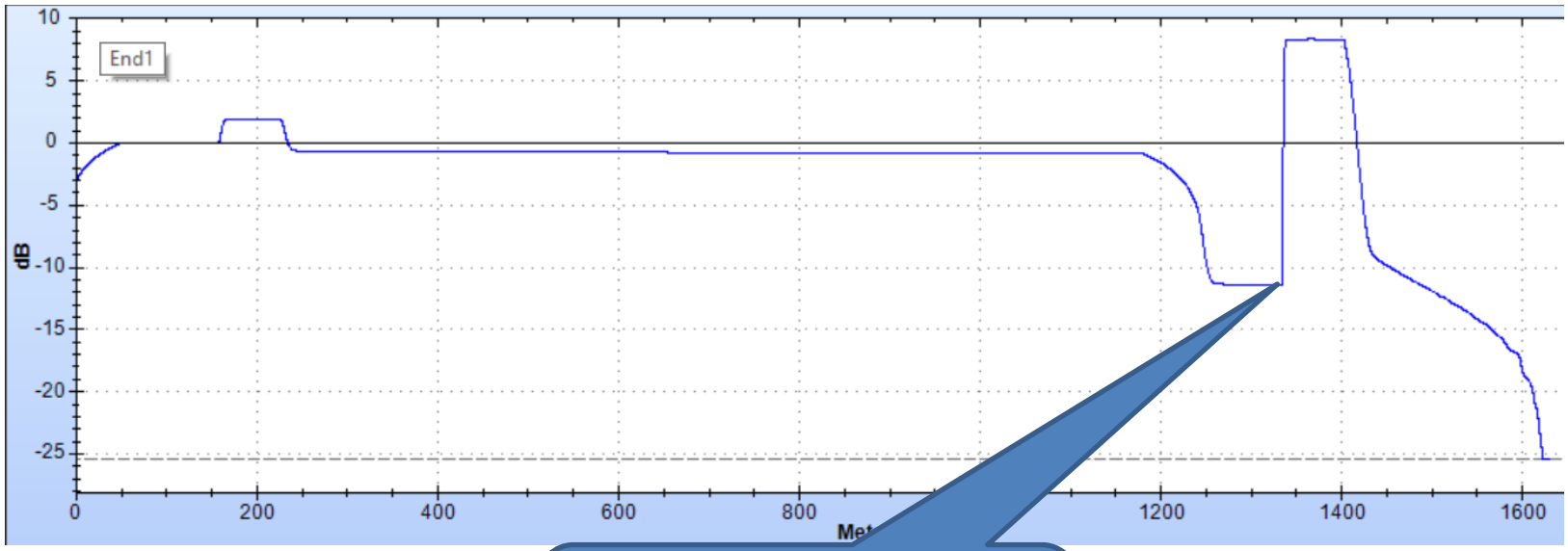


Connector

Here is a sample trace at 1625



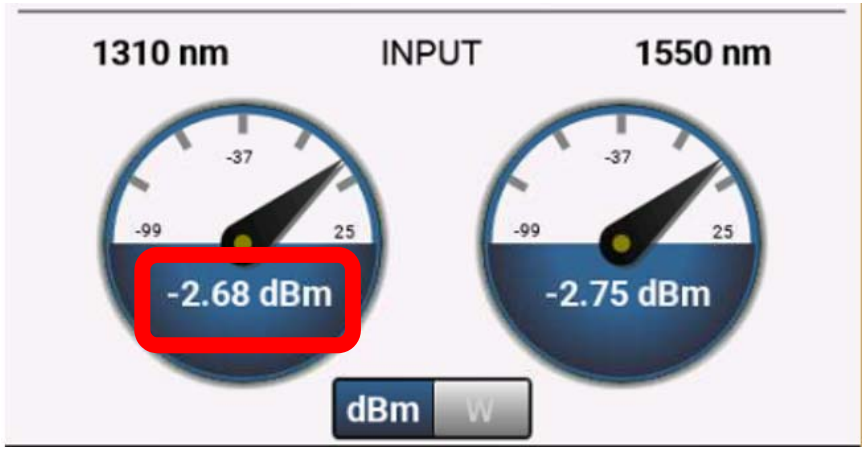
Here is a sample trace at 1625



Reflective Event at end of fiber

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 Resul

Technician can download test setups and cable IDs on the tester in the field

Test Instrument

Project Manager can track job progress anytime

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						

Cloud based Storage Site

Technician can upload Test Results from the job site

Test Instrument

Asset Manager can track last used location, software version and calibration status*

Reports Administrator can download test 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

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Everett, WA 98271

Amelia Mannarino

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