Fiber Testing 101
Essentials Every Network Analyst Needs to Know

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Workshop format

The Workshop is going to start with three short lecture style power point presentations going over the following topics:

1. Fiber cleaning / inspection
2. Power Meters
3. OTDR

- Refreshment and Bio break

- After the break we will split into three groups and rotate through three hands on demo stations.
- Demo on screen of Ethernet Testing using a set of test equipment back to back
  - RFC & EtherSAM

Fiber Inspection

BCNET

Fiber Optic types

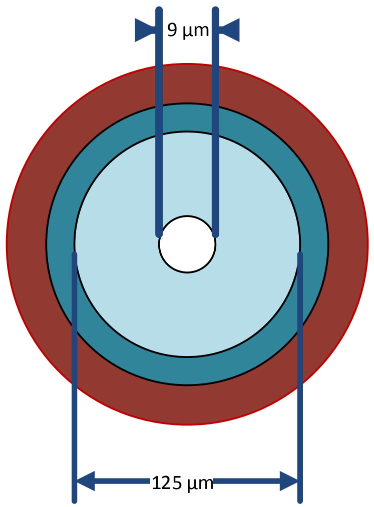
An optical fiber is a flexible, transparent fiber made by drawing glass or plastic to a diameter slightly thicker than of a human hair

Fiber optic technology has overtaken copper in data centers

Allows higher speeds and longer distances

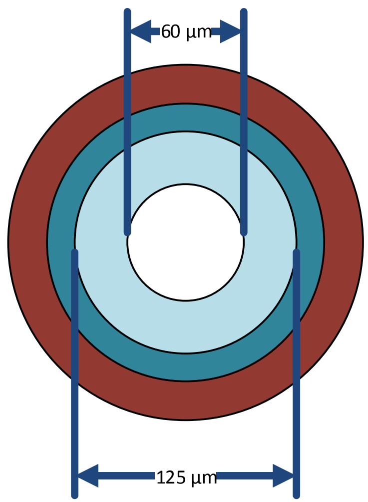
Density in patch panel, cable routing/ducting,

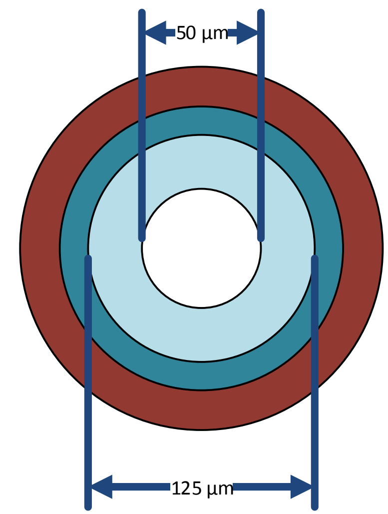
Single Mode Fiber



- Fiber with a small diametral core that allows only one mode of light to propagate
- It is typically used in long distance
- Less number of light reflections
- Higher bandwidth runs
- Used by Telcos, CATV companies, and Colleges and Universities.

Multimode Fiber





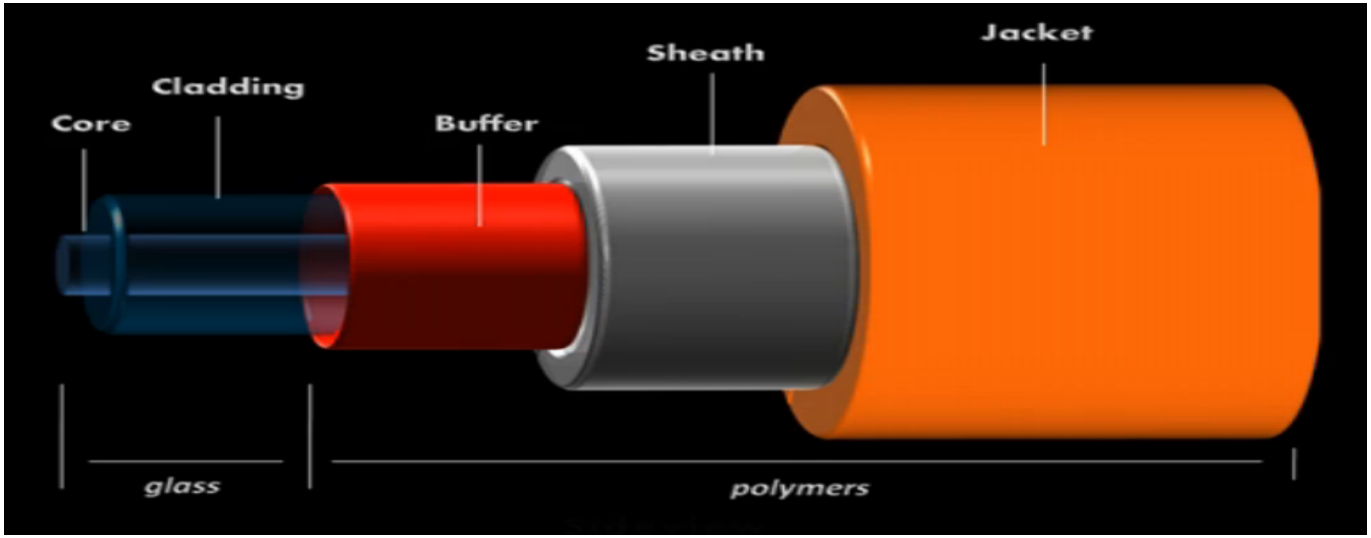
- Fiber with large core diameter that allows multiple modes of light to propagate.
- High dispersion and attenuation rate
- It is typically used for short distance
- Data and audio/video applications in LANs and Data Centre.
- Four types of MM cable

Multimode Fiber cable comparison

<table>
<tr><th>Category</th><th>Bandwidth
850nm / 1300nm</th><th>1000BASE-SX
Distance</th><th>10GBASE-SR
Distance</th><th>40GBASE-SR4 &
100GBASE-SR10
Distance</th></tr>
<tr><td>OM1
(62.5/125)</td><td>200 / 500 MHz·km</td><td>275m</td><td>33m</td><td>Not supported</td></tr>
<tr><td>OM2
(50/125)</td><td>500 / 500 MHz·km</td><td rowspan="3">550m</td><td>82m</td><td>Not supported</td></tr>
<tr><td>OM3
(50/125)</td><td>1500 / 2000 MHz·km</td><td>300m</td><td>100m</td></tr>
<tr><td>OM4
(50/125)</td><td>3500 / 4700 MHz·km</td><td>400m</td><td>100m</td></tr>
</table>

“OM” Stand for *optical multimode*

Fiber Optic Cable Structure



Core – Transparent plastic or glass through which light travels

Cladding – Glass covering surrounding the core that acts as a mirror to reflect light back into the core. This is called total internal reflection

Buffer – Coats and protects the fiber

Sheath – Reinforces the integrity of data transmission through the optical fibers in the cable

Protective outer jacket – Extruded PVC is typical

Fiber Connectors

An optical fiber connector terminates the end of an optical fiber, and enables quicker connection

Used to join two sections of optical fiber, or to connect the fiber to telecommunications equipment

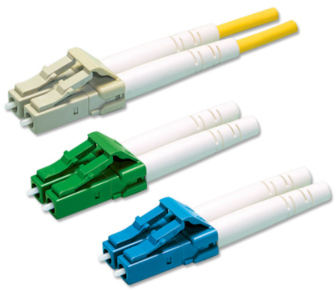
Common Fiber connector

SC – Subscriber Connector

- “Sam Charlie”
- Push/pull connector
- 2.5 mm ferrule

LC – Lucent Connector

- “Larry Charlie”
- Snap coupling
- 1.25mm ferrule
- Small factor



Common Fiber connector

FC – Fixed Connector

- “Frank Charlie”
- 2.5 mm ferrule
- Screw coupling

ST – Straight Tip

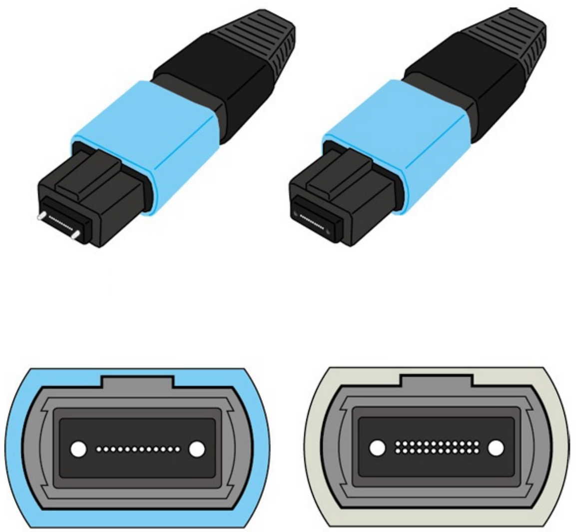
- “Stick Twist”
- Long ferrule 2.5 mm
- Bayonet mount

Common Fiber connector

MPO

Multi-fiber Push-On

- Also called MTP
- Up to 72 fiber connections
- Snap (multiplex push-pull coupling)
- 2.5×6.4 mm Ferrule
- Ribbon Fiber Cables



12

24

Common Fiber connector

Air Gap

PC

UPC

APC

Why to inspect and clean?

- Fiber connections are highly sensitive to dust.
- Dust is invisible to the naked eye
- Signal could be slightly disturbed or complete signal loss
- With other losses, this could mean exceeding your power budget

Best Practices

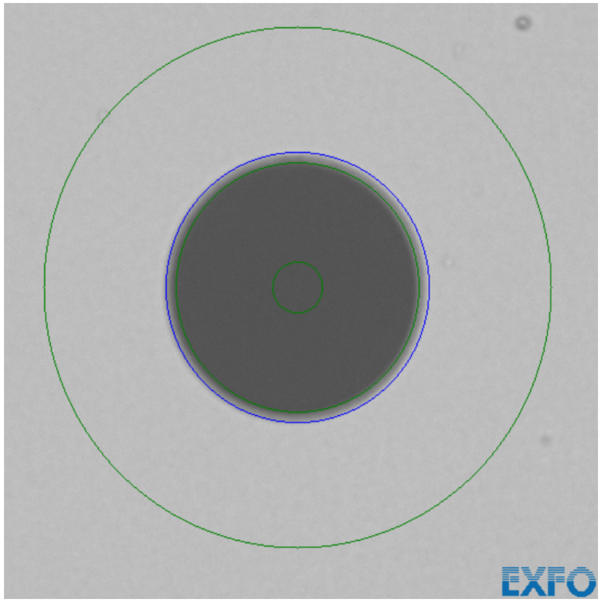
First Cleaning

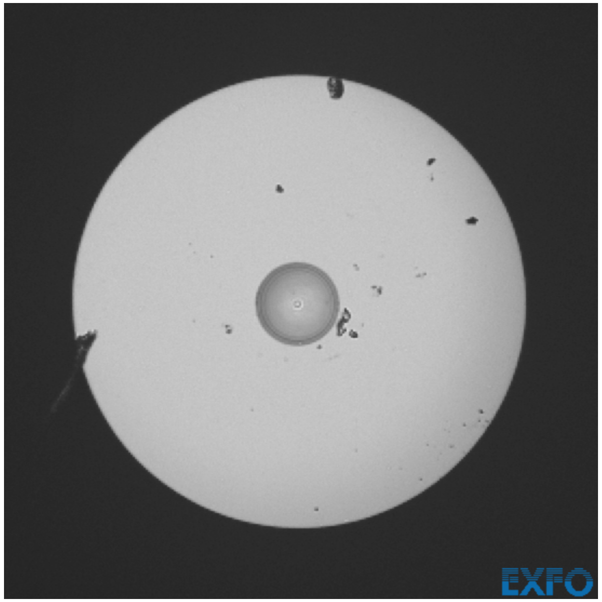
Second Cleaning

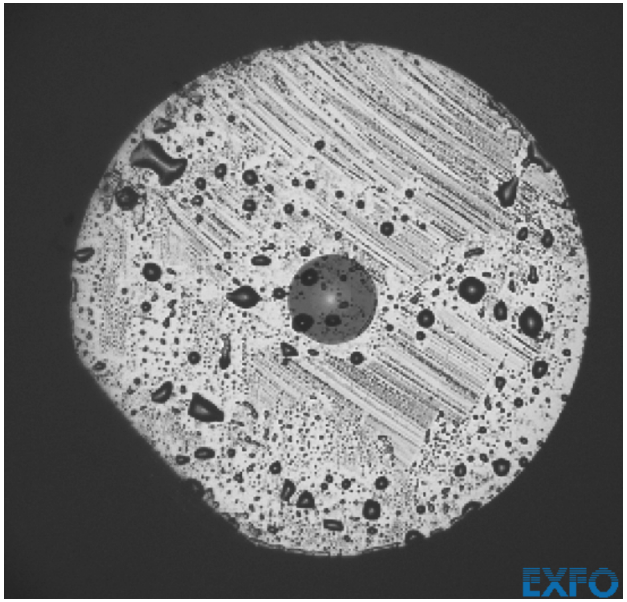
Third Cleaning

Tools for fiber inspection and cleaning

Why to inspect and clean?







What is a dust cap and what does it do?

To protect the connector from dust?

How is it possible?

To protect from other contaminants?

- Dust is everywhere
- Cap manufacture
- Unused caps

A dust cap can introduce them to the polished end-face.

No!

Why use dust Caps?

- Dust caps do a great job at protecting connector end-faces from contact with objects that can scratch, crack or damage the polished core of the fiber
- Ideal for protecting connectors from physical damage while in storage or in transit
- Install dust caps on any fiber optic connector that is not actively in use.

Questions?

Power Meters

1000Base Fiber Optic Transceiver Standard types:

Type of Optic	Media	TX Wavelength	Measured wavelength	Max. Distance	Special Notes
1000Base-SX 1000Base-SX	(OM1) 62.5 MMF (OM2) 50 MMF	770nm – 860nm	850nm	656ft (220m) 1640ft (550m)	
1000Base-LX 1000Base-LX	(OM1) 62.5 MMF SMF	770nm – 860nm	850nm	1640ft (550m) (5km)	Mode conditioning cable needed after (300m)
1000Base-LX10 1000Base-LH 1000Base-LX/LH	SMF	1270nm – 1355nm	1310nm	(10km)	This optic will only work on SMF
1000Base-EX	SMF	1270nm – 1355nm	1310nm	(40km)	
1000Base-ZX	(SMF	1550nm	1550nm	(70 – 120km)	

1000Base-LX name is commonly used by users to refer to the 10km Optic but the IEEE spec. shows it as only having a range of 5km.

1000Base-LX10 was added to the IEEE standard 6 yrs later. It is widespread use by vendors as a proprietary extension called 1000Base-LX/LH or 1000Base-LH

1000Base-EX sometimes referred to as LH (long haul) and is easily confused with 1000Base-LX10 or 1000Base-ZX because the use of –LX(10), -LH, -EX and –ZX is ambiguous between vendors

10GBase Fiber Optic Transceiver Standard types:

Type of Optic	Media	TX Wavelength	Measured wavelength	Max. Distance
10GBase-SR	(OM1) 62.5 MMF (OM2) 50 MMF (OM3) SMF	840nm – 860nm	850nm	108ft (33m) 270ft (82m) 985ft (300m)
10GBase-LR	SMF	1260nm – 1355nm	1310nm	6.2miles (10km)
10GBase-ER	SMF	1530nm – 1565nm	1550nm	24.8miles (40km)
10GBase-ZR	SMF	1530nm – 1565nm	1550nm	49.6miles – 74.5miles (80km – 120km)

10GBase-ZR is not officially part of the IEEE standard but is more a manufacturers created specification based on the 80km PHY Sonet standard.

100GBase Fiber Optic Transceiver Standard types:

Type of Optic	Media	Media Count	Lanes	Type of Connector	TX Wavelength	Max. Distance
100GBase-SR4	(OM3) MMF (OM4) MMF	4	4	MPO (MTP12)	850nm	230ft (70m) 328ft (100m)
100GBase-SR10	SMF	10	10	MPO (MTP24)	850nm	328ft (100m) 492ft (150m)
100GBase-LR4	SMF	1	4	LC	1295.56nm,1300.05nm, 1304.59nm, 1309.14nm	6.2miles (10km)
100GBase-ER4	SMF	1	4	LC	1295.56nm,1300.05nm, 1304.59nm, 1309.14nm	24.9miles (40km)
100GBase-ZR Non IEEE standard	SMF	1	4	LC	1546.119nm	49.7miles (80km)

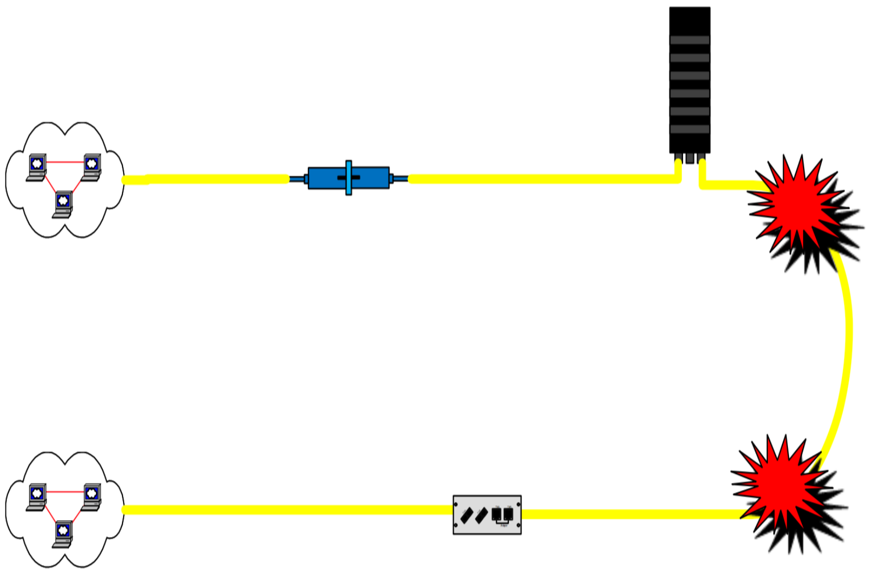
To perform Power Meter testing on an MPO connector to verify connectivity and Insertion Loss, you will need:

- MPO breakout cable of the right type (12 or 24)

To perform a verification of the Optic there are various strategies but they would all need additional test equipment especially when looking at LR, ER and ZR.

Insertion Loss - IL

- Insertion loss or IL is a term used to describe the power loss along an optical fiber link/circuit.
- It is due to the natural attenuation of the Fiber cable as well as components such as:
  - Connectors
  - Splices
  - Impairments
    - such as Macro bends
    - faulty components



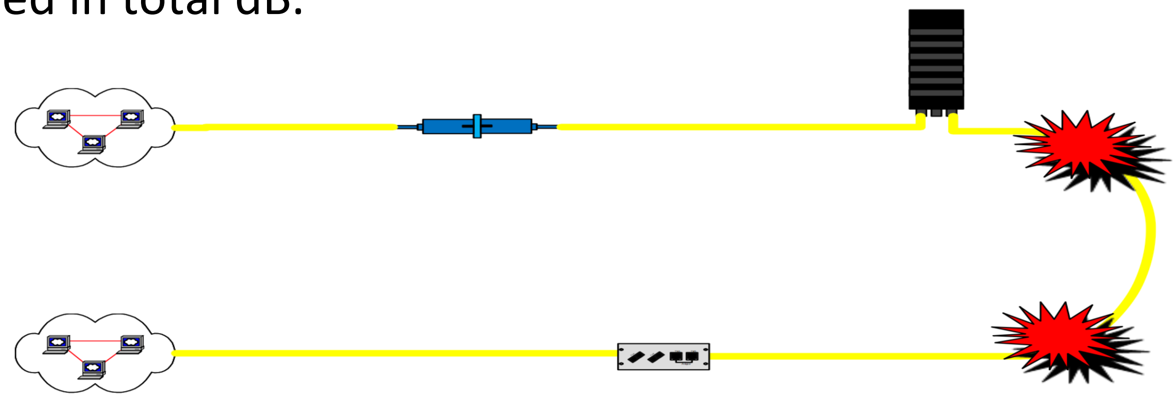
Insertion Loss Continued

- Measured in dB = Decibel
- It is a Logarithmic scale to tell us what percentage of original power will be present after transmission of the fiber link

Loss VS % of remaining power	
0.05 dB	98.2 %
1 dB	79.4 %
3 dB	50 %
10 dB	10%
20 dB	1 %
30 dB	0.1 %
40 dB	0.01 %

Optical Loss Budgets

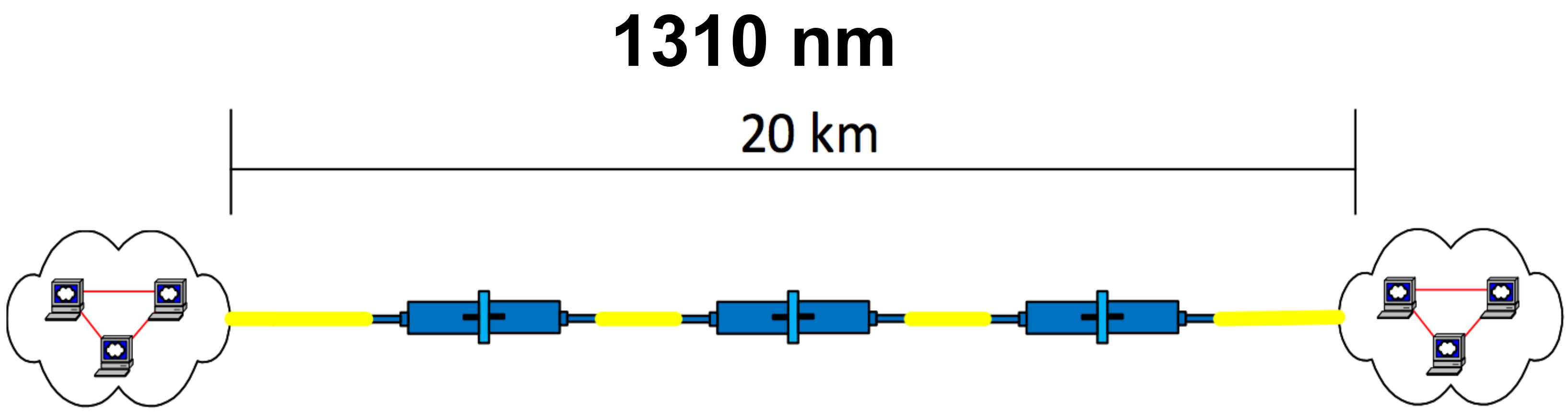
The total calculated power loss in an optical link or span. Calculation is derived from the sum of all losses including fiber attenuation, splices, components and connections plus a margin of error. Measured in total dB.



Typical Loss calculation values

- Fiber cable measured @ 1550 nm = 0.2 dB/km
- Fiber cable measured @ 1310 nm = 0.35 dB/km
- Connectors = 0.35 dB per connector pair
- Fusion splices typically have very little or no loss

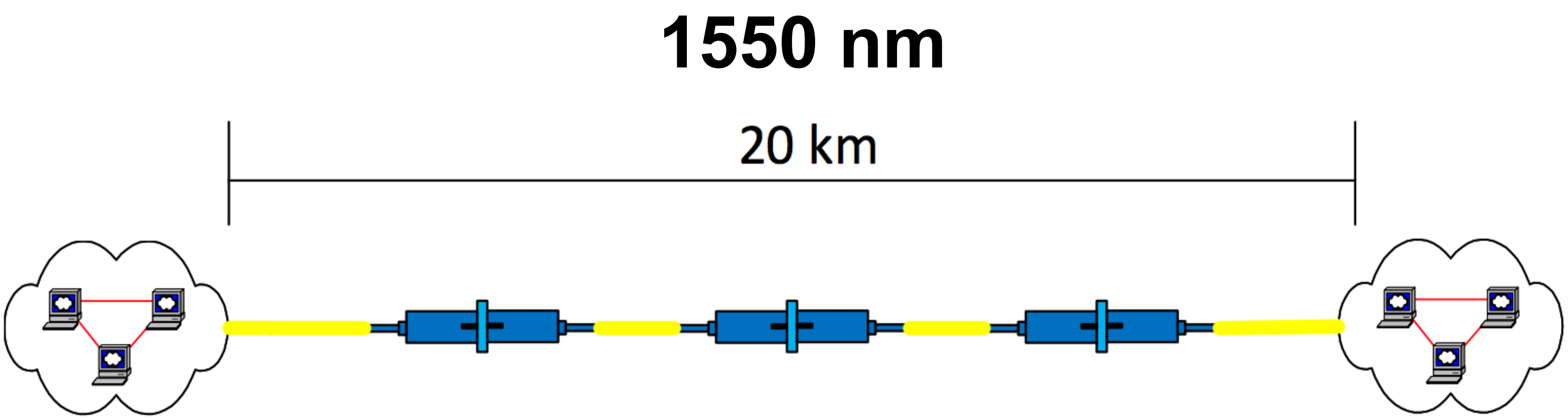
Loss Budgets example 1



0.35 dB/km @ 1310nm
0.35 db/km X 20km = 7.00 dB
0.35 db per connector pair
0.35dB X 3 = 1.05 dB
Margin of error = 2dB

Total Loss
10.05 dB

Loss Budget example 2



0.2 dB/km @ 1550nm
0.2 db/km X 20km = 4.00 dB
0.35 db per connector pair
0.35dB X 3 = 1.05 dB
Margin of error = 2dB

Total Loss
7.05 dB

Insertion Loss Measuring

Reference…

Test Jumper 1 Test Jumper 2

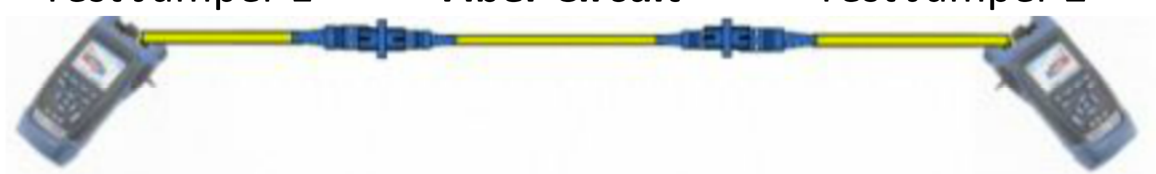
To measure the Insertion Loss we first need to measure the light source and set that as a reference to the Power Meter

- The light source can be a meter or a optical transceiver

Then we connect up the Fiber circuit between the source and Power Meter and this will give you the IL (Insertion Loss)

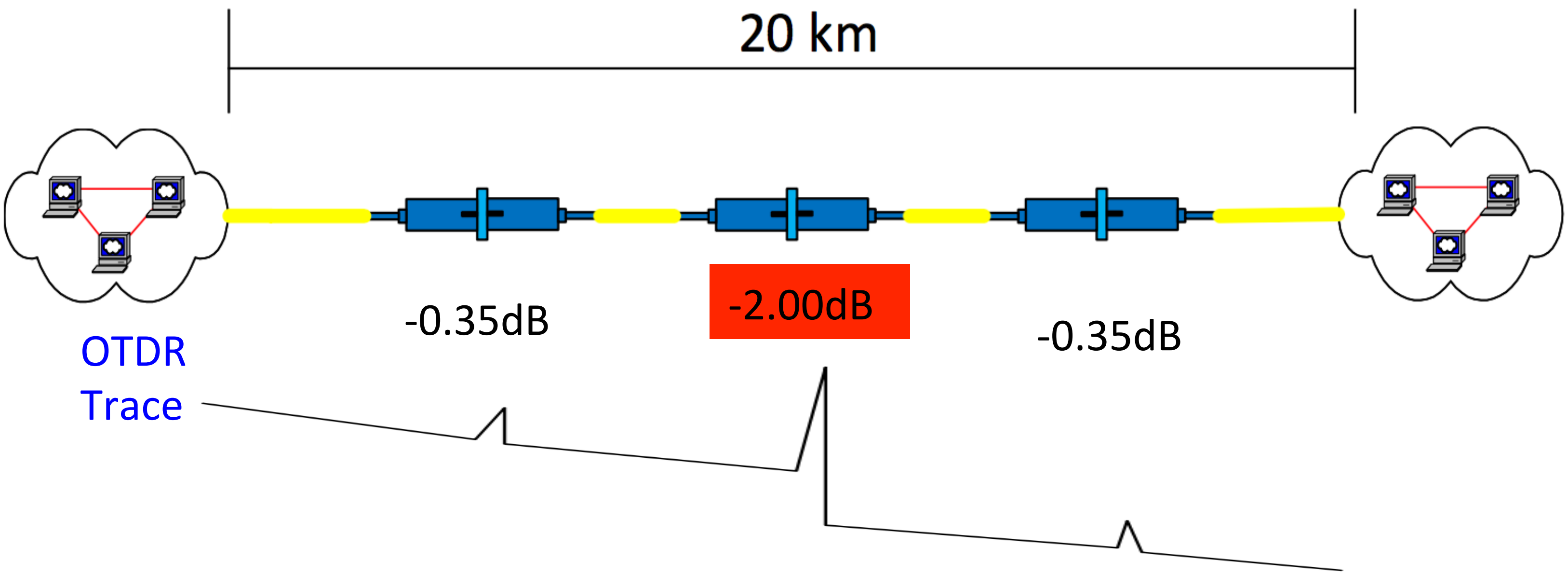
The Power Meter should be set up to measure in dB

Test Jumper 1 **Fiber Circuit** Test Jumper 2



Insertion Loss

When using a power meter and we are seeing Insertion Loss higher than calculated or expected, then we would need other trouble shooting tools to pin point the cause of the excessive loss such as an OTDR.



The difference between dBm and dB and when to use them

Definition of dBm is referencing a power ratio of the measured power referenced to one milliwatt

- You would be using the dBm unit of measurement on you Power Meter when measuring the optic laser power.

Definition of dB is a logarithmic unit to express the ratio of two values of a physical quantity.

- You would using the dB unit of measurement when referencing the IL or Optical Budget loss.

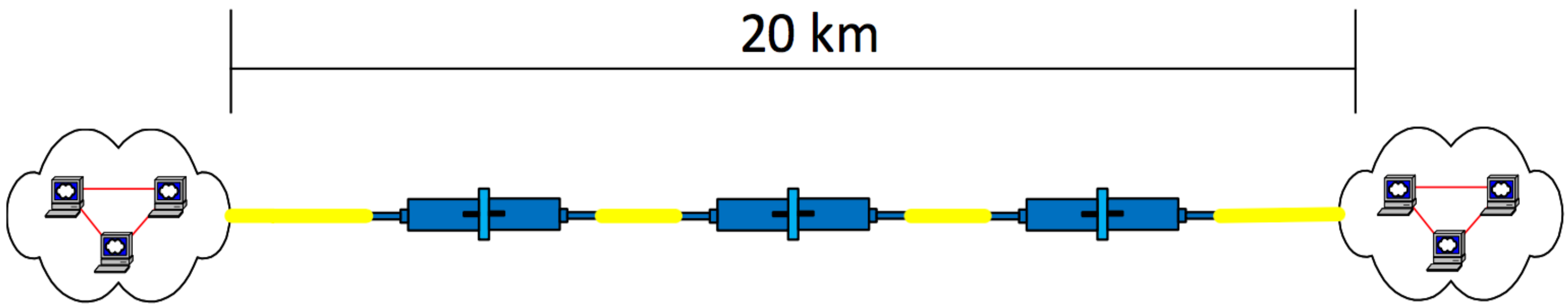
Optical Interface Specifications Juniper 10GBase-SR

Parameter	10-GBase-S
Transceiver model number	XFP-10G-S
Optical interface	Multimode
Transceiver type	XFP
Standard	IEEE 802.3ae—2002
Maximum distance	50/125 MMF cable, 2000 MHz-km: 984 feet/300 m
	50/125 MMF cable, 500 MHz-km: 269 feet/82 m
	50/125 MMF cable, 400 MHz-km: 217 feet/66 m
	62.5/125 MMF cable, 200 MHz-km: 108 feet/33 m
	62.5/125 MMF cable, 160 MHz-km: 85 feet/26 m
Transmitter wavelength	840 through 860 nm
Average launch power	–4.5 through –1.0 dBm
Average receive power	–9.9 through –1.0 dBm
Receiver saturation	–1.0 dBm
Receiver sensitivity	–9.9 dBm

Optical Interface Specifications
Juniper 10GBase-LR

Parameter	10-GBase-L
Optical interface	Single-mode
Average launch power	−8.2 through 0.5 dBm
Average receive power	−14[illegible]
Receiver saturation	0.5 dBm
Receiver sensitivity	−14.4 dBm

1310 nm



0.35 dB/km @ 1310nm
0.35 db/km X 20km = 7.00 dB
0.35 db per connector pair
0.35dB X 3 = 1.05 dB

Total Loss
8.05 dB

Power Meter

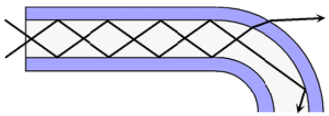
Questions?

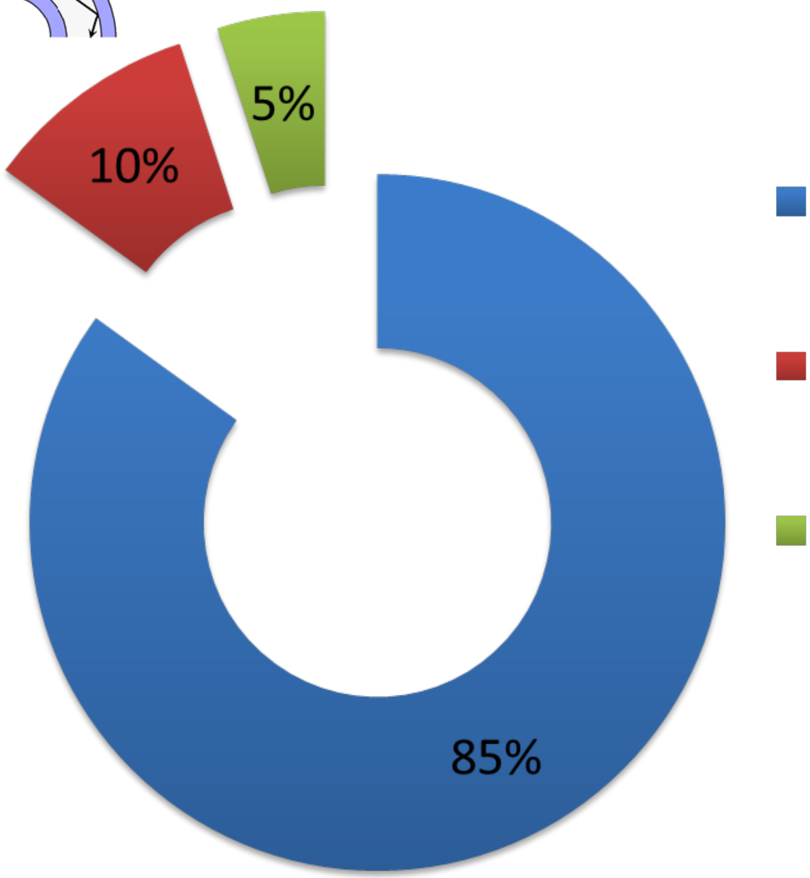
From OTDR 101 to
Intelligent Optical link Mapper
IOLM

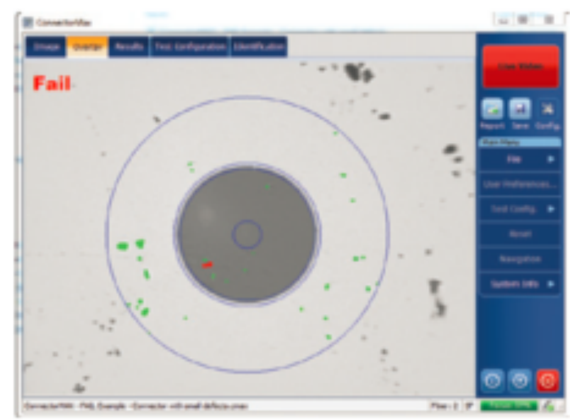
EXFO

Installation best practices

Connector cleaningness and macrobending



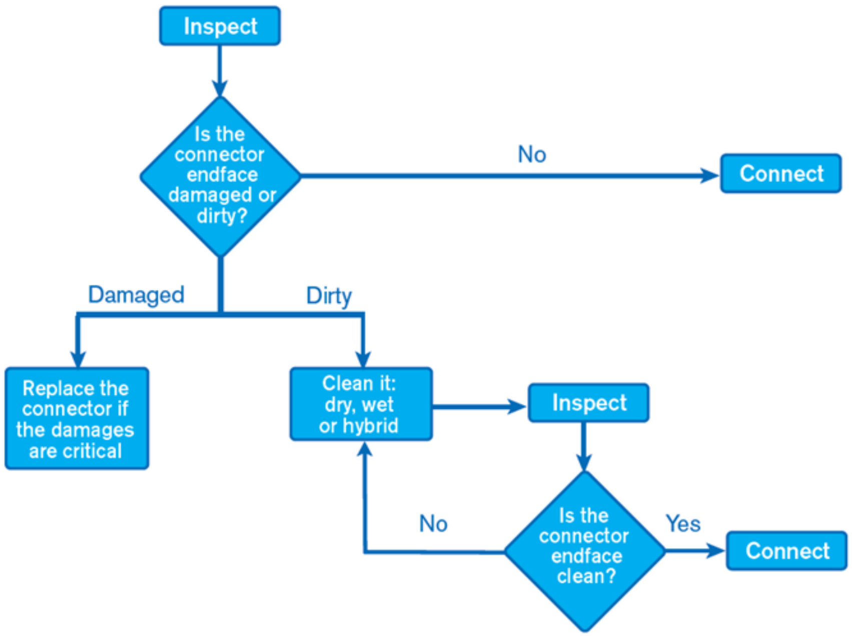




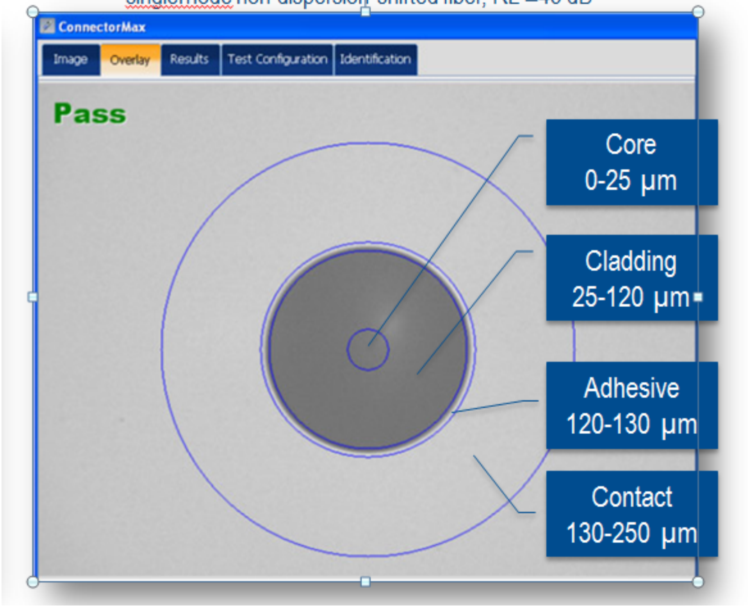
Defective connector failing acceptance criteria.

Installation best practices
Connector cleaningness

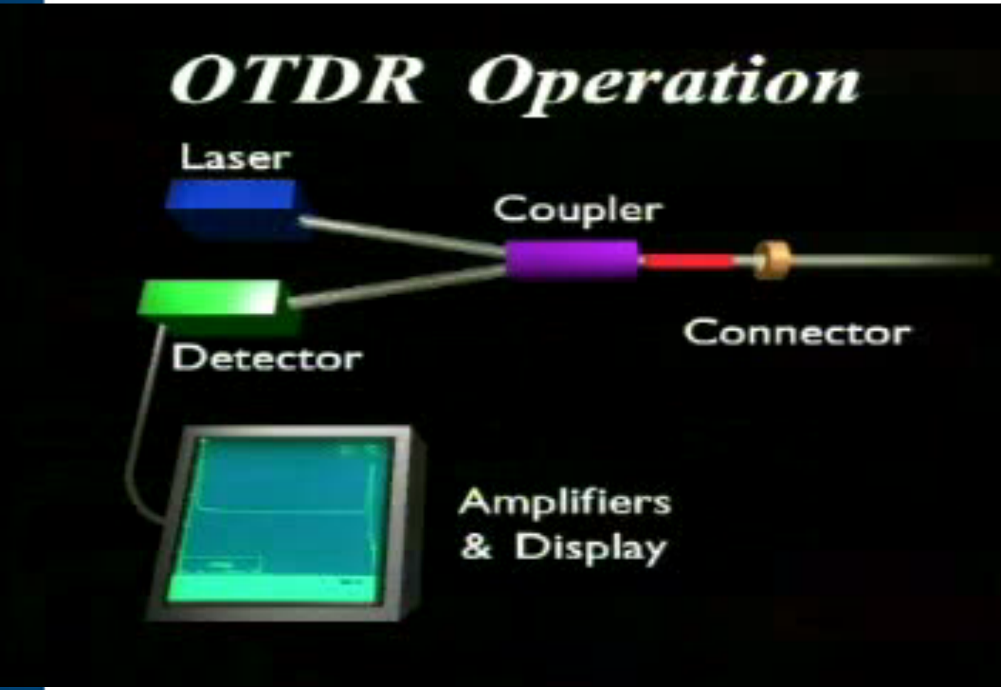
A visual inspection of the end faces of connectors could be enhanced buy using a software analysis



IEC zone sizes for polished connectors, singlemode non-dispersion shifted fiber, RL ≥45 dB

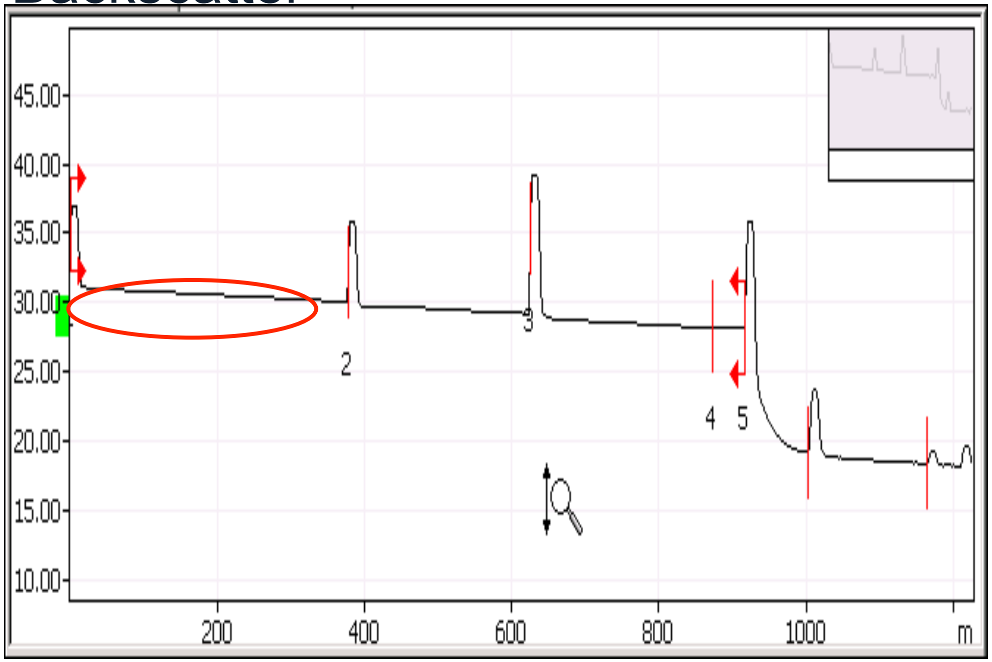


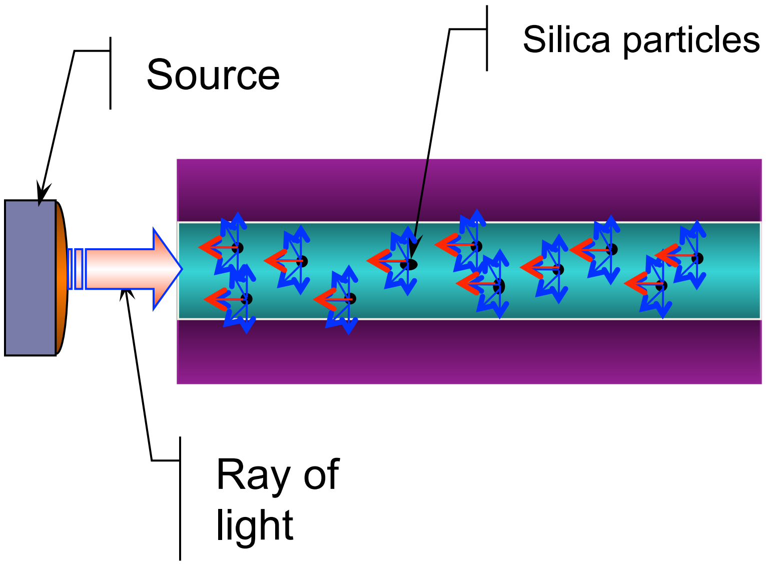
- Laser / Coupler / Photodetector
  - Fresnel Reflections along the fiber are measured
  - Rayleigh Backscatter along the fiber is measured



Rayleigh Backscattering

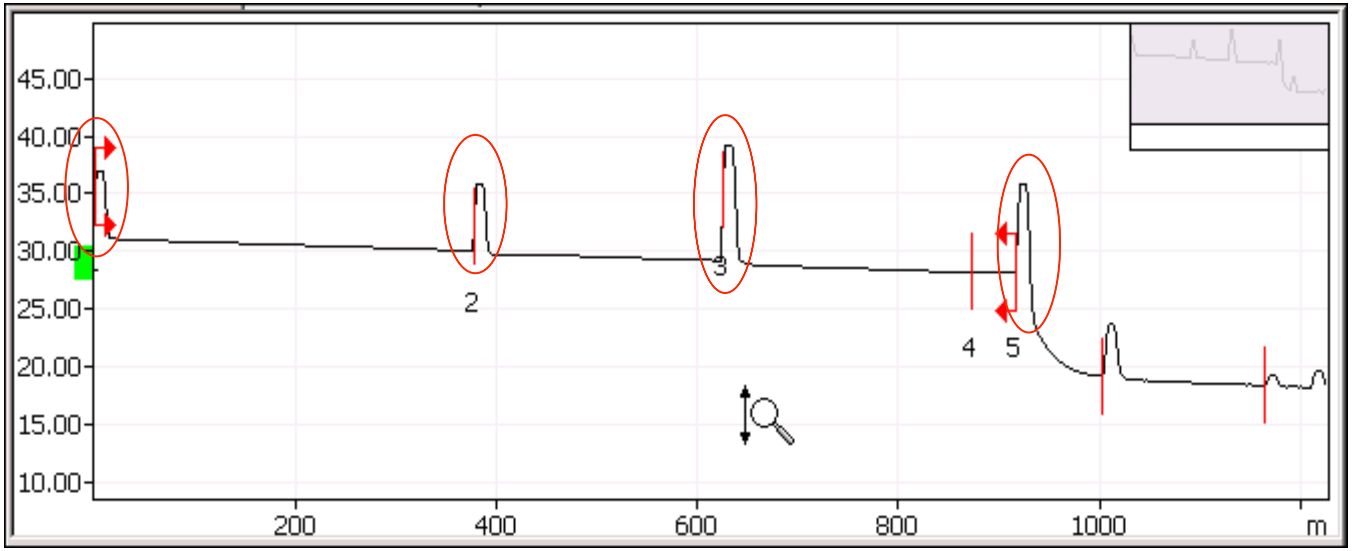
- Comes from the “Natural” reflection of the fiber
- The OTDR will use the Rayleigh back reflections to measure fiber’s attenuation (dB/Km)
- Back reflection level around -75 dB
- Higher wavelength will be less attenuated by the Rayleigh Backscatter





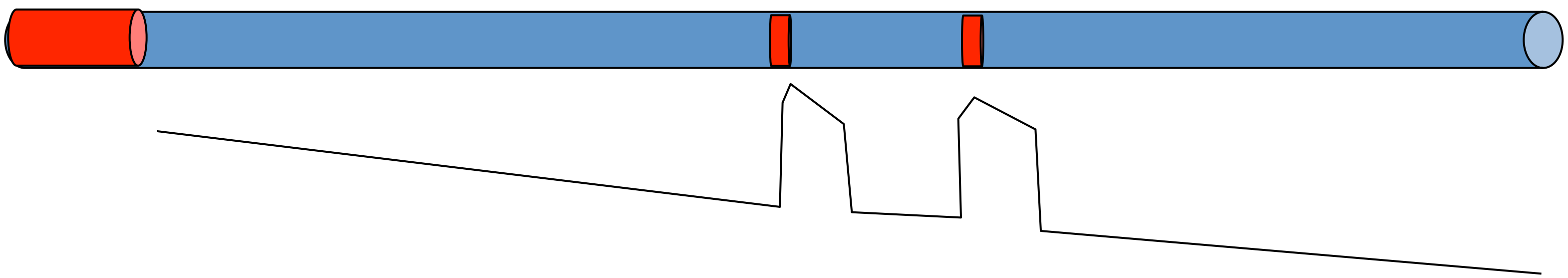
Fresnel back reflections

- Will come from abrupt changes in the IOR, ex: (glass/air)
  - **Fiber break, mechanical splice, bulkheads, connectors**
- Will show as a “spike” on the OTDR trace
- UPC reflection is typically -55dB and APC -65dB (as per ITU)
- Fresnel reflections will be approximately 20 000 times higher than fiber’s backscattering level
- Will create a « Dead Zone » after the reflection

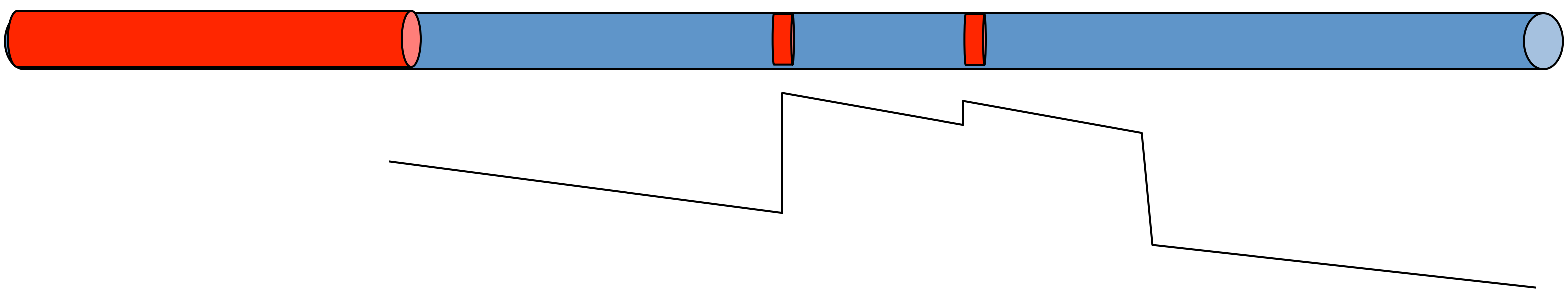


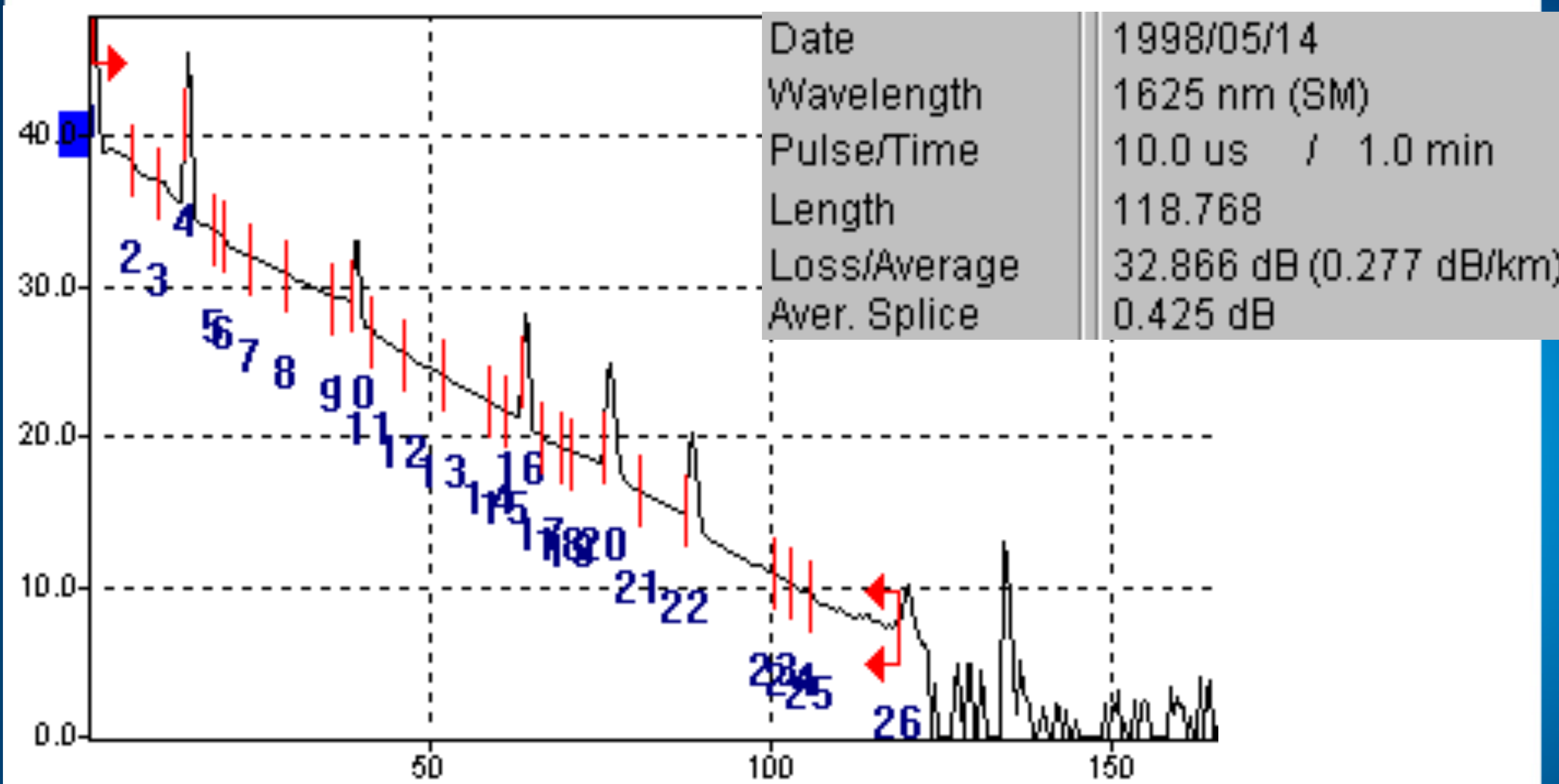
How does an OTDR Work?

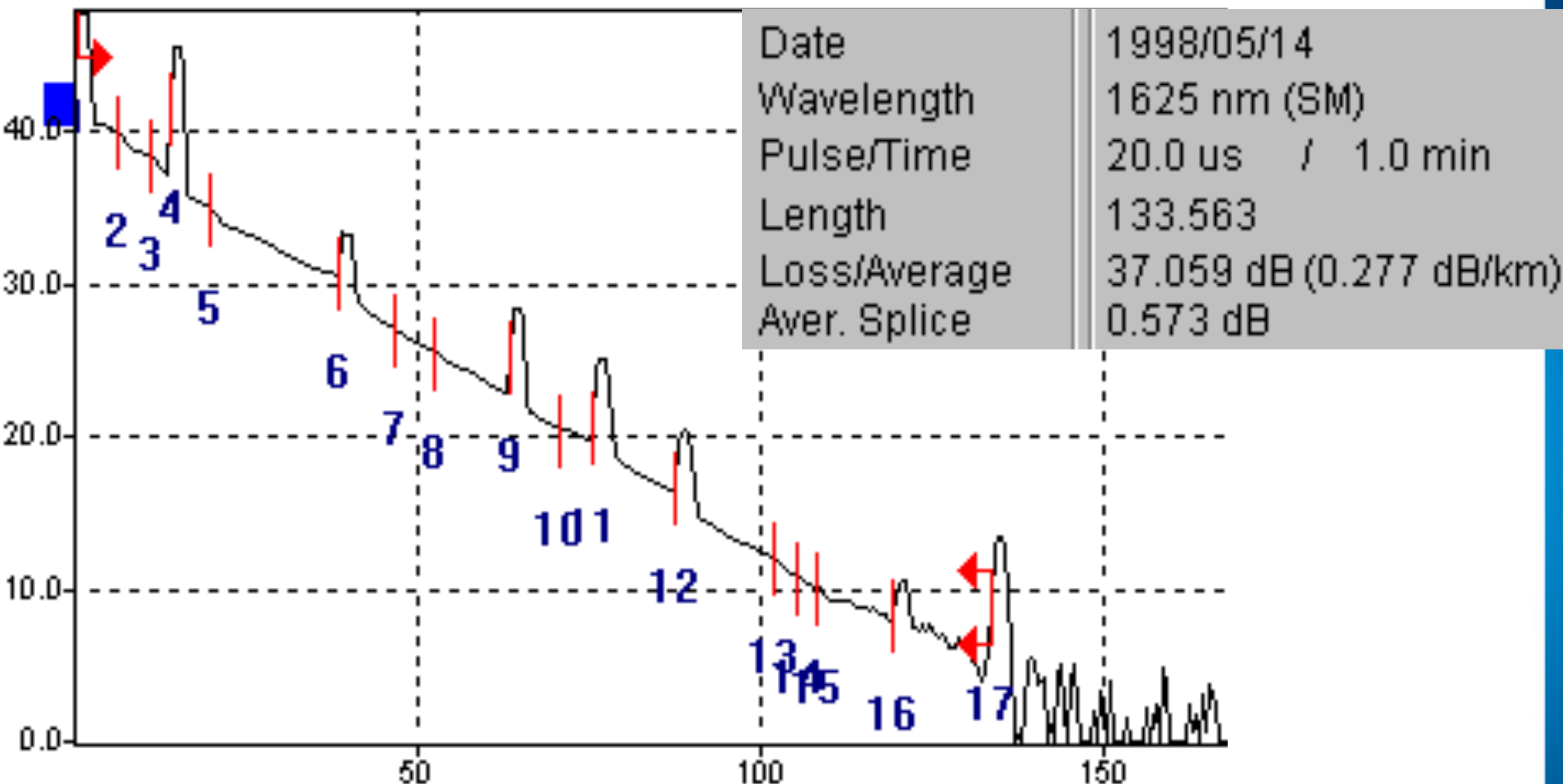
Short Pulse : more resolution but less energy



Long Pulse width: more energy but less resolution




Date
1998/05/14
Wavelength
1625 nm (SM)
Pulse/Time
10.0 us / 1.0 min
Length
118.768
Loss/Average
32.866 dB (0.277 dB/km)
Aver. Splice
0.425 dB
40.0
30.0
20.0
10.0
0.0
50
100
150


Date
Wavelength
Pulse/Time
Length
Loss/Average
Aver. Splice
1998/05/14
1625 nm (SM)
20.0 us / 1.0 min
133.563
37.059 dB (0.277 dB/km)
0.573 dB
40.0
30.0
20.0
10.0
0.0
50
100
150
2
3
4
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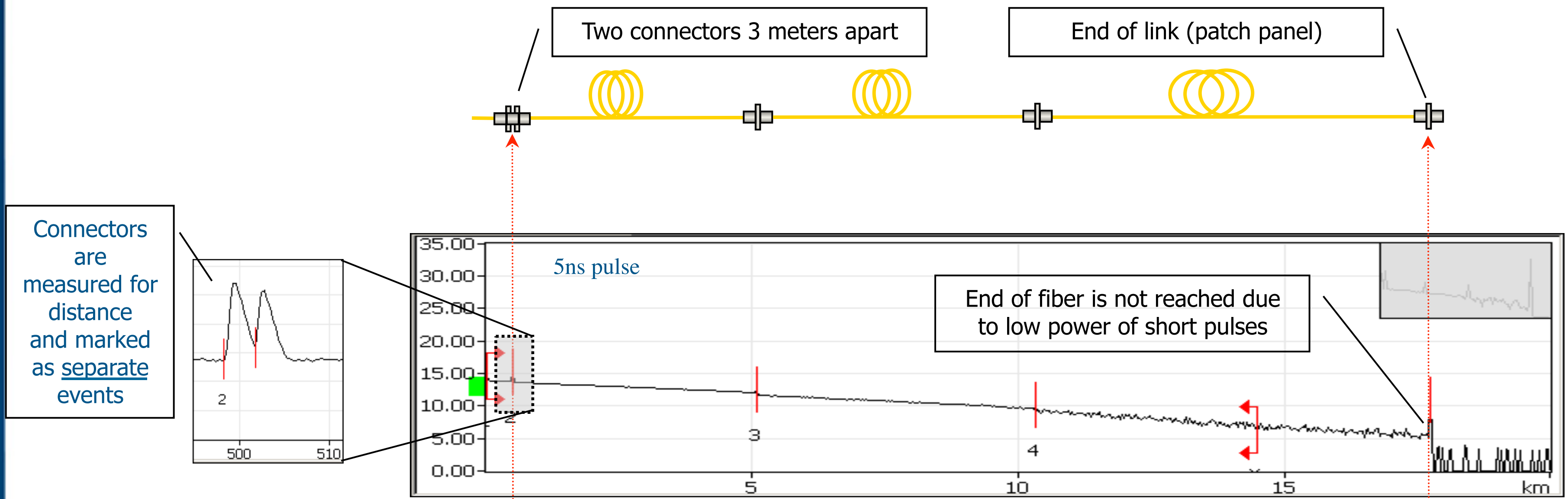
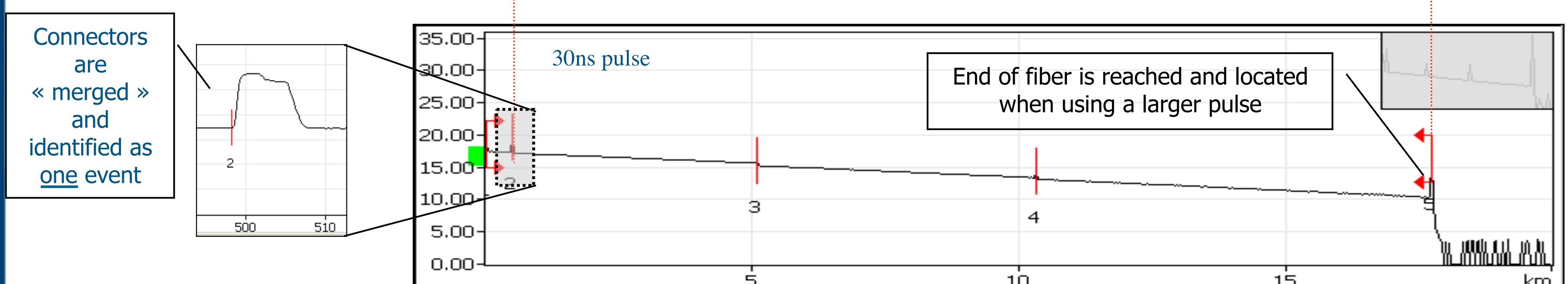
17

OTDR specifications & limitations

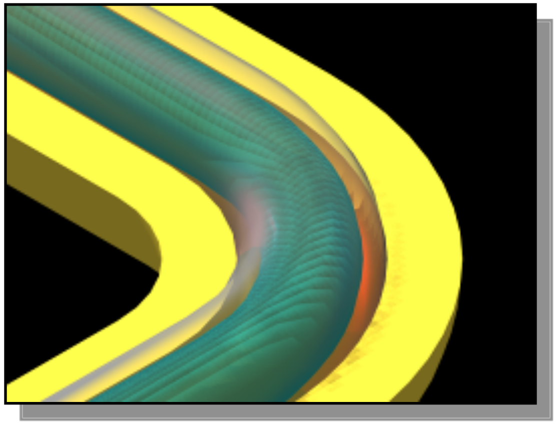
Short pulses will give a better resolution but less dynamic range:

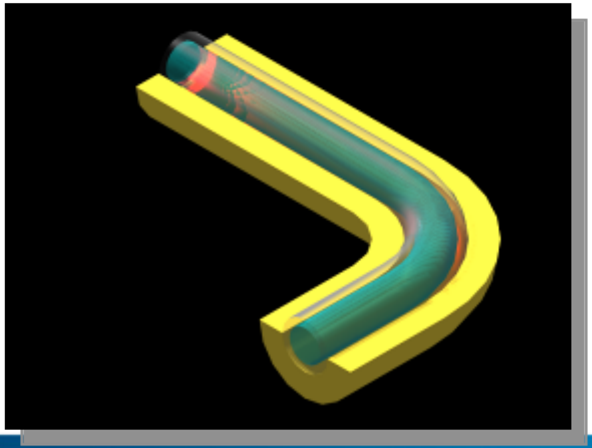


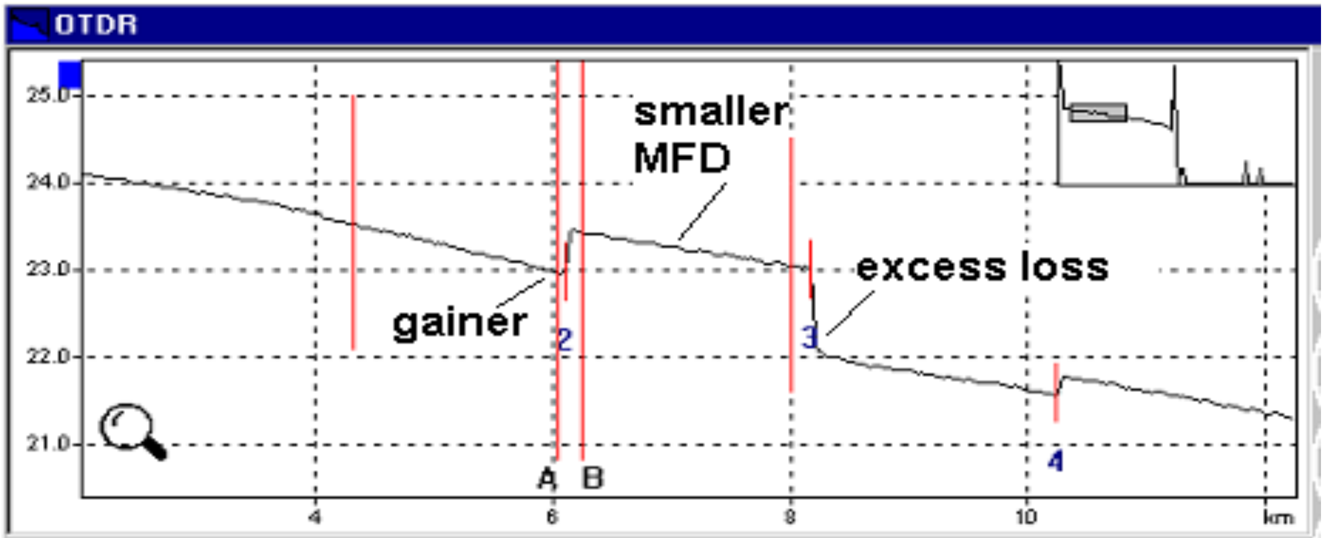
Long pulses will give a better dynamic range but less resolution:

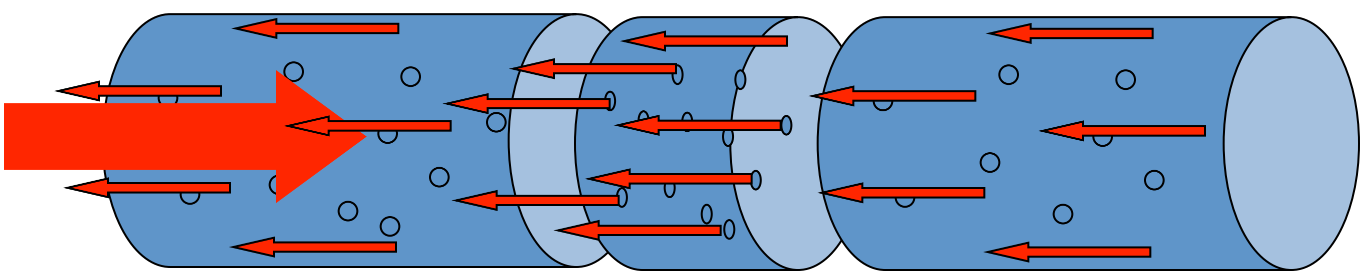


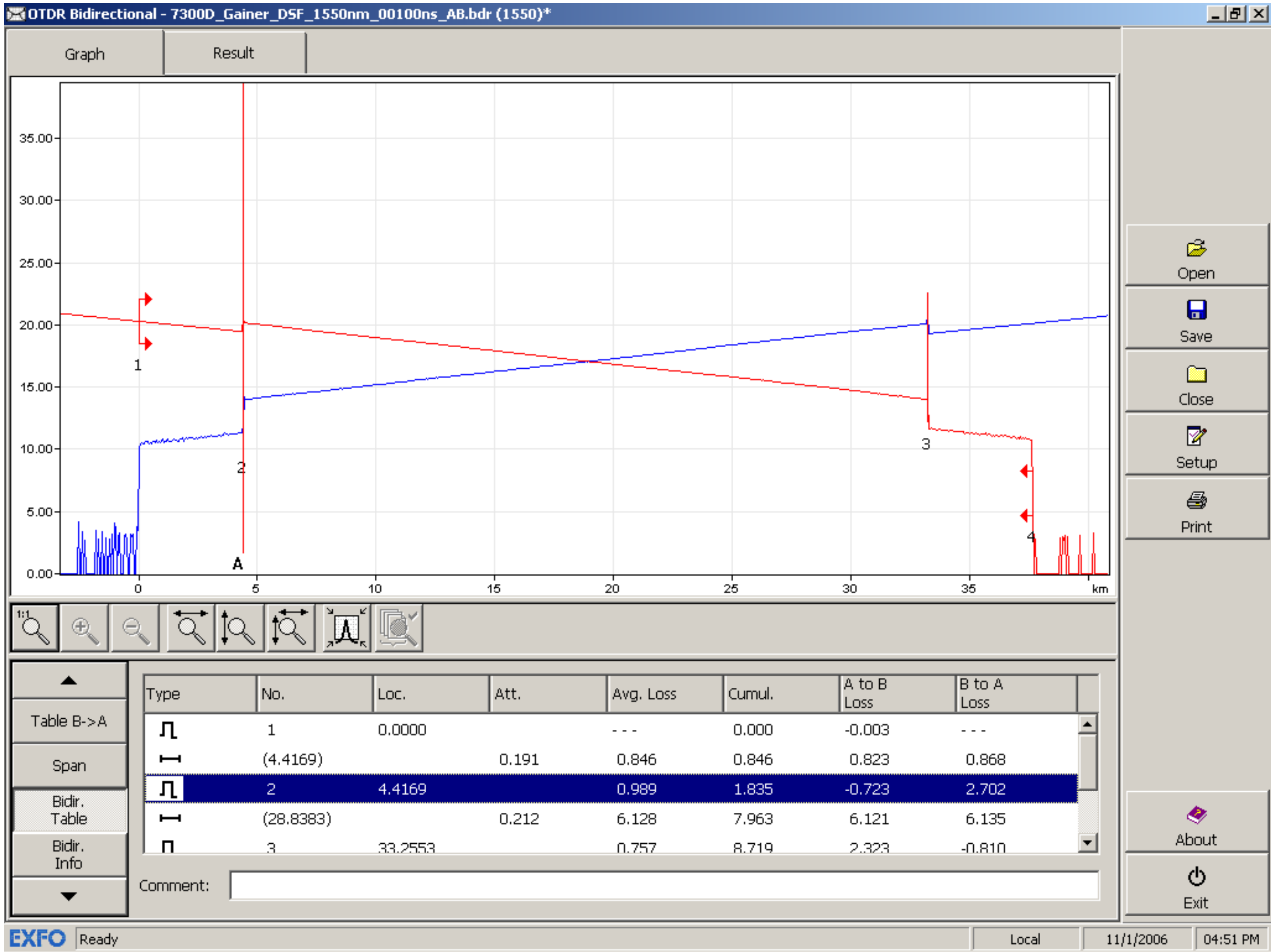
A fiber curvature that causes loss of light

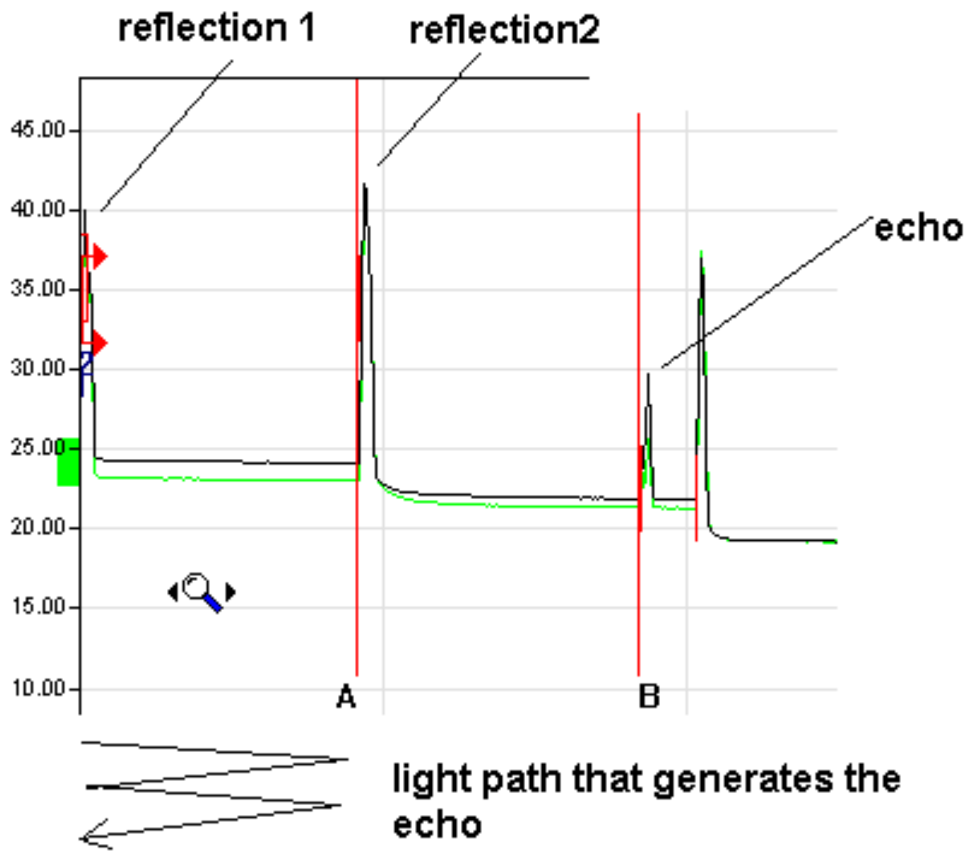





OTDR
25.0
24.0
23.0
22.0
21.0
smaller
MFD
gainer
excess loss
2
3
4
A
B
4
6
8
10
km




OTDR Bidirectional - 7300D_Gainer_DSF_1550nm_00100ns_AB.bdr (1550)*
Graph
Result
Open
Save
Close
Setup
Print
About
Exit
Table B->A
Span
Bidir. Table
Bidir. Info
Type | No. | Loc. | Att. | Avg. Loss | Cumul. | A to B Loss | B to A Loss
1 | 0.0000 | - - - | 0.000 | -0.003 | - - -
(4.4169) | 0.191 | 0.846 | 0.846 | 0.823 | 0.868
2 | 4.4169 | 0.989 | 1.835 | -0.723 | 2.702
(28.8383) | 0.212 | 6.128 | 7.963 | 6.121 | 6.135
Comment:
EXFO
Ready
Local
11/1/2006
04:51 PM

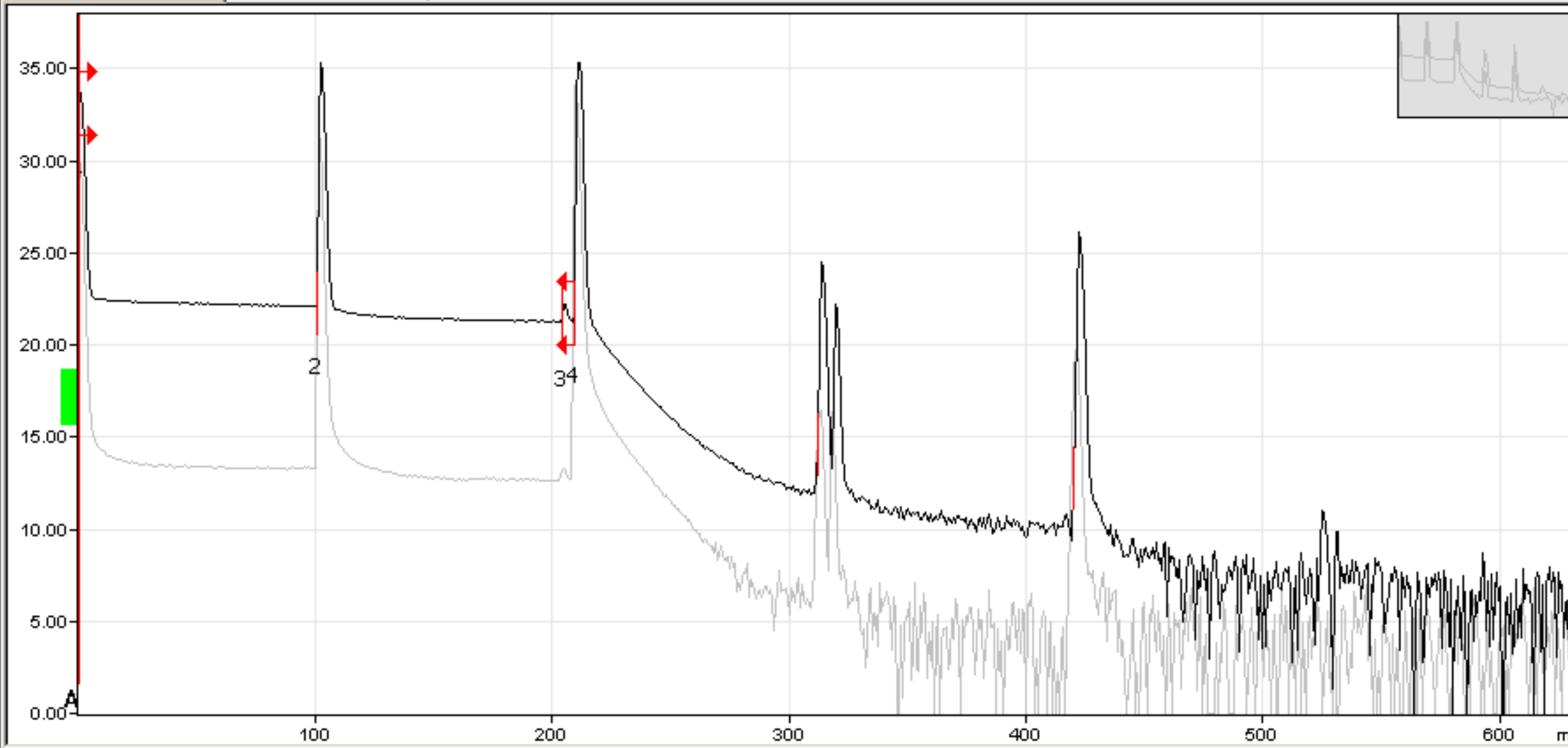


Echos are more frequent in multimode because of high reflectance connectors.

In this example the echo is located at twice the distance of reflectance 2.

OTDR Advanced - File0001.trc (850 nm)

Graph | Result



Spacing...

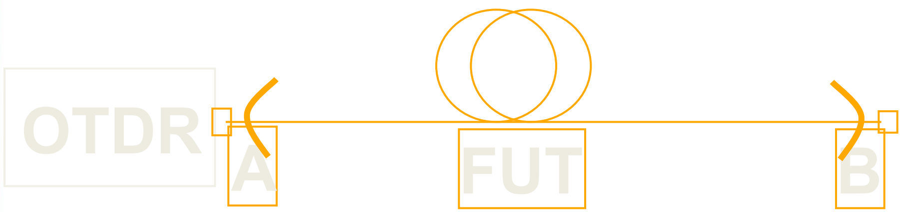
Event
Span
Measure
Trace Info

Type	No.	Loc.	Loss	Refl.	Att.	Cumul.
	1	0.0000	- - -	>-41.9	@22.4dB	0.000
	(0.1010)		0.372		3.687	0.372
	2	0.1010	0.258	>-38.2		0.631
	(0.1030)		0.524		5.092	1.155
	3	0.2040	0.017	-66.5		1.172

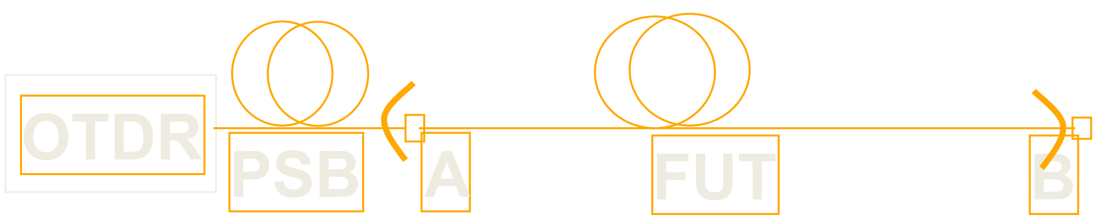
Comment:

Change...
Insert...
Delete
Analyze

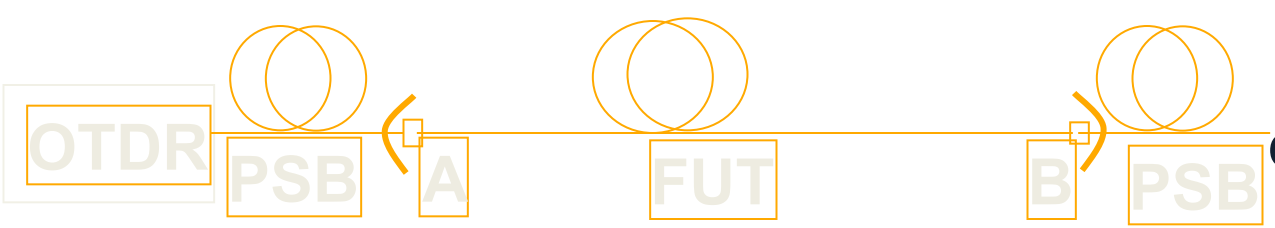
Open
Save
Close
Setup
Print
About
Exit



Link budget = FUT (excluding connectors A and B)

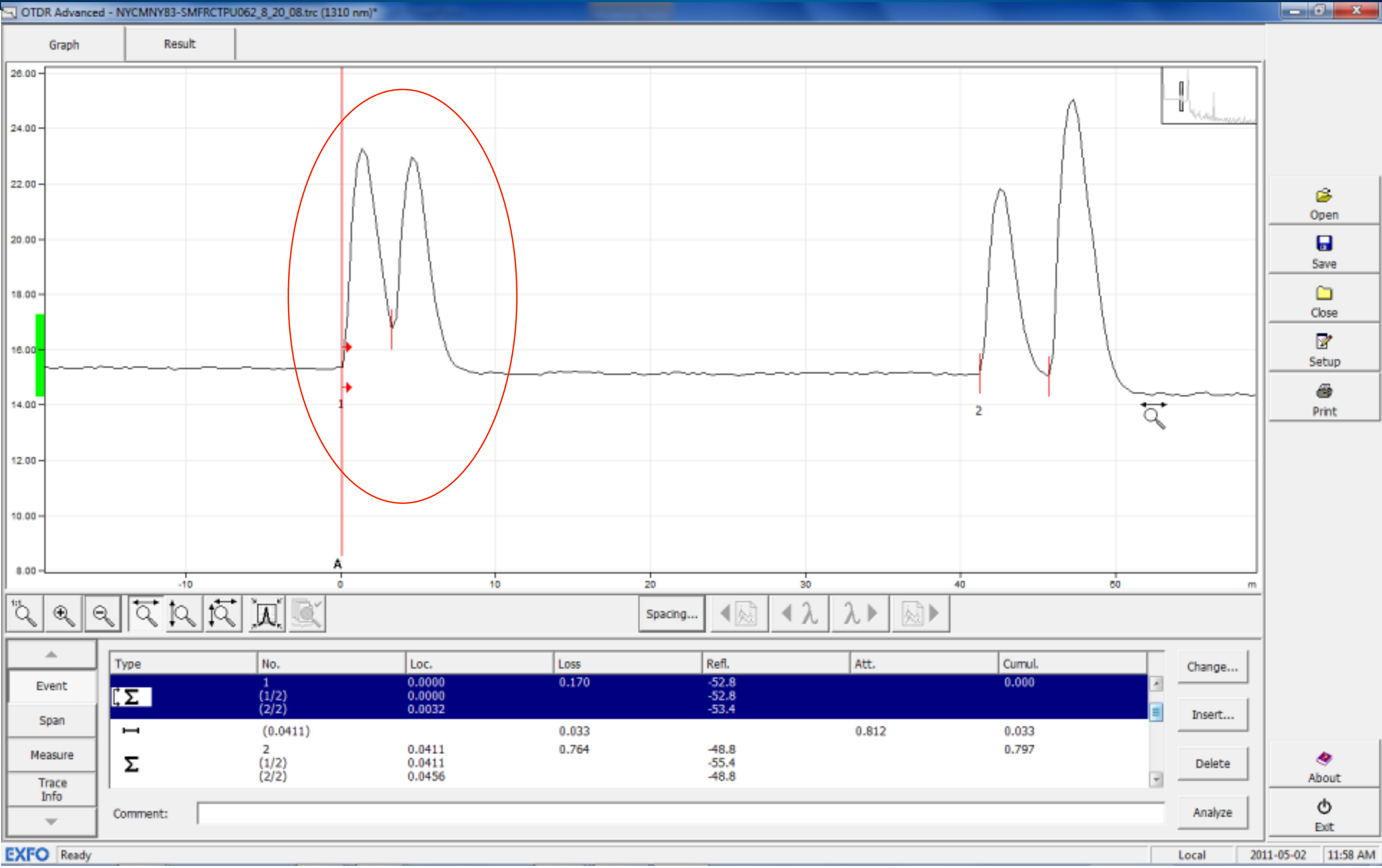


Link budget = connector A +FUT



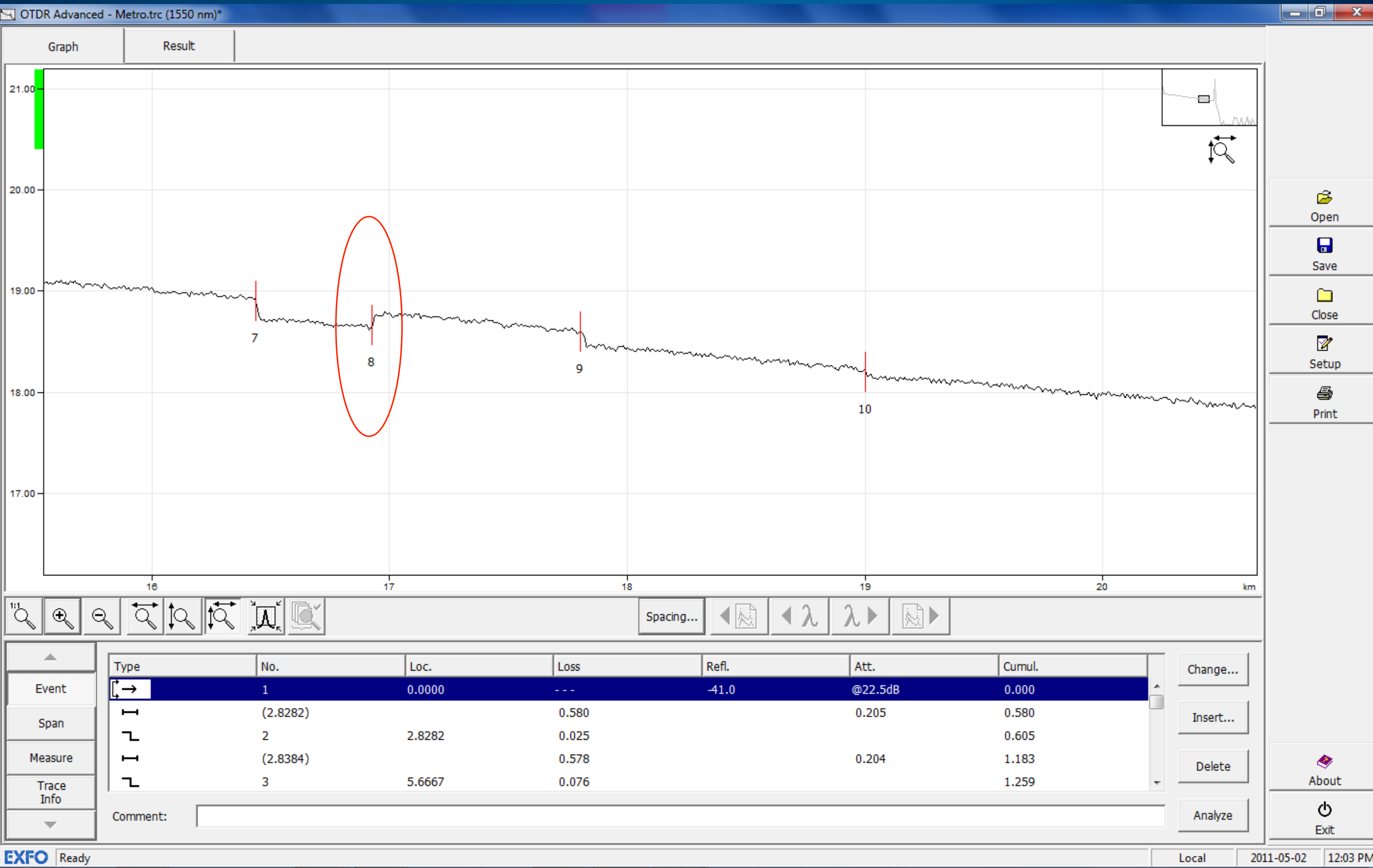
Link budget = connector A + FUT + connector B

What is this?

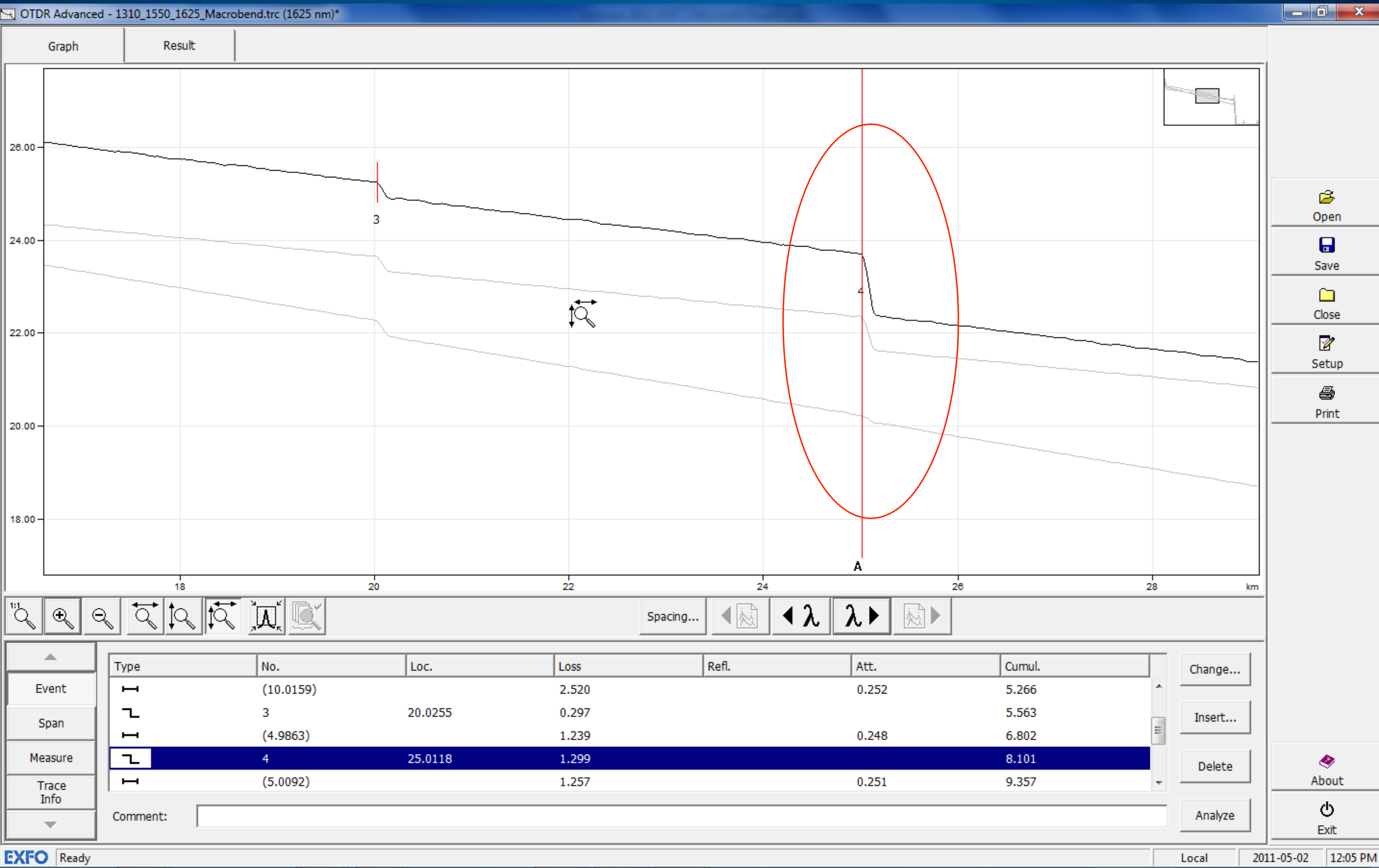


Type	No.	Loc.	Loss	Refl.	Att.	Cumul.
Σ	1 (1/2) (2/2)	0.0000 0.0000 0.0032	0.170	-52.8 -52.8 -53.4		0.000
⟼	(0.0411)		0.033		0.812	0.033
Σ	2 (1/2) (2/2)	0.0411 0.0411 0.0456	0.764	-48.8 -55.4 -48.8		0.797

What is this?


OTDR Advanced - Metro.trc (1550 nm)*
Graph
Result
21.00
20.00
19.00
18.00
17.00
7
8
9
10
16
17
18
19
20
km
Open
Save
Close
Setup
Print
Spacing...
Event
Span
Measure
Trace Info
Type
No.
Loc.
Loss
Refl.
Att.
Cumul.
1
0.0000
- - -
-41.0
@22.5dB
0.000
(2.8282)
0.580
0.205
0.580
2
2.8282
0.025
0.605
(2.8384)
0.578
0.204
1.183
3
5.6667
0.076
1.259
Change...
Insert...
Delete
Analyze
Comment:
About
Exit
EXFO
Ready
Local
2011-05-02
12:03 PM

What is this?

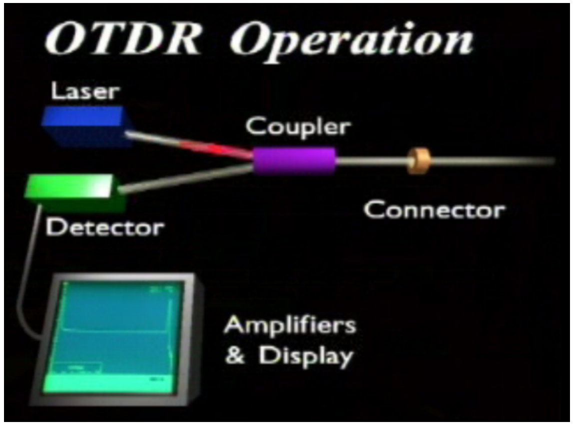


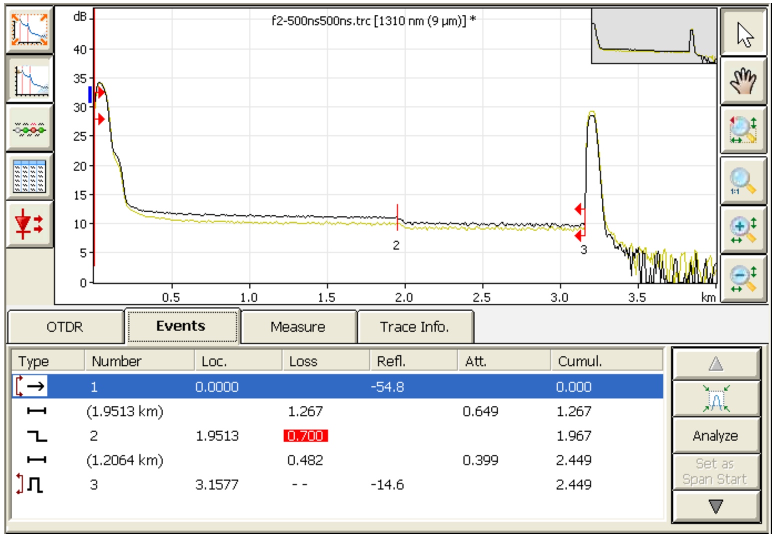
OTDR Advanced - 1310_1550_1625_Macrobend.trc (1625 nm)*
Graph
Result
26.00
24.00
22.00
20.00
18.00
18
20
22
24
26
28
km
3
4
A
Open
Save
Close
Setup
Print
Spacing...
Event
Span
Measure
Trace Info
Type
No.
Loc.
Loss
Refl.
Att.
Cumul.
(10.0159) 2.520 0.252 5.266
3 20.0255 0.297 5.563
(4.9863) 1.239 0.248 6.802
4 25.0118 1.299 8.101
(5.0092) 1.257 0.251 9.357
Comment:
Change...
Insert...
Delete
Analyze
About
Exit
EXFO
Ready
Local
2011-05-02
12:05 PM

Installation best practices

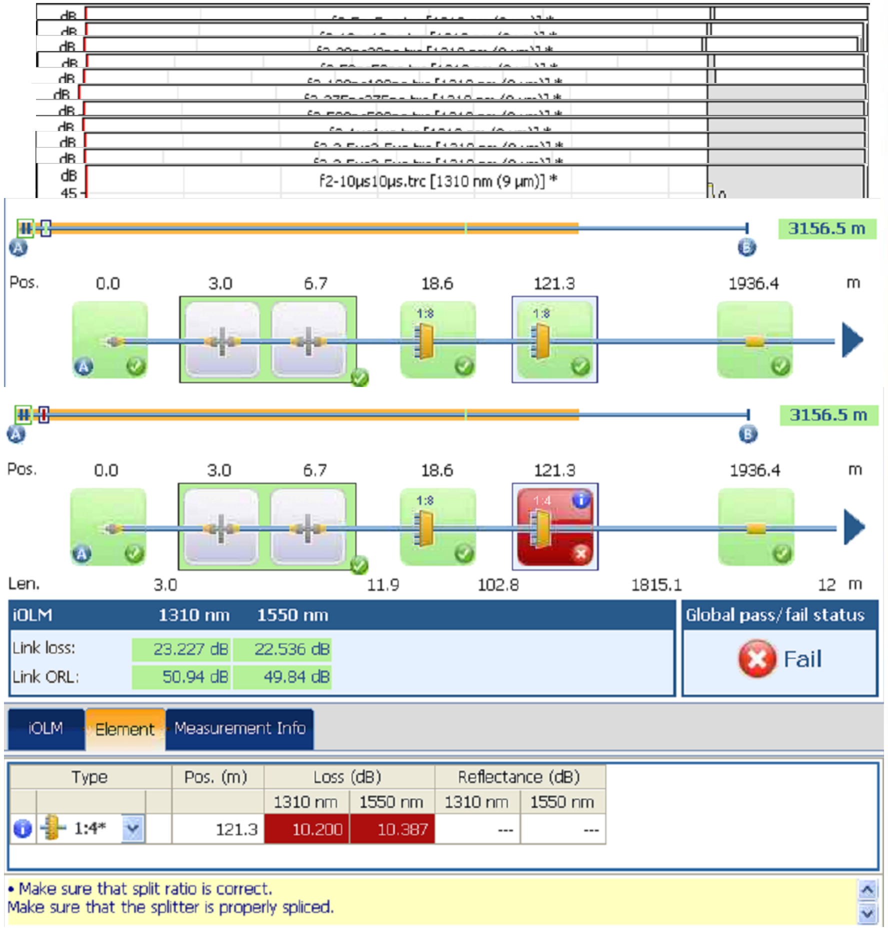
Using Intelligent optical link mapper **IOLM™** instead of the good old **OTDR**

OTDR: Single pulse

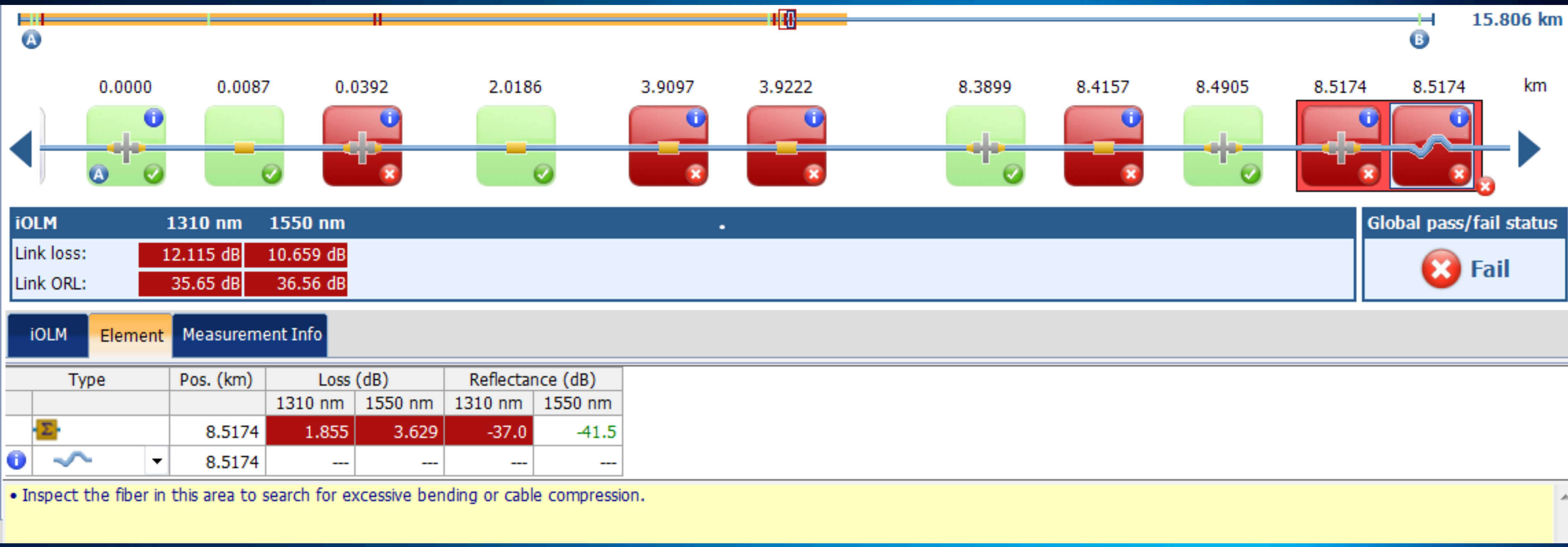


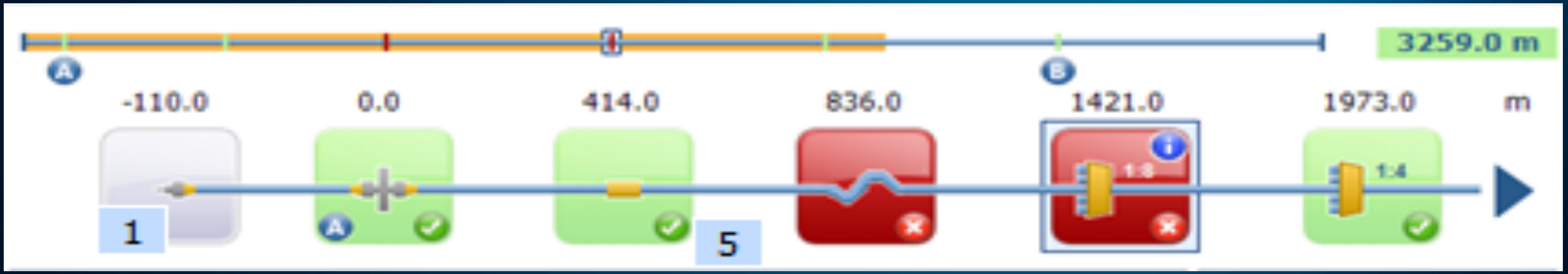


IOLM™: Multipulses with smart recognition and diagnostic



iOLM results





Troubleshooting with OTDR/IOLM on live fiber

› A filtered out of band OTDR/IOLM is able to test a live fiber showing stress or excess loss.

› An optional Power measurement is also available on the live Port

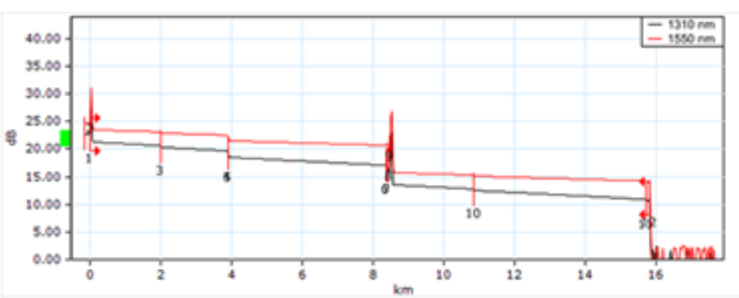
iOLM report now includes real OTDR trace

Link View

Element Table

Type	No.	Pos. (km)	Loss (dB)		Refl. (dB)		Diagnostic
			1310 nm	1550 nm	1310 nm	1550 nm	
Connector		-0.1581	0.124	0.097	-67.5	-69.6	
Connector	1	0.0000	0.047	0.048	-77.8	---	• The connection between the launch fiber and the tested link was not found. Make sure that the specified length corresponds to the launch fiber used. Use measure functionality to get the exact length of the launch fiber.
Group	2	---	1.351	1.058	-48.1	-48.8	
+ Connector		0.0316	---	---	-48.1	-48.9	
+ Connector		0.0346	---	---	-41.7	-42.9	
Splice	3	2.0092	0.303	0.238	---	---	
Splice	4	3.9008	0.558	0.482	---	---	• Make sure that the fiber is properly spliced. The loss could due to a low-reflectance (APC) connector.
Splice	5	3.9146	0.614	0.537	---	---	• Make sure that the fiber is properly spliced. The loss could due to a low-reflectance (APC) connector.
Connector	6	8.3828	0.387	0.257	-61.6	-62.0	
Splice	7	8.4076	0.960	0.860	---	---	• Make sure that the fiber is properly spliced. The loss could due to a low-reflectance (APC) connector.
Connector	8	8.4826	0.305	0.237	-45.9	-46.9	
Group	9	---	1.820	3.546	-35.2	-39.7	
+ Connector		8.5097	1.820	3.546	-35.2	-39.7	• The connector or bulkhead is damaged, dirty or not well connected. Inspect and clean as needed.
+ Macrobend		8.5097	---	---	---	---	• Inspect the fiber in this area to search for excessive bending or cable compression.
Splice	10	10.843	0.205	0.184	---	---	
Splice	11	15.705	0.227	0.198	---	---	
Connector	12	15.805	---	---	-57.4	-62.1	• To characterize loss and include the element in link loss and ORL, a receive fiber is required.

OTDR Graphic



QUESTIONS?

Could you please use the link listed below to fill out a Pre-Conference Workshop Survey. If you fill out the Survey you will be entered to win a Fitbit Alta.

Survey URL:
http://surveys.bc.net/s/workshop-survey-2016/